SESAM USER MANUAL

Framework

Steel Frame Design

Valid from Framework version V4.4-00



Sesam user Manual

Framework

Date: 2023-06-27

Valid from Framework version V4.4-00

Prepared by: Digital Solutions at DNV

E-mail support: software.support@dnv.com

E-mail sales: digital@dnv.com

©DNV AS. All rights reserved

This publication or parts thereof may not be reproduced or transmitted in any form or by any means, including copying or recording, without the prior written consent of DNV AS.

Table of contents

1 Introduction . . . 1
1.1 Framework – Post-processor for Frame Structures . . . 1
1.2 Framework in the Sesam System . . . 1
1.3 How to read this Manual . . . 2
1.4 Framework Extensions . . . 2
1.5 Status List . . . 3
2 Features of Framework . . . 4
2.1 Post-processing capabilities . . . 4
2.1.1 Code checks . . . 4
2.1.2 Fatigue analysis . . . 7
2.1.2.1 General introduction . . . 7
2.1.2.2 Deterministic fatigue analysis . . . 9
2.1.2.3 Spectral fatigue analysis . . . 11
2.1.2.4 Stochastic fatigue analysis . . . 13
2.1.2.5 Time history fatigue analysis . . . 14
2.1.2.6 Direct Deterministic fatigue analysis . . . 15
2.1.3 Earthquake analysis . . . 16
2.1.4 Wind fatigue analysis . . . 19
2.1.4.1 General . . . 19
2.1.4.2 Overview of theoretical basis and assumptions . . . 19
2.1.4.3 Wind state . . . 20
2.1.4.4 Wind spectra and coherence models . . . 21
2.1.4.5 Hotspot stress spectrum . . . 22
2.1.4.6 Wind force on a member . . . 23
2.1.4.7 Eigenvalue calculation . . . 24
2.1.4.8 Vortex shedding induced vibrations . . . 24
2.1.4.9 The structural model . . . 25
2.1.4.10 Joint geometry . . . 25
2.1.4.11 Analysis planes . . . 25
2.1.4.12 SCF schemes . . . 26
2.1.4.13 SN curves . . . 26
2.1.4.14 Calculation of buffeting fatigue damage . . . 27
2.1.4.15 Calculation of vortex shedding induced fatigue damage . . . 27
2.1.4.16 Run scenarios . . . 28
2.1.4.17 Input . . . 28
2.1.4.18 Output . . . 28
2.2 Loading and load combinations . . . 29
2.2.1 Calculation of joint results . . . 30
2.2.1.1 Graphical presentation of joint displacements . . . 30
2.2.2 Calculation of members forces and moments . . . 30
2.2.2.1 Graphical presentation of member forces and moments . . . 31
2.2.3 Calculation of stresses . . . 31
2.3 Structural input data . . . 35
2.3.1 Young’s modulus . . . 35
2.3.2 Yield strength . . . 35
2.3.3 Material constant . . . 35
2.3.4 CHORD and ALIGNED members . . . 35
2.3.4.1 Near Chord Rule . . . 37
2.3.5 CANS . . . 38
2.3.6 STUBS . . . 39
2.3.7 Joint Gap and Joint overlap . . . 39
2.3.8 Joint Type . . . 40
2.3.9 Positions for code check . . . 41

2.3.10 Local coordinate system . . . 42
2.3.11 Member buckling lengths . . . 42
2.3.12 Effective length factors . . . 42
2.3.13 Unsupported flange length . . . 45
2.3.14 Fabrication method . . . 45
2.3.15 Buckling curve . . . 45
2.3.16 Lateral buckling factor . . . 46
2.3.17 Moment reduction factors . . . 46
2.3.18 Stiffener spacing . . . 46
2.4 Environmental Input . . . 47
2.4.1 Sea water density and acceleration due to gravity . . . 47
2.4.2 Water depth . . . 47
2.4.3 Wave height . . . 47
2.4.4 Wave length . . . 47
2.4.5 Water plane . . . 47
2.4.6 Individual wave data . . . 47
2.4.7 Wave load factor . . . 47
2.4.8 Wave spreading function . . . 48
2.4.9 Wave spectrum shape . . . 49
2.4.10 Wave direction probability . . . 49
2.4.11 Wave statistics . . . 49
2.5 Fatigue Analysis input . . . 51
2.5.1 Regular SN Curves . . . 51
2.5.2 Primary SN Curves . . . 55
2.5.3 Unit of stress in SN curves . . . 57
2.5.4 Default SN curves . . . 57
2.5.5 Minimum stress concentration factors (SCF) . . . 57
2.5.6 Global stress concentration factors (SCF) . . . 57
2.5.7 Local stress concentration factors (SCF) . . . 58
2.5.8 Parametric stress concentration factors (SCF) . . . 59
2.5.9 Butt-weld and Cone transition SCFs . . . 60
2.5.10 Fatigue Check Positions for Tubular Joints . . . 61
2.5.11 Include Chord stresses in fatigue analysis . . . 62
2.5.12 Butt-weld fatigue check positions . . . 63
2.5.12.1 Default SCF and SN curve assignment . . . 65
2.5.13 User specified fatigue check positions . . . 66
2.5.13.1 Fatigue Positions Option . . . 66
2.5.13.2 Modify Fatigue Positions . . . 67
2.5.13.3 Add individual fatigue position . . . 68
2.5.13.4 Default SCF and SN curve assignment . . . 69
2.5.13.5 Commments . . . 69
2.6 Other Miscellaneous input . . . 70
2.6.1 Load case identification . . . 70
2.6.2 Mandatory and optional input data . . . 71
3 User’s guide to Framework . . . 75
3.1 Getting started – graphical user interface and reading a model . . . 75
3.1.1 DEFINE options prior to opening SIN file . . . 79
3.1.2 Present a display of the model . . . 80
3.2 How to assign CHORDS . . . 80
3.2.1 Automatic assignment of CHORD and BRACES . . . 80
3.2.2 Global CHORD assignments . . . 83
3.2.3 Local CHORD assignments . . . 83
3.3 How to assign CAN and STUB sections . . . 85
3.3.1 CAN assignments . . . 85

3.3.2 STUB assignments . . . 87
3.3.3 How to assign joint-type and gap . . . 89
3.4 How to specify parametric SCFs . . . 90
3.5 How to specify Butt-weld and Cone-Transition SCFs . . . 91
3.6 How to handle UNIT system in fatigue analysis . . . 94
3.6.1 Convert stress in S-N curves . . . 94
3.6.2 Convert built-in length parameters (Specify Unit-Length-factor) . . . 95
3.7 The model and loads for code checks, fatigue and earthquake analyses . . . 95
3.7.1 The steel properties . . . 95
3.7.2 The loads for code checks . . . 96
3.7.3 The loads for deterministic fatigue analysis . . . 96
3.7.4 The loads for spectral fatigue analysis . . . 96
3.7.5 The loads for stochastic fatigue analysis . . . 97
3.7.6 The loads for earthquake analysis . . . 98
3.8 How to perform a yield check . . . 98
3.9 How to perform a stability check . . . 99
3.10 How to perform a member check . . . 101
3.11 How to perform a cone check . . . 102
3.12 How to perform a punching shear check . . . 103
3.13 Recommended application for fatigue analysis . . . 104
3.14 How to perform a deterministic fatigue analysis . . . 106
3.15 How to perform a spectral fatigue analysis . . . 108
3.16 How to perform a stochastic fatigue analysis . . . 110
3.17 How to perform a time history fatigue analysis . . . 112
3.18 How to perform an earthquake analysis . . . 113
3.18.1 Fundamental procedures for earthquake analysis . . . 114
3.18.2 Additional features for earthquake analysis . . . 118
3.19 How to perform a joint redesign . . . 124
3.20 How to perform member redesign . . . 124
3.21 How to compute material take-off . . . 125
3.22 How to close the design loop by linking Preframe . . . 125
3.23 How to create a hidden surface display . . . 126
3.24 How to create a deformed shape display . . . 126
3.25 How to create a force/moment diagram display . . . 128
3.26 How to perform a wind fatigue analysis . . . 128
3.26.1 File and file names . . . 129
3.26.2 Modelling of the structure . . . 130
3.26.3 Generation of wind loads . . . 130
3.26.4 Calculation of element forces from wind loading . . . 133
3.26.5 Calculation of eigenvalues, eigenvectors and element mode shape forces . . . 133
3.26.6 Merge of static and dynamic Results Interface Files . . . 133
3.26.7 Execution of wind fatigue analysis . . . 134
3.26.7.1 FILE command . . . 134
3.26.7.2 ASSIGN WIND-FATIGUE command . . . 134
3.26.7.3 CREATE WIND-FATIGUE command . . . 136
3.26.7.4 DEFINE WIND-FATIGUE command . . . 136
3.26.7.5 DELETE WIND-FATIGUE command . . . 138
3.26.7.6 PRINT WIND-FATIGUE command . . . 138
3.26.7.7 RUN WIND-FATIGUE command . . . 139
3.26.8 Program limitations and example of use . . . 139
3.27 How to perform a Direct Deterministic Fatigue . . . 139
3.28 How to specify initial Fatigue Damage . . . 142
3.28.1 Fatigue Part Damage . . . 142
3.28.2 Output a fatigue part damage file . . . 142

3.28.3 Import a fatigue part damage file . . . 143
4 Execution of Framework . . . 145
4.1 Program environment . . . 145
4.1.1 Starting Framework in graphics mode . . . 145
4.1.2 Starting Framework in batch run . . . 145
4.1.3 Files and data safety . . . 146
4.2 Program requirements . . . 146
4.2.1 Execution time . . . 146
4.2.2 Storage space . . . 147
4.3 Details on line mode syntax . . . 147
4.3.1 How to get help . . . 148
4.3.2 Command input files . . . 148
4.3.3 Accessing default values . . . 148
4.3.4 Abbreviation and wildcards . . . 149
4.3.5 Input of a text or name or numerical value . . . 149
4.3.6 Selecting a single alternative from a list . . . 149
4.3.7 Selecting several alternative from a list . . . 150
4.3.8 Entering a vector or matrix of values . . . 150
4.3.9 Setting and clearing loops in a command . . . 151
4.3.10 Inserting a command into another command . . . 152
4.3.11 Aborting all or parts of a command . . . 152
4.3.12 Access to the operating system . . . 152
4.3.13 Appending input lines . . . 152
4.3.14 Viewing the current status of a command . . . 153
4.3.15 Comments . . . 153
4.4 Details on graphic mode . . . 153
4.4.1 How to get help . . . 154
4.4.2 Dialogue boxes and their contents . . . 154
4.4.3 The standard buttons in a dialogue box . . . 156
4.4.4 Selecting several alternatives from a list . . . 157
4.4.5 Entering a prefixed list . . . 158
4.4.6 Entering a vector or matrix of values . . . 159
4.4.7 Journalling from graphics mode . . . 160
5 Command description . . . 161
ASSIGN . . . 162
ASSIGN CAN . . . 164
ASSIGN CAN JOINT . . . 165
ASSIGN CAN CHORD . . . 166
ASSIGN CAN NONE . . . 167
ASSIGN CHORD . . . 168
ASSIGN EARTHQUAKE-DAMPING-FUNCTION . . . 169
ASSIGN EARTHQUAKE SPECTRUM . . . 170
ASSIGN FATIGUE-PART-DAMAGE . . . 171
ASSIGN FATIGUE-PART-DAMAGE READ-FILE . . . 173
ASSIGN FATIGUE-SAFETY-FACTOR . . . 174
ASSIGN INDIVIDUAL-WAVE . . . 175
ASSIGN JOINT-CHORD-LENGTH . . . 177
ASSIGN JOINT-GAP . . . 178
ASSIGN JOINT-GROUTED . . . 179
ASSIGN JOINT-OVERLAP . . . 180
ASSIGN JOINT-RING-STIFFENER . . . 181
ASSIGN JOINT-TYPE . . . 184
ASSIGN LOAD-CASE . . . 186
ASSIGN LOCAL-COORDINATE-SYSTEM . . . 187

ASSIGN MATERIAL . . . 189
ASSIGN POSITIONS . . . 190
ASSIGN POSITIONS sel-mem CODE-CHECK . . . 191
ASSIGN POSITIONS sel-mem FATIGUE-CHECK . . . 193
ASSIGN SCF . . . 195
ASSIGN SCF JOINT . . . 196
ASSIGN SCF MEMBER . . . 199
ASSIGN SECTION . . . 205
ASSIGN SN-CURVE . . . 206
ASSIGN STABILITY . . . 207
ASSIGN STABILITY sel-mem AISC-LSEC-METHOD . . . 209
ASSIGN STABILITY sel-mem BUCKLING-CURVE-Y . . . 210
ASSIGN STABILITY sel-mem BUCKLING-CURVE-Z . . . 211
ASSIGN STABILITY sel-mem BUCKLING-LENGTH . . . 212
ASSIGN STABILITY sel-mem FABRICATION . . . 213
ASSIGN STABILITY sel-mem FLOODING-STATUS . . . 214
ASSIGN STABILITY sel-mem KXT . . . 215
ASSIGN STABILITY sel-mem KY . . . 216
ASSIGN STABILITY sel-mem KZ . . . 217
ASSIGN STABILITY sel-mem LATERAL-BUCKLING-FACTOR . . . 218
ASSIGN STABILITY sel-mem LSEC-CONNECTION . . . 219
ASSIGN STABILITY sel-mem MOMENT-REDUCTION-FACTOR . . . 220
ASSIGN STABILITY sel-mem NORSOK_ISO-AXIAL-COMPRESSION . . . 222
ASSIGN STABILITY sel-mem STIFFENER-SPACING . . . 223
ASSIGN STABILITY sel-mem UNSUPPORTED-FLANGE-LENGTH . . . 224
ASSIGN STABILITY sel-mem UNSUPPORTED-BTM-FLANGE-LENGTH . . . 225
ASSIGN STUB . . . 226
ASSIGN STUB BRACE . . . 227
ASSIGN STUB JOINT . . . 228
ASSIGN STUB NONE . . . 229
ASSIGN THICKNESS-CORRECTION . . . 230
ASSIGN WAVE-DIRECTION-PROBABILITY . . . 232
ASSIGN WAVE-LOAD-FACTOR . . . 233
ASSIGN WAVE-SPECTRUM-SHAPE . . . 234
ASSIGN WAVE-SPREADING-FUNCTION . . . 236
ASSIGN WAVE-STATISTICS . . . 237
ASSIGN WIND-FATIGUE . . . 238
ASSIGN WIND-FATIGUE WIND-TYPE . . . 240
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U . . . 242
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V . . . 244
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W . . . 245
ASSIGN WIND-FATIGUE WIDE-BAND-CORRECTION . . . 246
ASSIGN WIND-FATIGUE COHERENCE-MODEL (removed) . . . 247
ASSIGN WIND-FATIGUE GUST-DIRECTION-MOMENT . . . 248
ASSIGN WIND-FATIGUE SN-CURVE . . . 251
ASSIGN WIND-FATIGUE JOINT-SCF . . . 252
ASSIGN WIND-FATIGUE JOINT-SCF READ . . . 255
ASSIGN WIND-FATIGUE BENT-CAN-SCF . . . 257
ASSIGN WIND-FATIGUE VORTEX-DIMENSION . . . 258
ASSIGN WIND-FATIGUE VORTEX-FIXITY . . . 259
ASSIGN WIND-FATIGUE RUN-SCENARIO . . . 261
ASSIGN WIND-FATIGUE STRESS-PRINT-OPTIONS . . . 263
CHANGE . . . 264
CHANGE MATERIAL . . . 265

CHANGE SECTION . . . 266
CHANGE SECTION-PROPERTY . . . 267
CHANGE HOTSPOTS . . . 269
CHANGE SN-CURVE . . . 270
CHANGE WAVE-SPREADING-FUNCTION . . . 272
CHANGE WAVE-STATISTICS . . . 273
CHANGE WIND-FATIGUE . . . 275
CHANGE WIND-FATIGUE SECTION-DIMENSIONS . . . 276
CREATE . . . 277
CREATE EARTHQUAKE-DAMPING-FUNCTION . . . 278
CREATE EARTHQUAKE-SPECTRUM . . . 279
CREATE FATIGUE-LOAD-SERIES . . . 280
CREATE JOINT . . . 282
CREATE LOAD-COMBINATION . . . 283
CREATE MEMBER . . . 285
CREATE MATERIAL . . . 286
CREATE SECTION . . . 287
CREATE SECTION name text PIPE . . . 288
CREATE SECTION name text SYMMETRIC-I . . . 289
CREATE SECTION name text UNSYMMETRIC-I . . . 290
CREATE SECTION name text ANGLE . . . 291
CREATE SECTION name text CHANNEL . . . 292
CREATE SECTION name text BOX . . . 293
CREATE SECTION name text BAR . . . 294
CREATE SECTION name text GENERAL . . . 295
CREATE SECTION name text RING-STIFFENER-T . . . 296
CREATE SECTION name text RING-STIFFENER-FLAT . . . 297
CREATE SN-CURVE . . . 298
CREATE WAVE-SPREADING-FUNCTION . . . 300
CREATE WAVE-STATISTICS . . . 301
CREATE WIND-FATIGUE . . . 303
CREATE WIND-FATIGUE ANALYSIS-PLANES . . . 304
CREATE WIND-FATIGUE STATIC-WIND-LOADS . . . 305
DEFINE . . . 306
DEFINE AISC . . . 309
DEFINE BEAM-SPLIT . . . 311
DEFINE BUCKLING-LENGTH-DUMP . . . 312
DEFINE CODE-OF-PRACTICE-VERSION . . . 313
DEFINE CONE-PARAMETERS . . . 315
DEFINE CONSTANTS . . . 316
DEFINE ECCENTRICITY . . . 317
DEFINE FATIGUE-CHECK-WELD-ROOT . . . 318
DEFINE FATIGUE-CONSTANTS . . . 319
DEFINE FATIGUE-DAMAGE-TO-FILE . . . 325
DEFINE FATIGUE-DUMP . . . 327
DEFINE FATIGUE-PARAMETERS INCLUDE-CHORD-STRESS . . . 330
DEFINE FATIGUE-PARAMETERS SN-CURVE-THICKNESS-EFFECT . . . 331
DEFINE FATIGUE-RAINFLOW-COUNTING . . . 332
DEFINE FATIGUE-SAFETY-FACTOR . . . 333
DEFINE FATIGUE-STRESS-TIME-SERIES-ON-FILE . . . 334
DEFINE GEOMETRY-VALIDITY-RANGE . . . 336
DEFINE HOTSPOTS . . . 337
DEFINE HYDROSTATIC-DATA . . . 338
DEFINE HYDROSTATIC-DATA GRAVITY . . . 339

DEFINE HYDROSTATIC-DATA WATER-DEPTH . . . 340
DEFINE HYDROSTATIC-DATA WATER-DENSITY . . . 341
DEFINE HYDROSTATIC-DATA WAVE-HEIGHT . . . 342
DEFINE HYDROSTATIC-DATA WAVE-LENGTH . . . 343
DEFINE HYDROSTATIC-DATA WATER-PLANE . . . 344
DEFINE HYDROSTATIC-DATA ACTION-FACTOR-OPERATING . . . 345
DEFINE HYDROSTATIC-DATA ACTION-FACTOR-STORM . . . 346
DEFINE ISO . . . 347
DEFINE JOINT-PARAMETERS . . . 352
DEFINE JOINT-PARAMETERS CAN-DIAMETER-FRACTION . . . 353
DEFINE JOINT-PARAMETERS MERGE-DIAMETER-FRACTION . . . 354
DEFINE JOINT-PARAMETER MINIMUM-FREE-CAN-LENGTH . . . 355
DEFINE JOINT-PARAMETER MINIMUM-FREE-STUB-LENGTH . . . 356
DEFINE JOINT-PARAMETER MINIMUM-GAP-LENGTH . . . 357
DEFINE JOINT-PARAMETER MINIMUM-GAP-RESET . . . 358
DEFINE JOINT-PARAMETER STUB-DIAMETER-FRACTION . . . 359
DEFINE JOINT-PARAMETERS LOADPATH-FORCE-RATIO-LIMIT . . . 360
DEFINE JOINT-PARAMETERS JOINT-IDENTIFICATION . . . 361
DEFINE JOINT-PARAMETERS GROUTED-JOINT . . . 362
DEFINE JOINT-TYPE-VALIDATE . . . 363
DEFINE LOAD . . . 364
DEFINE LRFD-CODE-CHECK . . . 365
DEFINE LRFD-RESISTANCE-FACTORS . . . 366
DEFINE MEMBER-CHECK-PARAMETERS . . . 368
DEFINE MEMBER-CHECK-PARAMETERS CALCULATION-METHOD . . . 369
DEFINE MEMBER-CHECK-PARAMETERS ELASTIC-CAPACITY-ONLY . . . 370
DEFINE MEMBER-CHECK-PARAMETERS REFERENCE-YOUNGS-MODULUS-KSI . . . 371
DEFINE MEMBER-CHECK-PARAMETERS REFERENCE-YOUNGS-MODULUS-MPA . . . 372
DEFINE MEMBER-CHECK-PARAMETERS SECTION-CAPACITY-CHECK . . . 373
DEFINE MEMBER-CHECK-PARAMETERS STABILITY-CAPACITY-CHECK . . . 374
DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR . . . 375
DEFINE MEMBER-CHECK-PARAMETERS VON-MISES-CHECK . . . 376
DEFINE MEMBER-CODE-CHECK-DUMP . . . 377
DEFINE MEMBER-REDESIGN . . . 378
DEFINE NEAR-CHORD-RULE . . . 379
DEFINE NORSOK . . . 380
DEFINE PARAMETRIC-SCF . . . 383
DEFINE POSITION-BOTH-SIDES . . . 387
DEFINE PREFRAME-INPUT . . . 388
DEFINE PRESENTATION . . . 389
DEFINE PRESENTATION DISPLAY . . . 390
DEFINE PRESENTATION FORCE . . . 393
DEFINE PRESENTATION PRINT . . . 395
DEFINE PRESENTATION RESULT . . . 397
DEFINE PRESENTATION STRESS . . . 398
DEFINE PRESENTATION STRESS . . . 400
DEFINE READ-CONCEPTS . . . 402
DEFINE READ-NAMED-SETS . . . 403
DEFINE SECTION-OVERRULE . . . 404
DEFINE TIME-HISTORY-FATIGUE-TIME . . . 405
DEFINE WIDE-BAND-CORRECTION-FACTOR . . . 406
DEFINE WIND-FATIGUE . . . 407
DEFINE WIND-FATIGUE WIND-PARAMETERS . . . 408
DEFINE WIND-FATIGUE COHERENCE-COEFFICIENTS . . . 410

DEFINE WIND-FATIGUE WIND-DIRECTIONS . . . 411
DEFINE WIND-FATIGUE WIND-SPEEDS . . . 412
DEFINE WIND-FATIGUE WIND-PROBABILITIES . . . 413
DEFINE WIND-FATIGUE DRAG-CORRECTION-FACTORS . . . 415
DEFINE WIND-FATIGUE BENT-CAN-DAMAGE . . . 417
DEFINE WIND-FATIGUE VORTEX-PARAMETERS . . . 418
DEFINE WIND-FATIGUE DEFAULT-MEMBER-FIXITIES . . . 419
DEFINE WIND-FATIGUE DEBUG-PRINT . . . 420
DELETE . . . 421
DELETE WIND-FATIGUE . . . 422
DISPLAY . . . 423
DISPLAY CODE-CHECK-RESULTS . . . 424
DISPLAY DIAGRAM . . . 425
DISPLAY EARTHQUAKE-SPECTRUM . . . 426
DISPLAY FATIGUE-CHECK-RESULTS . . . 427
DISPLAY LABEL . . . 428
DISPLAY MEMBER . . . 429
DISPLAY PRESENTATION . . . 430
DISPLAY SHAPE . . . 431
DISPLAY SN-CURVE . . . 432
DISPLAY SN-CURVE-SORTED . . . 433
DISPLAY STABILITY . . . 434
DISPLAY SUPERELEMENT . . . 435
DISPLAY Stress Transfer Function . . . 436
FILE . . . 437
FILE OPEN . . . 438
FILE TRANSFER . . . 439
FILE INTERROGATE . . . 440
FILE EXIT . . . 441
PLOT . . . 442
PRINT . . . 443
PRINT ACCELERATION . . . 445
PRINT ACTIVE-SETTINGS . . . 446
PRINT CHORD-AND-BRACE . . . 447
PRINT CODE-CHECK-RESULTS . . . 448
PRINT CODE-OF-PRACTICE . . . 450
PRINT DEFLECTION . . . 451
PRINT DISPLACEMENT . . . 452
PRINT EARTHQUAKE-CHECK-TYPE . . . 453
PRINT EARTHQUAKE-DAMPING-FUNCTION . . . 454
PRINT EARTHQUAKE-SPECTRUM . . . 455
PRINT EARTHQUAKE-BASE-LOADS . . . 456
PRINT FATIGUE-CHECK-RESULTS . . . 458
PRINT FATIGUE-CHECK-TYPE . . . 459
PRINT FORCE . . . 460
PRINT HYDROSTATIC-DATA . . . 461
PRINT JOINT . . . 462
PRINT JOINT MEMBER-FORCES . . . 463
PRINT JOINT REACTION-FORCES . . . 464
PRINT LOAD-CASE . . . 466
PRINT LOAD-SET . . . 467
PRINT LRDF-RESISTANCE-FACTORS . . . 468
PRINT MATERIAL . . . 469
PRINT MEMBER . . . 470

PRINT MODE-SHAPE . . . 471
PRINT MODAL-MASS . . . 472
PRINT RUN . . . 473
PRINT SECTION . . . 474
PRINT SN-CURVE . . . 475
PRINT SN-CURVE-SORTED . . . 476
PRINT STRESS . . . 477
PRINT SUPERELEMENT . . . 478
PRINT SUPPORT-REACTIONS . . . 479
PRINT VELOCITY . . . 480
PRINT WAVE-DIRECTIONS . . . 481
PRINT WAVE-LOAD-FACTORS . . . 482
PRINT WAVE-SPREADING-FUNCTION . . . 483
PRINT WAVE-STATISTICS . . . 484
PRINT WIND-FATIGUE . . . 485
RUN . . . 487
RUN CONE-CHECK . . . 488
RUN EARTHQUAKE-CHECK . . . 489
RUN FATIGUE-CHECK . . . 490
RUN HYDROSTATIC-CHECK . . . 491
RUN MEMBER-CHECK . . . 492
RUN PUNCH-CHECK . . . 493
RUN REDESIGN . . . 494
RUN STABILITY-CHECK . . . 495
RUN YIELD-CHECK . . . 496
RUN WIND-FATIGUE-CHECK . . . 497
SELECT . . . 498
SELECT CODE-OF-PRACTICE . . . 499
SELECT EARTHQUAKE-CHECK-TYPE . . . 500
SELECT FATIGUE-CHECK-TYPE . . . 501
SELECT JOINTS . . . 502
SELECT LOAD-CASE . . . 504
SELECT LOAD-SET . . . 505
SELECT MEMBERS . . . 506
SELECT MODE-SHAPE . . . 508
SELECT SET . . . 509
SET . . . 510
SET COMPANY-NAME . . . 511
SET DISPLAY . . . 512
SET DISPLAY COLOUR . . . 513
SET DISPLAY DESTINATION . . . 514
SET DISPLAY DEVICE . . . 515
SET DISPLAY WORKSTATION-WINDOW . . . 516
SET DRAWING . . . 517
SET DRAWING CHARACTER-TYPE . . . 518
SET DRAWING FONT-SIZE . . . 519
SET DRAWING FONT-TYPE . . . 520
SET DRAWING FRAME . . . 521
SET DRAWING GRID . . . 522
SET GRAPH . . . 523
SET GRAPH LINE-OPTIONS . . . 524
SET GRAPH XAXIS-ATTRIBUTES . . . 525
SET GRAPH YAXIS-ATTRIBUTES . . . 526
SET PLOT . . . 527

SET PLOT COLOUR . . . 528
SET PLOT FORMAT . . . 529
SET PLOT FILE . . . 530
SET PLOT PAGE-SIZE . . . 531
SET PRINT . . . 532
SET PRINT DESTINATION . . . 533
SET PRINT FILE . . . 534
SET PRINT PAGE-HEIGHT . . . 535
SET PRINT PAGE-ORIENTATION . . . 536
SET PRINT SCREEN-HEIGHT . . . 537
SET TITLE . . . 538
TASK . . . 539
VIEW . . . 540
VIEW FRAME . . . 541
VIEW PAN . . . 542
VIEW POSITION . . . 543
VIEW ROTATE . . . 544
VIEW ZOOM . . . 546
VIEW XYPAN . . . 547
VIEW XYZOOM . . . 548
6 Wind fatigue design . . . 549
6.1 Purpose . . . 549
6.2 Scope . . . 549
6.3 Overview and assumptions . . . 549
6.3.1 Overview . . . 549
6.3.2 Assumptions . . . 553
6.3.3 Scope of analysis . . . 553
6.4 The spectral approach . . . 553
6.5 The nature of the wind . . . 553
6.6 Wind spectra . . . 554
6.7 Wind spectra and coherence models . . . 557
6.8 A spectral forcing function . . . 558
6.8.1 Wind force on a member . . . 558
6.8.2 The wind force on a degree of freedom . . . 560
6.8.3 Spectral relationships . . . 561
6.9 Vortex shedding induced vibrations . . . 563
6.9.1 Determination of mode shape and fundamental frequency of a brace . . . 563
6.9.2 Brace oscillation amplitude calculation . . . 565
6.9.3 Member end damage calculation . . . 567
6.9.4 Member centre damage calculation . . . 568
6.10 Condensation of forces . . . 568
6.11 Stress concentration factors . . . 568
6.11.1 An overview . . . 568
6.11.2 Components of the hot-spot stresses . . . 568
6.11.3 The stress concentration factor (SCF) Schemes . . . 569
6.11.4 Non-standard joints . . . 570
6.11.5 Efthymiou scheme . . . 570
6.12 The hot-spot stress transfer function from point forcing . . . 570
6.12.1 The dynamic equation . . . 570
6.12.2 Results from the eigenvalue problem . . . 571
6.12.3 The structure displacement vector from a point force . . . 572
6.12.4 Hot-spot stresses from a point force . . . 573
6.13 Hot-spot stress power spectrum . . . 574
6.13.1 The hot-spot stress power spectra . . . 574

6.13.2 Integrating the hot-spot stress power spectra . . . 576
6.14 Calculation of fatigue life . . . 578
6.14.1 Assumptions . . . 578
6.14.2 Damage evaluation . . . 578
Appendix A Tutorial examples . . . 580
A.1 Example 1 – Code check, deterministic-, stochastic-, and spectral fatigue . . . 580
A.1.1 Joint numbers . . . 581
A.1.2 Member numbers . . . 582
A.1.3 Shaded view . . . 583
A.1.4 Preframe journal file – X108APREFRAME1_IN.JNL . . . 584
A.1.5 Finite element model . . . 587
A.1.6 Wajac data file for deterministic wave load – X108BWAJAC.INP . . . 597
A.1.7 Wajac data file for stochastic wave load – X108CWAJAC.INP . . . 597
A.1.8 Wajac data file for spectral fatigue wave loads – X108DWAJAC.INP . . . 597
A.1.9 Sestra data file for deterministic wave analysis – X108BSESTRA.INP . . . 599
A.1.10 Sestra data file for stochastic wave analysis – X108CSESTRA.INP . . . 599
A.1.11 Sestra data file for the analysis of the spectral fatigue waves – X108DSESTRA.INP . . . 599
A.1.12 Framework journal file for deterministic fatigue – X108BFRAMEWORK_IN.JNL . . . 600
A.1.13 Framework journal file for stochastic fatigue – X108CFRAMEWORK_IN.JNL . . . 611
A.1.14 Framework journal file for spectral fatigue – X108DFRAMEWORK_IN.JNL . . . 615
A.1.15 Results from deterministic fatigue analysis . . . 620
A.1.15.1 X108B_SNTEST.LIS . . . 620
A.1.15.2 X108BBUTT.LIS . . . 629
A.1.15.3 X108BDETFAT.LIS . . . 641
A.1.15.4 X108BFATADD.LIS . . . 662
A.1.16 Results from stochastic fatigue analysis . . . 686
A.1.16.1 X108CFATADD.LIS . . . 686
A.1.16.2 X108CFRAMEWORK.LIS . . . 698
A.1.17 Results from spectral fatigue analysis – X108DFRAMEWORK.LIS . . . 702
A.2 Example 2 – Wind induced fatigue . . . 713
A.2.1 Joint numbers . . . 713
A.2.2 Member numbers . . . 714
A.2.3 Shaded view . . . 715
A.2.4 Prepost journal file for converting SIF to SIN – X505BREPOST_IN.JNL . . . 716
A.2.5 Framework journal file for wind fatigue – X505BFRAMEWORK_IN.JNL . . . 717
A.2.6 Framework results from wind fatigue . . . 722
A.2.6.1 Listing file – X505BFrameworkWind.Lis . . . 722
A.2.6.2 Diagnostics file – X505BDiagnostics.txt . . . 808
A.3 Example 3 – Direct Deterministic Fatigue (X31314K) . . . 827
A.3.1 Wajac input file – DirectFatWajac.INP . . . 834
A.3.2 Sestra data file – DirectFat_Sestra.Inp . . . 835
A.3.3 Framework journal file for Direct Deterministic fatigue – DirectFat_FRAMEWORK_IN.JNL . . . 837
A.3.4 Results from Direct Deterministic Fatigue analysis–DirectFat_Framework.LIS . . . 839
Appendix B Theoretical information . . . 846
B.1 Use of the NORSOK code of practice . . . 847
B.1.1 NORSOK N-004 Rev. 2 . . . 848
B.1.2 NORSOK N-004 Rev. 3 . . . 855
B.2 Use of the EUROCODE / NS3472 code of practice . . . 856
B.3 Automatic buckling factor calculations . . . 863
B.3.1 How to use the automatic buckling length (effective length factor) facility . . . 863
B.3.2 Calculation of buckling length (effective length factor) . . . 864
B.3.3 Calculation of rotational spring stiffness . . . 865
B.3.4 Calculation of lateral spring stiffness . . . 867
B.3.5 Dump data of spring stiffnesses and buckling factors . . . 868

B.4 Codified SN Curves . . . 870
B.4.1 SN Curve Equations . . . 871
B.4.2 SN Curve Parameters . . . 873
B.5 Wide Band Correction Factor for Spectral Fatigue Analysis . . . 877
B.5.1 General . . . 877
B.5.2 Wirsching-Light correction factor . . . 877
B.5.3 Gusto empirical correction method for wind fatigue . . . 878
B.6 Power spectra and coherence models . . . 879
B.6.1 Power spectra . . . 879
B.6.2 Coherence Models . . . 880
B.7 SCF formulae and generalised influence functions . . . 882
B.7.1 Dump of intermediate results . . . 883
B.8 SCF of Butt-weld and Cone Transition . . . 887
B.8.1 SCF of buttweld connections RP-C203:2020 and 2021 . . . 887
B.8.2 SCF of butt-weld connections DNVGL-RP-C203:2014 . . . 888
B.8.3 SCF formula for cone transition . . . 890
B.9 Efthymiou SCF of tubular joints . . . 892
B.10 Lotsberg's update to Efthymiou SCF . . . 901
Appendix C Earthquake analysis . . . 902
C.1 General introduction . . . 902
C.2 Stochastic Analysis of Response of Linear Systems . . . 902
C.2.1 Introduction . . . 902
C.2.2 Definition of a Stochastic Process . . . 902
C.2.2.1 Stationarity . . . 902
C.2.2.2 Ergodicity . . . 902
C.2.2.3 Ensemble Averages in Time and Frequency Domain . . . 902
C.2.2.4 Spectral Moments . . . 904
C.2.2.5 Gaussian Processes . . . 904
C.2.3 Modeling Earthquake Ground Motions as Stochastic Processes . . . 904
C.2.4 Probability Distribution of the Peak . . . 905
C.2.5 Response of Linear SDF Oscillator to Stationary Base Excitation . . . 906
C.2.6 Response of Linear MDF System to Uni-Directional Stationary Base Excitation . . . 906
C.2.7 Correlation between Modal Responses . . . 907
C.2.8 Use of Response Spectra in Stochastic Analysis . . . 908
C.3 Modeling Multi-Directional Components of Ground Motion . . . 911
C.3.1 Introduction . . . 911
C.3.2 Penzien's Model of Ground Motion Components . . . 911
C.3.3 Transformation to Principal Directions . . . 911
C.3.4 Correlation Coefficient between Ground Motion Components . . . 912
C.3.5 Power Spectral Density Shapes for Ground Motion Components . . . 913
C.3.6 Relative Intensities for Ground Motion Components . . . 915
C.4 Structural Response to Multi-Directional Seismic Excitation . . . 915
C.4.1 Spectral Moments of Response . . . 915
C.5 Computation of Earthquake Response in Framework . . . 920
C.6 Code checking of earthquake response . . . 921
C.6.1 Load-combinations with Static and Earthquake Response Forces . . . 921
C.6.2 Limitations in the Code Checking of Earthquake Response . . . 923
Appendix D Calculation of stresses and stress resultant . . . 924
D.1 Geometric Properties of Plane Areas . . . 924
D.2 Limitations in the stress calculations . . . 926
D.2.1 Axis of symmetry . . . 927
D.2.1.1 The product of inertia for an L-section . . . 928
D.2.2 Twist and shear centre . . . 929
D.2.2.1 Shear centre for an open general section . . . 930

D.2.2.2 Shear centre for a channel section with one axis of symmetry . . . 932
D.2.3 Concentrated loads . . . 935
D.2.4 Tapered beams . . . 936
D.3 Sign convention of internal stress resultants . . . 936
D.4 Calculation of maximum stress components . . . 944
D.4.1 General explanation of stress output . . . 945
D.4.2 Notation and basic formulae . . . 945
D.4.3 Formulae used for static load cases . . . 946
D.4.4 Formulae used for dynamic load cases . . . 946
D.4.5 Formulae used for combined load cases . . . 947
D.5 General section stresses . . . 947
D.6 Calculation of equivalent stresses . . . 948
D.6.1 Equivalent stresses in a pipe element . . . 948
D.6.2 Equivalent stresses in I- or H-beams . . . 949
D.6.3 Equivalent stresses in channel elements . . . 949
D.6.4 Equivalent stresses in box elements . . . 950
D.6.5 Equivalent stresses in general beam elements . . . 951
D.7 Transformation to In-plane/Out-of-plane Co-ordinate System . . . 951
D.7.1 Transformation angle . . . 951
D.7.2 Transformation of element bending moments to in-plane/out-of-plane moments . . . 952
Appendix E Code check according to API and AISC – working strength design . . . 953
E.1 General description . . . 953
E.2 Yield check . . . 953
E.2.1 Yield check pipe elements . . . 953
E.2.2 Yield check I- or H-beams . . . 956
E.2.2.1 Check for normal stresses [AISC formula H1-2] . . . 956
E.2.2.2 Check for shear stresses . . . 960
E.2.3 Yield check channel section . . . 961
E.2.3.1 Check for normal stresses [AISC formula H1-2] . . . 961
E.2.3.2 Check for shear stresses . . . 962
E.2.4 Yield check box section . . . 963
E.2.4.1 Check for normal stresses [AISC formula H1-2] . . . 963
E.2.4.2 Check for shear stresses . . . 965
E.2.5 Yield check general beam section . . . 965
E.2.5.1 Check for normal stresses . . . 966
E.2.5.2 Check for shear stresses . . . 966
E.2.5.3 Combined stress check . . . 966
E.3 Stability check . . . 969
E.3.1 Stability check pipe elements . . . 969
E.3.1.1 Hydrostatic collapse . . . 972
E.3.1.2 Axial tension and hydrostatic collapse interaction . . . 973
E.3.1.3 Axial compression and hydrostatic pressure . . . 973
E.3.2 Stability check I- or H- elements . . . 974
E.3.2.1 General . . . 974
E.3.2.2 Element and section criteria . . . 976
E.3.2.3 Allowable stresses . . . 976
E.3.3 Stability check channel elements . . . 976
E.3.3.1 General . . . 976
E.3.3.2 Element and section criteria . . . 977
E.3.3.3 Allowable stresses . . . 977
E.3.4 Stability check box elements . . . 977
E.3.4.1 General . . . 977
E.3.4.2 Element and section criteria . . . 978
E.3.4.3 Allowable stresses . . . 979

E.3.5 Stability check of general beam elements . . . 980
E.4 Punching shear check . . . 981
E.4.1 Simple joints . . . 981
E.4.2 Overlapping joints . . . 984
E.5 Nomenclature . . . 985
Appendix F Code check according to API and AISC – load and resistance factor design . . . 986
F.1 General description . . . 986
F.2 Yield check . . . 987
F.2.1 Yield check pipe elements . . . 987
F.2.2 Yield check I- or H-beams . . . 989
F.2.2.1 Check for Normal Stresses [AISC formula H1-1] . . . 989
F.2.2.2 Check for Shear Stresses . . . 992
F.3 Stability Check . . . 993
F.3.1 Program logic and output . . . 993
F.3.2 Stability check pipe elements . . . 993
F.3.2.1 Hydrostatic collapse . . . 995
F.3.2.2 Axial tension and hydrostatic collapse interaction . . . 996
F.3.2.3 Axial compression and hydrostatic pressure . . . 997
F.3.3 Stability check I- or H-elements . . . 997
F.3.3.1 General . . . 997
F.3.3.2 Element and section criteria . . . 998
F.3.3.3 Nominal strength . . . 999
F.3.3.4 Interpretation of Framework result table . . . 999
F.4 Punching shear check . . . 1000
F.4.1 Simple joints . . . 1000
F.4.2 Overlapping joints . . . 1003
Appendix G Code check according to NPD/NS3472 . . . 1004
G.1 General description . . . 1004
G.2 Yield check . . . 1004
G.3 Stability checks according to the NPD/NS3472 codes . . . 1005
G.3.1 Stability check of pipe Elements . . . 1005
G.3.1.1 Interaction Effects from Local Buckling for Pipe Elements . . . 1005
G.3.1.2 Default value for column buckling factors . . . 1005
G.3.1.3 Interpretation of Framework result table . . . 1006
G.3.2 Stability check of non-pipe elements . . . 1006
G.3.2.1 Calculation of axial compression buckling strength . . . 1008
G.3.2.2 Calculation of lateral buckling strength . . . 1009
G.3.2.3 Flexural-torsional buckling . . . 1010
G.3.2.4 Local buckling of web and/or flange . . . 1011
G.3.2.5 Calculation of Design Moments . . . 1012
G.3.2.6 Calculation of usage factors for non-pipe members . . . 1016
G.4 Punching shear check . . . 1019
G.5 Nomenclature . . . 1020
Appendix H Deterministic fatigue analysis (discrete wave approach) . . . 1021
H.1 Summary . . . 1021
H.2 Theoretical description . . . 1021
H.2.1 Wave data . . . 1021
H.2.2 Wave loading . . . 1021
H.2.3 Member forces . . . 1021
H.2.4 Stress Calculation for pipe elements . . . 1021
H.2.4.1 Kuang Formulas . . . 1025
H.2.4.2 Wordsworth/Smedley Formulas . . . 1026
H.2.4.3 Notes . . . 1026
H.2.4.4 Efthymiou Formulas . . . 1027

H.2.4.5 Marshall reduction factor . . . 1027
H.2.5 Long term distribution of stress ranges . . . 1027
H.2.6 SN curves . . . 1028
H.2.7 Calculation of accumulated fatigue damage . . . 1029
Appendix I Spectral fatigue analysis (time domain analysis) . . . 1030
I.1 Introduction . . . 1030
I.2 Deterministic wave load Calculation . . . 1030
I.3 Transfer function computation . . . 1031
I.3.1 Stress Concentration Factors . . . 1031
I.4 Wave statistics . . . 1032
I.4.1 Short term and long term wave conditions . . . 1032
I.4.2 Wave scatter diagram . . . 1032
I.5 Damage calculation . . . 1032
I.5.1 Main wave direction, spreading function and stress transfer function . . . 1032
I.5.2 Stress response spectrum . . . 1033
I.5.3 SN curves . . . 1033
I.5.4 Formula of Damage Calculation . . . 1033
Appendix J Stochastic fatigue analysis (frequency domain fatigue analysis) . . . 1035
J.1 Introduction . . . 1035
J.2 Theoretical description . . . 1035
J.2.1 Wave loading . . . 1035
J.2.2 Member forces . . . 1035
J.2.3 Stress Concentration Factors . . . 1035
J.2.4 Short term description of sea states . . . 1035
J.2.5 Main wave direction stress transfer function . . . 1037
J.2.6 Stress response spectrum . . . 1037
J.2.7 SN curves . . . 1037
J.2.8 Calculation of partial damage for one sea state . . . 1037
J.2.9 Calculation of accumulated damage . . . 1038
Appendix K Notation used in the text . . . 1039
Appendix L Program limitations . . . 1040

1 Introduction

1.1 Framework – Post-processor for Frame Structures

Framework is Sesam's program for post-processing of results from linear structural analysis of frame structures. The features include checks against allowable stress levels, member stability, punching shear, fatigue, and earthquake analysis.

Framework is characterised by:

- Interactive menu-based input
- Flexible graphical and tabular presentation of results
- Analysis results checked against rules defined by internationally recognised codes

You should be familiar with the rules and procedure of the type of post-processing you want to do as this user manual is not intended to cover such. For example, if you want to do a code check according to the API rules you should know this code of practice and if you want to do a fatigue analysis you should be familiar with the procedure of such analysis.

1.2 Framework in the Sesam System

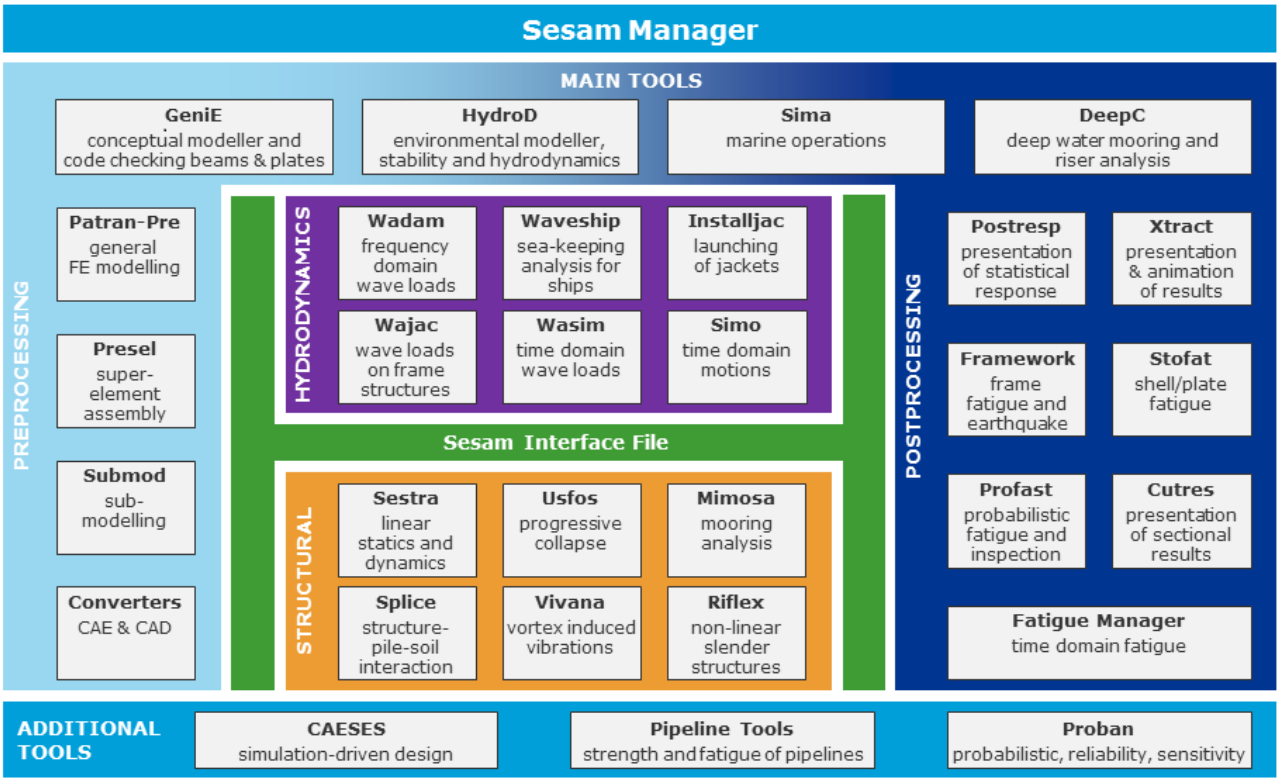


Figure 1.1: Sesam overview

Sesam is comprised of concept modellers, pre-processors, environmental analysis programs, structural analysis programs and post-processors. An overview of Sesam is shown in Figure 1.1. Frame type structures are typically modelled in Sesam GeniE (and Presel if including the superelement technique). Hydrodynamic loads, if relevant, are computed by the hydrodynamic analysis program Wajac. The linear structural analysis is performed by Sestra. Finally, the structural analysis results are read into Framework for post-processing.

1.3 How to read this Manual

Section 2 describes the post-processing capabilities of Framework together with post-modelling features (adding data irrelevant for the structural analysis). Information on the types of loading and load combinations that can be handled by the different types of post-processing is also provided. The section is organised as follows:

- Section 2.1 summarises the post-processing capabilities provided for code checks, fatigue analysis and earthquake analysis.
- Section 2.2 provides information on the loads, load combinations and on the calculation of displacements, velocities, accelerations, forces and stresses.
- Section 2.3 explains in general terms the use of all input data that is defined through the commands.
- Table 2.2 contains important information that can be used to determine the data required for a particular analysis.

Section 3 User's guide to Framework contains examples of various post-modelling features and analysis capabilities which are illustrated through the use of a small two-dimensional jacket structure. Section 4 Execution of Framework contains more special information not intended for the new user using Sesam Manager to control his Sesam analysis. The chapter explains how to start Framework outside Sesam Manager and operate it in line-mode (not using the graphical user interface). The files used by Framework are also explained. Practical information is provided on how to operate Framework and manipulate its files in various ways. Built-in and hardware dependent requirements and limitations are also described. Section 5 Command description provides an alphabetically sorted description of all commands and associated input data.

Appendix A – Tutorial examples – contains two examples which are part of the Framework installation.

Appendix B – Theoretical information – contains additional information regarding

- Use of the NORSOK code of practice. (Appendix B.1)
- Use of the EUROCODE / NS3472 code of practice. (Appendix B.2)
- Automatic buckling factor calculations. (Appendix B.3)
- Codified S-N Curves. (Appendix B.4)
- Wide Band Correction Factor for Spectral Fatigue Analysis. (Appendix B.5)
- Power spectra and coherence models. (Appendix B.6)
- SCF formulae and generalised influence functions (Appendix B.7)

Appendix D – Calculation of stresses and stress resultant, Appendix H – Deterministic fatigue analysis (discrete wave approach), Appendix I – Spectral fatigue analysis (time domain analysis), and Appendix J – Stochastic fatigue analysis (frequency domain fatigue analysis) – contain background material to the fatigue analyses available in Framework.

Note that many of the commands used in Framework are particularly designed for use with jacket structures (i.e. structures with members having tubular cross sections) and hence will be irrelevant to use when working with other kind of structures.

Appendix L provides the current Framework model size limitations.

1.4 Framework Extensions

Framework is available in a basic version with extensions. The extensions contain the various codes of practice plus the fatigue and earthquake analysis features. The extensions are (see Section 2.1 for more details):

- Extension API containing the code API-AISC-WSD

- Extension LRFD containing the code API-AISC-LRFD
- Extension NPD containing the code NPD-NS3472(rel. 2) / NORSOK
- Extension FATG containing the fatigue analysis features
- Extension EURO containing the code EUROCODE-NS3472(rel. 3)
- Extension ERQK containing the earthquake analysis features
- Extension WIND containing the gust wind fatigue analysis features
- Extension GRPH containing model display features (the commands DISPLAY, PLOT and VIEW)

1.5 Status List

There exists for Framework (as for all other Sesam programs) a Status List providing additional information.

This may be:

- Reasons for update (new version)
- New features
- Errors found and corrected
- Etc.

2 Features of Framework

2.1 Post-processing capabilities

2.1.1 Code checks

The code checks available are as follows:

- Yield
- Stability
- Member (combined yield and stability)
- Hydrostatic collapse
- Punching shear limit
- Conical transition

A yield check of a frame structural member is performed to assess whether the member is subjected to acceptable stress levels. This check is performed through the use of a 'yield interaction equation'. This equation is stipulated by the code of practice and delivers as result a usage factor. If this usage factor is less than 1.0 then the member is classed as 'safe'. If the usage factor is greater than 1.0 then the member is classed as 'unsafe' and this is highlighted by the program. A yield check on a member is by default performed at three positions: at the two ends of the member and at the midpoint. However, the user may assign additional positions along the member to be checked.

A stability check is performed on a frame structural member to assess potential failure due to buckling phenomena. As for the yield check this assessment is made through the use of a 'stability interaction equation' which delivers the usage factor.

A hydrostatic collapse check is performed to assess the member induced stresses due to the action of hydrostatic pressure and other externally applied loads. This check is for NPD-NS3472 and NORSOK integrated with the stability check.

A punching shear check is performed on the brace member at a joint to assess the shear through the chord. As for the other checks this assessment is made through the use of a 'punching shear interaction equation' which delivers a usage factor. The punching shear check is performed for all braces at selected joints.

A cone check is performed to assess the stresses in the transition between cone and cylinder. As for the other checks this assessment is made through the use of a 'conical transition interaction equation' which delivers a usage factor. The cone check is performed for cylinder and cone at both ends of the conical transition.

Note that API supersedes the AISC rules for tubular members. As codes of practice are updated consult the Framework Status List to obtain the code edition valid for your version of the program.

For the API-AISC-WSD code of practice, the allowable stress are automatically increased as follows:

- Operating conditions: 0%
- Storm conditions: 33.3%
- Earthquake conditions: 70%

Section types that may be code checked are:

- Tubular sections (PIPE).
- Symmetrical/un-symmetrical I or H sections (I).
- Channel sections (CHAN).
- Box sections (BOX).
- Massive bar sections (BAR).

- General sections (GENE).

Table 2.1: Codes of practice

API-AISC-WSD			
American Institute of Steel Construction	9th ed.	1989	[50]
American Petroleum Institute	RP2A 21th ed.	2000	[31]
API-AISC-LRFD			
American Institute of Steel Construction	LRFD	1999	[29]
American Petroleum Institute	RP2A 1st ed.	1993	[36]
NPD-NS3472			
Norwegian Petroleum Directorate	Volume 2	1994	[35]
Norwegian Standard Association	NS3472 2nd ed.	1984	[38]
NORSOK			
Norwegian Technology Standards Inst.	N-004, Rev 2	2004	[57]
Norwegian Technology Standards Inst.	N-004, Rev 3	2013	[58]
EUROCODE-NS3472			
European Committee for Standardization	ENV 1993-1-1	1992	[19]
Norwegian Standard Association	NS3472, 3rd ed.	2001	[13]
ISO 19902			
International Standard	1st ed.	2007	[33]
ANSI/AISC 360-10			
American Institute of Steel Construction		2010	[41]
API			
American Petroleum Institute	RP2A WSD 21st ed.	2007	[54]

Stresses in a cross section are calculated at a set of pre-defined stress point. The code checks are performed at some of these points in order to assess the maximum (i.e. worst) interaction ratio, and therefore to determine the point on the section that is prone to failure. A full description of where stresses are calculated for various section types in the case of code checks may be found in Section 2.2.3.

Table 2.2 shows for each code of practice the type of check that may be performed and the section type that may be processed.

For NPD-NS3742 (rel. 2) and NORSOK hydrostatic collapse is implemented as a part of the stability / member check.

For NORSOK and EUROCODE-NS3472 (rel. 3) the yield and stability checks have been merged into one member check. It is also an option to run a combined yield, stability and hydrostatic check for the API-AISC codes of practice.

It is also possible to perform member redesign / resize in connection with yield, stability, member and hydrostatic checks, and joint strengthening in connection with punching shear check.

Table 2.2: Codes of practice and types of checks

Code of practise	Check	Member section					
		PIPE	I	CHA	BOX	BAR	GEN
API-AISC-WSD	Yield	X	X	X	X		X
	Stability	X	X	X	X		X
	Punching shear limit	X					
	Hydrostatic collapse	X					
	Conical transition	X					
API-AISC-LRFD	Yield	X	X	X	X		X
	Stability	X	X	X	X		X
	Punching shear limit	X					
	Hydrostatic collapse	X					
	Conical transition	X					
NPDNS3472 (rel. 2)	Yield	X	X	X	X		X
	Stability	X	X	X	X		X
	Punching shear limit	X					
	Hydrostatic collapse	X					
	Conical transition	X					
NORSOK	Member	X					
	Punching shear limit	X					
	Hydrostatic collapse	X					
	Conical transition	X					
EUROCODE-NS3472 (rel. 3), AISC 360-10	Member	X	X	X	X		X

The available ways of combining loads for use in code checks are shown below:

Static	One or a combination of static load cases
Freq	One load case from a frequency domain analysis
Time	One or a combination of load cases from a time domain analysis
Earth	One load case from an earthquake analysis
Static+Freq	Combination of above alternatives
Static+Time	Combination of above alternatives
Static+Earth	Combination of above alternatives

Prior to performing a code check analysis, it is usual first to model local details on a structure. Local details do not in general affect the global behaviour of the structure, but may significantly affect the behaviour of individual members.

This post-modelling can be performed in Framework through the definition of the appropriate input data.

The modelling tools available in Framework include:

- Automatic and explicit definition of CHORD and BRACE members.
- Assignment of a CAN section at a joint. The CHORD member (and the possibly ALIGNED CHORD member) at the joint automatically inherits the CAN section geometry at that joint.
- Definition of a STUB section, typically assigned to a BRACE member.
- Use of effective length factors for modelling in-plane and out-of-plane buckling effects.
- Definition or automatic calculation of moment amplification reduction factors, to account for secondary moments due to axial loads in buckling calculations.
- Definition of different yield strength at different parts of the structure to account for differences in the grade of steel. Yield strength is defined through a material property.
- Modelling joints, gaps, and overlapping joints.
- Section re-definition.

For each of the codes of practice and code check type, all input data used, mandatory and optional, is shown in Table 2.7 through Table 2.9 and described in Section 2.6.2.

Usually, the procedure adopted for a code check analysis is as follows:

- Modelling of local details.
- Creation of load combinations with the appropriate factors.
- Execution of code check.
- Evaluation of results using print and display features.

The format and explanation of the results from code checks can be found in Appendix A.

2.1.2 Fatigue analysis

2.1.2.1 General introduction

A fatigue analysis in Framework is performed on a frame structural member in order to assess whether that member is likely to suffer failure due to the action of repeated loading. This assessment is made using Miners rule of cumulative damage, which delivers a usage factor representing the amount of fatigue damage that a member has suffered during the specified period. A fatigue analysis in Framework can be performed using either:

- a deterministic approach (see Section 2.1.2.2),
- a spectral approach (see Section 2.1.2.3),
- a stochastic approach (see Section 2.1.2.4),
- a time history approach (see Section 2.1.2.5).
- a direct deterministic approach (see Section 2.1.2.6).

The approaches are compared in Table 2.3. A factor influencing the development of fatigue failure is the overall geometry of the joint and the detailed geometry of its welds. For any particular type of loading, the joint geometry governs the value of the stress concentration in the region where fatigue cracking is likely to initiate. This region is termed as the hotspot. In Framework, hotspot stress concentration factors (SCFs) may be specified by the user. For tubular members only, the user may alternatively have the SCFs automatically calculated by the program using a set of parametric equations based on the joint type (K, YT, X, etc.). Each hotspot is associated with 3 stress concentration factors (referred to herein as a set). These are:

- SCF for axial stresses,
- SCF for in-plane bending stresses,

- SCF for out-of-plane bending stresses.

For tubular members, SCFs are normally assigned at 8 hotspots per weld side. The hotspots are equally spaced around the pipe circumference. For non-tubular members, 4 hotspots are normally used as shown in Section 2.2.3. A SCF is defined as the factor by which the nominal stress due to pure axial force or pure in-plane/out-ofplane bending (at the stress point in question) must be multiplied in order to give the hotspot stress used in the damage calculation. The parametric SCFs may be calculated based on formulas by:

- Kuang for YT, K and KT joints / Wordsworth and Smedley for X joints.
- Efthymiou for X, YT, K and KT joints.
- Lloyd's Register for gap K and KT joints.
- Smedley and Fisher for SCF ratios for ring stiffened tubular joints (modify parametric SCFs).
- NORSOK standard for SCFs at butt welds and conical transitions (moved to DNV-RP-C203).

The user defined SCFs are referred to as GLOBAL and LOCAL. GLOBAL SCFs define a set of stress concentration factors which, unless other assignments are made, will be applied:

- to all members.
- at all hotspots.
- at both ends.

LOCAL SCFs define a set of stress concentration factors assuming a variety of SCF distributions:

- to a specific member.
- to one or both ends.
- to a selected (chord/brace) or both weld sides.

If the user wants to delete a local SCF assignment, the option GLOBAL SCFs may be reassigned to selected joints.

When parametric SCFs are assigned to members at selected joints and joint type is set to LOADPATH, the SCFs will then be calculated based on the classification of brace type given by the load path (similar to the joint classification done in the punching shear check, see [33] and [54]). The resulting SCFs at the different hotspots will then be the percentage accumulated SCF according to the behaviour of the brace. E.g. for a brace which is classified as 40% YT and 60% KTK the SCFs will be: SCF(as YT)*0.4 + SCF(as KTK)*0.6. When selecting SCF calculations according to Efthymiou the influence function formulation may also be used.

For a deterministic analysis (deterministic and spectral fatigue) with joint type set to LOADPATH the brace type (and hence the SCFs) will be calculated for every step at each wave (waves of various heights and direction) used to obtain the stress history for the selected members at the investigated positions and hotspots. For a stochastic analysis with joint type set to LOADPATH the brace type (and hence the SCFs) will be calculated for each harmonic wave (waves of unit amplitude at certain phase angle) used to obtain the stress transfer functions for the selected members at the investigated positions and hotspots. For a time history fatigue analysis with joint type set to LOADPATH the brace type (and hence the SCFs) will be calculated for each time step used to obtain the stress transfer functions for the selected members at the investigated positions and hotspots. For more information on parametric SCFs, see Section 2.3.34 and Framework Theory Manual [26] Section 7.2.4.

Forces and moments for a fatigue analysis are required to be transformed into an in-plane and out-of-plane coordinate system. This transformation is derived from the definition of CHORD and BRACE members and the local axis system for each member.

Another factor influencing the development of fatigue failure, is the type, amplitude, mean level and distribution of the applied loads. The applied nominal stress history, as increased locally at the hotspot, generates

the stressing sequence which controls fatigue crack initiation and subsequent failure. In calculating the fatigue life of a joint, the sequence of stressing is not taken into account as fatigue life is calculated using the number of cycles computed for discrete hotspot stress ranges, together with an appropriate SN fatigue design curve, utilising the Miners rule.

The SN curves in Framework may be user defined or predefined in the program. In the latter case, selected DNVGL, API, ISO19902, NS3472, NORSOK, HSE, ABS and DOE curves are available. It is also possible to incorporate thickness effects in the SN curve by factoring the hotspot stresses. For members with non-pipe cross sections, the actual thickness used when calculating the thickness correction factor is the maximum plate thickness (flange or web) from the section.

The loads for a fatigue analysis must be computed from a hydrodynamic analysis using a deterministic or a stochastic approach. Deterministic in this context, implies that the computed loads are 'real' while stochastic implies that the computed loads are 'complex', comprising of real and imaginary components. The Wajac [60] computer program may be used to compute hydrodynamic loads for subsequent fatigue analysis in Framework. For stochastic fatigue Wadam may also be used to compute the hydrodynamic loads.

A member will as default have two fatigue check positions at each member end, denominated CHORDSIDE and BRACE-SIDE of the weld. They are both required when using parametric SCFs for brace members. The position names will also include the relative position along member axis, i.e the four default positions are named:

`CHORD-SIDE-0.0000` (position 1 at member end 1)

`BRACE-SIDE-0.0000` (position 2 at member end 1)

`BRACE-SIDE-1.0000` (position 3 at member end 2)

`CHORD-SIDE-1.0000` (position 4 at member end 2)

However, if a member end has assignments which implies that the calculated damages of the chord side and brace side positions of the weld are equal, damage is calculated and printed for only one of the positions, i.e. position 1 at member end 1 and position 3 at member end 2. In the result files the weld side is denominated 'BOTH-SIDES' in such a case. This is made consistent for assignments affecting the damage calculation such as SCF-rules, SN-curves, thicknesses and thickness corrections.

2.1.2.2 Deterministic fatigue analysis

A deterministic fatigue analysis requires a deterministic hydrodynamic analysis (Wajac) followed by a static structural analysis (Sestra). Deterministic loads are obtained by 'stepping' waves of various heights and directions through the structure in order to obtain (through a structural analysis) a 'stress history' for each member at each of its hotspots.

It is important to note that NO OTHER LOADS (e.g. gravity, etc.) should be present in the Input Interface File during the execution of the structural analysis.

Consult Appendix L for the limitations in Framework regarding the wave conditions that can be specified in the hydrodynamic analysis.

For each of the wave directions specified in the hydrodynamic analysis, it is necessary, in Framework, to specify the total number of waves passing through the structure. A long term distribution of wave heights is then produced for each of the wave directions in order to obtain, for each wave height, the associated number of waves. The long term distribution of wave heights may be obtained using either a long term Weibull distribution or a piece-wise linear distribution in H-logN space.

The analysis steps carried out in Framework are as follows:

- The long term stress range distribution is derived at each hotspot (BRACE and CHORD side) for each of the wave directions. The long term stress range distribution may be created on the basis of up to 10 wave heights. Each of the discrete stress range values is derived by calculating the largest hotspot stress difference from the different wave positions. Thus a maximum of 10 stresses may be calculated for each hotspot and each wave direction.

Table 2.3: Sesam fatigue analyses compared

Fatigue Analysis (*line mode command*: METHOD) Description	Pros & Cons of the fatigue analysis method
Deterministic (*line mode command*: DETERMINISTIC) Deterministic fatigue analysis based on loading from deterministic individual waves	The deterministic fatigue analysis method is for dynamically insensitive structures in shallow to medium water depths where non-linearities in the wave force such as drag and variable submergence are of importance. The energy content of the sea-states is not directly represented in the method so judgement and experience is required in selecting the discrete waves to include in the analysis.
Spectral (*line mode command*: SPECTRAL) Spectral fatigue analysis based on transfer functions from deterministic individual waves	The spectral fatigue analysis method is for dynamically insensitive structures in shallow to medium water depths where non-linearities in the wave force such as drag and variable submergence are of importance. The method properly represents the energy content of the sea-states.
Stochastic (*line mode command*: STOCHASTIC) Spectral fatigue analysis based on transfer functions from linearised frequency domain waves	The stochastic fatigue analysis method is for dynamically sensitive and insensitive structures in deep water where the non-linearities in the wave force are less important. The structural dynamic analysis, if required, may be computer intensive. The method properly represents the energy content of the sea-states.
Time history (*line mode command*: TIME-HISTORY) Time history fatigue analysis based on loading from a time domain simulation	The time history fatigue analysis method is for studies allowing inclusion of wave force non-linearities as well as structural dynamics. The method is computer intensive involving a large number of time domain simulations in order to capture the energy of the sea-states properly.
Direct Deterministic (*line mode command*: DIRECT-DETERMINISTIC) Direct Deterministic fatigue analysis based on any load or load combination; either individual wave loads or static loads	The direct deterministic fatigue method is for the purpose to approximately estimate the fatigue impact due to certain “determined” (known) loading scenario. Any cyclic loading type is applicable. The number that the load case or load combination repeats must be provided. Note: currently, the load from frequency domain is not supported.

- The long term stress range distribution is discretized into 100 blocks, with each block having the same length.
- The average stress range for each of the 100 blocks is then calculated in order to determine the number of cycles to failure (from the SN curve) for each of the wave directions.
- Miners rule of cumulative damage is then used to sum the damage at each hotspot from each of the wave directions.

All data, mandatory and optional, used in the deterministic fatigue analysis are shown in Table 2.10 and are described in Section 2.6.2.

Usually, the procedure adopted for a deterministic fatigue analysis is as follows:

- Definition of fatigue constants (target fatigue life, global SCFs, etc.)
- Assignment of CHORD members
- Modelling of local details (assignment of CAN and STUB sections, etc.).
- Assignment of joint type and joint gap/overlap data.
- Assignment of SCFs.
- Assignment of SN curve.
- Assignment of individual wave data.
- Execution of fatigue analysis.
- Printing of results.

With joint type set to LOADPATH, the brace type (and hence the SCFs) will be calculated for each step in each wave (waves of various heights and direction) used to obtain the stress history for the selected members at the investigated positions and hotspots.

For joint type LOADPATH used in combination with parametric SCFs, the print of the results will report SCFs partly according to joint geometry and partly according to the actual worst hotspot. The SCFaxC and SCFaxS are the hotspots for the Crown and Saddle positions independent of worst hotspot regarding fatigue. The SCFipb and SCFopb are the SCFs for crown position from in-plane bending and saddle position from out-of-plane bending (also independent of worst hotspot regarding fatigue). The SCFax is the actual SCF for axial force used for the hotspot reported to be governing. Hence, if the worst hotspot is a saddle point (1 or 13) the SCFaxS is reported, if a crown point (7 or 19) the SCFaxC is reported, and if any points in between (4, 10, 16 or 22) the average value SCF of crown and saddle is used.

For the explanation and format of results see Appendix A.

It is also possible to perform deterministic fatigue analysis of general cyclic loads. An auxiliary program named DetSfile may be used to generate the Sx.FEM file necessary for Sestra and Framework to treat the loads as wave loads. Each stress range caused by cyclic loading must be represented by 2 load cases defined in Preframe (in Genie now) and combined in Presel. Please consult the DNV – Software download for example input and the auxiliary program DetSfile. This feature can be replaced by using the Direct Deterministic Fatigue method 2.1.2.6.

2.1.2.3 Spectral fatigue analysis

Similar to the deterministic fatigue analysis, a spectral fatigue analysis requires a deterministic hydrodynamic analysis (Wajac) followed by either a static structural analysis or dynamic wave response analysis by (Sestra). The loads to calculate (through a structural analysis) hotspot stress transfer functions are obtained by 'stepping' selected design waves of various heights and directions through the structure. In the dynamic wave response analysis, the structural response of steady state at specified time steps of each wave are output into the result file. See Sestrauser document for details. It is recommended to skip dead loads (e.g. gravity, etc.) in spectral wave fatigue analysis.

The maximum allowed number of time steps of a wave cycle is 36 steps in static wave analysis and 35 in dynamic wave analysis. For the other limitations, consult Appendix L for the limitations in Framework regarding the wave conditions that can be specified in the hydrodynamic analysis.

Unlike the deterministic fatigue method requiring the long term distribution of wave heights, the spectral fatigue analysis is based on the short term distribution of the stress response to every input sea-states and assumes the response follows Rayleigh distribution. The long term statistics of hotspots stress range shall be obtained by accumulating the corresponding short term stress statistics. A set of stress transfer function for each direction for each member at each of the hotspots is calculated in Framework . In general, to get the stress transfer functions the number of individual waves required in a spectral fatigue analysis is more than those for a deterministic fatigue analysis. Also, more efforts are needed to select those design waves with appropriate wave period and wave height. Some associated references, e.g. ISO 19902-2007 and API RP2A, can be used to guide the selection of wave height and periods.

The spectral fatigue analysis differs from the stochastic analysis on how to get the stress range transfer function. By contrast, spectral fatigue does not require the harmonic wave input with unit amplitude, does not need linearization of wave forces, does not use the corresponding real and imaginary components of harmomic response as the transfer function, while these are needed in the stochastic fatigue analysis. In spectral fatigue, the stress range for an individual wave is calculated through the load steps over one wave period which is similar to the deterministic analysis. Except for the transfer functions, the procedure to calculate fatigue damage in the spectral method is similar to that in a stochastic fatigue analysis. The related wave statistics data are the same as those in the subsequent section 2.1.2.4, such as wave scatter diagram, wave direction probabilities, wave spectrum shapes, sea spreading function. The closed-formula of damage calculation is employed for one sea-state. The total damage at one hot spot is accumlated by the partial damage from all sea-states in all directions.

The analysis steps carried out in Framework are as follows:

- The stress range transfer functions for each hotspot is calculated. The stress range is obtained from the wave load steps after the structural analysis for each deterministic wave at certain wave period. The transfer function is equal to the stress range scaled by the corresponding wave height.
- The square modulus of elementary wave direction transfer functions, are multiplied with the spreading function weights, in order to generate the modulus of the stress transfer function for each of the wave directions.
- The wave spectrum corresponding to significant wave height Hs and zero-crossing wave period Tz is multiplied by the modulus of the hotspot stress transfer function for each of the wave directions in order to provide the hotspot stress response spectrum.
- Partial damage is calculated for each sea-state and wave direction using the SN curve.
- Partial damages are weighted over the sea-states and wave directions in order to assess the total damage.

All data, mandatory and optional, used in the spectral fatigue analysis are shown in Table 2.10 and are described in Section 2.6.2.

Usually, the procedure adopted for a spectral fatigue analysis is as follows:

- Definition of fatigue constants (target fatigue life, default SN curve, global SCFs, etc.)
- Assignment of CHORD members (optional; chord and brace can be automatically determined by the program)
- Modelling of local details (assignment of CAN and STUB sections, etc., if necessary).
- Assignment of joint type and joint gap/overlap data.
- Assignment of SCFs (to joint and to member’s intermediate positions).
- Assignment of SN curve.

- Assignment of seastate data (wave statistics, wave direction probability).
- Execution of fatigue analysis.
- Printing of results.

With joint type set to LOADPATH, the brace type (and hence the SCFs) will be calculated for each step in each wave (waves of various heights and direction) used to obtain the stress history for the selected members at the investigated positions and hotspots. The format of the print-out of results for LOADPATH joint type is the same as that in deterministic fatigue in the previous section. For the explanation and format of results see Appendix A.

2.1.2.4 Stochastic fatigue analysis

A stochastic fatigue analysis requires a linearised frequency domain hydrodynamic analysis (Wajac) followed by a quasi-static or dynamic structural analysis (Sestra). Load transfer functions are obtained by passing a harmonic waves of unit amplitude at different frequencies and directions through the structure in order to obtain (through a structural analysis) a set of stress transfer functions for each direction for each member at each of its hotspots.

It is important to note that NO OTHER LOADS (e.g. gravity, etc.) should be present in the Input Interface File during the execution of the structural analysis.

Consult Appendix L for the limitations in Framework regarding the wave conditions that can be specified in the hydrodynamic analysis.

Other wave related data are required to be defined in Framework and these are as follows:

- Short term sea-states and corresponding probabilities in order to describe the long term distribution of the short term sea-states. A short term sea-state is characterised by a significant wave height, denoted as Hs, and a zero up-crossing period, denoted as Tz. The sum of the probabilities for all sea-states must be 1.00.
- Probability of occurrence for each of the wave directions defined during the hydrodynamic analysis. The sum of the probabilities for all wave directions must be 1.00.
- The wave spectrum shape used may be either a JONSWAP, Pierson-Moskowitz, Gamma or ISSC spectrum. The same wave spectrum shape may be used for all the sea-states, or assigned individually for parts of the scatter diagram. If the wave statistics has been defined through an 'all parameter scatter diagram', all necessary parameters are given through the `CREATE WAVE-STATISTICS` command, and hence a wave spectrum shape shall not be assigned to the wave statistics.
- Sea spreading data in order to define the number of elementary wave directions and the associated energy content. The number of elementary wave directions may be arbitrary. The sum of the energy content for all elementary wave directions must be 1.00. Note that the spacing of the elementary wave directions should be the same as that of the main wave-directions. The spreading data is assigned to the scatter diagram.

The analysis steps carried out in Framework are as follows:

- The square modulus of elementary wave direction transfer functions, are multiplied with the spreading function weights, in order to generate the modulus of the stress transfer function for each of the wave directions.
- The wave spectrum corresponding to Hs and Tz is multiplied by the modulus of the hotspot stress transfer function for each of the wave directions in order to provide the hotspot stress response spectrum.
- Partial damage is calculated for each sea-state and wave direction using the SN curve.
- Partial damages are weighted over the sea-states and wave directions in order to assess the total damage.

All data, mandatory and optional, used in the stochastic fatigue analysis are shown in Table 2.10 and are described in Section 2.6.2.

Usually, the procedure adopted for a stochastic fatigue analysis is as follows:

- Definition of fatigue constants (target fatigue life, global SCFs, etc.)
- Assignment of CHORD members
- Modelling of local details (assignment of CAN and STUB sections, etc.).
- Assignment of joint type and joint gap/overlap data.
- Assignment of SCFs.
- Assignment of SN curve.
- Assignment of seastate data.
- Execution of fatigue analysis.
- Printing of results.

With joint type set to LOADPATH, the brace type (and hence the SCFs) will be calculated for each harmonic wave (waves of unit amplitude with different frequencies and directions) used to obtain the stress transfer functions for the selected members at the investigated positions and hotspots. The brace axial forces for loadpath balance are obtained at certain phase angle. The default phase angle is 0. User can specify the phase angle by command DEFINE CONSTANTS PHASE-ANGLE. The first phase angle in the list will be applied to extract brace loads.

For joint type LOADPATH used in combination with parametric SCFs, the print of the results will report SCFs partly according to joint geometry and partly according to the actual worst hotspot. The SCFaxC and SCFaxS are the hotspots for the Crown and Saddle positions independent of worst hotspot regarding fatigue. The SCFipb and SCFopb are the SCFs for crown position from in-plane bending and saddle position from out-of-plane bending (also independent of worst hotspot regarding fatigue). The SCFax is the actual SCF for axial force used for the hotspot reported to be governing. Hence, if the worst hotspot is a saddle point (1 or 13) the SCFaxS is reported, if a crown point (7 or 19) the SCFaxC is reported, and if any points in between (4, 10, 16 or 22) the average value SCF of crown and saddle is used.

For the explanation and format of results see Appendix A.

2.1.2.5 Time history fatigue analysis

The time history fatigue calculation in Framework is based on the rainflow counting method [71]. The method counts the number and sizes of peaks and valleys of the stress time series which together with SN curve data are used to calculate fatigue damage values.

A time history fatigue analysis requires that the Result Interface File read by Framework contains time series of the load transfer functions. When reading the load transfer functions, Framework counts the number of time instants to distinguish between a deterministic and a time history fatigue approach. A time history fatigue approach is automatically established when the number of time instants per wave is larger than 36.

Time series of the member forces are obtained by performing a quasi-static analysis in Sestra for the time history loading. If both wave- and wind loads are present, the loads must be combined before running Sestra. Time series of the wave loading may be established by performing time series wave load analyses in Wajac. Time series of wind loading are not possible to generate in Sesam and must be provided from other sources, e.g. load files established from in-field wind measurement data.

By default Framework calculates fatigue damages per unit time and no fatigue safety factors are applied. Alternative settings are however possible, see Section 3.17.

The fatigue damage results may be printed to file in a SIF format. Dump prints of fatigue damages, stress ranges and time history of the fatigue stresses are also possible and time histories of the fatigue stresses

may be printed on format applicable for spreadsheets, see Section 3.17.

2.1.2.6 Direct Deterministic fatigue analysis

A new "Direct Deterministic" fatigue is introduced since Framework v3.14 to perform the fatigue analysis for general cyclic loads. It is a simplified method to estimate the fatigue damage of the structure subject to the "determined" cyclic load. It is called **DIRECT** to differentiate this method from the Deterministic Fatigue analysis in Section 2.1.2.2.

The old Deterministic method 2.1.2.2 focuses on the offshore structure under the action of oceanic wave loads. It requires a deterministic hydrodynamic analysis (Wajac) followed by a static structural analysis (Sestra). The so called "Deterministic" means the hydrodynamic analysis is done by stepping "deterministic" waves through the structure. The structrual stress and its long term history for damage calculation are obtained from the deterministic wave analysis, unlike the "Stochastic" or "Spectral" method involving wave spectrum and transfer functions.

By contrast, the "Direct" Deterministic method is a more general method that can be applied not only for oceanic wave loads but also any load or load combination. The number of cycles that the load or load combination repeats must be "directly" provided. Then, the hot spot stresses at the critical positions are computed from the nominal forces resulted from the load or load combination multiplied with appropriate stress concentration factors. The stress range is calculated under certain algorithm. The allowed cycles to failure for a stress range is characterized by the S-N curve. The fatigue damage is obtained by Palmgren-Miners rule. The accumulated damage can be expressed by:

$$\mathrm{D} = \mathrm{FS} \cdot \frac{\mathrm{TFL}}{\mathrm{FET}} \cdot \sum_{i=1}^{\mathrm{N}_{FLS}} \frac{n(S_i)}{N(S_i)} \cdot w_i \tag{2.1}$$

where

FLS	Fatigue Load Series;
N_{FLS}	number of fatigue load series contributing to the total damage;
FS	Fatigue Safety Factor;
TFL	Target fatigue life;
FET	Fatigue exposure time;
$n(S_i)$	cycles number that the fatigue load series repeats during fatigue exposure time,
$N(S_i)$	allowed cycles number of stress range S_i from S-N curve,
S_i	stress range of i-th fatigue load series;
w_i	weight factor multiplied to the damage of i-th fatigue load series.

Again, no long term stress range distribution is involved, unlike the Deterministic Fatigue analysis in Section 2.1.2.2.

The analysis steps carried out in Framework are as follows:

1. Create Fatigue Load Series (FLS), each of which consists of one or more basic load case or load combination. Multiple FLS can be created. All these FLS will be involved in a run of Direct Deterministic Fatigue. For each FLS,
   (a) provide the repeated cycles number $n(S_i)$ over fatigue exposure time;
   (b) specify the weight factor w_i that will be multiplied to the damage due to the FLS; The weight can be any non-negative real number. User may give $w_i = 0$ for the FLS that is to be ignored in the fatigue run.
   (c) enter the list of basic load cases or load combinations;
   (d) specify the method to calculate stress range. There are 4 options to get the stress range: MAXMIN, SRSS, Linear-Comb, and Absolute-Comb.
2. Calculate the stress range from the load cases belonging to the FLS.
3. Calculate the fatigue damage resulted by every FLS using standard S-N curves.

4. Miners rule of cumulative damage is then used to sum the damage at each hotspot from all fatigue load series if there are multiple FLS; the total damage is weighted by the associated factor and multiplied by safety factor and the ratio of design life over fatigue exposure time.

The data restriction to direct deterministic fatigue analysis is very little. In general, any results file obtained from a time domain or quasi-static analysis is applicable. The basic procedure performing a fatigue analysis is the same as the other fatigue analysis types. Usually, the procedure adopted for a deterministic fatigue analysis is as follows:

- Selecte Fatigue check type to DIRECT-DETERMINISTIC. This step is required to inform the program to skip automatic switching to deterministic or spectral fatigue when there are wave load results.
- Definition of fatigue constants (target fatigue life, fatigue exposure time, splash-zone, default SCF formula, global SCF, etc.)
- Assignment of CHORD members and modelling of local details (Assignment of CAN and STUB sections, etc.) if necessary.
- Assignment of joint type and joint gap/overlap data;
- Assignment of SCFs to joints;
- Assignment of SCF to members if the default butt-weld SCF formula is not applicable;
- Assignment of SN curve to all positions if the default SN curve is not applicable.
- Create Fatigue Load Series. (Unique for Direct Deterministic Fatigue)
- Print Fatigue Analysis Type to confirm Fatigue Load Series. (Recommended for Direct Deterministic Fatigue)
- Run fatigue analysis.
- Printing of results.

With joint type set to LOADPATH, the brace type (and hence the SCFs) will be calculated for each load case used to obtain the stress history for the selected members at the investigated positions and hotspots. For joint type LOADPATH used in combination with parametric SCFs, the format and rules of print of the results is the same as the other fatigue types. See Section Par:Deterministic fatigue analysis.

For the sample input and format of results see Section 3.27 and Appendix A.3.

2.1.3 Earthquake analysis

An earthquake analysis in Framework may be performed on frame type structures in order to check that, in the event of an earthquake, structural members have adequate capacity to prevent structural collapse. Results from an earthquake analysis may be used to perform code checks. More information on this is given later in this section.

The earthquake analysis is based on linear earthquake response techniques using modal combination rules.

The following modal combination rules are available in Framework

- Complete Quadratic Combination method; CQC
- Square Root Sum of Squares method; SRSS
- Naval Research Laboratory method; NRL
- ABSolute sum of each modal response; ABS
- The method recommended in API RP-2A; APIC

For more information on the theory, see Appendix C.

The basic data required prior to executing an earthquake analysis are as follows:

1. The solution to the eigenvalue problem
2. Calculation of modal load factors
3. Definition of ground motion.

Eigenfrequencies and modal load factors are computed from a linear eigenvalue analysis (e.g. Sestra) while the ground motion data are specified in Framework.

Ground motion data may be given in terms of motion response spectra with linear interpolation between spectral ordinates, specified for arbitrary frequencies. Motion response spectra may be defined for:

- Displacement
- Velocity
- Acceleration

Response spectra may be defined for each of the global X-, Y- and Z-directions.

Results from an earthquake analysis may be calculated for:

- Joint displacements
- Joint velocities
- Joint accelerations
- Member forces

An earthquake analysis is performed taking into account a finite number of modes. The number of modes is selected by the user.

The following limitations apply to an earthquake analysis:

- Only beam members may be analysed for earthquake response.
- Maximum number of modes that may be accounted for is 1000.
- In the CQC modal combination rule a cut-off is used for the correlation coefficient. When the correlation coefficient is less than 0.1 the cross-modal terms are ignored in the analysis.
- Response spectra may be scaled for each motion component. The factors will scale the spectral ordinates for all modes (i.e. frequencies) for which the spectral ordinates were originally defined.
- Modal damping may be constant or frequency dependent. Results from an earthquake analysis may be code checked, and the following restrictions must be noted.
- Only members with double symmetric sections can be code checked. See also Table 2.2 for available sections.
- Only earthquake checks producing member FORCES can be code checked.
- Earthquake checks producing joint displacements, velocities and accelerations or member stresses CANNOT be code checked.
- Earthquake mode shapes CANNOT be code checked.
- An earthquake result can be combined with a single static load case or as part of a combination of several static load cases. For more comments on load combinations see Section 2.2.

The earthquake response produces forces and moments that have lost their phase and sign because the response spectrum method is used. The combination of static loads and earthquake responses relates to member's and joint's code checking. If an earthquake load case is to be combined with a static load case then Prepost must first be used to MERGE the Results Interface Files produced by the static and eigenvalue analyses. The order of merging is not important unless the report of Effective Modal Mass is demanded.

To obtain a correct total mass from two separately analyses, the eigenvalue analysis result MUST be the primary one (*.*SIN* format) when merging two Results Interface Files in Prepost.

The load case combinations in Framework are performed as follows:

- For yield and punching shear code checks:
  The sign of each normal and shear force component (for each member) produced for the earthquake load case is adjusted so that it has the same sign as produced by the static load case. For example, a member under tension (or compression) from the static load case will be under greater tension (or compression) after the earthquake load case is added.
- For a stability code check:
  The normal moment components (M_y and M_z) are combined using the same procedure as for the yield and punching shear code checks. Shear components are not relevant. The axial normal force component (for each member) produced for the earthquake load case, is always considered compressive. This is to ensure that after the earthquake and static load cases are combined, each member is under greater compressive load than from each individual load case. If only an earthquake load case (including member FORCEs) is required to be code checked, then a single load combination must be created comprising of the earthquake load case and a load factor of 1.0 (i.e. positive). This load combination will then automatically cause all members to be under axial compressive loads.
- For a member (combined yield and stability) code check:
  The normal moment components (M_y and M_z) are combined using the same procedure as for the yield and punching shear code checks. Shear components are not relevant. The axial normal force component (for each member) produced for the earthquake load case, is checked for two cases, i.e. investigating for maximum tension force and maximum compression force. If only an earthquake load case (including member FORCEs) is required to be code checked, then a single load combination must be created comprising of the earthquake load case and a load factor of 1.0 (i.e. positive). This load combination will then automatically cause all members to be under axial compressive loads.
- **Earthquake** type of Load Combination

  Above cases are valid for the “Static” type of load combination. `CREATE LOAD-COMBINATION` command has another type: “Earthquake”, in addition to Static. If a load combination is of “Earthquake” type, for the **axial component** of member forces or joint motions, there are three ways to sum the component from basic static loadcases and the earthquake response. They are

  – Maximum: use the same procedure as for the yield, i.e. adding the earthquake response to the static component with the same sign of the static component;

  – Tension: assume the earthquake response is tensile, adding “$+$” earthquake response to the static component;

  – Compression: assume the earthquake response is compressive, adding “$-$” earthquake response to the static component.

  The other components such as shear forces, bending moments, and torque, are calculated as the “MAXIMUM” method, i.e. Static component $+$ or $-$ QUAKE component for larger |ABS| value. The static component always has the conventional sign during combination.

  The “Earthquake” type load combination has been assigned with the “Earthquake” design condition automatically. It is not necessary to use command `ASSIGN LOAD-CASE` to specify the loadcase condition as the “Static” type. The member forces depend on the “Earthquake” type and the selected axial option only, and do not change with different code check types. Conseqently, user must include all necessary load cases and load combinations in the required code check. See Appendix C.6 for more details.

2.1.4 Wind fatigue analysis

2.1.4.1 General

This section gives a description of major features related to wind fatigue analysis in Framework. Wind fatigue analysis is performed according to the theoretical basis described in Framework Theory Manual - Wind Fatigue Design [24]. Wind fatigue is implemented as a separate analysis module in Framework and runs by its own when the run command is executed. Input specification is an integrated part of Framework. Input commands of wind fatigue are described in Section 5.

The wind fatigue module has its own internal data storage, separate from the data base of Framework. Many features of Framework are thus not available to wind fatigue calculations. Postprocessing facilities are limited to tabulated prints of fatigue damages of brace/joint intersections. The `TASK WIND-FATIGUE-CHECK` command in the graphic user interface mode makes only commands relevant for wind fatigue visible.

2.1.4.2 Overview of theoretical basis and assumptions

The Framework wind fatigue module evaluates fatigue damage of frame structures subjected to wind loading. Buffeting loads due to wind gusts and the vortex shedding effects due to steady state wind are considered. Wind fatigue due to buffeting loads is treated by the power spectral density method (or termed energy spectrum or wave spectrum method) and the damage is a function of the overall structural response. The effects of vortex shedding induced fatigue are treated by evaluation of individual member responses. The two effects are calculated on the assumption that they are uncoupled and are summed to give the overall fatigue damages of joints and members in the structure. The Framework wind fatigue module receives input information in terms of the eigen-modes of a structure, coupled with statistical data on the annual wind distribution and associated drag factors.

The fatigue analysis is based on annual wind data. The annual wind data are characterized by a set of wind states, considered to represent the climate for the year. For each of these wind states, the response stress power spectra at local "hot spots" within a particular joint are evaluated.

For buffeting fatigue calculations the hotspot power spectrum response is divided into a quasi-static response part and a dynamic response part, see Figure 2.1. The quasi-static part of the power spectrum covers the low frequency non-resonant response. This spectrum has a broad peak at low frequencies but is treated as a narrow band at its peak frequency. The resulting damage is then multiplied by a broad band correction factor accounting for the broadness of wind spectrum, see Appendix B.5 Wide Band Correction Factor for Spectral Fatigue Analysis. An alternative to this approach has been implemented where the broad band nature of the quasi-static part of the power spectrum is accounted for by using the Wirsching correction factor for wide banded processes.

The dynamic response consists of the excited resonant modes. It is partitioned into the separate resonant modal responses; for each of these an independent damage assessment is made. This assumes that each response is narrow band and independent of the others.

Vortex shedding from brace members may induce oscillations in individual braces. These are local modes rather than overall structural modes. It is assumed that the vortex shedding effects are of significance for fatigue only if they induce oscillations in the first mode of the brace.

The quasi-static part of the power spectra covers the low frequency non-resonant response. This spectrum has a broad peak at low frequencies but is treated as a narrow band at its peak frequency with one third of the stress variance of the low frequency broad band stress spectrum. The resulting damage is then multiplied by 10. This approach assumes that the quasi-static contribution to the damage is small, so that a rigorous evaluation is not required.

For each of these dynamic and static partitions a Rayleigh distribution of the "hot spot" stress range versus the number of cycles is assumed. The variance is given by the integral under the power spectrum. Fatigue damage may then be evaluated by application of the Palmgren-Miner relationship and use of a recognised SN-curve (see Section 6.14).

Vortex shedding from brace members may induce oscillations in individual braces. These are local modes

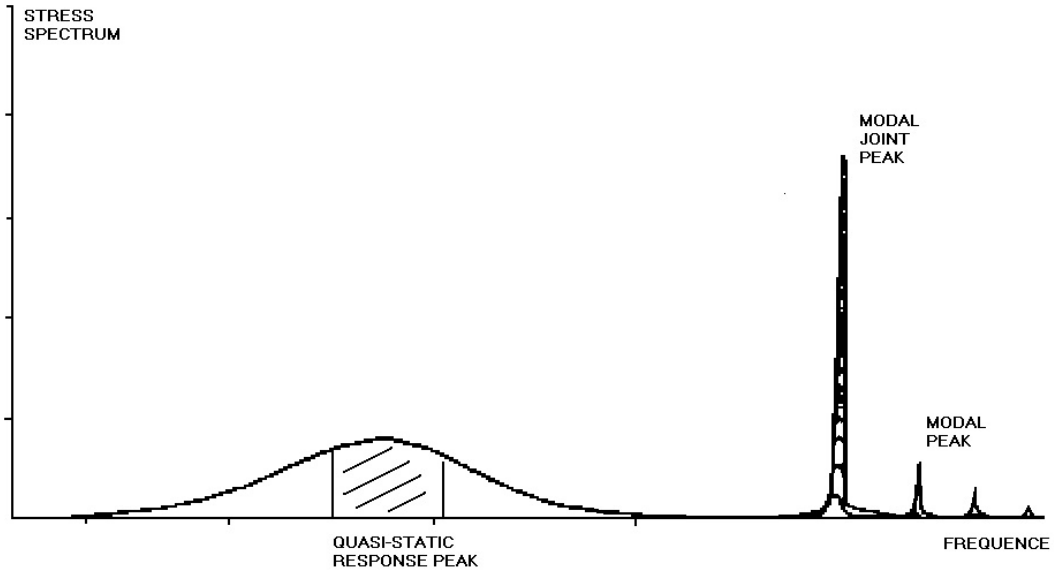


Figure 2.1: Typical hotspot stress spectrum due to wind loading

rather than overall structural modes. It is assumed that the vortex shedding effects are only of any significance for fatigue if they induce oscillations in the first mode of the brace.

The overview of this solution method is shown in Figures 6.1 to 6.4.
The major assumptions made for wind fatigue calculation are:

1. buffeting damage is dominated by low frequency resonant modes
   this implies:
   - separate narrow-band damage evaluation for the resonant modal responses is conservative
   - the greatest hot spot stresses within a modal response cycle occur at maximum modal amplitude
   - Guyan reduction may be used to reduce the mass and stiffness matrices without significant loss of accuracy to the low modes, see Section 6.8. (Note: The Framework wind fatigue assumes all non-fixed translational degrees of freedoms (dof) to be set to master degrees of freedoms.)
2. the greatest hotspot stresses within a modal response cycle occur at maximum modal amplitude
3. the structure is made of welded tubular members
4. parametric SCF equations or user specified SCFs are used to evaluate joint stress concentrations
5. wind forces are parameterized as linear fluctuating components super-imposed upon mean wind profiles
6. wind gust velocities in the mean wind direction and normal to the mean wind both horizontally and vertically are statistically independent
7. member drag coefficients are invariant under the fluctuating wind component and are proportional to the mean wind speed
8. vortex shedding induced member oscillations and fatigue are uncoupled from any buffeting induced vibrations and damage

2.1.4.3 Wind state

The energy content of wind as a function of frequency is demonstrated in the form of a power spectrum averaged over a year, as shown in Figure 6.5, taken from [66]. Two dominant peaks occur in this figure. The lower frequency peak is associated with cycles with a period of the order 2-3 days and is due to the passage of large-scale atmospheric depressions. The higher frequency peak has significant energy in the range 10 minutes to 1 second. It is this part of the spectrum, which is of interest to structural designers and is commonly known as the gust spectrum. There is apparently a lack of wind energy with periods between 10 minutes and two hours. It can clearly be assumed that fatigue, which depends on changes in wind speed, is not significantly affected by cycles of length greater than two hours.

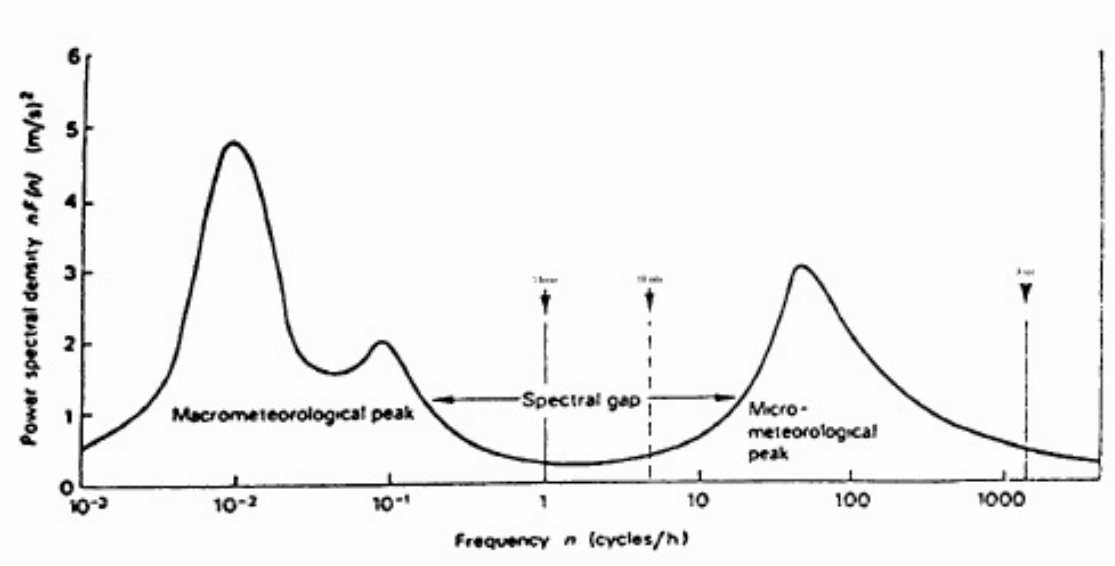


Figure 2.2: Spectrum of horizontal wind speed, from [66]

For the purpose of fatigue analysis, the wind speed is averaged over a suitable period and the wind is then represented in that time as having a constant mean value and direction, upon which fluctuations or gusts are superimposed. Although a period of about ten minutes would appear to be desirable as an averaging period in order to reflect the influence of the short-term storms, a period of one hour has traditionally been used. It is for this time that data are usually available, see, for example, [74]. The API and NORSOK power laws represent the variation of mean wind speed with height relationship based on the drag at the earth's surface.

While the mean wind in any given hour is represented by speed and direction, the gust components are statistically described by three parameters: probability distribution, power spectrum (sometimes cross-power spectrum) and cross-correlation function.

The probability distribution describes the ratio or percentage of time a certain wind speed is likely to occur, the power spectra reflect the energy content of the wind as a function of frequency, and the cross-correlation function indicates the way in which the gusts are spatially correlated.

The probability distribution can be obtained from measurements; but standard formulae exist for describing this as a function of mean wind speed, ([7] and [48]). A set of wind states may, for instance be formed by taking wind measurements, over a period of one year, to show the number of hours per year the hourly mean wind is blowing for each speed and direction. The measurements are normally taken at 10m above ground or sea level. For each of these, three parameterized gust spectra are calculated, and a resultant damage assessment made. The total annual damage is obtained by adding these damage assessments in proportion to the fraction of a year in which they are generated.

2.1.4.4 Wind spectra and coherence models

The cross-power spectrum $S(r, f)$ of the wind may be approximated by a frequency dependent part $S(f)$, termed spectral density or wind spectrum, and a spacial dependent part, $coh(r, s, f)$, termed wind coherence:

$$S(r, s, f) = S(f) \cdot coh(r, s, f). \tag{2.2}$$

The wind coherence describes the cross-correlation coefficients between the spectral densities of two points (r, s) in space and is a function of the separation of the points.

Five wind spectra are available in Framework:

1. the HARRIS spectrum representing gust components in the mean wind direction ([7])

Table 2.4: Possible combinations of wind spectrum and coherence model

Wind spectrum	**Wind component**	**Coherence options**				
		Model 1	Model 2	Model 3	Model 4	Model 5
		Gusto 1	Gusto 2	General	Davenport	NPD
Harris	u	Yes		Yes	Yes	
Davenport	u		Yes	Yes	Yes	
NPD	u					Yes
Panofsky lateral	v		Yes	Yes	Yes	
Panofsky vertical	w		Yes	Yes	Yes	

2. the DAVENPORT spectrum representing gust components in the mean wind direction ([48])
3. the NPD spectrum representing gust components in the mean wind direction (Frøya in [22] and [40])
4. the PANOFSKY LATERAL spectrum representing gust components lateral across to the mean wind ([48])
5. the PANOFSKY VERTICAL spectrum representing gust components vertical across to the mean wind ([48])

The HARRIS and DAVENPORT spectra are independent of height (z) and is linearly dependent on the drag at the ground surface. The PANOFSKY and NPD spectra depend on the height (z).

The first three are spectra representing the gusts in the same direction as the mean wind, the fourth is for lateral (horizontal) gusts across the mean wind and the fifth is for vertical gusts across the mean wind.

The following coherence models are available in Framework:

1. the GUSTO 1 coherence model associated with the Harris wind spectrum
2. the GUSTO 2 coherence model associated to the Davenport and Panofsky wind spectra
3. the GENERAL coherence model associated with the Harris, Davenport and Panofsky wind spectra
4. the DAVENPORT coherence model associated with the Harris, Davenport and Panofsky wind spectra
5. the NPD (Frøya in [22]) coherence model

Possible combinations of wind spectrum and coherence model implemented in Framework are given in Table 6.3. The spectra and coherence models are defined and further discussed in Appendix B.6.

2.1.4.5 Hotspot stress spectrum

The most appropriate technique for determining wind induced cyclic stresses is referred to as the frequency domain or power spectral density approach.

A power spectrum describes a time dependent variable relating the energy distribution over a range of frequencies. Analysis methods whereby output spectra are obtained from input spectra via transfer functions are required for a random process such as wind, where only a statistical description of the environmental forces can be given. In the spectral analysis method of fatigue due to wind, the stress spectrum is obtained from the input wind spectrum via the structure stress transfer function. Because of the nature of the fluctuating wind force, there is, to good accuracy, a direct linear relationship between the wind speed spectrum and wind force spectrum which by definition is the cross-power spectrum of the fluctuating wind forces. This allows the structure's stress spectra to be linearly related to wind speed spectra. An approximation to the cross-power spectral density function of the buffeting wind loads is represented in terms of the power

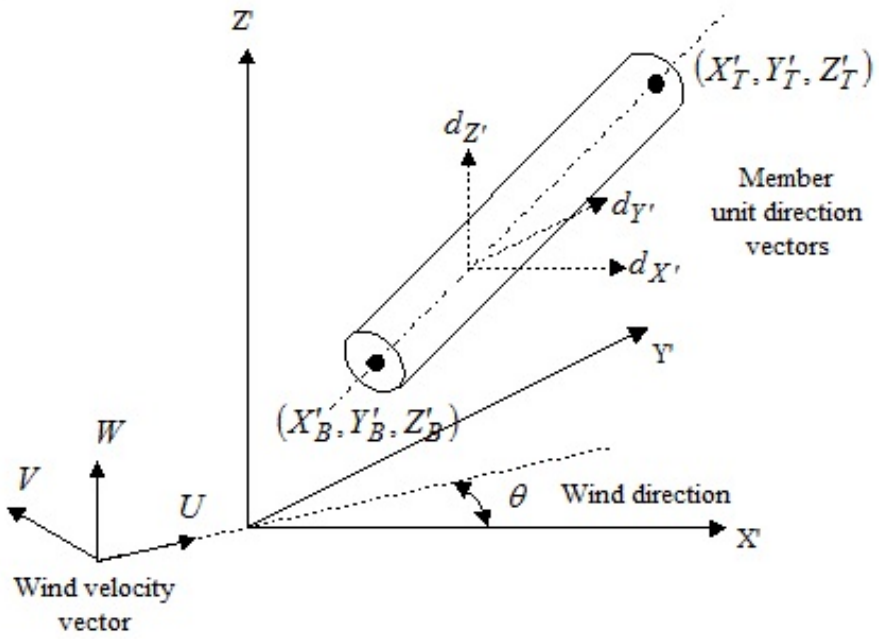


Figure 2.3: Wind forces on a member

spectra for the fluctuating wind. It is then used in the derivation of hotspot stress power spectra. For further details, see Chapter 8 of Framework Theory Manual - Wind Fatigue Design [24].

A typical hotspot stress spectrum consisting of a quasi-static response peak and modal joint peaks from the dynamic response of the excited resonant modes is shown in Figure 2.1.

2.1.4.6 Wind force on a member

The general form for the wind force on a member, as shown in Figure 2.3, is given by

$$\mathbf{F} = \frac{1}{2}\rho C_d D L |\mathbf{u}_n| \mathbf{u}_n, \tag{2.3}$$

where ρ is the mass density of the air, C_d is the member drag coefficient, D is the member diameter, L is the member length, and $\mathbf{u}_n$ is the wind velocity vector normal to the member.

The above form (the Morison formula 2.3) can be expanded by splitting the wind velocity vector into a mean velocity (u_{mean}) and three fluctuating gust components. A gust component denoted $u^g = u^d$ longitudinal to the mean wind direction, a gust component denoted $v^g = v^d$ lateral to the mean wind direction, and a gust component denoted $w^g = w^d$ vertical to the mean wind direction. Then the wind force vector may be written as

$$\mathbf{F}(t) = \mathbf{F}_{\langle u \rangle u^d} + \mathbf{F}_{\langle u \rangle v^d} + \mathbf{F}_{\langle u \rangle w^d}, \tag{2.4}$$

where the resulting force vector has been divided into three separated vectors representing forces due to the three wind gust components u^d, v^d, w^d, respectively. Further notice that time dependency is indicated by setting $\mathbf{F} = \mathbf{F}(t)$. Features are available in Wajac to generate the three fluctuating wind force components to be used in wind fatigue calculations. Parameters used in Wajac to generate of the wind forces, which are also required in the wind fatigue calculation, are transferred to the wind fatigue module through the Results Interface File.

Wind forces may be generated for a series of wind directions and water depths in Wajac. For each water depth the same wind directions are applied. Three load cases are established for each wind direction. A

maximum of six wind directions for the same water depth may be handled by the wind fatigue module. The number of wind directions in Wajac may, however, be larger than six. In the wind fatigue module the user selects wind directions and water depth that shall be transferred and used in the fatigue analysis.

The wind forces on the structure depend on the wind velocity at the position where the wind acting. The wind velocity varies with the elevation above the ground. The variation is described by the wind profile function given by

$$u' = U_{10} \cdot f(z),$$

where U_{10} is the wind velocity at the height of 10m and $f(z)$ is the wind profile function. Four wind profile functions are available for the wind fatigue analysis; API normal, API extreme, NORSOK normal and NORSOK extreme. The wind profile to be used is selected in Wajac for calculation of the wind forces. The same wind profile applied in Wajac must be applied in Framework and the user can not select wind profile directly in Framework. The wind profile equations are given in the User Manual of Wajac.

Wind fatigue may be evaluated for a series of wind speeds different from the basic wind speed applied in Wajac. The wind forces calculated in Wajac are scaled to match the wind speeds for which the wind fatigue is evaluated. The wind speed of the first wind direction in Wajac is taken as the reference speed in this scaling process. It is thus of importance that the same speed is applied to all wind directions in Wajac, otherwise the wind forces will be scaled with respect to a wrong speed in the wind fatigue analysis module.

In Wajac the wind forces are calculated for one wind speed using a drag coefficient relevant for this speed. However, when fatigue are evaluated for other wind speeds, the drag coefficient may change, since the Reynolds number changes with the speed value. A change in drag coefficient affects the resultant wind forces in the structure. Drag correction factors are applied in the wind fatigue analysis so that the user may correct for changing drag coefficients when scaling the wind forces to the appropriate wind speeds.

Wajac produces a load file containing element line loads of the wind forces. Wind loads as well as element stresses are used in wind fatigue calculation. A static finite element analysis (performed by Sestra, [32]) must be carried out to establish the element stresses of the structure caused by the wind loading.

Further details on wind load generation are given in Section 3.26 and in the Wajac User Manual [60].

2.1.4.7 Eigenvalue calculation

The wind fatigue analysis uses eigenvalues, eigenvectors and the resultant stresses from eigendeformations of the structure. These may be calculated by Sestra, [32]. The eigenvectors must be mass normalised.

Consult Appendix L for the limitations in Framework regarding the number of eigenvalues that can be applied in the wind fatigue calculation.

2.1.4.8 Vortex shedding induced vibrations

Vortex shedding in steady winds may induce oscillations of individual members. It is assumed that the vortex shedding effects are only of any significance for fatigue if they induce oscillations in the first mode of the brace. Higher modes are ignored. This is a reasonable assumption for tubular structural steel members that are used in typical flare towers. For long slender members this may be inaccurate as fatigue from a higher mode may dominate the member's life. Unsuitable applications would be the consideration of a long solid tie member used to support a tower or the cables of guyed masts. The combination of long length, small bending stiffness and relatively high mass per unit length could mean that the fundamental mode lies below the vortex shedding frequency, but that a higher mode could be excited. Non linear geometric effects may also become important. The user should check that higher modes and non linear geometric effects are unlikely to occur.

Only cross-flow oscillations are considered. In-line vibrations are ignored. The fundamental equation for the dynamic bending behaviour of a beam is used to derive at the first mode of vibration for a brace. The support conditions at the joints are of fundamental importance for the vibration response of the brace and may affect the fatigue life significantly. The dynamic equation is solved for a beam supported by rotational springs at

the ends. Various support conditions may thus be simulated and the effect of various member end fixities on the fatigue life may be evaluated. A detailed outline of the derivation is described in [24]. A maximum of five fixity conditions, ranging from simply supported to fully fixed beam ends may be investigated. Vortex shedding induced fatigue damages are calculated at the member ends and at the point of highest curvature along the member span. The last is reported as 'member centre damage' in the out-print. The SCF applied at the member centre span should be that associated with the closure weld. One SCF value must be supplied. This value is used in the evaluation of all member centre span damages.

2.1.4.9 The structural model

Structures modelled by two noded beam elements with uniform tubular sections may be analysed for wind fatigue damage. The model may, however, include non-tubular beams. These beams are skipped in the fatigue analysis but wind load effect generated by these beams are accounted for. The fatigue module is primarily intended for fatigue calculations of frame structures such as flare towers.

Consult Appendix L for the limitations in Framework regarding the size of the model.

2.1.4.10 Joint geometry

The wind fatigue module determines the chords of the joints and classifies the joints by its own during the analysis process. A joint is defined as a planar structure where two or more elements meet. Joints are classified on basis of the number of elements meeting at the joint. User specified analysis planes serve as the planar structures within which joints are classified. Fatigue damage is calculated only for node/element intersections forming planes parallel to an analysis plane. When a node has no or only one element parallel to an analysis plane no joint is established for that node/analysis plane and no fatigue damage is calculated.

Elements meeting at a joint may either be chord or braces. The chord is taken as the pair of co-linear elements of greatest diameter, all other elements are taken as braces. If there is more than one pair of co-linear elements of same maximum diameter, the chord is assumed to be the pair with the greatest thickness.

If a joint has no pair of co-linear elements (e.g. corner joints of a frame) joint classification of Framework is tried. If chord and braces are determined by Framework chord and brace definition of Framework applies. If chord and no braces are determined no damage calculation is performed. If only braces are determined the joint is classified as a bent can.

When chord and braces are determined, the joints may be classified as *T*, *K*, *KT*, *X*, non-standard or impossible according to the following rule:

- *T* joint: there is a chord and one brace
- *K* joint: there is a chord and two braces
- *KT* joint: there is a chord and three braces
- *X* joint: there is a chord, two braces where the chord and braces are pairs of co-linear members
- Non-standard joint: there is a chord and more than three braces. Non-standard joints are treated as *T* joint
- Impossible joint: there is a chord and more than six braces. No damage calculation is performed

The classification does not distinguish between braces on the same and opposite side of the chord.

A joint is classified as a bent can when only two aligned members meet at the joint.

Note that the classification of a joint is related to a given analysis plane and its orientation in space. Joints are classified within each analysis plane for each node included in the wind fatigue analysis. The classification is reported in the diagnostics file (`<run name>Diagnostics.txt`).

2.1.4.11 Analysis planes

An analysis plane is a planar surface define by the user. Analysis planes are used to select joints to be included in the fatigue calculation. Only joint-brace connections parallel to the selected analysis planes

are analysed.'Parallel' is linked to an angular tolerance limit specified by the user (see command DEFINE WIND-FATIGUE WIND-PARAMETERS). Out-of-plane elements meeting at the same node are not considered in the joint classification and in the fatigue analysis.

Crown-, saddle-, heel- and toe positions of the chord/brace intersections, see Figure 5.6, are determined by the analysis planes and the joint geometry.

2.1.4.12 SCF schemes

Stress concentrations occur in the welded tubular joints. To evaluate the stress concentrations or 'hotspot stresses' (HSS), empirically derived stress concentration factors (SCF) based on joint geometry are used.

Three parametric SCF schemes are available:

- Efthymiou scheme for *T*, *K*, *KT* and *X* joints. Efthymiou equations are applied.
- Lloyd's Register scheme for *T*, *K* and *KT* joints. *T* joint uses Wordsworth and Smedely equations. *K* and *KT* joints use Wordsworth and Smedely unbalanced out-of-plane equations for out-of-plane bending and Kuang balanced axial and in-plane equations for axial load and in-plane bending.
- Original scheme for *T*, *K* and *KT* joints. Only in-plane and axial SCFs are considered. Wordsworth and Smedely equations are used. *KT* joint is considered as *K* for the outer braces plus *T* for the middle brace.

The SCF schemes are described in details in [24].

SCFs may alternatively be assigned by Framework or supplied by the user. SCF assignment by Framework is according to joint classifications based on joint geometry and parametric SCF equations of Framework (Efthymiou, Kuang, Wordsworth), which in some cases may differ from joint classifications and SCF values generated by the wind fatigue module. If the parametric SCFs are less than the minimum parametric SCF values (see command DEFINE FATIGUE-CONSTANTS), the minimum values are applied.

By the Read/Local and Read/Global options (command ASSIGN WIND-FATIGUE JOINT-SCF) the user may override selected SCF values assigned by Framework or enter all SCFs values. No minimum SCF values are applied to these options. However, a message is printed to the DIagnostics file if SCFs are zero. Default global SCFs are entered by the command DEFINE FATIGUE-CONSTANTS.

Note that joint classifications based on load-path is not applicable for the wind fatigue module.

The default parametric SCF scheme (see command DEFINE WIND-FATIGUE WIND-PARAMETERS) are applied to all joint-brace connections which have no assigned SCFs. Default SCF schemes are Efthymiou and Lloyd's Register.

Bent can SCFs are assigned by the command ASSIGN WIND-FATIGUE BENT-CAN-SCF. No parametric SCF schemes are applied for bent cans. Bent cans which have no user assigned SCFs take the default global SCF values. No minimum SCF values are applied to bent cans.

Distribution of the HSSs around the weld is found on basis of the SCFs, under loading produced by a mean wind state (static loading). When a tower is subject to wind buffeting, i.e., dynamic eddy loading, the maximum HSS at a joint, for each mode of response, is assumed to occur in the same place as for the static loading. This is a reasonable assumption, in that buffeting fatigue effects on flare towers are normally dominated by the cantilever modes of response. These strongly resemble the static response of the tower.

HSSs are found for each brace/chord intersection separately, for both the chord and brace side of the weld.

2.1.4.13 SN curves

SN curves may be selected from the SN curve library of Framework or the user may create his own SN curves to be used in the wind fatigue analysis. The DOE-T, DOE-F, DOE-F2 and DOE-E SN curves for structures in air, see [18], have been included in the SN curve library of Framework.

SN curves may be assigned to individual joint-brace connections and bent can joints. If no assignment is made for a joint, the default SN curve is applied.

Thickness corrections to the SN curves are also possible.

2.1.4.14 Calculation of buffeting fatigue damage

The following assumptions are made:

- The hotspot stress power spectrum is characterized by a quasi-static response and several separated sharp peaks at the structural resonances. The stress spectrum is discretized into a finite number of frequency bands covering the submodal and modal peaks.
- The integral under the peaks (or frequency bands) is the variance of the stress amplitude at the frequency associated with the peaks.
- The stress amplitude within each frequency band has a Rayleigh distribution. This is true for narrow band processes. The sub-modal section is split into three portions, each of which is treated as having a Rayleigh distribution.
- Each frequency band fatigue is directly related to the number of cycles experienced in each stress range through the Palmgren-Miner relationship.
- The number of cycles to fatigue at any stress range (amplitude) may be found from standard SN curves.

The damage evaluated over all stress ranges is obtained by integrating over all possible stress amplitudes. The design fatigue life is assumed to be one year. The total annual damage is the sum of the damages over all the frequency bands and all the wind states. The estimated fatigue life is the reciprocal of the total fatigue damage.

2.1.4.15 Calculation of vortex shedding induced fatigue damage

It is assumed that vortex shedding effects are only of any significance if they induce oscillations in the first mode of a brace. The first natural frequency and its associated mode shape are determined by solving the fundamental equation for the dynamic bending behaviour of a thin beam.

The frequency at which vortices are shed from the opposite side of a brace member is dependent on the Reynolds' number of the fluid flow. The mean wind speed component normal to the brace is used to calculate the Reynolds' number in conjunction with the outer diameter of the brace. From the Reynolds' number the vortex shedding frequency may be estimated and a critical velocity is defined as that which will cause resonant vortex shedding. If the vortex shedding frequency is sufficiently removed from the natural frequency of transverse oscillations of the brace there will not be any resonance and the amplitude will be neglected. If the ratio of the two frequencies is close to unity, the amplitude of oscillations will be significant, that is high stress levels and hence structural fatigue will be caused. Wind velocities in the range of 60 to 140 per cent of the critical vortex shedding velocity will excite oscillations that cause damage. Velocities outside this range is ignored.

For each brace member the wind velocities that occur throughout the year are resolved into normal components. This is done by decomposing the statistical data on wind speeds, directions and the portion of the year that such winds occur, into discrete ranges at constant speeds. The effect of each wind range and its associated velocity is then considered in isolation. The total damage induced by each wind speed range from each direction is then summed to give the total structural damage.

The amplitudes of response at the resonant vortex shedding frequency is calculated, see [24]. The amplitude of the vibrations is determined as a factor of the resonant amplitude. From the displacement amplitude and the mode shape, the brace section properties are used to calculate the member stresses at the two ends. The raw member stresses are then factored by the stress concentration factors (SCFs) to give the local hot spot stresses. Note that the stress range, which is twice the stress amplitude, is needed for fatigue damage calculations. The damage is evaluated using the Miner's law approach in an analogous manner to the buffeting damage.

The mode and frequency are highly dependent on the conditions of member end fixity. In general these are not known to any degree of accuracy, therefore the user is allowed to investigate ranges of fixity. Low end fixity reduces the natural frequency and the member end damage that occurs, high end fixity produces a higher natural frequency and associated with it the possibility of higher end moments and damages.

The member centre damage is calculated in a similar manner to the member end damage. The SCF for the member centre is applied as a blanket value to the entire structure. This value is supplied from the input data and there are no calculations involved to derive the value. This user specified SCF should represent the typical value that would be associated with a single-sided girth closure weld. It will depend on the quality control of the welding process, the out of roundness and the mismatch that are permissible in the fabricated tubular structure.

The approach used is conservative. The damage is evaluated at the section on the brace's length that has the maximum curvature, and hence bending moment. The member's displaced shape is examined at 100 equally spaced positions along its length to determine the greatest curvature. It is unlikely, although possible, that the position of maximum moment would coincide with a closure weld.

2.1.4.16 Run scenarios

Fatigue damage calculations may be performed for a single brace or for multi braces.

The single brace case allows fatigue analysis to be carried out for one joint, one wind direction, one analysis plane and several eigen-modes. Compressed or comprehensive print of results may be requested. The comprehensive output is solely for fatigue analysis of a single inspection point around the weld.

The multi brace case allows fatigue analysis to be carried out for several joints, wind directions, analysis planes and eigen-modes. A compressed output is produced.

Several fatigue runs may be executed in sequence. Between each run input values may be changed, however, the Rn.SIN file can not be changed.

2.1.4.17 Input

The solution technique used in the wind fatigue analysis requires a significant amount of input information such as geometry and modelling data of the structure, eigenvalues, eigenvectors, stresses from eigen-deformations, stresses from gust wind loading, wind loads and direct input parameters. The input information except for the direct input data must be contained in a Rn.SIN (and a Ln.FEM file if the static wind loads are not contained in the Rn.SIN file) which is read by the wind fatigue module. The files must be generated in advance of the wind fatigue analysis, see Section 3.26. The Ln.FEM file contains the static wind loads.

Wind parameters and other direct input are entered by the commands of Framework, see Section 5.

When the `RUN WIND-FATIGUE-CHECK` command is executed a control of input is performed before the fatigue analysis is started. If input errors exist, the execution is stopped and messages printed to the screen.

2.1.4.18 Output

The wind fatigue module produces tabulated prints of the fatigue damage results. The results are printed to the <Run>Framework.lis file, where the prefix Run is the run name entered by the user to the `RUN` command. For a series of fatigue runs executed in sequence, the output is printed to the same file if the run name is the same for all runs. For different run names, the results are printed to different files.

The compressed output contains one line of print for each chord/brace intersection and bent can brace included in the fatigue analysis. The fatigue damage is printed for all eight inspection points around the weld for the chord side and the brace side.

Fatigue damages are reported for each wind direction and in sum for all wind directions. Buffeting damages and vortex shedding induced damages are reported separately and in sum. Vortex shedding damages are reported for the member ends as well as the point of highest curvature along the member span. The twenty largest damages are printed in ranked order.

If more detailed fatigue information is required for a specific chord/brace intersection, a single brace case run must be executed using the comprehensive output option.

Dump print of hotspot stresses and stress spectrum data is possible during the fatigue calculation process by setting print options by the command `ASSIGN WIND-FATIGUE STRESS-PRINT-OPTIONS`. The print options must be set prior to execution of the RUN command. The stress data are printed to the file `runnameFramework.dmp`, where `runname` is the name of the run.

Diagnostics and messages are printed to the RunDiagnostics.txt file during the fatigue analysis. Classification of the joints as well as SN curves, SCF schemes and SCF factors for the joint connections are printed.

The fatigue lives, which are the inverse of the annual damages, are printed to the unformatted file `RunLive.frs`.

2.2 Loading and load combinations

Load combinations in Framework may be created by adding load cases together. Once a load combination is created, it is then referred to just like another load case.

Load cases may be required to be combined in order to:

- Calculate displacements
- Calculate velocities
- Calculate accelerations
- Calculate forces
- Calculate stresses
- Perform code checks

In Framework the following type of load cases may be combined:

- Static load cases.
  Any number of static load cases may be combined by use of the STATIC alternative in the CREATE LOAD-COMBINATION command. The resulting load combination (referred to herein as a static load combination) may be used for:
  - calculation of displacements
  - calculation of forces
  - calculation of stresses
  - code check analysis
- Static load case(s) plus dynamic load case(s).
  Dynamic load cases can be added to static load cases. The load combination is created by adding one dynamic result case by use of the SCAN alternative in the CREATE LOAD-COMBINATION command, or several dynamic result cases by use of the QUASI-STATIC alternative in the CREATE LOAD-COMBINATION. When using the SCAN alternative the program will scan through the dynamic result case to find the maximum response in combination with the static loads. When using the QUASI-STATIC alternative the user must specify the phase angle(s) to be used. The resulting load combination may be used for:
  - calculation of displacements
  - calculation of velocities
  - calculation of accelerations
  - calculation of forces
  - calculation of stresses
  - codecheck analysis

For more information on code checks for earthquake load cases, see Section 2.1.3.

- Dynamic load cases.
  Any number of dynamic load cases may be added together by use of the QUASI-STATIC alternative in the CREATE LOAD-COMBINATION command. Dynamic load cases are combined at user defined phase

angles.
Earthquake mode shapes CANNOT be combined (other than of course during the earthquake analysis).
Earthquake load cases CANNOT be combined.

2.2.1 Calculation of joint results

Joint results (displacements, velocities and accelerations) for all external loadcases are calculated during the structural analysis. Joint results for load combinations created in Framework are calculated by Framework.

Joint results are calculated with respect to a global axis system. Results are dependent on the type of loadcase:

- For a static loadcase or a static load combination, translations and rotations are presented.
- For a dynamic loadcase, the maximum amplitude of each component (displacement, velocity, acceleration) is presented together with the corresponding phase angle.
- For a combination of a dynamic and one or more static loadcases the following is presented:
  - static translations and rotations,
  - the maximum amplitude of each component (displacement, velocity, acceleration) due to the dynamic loadcase with the corresponding phase angle, and
  - the combined maximum translations and rotations.

Note that joint components for a specific phase angle CANNOT be presented.

2.2.1.1 Graphical presentation of joint displacements

The deformed shape may be displayed on top of the undeformed shape or alone, for quick evaluation of displacement results.

2.2.2 Calculation of members forces and moments

Member forces for all external loadcases are calculated during the structural analysis.

Member forces for load combinations created in Framework are calculated by Framework.

Member forces are presented with respect to the member local axis system and are by default calculated at three positions along the member length – at the end joints and at the midpoint. For more information on the sign convention see Appendix D.3.

The presentation of results is dependent on the type of loadcase:

- For a static loadcase or load combination, forces and moments are presented (computed at the centroid of the cross section)
- For a dynamic loadcase, the maximum amplitude of each component (force, moment) is presented together with the corresponding phase angle
- For loadcase a combination of a dynamic and one or more static loadcases the following is presented:
  - static forces and moments at the cross section centroid,
  - maximum amplitude of each component (force, moment) due to the dynamic loadcase with the corresponding phase angle, and
  - the combined maximum components (force, moment)

Note that components (force, moment) for a specific phase angle CANNOT be presented.

When calculating section forces in an arbitrary position along a member the forces will be calculated based on the element forces at the start node of the element and the loads (distributed and point loads) applied to the element.

Note that the analysis program Sestra saves beam element forces onto the Results Interface File only when the ISEL1 parameter on the RSEL command is set to 1.

This is the default option when running from the Sesam Manager.

2.2.2.1 Graphical presentation of member forces and moments

The member forces and moments may be displayed on the model. The following conventions apply:

- Axial force (FX) is drawn in the direction of member local y-axis when positive (tensile).
- Shear force (QY) is drawn in the direction of member local y-axis when positive.
- Shear force (QZ) is drawn in the opposite direction of member local z-axis when positive.
- Torsional moment (MX) is drawn in the direction of member local y-axis when positive.
- Bending moment (MY) about member local y-axis is drawn in the opposite direction of member local z-axis when positive, i.e. the diagram is drawn on the tensile side of the member.
- Bending moment (MZ) about member local z-axis is drawn in the opposite direction of member local y-axis when positive, i.e. the diagram is drawn on the tensile side of the member.

On a colour display, the diagram is drawn in **red** for positive values of the force/moment components and in **blue** for negative values.

2.2.3 Calculation of stresses

Stresses are normally calculated at three positions along the member's length, that is at the two ends and at the midpoint. The user is, however, free to add more positions along the member using absolute or relative coordinates. When using relative coordinates, a value of 0.0 corresponds to end 1 (first joint), 0.5 to the midpoint and 1.0 to end 2 (second joint) of the member. The relative coordinates (or joint names) are presented in tables of stresses or code check results.

The stresses at a position along the member are calculated at pre-defined points on the member's cross section. These points are normally referred to herein as stress points (or hotspots in conjunction with fatigue analysis). Stresses are computed from resulting member forces relative to a local coordinate system. Detailed information on stress calculations can be found in Appendix D.

Stresses may be computed for the following section types:

- Tubular sections (PIPE)
- Symmetrical/un-symmetrical I or H sections (I)
- Channel sections (CHAN)
- Box sections (BOX)
- Boxed Plate Girder (PGBOX)
- Double-web Plate Girder (PGDOW)
- Massive bar sections (BAR)
- General sections (GENE)
- Angle sections (L). (Angles defined with web on negative Y-axis only)

For box sections the stress points may be defined in centre of flange / web thickness (default option, as shown in Figure 2.4) or at extreme fibre, see command:

```
DEFINE HOTSPOTS EXTREME-LOCATION
```

Figure 2.4 illustrates the stress point (hotspot) numbering system employed in Framework for the various sections and flags the points that as default are applied for code checks and printout of member stresses.

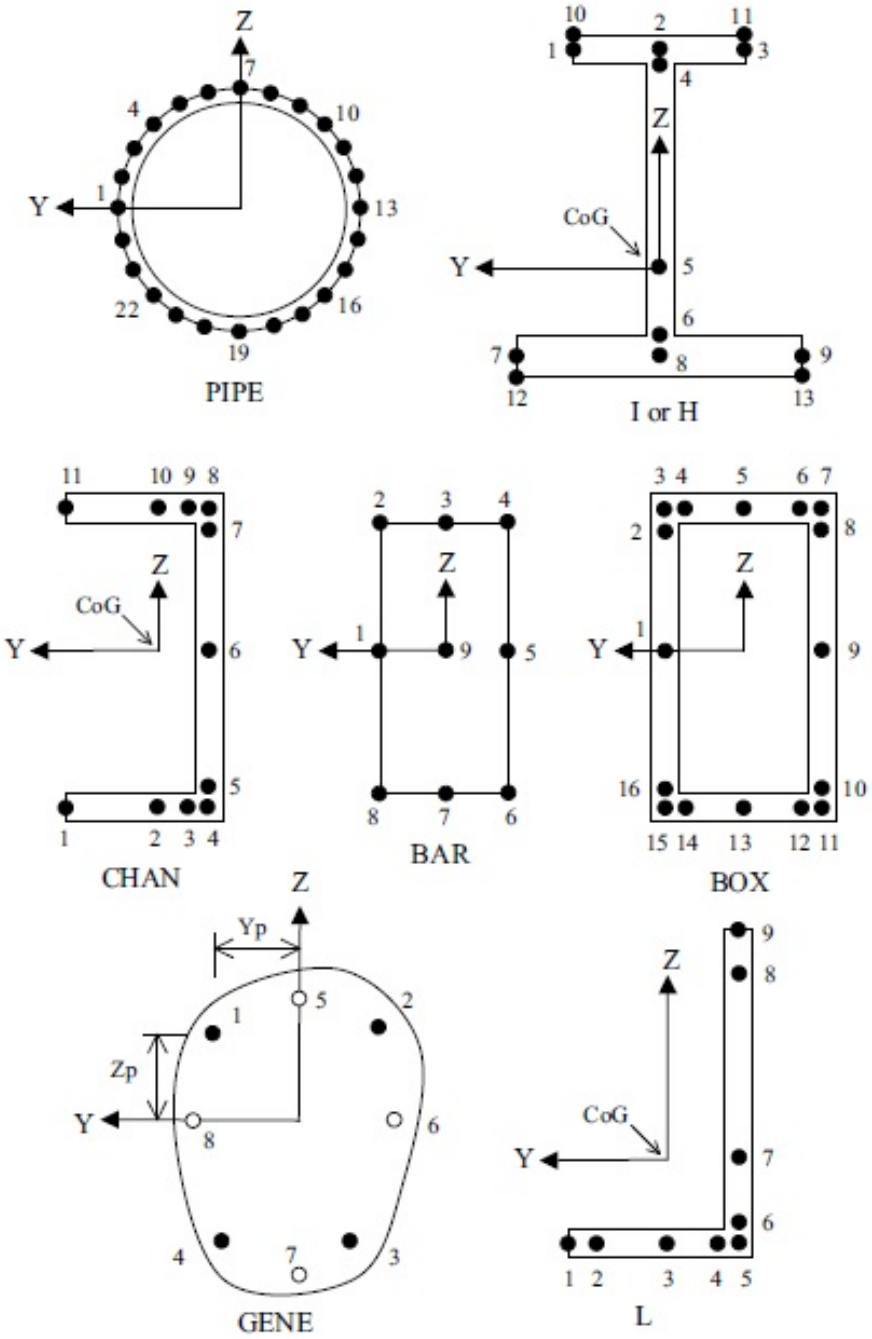


Figure 2.4: Code check stress point (hotspot) numbering system for the various sections

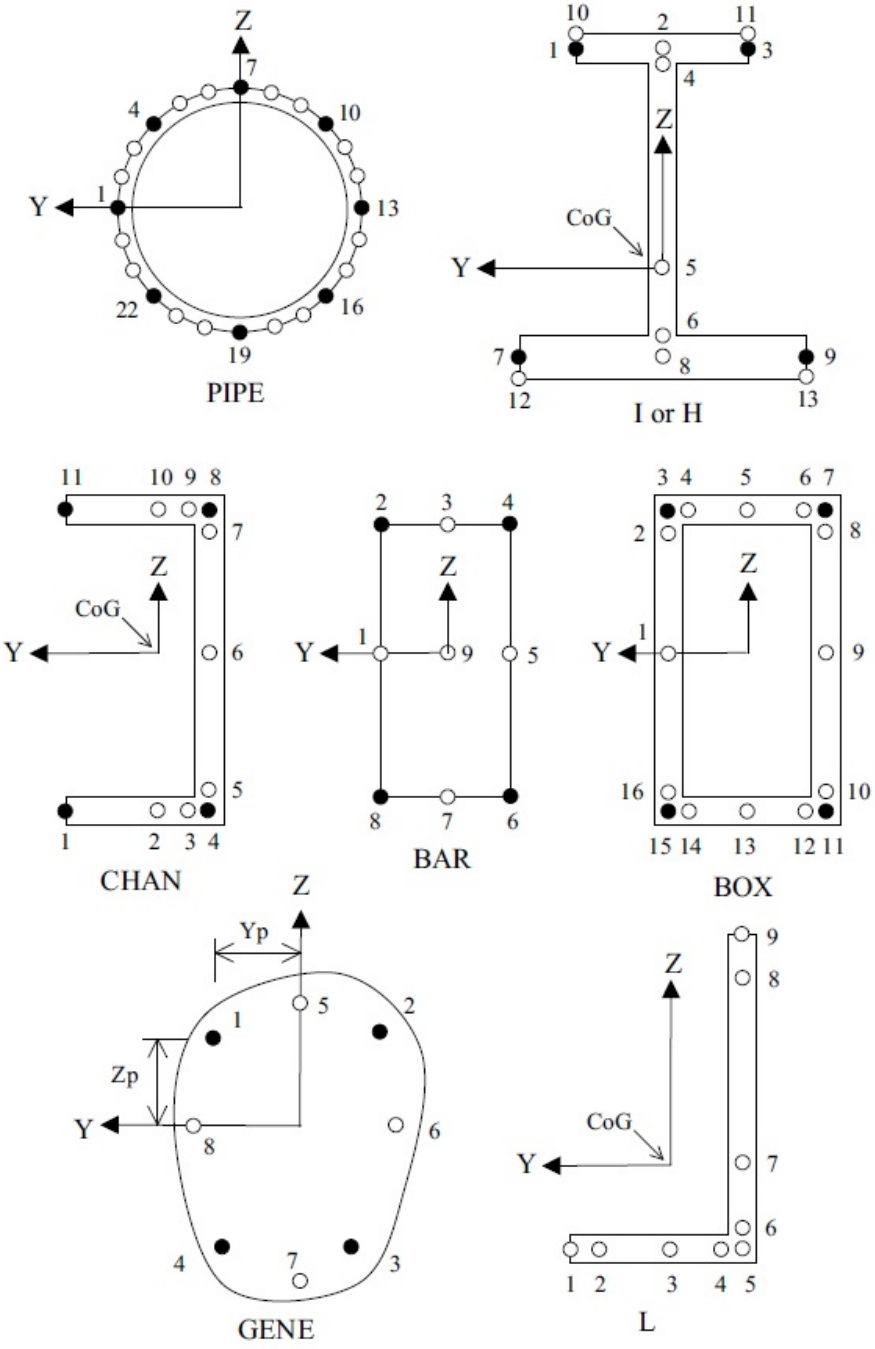


Figure 2.5: Fatigue stress point (hotspot) numbering system for various sections

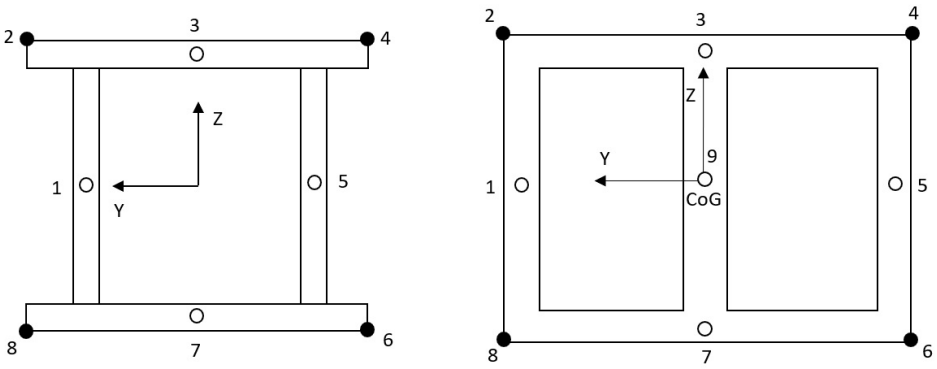


Figure 2.6: Fatigue stress point (hotspot) numbering for Boxed Plate Girder and Double-web Plate Girder

The stress components calculated at each stress point are as follows:

`SIG (PX)`	Normal stress due to axial force alone
`TAU (PY)`	Shear stress due to shear force in y direction
`TAU (PZ)`	Shear stress due to shear force in z direction
`TAU (MX)`	Shear stress due to torsional moment
`SIG (MY)`	Normal stress due to bending moment about y-axis
`SIG (MZ)`	Normal stress due to bending moment about z-axis

The maximum stress component for a section is found by calculating the equivalent stress at each of the stress points (hotspots) on the section and then storing the maximum value. Equivalent stresses are calculated according to the Von Mises criteria. For more information see Appendix D.4.

The presentation of the results is dependent on the type of loadcase:

- For a static loadcase, the following results are presented:
  - maximum equivalent stress and the corresponding stress point identification number
  - maximum normal stress and the corresponding stress point identification number

Note that the individual stress components will add up to the maximum equivalent stress.

- For a dynamic loadcase, the following results are presented:
  - maximum equivalent stress with the corresponding phase angle (in degrees) and corresponding stress point identification number
  - maximum normal stress with the corresponding phase angle (in degrees) and corresponding stress point identification number
- For a combination of a dynamic and one or more static loadcases the following results are presented:
  - maximum equivalent stress with the corresponding phase angle (in degrees) and corresponding stress point identification number
  - maximum normal stress with the corresponding phase angle (in degrees) and corresponding stress point identification number

Note that the individual stress components add up to the maximum equivalent (or normal) stress, since they all belong to the stress point having the largest equivalent (or normal) stress.

Individual stress components may be presented for a specific phase angle. In addition the corresponding equivalent and normal stress with the stress point identification number is presented.

For general beam normal (but not equivalent) stress is presented. The sections of Double-web Plate Girder and Boxed Plate Girder do not have strength code check. The stress presentation for these two sections may not display as the same logic of the other section types.

Figure 2.5 and 2.6 present the stress point (hotspot) numbering system employed in the fatigue check of Framework for the various section types. The fatigue check on members of Double-web Plate Girder and Boxed Plate Girder sections is supported.

2.3 Structural input data

There is no specific units requirement in Framework. However, units must be consistent with the units used in the preceding structural analysis. Default values of physical constants in Framework are based on the assumption of SI base units (metres, kilograms, Newtons).

2.3.1 Young's modulus

Some code check equations, for example AISC width to thickness ratio criteria, require that the yield strength is expressed in units of Ksi (Kips per square inch). Since units in Framework may be arbitrary (but consistent), the yield strength in Ksi is evaluated using the following expression

$$\frac{Fy_{ksi}}{Fy_{inp}} = \frac{E_{ksi}}{E_{inp}},$$

hence

$$Fy_{ksi} = \frac{E_{ksi}}{E_{inp}} \times Fy_{inp},$$

where

Fy	is yield strength
E	is Young's modulus
ksi	implies units in ksi
inp	implies units used in model.

Hence, Framework requires a value for E in units of ksi and this value is explicitly defined within Framework as $30,458ksi$, which is equivalent to $210 \times 10^9 N/m^2$.

Note that from version 3.2-01 the source code in Framework for the AISC LRFD code check has been updated to reflect the formulas written on the form of $\sqrt{E/F_y}$ which was introduced in the December 1999 edition of the AISC Specification

2.3.2 Yield strength

The yield strength of each member is associated with its material. By default, the yield strength of each material is computed from Young's modulus as $E/1050.0$, which is equivalent to $200 \times 106N/m^2$ when E is $210 \times 10^9 N/m^2$. The yield strength of each material may be changed. Some preprocessors (e.g. GeniE) writes the material yield stress to the material definition card (MISOSEL) on the SESAM Interface File. When the material yield stress is available Framework will use this information.

2.3.3 Material constant

The material constant accounts for material deficiencies. The yield stresses is reduced by dividing by this constant. By default this is set to 1.15.

The material constant applies to the NPD-NS3472, NORSOK and EUROCODE-NS3472 code checks.

2.3.4 CHORD and ALIGNED members

CHORD members in Framework are assigned at joints with several tubular members. Once a CHORD member is assigned at a joint, then all other tubular members (except the ALIGNED member) connected to that joint will be considered as BRACE members (the exception to this is when a LOCAL CHORD assignment is

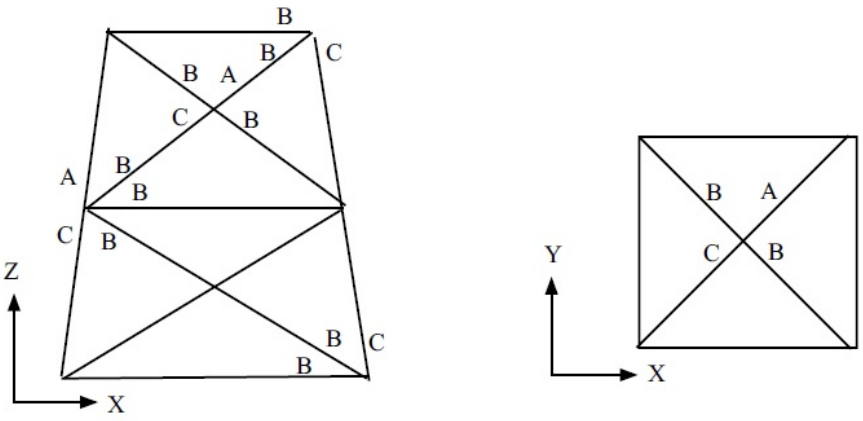


Figure 2.7: Default chord and brace assignments

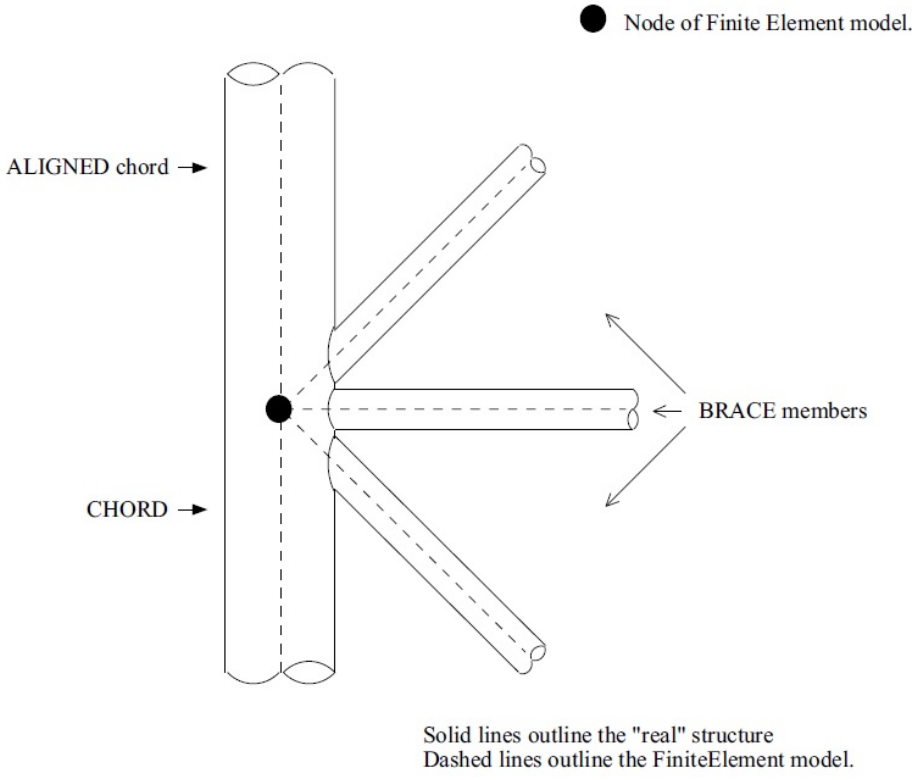


Figure 2.8: CHORD, ALIGNED and BRACE members

used; see later). Note that no command exists in Framework to explicitly define BRACE members. A BRACE member is always identified by its corresponding CHORD. It is possible that a member is a CHORD at one end while a BRACE at the other, or a CHORD at both ends or a BRACE at both ends.

CHORD and ALIGNED members at a joint are automatically determined by the program and may also be explicitly defined by the user. The use of CHORD and ALIGNED members is only applicable for tubular members. If both tubular and non-tubular members are connected at a joint, then all non-tubular members will be disregarded during the automatic or manual CHORD assignments.

When the automatic feature is used, all joints are scanned, and at each joint the program determines the member with the LARGEST diameter. If several potential chords with the same diameter are detected, the one with the largest thickness will be preferred. If at that joint another member exists and is also at a straight line (i.e. is aligned) with the CHORD member then that member qualifies as the ALIGNED chord for that CHORD at that joint. The concept of the ALIGNED chord may be used in calculations where the CHORD length is required, e.g. in the calculation of parametric stress concentration factors (see Appendix H.2.4). The 'effective' CHORD length is then taken as the sum of the actual CHORD length and the length of the ALIGNED chord. The CHORD length may also be given by the user, see command ASSIGN JOINT-CHORD-LENGTH.

The identification of aligned members is based on the BRACE TOLERANCE, which may be modified by the user. Initially, this has a value of 15 degrees. If the angle between a member and its aligned element is less than this angle, it will become a CHORD, otherwise it will become a BRACE.

For jacket legs, the lower of the two members that qualify as chord will become CHORD and the upper will become ALIGNED chord if they have the same diameter and thickness.

For cross braces (where 4 members with same diameter and thickness meet) the member having the smallest (or most negative) values of coordinates x and y, x and z or y and z will be selected as CHORD.

In Figure 2.7, C denotes a CHORD, A denotes an ALIGNED chord and B denotes a BRACE member end. The default assignments for two K joints, a KT joint and a vertical X joint is shown in the view of a vertical panel. In the horizontal plane view, default assignments for an X joint is shown.

If a member is manually assigned at a joint as a CHORD, then it is NOT necessary for that member to have the largest diameter at that joint.

Two types of manual CHORD assignments are available; GLOBAL and LOCAL.

When the GLOBAL assignment is used and a CHORD is assigned at a joint, then ALL other (tubular) members at that joint are the BRACE members of the assigned CHORD.

When the LOCAL assignment is used and a CHORD is assigned at a joint then only a user defined member at that joint is the BRACE of the assigned CHORD.

It should also be noted that chords which in the modelling tool are modelled as continuous members spanning across structural joints must be split at structural joints if incoming braces are going to be checked for punching shear capacity or fatigue damage (when using parametric SCFs), see command DEFINE BEAM-SPLIT.

Figure 2.8 shows a typical joint and illustrates the concept of a CHORD and ALIGNED chord.

See Section 3.2 for an illustrated example.

2.3.4.1 Near Chord Rule

The method above to differentiate the chord member and the aligned member of a brace depends on the local coordinate system of the chord. The chord determination for a brace may rely on the orientation of the jacket. As mentioned above, for the leg on an in-place jacket, the lower member would be the chord and the upper member be the aligned member. If the jacket lays horizontally during transportation, the orientation of the local coordinate system of the chord beam would govern the determination of chord and align member. It can be seen that the chord member and the aligned member might alter when rotating the jacket from vertical place to horizontal place. The original method is applicable for a single fatigue analysis. However,

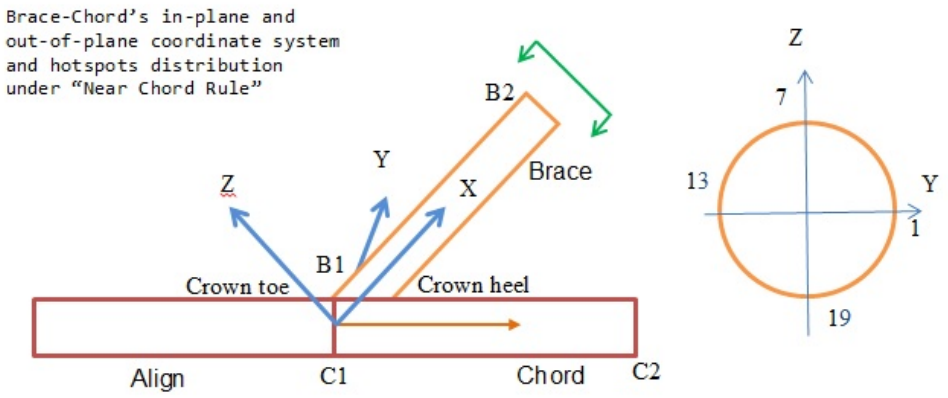


Figure 2.9: In-plane and out-of-plane coordinate system with Near Chord Rule

if the damage at each individual hotspot needs to be investigated in two separated fatigue analyses, for example, in-place and towing, this method may have problems. The hotspots distribution depends on the chord-brace pair and the in-plane and out-of-plane coordinate system. See D.7 and H.2.4. If the chord and aligned members swap, the hotspot distribution might vary.

Near Chord Rule: A new chord rule is introduced in Framework v3.14. The purpose is to have the brace-chord pair not to change when the structure and its load pattern are subject to a rotation.

- For a brace of brace angle $\theta < 90$ degree, the chord is determined by the one near to the brace, i.e. making an acute angle with the brace;
- For a brace of brace angle $\theta = 90$ degree of a T joint,
  1. the finite element with longer length is the chord;
  2. if the length equals, the finite element whose end 1 at common node is the chord, i.e. the local x axis origin from the common node;
  3. if both elements have the same end 1 or end 2 at common node, use the finite element with earlier appearance in the concept name list in the FEM file as the chord.
  4. if all above conditions fail, use the finite element with smaller element number as the chord. (the conditional re-meshing or mesh locking is necessary.)

The chord determination will not depend on the structure's orientation or the local coordinate system. The brace-chord in-plane and out-of-plane coordinate system can be decided and is unique w.r.t a brace at the joint. Figure 2.9 demostrates a typical brace-chord plane with the Near Chord Rule. The X axis is along the brace, always positive pointing from the commond node connecting brace and chord to the brace end. The Y axis is the normal vector N to the brace-chord plane, defined by the vector cross product of $X \times X_{LChord}$, where X_{LChord} is a unity vector along the chord, always positive pointing from the commond node to the chord end (not align end). The hotspots distribution on the brace's cross section is shown in Figure 2.9. For a brace at the joint, the location of hotspots: 1-7-13-19 is determined and will not alter with the rotation of the structure.

Use the command `DEFINE NEAR-CHORD-RULE On` to turn on the new chord rule. The new rule is not working in WindFat module.

2.3.5 CANS

A CAN section (which is tubular) is identified by a section name. This CAN section may be assigned either to a joint of the structural model, or it may be assigned directly to the chord or the aligned chord member.

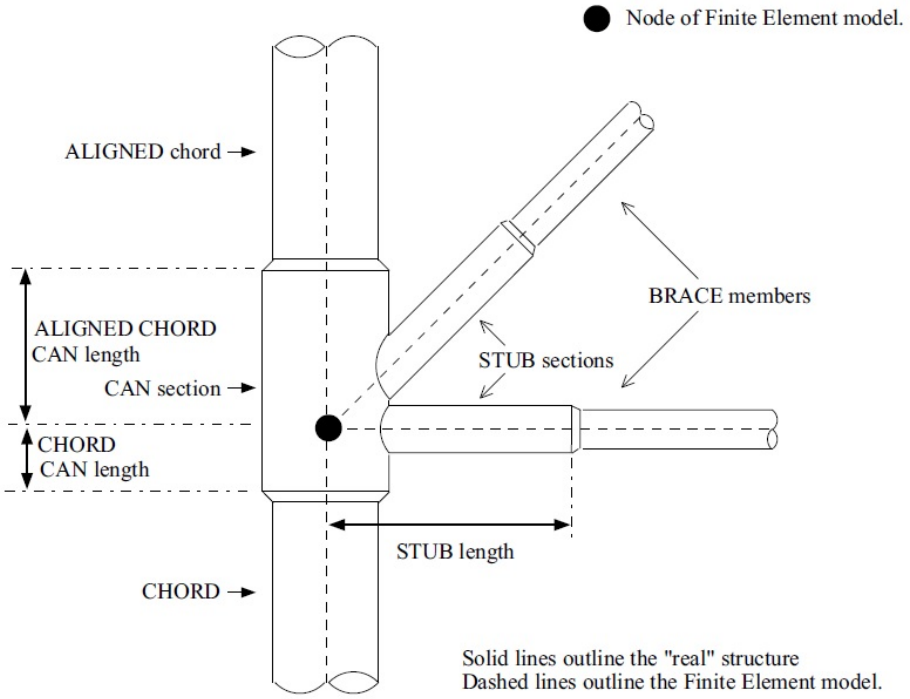


Figure 2.10: Illustration of CAN and STUB sections

If a CAN section is assigned at a joint then the CHORD and the ALIGNED chord (if any) at that joint automatically inherit the CAN section geometry.

In order for a CAN section to be assigned (directly or indirectly) to a member (CHORD or ALIGNED chord) it is required that the diameter of the CAN section is not less than the nominal diameter of the member.

Figure 2.10 shows a typical joint and illustrates the concept of CANS.

CAN sections defined as conceptual information on the Results File will be read by Framework.

See Section 3.3 for an illustrated example.

2.3.6 STUBS

STUB sections are normally assigned to BRACE members. A STUB section (which is tubular) is identified by a section name. This STUB section may be assigned to a joint of the structural model or directly to a brace at a joint.

In order for a STUB section to be assigned to a brace, it is necessary that the diameter of the STUB section is not less than the nominal diameter of the brace.

Figure 2.10 shows a typical joint and illustrates the concept of STUBS.

STUB sections defined as conceptual information on the Results File will be read by Framework.

See Section 3.3 for an illustrated example.

2.3.7 Joint Gap and Joint overlap

The gap length is defined as the distance, on the chord wall, between the weld toes of the two brace members. Such a joint is illustrated in Figure 2.11.

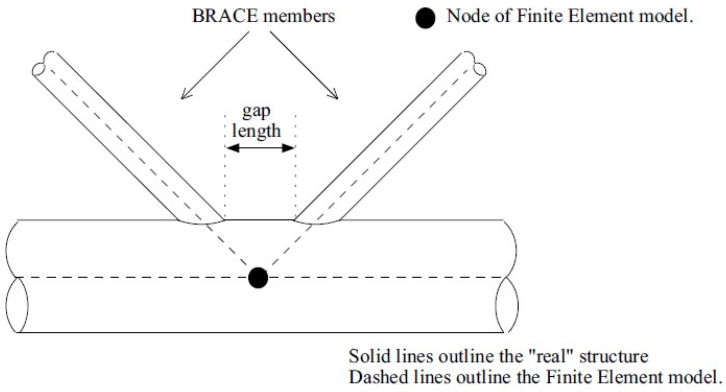


Figure 2.11: Non overlapped joint

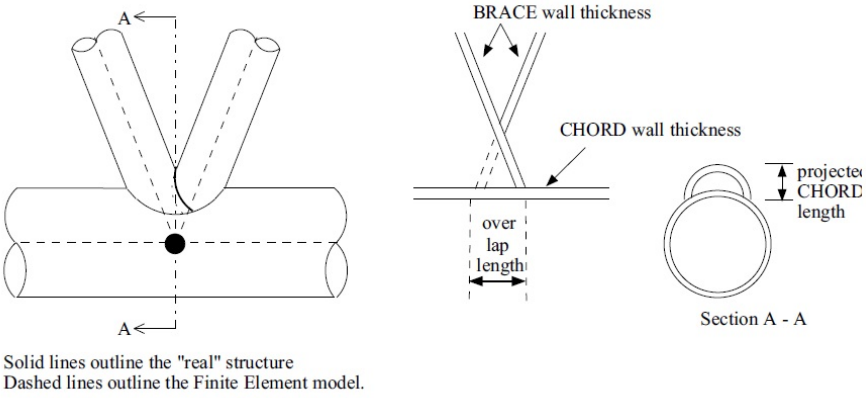


Figure 2.12: Overlapped joint

An overlapped joint is illustrated in Figure 2.12. The gap length is only used in conjunction with K, KTT or KTK joints.

When calculating Efthymiou SCFs, the overlap shall be specified as a negative gap value on the overlapping brace. It is only required to specify one gap value for a K-joint, the program will select the largest value of the ones assigned to the two braces. For a KT joint, the gap or overlap values shall be specified for the two KTK braces.

2.3.8 Joint Type

This defines the joint type at the end of a BRACE member. Five different joint types are available, namely:

YT (T or Y joint)
X
K
KTT (T part of a KT joint)
KTK (K part of a KT joint)

By default, all joints are assumed to be YT.

The punching shear code checks only use YT, X or K joints, that is because the formulas for K joints are used for KTK and KTT classified braces. In general, an X joint is the most conservative choice.

The choice of joint classification may be based on the actual geometry only or also on the force distribution

Table 2.5: Joint type classification

Number of braces:		Joint type based on:		
Same side	Oppo-site side	GEOMETRY (only)	LOADPATH (possibly in addition)	
1	0	YT		
2	0	K	YT	
3	0	KTK	YT	(upper/lower brace)
3	0	KTT	YT	(middle brace)
4	0	Impossible		
1	>0	X	YT	
2	>0	K	YT,X	
3	>0	KTK	YT,X	(upper/lower brace)
3	>0	KTT	YT,X	(middle brace)
4	>0	Impossible	YT,X	

at the joint (API [31] section 4.3). For a punching shear check it is recommended to use the classification based on load path.

All five joint types may be accounted for in the calculation of parametric SCFs for a fatigue analysis. In general, YT and X joints produce the more conservative results.

When the user specifies that the joint type shall be based on joint GEOMETRY, the joint type will be determined as follows: Provided the chord member and aligned member have been determined by the program or specified by user, the number of braces in the same plane formed by the target brace and the chord will counted; according to the number of near and far side braces, the joint type of the target brace is determined; The user specified BRACE TOLERANCE angle (default 15 degrees) is used in order to determine if neighbouring braces are in the same plane as the current brace. The classification is made as shown in Table 2.5.

When LOADPATH is selected as the JOINT TYPE, the percentage of each possible joint type will be determined. The share split is based on the potential balance relationship of the punching shear forces between the target brace and the other near side or far side braces. The sum of the percentages is 100%. There is a lower limit on the brace axial force ratio. If the ratio of axial force on the target brace divided by the maximum axial force on braces in the same chord-brace plane is less than the limit, i.e. the axial force on current brace is too small to split, the loadpath balance check will be skipped. See command DEFINE JOINT-PRAMETERS LOADPATH-FORCE-RATIO-LIMIT for details.

2.3.9 Positions for code check

By default, a member modelled from a single finite element has 3 code check positions, namely both ends and the midpoint of the member.

If a member is modelled from several finite elements, code check positions are created at all finite element nodes and at the mid point of all finite elements with a length exceeding a certain fraction of the total member length. If a member is modelled with conceptual reinforcement CAN or Stub, code check positions will be added at the interface of two cross sections.

The user may assign code check positions along the member, using absolute or relative coordinates. Relative coordinates should be used when updating several members of different lengths. The relative coordinate system along the member has a coordinate 0.0 at first joint (end 1), 0.5 at midpoint and 1.0 at the second joint (end 2). See Figures 2.13. With command `ASSIGN POSITIONS`, the code check positions may “evenly” distribute along the member. The maximum fraction of total member length is needed for adding new positions. If a member consists of multiple finite elements, the evenly spaced positions are not introduced if the element’s size is under the specified maximum fraction.

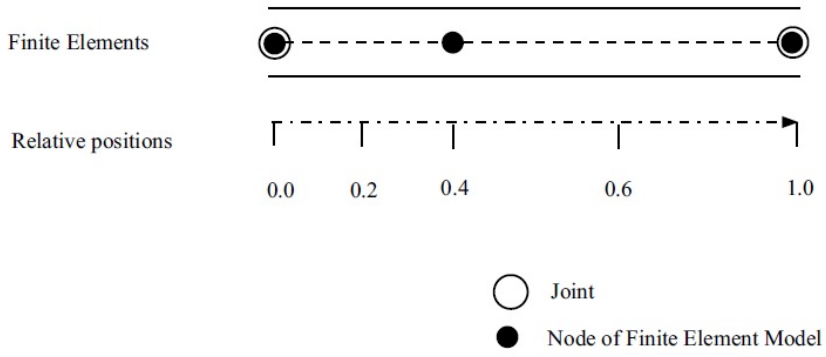


Figure 2.13: Member relative coordinate system

2.3.10 Local coordinate system

By default the member local coordinate system is based on the finite element local coordinate system (as established in e.g. Genie or Preframe).

Member forces are always presented in the member local coordinate system. For modelling of stability check properties and presentation (display and print) of member forces it is possible to re-assign a new member local coordinate system.

For tubular cross-sections which have equal stiffness properties independent of the local axes, the stability axes should normally be oriented according to the frame of which the member is a part.

For non-tubular cross-sections having different moments of inertia about local axes it may be dangerous to change the local axes. Changes to the orientation of the cross-section axes involve changes to the overall stiffness properties of the finite element model, and should eventually involve a new finite element analysis. But if axial force is the major load and bending moments are small, or the section has similar cross-section properties about different axes, then the orientation of stability axes may perhaps be changed without introducing too large errors.

When joining several finite elements into one member, it is required that all finite elements have the same local coordinate system.

2.3.11 Member buckling lengths

The user can specify the member buckling lengths Ly and Lz, which overrides the default buckling lengths (length between joints). The specified lengths will then be used in any calculation involving the buckling lengths, e.g. stability code checks for calculation of the effective lengths and the Euler buckling stress.

Instead of (or in addition to) specifying buckling lengths in order to modify the effective column length, the user can specify effective length factors Ky and Kz.

Automatic calculation of buckling length / effective length factors for members with pipe sections are described at end of Section 2.3.12.

2.3.12 Effective length factors

The effective length factors are used for estimating the interaction effects of the total frame on a compression member which is under investigation for stability failure. This method uses effective length factors K to equate the strength of a compression member of length l to an equivalent pin ended member of length Kl subject to axial load only.

If enough axial load is applied to the single column shown in Figure 2.14, the column depends entirely on its own bending stiffness for resistance to lateral deflection. The effective length of this member (Kl) will

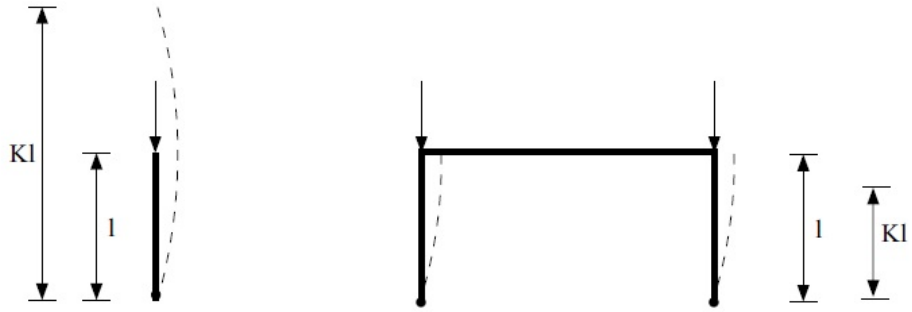


Figure 2.14: Axis load applied to a column

exceed its actual length. If however, this column is part of a frame, the effective length of the same column is less than its actual length due to the restraint (because of resistance to joint rotation) provided by the lateral member. In general the effective length factor may be less, equal or greater than unity.

GREAT CARE MUST BE EXERCISED when assigning effective length factors to members in Framework as it is easy to assign incorrect values unless the concept deployed is fully realised.

In Framework, two effective length factors may be assigned for each member, Kz associated with a moment about a members local z-axis (i.e. buckling in the local x-y plane) and Ky associated with a moment about a members local y-axis (i.e. buckling in the x-z plane).

The default orientation of the local axis system assigned in the pre-processing module, e.g. Genie or Preframe [51] must also be realised. (Now, modeling in Genie is recommended.) This default axis system is oriented such that for members NOT parallel to the global Z-axis the member local x-z plane is parallel to the global Z-axis, while members parallel with the global Z-axis will have its member local z-axis parallel with the global Y-axis. Depending on the brace configuration Ky and Kz will require different values. An example of this is shown in Figures 2.15 and 2.16.

For a member which is not parallel to any of the global planes, the end moments will be calculated about the Genie model or Preframe default member axis system which WILL NOT coincide with the members buckling planes.

When necessary it is important to define, in Genie or Preframe, an appropriate local axis system for the members that will be checked for stability in Framework.

For the brace configuration denoted A, member 1 is restrained from buckling in the global Z-X plane (also in the member's local z-x plane) due to the brace configuration in the vertical plane (Z-X). In this case, the effective length factors may be assigned, say, as:

For the brace configuration denoted B, member 1 is restrained from buckling in the global X-Y plane (also in the member's local x-y plane) due to the brace configuration in the horizontal plane (X-Y). In this case, the effective length factors may be assigned, say, as:

The effective length factors may also be calculated automatically by the program. This feature is available for tubular frames only, i.e. typically a jacket structure. The automatic buckling length calculation feature is activated in a similar way as other stability parameters.

The automatic buckling factor option calculates buckling factors for each element which is part of the member. In the code check, the critical axial capacity is calculated at each code check position based on where the position is located, i.e. at which element the check position is located.

The buckling parameter is calculated using an eigenvalue analysis. The critical axial compressive force will be equal in every beam element which is a part of the member. This is due to the fact that the member is

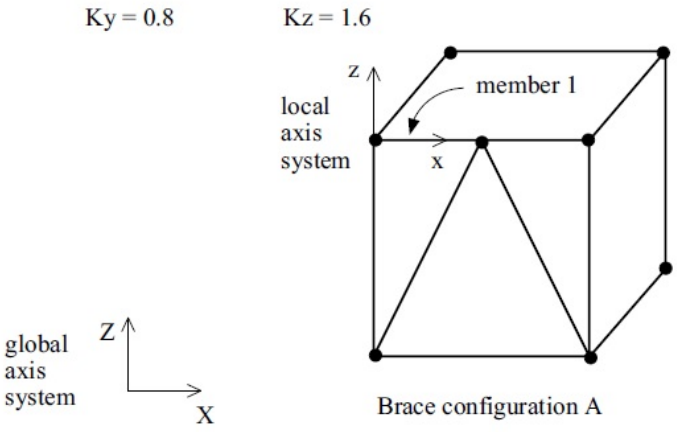


Figure 2.15: Assignment of Ky and Kz for brace configuration A

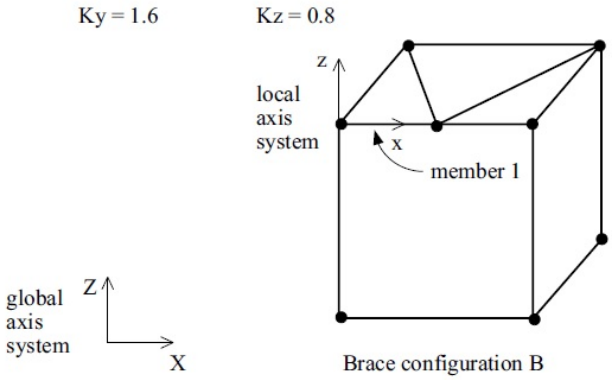


Figure 2.16: Assignment of Ky and Kz for brace configuration B

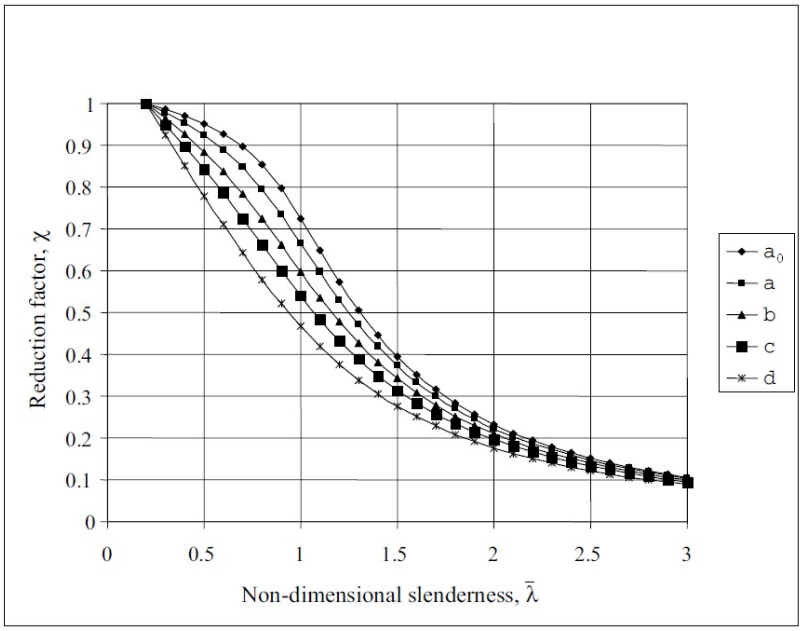


Figure 2.17: EC3 / NS 3472 buckling curves

regarded as one system, hence if one single member (beam element) in the member reaches the critical axial force, the member itself has reached the critical axial force also. The effective length factors for the different beam elements are dependant of the axial load in the beam.

Framework calculates the 'supporting' spring stiffnesses automatically. The planes in which the springs acts are given by the in-plane and out-of-plane definition for the member.

See Appendix B for details regarding calculations of effective length factors and the 'supporting' spring stiffnesses.

2.3.13 Unsupported flange length

The user can specify the length between lateral supports on the compression flange for a member, which is required to be checked for lateral buckling or flexural torsional buckling.

The default value assumed is the length between the joints.

The unsupported length of the compression flange is used for the checking of I and channel sections for API-AISC and NPD-NS3472 stability checks and EUROCODE-NS3472 member check.

2.3.14 Fabrication method

The fabrication method may be specified as welded or rolled.

The information will be used in the calculation of the lateral buckling resistance factor during the NPD-NS3472 and EUROCODE-NS3472 stability calculations for non-tubular member. It will also be used for determining the limiting width thickness ratio for non-tubular members during the API-AISC stability calculations.

2.3.15 Buckling curve

The characteristic axial compressive buckling strength of a member is assessed from a set of curves provided by the NS3472 and EUROCODE codes of practice. Example from NS3472 is shown in Figure 2.17.

These curves are labelled A, B, C, etc. Each member may be assigned two different buckling curves; one for buckling caused by a moment about the member's local y-axis and the other for buckling caused by a

moment about the member's local z-axis. Conservatively, non-tubular members may be assigned curve C (default) while for tubular members it is usual to assign curve A (default).

The EUROCODE-NS3472 code of practice may also automatically select buckling curves based on profile shape for I(H) and BOX profiles.

This option is used in stability check for both tubular and non-tubular members.

2.3.16 Lateral buckling factor

The lateral buckling factor (usually denoted C_b for AISC and Ψ for NS3472 and EUROCODE) is used for calculation of the bending capacity of non-tubular members in the stability checks. Lateral buckling may be the mode of buckling failure for a member under axial compressive load and a 'large' moment about its strong axis. It can simply be described as Euler buckling of the compression flange about its strong axis.

The lateral buckling factor may be user defined, or automatically calculated. A default value of 1.0 is assumed.

2.3.17 Moment reduction factors

The moment (amplification) reduction factors are used in stability calculations. The application of a moment along the un-braced length of members under compressive load, generates a secondary moment equal to the product of the resulting eccentricity and the applied axial compressive load. The secondary moment is not reflected in the computed bending stress f_b. To provide for this added moment, the computed bending stress is multiplied (and therefore amplified) by the factor:

$$\frac{1}{1-\frac{f_a}{F_e}}$$

where f_a is the acting axial stress and F_e is the Euler buckling stress with a factor of safety. However, depending on the applied moment diagram the amplification factor for the computed bending stress may overestimate the extent of the secondary moment. To take care of this, the amplification factor may be modified, as required, by the moment amplification reduction factor, usually denoted C_m. The computed bending stress is then factored by:

$$\left(\frac{1}{1-\frac{f_a}{F_e}}\right) C_m$$

Two values of C_m or each member are required for stability calculations; C_{my} and C_{mz}. C_m values for members may be user defined or calculated by the program.

A default value of 1.0 is assumed for C_{my} and C_{mz}. In order to comply with the code of practice used, the correct code of practice must be selected.

For EUROCODE and NS3472 (release 3) it is the equivalent uniform moment factors b (i.e. not the moment amplification factor k) which are calculated or given by the user.

2.3.18 Stiffener spacing

The spacing between ring stiffeners for tubular members may be specified.

A default value corresponding to the member length is assumed.

This value is used for hydrostatic collapse and hydrostatic stability calculations (for tubular members only) according to API-AISC-WSD, API-AISC-LRFD and NORSOK code checks.

This value is also used to give the spacing between web stiffeners according to API-AISC-WSD, API-AISC-LRFD and EUROCODE-NS3472 code checks.

2.4 Environmental Input

2.4.1 Sea water density and acceleration due to gravity

This data is used for hydrostatic collapse and hydrostatic stability calculations (for tubular members only) as indicated in Tabls 2.7 to 2.9.

Default sea water density $= 1025 kg/m^3$.

Default gravity $= 9.81 m/s^2$.

2.4.2 Water depth

This defines the average water depth. The definition of water depth is MANDATORY only for hydrostatic collapse and hydrostatic stability calculations (for tubular members only) as indicated in Tables 2.7 to 2.9.

2.4.3 Wave height

This is used in order to account for the wave induced hydrostatic pressure. If the wave height is not defined then calm sea condition is assumed and hydrostatic calculations are performed up to the mean water level.

The definition of wave height is OPTIONAL for hydrostatic collapse and hydrostatic stability calculations (for tubular members only) as indicated in Tables 2.7 to 2.9.

2.4.4 Wave length

This is used in order to account for the wave induced hydrostatic pressure. If the wave length is not defined then calm sea condition is assumed and hydrostatic calculations are performed up to the mean water level.

The definition of the wave length is only required when a wave height has been defined.

2.4.5 Water plane

This defines the orientation of the water plane with respect to the global axis system (defined at the preprocessing stage) of the structural model.

If one of the global axes is normal to the water plane, then the intersection of this axis with the water plane together with the direction of the axis and the water depth, define all members that are below the mean water level.

Alternatively, the water plane orientation may be established by defining the global coordinates of any three points that lie in the water plane. This, together with the water depth, define all members that are below the mean water level.

The definition of water plane is MANDATORY only for hydrostatic collapse and hydrostatic stability calculations (for tubular members only) as indicated in Tables 2.7 to 2.9.

2.4.6 Individual wave data

The total number of waves passing through the structure, for each of the wave directions analysed, is required to be specified when performing a deterministic fatigue analysis.

A long term distribution of wave heights is produced for each of the wave directions, and for each of the wave heights a certain associated number of waves is derived from the long term distribution curve. This curve may be specified as linear, which corresponds to a long term Weibull distribution, or it may be specified as piece-wise linear.

Both of the long term distribution curves available are shown in Figure 2.18. Also see Figure 2.19.

2.4.7 Wave load factor

This defines the load factor (DAF) that may be applied to each of the wave directions and heights analysed in a deterministic fatigue analysis. The stress ranges (inclusive SCF) at each hotspot calculated for each

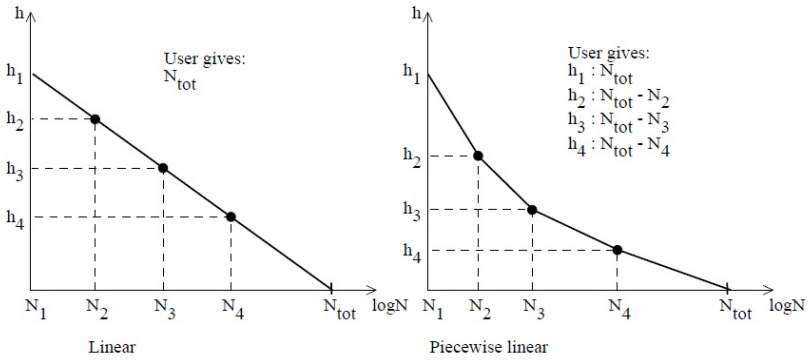


Figure 2.18: Long term distributions of wave heights

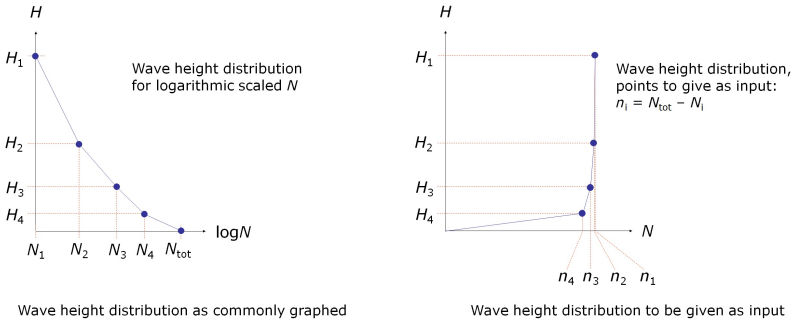


Figure 2.19: Long term wave height distribution to be given as input

individual wave is then multiplied with the given load factor.

2.4.8 Wave spreading function

Wave spreading accounts for the energy spreading of waves in a short crested sea-state.

Positive angles are measured counter-clockwise with respect to the current main wave direction.

The spreading function may be defined as a continuous cosine power function or as a discretised function.

If a discretised spreading function is given, then the wave direction spacing must correspond to the wave direction spacing used in the hydrodynamic analysis. For each of the elementary wave directions the asso-

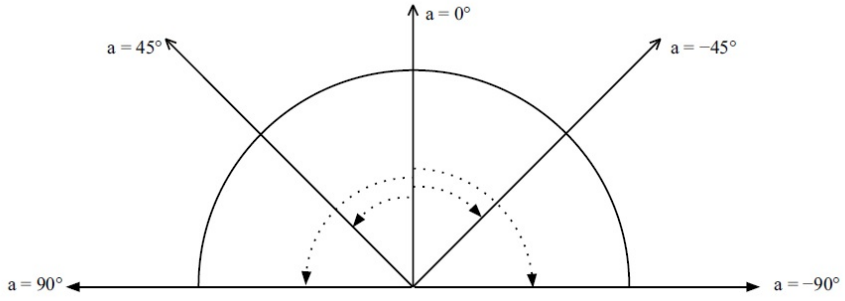


Figure 2.20: Angles relative to main direction assuming spreading of five elementary wave directions

ciated energy content is required to be defined. The sum of all energies must be equal to 1.00.

If an analytical function is used, the spreading function is integrated over the interval adjacent to the current direction.

The angles relative to the main wave directions, assuming 5 elementary wave directions are shown in Figure 2.20.

2.4.9 Wave spectrum shape

The definition of a wave spectrum shape is required in order to calculate stress response during a stochastic fatigue analysis. The types of wave spectrum shapes available are `Pierson-Moskowitz`, `JONSWAP`, `Gamma`, `ISSC`, and `Torsethaugen`.

The wave spectrum shape must be consistent to the wave statistics, i.e. the wave scatter diagram must be assigned with appropriate wave spectrum shape. For example, the `ISSC` spectrum shall be assigned to `ISSC` type wave statistics; The `Torsethaugen` spectrum must be assigned to an "Hs-Tp" wave statistics; `JONSWAP` and `Pierson-Moskowitz` spectra are allowed for regular scatter diagram with Hs and Tz, and "Hs-Tp" type scatter diagram. A wave spectrum is defined with the significant wave height and a characteristic wave period. `JONSWAP` and `Pierson-Moskowitz` spectra have expressions in either zero up-crossing period Tz or peak period Tp. `ISSC` uses the mean wave period T1; `Torsethaugen` spectrum uses the peak period Tp. For more information on this see Section 2.4.11.

If the wave statistics has been defined through an "All parameter scatter diagram", e.g. the `Ochi-Hubble` spectrum, all necessary parameters are given through the `CREATE WAVE-STATISTICS` command, and hence a wave spectrum shape shall not be assigned to the wave statistics. For more information on the wave spectra see Stofat User Manual [53] Appendix B 1.4 Wave Spectrum.

A `JONSWAP` wave spectrum is normally used to simulate a seastate which is not fully developed, often caused by a high wind speed, while the `Pierson-Moskowitz` spectrum is appropriate for fully developed seastates.

The `ISSC` spectrum [4] is the recommended sea spectrum from the International Ship and Offshore Structure Congress. The spectrum is recommended for open sea conditions and fully developed sea by the 15th International Towing Tank Conference (ITTC).

The `Torsethaugen` spectrum is a double peak spectral model developed based on measured spectra for Norwegian waters (Haltenbanken and Statfjord). The sea state is described by superposing a part according to locally wind generated sea on another part according to swell. Each of the parts is described by a generalized Jonswap spectrum. For the detailed information on Torsethaugen wave spectrum, please refer to Stofat User Manual [53] Appendix B 1.4 Wave Spectrum.

For more information on the wave spectra see Appendix J.2.4.

The definition of wave spectrum is OPTIONAL for a stochastic fatigue analysis as shown in Table 2.10. A Pierson-Moskowitz wave spectrum is assumed by default.

2.4.10 Wave direction probability

This defines the probability of occurrence for each main wave direction specified in the hydrodynamic analysis. This data is required in order to calculate the contribution of each main wave direction to the gross fatigue damage.

The definition of the wave direction probability is MANDATORY for a stochastic fatigue analysis as indicated in Table 2.10.

2.4.11 Wave statistics

For a stochastic fatigue analysis the probable history of loading throughout the life of the structure is required. The waves that induce this loading are usually presented in the form of a scatter diagram. A scatter diagram gives the probability of occurrence of a short term seastate described statistically by parameters,

for instance significant wave height (Hs) and zero up-crossing period (Tz). A typical scatter diagram is shown below.

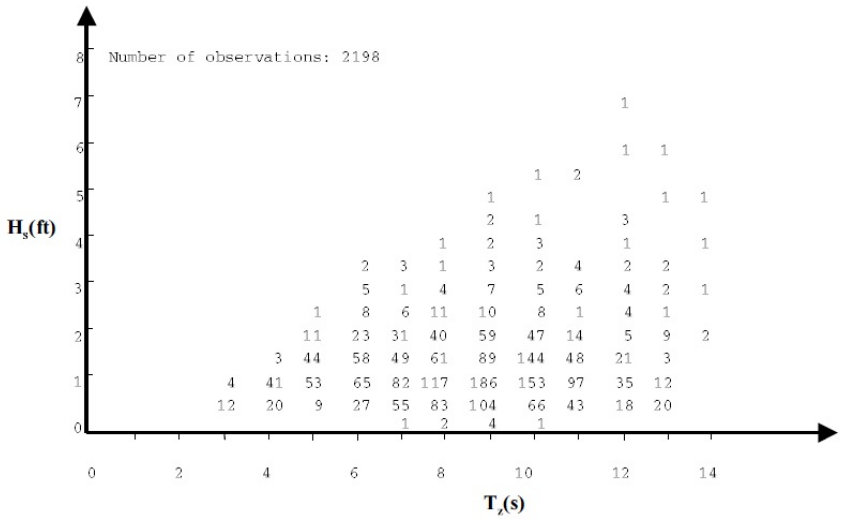


Figure 2.21: Scatter diagram

A seastate may be identified by a set of Hs and Tz values. For each seastate, Hs and Tz are required to be defined in the program. In addition, the probability of occurrence of each seastate must be specified in order to calculate the contribution of each individual seastate to the gross fatigue damage. Framework allows three formats of seastate occurrence input: Probability, Occurrence Number, and Percentage.

For fatigue analysis, there are four types of scatter diagram available in the program: regular SCATTER-DIAGRAM, ISSC-SCATTER-DIAGRAM, Hs-Tp, and ALL-PARAM-SCATTER. Some wave scatter diagram consists of seastates defined by Hs and Tp values, where Tp is the peak spectral period of the wave. In this case, the peak period Tp should be input in place of Tz. When using wave statistics according to ISSC [4] it is T1 (mean wave period) that is used for a seastate.

The wave spectrum shape associated with the wave scatter diagram can be specified through command: `ASSIGN WAVE-SPECTRUM-SHAPE`. In Framework all seastates may be associated with the same wave spectrum shape, or different shapes may be assigned to different parts of the scatter diagram. This may be a Pierson-Moskowitz, JONSWAP, Gamma, Torsethaugen or ISSC wave spectrum. Pierson-Moskowitz and JONSWAP wave spectrum can be assigned to a wave statistics of either regular “SCATTER-DIAGRAM” type or “Hs-Tp” type; Torsethaugen spectrum can only be assigned to a wave statistics of “Hs-Tp” type. The ISSC scatte diagram usually pairs with an ISSC wave spectrum. If the wave statistics has been defined through an “all parameter scatter diagram”, all necessary parameters are given through the `CREATE WAVE-STATISTICS` command, and hence a wave spectrum shape shall not be assigned to the wave statistics in this case. For more details on the wave spectrum, see Section 2.4.9.

A seastate is associated with a wave spreading function. In Framework all seastates may be associated with the same wave spreading function, or different functions may be assigned to different parts of the scatter diagram. For more details on the wave spreading, see Section 2.4.8.

The definition of seastates is MANDATORY for a stochastic fatigue analysis as indicated in Table 2.10.

2.5 Fatigue Analysis input

2.5.1 Regular SN Curves

The concept of an SN curve is used to define the fatigue characteristics of a material subjected to a repeated cycle of stress of constant magnitude. The SN curve delivers the number of cycles required to produce failure for a given magnitude of stress. The SN curve may be selected from the library curves (using SI base units Newton and meter) or it may be user defined.

The program default SN curve, the DNV-X curve, is similar to the X-curve stipulated by the American Welding Society, AWS D1.1 1972 section 10. The library contains a subset of DNV [52], API, NS3472, NORSOK, HSE [34], [30] ABS [14] and DOE [18] curves.

The SN curves should be applied according to the service condition of the fatigue position. For instance, the joint connection can be located in air, be submerged in sea water, or be located in the splash zone. Some SN curves from major authorities or standard association are predefined in Framework and the other post-processing modules of Sesam.

These SN curves are named with a specific corrosion environment and are called ***regular*** type. The name of a *regular* SN curve usually contains a suffix appended to the SN curves name from the standard institutes and authortities. The suffix label is to differentiate where the SN curve should be applied. Hence, every SN curve has a unique name. For example, “API-WJ" is the primary name of API RP2A weld joint SN curve. The primary SN curve is related to 3 *regular* SN curves: “API-WJ-A" or "HSE-T-IA" for in-air, “API-WJ-CP" for in sea with cathodic protection, and “API-WJ-FC" for free corrosion. Similarly, DNV2010_B2 or DNV2010_T is the primary type. The SN curve whose name contains a suffix label representing the corrosion condition is of the *regular* type. There are various suffix labels such as “A", “IA" or “AIR" for “in-air", “S" or “SEA" or “SEACP" for “in-sea", and “FC" or “SEAFC" for “free corrosion in splash zone". The name rule applies to API, ABS, ISO 19902 [33], Norsok and DNV 2010 SN curves libraries. Some SN curves, such as DNV-X, DOE-E, DOE-F, DOE-F2, DOE-T, do not use this naming method. The user can read Table 2.6 that shows the libraries of predefined *regular* SN curves.

The complete list of available ***regular*** SN curves in Framework:

ABS-B-A	ABS-B-CP	ABS-B-FC
ABS-C-A	ABS-C-CP	ABS-C-FC
ABS-D-A	ABS-D-CP	ABS-D-FC
ABS-E-A	ABS-E-CP	ABS-E-FC
ABS-F-A	ABS-F-CP	ABS-F-FC
ABS-F2A	ABS-F2CP	ABS-F2FC
ABS-G-A	ABS-G-CP	ABS-G-FC
ABS-T-A	ABS-T-CP	ABS-T-FC
ABS-W-A	ABS-W-CP	ABS-W-FC
API-CJ-A	API-CJ-CP	API-CJ-FC
API-WHPEENING-A	API-WHPEENING-CP	API-WHPEENING-FC
API-WJ-A	API-WJ-CP	API-WJ-FC
API-WPROFILE-A	API-WPROFILE-CP	API-WPROFILE-FC
API-WTBGRIND-A	API-WTBGRIND-CP	API-WTBGRIND-FC
API-X-A	API-X-CP	API-X-FC
API-XP-A	API-XP-CP	API-XP-FC

continued . . .

API-X	API-XP	
DNV-X		
DNV2010_B1-AIR	DNV2010_B1-SEACP	DNV2010_B1-SEAFC
DNV2010_B2-AIR	DNV2010_B2-SEACP	DNV2010_B2-SEAFC
DNV2010_C-AIR	DNV2010_C-SEACP	DNV2010_C-SEAFC
DNV2010_C1-AIR	DNV2010_C1-SEACP	DNV2010_C1-SEAFC
DNV2010_C2-AIR	DNV2010_C2-SEACP	DNV2010_C2-SEAFC
DNV2010_CN-AIR	DNV2010_CN-SEACP	DNV2010_CN-SEAFC
DNV2010_D-AIR	DNV2010_D-SEACP	DNV2010_D-SEAFC
DNV2010_E-AIR	DNV2010_E-SEACP	DNV2010_E-SEAFC
DNV2010_F-AIR	DNV2010_F-SEACP	DNV2010_F-SEAFC
DNV2010_F1-AIR	DNV2010_F1-SEACP	DNV2010_F1-SEAFC
DNV2010_F3-AIR	DNV2010_F3-SEACP	DNV2010_F3-SEAFC
DNV2010_G-AIR	DNV2010_G-SEACP	DNV2010_G-SEAFC
DNV2010_HS-BMAIR	DNV2010_HS-BMVAM	DNV2010_HS-SEACP
DNV2010_T-AIR	DNV2010_T-SEACP	DNV2010_T-SEAFC
DNV2010_UM-BM		
DNV2010_UM-TC		
DNV2010_W1-AIR	DNV2010_W1-SEACP	DNV2010_W1-SEAFC
DNV2010_W2-AIR	DNV2010_W2-SEACP	DNV2010_W2-SEAFC
DNV2010_W3-AIR	DNV2010_W3-SEACP	DNV2010_W3-SEAFC
DNVGL2016_T-A	DNVGL2016_T-CP	DNVGL2016_T-FC
DOE-E	DOE-F DOE-F2	DOE-T
HSE-C-CP	HSE-C-FC	HSE-C-IA
HSE-E-CP	HSE-E-FC	HSE-E-IA
HSE-F-CP	HSE-F-FC	HSE-F-IA
HSE-F2CP	HSE-F2FC	HSE-F2IA
HSE-G-CP	HSE-G-FC	HSE-G-IA
HSE-P-CP	HSE-P-FC	HSE-P-IA
HSE-T-CP	HSE-T-FC	HSE-T-IA
HSE-W-CP	HSE-W-FC	HSE-W-IA
HSEnew-T-CP	HSEnew-T-FC	HSEnew-T-IA
HSEnew-CJ-CP	HSEnew-CJ-FC	HSEnew-CJ-IA

continued . . .

NO-B1-S	NO-B2-S	NO-C-S
NO-C1-S	NO-C2-S	NO-D-S
NO-E-S	NO-F-S	NO-F1-S
NO-F3-S	NO-G-S	NO-T-S
NO-W1-S	NO-W2-S	NO-W3-S
NS-B-SEA	NS-C-SEA	NS-D-SEA
NS-E-SEA	NS-F-SEA	NS-F2-SE
NS-G-SEA	NS-T-SEA	NS-W-SEA
ISO-CJ-A	ISO-CJ-CP	ISO-CJ-FC
ISO-OJB-A	ISO-OJB-CP	ISO-OJB-FC
ISO-OJC-A	ISO-OJC-CP	ISO-OJC-FC
ISO-OJD-A	ISO-OJD-CP	ISO-OJD-FC
ISO-OJE-A	ISO-OJE-CP	ISO-OJE-FC
ISO-OJF-A	ISO-OJF-CP	ISO-OJF-FC
ISO-OJF2-A	ISO-OJF2-CP	ISO-OJF2-FC
ISO-OJG-A	ISO-OJG-CP	ISO-OJG-FC
ISO-OJW1-A	ISO-OJW1-CP	ISO-OJW1-FC
ISO-TJ-A	ISO-TJ-CP	ISO-TJ-FC
ISO-TJHP-A	ISO-TJHP-CP	ISO-TJHP-FC
ISO-TJWTG-A	ISO-TJWTG-CP	ISO-TJWTG-FC

Note: API-X and API-XP SN curves are changed back to the regular type in Framework V4.0 for the purpose to compatible to old analysis model and the other Sesam modules. API-X and API-XP represent the SN curves in API RP2A 20th edition for under sea water with cathodic protection.

Table 2.6: Library of predefined *regular* SN Curves

API RP2A 20th API RP2A 21st, 2000	Curves in air named API-n-A Curves for sea water, cathodic protection, named API-n-CP, curves for sea water, free corrosion, named API-n-FC, where “n‘" can be curve name X or XP.
DNVGL2016_T	DNVGL RP C203 2016 version Tubular Joint curves (1) in air named DNVGL2016_T-A; (2) with cathodic protection named DNVGL2016_T-CP (3) free corrosion named DNVGL2016_T-FC
API RP2A 21st, 2010 API RP2A 22nd, 2014	‘API-WJ-n’ for weld joint, ‘API-CJ-n’ for cast joint, ‘API-WPROFILE-n’ for weld joint with weld improvement “profile", ‘API-WTBGRIND-n’ for weld improvement “weld toe burr grind", ‘API-WHPEENING-n’ for weld improvement “Hammer peening", where “n" can be “A" for in air, “CP" for sea water, cathodic protection, and “FC" for sea water, free corrosion.
ISO 19902:2007	‘ISO-TJ-n’ for tubular joint, ‘ISO-CJ-n’ for cast joint, ‘ISO-TJHP-n’ for tubular joint with weld improvement “Hammer peening", ‘ISO-TJWTG-n’ for weld improvement “weld toe grinding", ‘ISO-OJB-n’, ‘ISO-OJC-n’, ‘ISO-OJD-n’, ‘ISO-OJE-n’, ‘ISO-OJF-n’, ‘ISO-OJF2-n’, ‘ISO-OJG-n’, ‘ISO-OJW1-n’ for other joints, where “n" can be “A" for in air, “CP" for sea water, cathodic protection, and “FC" for sea water, free corrosion.
DNV	DNV-X
DNV RP-C203-2010	1) Curves in air named DNV2010_n-AIR, 2) curves for sea water, cathodic protection, named DNV2010_n-SEACP, 3) curves for sea water, free corrosion, named DNV2010_n-SEAFC, 4) curves for high strength steel in air and for sea water with cathodic protection, named DNV2010_HS-AIR, DNV2010_HS-SEACP, 5) curves for small diameter pipe umbilicals, base material and thickness correction DNV2010_UM-BM, DNV2010_UM-TC
NS3472	Curves for sea water, cathodic protection, named NS-n-SEA, n = curve name
NORSOK (DNV-RP-C203)	Curves for sea water, cathodic protection named NO-n-S, n = curve name
HSE [34]	Curves for sea water cathodic protection named HSE-n-CP, free corrosion named HSE-n-FC, and in air named HSE-n-IA, n = curve name
HSE [30] OTH 92 390	Curves for sea water cathodic protection named HSEnew-n-CP, free corrosion named HSEnew-n-FC, and in air named HSEnew-n-IA, n = curve name
ABS	Curves for sea water cathodic protection named ABS-n-CP, free corrosion named ABS-n-FC, and in air named ABS-n-A, n = curve name
DOE (in air)	Curves in air named DOE-n, n = curve name

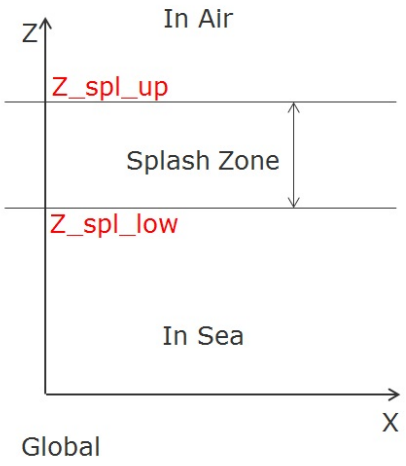


Figure 2.22: The splash zone

2.5.2 Primary SN Curves

The other type of SN curve is the primary type that uses the ***primary*** curve name itself without suffix. Choosing the *primary* type SN curve will activate “automatic elevation dependency". Then, Framework will automatically calculate the elevation of the fatigue position and apply the associated SN curve data to this position. Framework assumes the fatigue position located above splash zone is “in air" and located below splash zone “in sea water" with appropriate cathodic protection; and for conservative purpose assumes the position inside splash zone is “free corrosion".

The available *primary* SN curves in Framework are:

API20-X	API20-XP		
API-WJ	API-WHPEENING	API-WPROFILE	API-WTGRIND
API-CJ			
DNV2010_B1	DNV2010_B2	DNV2010_C	
DNV2010_C1	DNV2010_C2	DNV2010_Cast	DNV2010_D
DNV2010_E	DNV2010_F	DNV2010_F1	DNV2010_F3
DNV2010_G	DNV2010_HS	DNV2010_T	DNVGL2016_T
DNV2010_W1	DNV2010_W2	DNV2010_W3	
ISO-CJ	ISO-OJB	ISO-OJC	
ISO-OJD	ISO-OJE	ISO-OJF	
ISO-OJF2	ISO-OJG	ISO-OJW1	
ISO-TJ	ISO-TJHP	ISO-TJWTG	
HSEnew-T	HSEnew-CJ		

Note: API20 represents API RP2A 20th edition.

In order to let Framework apply the automatic elevation dependency, there are two constants that need to be defined under the `DEFINE->Fatigue Constants` menu:

Splash Zone Upper Limit Elevation, `Z_spl_up`,

Splash Zone Lower Limit Elevation, `Z_spl_low`.

Above the elevation `Z_spl_up` is the part of the structure in air. Below `Z_spl_low` is the part of the structure under sea water with cathodic protection. In between is the splash zone in which the structure is assumed to have free corrosion as explained in [42], see also Figure 2.22. Usually, the upper limit `Z_spl_up` should be above the lower limit `Z_spl_low`.

The associated command lines are:

```
DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-UPPER-LIMIT-ELEVATION Z_spl_up
DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-LOWER-LIMIT-ELEVATION Z_spl_low
```

The default value of splash zone upper and lower limits are 0.

Again, the automatic elevation dependency feature is effective only when a *primary* SN curve is selected at this position. The user still can choose the regular SN curve with specific elevation when necessary at a certain position. But the user should be aware of where this position is to avoid applying the wrong SN curve. It is recommended to define the splash zone limits when using the automatic elevation detection in practice. If the splash zone information is not desired, user should ignore the primary type SN curve and use the regular SN curve instead.

When user selects SN curves with the Splash zone defined in Fatigue constants, for instance API-WJ curve, there are four possibilities of selecting the curves:

- Select API-WJ: In this case the program automatically detects the elevation of the position at the connection or on the member. Then the program uses proper SN curve data based on the location of the fatigue check position (in the water, splash zone or in the air). This should normally be selected if user does not have particular need.
- Select API-WJ-A: in this case the SN curve data in air will be used regardless of the location of the position;
- Select API-WJ-CP: in this case the SN curve data with anode protection will be used regardless of the location of the position;
- Select API-WJ-FC: in this case the SN curve in splash zone will be used regardless of the location of the position.

Restrictions:

- The `CREATE` and `DELETE SN-CURVE` commands do not support the *primary* SN curves. When adding a user defined SN curve, user should follow the instruction in the associated part of the Framework User's Manual.
- The `DISPLAY SN-CURVE` and `PRINT SN-CURVE` commands do not support the *primary* SN curves. The user can see the data of regular SN curves. The elevation dependent (*primary*) SN curves are not shown in the SN curves-sorted list.
- The automatic elevation detection feature is not available in WindFatigue module, and not available in Stofat and Postresp either.
- All *primary* SN curves and the regular SN curve of API-WPROFILE-n are not applicable in Wind Fatigue module of Framework.

The user defined SN curve requires the definition of slopes and intersection points. A maximum of three slopes (and two intersection points) may be specified. A consistent set of units (model units) must be used. The Marshall reduction factor is used to modify the BRACE side SCFs of T, Y, K, KTK, KTT joints. This factor will only be used (if specified) by tubular members. For more information on this please consult Appendix H.2.4. It is possible to incorporate thickness effects in the SN curve by factoring the hotspot stresses. Note that the predefined NORSOK, DOE, ABS and HSE curves have thickness correction as part of their definition. For more information on this please consult Appendix H.2.6.

2.5.3 Unit of stress in SN curves

The built-in library SN curves are stored in SI base units (stress in Pascal, N/m^2). The structural model can be created in various unit systems. The hotspot stress is calculated in the model's unit system. When applied in the SN curve, the hotspot stress must have the matched unit to SN curve to get the correct fatigue life. After Framework v4.3, if the structural analysis is performed by using the latest Genie package, the unit of force and length are stored in the result file. Then, Framework program will read the stored units and convert the stress in the built-in SN curves to the stress unit of the model. User won't need to concern about the application of hotspot stress range in SN curves.

However, if the structural analysis is performed by old programs, the conversion will be based on the assumption that the Young's modulus of the material corresponds to steel (with $E = 2.1 \times 10^{11} N/m^2$). User should notice if the Young's Modulus of the modelled structure is not equal to $E = 2.1 \times 10^{11} N/m^2$, the hotspot stress range will be factored before applying the SN curve. See section 3.6.1 for more details.

2.5.4 Default SN curves

There are global default SN curves in Framework. The command

```
DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE
```

specifies the SN curve at those pre-generated fatigue positions. Framework v4.3 introduces another default SN curve particularly at the buttweld connections. Using command

```
DEFINE FATIGUE-CONSTANTS DEFAULT-BUTTWELD-SN-CURVE DNV2010_D
```

the specified SN curve will be automatically assigned to the buttweld positions generated by the program. See Section 2.5.12 for more details on the buttweld fatigue positions.

Notice that in order to make the default SN curves effective at the pre-generated fatigue positions, the command `DEFINE FATIGUE CONSTANTS` must be applied before `FILE OPEN` and `FILE TRANSFER`.

2.5.5 Minimum stress concentration factors (SCF)

The MINIMUM SCFs are used for a fatigue analysis if, and only if, stress concentration factors are calculated by the program using parametric equations. The definition of the minimum SCFs ensures that if the program calculated SCFs are less than the defined minimum values, these minimum values will be used for the calculation of stresses. If parametric SCFs are used and the minimum SCFs have not been redefined by the user, then the minimum SCFs default to a value of 2.5.

Minimum SCFs, as well as parametric SCFs, can only be used in conjunction with tubular members.

Minimum SCFs are defined for axial, in-plane and out-of-plane bending stresses at ALL hotspots (8 in total), or separate for chord side and brace side with specific minimum values for both axial saddle and axial crown positions. For more information on this consult Appendix H.2.4.

Minimum SCF of butt-weld and cone transition positions is available to restrict the stress concentration factor calculated by formula.

Overriding of minimum SCFs is done by redefining their values.

The definition of minimum SCFs is OPTIONAL as shown in Table 2.10. However, it is MANDATORY that either parametric, or GLOBAL and/or LOCAL SCFs are defined for a fatigue analysis.

2.5.6 Global stress concentration factors (SCF)

The GLOBAL SCFs are only used for a fatigue analysis. It defines the axial, in-plane and out-of-plane stress concentration factors to be used for all hotspots at BOTH ends of all members. Use commands, for example,

```
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 2.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 2.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 1.6
```

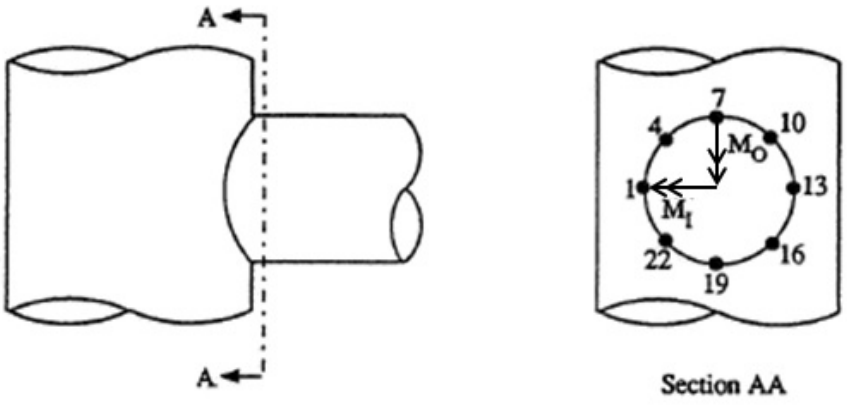


Figure 2.23: Hotspot numbering system for a tubular cross section

The GLOBAL SCFs will be applied to all joints/members where no other assignments have been made.

Overriding GLOBAL SCFs values is done by redefining their values.

If GLOBAL SCFs have been specified as well as LOCAL or parametric SCFs then LOCAL or parametric SCFs take the highest priority and will be used for the fatigue analysis.

It is possible to have different classes of SCFs assigned at the end of a member, e.g. GLOBAL at one end and LOCAL at the other.

The definition of GLOBAL SCFs is OPTIONAL as shown in Table 2.10. However, it is MANDATORY that either parametric, or GLOBAL or LOCAL SCFs are defined for a fatigue analysis.

2.5.7 Local stress concentration factors (SCF)

The LOCAL SCFs are only used for a fatigue analysis. It defines the stress concentration factors associated with axial stress and in-plane and out-of-plane bending stresses for a specific member.

If, say, both LOCAL and GLOBAL SCFs have been defined, then the LOCAL SCFs take the highest priority and will be used for the fatigue analysis.

LOCAL SCFs may be assigned to a member with a tubular, general, I, box, channel or angle section.

SCFs for a tubular section are defined at pre-defined points on the cross section, termed hotspots. Each hotspot is identified by a number. The hotspot numbering system is relative to an in-plane/out-of-plane coordinate system as illustrated in Figure 2.23. For more information see Appendices D.7 and H.2.4.

For a GENERAL and other non-pipe sections 4 hotspots (corresponding to section corners) are default.

LOCAL SCFs may be assigned either to a specific end or at both ends of an member. In addition they may be assigned for the following weld sides:

- BRACE side only
- CHORD side only
- BRACE and CHORD side

A choice of SCF distributions is also available and these are as follows:

- UNIFORM
- BI-SYMMETRIC
- SYMMETRIC
- NON-SYMMETRIC

- CROWN-SADDLE

The UNIFORM SCF distribution is appropriate when each stress concentration factor (i.e. axial or in-plane or out-of-plane) has the same value at ALL hotspots. Each hotspot (on the chosen weld side) is then assigned the same set of SCFs (i.e. axial, in-plane and out-of-plane).

The BI-SYMMETRIC SCF distribution is appropriate when the stress concentration factors at the hotspots can be completely defined by a quarter-plane of symmetry thus only requiring the definition of SCFs at three hotspots. SCFs at hotspots 1, 4 and 7 must be specified. The BI-SYMMETRIC SCF distribution may only be used in conjunction with tubular members.

The SYMMETRIC SCF distribution is appropriate when the stress concentration factors are symmetric about an axis or a plane thus only requiring the definition of SCFs at five hotspots. The plane of symmetry is the joint plane (through hotspots 7 and 19). SCFs at hotspots 1, 4, 7, 19 and 22 must be specified. The SYMMETRIC SCF distribution may only be used in conjunction with tubular members.

The NON-SYMMETRIC SCF distribution is appropriate when the stress concentration factors are completely unsymmetric. SCFs at all hotspots are then required to be defined.

The CROWN-SADDLE SCF distribution is appropriate when the axial SCFs are different at the crown and saddle points, but the bending SCFs are uniform.

- SCF associated with axial stresses at crown point.
- SCF associated with axial stresses at saddle point.
- SCF associated with in-plane bending stresses at crown point.
- SCF associated with out-of-plane bending stresses at saddle point.

The program then automatically assigns:

- the axial SCF at crown point to hotspots 7 and 19
- the axial SCF at saddle point to hotspots 1 and 13
- the in-plane bending SCF at crown point to hotspots 4, 7, 10, 16, 19 and 22
- the out-of-plane bending SCF at saddle point to hotspots 22, 1, 4, 10, 13 and 16

In addition:

- the axial SCF at hotspots 4, 10, 16 and 22 is calculated as the mean value of the axial SCFs at crown and saddle.
- the in-plane bending SCF is set to zero at hotspots 1 and 13
- the out-of-plane bending SCF is set to zero at hotspots 7 and 19

With the CROWN-SADDLE SCF distribution the in-plane and out-of-plane bending SCFs may be factored (by user defined bending SCF factors) at evenly numbered hotspots. The CROWN-SADDLE SCF distribution may only be used in conjunction with tubular members.

The definition of LOCAL SCFs is OPTIONAL as shown in Table 2.10. However it is MANDATORY that either parametric or LOCAL SCFs are defined for a fatigue analysis, unless the GLOBAL SCFs may be used for all members.

2.5.8 Parametric stress concentration factors (SCF)

The **Parametric** SCFs are particularly applied for a fatigue analysis of tubular joint connections of certain chord-brace type. Parametric SCFs associated with axial stresses, in-plane and out-of-plane bending stresses will be calculated at a member end for both the CHORD and BRACE side of the weld provided:

- the members (chord and brace) have tubular cross sections
- a parametric formula has been assigned for BOTH weld sides at member ends

Parametric SCFs are dependent on:

- joint type (K,YT, etc.)
- joint geometry (CHORD and BRACE data) and loadpath
- joint gap/overlap data

and are calculated based on equations by:

- Kuang for YT, K, and KT joints / Wordsworth and Smedley for X joints
- Efthymiou for X, YT, K and KT joints
- Lloyd's Register for gap K and KT joints [3]
- Smedley and Fisher [92] for SCF ratios for ring stiffened tubular joints (modify SCFs calculated according to Efthymiou and Lloyd's)

The Kuang and Lloyd's formulas are only applicable to non-overlapping joints.

The Efthymiou SCFs [72] and [82] may be calculated according to model C, B or A. Models B and A take loadpath into consideration and is called influence function formulations. Model A includes multiplanar effects, while model B excludes braces in other planes than the brace under consideration. Model C is a conventional approach with the following simplifications:

- axial load in K, KT & X joints assumed to be balanced
- out-of-plane bending in K & KT joints is assumed to be unbalanced
- out-of-plane bending in X-joints is assumed to be balanced
- in-plane bending in K-joints is assumed to be unbalanced

When printing fatigue results when Efthymiou SCFs equations are used, it is always the geometric Efthymiou SCFs model C that are printed. No LOADPATH SCFs are printed.

2.5.9 Butt-weld and Cone transition SCFs

The `BUTT-WELD` and `CONE-TRANSITION` SCFs are applied for a fatigue analysis only. They should be assigned to intermediate positions on a tubular member, which model the welded area between two pipes or between pipe and cone transition. It is recommended to model these welds as the segment junction of a conceptual beam member. For example, the CAN and Stub segements need to be assigned with butt-weld SCF at the junctions. Using `BUTT-WELD` and `CONE-TRANSITION` SCFs at member ends is not allowed.

For a well-defined structure model, by reading in the solution SIN file, the program will automatically identify the locations where the PIPE section changes and create fatigue check positions at the two sides of a section transition of Can segment, Stub segment, and the other regular beam segments. By default, the **Butt-weld** SCF is assigned to these PIPE section transitional positions; The **Cone transition** SCF is assigned to the cone-tube junctions.

The SCF formula are supported as follows:

- Butt-weld SCF
  - **DNVGL RP-C203:2020** [45] and the new **DNV RP-C203** [100]: Eqn(3.3.4) for equal thickness connections; Eqn(3.3.5) and Eqn(3.3.6) for connections with thickness transition. This RP-C203 standards consider the weld toes and weld roots separatedly, and welding from outside or both-sides separatedly. Framework supports the buttweld root fatigue for `DNVGL-RPC203-2020` option assuming welding from outside. The program assumes the welding is from both-sides and skips weld root if using the `DNV-RPC203-BSWD` option. See Appendix B.8 for more details.
  - Eqn(3.3.4) in **DNVGL-RP-C203:2014** [42] for equal thickness connections, and Eqn(3.3.5) for connections with thickness transition. This option assumes the thcikness transition is at outside and takes Eqn(3.3.5) which yields a larger SCF.

  - Eqn(C.2.10) in **Norsok Standard N-004:1998** [56]

- Cone-transition SCF
  - Un-stiffened cone Eqn(3.3.12-13) and stiffened cone Eqn(3.3.14) in **DNVGL-RP-C203:2014**
  - Stiffened cone Eqn(C.2.14) in **Norsok Standard N-004:1998**

The default SCF formula can be selected in command

```
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA
```

Note that there is no DNVGL-RP-C203:2020 or 2021 option for Conical transition. Although `DNVGL-RPC203-2020` or `DNV-RPC203-BSWD` is selected by the command, the program will consider it is the same as DNVGL-RP-C203:2014 when calculating SCF for cones. For the details of SCF formula, please refer to Appendix B.8. The default SCF rule and SCF formula can be modified using `ASSIGN SCF MEMBER` command for each position.

2.5.10 Fatigue Check Positions for Tubular Joints

A fatigue analysis is often performed at the joint connections and the intermediate non-ending welded connections of beam member. During the process of reading in a result interface file, `Rn.SIN`, Framework will *automatically* identify the finite element ends or the conceptual member ends, and then generate the fatigue check positions for each member. By default, two fatigue check positions will be generated for each member end, i.e. `CHORD-SIDE` and `BRACE-SIDE` at relative location 0.0 or 1.0. *Notice that: for the welded location on NON-TUBULAR cross sections, the default positions are initially generated the same as pipe section but will be merged to so called BOTH-SIDES during fatigue analysis run. The automated positions merging is also effective for positions on chord member or member end not at a joint.*

At a tubular joint, Framework determines the chord and aligned chord members at a tubular joint, and the brace members connected to them. Then, the fatigue positions at `CHORD-SIDE`, `BRACE-SIDE` represents the weld lines on chord side and brace side where the hotspots are considered differently. The `GLOBAL` SCF rule is assigned as default. The particular type of parametric SCF formula needs to be specified for all joints by using `ASSIGN SCF JOINT`. When a `Parametric SCF` is applied to joint fatigue check, (see Section 2.5.8) the program calculates the hotspot stress by multiplying the brace nominal stresses with corresponding SCFs, e.g. SCF at crown/saddle points of chord or brace.

Framework supports the fatigue check for the joint welded from one side. Refer to the Appendix F10 in DNVGL RP-C203 [45] and DNV RP-C203:2021 [100]. The Figure 2.24 shows the location of fatigue "hotspots". Note that the weld toe and root are modelled by the fatigue positions in Framework.

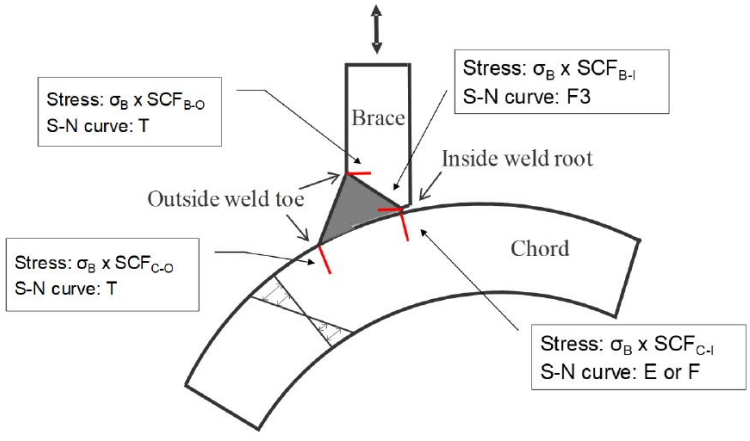


Figure 2.24: Potential fatigue cracks, nominal stress and SCF in simple tubular joints (Figure F-17 of DNVGL RP-C203 [45] and DNV RP-C203:2021 [100])

The facts regarding fatigue check for the joint welded from one side are summarized as follows:

- The command `DEFINE FATIGUE-CHECK-WELD-ROOT ON` will trigger the function of weld root fatigue check. To be effective, it must be issued prior to commands of `FILE OPEN` and `FILE TRANSFER`.
- The program will automatically generate two weld root positions, `CHORD-ROOT` and `BRACE-ROOT` on a brace end at the tubular joint in addition to the existing `BRACE-SIDE` and `CHORD-SIDE` positions that represents weld toes.
- Framework will *automatically* assign the SN curve of "DNV2010_F3-AIR" to `BRACE-ROOT` position and assign the SN curve "DNV2010_F-AIR" or "DNV2010_E-AIR" to `CHORD-ROOT` position according to the thickness of the brace. The SN curve on the weld toe positions depends on the option `DEFAULT SN CURVE` at command `DEFINE FATIGUE-CONSTANTS`. The SN curve at a position can be overridden by the command `ASSIGN SN CURVE`.
- The SCF at weld toes and roots depends on what is specified by the command `ASSIGN SCF JOINT`, otherwise, the GLOBAL SCF is assigned. There is no pre-specified parametric SCF at joints.
- The hotspot stress at the inside weld roots is calculated according to the guide in DNVGL RP-C203 [45] and and DNV RP-C203:2021 [100]. In brief, the reduction factor R is calculated and multiplied to the recommended parameteric SCF from the original Efthymiou formula [72]. (Note that the reduction factor R is not interpolated when the parameter β is greater than 0.85; instead, the R factor is calculated based on the upper limit $\beta = 0.85$.)
- Therefore, only parametric SCF options, EFTHYMIOU and LOTSBERG, are allowed at the weld root positions. GLOBAL and LOCAL SCF options are always allowed.
- The option of `DEFINE FATIGUE-CHECK-WELD-ROOT` is OFF by default. There will be NO weld roots. The fatigue check remains the same as the previous.

If the weld root fatigue analysis at joints is not preferred on the entire structure, then do not use the command `DEFINE FATIGUE-CHECK-WELD-ROOT ON`. As an alternative, the weld root positions can be defined on an individual member or a set of members by the command `ASSIGN POSITIONS` see section 2.5.13 for details.

2.5.11 Include Chord stresses in fatigue analysis

The stress concentration factors for tubular joints mentioned previously, e.g. the original Efthymiou [72] or App.B of DNVGL RP-C203 [45] are due to the loads in the brace. The latest research shows the nominal cyclic stresses in the chord member can affect the fatigue damage too. The combination of brace action and chord action determines the fatigue crack propagation in the welded region. The contribution from chord is usually small because the chord loading usually does not cause serious local bending of the chord wall. When significant dynamic stresses exist in chord, the hot spot stress at the crown toe and heel should be added to the corresponding hot spot stresses induced by the brace loads. The contribution of chord stresses at saddle hotspots are neglectable.

Framework is able to take into account the in-plane bending stress and the axial stress of the chord member in the fatigue analysis of a tubular joint. The chord in-plane bending stress is included in the parametric SCF of LOTSBERG which upgrades the original EFTHYMIOU SCF formula. Please refer to Appendix B.10 and DNVGL RP-C203 [45] for more detail regarding the LOTSBERG SCF formula. The SCF option of LOTSBERG can be selected in the command `ASSIGN SCF MEMBER` and `ASSIGN SCF JOINT`.

Based on the guidance of DNVGL RP-C203:2020 edition [45], Framework considers the chord axial stresses that are included in the hot spot stress range calculation at the crowns on the chord side. The contribution from the chord axial stress is obtained by multiplying the nominal chord stress at the crown toe and the crown heel by an additional stress concentration factor. The factored chord axial stress is added onto the hot spot stress due to brace loadings. The stress range at the chord crowns is the result of the cycle of combined brace loading and chord axial stress. The DNVGL RP-C203 recommends the braces can be considered as attachments to the chord for loads in the axial direction of the chord. Due to this, the axial stress in the chord should be increased by a $SCF = 1.20$ for calculation of additional hot spot stress for

dynamic loading in the axial direction of the chord. As recommended by API RP2A WSD [16], the effect of nominal cyclic stresses in the chord member may be covered by including the stress due to axial load in the chord can member with $SCF = 1.25$ at the chord crown location only.

In Framework program,

- To activate the chord axial stress in fatigue analysis, two commands are required.

  ```
  DEFINE FATIGUE-PARAMETERS INCLUDE-CHORD-STRESS ON SCFatt

  DEFINE NEAR-CHORD-RULE ON,
  ```

  where SCFatt is the attachment SCF which is recommened between 1.20 to 1.25, and the near chord rule will restrict the relation of brace and its corresponding chord member.

- $\text{Hotspot stress at chord crown} = SCF \times \text{Brace Nominal Stresses} + SCF_{att} \times \text{Chord axial stress}$. The tensile or compressive sign of the chord axial stress is preserved, i.e. "+" if chord axial stress is tensile or "-" if compressive. Accordingly, the chord action and brace action are summed arithmetically at the hotspot. The hotspot stress range can become larger or smaller after summing the chord axial stress. Framework does not do stress tensor analysis at the hotspot.
- The chord axial stress will ONLY be included at a position at a BRACE END, i.e. a tubular joint with determined brace and chord. All intermediate positions, nodes, and free nodes will be skipped.
- The chord stress will ONLY be added at the hotspots on the chord side. It means only the fatigue check position of CHORD-SIDE and CHORD-ROOT will have it. It will not act at BRACE-SIDE or BRACE-ROOT.
- The chord axial stresses are calculated using the stored cross section properties. It means if there is any section property override, the new section properties will be applied. If there is a new cross section created in Framework and assigned to the chord member, the new cross section property is applied.
- For each crown, the axial force of the chord on which the crown locates is applied. The chord member and aligned chord member can have different and even opposite axial forces. Thus, the chord stresses can be different on two crowns when they span over two members. Instead of making any average, Framework calculates the individual chord axial stress at hotspot 7 and 19 that correspond to the crowns. Hotspot 7 is on the side toward the aligned chord, and hotspot 19 is on the side of chord member.
- The chord axial stress does not appear in SCF but adds to the part of hotspot stress coming from brace nominal forces and regular SCF. The chord axial stress inclusion is independent to SCF. Thus, this feature is effective to all joint SCF options.
- The inclusion of chord axial stress action is valid for time domain analysis only, such as Direct Deterministic Fatigue, Deterministic Fatigue, Spectral Fatigue, and Time History Fatigue. The stress range at the hotspot is the combined result of the brace action and chord action in one load cycle.

2.5.12 Butt-weld fatigue check positions

Framework has upgraded the functions for butt-weld fatigue analysis. In general, at CAN/STUB interfaces, Cone-Tubular junctions and other butt weld connections, the fatigue analysis should be performed. For a well-defined structural model in the latest GeniE package, e.g. the beam segments are defined on a member, the segments information is stored as part of the concept model in the result file. Then, Framework will *automatically* locate the transitions (can/stub/cone/segment), generate the associated fatigue check positions, and then assign the default SCF and SN curve for tubular butt weld connections. The user does not need to handle the butt-weld fatigue positions one by one, i.e. NO applying ASSIGN SCF and ASSIGN SN Curve at buttweld positions unless necessary. (In Framework programs before v3.13, the user needs to use the `ASSIGN POSITIONS` command to turn on the positions at section transitions, and use the `ASSIGN SCF MEMBER` and `ASSIGN SN CURVE MEMBER` commands to these positions one by one.)

Similar to joint fatigue 2.5.10, Framework is capable to do weld root fatigue at tubular butt weld connections. When the commands

- DEFINE FATIGUE-CHECK-WELD-ROOT ON
- DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2020

are issued before reading in the result file,i.e. FILE OPEN and FILE TRANSFER, Framework will generate both weld toe and weld root positions at the cross-section transitions and beam segment interface, except for cone. Figure 2.25 (a) shows an example of a member with a cone and other segments. In addition to the fatigue positions at tubular joints , the buttweld positions will be

```
CHORD-SIDE-0.0000      - Chord side weld toe at Member end 1
BRACE-SIDE-0.0000      - Brace side weld toe at Member end 1
CHORD-ROOT-0.0000      - Chord side weld root at Member end 1
BRACE-ROOT-0.0000      - Brace side weld root at Member end 1
Section-SCT5-0.2498      - Tubular side at junction of cone
Section-C1_46-0.2498     - Conical side at junction of cone
Section-C2_46-0.3605       (No weld root position at cone's junction)
Section-4-0.3605
ROOTSect4-0.7912         - Weld root position at segment interface
Section-4-0.7912         - Weld toe position at segment interface
BRACE-ROOT-0.9999      - Brace side weld root at Member end 2
CHORD-ROOT-0.9999      - Chord side weld root at Member end 2
BRACE-SIDE-1.0000      - Brace side weld toe at Member end 2
CHORD-SIDE-1.0000      - Chord side weld toe at Member end 2
```

In general, one position located at each side of an interface is added, i.e. two positions for every cross section transition. If there is no cross section change between two segments, only one fatigue position is generated.

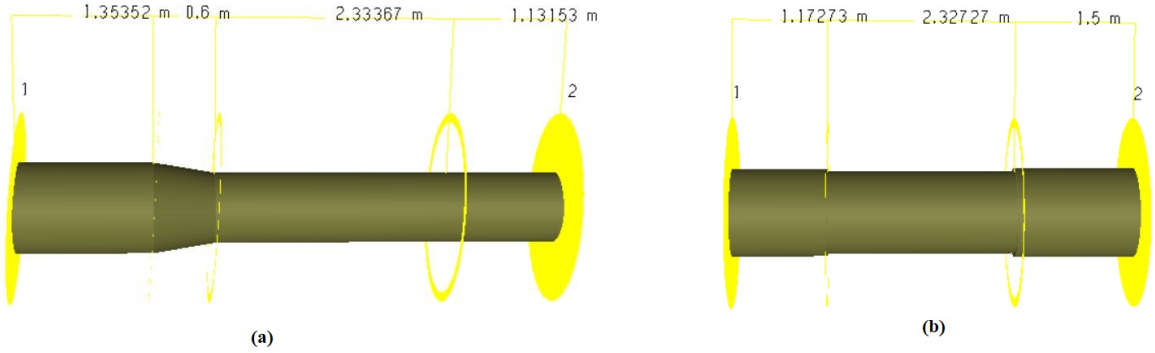


Figure 2.25: Fatigue positions at buttweld connections

Figure 2.25(b) shows a member with different sections. The automatically generated positions can be

```
BOTH-SIDES-0.0000
Section-SCT4LONG-0.2345          - Weld toe position at section SCT4LONG side
Section-SCT1-0.2346              - Weld toe position at section SCT1 side
ROOTSectSCT4LONG-0.2345          - Weld root position at section SCT4LONG side
ROOTSectSCT1-0.2346              - Weld root position at section SCT1 side
Section-SCT1-0.7000
Section-SCT3CCC-0.7000
ROOTSectSCT1-0.7000
ROOTSectSCT3CCC-0.7000
BOTH-SIDES-1.0000
```

Note that, **The weld root positions at Buttweld connections are generated only when the Buttweld SCF option in** DEFINE FATIGUE-CONSTANTS **is** DNVGL-RPC203-2020. In other word, if DEFINE FATIGUE-CHECK-WELD-ROOT

is **ON**, but the Buttweld SCF option is **NOT** DNVGL-RPC203-2020, e.g. the option DNV-RPC203-BSWD, the weld root positions at buttweld connections will be turned off but the weld roots at joint will still be active. For example, a member with cross section change at distance 0.75 can have positions:

```
CHORD-SIDE-0.0000      - Chord side weld toe at Member end 1
BRACE-SIDE-0.0000      - Brace side weld toe at Member end 1
CHORD-ROOT-0.0000      - Chord side weld root at Member end 1
BRACE-ROOT-0.0000      - Brace side weld root at Member end 1
Section-PIPEA-0.7500     - Regular buttweld position at cross section PIPEA
Section-PIPEB-0.7500     - Regular buttweld position at cross section PIPEB
BRACE-ROOT-0.9999      - Brace side weld root at Member end 2
CHORD-ROOT-0.9999      - Chord side weld root at Member end 2
BRACE-SIDE-1.0000      - Brace side weld toe at Member end 2
CHORD-SIDE-1.0000      - Chord side weld toe at Member end 2
```

If DEFINE FATIGUE-CHECK-WELD-ROOT is **OFF**, and the Buttweld SCF option is **NOT** DNVGL-RPC203-2020, the program will skip all weld root positions. In this case, the fatigue positions at member shown in Figure 2.25 (a) will become

```
CHORD-SIDE-0.0000         - Chord side weld toe at Member end 1
BRACE-SIDE-0.0000         - Brace side weld toe at Member end 1
Section-SCT5-0.2498       - Tubular side at junction of cone
Section-C1_46-0.2498      - Conical side at junction of cone
Section-C2_46-0.3605
Section-4-0.3605
Section-4-0.7912           - Regular buttweld position at segment interface
BRACE-SIDE-1.0000
CHORD-SIDE-1.0000
```

In this case, the pre-defined positions remain the same as the program before v4.3.

Note that the program uses the concept model information to generate the buttweld fatigue positions. When the concept model is not available or it is deactivated by the command DEFINE READ-CONCEPTS OFF, the program will not generate buttweld positions because all beam elements are of two nodes and there is no transition in the middle. If the user wants the buttweld positions to be generated by the program, it is applicable to use the command CREATE MEMBER to form finite elements into a capacity member, and ASSIGN POSITIONS FATIGUE-CHECK OPTIONS to generate the desired positions (see 2.5.13). In this case, the program can only add positions at the place where the cross section changes. For the weld at two equal sections, the "Intermediate" option at ASSIGN POSITIONS can be applied if the member is created properly.

2.5.12.1 Default SCF and SN curve assignment

After the fatigue positions are generated, Framework will specify the associated default SCF rule at the butt-weld positions. By default, the *Buttweld SCF* rule will be assigned to the section and segment transition positions. The *Cone-Transition SCF* rule will be assigned particularly to the positions at cone-tubular junctions. The SCF formula is specified in the command

```
DEFINE-FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-OPTION
```

(*Note: Framework v3.12 and the previous set the default SCF rule to GLOBAL at these positions.*) If the Butt-Weld SCF option is **DNVGL-RPC203-2020**, Framework will calculate SCF according to the RP-C203 [45] and [100]. The weld toe and weld root at a butt weld connection have individual SCF and the weld is made at outside only. If the Butt-Weld SCF option is **DNV-RPC203-BSWD**, Framework assumes the weld is made at both-sides and skips the weld root at the buttweld but keeps the weld toes only. See more details in command description of ASSIGN SCF MEMBER and Appendix B.8.

Framework will also assign the default SN curve to the butt-weld positions. The name of SN curve is determined by command DEFINE-FATIGUE-CONSTANTS DEFAULT BUTTWELD-SN-CURVE. However, the default SN curve at weld root is the one recommended by the RP-C203 [45] that may not be the same as the other weld toes. The program uses DNV2010_F3 as the default SN curve at buttweld root. For the weld toes, the

default Buttweld SN curve will be assigned. The SN curve at the position can be modified by using command `ASSIGN SN CURVE MEMBER`.

Note that, to be effective, the relevant options at `DEFINE-FATIGUE-CONSTANTS` must be specified prior to reading the result file.

2.5.13 User specified fatigue check positions

The previous sections Section 2.5.10 and 2.5.12 show that there are pre-defined positions generated by the program when reading in the result SIN file. This section will show after the default positions are generated the fatigue check or code check positions can be modified or re-defined for each run if necessary. This function is critical because some fatigue or code check properties must be assigned on the particular position. The positions must be adjusted or re-generated before the assignment. For example, the commands

```
ASSIGN SN-CURVE MEMBER
ASSIGN SCF MEMBER
```

require the fatigue positions must be available in advance.

2.5.13.1 Fatigue Positions Option

This section focus on the fatigue check positions. Use the command:

```
ASSIGN-POSITIONS sel-mem FATIGUE-CHECK OPTIONS ...
```

or via the menu dialogbox. The fatigue positions can be modified on one or a set of members.

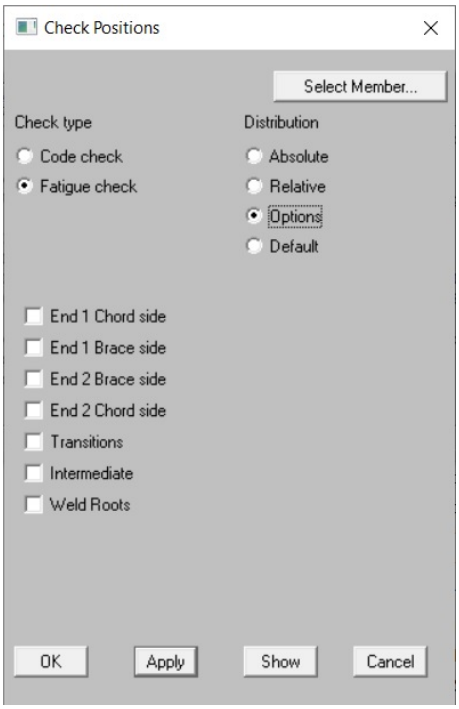


Figure 2.26: Assign Fatigue positions Options

The **Options** include:

- “End 1 Chord side”, “End 1 Brace side”, “End 2 Chord side” , “End 2 Brace side”, i.e. the positions representing the welds at chord-brace interception;
- “Transitions”, i.e. the positions at cross section or segment transitions;
- “Intermediate” i.e. the positions at finite elements interface;

- “Weld Roots” - the positions at weld roots of chord-brace joint and butt weld tubular connections.

The option of "Weld Roots" is effective when it is combined with one or all of these *End* options, or *Transitions* option. It does not work when combining with *Intermediate*, i.e. weld root positions are **NOT** generated at the finite element nodes in the middle of the member meshed into multiple finite elements. The *Intermediate* option usually remains **OFF** when performing weld root fatigue analysis. For example, the command

```
ASSIGN POSITIONS CURRENT FATIGUE-CHECK OPTIONS ON ON ON ON ON OFF ON
```

will generate weld root positions at the tubular joint and buttweld connections, if there are any, on the CURRENT member selection. Consequently, it is required to model the butt welded tubulars by segment in the concept model in order to make use of the program default buttweld fatigue positions. Framework does not support having weld root positions only. It means the command, with only "Weld Roots" ON,

```
ASSIGN POSITIONS ( ) FATIGUE-CHECK OPTIONS OFF OFF OFF OFF OFF OFF ON
```

will not generate any position. When "Weld Roots" option is combined with "Transitions", the buttweld roots position will be generated **only if** `DNVGL-RPC203-2020` is selected at `BUTTWELD CONE SCF FORMULA`. The "Weld Roots" option at `ASSIGN POSITIONS` is independent to the command `DEFINE FATIGUE-CHECK-WELD-ROOT` that is unrelated with the command `ASSIGN POSITIONS`.

2.5.13.2 Modify Fatigue Positions

The command `ASSIGN POSITIONS` of fatigue can be useful in the scenario when most of the members in a structure follow the global SCF setting and a different SCF setting has to be assigned to a certain members.

For example, the fatigue analysis is mostly performed on the weld toes but the weld root fatigue check is required only at a few places of the structure. To reduce computer time, the global option `DEFINE FATIGUE-CHECK-WELD-ROO` is not turned on. The program firstly generates the weld toes positions. Then, the user can use the following commands

```
SELECT MEMBERS ONLY rt-chk
ASSIGN POSITIONS () FATIGUE-CHECK OPTIONS ON ON ON ON OFF OFF ON
```

to modify the fatigue positions on member set called "rt-chk" that includes those members where the weld roots need to be checked. These commands will re-generate the positions on the members of this set and allow to do the weld root fatigue check.

Another example is to re-define the fatigue positions for a few members with buttweld connections welded on both-sides. Suppose the global SCF optoin is

```
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2020
DEFINE FATIGUE-CHECK-WELD-ROOT ON
```

After reading the result file, the program will generate the weld roots at joints and buttweld connections. If member BM01 has the both-sides buttweld welding, the following commands can be used

```
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNV-RPC203-BSWD
ASSIGN POSITIONS BM01 FATIGUE-CHECK OPTIONS ON ON ON ON ON OFF OFF
```

The first command changes the global option for both-sides buttweld. The second command removes the existing fatigue positions and re-generate the positions without weld roots.

Similarly, if most of members have buttweld welding from bothsides and only member BM02 has buttweld welding from the outside where the weld root check is required, the command

```
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNV-RPC203-BSWD
```

will let the program skip the weld roots at buttweld connections. Then, the commands

```
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2020
ASSIGN POSITIONS BM02 FATIGUE-CHECK OPTIONS ON ON ON ON ON OFF ON
```

will re-generate the fatigue positions at weld toes and roots of the buttweld connections on member BM02. After thses steps, the user can apply ASSIGN SCF MEMBER command to specify the SCF rule on the weld toes and roots if the default setting is not desired.

2.5.13.3 Add individual fatigue position

In practice, the program pre-defined positions may not cover all places that require the fatigue analysis. At certain place, e.g. where some attachment is mounted, the attachment may not be modelled. The parametric SCF formula may not be available for some situation. In these cases, the program default positions or the SCF assignment are not sufficient. Framework supports adding fatigue check positions on any place of the member. For example, a position named "MidPoint" is added at distance 0.50 and another position named "QUAT" at distance 0.75 of member BM10.

```
SELECT MEMBERS ONLY BM10
ASSIGN POSITIONS ( ) FATIGUE-CHECK RELATIVE ( ONLY
    CHORD-SIDE     0.0
    BRACE-SIDE     0.0
    CHORD-ROOT     0.00005
    BRACE-ROOT     0.00005
    BRACE-ROOT     0.99995
    CHORD-ROOT     0.99995
    BRACE-SIDE     1.0
    CHORD-SIDE     1.0
    MidPoint       0.50   )
ASSIGN POSITIONS CURRENT FATIGUE-CHECK RELATIVE INCLUDE QUAT    0.75
```

However, the default SCF and SN curve assignment feature is **NOT** available at the individual position that the user specifies. In fact, for a general user defined fatigue position for butt-weld connection, the identification of cross section transition by the program may be inaccurate, thus the SCF formula is NOT applicable as expected. Using LOCAL or GLOBAL SCF is recommended.

Naming the individual fatigue position by "ROOT" is **NOT** recommended. The following command is valid in the program,

```
SELECT MEMBERS ONLY BM01
ASSIGN POSITIONS ( ) FATIGUE-CHECK RELATIVE ( ONLY
    CHORD-SIDE     0.0
    BRACE-SIDE     0.0
    CHORD-ROOT     0.00005
    BRACE-ROOT     0.00005
    BRACE-ROOT     0.99995
    CHORD-ROOT     0.99995
    BRACE-SIDE     1.0
    CHORD-SIDE     1.0)
```

which defines the positions named CHORD-ROOT and BRACE-ROOT at the ends of member BM01. The relative distance 0.5e-4 to the member ends is required. Then, the weld root fatigue at the joints can be done after assigning proper SCF and SN curve.

Using the position name starting with "ROOT" to mimic the program's pre-defined butt weld root positions such as

```
ASSIGN POSITIONS ( ) FATIGUE-CHECK RELATIVE ( ONLY
    CHORD-SIDE          0.0
    BRACE-SIDE          0.0
    BRACE-SIDE          1.0
    CHORD-SIDE          1.0
    ROOT_SECadd1        0.5
    ROOT_SECadd2        0.75     )
```

is **NOT** recommended either. The user should be cautious on that the weld root SCF may not be calculated as expected if doing so.

2.5.13.4 Default SCF and SN curve assignment

The automated default SCF assignment is effective at buttweld fatigue positions when applying FATIGUE-CHECK **OPTIONS**. However, there are some limitations:

- For the “Intermediate” option, the automated SCF assignment is only valid at positions that match the place of section transition. If the mesh is fine and there are multiple finite elements on a beam segment, the default SCF of the position at element ends that are not segment junction is `GLOBAL`. It means NO particular SCF rule is assigned.
- This automated procedure of position generation and default SCF assignment is made on the conceptual model. If the fatigue analysis is performed on a finite element based superelement model, (e.g. turn off the concept model by `DEFINE READ-CONCEPTS OFF` prior to reading in the `Rn.SIN` file) the automated procedure above does not work. The default SCF rule at each finite element end is `GLOBAL`. User still has to assign SCF to every finite element.
- The default SCF rule for an individual additional position using for example `FATIGUE-CHECK RELATIVE` is `GLOBAL`. The default SN curve is the one from the command `DEFINE FATIGUE-CONSTANTS DEFAULT SN CURVE` when the position is at the member end or from the `DEFAULT BUTTWELD SN CURVE` option if the position is in the middle of the member.
- For BUTTWELD positions, the default SCF will be assigned at the weld toes and roots based on the RP-C203-2020. The default SN curve is the one from `DEFAULT BUTTWELD SN CURVE`.
- Framework has the feature to preserve some existing SCF and SN curve assignments at the previously existing positions after one or more new positions are inserted. For example, BM1 is originally defined with all end positions and section transitional positions with weld roots. Another position "SectA" at 0.5 is added.

```
SELECT MEMBERS ONLY BM1
ASSIGN POSITIONS ( ) FATIGUE-CHECK OPTIONS ON ON ON ON ON OFF ON
ASSIGN POSITIONS ( ) FATIGUE-CHECK RELATIVE ( ONLY
    CHORD-SIDE          0.0
    BRACE-SIDE          0.0
    CHORD-ROOT          5.0e-05
    BRACE-ROOT          5.0e-05
    ROOTSectPIPE_1      0.19997
    Section-PIPE_1      0.19999
    Section-PIPE_2      0.20001
    ROOTSectPIPE_2      0.20003
    BRACE-ROOT          0.99995
    CHORD-ROOT          0.99995
    BRACE-SIDE          1.0
    CHORD-SIDE          1.0
    SectA               0.5     )
```

  In this case, the SCF and SN curve assignments at those previously existing positions will be kept. However, for the new position SectA, it is necessary to assign the desired SCF and SN curve by user. Notice that this assignment preservation function may not applicable for a general ASSIGN POSITIONS procedure. If some of the existing positions are removed at the same time, the original SCF and SN curve assignments can be lost, and it can affect the assignment at the other positions too. User should be cautious on it and must confirm the positional assignments before running the fatigue analysis. Member Fatigue Check Data report should be reviewed.

For tubular joints, there is no default parametric SCF assigned at the End positions but GLOBAL SCF. The user needs apply the command `ASSIGN SCF JOINT` and `ASSIGN SN CURVE JOINT` if necessary.

2.5.13.5 Commments

- Using `FATIGUE-CHECK OPTIONS` is recommended over the individual addition like `FATIGUE-CHECK RELATIVE` in order to make use of the default SCF and SN curve assignment.

- After using FATIGUE-CHECK RELATIVE to add a new position on the member, user needs to assign the LOCAL SCF or use GLOBAL SCF at that position.
- The automatically generated fatigue positions and the default SCF and SN curve assignment can be not ideal. If it happens, the command

  ```
  ASSIGN POSITIONS ( ) FATIGUE-CHECK OPTIONS OFF OFF OFF OFF OFF OFF OFF
  ```

  with ALL options OFF will remove all the positions on the selected members. Then, the necessary ASSIGN POSITIONS command can be issued again to re-generate the positions.
- **It is always required to check the SCF and SN curve assignment over the entire beam member after the command ASSIGN POSITIONS is applied on that member.** The report by PRINT MEMBER FATIGUE CHECK DATA demonstrates the current assignments.

2.6 Other Miscellaneous input

2.6.1 Load case identification

In many senarios, selecting or entering a load case is required. For instance, commands ASSIGN LOAD-CASE PRINT LOAD-CASE CREATE LOAD-COMBINATION CREATE FATIGUE-LOAD-SERIES. Framework supports four ways to identify loadcases stored in the result SIN file. This can be selected with command DEFINE LOAD before reading in the result file. The default is using INTERNAL-RESULT-ID, the load case sequential number that is determined when doing FEM analysis. Alternatively, LOAD-CASE-NAME generated in concept model can be used. It is suitable for simple static structural analysis. Note that RESULT-CASE-NAME is recommended if an advanced analysis has been performed, for example, hydrodynamic wave loads, pile-soil interaction (SPLICE), and superelement. Instead of load case, the resultcase created or re-organized by solver is easier to identify.

Table 2.7: Mandatory and optional input data

	API-AISC-WSD & API-AISC-LRFD						
	Pipe					Non-pipe	
	Yield	Stability	Hydrostatic Collapse	Punch	Cone	Yield	Stability
Young's modulus	Optional	Optional	Optional		Optional	Optional	Optional
Yield strength	Optional	Optional	Optional	Optional	Optional	Optional	Optional
Material constant							
Chord				Optional			
CAN	Optional			Optional			
STUB	Optional			Optional			
Joint gap				Optional			
Joint type				Optional			
Fabrication method						Optional	Optional
Buckling lengths		Optional	Optional				Optional
Unsupported flange length							Optional
Effective length factor		Optional	Optional				Optional
Buckling curve							
Lateral buckling factor							Optional
Local/Global bending moment	Optional						Optional
Moment reduction factor		Optional	Optional				Optional
Stiffener spacing			Optional		Optional		
Flooding status			Optional		Optional		
Sea water density and gravity			Mandatory		Optional		
Water depth			Mandatory		Optional		
Wave height			Optional		Optional		
Wave length			Optional		Optional		
Water plane			Mandatory		Optional		

2.6.2 Mandatory and optional input data

For each of the codes of practice and code check type – all input data used, mandatory and optional, are shown in Table 2.7 through Table 2.9.

All data, mandatory and optional, used in deterministic and stochastic fatigue analysis are shown in Table 2.10.

Table 2.8: Mandatory and optional input data

	NPD-NS3472(rel.2)					
	Pipe				**Non-pipe**	
	Yield	Stability	Punch	Cone	Yield	Stability
Young's modulus		Optional		Optional		Optional
Yield strength	Optional	Optional	Optional	Optional	Optional	Optional
Material constant	Optional	Optional	Optional	Optional	Optional	Optional
Chord			Optional			
CAN	Optional		Optional			
STUB	Optional		Optional			
Joint gap			Optional			
Joint type			Optional			
Fabrication method					Optional	
Buckling lengths		Optional				Optional
Unsupported flange length						Optional
Effective length factor		Optional				Optional
Buckling curve		Optional				Optional
Lateral buckling factor						Optional
Moment reduction factor		Optional				Optional
Stiffener spacing				Optional		
Flooding status		Optional		Optional		
Sea water density and gravity	Optional2	Optional		Optional		
Water depth	Optional2	Optional		Optional		
Wave height	Optional	Optional		Optional		
Wave length	Optional	Optional		Optional		
Water plane	Optional2	Optional		Optional		

where

Optional2 Optional, but see relevant notes in Section 2

Table 2.9: Mandatory and optional input data

	NORSOK & ISO 19902			**EUROCODE - NS3472(rel. 3)**
	Pipe			**All profiles**
	Member	Punch	Cone	Member
Young's modulus	Optional		Optional	Optional
Yield strength	Optional	Optional	Optional	Optional
Material constant	Optional	Optional	Optional	Optional
Chord		Optional		
CAN	Optional	Optional		
STUB	Optional	Optional		
Joint gap		Optional		
Joint type		Optional		
Fabrication method	Optional			Optional
Buckling lengths	Optional			Optional
Unsupported flange length				Optional
Effective length factor	Optional			Optional
Buckling curve				Optional
Lateral buckling factor				Optional
Local/Global bending moment	Optional			Optional
Moment reduction factor	Optional			Optional
Stiffener spacing	Optional		Optional	Optional
Flooding status	Optional		Optional	
Partial Hydrostatic Factor Storm	Optional3		Optional3	
Partial Hydrostatic Factor Operating	Optional3		Optional3	
Cone length for hoop buckling strength	Optional		Optional	
Joint Grouting		Optional		
Sea water density and gravity	Optional2		Optional	
Water depth	Optional2		Optional	
Wave height	Optional		Optional	
Wave length	Optional		Optional	
Water plane	Optional2		Optional	

where

Optional2 Optional, but see relevant notes in Section 2

Optional3 Only available for Norsok Rev. 3, February 2013.

Table 2.10: Mandatory and optional input data

	Deterministic Fatigue		**Stochastic Fatigue**		**Spectral Fatigue**	
	Pipe	**Other**	**Pipe**	**Other**	**Pipe**	**Other**
Young's modulus						
Yield strength						
Material constant						
Chord	*Optional2*		*Optional2*		*Optional2*	
CAN	Optional		Optional		Optional	
STUB	Optional		Optional		Optional	
Joint gap	**Recom**		**Recom**		**Recom**	
Joint type	**Recom**		**Recom**		**Recom**	
Sea water density						
and gravity						
Water depth						
Wave height						
Wave length						
Water plane						
Individual waves	**Mandatory**	**Mandatory**				
Wave spreading			Optional	Optional	Optional	Optional
Wave spectrum shape			Optional	Optional	Optional	Optional
Wave statistics			**Mandatory**	**Mandatory**	**Mandatory**	**Mandatory**
Wave direction probability			**Mandatory**	**Mandatory**	**Mandatory**	**Mandatory**
Fatigue constants	*Optional2*		*Optional2*		*Optional2*	
Default SN curve	**Mandatory**	**Mandatory**	**Mandatory**	**Mandatory**	**Mandatory**	**Mandatory**
Splash zone limits	**Recom**	**Recom**	**Recom**	**Recom**	**Recom**	**Recom**
SN curve (assignment)	*Optional2*	*Optional2*	*Optional2*	*Optional2*	*Optional2*	*Optional2*
Joints SCF	**Recom**		**Recom**		**Recom**	
Butt-weld/cone SCF	**Recom**		**Recom**		**Recom**	
Local SCF	*Optional2*	*Optional2*	*Optional2*	*Optional2*	*Optional2*	*Optional2*

where

Optional2: Optional, but see relevant notes in Section 2

Recom: Recommended for the best application although analysis still proceeds without ASSIGNMENT. Some default assignment may not bt optimal. Please refer to relevant notes in Section 2.

3 User's guide to Framework

This chapter is aimed to enhance the user's understanding in using Framework through the use of small illustrative examples.

Section 3.1 through Section 3.7 provide examples on the use of various modelling features available while Section 3.8 through Section 3.18 provide examples on how to perform code checks, fatigue and earthquake analyses. The subsequent sections provide examples of special features.

3.1 Getting started – graphical user interface and reading a model

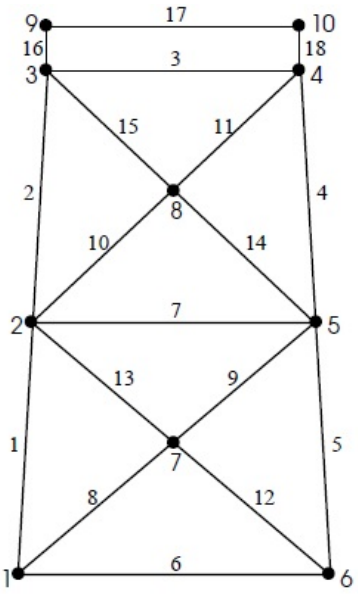


Figure 3.1: Finite element model of two dimensional frame

Table 3.1: Member properties and connectivity data

EXT. EL.	INT. EL.	EL. TYPE	MAT. NO.	SECT. NO.	SECT. TYPE	SECT. D H TH	ELEMENT LENGTH FLEXIBLE PART	NODE 1	NODE 2
1	1	BEAS	1	1	PIPE	3.00	15.051993	1	2
2	12	BEAS	1	1	PIPE	3.00	15.051993	2	3
3	13	BEAS	1	1	PIPE	3.00	15.000000	3	4
4	2	BEAS	1	1	PIPE	3.00	15.051993	4	5
5	14	BEAS	1	1	PIPE	3.00	15.051993	5	6
6	15	BEAS	1	2	PIPE	1.50	20.000000	6	1
7	7	BEAS	1	2	PIPE	1.50	17.500000	2	5
8	8	BEAS	1	2	PIPE	1.50	12.806249	1	7
9	9	BEAS	1	2	PIPE	1.50	11.205467	7	5
10	10	BEAS	1	2	PIPE	1.50	11.907948	2	8
11	11	BEAS	1	2	PIPE	1.50	10.206811	8	4
12	6	BEAS	1	2	PIPE	1.50	12.806249	6	7
13	5	BEAS	1	2	PIPE	1.50	11.205467	7	2
14	3	BEAS	1	2	PIPE	1.50	11.907947	5	8
15	4	BEAS	1	2	PIPE	1.50	10.206812	8	3
16	16	BEAS	1	3	I	2.00	5.0000000	3	9
17	17	BEAS	1	3	I	2.00	15.000000	9	10
18	18	BEAS	1	3	I	2.00	5.0000000	10	4

In all examples, the required Framework commands are shown.

The two dimensional jacket structure shown in Figure 3.1 is used throughout the examples that follow. Table 3.1 summarises the member properties and connectivity data.

The graphic mode program of Framework does not run alone. User can access to Framework through Sesam-Genie and Sesam Manager. Before activating Framework you should provide or locate a Sesam Results Interface file in direct access Norsam format (SIN). If you have a Results files in Formatted (SIF) or Unformatted format (SIU), then use Prepost to establish a SIN file. Usually, user will be asked to use an existing Framework database file or start a new run, Figure 3.2.

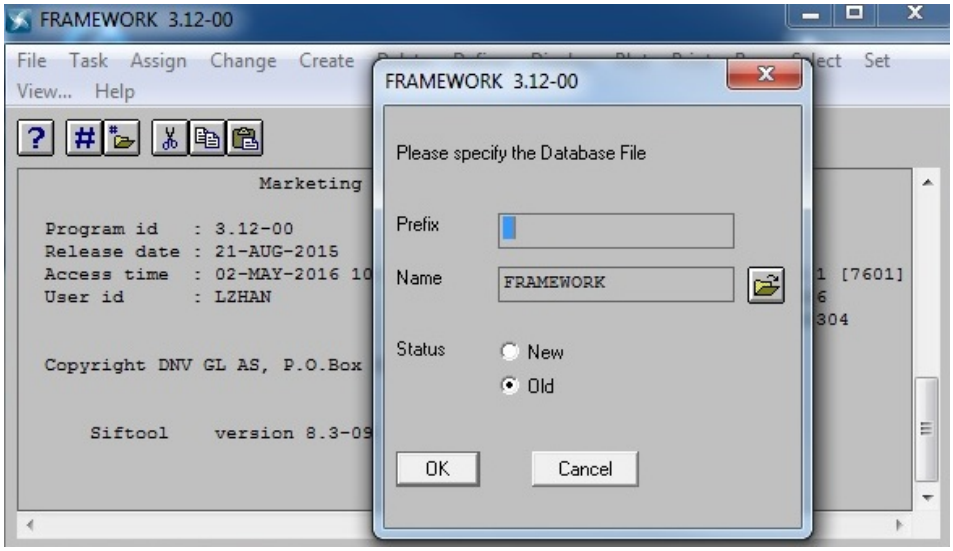


Figure 3.2: Choose Framework existing MOD file or start new run

Start a Framework run usually involves two steps, (see Figure 3.3) i.e. OPEN the results file and TRANSFER the model (superelement) data into the Framework model. It is also shown as "Step 1" in the message screen of Figure 3.5. The relevant commands are:

```
FILE OPEN SIN-DIRECT-ACCESS 'Prefix' R1
FILE TRANSFER 1 JACKET LOADS None
```

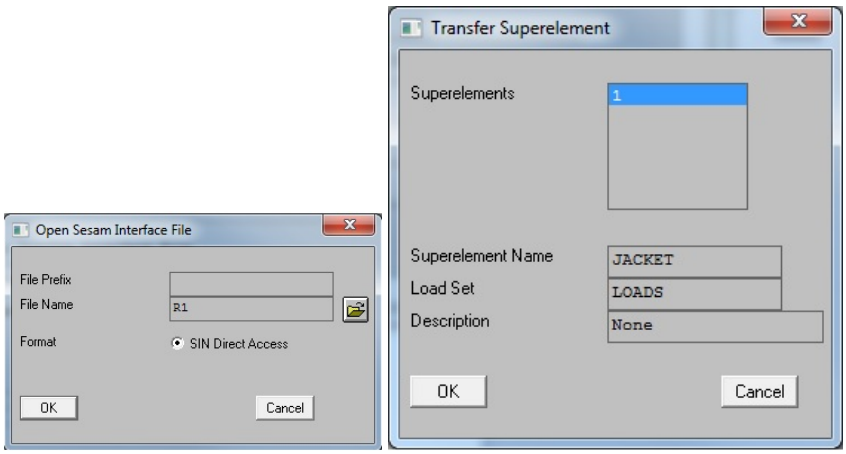


Figure 3.3: The Framework File Open and Transfer

After SIN file is read in and data has been transfered, the menu in Framework window will be lighted on, shown in 3.4. As comparison, before reading data see 3.5, some menu is greyed out.

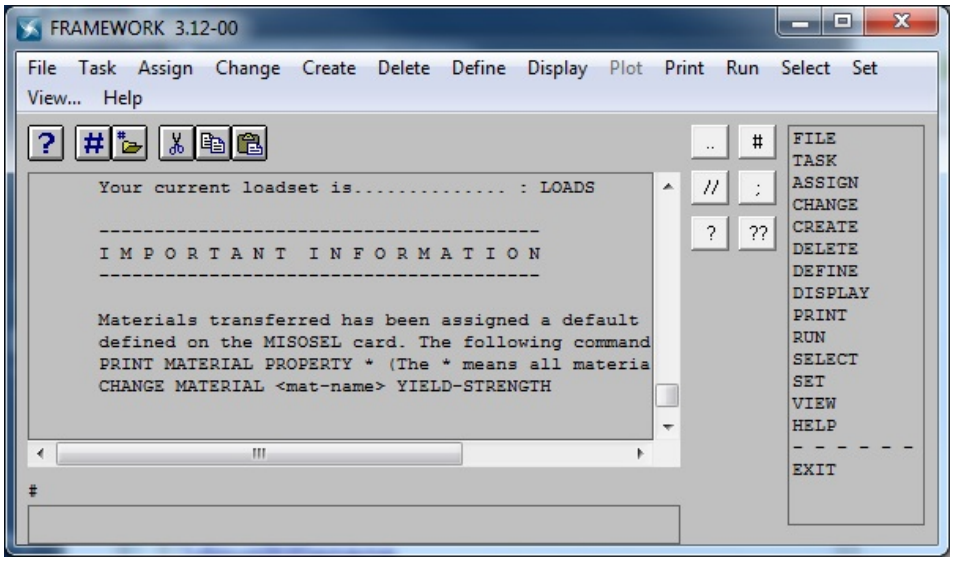


Figure 3.4: The Framework main window

Pushing the # button on top of the main window leads to the line mode. The window will expand to show available menu alternatives on the right hand side and open a command line input field at the bottom, see Figure 3.5. Menu selections can then be activated by picking from the right hand side menu or typing directly into the command line input field. This way of giving user input may be combined by use of the put-down/pop-up menus.

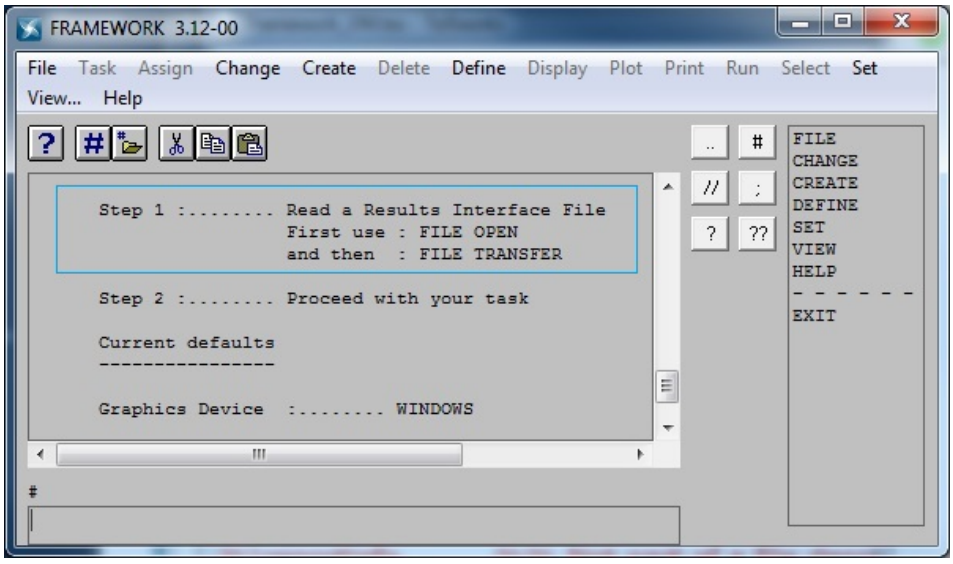


Figure 3.5: The Framework main window

Enter data into the File open menu

Open a Results Interface file by issuing the following command:

```
FILE OPEN

Give File Format? /SIN-DIRECT-ACCESS/SIN
Give File Prefix? / / STA
```

```
Give File Name? /R1/ R1
      Use command FILE TRANSFER in order to select ONE superelement
```

Then transfer one superelement by issuing the following command:

```
FILE TRANSFER
```

```
      ------------------------------------------------------------
      |         THE CONTENTS OF YOUR RESULTS FILE IS AS FOLLOWS    |
      ------------------------------------------------------------|
      |    S U P E R E L E M E N T                      | F I L E  |
      |-----------------------------------------------------------|
      |  Key   Type  Index  Text/Route                  |  Ref-Id  |
      |-----------------------------------------------------------|
      |    1      1   N/A   +                           |     1    |
      ------------------------------------------------------------
Select Superelement to process - Give Key? /1/ 1
Give Name to Superelement? /JACKET/ DEMO
Give Name to Load Set? /LOADS/ STATIC_LOADS
Give Load Set description? /None/ 'Static loads'
      Transferring Geometry of Superelement DEMO
      Transferring Materials..... Please wait
      Number of Materials Transferred..... :      1
      Transferring Sections..... Please wait
      Number of Sections Transferred..... :      3
      Transferring Joints..... Please wait
      Number of Joints Transferred..... :     10

      Transferring Members..... Please Wait
      Number of Members Transferred..... :     18

      Assigning CHORD and BRACE members.... Please wait
      Number of joints searched ..... :     10
      Number of joint chord assignments.... :     10
      Number of joint brace assignments.... :     10
      Number of joints with aligned members :      0
      Number of joints with no assignments. :      2

      Transferring Structural Concepts..... Please Wait
      No Member Concepts Transferred
      No Cones Transferred
      No Stubs Transferred
      No Cans Transferred
      No Pile Concepts Transferred
      Transferring Named Sets..... Please Wait
      No Sets Transferred
      Transfer of Superelement Geometry Completed
      Your current superelement is..... : DEMO
      Transferring Loadcases..... Please wait
      Number of Loadcases Transferred..... :      3
    * You may NOT perform a fatigue analysis
      Fatigue check type is set to ..... : NONE
      Your current loadset is..... : STATIC_LOADS

      ---------------------------------------
      I M P O R T A N T  I N F O R M A T I O N
      ---------------------------------------

      Each material transferred, has been assigned a default yield
      Therefore you may find the following two commands very useful
      PRINT MATERIAL PROPERTY * \(The * means all materials\)
```

```
CHANGE MATERIAL PROPERTY <mat-name> YIELD-STRENGTH

For other defaults use: PRINT MEMBER & PRINT JOINT commands
```

Framework reads any member concept information defined on the Results Interface File and creates the member definitions when establishing the Framework model file. Definitions of can, stub and conical member segments are also read from the Results Interface File.

The member concept definition on the Results Interface File is also used to hold non-geometric information, i.e. hydrodynamic properties and stability parameters. Framework also reads the stability parameters (buckling length and effective length factor) and the flooding coefficient assigned to the members. The flooding coefficient (i.e. flooding status; either non-flooded (value = 0.0), or flooded (value = 1.0)) is used when calculating yield and stability utilisation of a member with pipe cross section exposed to hydrostatic water pressure.

When conceptual information is read from the Results Interface File instructing Framework to create a conical member segment between two pipe segments, then two new cross sections will be created. The outer diameter and wall thickness for the new sections (for each cylinder-cone transition) will be:

Diameter	= Diameter of cylinder (pipe) in transition
Wall thickness	= Wall thickness of pipe element used in stiffness analysis

The new cross sections will be named as `Cx_yyyyy`, where:

`x`	= 1 or 2 for start and end of cone respectively
`yyyyy`	= unique concept number given on the Results Interface File

Optionally, the Sesam Interface File elastic material definition card MISOSEL can contain data regarding yield strength. Framework will use this data when available.

How to establish load case names based on available information on the results file must be set prior to opening the results file, and selection alternatives are:

- INTERNAL-RESULT-ID, i.e. create name from internal (sequential) load number – the default
- EXTERNAL-RESULT-ID, i.e.create name from external load number, e.g. result combination defined in Prepost
- LOAD-CASE-NAME, i.e. use load case name when available. Defined on result file by use of the TDLOAD card
- RESULT-CASE-NAME, i.e. use result case name when available. Defined on result file by use of the TDRESREF card

Note 1: Framework can only process 2-noded structural beam elements

3.1.1 DEFINE options prior to opening SIN file

Before`FILE OPEN` and `FILE TRANSFER`, the model from the results interface file, Rx.SIN, it is possible, and somtimes necessary, to switch off reading the conceptual information (member definitions and names (members, nodes, materials, sections)) when establishing the Framework model. It is also possible to skip reading the named sets (element sets and / or joint (node) sets).

```
DEFINE READ-CONCEPTS OFF
DEFINE BEAM-SPLIT STRUCTURE ALL-JOINTS
DEFINE BEAM-SPLIT SECTION PIPE-ONLY
```

It is also recommended to apply DEFINE FATIGUE-CONSTANTS and some other DEFINE commands before file open and transfer. For example,

Table 3.2

Annotation	Status	Colour
C	Chord	Yellow
B	Brace	Red
L	Local chord	Orange
S	Support or free end	Green
P	Probably a pile	Green
N	Non-tubular	Green
E	Tubular, no specific role	Green

```
DEFINE NEAR-CHORD-RULE ON
DEFINE FATIGUE-CHECK-WELD-ROOT ON
DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE API-WJ
DEFINE FATIGUE-CONSTANTS FABRICATION-TOLERANCE-OPTION 0.15TS
DEFINE FATIGUE-CONSTANTS DEFAULT-FABRICATION-TOLERANCE 0.034
DEFINE FATIGUE-CONSTANTS INHERENT-SN-MISALIGNMENT-FACTOR 0.043
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2020
DEFINE FATIGUE-CONSTANTS DEFAULT-BUTTWELD-SN-CURVE DNV2010_E
```

Framework will stores API-WJ curve as the default SN curve for the fatigue check positions at tubular joints and DNV2010_E at auto-generated buttweld fatigue positions. It is possible to change it to the one that user needs for convenience aftter the model is read in. When the command of DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE is not applied prior to opening the SIN file, DNV-X curve will be assigned.

3.1.2 Present a display of the model

If you are running on a terminal capable of producing a graphic display then set the kind of device you are using (e.g. an X-terminal).

```
SET DISPLAY DEVICE X
```

Let the program display the finite element model:

```
DISPLAY SUPERELEMENT
```

Let the program display members and joints:

```
SELECT MEMBER ALLDISPLAY MEMBER
```

Change the view to a more convenient angle:

```
VIEW ROTATE TO 90. 0. 0.Annotate the display:
DISPLAY LABEL MEMBER-NAME ON
DISPLAY LABEL JOINT-NAME ON
```

To create a hardcopy plot of current display, simply type:.

```
PLOT
```

3.2 How to assign CHORDS

3.2.1 Automatic assignment of CHORD and BRACES

The program will automatically assign chords and braces as explained in Section 2. The user may verify the selections made by the program by display and printed output. Legend as shown in Table 3.2.

To obtain a visual inspection use the commands:

```
SELECT JOINT ALL
DISPLAY JOINT
```

On a colour monitor, the status may now bee seen from colour coding. On a monochrome monitor, the user may request the single letter annotations defined above to be put on each member end.

```
DISPLAY LABEL CHORD-AND-BRACE ON
```

To obtain a screen printout of the assignments made by the program at each joint, the following command is used:

```
PRINT CHORD-AND-BRACE ALL
```

where:

```
Joint    Member   Type  Diameter   Thick    Yield   Chord    Can/Stub  Length
-------------------------------------------------------------------------------
1        1        CHORD 3.000E+00 3.00E-02 2.00E+08
         8        BRACE 1.500E+00 1.50E-02 2.00E+08 1
         6        BRACE 1.500E+00 1.50E-02 2.00E+08 1

2        1        CHORD 3.000E+00 3.00E-02 2.00E+08
         2        ALIGN 3.000E+00 3.00E-02 2.00E+08
         13       BRACE 1.500E+00 1.50E-02 2.00E+08 1
         7        BRACE 1.500E+00 1.50E-02 2.00E+08 1
         10       BRACE 1.500E+00 1.50E-02 2.00E+08 1

3        2        CHORD 3.000E+00 3.00E-02 2.00E+08
         15       BRACE 1.500E+00 1.50E-02 2.00E+08 2
         3        BRACE 3.000E+00 3.00E-02 2.00E+08 2
         16       Non-tubular member

4        4        CHORD 3.000E+00 3.00E-02 2.00E+08
         11       BRACE 1.500E+00 1.50E-02 2.00E+08 4
         3        BRACE 3.000E+00 3.00E-02 2.00E+08 4
         18       Non-tubular member

5        5        CHORD 3.000E+00 3.00E-02 2.00E+08
         4        ALIGN 3.000E+00 3.00E-02 2.00E+08
         14       BRACE 1.500E+00 1.50E-02 2.00E+08 5
         7        BRACE 1.500E+00 1.50E-02 2.00E+08 5
         9        BRACE 1.500E+00 1.50E-02 2.00E+08 5
6        5        CHORD 3.000E+00 3.00E-02 2.00E+08
         12       BRACE 1.500E+00 1.50E-02 2.00E+08 5
         6        BRACE 1.500E+00 1.50E-02 2.00E+08 5

7        8        CHORD 1.500E+00 1.50E-02 2.00E+08
         9        ALIGN 1.500E+00 1.50E-02 2.00E+08
         13       BRACE 1.500E+00 1.50E-02 2.00E+08 8
         12       BRACE 1.500E+00 1.50E-02 2.00E+08 8

8        10       CHORD 1.500E+00 1.50E-02 2.00E+08
         11       ALIGN 1.500E+00 1.50E-02 2.00E+08
         14       BRACE 1.500E+00 1.50E-02 2.00E+08 10
         15       BRACE 1.500E+00 1.50E-02 2.00E+08 10

9        16       Non-tubular member
         17       Non-tubular member

10       17       Non-tubular member
         18       Non-tubular member
```

The basis for which a member qualifies as a CHORD or an ALIGNED chord when the automatic feature is used, is fully described in Section 2.3.4.

To obtain more detail information about joint 1, the following command is used:

```
PRINT JOINT PUNCH-CHECK-DATA 2
```

which shows:

```
Joint ..: 2
          Member ..: 1
          Status ..: CHORD
                     Diameter ......:  3.000E+00
                     Thickness .....:  3.000E-02
                     Yield .........:  2.000E+08
                     No. of braces .:  3
          Member ..: 13
          Status ..: BRACE
                     Diameter ......:  1.500E+00
                     Thickness .....:  1.500E-02
                     Yield .........:  2.000E+08
                     Joint type ....:  YT /MANU
                     Gap ...........:  0.000E+00
                     Chord angle ...:  56.10
                     Brace/Chord dia:  0.50
                     I/O angle .....:  0.00
                     Chord member ..:  1
                     Diameter ......:  3.000E+00
                     Thickness .....:  3.000E-02
                     Yield .........:  2.000E+08
          Member ..: 7
          Status ..: BRACE
                     Diameter ......:  1.500E+00
                     Thickness .....:  1.500E-02
                     Yield .........:  2.000E+08
                     Joint type ....:  YT /MANU
                     Gap ...........:  0.000E+00
                     Chord angle ...:  85.24
                     Brace/Chord dia:  0.50
                     I/O angle .....:  0.00
                     Chord member ..:  1
                     Diameter ......:  3.000E+00
                     Thickness .....:  3.000E-02
                     Yield .........:  2.000E+08
          Member ..: 10
          Status ..: BRACE
                     Diameter ......:  1.500E+00
                     Thickness .....:  1.500E-02
                     Yield .........:  2.000E+08
                     Joint type ....:  YT /MANU
                     Gap ...........:  0.000E+00
                     Chord angle ...:  42.53
                     Brace/Chord dia:  0.50
                     I/O angle .....:  0.00
                     Chord member ..:  1
                     Diameter ......:  3.000E+00
                     Thickness .....:  3.000E-02
                     Yield .........:  2.000E+08
          Member ..: 2
          Status ..: ALIGN
                     Diameter ......:  3.000E+00
                     Thickness .....:  3.000E-02
                     Yield .........:  2.000E+08
```

```
                    No. of braces .:  0
```

See Figure 3.1 and corresponding element print in Table 3.1.

3.2.2 Global CHORD assignments

A global CHORD assignment at a joint (in contrast with the local CHORD assignment, described in the next section), 'influences' the 'status' of all members connected to that joint. This command will override, at that joint, any previous CHORD assignment made.

With reference to Figure 3.1, if at joint 2, member 2 (instead of member 1) is required to be assigned as the CHORD, and ALSO that members 7, 10 and 13 become the BRACES of CHORD 2, then the following command must be used:

```
ASSIGN CHORD GLOBAL 2 2
```

which shows:

```
      At Joint.....................................        2
      Member        2 is the.......................... CHORD
      Member        1 is the..........................ALIGNED-CHORD
      Member       13 assigned as a..................... BRACE
      Member        7 assigned as a..................... BRACE
      Member       10 assigned as a..................... BRACE
```

With reference to Figure 3.1, if at joint 8, member 14 (instead of member 10) is required to be assigned as the CHORD, and ALSO that member 10 and 11 become the BRACES, then the following command must be used:

```
ASSIGN CHORD GLOBAL 14 8
```

To confirm the effect of the above command the following PRINT may be used:

```
PRINT CHORD-AND-BRACE ( ONLY 2 10 )
```

which shows:

```
Joint    Member   Type  Diameter   Thick    Yield   Chord    Can/Stub  Length
------------------------------------------------------------------------------
2        2        CHORD 3.000E+00 3.00E-02 2.00E+08
         1        ALIGN 3.000E+00 3.00E-02 2.00E+08
         13       BRACE 1.500E+00 1.50E-02 2.00E+08 2
         7        BRACE 1.500E+00 1.50E-02 2.00E+08 2
         10       BRACE 1.500E+00 1.50E-02 2.00E+08 2
```

See Figure 3.1 and corresponding element print in Table 3.1.

3.2.3 Local CHORD assignments

A local CHORD assignment at a joint (in contrast with the global CHORD assignment, described in the previous section), 'influences' the 'status' of a user specified member connected to that joint. This command will override, at that joint, any previous CHORD assignment made.

Local chord assignments must NOT be made at joints where classification based on geometry or loadpath is used.

With reference to Figure 3.1, if at joint 2 it is required that member 10 is assigned member 7 as its CHORD, then the following command must be used:

```
ASSIGN CHORD LOCAL 2 7 10
```

which shows:

```
      At joint.....................................        2
      Member        7 is assigned as a local.......... CHORD
      Member       10 is assigned as its local....... BRACE
```

and thus overrides the previous status of member 10.

To confirm the effect of the above command the following PRINT may be used:

```
PRINT CHORD-AND-BRACE 2
```

which shows:

```
Joint    Member   Type  Diameter   Thick    Yield   Chord    Can/Stub  Length
-------------------------------------------------------------------------------
2         2        CHORD 3.000E+00 3.00E-02 2.00E+08
          1        ALIGN 3.000E+00 3.00E-02 2.00E+08
          13       BRACE 1.500E+00 1.50E-02 2.00E+08 2
          7        CH/BR 1.500E+00 1.50E-02 2.00E+08 2
          10       BRACE 1.500E+00 1.50E-02 2.00E+08 7
```

EXT. EL.	INT. EL.	EL. TYPE	MAT. NO.	SECT. NO.	SECT. TYPE	SECT. D H TH	ELEMENT LENGTH FLEXIBLE PART	NODE 1	NODE 2
1	1	BEAS	1	1	PIPE	3.00	15.051993	1	2
2	12	BEAS	1	1	PIPE	3.00	15.051993	2	3
3	13	BEAS	1	1	PIPE	3.00	15.000000	3	4
4	2	BEAS	1	1	PIPE	3.00	15.051993	4	5
5	14	BEAS	1	1	PIPE	3.00	15.051993	5	6
6	15	BEAS	1	2	PIPE	1.50	20.000000	6	1
7	7	BEAS	1	2	PIPE	1.50	17.500000	2	5
8	8	BEAS	1	2	PIPE	1.50	12.806249	1	7
9	9	BEAS	1	2	PIPE	1.50	11.205467	7	5
10	10	BEAS	1	2	PIPE	1.50	11.907948	2	8
11	11	BEAS	1	2	PIPE	1.50	10.206811	8	4
12	6	BEAS	1	2	PIPE	1.50	12.806249	6	7
13	5	BEAS	1	2	PIPE	1.50	11.205467	7	2
14	3	BEAS	1	2	PIPE	1.50	11.907947	5	8
15	4	BEAS	1	2	PIPE	1.50	10.206812	8	3
16	16	BEAS	1	3	I	2.00	5.0000000	3	9
17	17	BEAS	1	3	I	2.00	15.000000	9	10
18	18	BEAS	1	3	I	2.00	5.0000000	10	4

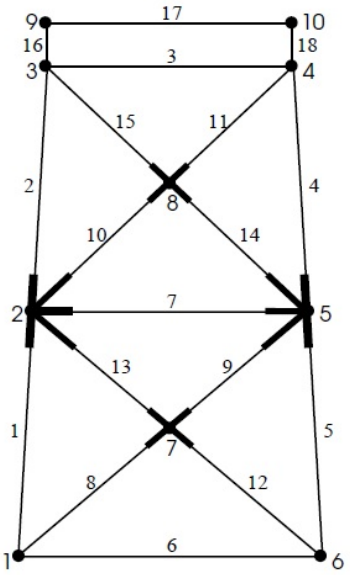


Figure 3.6: Position of CAN and STUB section

3.3 How to assign CAN and STUB sections

3.3.1 CAN assignments

Figure 3.6 shows the finite element model (as in Figure 3.1) but in addition it highlights, in heavy lines, the CAN and STUB sections at the end of various members. Figure 3.7 shows, as an example, the detailed joint configuration at joint 2.

Before this CAN section is assigned it must be created using the command:

```
CREATE SECTION CAN4000 'Can section' PIPE 4.0 0.04
```

A material with yield strength of $400 \times 10^6 N/m^2$ is also created in order that is assigned to the CAN section. This is done using the following command:

```
CREATE MATERIAL MAT400 'Can material' 2.1E+11 400.E+6 7850. 0.3 0.0 0.0
```

To assign the CAN section at joint 2 use the following command:

```
ASSIGN CAN JOINT 2 CAN4000 MAT400 0.0 0.0
```

where

CAN4000	is the CAN section name
MAT400	is the CAN section material

The effect of the CAN assignment is that the CHORD and ALIGNED chord at joint 2 inherit the CAN section properties at that joint. To confirm this, the following command is used:

```
PRINT CHORD-AND-BRACE ONLY 2
```

which shows;

```
Joint    Member   Type  Diameter   Thick    Yield   Chord    Can/Stub  Length
-------------------------------------------------------------------------------
2        2        CHORD 4.000E+00 4.00E-02 4.00E+08          CAN4000  0.000E+00
         1        ALIGN 4.000E+00 4.00E-02 4.00E+08          CAN4000  0.000E+00
         13       BRACE 1.500E+00 1.50E-02 2.00E+08 2
```

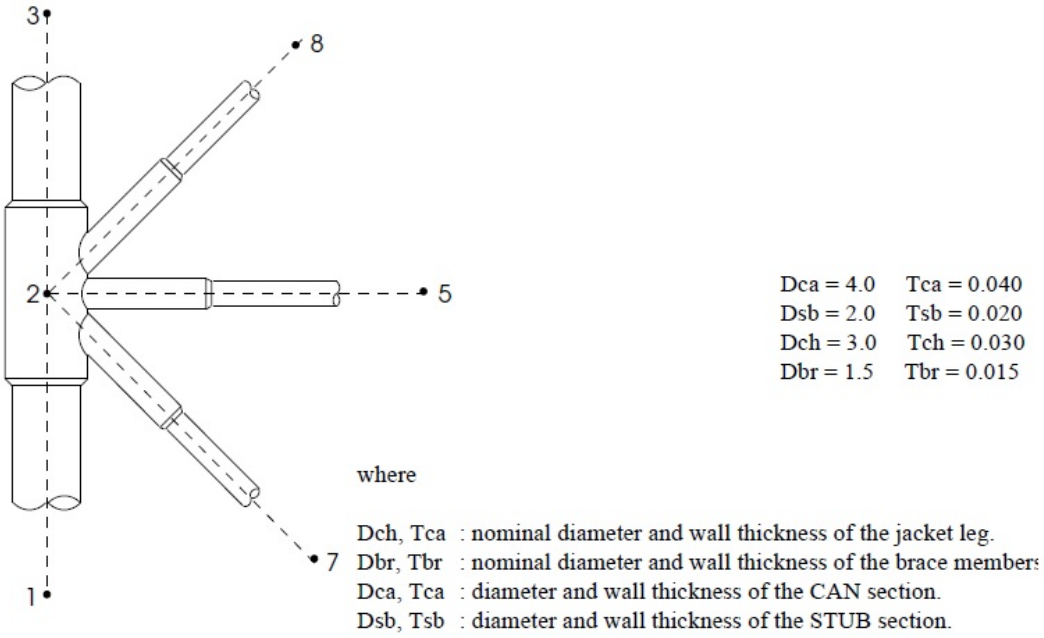


Figure 3.7: Detailed joint configuration at joint 2

```
7         BRACE 1.500E+00 1.50E-02 2.00E+08 2
10        BRACE 1.500E+00 1.50E-02 2.00E+08 2
```

3.3.2 STUB assignments

To assign the STUB section to all braces at joint 2 (see Figure 3.7) use the following command:

```
CREATE SECTION STB2000 'Stub section' PIPE 2.0 0.02
CREATE MATERIAL MAT380 'Stub material' 2.1E+11 380.E+6 7850. 0.3 0.0 0.0
ASSIGN STUB JOINT 2 STB2000 MAT380 0.0
```

where:

STB2000	is the STUB section name
MAT380	is the STUB section material

The PRINT command:

```
PRINT CHORD-AND-BRACE 2
```

shows:

```
Joint    Member   Type  Diameter   Thick    Yield   Chord    Can/Stub  Length
-------------------------------------------------------------------------------
2        2        CHORD 4.000E+00 4.00E-02 4.00E+08          CAN4000  0.000E+00
         1        ALIGN 4.000E+00 4.00E-02 4.00E+08          CAN4000  0.000E+00
         13       BRACE 2.000E+00 2.00E-02 3.80E+08 2        STB2000  0.000E+00
         7        BRACE 2.000E+00 2.00E-02 3.80E+08 2        STB2000  0.000E+00
         10       BRACE 2.000E+00 2.00E-02 3.80E+08 2        STB2000  0.000E+00
```

See Figure 3.6 and corresponding element print in Table 3.1.

Note:

- The commands `ASSIGN CAN` and `ASSIGN STUB` are recommended to apply on the tubular joints where no conceptual CAN or Stub segment has been defined in preprocessing program, like Genie.
- In order for a CAN/Stub section to be assigned (directly or indirectly) to a member, it is required that the diameter of the CAN/Stub section is not less than the nominal diameter of the member. That is, the assigned cross section should in general form a reinforcement to the original member.
- The "Mannual" specified length of the CAN or Stub must be less than the total length of the beam member (chord and aligned). The "AUTOMATIC" option of `ASSIGN CAN JOINT` needs a specification by the `DEFINE JOINT-PARAMETER MINIMUM-FREE-CAN-LENGTH` command which sets the minimum free can length value.
- Some caution needs to be taken if there are conceptual CAN/Stub segments at the joint in Genie's model. Framework will take the conceptual CAN/Stub definition as long as it is available. The cross section and segment properties are directly applied in punch shear code check of the joint. For the latest API, ISO, Norsok standards, these properties have influence on the utilization of the joint. User should be cautious when using "Automatic" can or stub feature in Genie. It is advised to ensure the cross section and segment properties of CAN/Stub are correct before Framework reads in the result file.
- It is required to model the concept CAN/Stub segment by "one" beam element because Framework is not meant to handle situations where reinforcement cans are divided into multiple beam elements. Hence, when reading Genie's models, user must ensure that all beam segments representing joint reinforcements are represented by one finite element only.
- If there are existing conceptual CAN/Stub segments, the commands,`ASSIGN CAN` and `ASSIGN STUB`, can override the section and segment properties applied in punch shear code check.
- The command `ASSIGN CAN` is applicable only for tubular joint. It is recommended to use this command for every tubular joint or chord member. Applying the assignment to a set of joints or members might involve errors if there are non-tubular members in the set.

3.3.3 How to assign joint-type and gap

All members as default get default joint type values (YT).

It is simple to have the program decide joint type based on geometry using the command:

```
ASSIGN JOINT-TYPE ALL ALL GEOMETRY
```

For punch checks, the joint type may also be specified to be load path type dependent using the command:

```
ASSIGN JOINT-TYPE ALL ALL LOADPATH
```

The result of the assignments above may be reviewed using display features:

```
SELECT JOINT ALL
DISPLAY JOINT
DISPLAY LABEL JOINT-TYPE ON
DISPLAY LABEL CHORD-AND-BRACE OFF
```

With reference to Figure 3.6, say that it is required to specify that member 10 at joint 2 is the K part of a KT joint. This may be obtained by using the classification based on joint geometry, or alternatively by manual assignment using the command:

```
ASSIGN JOINT-TYPE 10 2 KTK
```

To assign a gap of 20 mm at joint 2 for brace 10, use:

```
ASSIGN JOINT-GAP 10 2 0.02
```

The PRINT command:

```
PRINT JOINT PUNCH-CHECK-DATA 2
```

shows:

```
Joint ..: 2
          Member ..: 1
          Status ..: ALIGN
                     Diameter ......:  4.000E+00
                     Thickness .....:  4.000E-02
                     Yield .........:  4.000E+08
                     No. of braces .:  0
          Member ..: 13
          Status ..: BRACE
                     Diameter ......:  2.000E+00
                     Thickness .....:  2.000E-02
                     Yield .........:  3.800E+08
                     Joint type ....:  KTK/LOAD
                     Gap ...........:  0.000E+00
                     Chord angle ...:  56.10
                     Brace/Chord dia:  0.50
                     I/O angle .....:  180.00
                     Chord member ..:  2
                     Diameter ......:  4.000E+00
                     Thickness .....:  4.000E-02
                     Yield .........:  4.000E+08
          Member ..: 7
          Status ..: BRACE
                     Diameter ......:  2.000E+00
                     Thickness .....:  2.000E-02
                     Yield .........:  3.800E+08
                     Joint type ....:  KTT/LOAD
                     Gap ...........:  0.000E+00
                     Chord angle ...:  85.24
```

```
            Brace/Chord dia:  0.50
            I/O angle .....:  180.00
            Chord member ..:  2
            Diameter ......:  4.000E+00
            Thickness .....:  4.000E-02
            Yield .........:  4.000E+08
Member ..: 10
Status ..: BRACE
            Diameter ......:  2.000E+00
            Thickness .....:  2.000E-02
            Yield .........:  3.800E+08
            Joint type ....:  KTK/MANU
            Gap ...........:  2.000E-02
            Chord angle ...:  42.53
            Brace/Chord dia:  0.50
            I/O angle .....:  180.00
            Chord member ..:  2
            Diameter ......:  4.000E+00
            Thickness .....:  4.000E-02
            Yield .........:  4.000E+08
Member ..: 2
Status ..: CHORD
            Diameter ......:  4.000E+00
            Thickness .....:  4.000E-02
            Yield .........:  4.000E+08
            No. of braces .:  3
```

confirming the intended joint assignments.

3.4 How to specify parametric SCFs

With reference to Figure 3.6 it is required that parametric SCFs are calculated at either end of member 10. In order that parametric SCFs are calculated at each end of the member, it is necessary that for each end:

- the corresponding CHORD member has been assigned
- the desired joint type (e.g. K, X, YT, etc.) has been assigned
- the actual gap/overlap data has been assigned for K type joints

CAN and STUB section data will also be accounted for if assigned.

It is assumed that the following commands have been issued:

```
ASSIGN CAN JOINT 2 CAN4000 MAT400 0.0 0.0
ASSIGN CAN JOINT 5 CAN4000 MAT400 0.0 0.0
SELECT JOINT ( ONLY 2 5 7 8 )
ASSIGN STUB JOINT CURRENT STB2000 MAT380 0.0
SELECT JOINT ( ONLY 7 8 )
ASSIGN CAN JOINT CURRENT STB2000 MAT380 0.0 0.0
```

Joint type may be automatically assigned by:

```
ASSIGN JOINT-TYPE ALL ALL GEOM
```

or alternatively manually:

```
ASSIGN JOINT-TYPE 10 8 X
ASSIGN JOINT-TYPE 10 2 KTK
```

Gap value for the KTK brace:

```
ASSIGN JOINT-GAP 10 2 0.02
```

To specify computation of parametric SCFs for joints at each end of brace member 10:

```
ASSIGN SCF JOINT 10 8 None PARAMETRIC WORDSWORTH
ASSIGN SCF JOINT 10 2 None PARAMETRIC KUANG
```

To set a minimum acceptable threshold value of 2.5, although this is the default, for each of the SCFs (axial, in-plane and out-of-plane) the following command is issued:

```
DEFINE FATIGUE-CONSTANTS AXIAL-MINIMUM-SCF 2.5
DEFINE FATIGUE-CONSTANTS IN-PLANE-MINIMUM-SCF 2.5
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-MINIMUM 2.5
```

The SCFs for member 10 are automatically calculated by the program whenever their use is wanted.

To print the SCFs (parametric or otherwise) for member 10, the following PRINT command must be issued:

```
PRINT MEMBER FATIGUE-CHECK-DATA 10
```

which gives:

```
Member Joint/Po SecTy WeldSide SNcurve SCFrule Symmet Hot SCFax
                                                SCFipb   SCFopb
-----------------------------------------------------------------
10        2     PIPE  BOTH-SID DNV-X   KUANG
          8     PIPE  BOTH-SID DNV-X   WORDSWOR
```

When printing the Efthymiou parametric SCFs it is always the geometric Efthymiou SCFs model C that is printed. No LOADPATH SCFs are printed.

3.5 How to specify Butt-weld and Cone-Transition SCFs

By default, **Butt-Weld** SCF is assigned to those positions at two sides of CAN/STUB segment interface and other cross-section transition. The **Cone-Transition** SCF is assigned to the positions at cone-tubular junctions. In general, the program is able to automatically specify the associated default SCF formula to the positions at section transitions. User does not have to use `ASSIGN SCF MEMBER` command to these positions one by one. The global default SCF formula is based on the selection in command `DEFINE-FATIGUE-CONSTANTS`.

The sample `DEFINE` commands below show *DNVGL-RPC203-2014* is set as the SCF formula, and *0.15TS* is the fabrication toleracne option. These will be the global default. It is always allowed to override the global option by `ASSIGN SCF MEMBER` command.

```
DEFINE FATIGUE-CONSTANTS FABRICATION-TOLERANCE-OPTION 0.15TS
DEFINE FATIGUE-CONSTANTS DEFAULT-FABRICATION-TOLERANCE 0.0
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2014
```

It is necessary to set up a minimum SCF for Butt-weld and conical transition.

```
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-MIN-SCF 1.0
```

It is recommended but not requried to use the command of `DEFINE FATIGUE-CONSTANTS` before openning the `Rn.SIN` file, as makes the preferred options available for the automated default SCF assignment. Using the `DEFINE` command after the `Rn.SIN` file is open is still allowed for Butt-weld and Cone SCF options and may happens often when entering the grasphic mode of Framework via Genie. In the line mode, it is very possible that the some of the `DEFINE FATIGUE-CONSTANTS` command, e.g. `FABRICATION-TOLERANCE-OPTION` and `BUTTWELD-CONE-SCF-FORMULA` are missing, and only command `DEFAULT-FABRICATION-TOLERANCE` is available. In this case, The SCF formula `DNVGL-RPC203-2014` will be the default, and *0.15TS* is the default fabrication tolerance. If none of `DEFINE FATIGUE-CONSTANTS` command has been used, the program will skip calculating butt-weld and cone SCF but use `Global Axial SCF`. If `BUTT-WELD` or `CONE-TRANSITION` SCF rule happen to be applied at member's end positions, the SCF rule will be changed to **GLOBAL**.

Some sample commands to specify Butt-weld and Cone-Transition SCF are shown below. The commands are not being used in any example of this user manual but to show the format to write a valid command. Suppose there are a group of members, named $\mathrm{BM1}$, $\mathrm{BM3}$, $\mathrm{BM4}$, $\mathrm{BM6}$. There are multiple segments on these

members. In general, the default Butt-weld and Cone-Transition SCF assignment is finished when reading the result `Rn.SIN` file into Framework . It is possible that the global SCF option in `DEFINE FATIGUE-CONSTANTS` is not appropriate for particular positions. Then, the command `ASSIGN SCF MEMBER` can be applied in this case as the local override. The dialogbox in the graphic mode is shown in Figure 3.8.

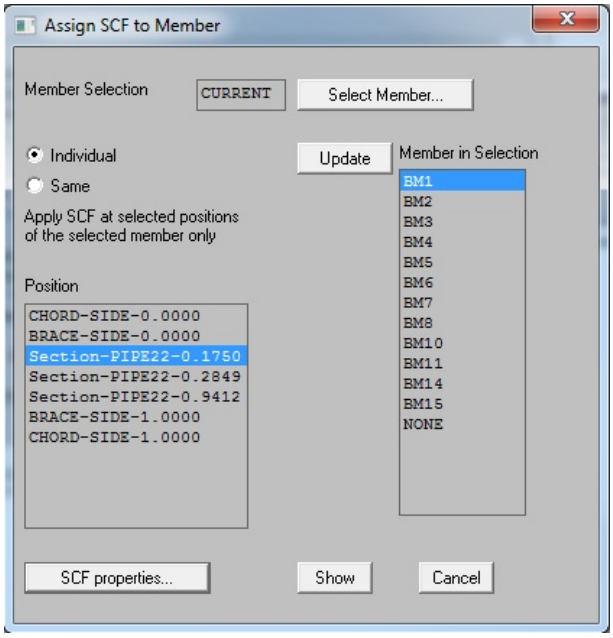


Figure 3.8: Sample dialogbox of ASSIGN SCF to Member

For example, $\mathrm{BM4}$ has a cross-section change from section $\mathrm{COL_3}$ to section $\mathrm{COL_4}$ at relative location 0.5. The `BUTT-WELD` SCF formula uses DNVGL RPC203:2014 at the positions. Instead of the global default *0.15TS*, the fabrication tolerance on $\mathrm{BM4}$ needs to be *0.30TS* and the thickness transition slope is 2.5, not the default 4.0; Use the command to override:

```
ASSIGN SCF MEMBER CURRENT BM4 INDIVIDUAL
( ONLY Section-COL_3-0.5000
       Section-COL_4-0.5000 ) None BUTT-WELD DNVGL-RPC203-2014 0.30TS 2.5 0.0
```

If the fabrication tolerance must be a fixed constant, say 5 mm, use the *MANUAL* option.

```
ASSIGN SCF MEMBER CURRENT BM4 INDIVIDUAL
( ONLY Section-COL_3-0.5000
       Section-COL_4-0.5000 ) None BUTT-WELD DNVGL-RPC203-2014 MANUAL 0.005 2.5 0.0
```

Another situation is that the cross section on two sides of the welded connection is identical, i.e. there is no section change. Then, to calculate the SCF, the width of weld at surface is needed. It can be entered "locally" following the slope. If 0.0 is left, the program will use the pipe thickness as the width; if it is known, like 1.5 cm, use the command:

```
ASSIGN SCF MEMBER CURRENT BM4 INDIVIDUAL
( ONLY Section-COL_5-0.75000) None BUTT-WELD DNVGL-RPC203-2014 MANUAL 0.005 4.0 0.015
```

Similarly, $\mathrm{BM6}$ has a cross-section change from section $\mathrm{BM_3}$ to section $\mathrm{BM_4}$ at relative location 0.55, but the Norsok Standard N-004: 1998 SCF formula is needed. Use the commands:

```
ASSIGN SCF MEMBER CURRENT BM6 INDIVIDUAL
( ONLY Section-BM_3-0.5500
       Section-BM_4-0.5500 ) None BUTT-WELD NORSOK-N004-1998 WITH-SLOPE 4.0
ASSIGN SCF MEMBER CURRENT BM6 INDIVIDUAL
```

```
( ONLY Section-BM_3-0.5500
       Section-BM_4-0.5500 ) None BUTT-WELD NORSOK-N004-1998 MANUAL 0.005 0.05
```

Another situation is that the thicknesses at two sides of the position are equal. It usually happens on pile members, or any member with a welded connection but without section changes. Assume it is on the middle of BM2. The weld width needs to be specified, say 2 cm. Sample commands are:

```
ASSIGN SCF MEMBER CURRENT BM2 INDIVIDUAL
( ONLY Section-PIPE20-0.5000) None BUTT-WELD DNVGL-RPC203-2014 MANUAL 0.005 4.0 0.02
ASSIGN SCF MEMBER CURRENT BM2 INDIVIDUAL
( ONLY Section-PIPE20-0.5000) None BUTT-WELD NORSOK-N004-1998 MANUAL 0.005 0.02
```

BM1 contains a conical segment which is unstiffened. Give the DNVGL SCF to the junction and leave the stiffeners' size being zero.

```
ASSIGN SCF MEMBER CURRENT BM1 INDIVIDUAL
( ONLY Section-COL_1-0.8000
       Section-C1_8-0.8000 ) None CONE-TRANSITION DNVGL-RPC203-2014 MAXIMUM 0.0
    0.0 0.0
```

The following commands specify the ring-stiffened cone junction at BM1 and BM3. The DNVGL 2014 and Norsok 1998 codes require difference input to define the stiffener geometry.

```
ASSIGN SCF MEMBER CURRENT BM3 INDIVIDUAL
( ONLY Section-COL_1-0.8000
       Section-C1_13-0.8000 ) None CONE-TRANSITION DNVGL-RPC203-2014 MAXIMUM 0.01
    0.03 0.05
ASSIGN SCF MEMBER CURRENT BM1 INDIVIDUAL
( ONLY Section-C2_8-0.8500
       Section-COL_3-0.8500 ) None CONE-TRANSITION NORSOK-N004-1998 OUTSIDE 0.03
    0.05
```

Above shows the command using *Member in Selection* list to get the INDIVIDUAL member. It results in the command format of

ASSIGN SCF MEMBER **CURRENT** + **Member's Name** + INDIVIDUAL + (Positions) ... + SCF ...

Alternatively, enter the member's name in *Member Name* box. The resultant command is

```
ASSIGN SCF MEMBER BM3 BM3 INDIVIDUAL
( ONLY Section-C2_13-0.8500
       Section-COL_3-0.8500 ) None CONE-TRANSITION DNVGL-RPC203-2014 MAXIMUM 0.0
    0.0 0.0
```

The command is in the format of

ASSIGN SCF MEMBER **Member's Name** + **Same Name** + INDIVIDUAL + (Positions) ... + SCF ...

In case the target member is not included in the CURRENT member set, it is still allowed to assign SCF rule to the member. For example, the following SELECT MEMBERS commands let the current set only consists of BM1 and BM3.

```
SELECT MEMBERS ONLY BM1
SELECT MEMBERS INCLUDE BM3
```

Use **NONE** following the member name BM6 because BM6 is not in the current member selection.

```
ASSIGN SCF MEMBER BM6 NONE INDIVIDUAL
( ONLY Section-BM_4-0.4500
       Section-BM_3-0.4500 ) None BUTT-WELD DNVGL-RPC203-2014 MANUAL 0.005 4.0
```

The command is in the format of

ASSIGN SCF MEMBER + **Member's Name** + **NONE** + INDIVIDUAL + (Positions) ... + SCF ...

The assignment option INDIVIDUAL has the alternative option SAME. However, using the **SAME** option must be cautious because it has very strict limitation, i.e. the position distribution on the selected members must be the same. In other word, the SAME option may not work as expected unless the position ID and location on the member from the CURRENT member set match the selected position in parenthesis **exactly**. Therefore, user needs much caution to use the SAME option. In general, **The SCF assignment to individual member is recommended.** For more details, see the command description ASSIGN SCF MEMBER.

In addition, the fatigue check positions can be modified by command ASSIGN POSITIONS. For example, running a butt-weld only fatigue check without joint connections needs to use the command

```
ASSIGN POSITIONS ( ) FATIGUE-CHECK OPTIONS OFF OFF OFF OFF ON OFF OFF
```

which turns ON the positions at *Section transition* only and ignores the joint positions and FE beam ends with the identical sections.

However, **for those manually added positions, the LOCAL SCF is recommended.** In this case, the automated SCF assignment is NOT effective. For example, one new position at 0.7 of BM6 is inserted. The default SCF rule may become GLOBAL.

```
ASSIGN POSITIONS ( BM6 ) FATIGUE-CHECK RELATIVE ( ONLY
    CHORD-SIDE       0.0
    BRACE-SIDE       0.0
    Section-BM_4     0.44999
    Section-BM_3     0.45001
    Section-BM_3     0.54999
    Section-BM_4     0.55001
    NewPos           0.70     ! Manually inserted
    BRACE-SIDE       1.0
    CHORD-SIDE       1.0     )
```

For the manually defined position, whether there is the section size change or not may NOT be identified by the program correctly. The assignment of SCF rule for the design standards may not work. The program will show ERROR or *ILLEGAL* in the report. The GLOBAL axial SCF or other un-desired value may be applied. Using LOCAL in ASSIGN SCF MEMBER command can avoid that. For example,

```
ASSIGN SCF MEMBER CURRENT BM6 INDIVIDUAL ( ONLY NewPos ) None LOCAL
    UNIFORM 2.5 2.5 2.5
```

3.6 How to handle UNIT system in fatigue analysis

3.6.1 Convert stress in S-N curves

SESAM programs use SI unit system as the default, i.e. length in *Meter* and force in *Newton*. Accordingly, the stress is in *Pascal or Pa*. The S-N curves published in the code standards such as API, HSE, and DNVGL are expressed in certain stress unit (e.g. MPa or ksi). The data of build-in S-N curves in Framework uses the stress unit of *Pa*. Thus, prior to applying S-N curve in damage calculation, it is necessary to convert the stress of the S-N curve to the corresponding stress unit applied in the model if it is not SI. This conversion is performed by Framework. By using the latest GeniE (after v7.14) and new solver Sestra v10, there is a UNIT card in the result SIN file, storing the default length and force unit converting factors. The program will use the length factor and force factor to imply the stress converting factor (i.e. $StressFactor = ForceFactor/(LengthFactor)^2$). Users do not need to enter any converting factors.

If the UNIT card is not available in the result file, the program converts the stress of S-N curve to the modelled stress unit according to the factor of the stored material's Young's Modulus over the default Young's Modulus, E=2.1E+11 Pa. Since the Reference Young's Moudulus E in commands DEFINE MEMBER-CHECK-PARAMETERS REFERENCE-YOUNGS-MODULUS is not effective for fatigue analysis and the default E is not adjustable, user should pay attention if the material in the model does not take 2.1E+11 Pascal as the Young's Modulus. The difference in Young's Modulus can result in un-expected fatigue damage difference.

3.6.2 Convert built-in length parameters (Specify Unit-Length-factor)

The program by default uses *Meter* as the length unit. Some built-in length parameters, for example, the reference thickness of S-N curves and the allowed fabrication tolerance of a butt-weld tubular connection, are stored in the unit of *Meter* in the program. If a model with English units (inch, ft), or other metric units (mm or cm) is in analysis, it is required to make the unit system consistent when comparing the modelled dimension with these built-in length parameters. The latest programs store a UNIT card. Framework uses the length factor in the UNIT card to convert the built-in length parameters to the unit system in the model, then compare the modelled length with the parameters. Therefore, using the latest programs, it is not necessary to enter the length converting factor.

If the UNIT card is not available in the result file, user needs to use command in Framework,

`DEFINE-MEMBER-CHECK-PARAMETER UNIT-LENGTH-FACTOR`

to define a converting factor, which is multiplied to those built-in length parameters and lets the built-in length match the unit that is being used in the model. The factor can be figured out as follows:

$$\text{Factor} = \frac{1.0 \quad \text{Meter}}{1.0 \quad \text{Unit of Model}}$$

$$1.0 \quad \text{Meter} = 1.0 \times \frac{\text{Meter}}{\text{Unit of Model}} \times \text{Unit of Model}$$

For example, an Finite Element model is built in the unit of "mm", the command below should be issued

`DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR 1000.0 ! Model in mm`

which means 1 Meter in the program will be used as 1000 mm.

If the model is built in the English unit of foot, "FT",

`DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR 3.281 ! Model in FT`

For some common units, the following factors are needed.

$$1.0 \quad \text{Meter} = 1.0 \times 1000 \quad \text{mm} = 1.0 \times 39.37 \quad \text{in} = 1.0 \times 3.2808 \quad \text{ft}$$

3.7 The model and loads for code checks, fatigue and earthquake analyses

3.7.1 The steel properties

The model used to perform code checks, fatigue and earthquake analyses is identical to that deployed for illustrating the use of the various modelling features provided within Framework and is shown in Figure 3.6.

The steel properties assumed are as follows:

Young's modulus of elasticity	$210 \times 10^9 N/m^2$
Material yield strength	$356 \times 10^6 N/m^2$

To change the default yield strength the following command must be used:

```
CHANGE MATERIAL 1 YIELD-STRENGTH 356.E+6
```

3.7.2 The loads for code checks

The loads applied to the jacket model shown in Figure 3.6 are as follows:

- Load case 1: Uniformly distributed load on member 17 which represents the weight of deck equipment
- Load case 2: Point load on joint 3 to simulate, say, wind forces.
- Load case 3: Jacket self weight

It is required to consider the action of all three loadcases simultaneously and in order to do this, a load combination is created through the following command:

```
CREATE LOAD-COMBINATION STATIC 'static combination' STATIC (1 1.0 2 1.0 3 1.0)
```

where `STATIC` is the load combination name.

To assign this load combination as a storm loadcase (required for the API-AISC-WSD check), use:

```
ASSIGN LOAD-CASE STATIC CONDITION STORM
```

3.7.3 The loads for deterministic fatigue analysis

The loads applied to the jacket model shown in Figure 3.6 are deterministic wave loads calculated by the hydrodynamic Sesam program Wajac [60]. In Wajac the following data were specified:

Water depth	$43.5m$
sea-water density	$1025Kg/m^3$
Normal drag coefficient	1.0
Inertia coefficient	2.0

The waves considered are shown in Table 3.3. The linear wave theory – Airy wave theory – is often used. Other theories such as Stokes' 5th order wave theory or cnoidal wave are also available, see the Wajac user manual for the details.

Table 3.3

Height (m)	Period (s)	Direction (deg)
4.0	8.0	0.0
3.0	5.0	0.0
6.0	8.0	45.0
5.0	7.0	45.0
6.0	9.0	90.0
5.0	8.0	90.0
4.0	7.0	90.0
3.0	6.0	90.0
2.0	5.0	90.0

3.7.4 The loads for spectral fatigue analysis

The loads for spectral fatigue analysis are similar to a deterministic fatigue analysis shown in Section 3.7.3. They are deterministic individual waves whose wave height and wave period can be specified in Genie or Wajac . The wave periods and heights considered are shown in Table 3.4.

Table 3.4

Height (m)	Period (s)	Direction (deg)
0.8	3.0	0, 45, 90
3.0	6.5	0, 45, 90
6.0	8.0	0, 45, 90
8.0	9.2	0, 45, 90
12.0	11.2	0, 45, 90
15.0	12.6	0, 45, 90

Note that the wave period and wave height should be chosen appropriately in order to capture the peak structural response and generate the proper stress range transfer functions. The wave theory and number of steps can be input in SEA line and SEAOPT line of Wajacinput file or in Genie. Similar to the deterministic method, the wave theory of the wave loads in a spectral fatigue analysis is not limited to the linear (Airy) wave theory. The linearization of the drag term of wave loads is not required. By contrast, the wave loads in a stochastic fatigue analysis Section 3.7.5 are linearized on the drag forces and limited to Airy wave theory with unit wave amplitude (harmonic form in frequency domain). See the Wajac user manual for more details.

In Wajac the following hydrodynamic data were specified:

Water depth	$43.5m$
Sea-water density	$1025Kg/m^3$
Normal drag coefficient	1.0
Inertia coefficient	2.0
Wave directions	0, 45 and 90 degrees with respect to the global X-axis

3.7.5 The loads for stochastic fatigue analysis

The loads applied to the jacket model shown in Figure 3.6 are stochastic wave loads calculated by the hydrodynamic Sesam program Wajac [60]. A statistical linearisation for the drag forces was deployed using a `JONSWAP` wave spectrum. In Wajac the following data were specified:

Water depth	$43.5m$
Sea-water density	$1025Kg/m^3$
Normal drag coefficient	1.0
Inertia coefficient	2.0
Wave spectrum	`JONSWAP` with $Hs = 7.0m$ and $Tz = 8.0sec$
Wave directions	0, 45 and 90 degrees with respect to the global X-axis

The wave periods considered are shown in Table 3.5. Only linear Airy wave can be used. And the waves are harmonic waves of unit wave amplitude. User only needs to define the wave periods or frequencies for every direction.

Table 3.5

Period (s)	Frequency (rad/sec)
6.28	1.000
13.34	0.471
20.40	0.308
24.43	0.229
34.53	0.182
41.61	0.151
48.70	0.129
55.60	0.113
62.83	0.100

3.7.6 The loads for earthquake analysis

An eigenvalue analysis was performed for the model shown in Figure 3.6, solving for the lowest 15 frequencies and modal load factors. The results for the eigenfrequencies are shown in Table 3.6.

Table 3.6

Mode	Frequency	
	Hertz	Rad/sec
1	0.1937E+01	0.1217E+02
2	0.5646E+01	0.3547E+02
3	0.8994E+01	0.5651E+02
4	0.9644E+01	0.6060E+02
5	0.1305E+01	0.8199+02
6	0.1668+01	0.1048+02
7	0.1726E+01	0.1085E+02
8	0.1914E+01	0.1203E+02
9	0.2217E+01	0.1993E+02
10	0.2663E+01	0.1673e+02
11	0.2687E+01	0.1688E+02
12	0.2822E+01	0.1773E+02
13	0.2942E+01	0.1848E+02
14	0.3589E+01	0.2255+02
15	0.3648E+01	0.2292E+02

See Figure 3.6 and corresponding element print in Table 3.1.

3.8 How to perform a yield check

With reference to Figure 3.6, a yield check is performed for all members in the jacket model according to the API-AISC-WSD codes of practice.

For information on the loadcases analysed see Section 3.7.2.

All members in the jacket model will be checked, and results may be printed or displayed for members that exceed a 'usage factor' (i.e. interaction ratio) of 0.0.

The following command selects the **API-AISC-WSD** codes of practice:

```
SELECT CODE-OF-PRACTICE API-AISC-WSD
```

To perform a yield check for all members, the following command is used:

```
RUN YIELD-CHECK RUN1 'Yield check' ALL STATIC
```

Usage factors computed by the check may be displayed:

```
DISPLAY CODE-CHECK-RESULTS RUN1 WORST-LOADCASE MAX-USAGE-FACTOR 1.0
```

Results may be printed either on the screen or on a file. To direct all output to a file, and print in landscape, use the following commands:

```
SET PRINT DESTINATION FILE
SET PRINT PAGE-ORIENTATION LANDSCAPE
```

To print (for each member) the highest usage factor (even though only one loadcase has been checked) use the following command:

```
PRINT CODE-CHECK-RESULTS RUN1 WORST-LOADCASE FULL ABOVE 0.0
```

Example results obtained from a yield check are shown in Appendix A.1. The notation used in the heading from an AISC-API-WSD check is shown below:

```
NOMENCLATURE:
 Member      Name of member
 LoadCase    Name of loadcase
 CND         Operational, storm or earthquake condition
 Type        Section type
 Joint/Po    Joint name or position within the member
 Outcome     Outcome message from the code check
 UsfNorm     Usage factor due to acting normal stress
 UsfSher     Usage factor due to acting shear stress
 UsfComb     Usage factor due to combined stress (general sections only)
 fa          Acting axial stress
 fby         Acting bending stress about y-axis
 fbz         Acting bending stress about z-axis
 fv          Acting shear stress
 MaxCom      Maximum acting combined stress (general sections only)
 Phase       Phase angle in degrees
 Hot-Norm    Hotspot name corresponding to UsfNorm
 Hot-Sher    Hotspot name corresponding to UsfSher
 Hot-Comb    Hotspot name corresponding to UsfComb
 Fa          Allowable axial stress
 Fby         Allowable bending stress about y-axis
 Fbz         Allowable bending stress about z-axis
 Fv          Allowable shear stress
 FalCom      Allowable combined stress (general sections only)
```

See Figure 3.6 and corresponding element print in Table 3.1.

3.9 How to perform a stability check

With reference to Figure 3.6 a stability check is performed for all members in the jacket model according to the API-AISC-WSD codes of practice.

For information on the loadcases analysed see Section 3.7.2.

All members in the jacket model will be checked, and results may be printed or displayed for members that exceed a 'usage factor' (i.e. interaction ratio) of 0.0.

The following command selects the **API-AISC-WSD** codes of practice:

```
SELECT CODE-OF-PRACTICE API-AISC-WSD
```

To assign a value of 0.8 and 1.6 for Ky and Kz effective length factors to all members in the structural model, the following commands must be used:

```
ASSIGN STABILITY ALL KY 0.8
ASSIGN STABILITY ALL KZ 1.6
```

To check member stability data the following command is used:

```
PRINT MEMBER STABILITY-CHECK-DATA ALL
```

To perform a stability check for all members, the following command is used:

```
RUN STABILITY-CHECK RUN2 'Stability check' ALL STATIC
```

Usage factors computed by the check may be displayed:

```
DISPLAY CODE-CHECK-RESULTS RUN2 WORST-LOADCASE MAX-USAGE-FACTOR 1.0
```

Results may be printed either on the screen or on a file. To direct all output to a file, and print in landscape, use the following commands:

```
SET PRINT DESTINATION FILE
SET PRINT PAGE-ORIENTATION LANDSCAPE
```

To print (for each member) the highest usage factor (even though only one loadcase has been checked) use the following command:

```
PRINT CODE-CHECK-RESULTS RUN2 WORST-LOADCASE FULL ABOVE 0.0
```

Example results obtained from a stability check are shown in Appendix A.1. The notation used in the heading from an AISC-API-WSD check is shown below:

```
Member      Name of member
LoadCase    Name of loadcase
CND         Operational, storm or earthquake condition
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
UsfTot      Total usage factor: UsfTot = UsfAx + UsfMy + UsfMz
UsfAx       Usage factor due to axial compressive stress
fa          Acting axial stress
fby         Acting bending stress about y-axis
fbz         Acting bending stress about z-axis
Fey         Euler buckling stress for bending about y-axis
Ky          Effective length factor for bending about y-axis
Ly          Buckling length for bending about y-axis
Phase       Phase angle in degrees
UsfMy       Usage factor due to bending about y-axis
Fa          Allowable axial stress
Fby         Allowable bending stress about y-axis
Fbz         Allowable bending stress about z-axis
Fez         Euler buckling stress for bending about z-axis
Kz          Effective length factor for bending about z-axis
Lz          Buckling length for bending about z-axis
UsfMz       Usage factor due to bending about z-axis
Cmy         Moment reduction factor for bending about y-axis
Cmz         Moment reduction factor for bending about z-axis
Cb          Lateral buckling factor (for I, H or channel sections only)
Lb          Unsupported flange length (for I, H or channel sections only)
```

See Figure 3.6 and corresponding element print in Table 3.1.

3.10 How to perform a member check

With reference to Figure 3.6 a member (combined yield and stability) check is performed for all members in the jacket model according to the NORSOK codes of practice.

For information on the loadcases analysed see Section 3.7.2.

All members in the jacket model will be checked, and results may be printed or displayed for members that exceed a usage factor (i.e. interaction ratio) of 0.0.

The following command selects the **NORSOK** codes of practice:

```
SELECT CODE-OF-PRACTICE NORSOK
```

To assign a value of 0.8 and 1.6 for Ky and Kz effective length factors to all members in the structural model, the following commands must be used:

```
ASSIGN STABILITY ALL KY 0.8
ASSIGN STABILITY ALL KZ 1.6
```

To check member stability data the following command is used:

```
PRINT MEMBER STABILITY-CHECK-DATA ALL
```

To perform a member check for all members, the following command is used:

```
RUN MEMBER-CHECK MCHK 'Member check' ALL STATIC
```

Usage factors computed by the check may be displayed:

```
DISPLAY CODE-CHECK-RESULTS MCHK WORST-LOADCASE MAX-USAGE-FACTOR 1.0
```

Results may be printed either on the screen or on a file. To direct all output to a file, and print in landscape, use the following commands:

```
SET PRINT DESTINATION FILE
SET PRINT PAGE-ORIENTATION LANDSCAPE
```

To print (for each member) the highest usage factor (even though only one loadcase has been checked) use the following command:

```
PRINT CODE-CHECK-RESULTS MCHK WORST-LOADCASE FULL ABOVE 0.0
```

Example results obtained from a stability check are shown in Appendix A.1. The notation used in the heading from a NORSOK check is shown below:

```
NOMENCLATURE:
 Member      Name of member
 LoadCase    Name of loadcase
 CND         Operational, storm or earthquake condition
 Type        Section type
 Joint/Po    Joint name or position within the member
 Outcome     Outcome message from the code check
 Usfac       Total usage factor
 fy          Material yield strength
 Gamma-m     Material factor
 Kly         Effective length factor * buckling length in y direction
 Klz         Effective length factor * buckling length in z direction
 fcle        Characteristic elastic local buckling strength
 fhe         Elastic hoop buckling strength
 spSd        Design hoop stress due to hydrostatic pressure
 Phase       Phase angle in degrees
 SctNam      Section name
 EleNum      Element number
 UsfaN       Usage factor due to axial force
 Nsd         Design axial force (stress when hydrostatic pressure)
```

```
 fc          Characteristic axial compressive strength
 fcl         Characteristic local buckling strength
 Ney         Euler buckl. strength y direction (stress when hydr. pressure)
 Nez         Euler buckl. strength z direction (stress when hydr. pressure)
 Nrd         Design axial resistance (stress when hydrostatic pressure)
 fh          Characteristic hoop buckling stress
 UsfaM       Usage factor due to bending moment
 MySd        Design bending moment about y-axis (stress when hydr. pressure)
 MzSd        Design bending moment about z-axis (stress when hydr. pressure)
 Cmy         Moment reduction factor about y-axis
 Cmz         Moment reduction factor about z-axis
 fm          Characteristic bending strength
 Mrd         Design bending resistance (stress when hydrostatic pressure)
 sqSd        Capped-end design axial compression stress
```

See Figure 3.6 and corresponding element print in Table 3.1.

3.11 How to perform a cone check

With reference to Figure 3.6 a cone check may be performed for all members in the jacket model with conical transition defined according to the NORSOK codes of practice.

For information on the loadcases analysed see Section 3.7.2.

All members in the jacket model will be checked, and results may be printed or displayed for members that exceed a 'usage factor' (i.e. interaction ratio) of 0.0.

The following command selects the **NORSOK** codes of practice:

```
SELECT CODE-OF-PRACTICE NORSOK
```

Note that code check positions must be defined at start and end of conical transitions. By default code check positions will be assigned to these locations when the Framework model is established.

To perform a cone check for all members with conical transition, the following command is used:

```
RUN CONE-CHECK CCHK 'Cone check' ( WITH-CONE ALL ) STATIC
```

Usage factors computed by the check may be displayed:

```
DISPLAY CODE-CHECK-RESULTS CCHK WORST-LOADCASE MAX-USAGE-FACTOR 1.0
```

Results may be printed either on the screen or on a file. To direct all output to a file, and print in landscape, use the following commands:

```
SET PRINT DESTINATION FILE
SET PRINT PAGE-ORIENTATION LANDSCAPE
```

To print (for each member) the highest usage factor (even though only one loadcase has been checked) use the following command:

```
PRINT CODE-CHECK-RESULTS CCHK WORST-LOADCASE FULL ABOVE 0.0
```

Example results obtained from a stability check are shown in Appendix A.1. The notation used in the heading from a NORSOK check is shown below:

```
NOMENCLATURE:
 Member      Name of member
 LoadCase    Name of loadcase
 CND         Operational, storm or earthquake condition
 Type        Section type
 Joint/Po    Joint name or position within the member
 Outcome     Outcome message from the code check
 Usfact      Max usage factor of cone and cylinder side
 fy          Material yield strength
 Gamma-m     Material factor
```

```
sequSd      Equivalent design axial stress within the conical transition
sacSd       Design axial stress at the section within the cone
smcSd       Design bending stress at the section within the cone
fclc        Local buckling strength of conical transition
shSd        Design hoop stress due to external hydrostatic pressure
Phase       Phase angle in degrees
SctNam      Section name
Usfcon      Usage factor cone side
Dj          Cylinder diameter at junction
tc          Cone wall thickness
satSd       Design axial stress in tubular section at junction
smlcSd      Local design bending stress at the tubular side of junction
shcSd       Design hoop stress due to unbalanced radial line force
fcj         Characteristic axial (local) compressive strength
shjSd       Net design hoop stress
Usfcyl      Usage factor cylinder side
alpha       Angle (deg.) between cylinder and cone
t           Tubular wall thickness
smtSd       Design bending stress in tubular section at junction
smltSd      Local design bending stress at the cone side of junction
stotSd      Resulting total design stress in axial direction
fh          Characteristic hoop buckling strength
```

Note that conical transitions cannot be defined in Framework, but must be defined in Genie or Preframe (or defined as conceptual information on the Input Interface File (prior to running Sestra) or on the Results File).

3.12 How to perform a punching shear check

With reference to Figure 3.6 a punching shear check is performed at joints 2, 5, 7 and 8 according to the API-AISC-WSD codes of practice. Note that all braces at the joints shall be checked.

For information on the loadcases analysed see Section 3.7.2.

Results shall be printed for the worst brace at each of the joints checked.

The following command selects the **API-AISC-WSD** codes of practice:

```
SELECT CODE-OF-PRACTICE API-AISC-WSD
```

Prior to the check the following commands are issued in order to model Can and Stub sections:

Create Can/Stub section and material:

```
CREATE SECTION CAN4000 'Can section' PIPE 4.0 0.04
CREATE SECTION STB2000 'Stub section' PIPE 2.0 0.02
CREATE MATERIAL MAT400 'Can material' 2.1E+11 400.E+6 7850. 0.3 0.0 0.0
CREATE MATERIAL MAT380 'Stub material' 2.1E+11 380.E+6 7850. 0.3 0.0 0.0
```

Make assignments:

```
ASSIGN CAN JOINT 2 CAN4000 MAT400 0.0 0.0
ASSIGN CAN JOINT 5 CAN4000 MAT400 0.0 0.0
SELECT JOINT ( ONLY 2 5 7 8 )
ASSIGN STUB JOINT CURRENT STB2000 MAT380 0.0
SELECT JOINT ( ONLY 7 8 )
ASSIGN CAN JOINT CURRENT STB2000 MAT380 0.0 0.0
Assign joint type to be determined from loadpath:
ASSIGN JOINT-TYPE ALL ALL LOADPATH
```

Assign a gap of 50 mm (approx. 2 inches) for all braces at all joints (in lieu of more accurate computation):

```
ASSIGN JOINT-GAP ALL ALL 0.05
```

To check joint punch data the following command is used:

```
PRINT JOINT PUNCH-CHECK-DATA ( ONLY 2 5 7 8 )
```

To perform the punch check the following command is used:

```
RUN PUNCH-CHECK RUN3 'Punch check' ( ONLY 2 5 7 8 ) STATIC
```

Results may be presented as annotations on a display of the model.

```
DISPLAY CODE-CHECK-RESULTS RUN3 WORST-LOADCASE MAX-USAGE-FACTOR 1.0
```

Results may be printed either on the screen or on a file. To direct all output to a file, and print in landscape, use the following commands:

```
SET PRINT DESTINATION FILE
SET PRINT PAGE-ORIENTATION LANDSCAPE
```

To print (for each joint) the brace with the highest usage factor (even though only one has been checked) use the following command:

```
PRINT CODE-CHECK-RESULTS RUN3 WORST-LOADCASE ABOVE 0.0
```

Example results obtained from a punch check are shown in Appendix A.1. The notation used in the heading from an AISC-API-WSD check is shown below:

```
NOMENCLATURE:
 Joint       Name of joint
 Brace       Member name of the brace
 LoadCase    Name of loadcase
 CND         Operational, storm or earthquake condition
 Jnt/Per     Joint type
 Outcome     Outcome message from the code check
 Usfac1      Usage factor according to API 4.1-1
 P           Acting axial force
 Moipb       Acting in-plane moment
 Moopb       Acting out-of-plane moment
 Alpha       Moment transformation angle from local to in-plane/out-of-plane
 Qup         Ultimate strength factor due to axial force
 Qfp         Factor accounting chord stress due to axial force
 Dbrace      Brace diameter
 Chord       Member name of the corresponding chord
 Phase       Phase angle in degrees
 Usfac2      Usage factor according to API 4.3.1-5a or API 4.3.2-2
 Pa          Allowable axial force
 Maipb       Allowable in-plane moment
 Maopb       Allowable out-of-plane moment
 Theta       Angle between brace and chord in degrees
 Quipb       Ultimate strength factor due to in-plane moment
 Qfipb       Factor accounting chord stress due to in-plane moment
 Dchord      Chord diameter
 Usfac3      Usage factor according to API 4.3.1-5b
 Method      Method used for joint type assignment (1=MAN,2=GEO,3=LOA)
 Gap         Gap value used for K/KTT/KTK joint (negative if overlap)
 Quopb       Ultimate strength factor due to out-of-plane moment
 Qfopb       Factor accounting chord stress due to out-of-plane moment
 Beta        Diameter Brace / Diameter Chord
```

See Figure 3.6 and corresponding element print in Table 3.1.

3.13 Recommended application for fatigue analysis

The sections from 3.14 to 3.17 will introduce the basic procedure to perform fatigue analysis of some common types. Beside those, there are several topics that need to be addressed for the best practice of using

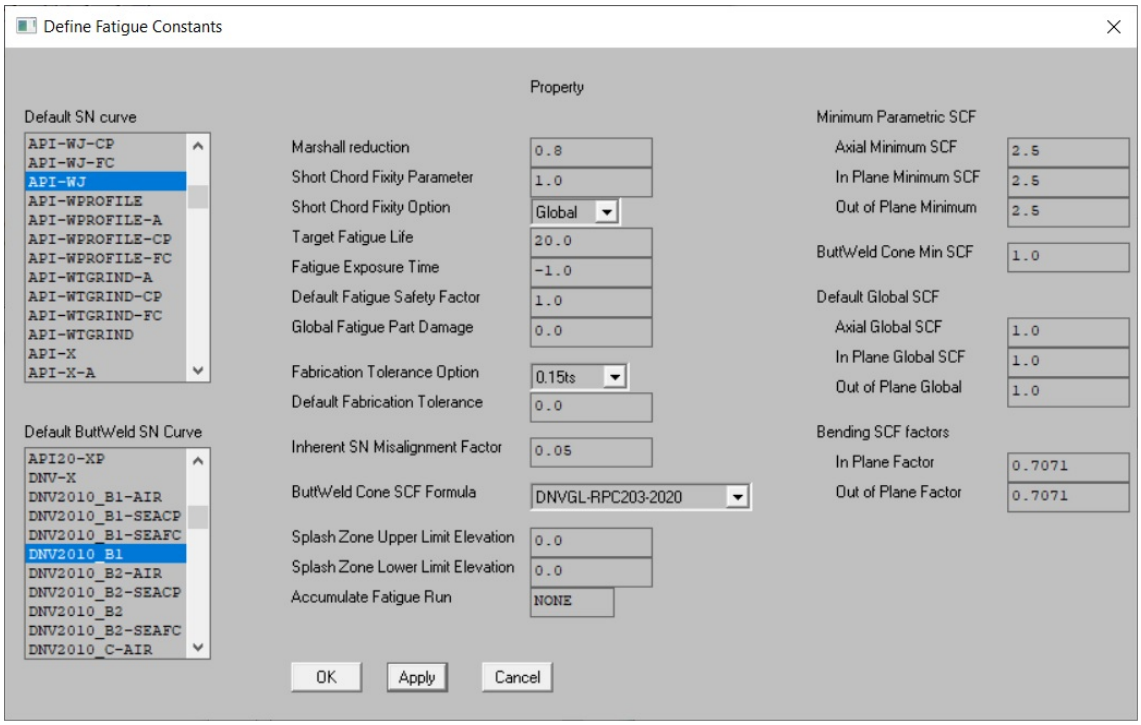


Figure 3.9: Dialog window of command DEFINE-FATIGUE-CONSTANTS

Framework do the fatigue analysis. The command `DEFINE FATIGUE-CONSTANTS` is important to set up the global default options. Some of them are required for the generation of fatigue check positions.

- **Specify fatigue analysis options.** It is highly recommended to specify some fatigue check options before reading in the result file. It includes: for instance, all options in `DEFINE FATIGUE-CONSTANTS`, `DEFINE NEAR-CHORD-RULE` and `DEFINE FATIGUE-CHECK-WELD-ROOT` if the weld root fatigue analysis is required.
- **Weld root fatigue analysis** is supported. It is done at the weld root fatigue positions available at tubular joints and buttweld connections. See section 2.5.10 and 2.5.12.
- **Default SN curves assignment.** Framework has allowed two different default SN curves.

  `DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE`

  determines all default SN curve selection except for the buttweld positions. This selection will be applied at the transitions when the default buttweld SN curve is not available in some situation. The other option,

  `DEFINE FATIGUE-CONSTANTS DEFAULT-BUTTWELD-SN-CURVE`

  specifies the SN curve at the buttweld fatigue positions that usually locate in the middle of the member. Note that the default SN curves at weld root positions is not selectable but pre-defined according DNVGL RP-C203 standard.
- **Default buttweld fatigue positions.** The default buttweld fatigue check positions will be generated by the program at the cross section transitions or the segment transitions. If there are concept model information, this generation procedure is done automatically when reading the result SIN file. If FEM model is available only, the commands `CREATE MEMBER` and `ASSIGN POSITIONS` can be used to generate positions.
- **Default SCF assignments** are available at buttweld connections. The command

```
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA
```

determines the selection. For example, the option of `DNVGL-RPC203-2020` allows to generate the butt weld root fatigue position and the option `DNV-RPC203-BSWD` does not generate the weld root positions.

- **Chord stresses included in fatigue analysis** can be triggered by using the command

  ```
  DEFINE FATIGUE-PARAMETERS INCLUDE-CHORD-STRESS
  ```

  Note that this option considers the chord **axial stress** in fatigue check of tubular joints. The stochastic fatigue analysis is excluded. `DEFINE NEAR-CHORD-RULE` must be turned ON before the result SIN file is read in by `FILE OPEN` and `FILE TRANSFER`.

- **Fatigue damage file output** is supported. See section 3.28.

3.14 How to perform a deterministic fatigue analysis

With reference to Figure 3.6, a deterministic fatigue analysis is performed for selected BRACE members in the jacket model, at selected joints, as well as for member 16.

Note: a maximum of 36 steps (10 degree intervals) for a deterministic wave cycle can be used. If the number of steps in a wave cycle is more then 36, Framework automatically assumes the time history fatigue will be performed.

It is assumed that the desired 'local' modelling (CHORDS, CANS etc.) of members and joints has been performed through the commands shown in Section 3.2 and Section 3.3 and that NO other commands have been issued.

For information on the hydrodynamic loading see Section 3.7.3.

Results may be printed or displayed for all the members that are checked.

Table 2.10 may be used for guidance in order to ensure that data mandatory for the execution of the analysis are in-fact defined.

As indicated by Table 2.10 the following data must be assigned:

- Wave data
- An SN curve
- Stress concentration factors

The wave data assignment corresponds to the definition of the total numbers of waves passing through the structure for each of the wave directions analysed.

In this example, 3 wave directions were analysed, 0, 45 and 90 deg.

The commands necessary to be issued in order to assign the number of waves passing through the structure for each of the wave directions are as follows:

For the 0 deg wave:

```
ASSIGN INDIVIDUAL-WAVE 0 LINEAR 1.03E+8
```

For the 45 deg wave;

```
ASSIGN INDIVIDUAL-WAVE 45 LINEAR 1.88E+7
```

For the 90 deg wave;

```
ASSIGN INDIVIDUAL-WAVE 90 LINEAR 2.53E+8
```

Note that for all three assignments a linear $H - \log N$ curve was requested.

If the user wants to apply the DNV-X curve (identical to the AWS D1.1 1972 X curve) no additional input is required. All members get as default the DNV-X curve assigned. If DNV-X is not the right SN curve, user needs to use ASSIGN SN curve command to change the SN curve at joint or member.

In this example GLOBAL stress concentration factor are used. The commands necessary to be used is:

```
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 5.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 5.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 5.0
```

where a value of 5.0 is assigned for the SCFs associated with axial stresses and in-plane and out-of-plane bending stresses.

It is required to perform the deterministic fatigue analysis for the following members: 8 11 12 15 16. To perform the deterministic fatigue analysis the following command is used;

```
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 1.0
RUN FATIGUE-CHECK DETFAT 'DETERMINISTIC FATIGUE ANALYSIS' ALL
   ( ONLY 8 11 12 15 16 )
```

To print the results the following command is used:

```
PRINT FATIGUE-CHECK-RESULTS DETFAT SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
```

The results obtained from a deterministic fatigue analysis are shown in Appendix A.1. The notation used for the output is explained below.

```
NOMENCLATURE:
Member     Name of member
Type       Section type
Joint/Po   Joint name or position within the member
Outcome    Outcome message from the code check
Damage     Accumulated damage
Life       Fatigue life
WeldSide   Side of weld
Hot        Hotspot (stress point) with maximum damage
SCFrule    Method used for SCF calculation
SCFax      SCF for axial force
SCFipb     SCF for in-plane bending
SCFopb     SCF for out-of-plane bending
SNcurve    SN curve name
Alpha      Moment transf. angle from local in-plane/out-of-plane coord. system
Symmet     Symmetry in SCF specification
DiaBra     Brace diameter
ThiBra     Brace thickness
Gap        Gap between braces
ThiFac     Thickness correction factor on SN-curve
Theta      Angle between brace and chord in degrees
Jtype      Joint type
DiaCho     Chord diameter
ThiCho     Chord thickness
LenCho     Chord length
QR         Marshall reduction factor applied on SCFs
```

See Figure 3.6 and corresponding element print in Table 3.1.

It is also possible to perform deterministic fatigue analysis of general cyclic loads, i.e. without running Wajac to define deterministic wave loads. An auxiliary program named DetSfile (available on Windows only) may be used to generate the 'Sx.FEM' file necessary for Sestra and Framework to treat the loads as wave loads. Each stress range caused by cyclic loading must be represented by 2 load cases defined in Genie or in Preframe and combined in Presel. Please contact Software Support for example input and the auxiliary program DetSfile. In such cases it is very important that the user sets the FATIGUE-EXPOSURE-TIME equal to -2 years to skip long term distribution of the stress ranges. The fatigue exposure time parameter is used to instruct Framework to not divide stress ranges into blocks.

3.15 How to perform a spectral fatigue analysis

A spectral fatigue analysis is required to be performed for members 8 and 12 and 16 in the jacket model shown in Figure 3.6. Refer to Section 3.7.4, the hydrodynamic wave loading with appropriate wave heights and wave periods of all directions are defined and created by Wajacin the time domain; a structural finite element analysis is done by Sestra; the results of the wave load cases are stored in the result interface file Rn.SIN that is read into Framework. The program will automatically organize the wave heights and periods data reading from Rn.SIN file. The stress range transfer functions are calculated automatically at every wave period. To correctly perform the spectral fatigue analysis, some caution is needed to make wave load cases and wave directions in Wajacmatched correspondingly. In Framework, user needs to specify wave statistics, wave direction probability, wave spreading function, and parameters for stress concentration factors.

The chord and brace relation of members connected at a joint can be automatically decided by Frameworkas default. For some particular It is assumed that the desired 'local' modelling (CHORDS, CANS etc.) of members and joints has been performed through the commands shown in Section 3.2 and Section 3.3 and that NO other commands have been issued.

Table 2.10 may be used for guidance in order to ensure that data mandatory for the execution of the analysis are in-fact defined.

As indicated by Table 2.10 the following data are required or recommended:

- Fatigue target life
- An SN curve
  DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE API-WJ
- Splash zone elevation limits.
  DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-UPPER-LIMIT-ELEVATION 45.0
  DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-LOWER-LIMIT-ELEVATION 40.0
  This information is to be used to automatically determine the elevation dependent SN curve data. The elevation should be entered in the same unit as in the structural model.
- Joint Type
  ASSIGN JOINT-TYPE DEFAULT ( ) GEOMETRY
  The geometry type will let the program determine chord and brace connection relation and the associated type of the brace member under concern.
- Joint gap
  ASSIGN JOINT-GAP ALL ( ) AUTOMATIC
  The gap between two k type braces will be calculated by the program.
- Stress concentration factors at joints
  The parametric formula such as EFTHYMIOU, or KUANG can be used. To make the best use of the parametric formula, the joint type and gap should be specified properly.
  ASSIGN SCF JOINT ALL ( ) None PARAMETRIC EFTHYMIOU
- Stress concentration factors at butt-weld and conical transitions
  The weld transition of butt-weld or conical-tubular junctions usually appears at intermediate positions of a member. The program currently does not automatically specify parametric SCF formula to butt-weld transitions. The GLOBAL SCF is the default. If necessary, user needs to specify SCF on a member. The commands are for example

```
ASSIGN SCF MEMBER CURRENT ( ONLY
    Section-PIPExxx-0.2050
    Section-Cxxx-0.2050
    Section-Cxxx-0.2350
    Section-PIPExxx-0.2350 ) None CONE-TRANSITION MAXIMUM 0.0 0.0
ASSIGN SCF MEMBER DEFAULT ( ONLY Section-xxx-0.6250 ) None BUTT-WELD WITH-SLOPE   4.0
```

If the fatigue positions at section transitions do not show up, user needs to assign the fatigue positions to segmented member with appropriate option by commands, like

```
ASSIGN POSITIONS ( ) FATIGUE-CHECK DEFAULT
ASSIGN POSITIONS ( ) FATIGUE-CHECK OPTIONS ON ON ON ON ON OFF
```

The sea data assignments correspond to the definition of the following

- Probability of occurrence for each of the wave directions defined during the hydrodynamic analysis.
  In this example, 3 wave directions were analysed with directions 0, 45 and 90 deg
  To assign the wave direction probabilities the following command is used:

```
ASSIGN WAVE-DIRECTION-PROBABILITY
  LOOP
%%% Dir Prob
    0  0.3
   45 0.3
   90 0.4
END
```

- Short term sea-states and corresponding probabilities.
  In this example, 6 short term sea-states were used.
  Create the scatter diagram:

```
CREATE WAVE-STATISTICS 'SCATTER' ARBITRARY DATA
    SCATTER-DIAGRAM PROBABILITY
    (
%%%   Hs    Tz    Prob
     1.75  4.75  0.249
     1.25  6.25  0.236
     3.25  6.25  0.206
     1.75  7.75  0.086
     3.25  7.75  0.117
     4.75  7.75  0.106
    )
```

Assign scatter diagrams for each of the main wave directions:

```
ASSIGN WAVE-STATISTICS
  LOOP
      0 SCATTER
     45 SCATTER
     90 SCATTER
  END
```

- The prevailing wave spectrum. In this example a JONSWAP wave spectrum was used with parameters
  gamma = 3.3
  sigma A = 0.07
  sigma B = 0.09
  To assign the JONSWAP wave spectrum to the scatter diagram the following command is used:

```
ASSIGN WAVE-SPECTRUM-SHAPE SCATTER JONSWAP 3.3 0.07 0.09 ALL
```

- Sea spreading data to define the number of elementary wave directions and the associated energy content. In this example 3 elementary wave directions were considered.
  To create the sea spreading data, the following command is used:

```
 CREATE WAVE-SPREADING-FUNCTION DIS2 'DISCRETIZED COS**2'
    USER-DEFINED
     (
%%%  Dir  Weight
       0  0.50
      45  0.25
```

```
 90  0.25
)
```

The built-in power cosine type spreading function can also be defined.

```
CREATE WAVE-SPREADING-FUNCTION SP1 cos2 COSINE-POWER 2
```

The spreading function must be assigned to scatter diagram to be checked. The user defined function is used in this example.

```
ASSIGN WAVE-SPREADING-FUNCTION SCATTER DIS2 ALL
```

The GLOBAL stress concentration factors can also be used if necessary. They are defined as the fatigue constants:

```
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 5.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 5.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 5.0
```

where a value of 5.0 is assigned for the SCFs associated with axial stresses and in-plane and out-of-plane bending stresses.

To perform a spectral fatigue analysis, calculating the fatigue damage for 20 years, the following command is used:

```
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
```

It is required to use **SELECT FATIGUE-CHECK-TYPE** to inform the program to do the spectral fatigue and avoid any automatic switching to the deterministic analysis type since both deterministic and spectral methods share the same result type from a time domain wave loading analysis.

```
SELECT FATIGUE-CHECK-TYPE SPECTRAL
RUN FATIGUE-CHECK SFA 'SPECTRAL FATIGUE ANALYSIS' ALL
   ( ONLY 8 11 12 15 16 )
```

Results may be printed or displayed for all members checked with a usage factor greater than 0.03. To print the results, the following command is used:

```
PRINT FATIGUE-CHECK-RESULTS SFA
   SELECTED-MEMBERS CURRENT FULL ABOVE 0.03
```

The notation used for the output is the same as the NOMENCLATURE for stochastic fatigue.

3.16 How to perform a stochastic fatigue analysis

A stochastic fatigue analysis is required to be performed for members 8 and 12 and 16 in the jacket model shown in Figure 3.6.

It is assumed that the desired 'local' modelling (CHORDS, CANS etc.) of members and joints has been performed through the commands shown in Section 3.2 and Section 3.3 and that NO other commands have been issued.

For information on the hydrodynamic loading see Section 3.7.5.

Results may be printed or displayed for all members checked with a usage factor greater than 0.03.

Table 2.10 may be used for guidance in order to ensure that data mandatory for the execution of the analysis are in-fact defined.

As indicated by Table 2.10 the following data must be assigned:

- Seastate data
- An SN curve
- Stress concentration factors
  The sea data assignments correspond to the definition of the following

- Probability of occurrence for each of the wave directions defined during the hydrodynamic analysis.
  In this example, 3 wave directions were analysed with directions 0, 45 and 90 deg
  To assign the wave direction probabilities the following command is used:

```
ASSIGN WAVE-DIRECTION-PROBABILITY
  LOOP
%%% Dir Prob
    0 0.0
   45 1.0
   90 0.0
END
```

- Short term sea-states and corresponding probabilities.
  In this example, 6 short term sea-states were used.
  Create the scatter diagram:

```
CREATE WAVE-STATISTICS SCATTER 'ARBITRARY DATA
    SCATTER-DIAGRAM PROBABILITY
    (
%%%   Hs    Tz    Prob
     1.75  4.75  0.249
     1.25  6.25  0.236
     3.25  6.25  0.206
     1.75  7.75  0.086
     3.25  7.75  0.117
     4.75  7.75  0.106
    )
```

  Assign scatter diagrams for each of the main wave directions:

```
ASSIGN WAVE-STATISTICS
  LOOP
      0 SCATTER
     45 SCATTER
     90 SCATTER
  END
```

- The prevailing wave spectrum. In this example a JONSWAP wave spectrum was used with parameters
  gamma = 3.3
  sigma A = 0.07
  sigma B = 0.09
  To assign the JONSWAP wave spectrum to the scatter diagram the following command is used:

```
ASSIGN WAVE-SPECTRUM-SHAPE SCATTER JONSWAP 3.3 0.07 0.09 ALL
```

  Sea spreading data in order to define the number of elementary wave directions and the associated energy content. In this example 3 elementary wave directions were considered.
  To create the sea spreading data, the following command is used:

```
CREATE WAVE-SPREADING-FUNCTION DIS2 'USER SPECIFIED'
   USER-DEFINED
    (
%%% Dir Weight
      -45 0.25
       45 0.25
    )
```

  The spreading function must be assigned to scatter diagram to be checked.

```
ASSIGN WAVE-SPREADING-FUNCTION SCATTER DIS2 ALL
```

In this example GLOBAL stress concentration factors are used. The command necessary to be given is:

```
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 5.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 5.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 5.0
```

where a value of 5.0 is assigned for the SCFs associated with axial stresses and in-plane and out-of-plane bending stresses.

To perform a stochastic fatigue analysis, calculating the fatigue damage for one year, the following command is used:

```
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 1.0
RUN FATIGUE-CHECK STOFAT 'STOCHASTIC FATIGUE ANALYSIS' ALL
   ( ONLY 8 11 12 15 16 )
```

To print the results for the members checked with a usage factor of 0.03 or greater, the following command is used:

```
PRINT FATIGUE-CHECK-RESULTS STOFAT
   SELECTED-MEMBERS CURRENT FULL ABOVE 0.03
```

The results obtained from the stochastic fatigue analysis are shown in Appendix A.1. The notation used for the output is explained below.

```
NOMENCLATURE:
 Member    Name of member
 Type      Section type
 Joint/Po  Joint name or position within the member
 Outcome   Outcome message from the code check
 Damage    Accumulated damage
 Life      Fatigue life
 WeldSide  Side of weld
 Hot       Hotspot (stress point) with maximum damage
 SCFrule   Method used for SCF calculation
 SCFax     SCF for axial force
 SCFipb    SCF for in-plane bending
 SCFopb    SCF for out-of-plane bending
 SNcurve   SN curve name
 Alpha     Moment transf. angle from local in-plane/out-of-plane coord. system
 Symmet    Symmetry in SCF specification
 DiaBra    Brace diameter
 ThiBra    Brace thickness
 Gap       Gap between braces
 ThiFac    Thickness correction factor on SN-curve
 Theta     Angle between brace and chord in degrees
 Jtype     Joint type
 DiaCho    Chord diameter
 ThiCho    Chord thickness
 LenCho    Chord length
 QR        Marshall reduction factor applied on SCFs
```

3.17 How to perform a time history fatigue analysis

Requirements and assumptions for time history fatigue analysis:

- A time history fatigue analysis is decided upon by the program itself when reading the Result Interface (SIN) File. Execution is performed by the command RUN FATIGUE-CHECK.
  The time series must contain load transfer functions of all relevant loadings such as wave- and wind loads. Time series of the load transfer functions are obtained by performing quasi-static analysis in Sestra. If both wave- and wind loads are present, the loads must be combined before running Sestra.
  Time series of the wave loading may be established by performing time series wave load analyses in Wajac. Time series of wind loading are not possible to generate in Sesam and must be provided from other sources, e.g. load files established from in-field wind measurement data.

- Framework will automatically distinguish between time series wave loads and deterministic wave loads. The time series must have more than 36 time instants to be recognized as time series wave loads. No other types of fatigue analysis, stochastic or deterministic, is possible when a time history approach is detected. It means a stochastic or deterministic fatigue analysis data should not be mixed with time history fatigue data on a same result interfacr file.
- One fatigue check can only process one time series for each wave direction. The normal approach is to run one time series at one time of fatigue analysis.
- Wave spreading functions and wave direction probabilities are not accounted for.
- The fatigue exposure time for the calculated damage results is by default 1 second, i.e damage per unit time is calculated. Alternative time setting is, however, possible by the command `DEFINE TIME-HISTORY-FATIGUE-TIME`.
- You may define a time range within the time series and the time step interval for the fatigue calculation by the command `DEFINE TIME-HISTORY-FATIGUE-TIME`. By default the entire time series and a time step interval of 1 are applied.
- You may define a stress level which decides if time series fatigue calculation shall be executed or not for a hotspot. At least one stress peak in the hotspot stress time series must exceed the stress level if damage calculation shall be executed, see command `DEFINE TIME-HISTORY-FATIGUE-TIME`.
- Fatigue safety factors are by default not accounted for but may be turned on by the command `DEFINE FATIGUE-SAFETY-FACTOR ON`. Safety factors are given by the command `ASSIGN FATIGUE-SAFETY-FACTOR`.
- Fatigue damage results may be printed to file in a *SIF* format by the command `DEFINE FATIGUE-DAMAGE-TO-FILE ON`. By default print to file is not executed. When printing, a default name of the fatigue result file is automatically established according to the name of Result Interface File read by Framework. For example, the default name *frameF1.SIF* is adopted when the Result Interface File name is *frameR1.SIN*. The fatigue results are identified by the RVFATDAM and TDFATDAM records. The damage file is relevant only for Fatigue Manager.
- Dump print of fatigue damage results, time histories of the fatigue stresses and time series stress ranges may be printed by the command DEFINE FATIGUE-DUMP. By default dump print is not executed. The dump files are named according to the name of Result Interface File. The file names frameD1.DMP and frameD1.TMS are applied for the fatigue damage results and time histories of the fatigue stresses, respectively, when the Result Interface File name is frameR1.SIN.
  Dump print of time history fatigue stresses may be printed on format applicable for spreadsheets by applying the command SET PRINT DESTINATION CSV-FILE prior to run execution
- Only commands relevant for the time history fatigue analysis are presented in the dialogue when the command TASK TIME-HISTORY-FATIGUE-DAMAGE is applied

3.18 How to perform an earthquake analysis

Sesam-Framework supports *Response Spectrum Analysis* (RSA) of earthquake responses. This technical note summerizes the basic features and latest development of earthquake analysis in Framework. The pre-requisites of using Framework to perform an earthquake analysis are

1. The design seismic spectrum is available. The associated damping is provided. The site-specific influence has been considered if there is.
2. The mode shapes analysis on the structure has been finished. The mass model is well defined, i.e. including the structural weight, equipments, marine growth, entrapped water, hydrodynamic added mass, and other miscellaneous masses. The impact of nonlinearity of soil-structure interaction has been considered if necessary.

In addition, it is worth highlighting the identification of load cases because the load combination of static load cases and the inertial earthquake load is generally required in an earthquake analysis. The option to

use **RESULT-CASE-ID** is recommended in `DEFINE LOAD` command. The command should be issued before opening the result SIN file. More details can be found in `DEFINE LOAD` description and section 2.6.1

3.18.1 Fundamental procedures for earthquake analysis

The analysis of a jacket under seismic excitations is a base driven *structural dynamics* problem. A detailed theory background is provided in Appendix C. This section introduces the pre-requisites, assumptions, and basic steps to perform an earthquake analysis in Framework.

Table 3.7: A sample design response spectrum of Displacement

Frequency (rad/sec)	**Spectral ordinates (Length units)**
2.1	50
12.2	100
35.5	200
56.5	300
60.6	400
82.0	500
104.8	600
108.5	500
120.3	400
139.3	200

1. A static analysis has been performed to obtain the structural static response under gravity, buoyancy, equipments, and other static loads.
2. An eigenvalue analysis has been performed and the results for the sufficient number of mode shapes and modal load factors have been obtained. For more information on the eigenvalue solver and the modal load factors relevant to earthquake, see the Appendices of Sesam-Sestra Users Manual [32]. The nonlinearity of foundation must be considered if soil-structure interaction is included.
3. The result files from static analysis and eigenvalue analysis must be MERGEd by SESAM**-Prepost** module to a single result Rn.SIN file to be opened in Framework. It is recommended to use the eigenvalue result interface file as the primary file 1 of **.SIN* format in Prepost and MERGE the static result file to it. (**Note: When the static result file is the primary file 1 and the eigenvalue result file is file 2, the mass from self-weight, dead loads, marine growth, and hyrdodynamic added mass must be well defined such that the mass in static analysis is the same as that in eigenvalue analysis.** As a result, the index of mode shape in the "merged' result file is offset after all static basic loadcases. The 1st mode shape becomes $N_{staticLC} + 1$.)
4. The design response spectrum of earthquake excitation must be defined. The method of Response Spectrum Analysis (RSA) is employed in Framework's earthquake analysis. The seismic excitations on the jacket are stochastic and usually characterized in terms of a design response spectrum. For example, a displacement spectrum is shown in Table 3.7. The acceleration type of response spectrum is common too. Prior to performing the earthquake analysis it is MANDATORY that the excitation response spectrum is defined. The spectrum is a function of frequency.
5. The modal damping for earthquake response must be defined. It can be either a constant or a function of frequency.
6. The 3 global directions can be assigned with different response spectra and damping coefficients. The earthquake spectrum can be scaled for each direction individually. The directional correlation of earthquake spectrum is ignored in Framework.
7. In Framework, a certain number of mode shapes participating in *mode superpoistion* and *modal combination* of earthquake responses can be selected. It is not necessary to include all mode shapes solved

into the earthquake analysis.

8. The method of *modal combination* of earthquake responses must be selected. CQC and SRSS methods are commonly applied. For more information, see Section 2.1.3 of this manual. In CQC modal combination, when the modal correlation coefficient is less than 0.1 the cross-modal terms are ignored in the analysis; and the directional terms are combined the same as SRSS rule.
9. The quantity of response under earthquake excitation must be selected to output. There are four types: Member Force, Joint Displacement, Joint Velocity, and Joint Acceleration. See Section 2.1.3 for more information.
10. The members or joints considered in the earthquake analysis must be selected.
11. RUN earthquake check in Framework. This step creates a new result case (loadcase) storing the selected response quantity on selected members (joints). Each time of RUN earthquake check can only produce one type of quantity.
12. CREATE the load combination of basic static loadcase and the earthquake response loadcase.
13. Specify the loadcase condition of the load combination as "Earthquake"; Select a required design standard to do code check; Activate CRITICAL Joint check if needed by the standard.
14. RUN code checking on members and joints for the load combination. Only earthquake load combination containing member FORCES can be code checked.
15. The joint motions: Displacement, Velocity, and Acceleration may be required to check the servicebility under earthquake excitation. Another earthquake run is needed to output the modal combination at selected joints. However, the loadcase of joint motion CANNOT be included in the code check and print force.

To perform the earthquake analysis the following commands are needed in general:

- Select the type of modal combination rule to be used for the earthquake analysis and the type of desired output:

  ```
  SELECT EARTHQUAKE-CHECK-TYPE CQC FORCE
  ```

  If the function to skip mid-point positions is needed, this command should be placed before `FILE OPEN`.

- Create an earthquake damping function:

  ```
  CREATE EARTHQUAKE-DAMPING-FUNCTION DAMP1 None
  CONSATANT 0.05
  ```

- Assign the earthquake damping function DAMPING to the global X-direction:

  ```
  ASSIGN EARTHQUAKE-DAMPING-FUNCTION X DAMP1
  ASSIGN EARTHQUAKE-DAMPING-FUNCTION Y DAMP1
  ASSIGN EARTHQUAKE-DAMPING-FUNCTION Z DAMP1
  ```

  The damping is the modal damping factor, i.e. fraction of critical modal damping.

- Create design earthquake response spectrum. For example, a displacement spectrum can be

  ```
  CREATE EARTHQUAKE-SPECTRUM DIS_SPEC None DISPLACEMENT
     (
          2.1   50
          12.2 100
          35.5 200
          56.5 300
          60.6 400
          82.0 500
         104.8 600
         108.5 500
         120.3 400
  ```

```
        139.3 200
    )
```

An acceleration spectrum can be

```
CREATE EARTHQUAKE-SPECTRUM ACCSPEC None ACCELERATION
    (
    ONLY
    1.256    0.785
    1.884    1.373
    3.768    2.453
    12.56    4.218
    34.54    5.788
    169.56   2.649
    219.8    2.649
    )
```

In Framework, the earthquake spectra are input as a function of angular frequency, $\omega = 2\pi/T$, which must be in an increasing order. The maximum number of function points of a damping function and an earthquake spectrum function is 1000.

- Assign the earthquake spectrum DIS_SPEC to the global X-direction and signify a scaling factor:

```
ASSIGN EARTHQUAKE-SPECTRUM X DIS_SPEC 1.0
ASSIGN EARTHQUAKE-SPECTRUM Y DIS_SPEC 1.0
ASSIGN EARTHQUAKE-SPECTRUM Z DIS_SPEC 0.5
```

These commands mean the earthquake excitations are applied in 3 global directions simultaneously. Each direction can be assigned with a different spectrum.

- Select mode shapes to be considered and put them in the CURRENT set: Only the lowest 10 mode shapes will be considered during the earthquake analysis.

```
SELECT MODE-SHAPE ( ONLY GROUP 1 10 1 )
```

- Investigate the effective modal mass of selected mode shapes

```
PRINT MODAL-MASS ( )
```

- Investigate the total base responses under earthquake excitations.

```
PRINT EARTHQUAKE-BASE-LOADS OFF ON ON ALL ORIGIN
PRINT EARTHQUAKE-BASE-LOADS OFF ON OFF Y  0.  0.  -55.
```

A user specified point to which the moments are summed can be defined as the second command above.

- Run an earthquake analysis for the global X-direction only on all current selected members according to the pre-selected mode combination rule and output. The results are stored as loadcase "QUAKE".

```
RUN EARTHQUAKE-CHECK QUAKE 'CQC with displacement spectrum in X direction'
X ALL CURRENT
```

- Print the resulting member stresses for all members.

```
PRINT STRESS FULL NORMAL-STRESS ALL QUAKE
```

- Combine static loadcases and the created earthquake loadcase in a load combination.

```
CREATE LOAD-COMBINATION CEQUT 'Axial Tension Response' EARTHQUAKE TENSION ( ONLY
    1          1.0
    2          1.0
    QUAKE     1.0 )
CREATE LOAD-COMBINATION CEQUC 'Axial Compression Response' EARTHQUAKE COMPRESSION ( ONLY
    1          1.0
```

```
    2          1.0
    QUAKE     1.0 )
```

- Print out the member forces of the load combinations and the earthquake loadcase.

```
SELECT LOAD-CASE ONLY QUAKE
SELECT LOAD-CASE INCLUDE CEQUT
SELECT LOAD-CASE INCLUDE CEQUC
PRINT FORCE ( ) ( )
```

- Choose the code standard for code checking. Framework supports the member code check and punch shear check of tubular joints as per API RP2A.

```
SELECT CODE-OF-PRACTICE API-AISC-WSD
DEFINE CODE-OF-PRACTICE-VERSION AISC 2010
```

- Select the load combination to do code check.

```
SELECT LOAD-CASE ONLY CEQUT
SELECT LOAD-CASE INCLUDE CEQUC
```

- Select the members and joints that are considered. Then, run code check.

```
SELECT MEMBERS ONLY ALL
RUN MEMBER-CHECK MCH1 None ( ) ( )
SELECT JOINTS ONLY ALL
RUN PUNCH-CHECK PCH None ( ) ( )
```

- Make API *100 % strength* check on critical joints. Use command `DEFINE JOINT-PARAMETERS` to notify the program to do the 100% strength check of API. It is recommended to define a particular "Set" in advance storing the critical joints.

```
DEFINE JOINT-PARAMETERS JOINT-IDENTIFICATION CRITICAL
SELECT JOINTS ONLY SET JTonLeg
RUN PUNCH-CHECK PCHCrit None ( ) ( )
```

- Investigate the code check results.

```
PRINT CODE-CHECK-RESULTS MCH1 SELECTED-MEMBERS-AND-LOADCASES ( ) ( ) FULL  ABOVE 0.0
PRINT CODE-CHECK-RESULTS PCH SELECTED-JOINTS-AND-LOADCASES ( ) ( ) FULL ABOVE  0.0
PRINT CODE-CHECK-RESULTS PCHCrit SELECTED-JOINTS-AND-LOADCASES ( ) ( ) FULL ABOVE  0.0
```

- Change the earthquake check type to joint quantity, e.g. Displacement.

```
SELECT EARTHQUAKE-CHECK-TYPE CQC DISPLACEMENT
SELECT JOINTS INCLUDE ALL
```

  Since one `RUN EARTHQUAKE-CHECK` command only produces one loadcase for the selected response, another RUN command is required for joint Displacement.

- Create another loadcase of joint displacement.

```
RUN EARTHQUAKE-CHECK QUKDis None ALL ( ) ( )
```

  The joint displacement responses are stored in a new loadcase "QUKDis". The loadcase of joint Displacement can also be combined with basic static load cases.

```
CREATE LOAD-COMBINATION Dispmax 'Axial Tension Response' EARTHQUAKE MAXIMUM ( ONLY
    1          1.0
    2          1.0
    QUKDis     1.0 )
```

- Print out the joint displacement.

```
SELECT LOAD-CASE ONLY QUKDis
SELECT LOAD-CASE INCLUDE Dispmax
PRINT DISPLACEMENT ( ) ( )
```

3.18.2 Additional features for earthquake analysis

1. New report to output earthquake base responses

   The new command **PRINT Earthquake Base Loads** provides a way for user to get the base reactions under seismic excitation in Framework. The base response can be used to obtain the appropriate equivalent foundation springs. The base reactions are summerized from all supported joints. The joints of fixed boundary condition and spring supports are considered. The reaction forces at a joint are calculated as the balancing force resultant contributed from all connected beam elements to the joint. The point loads at the node are included too. The total base reaction is a summation of all joint reactions. The Beam element with 2 nodes is included but Shell, Solid, Membrane elements and Ground springs are ignored. The forces and moments on each element end connected to the joint are transformed to the global coordinate system and then summed up. In the total moment reactions, the moments around the Global axes are accumulated from all contributing joints, with the moment contributed from shear forces included. The "Global axes" means the coordinate system at the origin of the superelement. Alternatively, a user specified point to which the moments are summed can be defined as the "Reactions Center". See the sample dialogbox in Figure 3.10.

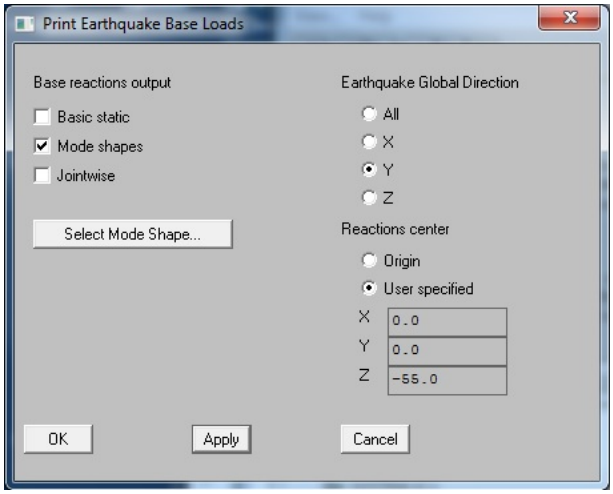


Figure 3.10

If the excitations from all 3 global directions are applied, the total base responses are combined as the square root of the sum of square of 3 directional results.

For instance, a sample report showing the modal responses and base reactions for X-direction earthquake can be

```
                                Earthquake Base Loads                                SUB PAGE:     1

 NOMENCLATURE:

 LC / JNT    Name of loadcase or Joint
 P           Property. S: Static LC; M: Modal shape; J: Joint
 FX          Force in X-direction
 FY          Force in Y-direction
 FZ          Force in Z-direction
 MX          Moment about the X-axis (wrt. global origo)
 MY          Moment about the Y-axis (wrt. global origo)
 MZ          Moment about the Z-axis (wrt. global origo)
```

```
Only joints of fixed or spring support are included.
Moments around global axes are accumulated from all contributing joints.
Global axes mean the coordinate system of the superelement.


         BASE REACTIONS

LC / JNT P        FX             FY             FZ             MX             MY             MZ
-------------------------------------------------------------------------------------------------
7        M          0.000       51607.691          0.000    -435830.125          0.000         -0.008
8        M     -51190.906           0.000          0.000          0.031    -500373.000          0.000
9        M          0.000           0.000          0.000          0.031         -0.016    -554619.562
10       M         -0.092    -271103.844          0.172   -5910121.500         16.000          2.375
11       M          0.222         -0.199       5611.873         -1.648        -40.666         -6.438
12       M     324687.438         -0.430         -0.750         -1.875   -6654291.500        -16.312
13       M         -1.728     -39527.914          1.984    1783126.250        291.125         47.891
14       M         -4.527           0.867          2.875        -46.000        708.250     823562.000
15       M        -20.688         -9.811       9775.984       -637.266       2875.828        525.727
16       M        996.485        -18.161        -11.922       -600.812    3394498.250        137.476

Reactions Center:
       X =     0.0
       Y =     0.0
       Z =   -55.0


NOMENCLATURE:

Mode            Name of the modal result case
AngFrq          Angular frequency, OMEGA=2*PI*f=2*PI/T
SPEC            Design seismic spectrum at modal freqency
DAMP            Damping ratio of the vibration mode
MLF             Modal Load Factor of the direction
Acceleration    Modal acceleration response (Accl)
Velocity        Modal velocity response (Vel)
Displacement    Modal displacement response (Disp)


         MODAL RESPONSES IN ( SRSS) EARTHQUAKE ANALYSIS AT DIRECTION:  X

Mode      AngFrq        SPEC    Damp        MLF       Acceleration      Velocity    Displacement
-------------------------------------------------------------------------------------------------
 7         8.1994      3.4812  0.050         -0.000         -0.000         -0.000         -0.000
 8         8.3977      3.5188  0.050        725.889       2554.264        304.162         36.220
 9         9.3884      3.7000  0.050          0.000          0.000          0.000          0.000
 10       15.0381      4.4624  0.050          0.000          0.000          0.000          0.000
 11       15.9918      4.5491  0.050          0.000          0.000          0.000          0.000
 12       16.0883      4.5576  0.050      -1254.417      -5717.167       -355.361        -22.088
 13       16.9458      4.6323  0.050          0.000          0.002          0.000          0.000
 14       17.0699      4.6428  0.050          0.001          0.007          0.000          0.000
 15       18.6263      4.7713  0.050          0.009          0.044          0.002          0.000
 16       19.0736      4.8069  0.050         -2.759        -13.261         -0.695         -0.036


    X-DIRECTION EARTHQUAKE BASE LOADS

          SHEAR  X:     7.4075205E+06
          SHEAR  Y:     9.5173368E+00
          MOMENT X:     4.8188091E+01
          MOMENT Y:     1.4809373E+08
          VERTI  Z:     1.6617340E+01
          MOMENT Z:     3.6081937E+02
```

The modal response to earthquake excitation is calculated according to the response spectrum analysis method. The total base response is the modal combination of the base response of all modes. To get the modal responses and modal combination, the earthquake spectrum, damping function for earthquake must be input in advance. The modal combination rule of the modal base reactions applies

the same rule specified in command SELECT EARTHQUAKE-CHECK-TYPE. The default modal combination rule is the "CQC" method.

If the excitations from all 3 global directions are applied, the total base responses are combined as the square root of the sum of square of 3 directional results.

2. Improved Effective Modal Mass report

The new Effective Modal Mass (EMM) report shows not only the EMM of each mode, but also the individual and accumulative modal mass fraction to the total mass at every direction. The advantage is to supply user the flexibility to investigate the contribution from "selected" modes instead of all modes. A sample report is demonstrated below.

```
                                    Effective Modal Mass (EMM)
                                    (modal load factors squared)

 NOMENCLATURE:

 Mode      Loadcase name of the mode shape
 Period    Period of mode, T
 EMM(X)    X-direction effective modal mass
 EMM(Y)    Y-direction effective modal mass
 EMM(Z)    Z-direction effective modal mass
 DMM(X)    Fraction to total X mass
 DMM(Y)    Fraction to total Y mass
 DMM(Z)    Fraction to total Z mass
 AMM(X)    X-direction acumulated mass fraction
 AMM(Y)    Y-direction accumulated mass fraction
 AMM(Z)    Z-direction accumulated mass fraction


 Mode  Period  EMM(X)    EMM(Y)    EMM(Z)   DMM(X)  DMM(Y)  DMM(Z)  AMM(X)  AMM(Y)  AMM(Z)
 ------------------------------------------------------------------------------------------
 7      0.766  2.02E-21  5.89E+05  2.11E-24  0.0000  0.2164  0.0000  0.0000  0.2164  0.0000
 8      0.748  5.27E+05  2.05E-21  3.33E-16  0.1954  0.0000  0.0000  0.1954  0.2164  0.0000
 9      0.669  2.73E-18  4.57E-16  1.20E-30  0.0000  0.0000  0.0000  0.1954  0.2164  0.0000
 10     0.418  4.47E-11  1.44E+06  2.02E-09  0.0000  0.5279  0.0000  0.1954  0.7443  0.0000
 11     0.393  6.82E-11  1.10E-10  4.82E+02  0.0000  0.0000  0.0003  0.1954  0.7443  0.0003
 12     0.391  1.57E+06  1.48E-08  1.26E-07  0.5836  0.0000  0.0000  0.7790  0.7443  0.0003
 13     0.371  1.52E-07  1.89E+04  1.16E-06  0.0000  0.0070  0.0000  0.7790  0.7513  0.0003
 14     0.368  1.98E-06  1.19E-05  9.44E-06  0.0000  0.0000  0.0000  0.7790  0.7513  0.0003
 15     0.337  8.37E-05  9.18E-04  7.95E+02  0.0000  0.0000  0.0004  0.7790  0.7513  0.0007
 16     0.329  7.61E+00  9.55E-04  1.13E-04  0.0000  0.0000  0.0000  0.7791  0.7513  0.0007

 Direction           X             Y             Z
 Sum of EMM          2.1005E+06    2.0453E+06    1.2765E+03
 Total Mass          2.6962E+06    2.7225E+06    1.8825E+06
```

Note: As mentioned previously, when merging the result file of eigenvalue analysis into the static analysis result, the mass from self-weight, dead loads, marine growth, and hyrdodynamic added mass must be well defined in static analysis such that the mass in static analysis is the same as that in eigenvalue analysis. As a result, the index of mode shape in the "merged' result file is offset after all static basic loadcases. For example, it starts from case 7 above.

3. New **Earthquake** type of Load Combination

The load combination created in Framework by **CREATE LOAD-COMBINATION** command has a new type: "Earthquake" in addition to existing types: Static, Quasi-static, and Scan. The earthquake response produces forces and moments that have lost their phase and sign because the response spectrum method is used. The earthquake induced components are non-negative by definition while the static components have the conventional signs. The combination of static loads and earthquake responses relates to member's and joint's code checking required by API RP2A.

For the **axial component** of member forces, an Earthquake type load combination has three ways to sum the force from basic static loadcases and the earthquake response. They are Maximum, Tension,

Compression.

- Maximum: get the largest absolute value by adding the earthquake response to the static component with the same sign of the static component;
- Tension: assume the earthquake response is tensile, adding "+" earthquake response to the static component;
- Compression: assume the earthquake response is compressive, adding "−" earthquake response to the static component.

The three options are described in Table 3.8.

Table 3.8: **Axial Component** combination of Earthquake type Load Combination

MAXIMUM	Static + or − EARTHQUAKE, whichever yields the larger |ABS| value.
TENSION	Static + EARTHQUAKE
COMPRESSION	Static − EARTHQUAKE
	Note: *The static component always has the sign.*

The other components such as shear forces, bending moments, and torque, are calculated as the "MAXIMUM" method, i.e. Static component + or − QUAKE component for larger |ABS| value. The static component always has the conventional sign during combination. See the command description and Appendix C.6 for more details.

The "Static" type load combination that has been used for earthquake response check is still available. If the load combination is defined as the"Static" type, it is required to use command `ASSIGN LOAD-CASE Earthquake` to specify the loadcase condition. By contrast, when a load combination is created as the "Earthquake" type, the design condition of this load combination is automatically set up to EARTHQUAKE. It is not necessary to use command `ASSIGN LOAD-CASE` to specify the loadcase condition again. Different messages show for two types of load combination. For instance,

```
CREATE LOAD-COMBINATION CSTAT None STATIC ( QUAKE5 1.0 1 1.0 2 1.0)
      Load combination created and assigned OPERATING condition
CREATE LOAD-COMBINATION CMAXIM None EARTHQUAKE MAXIMUM ( ONLY
    1          1.0
    2          1.0
    QUAKE5     1.0 )
      Load combination created and assigned EARTHQUAKE condition
```

The Earthquake type load combination is also applicable for the joint motions under earthquake excitation: Displacement, Velocity, Acceleration. However, the axial component option of new Earthquake type load combination has no effects on joint results. In detail, the program reports the same maximum absolute value at all components of joint motions for an Earthquake type load combination no matter which option of axial component is selected. The Maximum, Tension or Compression option in Earthquake type load combination does not have any difference for joint motions. In brief, any type of load combination (static or earthquake) of joint motion results will show the same values.

4. Improved report of PRINT member forces for code checking

   Prior to release v3.15, the load combination of static load and earthquake induced load can only be defined as the "Static" type. During code checking, the program applies the greater tensile member loads for the member's YIELD check and automatically switches to the greater compressive load for the member's STABILITY check. In a MEMBER check, both YIELD and STABILITY checks are performed. The

program can apply appropriate member forces in the associated code checking. However, by using **PRINT FORCE** command, the program only prints out the member forces combined by the MAXIMUM method for the "Static" type load combination. The MAXIMUM combined member forces are those appropriate in YIELD check. The program was not able to show the required member forces applied in STABILITY check.

Since v3.15, if the load combination is created as the "Earthquake" type, `PRINT FORCE` (or `PRINT STRESS`) command reports the member forces for the associated combination method, i.e. Maximum, Tension or Compression. The member forces are exactly those to be applied in code checking on the load combination. The program does not swith code checking forces for one load combination. The member forces depend on load combination type only, and do not change with different code check types. Conseqently, user must include all necessary load cases and load combinations in the code check. See Appendix C.6 for more details.

Again, the "Static" type load combination is still available for the situation in which the "auto-switch" feature is preferred.

5. Automatic skipping mid-point code check positions in earthquake analysis.

   The mode superposition method and the modal combination (e.g. CQC or SRSS) of earthquake responses manipulate the modal member forces from eigenvalue analysis on the finite element model. In Framework, the command `RUN EARTHQUAKE-CHECK` creates a loadcase storing the modal combined earthquake induced member internal forces. Obviously, the forcing results are valid at the finite element nodes only because, generally, the modal forces and the resultant earthquake induced forces are only meaningful at nodes. There are no distributed member loads created by the earthquake RUN in Framework. The combined earthquake responses are not at a state of equilibrium. In this case, the statically calcualted or interpolated sectional forces and moments at any mid-point positions of a linear 2-node beam element are invalid. **Exception:** The half span position can be kept for the high order beam element as long as the mode shapes of FE model are solved with the beam's mid-node in the eigenvalue analysis.

   The program since release v3.15 adds a feature to automatically screen out the mid-point positions of beam elements and keep the positions at FE node only. To do this, the command `SELECT EARTHQUAKE TYPE` must be used before command `FILE OPEN` reading the result Rn.SIN file. For example,

   ```
   SELECT EARTHQUAKE-CHECK-TYPE CQC FORCE
   FILE OPEN SIN-DIRECT-ACCESS 'Merged_' R1
   FILE TRANSFER 1 EQ-MODEL LOADS 'Earthquake Analysis'
   ```

   If so, a specified earthquake analysis method exists when the program reads the result Rn.SIN file. The program will automatically create the code check positions at finite element nodes of a concept member. The mid-point positions of each finite element are excluded. Those positions, such as at cross section and material change or segment junctions, are included. Then, `RUN EARTHQUAKE-CHECK` will not calculate the earthquake induced member forces at the mid-point positions. `PRINT FORCE` and code checking will not process those positions either. If the feature of auto-creating positions is not desired, user can always modify the code check positions by `ASSIGN Position` command. If the auto-exclusion of mid-point positions is not necessary, user can ignore the place where the command `SELECT EARTHQUAKE TYPE` is.

6. DEFINE critical joints to run *100% strength check* as per API RP2A.

   The design standard API RP2A [16] requires, when doing tubular joint check for earthquake loading, the chord capacity shall be at least 100% of the brace effective strength that is defined as the yield load of the brace in tension or the ultimate buckling load the brace in compression. It is called *100% strength check* for earthquake loading. To inform the program to run *100% strength check* when doing punch shear check, it is required to

   (a) Select joints that are critical and need *100% strength check*;

(b) Select load cases or load combinations that are of "Earthquake" design condition.

(c) Turn on critical joint identification by command

```
DEFINE JOINT-PARAMETERS JOINT-IDENTIFICATION CRITICAL
```

The *100% strength check* will be performed on the selected joints and loadcases.

7. Handling inconsistent loadcases at `PRINT Displacement`, `PRINT Force`, and RUN code check.

   An earthquake loadcase can be "Force", or joint results: "Displacement, Velocity, Acceleration". PRINT Displacement or PRINT Force. The requested printing will continue for the other loadcases. For example, for an earthquake LC of "Force", Print Displacements is not available; Print warning:

```
** Joint displacements not available for earthquake loadcase
   ... Basic LC:   QUAKE5  , at node     143
** Joint displacements not available for earthquake loadcase
   Load combination:    CSTAT
   Basic loadcase:     QUAKE5     , at node     62
```

   For an earthquake load case of joint results, e.g. "Displacement, Velocity, Acceleration", PRINT Force feature is not applicable. The program will print warnings, for instance,

```
** No member forces found for earthquake loadcase     QUK2
   Error occurs at Member BM1      , loadcase     QUK2 , skipped!
** No member forces calculated for earthquake loadcase
   Load combination:    LCMB1
   Basic loadcase:       QUK2
   Error occurs at Member BM1      , loadcase    LCMB1 , skipped!
```

   The joint result load cases should not do any code checks. If a joint result load case is included in code check, the following message will be shown and the load case is skipped.

```
   Now starting code check on member     BM16  ....    JT10 - JT9
** No member forces found for earthquake loadcase     QUK2
```

3.19 How to perform a joint redesign

Framework has an option for a simple joint redesign computation based on a punch check run.

The cross section assignments of the CHORD CAN section assignment in the database will be modified.

A summary of the redesign process is printed on the screen during the redesign run.

Example:

```
RUN REDESIGN PUNCH1 1.0
% sect mat
  ( 30  1
    33  1
    36  1 )
 RESIZE
```

In this case the run name is PUNCH1, the target usage factor is 1.0 and cross sections 30, 33 and 36 will be tried in conjunction with material 1.

Note the following:

The cross section and material assignments to be tested must be given in order of increasing strength

Only the RESIZE option is available, at a later stage an OPTIMISE option will be considered for implementation

The lengths of the cans that are assigned to the chord members is an initial guess, and must be verified by the user

3.20 How to perform member redesign

Framework has an option to perform a redesign / resize of members not satisfying the usage factor target level. A redesign may be investigated in connection with yield, stability, member or hydrostatic code checks.

The commands used to control the redesign feature are as follows:

1. Global switch used to select the redesign mode ON or OFF. Default = OFF, hence perform an ordinary code check. When switched to ON, the code check runs will enter a redesign mode. The code check run will then try to find the cross section that will satisfy the target usage factor.

   ```
   DEFINE MEMBER-REDESIGN OPTIONS REDESIGN-MODE ON / OFF
   ```

2. Switch used to select if the redesign process only shall use sections of equal type as originally assigned the member. Default = ON, i.e. do not try sections of other types.

   ```
   DEFINE MEMBER-REDESIGN OPTIONS LOCK-SECTION-TYPE ON / OFF
   ```

3. Switch used to select if the proposed section automatically shall be assigned to the member. Default = OFF, i.e. do not assign.

   ```
   DEFINE MEMBER-REDESIGN OPTIONS ASSIGN-SECTION ON / OFF
   ```

4. Switch used to select if the redesign process shall continue when the already assigned section satisfies the target usage factor. Default = OFF, i.e. do not try to optimise (select a smaller section) if the current section is acceptable.

   ```
   DEFINE MEMBER-REDESIGN OPTIONS ALLOW-OPTIMIZE ON / OFF
   ```

5. Defines the target usage factor when running redesign. Default value = 1.0.

   ```
   DEFINE MEMBER-REDESIGN OPTIONS TARGET-USAGE-FACTOR value
   ```

A list of sections to be used in the redesign process must be defined. This list must contain the sections in a prioritised order with respect to preferred sections to use. The section on top of the list will be checked first, hence order from 'weak' to 'strong' sections. Use the command:

```
DEFINE MEMBER-REDESIGN SECTION-LIST ( ONLY sec1 sec2 ... )
```

During the redesign process the various results are reported in the message field (and written to the MLG file). The results from the 'final selection' may be printed by use of the ordinary code check print command PRINT CODE-CHECK-RESULTS.

3.21 How to compute material take-off

Framework has an option for simplified material takeoff computations.

Three different commands are available:

PRINT MATERIAL TAKE-OFF prints an overview of the total lengths, weights and surface areas identified by material and cross section names for a selection of members.

PRINT MEMBER TAKE-OFF prints an overview of can/stub and mid-section cross section and material, segment lengths and mass for a selection of members.

PRINT JOINT TAKE-OFF prints an overview of sections and materials for a selection of joints. Only the lengths and masses of adjoining cans and stubs will be included.

Note the following:

Assignment of can and stub lengths (measured from the centre node of the joint) is required.

A simplified cutoff calculation of the brace members due to the chord diameter is performed.

Point masses are NOT included.

Eccentricities are NOT taken into account.

3.22 How to close the design loop by linking Preframe

Geometric modifications performed in Framework during the design process may be transferred back into the Preframe model by a command input file created by Framework. *Now, Genie is recommended to do the redesign*.

The following type of changes are transferred to Preframe:

- New sections created (currently only PIPE, I/H and BOX)
- Modified sections (currently only PIPE, I/H and BOX)
- Section assignments
- New materials (currently no yield and tensile stress)
- Modified materials (currently no yield and tensile stress)
- Material assignments
- Create members (merging of existing members)
- Assign can and stub sections
- Modified can and stub sections
- Assign stability parameters (currently buckling length and effective length factor)
- Modified stability parameters (currently buckling length and effective length factor)

This feature is activated by the command:

```
DEFINE PREFRAME-INPUT ON
```

The input file will contain Preframe input commands corresponding to the changes done in the Framework model from point of establishment to current status.

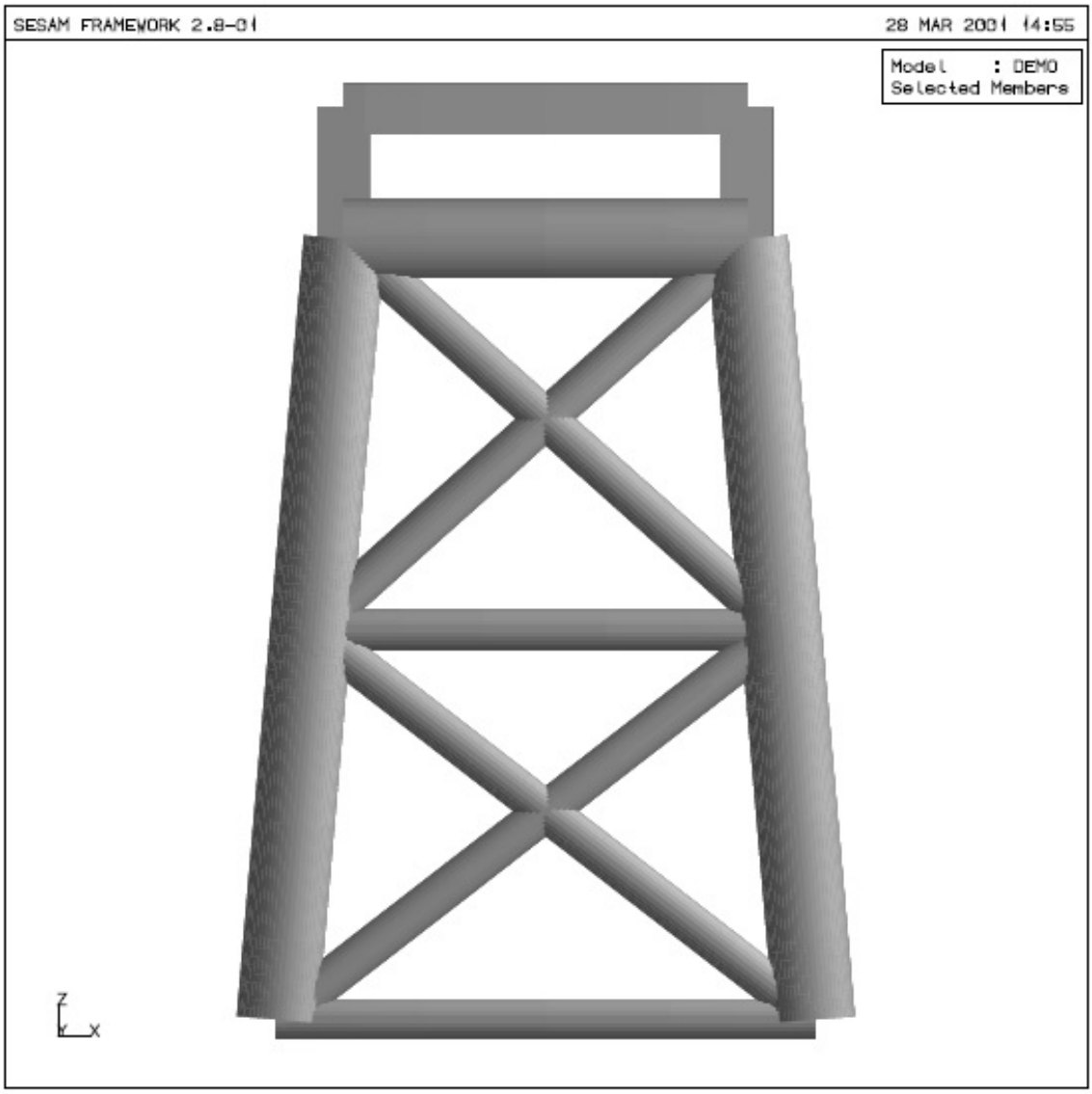


Figure 3.11: Hidden surface display example

The file name for the Preframe journal file is prefixFW2PF.JNL, where prefix is the user defined print file prefix (Use command SET PRINT FILE prefix name).

3.23 How to create a hidden surface display

Display the model with a hidden surface plot .

```
DISPLAY MEMBER
DISPLAY PRESENTATION HIDDEN 1.0
```

The output from this command can be as shown in Figure 3.11.

3.24 How to create a deformed shape display

Display the deformed shape for load combination STATIC:

```
DISPLAY SHAPE OVERLAY STATIC 1.0 0.0 LINEAR
```

The output from this command can be as shown in Figure 3.12.

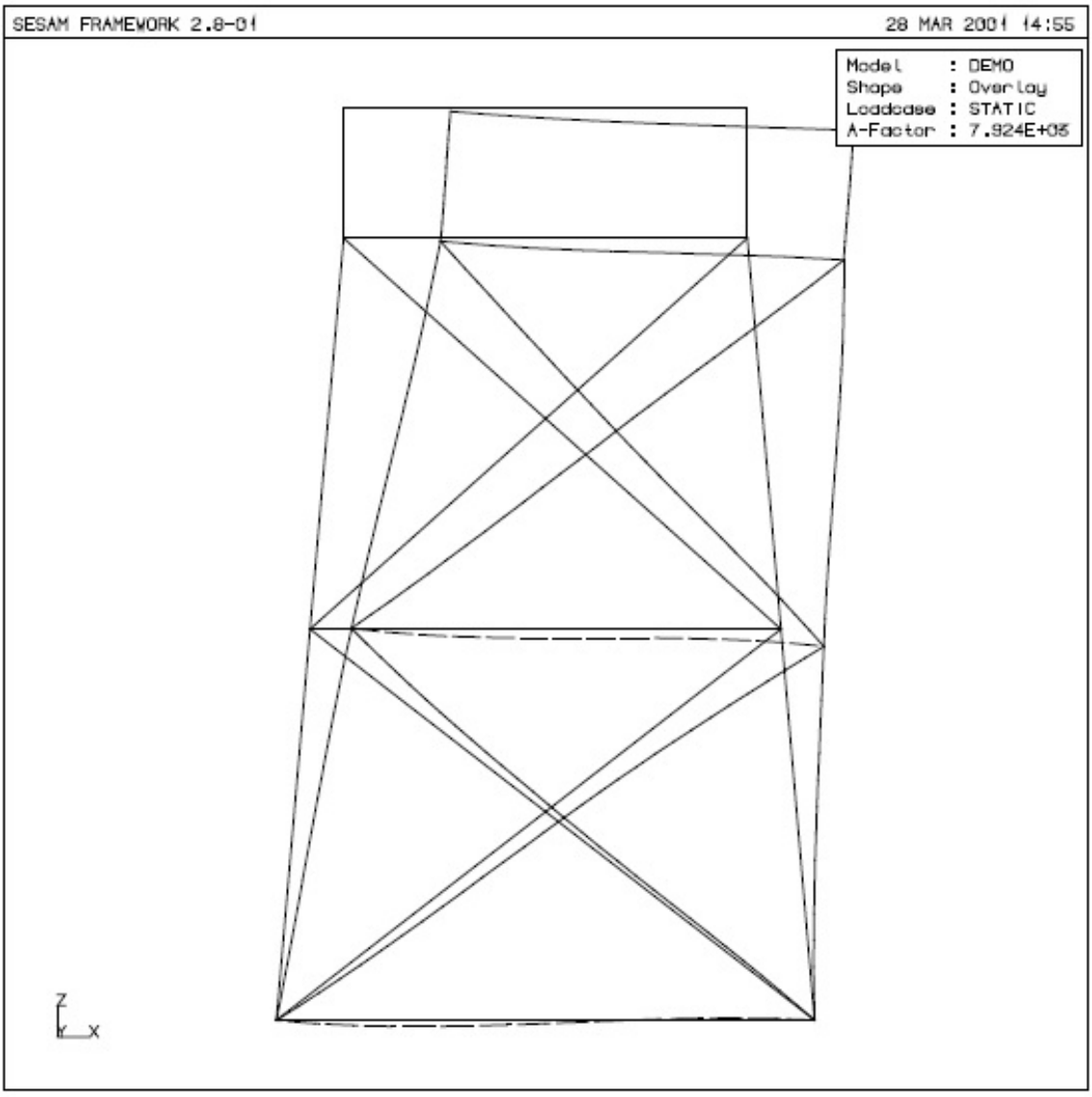


Figure 3.12: Deformed shape display example

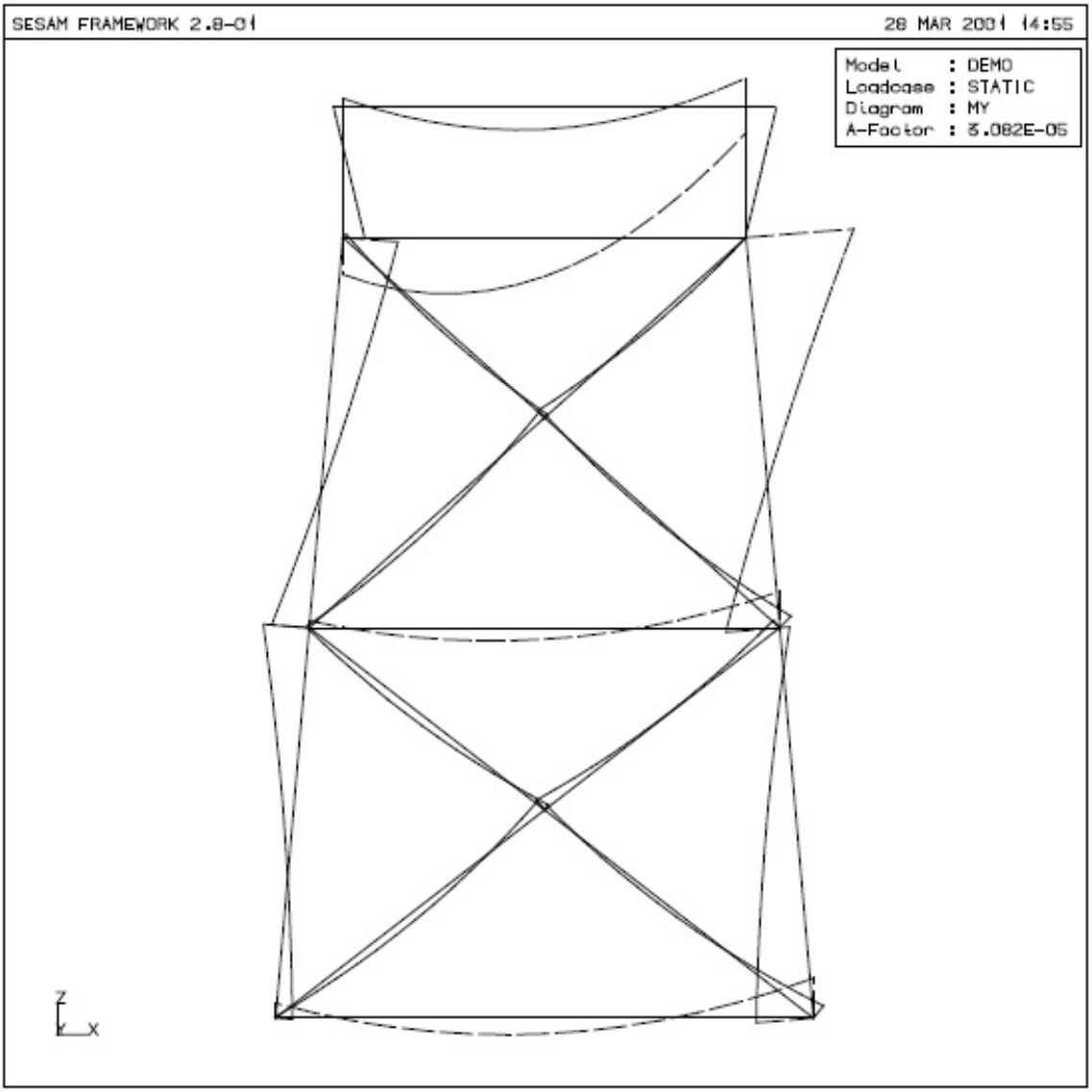


Figure 3.13: Force/moment diagram display example

3.25 How to create a force/moment diagram display

Diagrams of member forces/moments may be displayed for load cases or load combinations created in Framework.

Display the bending moment MY for load combination STATIC:

```
DISPLAY DIAGRAM STATIC MY 1.0
```

The output from this command can be as shown in Figure 3.13.

3.26 How to perform a wind fatigue analysis

Before a wind fatigue analysis can be executed a SIN file containing modelling data, eigenvalues, normalised eigenvectors, resultant stresses from eigendeformations and resultant stresses from the wind loading must be created. Also, a FEM file containing the wind loads is required if the static wind loads are not contained in the SIN file. For more information, see RSEL line description in Sestra user's manual[32], and Sesam Manager's reference for switching on storing of beam distributed loads. Necessary steps to generate input

data and the required files are shown below.

Step	Description	Program	In files	Out files
1	Modelling of the structure	Genie (or Preframe)	graphic mode or direct input xml, js, gnx, (model.jnl of Preframe)	Tn.FEM
2	Generation of wind loads	Wajac	Tn.FEM direct input (wajac.inp)	Ln.FEM Sn.FEM wajac.lis
3	Calculation of element stresses from the wind loading	Sestra	Tn.FEM Ln.FEM Sn.FEM direct input (static.inp)	Rn.SIN or Rn.SIF sestra.lis
4	Calculation of eigenvalues, normalised eigenvectors and element stresses from eigendeformations	Sestra	DTn.FEM direct input (dynamic.inp)	DRn.SIN or DRn.SIF sestra.lis
5	Merging of Rn.SIN and DRn.SIF files into Rn.SIN file	Prepost	Rn.SIN DRn.SIF	Rn.SIN
6	Execution of wind fatigue analysis	Framework	Rn.SIN (Ln.FEM)[1] direct input (graphic mode or windfatigue.jnl)	RunFramework.lis RunDiagnostics.txt RunLives.frs

3.26.1 File and file names

The full names of the files are:

prefixTn.FEM	Input Interface File (formatted)
prefixRn.SIN	Results Interface File (Norsam format)
prefixRn.SIF	Results Interface File (formatted)
prefixLn.FEM	Loads Interface File (formatted)
prefixSn.FEM	Analysis Control Data File used by Sestra (formatted)

The prefix may contain device, disk and a user-defined name, and n is the superelement number. The model file DTn.FEM is a copy of Tn.FEM, where "D" is to distinghuish the model will be used for a dynamic analysis.

Note 1: In Wajac the prefix for the S-file will be the same as the one for the L-files (controlled by FWAVE command in Wajac) whereas in Sestra the prefix for the S-file must be the same as the one used for the T-files. This means that if the prefix given by the FMOD and FWAVE commands in Wajac differ then the S-file must be renamed after running Wajac prior to running Sestra.

[1] The static wind element loads will be read from the Ln.FEM file if they are not contained in the Rn.SIN file. Element loads are printed to the Rn.SIN file if the RSEL command with parameter ISEL1=1 is included in the Sestra input of the static wind load analysis.

prefixFramework.lis	Results file of the wind fatigue module
prefixDiagnostic.txt	Diagnostics and message file of the wind fatigue module
prefixLives.frs	Fatigue lives file (unformatted) of the wind fatigue module

The prefix is the run name entered to the RUN command by the user.

name.inp	Files Containing commands and input data for Wajac and Sestra
name.jnl	Journal files for Preframe and Framework containing commands and data for the programs. These files may be established by the user or they may be generated by the programs by entering data in the graphic user interface mode
name.lis	Files containing summary of results from Wajac and Sestra

The name may be a user-defined name.

3.26.2 Modelling of the structure

The model must consist of 2 nodes 3D beam elements. Wind fatigue is performed only for beam elements with uniform tubular pipe sections, however, static wind load effect is accounted for for all 2 nodes 3D beam elements in the model which includes beams with non-pipe sections and non-structural beams. The static wind loads are established by Wajac.

Node and element numbers may be in arbitrary order. The structure may be fixed to the ground or supported by spring-to-ground elements. The model may be established by using Preframe, Prefem or a program that generate a Tn.FEM file. Now, Genie is recommended for FE modeling.

3.26.3 Generation of wind loads

The wind loads may be generated by Wajac. Wajac reads the Tn.FEM model file and prints results to the Ln.FEM and Sn.FEM files. The Ln.FEM file contains the wind loads (distributed element pressures).

The analysis data controlling the Wajac analysis is given in the Wajac input file which must have the extension inp (e.g. wajac.inp). The input file must be prepared before the Wajac run is started. A detailed description of the Wajac input is given in the Wajac User Manual. Relevant input for wind load generation is, however, explained below.

Data for wind load calculations are specified by the commands WIND, SEA and SEAOPT which are mandatory, and optionally by the commands CDWN, CDWR and CONS.

Information about the wind-field is given by the WIND command which contains the wind direction/wind profile index (WID), the mean wind velocity (VEL), the wind angle (ANGLE), the gust factor (GUSTF), the velocity level (H0), the height exponent (HEXP), the mean wind period ratio (PRAT) and the option parameter (IFORM) to select wind velocity profile equation. The user may choose between three different wind profile formulae by the IFORM = 0,1,2 (Eqs. 2.27, 2.28 and 2.29 in Wajac User Manual, respectively). The last two parameters of the WIND command may be omitted if the default wind profile (IFORM = 0) is applied.

An arbitrary number of WIND commands may be given. A minimum of one WIND command must be given if wind loads are to be evaluated. By default, the air drag coefficients are assumed to be a known function of the Reynolds number. Optionally, the drag coefficients may be specified as a function of the Reynolds number by the CDWR command or for specified members by CDWN. Information given on CDWN will supersede specifications by CDWR.

Wind loads are calculated when the deterministic load calculation command SEA is used. This is done by connecting each SEA command with one of the WIND commands specified (similarly to CRNT). To do this one has to use var.2 of SEA in Table3.14. Only the first two parameters (ISEA) and (THEO) are required for wind load calculations. The index (ISEA) refers to additional data specified on the SEAOPT command and (THEO) identify the wave theory to be used, which has the value 9.0 for wind load calculations.

Reference to the WIND command is given on SEAOPT command by the WID parameter. Relevant parameters for wind load calculations are; seastate index (ISEA), stretching of the wind profile index (CSTR), load calculation index (LOAD), wind profile index (WID), wind load calculation method index (WIMET). For wind

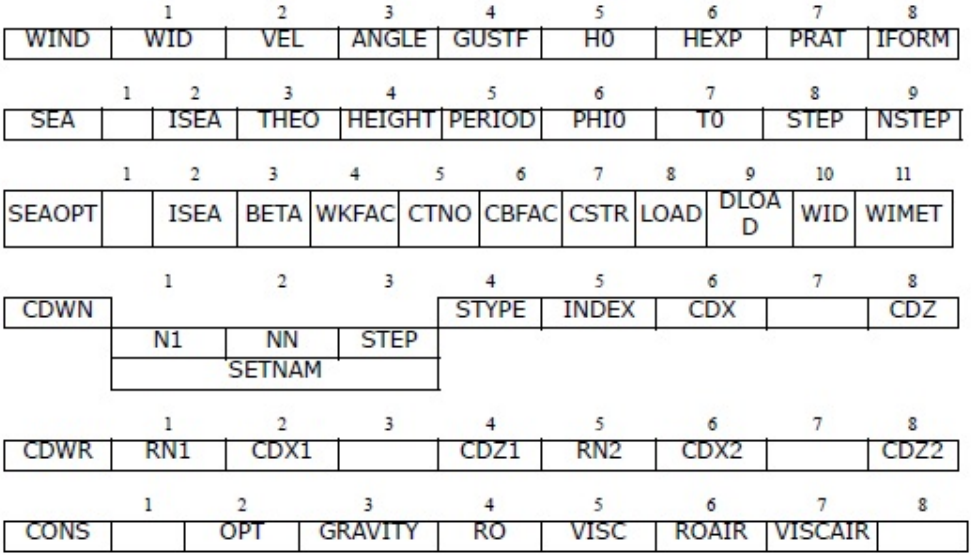


Figure 3.14: Wajac input for generation of Wind Loads

load calculations CST=-1, LOAD=1 and WIMET=1. By specifying WIMIET=1, the wind loads calculated are prepared for gust induced wind fatigue calculations in Framework which means that three wind load cases are produced for each wind direction. In the load calculation and evaluation of the Reynolds number the equivalent diameter D may be redefined by SPEC/SPEX command. If only wind loads are required calm sea condition must be specified on the SEA command and buoyancy loads must be excluded by SEAOPT.

Wind loads may be calculated for several water depths by repeating the DETPH command. The same wind directions apply for all water depths and the number of wind load cases generated for the first water depth are increased repeatedly for each additional water depth. In combination with the mudline level (command MUD), the z-distance of the global coordinate reference system to the still water level is calculated. (positive z-distance means that coordinate reference system is below the still water level). This z-distance is added to the global coordinates of structure to get the height above the sea level. It of importance to enter correct combinations of mudline level and water depths to get correct calculated wind loads. All relevant parameters entered to Wajac are transferred to and used in the wind fatigue module.

Default values are used for the air density (ROAIR) and viscosity coefficients (VISCAIR), unless they are specified by the CONS command. Default values are ROAIR$= 1.226 kg/m^3$ and VISCAIR$= 1.462 \times 10^{-5} \mu^2/\sigma$.

The MPRT command is used to print the calculated wind loads to file (wajac.lis) so that the user may control the results.

An input file to Wajac for wind load calculation may be as follows:

```
WAJAC
TITL STATIC WIND LOADS FOR INPUT TO WIND FATIGUE ANALYSIS
C    Prefix for Input Interface
C         PREFIX
C    FMODE
C    Prefix for Wind Load Interface Generation
C         PREFIX                                  FORM
FWAVE                                            FORMATTED
C    Identify the model for which loads will be calculated
C                   ILFSAV    ISETOP
MODE                  1.        1.
C    Units and constant definitions
C         OPT       GRAVITY   RO        VISC      ROAIR     VISCAIR
CONS                                               1.225     1.5E-12
```

```
C   Dataset GEOM
C
GEOM
C
C   Mudline elevation
C         Z
MUDP      -10.0
C    Dataset HYDR
HYDR
C    Air drag coefficients for specific members
C         N1        NN        STEP      STYP INDX CDX       CDZ
C    CDWN      1.        24.       1.        1.   1.   1.2       1.2
C    Air drag coefficients as a function of Reynolds numbers
C         Rn1       CDX1      CDZ1 RN2  CDX2      CDZ1
C    CDWR
C    Dataset LOAD
LOAD
C    Member force printout specification
C         N1        NN        STEP      STYPE     INDEX     ISEA      ISTEP
MPRT      1.        24.       1.        1.        1.        1.        1.
MPRT      1.        24.       1.        1.        1.        2.        1.
MPRT      1.        24.       1.        1.        1.        3.        1.
C
C    Water depth
DPTH       10.0
DPTH       12.0
DPTH       15.0
C    Wind profile
C    WID  VEL       ANGLE     GUSTF     H0        HEXP
WIND 1.   30.         0.      1.0       10.       0.125
WIND 2.   30.        30.      1.0       10.       0.125
WIND 3.   30.        60.      1.0       10.       0.125
WIND 4.   30.        90.      1.0       10.       0.125
WIND 5.   30.       120.      1.0       10.       0.125
WIND 6.   30.       150.      1.0       10.       0.125
C    Deterministic load calculation
C    OPT  ISEA THEO HEIGHT    PERIOD    PH10      T0        STEP      NSTEP
SEA       1.   9.
SEA       2.   9.
SEA       3.   9.
SEA       4.   9.
SEA       5.   9.
SEA       6.   9.
C    Additional data for deterministic load calculation
C         ISEA BETA WKFC CTNO CBFC CSTR LOAD DLOA WID  WIMET
SEAOPT    1.                    -1.  1.        1.   1.
SEAOPT    2.                    -1.  1.        2.   1.
SEAOPT    3.                    -1.  1.        3.   1.
SEAOPT    4.                    -1.  1.        4.   1.
SEAOPT    5.                    -1.  1.        5.   1.
SEAOPT    6.                    -1.  1.        6.   1.
END
```

The wind loads are defined, calculated and stored for only 1 wind speed per direction. This will simplify the static wind analysis. The wind forces of the reference wind speed will be stored in the result SIN file. The wind profile data is also stored and passed to Framework for the wind fatigue module. In Framework's input file, the wind speeds that contribute to wind buffeting fatigue are specified. The associated wind forces of those wind speeds are scaled according to the wind force of the reference wind speed.

3.26.4 Calculation of element forces from wind loading

A static analysis by Sestra, using the wind loads calculated by Wajac, is carried out to calculate the element forces generated by the gust wind loading. Sestra reads the Ln.FEM and Sn.FEM output files from Wajac and the model file Tn.FEM. Analysis control data for the static Sestra analysis may be as follows:

```
COMM Static analysis with superelement 1
COMM CHECK ANTP      MOLO STIF RTOP LBCK      PILE     CSING      SIGM
CMAS    0.   1.        0.   0.   0.   0.        0.   0.        0.
RNAM       NORSAM
LNAM       FORMATTED
COMM INAM
ITOP  1.
COMM RTRAC PRNT STOR EQUI SEL1 SEL2 SEL3 ...
RETR    3.   0.   0.   0.   0.   0.   0.   0.
COMM ISEL1 ISEL2 ISEL3 ...
RSEL    1.   0.   0.   0.   0.   0.   0.   0.
Z
```

By the RNAM, LNAM and INAM commands prefixes of the Results Interface File (Rn.SIN), the Loads Interface Files (Ln.FEM and Sn.FEM) and Input Interface File (Tn.FEM) may be specified, respectively.

The results of the static analysis are stored on a SIN or SIF file. Sestra prints a lis file (sestra.lis) containing summary of the analysis results. ISEL1 = 1 of the RSEL command initiates print of the static wind element loads to the SIN or SIF file.

3.26.5 Calculation of eigenvalues, eigenvectors and element mode shape forces

An eigenvalue analysis is performed by Sestra to calculate eigenvalues, mass normalised eigenvectors and element mode shape forces of the beam elements. Analysis control data for an eigenvalue calculation by Sestra may be as follows:

```
COMM Householder eigenvalue analysis requesting 10 modes for superelement 1
COMM CHECK ANTP      MOLO STIF RTOP LBCK      PILE     CSING      SIGM
CMAS    0.   2.        1.   0.   0.   0.        0.   0.        0.
RNAM  D    FORMATTED
ITOP  1.
INAM  D
COMM RTRAC PRNT STOR EQUI SEL1 SEL2 SEL3 ...
RETR    3.   0.   0.   0.   0.   0.   0.   0.
COMM EIGL   10.             4.                        1.
EIGH   10.
IDTY    1.
DYMA    2.
```

Ten eigenvalues are calculated according to the Householder's method (EIGH 10) with diagonal mass matrix (DYMA 2). The analysis results may be stored on a SIN or SIF file. Sestra prints a lis file (sestra.lis) containing summary of the results.

Note 1: MOLO = 1 of the CMAS command initiates calculation and storage of element mode shape forces on the Results Interface File, otherwise no element mode shape forces are stored. **If no element mode shape forces are stored, the damage contribution from the dynamic response in the wind fatigue calculation will be zero**.

3.26.6 Merge of static and dynamic Results Interface Files

The Results Interface Files of the static analysis and the eigenvalue analysis of Sestra must be merged into one common file. The merge is performed by accessing Prepost. The procedure for merging two files is described in section 3.1.2 in the Prepost User Manual.

The merge procedure requires one of the files to be a SIN file and the other to be a SIF or SIU file. In the present case the static results are contained in the Rn.SIN file and the eigenvalue results in the DRn.SIF file.

The output merge file is the Rn.SIN file. Note that the input SIN file is overwritten in the merge process. The SIF file results are appended the SIN results in the merge.

It does not matter for the wind fatigue calculation whether the static wind load results and eigenvalue results are contained in the SIN and SIF files, respectively, or vice versa when being merged.

3.26.7 Execution of wind fatigue analysis

The wind fatigue module reads the merged results interface file (Rn.SIN) containing modelling data, results of the static analysis and results of the eigenvalue analysis Only first level superelements can be read and only one superelement can be handled at the time. If the element wind loads are not contained in the SIN the wind fatigue module also reads the Ln.FEM file, otherwise not.

Analysis control data must be prepared before the wind fatigue analysis can be executed. Framework must be started and the input entered either by reading a journal file where data have been prepared in advance or using the menus and dialogue boxes of the graphic user interface. A combination where input read file is modified and extended in the graphic mode is also possible.

Note that the wind fatigue module cannot utilise member (concept) names, only element numbers can be used. To avoid this limitation the command DEFINE READ-CONCEPTS OFF may be applied. When set to OFF member information and member attribute data defined on the concept data cards (in the result file) will not be transferred when the model is established. The command must be set prior to opening and transferring model and results from the result file, i.e prior to the FILE OPEN command.

3.26.7.1 FILE command

Prefix and name of the database file must be specified when starting Framework. The data base file is opened by the FILE OPEN command and transferred to Framework by the FILE TRANSFER command.

```
FILE OPEN SIN-DIRECT-ACCESS ' ' R1
FILE TRANSFER 1 JACKET LOADS None
```

Framework contains a wide range of features that are not relevant for wind fatigue calculations. The TASK WIND-FATIGUE-CHECK command, available in the graphic mode, makes only commands relevant for wind fatigue calculations visible and hides non relevant commands.

3.26.7.2 ASSIGN WIND-FATIGUE command

Eight data groups are assigned by the ASSIGN WIND-FATIGUE command; wind type, wind profile, SN curve, joint SCF, bent can SCF, vortex dimension, vortex fixity and run scenario parameters.

The wind type to be used is assigned by ASSIGN WIND-FATIGUE WIND-TYPE. Three choices are possible; buffeting wind, vortex shedding wind or a combination of the two. Specification of the wind band is required for the vortex wind. The user may select between narrow, broad or broad and narrow bands.

```
ASSIGN WIND-FATIGUE WIND-TYPE WIND-BUFFETING
ASSIGN WIND-FATIGUE WIND-TYPE VORTEX-SHEDDING
ASSIGN WIND-FATIGUE WIND-TYPE WIND-BUFFETING-AND-VORTEX-SHEDDING
    BROAD-AND-NARROW
```

The wind profile applied in the Wajac run are applied automatically in the wind fatigue module. Three choices are possible in Wajac; API, NORSOK normal wind and NORSOK extreme wind profile, represented by Eqs. (2.27), (2.28) and (2.29) in the Wajac User Manual, respectively. Default is API wind profile.

Wind spectrum is selected by the command `ASSIGN WIND-FATIGUE WIND-SPECTRUM`. In mean wind direction three choices are possible; Harris-, Davenport- and NPD spectrum. In lateral across and vertical across directions to the mean wind the Panofsky wind spectra are applied. The lateral across and vertical across gust wind components may switched on/off.

```
ASSIGN WIND-FATIGUE WIND-SPECTRUM DAVENPORT ON ON
```

SN curves for joints are assigned by `ASSIGN WIND-FATIGUE SN-CURVE JOINT` and for bent cans by `ASSIGN WIND-FATIGUE SN-CURVE BENT-CAN`. Any SN curve of the SN curve library of Framework may be selected as

well as SN curves created by the user. Thickness corrections to the SN curves may be assigned or switch off by ASSIGN THICKNESS-CORRECTION.

```
ASSIGN WIND-FATIGUE SN-CURVE JOINT DEFAULT ( ) DOE-T
ASSIGN WIND-FATIGUE SN-CURVE BENT-CAN ( ) NO-F3-S
ASSIGN THICKNESS-CORRECTION DOE-T ARBITRARY 0.032 0.022 0.25
```

SCFs are assigned to joints by ASSIGN WIND-FATIGUE JOINT-SCF. SCFs are assigned by the wind fatigue module itself when one of the options EFTHYMIOU, LLOYDS or ORIGINAL are selected. By selecting the READ option three possibilities appear. SCFs are assigned by Framework when a parametric SCF scheme is chosen. Global SCFs are applied when GLOBAL is chosen, and the user may specify SFCs when LOCAL is chosen. Global SCFs are specified by DEFINE FATIGUE-CONSTANTS.

Bent can SCFs are assigned by ASSIGN WIND-FATIGUE BENT-CAN-SCF. A bent can occurs when no chord but two or more braces meet a joint. Global SCFs are applied to bent cans which have no user assigned SCFs.

SCFs assigned by the READ option requires that joints and members are selected before SCFs are assigned. Joints and members are selected by SELECT JOINTS and SELECT MEMBERS commands, see below. In graphic mode click the [Select joint] and [Select brace] buttons of the dialog boxes. If READ option is applied those joint-brace connections that are not assigned SCFs by the READ option will have SCFs according to the default parametric SCF scheme. The default SCF scheme (EFTHYMIOU or LLOYDS) are specified by the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

Note that the **Minimum Parametric SCF** specified by DEFINE FATIGUE-CONSTANTS supersede parametric SCFs less than these values. This does not apply to SCF generated by the READ/LOCAL and READ/GLOBAL options.

```
ASSIGN WIND-FATIGUE JOINT-SCF EFTHYMIOU
ASSIGN WIND-FATIGUE JOINT-SCF READ ALL ( ) PARAMETRIC EFTHYMIOU
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 201
SELECT MEMBERS EXCLUDE ALL
SELECT MEMBERS INCLUDE 10
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
     CROWN-SADDLE 8.09 11.55 3.31 8.32
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
     CROWN-SADDLE 4.18  9.05 2.85 6.27
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 205
ASSIGN WIND-FATIGUE BENT-CAN-SCF ( ) LOCAL 5.0 5.0 5.0 5.0 ALL
```

It may be necessary to modify element dimensions (length, diameter, thickness) in the vortex fatigue calculations if a brace has been divided into several elements in order to access correct vibration mode of the brace. Element dimensions may be modified by ASSIGN WIND-FATIGUE VORTEX-DIMENSION. If only the length of an element is to be modified the original diameter and thickness are retained when 0.0 is specifying for the two parameters. This command does not affect the original dimensions applied in buffeting fatigue calculations.

```
ASSIGN WIND-FATIGUE VORTEX-DIMENSION CURRENT 10.0 0.0 0.0
```

Member ends fixity applied in vortex induced fatigue calculations are assigned by ASSIGN WIND-FATIGUE VORTEX-FIXITY. Lower and upper bound values of the member ends fixity, the number of fixity steps and joint numbers of the member ends are specified. The fixity values must be in the range from 0.0 (pin-jointed end) to 1.0 (fully fixed end), or -1.0. Maximum of 5 fixity steps may be investigated. Linear interpolations between the lower and upper bound values are used to find the fixity values of the various steps. Member ends that are not assigned fixity will take default fixity specified by DEFINE WIND-FATIGUE DEFAULT-MEMBER-FIXITIES.

```
ASSIGN WIND-FATIGUE VORTEX-FIXITY MEMBER-ENDS ( ONLY
    203   202   5   0.1   0.95  0.1   0.95
```

```
    205   302   2   0.4   0.6   0.4   0.6 )
```

Run execution parameters are assigned by ASSIGN WIND-FATIGUE RUN-SCENARIO. Two run cases are possible; single brace case and multi brace case. The single brace case allows one joint/brace connection, one wind direction and several dynamic modes to be considered. A compressed or a comprehensive print of results may be requested. If the comprehensive print option is chosen, an inspection point around the weld at the chord side or at the brace side must be specified. The multi brace case allows several joints, analysis planes, wind directions and dynamic modes to be considered. Start and end values are specified. The MULTI-BRACE-CASE-SELECT-JOINTS option allows to select joints from the structure randomly by the SELECT JOINT command. All joints, analysis planes and wind directions from the start value to end value is included in the analysis. Among the specified joints only joint/brace intersections parallel to the specified analysis planes are considered. If n dynamic modes are specified, the first n modes are considered. Show of progress of the run may be switched on/off for the multibrace case. A compressed print of results is produced for the multi brace case.

```
ASSIGN WIND-FATIGUE RUN-SCENARIO SINGLE-BRACE-CASE 3 406 210 1 2 COMPRESSED
ASSIGN WIND-FATIGUE RUN-SCENARIO SINGLE-BRACE-CASE 3 406 210 1 2 COMPREHENSIVE
    4 BRACESIDE
ASSIGN WIND-FATIGUE RUN-SCENARIO MULTI-BRACE-CASE 3 6 102 303 1 1 2 ON
SELECT JOINTS ( ONLY SET JTPRITUB SET JTSECTUB )
ASSIGN WIND-FATIGUE RUN-SCENARIO MULTI-BRACE-CASE-SELECT-JOINTS 1 6 1 6 3 ON
```

Options for dump print of hotspot stresses and stress spectrum data are assigned by ASSIGN WIND-FATIGUE STRESS-PRINT-OPTIONS. Prints may be performed for selected wave directions, joints, analysis planes and hotspots of the joints. Stress data are printed to the file runnameFramework.dmp, where runname is the name of the run. The print is performed during the fatigue calculation run and the print options must therefore be assigned prior to the run execution.

```
ASSIGN WIND-FATIGUE STRESS-PRINT-OPTIONS ON ON 1 3 201 203 1 1 1 8
```

3.26.7.3 CREATE WIND-FATIGUE command

The user may create its own SN curves by the command CREATE SN-CURVE. The parameters of the SN Curve must be compatible with the input units applied. No correction of the SN curve parameters to the current unit of the analysis is performed for user defined SN curves.

```
CREATE SN-CURVE NEW_T USER NONE 3.0 5.263E4 7.0 ALIGNED-WITH-FIRST
```

Analysis planes are created by the command CREATE WIND-FATIGUE ANALYSIS-PLANES. An analysis plane is created on basis of specifying three nodes in the structure. The three nodes can not be co-linear. A maximum of 10 analysis planes may be created.

```
CREATE WIND-FATIGUE ANALYSIS-PLANES ( ONLY
    101   203   301
    102   205   302
    103   201   303 )
```

Nodal point wind loads are established by reading the Rn.SIN file if the static element wind loads have been printed to this file. If not, the Ln.FEM file is read the command CREATE WIND-FATIGUE STATIC-WIND-LOADS must be applied if wind loads from others than the first six wind directions are to be considered in the fatigue analysis, otherwise this command should not be accessed. When applied, the command should always follow the DEFINE WIND-FATIGUE WIND-DIRECTIONS command by which new wind directions are specified. Note that this command is shown shaded and made invalid in the graphic user interface when the static element wind loads are contained in the SIN file.

```
CREATE WIND-FATIGUE STATIC-WIND-LOADS FEM-SEQUENTIAL ' ' L1
```

3.26.7.4 DEFINE WIND-FATIGUE command

Minimum parametric and default global SCFs are defined by the command DEFINE FATIGUE-CONSTANTS. The minimum parametric SCFs apply only to SCFs generated by parametric SCF schemes.

```
DEFINE FATIGUE-CONSTANTS AXIAL-MINIMUM-SCF 2.5
DEFINE FATIGUE-CONSTANTS IN-PLANE-MINIMUM-SCF 2.5
```

```
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-MINIMUM 2.5
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 1.0
```

The DEFINE WIND-FATIGUE command contains seven data groups; buffeting wind parameters, wind directions, wind speeds, wind probabilities, drag correction factors, vortex wind parameters and default member fixations. Buffeting wind parameters are specified by DEFINE WIND-FATIGUE WIND-PARAMETERS. The parameters are: constant of coherence function, ground roughness coefficient, turbulence length scales for Davenport and Harris wind spectra, default SN curve, default SCF scheme, damping ratio, chord length/diameter ratio, angular tolerance for analysis planes, lower limit of printed damage values in table print of results, mimimum wind force accouted for relative to maximum force component and limit value on coherence terms accounted for. The angular tolerance parameter is used to decide on which joint/brace intersections shall be associated with which analysis plane.

```
DEFINE WIND-FATIGUE WIND-PARAMETERS
8.0 0.015 1200.0 1800.0 DOE-T EFTHYMIOU 0.01 30.0 1.0 1.E-12 1.E-5 1.E-3
```

By the DEFINE WIND-FATIGUE WIND-DIRECTIONS command wind directions and water depth are defined. In graphic mode they are selected from list boxes of those used in the Wajacanalysis. Up to **six wind directions** may be selected. Only wind directions of one water depth may be considered in the same run. By accessing the wind fatigue module the first six directions (if six directions exits) of the first water depth are transferred to the wind fatigue module. In line mode input the wind directions and water depth specified must comply with those used in the Wajac.

```
DEFINE WIND-FATIGUE WIND-DIRECTIONS ( ONLY 0.0 30.0 60.0 90.0 120.0 150.0 ) 10.0
```

Wind speeds, wind probabilities and drag correction factors are specified by DEFINE WIND-FATIGUE WIND-SPEEDS, DEFINE WIND-FATIGUE WIND-PROBABILITIES and DEFINE WIND-FATIGUE DRAG-CORECTION-FACTORS, respectively. The wind speeds should correspond to speed values at a height of 10 m above ground or sea level. The speeds must have the same unit as the wind speed used in Wajac and should be in m/s. The same wind speeds are applied to all wind directions. Wind probabilities and drag correction factors are specified for each wind speed and each wind direction, which means that n times m values must be entered if n wind directions and m wind speeds have been specified. The wind probabilities are the annual probabilities associated with the corresponding wind speeds and wind directions. The probabilities from all directions should sum to 1.0, which is recomended. Alternatively, the sum is the probability associated with each direction. Note that damages are reported for each wind direction and in sum over all directions. If the sum of probabilities is not 1.0, the program does not normalize or average the damage for the fraction. User should pay attention to this case.

The wind loads and element forces, calculated by Wajac/Sestra are scaled to sizes that correspond to the wind speeds applied in the fatigue calculations. The wind speeds as well as the drag correction factors are included in this scaling. The drag correction factors correct for the effect that the drag coefficient may change, and hereby the wind loading, when the Reynolds number changes. The Reynolds number is a function of the wind speed and thus wind speeds others than the speed applied in Wajac, may give rise to change in drag coefficient. In the formula applied in Wajac, when the Reynolds number is over certain value, the drag coefficient is not a constant but drops. As a result, the actual wind dragging forces do not grow proportionally to the square of wind speed. A proper calculation of the drag correction factors can run a number of wind load cases by Wajac at varying wind speeds, obtain the associated base shears, and get the ratios between the base shear forces of each wind speed over that from the basic wind speed. Thus, the drag correction factors are usually 1.0 for the reference wind speed, and are the corresponding base shear ratios for the other wind speeds of every direction. Wajac stores the wind forces for one wind speed at each direction. This is the reference wind speed. Then Framework will multiply the wind force of the reference wind speed with the drag correction factor to yield the wind forces of the associated wind speeds specified in Framework.

```
DEFINE WIND-FATIGUE WIND-SPEEDS ( ONLY
    10.0 15.0 20.0 25.0 30.0 )
DEFINE WIND-FATIGUE WIND-PROBABILITIES VARIABLE-PROBABILITIES ( ONLY
```

```
    0.30 0.25 0.20 0.15 0.10
    0.35 0.20 0.20 0.15 0.10
    0.40 0.20 0.15 0.15 0.10
    0.36 0.22 0.21 0.11 0.10 )
DEFINE WIND-FATIGUE DRAG-CORRECTION-FACTORS VARIABLE-FACTORS ( ONLY
    1.0 0.90 0.80 0.75 0.70
    1.0 0.91 0.81 0.76 0.71
    1.0 0.92 0.82 0.77 0.72
    1.0 0.95 0.85 0.80 0.75 )
```

Parameters applied in vortex fatigue calculations are specified by `DEFINE WIND-FATIGUE VORTEX-PARAMETERS`. Eleven parameters are included. Default values are available in the graphic user interface mode. Default vortex member ends fixity are specified by `DEFINE WIND-FATIGUE DEFAULT-VORTEX-FIXITIES`. Lower and upper bound values of the fixity and the number of fixity steps are specified.

```
DEFINE WIND-FATIGUE VORTEX-PARAMETERS
    1.225 0.000015 1.0 0.2 4.0 0.1 2.1E11 7380. 1.0E-04 1245. 1.6
DEFINE WIND-FATIGUE DEFAULT-MEMBER-FIXITIES 0.2 0.8 5
```

3.26.7.5 DELETE WIND-FATIGUE command

User defined SN curves may be deleted by the command DELETE SN-CURVE.

```
DELETE SN-CURVE NEW-T
```

Assigned bent can SN curves, bent can SCFs and vortex dimensions for joint connections and members may be deleted by the command `DELETE WIND-FATIGUE BENT-CAN-SN-CURVE`, `DELETE WIND-FATIGUE BENT-CAN-SCF`, `DELETE WIND-FATIGUE VORTEX-DIMENSION`, respectively. Values of all or selected joints/members may be deleted.

```
DELETE WIND-FATIGUE BENT-CAN-SN-CURVE SELECT CURRENT
DELETE WIND-FATIGUE BENT-CAN-SCF ALL
DELETE WIND-FATIGUE VORTEX-DIMENSION SELECT CURRENT
```

3.26.7.6 PRINT WIND-FATIGUE command

Control print of the wind fatigue input data is possible by `PRINT WIND-FATIGUE INPUT`. Various data groups may be selected for print, see below. The number of members, joints, wind directions, eigenmodes and static load cases for which input data shall be printed, may be chosen as ALL or a specified number. The print may be guided to screen or file by `SET PRINT DESTINATION`. Default is print to the screen.

The print of stress concentration factors includes also print of SCF factors and SN curves applied in the last fatigue calculation run carried out.

```
PRINT WIND-FATIGUE INPUT SELECT-MEMBERS NO. 201
PRINT WIND-FATIGUE INPUT SELECT-JOINTS ALL
PRINT WIND-FATIGUE INPUT SELECT-WIND-DIRECTIONS NO. 1
PRINT WIND-FATIGUE INPUT SELECT-EIGENMODES ALL
PRINT WIND-FATIGUE INPUT SELECT-STATIC-LOAD-CASES ALL
PRINT WIND-FATIGUE INPUT JOINT-COORDINATES ON
PRINT WIND-FATIGUE INPUT MEMBER-DATA OFF
PRINT WIND-FATIGUE INPUT WIND-PARAMETERS OFF
PRINT WIND-FATIGUE INPUT VORTEX-WIND-PARAMETERS OFF
PRINT WIND-FATIGUE INPUT SN-CURVES ON
PRINT WIND-FATIGUE INPUT STRESS-CONCENTRATION-FACTORS OFF
PRINT WIND-FATIGUE INPUT EIGENVALUES-AND-EIGENMODES ON
PRINT WIND-FATIGUE INPUT EIGENMODE-ELEMENT-FORCES OFF
PRINT WIND-FATIGUE INPUT STATIC-WIND-LOAD-CASES ON
PRINT WIND-FATIGUE INPUT STATIC-ELEMENT-FORCES OFF
PRINT WIND-FATIGUE INPUT STATIC-NODAL-POINT-WIND-LOADS OFF
PRINT WIND-FATIGUE INPUT SUM-OF-STATIC-WIND-LOADS OFF
PRINT WIND-FATIGUE INPUT RUN-SCENARIO ON
```

3.26.7.7 RUN WIND-FATIGUE command

Execution of the wind fatigue analysis is initiated by RUN WIND-FATIGUE-CHECK. A check of the input is performed before the analysis is started. All relevant input data groups related to wind fatigue (items of the ASSIGN WIND-FATIGUE, CREATE WIND-FATIGUE and DEFINE WIND-FATIGUE commands) must have been entered (i.e. click on OK or APPLY buttons of the dialogue boxes) before the analysis can start. If the check of input is successful the fatigue analysis starts. If not, a message is printed to the screen and the run is stopped. Note that the run name is used as prefix for the fatigue results and diagnostics files.

```
RUN WIND-FATIGUE-CHECK TOWER 'Example case'
```

3.26.8 Program limitations and example of use

A limited number wind directions, analysis planes, etc. can be handled by the wind fatigue module. The limitations are given in Appendix L.

An example of wind fatigue analysis of a frame structure subjected to gust wind loading and vortex shedding induced vibrations is given in Appendix A.2. A multi brace fatigue analysis is performed. The example includes table print of the analysis results.

3.27 How to perform a Direct Deterministic Fatigue

A Direct Deterministic Fatigue analysis is performed for a 2-dimensional frame shown in Appendix A.3. There are 5 load cases defined in Genie. One from explicit loads, the other four from wave analysis.Similarly, the hydrodynamic wave loading with appropriate wave heights and wave periods of all directions are defined and created by Wajacin the time domain; a structural finite element analysis is done by Sestra; the results of the basic load case and the wave load cases are stored in the result interface file Rn.SIN that is read into Framework. In Framework, user needs to specify fatigue load series, and the necessary options to do fatigue analysis.

Note: some caution should be made on the ID or name of load cases in CREATE FATIGUE-LOAD-SERIES if the results are obtained through advanced hydrodynamic or pile-soil interaction analysis. Instead of loadcase, the resultcase created or re-organized by solver is easier to identify. The option to use **RESULT-CASE-ID** is recommended in DEFINE LOAD command. The command should be issued before opening the result SIN file. More details can be found in DEFINE LOAD description and section 2.6.1

The chord and brace relation of members connected at a joint can be automatically decided by Frameworkas default. For some particular It is assumed that the desired 'local' modelling (CHORDS, CANS etc.) of members and joints has been performed through the commands shown in Section 3.2 and Section 3.3 and that NO other commands have been issued.

The following data are commonly needed for a fatigue analysis:

- Fatigue target life and safety factor

  ```
  DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
  DEFINE FATIGUE-CONSTANTS FATIGUE-EXPOSURE-TIME -1.0
  DEFINE FATIGUE-CONSTANTS DEFAULT-FATIGUE-SAFETY-FACTOR 1.0
  ```

- A default SN curve

  ```
  DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE API-XP
  ```

- Splash zone elevation limits.

  ```
  DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-UPPER-LIMIT-ELEVATION 5.0
  DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-LOWER-LIMIT-ELEVATION -2.0
  ```

  This information is to be used to automatically determine the elevation dependent SN curve data. The elevation should be entered in the same unit as in the structural model.

- Joint Type and Gap option

  ```
  ASSIGN JOINT-TYPE ALL ( ) LOADPATH
  ASSIGN JOINT-GAP ALL ( ) AUTOMATIC
  ```

The LOADPATH type will use what the program has determined about chord and brace connection relation and the associated type of the brace member under concern. Also, the load split due to load path is calcualted and the percentage will be applied as the weight on the combined SCF of joint; The gap between two k type braces will be calculated by the program.

- Stress concentration factors at joints
  The parametric formula such as EFTHYMIOU, or KUANG can be used. To make the best use of the parametric formula, the joint type and gap should be specified properly.
  `ASSIGN SCF JOINT ALL ( ) None PARAMETRIC EFTHYMIOU`
- The GLOBAL stress concentration factors can also be used if necessary. They are defined as the fatigue constants:

```
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 1.0
```

- SCF formula at butt-weld and conical transitions

```
DEFINE FATIGUE-CONSTANTS FABRICATION-TOLERANCE-OPTION 0.15TS
DEFINE FATIGUE-CONSTANTS DEFAULT-FABRICATION-TOLERANCE 0.0
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2014
```

To perform a Direct Deterministic Fatigue analysis, let Framework read in the result .SIN file.

```
FILE OPEN SIN-DIRECT-ACCESS 'DirectFat_' R1
FILE TRANSFER 1 JACKET LOADS None
```

It is required to use **SELECT FATIGUE-CHECK-TYPE** to inform the program to do direct deterministic fatigue and avoid any automatic switching to deterministic and spectral fatigue when there are wave loads.

```
SELECT FATIGUE-CHECK-TYPE DIRECT-DETERMINISTIC
```

The key step for a Direct Deterministic Fatigue analysis is to **CREATE FATIGUE-LOAD-SERIES**. It may be necessary to use load combinations that are not defined before. Framework has the feature to create new load combinations from the basic load cases. For example,

```
CREATE LOAD-COMBINATION LCOMB None STATIC ( ONLY
    2     1.333
    4     1.333 )
```

Now, two fatigue load series are created. One of them uses the new load combination and chooses MAXMIN stress range method; the other uses SRSS method.

```
CREATE FATIGUE-LOAD-SERIES SR1 None 1.0E4 1.0 BY-LOADCASE MAXMIN ( ONLY
    LCOMB      1.0
    LCOMB     -1.0 )
CREATE FATIGUE-LOAD-SERIES SR2 None 1.0E3 1.0 BY-LOADCASE SRSS ( ONLY
    2     1.0
    3     1.0
    4     1.0
    5     1.0 )
```

After the fatigue load series are created, it is recommended to confirm them using command `PRINT FATIGUE-CHECK-TYPE`. The existing fatigue load series will be printed out.

```
   ........ Direct Deterministic Fatigue .........
  Fatigue Load Series ............ NAME       CYCLES         WEIGHT
                                   SR1      0.1000000E+05     1.000
      LC   NO.   NAME     Factor
           1    LCOMB    1.000
           2    LCOMB    -1.000
      Stress Range calculation option: MaxMin
```

```
 Fatigue Load Series ..... NAME       CYCLES         WEIGHT
                           SR2      0.1000000E+04     1.000
     LC   NO.   NAME     Factor
          1    2        1.000
          2    3        1.000
          3    4        1.000
          4    5        1.000
     Stress Range calculation option: SRSS
```

Currently, there is no CHANGE feature to modify an existing fatigue load series. If any un-wanted fatigue load series exists, user has to DELETE it and CREATE it again.

A dump file showning the intermediate results can be printed. Direct Deterministic Fatigue shares the same dump file option with regular Deterministic Fatigue. Only the command for HOTSPOT-STRESS-RANGE is needed to activate the DUMP print.

```
DEFINE FATIGUE-DUMP FILE-NAME FRAMEWORK
DEFINE FATIGUE-DUMP HOTSPOT-STRESS-RANGE ON
```

Then, the fatigue analysis can be run on selected members.

```
SELECT MEMBERS INCLUDE ALL
RUN FATIGUE-CHECK DDF None ALL ( )
```

The results may be printed or displayed for all members checked with a usage factor greater than 0.0. To print the results, the following command is used:

```
PRINT FATIGUE-CHECK-RESULTS DDF SELECTED-MEMBERS ( ) FULL ABOVE 0.0
```

The notation used for the output is the same as the NOMENCLATURE for stochastic fatigue. An example of Direct Deterministic Fatigue analysis of a simple 2-dim frame structure subjected to explicit loads and wave loads is given in Appendix A.3.

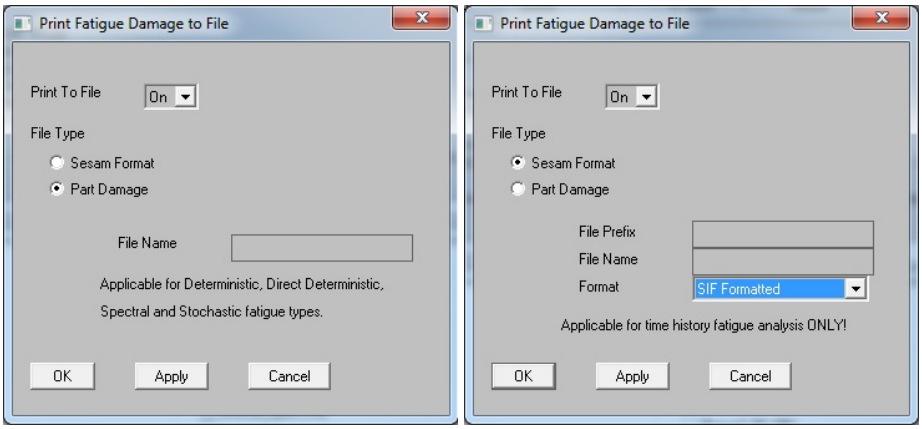


Figure 3.15: Dialogbox of DEFINE Fatigue Damage to File

3.28 How to specify initial Fatigue Damage

3.28.1 Fatigue Part Damage

There are 4 ways to define the initial fatigue damage:

1. DEFINE Fatigue Constants ACCUMULATE-FATIGUE-RUN run-name
2. DEFINE Fatigue Constants GLOBAL-FATIGUE-PART-DAMAGE value (if no LOCAL FPD, the GLOBAL value is to be used.)
3. ASSIGN Fatigue Part Damage Joint or Member
4. ASSIGN Fatigue Part Damage <Read File>,

where method (1) is exclusive to the others. In detail, methods (2,3,4) consider the fatigue part damage as the property of one fatigue check position while method (1) stores the damage as the result of a fatigue run. The initial damage can be imported from either FPD or a Run, not both.

Method (4) requires to save a damage file in the previous fatigue analysis. The feature to output fatigue damage to file has been expanded since release v3.14. The detailed guide is given in the next Section 3.28.2 and 3.28.3.

3.28.2 Output a fatigue part damage file

The damage file output used to be available for Time History fatigue analysis only. Since release v3.14, the damage file output and import can be applied for Deterministic, Direct Deterministic, Spectral and Stochastic fatigue analysis types as well. There are two file formats supported for a fatigue damage file: one is the standard Sesam formatted file, *.SIF* that is only applicable for Time History fatigue analysis; and the other is the new format *.FPD* file for the other fatigue analysis types.

To save a standard Sesam format file, SIN or SIF, use the command

```
DEFINE FATIGUE-DAMAGE-TO-FILE ON filename
```

The associated dialogbox is shown in Figure 3.15.

To save a *.FPD file, the command is

```
DEFINE FATIGUE-DAMAGE-TO-FILE ON PART-DAMAGE filename
```

The DEFINE command must be issued before the fatigue analysis run. During the fatigue run, the program will output a part damage file with extension *.FPD*. The file does not have prefix and is stored at the default Framework workspace folder. User can specify the filename. The extension *.FPD* will automatically append on the filename's text. If the place of "filename" is empty, e.g. `...ON PART-DAMAGE ' '`, the program will use Damage_*runname.FPD* as the default name. After the fatigue damage file is specified, the damage of

all hotspots at every fatigue position of the members included in the current fatigue run will be saved to a binary file. If there is already a file with the same filename, or the filename is repeated, the old existing file will be renamed to a standard **.bak* file.

3.28.3 Import a fatigue part damage file

The command to import a fatigue damage file is:

```
ASSIGN FATIGUE-PART-DAMAGE READ-FILE <Filename.FPD>
```

The program will read each member on damage file and look it up from the current database. The members' name strored in the damage file and created in the current Framework run is critical. The member name should match when identifying the member on damage file in the database. In order to combine the damage at each hotspot correctly, there are a few restrictions on the application of damage file output and import. Some preparation work must be done prior to saving a damage file.

1. **Near Chord Rule** is recommended to be "ON". The default is "OFF". This is a new option available since release v3.14. The original method to differentiate the chord member and the aligned member of a brace depends on the local coordinate system of the chord. See 2.3.4. With the original method, the chord member and aligned member may swap if the structure rotates from vertical to horizontal place. The Near Chord Rule is to avoid chord member changing in this scenario. It is strongly recommended to use the command `DEFINE NEAR-CHORD-RULE ON` before opening the result .SIN file when the damage output/import is to be performed.
2. The "Read Concept" option in Framework is recommended to be ON which is the default. It is suggested to make the member's concept name match in the damage file and in the result SIN file. In general, user needs confirm the option about member's name is consistent before importing the damage file. The member's name in FEM model and conceptual model usually do not match. Note that the member's name in the FEM (or superelement) model is the finite element's external number. In this case, the finite element numbers very likely change due to re-meshing. In two analyses, the FEM model can vary; two members with the same name may be different. It is not guaranteed that the members and positions match although their names (element NO.) are the same. Therefore, using FEM model in damage file output and import is not recommended.
3. The BEAM-SPLIT option may impact the name of concept member. The option must be consistent, i.e., the SPLIT options in current Framework run must be identical to what has been issued when generating the damage file.
4. The number of fatigue positions on two matched members must equal and the position ID must match. (Except for SIF file, which does not include position's name.) Therefore, if ASSIGN Position commands have been used when generating the damage file, it is required to repeat the commands before reading the damage file.
5. The cross section type of the associated positions of two matched members must be the same. (Except for SIF file, which does not include cross section information)
6. The damage values at all hotspots are considered as the Fatigue Part Damage (FPD) of the fatigue check position; the damage stored in file will overrule the existing FPD if there is any; the damage will not accumulate to existing FPD. Using the command ASSIGN Fatigue Part Damage to Joint or Member will override the FPD from the damage file too.
7. The FPD rule on hotspot distribution will become "LOCAL" and "NON-SYMMETRIC" for members with damage stored in file.
8. The calculated fatigue damage will be accumulated with FPD that is the initial damage.
9. Support fatigue damage file with both new format *.FPD* file and Sesam formatted file, *.SIF*, which is for Time History fatigue analysis. In a SIF formatted damage file, the TDFATDAM and RVFATDAM lines must match, i.e. have equal member's number and positions number.

New commands:

```
ASSIGN FATIGUE-PART-DAMAGE READ-FILE Damage_DDT1.FPD
DEFINE FATIGUE-DAMAGE-TO-FILE ON PART-DAMAGE file name
```

During the process of reading in the damage file, some messages will be printed to the MLG file. A successful member identification and damage readin usually generates the following messages.

```
       On file member:     M141   4 Positions; Dscr: $CT$Bm_503L_603L
        - Matched members have different name:     M141      M177
        - Member found and Positions number equal.
        - Initial damage of member     M177 in model has been updated.

      On file member:     BM15   6 Positions
       - Member found and Positions number equal.
       - Initial damage of member     BM15 in model has been updated.
```

When the file read is done, a summary will be shown as below.

```
       Reading damage file DONE ---:  304 members on file;
                                ---:  116 in database updated.
     * WARNING:  188 Un-found/Un-matched members
```

If there is any problem, such as member not found, inconsistent use of FEM model and concept model, un-matched positions or cross sections, and un-matched chord of the brace, the messages will be like the following.

```
       On file member:     M196   4 Positions; Dscr: $CT$Bm_8026_8027
        - NO matched member found in result SIN. <Skip!>

   ** Damage file is based on FEM model. Current database is on concept!

      On file member:     BM21   5 Positions
       - Member found but positions number not equal. <Skip this member.>

      On file member:      BM4   5 Positions
       - Member found and Positions number equal.
    *  Warning - members have different chord at end 2:       13
               - Member      BM4 in model has Chord: M41   $CT$Bm21_test_0001
               -                               Align: $NONE
               - Member      BM4  on file has Chord: $NONE
               -                               Align: $NONE
       - Initial damage of member      BM4 in model has been updated.

      On file member:     BM21   4 Positions
       - Member found and Positions number equal.
       - Position  1 not matched on SECT type: GIORHR-GPIPE
         Skip this position.
       - Position  2 not matched on SECT type: GIORHR-GPIPE
         Skip this position.
       - Position  3 not matched on SECT type: GIORHR-GPIPE
         Skip this position.
       - Position  4 not matched on SECT type: GIORHR-GPIPE
         Skip this position.
       - Initial damage of member     BM21 in model has been updated.
```

It is strongly recommended to check the MLG file after the damage file is read in. In some case, the modification to the model or even re-generating the damage file is necessary.

4 Execution of Framework

Framework is available in the following hardware environments:

- PCs that run Windows 7 64 bit and Windows 8.1 64 bit operating systems

Framework may be run in two different modes:

- In interactive graphics mode with menus and dialogue boxes where input may be given using a mouse as well as the keyboard. The interactive graphics mode facilities are described in Section 4.4, in addition this mode also gives access to the line mode facilities.
- In batch mode, which uses the line mode syntax and facilities described in Section 4.3.

The start up of Framework in the two different modes is described in Section 4.1. This section also describes the files that Framework uses.

The program requirements and limitations are described in Section 4.2 and in Appendix L.

4.1 Program environment

Framework accesses the Sesam Results Interface File on direct access (SIN) format.

The Sesam analysis program Sestra will by default store the results on direct access NORSAM (SIN) format.

Sestra may also store the results in formatted and unformatted sequential files (SIF and SIU, respectively) in which case the Sesam program Prepost must be executed in order to create a SIN file, see the Prepost User Manual for advise.

How to start the program in the different modes is described below.

4.1.1 Starting Framework in graphics mode

Framework can be started from Sesam Manager provided there is a results file (SIN file) stored in the Sesam Manager repository.

Sesam Manager will establish the initial Framework input for opening the results file and transferring the superelement into the Framework database (MOD) file. Sesam Manager allows specifying the superelement number and key in case these differ from the default value 1.

Framework can now be operated as described in Section 4.4.

To exit the program, choose the Exit option under the File menu. Framework will then close all open files and exit.

4.1.2 Starting Framework in batch run

Framework must be run in line mode during a batch run.

The batch command file can look like this:

```
<prompt> \<path>\framework[.exe] /status=new /interface=line /command='filname' /forced-exit
```

This command will start Framework and establish a new database (`/status=new`), run the program in line mode (`/interface=line`), use command input defined on file 'filename' (`/command='filename'`) and exit the program after executing the input commands (`/forced-exit`). The referred input file must be a text (ASCII) file with file extension JNL containing the Framework input commands.

The header and messages given by Framework will appear on the LOG file.

4.1.3 Files and data safety

Table 4.1

File type	Extension	Reads from	Writes to	Format
DATABASE	.MOD	YES	YES	Binary
Result Interface	.SIN	YES	NO	Binary
JOURNAL	.JNL	NO	YES	ASCII
COM.INPUT	.JNL	YES	NO	ASCII
PRINT	.LIS	NO	YES	ASCII
PLOT	.PLO	NO	YES	Binary

The DATABASE (also named MODEL file) is a direct access file that is used to keep the model and code/fatigue check results. It has the extension: '.MOD'.

The RESULTS INTERFACE FILE (often named SIN-file) file is a direct access file that keeps the results from the finite element analysis. This file is only read from, but must always be kept available in the same location after first accessed using the FILE READ command. It has the extension: '.SIN'.

The JOURNAL (also named COMMAND LOG) file is used to keep a log of most of the commands that are accepted during a Framework session. If an existing (OLD) database is opened, the journal will be appended to the corresponding old journal file if this exists. The journal file has the extension '.JNL'.

The COMMAND INPUT file is used to read commands and data into Framework. The usage of command input files is described in Section 4.3. The default extension of a command input file is '.JNL', but this default is not used if another extension is specified.

The PRINT file is used to keep output from the PRINT command when the print destination is set to file. The extension of the print file is '.LIS'. The print file name and settings is specified using the command: SET PRINT. It is possible to use more than one print file during the same Framework session, but only one can be open at a time.

The PLOT file is used to keep output from the PLOT command and from the DISPLAY command when the display destination is set to file. The plot file name and settings is specified using the command: SET PLOT. The extension of the plot file depends on the plot format used. If the Sesam neutral format is used, the extension is '.PLO'. Several other formats are available, including Postscript with extension '.PS'. It is possible to use more than one plot file during the same Framework session, but only one can be open at a time.

Framework has been designed to protect the user against loss of valuable data. Thus, for some of the errors that may occur, Framework will close the database file before exiting the program. It is however not always possible to catch a program crash and close the database file properly when it happens.

If the database file has been corrupted, the information may be reconstructed by use of the journal file. It is therefore recommended to take good care of the journal files. It can also be a good idea to take backup copies of the journal and database file regular intervals.

4.2 Program requirements

4.2.1 Execution time

The execution time depends heavily on the type of analysis and on the model functions that are used.

The most time consuming command is RUN. When checking all members and all loadcases for a model, use of the batch mode is recommended.

4.2.2 Storage space

Table 4.2

Analysis type	Number of loadcases	Size of SIN file (K bytes)	Size of model file (K bytes) Before check / After check
Code Checks	24	225	416 / 6.240
Deterministic fatigue	72	626	432 / 480
Stochastic fatigue	20	306	416 / 448

The initial size of the database is about 150 KB. The FILE READ command will usually not expand the database very much, since the actual results are not transferred from the SIN file. The most significant contributor is the storage of analysis results after RUN commands.

Framework has been designed such that results from previous code check and fatigue check runs are retained. If the database becomes too large, it may be recommended to start again with a clean database, read the model and results again, and redo all assignments and model changes by running an edited command log file.

As an example, for the jacket model shown in Appendix A, the size of the SIN files produced by Sestra/Prepostwere as given in Table 4.2. After the model had been read into Framework, the model size was as given in the last column, before the slash. Finally, after additional data had been assigned, code check/fatigue analysis performed and results stored, the model files reached the size given after the slash, in the last column.

4.3 Details on line mode syntax

The line mode environment in Framework is very powerful. It has many features and provides a great flexibility to the user. This section describes the facilities one by one. Even when running graphics mode, the line mode environment is available through the command input line.

There are two modes of operation inside the line mode environment, called 'command mode' and 'programming mode'.

Command mode is the commonly used mode, it is used to give commands to Framework. A new input line always starts in command mode. To switch to/from programming mode inside an input line, type the dollar sign: $.

Programming mode is used basically to calculate numerical values. These values can then be used in a command if desired, or they can be viewed as results. Programming mode will have limited value for Framework use.

When moving through the commands, Framework will present a prompt, possibly followed by a default in / /. The main command level is signified by the prompt: No default is presented here. The main commands are ASSIGN, CREATE etc. These are described in section 5. When moving inside a command the prompt will change and a default may be presented.

Different items on the command line are separated by blank spaces, except if it is text that is protected inside quotes. In special cases, the blank space may be left out. Such cases are documented in the sections below.

Framework does not require line breaks anywhere, except for a few cases in programming mode (these are not included in this manual). Thus several commands can be typed into the same command input line. This is however not recommended as it easy to lose oversight in such a case.

In the following, input typed by the user is shown in bold face while prompts given by Framework are shown as ordinary text.

4.3.1 How to get help

Context sensitive help is available in command mode at any time using any of these methods:

Type: ?	to get a brief description of what Framework is expecting right now
Type: <text>?	during a selection between alternatives to see all the alternatives that match <text>. <text> may contain wildcards or be an abbreviation
Type: ??	to get a more descriptive help text, showing how to proceed.

There is also a HELP menu under the main menu, giving on-line access to the items that are described here.

4.3.2 Command input files

Line mode commands may be read from a file as well as typed directly into Framework. Such a file may contain any syntax that is allowed in line mode, including reading another command input file.

To read in a command input file, type an @ followed by the file name. To read parts of the file, specify the number of lines to read after the file name. If the file name does not have a suffix (i.e. a dot and the following part), Framework adds '.JNL' to the name.

Framework may have more than one command input file open at one time. It will always read the files sequentially, finishing the last opened file first. To get a list of the currently open files, type: @?

The last opened command input file may be closed explicitly by typing the @ followed by two dots: @..

When a command input file is being read, the lines read are echoed on the screen and logged on the journal file. Programming expressions are logged as comments and the resulting values are logged as part of the command. The @ command itself is not logged on the journal file.

If an error is found inside a command input file, Framework stops reading the file and skips the remaining part of the line where the error was found.

Framework will also stop reading of a command input file if it finds a line containing only an @

The commands used to manipulate command input files are summarised below.

@filename	Read the named file from the top. Reading will stop is an error if found, or at the end of the file, or if a line with only an @ is found. There may be one or more blank spaces between @ and the file name
@filename <n>	Read <n> lines of the named file from the top. Reading will stop if an error is found, or if a line with only an @ is found. There may be one or more blank spaces between @ and the file name
@	Continue reading the presently open file. Reading will stop if an error is found, or at the end of the file, or if a line with only an @ is found
@ <n>	Continue reading the presently open file. Reading will stop if an error is found, or if a line with only an @ is found
@..	Close the last opened command input file. There cannot be any blank space between @ and the dots
@?	Show the name and status of the currently open command input file(s)

4.3.3 Accessing default values

Framework will in many cases supply a default value when input is requested. The default value will be presented in / /. An example:

```
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE
Target fatigue life ? /1.0/
```

The default may be accepted using one of the following methods:

<Return>	(i.e. an empty input line) to accept the current default
: (colon)	to accept the current default. The colon must be preceded by a blank if it is not the first item on the command line. However, several colons may follow each other without intervening spaces
; (semicolon)	to keep accepting defaults as long as they are presented, or until the command is complete. The semicolon must be preceded by a blank space if it is not the first item on the command line. However, several semicolons may follow each other without intervening spaces.

Please note that an empty line in a command input file will not be interpreted as a default. The colon and semicolon may be written into a command input file.

A colon or semicolon is never logged on the journal file. Instead, the substituted default value(s) is logged.

4.3.4 Abbreviation and wildcards

Framework offers two methods to shortcut selection of elements in a list: Abbreviation and the use of wildcards.

Abbreviation allows abbreviation of alternatives up to hyphens, as long as the abbreviation is unique. Thus, CODE-CHECK may be abbreviated to any of: CODE, C-C, CODE-C as long as the abbreviation is unique between the alternatives presented.

Wildcards consist of the following two characters:

*	substitutes for any number of characters. It also matches nothing
&	substitutes for any one character. It must match exactly one character

As an example, *y&&& matches xabycc1 and xy111 but not xaby11.

Abbreviation and wildcards may not be mixed in the same matching expression.

4.3.5 Input of a text or name or numerical value

Numerical values can be input in a very free format in Framework. Floating point numbers as: 1000 1. .54 1e-44 .1e5 are all accepted.

Whole numbers can be specified as floating point numbers, as long as the decimal part vanishes. Examples of whole numbers: 1000 1. .1e4

Names can be up to 8 characters long and may contain any alphanumeric character as well as the underscore (_) and the hyphen (-). A name may be a pure number, or may begin with an alphanumeric character. The input case of a name is NOT preserved, but is converted to upper case.

Text must be protected in single quotes (’ ’) if it contains blank space(s) and/or special characters and maximum 72 characters.

4.3.6 Selecting a single alternative from a list

In many cases, Framework will require a selection of a single alternative from a list. An example is right at the start, at the main prompt: # , where the main commands are presented for selection. The selection need not be a selection between commands, it could also be a selection between named objects or between numerical values.

In selection of a single value abbreviation is allowed (see Section 4.3.4), but wildcards cannot be used. An exact match is always preferred. Thus it is possible to select an item that is an abbreviation of another item in the list by typing the item exactly.

A single question mark: ? will show all items in the list. Prefixing the question mark with a a text: <text>? will show all items in the list matching <text>.

The input text may be typed in upper or lower case as desired, Framework disregards the case of the text when it does the comparison.

The input text used to make the selection is not logged on the journal file. Instead, the selected value is logged as it is presented in the list.

4.3.7 Selecting several alternative from a list

In some cases, a list of items is presented, from which one or more items can be selected. An example is the PRINT SN-CURVE command, where a number of variables may be selected for print. The graphical user interface will look like Figure 4.4 when a list is available.

In this selection, both wildcards and abbreviation may be used (but not inside the same text).

The syntax for the selection allows for more flexibility than in the single selection case, because it may be of interest to keep modifying the selection for some time before accepting it. The selection process consists of one or more selection operations, each of which follow the syntax described below. If more than one operation is required to complete the selection, the selection must be enclosed in parentheses: ( )

The syntax for a single selection operation is:

INCLUDE <text>	Include the item(s) matching <text> in the selection. Set the default status to INCLUDE. Any items specified after this will be included in the selection until the status is changed
ONLY <text>	Set the current selection to the item(s) matching <text>. Set the default status to INCLUDE. Any items specified after this will be included in the selection until the status is changed
EXCLUDE <text>	Exclude the item(s) matching <text> from the selection. Set the default status to EXCLUDE. Any items specified after this will be excluded from the selection until the status is changed
<text>	Include or exclude the items matching <text>, depending on the default status. The initial default status is INCLUDE

In the case of a selection of numerical values, or of a selection between names (which can be integer values), the <text> can be substituted with the interval expression:

```
GROUP <from> <to> <step>
```

which expands to the values: <from>, <from> + <step>, <from> + 2 * <step>, ...

up to but not exceeding <to>.

When a default selection is being presented, or if the left parentheses has been typed as input, Framework presents the right parenthesis as default: /)/.

A single question mark: ? will show all items in the list, listing the selected items in parenthesis. Prefixing the question mark with a text: <text>? will show all items in the list matching <text>.

Examples:

```
PRINT SN-CURVE *
```

will print all SN-CURVES.

```
PRINT SECTION ( * EXCLUDE 1* )
```

will print all sections except those with name starting with 1.

4.3.8 Entering a vector or matrix of values

The syntax for entering a vector or matrix of values is an extension of the syntax for selecting values from a list. In this case there is no fixed list to select from. Instead the items are inserted and manipulated as the vector/matrix is entered.

The term vector is used for the case where the input is one dimensional. An example of this is entering parameter values in the DEFINE CONSTANT PHASE-ANGLE command.

The term matrix is used for the case where the input is multidimensional. An example of this is the input of local stress concentration factors. Like a vector is built up from single items, a matrix is built from rows. There cannot be an unequal number of items in two different columns of a matrix.

The input of a vector/matrix is consists of one or more operations. If more than one operation is required (as it most likely will be), they must be enclosed in parentheses.

The syntax of one operation is (<row> refers to a single value in a vector or to a row in a matrix):

INCLUDE <row>	Include the specified <row> as the last row. Set the default status to INCLUDE. Until the status is changed, rows that are entered will be added at the end.
EXCLUDE <row>	Exclude the specified <row>. Set the default status to EXCLUDE. The next row(s) that are entered will also be excluded until the default status is changed. Wildcards may be used to specify <row>. All matching rows will be excluded
ONLY <row>	Include only <row> in the matrix, clearing any previous contents first. Set the default status to INCLUDE. Until the status is changed, rows that are entered will be added at the end
INSERT-BEFORE <row1> <row2>	Insert <row2> before <row1>. Set the default status to INSERT-BEFORE. Until the status is changed, rows will be keep being inserted before <row1> (immediately after the last row entered). Wildcards may be used to specify <row1>, provided that one row is matched uniquely
OVERWRITE <row1> <row2>	Overwrite <row1> with <row2>. Set the default status to OVERWRITE. The next row(s) that are entered will continue overwriting until the default status is changed, scrolling down as they do so. When the last row has been overwritten, the default status is changed to INCLUDE. Wildcards may be used to specify <row1>, provided that one row is matched uniquely
LIST	List the contents of the matrix
<row>	Insert, Exclude or overwrite, using <row>, depending on the default status. The initial default status is INCLUDE

When a default vector/matrix is being presented, or if the left parenthesis has been typed as input, Framework presents the right parenthesis as default: /)/.

A single question mark will show the possible alternatives in the matrix.

Use LIST to see the rows in the matrix.

4.3.9 Setting and clearing loops in a command

When a command is completed, Framework will by default go back to the main prompt: #. If a command is to be repeated many time in slightly different versions, it can be desirable to not go back to the main prompt, but rather to some intermediate level. This is accomplished by typing in the text: LOOP at the point where the command is to be repeated. The loop is removed by typing END at the loop point, or by aborting the command using the double dot (..).

Example:

```
ASSIGN WAVE-DIRECTION-PROBABILITY
LOOP
 0 0.25
 45 0.65
```

```
 90 0.10
END
```

4.3.10 Inserting a command into another command

It is possible to insert a command at any point while in command mode (not in programming mode). This is done by simply typing the main prompt: # followed by the inserted command.

Framework will finish the new command, and then return to the point in the previous command, where the new command was inserted.

This is useful e.g. for catching up on settings or definitions that was forgotten while inside a PRINT or DISPLAY command, or for printing out objects to see what they contain. The following example illustrate this:

```
DISPLAY MEMBER # SELECT MEMBERS ONLY
```

The same command cannot be entered recursively, e.g. it is not allowed to insert a PRINT MEMBER command inside another PRINT MEMBER command.

Commands can be nested this way to as many levels as desired. However, to nest with more than one level may be confusing and is not recommended. The current status may be seen by typing: -?. This facility is described in Section 4.3.14.

4.3.11 Aborting all or parts of a command

To abort a command, type two dots after each other (..). Please note that all entries on the command line up to the double dot will be processed before the command is aborted.

The double dot clears all loops and previous input in the command and then presents the main prompt: #.

A double dot is not logged, except for one case: If it is used after an inserted command has been completed. The reason is, that the completion of the inserted command causes the first part of the command to be logged before the inserted command. It is therefore necessary to log the double dot in this case, so that the log file will have a correct syntax.

To abort parts of a command, going back to the last LOOP or to the point of a left parenthesis in a multiple selection or a vector or a matrix, type: <<<.

Ctrl C may also be used to abort a command (hold the Control (often named ‘Ctrl’) key while typing C). Usage of Ctrl C will throw away all of the input of the command line as well as abort the command. Unlike the double dot, the input before the Ctrl C is not processed. Ctrl C may also be used to abort a running analysis.

4.3.12 Access to the operating system

It is possible to issue a command to the operating system at any point in a Framework command (not from programming mode). This is done by typing an exclamation mark: ! followed by the operating system command. Everything on the input line after the exclamation mark is sent to the operating system.

Giving only ! on the command line will open a new sub-process. It must be terminated using the command LOGOUT.

This facility is very useful for obtaining directory listings, editing files (e.g. input files), spawning into the operating system to do more complicated tasks, etc.

This facility is also available from the command input line in graphics mode, but, when used here the output from the operating system will appear in the terminal window from which Framework was started.

4.3.13 Appending input lines

After receiving an input line, Framework will process the input, unless told otherwise. The way to suspend processing of an input line is to type a backslash: \ as the last character in the line. Framework will then issue the append prompt: ».

4.3.14 Viewing the current status of a command

Some commands are long, and it may be difficult to keep track of what has actually been given as input. In other cases where commands have been inserted, it is good to be able to see what the current command(s) actually look like to Framework. For this reason, the command: -? has been introduced.

4.3.15 Comments

A comment may be typed anywhere in a command while in command mode (not in programming mode). Comments are prefixed by the percent sign: %. Everything from the percent sign to the end of the line is treated as a comment. A comment need not be the first item on a line. Examples:

```
DEFINE CONSTANT GRAVITY 9.81 \% Assume units Newton and Metres
% This is a comment.
```

4.4 Details on graphic mode

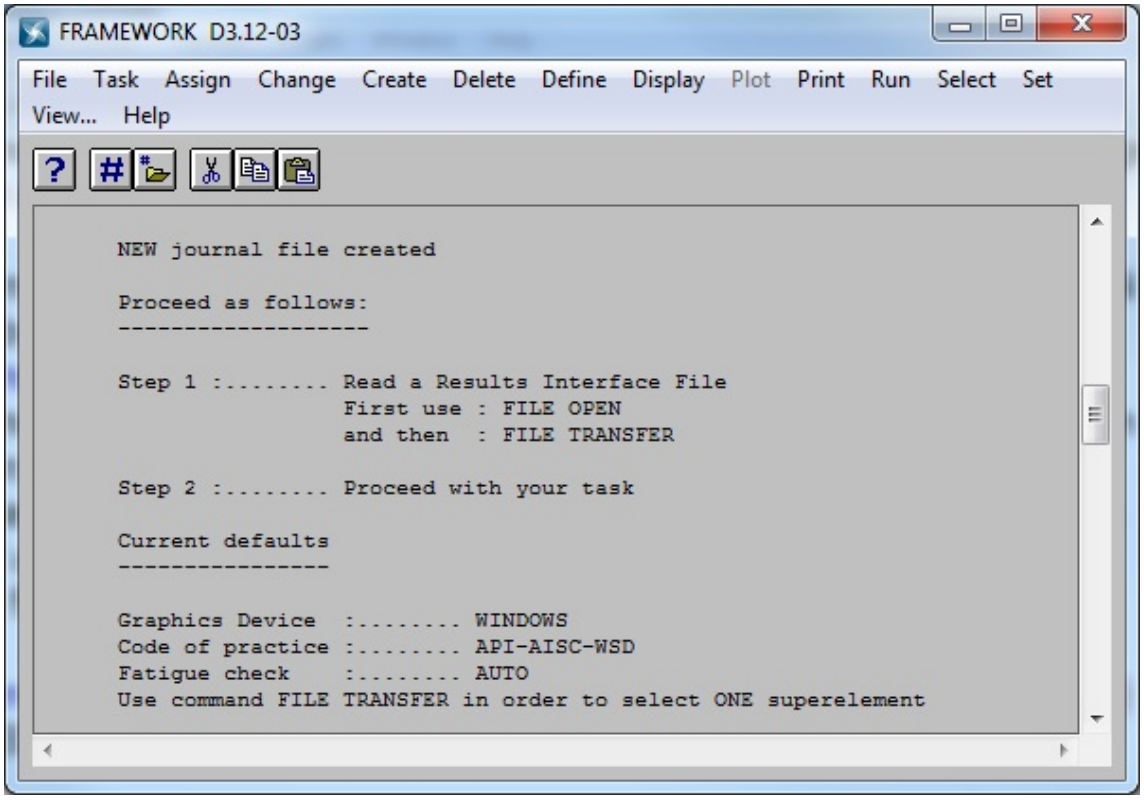


Figure 4.1: The main window

The Frameworkgraphics environment offers a main window with the following parts (from top to bottom):

- Title bar. This is the name of the program that is being run
- Main menu. This menu gives access to all the commands of Framework
- Message area. This is used to show messages to the user, plus commands that have been typed into the command input line, as well as those that have been read form command input files.
- Command input line. This line contains the prompt for line mode input (showing the default when this is available), followed by a field which is used to type line mode commands. All facilities that are described in Section 4.3 are available through this line.

If the main window is dialogue, all the open dialogue boxes disappear into the icon. They pop up again when the main window is popped up. In addition to this, the graphics environment consists of:

- Pulldown menus. These are pulled down from the items in the main menu. They are activated by clicking on an item in the main menu with the left mouse button, or by holding the left mouse button down on an item in the main menu. Similarly, some of the items in a pulldown menu may have a submenu sliding sideways from the parent menu. To select an item in a pulldown menu, click on it or drag the mouse pointer to the item and release the button.
- Dialogue boxes. Much of the user interaction will happen through dialogue boxes. Those items in the pulldown menus that have three dots following the item label, all open a dialogue box when selected. The dialogue box is described more fully in Section 4.4.2.
- Print window. After the first Print command has been issued, a print window will pop up. This is a scrollable window, that contains all the output from the Print command, that is directed to the screen. The window has a limited buffer, so if a single print command generates excessive amounts of print, some of it may disappear out of the top of the window. The print window may be iconized separately from the main window. It is possible to print inside an iconized print window. It does however not pop up automatically from an iconized state when something is printed.

4.4.1 How to get help

There is a Help menu under the main menu, which contains much useful on-line information.

4.4.2 Dialogue boxes and their contents

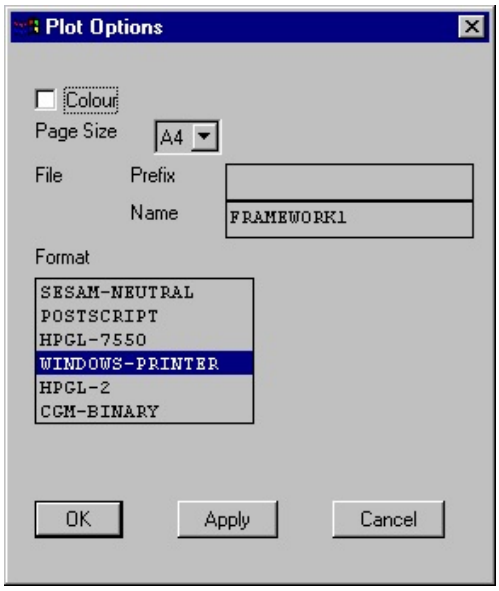


Figure 4.2: The Set Plot dialogue box

A dialogue box is used to pass information from the user to Framework. Most dialogue boxes also present the current defaults, and thus may be used to pass information from Framework to the user.

The typical entries in a dialogue box are: **Input fields**, **Menus** and **Pushbuttons**.

An Input field can contain a text, a name, a whole number or a numerical value. The Set Plot dialogue box contains two input fields: the file prefix and the file name description. To type into the field, click in it first using the left mouse button. In some input fields, the text can be longer than the width of the field as shown in the dialogue box. The text will then scroll if typed beyond the width of the input field.

Menus come in four different types: **Togglebuttons**, **Radio boxes**, **Option menus** and **Scrollable lists**.

Selecting in a menu may cause considerable changes in the layout of the dialogue box. This will depend on the dialogue box in use.

A **Togglebutton** is a button that has two states: On and Off. One examples is given in the Set Plot box, where the Colour button is Off. Click on the button or on the corresponding label to switch the status of the button.

A **Radio box** is a collection of togglebuttons, where only one of the buttons can be active at any one time. All buttons are visible on the screen simultaneously. An example is the Members buttons the Select Member box. Click on a button or on the corresponding label to select that button.

An **Option menu** is similar to a radio box, in that it presents a number of alternatives, of which only one is active at any one time. It is however operated differently. Click on the menu (not the corresponding label) to bring up the list of alternatives. Then click on an alternative to select it. Alternatively, click on the menu and hold the button down, then move the mouse pointer through the menu to the selected value, and then release the mouse button. Page size menu in the Set Plot box is an example of an option menu.

A **Scrollable list** is a list of alternatives, that is presented in a scrollable box. Such a menu is used in order to preserve space, or because the items in the list cannot be predicted before the menu is used. Use the scrollbar to manoeuvre through the list, and select a value by clicking on it. Only one value can be selected at any one time. The Format list in the Set Plot box is an example of a scrollable list.

A **Pushbutton** is a button, that causes an action to happen when it is clicked on.

OK, Apply and Cancel buttons are represented in the Set Plot box shown above. All dialogue boxes have a standard set of buttons at the bottom of the box. These buttons are described later in this section.

If the label of a pushbutton is followed by three dots, the button will open a new dialogue box. The Assign dialogue boxes often contain pushbuttons that provide a shortcut to boxes placed under the Select main command.

In addition to these items, there are a few more complex input items, that are described in the following sections.

4.4.3 The standard buttons in a dialogue box

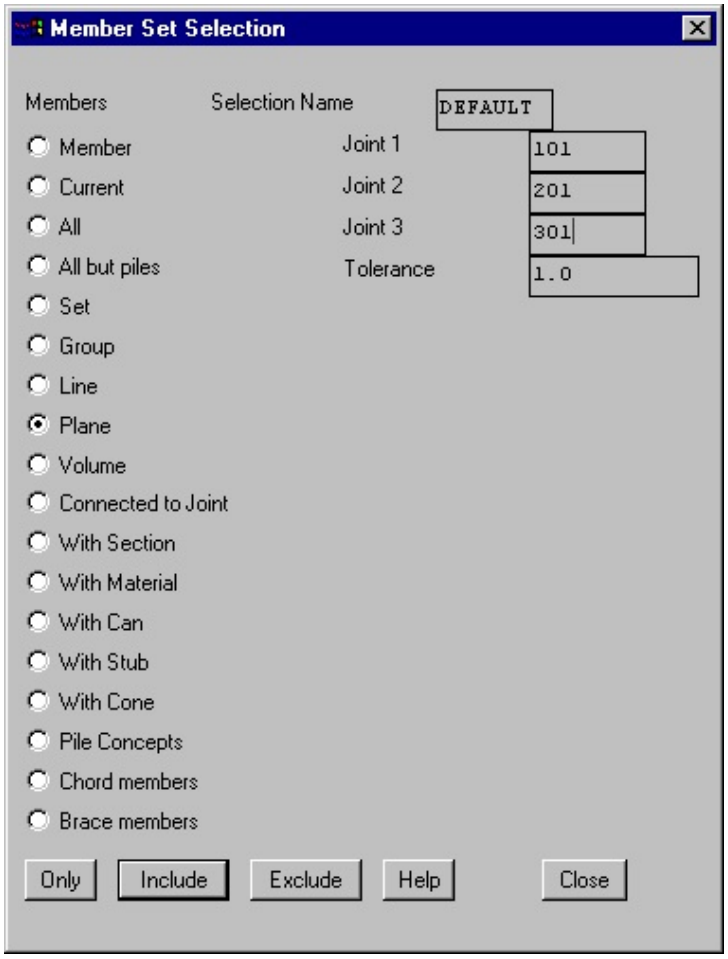


Figure 4.3: The Select Member dialogue box

A dialogue box will contain one or more of these standard buttons, placed at the bottom of the box:

OK	Accept the contents of the box and close the box. The box will not be closed if there is an error in the information inside the box
Apply	Accept the contents of the box. The box is not closed
Cancel	Close the box without accepting the contents

All dialogue boxes have a default pushbutton, that is activated by typing <Return> when the dialogue box is active. This pushbutton is the OK or the Apply button. The default button will be highlighted or framed.

4.4.4 Selecting several alternatives from a list

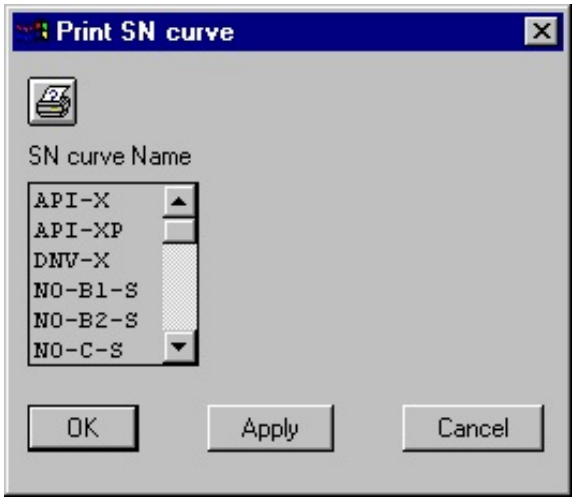


Figure 4.4: The Print SN-Curve dialogue box

In e.g. the PRINT SN-CURVE command, a scrollable list of all curves is presented. Any number of variables can be selected from this list for print. Selected values are marked by highlighting.

The basic way to select values is to click on a value, and then drag the mouse through the list. All values that the mouse pointer is dragged through are selected, and any previously selected value becomes unselected. To modify an existing selection, hold the Control key down while clicking in the list or dragging the mouse pointer through the list. All items that are clicked on while the Control key is held will reverse their selection status.

4.4.5 Entering a prefixed list

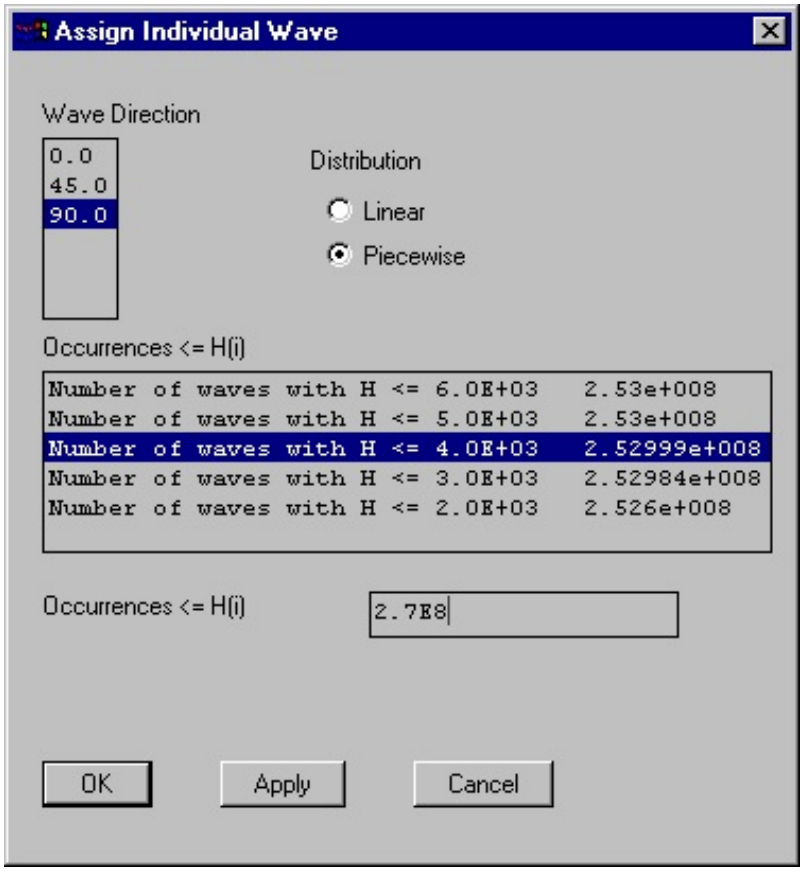


Figure 4.5: The Assign Individual waves dialogue box

The prefixed list is used to enter a number of values, that is unknown until the time the box is used, where each value has a prefix (or prompt). It is used to input distribution parameters, function arguments and starting point values.

In line mode, the list is simply traversed sequentially from top to bottom. In graphics mode, the accompanying input field (located just below the box) is used to input and change values. The procedure used to change or input a value is:

- Select the corresponding row in the box. Doubleclick on the row if desired to transfer the current value to the input field. If no row is selected, the first row is implicitly used.
- Type the correct value in the input field.
- Hit <Return> in the input field to transfer the value to the box. The next row in the box will then be selected and the input field will be cleared.

Thus it is possible to input values sequentially into the box by clicking on the input field and then typing the values one by one, with each value followed by a <Return>.

4.4.6 Entering a vector or matrix of values

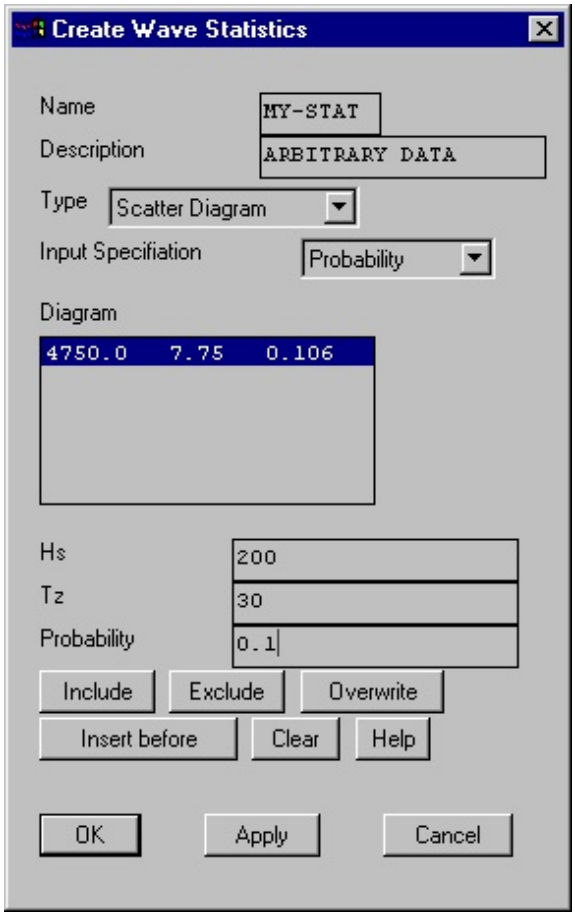


Figure 4.6: The Create Wave-Statistics dialogue box

In many cases a vector or matrix of values must be input. An Example is entering a scatter diagram by the Create Wave-statistics command.

The graphics mode input of this is quite flexible. The values are presented in columns in a scrollable box. Under the box is one input field for each column in the matrix (one field if it is a vector). Under the input field(s) are two rows of buttons, that are used to manipulate the contents of the box.

Type values into the input fields, and hit <Return> in the last (bottom) field. The values are then inserted at the bottom, or before the selected row, or will overwrite the selected row, depending on the default status. The initial status is Include, which inserts values at the bottom. The input fields are cleared after the insertion is complete. Instead of pressing <Return>, a button may be pressed. The effect of this is:

Include	Include the values in the input field(s) at the bottom, then clear the input fields. Sets the default status to Include.
Exclude	Exclude all selected rows from the matrix/vector. Sets the default status to Exclude.
Overwrite	Overwrite the selected row with the contents of the input fields. Only one row can be selected in the scrollable box. The next row (if any) will then be selected, and the default status will be set to Overwrite. The input fields will be cleared.
Insert before	Insert the contents of the input fields before the selected row. Only one row can be selected in the scrollable box. The default status will be set to 'Insert before'. The input fields will be cleared.

Clear	Clear the contents of the matrix. NOTE: There is no way to get the cleared contents back, other than perhaps cancelling the dialogue box and opening it again.
Help	Pressing this is equivalent to pressing the help button while the scrollable box has the input focus. It provide on-line access to a description of how to use the matrix/vector.

4.4.7 Journalling from graphics mode

All commands that are accepted from graphics mode are logged on the journal file. The commands are logged in a format that can be read into the corresponding line mode command.

There is one case, that deserves attention:
Some dialogue boxes contain many line mode commands. An example is the Set Plot dialogue box. Since all the visible contents of a dialogue box are selected when the OK or Apply button is pressed, even if only parts of the box has been changed, all possible commands in the box will be logged.

Pressing the OK or Apply button in this box will generate the following log:

```
SET PLOT
  LOOP
  COLOUR OFF
  FILE ' ' FRAMEWORK
  FORMAT SESAM-NEUTRAL
  PAGE-SIZE A4
  END
```

5 Command description

The hierarchical structure of the commands and numerical data is documented in this chapter by use of tables. How to interpret these tables is explained below. Examples are used to illustrate how the command structure may diverge into multiple choices and converge to a single choice.

In the example below command A is followed by either of the commands B and C. Thereafter command D is given. Legal alternatives are, therefore, A B D and A C D.

A	B	D
	C	

In the example below command A is followed by three selections of either of commands B and C as indicated by *3. For example: A B B B, or: A B B C, or A C B C, etc.

A	B	*3
	C	

In the example below the three dots in the left-most column indicate that the command sequence is a continuation of a preceding command sequence. The single asterisk indicate that B and C may be given any number of times. Conclude this sequence by the command END. The three dots in the right-most column indicate that the command sequence is to be continued by another command sequence.

. . .	A	B	*	. . .
		C		
		END		

In the example below command A is followed by any number of repetitions of either of the sequences B D and C D. Note that a pair of braces ({ }) is used here merely to define a sequence that may be repeated. The braces are not commands themselves.

A	{	B	D	}
		C		

The characters A, B, C and D in the examples above represent parameters being COMMANDS (written in upper case) and numbers (written in lower case). All numbers may be entered as real or integer values. Brackets ([ ]) are used to enclose optional parameters.

Note 1: A parameter followed by a '+' means that a selection of one or more numerical values, names or text strings shall be done from a list of items.

Note 2: The command END is generally used to end repetitive entering of data. Using double dot (..) rather than END to terminate a command will, depending on at which level in the command it is given, save or discard the data entered. Generally, if the data entered up to the double dot is complete and self-contained the double dot will save the data. If in doubt, it is always safest to leave a command by entering the required number of END commands.

Entering data in graphics mode is described in Section 4.

ASSIGN

ASSIGN	CAN	subcommands	data
	CHORD		
	EARTHQUAKE-DAMPING-FUNCTION		
	EARTHQUAKE-SPECTRUM		
	FATIGUE-PART-DAMAGE		
	FATIGUE-SAFETY-FACTOR		
	INDIVIDUAL-WAVE		
	JOINT-CHORD-LENGTH		
	JOINT-GAP		
	JOINT-OVERLAP		
	JOINT-RING-STIFFENER		
	JOINT-TYPE		
	LOAD-CASE		
	LOCAL-COORDINATE-SYSTEM		
	MATERIAL		
	POSITIONS		
	SCF		
	SECTION		
	SN-CURVE		
	STABILITY		
	STUB		
	THICKNESS-CORRECTION		
	WAVE-DIRECTION-PROBABILITY		
	WAVE-LOAD-FACTOR		
	WAVE-SPECTRUM-SHAPE		
	WAVE-SPREADING-FUNCTION		
	WAVE-STATISTICS		
	WIND-FATIGUE		

Purpose:
To assign data that are related to the modelling of the structure in preparation for a post-processing analysis.

Parameters:

CAN	To assign/deassign a CAN section to one or more chord members.
CHORD	To assign CHORD & BRACE members at tubular connections.
EARTHQUAKE-DAMPING-FUNCTION	To assign earthquake damping functions.
EARTHQUAKE-SPECTRUM	To assign earthquake response spectra.
FATIGUE-PART-DAMAGE	To assign fatigue initial part damage.
FATIGUE-SAFETY-FACTOR	To assign fatigue damage safety factor.
INDIVIDUAL-WAVE	To assign deterministic wave data.
JOINT-CHORD-LENGTH	To assign joint chord length to be used in parametric SCF calculations.
JOINT-GAP	To assign gap at the end of a brace member.
JOINT-OVERLAP	To assign an overlap at the end of a brace member.
JOINT-RING-STIFFENER	To assign ring stiffener to the end of a brace.
JOINT-TYPE	To assign joint type at the end of a brace member.
LOAD-CASE	To assign data related to a loadcase.
LOCAL-COORDINATE-SYSTEM	To assign a local coordinate system to selected members.
MATERIAL	To assign a material to selected members.
POSITIONS	To assign code check positions to selected members.
SCF	To assign stress concentration factors to selected members.
SECTION	To assign a section to selected members.
SN-CURVE	To assign SN-curves to selected members.
STABILITY	To assign stability data to selected members.
STUB	To assign/deassign a stub section to one or more braces.
THICKNESS-CORRECTION	To assign thickness correction to a SN curve.
WAVE-DIRECTION-PROBABILITY	To assign the probability of a wave direction.
WAVE-LOAD-FACTOR	To assign wave load factor (DAF) to wave direction.
WAVE-SPECTRUM-SHAPE	To assign wave spectrum shape to wave statistics.
WAVE-SPREADING-FUNCTION	To assign wave spreading function to wave statistics.
WAVE-STATISTICS	To assign wave statistics to a wave direction.
WIND-FATIGUE	To assign data for wind fatigue calculation.

All subcommands and data are fully explained subsequently as each command is described in detail.

ASSIGN CAN

...	CAN	JOINT	data
		CHORD	
		NONE	

PURPOSE:

To assign a CAN section either to a joint or directly to a CHORD member or to remove a CAN section from a joint or a CHORD member.

PARAMETERS:

JOINT	Instructs the program to assign a CAN section at a joint. The CHORD and the member ALIGNED to the CHORD (if any) at that joint shall then be assigned the CAN properties specified subsequently.
CHORD	Instructs the program to assign a CAN section at a specific end of a CHORD member.
NONE	Instructs the program to remove a CAN section assigned at one or more joints or at a specific end of a CHORD member.

All data are fully explained subsequently as each command is described in detail.

ASSIGN CAN JOINT

...	JOINT	joint	sec	mat	cho-len	alg-len
			-name	-name	AUTOMATIC	AUTOMATIC

PURPOSE:
To assign a CAN section a a given joint. The CHORD and the member ALIGNED to the CHORD (if any) at that joint shall then be assigned the CAN properties specified subsequently.

PARAMETERS:

joint	Name of joint that will be assigned the CAN section.
sec-name	Name of CAN section. Note that this must be a tubular section.
mat-name	Material name to be assigned to the CAN section.
cho-len	Length of CAN section on the CHORD member.
alg-len	Length of CAN section on the ALIGNED CHORD member (give 0.0 if none).
AUTOMATIC	Calculate automatically in accordance with the guidelines for joint design as given in API / NPD / NORSOK.

NOTES:
The CHORD and ALIGNED member CAN lengths are used for material take-off and for code checks if checking more than 3 positions along the member (default is only both ends and mid point).

In order for a CAN/Stub section to be assigned (directly or indirectly) to a member, it is required that the diameter of the CAN/Stub section is not less than the nominal diameter of the member. That is, the assigned cross section should in general form a reinforcement to the original member. The “Mannual” specified length of the CAN or Stub must be less than the total length of the beam member.

The AUTOMATIC option needs a specification by the `DEFINE JOINT-PARAMETER MINIMUM-FREE-CAN-LENGTH` command which sets the minimum free can length value. The `ASSIGN CAN JOINT` command description reads for AUTOMATIC: “Calculate automatically in accordance with the guidelines for joint design as given in API / NPD / NORSOK.” Note that the “minimum free can length” has the default value 0.0 and hence must be set by the user, see command `DEFINE JOINT-PARAMETER MINIMUM-FREE-CAN-LENGTH`. Model length units must be used. The criteria "fraction of chord diameter" is default set to 0.25 and hence 0.25*Diam is the only criteria used as default.

It is required to model the concept CAN/Stub segment by one beam element in preprocessing programs, like Genie or Preframe, because Framework is not meant to handle situations where reinforcement cans are divided into multiple beam elements. Hence, when reading Genie’s models, user must ensure that all beam segments representing joint reinforcements are represented by one finite element only.

If there are existing conceptual CAN/Stub segments, the Framework commands,`ASSIGN CAN` and `ASSIGN STUB`, will override the section and segment properties in punch shear code check.

See also:

```
ASSIGN CAN NONE...
ASSIGN CAN CHORD...
DEFINE JOINT-PARAMETER...
```

EXAMPLE:

```
ASSIGN CAN JOINT 100 CAN100 MAT1 AUTOMATIC 1.2
```

ASSIGN CAN CHORD

...	CHORD	joint	chord	sec-name	mat-name	can-len
						AUTOMATIC

PURPOSE:

To assign a CAN section at a specific end of a CHORD member.

PARAMETERS:

joint	Name of joint identifying the CHORD end where the CAN section shall be assigned.
chord	CHORD (or ALIGNED-CHORD) member name to be assigned the CAN section.
sec-name	Name of CAN section. Note that this must be a tubular section.
mat-name	Material name to be assigned to the CAN section.
can-len	Length of CAN section on the CHORD member.
AUTOMATIC	Calculate automatically in accordance with the guidelines for joint design as given in API / NPD / NORSOK.

NOTES:

The CHORD and ALIGNED member CAN lengths are used for material take-off and for code checks if checking more than 3 positions along the member (default is only both ends and mid point).

The given length must be less or equal to half the element length.

See also:

```
ASSIGN CAN NONE...
ASSIGN CAN JOINT...
DEFINE JOINT-PARAMETER...
PRINT CHORD-AND-BRACE...
```

EXAMPLES:

```
ASSIGN CAN CHORD 100 1011 CAN100 MAT1 2.0
```

ASSIGN CAN NONE

...	NONE	joint	chord

PURPOSE:

To remove a CAN section from a specific joint.

PARAMETERS:

joint	Name of joint where a CAN section is to be removed.
chord	Name of CHORD for which to remove the CAN section. The alternative ALL shall remove the CAN section from both the CHORD & the ALIGNED CHORD (if any).

NOTES:

See also:

```
ASSIGN CAN JOINT...
ASSIGN CAN CHORD...
ASSIGN CHORD...
PRINT CHORD-AND-BRACE...
```

EXAMPLES:

```
ASSIGN CAN NONE 100 ALL
```

ASSIGN CHORD

...	CHORD	GLOBAL	joint	chord	
		LOCAL	joint	loc-chord	loc-brace

PURPOSE:

To manually assign CHORD & BRACE members at a tubular connection.

PARAMETERS:

GLOBAL	To explicitly, at a joint, assign the chord member. All other tubular members connected to that joint will implicitly be classified brace members. Non tubular members are ignored.
LOCAL	To explicitly, at a joint, assign the chord member and in addition to explicitly assign the corresponding brace member.
joint	Joint name for which the chord assignment shall be made.
chord	Name of member to be assigned as the global chord.
loc-chord	Name of member to be assigned as the local chord.
loc-brace	Name of member to be assigned as the brace of the local chord.

NOTES:

See also:

```
PRINT CHORD-AND-BRACE...
DEFINE CONSTANTS MINIMUM-BRACE-ANGLE...
```

EXAMPLES:

```
ASSIGN CHORD GLOBAL 100 1011
```

ASSIGN EARTHQUAKE-DAMPING-FUNCTION

...	EARTHQUAKE-DAMPING-FUNCTION	X Y Z	damp-name

PURPOSE:

To assign a damping function in a particular global direction.

PARAMETERS:

X	The earthquake damping shall be applied in global direction X.
Y	The earthquake damping shall be applied in global direction Y.
Z	The earthquake damping shall be applied in global direction Z.
damp-name	Name of damping function to be associated with the specified global direction.

NOTES:

See also:

```
CREATE EARTHQUAKE-DAMPING-FUNCTION...
PRINT EARTHQUAKE-DAMPING FUNCTION
```

EXAMPLES:

```
ASSIGN EARTHQUAKE-DAMPING-FUNCTION X D005
```

ASSIGN EARTHQUAKE SPECTRUM

.. .	EARTHQUAKE-SPECTRUM	X	spec-name	scale-fac-tor
		Y		
		Z		

PURPOSE:

To assign an earthquake spectrum in a particular global direction.

PARAMETERS:

X	The earthquake spectrum shall be applied in global direction X.
Y	The earthquake spectrum shall be applied in global direction Y.
Z	The earthquake spectrum shall be applied in global direction Z.
spec-name	Spectrum name to be assigned in the specified direction.
scale-factor	Scaling factor to be applied to the earthquake spectrum in the specified direction.

NOTES:

See also:

```
CREATE EARTHQUAKE-SPECTRUM...
PRINT EARTHQUAKE-SPECTRUM
```

EXAMPLES:

```
ASSIGN EARTHQUAKE-SPECTRUM X API 0.5
```

ASSIGN FATIGUE-PART-DAMAGE

...	FATIGUE-PART-DAMAGE	JOINT	brace	sel-jnt	text	GLOBAL		
						LOCAL	BOTH-SIDES	...
							CHORD-SIDE	
							BRACE-SIDE	
		MEMBER	sel-mem	posi-tions	text	GLOBAL		
						LOCAL		...

...	UNIFORM	damage
	BI-SYMMETRIC	{hot, damage}*3
	SYMMETRIC	{hot, damage}*5
	NON-SYMMETRIC	{hot, damage}*8

PURPOSE:

To assign fatigue initial part damage to members at selected joints or positions.

PARAMETERS:

JOINT	Signifies that part damage shall be defined at a joint.
MEMBER	Signifies that part damage shall be defined at a member.
brace	Name of brace to be assigned to the part damage. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS). Only if the name of a single chord or a single non-pipe member is given in the position of the brace member name, the assignment of LOCAL or GLOBAL will be allowed for non-brace members.
sel-jnt	Joints where part damage definition shall be assigned. For valid alternatives see command SELECT JOINTS.
sel-mem	Members where part damage definition shall be assigned. For valid alternatives see command SELECT MEMBERS.
positions	Select fatigue check positions to which the part damage shall be applied. See command ASSIGN POSITION sel-mem FATIGUE-CHECK regarding defining positions.
text	A descriptive text.
GLOBAL	The user specifies that the global (default) part damage values shall be applied.
LOCAL	The user specifies all part damage values.
BOTH-SIDES	The same part damage is applied to both chord-side and brace-side of the weld. This option should also be applied for CHORD member or a non-pipe member.
CHORD-SIDE	The part damage is applied for the chord side of the weld.
BRACE-SIDE	The part damage is applied for the brace side of the weld.
UNIFORM	The same values applies to all hotspots.
BI-SYMMETRIC	The distribution is double symmetric about the in-plane bending axis and about the out-of-plane bending axis. 3 hotspots with part damage values each must be specified
SYMMETRIC	The distribution is symmetric about the out-of-plane bending axis. The 5 required hotspots for a pipe are numbered 1, 4, 7, 19, 22. This option may only be used for members with pipe section.
NON-SYMMETRIC	The distribution has no symmetry. The user must specify part damage values for all active hotspots. For a pipe section, the 8 required hotspots are numbered 1, 4, 7, 10, 13, 16, 19, 22
damage	The initial part damage to assign.

hot Hot spot identification.

NOTES:

When giving position names defining where to apply the SCF rule use the input syntax as shown in the example at the end of this command description. Hence, enclose the positions in parentheses and start with ONLY inside the parentheses to avoid any misunderstandings regarding where to apply the damage data. The available positions (i.e. the program generated position names) can be listed by use of the command PRINT MEMBER FATIGUE-CHECK-POSITIONS.

When assigning part damage with specification LOCAL and distribution BI-SYMMETRIC, SYMMETRIC or NON-SYMMETRIC warning messages with respect to if values for all necessary hotspots are given is limited. The hotspots which must be assigned values are specified in parameter list above. An exception from above is when the active hotspots for the members cross section have been changed (see command CHANGE HOT-SPOTS section-name descr FATIGUE {hot}*).

See also:

```
DEFINE FATIGUE-CONSTANTS...
PRINT MEMBER FATIGUE-CHECK-DATA...
PRINT MEMBER FATIGUE-CHECK-POSITIONS...
```

EXAMPLES:

```
ASSIGN F-P-D JOINT ALL 315 'Wave Slam' LOCAL BOTH-SIDES UNIFORM 0.0167

ASSIGN F-P-D MEMBER CURRENT ( ONLY END1-0.0000 MID-0.5000 END2-1.0000 )
     'Wave Slam' LOCAL UNIFORM 0.02
```

ASSIGN FATIGUE-PART-DAMAGE READ-FILE

...	FATIGUE-PART-DAMAGE	READ-FILE	filename

PURPOSE:
To assign fatigue initial part damage to members by reading a fatigue damage file.

PARAMETERS:

filename name of the fatigue damage file output by previous fatigue runs.

NOTES:
The filename's extension or suffix allowed is *.FPD* or *.SIF*. The file with extension *.FPD* is created when running Deterministic, Direct Deterministic, Spectral and Stochastic fatigue if the option of `Fatigue Damage to File` is turned on. This file is binary and unformatted.

By default, the program will find the given filename in the current Framework's workspace directory. The filename does not have prefix in the command. Therefore, the full path of the directory and filename must be provided if the damage file is not stored in the default Framework folder. It is recommended to move the damage file to an appropriate place before importing it. In case the full file path exceeds the allowed limit of Framework program, it is advised using Sesam Manager to run Framework and provide the relative file path, for example "`'..\_repository\filename.FPD'`" in Framework input file, where "`..\`" represents the parent directory of the current working directory.

The file with extension *.SIF* is for time history fatigue analysis only. The *.SIF* file is a formatted file in the standard Sesam file format. The fatigue results are identified by the RVFATDAM and TDFATDAM records. Therefore, the file type must be **SIF-FORMATTED**.

See also:

`DEFINE FATIGUE-DAMAGE-TO-FILE...`

EXAMPLE:

```
ASSIGN FATIGUE-PART-DAMAGE READ-FILE DamageDet1.FPD
ASSIGN FATIGUE-PART-DAMAGE READ-FILE
  'C:\Projects\framework\Damage\_Det1.FPD'
```

ASSIGN FATIGUE-SAFETY-FACTOR

...	FATIGUE-SAFETY-FACTOR	JOINT	brace		sel-jnt	safac
		MEMBER	member		safac	
		MEMBER	mem-ber	INDIVIDUAL	{safac}*	

PURPOSE

To assign fatigue damage safety factor to members at selected joints or positions.

PARAMETERS:

JOINT	Signifies that the safety factor shall be defined at a joint.
MEMBER	Signifies that the safety factor shall be defined at member fatigue check positions.
INDIVIDUAL	Signifies that the safety factor shall be defined individually at each member fatigue check position.
brace	Brace name to be assigned the safety factor. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS). Only if the name of a single chord or a single non-pipe member is given in the position of the brace member name, the safety factor assignment will be allowed for a non-brace member.
sel-jnt	Joints where the safety factor shall be assigned. For valid alternatives see command SELECT JOINTS.
member	Member where the safety factor shall be assigned.
safac	Value of safety factor.

NOTES:

Note that the nominal fatigue life is multiplied with the fatigue safety factors directly.

See also:

```
DEFINE FATIGUE-CONSTANTS...
DEFINE FATIGUE-SAFETY-FACTOR
PRINT MEMBER FATIGUE-CHECK-DATA
```

EXAMPLES:

```
ASSIGN FATIGUE-SAFETY-FACTOR MEMBER ALL 1.1
```

ASSIGN INDIVIDUAL-WAVE

...	INDIVIDUAL-WAVE	wave-dir	LINEAR	waves
			PIECEWISE	{occurr}*

PURPOSE:
Assign a wave height distribution to a wave direction for deterministic fatigue analysis.

PARAMETERS:

wave-dir	Wave direction to be assigned the wave height distribution.
LINEAR	Distribution is linear in h $-\log$ N scale.
PIECEWISE	Distribution is piecewise linear in h-$\log$ N scale.
waves	Total number of waves for this wave direction.
occurr	Number of waves that are $\leq h_i$ for each of the wave heights for this direction with wave heights h_i sorted in descending order. The specified value for h_1 corresponds to the total number (N_{tot}) of waves for this wave direction.

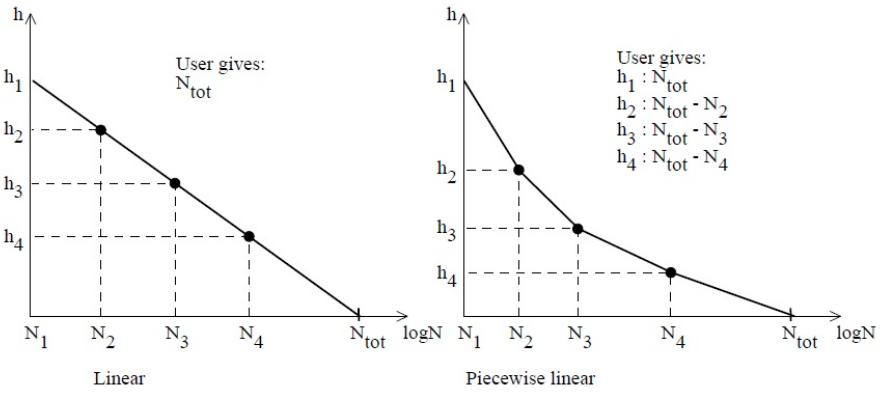


Figure 5.1: Long term wave height distribution

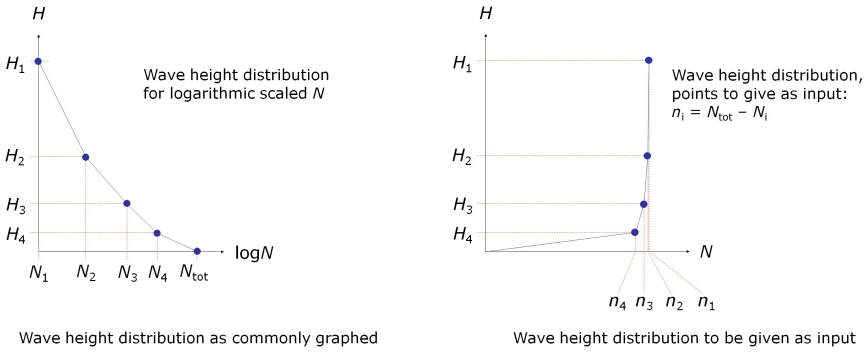


Figure 5.2: Long term wave height distribution to be given as input

NOTES:
The N values shown in Figure 5.1 correspond to the number of waves greater than the referred wave.

The total number of waves for all wave directions shall correspond to the total number of waves during the period in years specified in the command `DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE`.

While a long term wave height distribution is commonly sketched as shown in Figure 5.1 the input to give is as shown to the right in Figure 5.2.

See also:

```
DEFINE FATIGUE-CONSTANTS...
ASSIGN WAVE-LOAD-FACTOR
PRINT WAVE-DIRECTIONS
```

ASSIGN JOINT-CHORD-LENGTH

...	JOINT-CHORD-LENGTH	brace	sel-jnt	length

PURPOSE:
To assign specific chord length used for parametric SCF calculations to each brace in a joint.

PARAMETERS:

brace	Brace name for which the grouted option shall be assigned. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command `SELECT MEMBERS`).
sel-jnt	Joints where the grouted option shall be assigned. (see command SELECT JOINTS)
length	Value of chord length.

NOTES:
By default the chord length is then the sum of length of joint chord and length of aligned chord. To reset the default length, being the sum of chord length and length of aligned chord, use the command: ASSIGN JOINT-CHORD-LENGTH brace sel-jnt DEFAULT.

When $length$ is given, the parameter α in EFTHYMIOU SCF formula is

$$\alpha = 2 * length/D_{chord}$$

.

EXAMPLE:

```
ASSIGN JOINT-CHORD-LENGTH ALL JT1 10.0
```

ASSIGN JOINT-GAP

.. .	JOINT-GAP	brace	sel-jnt	gap
				AUTOMATIC

PURPOSE:

To assign a gap to K type joints.

PARAMETERS:

brace	Brace name to be assigned the gap. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS).
sel-jnt	Joints where the gap shall be assigned. For valid alternatives see command SELECT JOINTS.
gap	Value of gap.
AUTOMATIC	Calculate and assign gap value based on geometry (incl. eccentricity).

NOTES:

By default all joints are assigned a zero gap.

For a fatigue analysis, the command JOINT-GAP with a negative gap may be used for the computation of parametric SCFs using Efthymiou formulas. The negative gap value shall be assigned to the overlapping brace

The calculation of the gap length is based on the assumption of a plane joint. This is in correspondence with the assumptions made for geometric joint classifications. The calculated values will thus be appropriate input values for code checking purpose and SCF calculations.

See also:

```
ASSIGN JOINT-TYPE ...
PRINT JOINT PUNCH-CHECK-DATA ...
```

EXAMPLES:

```
ASSIGN JOINT-GAP ALL 1000 AUTOMATIC
```

ASSIGN JOINT-GROUTED

...	JOINT-GROUTED	brace	sel-jnt	NONE	
				DOUBLE-SKIN	Tp
				MANUAL	Te

PURPOSE:
To assign (and change) joint grouted options at the end of a brace member. The grout is actually filled inside the chord member, but the option is assigned to the braces for the convenience .

PARAMETERS:

brace	Brace name for which the grouted option shall be assigned. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command `SELECT MEMBERS`).
sel-jnt	Joints where the grouted option shall be assigned. (see command SELECT JOINTS)
DOUBLE-SKIN	The grouted joint has the annulus between the chord and an inner member filled with grout (double-skin grouted joints)
Tp	Inner member (pile) thickness
MANUAL	The grouted joint is double-skin. The equivalent chord thickness is user specified although the inner pile is not modelled.
Te	The equivalent chord thickness to be applied in the SCF formula of simple joints.
NONE	The joint is NOT grouted. (Default)

NOTES:
Currently, Framework only supports the double-skin grouted joint. The fully-grouted joint is not supported. The `DOUBLE-SKIN` grouted joint option is based on the clause *3.3.5.3 Annulus between tubular members filled with grout* of DNV-RP-C203, 2021 [100]. The grouted joints can be treated as simple joints, except that the chord thickness in SCF calculation for brace and chord shall be substituted with an equivalent chord wall thickness $T_e = T + 0.45T_p$, where T_p is entered by this commmand.

The `MANUAL` option defines the double-skin grouted joint too. The difference is that MANUAL option allows to enter an equivalent chord thickness T_e, which will be applied directly in the SCF formula of simple joints, instead of using the equation of T_e in Ref [100]. The SCF equations in the DNV RP-C203 are referred to the stress concentration factors in Ref [72]. When the selected SCF option is neither `Efthymiou` nor `Lotsberg` in Framework, it is advised for the user to enter the appropriate equivalent chord thickness.

The NONE option is to change the joints that are previously assigned as grouted to non-grouted. Non-grouted is the default for a tubular joint in Framework.

EXAMPLE:

```
SELECT JOINTS ONLY JT1
ASSIGN JOINT-GROUTED ALL ( ) DOUBLE-SKIN 0.0111
ASSIGN JOINT-GROUTED BM1 JT1 MANUAL 0.0321
ASSIGN JOINT-GROUTED BM4 JT2 DOUBLE-SKIN 0.022222
SELECT JOINTS ONLY ALL
ASSIGN JOINT-GROUTED ALL ( ) NONE
```

ASSIGN JOINT-OVERLAP

...	JOINT-OVERLAP	brace	sel-jnt	over-lap	tw	l1	l	l2

PURPOSE:

To assign/deassign an overlap at the end of a brace member.

PARAMETERS:

brace	Brace name for which overlap data shall be assigned/deassigned. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS).
sel-jnt	Joints where the overlap shall be assigned. For valid alternatives see command SELECT JOINTS.
over-lap	Value of overlap. This must be a positive number.
tw	Minimum thickness of weld throat or brace.
l1	Circumference of chord-brace contact.
l	Circumference of brace.
l2	Projected chord length.

NOTES:

The circumference of the brace (l), must be greater than the circumference of the chord-brace contact (l1).

For a fatigue analysis, the command JOINT-GAP with a negative gap may be used for the computation of parametric SCFs using Efthymiou formulas.

EXAMPLES:

```
ASSIGN JOINT-OVERLAP 1100 1000 0.05 0.03 0.04 0.1
```

ASSIGN JOINT-RING-STIFFENER

...	JOINT-RING-STIFFENER	brace	sel-jnt	nof	...

...	name		...	AUTOMATIC
	INDIVIDUAL	name*nof		separation

PURPOSE:
To assign (and change) ring stiffeners at the end of a brace member. The ring stiffeners are actually located inside the chord member, but the stiffeners are assigned to the braces.

PARAMETERS:

brace	Brace name for which stiffener data shall be assigned. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS).
sel-jnt	Joints where the stiffeners shall be assigned. For valid alternatives see command SELECT JOINTS.
nof	Number of stiffeners (maximum 4 stiffeners).
INDIVIDUAL	The assignment refers to rings with different names.
name	Ring stiffener name (Ref. CREATE SECTION ...).
AUTOMATIC	Use automatic calculation of average ring separation.
separation	Manually give the value for average ring separation.

NOTES:
Based on the ring stiffener geometry and location beneath the brace (inside the chord) SCF ratios according to “Stress Concentration Factors for Ring-Stiffened Tubular Joints, P. Smedley and P. Fisher, Lloyd’s Register of Shipping, London, U.K." [92] are calculated. These correction factors are used to modify the Efthymiou and Lloyd’s parametric SCFs.

The AUTOMATIC ring separation is controlled by the DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT command.

To verify stiffener assignments, use the command PRINT JOINT RING-STIFFENERS joint and/or switch on the DISPLAY LABEL JOINT-RING-STIFFENER when using the command DISPLAY JOINT. The text RS*n will then appear at the brace end, where n = number of stiffeners assigned. To remove ring stiffeners, use the command DELETE RING-STIFFENER.

How to handle SCF ratio calculation regarding geometric limitations in ring stiffeners, i.e. the b, g, t, a, ... ratios is controlled by the command DEFINE PARAMETRIC-SCF RING-STIFFENER-GEOMETRY.

How to handle SCF ratio calculation regarding limitations in the chord and ring parameters, i.e. the R_{tau}, K_2, K_1 and I_{mod} ratios is controlled by the command DEFINE PARAMETRIC-SCF RING-STIFFENER-PARAMETER.

Short chord correction factors are excluded when ring stiffeners are assigned.

Lloyd’s Register do not recommend ring-stiffening joints with $b > 0.8$. However, if a joint with $b > 0.8$ is to be analysed, the SCF ratio at the saddle position shall be neglected, i.e. use the unstiffened saddle SCF only. This recommendation can be overruled by the command DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF OVERRULE.

NORSOK C.2.6.3.4 (DNV-RP-C203 sect 3.3.4) “Stress concentration factors for stiffened tubular joints" says: “The maximum of the saddle and crown value should be applied around the whole brace/chord intersection". This statement has been interpreted to govern for axial SCFs and based on the resulting SCF, i.e. SCForiginal * SCFratio. This has been used as default when ring stiffeners are assigned. To switch off, use the command DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM OFF.

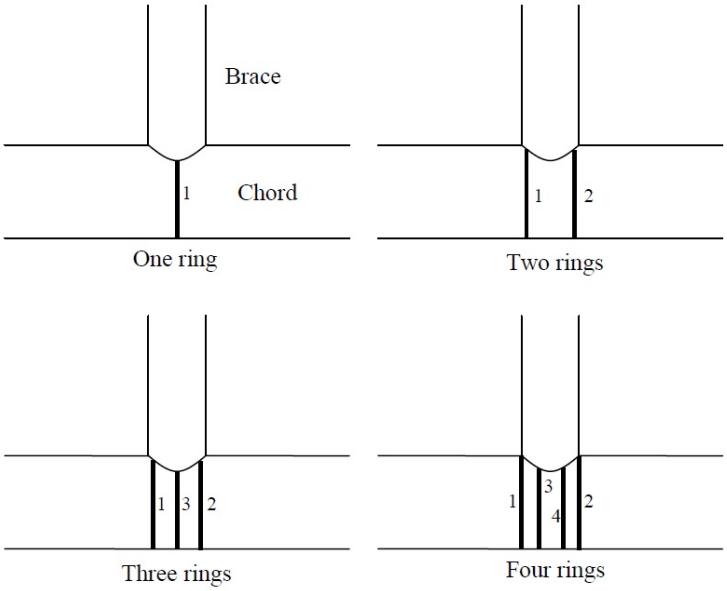


Figure 5.3: Location of ring stiffeners

The eight SCF ratios reported by Framework when printing parametric SCFs and running fatigue analysis are the following:

```
1 => SCF ratio for axial stress in the brace, saddle position
2 => SCF ratio for axial stress in the brace, crown position
3 => SCF ratio for in-plane bending in the brace (crown)
4 => SCF ratio for out-of-plane bending in the brace (saddle)
5 => SCF ratio for axial stress in the chord, saddle position
6 => SCF ratio for axial stress in the chord, crown position
7 => SCF ratio for in-plane bending in the chord (crown)
8 => SCF ratio for out-of-plane bending in the chord (saddle)
```

The minimum SCF value used is the largest value of:

```
a) Calculated value
b) Minimum parametric SCFs defined through commands:
   DEFINE FATIGUE-CONSTANTS AXIAL-MINIMUM-SCF value
   DEFINE FATIGUE-CONSTANTS IN-PLANE-MINIMUM-SCF value
   DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-MINIMUM value
c) Minimum SCF according to Smedley and Fisher document, i.e.:
   Chord side, axial                : 1.5
   Chord side, in-plane bending     : 1.5
   Chord side, out-of-plane bending : 1.5
   Brace side, axial                : 2.5
   Brace side, in-plane bending     : 1.5
   Brace side, out-of-plane bending : 2.5
```

See also:

```
CREATE SECTION...
PRINT JOINT RING-STIFFENERS...
DISPLAY LABEL JOINT-RING-STIFFENER...
DELETE RING-STIFFENER...
DEFINE PARAMETRIC-SCF...
```

EXAMPLE:

```
ASSIGN JOINT-RING-STIFFENER ALL ( ONLY 5 ) 2 RING1 AUTOMATIC
```

ASSIGN JOINT-TYPE

. . .	JOINT-TYPE	brace	sel-jnt	X					
				YT					
				KTK					
				K					
				KTT					
				INTERPOLATE	%yt	%x	%k	%ktk	% ktt
				GEOMETRY					
				LOADPATH					

PURPOSE:
To assign a joint type at the end of a brace member, which is required for a punch check or a fatigue check using parametric SCFs.

PARAMETERS:

brace	Brace name for which stiffener data shall be assigned. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command `SELECT MEMBERS`).
sel-jnt	Joints where the stiffeners shall be assigned. For valid alternatives see command SELECT JOINTS.
X	The joint type is 100 % X.
YT	The joint type is 100 % YT.
K	The joint type is 100 % K.
KTK	The joint type is 100 % KTK.
KTT	The joint type is 100 % KTT.
INTERPOLATE	The joint type is a mixture of two or more joint types.
%x	Percentage for joint type X.
%yt	Percentage for joint type YT.
%k	Percentage for joint type K.
%ktk	Percentage for joint type KTK.
%ktt	Percentage for joint type KTT.
GEOMETRY	The joint type will be determined from joint topology
LOADPATH	The joint type will be determined from instantaneous load path

NOTES:
By default all joints are assigned as 100% YT.

For joint type LOADPATH used for a fatigue analysis, the percentage of each possible joint type is determined by the equilibrium of brace punching shear forces. The SCF applied at each hotspot is weighted for all possible joint types according to the percentage. The print of the fatigue check results will report SCFs calculated according to joint geometry. When using parametric SCF definitions, e.g. Efthymiou's, in stochastic fatigue and SCF calculations based on joint LOADPATH, the force flow used is based on one wave phase step. The phase is the first phase angle defined through the command `DEFINE CONSTANTS PHASE-ANGLE` (list of angles). This limitation is valid for all three Efthymiou's calculation models (A, B and C). For Efthymiou parametric SCFs it is always the joint type GEOMETRY with Efthymiou model C SCFs that are printed.

User has the flexibility to specify one particular joint type. Also, the loadpath percentage split can be skipped at the braces with very small brace load that can lead to inconsistent loadpath classification. The command to define a brace axial force ratio to skip loadpath check is

```
DEFINE JOINT-PARAMETERS LOADPATH-FORCE-RATIO-LIMIT
```

The determination of joint type based on interpolate may not be used for a fatigue analysis.

See also:

```
PRINT JOINT PUNCH-CHECK-DATA...
```

EXAMPLE:

```
ASSIGN JOINT-TYPE ALL ALL YT
ASSIGN JOINT-TYPE 1 100 X
```

ASSIGN LOAD-CASE

...	LOAD-CASE	sel-lcs	CONDITION	OPERATING	
				STORM	
				EARTHQUAKE	
				YIELD-FACTOR	factor
			DESCRIPTION	lcs-text	

PURPOSE:

To assign either the condition or description of selected loadcases.

PARAMETERS:

sel-lcs	Loadcases to be assigned condition or description. For valid alternatives see command SELECT LOAD-CASES.
CONDITION	The loadcase condition shall be defined.
OPERATING	The loadcases specified are due to operating conditions (factor =1.0).
STORM	The loadcases specified are due to storm conditions (factor=1.33).
EARTHQUAKE	The loadcases specified are due to earthquake conditions (factor=1.7).
YIELD-FACTOR	The user assigns an arbitrary factor to the yield strength
factor	The factor to be multiplied with the allowable yield strength
DESCRIPTION	Loadcase description shall be given.
lcs-text	Description associated with selected loadcases.

NOTES:

This command is only effective for the API/AISC-WSD code checks.

OPERATING gives a factor of 1.0, STORM a factor=1.33 and EARTHQUAKE a factor of 1.7.

See also:
`PRINT LOAD-CASE...`

EXAMPLES:

```
ASSIGN LOAD-CASE ALL CONDITION STORM
ASSIGN LOAD-CASE 1 DESCRIPTION 'H=5,T=8, direction = 0 Deg'
```

ASSIGN LOCAL-COORDINATE-SYSTEM

...	LOCAL-COORDINATE-SYSTEM	sel-mem	Z	.. .	X-AXIS-DIRECTION			
					Y-AXIS-DIRECTION			
					Z-AXIS-DIRECTION			
					LOCAL-Y-AXIS-DIRECTION			
			Y		LOCAL-Z-AXIS-DIRECTION			
					CHORD-PLANE			
					DIRECTION	dx	dy	dz
					JOINT	name		
					POINT	x	y	z

PURPOSE:

To assign a local coordinate system (re-define direction of local y- or z-axis) to selected members. The local coordinate system is used for stability checks and results presentation. This command is only able to rotate the y- and z-axes about the x-axis. The x-axis is fixed along the member neutral axis.

PARAMETERS:

sel-mem	Members to be assigned a new local coordinate system. For valid alternatives see command SELECT MEMBERS.
Y	Definition of element local y-axis follows.
Z	Definition of element local z-axis follows.
X-AXIS-DIRECTION	Axis points in the direction of global X-axis (superelement coordinate system)
Y-AXIS-DIRECTION	Axis points in the direction of global Y-axis (superelement coordinate system)
Z-AXIS-DIRECTION	Axis points in the direction of global Z-axis (superelement coordinate system)
LOCAL-Y-AXIS-DIRECTION	Corresponds to local y-axis of member.
LOCAL-Z-AXIS-DIRECTION	Corresponds to local z-axis of member.
CHORD-PLANE	The axis shall lie in the plane of the CHORD element (as at end 1 of the member).
DIRECTION dx dy dz	Defines an axis system normal to the member (superelement coordinate system).
JOINT name	Axis points in the direction of a joint with identification name
POINT x y z	Axis points in the direction of a point with coordinates x y z (superelement coordinate system)

NOTES:

A member retains the local coordinate system which was assigned to it during the preprocessing (e.g. Preframe).

For NON-TUBULAR sections only the options LOCAL-Y-AXIS-DIRECTION and LOCAL-Z-AXIS-DIRECTION may be used.

It is sufficient to specify the direction of either Y-axis or Z-axis, since the other axes of the element will be determined according to the longitudinal axis of the element and the right-hand rule.

Definition by CHORD-PLANE is not recommended, use a guiding joint instead since this guarantees consistent (and predictable) behaviour.

See also:

`PRINT MEMBER`

EXAMPLES:

```
ASSIGN LOCAL-COORDINATE ( ONLY 1 ) Y Z-AXIS-DIRECTION
```

ASSIGN MATERIAL

...	MATERIAL	mat-name	sel-mem

PURPOSE:

To assign a material to selected members.

PARAMETERS:

mat-name	Material name to be assigned to the selected members.
sel-mem	Members to be assigned the material. For valid alternatives see command SELECT MEMBERS.

NOTES:

A member retains the material name which was assigned to it during the preprocessing (e.g. Preframe).

See also:

```
CREATE MATERIAL...
CHANGE MATERIAL...
PRINT MEMBER GEOMETRY-AND-MATERIAL
```

EXAMPLES:

```
ASSIGN MATERIAL MAT1 ALL
```

ASSIGN POSITIONS

...	POSITIONS	sel-mem	CODE-CHECK FATIGUE-CHECK	subcommands	data

PURPOSE:

To assign check positions to selected members.

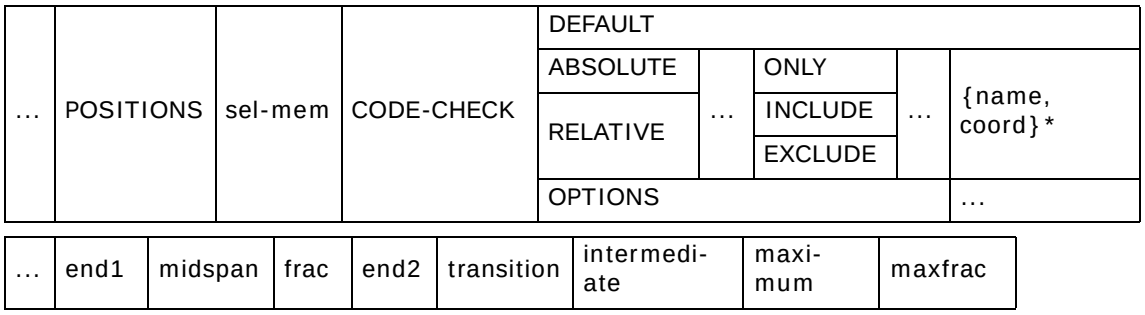
PARAMETERS:

sel-mem	Members to be assigned the positions. For valid alternatives see command SELECT MEMBERS.
CODE-CHECK	Assign positions to be used in code check (yield, stability, cone, member) and when printing member data, stresses and forces.
FATIGUE-CHECK	Assign positions to be used in fatigue check.

All subcommands and data are fully explained subsequently as each command is described in detail.

When assigning positions for use in code check or fatigue by use of the alternatives ABSOLUTE or RELATIVE combined with INCLUDE or EXCLUDE please note that the INCLUDE / EXCLUDE statement just modifies the overall position definition which will be applied to all members in the selection. This overall (common) definition is based on the existing position definition for the “first member” in the active member selection. Hence, modify members one by one for members which do not have identical positions before any change in position definition and always check actual positions after assignment.

ASSIGN POSITIONS sel-mem CODE-CHECK



PURPOSE:

To assign code check positions to selected members.

PARAMETERS:

sel-mem	Members to be assigned the positions. For valid alternatives see command SELECT MEMBERS.
DEFAULT	Default positions are assigned.
ABSOLUTE	Positions defined as absolute distance.
RELATIVE	Positions defined as relative distance.
ONLY	Modify existing defined positions to contain given positions only.
INCLUDE	Add positions to existing defined positions.
EXCLUDE	Remove positions from existing defined positions.
name	User defined identification of position (is not yet stored in the database).
coord	Absolute (when ABSOLUTE) or relative (when RELATIVE) distance measured from End 1 (first joint) of the member.
OPTIONS	Optional way of defining location of positions.
end1	Position at start of member, select ON or OFF
midspan	Position at midspan of element / member, select ON or OFF
frac	Defines the minimum fraction (of total member length) a member segment must have prior to introducing a position at segment midspan
end2	Position at end of member, select ON or OFF
transition	Positions at transitions from one section size to another, e.g. if a can or stub section has been assigned to a member, select ON or OFF
intermediate	Positions at start/end of each element in member after e.g. use of the command CREATE MEMBER, select ON or OFF
maximum	Positions evenly spaced, limited by maximum 50, select ON or OFF
maxfrac	Defines the fraction of total member length where new positions are introduced. The lowest allowable interval value = 0.02, i.e. maximum 50 positions allowed per member

NOTES:

A member will as default have CODE-CHECK positions where stress analysis results are present. That is normally at both ends and at the middle of each finite element that makes up the member. If a member consists of several finite elements, additional positions may be created.

The use of ABSOLUTE coordinates must only be applied to members of same length.

When more than one position is given (alternatives RELATIVE and ABSOLUTE), the positions must be enclosed in parentheses as shown in example below.

If the model contains members spanning across support points or structural joints, is important to define positions at both sides of an intermediate joint for these members. Use the intermediate parameter explained above in combination with the command DEFINE POSITION-BOTH-SIDES ON.

See also:

```
PRINT STRESS
DEFINE POSITION-BOTH-SIDES ON
```

EXAMPLES:

```
ASSIGN POSITIONS ALL CODE-CHECK RELATIVE ( ONLY END1 0.0 MID 0.5 END2 1.0 )
ASSIGN POSITIONS ALL CODE-CHECK OPTIONS ON ON 0.4 ON ON ON ON 0.2
```

If you want to assign similar code check positions to several members which have different definitions of check positions you need to first define the 'simplest form' and then define the wanted check positions. See below:

```
% First define one check position at start of each member. Note that empty
% brackets ( ) means current selection of members.
ASSIGN POSITIONS ( ) CODE-CHECK OPTIONS ON OFF 0.4 OFF OFF OFF OFF 0.2
% Then e.g. define 3 positions, at start (P1), midpoint (P2) and end (P3)
ASSIGN POSITIONS ( ) CODE-CHECK RELATIVE ( ONLY P1 0.0 P2 0.5 P3 1.0 )
```

ASSIGN POSITIONS sel-mem FATIGUE-CHECK

<table>
<tr><td rowspan="5">. . .</td><td rowspan="5">POSITIONS</td><td rowspan="5">sel-mem</td><td rowspan="5">FATIGUE-CHECK</td><td colspan="5">DEFAULT</td></tr>
<tr><td>ABSOLUTE</td><td></td><td>ONLY</td><td></td><td></td></tr>
<tr><td rowspan="2">RELATIVE</td><td rowspan="2">. . .</td><td>INCLUDE</td><td rowspan="2">. . .</td><td rowspan="2">{segment, coord}</td></tr>
<tr><td>EXCLUDE</td></tr>
<tr><td>OPTIONS</td><td colspan="3">. . .</td></tr>
</table>

. . .	end1-cs	end1-bs	end2-bs	end2-cs	transition	intermediate	weld-roots

PURPOSE:
To assign fatigue check positions to selected members.

PARAMETERS:

sel-mem	Members to be assigned the positions. For valid alternatives see command SELECT MEMBERS.
DEFAULT	Default positions are assigned.
ABSOLUTE	Positions defined as absolute distance.
RELATIVE	Positions defined as relative distance.
ONLY	Modify existing defined positions to contain given positions only.
INCLUDE	Add positions to existing defined positions.
EXCLUDE	Remove positions from existing defined positions.
segment	User defined identification of position.
coord	Absolute (when ABSOLUTE) or relative (when RELATIVE) distance measured from End 1 (first joint) of the member.
OPTIONS	Optional way of defining location of positions.
end1-cs	Position at start of member, chord side, select ON or OFF
end1-bs	Position at start of member, brace side, select ON or OFF
end2-bs	Position at end of member, brace side, select ON or OFF
end2-cs	Position at end of member, chord side, select ON or OFF
transition	Positions at transitions from one section size to another, e.g. if a can or stub section has been assigned to a member, select ON or OFF
intermediate	Positions at start/end of each element in member after e.g. use of the command CREATE MEMBER, select ON or OFF
weld-roots	Positions at weld roots, select ON or OFF.

NOTES:
A member will as default have two FATIGUE-CHECK positions at each member end, denominated CHORD-SIDE and BRACE-SIDE. They are both required when using parametric SCFs for brace members.The position names will also include the relative position along member axis, i.e the four default positions will be named:

```
CHORD-SIDE-0.0000
BRACE-SIDE-0.0000
BRACE-SIDE-1.0000
CHORD-SIDE-1.0000
```

If the weld roots fatigue positions are required at tubular joints, the default fatigue check positions on a member can become

```
    CHORD-SIDE          0.0
    BRACE-SIDE          0.0
    CHORD-ROOT          5.0e-05
    BRACE-ROOT          5.0e-05
    BRACE-ROOT          0.99995
    CHORD-ROOT          0.99995
    BRACE-SIDE          1.0
    CHORD-SIDE          1.0
```

Another two positions `CHORD-ROOT` and `CHORD-ROOT` are generated. The weld root positions are available for the tubular butt weld connections as well. See Section 2.5.13 User specified fatigue check positions for details.

The use of ABSOLUTE coordinates must only be applied to members of same length. The true position names referred to in the `ASSIGN SCF MEMBER` and `ASSIGN FATIGE-PART-DAMAGE MEMBER` commands are merged based on the segment and absolute or relative coordinates given. Example; segment = P1 and coord = 0.3 gives the position name P1-0.3000. Absolute position coordinates are translated to relative coordinates when used in the position name. Use the command `PRINT MEMBER FATIGUECHECK-POSITIONS` to list the actual position names.

When more than one position is given (alternatives RELATIVE and ABSOLUTE), the positions must be enclosed in parentheses as shown in example below. See also:

```
PRINT MEMBER FATIGUE-CHECK-DATA
PRINT MEMBER FATIGUE-CHECK-POSITIONS...
```

EXAMPLES:

```
ASSIGN POSITIONS ( ) FATIGUE-CHECK OPTIONS ON ON ON ON ON OFF ON

ASSIGN POSITIONS ( ) FATIGUE-CHECK RELATIVE ( ONLY
    CHORD-SIDE          0.0
    BRACE-SIDE          0.0
    CHORD-ROOT          5.0e-05
    BRACE-ROOT          5.0e-05
    ROOTSectPIPE1      0.19997
    Section-PIPE1      0.19999
    Section-PIPE2      0.20001
    ROOTSectPIPE2      0.20003
    ROOTSectPIPE2      0.49997
    Section-PIPE_2      0.49999
    SectA               0.5
    ROOTSectPIPE2      0.79997
    Section-PIPE2      0.79999
    Section-PILE3      0.80001
    ROOTSectPILE3      0.80003
    BRACE-ROOT          0.99995
    CHORD-ROOT          0.99995
    BRACE-SIDE          1.0
    CHORD-SIDE          1.0
    Sectb               0.75    )

ASSIGN POSITIONS CURRENT FATIGUE-CHECK RELATIVE INCLUDE QUD    0.75
```

ASSIGN SCF

...	SCF	JOINT
		MEMBER

PURPOSE:

To assign SCFs (Stress Concentration Factors) to members at selected joints or positions.

PARAMETERS:

JOINT	Signifies that SCFs shall be defined at a joint.
MEMBER	Signifies that SCFs shall be defined at a member.

All subcommands and data are fully explained subsequently as each command is described in detail.

ASSIGN SCF JOINT

. . .	JOINT	brace	sel-jnt	text	GLOBAL		
					LOCAL	BOTH-SIDES	. . .
						CHORD-SIDE	
						BRACE-SIDE	
					PARAMETRIC	EFTHYMIOU	
						LLOYDS	
						KUANG	
						WORDSWORTH	
						LOTSBERG	scf_att

. . .	UNIFORM	scf_ax, scf_ipb, scf_opb
	CROWN-SADDLE	scf_axc, scf_axs, scf_ipb, scf_opb
	BI-SYMMETRIC	{hot, scf_ax, scf_ipb, scf_opb}*3
	SYMMETRIC	{hot, scf_ax, scf_ipb, scf_opb}*5
	NON-SYMMETRIC	{hot, scf_ax, scf_ipb, scf_opb}*8

PURPOSE:
To assign SCFs (Stress Concentration Factors) at selected joints.

PARAMETERS:

JOINT	Signifies that SCFs shall be defined at a joint.
brace	Name of brace to be assigned to the SCF. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS). Only if the name of a single chord or a single non-pipe member is given in the position of the brace member name, the assignment of LOCAL or GLOBAL SCFs will be allowed for non-brace members.
sel-jnt	Joints where SCF definition shall be assigned. For valid alternatives see command SELECT JOINTS.
text	A descriptive text.
GLOBAL	The user specifies that the global (default) SCF values shall be applied.
LOCAL	The user specifies all SCF values.
PARAMETRIC	The user specifies the parametric formulas to be used in SCF computations.
BOTH-SIDES	The same SCF specification is applied to both chord-side and brace-side of the weld. This option should also be applied for CHORD member or a non-pipe member.
CHORD-SIDE	The SCF specification is applied for the chord side of the weld.
BRACE-SIDE	The SCF specification is applied for the brace side of the weld.

EFTHYMIOU	Use the Efthymiou formulas. These parametric SCFs may be applied for all joint types.
LLOYDS	Use Lloyd's formulas. These parametric SCFs may be applied for gap K and KT joints. If applied to other joint types, Efthymiou formulas will be used.
KUANG	Use Kuang formulas. These parametric SCFs may be applied for all joint types except X-joints.
WORDSWORTH	Use the Wordsworth formulas. These parametric SCFs may be applied for X joints only.
LOTSBERG	Use LOTSBERG SCF formulas, the parametric SCFs proposed in DNVGL RP-C203:2014 and 2016. Lotsberg formula modified T type SCFs at crown hot spots under axial brace loads by including chord bending stresses.
scf_att	stress concentration factor for an attachment; default 1.20.
UNIFORM	The same values applies to all hotspots. 3 SCF values shall be given.
CROWN-SADDLE	The SCF values are specified at the crown and saddle points. Values for other hotspots are derived, see Framework Theory Manual section 7.2.4. 4 SCF values shall be given. This option may only be used for members with pipe section, and only at positions at member ends.
BI-SYMMETRIC	The SCF distribution is double symmetric about the in-plane bending axis and about the out-of-plane bending axis. 3 hotspots with 3 SCF values each must be specified
SYMMETRIC	The SCF distribution is symmetric about the out-of-plane bending axis. The 5 required hotspots for a pipe are numbered 1, 4, 7, 19, 22. This option may only be used for members with pipe section.
NON-SYMMETRIC	The SCF distribution has no symmetry. The user must specify SCF values for all active hotspots. For a pipe section, the 8 required hotspots are numbered 1, 4, 7, 10, 13, 16, 19, 22.
scf_ax	SCF for axial force.
scf_ipb	SCF for in-plane bending.
scf_opb	SCF for out-of-plane bending.
scf_axc	SCF for axial force at crown.
scf_axs	SCF for axial force at saddle.
hot	Hot spot identification.

NOTES:
When assigning SCFs with specification LOCAL and distribution BI-SYMMETRIC, SYMMETRIC or NON-SYMMETRIC warning messages with respect to if SCFs for all necessary hotspots are given is limited. The hotspots which must be assigned SCFs are specified in parameter list above. An exception from above is when the active hotspots for the members cross section have been changed (see command CHANGE HOTSPOTS section-name descr FATIGUE hot*).

If Lloyds formulas are assigned to other joint types than gap K and KT joints Efthymiou formulas will be used when calculating the SCFs. However, any print reporting SCFs will show that Lloyd's has been assigned. When using Efthymiou SCFs the default behaviour is to calculate SCFs according to the conventional approach called model C. It is also possible to use the influence function formulation including or excluding multiplanar effects, models A and B respectively. See the command DEFINE PARAMETRIC-SCF

INFLUENCEFUNCTION- METHOD.

LOTSBERG SCF formulas are parametric SCFs, proposed in DNVGL RP-C203 [42], [43], [44]. See Appendix B.10. It updates the SCF at crowns of brace side and chord side of YT joint by considering the chord bending stress. This option may be applied as an alternative to the original EFTHYMIOU SCF formula. When it is selected, only the SCF at crown hot spots changes. All the other SCFs are the same as the original EFTHYMIOU SCF formula. The LOTSBERG SCF must be applied to the joints of LOADPATH type. A dump file will be printed to see the intermediate result of EFTHYMIOU SCFs and Lotwberg update. See DEFINE FATIGUE-DUMP command.

See also:

```
DEFINE FATIGUE-CONSTANTS...
PRINT MEMBER FATIGUE-CHECK-DAT
DEFINE PARAMETRIC-SCF
```

EXAMPLES:

```
ASSIGN SCF JOINT 33115 ONLY 3110 ' ' LOCAL BOTH-SIDES BI-SYMMETRIC
( 1 1.60 2.00 3.00
4 1.50 2.50 3.60
7 1.20 2.00 3.00 )
ASSIGN SCF JOINT 35415 CONNECTED-TO-MEMBER 35415 None GLOBAL
ASSIGN SCF JOINT 35415 CONNECTED-TO-MEMBER 35415 None PARAMETRIC KUANG
```

ASSIGN SCF MEMBER

...	MEMBER	sel-mem	mem-name	assign-opt			BUTT-WELD	...
							CONE-TRANSITION	...
					positions	text	GLOBAL	
							LOCAL	...
							PARAMETRIC	...

...	BUTT-WELD	DNVGL-RPC203-2020 DNV-RPC203-BSWD	fabtolFactor	SNmisFactor	slope	weld width
		DNVGL-RPC203-2014	0.10TS 0.15TS 0.30TS	slope	weld width	
			MANUAL	fabtol	slope	
		NORSOK-N004-1998	WITH-SLOPE	slope		
			MANUAL	delta	length	

...	CONE-TRANSITION	DNVGL-RPC203-2014	OUTSIDE INSIDE MAXIMUM	thickness	height	location
		NORSOK-N004-1998	OUTSIDE INSIDE MAXIMUM	area	location	

...	LOCAL	UNIFORM	scf_ax, scf_ipb, scf_opb
		BI-SYMMETRIC	{hot, scf_ax, scf_ipb, scf_opb}*3
		SYMMETRIC	{hot, scf_ax, scf_ipb, scf_opb}*5
		NON-SYMMETRIC	{hot, scf_ax, scf_ipb, scf_opb}*8

...	PARAMETRIC	EFTHYMIOU	
		LLOYDS	
		KUANG	
		WORDSWORTH	
		LOTSBERG	scf_att

PURPOSE:
To assign SCFs (Stress Concentration Factors) to member fatigue check positions.

PARAMETERS:

MEMBER	Signifies that SCFs shall be defined at a member.
sel-mem	Members where SCF definition shall be assigned.
	The possible alternative may be `CURRENT` or a particular member's name.
	For other valid alternatives see command `SELECT MEMBERS`.
mem-name	Name of the member whose positions are shown in the position list.
	Use the name of selected member in the current set if *sel-mem* is `CURRENT`.
	Use `NONE` if *sel-mem* is a member's name that is not included in current set.
assign-opt	`INDIVIDUAL` or `SAME`
positions	Select fatigue check positions to which the SCFs shall be applied.
	the positions list comes from the member with *mem-name*
	if *sel-mem* uses `CURRENT`.
text	A descriptive text.
BUTT-WELD	User may specify the butt weld SCF formula option that overrides the global Buttweld SCF option at `DEFINE FATIGUE-CONSTANTS`. The available options are
	DNVGL-RPC203-2020, **DNV-RPC203-BSWD**, **DNVGL-RPC203-2014**, **Norsok-N004-1998**.
	The SCF formula are according to Sections 3.3.7.2 and 3.3.7.3 in DNVGL RP-C203:2020 edition [45] for buttweld welding from the outside and DNV RP-C203:2021 [100] for buttweld welding from both sides, DNVGL-RP-0005:2014-06-RP-C203 [42], and Section C.2.6.3.7 in Norsok N-004:1998 [56]
TS	The smaller thickness at the butt-weld tubular connection. 0.10TS, 0.15TS and 0.30TS corresponds to the fabrication categories: special, primary and secondary, respectively in DNV OS C401 [21].
slope	Slope to be used (default = 4 (for slope 4:1)).
weld width	Width of weld at surface for the welded connection with equal thickness. Sections 3.3.7.2 in RP-C203 [42], [45] and [100].
MANUAL	For DNVGL RP-C203:2014 option, the user specifies a particular fabrication tolerance value and the transition slope
	For NORSOK option, the user specifies butt weld with manually given transition length and eccentricity.
WITH-SLOPE	The user specifies butt weld with fabricated slope, see Figure C.2-11 in Norsok N-004:1998.
fabtol	The local eccentricity from fabrication at the position for DNVGL-RP-0005:2014.
delta	Eccentricity (delta) value to be added to the global fabrication tolerance (default = 0.0).
length	Length (L) over which eccentricity is distributed (default = 0.0).
fabtolFactor	the unitless factor to multiply with TS to obtain the parameter δ_m in the SCF formula from Eqn(3.3.4) to (3.3.6) in DNVGL RP-C203:2020 [45] and DNV RP-C203:2021 [100] (default = 0.0); This value will override the global fabrication tolerance in command `DEFINE FATIGUE CONSTANTS`.

SNmisFactor	the misalignment inherent in the SN data and analysis procedure for as welded butt welds. (default = 0.0). This value will override the global fabrication tolerance in command DEFINE FATIGUE CONSTANTS.
CONE-TRANSITION	The user specifies that SCF at conical transition shall be applied, formulae according to DNVGL-RP-0005:2014-06-RP-C203 and Norsok N-004:1998
OUTSIDE	To calculate SCF on the outside.
INSIDE	To calculate SCF on the inside.
MAXIMUM	To use maximum value of inside and outside SCFs.
area	Area (Ar) of ring stiffener without effective shell (default = 0.0), for NORSOK option.
location	Distance (delta) from intersection line to stiffener (default = 0.0), for both NORSOK and DNVGL-RPC203 2014 option.
thickness	web thickness of the stiffener for DNVGL-RPC203 2014 option.
height	web height of the stiffener for DNVGL-RPC203 2014 option.
GLOBAL	The user specifies that the global (default) SCF values shall be applied.
LOCAL	The user specifies all SCF values.
UNIFORM	The same values applies to all hotspots. 3 SCF values shall be given.
BI-SYMMETRIC	The SCF distribution is double symmetric about the in-plane bending axis and about the out-of-plane bending axis. 3 hotspots with 3 SCF values each must be specified.
SYMMETRIC	The SCF distribution is symmetric about the out-of-plane bending axis. The 5 required hotspots for a pipe are numbered 1, 4, 7, 19, 22. This option may only be used for members with pipe section.
NON-SYMMETRIC	The SCF distribution has no symmetry. The user must specify SCF values for all active hotspots. For a pipe section, the 8 required hotspots are numbered 1, 4, 7, 10, 13, 16, 19, 22.
scf_ax	SCF for axial force.
scf_ipb	SCF for in-plane bending.
scf_opb	SCF for out-of-plane bending.
hot	Hot spot identification.

NOTES:

There are default fatigue check positions created for each member, i.e. CHORD-SIDE, BRACE-SIDE at member ends, and positions at CAN/STUB segment transition and other cross-section transition. If additional positions are needed, or the positions for the analysis run needs to change, user can modify the position option. See command ASSIGN POSITION sel-mem FATIGUE-CHECK regarding defining positions.

When giving position names defining where to apply the SCF rule use the input syntax as shown in the example at the end of this command description. Hence, enclose the positions in parentheses and start with ONLY inside the parentheses to avoid any misunderstandings regarding where to apply the SCFs. The available positions (i.e. the program generated position names) can be listed by use of the command PRINT MEMBER FATIGUE-CHECK-POSITIONS.

The assignment option **assign-opt** has two alternatives: INDIVIDUAL or SAME, which is introduced since v3.13. The INDIVIDUAL option is the default. It means the specified SCF properties at the selected positions are assigned to a single member only. The member can be picked from the *Member in Selection* list or

entered in the *Member Selection* textbox. The other members will not be influenced. If the option is SAME, the SCF properties at the selected positions apply to all the "same" position in CURRENT (DEFAULT) member set. The program will searches over all members in the CURRENT set. If both the position's ID and location distance on a member **exactly** match what are selected from the position list, the specified SCF properties will be assigned to the position. Since the restriction of matching two positions is very tight, user should use caution in applying the SAME assignment option.

There are several restriction on SCF assignement. The PARAMETRIC SCF rule is usually applied for tubular joint connection. It is valid only at member's ending positions. This option is greyed out if the selected position locates in the middle of the member. By contrast, assigning BUTT-WELD or CONE-TRANSITION SCF to a position at member's end won't work. If the CONE-TRANSITION alternative is assigned to a transition with no true cone junction, the SCF calculation will fail and the global axial SCF will be used. A message similar to

```
Brace      BM3 at position 0.0 BRACE-SIDE in joint      JT1
     Brace at Section-COL_3. Neutral coordinate 0.47999
   * Illegal SCF: Non-conical position assigned CONE SCF;
     Global SCFax used at Member      BM3  transition 0.48
```

will be given, and on the print of results the text *ILLEGAL* will appear at the SCFrule location in the print table. Assigning BUTT-WELD SCF rule to a cone-tubular junction will calculate a butt weld SCF with actual outer diameter and thickness of sections at the cone-tubular junction, but neglect that it is actually a conical transition.

When assigning SCFs with specification LOCAL and distribution BI-SYMMETRIC, SYMMETRIC or NON-SYMMETRIC warning messages with respect to if SCFs for all necessary hotspots are given is limited. The hotspots which must be assigned SCFs are specified in parameter list above. An exception from above is when the active hotspots for the members cross section have been changed (see command CHANGE HOTSPOTS section-name descr FATIGUE {hot}*).

The formulae used for butt welds and conical transitions are according to DNVGL-RP-0005:2014-06-RP-C203 [42] sections 3.3.7 "Tubular butt weld connections" and 3.3.9 "Stress concentration factors for conical transitions". The buttweld SCF has new options referring to DNVGL RP-C203:2020 [45] and DNV RP-C203:2021 [100]. But the conical transition SCF does not have the new option. For Norsok N-004:1998 [56], Section C.2.6.3.7 "Stress Concentration Factors for Tubular Butt Weld Connections" and the stiffened cone part of Section C.2.6.3.9 "Conical transitions" are used.

For **BUTT-WELD** connections, a **global** variable is used to account for the tubular out of roundness and centre eccentricity due to fabrication imperfections. This value is defined by the command DEFINE FATIGUE-CONSTANTS FABRICATION-TOLERANCE-OPTION .

For **NORSOK** option, the total eccentricity and thickness transition length applied in Eqn(C.2.10) will be

- WITH-SLOPE

$$\delta = \text{global fabrication tolerance} + (T/2 - TS/2)$$
$$L = \textit{Slope} * (T - TS)$$

  where T is the larger thickness;

- MANUAL

$$\delta = \text{global fabrication tolerance} + \textit{delta},$$
$$L = \textit{length}$$

  where *delta* is the user input eccenctricity. If zero (default value) is given as input to *delta* and/or *length* for butt weld with MANUAL option, then the following values will be used ([46]):

$$\delta = \text{global fabrication tolerance} + (T/2 - TS/2),$$
$$L = T/2 + TS/2.$$

For **DNVGL RP-C203-2014** buttweld SCF, the local fabrication tolerance options at this command are: 0.10TS, 0.15TS, 0.30TS, MANUAL. The local option will override the global fabrication tolerance option in command

`DEFINE-FATIGUE-CONSTANTS FABRICATION-TOLERANCE-OPTION`

For **DNVGL-RPC203-2020** and **DNV-RPC203-BSWD** buttweld SCF, there is no fabrication tolerance options at this command but the fabtol factor. When the fabtol factor is specified, it will determine the magnitude of the eccentricity (misalignment) from fabrication. The inherent misalignment of SN curve data in this command will override the global counterpart at command

`DEFINE FATIGUE-CONSTANTS INHERENT-SN-MISALIGNMENT-FACTOR`

The use of the parameters in the SCF formula refers to Appendix B.8 for details.

The **CONE-TRANSITION** SCF formula Eqn(C.2.14) of Norsok N-004:1998 [56] is used for both unstiffened and ring stiffened cone junctions (see DNV-RP-C205:2005 [46]). For DNVGL SCF at cone transition, there is no new option for 2020 edition, unlike Buttweld Transition. Eqn(3.3.12) and Eqn(3.3.13) in DNVGL-RP-C203:2014 are applied for un-stiffened cone junction and Eqn(3.3.14-3.3.15) for ring-stiffened cone junction. The un-stiffened cone SCF formula does not tell the hotspot location at outside or inside. Therefore, the *SCF Alternative* option `OUTSIDE` / `INSIDE` / `MAXIMUM` are actually not effective and to be ignored for non-stiffened cone. See Appendix B.8 for details.

It is not possible to assign more than one SN curve to each fatigue check position. Hence it may be necessary to perform more than one fatigue analysis to cover combinations of SCFs and SN curves.

It is always recommended to review the SCF assignment before running any fatigue analysis. The SCF on member can be reviewed in the report of member's fatigue check data. Use command `PRINT MEMBER FATIGUE-CHECK-DATA`. The report shows the SCFs at member's intermediate non-end positions. For the SCFs at a joint connection, use `PRINT-JOINT-Parametric SCF`. When printing **Member-Fatigue Check Data**, five of the print table fields will contain text/data as shown below:

Field	**Butt-Weld**	**Cone-Transition**			**Local**
		DNVGL		NORSOK	
		Un-stiffened	Stiffened	Stiffened	
SCFrule	BUTT-DNV BUTT-NOR **BUTT2020** **BUTTDBSW**	CONE-DNV	CONE-DNV	CONE-NOR	LOCAL
Symmet	0.10TS 0.15TS 0.30TS MANUAL	OUTSIDE,INSIDE,MAXIMUM			UNIFORM BI-SYMM SYMMETR NON-SYM
SCF	SCF	SCF	SCF	SCF	SCFax
Para1	Total Eccentricity	Tc	SCFadd	SCFadd	SCFipb
Para2	length, weld width	$\tan\alpha$	$\tan\alpha$	stiffener area	SCFopb

See also:

```
DEFINE FATIGUE-CONSTANTS...
PRINT MEMBER FATIGUE-CHECK-DATA...
PRINT MEMBER FATIGUE-CHECK-POSITIONS...
```

EXAMPLES:

```
ASSIGN SCF MEMBER CURRENT BM1 INDIVIDUAL ( ONLY Section-C2_31-0.5000 ) None
    CONE-TRANSITION NORSOK-N004-1998 MAXIMUM 0.03 0.05
ASSIGN SCF MEMBER CURRENT BM1 INDIVIDUAL ( ONLY Section-BR1_3-0.7500
    Section-BR1_2-0.7500 ) None BUTT-WELD DNVGL-RPC203-2014 0.30TS 4.0 0.0
ASSIGN SCF MEMBER BM3 BM3 INDIVIDUAL ( ONLY Section-BR1_3-0.1159 ) None
    BUTT-WELD DNVGL-RPC203-2014 MANUAL 0.005 4.0 0.0
ASSIGN SCF MEMBER CURRENT BM1 SAME ( ONLY Section-BR1_3-0.5000 ) None LOCAL
    UNIFORM 2.5 2.5 2.5
```

ASSIGN SECTION

...	SECTION	sec-name	sel-mem

PURPOSE:

To assign a section to selected members.

PARAMETERS:

sec-name	Name of section to be assigned to the selected members.
sel-mem	Members to be assigned the section. For valid alternatives see command SELECT MEMBERS.

NOTES:

A member retains the section name which was assigned to it during the preprocessing (e.g. Preframe).

See also:

```
CREATE SECTION...
PRINT MEMBER GEOMETRY-AND-MATERIAL...
```

EXAMPLES:

```
ASSIGN SECTION P100012 ALL
```

ASSIGN SN-CURVE

...	SN-CURVE	JOINT	brace		sel-jnt	sn-name
		MEMBER	member		sn-name	
		MEMBER	mem-ber	INDIVIDUAL	{sn-name}*	

PURPOSE

To assign an SN-curve to members at selected joints or positions.

PARAMETERS:

JOINT	Signifies that the SN-curve shall be defined at a joint.
MEMBER	Signifies that the SN-curve shall be defined at member fatigue check positions.
INDIVIDUAL	Signifies that the SN-curve shall be defined individually at each member fatigue check position.
brace	Brace name to be assigned the SN-curve. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS). Only if the name of a single chord or a single non-pipe member is given in the position of the brace member name, the SN-curve assignment will be allowed for a non-brace member.
sel-jnt	Joints where the SN-curve shall be assigned. For valid alternatives see command SELECT JOINTS.
member	Member where the SN-curve shall be assigned.
sn-name	Name of SN-curve to be assigned. For the INDIVIDUAL option an SN-curve name must be given for each fatigue check position defined.

NOTES:

Use the commands PRINT SN-CURVE and DISPLAY SN-CURVE to see curve data and shape.

Use the name API-XP to represent the library API-X' curve (P for prime).

Several curves have been defined in the SN curve library, see Section 2.3.30 SN curve.

Default thickness correction factors have been predefined for the SN library NORSOK, DOE, ABS, HSE and DNV RP-C203-2010 SN-curves. The correction reference thickness and cut-off thickness are applied in SI unit meters. The thickness corrections are converted to current length unit by use of the command: DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR value.

Note that convertion of thickness corrections to current length unit by the length unit factor applies to library SN-curves with predefined thickness corrections. For all other SN-curves, thickness corrections must be assigned in current length unit of the structure by the command ASSIGN THICKNESS-CORRECTION. Reassignment of thickness corrections of library SN-curves with predefined thickness correction (by command ASSIGN THICKNESS-CORRECTION) must be given in the SI length unit meter.

For members with non-pipe cross sections, the actual thickness used when calculating the thickness correction factor is the maximum plate thickness (flange or web) from the section.

See also:

```
CHANGE SN-CURVE...
CREATE SN-CURVE...
PRINT SN-CURVE...
DISPLAY SN-CURVE...
ASSIGN THICKNESS-CORRECTION...
```

EXAMPLES:

```
ASSIGN SN-CURVE JOINT ALL 1000 API-X
```

ASSIGN STABILITY

...	STABILITY	sel-mem	AISC-LSEC-METHOD	subcom-mands	data
			BUCKLING-CURVE-Y		
			BUCKLING-CURVE-Z		
			BUCKLING-LENGTH		
			FABRICATION		
			FLOODING-STATUS		
			KXT		
			KY		
			KZ		
			LATERAL-BUCKLING-FACTOR		
			LSEC-CONNECTION		
			MOMENT-REDUCTION-FACTOR		
			NORSOK_ISO-AXIAL-COMPRESSION		
			STIFFENER-SPACING		
			UNSUPPORTED-BTM-FLANGE-LENGTH		
			UNSUPPORTED-FLANGE-LENGTH		

PURPOSE:

To assign stability data which are effective primarily for stability check calculations. All subcommands and data are fully explained subsequently as each command is described in detail.

PARAMETERS:

sel-mem	Select members for which to assign stability data. For valid alternatives see command SELECT MEMBERS.
AISC-LSEC-METHOD	To assign the L section calculation method of the AISC code.
BUCKLING-CURVE-Y	To assign a Buckling curve for buckling about a member's local y-axis (in the local z-x-plane).
BUCKLING-CURVE-Z	To assign a Buckling curve for buckling about a member's local z-axis (in the local x-y-plane).
BUCKLING-LENGTH	To assign the buckling length for buckling about a member's local y- and z-axes (in the local z-x- and x-y-planes).
FABRICATION	To assign the method used during fabrication of the member.
FLOODING-STATUS	To assign flooding status for tubular members
KXT	To assign an effective length factor for torsional buckling.
KY	To assign an effective length factor for buckling in a member's local x-z plane (i.e. about local y-axis).
KZ	To assign an effective length factor for buckling in a member's local x-y plane (i.e. about local z-axis).
LATERAL-BUCKLING-FACTOR	To assign the lateral buckling factor.
LSEC-CONNECTION	To assign the L section profile connection to the structure.
MOMENT-REDUCTION-FACTOR	To assign the moment (amplification) reduction factor.
NORSOK_ISO-AXIAL-COMPRESSION	To assign option with respect to axial compression according to NORSOK commentary.
STIFFENER-SPACING	To assign stiffener spacing for tubular members

UNSUPPORTED-BTM-FLANGE-LENGTH	To assign the unsupported length between lateral support of bottom flange.
UNSUPPORTED-FLANGE-LENGTH	To assign the unsupported length of the compression flange.

All subcommands and data are fully explained subsequently as each command is described in detail.

ASSIGN STABILITY sel-mem AISC-LSEC-METHOD

...	sel-mem	AISC-LSEC-METHOD	NONE
			E5-A
			E5-B

PURPOSE:

To assign the L section calculation method of the AISC code.

PARAMETERS:

sel-mem	Members to be assigned L section calculation method. For valid alternatives see command SELECT MEMBERS.
NONE	No method assigned.
E5-A	Assign method E5 a).
E5-B	Assign method E5 b).

NOTES:

See also:
`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY ( ) AISC-LSEC-METHOD E5-A
```

ASSIGN STABILITY sel-mem BUCKLING-CURVE-Y

...	sel-mem	BUCKLING-CURVE-Y	NONE
			A0
			A
			AUTO
			B
			C
			D

PURPOSE:

To assign buckling curves that will be used to calculate the characteristic axial compressive buckling strength of selected members. The curve is assigned for buckling about the member's local y-axis (in the local z-x-plane). This command is valid for both tubular and non tubular members.

PARAMETERS:

sel-mem	Members to be assigned the buckling curve. For valid alternatives see command SELECT MEMBERS.
A0	Buckling curve A0 shall be assigned to the selected members. (EUROCODE and NS3472 release 3 only)
A	Buckling curve A shall be assigned to the selected members.
AUTO	Buckling curve shall automatically be assigned to the selected members. (EUROCODE and NS3472 release 3 only)
B	Buckling curve B shall be assigned to the selected members.
C	Buckling curve C shall be assigned to the selected members.
D	Buckling curve D shall be assigned to the selected members. (EUROCODE and NS3472 release 3 only)

NOTES:

By default, for tubular members, buckling curve A is assigned.

By default, for non-tubular members, buckling curve C is assigned.

The buckling curves are only used for the NPD/NS3472 and EUROCODE code check.

When assigning the AUTO option available for EUROCODE and NS3472 release 3, the buckling curves to be used for I (H) sections and welded box sections will automatically be selected. For pipe profiles and rolled box sections curve A is used as default for both axes. For other profile types than mentioned above curve C is used as default for both axes.

See also:

```
ASSIGN STABILITY sel-mem BUCKLING-CURVE-Z...
PRINT MEMBER STABILITY-CHECK-DATA...
```

EXAMPLES:

```
ASSIGN STABILITY WITH-SECTION I30400 BUCKLING-CURVE-Y B
```

ASSIGN STABILITY sel-mem BUCKLING-CURVE-Z

...	sel-mem	BUCKLING-CURVE-Z	NONE
			A0
			A
			AUTO
			B
			C
			D

PURPOSE:

To assign buckling curves that will be used to calculate the characteristic axial compressive buckling strength of selected members. The curve is assigned for buckling about the member's local z-axis (in the local x-y-plane). This command is valid for both tubular and non tubular members.

PARAMETERS:

sel-mem	Members to be assigned the buckling curve. For valid alternatives see command SELECT MEMBERS.
A0	Buckling curve A0 shall be assigned to the selected members. (EUROCODE and NS3472 release 3 only)
A	Buckling curve A shall be assigned to the selected members.
AUTO	Buckling curve shall automatically be assigned to the selected members. (EUROCODE and NS3472 release 3 only)
B	Buckling curve B shall be assigned to the selected members.
C	Buckling curve C shall be assigned to the selected members.
D	Buckling curve D shall be assigned to the selected members. (EUROCODE and NS3472 release 3 only)

NOTES:

By default, for tubular members, buckling curve A is assigned.

By default, for non-tubular members, buckling curve C is assigned.

The buckling curves are only used for the NPD/NS3472 and EUROCODE code check.

When assigning the AUTO option available for EUROCODE and NS3472 release 3, the buckling curves to be used for I (H) sections and welded box sections will automatically be selected. For pipe profiles and rolled box sections curve A is used as default for both axes. For other profile types than mentioned above curve C is used as default for both axes.

See also:

```
ASSIGN STABILITY sel-mem BUCKLING-CURVE-Y...
PRINT MEMBER STABILITY-CHECK-DATA...
```

EXAMPLES:

```
ASSIGN STABILITY WITH-SECTION I30400 BUCKLING-CURVE-Z B
```

ASSIGN STABILITY sel-mem BUCKLING-LENGTH

...	sel-mem	BUCKLING-LENGTH	AUTOMATIC		
			LATERAL-SUPPORT-AUTO		
			LENGTH-BETWEEN-JOINTS		
			MANUAL	Ly	Lz

PURPOSE:

To assign the buckling length of one or more members for buckling about the local y- and z-axes (in the local z-x- and x-y-planes).

PARAMETERS:

sel-mem	Members to be assigned buckling lengths. For valid alternatives see command SELECT MEMBERS.
AUTOMATIC	Perform an automatic buckling length calculation of tubular members in NORSOK and API member and stability code checks.
LATERAL-SUPPORT-AUTO	Perform an automatic buckling length calculation of tubular members in NORSOK and API member and stability code checks with lateral spring stiffness at start and end of member set to 1.0.
LENGTH-BETWEEN-JOINTS	The length between joints shall be used for the computation of both buckling lengths.
MANUAL	Buckling lengths shall be user specified.
Ly	Buckling length for buckling in the member's local x-z plane.
Lz	Buckling length for buckling in the member's local x-y plane.

NOTES:

By default the buckling length of each member is computed as its length between joints.

The automatic buckling length option calculates buckling factors for each element which is part of the member. In the code check the critical axial capacity is calculated for each code check position using the buckling factors for the element corresponding to the check position.

The effective length factors which by default are set to 1.0 for both y and z-axes are not used for members with the automatic calculation activated. One exception is if the automatic buckling calculation fails. The buckling length will then be equal to the member length multiplied with the manually given effective length factors.

When the alternative LATERAL-SUPPORT-AUTO is used, the rotational and lateral spring stiffnesses are not calculated by the program. The lateral springs are under these condition set to 1.0 (i.e. supported) for start and end node of the member, and the effective length factors are calculated based on these support spring stiffnesses only. Hence, this option may be used to neglect the stiffness of incoming members on intermediate nodes, e.g. riser supports along a jacket leg.

The largest value of Ly and Lz will be assumed as the value of the 'chord length' in the case of using parametric SCFs, when there is no aligned element. If there is an aligned element, the total length of the aligned element will be added to the largest of Ly and Lz. This default may be overruled by the command ASSIGN JOINT-CHORD-LENGTH.

See also:

```
PRINT MEMBER STABILITY-CHECK-DATA...
```

EXAMPLES:

```
ASSIGN STABILITY 100 BUCKLING-LENGTH MANUAL 15.5 7.3
```

ASSIGN STABILITY sel-mem FABRICATION

...	sel-mem	FABRICATION	NONE
			ROLLED
			WELDED

PURPOSE:

To assign the fabrication method of selected members. This command is effective for non-tubular members only.

PARAMETERS:

sel-mem	Members to be assigned fabrication method. For valid alternatives see command SELECT MEMBERS.
NONE	No fabrication method assigned.
ROLLED	Signifies a rolled type of construction.
WELDED	Signifies a welded type of construction.

NOTES:

By default the fabrication method is set to WELDED for all members.

This parameter is not applicable for members with PIPE or GENERAL cross section.

See also:

`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY ONLY WITH-SECTION I30400 FABRICATION WELDED
```

ASSIGN STABILITY sel-mem FLOODING-STATUS

...	sel-mem	FLOODING-STATUS	NONE
			FLOODED
			NON-FLOODED

PURPOSE:

To assign flooding status to selected members. The flooding status is used to evaluate if a pipe member is exposed to external water pressure when immersed, and used in yield and stability / hydrostatic checks.

PARAMETERS:

sel-mem	Members to be assigned flooding status. For valid alternatives see command SELECT MEMBERS.
NONE	The flooded status is not assigned.
FLOODED	The member is flooded.
NON-FLOODED	The member is not flooded.

NOTES:

By default the flooding status is set to NON-FLOODED for all members.

The flooding status is updated according to flooding information defined on the results file, i.e. conceptual information defined in e.g. Preframe.

See also:

`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY ( ONLY WITH-SECTION P100040 ) FLOODING-STATUS FLOODED
```

ASSIGN STABILITY sel-mem KXT

...	sel-mem	KXT	kxt-fact

PURPOSE:

To assign an effective length factor for torsional buckling.

PARAMETERS:

sel-mem	Members to be assigned torsional buckling length factor. For valid alternatives see command SELECT MEMBERS.
kxt-fact	Value of the effective length factor Kxt.

NOTES:

By default the effective length factor Kxt is set to unity

See also:

```
ASSIGN STABILITY sel-mem KY...
ASSIGN STABILITY sel-mem KZ...
PRINT MEMBER STABILITY-CHECK-DATA...
```

EXAMPLES:

```
ASSIGN STABILITY ALL KXT 1.4
```

ASSIGN STABILITY sel-mem KY

...	sel-mem	KY	ky-fact

PURPOSE:

To assign the effective length factor for one or more members for buckling in local x-z plane (i.e. about local y-axis).

PARAMETERS:

sel-mem	Members to be assigned buckling length factor. For valid alternatives see command SELECT MEMBERS.
ky-fact	Value of the effective length factor Ky.

NOTES:

By default the effective length factor Ky is set to unity.

For NPD-NS3472 code check, Ky will be calculated by the program according to NPD section 3.2.4.4 if Ky is assigned a value less than 0.001.

The largest value of Ky and Kz assigned to a chord member will be assumed as the value of the 'chord end fixity parameter' in the case of fatigue analysis using Efthymiou SCFs. Note that in this case Ky and Kz must be given in the range [0.5,1.0], where 0.5 corresponds to a fixed chord and 1.0 corresponds to a pinned chord.

See also:

```
ASSIGN STABILITY sel-mem KXT...
ASSIGN STABILITY sel-mem KZ...
PRINT MEMBER STABILITY-CHECK-DATA...
```

EXAMPLES:

```
ASSIGN STABILITY ALL KY 0.8
```

ASSIGN STABILITY sel-mem KZ

...	sel-mem	KZ	kz-fact

PURPOSE:

To assign the effective length factor for one or more members for buckling in local x-y plane (i.e. about local z-axis).

PARAMETERS:

sel-mem	Members to be assigned buckling length factor. For valid alternatives see command SELECT MEMBERS.
kz-fact	Value of the effective length factor Kz.

NOTES:

By default the effective length factor Kz is set to unity

For NPD-NS3472 code check, Kz will be calculated by the program according to NPD section 3.2.4.4 if Ky is assigned a value less than 0.001.

The largest value of Ky and Kz assigned to a chord member will be assumed as the value of the 'chord end fixity parameter' in the case of fatigue analysis using Efthymiou SCFs. Note that in this case Ky and Kz must be given in the range [0.5,1.0], where 0.5 corresponds to a fixed chord and 1.0 corresponds to a pinned chord.

See also:

```
ASSIGN STABILITY sel-mem KXT...
ASSIGN STABILITY sel-mem KY...
PRINT MEMBER STABILITY-CHECK-DATA...
```

EXAMPLES:

```
ASSIGN STABILITY ALL KZ 1.2
```

ASSIGN STABILITY sel-mem LATERAL-BUCKLING-FACTOR

...	sel-mem	LATERAL-BUCKLING-FACTOR	AUTO
			Cb

PURPOSE:

To assign the lateral buckling factor to selected members. The lateral buckling factor is usually denoted Cb according to AISC and Ψ according to NS3472.

PARAMETERS:

sel-mem	Members to be assigned lateral buckling factor. For valid alternatives see command SELECT MEMBERS.
AUTO	The lateral buckling factor shall be computed automatically, according to the moment distribution along the member length.
Cb	Value of the lateral buckling factor manually specified by the user.

NOTES:

By default, the value of the lateral buckling factor is set to unity.

The lateral buckling factor is not applicable for members with PIPE cross section.

The AUTO option is only applicable for API-AISC-WSD, API-AISC-LRFD and EUROCODE/NS3472.

See also:

```
PRINT MEMBER STABILITY-CHECK-DATA...
```

EXAMPLES:

```
ASSIGN STABILITY ONLY WITH-SECTION I30400 LATERAL-BUCKLING-FACTOR AUTO
```

ASSIGN STABILITY sel-mem LSEC-CONNECTION

...	sel-mem	LSEC-CONNECTION	NONE
			LONG-LEG
			SHORT-LEG

PURPOSE:

To assign the L section calculation method of the AISC code if L section profile is connected to the structure via its long or short leg.

PARAMETERS:

sel-mem	Members to be assigned for the LSEC connection. For valid alternatives see command SELECT MEMBERS.
NONE	No connection is assigned.
LONG-LEG	Assign L section connection via its long leg.
SHORT-LEG	Assign L section connection via its short leg.

NOTES:

Default connection is LONG-LEG

See also:

`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY ( ) LSEC-CONNECTION LONG-LEG
```

ASSIGN STABILITY sel-mem MOMENT-REDUCTION-FACTOR

...	sel-mem	MOMENT-REDUCTION-FACTOR	MANUAL	Cmy	Cmz
			AISC		
			API-A		
			API-B		
			API-C		
			EUROCODE		
			ISO-1		
			ISO-2		
			ISO-3		
			ISO-2-3		
			NONE		
			NORSOK-A		
			NORSOK-B		
			NORSOK-C		
			NORSOK-B-C		
			NS3472		

PURPOSE:

To assign the moment (amplification) reduction factor for selected members. The factor is usually denoted Cm according to AISC and NORSOK, m according to NS3472 (release 2) and β according to EUROCODE and NS3472 (release 3).

PARAMETERS:

sel-mem	Members to be assigned moment reduction factor. For valid alternatives see command SELECT MEMBERS.
MANUAL	The Cm factors shall be manually specified by the user.
Cmy	Value of Cm for buckling about the member's local y-axis (in the local z-x-plane).
Cmz	Value of Cm for buckling about the member's local z-axis (in the local x-y-plane).
AISC	The Cm values shall be computed according to AISC.
API-A	The Cm values shall be computed according to the API equation a.
API-B	The Cm values shall be computed according to the API equation b.
API-C	The Cm values shall be computed according to the API equation c.
EUROCODE	The β values shall be computed according to EUROCODE
ISO-1	The Cm values shall be computed according to the ISO standard equation 1
ISO-2	The Cm values shall be computed according to the ISO standard equation 2
ISO-3	The Cm values shall be computed according to the ISO standard equation 3
ISO-2-3	The Cm values shall be computed according to the ISO standard equation 2 or 3
NONE	Use acting moment at code check position (NORSOK only)
NORSOK-A	The Cm values shall be computed according to NORSOK alternative (a)
NORSOK-B	The Cm values shall be computed according to NORSOK alternative (b)
NORSOK-C	The Cm values shall be computed according to NORSOK alternative (c)

NORSOK-B-C	The Cm values shall be computed according to NORSOK alternative (b) or (c) dependant of transverse loading
NS3472	The m (β) values shall be computed according to NS3472

NOTES:

By default, all members have a MANUAL assignment where both values for Cm are set to unity.

Select MANUAL or one of the appropriate alternatives dependant of selected code of practice.

For EUROCODE and NS3472 (release 3) it is the equivalent uniform moment factors β (i.e. not the moment amplification factor k) which are calculated or manually given through this command.

See also:

`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY ALL MOMENT-REDUCTION-FACTOR API-B
```

ASSIGN STABILITY sel-mem NORSOK_ISO-AXIAL-COMPRESSION

...	sel-mem	NORSOK_ISO-AXIAL-COMPRESSION	NONE
			EXCLUDE-COMMENTARY
			INCLUDE-COMMENTARY

PURPOSE:

Option regarding use of the Commentary in NORSOK and ISO standards commentary sections.

PARAMETERS:

sel-mem	Members to be assigned stiffener spacing. For valid alternatives see command SELECT MEMBERS.
NONE	None commentary part.
EXCLUDE-COMMENTARY	Disregard the commentary part.
INCLUDE-COMMENTARY	Use the commentary part (Default).

NOTES:

According to the NORSOK standard section Comm. 6.3.3 “Axial compression”, members with two or more different cross sections can calculate the design compressive resistance Nc,Rd as given in equations 12.1 and 12.2. This stability parameter has been introduced to make it possible to switch off using this part of NORSOK, i.e. calculating the characteristic axial compressive strength as given in NORSOK section 6.3.3 using the characteristic local buckling strength corresponding to the cross section defined at each code check position. See also the ISO standard equations (A.13.2-1) and (A.13.2-2).

See also:

`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY ALL NORSOK_ISO-AXIAL-COMPRESSION EXCLUDE-COMMENTARY
```

ASSIGN STABILITY sel-mem STIFFENER-SPACING

...	sel-mem	STIFFENER-SPACING	LENGTH-BETWEEN-JOINTS
			CONE-LENGTH
			Lh

PURPOSE:
To assign the stiffener spacing to selected members.

PARAMETERS:

sel-mem	Members to be assigned stiffener spacing. For valid alternatives see command `SELECT MEMBERS`.
LENGTH-BETWEEN-JOINTS	The length between joints shall be used as stiffener spacing.
CONE-LENGTH	The geometric length of the cone shall be used as stiffener spacing.
Lh	Value of the stiffener spacing manually specified by the user.

NOTES:
By default, the value of the stiffener spacing is set to length between joints.

The CONE-LENGTH option is to be used for conical transition when calculating the geometric parameter “mu" used in the ISO 19902 standard, section 13.2.6.2 “Hoop buckling", see [41] and Norsok N-004 rev. 3, section 6.3.6 “Hydrostatic pressure", see [58].

See also:

`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY ONLY WITH-SECTION P30400 STIFFENER-SPACING 0.8
```

ASSIGN STABILITY sel-mem UNSUPPORTED-FLANGE-LENGTH

...	sel-mem	UNSUPPORTED-FLANGE-LENGTH	LENGTH-BETWEEN-JOINTS
			flange-len

PURPOSE:

To assign the unsupported length of the compression flange for one or more members.

PARAMETERS:

sel-mem	Members to be assigned unsupported flange length. For valid alternatives see command SELECT MEMBERS.
LENGTH-BETWEEN-JOINTS	The length between joints shall be used for computation of the unsupported flange length.
flange-len	Value of the unsupported flange length.

NOTES:

By default the unsupported flange length is the computed length between joints.

This parameter is not applicable for members with PIPE or GENERAL cross sections.

See also:
`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY 200 UNSUPPORTED-FLANGE-LENGTH 13.5
```

ASSIGN STABILITY sel-mem UNSUPPORTED-BTM-FLANGE-LENGTH

...	sel-mem	UNSUPPORTED-BTM-FLANGE-LENGTH	LENGTH-BETWEEN-JOINTS
			flange-len

PURPOSE:

To assign unsupported bottom flange length for one or more members.

PARAMETERS:

sel-mem	Members to be assigned unsupported bottom flange length. For valid alternatives see command SELECT MEMBERS.
LENGTH-BETWEEN-JOINTS	The length between joints shall be used for computation of the unsupported bottom flange length.
flange-len	Value of the unsupported flange length.

NOTES:

This command applies to AISC 360-10 code check only.

By default the unsupported bottom flange length is the computed length between joints.

This parameter is not applicable for members with PIPE or GENERAL cross sections.

See also:
`PRINT MEMBER STABILITY-CHECK-DATA...`

EXAMPLES:

```
ASSIGN STABILITY 200 UNSUPPORTED-BTM-FLANGE-LENGTH 12.5
```

ASSIGN STUB

...	STUB	BRACE	data
		JOINT	
		NONE	

PURPOSE:

To assign a STUB section either to a joint or directly to a brace member or to remove a STUB section from a joint or a BRACE member.

PARAMETERS:

JOINT	Instructs the program to assign a STUB section at a joint. All brace members at that joint shall then be assigned the STUB properties specified subsequently.
BRACE	Instructs the program to assign a STUB section at a specific end of a BRACE member.
NONE	Instructs the program to remove a STUB section assigned at one joint or at a specific end of a BRACE member.

All data are fully explained subsequently as each command is described in detail.

ASSIGN STUB BRACE

...	BRACE	joint	brace	sec-name	mat-name	stb-length
						AUTOMATIC

PURPOSE:

To assign a STUB section at a specific end of a BRACE member.

PARAMETERS:

joint	Name of joint identifying the brace end where the STUB section shall be assigned.
brace	Name of brace to be assigned the STUB section. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS).
sec-name	Name of STUB section. Note that this must be a tubular section.
mat-name	Material name to be assigned to the STUB section.
stb-length	Length of STUB section.
AUTOMATIC	Calculate automatically in accordance with the guidelines for joint design as given in API / NPD / NORSOK.

NOTES:

The BRACE member STUB lengths are used for material take-off and for code checks if checking more than 3 positions along the member (default is only both ends and mid point).

The stub length must be less or equal to half the element length.

See also:

```
ASSIGN STUB NONE...
ASSIGN STUB JOINT...
DEFINE JOINT-PARAMETERS...
PRINT CHORD-AND-BRACE...
```

EXAMPLES:

```
ASSIGN STUB BRACE 100 2000 STUB100 MAT1 AUTOMATIC
```

ASSIGN STUB JOINT

...	JOINT	joint	sec-name	mat-name	stb-len
					AUTOMATIC

PURPOSE:

To assign a STUB section at a given joint. All brace members at that joint shall then be assigned the STUB properties specified subsequently.

PARAMETERS:

joint	Name of joint that will be assigned the STUB section.
sec-name	Name of STUB section. Note that this must be a tubular section.
mat-name	Material name to be assigned to the STUB section.
stb-len	Length of STUB section.
AUTOMATIC	Calculate automatically in accordance with the guidelines for joint design as given in API / NPD / NORSOK.

NOTES:

The BRACE member STUB lengths are used for material take-off and for code checks if checking more than 3 positions along the member (default is only both ends and mid point).

The stub length must less or equal to half the element length.

See also:

```
ASSIGN STUB NONE...
ASSIGN STUB BRACE...
DEFINE JOINT-PARAMETERS...
PRINT CHORD-AND-BRACE...
```

EXAMPLES:

```
ASSIGN STUB JOINT 100 STUB100 MAT1 1.0
```

ASSIGN STUB NONE

...	NONE	joint	brace

PURPOSE:

To remove a STUB section from a specific joint.

PARAMETERS:

joint	Name of joint where a STUB section is to be removed
brace	Name of brace for which to remove the STUB section. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS).

NOTES:

See also:

```
ASSIGN STUB JOINT...
ASSIGN STUB BRACE
ASSIGN CHORD...
PRINT CHORD-AND-BRACE...
```

EXAMPLES:

```
ASSIGN STUB NONE 2000
```

ASSIGN THICKNESS-CORRECTION

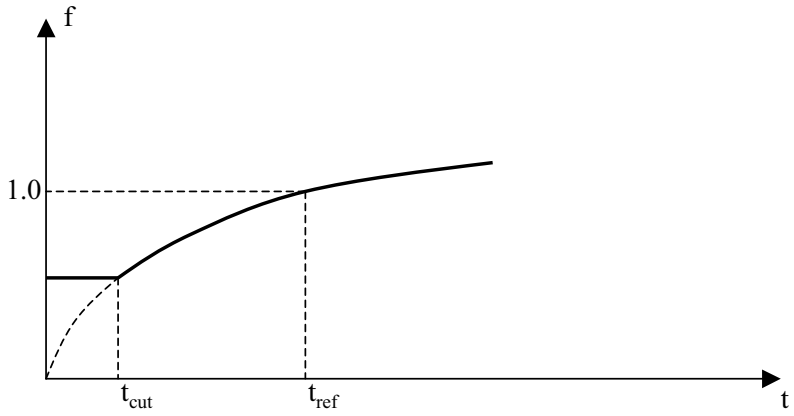
...	THICKNESS-CORRECTION	name	NONE			
			STANDARD-T-CURVE		tref	
			ARBITRARY	tref	tcut	texp

PURPOSE:

To assign thickness correction to a SN-curve.

PARAMETERS:

name	SN-curve name.
NONE	No thickness correction applies.
STANDARD-T-CURVE	Standard T-curve (tcut=tref, texp=0.25). The reference thickness may e.g. be 0.032 metres, but must be given in current consistent units.
ARBITRARY	User specifies all the parameters used in the thickness correction formula.
tref	Reference thickness, for which the SN-curve is valid without correction.
tcut	Cut-off thickness. If the actual thickness is smaller, the cut-off thickness is applied in the formula below.
texp	Exponent.



The SN-curve thickness correction factor is calculated as:

$f = (t_{cut} / t_{ref})^{texp}$ for $t \le t_{cut}$

$f = (t / t_{ref})^{texp}$ for $t > t_{cut}$

Figure 5.4 Thickness correction factor

NOTES:

SN-curves have no thickness correction assigned at creation, except for some predefined curves as described below.

Default thickness correction factors have been predefined for the built-in NORSOK, DOE, ABS, HSE and DNV RP-C203-2010 SN curves. The correction reference thickness and cut-off thickness are applied in SI unit meters. The thickness corrections are converted to current length unit by use of the command: DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR value.

Note that convertion of thickness corrections to current length unit by the length unit factor applies to library SN-curves with predefined thickness corrections. For all other SN-curves, thickness corrections must be assigned in current length unit of the structure. Reassignment of thickness corrections of library SN-curves with predefined thickness correction must be given in the SI length unit meters.

For members with non-pipe cross sections, the actual thickness used is the maximum plate thickness (flange or web) from the section.

See also:

`CREATE SN-CURVE...`

EXAMPLES:

```
ASSIGN THICKNESS-CORRECTION DNV-T STANDARD-T-CURVE 0.032
```

ASSIGN WAVE-DIRECTION-PROBABILITY

...	WAVE-DIRECTION-PROBABILITY	wave-dir	probability

PURPOSE:

To assign a probability associated with a wave direction, for a stochastic fatigue analysis.

PARAMETERS:

wave-dir	Wave direction.
probability	Probability associated with wave direction.

NOTES:

The initial values of all wave direction probabilities are 0.0.

The sum of wave direction probabilities must be 1.0.

See also:
`PRINT WAVE-DIRECTION`

EXAMPLES:

```
ASSIGN WAVE-DIRECTION-PROBABILITY 0 1.0
```

ASSIGN WAVE-LOAD-FACTOR

...	WAVE-LOAD-FACTOR	wave-dir	factor	
			INDIVIDUAL	{factor}*n

PURPOSE:

Assign a wave load factor (DAF) to a wave direction for deterministic fatigue analysis.

PARAMETERS:

wave-dir	Wave direction to be assigned the wave load factor.
INDIVIDUAL	Assign individual wave load factors to each wave height within wave direction.
factor	Load factor to be applied.

NOTES:

The stress ranges at each hotspot calculated for each individual wave is multiplied with the load factor given (in addition to the given SCF).

See also:

`PRINT WAVE-LOAD-FACTORS`
`ASSIGN INDIVIDUAL-WAVE`

ASSIGN WAVE-SPECTRUM-SHAPE

. . .	WAVE-SPECTRUM-SHAPE	WaveStat-Name	PIERSON-MOSKOWITZ				. . .
			ISSC				
			JONSWAP	gamma	sigmaA	sigmaB	
			GENERAL-GAMMA		facL	facN	
			TORSETHAUGEN		Full		
					Simplified		

. . .	ALL				
	PART	lowHs	uppHs	lowTz	uppTz

PURPOSE:
To assign a wave spectrum shape to a wave scatter diagram. The assignment may be to the total scatter diagram, or to a selected part of the diagram. The assignments will override the previous assignments.

PARAMETERS:

WaveStat-name	Name of wave statistics (scatter diagram).
PIERSON-MOSKOWITZ	A Pierson-Moskowitz spectrum shall be assigned to the wave statistics.
ISSC	An ISSC spectrum shall be assigned to the wave statistics of type ISSC.
JONSWAP	A JONSWAP spectrum shape shall be assigned to the wave statistics.
gamma	Peak enhancement factor of JONSWAP.
sigmaA	Left width of JONSWAP spectrum.
sigmaB	Right width of JONSWAP spectrum.
GENERAL-GAMMA	A GENERAL-GAMMA spectrum shape shall be assigned to the wave-statistics.
facL	Parameter L for the GENERAL-GAMMA spectrum.
facN	Parameter N for the GENERAL-GAMMA spectrum.
TORSETHAUGEN	A TORSETHAUGEN spectrum shape shall be assigned to the wave statistics.
option	“Full” and “Simplified” version is available.
ALL	The spectrum shape is assigned to all seastates in the wave-statistics.
PART	The spectrum shape is assigned to a subset of the wave-statistics, where [Hs, Tz] is between specified limits.
lowHs	Lowest Hs-value.
uppHs	Upper Hs-value.
lowTz	Lowest Tz-value. The period would be the associated type in Wave Statistics. See note below.
uppTz	Upper Tz-value.

NOTES: When the wave statistics has been defined through an “All parameter scatter diagram”, e.g. the Ochi-Hubble spectrum, all necessary parameters are given through the CREATE WAVE-STATISTICS command, and hence a wave spectrum shape shall not be assigned to the wave statistics, see Section 2.3.27 Wave spectrum shape.

For ISSC it is T1 (mean wave period) that shall be given as input (instead of Tz). For TORSETHAUGEN spectrum, the wave statistics must be of “Hs-Tp” type; then, the input wave period is the peak period Tp, instead of Tz. In particular, for PART option, Tz = T1, Mean period when ISSC spectrum and Tz = Tp, Peak period when Hs-Tp spectrum.

See also:

```
CREATE WAVE-STATISTICS ...
```

EXAMPLES:

```
ASSIGN WAVE-SPECTRUM-SHAPE SCATTERA JONSWAP 3.3 0.07 0.09 ALL
```

ASSIGN WAVE-SPREADING-FUNCTION

...	WAVE-SPREADING-FUNCTION	stat-name	spread-name	...
			NONE	

...	ALL				
	PART	lowHs	uppHs	lowTz	uppTz

PURPOSE:

To assign a spreading function to a wave statistics (scatter diagram).

PARAMETERS:

stat-name	Name of wave statistics (scatter diagram) to be assigned the spreading function.
spread-name	Name of spreading function to be assigned to stat-name.
NONE	No spreading is assigned, the sea is assumed to be long crested.
ALL	The spreading function is assigned to all seastates in the wave-statistics.
PART	The spreading function is assigned to a subset of the wave-statistics, where [Hs, T_z] is between specified limits.
lowH_s	Lowest H_s-value.
uppH_s	Upper H_s-value.
lowT_z	Lowest T_z-value.
uppT_z	Upper T_z-value.

NOTES:

For ISSC scatter diagram it is T1 (mean wave period) that shall be given as input (instead of Tz).

See also:

```
CREATE WAVE-STATISTICS...
CREATE WAVE-SPREADING-FUNCTION...
PRINT WAVE-SPREADING-FUNCTION...
```

EXAMPLES:

```
ASSIGN WAVE-SPREADING-FUNCTION SCATTERA SPREDA ALL
```

ASSIGN WAVE-STATISTICS

...	WAVE-STATISTICS	wave-dir	stat-name

PURPOSE:

To assign a wave statistics (scatter diagram) to a wave direction.

PARAMETERS:

wave-dir	Wave direction.
stat-name	Name of wave statistics (scatter diagram) to be associated with the wave direction wave-dir.

NOTES:

See also:

`CREATE WAVE-STATISTICS`

EXAMPLES:

```
ASSIGN WAVE-STATISTICS 0 SCATTERA
```

ASSIGN WIND-FATIGUE

. . .	WIND-FATIGUE	WIND-TYPE	. . .
		WIND-SPECTRUM-U	
		WIND-SPECTRUM-V	
		WIND-SPECTRUM-W	
		WIDE-BAND-CORRECTION	
		GUST-DIRECTION-MOMENT	
		SN-CURVE	
		JOINT-SCF	
		BENT-CAN-SCF	
		VORTEX-DIMENSION	
		VORTEX-FIXITY	
		RUN-SCENARIO	
		STRESS-PRINT-OPTIONS	

PURPOSE:
To assign data for wind fatigue calculation. All data are fully explained subsequently as each command is described in detail.

PARAMETERS:

WIND-TYPE	Instruct the program to assign a wind load type.
WIND-SPECTRUM-U	Instruct the program to assign wind spectra and coherence models in longitudinal along mean wind direction for the wind fatigue analysis.
WIND-SPECTRUM-V	Instruct the program to assign wind spectra and coherence models lateral (horizontal) to the mean wind direction for the wind fatigue analysis.
WIND-SPECTRUM-W	Instruct the program to assign wind spectra and coherence models vertical to the mean wind direction for the wind fatigue analysis.
WIDE-BAND-CORRECTION	Instruct the program to assign wide band correction method.
GUST-DIRECTION-MOMENT	Instruct the program to add or not add spectral moments of the wind gust directions U, V and W.
SN-CURVE	Instruct the program to assign SN curves to joint-brace connections and bent can joints.
JOINT-SCF	Instruct the program to assign stress concentration factors to the joints.
BENT-CAN-SCF	Instruct the program to assign stress concentration factors to bent can joints.
VORTEX-DIMENSION	Instruct the program to assign length, diameter and thickness of members for use in vortex shedding calculations.
VORTEX-FIXITY	Instruct the program to assign member end fixity values to be used in vortex shedding calculations.
RUN-SCENARIO	Instruct the program to assign run parameters for wind fatigue calculations.

STRESS-PRINT-OPTIONS	Instruct the program to assign options for print of hotspot stresses and stress spectrum data.

ASSIGN WIND-FATIGUE WIND-TYPE

...	WIND-TYPE	WIND-BUFFETING		
		VORTEX-SHEDDING	...	BROAD-AND-NARROW
				NARROW
		WIND-BUFFETING-AND-VORTEX-SHEDDING		BROAD

PURPOSE:

To assign wind load type to be used in evaluation of wind fatigue damage.

PARAMETERS:

WIND-BUFFETING

Calculate the fatigue damage for gust induced wind buffeting (default).

VORTEX-SHEDDING

Calculate the fatigue damage for vortex shedding induced wind effects.

The wind band effect parameter controls the consideration of the vortex shedding induced amplitudes of vibration.

WIND-BUFFETING-AND-VORTEX-SHEDDING

Calculate the fatigue damage for gust induced wind buffeting and vortex shedding induced wind effects.

BROAD-AND-NARROW

Consider vortex shedding induced fatigue damage to be caused by a combination of broad and narrow wind band effects.

For each wind speed used in the damage evaluation, the vibration amplitude will be calculated for both broad and narrow wind band effects. The larger of the two amplitudes will be used in the damage calculation. Any normal component of the wind that causes a narrow band response will cause a flag to be printed showing that this has occurred.

NARROW

Consider the fatigue damage to solely be caused by a narrow wind band effect.

Narrow wind band excitation is particular destructive as it arises to the natural frequency of the brace coincides, or almost coincides, with the frequency at which vortices are shed from the brace in a steady wind. This is the phenomenon of ‘lock-on’. Avoidance of ‘lock-on’ is a major objective of flare tower design.

BROAD

Consider the fatigue damage to solely be caused by a broad wind band effect.

NOTES:

The program considers the effect of wind buffeting and vortex shedding induced vibrations individually. The combined effect of both sources of fatigue may also be considered.

Wind buffeting damage is caused by fluctuations in gust wind velocities upon a mean wind speed. The fluctuations are described along, laterally across and vertically across the mean wind directions. A maximum of six wind directions may be considered in a fatigue analysis.

While the mean wind is represented by a speed and direction (see command DEFINE WIND-DIRECTIONS and DEFINE WIND-SPEEDS), the gust components are statistically described by three parameters: probability distribution (see command DEFINE WIND-PROBABILITIES), power spectra and cross correlation function.

The probability distribution describes the ratio of percentage of time a certain wind speed is likely to occur, the power spectra reflect the energy content of the wind as a function of frequency, and the cross-correlation function indicates the way in which the gusts are spatially correlated.

The following wind spectra are applied:

The HARRIS, DAVENPORT or NPD spectrum for wind gusts in longitudinal direction to the mean wind.

The PANOFSKY LATERAL spectrum for wind gusts lateral (horizontal) across the mean wind direction.

The PANOFSKY VERTICAL spectrum for wind gusts vertical across the mean wind direction.

Vortex shedding induced fatigue is caused by steady state wind which generates wind induced vortex shedding vibrations. Oscillation modes of individual braces are considered. It is assumed that only the first mode is of any significance for fatigue damage, which is a reasonable assumption for tubular structural steel members that are used in typical flare towers. Only cross-flow oscillations are considered, in-line vibrations are ignored.

The oscillation mode and frequency are highly dependent on the conditions of member end fixity. In general these are not known to any degree of accuracy, so the program allows to investigate a range of fixities. Low end fixity reduces the natural frequency and the member end damage that occur. High end fixity produces higher natural frequency and associated with it the possibility of higher end moments. Member end fixities are assigned by the command ASSIGN WIND-FATIGUE VORTEX-FIXITY.

EXAMPLES:

```
ASSIGN WIND-FATIGUE WIND-TYPE WIND-BUFFETING
ASSIGN WIND-FATIGUE WIND-TYPE WIND-BUFFETING-AND-VORTEX-SHEDDING NARROW
```

ASSIGN WIND-FATIGUE WIND-SPECTRUM-U

. . .	WIND-SPECTRUM-U	HARRIS	COHERENCE-GUSTO1
			COHERENCE-GENERAL
			COHERENCE-DAVENPORT
		DAVENPORT	COHERENCE-GUSTO2
			COHERENCE-GENERAL
			COHERENCE-DAVENPORT
		NPD	COHERENCE-NPD

PURPOSE:
To assign wind spectra and coherence models in the longitudinal along mean wind direction for the wind fatigue analysis.

PARAMETERS:

HARRIS	Apply the Harris wind spectrum for gust components in the longitudinal along mean wind direction.
DAVENPORT	Apply the Davenport wind spectrum for gust components in the longitudinal along mean wind direction (Default).
NPD	Apply the NPD (Norwegian Petroleum Directorate) wind spectrum for gust components in the longitudinal along mean wind direction. In [47] (Clause 2.3.4) the NPD spectrum is called the Frøya wind spectrum.
COHERENCE-GUSTO1	Apply the Gusto 1 coherence model. This coherence function is possible only for the Harris wind spectrum.
COHERENCE-GUSTO2	Apply the Gusto 2 coherence model. This coherence function is possible only for the Davenport wind spectrum.
COHERENCE-GENERAL	Apply the General coherence model.
COHERENCE-DAVENPORT	Apply the Davenport coherence model.
COHERENCE-NPD	Apply the NPD coherence model.

NOTES:
One of the three spectra Harris, Davenport or NPD must be selected. Wind spectra and coherence models for the lateral and vertical wind gust directions are entered by the commands `ASSIGN WIND-FATIGUE WIND-SPECTRUM-V` and `ASSIGN WIND-FATIGUE WIND-SPECTRUM-W`, respectively.

The equations of the coherence models are outlined i Section 6.7.

User defined constants of the wind spectra and coherence models are entered by the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

The General coherence model contains 9 coefficients entered by the command DEFINE WIND-FATIGUE COHERENCE COEFFICIENTS. Coherence in mean wind direction is affected by coefficients 1-3, coherence lateral to the mean wind direction is affected by coefficients 4-6 and coherence vertical to the mean wind direction is affected by coefficients 7-9.

The NPD (Norwegian Petroleum Directorate) coherence model has no user specified constants. In [47] (Clause 2.3.4) the NPD coherence model is called the Frøya coherence spectrum. No other coherence models are available for the NPD wind spectrum.

Extension limit of the coherence models is given by the parameter 'Limit value on coherence effect. cohlim' of the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

If none of commands `ASSIGN WIND-FATIGUE WIND-SPECTRUM-*` is given, the default options for gust components will be used. The wind spectra and coherence functions:

- All gust components included
- U-gust: Davenport spectrum, Gusto2 coherence function
- V-gust: Panofsky Lateral spectrum, Gusto2 coherence function
- W-gust: Panofsky Vertical spectrum, Gusto2 coherence function

EXAMPLES:

```
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U HARRIS COHERENCE-GUSTO1
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U HARRIS COHERENCE-GENERAL
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U HARRIS COHERENCE-DAVENPORT
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U DAVENPORT COHERENCE-GENERAL
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U DAVENPORT COHERENCE-GUSTO2
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U DAVENPORT COHERENCE-DAVENPORT
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U NPD COHERENCE-NPD
```

Since Framework v3.15, this commands and the other 2 at V and W directions have superseded the old command `ASSIGN WIND-FATIGUE WIND-SPECTRUM` such as,

```
ASSIGN WIND-FATIGUE WIND-SPECTRUM HARRIS ON ON
ASSIGN WIND-FATIGUE WIND-SPECTRUM DAVENPORT ON ON
ASSIGN WIND-FATIGUE WIND-SPECTRUM NPD OFF ON
```

where the first ON/OFF determines whether the wind gust components lateral across to the mean wind direction is applied, and the second ON/OFF determines vertical components. The new commands require the sign U/V/W representing the components at along, lateral and vertical directions must be shown in the command. Then, the advantage is that the coherence model can be selected for each direction individually.

The relevant command `ASSIGN WIND-FATIGUE COHERENCE-MODEL` that is available in version v3.14 and before has been removed since v3.15. In older programs, the default coherence model is GUSTO for all directions if the ASSIGN command is missing. This was confusing. In general, the coherence model cannot be skipped but must pair with the associated wind spectrum type and direction. User can let the program ignore coherence effects by defining the limit of coherence to 1.0 in command `DEFINE WIND-FATIGUE WIND-PARAMETERS`. Now, the new command with direction sign `ASSIGN WIND-FATIGUE WIND-SPECTRUM-U` explicitly requires both wind spectrum function and the associated coherence model.

ASSIGN WIND-FATIGUE WIND-SPECTRUM-V

. . .	WIND-SPECTRUM-V	PANOFSKY-LATERAL	COHERENCE-GUSTO2
			COHERENCE-GENERAL
			COHERENCE-DAVENPORT
		LATERAL-OFF	

PURPOSE:
To assign wind spectrum and coherence models lateral (horizontal) to the mean wind direction for the wind fatigue analysis.

PARAMETERS:

PANOFSKY-LATERAL	Apply the Panofsky Lateral wind spectrum for gust components lateral to the mean wind direction (Default).
LATERAL-OFF	Turn off the effect of wind gust components in lateral wind direction.
COHERENCE-GUSTO2	Apply the Gusto 2 coherence model.
COHERENCE-GENERAL	Apply the General coherence model.
COHERENCE-DAVENPORT	Apply the Davenport coherence model.

NOTES:
Wind spectra and coherence models for the along and vertical wind gust directions are entered by the commands ASSIGN WIND-FATIGUE WIND-SPCTRUM-U and ASSIGN WIND-FATIGUE WIND-SPCTRUM-W, respectively.

The equations of the coherence models are outlined i Section 6.7.

User defined constants of the wind spectra and coherence models are entered by the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

The General coherence model contains 9 coefficients entered by the command DEFINE WIND-FATIGUE COHERENCE COEFFICIENTS. Coherence in mean wind direction is affected by coefficients 1-3, coherence lateral to the mean wind direction is affected by coefficients 4-6 and coherence vertical to the mean wind direction is affected by coefficients 7-9.

Extension limit of the coherence model is given by the parameter ‘Limit value on coherence effect. cohlim’ of the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

If the command is not given for lateral direction, the default options for gust components will be Panofsky Lateral spectrum and Gusto2 coherence function.

EXAMPLES:

```
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V PANOFSKY-LATERAL COHERENCE-GUSTO2
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V PANOFSKY-LATERAL COHERENCE-GENERAL
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V PANOFSKY-LATERAL COHERENCE-DAVENPORT
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V LATERAL-OFF
```

ASSIGN WIND-FATIGUE WIND-SPECTRUM-W

. . .	WIND-SPECTRUM-W	PANOFSKY-VERTICAL	COHERENCE-GUSTO2
			COHERENCE-GENERAL
			COHERENCE-DAVENPORT
		VERTICAL-OFF	

PURPOSE:
To assign wind spectrum and coherence models lateral (horizontal) to the mean wind direction for the wind fatigue analysis.

PARAMETERS:

PANOFSKY-VERTICAL	Apply the Panofsky Vertical wind spectrum for gust components vertical to the mean wind direction (Default).
VERTICAL-OFF	Turn off the effect of wind gust components in the vertical wind direction.
COHERENCE-GUSTO2	Apply the Gusto 2 coherence model.
COHERENCE-GENERAL	Apply the General coherence model.
COHERENCE-DAVENPORT	Apply the Davenport coherence model.

NOTES:
Wind spectra and coherence models for the along and lateral wind gust directions are entered by the commands ASSIGN WIND-FATIGUE WIND-SPCTRUM-U and ASSIGN WIND-FATIGUE WIND-SPCTRUM-V, respectively.

The equations of the coherence models are outlined i Section 6.7.

User defined constants of the wind spectra and coherence models are entered by the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

The General coherence model contains 9 coefficients entered by the command DEFINE WIND-FATIGUE COHERENCE COEFFICIENTS. Coherence in mean wind direction is affected by coefficients 1-3, coherence lateral to the mean wind direction is affected by coefficients 4-6 and coherence vertical to the mean wind direction is affected by coefficients 7-9.

Extension limit of the coherence model is given by the parameter ‘Limit value on coherence effect. cohlim’ of the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

If the command is not given for vertical direction, the default options for gust components will be Panofsky Vertical spectrum and Gusto2 coherence function.

EXAMPLES:

```
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W PANOFSKY-VERTICAL COHERENCE-GUSTO2
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W PANOFSKY-VERTICAL COHERENCE-GENERAL
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W PANOFSKY-VERTICAL COHERENCE-DAVENPORT
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W VERTICAL-OFF
```

ASSIGN WIND-FATIGUE WIDE-BAND-CORRECTION

. . .	WIDE-BAND-CORRECTION	GUSTO-EMPIRICAL-METHOD
		WIRSCHING-CORRECTION-FACTOR
		NONE

PURPOSE:
To assign correction method for wide banded static wind load spectrum.

PARAMETERS:

GUSTO-EMPIRICAL-METHOD	Use original empirical method described in Appendix B.5.
WIRSCHING-CORRECTION-FACTOR	Use Wirsching correction factor described in Appendix B.5.
NONE	Use no correction factor (narrow-band solution).

NOTES:

The quasi-static part of the wind power spectra covers the low frequency non-resonant response. The quasi-static spectrum has a broad peak at low frequencies but is treated as a narrow band at its peak frequency. The above methods correct the obtained damage of the narrow band solution by a correction factor accounting for the wide banded load spectrum. The methods are described in Appendix B.5. Damage of the narrow band solution is obtained by the NONE option.

By the Wirsching correction factor method the narrow band assumption of the stress spectrum, the fatigue theory is based on, is corrected by a factor for wide banded stress spectra. The factor is a function of the spectral width of the stress spectrum and is applied directly to the calculated damage value, see Appendix B.5.

EXAMPLES:

```
ASSIGN WIND-FATIGUE WIDE-BAND-CORRECTION WIRSCHING-CORRECTION-FACTOR
ASSIGN WIND-FATIGUE WIDE-BAND-CORRECTION EMPIRICAL-METHOD
ASSIGN WIND-FATIGUE WIDE-BAND-CORRECTION NONE
```

ASSIGN WIND-FATIGUE COHERENCE-MODEL (removed)

. . .	COHERENCE-MODEL	GENERAL
		GUSTO
		NPD

PURPOSE:
To assign wind coherence model for the wind fatigue analysis. See new commands

```
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W
```

ASSIGN WIND-FATIGUE GUST-DIRECTION-MOMENT

. . .	GUST-DIRECTION-MOMENT	ADD
		NO-ADD

PURPOSE:
To assign whether the spectral moments of the wind gust directions shall be added or not.

PARAMETERS:

ADD	Add spectral moments of the wind gust directions (default) .
NO-ADD	Do not add spectral moments of the wind gust directions.

NOTES:
Wind gusts lateral and vertical to the wind direction contribute to the overall damage from the buffeting wind loading. In Wajac wind loads are generated for all three directions for each wind load case, i.e. longitudinal-, lateral- and vertical to the applied wind direction. The longitudinal direction (U) is always included in the damage calculation while the lateral (V) and vertical (W) directions are optional. One or both may be skipped, see command `ASSIGN WIND-FATIGUE WIND-SPECTRUM`. Default is inclusion of all three directions.

The option `NO-ADD` implies that spectral moments of the individual wind gust directions are used to calculate damages of each gust direction whereupon the damages are added to the overall damage of the current wind direction. This applies both for the quasi-static damage and for the damages of the dynamic resonant modes.

The `ADD` option (default) implies that the wind gust directions are handled in the following way:

- Longitudinal direction (U) is always included and can not be skipped;
- Any combination of lateral (V) and vertical (W) directions may be included.

The damage calculation is performed as follows:

- Quasi-static response: Damages are calculated for the longitudinal direction (U) and added to the damage of the lateral (V) and vertical (W) directions where the spectral moments of these two directions are added together if both directions are included. The peak frequency f_{pk} of each individual wind spectrum is used decide on the total number of stress cycles of each wind gust direction. The peak frequency f_{pk} used is the frequency for the maximum value of the stress spectrum and not the calculated peak frequency $\sqrt{\frac{\lambda_4}{\lambda_2}}$, where λ_n is the n-th order response spectral moment.
- Dynamic resonance modes: Spectral moments of all three gust directions are added for the damage calculation of a resonance mode. Damages of the resonance modes are added to an overall damage of the dynamic response.

Hotspot damage calculation is performed as follows: One gust wind direction (U) included:

Direction		**U**
Quasi-static:		
	Spectra moment	M_{0SU}
	Damage direction	D_{SU}
	Static damage	$D_S = D_{SU}$
Dynamic	(loop over resonance modes):	

	Spectra moment :	M_{0DU}
	Damage direction :	D_{DU}
	Dynamic damage :	$D_D = D_{DU}$
	Resulting damage :	$D = D_S + D_D$

Two gust wind directions (U,V or U,W) included:

Direction		**U**	**V**	(**W**)
Quasi-static:				
	Spectra moment	M_{0SU}	M_{0SV}	(M_{0SW})
	Damage direction	D_{SU}	D_{SV}	(D_{SW})
	Static damage	$D_S = D_{SU} + D_{SV}$		(D_{SW})
Dynamic	(loop over resonance modes):			
	Spectra moment :	M_{0DU}	$M_{0DU} + M_{0DV}$	($M_{0DU} + M_{0DW}$)
	Damage direction :	D_{DU}	D_{DUV}	(D_{DUW})
	Dynamic damage :	$D_D = D_{DUV}$	(D_{DUW})	
	Resulting damage :	$D = D_S + D_D$		

Three gust wind directions (U,V,W) included:

Direction		**U**	**V**	**W**
Quasi-static:				
	Spectra moment	M_{0SU}	M_{0SV}	$M_{0SV} + M_{0SW}$
	Damage direction	D_{SU}	D_{SV}	D_{SVW}
	Static damage	$D_S = D_{SU} + D_{SVW}$		
Dynamic	(loop over resonance modes):			
	Spectra moment :	M_{0DU}	M_{0DV}	$M_{0DU} + M_{0DV} + M_{0DW}$
	Damage direction :	D_{DU}	D_{DV}	D_{DUVW}
	Dynamic damage :	$D_D = D_{DUVW}$		
	Resulting damage :	$D = D_S + D_D$		

For the quasi-static response the largest peak frequency f_{pk} of the wind spectra is applied in V and W direction is used when calculating DSVW.

The above calculation procedure assumes that wind loading in the three gust winds directions acts simultaneously and that stress variances of the gust winds can be linearly superimposed. The assumption will give

equal or higher damages compared to adding damages of individual gust directions based on the spectral moments of each direction, i.e;

$$D_{SU} + D_{SVW} > D_{SU} + D_{SV} + D_{SW}$$

$$D_{SUVW} > D_{DU} + D_{DV} + D_{DW}$$

EXAMPLES:

```
ASSIGN WIND-FATIGUE GUST-DIRECTION-MOMENT ADD
ASSIGN WIND-FATIGUE GUST-DIRECTION-MOMENT NO-ADD
```

ASSIGN WIND-FATIGUE SN-CURVE

...	SN-CURVE	JOINT	brace	sel-jnt	sn-name+
		BENT-CAN	sel-jnt	sn-name+	

PURPOSE

To assign an SN-curves to be used in the evaluation of wind fatigue damage.

PARAMETERS:

JOINT	Signifies that the SN-curve shall be assigned to joint-brace connections at a joint.
BENT-CAN	Signifies that the SN-curve shall be assigned to a bent can joint.
brace	Brace name to be assigned the SN-curve. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS).
sel-jnt	Joints where the SN-curve shall be assigned. For valid alternatives see command SELECT JOINTS.
sn-name+	Name of SN-curve to be assigned. Library or user defined SN-curve is selected from the SN-curve list box.

NOTES:

By pressing the Show button in the dialogue boxes, assigned SN curves for current joint selection is printed to the screen and to the mlg file.

Use the commands PRINT SN-CURVE and DISPLAY SN-CURVE to see curve data and shape.

Library SN curve parameters are converted to current units applied by a factor calculated as the Youngs modulus of elasticity divided by 2.1E11

Default thickness correction factors have been predefined for the predefined NORSOK, ABS, HSE, DOE and DNV RP-C203 2010 SN curves. The correction reference thickness and cut-off thickness are applied in SI unit meters.

Note that convertion of thickness corrections to current length unit of the structure by the length unit factor applies to library SN-curves with predefined thickness corrections. For all other SN-curves, thickness corrections must be assigned in current length unit of the structure. The length unit factor defined in Wajac is read from the SIN file and applied in the wind fatigue module of Framework. Reassignment of thickness corrections of library SN-curves with predefined thickness correction must be given in the SI length unit meters.

See also:

```
CHANGE SN-CURVE...
CREATE SN-CURVE...
PRINT SN-CURVE...
DISPLAY SN-CURVE...
```

EXAMPLES:

```
ASSIGN WIND-FATIGUE SN-CURVE JOINT ALL ( ) DOE-T
ASSIGN WIND-FATIGUE SN-CURVE BENT-CAN ( ) NO-F3-S
```

ASSIGN WIND-FATIGUE JOINT-SCF

...	JOINT-SCF	READ	...
		EFTHYMIOU	
		LLOYDS	
		ORIGINAL	

PURPOSE:

To assign SCFs (stress concentration factors) at joints to be used in the evaluation of wind fatigue damage.

It is recommended to select the READ option and apply SCF assigned by Framework since joint classification and parametric formulas are treated more extensively in Framework than in the wind fatigue module.

PARAMETERS:

READ	SCFs are computed by Framework or specified by the user (default setting).
EFTHYMIOU	SCFs are computed by the wind fatigue module according to the Efthymiou rule for K, T, KT or X joints. Non-standard joints are classified as T joint.
LLOYDS	SCFs are computed by the wind fatigue module according to the Lloyd's Register rule for K, T or KT joints. Non-standard joints are classified as T joint.
ORIGINAL	SCFs are computed by the wind fatigue module according to the Original rule for K, T or KT joints. Non-standard joints are classified as T joint.

NOTES:

If one of the EFTHYMIOU, LLOYDS or ORIGINAL options is applied after the READ option, assignments of the READ option are discarded in the analysis If the READ option is applied, all joint-brace connections that are not assigned SCFs by the READ option will have SCFs calculated according to the default parametric SCF scheme (EFTHYMIOU or LLOYDS). The default SCF scheme is specified by the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

The 'Minimum Parametric SCF' (command DEFINE FATIGUE-CONSTANTS) supersede parametric SCFs less than the minimum values.

The wind fatigue module classifies the joints by its own by means of the geometry of the structure and defined analysis planes. The analysis planes are defined by the user (command CREATE ANALYSIS-PLANES). A user specified tolerance angle (command DEFINE WIND-FATIGUE WIND-PARAMETERS) decides if neighbouring elements lies in the same plane or not. A joint is defined when two or more elements meet at a node in the same analysis plane.

Note that joint classifications based on load path is not applicable for the wind fatigue module.

The classification of a joint is related to a given analysis plane and its orientation in space. Joints are classified within each analysis plane for each node included in the wind fatigue analysis. The classification is reported in the Diagnostics file (run nameDiagnostics.txt).

To determine the joint type, the number of elements meeting at the node in the same plane are counted. Elements may either be chord or braces. The chord is taken as the pair of co-linear elements of greatest diameter, all other elements are taken as braces. If there is more than one pair of co-linear elements of same maximum diameter, the chord is assumed to be the pair with the greatest thickness.

If a node has no pair of co-linear elements (e.g. corner joints of a frame) joint classification of Framework is tried for the current node/analysis plane. If chord and braces are determined by Framework chord and brace definition of Framework applies. If chord and no braces are determined no fatigue damage is calculated. If only braces are determined the joint is classified as a bent can.

When chord and braces are determined, the joints is classified as T, K, KT, X, non-standard or impossible according to the following rule:

- T joint: there is a chord and one brace
- K joint: there is a chord and two braces
- KT joint: there is a chord and three braces
- X joint: there is a chord, two braces where the chord and braces are pairs of co-linear elements

- Non-standard joint: there is a chord and more than three braces. Non-standard joints are treated as T joint
- Impossible joint: there is a chord and more than six braces. No fatigue damage is calculated

The classification does not distinguish between braces on the same and opposite side of the chord.

Note that computations of parametric SCFs by the wind fatigue module do not handle overlapping braces of K- and KT joints or gaps of K joints larger than the chord diameter. The same is the case for KT joints when the mid brace deviates from normality to the chord with more than 5 degrees. Such joints are treated T joints. However, parametric SCFs computed by Framework (READ/PARAMETRIC option) handle such cases for the K and KT joints and may be applied.

The analysis planes determines heel and toe positions of the chord/brace intersections, see Figure 5.5. Fatigue damage is evaluated at 8 hotspot stress points around a chord/brace intersection, at the chord side and the brace side of the weld. The numbering system of the hotspots is shown in Figure 5.5.

A joint is classified as a bent can when only two elements within the analysis plane meet at the node.

- The following SCFs are applied:
- Axial SCF at saddle chord side of weld
- Axial SCF at crown chord side of weld
- Axial SCF at saddle brace side of weld
- Axial SCF at crown brace side of weld
- In-plane bending SCF at crown chord side of weld
- In-plane bending SCF at crown brace side of weld
- Out-of-plane bending SCF at saddle chord side of weld
- Out-of-plane bending SCF at saddle brace side of weld

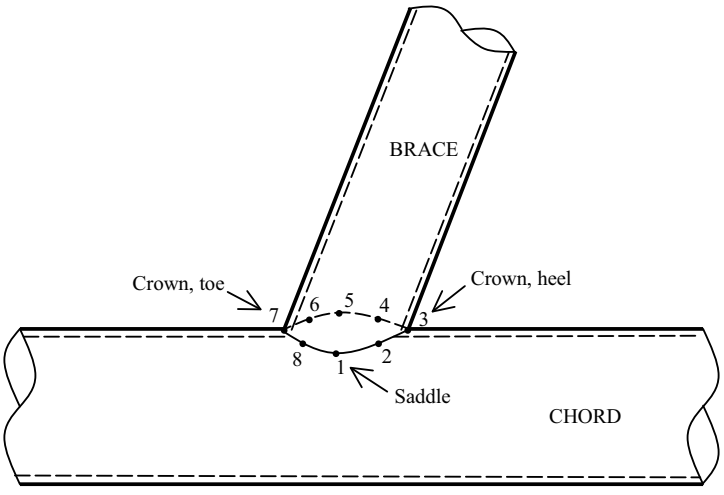


Figure 5.5 Stress points of chord / brace intersection

The SCF formulas applied by the wind fatigue module are described in Framework Theory Manual - Wind Fatigue.

EXAMPLES:

```
ASSIGN WIND-FATIGUE JOINT-SCF EFTHYMIOU
```

ASSIGN WIND-FATIGUE JOINT-SCF READ

...	READ	brace	sel-jnt	GLOBAL		
				LOCAL	BOTH-SIDES	...
					CHORD-SIDE	
					BRACE-SIDE	
				PARAMETRIC	EFTHYMIOU	
					KUANG	
					WORDSWORTH	

...	UNIFORM	scf_ax	scf_ipb	scf_opb	
	CROWN-SADDLE	scf_axc	scf_axs	scf_ipb	scf_opb

PURPOSE:

To assign SCFs (Stress Concentration Factors) computed by Framework or specified by the user.

PARAMETERS:

brace	Name of brace to be assigned to the SCF. Valid alternatives are: ALL (for selecting all braces) or brace name (for selecting a single brace) or CURRENT (see command SELECT MEMBERS).
sel-jnt	Joints where SCF definition shall be assigned. For valid alternatives see command SELECT JOINTS.
GLOBAL	Use global SCF values (default).
LOCAL	Use user specifies SCF values.
PARAMETRIC	The user specifies the formula set to be used in SCF computations by Framework.
CHORD-SIDE	The SCF specification is applied for the chord side of the weld.
BRACE-SIDE	The SCF specification is applied for the brace side of the weld.
BOTH-SIDES	The same SCF specification is applied to the chord and brace sides of the weld.
EFTHYMIOU	Use the Efthymiou formulas. May be applied for all joint types.
KUANG	Use Kuang formulas. May be applied for all joint types except X-joints.
WORDSWORTH	Use the Wordsworth formulas. May be applied for X joints only.
UNIFORM	The same values apply to all hotspots. 3 SCF values shall be given.
CROWN-SADDLE	The SCF values are specified at the crown and saddle points. Values for other hot-spots are derived. 4 SCF values shall be given.
scf_ax	SCF for axial force.
scf_ipb	SCF for in-plane bending.
scf_opb	SCF for out-of-plane bending.
scf_axc	SCF for axial force at crown.
scf_axs	SCF for axial force at saddle.

NOTES:

If one of the EFTHYMIOU, LLOYDS or ORIGINAL options is applied after the READ option, assignments of the READ option are discarded in the analysis If the READ option is applied, all joint-brace connections that are not assigned SCFs by the READ option will have SCFs calculated according to the default parametric SCF scheme (EFTHYMIOU or LLOYDS). The default SCF scheme is specified by the command DEFINE WIND-FATIGUE WIND-PARAMETERS.

Parametric SCFs (Efthymiou rule) computed by the wind fatigue module may differ somewhat from parametric SCFs computed by Framework. This is due to handling of validity ranges of geometric parameters included in the SCF equations which are not quite identical. Parametric SCFs computed by Framework are extensively tested and verified and are recommended used.

The 'Minimum Parametric SCF' (command DEFINE FATIGUE-CONSTANTS) supersede parametric SCFs less than the minimum values. Minimum values are not applied for the READ/GLOBAL and READ/LOCAL options.

EXAMPLES:

```
ASSIGN WIND-FATIGUE JOINT-SCF READ 10 ( ) LOCAL BOTH-SIDES CROWN-SADDLE 1.6 1.6 2.0
2.0
ASSIGN WIND-FATIGUE JOINT-SCF READ DEFAULT ( ) PARAMETRIC EFTHYMIOU
ASSIGN WIND-FATIGUE JOINT-SCF READ ALL ( ) GLOBAL
```

ASSIGN WIND-FATIGUE BENT-CAN-SCF

.. .	BENT-CAN-SCF	sel-jnt	GLOBAL					sel-apln	ALL	
			LOCAL	scf_axc	scf_axs	scf_ipb	scf_opb		PLANE	plnno

PURPOSE:

To assign SCFs (Stress Concentration Factors) at bent can joints. A bent can is a joint where no chord but two or more braces meet. A bent can is associated with an analysis plane. The plane formed by the brace elements must be parallel to the associated analysis plane.

PARAMETERS:

sel-jnt	Select joints for which bent can SCF definition shall apply. For valid alternatives, see command SELECT JOINTS.
GLOBAL	Use global SCF values (default)
LOCAL	The user specifies all SCF values
scf_axc	SCF for axial force at crown
scf_axs	SCF for axial force at saddle
scf_ipb	SCF for in-plane bending
scf_opb	SCF for out-of-plane bending
sel-apln	Select analysis plane to be associated with the bent can and the SCF values. For creation of analysis planes see command CREATE WIND-FATIGUE ANALYSIS-PLANES.
ALL	All analysis plane are selected
PLANE	Analysis plane plnno is selected
plnno	Analysis plane number. Numbering of the analysis planes is in the order they have been defined. The numbering starts at 1.

NOTES:

Members of joints where the wind fatigue module cannot determine a chord will be treated as bent can type members and apply bent can SCFs, see command ASSIGN WIND-FATIGUE JOINT-SCF.

The default global SCFs are assigned to bent cans which have no user assigned SCFs

EXAMPLES:

```
ASSIGN WIND-FATIGUE BENT-CAN-SCF ( ) LOCAL 5.0 5.0 5.0 5.0 PLANE 1
```

ASSIGN WIND-FATIGUE VORTEX-DIMENSION

...	VORTEX-DIMENSION	sel-mem	length	diameter	thickness

PURPOSE:

To assign length, diameter and thickness to individual members for use in vortex shedding induced fatigue calculations.

Buffeting damage calculations are unaffected by these data.

PARAMETERS:

sel-mem	Select members where the vortex dimension definition shall be assigned. For valid alternatives see command SELECT MEMBERS.
length	Member length to be used in the vortex shedding calculations. The value overrides the true spatial distance between end nodes of the member.
diameter	Member diameter to be used in the vortex shedding calculations. The value overrides the true diameter of the member. Enter 0.0 for using the true diameter.
thickness	Member thickness to be used in the vortex shedding calculations. The value overrides the true thickness of the member. Enter 0.0 for using the true thickness.

NOTES:

Stress concentration factors (SCF) used at member ends are based on unmodified diameters and thicknesses.

Resizing of members is of relevance when a brace has been modelled with more than one structural element and the whole length of the brace is required in the vortex shedding calculations.

As an example of use, consider a structural brace that has been subdivided into several shorter segments by intermediate nodes. The brace is of constant diameter and thickness. In the absence of the vortex dimensions data the individual elements of the brace will be analysed for vortex shedding based on their own lengths. The natural frequencies of the individual elements will be higher than the fundamental mode of the full brace and the dynamic response and fatigue damages will be inaccurately calculated. Typically there may be no excitation of the individual elements, whereas the full brace could show significant response amplitudes.

To avoid this difficulty the vortex shedding calculation should redefine the lengths of the two end elements of the brace to be equal to the full length of the brace. This will allow the SCFs at the end nodes of the brace to be used with the whole brace length. In this instance the brace diameter and thickness are not changed.

EXAMPLES:

```
ASSIGN WIND-FATIGUE VORTEX-DIMENSION 7 5.45 0.0 0.0
ASSIGN WIND-FATIGUE VORTEX-DIMENSION CURRENT 4.70 0.8 0.05
```

ASSIGN WIND-FATIGUE VORTEX-FIXITY

...	VORTEX-FIXITY	MEMBER-ENDS	...

...	(	ONLY	nod 1	nod 2	step s	min-fix1	max-fix1	min-fix2	max-fix2	)

PURPOSE:

To assign non-default member end fixities for individual braces for use in vortex shedding induced fatigue calculations.

PARAMETERS:

MEMBER-ENDS	Member end fixity data
ONLY	Mandatory attribute
( )	Mandatory parentheses
nod1	Node number of fixity end 1 of the brace
nod2	Node number of fixity end 2 of the brace.
steps	The number of fixity values to be investigated, including the two extreme values. Valid value: range 1 to 5.
minfix1	Lower bound fixity at nod1. Valid value: -1.0 or range 0.0 to 1.0.
maxfix1	Upper bound fixity at nod1. Valid value: -1.0 or range 0.0 to 1.0.
minfix2	Lower bound fixity at nod2. Valid value: -1.0 or range 0.0 to 1.0.
maxfix2	Upper bound fixity at nod2. Valid value: -1.0 or range 0.0 to 1.0.

NOTES:

Repeat the command as many times as is necessary for the members that are studied to override the default values defined by the command DEFINE WIND-FATIGUE DEFAULT-MEMBER-END FIXITIES.

The user supplied data are checked for each member to be analysed. If both nodes of the member appears as nod1 and nod2 (in either order) then the default values will be superseded for that member.

With the exception of the special case noted below, the fixity is given in terms of a non-dimensional parameter that lies in the range of 0.0 to 1.0. A value of 0.0 represents zero fixity, i.e. a pin-jointed end. A value of 1.0 represents infinite fixity, i.e. a fully fixed joint. Intermediate values relate to partial fixities. A fixity of 0.2 may be regarded as 20% fixed and 80% pinned.

Physically the member end fixity is given by the ratio (KL/EI). E is the material Young's modulus, L the member length between the two nodes nod1 and nod2, K the effective torsional spring stiffness and I the second moment of area of the member. The ratio (KL/EI) is a non-dimensional parameter related to the fixity. The fixity value is given by the relationship

$$\text{Fixity} = (2/\pi)\text{atan}(KL/EI)$$

which gives the required range of values between 0 and 1.

For investigation of a range of fixities a linear interpolation is used between the upper and lower bound values. The requested number of fixities must lie in the range 1 to 5.

The recommended procedure for defining the member end fixity is to consider the members coming into the joint at the node. The member's effective fixity is given by the relationship.

There is one special case that cannot be described by the above data input. For a cantilever member the fixity of the free end may be assigned the value -1.0 (assigned both for lower and upper bound fixity). The fixity at the root of the cantilever must be given as 1.0, i.e. fully fixed. Clearly it can not make physical sense to analyse a range of fixities for a cantilever. Accordingly any fixity of -1.0 must be considered in conjunction with a fixity of 1.0 at the member's other end. The number of fixities selected must be set to 1.

$$(KL)/(EI)_{eff} = (\Sigma(L/EI)_{Allmembers})/(L/EL)_{Member}$$

The non-dimensional fixity ratio parameter KL/EI is applied in the iteration for the mode shape of the brace. This fixity ratio is calculated by the program according to the above equation

$$\text{Fixratio} = (\text{KL/EI}) = \tan(\text{Fixity} \cdot \pi/2)$$

where Fixity is the user input value of the brace end fixity ranging from 0 to 1. The table below shows the Fixratio for some Fixity values

Fixratio	Fixity (user input)	Fixity description
Infinity	1.0	Fixed
100	0.9936	Partly fixed
50	0.9873	Partly fixed
20	0.9682	Partly fixed
10	0.9366	Partly fixed
5	0.8743	Partly fixed
2	0.7048	Partly fixed
1	0.5	Partly fixed
0.5	0.2952	Partly fixed
0.2	0.1256	Partly fixed
0.0	0	Pinned

EXAMPLES:

```
ASSIGN WIND-FATIGUE VORTEX-FIXITY MEMBER-ENDS ( ONLY
    201 202 4 0.1 0.9 0.3 0.7
    202 203 3 0.0 1.0 0.0 1.0
    203 202 5 0.1 0.95 0.1 0.95
    205 302 2 0.4 0.6 0.4 0.6 )
```

ASSIGN WIND-FATIGUE RUN-SCENARIO

...	RUN-SCENARIO	SINGLE-BRACE-CASE	...
		MULTI-BRACE-CASE	...
		MULTI-BRACE-CASE-SELECT-JOINTS	...

...	wndir	brace	nod	anapl n	ndy-mod	COMPRESSED			
						COMPREHENSIVE		inspnt	BRACESIDE
									CHORDSIDE
...	fwndir	lwndir	fnod	lnod	fanpln	lanpln	ndymod		ON
...	fwndir	lwndir			fanpln	lanpln	ndymod		OFF

PURPOSE:

To assign run case parameters for the fatigue damage analysis to be executed.

PARAMETERS:

SINGLE-BRACE-CASE — Single brace analysis.

wndir — Wind direction to be considered. Must comply with the wind directions analysed in Wajac. The wind directions are numbered in the sequence they are specified by the command DEFINE WIND-FATIGUE WIND-DIRECTIONS. Valid range of value: 1 to 6.

brace — Brace of the joint to be considered.

nod — Joint where damage is required.

anapln — Analysis plane of the joint. For creation of analysis planes, see command CREATE WIND-FATIGUE ANALYSIS-PLANES. Valid range of value: 1 to 10.

ndymod — Number of dynamic modes. The ndymod first modes will be considered. Valid range of value: 2 to 15.

COMPRESSED — Produce compressed print of the fatigue damage results. Condensed output will be generated for all inspection points around the chord/brace intersection.

COMPREHENSIVE — Produce comprehensive print of the fatigue damage results for the inspection point inspnt.

inspnt — Inspection point around the chord/brace intersection for which comprehensive print of results is produced, see Figure 5.5.

BRACESIDE — Output damage for brace side.

CHORDSIDE — Output damage for chord side.

MULTI-BRACE-CASE — Multi-brace analysis

MULTI-BRACE-CASE-SELECT-JOINTS — Multi-brace analysis selecting nodes and node sets for the run case by the SELECT JOINTS command.

fwndir — First wind direction to be considered in the multi-brace fatigue calculation. Must comply with the wind directions analysed in Wajac. The wind directions are numbered in the sequence they are specified by the command DEFINE WIND-FATIGUE WIND-DIRECTIONS. Valid range of value: 1 to 6.

lwndir — Last wind direction to be considered in the multi-brace calculation. Must comply with the wind directions analysed in Wajac. Valid range of value: 1 to 6.

The wind directions considered will go from fwndir to lwndir in steps of 1. lwndir must be equal or larger than fwndir.

fnod — First node to be considered in the multi-brace fatigue calculation.

lnod	Last node to be considered in the multi-brace fatigue calculation. The nodes considered are fnod, lnod and all nodes in between the two nodes. lnod must be equal or larger than fnod.
fanpln	First analysis plane to be considered in the multi-brace fatigue calculation. Valid range of value: 1 to 10.
lanpln	Last analysis plane to be considered in the multi-brace fatigue calculation. Valid range of value: 1 to 10. The analysis planes considered will go from fanpln to lanpln in steps of 1. lanpln must be equal or larger than fanpl.
ndymod	Number of dynamic modes. The ndymod first modes will be considered. Valid range of value: 2 to 15.
ON/OFF	Turn show progress of run execution ON/OFF

NOTES:

The single brace case allows only one joint, one brace, one analysis plane and one wind direction to be considered, while the multi-brace case allows consideration of several joints, braces, analysis planes and wind directions. The multi-brace case produces a compressed print of the fatigue results. If a comprehensive print is requested for a joint, the single brace case must be applied.

The overall eigenmodes of the structure are used in the buffeting damage calculations. The first 15 modes may be taken into account. Vortex shedding induced fatigue calculation considers cross-flow oscillation of individual braces, in-line vibrations are ignored. Only the first oscillation mode is used.

Wind buffeting damage is caused by fluctuations in gust wind velocities upon a mean wind speed. The fluctuations are described along (u'), laterally across (v') and vertically across (w') the mean wind direction. The Davenport u', Panofsky v' and Panofsky w' wind spectra are used for the three directions, respectively. A maximum of six wind directions may be considered in a fatigue analysis.

Fatigue damage results are reported for each individual wind direction and for the added sum of damage for all wind directions. One line of print is produced for each brace end of the joints considered in the analysis. Damages are reported for the eight inspection points around the chord/brace intersection, see Figure 5.5, at the chord and brace sides of the intersection. If vortex shedding induced fatigue is investigated, damage is also calculated for the point of maximum curvature along a member and reported as member centre damage. Buffeting and vortex shedding induced damages are reported separately and by sum.

The wind buffeting fatigue calculation is very time consuming. The calculation process includes integrations of the wind spectra which contain loops over the square of the number of translational degrees of freedom in the structure. These loops are again inner loops of loops over the number of wind directions, wind speeds, joints, analysis planes, braces, hotspots, wind spectra, wind states, static load cases and eigenmodes. The execution time increases rapidly with the size of the model and the number of joints, wind directions, eigenmodes and analysis planes included in the fatigue run. Care should therefore be taken in specifying too many joints, wind directions, analysis planes and eigenmodes in a same fatigue run. The analysis may rather be split into several smaller runs for the most fatigue sensitive joints.

EXAMPLES:

```
ASSIGN WIND-FATIGUE RUN-SCENARIO SINGLE-BRACE-CASE 1 10 2 1 2 COMPRESSED
ASSIGN WIND-FATIGUE RUN-SCENARIO SINGLE-BRACE-CASE 1 10 2 1 2 COMPREHENSIVE 4
       BRACESIDE
ASSIGN WIND-FATIGUE RUN-SCENARIO MULTI-BRACE-CASE 1 6 2 9 1 3 2 ON
SELECT JOINTS ONLY 2780
SELECT JOINTS INCLUDE 2610
SELECT JOINTS INCLUDE 260
SELECT JOINTS INCLUDE 277
ASSIGN WIND-FATIGUE RUN-SCENARIO MULTI-BRACE-CASE-SELECT-JOINTS 1 4 3 5 2 ON
```

ASSIGN WIND-FATIGUE STRESS-PRINT-OPTIONS

...	STRESS-PRINT-OPTIONS	ON	ON	
		OFF	OFF	

...	fwndir	lwndir	fjnt	ljnt	fanpln	lanpln	fhotspot	lhotspot

PURPOSE:

To assign options for print of hotspot stresses and stress spectrum data.

PARAMETERS:

ON/OFF — Turn print of hotspot stresses ON/OFF

ON/OFF — Turn print of stress spectrum data ON/OFF

fwndir — First wind direction to be considered. Must comply with the wind directions analysed in Wajac. The wind directions are numbered in the sequence they are specified by the command DEFINE WIND-FATIGUE WIND-DIRECTIONS. Valid range of values: 1 to 6.

lwndir — Last wind direction to be considered. Must comply with the wind directions analysed in Wajac. Valid range of values: 1 to 6.

The wind directions considered will go from fwndir to lwndir in steps of 1. lwndir must be equal or larger than fwndir.

fjnt — First joint to be considered.

ljnt — Last jnt to be considered.

The joints considered are fjnt, ljnt and all joints in between the two joints. ljnt must be equal or larger than fjnt.

fanpln — First analysis plane to be considered. Valid range of values: 1 to 10.

lanpln — Last analysis plane to be considered. Valid range of values: 1 to 10.

The analysis planes considered will go from fanpln to lanpln in steps of 1. lanplnr must be equal or larger than fanpln.

fhotspot — First hotspot to be considered. Valid range of values: 1 to 16.

lhotspot — Last hotspot to be considered. Valid range of values: 1 to 16.

NOTES:

Hotspots 1 to 8 are the braceside points and hotspots 9 to 16 are the chordside points, The hotspots are equally spaced around the pipe section countered in anticlockwise direction from local z-axis of the element.

The print takes place during the fatigue calculation process and the print options must therefore be assigned prior to the run execution command.

The hotspot stresses and stress spectrum data are printed to the file runnameFramework.dmp, where runname is the name of the current run.

EXAMPLES:

```
ASSIGN WIND-FATIGUE STRESS-PRINT-OPTIONS ON ON 1 3 2 9 1 2 1 8
```

CHANGE	MATERIAL	subcom-mands	data
	SECTION		
	SECTION-PROPRTY		
	HOTSPOTS		
	SN-CURVE		
	WAVE-SPREADING-FUNCTION		
	WAVE-STATISTICS		
	WIND-FATIGUE		

PURPOSE:

To change data associated with a material or data associated with an SN-curve.

PARAMETERS:

MATERIAL	Material property data shall be changed.
SECTION	Section geometry data shall be changed.
SECTION-PROPERTY	Section property data shall be changed.
HOTSPOTS	Section hotspot assignments shall be changed.
SN-CURVE	SN-curve data shall be changed.
WAVE-SPREADING-FUNCTION	A wave spreading function shall be changed.
WAVE-STATISTICS	Wave statistics data shall be changed.
WIND-FATIGUE	Wind fatigue data shall be changed.

All subcommands and data are fully explained subsequently as each command is described in detail.

CHANGE MATERIAL

...	MATERIAL	mat-name	DESCRIPTION	text
			YOUNGS-MODULUS	young
			YIELD-STRENGTH	yield
			TENSILE-STRENGTH	tensile
			DENSITY	dens
			POISSONS-RATIO	pois
			SPECIFIC-DAMPING	damp
			THERMAL-EXPANSION	alpha

PURPOSE:

To change the properties of a material.

PARAMETERS:

mat-name	Name of the material to be changed.
DESCRIPTION	The material description shall be changed.
text	New Descriptive text.
YOUNGS-MODULUS	Young's modulus of elasticity shall be changed.
young	New value for Young's modulus.
YIELD-STRENGTH	The yield strength shall be changed.
yield	New value for yield strength.
TENSILE-STRENGTH	The tensile strength shall be changed.
tensile	New value for tensile strength.
DENSITY	The material density shall be changed.
dens	New value for density.
POISSONS-RATIO	Poisons ratio shall be changed.
pois	New value for Poisons ratio.
SPECIFIC-DAMPING	Material damping shall be changed.
damp	New value of specific damping.
THERMAL-EXPANSION	The material thermal expansion shall be changed.
alpha	New value of thermal expansion coefficient.

NOTES:

The tensile strength is as default given the value 1.11 times the yield strength assigned when the Framework model is established. The tensile strength is used in the punching shear and cone capacity checks according to API.

Note that in older versions than 3.2-01 the default tensile strength was set to 1.5 times the yield strength.

See also:

```
ASSIGN MATERIAL...
CREATE MATERIAL...
PRINT MATERIAL...
```

EXAMPLES:

```
CHANGE MATERIAL 1 YIELD-STRENGTH 356E5
```

CHANGE SECTION

...	SECTION	sct-name	data

PURPOSE:

To change the geometric properties of a section

PARAMETERS:

sct-name	Name of section to be changed.
data	See CREATE SECTION

NOTES:

It is possible to tag / automatically modify the box shaped cross sections that shall use design wall thickness = 0.93 times the nominal wall thickness. This is required in AISC LRFD for profiles manufactured according to ASTM A500. See command CREATE SECTION sct-name text BOX.

See also:

```
ASSIGN SECTION
CREATE SECTION
PRINT SECTION
```

CHANGE SECTION-PROPERTY

...	SECTION-PROPERTY	sct-name	DESCR	value
			AREA	
			IT	
			IY	
			IZ	
			IYZ	
			WXMIN	
			WYMIN	
			SHARY	
			SHARZ	
			SHCENY	
			SHCENZ	
			SY	
			SZ	

PURPOSE:

To change the stiffness properties of a section.

PARAMETERS:

sct-name	Name of section to be changed.
DESCR	Text associated with section.
AREA	Effective cross-sectional area.
IT	Torsional moment of inertia about shear centre.
IY	Moment of inertia for bending about the local y-axis.
IZ	Moment of inertia for bending about the local z-axis.
IYZ	Product of inertia about y and z-axes.
WXMIN	Minimum section modulus for torsional stress about shear centre.
WYMIN	Minimum section modulus for bending about local y-axis.
WZMIN	Minimum section modulus for bending about local z-axis.
SHARY	Shear area in the local y-direction.
SHARZ	Shear area in the local z-direction.
SHCENY	Local y-coordinate of shear centre (location from centroid).
SHCENZ	Local z-coordinate of shear centre (location from centroid).
SY	Static area moment about local y-axis.
SZ	Static area moment about local z-axis.
value	New value of property.

NOTES:

It is possible to tag / automatically modify the box shaped cross sections that shall use design wall thickness = 0.93 times the nominal wall thickness. This is required in AISC LRFD for profiles manufactured according to ASTM A500. To set this tag the section DESCR text must start with “ASTM HSS”. When this option is used, the cross section geometry and stiffness properties are automatically updated. Hence the new values will

always be used, e.g. when printing section geometry, printing section stiffness properties, printing stresses and calculating usage factors (also for other codes of practice than AISC LRFD). If the section wall thickness has been modified in the preprocessor (modelling tool) or manually modified in Framework, do not use this feature.

See also:

```
CREATE SECTION...
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION-PROPERTY MYSEC_1 AREA 1.123E-3
CHANGE SECTION-PROPERTY SCT1 DESCRIPTION 'ASTM HSS example'
```

CHANGE HOTSPOTS

...	HOTSPOTS	section-name	descr	CODE-CHECK	hot+	
				COORDINATES	{hot, x-coo, y-coo}*	
				FATIGUE	hot+	
				SHEAR-COMBINATION	hot+	...

...	COMBINATION-RULE-1
	COMBINATION-RULE-2
	COMBINATION-RULE-3
	COMBINATION-RULE-4

PURPOSE:

To change the stress point or hotspot assignments to a cross section. 'Hotspot' is normally associated with fatigue analysis while 'stress point' is associated with code checking.

PARAMETERS:

section-name	Name of section to be changed.
descr	Descriptive text
CODE-CHECK	Stress points for code check are to be changed.
COORDINATES	Redefine coordinate of hotspot (GENERAL profile only).
FATIGUE	Hotspots for fatigue check are to be changed.
SHEAR-COMBINATION	Define shear stress combination rule to be used (GENERAL profile only).
hot	Selection of stress point or hotspot name(s). See Figure 2.2 and Figure 2.3 for naming convention.
x-coo	X coordinate of hotspot (GENERAL profile only).
y-coo	Y coordinate of hotspot (GENERAL profile only).
COMBINATION-RULE-1	Use combination rule 1.
COMBINATION-RULE-2	Use combination rule 2.
COMBINATION-RULE-3	Use combination rule 3.
COMBINATION-RULE-4	Use combination rule 4.

NOTES:

The shear combination rules are described in detail in the Theoretical Manual section 3.6.5. The default combination rule is 1.

See also:

```
CREATE SECTION ...
PRINT SECTION ...
```

CHANGE SN-CURVE

...	SN-CURVE	name	USER	txt	m0	s0		logN0	.. .
			LOGA		m0	logA0		logN0	
			STOCHASTIC		m0	logK0	sdk	logN0	
			UNCERTAINTY	sdk					

...	DEFAULT-TAIL				
	ALIGNED-WITH-FIRST				
	HORISONTAL-TAIL				
	ARBITRARY-TAIL	m1	ALIGNED-WITH-SECOND		
			HORISONTAL-TAIL	logN1	
			ARBITRARY-TAIL	logN1	m2

PURPOSE:

To change the properties of a SN-curve.

PARAMETERS:

name+	Name of the SN-curve
USER	Only user defined option available
LOGA	Option where the intercept of logN-axis and SN-curve, logA0, is given
STOCHASTIC	Option where the intercept of logN-axis and mean SN-curve, logK0 and the standard deviation of logK0, std, are given
UNCERTAINTY	Option where the standard deviation of logK0, std, is given
txt	Descriptive text of the SN-curve
m0	Slope of first segment
s0	Stress level at end first segment
logN0	Log cycles to failure at end first segment
logA0	Intercept of logN-axis and SN-curve
logK0	Intercept of logN-axis and mean SN-curve
sdk	Standard deviation of logK0. Note: logA0 = logK0 - 2*sdk
DEFAULT-TAIL	Second segment continues with m1 = 2*m0 - 1
ALIGNED-WITH-FIRST	Second segment continues with m1 = m0
HORISONTAL-TAIL	Second segment is horizontal
ARBITRARY-TAIL	Second segment is arbitrary
m1	Slope of second segment
ALIGNED-WITH-SECOND	Third segment continues with m2 = m1
HORISONTAL-TAIL	Third segment is horizontal
logN1	Log cycles to failure at end second segment
m2	Slope of third segment

NOTES:

When the LOGA and STOCHASTIC input options are applied, the input values of logA0, logK0 and stdk must be in accordance with the unit of the stresses applied in the analysis.

When LOGA option is applied the stress level s0 is calculated by:

$$\log_{10} s_0 = (\log_{10} A_0 - \log_{10} N_0) / m_0 \tag{5.1}$$

When STOCHASTIC option is applied the stress level s0 is calculated by:

$$\log_{10} s_0 = (\log_{10} K_0 - 2sdk - \log_{10} N_0) / m_0 \tag{5.2}$$

Calculation and conversion of SN curve parameters are thoroughly outlined in Appendix B 4.

EXAMPLES:

```
CHANGE SN-CURVE USE-X USER NONE 3.0 3.4 7.0 ARBITRARY-TAIL 5. HORISONTAL-TAIL 8.301
CHANGE SN-CURVE USE-Y USER NONE 3.0 3.4e+006 7.0 ALIGNED-WITH-FIRST
```

CHANGE WAVE-SPREADING-FUNCTION

...	WAVE-SPREADING-FUNCTION	name	text	COSINE-POWER	power
				USER-DEFINED	{wave-dir,weight}*

PURPOSE:

To modify a wave spreading function.

PARAMETERS:

name	Name of wave spreading function.
text	Text associated with the spreading function.
COSINE-POWER	The spreading function is represented by a cosine function.
power	Power of the cosine function.
USER-DEFINED	The spreading function shall be user defined.
wave-dir	Wave direction, relative to the main wave direction.
weight	Weight associated with wave direction.

NOTES:

The sum of weights must be 1.0.

See also:

```
ASSIGN WAVE-SPREADING-FUNCTION...
CREATE WAVE-SPREADING-FUNCTION...
```

EXAMPLES:

```
CHANGE WAVE-SPREADING-FUNCTION COS2 'Analytical cos**2' COSINE 2
```

CHANGE WAVE-STATISTICS

. . .	WAVE-STATISTICS	Name	Text	ALL-PARAM-SCATTER	. . .
				SCATTER-DIAGRAM	. . .
				ISSC-SCATTER-DIAGRAM	. . .
				Hs-Tp	. . .

with the subsequent input data for ALL-PARAM-SCATTER:

. . .	OCHI-HUBBLE	{Hss,Tps,Ls,Hsw,Tpw,Lw,prob} *
		{Hss,Tps,Ls,Hsw,Tpw,Lw,occr} *
		{Hss,Tps,Ls,Hsw,Tpw,Lw,percent % } *

with the subsequent input data for SCATTER-DIAGRAM, ISSC, and Hs-Tp type:

. . .	{Hs,Tz or Tp,prob} *
	{Hs,Tz or Tp,occr} *
	{Hs,Tz or Tp,percent % } *

PURPOSE:
To change a wave scatter diagram.

PARAMETERS:

name	Name of wave statistics.
text	Text associated with the wave statistics.
ALL-PARAM-SCATTER	The wave statistics and spectrum shape are defined through a all parameter scatter diagram.
SCATTER-DIAGRAM	The wave statistics is a regular wave scatter diagram.
ISSC-SCATTER-DIAGRAM	The wave statistics is an ISSC type scatter diagram.
Hs-Tp	The wave statistics (incl. the spectrum) depends on the significant wave height Hs and the peak spectral period Tp of the wave.
OCHI-HUBBLE	The wave statistics (incl. the spectrum) is a 6 parameter Ochi-Hubble spectrum.
Hss	Significant wave height, swell part.
Tps	Peak spectral period, swell part.
Ls	Shape factor (Lamda), swell part.
Hsw	Significant wave height, wind (sea) part.
Tpw	Peak spectral period, wind (sea) part.
Lw	Shape factor (Lamda), wind (sea) part.
prob	Probability of occurrence for one sea state.
occr	Number of occurrences for one sea state.
percent	The probabilty of occurrence in percentage.
Hs	Significant wave height of one sea state.
Tz	Zero up-crossing period for one sea state. T1 for ISSC.
Tp	Peak spectral period for Hs-Tp type of scatter diagram.

NOTES:
If the seastates of the scatter diagram are defined in terms of probability or percentage then the sum of all fractions of occurrence must be 1.0.

The program automatically identifies the type of scatter diagram and the format of occurrence when an existing wave statistics is selected. However, the scatter diagram type cannot be changed when using this command. It is not possible to switch between “probability”, “occurrence”, or “percentage” when using this command.

For ISSC scatter diagram it is T1 (mean wave period) that shall be given (instead of Tz).

See also:

```
CREATE WAVE-STATISTICS...
PRINT WAVE-STATISTICS...
DELETE WAVE-STATISTICS...
```

EXAMPLE:

```
CHANGE WAVE-STATISTICS SCAT1 simpldata HS-TP-SCATTER
( ONLY
    2.0    3.0    1027
    4.0    3.0    27
    2.0    4.5    5209
    4.0    4.5    2140
    6.0    4.5    17  )

CHANGE WAVE-STATISTICS WS1 'Scatter diagram for SESAM field' SCATTER-DIAGRAM
(ONLY 5.0 7.0 0.1
7.0 6.0 0.3
6.0 6.0 0.5
8.0 5.0 0.1 )
```

CHANGE WIND-FATIGUE

...	WIND-FATIGUE	SECTION-DIMENSIONS	...

PURPOSE:

To change data for wind fatigue calculation. All data are fully explained subsequently as each command is described in detail.

PARAMETERS:

SECTION-DIMENSIONS Instruct the program to change section dimensions of members.

CHANGE WIND-FATIGUE SECTION-DIMENSIONS

...	SECTION-DIMENSIONS	sel-mem	diame-ter1	diameter2	thickness1	thickness2

PURPOSE:

To change diameter and thickness of individual members for use in wind fatigue calculations.

Changes made by this command affect only the wind fatigue calculations. Section data saved in the data base of Framework are unaffected by these changes.

PARAMETERS:

sel-mem	Select members where the section dimensions shall be assigned. For valid alternatives see command SELECT MEMBERS.
diameter1	Diameter at end 1 to be used in the fatigue calculation. The value overrides the true diameter of the member. Enter 0.0 for using the true diameter.
diameter2	Diameter at end 2 to be used in the fatigue calculation. The value overrides the true diameter of the member. Enter 0.0 for using the true diameter.
thickness1	Thickness at end 1 to be used in the fatigue calculation. The value overrides the true thickness of the member. Enter 0.0 for using the true thickness.
thickness2	Thickness at end 2 to be used in the fatigue calculation. The value overrides the true thickness of the member. Enter 0.0 for using the true thickness.

NOTES:

Changes in the section dimensions of a member will change the stresses of the section and affect the calculated fatigue damage of the member.

Such changes may also affect the member which is selected as the chord of a joint. However, it also offers the possibility for the user, in a simple way, to force a member to be the chord of a joint in the case when all members meeting at the joint have a same diameter and thickness by given an infinitesimal increase to the section dimensions for the preferred chord member.

EXAMPLES:

```
CHANGE WIND-FATIGUE SECTION-DIMENSIONS CURRENT 0.2 0.2 0.0125 0.0125
```

CREATE	EARTHQUAKE-DAMPING-FUNCTION	subcommmands	data
	EARTHQUAKE-SPECTRUM		
	JOINT		
	LOAD-COMBINATION		
	MATERIAL		
	MEMBER		
	SECTION		
	SN-CURVE		
	WAVE-SPREADING-FUNCTION		
	WAVE-STATISTICS		
	WIND-FATIGUE		

PURPOSE:

To create various entities.

PARAMETERS:

EARTHQUAKE-DAMPING-FUNCTION	To create an earthquake damping function.
EARTHQUAKE-SPECTRUM	To create an earthquake spectrum.
JOINT	To create a joint, i.e reconnect braces connected to different joints onto a new joint.
LOAD-COMBINATION	To create a load combination.
MATERIAL	To create a material.
MEMBER	To create a member (joining existing members).
SECTION	To create a section.
SN-CURVE	To create an SN curve.
WAVE-SPREADING-FUNCTION	To create a wave spreading function.
WAVE-STATISTICS	To create a scatter diagram.
WIND-FATIGUE	To create data for wind fatigue calculation.

All subcommands and data are fully explained subsequently as each command is described in detail.

CREATE EARTHQUAKE-DAMPING-FUNCTION

. . .	EARTHQUAKE-DAMPING-FUNCTION	name	text	. . .

. . .	CONSTANT	damp
	FREQUENCY-DEPENDENT	{freq, damp}*

PURPOSE:
To create an earthquake damping funcction.

PARAMETERS:

name	Name of damping function.
text	Text associated with the damping function.
CONSTANT	Damping is constant (frequency independent).
FREQUENCY-DEPENDENT	Damping is frequency dependent.
freq	Angular frequency where damping is specified.
damp	Fraction of critical modal damping.

NOTES:
The values represents the fraction of critical damping. For example, a 5% of critical damping must be given as 0.05.

See also:

```
ASSIGN EARTHQUAKE-DAMPING-FUNCTION...
PRINT EARTHQUAKE-DAMPING-FUNCTION
```

EXAMPLE:

```
CREATE EARTHQUAKE-DAMPING-FUNCTION DAMP005 'Damping of 5%' CONSTANT 0.05
```

CREATE EARTHQUAKE-SPECTRUM

...	EARTHQUAKE-SPECTRUM	name	text	ACCELERATION	{angfrq, spec-val}*
				DISPLACEMENT	
				VELOCITY	

PURPOSE:

To create an earthquake spectrum.

PARAMETERS:

name	Name of earthquake spectrum.
text	Text associated with the earthquake spectrum.
ACCELERATION	An acceleration spectrum shall be specified.
DISPLACEMENT	A displacement spectrum shall be specified.
VELOCITY	A velocity spectrum shall be specified.
angfrq	Angular frequency where the spectral value shall be specified.
spec-val	Spectral value corresponding to this frequency.

NOTES:

The user may specify an arbitrary number of frequencies, but should cover the range of frequencies for which mode shapes have been computed. The spectrum ordinate for an arbitrary frequency is found using linear interpolation in log-log space.

The frequencies must be specified in increasing order. Spectrum ordinates of 0.0 should not be specified.

See also:

`ASSIGN EARTHQUAKE-SPECTRUM...`
`PRINT EARTHQUAKE-SPECTRUM...`

EXAMPLES:

```
CREATE EARTHQUAKE-SPECTRUM DISP 'Displacement spectrum' DISPLACEMENT
                                      ( ONLY 0.1  1E4
                                             0.5  2E4
                                             1.0  1E3
                                       )
```

CREATE FATIGUE-LOAD-SERIES

. . .	FATIGUE-LOAD-SERIES	name	text	cycles	weight	. . .

. . .	BY-LOADCASE	MAXMIN SRSS LINEAR-COMB ABSOLUTE-COMB	{load-case, factor}

. . .	BY-GROUP	MAXMIN SRSS LINEAR-COMB ABSOLUTE-COMB	{first-lcs, last-lcs, lcs-step, factor }

PURPOSE:
To create a Fatigue Load Series for Direct Deterministic fatigue.

PARAMETERS:

name	Name of Fatigue Load Series.
text	Text associated with the Fatigue Load Series.
cycles	Number that the Fatigue Load Series repeats over fatigue exposure time.
weight	Weight factor multiplied on the resultant damage due to this Fatigue Load Series.
BY-LOADCASE	This option is the general method to define a Fatigue Load Series.
loadcase	name of the loadcase, either basic load case or load combination.
factor	loadcase factor.
BY-GROUP	This option is usually used for wave load analysis which outputs a bunch of ordered (sequential) load cases.
first-lcs	Loadcase name to start the group selection.
last-lcs	Loadcase name to end the group selection.
lcs-step	Step in the group selection.
factor	Loadcase factor acting on all loadcases in the group.
MAXMIN	the difference of largest stress and smallest stress in load series.
SRSS	the square root of the sum of the squares of stresses in load series.
LINEAR-COMB	the arithmetic summation of all stresses in load series.
ABSOLUTE-COMB	the summation of the absolute value of all stresses in load series.

NOTES:
This command can be issued many times in a Direct Deterministic Fatigue analysis since the total fatigue damae may come from many sources. One Fatigue Load Series consists of one or multiple basic load cases or load combinations. All Fatigue Load Series created will contribute in the total damage accumulation. User can specify Weight Factor=0 for this load series. Currently, there is no CHANGE feature to modify an existing Fatigue Load Series. User can use the command `PRINT FATIGUE-CHECK-TYPE` to see the existing

Fatigue Load Series. The command `DELETE FATIGUE-LOAD-SERIES` can be used to remove the un-wanted load series.

The weight factor can be any non-negative real number. If a fatigue load series should be ignored in the analysis, enter 0.0 at Weight.

The loadcase name in BY-GROUP option must be the “Internal Result ID”, which usually is the FEM load number. The loadcase concept name or “Load case name” is not supported.

See also:

```
DELETE FATIGUE-LOAD-SERIES ...
PRINT FATIGUE-CHECK-TYPE
DEFINE LOAD NAMING-CONVENTION ...
```

EXAMPLE:

```
CREATE FATIGUE-LOAD-SERIES S1 None 10000000.0 1.0 BY-LOADCASE SRSS ( ONLY
    1     1.0
    2     1.0
    3     1.0
    4     1.0
    5     1.0 )
CREATE FATIGUE-LOAD-SERIES GS1 None 5000000.0 1.5 BY-GROUP MAXMIN 73 107 1 1.0
```

CREATE JOINT

...	JOINT	name	descr	master	joint1	joint2
		MULTIPLE-SELECT	name	descr	master	sel-jnt
		BY-DISTANCE	name	descr	master	dist

PURPOSE:

To merge braces connected to different joints into one common joint. The braces will then be attached to another joint than originally modelled. Hence, when a structural joint has been modelled with more than one node in the static model (instead of using element eccentricities) it is possible to reconnect the braces in order to classify the braces according to real joint geometry.

PARAMETERS:

name	Joint name.
descr	Text associated with joint.
master	Joint name for existing joint, selected as master.
joint1	Start joint for merge (located on chord / aligned chord).
joint2	End joint for merge (located on aligned chord / chord).
MULTIPLE-SELECT	Selection of joints to merge into master by use of ordinary joint select alternatives.
sel-jnt	Selection of joints, see SELECT JOINT.
BY-DISTANCE	Search in both directions along chord / aligned chord to search for joints to merge.
dist	Search distance (in both directions).

NOTES:

It is only joints along the chord / aligned chord in tubular joints that can be merged. After merging joints Framework will treat the new joint as if it had been modelled with one node and element eccentricities. The distance between the master joint and the joints to merge will be put on as member (brace) eccentricities.

The program will automatically detect if given joints are candidates for this merging operation. A check with respect to maximum allowed distance between master joint and the joints to be merged is also performed. The maximum allowed distance is controlled by the command: DEFINE JOINT-PARAMETERS MERGE-DIAMETER-FRACTION. Default = 2.0 * Diameter.

This maximum distance will overrule the distance given when using input alternative BY-DISTANCE above.

A good practice after merging joints will be to create members (chord and aligned chord) having the new joint as start or end joint.

See also:

```
PRINT CHORD-AND-BRACE ...
DEFINE JOINT-PARAMETERS MERGE-DIAMETER-FRACTION ...
```

EXAMPLES:

```
CREATE JOINT J4 'Merge from 3 to 5' 4 3 5
```

CREATE LOAD-COMBINATION

. . .	LOAD-COMBINATION	name	text	STATIC		{load-case, factor }
				QUASI-STATIC		{load-case, factor, phase}
				SCAN		{load-case, factor }
				EARTHQUAKE	MAXIMUM	{load-case, factor}
					TENSION	
					COMPRESSION	

PURPOSE:
To create a load combination.

PARAMETERS:

name	Name of load combination.
text	Text associated with the load combination.
STATIC	This option must be used in order to combine loadcases that are static.
QUASI-STATIC	This option must be used in order to combine one or more static loadcases with one or more dynamic loadcases, or to combine dynamic loadcases. Note that loadcases are combined for specific phase angles. For static loadcases, a phase angle is meaningless so any value may be specified as it will not be used.
SCAN	This option must be used to combine static loadcases with one dynamic load-case.
load-case	Load case name to be included in the combination. This must be a basic loadcase (i.e. NOT a load combination). The load-case can be an earthquake loadcase created by `RUN EARTHQUAKE-CHECK`.
factor	Loadcase factor.
phase	Phase angle (in degrees) for which a dynamic loadcase shall be combined.
	"{ }" means it is a list of selected load-case and factor.
EARTHQUAKE	This option is to combine static loadcases and an earthquake loadcase, created in `RUN EARTHQUAKE-CHECK`, followed by the method of axial component combination.
MAXIMUM	This method calculates the axial force component as Static axial force + or - QUAKE axial force, whichever yields the larger |ABS| value. The static component has conventional sign.
TENSION	This method calculates the axial force component as Static axial force + QUAKE axial force. The static component has conventional sign.
COMPRESSION	This method calculates the axial force component as Static axial force - QUAKE axial force. The static component has conventional sign.

NOTES:

The SCAN load combination will be checked (scanned) for the set of phase angles given in the command DEFINE CONSTANTS PHASE. Default is in the range of 0 to 345 degrees in step of 15 degrees.

The earthquake response produces forces and moments that have lost their phase and sign because the response spectrum method is used. The design standard like API RP2A requires that the earthquake force

components should be added to the associated static force components appropriately for structural member's code checking.

The methods, MAXIMUM, TENSION, COMPRESSION following EARTHQUAKE option, are three options to combine the static axial component and the axial earthquake response. The earthquake response is non-negative by definition while the static components have conventional sign. The axial component combination has the 3 options.

MAXIMUM	Static + or − EARTHQUAKE, whichever yields the larger |ABS| value.
TENSION	Static + EARTHQUAKE
COMPRESSION	Static − EARTHQUAKE
	Note: *The static component always has the sign.*

The other components such as shear forces, bending moments, and torque, are calculated as the MAXIMUM method, i.e. Static component + or - QUAKE component for larger |ABS| value. The sign of static component is always retained in combination. See Appendix C.6 for more information.

When a load combination is created as "EARTHQUAKE" type, the design condition of this load combination is automatically set to EARTHQUAKE. It is not necessary to use command `ASSIGN LOAD-CASE` to specify the condition again.

The Earthquake type load combination is also applicable for the joint motions under earthquake excitation: Displacement, Velocity, Acceleration. However, the axial component option of new Earthquake type load combination has no effects on joint results. In detail, the program reports the same maximum absolute value at all components of joint motions for an Earthquake type load combination no matter which option of axial component is selected. The Maximum, Tension or Compression option in Earthquake type load combination does not have any difference for joint motions. In brief, any type of load combination (static or earthquake) of joint motion results will show the same values.

See also:

```
ASSIGN LOAD-CASE...
PRINT LOAD-CASE...
DEFINE CONSTANTS PHASE
RUN EARTHQUAKE-CHECK
```

EXAMPLE:

```
CREATE LOAD-COMBINATION LC1 'None' STATIC ( 1 1.0 2 3.5 3 2.2 )
CREATE LOAD-COMBINATION LC2 'None' QUASI-STATIC ( 5 1.0 0.0 9 1.0 90.0 )
CREATE LOAD-COMBINATION CMAXIM None EARTHQUAKE MAXIMUM ( ONLY
    1          1.0
    QUAKE     1.0 )
CREATE LOAD-COMBINATION CEQUT None EARTHQUAKE TENSION ( ONLY
    1          1.0
    2          1.0
    QUAKE     1.0 )
CREATE LOAD-COMBINATION CEC2 None EARTHQUAKE COMPRESSION ( ONLY
    1          1.0
    2          1.0
    QUAKE5     2.0 )
```

CREATE MEMBER

...	MEMBER	COMBINE-AUTOMATIC			
		name	text	joint 1	joint2

PURPOSE:

To create a member (by joining existing members).

PARAMETERS:

COMBINE-AUTOMATIC	Automatic combination of elements.
name	Member name.
text	Text associated with member.
joint1	Joint name for end 1 of new member.
joint2	Joint name for end 2 of new member.

NOTES:

The existing members and intermediate joints not supporting any incoming braces on the line between the two joints will be marked as deleted.

Do not create members spanning across structural joints with incoming braces which later on are going to be checked for punching shear capacity or fatigue damage.

Stability assignments done may need to be repeated

See also:

`PRINT MEMBER ...`

EXAMPLES:

```
CREATE MEMBER LEG1 'Leg 1 between joint 1001 and 1003' 1001 1003
```

CREATE MATERIAL

...	MATERIAL	name	text	young	yield	dens	pois	damp	exp

PURPOSE:

To create a material.

PARAMETERS:

name	Material name.
text	Text associated with material.
young	Young's modulus of elasticity.
yield	Material yield strength.
dens	Material density.
pois	Poisson's ratio.
damp	Material specific damping.
exp	Thermal expansion coefficient.

NOTES:

See also:

```
ASSIGN MATERIAL...
CHANGE MATERIAL...
PRINT MATERIAL...
```

EXAMPLES:

```
CREATE MATERIAL M1 'Linear elastic' 207E9 250E6 7850 0.3 0.0 1.2E-5
```

CREATE SECTION

...	SECTION	name	text	PIPE	data
				SYMMETRIC-I	
				UNSYMMETRIC-I	
				ANGLE	
				CHANNEL	
				BOX	
				BAR	
				GENERAL	
				RING-STIFFENER-T	
				RING-STIFFENER-FLAT	

PURPOSE:

To create a section with a particular profile.

PARAMETERS:

name	Section name.
text	Text associated with section.
PIPE	Indicates that a pipe profile shall be created.
SYMMETRIC-I	Indicates that a symmetric-I section shall be created.
UNSYMMETRIC-I	Indicates that an unsymmetric-I section shall be created.
ANGLE	Indicates that an L section shall be created.
CHANNEL	Indicates that a channel section shall be created.
BOX	Indicates that a box section shall be created.
BAR	Indicates that a massive bar section shall be created.
GENERAL	Indicates that a general section shall be created.
RING-STIFFENER-T	Indicates that a ring stiffener shaped as T shall be created.
RING-STIFFENER-FLAT	Indicates that a flatbar ring stiffener shall be created.

All data are fully explained subsequently as each command is explained in detail.

CREATE SECTION name text PIPE

...	name	text	PIPE	diam	thk

PURPOSE:

To create a tubular section.

PARAMETERS:

name	Section name.
text	Text associated with section.
PIPE	Section is of tubular profile.
diam	Pipe outside diameter.
thk	Pipe wall thickness.

NOTES:

See also:

```
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION P70025 'd=700,t=25' PIPE 0.7 0.025
```

CREATE SECTION name text SYMMETRIC-I

...	name	text	SYMMETRIC-I	hz	bt	tf	tw	r

PURPOSE:

To create a symmetric I section.

PARAMETERS:

name	Section name.
text	Text associated with section.
SYMMETRIC-I	Section is of I symmetric profile.
hz	Height of section.
bt	Width of section.
tf	Flange thickness.
tw	Web thickness.
r	Fillet radius.

NOTES:

See also:

```
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION I400100 'hz=400,bt=100' SYMMETRIC-I 0.4 0.1 0.025 0.025 0
```

CREATE SECTION name text UNSYMMETRIC-I

...	name	text	UNSYMMETRIC-I	hz	tw	bft	tft	tfh	bfb	tfb	bfh

PURPOSE:

To create an unsymmetric I section.

PARAMETERS:

name	Section name.
text	Text associated with section.
UNSYMMETRIC-I	Section is of I unsymmetric profile.
hz	Height of section.
tw	Web thickness.
bft	Top flange width.
tft	Top flange thickness.
tfh	Width of top flange along positive y-axis.
bfb	Bottom flange width.
tfb	Bottom flange thickness.
bfh	Width of bottom flange along positive y-axis.

NOTES:

See also:

```
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION I400100 'NONE' UNSYMMETRIC-I
0.4 0.09 0.1 0.01 0.05 0.1 0.01 0.05
```

CREATE SECTION name text ANGLE

...	name	text	ANGLE	hz	bt	tf	tw	r

PURPOSE:

To create a section with an angle profile.

PARAMETERS:

name	Section name.
text	Text associated with section.
ANGLE	Section is of an angle profile.
hz	Height of section.
bt	Width of section.
tf	Flange thickness.
tw	Web thickness.
r	Fillet radius.

NOTES:

See also:

```
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION AN400100 'hz=400,bt=100' ANGLE 0.4 0.1 0.025 0.025 0
```

CREATE SECTION name text CHANNEL

...	name	text	CHANNEL	hz	bt	tf	tw	r

PURPOSE:

To create a section with a channel profile.

PARAMETERS:

name	Section name.
text	Text associated with section.
CHANNEL	Section is of a channel profile.
hz	Height of section.
bt	Width of section.
tf	Flange thickness.
tw	Web thickness.
r	Fillet radius.

NOTES:

See also:

```
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION CH400100 'hz=400,bt=100' CHANNEL 0.4 0.1 0.025 0.025 0
```

CREATE SECTION name text BOX

...	name	text	BOX	hz	bt	tf	tw

PURPOSE:

To create a section with a box profile.

PARAMETERS:

name	Section name.
text	Text associated with section.
BOX	Section is of a box profile.
hz	Height of section.
bt	Width of section.
tf	Flange thickness.
tw	Web thickness.

NOTES:

It is possible to tag / automatically modify the box shaped cross sections that shall use design wall thickness = 0.93 times the nominal wall thickness. This is required in AISC LRFD for profiles manufactured according to ASTM A500. To set this tag the section description text must start with “ASTM HSS”. The nominal thicknesses shall be given as input. When this option is used, the cross section geometry and stiffness properties are automatically updated. Hence the new values will always be used, e.g. when printing section geometry, printing section stiffness properties, printing stresses and calculating usage factors (also for other codes of practice than AISC LRFD). If the section wall thickness has been modified in the preprocessor (modelling tool) or manually modified in Framework, do not use this feature.

See also:

```
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION BX400100 'hz=400,bt=100' BOX 0.4 0.1 0.025 0.025
CREATE SECTION HSSBOX 'ASTM HSS example' BOX 300 200 10 10
```

CREATE SECTION name text BAR

...	name	text	BAR	hz	bt	bb

PURPOSE:

To create a section with a massive bar profile.

PARAMETERS:

name	Section name.
text	Text associated with section.
BAR	Section is of a massive bar profile.
hz	Height of section.
bt	Width of section at top.
bb	Width of section at bottom.

NOTES:

See also:

```
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION BAR_1 'hz=400,bt=bb=100' BAR 0.4 0.1 0.1
```

CREATE SECTION name text GENERAL

...	name	text	GENERAL	area	Ix	Iy	Iz	Iyz	Wxmin	Wymin	Wzmin	...

...	ShAry	ShArz	ShCeny	ShCenz	Sy	Sz

PURPOSE:

To create a section with a general (undefined) profile.

PARAMETERS:

name	Section name.
text	Text associated with section.
GENERAL	Section is of a general (undefined) profile.
area	Effective cross-sectional area.
Ix	Torsional moment of inertia about shear centre.
Iy	Moment of inertia for bending about the local y-axis.
Iz	Moment of inertia for bending about the local z-axis.
Iyz	Product of inertia about y and z-axes.
Wxmin	Minimum section modulus for torsional stress about shear centre.
Wymin	Minimum section modulus for bending about local y-axis.
Wzmin	Minimum section modulus for bending about local z-axis.
ShAry	Shear area in the local y-direction.
ShArz	Shear area in the local z-direction.
ShCeny	Local y-coordinate of shear centre (location from centroid).
ShCenz	Local z-coordinate of shear centre (location from centroid).
Sy	Static area moment about local y-axis.
Sz	Static area moment about local z-axis.

NOTES:

See also:

```
ASSIGN SECTION...
PRINT SECTION...
```

EXAMPLES:

```
CREATE SECTION G1 'Main topside beam' GENERAL
                  1E-2 0.2 0.3 0.4 0.0 1E-2 1E-3 1E-2 5E-3 5E-3 0.0 0.0 0.0 0.0
```

CREATE SECTION name text RING-STIFFENER-T

...	name	text	RING-STIFFENER-T	hz	bt	tf	tw

PURPOSE:

To create a T shaped ring stiffener.

PARAMETERS:

name	Section name.
text	Text associated with section.
RING-STIFFENER-T	Section is of a T shaped ring stiffener.
hz	Stiffener height.
bt	Width of flange.
tf	Flange thickness.
tw	Web thickness.

NOTES:

See also:

```
ASSIGN JOINT-RING-STIFFENER...
PRINT SECTION GEOMETRY...
```

EXAMPLES:

```
CREATE SECTION RING1 '0.3x0.25x0.025*0.02' RING-STIFFENER-T
0.3 0.25 0.025 0.02
```

CREATE SECTION name text RING-STIFFENER-FLAT

...	name	text	RING-STIFFENER-FLAT	hz	tw

PURPOSE:

To create a flatbar shaped ring stiffener.

PARAMETERS:

name	Section name.
text	Text associated with section.
RING-STIFFENER-T	Section is of a flatbar shaped ring stiffener.
hz	Stiffener height.
tw	Web thickness.

NOTES:

See also:

```
ASSIGN JOINT-RING-STIFFENER...
PRINT SECTION GEOMETRY...
```

EXAMPLES:

```
CREATE SECTION RING2 '0.3x0.02' RING-STIFFENER-FLAT 0.3 0.02
```

CREATE SN-CURVE

...	SN-CURVE	name	USER	text	m0	S0		logN0	...
			LOGA		m0	logA0		logN0	
			STOCHASTIC		m0	logK0	sdk	logN0	

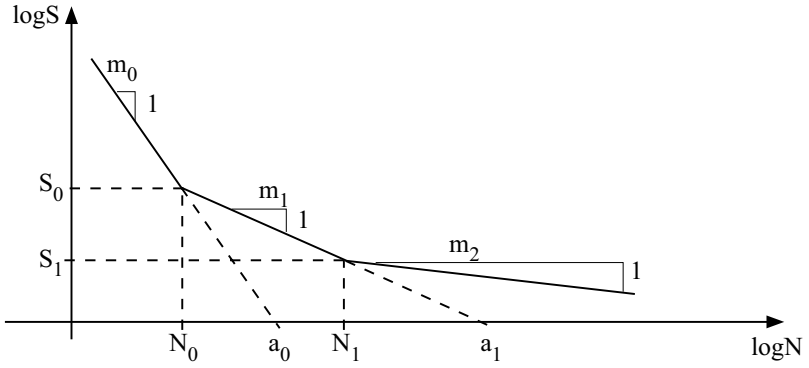
...	DEFAULT-TAIL				
	ALIGNED-WITH-FIRST				
	HORISONTAL-TAIL				
	ARBITRARY-TAIL	m1	ALIGNED-WITH-SECOND		
			HORISONTAL-TAIL	logN1	
			ARBITRARY-TAIL	logN1	m2

PURPOSE:

Create a SN-curve with up to 3 segments.

PARAMETERS:

name	SN-curve name.
USER	Only user defined option available.
text	Text associated with SN-curve.
m0	Inverse slope of first segment.
S0	Stress level at end first segment.
logN0	Log cycles to failure at end first segment.
logA0	Intercept of logN-axis and SN-curve
logK0	Intercept of logN-axis and mean SN-curve
sdk	Standard deviation of logK0. Note: logA0 = logK0 - 2*sdk
DEFAULT-TAIL	Second segment continues with m1 = 2*m0 - 1.
ALIGNED-WITH-FIRST	Second segment continues with m1 = m0.
HORISONTAL-TAIL	Second segment is horizontal.
ARBITRARY-TAIL	Second segment is arbitrary.
m1	Inverse slope of second segment.
ALIGNED-WITH-SECOND	Third segment continues with m2 = m1.
HORISONTAL-TAIL	Third segment is horizontal.
logN1	Log cycles to failure at end second segment.
m2	Inverse slope of third segment.



The number of cycles to failure (N) for a given stress range (S) is computed according to the following formula:

$$N \cdot S^m = a$$

$$\log N = \begin{cases} \log a_0 - m_0 \cdot \log S & \text{for } S > S_0 \\ \log a_1 - m_1 \cdot \log S & \text{for } S_1 < S < S_0 \\ \log a_2 - m_2 \cdot \log S & \text{for } S_2 < S_1 \end{cases}$$

Figure 5.6 Create SN-curve

NOTES:

Use the commands PRINT SN-CURVE and DISPLAY SN-CURVE to see curve data and shape.

The user defined SN curves must be defined using model units. (Note that the library curves use Newton and meter and should only be displayed together with user defined curves having the same units.)

When the LOGA and STOCHASTIC input options are applied, the input values of $\log A_0$, $\log K_0$ and stdk must be in accordance with the unit of the stresses applied in the analysis. When LOGA option is applied the stress level s0 is calculated by:

$$\log_{10} s_0 = (\log_{10} A_0 - \log_{10} N_0) / m_0$$

When STOCHASTIC option is applied the stress level s_0 is calculated by:

$$\log_{10} s_0 = (\log_{10} K_0 - 2sdk - \log_{10} N_0) / m_0$$

See also:

```
ASSIGN SN-CURVE...
CHANGE SN-CURVE...
PRINT SN-CURVE...
DISPLAY SN-CURVE...
```

EXAMPLES:

```
CREATE SN-CURVE DNVX USER 'Veritas X-curve' 4.1 34 8.29 HORISONTAL TAIL
```

CREATE WAVE-SPREADING-FUNCTION

...	WAVE-SPREADING-FUNCTION	name	text	COSINE-POWER	power
				USER-DEFINED	{wave-dir, weight}*

PURPOSE:

To create a wave spreading function.

PARAMETERS:

name	Name of wave spreading function.
text	Text associated with the spreading function.
COSINE-POWER	The spreading function is represented by a cosine function.
power	Power of the cosine function.
USER-DEFINED	The spreading function shall be user defined.
wave-dir	Wave direction, relative to the main wave direction.
weight	Weight associated with wave direction.

NOTES:

The sum of weights must be 1.0.

See also:
`ASSIGN WAVE-SPREADING-FUNCTION...`

EXAMPLES:

```
CREATE WAVE-SPREADING-FUNCTION COS2 'Analytical cos**2' COSINE 2
CREATE WAVE-SPREADING-FUNCTION DIS2 'Discretised cos**2' USER-DEF
                                    (  -45   0.25
                                         0   0.50
                                        45   0.25
                                    )
```

CREATE WAVE-STATISTICS

. . .	WAVE-STATISTICS	Name	Text	ALL-PARAM-SCATTER	. . .
				SCATTER-DIAGRAM	. . .
				ISSC-SCATTER-DIAGRAM	. . .
				Hs-Tp-SCATTER	. . .
				NORDENSTROM	parameters

with the subsequent input data for ALL-PARAM-SCATTER:

. . .	OCHI-HUBBLE	PROBABILITY	{Hss,Tps,Ls,Hsw,Tpw,Lw,prob} *
		OCCURENCE	{Hss,Tps,Ls,Hsw,Tpw,Lw,occr} *
		PERCENTAGE	{Hss,Tps,Ls,Hsw,Tpw,Lw,percent % } *

with the subsequent input data for SCATTER-DIAGRAM, ISSC, and Hs-Tp type:

. . .	PROBABILITY	{Hs,Tz or Tp,prob} *
	OCCURRENCE	{Hs,Tz or Tp,occr} *
	PERCENTAGE	{Hs,Tz or Tp,percent % } *

PURPOSE:
To create a wave scatter diagram.

PARAMETERS:

name	Name of wave statistics.
text	Text associated with the wave statistics.
ALL-PARAM-SCATTER	The wave statistics and spectrum shape are defined through a all parameter scatter diagram.
SCATTER-DIAGRAM	The wave statistics is a regular wave scatter diagram.
ISSC-SCATTER-DIAGRAM	The wave statistics is an ISSC type scatter diagram.
NORDENSTROM	The wave statistics is the Nordenstrom model.
Hs-Tp	The wave statistics (incl. the spectrum) depends on the significant wave height Hs and the peak spectral period Tp of the wave.
OCHI-HUBBLE	The wave statistics (incl. the spectrum) is a 6 parameter Ochi-Hubble spectrum.
Hss	Significant wave height, swell part.
Tps	Peak spectral period, swell part.
Ls	Shape factor (Lamda), swell part.
Hsw	Significant wave height, wind (sea) part.
Tpw	Peak spectral period, wind (sea) part.
Lw	Shape factor (Lamda), wind (sea) part.
PROBABILITY	The scatter diagram shall be defined in terms of probability for each set of Hs Tz or Tp values.
OCCURRENCE	The scatter diagram shall be defined in terms of occurrence for each set of Hs Tz or Tp values.

PERCENTAGE	The scatter diagram shall be defined in terms of percentage (%) for each set of Hs Tz or Tp values.
prob	Probability of occurrence for one sea state.
occr	Number of occurrences for one sea state.
percent	The probabilty of occurrence in percentage.
Hs	Significant wave height of one sea state.
Tz	Zero up-crossing period for one sea state. T1 for ISSC.
Tp	Peak spectral period for Hs-Tp type of scatter diagram.

NOTES:
If the seastates of the scatter diagram are defined in terms of probability or percentage then the sum of all fractions of occurrence must be 1.0.

When the wave statistics has been defined through the ALL-PARAM-SCATTER option, e.g. the Ochi-Hubble spectrum, all necessary parameters are given through the CREATE WAVE-STATISTICS command, and hence a wave spectrum shape shall not be assigned to the wave statistics, see Section 2.3.27 Wave spectrum shape.

The Nordenstrom model may NOT be used for fatigue analysis in Framework .

For ISSC scatter diagram it is T1 (mean wave period) that shall be given (instead of Tz).

The wave statistics of “Hs-Tp” type now can be assigned with wave spectrum shape, such as PIERSON-MOSKOWITZ, JONSWAP, and TORSETHAUGEN spectrum.

See also:

```
ASSIGN WAVE-STATISTICS...
PRINT WAVE-STATISTICS...
CHANGE WAVE-STATISTICS...
ASSIGN WAVE-SPECTRUM_SHAPE ...
```

EXAMPLE:

```
CREATE WAVE-STATISTICS WS1 'Scatter diagram for SESAM field' SCATTER PROBABILITY
( 5.0 7.0 0.1
7.0 6.0 0.3
6.0 6.0 0.5
8.0 5.0 0.1 )
```

CREATE WIND-FATIGUE

...	WIND-FATIGUE	ANALYSIS-PLANES	...
		STATIC-WIND-LOADS	

PURPOSE:

To create data for wind fatigue calculation.

PARAMETERS:

ANALYSIS-PLANES	Creates analysis planes.
STATIC-WIND-LOADS	Reads static wind loads from load result file (L#.FEM). This command is shaded in the graphic input mode and not applicable when the static wind element load are contained in the results interface file (R#.SIN).

All data are fully explained subsequently as each command is described in detail.

CREATE WIND-FATIGUE ANALYSIS-PLANES

...	ANALYSIS-PLANES	(	ONLY	nod1	nod2	nod2	)

PURPOSE:

Defines analysis planes which are used in assessing the fatigue damage. Triplets of three nodes define the analysis planes. The three nodes chosen for each plane must not all be co-linear.

A joint is defined as a planar set of members meeting at a node. Out-of-plane members meeting at the same node are not considered. Only joints lying parallel to the selected analysis plane are analysed (within the specified angular tolerance, see command DEFINE WIND-FATIGUE WIND-PARAMETERS).

PARAMETERS:

ONLY	Mandatory attribute
( )	Mandatory parentheses
nod1	First node used to form the analysis plane.
nod2	Second node used to form the analysis plane.
nod3	Third node used to form the analysis plane.

NOTES:

Triplets of three nodes are repeated for each analysis plane to be formed. A maximum of 10 analysis planes may be generated.

EXAMPLES:

```
CREATE WIND-FATIGUE ANALYSIS-PLANES ( ONLY
    101 203 301
    102 205 302
    103 201 303 )
```

CREATE WIND-FATIGUE STATIC-WIND-LOADS

...	STATIC-WIND-LOADS	FEM-SEQUENTIAL	prefix	name

PURPOSE:

This command reads the Wajac results file (L#.FEM file) containing distributed pressures or load intensity of the static wind loading. Resulting wind loads at the nodal points of the structure are calculated on basis of the distributed wind pressure loads.

Note: This command is shown shaded in the graphic input mode and not applicable when the static wind element loads are contained in the results interface file (R#.SIN). By including the RSEL command with parameter ISEL1=1 in the Sestra input of the static wind load analysis, element loads will be contained in the SIN file.

PARAMETERS:

FEM-SEQUENTIAL	Load results file on FEM sequential format
prefix	Prefix of the FEM file
name	Name of the FEM file.

NOTES:

When the Results Interface File (R#.SIN) is opened and read by the command FILE OPEN/TRANSFER, the load results file is also opened and read by the program. Static wind loads of the first six wind directions (if at least six wind directions are defined in Wajac) are read into the fatigue analysis program. If these wind directions are those that shall be included in the fatigue calculation, the present command needs not to be accessed.

If other wind directions are to be included (must have been defined in Wajac) they are assigned by the command DEFINE WIND-FATIGUE WIND-DIRECTIONS. When the wind directions change, the present command must be executed in order to transfer the wind loads of the requested wind directions. The dialogue window of the present command will immediately appear on the screen when the command DEFINE WIND-FATIGUE WIND-DIRECTIONS is executed.

Up to six wind directions may be included in a fatigue damage analysis. However, more than six wind directions may be generated by Wajac. Those directions assigned by the command DEFINE WIND-FATIGUE WIND-DIRECTIONS, which may be others than the first six, will be included in the wind fatigue analysis. Only wind directions of same angles as those generated by Wajac can be assigned for the fatigue analysis.

Note that if load cases for more than one water depth are generated in Wajac, only load cases of the same water depth may transferred and applied in a wind fatigue calculation run

EXAMPLES:

```
CREATE WIND-FATIGUE FEM-SEQUENTIAL ww L1
```

DEFINE

DEFINE	AISC	Sub-commands	data
	BEAM-SPLIT		
	BUCKLING-LENGTH-DUMP		
	CODE-OF-PRACTICE-VERSION		
	CONE-PARAMETERS		
	CONSTANTS		
	ECCENTRICITY		
	FATIGUE-CONSTANTS		
	FATIGUE-DAMAGE-TO-FILE		
	FATIGUE-DUMP		
	FATIGUE-PARAMETERS		
	FATIGUE-RAINFLOW-COUNTING		
	FATIGUE-SAFETY-FACTOR		
	FATIGUE-STRESS-TIME-SERIES-ON-FILE		
	GEOMETRY-VALIDITY-RANGE		
	HOTSPOTS		
	HYDROSTATIC-DATA		
	ISO		
	JOINT-PARAMETERS		
	JOINT-TYPE-VALIDATE		
	LOAD		
	LRFD-CODE-CHECK		
	LRFD-RESISTANCE-FACTORS		
	MEMBER-CHECK-PARAMETERS		
	MEMBER-CODE-CHECK-DUMP		
	MEMBER-REDESIGN		
	NORSOK		
	PARAMETRIC-SCF		
	POSITION-BOTH-SIDES		
	PREFRAME-INPUT		
	PRESENTATION		
	READ-CONCEPTS		
DEFINE	READ-NAMED-SETS	Sub-commands	data
	SECTION-OVERRULE		
	TIME-HISTORY-FATIGUE-TIME		
	WIDE-BAND-CORRECTION-FACTOR		
	WIND-FATIGUE		

PURPOSE:

To define general constants, fatigue data, hydrostatic data and various other design options.

PARAMETERS:

AISC	To define AISC code check parameters.
BEAM-SPLIT	To define if / how to split long beams defined on the results file.
BUCKLING-LENGTH-DUMP	To define if results from automatic buckling factor calculations shall be written to separate file.
CODE-OF-PRACTICE-VERSION	To define code of practice version of API RP2A WSD and AISC.
CONE-PARAMETERS	To define data used in check of conical transition.
CONSTANTS	To define global constant data.
ECCENTRICITY	To define if member end eccentricities shall be taken into account.
FATIGUE-CONSTANTS	To define global fatigue data.
FATIGUE-DAMAGE-TO-FILE	To define if fatigue damage results shall be save on file.
FATIGUE-DUMP	To define if intermediate results from fatigue damage calculations shall be written to separate file.
FATIGUE-PARAMETERS	To define SN curve thickness effects in joints.
FATIGUE-RAINFLOW-COUNTING	To switch between damage calculations based on closed form solution from spectral moments assuming Rayleigh distribution, and damage calculations based on generation of stress time series by FFT from stress autospectrum, i.e. rainflow cycle counting in time domain.
FATIGUE-SAFETY-FACTOR	To define if fatigue safety factors shall be taken into account.
FATIGUE-STRESS-TIME-SERIES-ON-FILE	To define writing and reading fatigue stress time series to and from file.
GEOMETRY-VALIDITY-RANGE	To define how to handle usage factors due to exceedance of geometric validity range.
HOTSPOTS	To define position of hotspots, centre of flange / web thickness or in extreme fibre.
HYDROSTATIC-DATA	To define hydrostatic data
ISO	To define ISO 19902 code check parameters.
JOINT-PARAMETERS	To define joint design parameters.
JOINT-TYPE-VALIDATE	To switch off (on) activation of joint type validation.
LOAD	To define naming convention to be used when establishing load case names (when reading results file).
LRFD-CODE-CHECK	To define options in connection with the AISC-LRFD yield and stability code check.
LRFD-RESISTANCE-FACTORS	To specify / change API-AISC-LRFD resistance factors.
MEMBER-CHECK-PARAMETERS	To define parameters used in member checks.
MEMBER-CODE-CHECK-DUMP	To define if results from member code check calculations shall be written to separate file.
MEMBER-REDESIGN	To define parameters used in connection with member code check redesign / resize.
PARAMETRIC-SCF	To define how to calculate parametric SCFs.
POSITION-BOTH-SIDES	To define how to assign code check positions at member intermediate joints.
PREFRAME-INPUT	To define if a journal input file to Preframe shall be generated when exiting Framework.

PRESENTATION	To define alternatives with respect to presentation of stress and results.
READ-CONCEPTS	To switch off (on) reading the concept information from the result file.
READ-NAMED-SETS	To alternatively switch off reading the named element and joint sets from the result file.
SECTION-OVERRULE	To define how to handle the CREATE SECTION command when the given section name already exist.
TIME-HISTORY-FATIGUE-TIME	To define duration of the fatigue exposure time of time history fatigue calculation.
WIND-FATIGUE	To define data for wind fatigue calculations.

All subcommands and data are fully explained subsequently as each command is described in detail.

DEFINE AISC

...	AISC	ASD-AXIAL-TENSION-SAFETY-FACTOR	SFax-ten
		ASD-AXIAL-COMPRESSION-SAFETY-FACTOR	SFax-com
		ASD-BENDING-SAFETY-FACTOR	SFbend
		ASD-SHEAR-SAFETY-FACTOR	SFshear
		ASD-TORSION-SAFETY-FACTOR	SFtors
		LRFD-AXIAL-TENSION-RESISTANCE-FACTOR	RFax-ten
		LRFD-AXIAL-COMPRESSION-RESISTANCE-FACTOR	RFax-com
		LRFD-BENDING-RESISTANCE-FACTOR	RFbend
		LRFD-SHEAR-RESISTANCE-FACTOR	RFshear
		LRFD-TORSION-RESISTANCE-FACTOR	RFtors
		USE-SECTION-F12_1	NO (default)
			YES
		TORSION-AS-PER-CHAPTER-G	INCLUDE (default)
			EXCLUDE
		DEFINE AISC USE-LOCAL-BENDING-MOMENT	OFF (default)
			ON

PURPOSE:
Define AISC 360-10 code check parameters, see [41]. This version is active both for ASD (WSD) and LRFD design approaches.

PARAMETERS:

ASD-AXIAL-TENSION-SAFETY-FACTOR SFax-ten	Specify Asd axial tension safety factor. Safety factor axial tension. Default = 1.67.
ASD-AXIAL-COMPRESSION-SAFETY-FACTOR SFax-com	Specify Asd axial compression safety factor. Safety factor axial compression. Default = 1.67.
ASD-BENDING-SAFETY-FACTOR SFbend	Specify Asd bending safety factor. Safety factor bending. Default = 1.67.
ASD-SHEAR-SAFETY-FACTOR SFshear	Specify Asd shear safety factor. Safety factor shear. Default = 1.67.
ASD-TORSION-SAFETY-FACTOR SFtors	Specify Asd torsion safety factor. Safety factor torsion. Default = 1.67.
LRFD-AXIAL-TENSION-RESISTANCE-FACTOR RFax-ten	Specify Lrfd axial tension resistance factor. Resistance factor axial tension. Default = 0.9.
LRFD-AXIAL-COMPRESSION-RESISTANCE-FACTOR RFax-comp	Specify Lrfd axial compression resistance factor. Resistance factor axial compression. Default = 0.9.
LRFD-BENDING-RESISTANCE-FACTOR RFbend	Specify Lrfd bending resistance factor. Resistance factor bending.

	Default = 0.9.
LRFD-SHEAR-RESISTANCE-FACTOR	Specify Lrfd shear resistance factor.
RFshear	Resistance factor shear.
	Default = 0.9.
LRFD-TORSION-RESISTANCE-FACTOR	Specify Lrfd torsion resistance factor.
RFtors	Resistance factor torsion.
	Default = 0.9.
USE-SECTION-F12_1	Specify use of section F12.1.
NO	Section F12.1 is not used (default).
YES	Section F12.1 is used for cross sections not covered in F2 through F11 regarding moment capacity. Usage factors are calculated and reported based on this.
TORSION-AS-PER-CHAPTER-G	Include/exclude torsion as per chapter G.
INCLUDE	Torsion as per chapter G (default).
EXCLUDE	Torsion is not included when calculating shear usage factor for open profiles.
USE-LOCAL-BENDING-MOMENTS	OFF/ON option for using local bending moments.
OFF	Local bending moments are not used (default).
ON	Actual/local bending moments are used at every code check position in stability check (not the maximum moments along the members).

NOTES:
The AISC 360-10 version is active both for ASD (WSD) and LRFD design approaches and is the default option when selecting `SELECT CODE-OF-PRACTICE API-AISC-WSD` and `SELECT CODE-OF-PRACTICE API-AISC-LRFD`.

The AISC 360-10 version is activated by the command `DEFINE CODE-OF-PRACTICE-VERSION AISC 2010`.

This edition of AISC is valid for the `RUN MEMBER-CHECK` only (not separate `YIELD-CHECK` or `STABILITY-CHECK` alternatives). The “old" AISC check, i.e. the AISC WSD 9th edition (1989) and the AISC LRFD (1999)) may be activated by the command `DEFINE CODE-OF-PRACTICE-VERSION AISC 1999`.

Note that the AISC 360-10 ASD member check does not automatically increase the allowable stress with one-third for Storm conditions as it should when run in context of API RP2A-WSD. Hence, these load conditions must be analysed separately with modified safety factors.

EXAMPLES:

```
DEFINE AISC ASD-AXIAL-TENSION-SAFETY-FACTOR 1.67
DEFINE AISC ASD-AXIAL-COMPRESSION-SAFETY-FACTOR 1.67
DEFINE AISC ASD-BENDING-SAFETY-FACTOR 1.67
DEFINE AISC ASD-SHEAR-SAFETY-FACTOR 1.67
DEFINE AISC ASD-TORSION-SAFETY-FACTOR 1.67
DEFINE AISC LRFD-AXIAL-TENSION-RESISTANCE-FACTOR 0.9
DEFINE AISC LRFD-AXIAL-COMPRESSION-RESISTANCE-FACTOR 0.9
DEFINE AISC LRFD-BENDING-RESISTANCE-FACTOR 0.9
DEFINE AISC LRFD-SHEAR-RESISTANCE-FACTOR 0.9
DEFINE AISC LRFD-TORSION-RESISTANCE-FACTOR 0.9
DEFINE AISC USE-SECTION-F12_1 NO
DEFINE AISC TORSION-AS-PER-CHAPTER-G INCLUDE
DEFINE AISC USE-LOCAL-BENDING-MOMENT OFF
```

DEFINE BEAM-SPLIT

...	BEAM-SPLIT	STRUCTURE	NONE
			CAN-REINFORCED
			ALL-JOINTS
		SECTION	ALL
			PIPE-ONLY

PURPOSE:

To define if / how to split long beams defined on the results file. In this context 'long beams' means beams (member concepts) spanning across structural joints. A structural joint is a joint were more than two beam elements are joined together, i.e. typically a brace to chord connection.

PARAMETERS:

STRUCTURE	Structure option.
NONE	Do not split, i.e. use as defined on the result file. (Default.)
CAN-REINFORCED	Split only at joints with can reinforcement.
ALL-JOINTS	Split at all structural joints.
SECTION	Section option.
ALL	Split independent of section type.
PIPE-ONLY	Split only for members with pipe section.

NOTES:

These switches must be set prior to the FILE OPEN and FILE TRANSFER commands are executed.

When a beam is split, each part will be given name suffix _1, _2 and so on, example: BM121 slit into two beams --> BM121_1 and BM121_2. Note that the name is limited to 8 characters. If the created name has more than 8 characters, the member will be given the name Mxxxx, where xxxx is the element number to the first element being part of the member. Chords must be split at structural joints if incoming braces are going to be checked for punching shear capacity or fatigue damage (when using parametric SCF's).

When a beam is split no buckling parameters will be read from the results file and hence not assigned to these members.

EXAMPLES:

```
DEFINE BEAM-SPLIT STRUCTURE ALL-JOINTS
DEFINE BEAM-SPLIT SECTION PIPE-ONLY
```

DEFINE BUCKLING-LENGTH-DUMP

...	BUCKLING-LENGTH-DUMP	ON
		OFF

PURPOSE:

To define if intermediate results from the automatic buckling factor calculations shall be written to separate file. This switch is also used in connection with information about web and flange classification when performing code check according to API-AISC-LRDF.

PARAMETERS:

ON	Activate this feature.
OFF	Turn off this feature. (Default behaviour.)

NOTES:

Automatic buckling factor calculations: For each member code check run, spring stiffnesses and buckling factors for each element being part of a member will be written to a separate file. The files will be named to identify the different runs according to the naming convention run-name BUCK.TMP, where 'run-name' is the name specified when performing the code check.

Web and flange classification: In connection with code check according to API-AISC-LRFD (member yield, stability, combined yield and stability) it is possible to get dump of data giving information about flange and web classification used for cross sections of type I/H, Box and Channel. For each member, each load case and each check position the following data is presented:

FLclass = Classification of flange

FLwtr = Actual width thickness ratio for flange

FLlam_r = Lambda_p (compact) for flange

FLlam_p = Lambda_r (non compact) for flange

Webclass = Classification of web

Webwtr = Actual height thickness ratio for web

Weblam_r = Lambda_p (compact) for web

Weblam_p = Lambda_r (non compact) for web

The dump files will be named to identify the different runs according to the following naming convention: run-nameBUCK.TMP.

For box sections these data will be given twice for each position. This because bending moment capacity with respect to the weak axis are calculated separately using 'webs as flanges' and 'flanges as webs'.

When running the combined yield and stability check this data will be presented twice, both for the yield and the stability part of the check.

See also:

```
ASSIGN STABILITY sel-mem BUCKLING-LENGTH AUTOMATIC
```

EXAMPLES:

```
DEFINE BUCKLING-LENGTH-DUMP ON
```

DEFINE CODE-OF-PRACTICE-VERSION

...	CODE-OF-PRACTICE-VERSION	API-RP2A-WSD	2002
			2007
		AISC	1999
			2010
		NORSOK-N-004	2004
			2013

PURPOSE:
To define the edition of code of practice to be activated when performing code check according to API RR2A WSD, AISC or NORSOK N-004.

PARAMETERS:

API-RP2A-WSD	Code check according to API RP2A WSD.
2002	Use 2002 edition.
2007	Use 2007 edition (default).
AISC	Code check according to API RP2A WSD.
1999	Use 1999 edition.
2010	Use 2010 edition (default).
NORSOK-N-004	Code check according to NORSOK N-004.
2004	Use 2004 edition.
2013	Use 2013 edition (default).

NOTES:
Code check of tubular joint connection may be performed according to API Recommended Practice 2A-WSD (API RP2A WSD) 21st Edition inclusive Errata & Supplement 3, October 2007, see [54] or the “old" joint check, i.e. up to Errata & Supplement 1, Dec. 2002, see [31]. The 2007 edition is the default option when selecting `SELECT CODE-OF-PRACTICE API-AISC-WSD`, i.e `DEFINE CODE-OF-PRACTICE-VERSION API-RP2A-WSD 2007`.

Member check may be performed according to AISC 360-10, i.e. “Specification for Structural Steel Buildings", June 22, 2010, see [41]. This version is active both for ASD (WSD) and LRFD design approaches. The 360-10 is the default option when selecting `SELECT CODE-OF-PRACTICE API-AISC-WSD` and `SELECT CODE-OF-PRACTICE API-AISC-LRFD`, i.e. `DEFINE CODE-OF-PRACTICE-VERSION AISC 2010`. This edition of AISC is valid for the `RUN MEMBER-CHECK` only (not separate `YIELD-CHECK` or `STABILITY-CHECK` alternatives). The “old" AISC check, i.e. the AISC WSD 9th edition (1989), [50] and the AISC LRFD (1999), [29] may be activated by the command: `DEFINE CODE-OF-PRACTICE-VERSION AISC 1999`.

Code check of tubular joint connections, members and conical transitions may be performed according to Norsok standard N-004 "Design of steel structures", Rev. 3, February 2013, [58]. The 2013 edition is the default option when selecting `SELECT CODE-OF-PRACTICE NORSOK`, i.e `DEFINE CODE-OF-PRACTICE-VERSION NORSOK 2013`.

Important:
The default version of the selected code of practice is the latest available release. Hence, if running an old command input file and a former version of the standard is wanted, the command resetting to a previous release of the code of practice must be added to the input file. E.g. if the 2002 release of API is wanted, add the command `DEFINE CODE-OF-PRACTICE-VERSION API-RP2A-WSD 2002` prior to any run commands.

These switches/options are global settings in Framework. Do not switch version between running code checks and printing results (at least, the same version used for a code check run must also be defined before printing results). This also applies to the command `PRINT ACTIVE-SETTINGS`.

See also:

```
SELECT CODE-OF-PRACTICE .....
PRINT ACTIVE-SETTINGS
```

EXAMPLES:

```
DEFINE CODE-OF-PRACTICE API-RP2A-WSD 2007
DEFINE CODE-OF-PRACTICE AISC 2010
DEFINE CODE-OF-PRACTICE-VERSION NORSOK-N-004 2013
```

DEFINE CONE-PARAMETERS

...	CONE-PARAMETERS	FABRICATION-TOLERANCE	value

PURPOSE:

To define the fabrication tolerance value to be used in check of conical transition (NPD code of practice only).

PARAMETERS:

value Fabrication tolerance to be used.

NOTES:

The allowable fabrication tolerance default is set to 0.005 times radius of cylinder (R).

See also:
`RUN CONE-CHECK ...`

EXAMPLES:

```
DEFINE CONE-PARAMETER FABRICATION-TOLERANCE 0.003
```

DEFINE CONSTANTS

...	CONSTANTS	GRAVITY	g
		MATERIAL-FACTOR	mat-fact
		MINIMUM-BRACE-ANGLE	min-angle
		PHASE-ANGLE	phase-angle*

PURPOSE:

To define global constants.

PARAMETERS:

GRAVITY	The acceleration due to gravity shall be defined.
g	Acceleration due to gravity.
MATERIAL-FACTOR	The material factor shall be defined.
mat-fact	Value of material factor (used in NPD/NS3472 check only).
MINIMUM-BRACE-ANGLE	The minimum angle of a brace with its chord shall be defined.
min-angle	Minimum angle that a member may form with a chord such that the member is considered as the chord's brace (in degrees).
PHASE-ANGLE	Phase angles shall be defined in order to compute dynamic load-cases at these phase angles during code checking or printing forces and stresses (in degrees).
phas-angle	Give one or more phase angles.

NOTES:

Default value of acceleration due to gravity is 9.81 m/s^2.

Default value of NPD/NS3472 material factor is 1.15.

Default minimum brace angle is 15 degrees.

Default phase angle is 0 degrees.

EXAMPLES:

```
DEFINE CONSTANTS PHASE-ANGLE ( ONLY 0 30 60 90 )
```

DEFINE ECCENTRICITY

...	ECCENTRICITY	ON
		OFF

PURPOSE:

To define if member end eccentricities shall be taken into account.

PARAMETERS:

ON	Eccentricities are shown. (Default behaviour.)
OFF	Turn off this feature.

NOTES:

Eccentricities are accounted for in all calculations with respect to member lengths and angles. The automatic gap/overlap calculation takes eccentricities defined in the preprocessor into account.

When switched off, it will affect the calculations as well as the display.

See also:

`PRINT MEMBER ECCENTRICITY-DATA sel-mem`

EXAMPLES:

```
DEFINE BUCKLING-LENGTH-DUMP ON
```

DEFINE FATIGUE-CHECK-WELD-ROOT

. . .	FATIGUE-CHECK-WELD-ROOT	OFF
		ON

PURPOSE:
Option to trigger the fatigue check on the weld roots

PARAMETERS:

OFF	Do not add weld root positions (Default program setting.)
ON	Add CHORD-ROOT and BRACE-ROOT position at a brace member end.

NOTES:
This command must be issued before reading in the result SIN file, i.e. using `FILE OPEN` and `FILE TRANSFER`. With this option being ON, Framework will automatically generate the fatigue positions of weld root at tubular joints. User needs to use `ASSIGN SCF JOINT` command to specify the SCF option. The joint parametric SCF of Efthymiou or Lotsberg option is required for the fatigue check of weld root. The other parametric SCF will not be applied at weld root fatigue. The default SN curve will be assigned to the weld root position. User does not need to assign SN curve at weld root unless necessary. See section 2.5.10 for details.

If the Buttweld SCF option is **DNVGL-RP-C203-2020**, the program will generate the weld root fatigue positions at tubular cross section or segment transitions, and automatcially assign the default SCF and the SN curve specifiied by command `DEFINE FATIGUE-CONSTANTS DEFAULT-BUTTWELD-SN-CURVE`.

To be effective, the command must be applied prior to reading the result file, i.e.`FILE OPEN` and `FILE TRANSFER`. This option is introduced since Framework v4.3. See section 2.5.12 for details.

Note that if the weld root fatigue check option is OFF with this command or this command is not issued, the fatigue check positions at weld roots will not be generated by the program. In this case, user has to use commnd `ASSIGN POSITION` to generate weld root positions, see section 2.5.13.

EXAMPLES:

```
DEFINE FATIGUE-CHECK-WELD-ROOT ON
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2020
DEFINE FATIGUE-CONSTANTS DEFAULT-BUTTWELD-SN-CURVE DNV2010_E
```

DEFINE FATIGUE-CONSTANTS

. . .	FATIGUE-CONSTANTS	TARGET-FATIGUE-LIFE	year
		FATIGUE-EXPOSURE-TIME	duration
		DEFAULT SN-CURVE	sn-curve
		DEFAULT-FATIGUE-SAFETY-FACTOR	safac
		BUTTWELD-CONE-SCF-FORMULA	scfEqn
		DEFAULT BUTTWELD-SN-CURVE	ButtSN
		FABRICATION-TOLERANCE-OPTION	fabOpt
		DEFAULT-FABRICATION-TOLERANCE	fabtol or fabtol-factor
		INHERENT-SN-MISALIGNMENT-FACTOR	SNmisFactor
		AXIAL-MINIMUM-SCF	SCFax-min
		IN-PLANE-MINIMUM-SCF	SCFipb-min
		OUT-OF-PLANE-MINIMUM	SCFopb-min
		BUTTWELD-CONE-MIN-SCF	SCFbtcn-min
		AXIAL-GLOBAL-SCF	SCFax-glo
		IN-PLANE-GLOBAL-SCF	SCFipb-glo
		OUT-OF-PLANE-GLOBAL	SCFopb-glo
		IN-PLANE-FACTOR	FACinp
		OUT-OF-PLANE-FACTOR	FACopb
		MARSHALL-REDUCTION	qrmin
		GLOBAL-FATIGUE-PART-DAMAGE	damage
		ACCUMULATE-FATIGUE-RUN	run-name
		SPLASH-ZONE-UPPER-LIMIT-ELEVATION	Z_spl_up
		SPLASH-ZONE-LOWER-LIMIT-ELEVATION	Z_spl_low
		SHORT-CHORD-FIXITY-PARAMETER	C
		SHORT-CHORD-FIXITY-OPTION	Option

PURPOSE:
Define global constants used when doing a fatigue analysis.

PARAMETERS:

TARGET-FATIGUE-LIFE	Target fatigue life in years (see note below).
year	Number of years (default value = 20.0).
FATIGUE-EXPOSURE-TIME	Fatigue exposure time (see note below).
duration	Give duration (default = -1.).
DEFAULT-SN-CURVE	Default SN-curve assigned to all pre-defined fatigue check positions at joints or user defined positions. (Must be issued prior to the `FILE OPEN` and `FILE TRANSFER` commands).
sn-curve	Curve name (default: DNV-X)

DEFAULT-FATIGUE-SAFETY-FACTOR	Fatigue safety (design) factor. (Must be issued prior to the `FILE OPEN` and `FILE TRANSFER` commands).
safac	Give the fatigue safety (design) factor (Default = 1.0).
BUTTWELD-CONE-SCF-FORMULA	The global default SCF option for butt-weld and conical transitions.
scfEqn	User can choose: **DNVGL-RPC203-2020** (default option) **DNVGL-RPC203-2014** **Norsok-N004-1998** **Global Axial SCF** **DNV-RPC203-BSWD**.
DEFAULT-BUTTWELD-SN-CURVE	Default SN curve to be assigned to the automatically generated Buttweld fatigue positions. (Must be issued prior to the `FILE OPEN` and `FILE TRANSFER` commands).
ButtSN	Curve name (default: DNV2010_E)
FABRICATION-TOLERANCE-OPTION	This global option is effective for DNVGL RPC203 butt-weld SCF formula (both -2014 and -2020).
fabOpt	User can choose between *0.10ts*, *0.15ts*, *0.30ts*, or *Manual*, where *ts* is the smaller thickness at the section transition and *0.10ts, 0.15ts, 0.30ts* correspond to the fabrication categories: special, primary and secondary, respectively in DNV OS C401 [21].
DEFAULT-FABRICATION-TOLERANCE	Global concentricity variable used to account for tubular out-of-roundness, centre eccentricity and fabrication tolerance for butt weld SCF calculation; to be used in different design codes, see the note below for the details. This variable is effective only if *Manual* is selected at `FABRICATION-TOLERANCE-OPTION`.
fabtol	If `BUTTWELD-CONE-SCF-FORMULA` is **DNVGL-RPC203-2014**, the variable is a quantity in length, to account for tubular out-of-roundness (concentricity), centre eccentricity and fabrication tolerance. (Default 0.0)
or fabtol-factor	If `BUTTWELD-CONE-SCF-FORMULA` is **DNVGL-RPC203-2020** or **DNV-RPC203-BSWD**, this variable is a unitless factor that multiplies the smaller thickness *ts* to define the magnitude of out-of-roundness or misalignment due to fabrication. (Default 0.0)
INHERENT-SN-MISALIGNMENT-FACTOR	This variable defines the misalignment inherent in the SN data and analysis procedure for as welded butt welds. δ_0 in **DNVGL-RPC203-2020** and **DNV-RPC203-BSWD**.
SNmisFactor	this variable is a unitless factor to multiply with smaller thickness *ts* to define the inherent misalignment in the SN curve. (Default 0.05)
AXIAL-MINIMUM-SCF	Minimum (parametric) SCF for axial force.

SCFax-min	Default value: 2.5.
IN-PLANE-MINIMUM-SCF	Minimum (parametric) SCF for in-plane bending.
SCFipb-min	Default value: 2.5.
OUT-OF-PLANE-MINIMUM	Minimum (parametric) SCF for out-of-plane bending.
SCFopb-min	Default value: 2.5.
BUTTWELD-CONE-MIN-SCF	Minimum SCF of butt-weld and cone transition
SCFbtcn-min	Default value: 1.0
AXIAL-GLOBAL-SCF	Global (default) SCF for axial force.
SCFax-glo	Default value: 1.0.
IN-PLANE-GLOBAL-SCF	Global (default) SCF for in-plane bending.
SCFipb-glo	Default value: 1.0.
OUT-OF-PLANE-GLOBAL	Global (default) SCF for out-of-plane bending.
SCFopb-glo	Default value: 1.0.
IN-PLANE-FACTOR	Correction factor applied for the in-plane bending SCF at hotspots 4, 10, 16 and 22, only for PIPE elements if the SCF distribution is CROWN-SADDLE or parametric. See Framework Theory Manual section 7.2.4.
FACinp	Default value: 0.7071.
OUT-OF-PLANE-FACTOR	Correction factor applied for the out-of-plane bending SCF, as above.
FACopb	Default value: 0.7071.
MARSHALL-REDUCTION	Minimum value of the Marshall reduction factor used for parametric SCFs.
qrmin	Default value: 0.8.
GLOBAL-FATIGUE-PART-DAMAGE	Manually assign initial fatigue damages to selected members.
damage	Specify initial global damage.
ACCUMULATE-FATIGUE-RUN	Define the fatigue damage of one fatigue run to be initial damage for a succeeding fatigue run.
run-name	Specify the name of the existing run.
SPLASH-ZONE-UPPER-LIMIT-ELEVATION	Assign upper limit elevation for the splash zone.
Z_spl_up	Upper limit elevation. Default value: 0.
SPLASH-ZONE-LOWER-LIMIT-ELEVATION	Assign lower limit elevation for the splash zone.
Z_spl_low	Lower limit elevation. Default value: 0.
SHORT-CHORD-FIXITY-PARAMETER	Assign Short Chord Fixity Parameter.
C	The default is 1.0. The user can input a different value if needed. Typically, a joint might be composed of a chord and aligned chord. The short chord parameter is retrieved only from the chord member. The aligned chord fixity parameter is not used.

SHORT-CHORD-FIXITY-OPTION	The user can choose between *Local* or *Global*.
Option	*Local* uses the information relative to buckling effective length for each member.
	Global uses the SHORT-CHORD-FIXITY-PARAMETER C for all members. This is the default.

NOTES:
The command `DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE` must be issued prior to the RUN command. It will have no effect on existing fatigue check results.

The command `DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE` and `DEFAULT-FATIGUE-SAFETY-FACTOR` must be issued prior to the `FILE TRANSFER` command. It will have no effect on existing members.

The default `FATIGUE-EXPOSURE-TIME=-1` means the entire target fatigue life will be used, i.e. FET=TFL. When setting the `FATIGUE-EXPOSURE-TIME` to a value greater than zero, this will be the duration that the wave occurrence data (deterministic fatigue) or the fatigue load series (direct deterministic fatigue) must correspond to. The user is then free to re-specify another `TARGET-FATIGUE-LIFE` without having to re-specify the number of wave cycles. None of these settings will affect the calculated fatigue life, but it will alter the calculated fatigue damage (Miners Sum).

The general expressions for the calculated fatigue damage (Miners Sum) versus calculated fatigue life:

Deterministic or	MSD = FPD + FSF x (TFL/FET)/ Fatlife
Direct Deterministic:	
Stochastic:	MSD = FPD + FSF x TFL / Fatlife
where:	MSD = Miner Sum Damage
	FPD = Fatigue Part Damage
	FSF = Fatigue Safety Factor
	TFL = Target Fatigue Life
	FET = Fatigue Exposure Time
	Fatlife = Calculated Fatigue Life

See also last part of Section 3.14 for another specific value which may be used for `TARGET-FATIGUE-LIFE`.

Please note that the reported fatigue damages for a Time-History fatigue analysis are determined by the input on command `DEFINE TIME-HISTORY-FATIGUE-TIME`.

Use of minimum SCFs in connection with parametric SCFs can also be defined through the commands given under
`DEFINE PARAMETRIC-SCF CHORD-BRACE-SEPARATE ON`.
However, minimum values less than 1.0 are not possible by this command.

Minimum SCFs are applied to the calculated parametric SCFs. There are, however, some restrictions related to the Efthymiou and Lloyds SCF rules. When values less than 1.0 are entered for all three minimum SCFs (axial, in-plane bending and out of plane bending), the minimum values are overruled by 1.0 by the program. However, when a value above 1.01 is entered for at least one minimum SCF, all minimum SCFs will apply as given, also values less than 1.0. E.g. by entering 0.4, 0.4, 0.4 for the axial, in-plane bending and out of plane bending SCFs, the program will overrule the minimum values and put 1.0 to all, while for 1.1, 0.4, 0.4 the given minimum values will apply.

The part of the structure in air is above the upper limit elevation level Z_spl_up. The part of the structure under sea water with cathodic protection is the part below the lower limit elevation level Z_spl_low. The splash zone is the zone between Z_spl_low and Z_spl_up. The program will check whether an elevation is greater than Z_spl_up. If it is true, the position is in-Air. Then, the program will check whether an elevation is smaller than Z_spl_low. If it is true, the position is under sea water. Otherwise, the position is considered inside splash zone. Usually, the upper limit Z_spl_up should be above the lower limit Z_spl_low. Inside the splash zone,Z_spl_low $<$ z $<$ Z_spl_up, the position at z is assumed to have free corrosion. That is, no corrosion protection in the splash zone is assumed. The limits of splash zone only affect the automatic elevation detection for the primary type of SN curves. It is recommended to define the splash zone limits when using the primary type of SN curves in practice. If the splash zone information is not desired, user should ignore the primary type SN curve and use the regular SN curve instead. User can print member's fatigue check positions report to check the location of each position w.r.t. splash zone.

For **Norsok Standard N004:1998** code [56], the parameter *fabtol* represents the global eccentricity caused by out-of-roundness and centre eccentricity at butt weld connections; Combining the global **fabtol** with the local eccentricity due to thickness difference gives the total eccentricity δ (misalignment of tubular butt-weld connection) in the SCF formula Eqn(C.2.10), with a certain thickness transition slope. Alternatively, the total eccentricity δ can be calculated by combining the global **fabtol** with the *MANUAL* eccentricity (see command ASSIGN SCF Member).

For **DNVGL RP C203:2014** code [42], the parameter *fabtol* at DEFAULT-FABRICATION-TOLERANCE is ignored for *0.10ts*, *0.15ts*, and *0.30ts* option because they correspond to *special, primary, secondary* fabrication categories, respectively. The user specified *fabtol* is only valid for the *Manual* option. The parameter δ_m in the SCF formula Eqn(3.3.5) will be determined either by *Manual* **fabtol** or by one of ****ts*. The global FABRICATION-TOLERANCE-OPTION and BUTTWELD-CONE-SCF-FORMULA can be overridden by the local SCF assignment at every fatigue check position (see command ASSIGN SCF Member).

For **DNVGL RP C203:2020** code [45], similarly, the variable represents *fabtolfactor* which is only effective when the *Manual* option is selected at DEFAULT-FABRICATION-TOLERANCE. Note that *fabtolfactor* is unitless and is to multiply with the smaller thickness ts to obtain the parameter δ_m in the SCF formula Eqn(3.3.5), i.e. $\delta_m = fabtolfactor \times ts$. By contrast, when the buttweld SCF formula is chosen as DNVGL RP-C203-2014, $\delta_m = fabtol$ where fabtol is the local override of the length of fabrication tolerance. And, for DNVGL RP-C203-2020, the inherent misalignment in SN curve δ_0 is determined by INHERENT-SN-MISALIGNMENT-FACTOR $\delta_0 = SNmisFac \times ts$.

The option **DNV-RPC203-BSWD** is implemented based on DNV RP-C203:2021 [100] and shares the same parameters as **DNVGL-RPC203-2020** option except that the BSWD option assumes the buttweld is made on bothsides and does not generate the weld root position at buttwelds. By contrast, **DNVGL-RPC203-2020** allows to generates weld root if the weld root option is ON. The BSWD option calculates the maximum SCF at the buttweld according to DNV RP-C203:2021.

An new option of **DEFAULT BUTTWELD-SN-CURVE** is introduced in Framework v4.3. The welding condition at butt weld connections is different from that at the tubular joint. The SN curve varies too. Accordingly, the one in **DEFAULT SN-CURVE** becomes the general global option assigned to the pre-defined fatigue check positions at joints or user defined positions. The new BUTTWELD-SN-CURVE will be specifically applied to the program generated buttweld fatigue positions. To be effective, both default SN curves must be selected prior to the FILE OPEN and FILE TRANSFER commands. For a well defined model, the default SN curves will be assigned automatically to the corresponding fatigue positions (both joints and buttweld transitions). User don't have to ASSIGN SN Curves unless it is necessary.

EXAMPLES:

```
DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE API-WJ
DEFINE FATIGUE-CONSTANTS MARSHALL-REDUCTION 0.8
DEFINE FATIGUE-CONSTANTS SHORT-CHORD-FIXITY-PARAMETER 1.0
DEFINE FATIGUE-CONSTANTS SHORT-CHORD-FIXITY-OPTION GLOBAL
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
DEFINE FATIGUE-CONSTANTS FATIGUE-EXPOSURE-TIME -1.0
```

```
DEFINE FATIGUE-CONSTANTS DEFAULT-FATIGUE-SAFETY-FACTOR 1.0
DEFINE FATIGUE-CONSTANTS GLOBAL-FATIGUE-PART-DAMAGE 0.0
DEFINE FATIGUE-CONSTANTS FABRICATION-TOLERANCE-OPTION 0.15TS
DEFINE FATIGUE-CONSTANTS DEFAULT-FABRICATION-TOLERANCE 0.03
DEFINE FATIGUE-CONSTANTS INHERENT-SN-MISALIGNMENT-FACTOR 0.05
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2020
DEFINE FATIGUE-CONSTANTS DEFAULT-BUTTWELD-SN-CURVE DNV2010_D
DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-UPPER-LIMIT-ELEVATION 0.0
DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-LOWER-LIMIT-ELEVATION 0.0
DEFINE FATIGUE-CONSTANTS ACCUMULATE-FATIGUE-RUN NONE
DEFINE FATIGUE-CONSTANTS AXIAL-MINIMUM-SCF 0.5
DEFINE FATIGUE-CONSTANTS IN-PLANE-MINIMUM-SCF 0.5
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-MINIMUM 0.5
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-MIN-SCF 0.5
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 1.333
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 1.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-FACTOR 0.7071
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-FACTOR 0.7071
FILE OPEN SIN-DIRECT-ACCESS '' Joint_R1
FILE TRANSFER 1 JACKET LOADS None
TASK FATIGUE-CHECK
SELECT FATIGUE-CHECK-TYPE DIRECT-DETERMINISTIC
```

DEFINE FATIGUE-DAMAGE-TO-FILE

. . .	FATIGUE-DAMAGE-TO-FILE	ON	file prefix	filename	SIF-FORMATTED
					SIN-DIRECT-ACCESS
					SIU-UNFORMATTED
			PART-DAMAGE	filename	
		OFF			

PURPOSE:
To switch ON/OFF for printing of fatigue damage results to file.

PARAMETERS:

OFF	Fatigue check results are not saved (Default).
ON	Fatigue check results are saved.
fileprefix	Prefix of file name.
filename	Name of file.
SIF-FORMATTED	A formatted file with extension .SIF is formed.
SIN-DIRECT-ACCESS	A direct access binary file with extension .SIN is formed (Default).
SIU-UNFORMATTED	An unformatted file with extension .SIU is formed.
	The filename and format above are only available for time history fatigue analysis.

PART-DAMAGE	With this option, a fatigue part damage file is saved.
filename	The filenname will have only one type of extension, *.FPD*, and does not have prefix.
	This above option is available for Deterministic, Direct Deterministic, Spectral and Stochastic fatigue analysis types.

NOTES:
The command must be issued before the fatigue run.

Until Framework v3.13, the command is applicable for time history fatigue analysis only. From version 3.14, the feature to output fatigue damage to file is available for Deterministic, Direct Deterministic, Spectral and Stochastic fatigue analysis types.

- Time History fatigue: Default values of fileprefix and filename are automatically established according to the name of Result Interface File read by Framework. The default name *frameF1.SIN* is adopted when the Result Interface File name is *frameR1.SIN*, i.e fileprefix is *frame*, filename is F1 and file extension is *.SIN*. The fatigue results are identified by the RVFATDAM and TDFATDAM records. The option with “Sesam Format” file is the exiting option for Time History fatigue. Do not use it for the other fatigue types. If this option happens to be used for the other fatigue analysis, no damage file will be generated. A warning message will be printed.
- Deterministic, Direct Deterministic, Spectral and Stochastic fatigue: Use **ON** followed by **PART-DAMAGE**. The program will output a part damage file with extension *.FPD*. The file does not have prefix and is stored at the default Framework workspace folder. User can specify the filename. The extension *.FPD* will automatically append on the filename’s text. If the place of "filename" is empty, e.g. `...ON PART-DAMAGE ' '`, the program will use Damage_*runname.FPD* as the default name. When a damage file with duplicated filename exists, the old file will be rename to a standard *.bak* file. The fatigue damages of the members included in the current fatigue run are saved for all the fatigue positions. The damage file can be imported either in the same Framework program session or in another

different session. Similarly, the *.FPD* type damage file cannot be used in a Time History fatigue analysis.

See also:

`ASSIGN FATIGUE-PART-DAMAGE READ-FILE ...`

EXAMPLES:

```
DEFINE FATIGUE-DAMAGE-TO-FILE ON frame F1 SIN-DIRECT-ACCESS
DEFINE FATIGUE-DAMAGE-TO-FILE ON PART-DAMAGE ' '
DEFINE FATIGUE-DAMAGE-TO-FILE ON PART-DAMAGE 'Jacket_top'
```

DEFINE FATIGUE-DUMP

. . .	FATIGUE-DUMP	FILE-NAME	name	
		Available when deterministic:		
		HOTSPOT-STRESS-RANGE	status	
		DAMAGE-PER-DIRECTION	status	
		DAMAGE-PER-HOTSPOT	status	
		STRESS-RANGE-DISTRIBUTION	status	
		Available when stochastic and spectral:		
		HOTSPOT-STRESS-TRANSFER-FUNCTION	status	
		MEMBER-NOMINAL-LOADS	status	
		MOMENTS-OF-RESPONSE-SPECTRUM	status	
		DAMAGE-PER-SEASTATE	status	
		DAMAGE-PER-DIRECTION	status	
		DAMAGE-PER-HOTSPOT	status	
		EXCEEDENCE-PROBABILITY	status	nlev
		STRESS-RANGE-DISTRIBUTION	status	nlev
		Available when time history:		
		TIME-FATIGUE-DAMAGE	status	
		FATIGUE-STRESS-TIME-SERIES	OFF	
			WORST-HOTSPOT	
			ALL-HOTSPOTS	
		TIME-SERIES-STRESS-RANGES	OFF	
			SORTED	
			UNSORTED	
		INFLUENCE-FUNCTION-SCFS	status	

PURPOSE:
To define if and which intermediate results from fatigue damage calculations that shall be written to separate file.

PARAMETERS:

FILE-NAME	Define dump file name.
name	The file name to be used. Default file name is FRAMEWORK.
HOTSPOT-STRESS-RANGE	Print of hot spot stress range.
DAMAGE-PER-DIRECTION	Print of damage per wave direction.
DAMAGE-PER-HOTSPOT	Print of damage per hotspot checked.
STRESS-RANGE-DISTRIBUTION	Print of stress range distributions.
HOTSPOT-STRESS-TRANSFER-FUNCTION	Print the hot spot stress transfer functions.
MEMBER-NOMINAL-LOADS	Print the axial forces and bending moments at member's end, which is used to calculate hotspot stresses. The bending moments have been transformed from member local moments to an in-plane and out of plane coordinate system. This command is for spectral fatigue only.

MOMENTS-OF-RESPONSE-SPECTRUM	Print the moments of response spectrum.
DAMAGE-PER-SEASTATE	Print damage per sea state.
EXCEEDENCE-PROBABILITY	Print the probability of exceedence of hot spot stress levels.
TIME-FATIGUE-DAMAGE	Print time fatigue damage results per hotspots checked.
FATIGUE-STRESS-TIME-SERIES	Print time series of hotspot fatigue stresses. Options OFF, WORST-HOTSPOT (worst damaged hotspot of each member position) or ALL-HOTSPOTS of members checked.
TIME-SERIES-STRESS-RANGES	Print stress ranges of executed time series. Options OFF, SORTED (in decreasing order) or UNSORTED.
INFLUENCE-FUNCTION-SCFS	Print influence function SCFs for model A and B to file InfluenceFunctionSCFs_<RunName>.dmp Print intermediate results of influence SCFs for model C that is the regular EFTHYMIOU SCF to a file named EFTHYSCFs_<RunName>.dmp.
status	Print status, ON / OFF.
nlev	Number of levels for which the probability of exceedence / stress ranges is calculated.

NOTES:
For intermediate fatigue results the dump file extension is DMP. For exceedence probabilities the extension is PEX. However, when dump alternative STRESS-RANGE-DISTRIBUTION is active, both DMP and PEX are used. The PEX contain dump data for all active hotspots, while the DMP file contain dump data for worst hotspot only. Since v3.13, another dump file with extension WLY will be generated when turning on MOMENTS-OF-RESPONSE-SPECTRUM dump. This report outputs the RMS of response stress range and cycles number for every seastate. The report is in the sequence of all positions of a member and re-organizes the format of brace-chord side positions if the position is at a tubular joint.

'nlev' is the user-defined number of levels for which the probability of exceedence / stress ranges is calculated. Maximum number of levels is 200. Default is 11. 'nlev' shall only be given if status is ON.

When dumping STRESS-RANGE-DISTRIBUTION, the distribution representing waves from all directions (omnidirectional) has wave direction 999.000. Due to large amount of dump data, it is strongly recommended not to activate EXCEEDENCE-PROBABILITY and STRESS-RANGE-DISTRIBUTION in one run.

The probability of exceedence is printed for user-defined number of stress levels for selected members during spectral fatigue analysis. The probability of exceedence is calculated for each sea state and for each wave direction.

The probability of exceedence is weighed with the number of cycles in each sea state for each direction divided with the total number of cycles. The stress levels for which probability of exceedence is printed, are calculated for 'nlev' equal stress level intervals between Sx and zero. Sx is the stress range expected to be exceeded once in n-years.

Dump files for time history fatigue results are named according to the name of the Result Interface File read by Framework. The file names frameD1.DMP and frameD1.TMS are applied for the fatigue damage results and time histories of the fatigue stresses, respectively, when the Result Interface File name is frameR1.SIN.

When print of 'Time Series Stress Ranges' is turned on, the print is combined with current print option of the 'Fatigue Stress Time Series'. When stress ranges are printed and the 'Fatigue Stress Time Series' option is turned off, stress ranges are printed for all hotspots.

Print of influence function SCFs may be performed for deterministic fatigue, stochastic fatigue, spectral fatigue and time domain fatigue. Detail print of all contributions to the total SCFs from the reference brace and inplane and multiplanar influence braces are printed for all load cases and for all brace end positions in

current print selection. For more details see Appendix B.7.1. Note that this command may easily generate very big dump files and should be used with care for a limited number of members.

A new dump print of RMS of hot spot stresses and the associated cycles is available for spectral and stochastic fatigue analysis; The stress RMS and cycles of all hotspots will be printed in a row. Each row corresponds to one sea state in the scatter diagram. A sample of print is as below.

```
Member  M7      (     JT2-JT1     )
Position  0.000
Joint  JT2
Chord  M41
Align  M35
SEA  DIR   Pct       STRMS_BRC_ 1    Cyc_BRC_ 1  STRMS_BRC_ 4    Cyc_BRC_ 4  ...
1    1   0.68139   0.334203E+07   0.126257E+07  0.766540E+07   0.145637E+07 ...
2    1   0.01791   0.631322E+07   0.344703E+05  0.147155E+08   0.383999E+05 ...
3    1   3.45539   0.390151E+07   0.534078E+07  0.734307E+07   0.619516E+07 ...
4    1   1.41984   0.733015E+07   0.215906E+07  0.134755E+08   0.246995E+07 ...
5    1   0.01128   0.106926E+08   0.170361E+05  0.193875E+08   0.192707E+05 ...
6    1   4.11489   0.384496E+07   0.581064E+07  0.702599E+07   0.669067E+07...
```

The dump print is active if the following 3 dump prints:

```
DEFINE FATIGUE-DUMP HOTSPOT-STRESS-TRANSFER-FUNCTION ON
DEFINE FATIGUE-DUMP MOMENTS-OF-RESPONSE-SPECTRUM ON
DEFINE FATIGUE-DUMP DAMAGE-PER-SEASTATE ON
```

The file is named RMSTZ_<RunName>.dmp.

A dump print file to show load path dependent SCF for spectral fatigue analysis is introduced. The file is named LPDSCF_<runname>.dmp. To activate it, turn on dump for member nominal load, HSSR transfer function, and influence function.

```
DEFINE FATIGUE-DUMP HOTSPOT-STRESS-TRANSFER-FUNCTION ON
DEFINE FATIGUE-DUMP MEMBER-NOMINAL-LOADS ON
DEFINE FATIGUE-DUMP INFLUENCE-FUNCTION-SCFS ON
```

Direct Deterministic Fatigue shares the same dump file option with regular Deterministic Fatigue. Only the command for HOTSPOT-STRESS-RANGE is needed.

EXAMPLES:

```
DEFINE FATIGUE-DUMP FILE-NAME RUN_ONE
DEFINE FATIGUE-DUMP FILE-NAME RUN_TIME
DEFINE FATIGUE-DUMP TIME-FATIGUE-DAMAGE ON
DEFINE FATIGUE-DUMP FATIGUE-STRESS-TIME-SERIES WORST-HOTSPOT
DEFINE FATIGUE-DUMP INFLUENCE-FUNCTION-SCFS ON
```

DEFINE FATIGUE-PARAMETERS INCLUDE-CHORD-STRESS

...	FATIGUE-PARAMETERS	INCLUDE-CHORD-STRESS	OFF	
			ON	SCF_{att}

PURPOSE:
Option to include chord axial stress in fatigue check of tubular joints. The stochastic fatigue analysis is excluded. `DEFINE NEAR-CHORD-RULE` must be turned ON.

PARAMETERS:

OFF	Do not include chord axial stress (Default program setting.)
ON	Add chord axial stress to chord side crown hotspots.
SCF_{att}	stress concentration factor for an attachment

NOTES:
The hot spot stress in the chord at the crown hotspots due to dynamic axial force in the chord are considered in addition to the hot spot stress range due to brace actions. The chord axial nominal stress multiplied with SCF_{att} is additionally added to the hotspot stress at the position of `CHORD-SIDE` and `CHORD-ROOT`. The sign chord nominal stress is kept. The stress range at the hotspot is the combined result of the brace action and chord action in one cycle. The inclusion of chord axial stress action is valid for time domain analysis only, such as direct deterministic fatigue, deterministic fatigue, spectral fatigue, and time history fatigue. If the crowns on chord locate on both the chord member and aligned chord member, the applied chord axial stresses on two crowns can be different. The crown at the side of chord member is hotspot 19 and the crown at the side of aligned chord member is hotspot 7.

SCF_{att} is the stress concentration factor for an attachement. As recommended in DNVGL RP C203, it can equal 1.20 by default. Notice that this factor does not affect the parameter scf_att in command ASSIGN SCF JOINT PARAMETRIC LOTSBERG. The SCF option LOTSBERG considers the chord bending stress. The SCF with the current command is the one for chord axial stress.

EXAMPLES:

```
DEFINE FATIGUE-PARAMETERS INCLUDE-CHORD-STRESS ON 1.20
```

DEFINE FATIGUE-PARAMETERS SN-CURVE-THICKNESS-EFFECT

. . .	FATIGUE-PARAMETERS	SN-CURVE-THICKNESS-EFFECT	DEFAULT
			OPTIONAL

PURPOSE:
Define SN curve thickness effects in joints

PARAMETERS:

SN-CURVE-THICKNESS-EFFECT	Define how to calculate the SN curve thickness effect for the chord side of a weld in a tubular joint connection. This global switch allow the fatigue calculations to use the brace thickness as the reference thickness when calculating the thickness effect correction at the chord side of the weld.
DEFAULT	Use the brace wall thickness for brace side of weld and chord wall thickness for chord side of weld. (Default program setting.)
OPTIONAL	Use brace wall thickness at both sides of the weld.

NOTES:
The option SN-CURVE-THICKNESS-EFFECT is effective for all latest API RP2A, ISO 19902, DNVGL RP-C203 SN curves that consider the thickness correction.

EXAMPLES:

```
DEFINE FATIGUE-PARAMETERS SN-CURVE-THICKNESS-EFFECT OPTIONAL
```

DEFINE FATIGUE-RAINFLOW-COUNTING

. . .	FATIGUE-RAINFLOW-COUNTING	OFF			
		ON	timstp	stpexp	seed

PURPOSE:
To switch between:

a. Damage calculations based on closed form solution from spectral moments assuming Rayleigh distribution. This is the default option.

b. Damage calculations based on generation of stress time series by FFT (Fast Fourier Transform) from stress autospectrum, i.e. rainflow cycle counting in time domain [71].

PARAMETERS:

OFF	Switch off Rainflow counting (default).
ON	switch on Rainflow counting method.
timstp	Time step (default = 0.2 sec).
stpexp	Time steps exponent in generating stress time series (default = 14, i.e. 214 steps).
seed	Seed for generation of random phase angles (default = 123456).

NOTES:
This option is relevant for stochastic fatigue damage analysis only.

EXAMPLES:

```
DEFINE FATIGUE-RAINFLOW-COUNTING ON 0.2 14 123456
```

DEFINE FATIGUE-SAFETY-FACTOR

...	FATIGUE-SAFETY-FACTOR	ON
		OFF

PURPOSE:

To define if fatigue safety factors shall be taken into account in time history fatigue damage calculation.

PARAMETERS:

ON	Fatigue safety factors are applied.
OFF	Turn off this feature. (Default)

NOTES:

This command is applicable for time history fatigue analysis only.

Fatigue safety factors are assigned by command ASSIGN FATIGUE-SAFETY-FACTORS.

EXAMPLES:

```
DEFINE FATIGUE-SAFETY-FACTOR ON
```

DEFINE FATIGUE-STRESS-TIME-SERIES-ON-FILE

...	FATIGUE-STRESS-TIME -SERIES-ON-FILE	OFF					
		ON	filpre	filnam	TXT	...	READ
					CSV		WRITE

PURPOSE:

To define writing and reading fatigue stress time series to and from file. The command is valid only for time history fatigue calculations.

PARAMETERS:

OFF	Switch off fatigue stress time series on file (default).
ON	Switch on stress time series on file.
filpre	File prefix
filnam	File name.
TXT	File extension .TXT for ascci text file format.
CSV	File extension .CSV for spreadsheet file format. Note that all decimals of real numbers must be replaced by commas when operating on the time series in the spreadsheet.

NOTES:

Stresses of time series read from file will supersede the fatigue stresses calculated from forces and moments of the SIN file. Stresses written to the file are stresses applied in the fatigue calculation including scf factors but not fatigue safety factor.

File data format:

For each wave direction there is one stress time series for each hotspot and for each position and for each element. Each time series are preceeded with 3 mandatory lines:

Line 1: Header text of 16 parameters:

```
 MemName    nMem    nPos    nHot    nDir    nSea  nStep    iMem    iPos    iHot
    iDir    iSea      TimeStart  TimeDuration       TimeStep        WaveDir
```

Line 2: Values of the above 16 parameters:

```
BM13          84       6       8       1       0     501       1       1       1
       1       0   0.00000E+00   2.00000E+01   4.00000E-02   3.15000E+02
```

Line 3: Header of stress time series:

```
         Time         Stress
```

Line 4 and all continuous lines until end of time series: Time series values:

```
 0.00000E+00  -1.72415E+06
 4.00000E-02  -1.84796E+06
 8.00000E-02  -1.97411E+06
 1.20000E-01  -2.10333E+06
   .....
   .....
```

Parameter description:

Name	Description	Type
MemName	Name of member	Character
nMem	Total number of members of current run	Integer
nPos	Number of positions of current member	Integer
nHot	Number of hotspots of each position	Integer
nDir	Number of directions	Integer
nSea	Number of sea states (= 0 if not relevant)	Integer

nStep	Number of time steps of time series	Integer
iMem	Current member	Integer
iPos	Current position	Integer
iHot	Current hotspot	Integer
iDir	Current direction	Integer
iSea	Current sea state (= 0 if not relevant)	Integer
TimeStart	Start time of time series	Real
TimeDuration	Duration of time series	Real
TimeStep	Size of time step	Real
WaveDir	Wave direction - in degrees	Real
Time	Instant of time	Real
Stress	Stress value at instant of time	Real

EXAMPLES:

```
DEFINE FATIGUE-STRESS-TIME-SERIES-ON-FILE ON Framework FST TXT WRITE
DEFINE FATIGUE-STRESS-TIME-SERIES-ON-FILE ON Framework FST TXT READ
DEFINE FATIGUE-STRESS-TIME-SERIES-ON-FILE ON Framework FST CSV WRITE
DEFINE FATIGUE-STRESS-TIME-SERIES-ON-FILE ON Framework FST CSV READ
```

DEFINE GEOMETRY-VALIDITY-RANGE

...	GEOMETRY-VALIDITY-RANGE	ON
		OFF

PURPOSE:

To define how to handle usage factors due to exceedance of geometric validity ranges.

The default way is to present the usage factor based on actual geometry, but indicate in the outcome column on the print that geometric values are outside the validity range given in the standard.

When switched ON, a unity check normally larger than 990.0 (the value is defined dependant of which geometric limitation that has been exceeded) is stored as the governing unity check.

This switch is also used to set the 'G-fail' usage factor as governing utilization when running punching shear check according to API code of practice. The 'G-fail' usage factor is the geometry check according to to API-WSD equation 4.1-1 / API-LRFD equation E.3-1.

PARAMETERS:

ON	Turn this feature on.
OFF	Turn off this feature. (Default behaviour.)

NOTES:

When switched ON, print maximum unity check does not give a proper sorting of the results.

EXAMPLES:

```
DEFINE GEOMETRY-VALIDITY-RANGE ON
```

DEFINE HOTSPOTS

...	HOTSPOTS	EXTREME-LOCATION	ON
			OFF

PURPOSE:

To select how to define positions of hotspots. This option switch is used to select if hotspots shall be defined in the extreme fibre of the section or in centre of flange / web thickness.

PARAMETERS:

ON	Hotspots in extreme fibre.
OFF	Hotspots in centre of flange / web thickness. (Default behaviour.)

NOTES:

The effect of this option is implemented for BOX sections only.

This switch must be set prior to establishing the Framework database (i.e. prior to FILE OPEN + TRANSFER) with respect to how to define hotspots for cross sections read from the results interface file.

It may be switched on and off when creating new cross sections inside Framework.

The X and Y hotspot coordinates are printed by use of the command:

```
PRINT SECTION HOTSPOTS
```

EXAMPLES:

```
DEFINE HOTSPOTS EXTREME-LOCATION ON
```

DEFINE HYDROSTATIC-DATA

...	HYDROSTATIC-DATA	GRAVITY	subcom-mands	data
		WATER-DEPTH		
		WATER-DENSITY		
		WAVE-HEIGHT		
		WAVE-LENGTH		
		WATER-PLANE		
		ACTION-FACTOR-OPERATING		
		ACTION-FACTOR-STORM		

PURPOSE:

To define data necessary for a hydrostatic collapse check.

PARAMETERS:

GRAVITY	Define acceleration due to gravity.
WATER-DEPTH	Define water depth.
WATER-DENSITY	Define sea-water density.
WAVE-HEIGHT	Define wave height.
WAVE-LENGTH	Define wave length.
WATER-PLANE	Define orientation of water plane.
ACTION-FACTOR-OPERATING	Define action factor applied to external hydrostatic pressure for operating load condition.
ACTION-FACTOR-STORM	Define action factor applied to external hydrostatic pressure for storm load condition.

All data are fully explained subsequently as each command is described in detail.

DEFINE HYDROSTATIC-DATA GRAVITY

...	GRAVITY	g

PURPOSE:

To define the acceleration due to gravity.

PARAMETERS:

g Acceleration due to gravity.

NOTES:

Default value is 9.81 m/s^2.

To be upward compatible with future versions of the program it is recommended to use the DEFINE CONSTANTS GRAVITY... command.

See also:

`PRINT HYDROSTATIC-DATA`

EXAMPLES:

```
DEFINE HYDROSTATIC-DATA GRAVITY 32.0
```

DEFINE HYDROSTATIC-DATA WATER-DEPTH

...	WATER-DEPTH	depth

PURPOSE:

To define the water depth.

PARAMETERS:

depth Water depth.

NOTES:

Default value is 0.

See also:
`PRINT HYDROSTATIC-DATA`

EXAMPLES:

```
DEFINE HYDROSTATIC-DATA WATER-DEPTH 100.0
```

DEFINE HYDROSTATIC-DATA WATER-DENSITY

...	WATER-DENSITY	rho

PURPOSE:

To define the water density.

PARAMETERS:

rho Water density.

NOTES:

Default value is 1025 Kg/m^3.

See also:
`PRINT HYDROSTATIC-DATA`

EXAMPLES:

```
DEFINE HYDROSTATIC-DATA WATER-DENSITY 1025E-9
```

DEFINE HYDROSTATIC-DATA WAVE-HEIGHT

...	WAVE-HEIGHT	wave-height

PURPOSE:

To define the wave height. If this is defined, the hydrostatic pressure shall include corrections due to the wave elevation.

PARAMETERS:

wave-height Wave height.

NOTES:

Default value is 0.

See also:

`PRINT HYDROSTATIC-DATA`

EXAMPLES:

```
DEFINE HYDROSTATIC-DATA WAVE-HEIGHT 15.5
```

DEFINE HYDROSTATIC-DATA WAVE-LENGTH

...	WAVE-LENGTH	wave-length

PURPOSE:

To define the wave length. If this is defined, the hydrostatic pressure shall include corrections due to the wave elevation.

PARAMETERS:

wave-length Wave length.

NOTES:

Default value is 0.

See also:

`PRINT HYDROSTATIC-DATA`

EXAMPLES:

```
DEFINE HYDROSTATIC-DATA WAVE-LENGTH 400
```

DEFINE HYDROSTATIC-DATA WATER-PLANE

...	WATER-PLANE	X-AXIS	coord			UP					
		Y-AXIS				DOWN					
		Z-AXIS									
		ARBIDTRARY	x1	y1	z1	x2	y2	z2	x3	y3	z3
		NONE									

PURPOSE:

To define the orientation of the water plane.

PARAMETERS:

X-AXIS	The superelement X-axis is normal to the water plane.
Y-AXIS	The superelement Y-axis is normal to the water plane.
Z-AXIS	The superelement Z-axis is normal to the water plane.
ARBITRARY	the water plane is arbitrarily oriented.
NONE	The water plane shall not be defined.
coord	Coordinate of the superelement axis (normal to the water plane) intersecting with the water plane.
UP	The axis normal to the water plane is pointing upwards (towards the blue sky).
DOWN	The axis normal to the water plane is pointing downwards (towards the rocky sea-bed).
x1 through z3	Coordinates (with respect to global axis system) of 3 points defining the water plane. The normal to the water plane (pointing up) is computed as the cross product between vectors 1_3 and 2_3.

NOTES:

Default water plane orientation is NONE.

See also:

`PRINT HYDROSTATIC-DATA`

EXAMPLES:

```
DEFINE HYDROSTATIC-DATA WATER-PLANE Z-AXIS 100 UP
```

DEFINE HYDROSTATIC-DATA ACTION-FACTOR-OPERATING

...	ACTION-FACTOR-OPERATING	afac

PURPOSE:

To define the action factor applied to external hydrostatic pressure in operating load condition for use in NORSOK N-004 member check and check of conical transitions.

PARAMETERS:

afac Action factor. Default value is 1.0

NOTES:

The action factor is multiplied by the water pressure.

See also:

`PRINT HYDROSTATIC-DATA`

EXAMPLES:

```
DEFINE HYDROSTATIC-DATA ACTION-FACTOR-OPERATING 2.0
```

DEFINE HYDROSTATIC-DATA ACTION-FACTOR-STORM

...	ACTION-FACTOR-STORM	afac

PURPOSE:

To define the action factor applied to external hydrostatic pressure in storm loading condition for use in NORSOK N-004 member check and check of conical transitions.

PARAMETERS:

afac Action factor. Default value is 1.0

NOTES:

The action factor is multiplied by the water pressure.

See also:

`PRINT HYDROSTATIC-DATA`

EXAMPLES:

```
DEFINE HYDROSTATIC-DATA ACTION-FACTOR-STORM 2.0
```

DEFINE ISO

. . .	ISO	Member check:	
		AXIAL-TENSILE-STRENGTH-FACTOR	SFax-ten
		AXIAL-COMPRESSIVE-STRENGTH-FACTOR	SFax-com
		BENDING-STRENGTH-FACTOR	SFbend
		SHEAR_TORSION-STRENGTH-FACTOR	SFshear-tors
		HOOP-BUCKLING-STRENGTH-FACTOR	SFhoop-buck
		USE-LOCAL-BENDING-MOMENT	OFF (default)
			ON
		Joint check:	
		JOINT-RESISTANCE-FACTOR	RFjoint
		JOINT-YIELD-STRENGTH-FACTOR	SFjoint-yield
		JOINT-BRACE-MEMBER-FACTOR	BMFjoint
		JOINT-AXIAL-Y-C1	C1Yjoint-ax
		JOINT-AXIAL-X-C1	C1Xjoint-ax
		JOINT-AXIAL-K-C1	C1Kjoint-ax
		JOINT-BRACE-MOMENT-C1	C1joint-bm
		JOINT-AXIAL-Y-C2	C2Yjoint-ax
		JOINT-AXIAL-X-C2	C2Xjoint-ax
		JOINT-AXIAL-K-C2	C2Kjoint-ax
		JOINT-BRACE-MOMENT-C2	C2joint-bm
		JOINT-X-TENSION-QU-FORMULA	ISO (default)
			OMAE
		JOINT-IDENTIFICATION	NON-CRITICAL (default)
			CRITICAL
		BRACE-UTILIZATION-UB	Ub

PURPOSE:
Define ISO 19902 code check parameters.

By this command it is possible to perform check of tubular members, tubular joints and conical transitions according to the ISO 19902 standard, First Edition, 2007-12-01, “Petroleum and natural gas industries - Fixed steel offshore structures", see [33].

PARAMETERS:

AXIAL-TENSILE-STRENGTH-FACTOR	Specify axial tension strength factor.
SFax-ten	Strength factor axial tension. Default = 1.05.
AXIAL-COMPRESSIVE-STRENGTH-FACTOR	Specify axial compression strength factor.
SFax-com	Strength factor axial compression. Default = 1.18.
BENDING-STRENGTH-FACTOR	Specify bending strength factor.
SFbend	Strength factor bending.

	Default = 1.05.
SHEAR_TORSION-STRENGTH-FACTOR	Specify shear torsion strength factor.
SFshear-tors	Strength factor shear torsion.
	Default = 1.05.
HOOP-BUCKLING-STRENGTH-FACTOR	Specify hoop buckling strength factor.
SFhoop-buck	Strength factor hoop buckling.
	Default = 1.25.
USE-LOCAL-BENDING-MOMENTS	OFF/ON option for using local bending moments.
OFF	Maximum moments along the members and not local bending moments are used (default).
ON	Actual/local bending moments are used at every code check position in stability check.
JOINT-RESISTANCE-FACTOR	Specify joint resistance factor.
RFjoint	Joint resistance factor.
	Default = 1.05.
JOINT-YIELD-STRENGTH-FACTOR	Specify joint yield strength factor.
SFjoint-yield	Strength factor to joint yield.
	Default = 1.05.
JOINT-BRACE-MEMBER-FACTOR	Specify joint brace member resistance factor.
BMFjoint	Resistance factor to joint brace member.
	Default = 1.17.
JOINT-AXIAL-Y-C1	Specify C1 coefficient axial Y-joint.
C1Yjoint-ax	C1 coefficient of axial Y-joint.
	Default = 25.0
JOINT-AXIAL-X-C1	Specify C1 coefficient axial X-joint.
C1Xjoint-ax	C1 coefficient of axial X-joint.
	Default = 20.0
JOINT-AXIAL-K-C1	Specify C1 coefficient axial YK-joint.
C1Kjoint-ax	C1 coefficient of axial K-joint.
	Default = 14.0
JOINT-BRACE-MOMENT-C1	Specify C1 coefficient joint brace moment.
C1joint-bm	C1 coefficient of joint brace moment.
	Default = 25.0
JOINT-AXIAL-Y-C2	Specify C2 coefficient axial Y-joint.
C2Yjoint-ax	C2 coefficient of axial Y-joint.
	Default = 11.0
JOINT-AXIAL-X-C2	Specify C2 coefficient axial X-joint.
C2Xjoint-ax	C2 coefficient of axial X-joint.
	Default = 22.0
JOINT-AXIAL-K-C2	Specify C2 coefficient axial YK-joint.
C2Kjoint-ax	C2 coefficient of axial K-joint.
	Default = 43.0
JOINT-BRACE-MOMENT-C2	Specify C2 coefficient joint brace moment.
C2joint-bm	C2 coefficient of joint brace moment.
	Default = 43.0
JOINT-X-TENSION-QU-FORMULA	Specify formula to be used for the Qu factor in connection with X-joints with braces in tension.
ISO	Use Qu formula in ISO standard (default).
OMAE	Use Qu of formula (8) given in paper OMAE2008-57650, i.e. $Qu = 6.4 \cdot \gamma^{0.6 \cdot \beta^2}$.
JOINT-IDENTIFICATION	Joint identification of critical/non-critical joints for capacity checks. Critical and non-critical joints must be handled in separate runs.
NON-CRITICAL	Non-critical joints (default).

CRITICAL	Critical joints. Enter brace member usage factor by the parameter BRACE-UTILIZATION-UB.
BRACE-UTILIZATION-UB	Specify brace utilization factor.
Ub	Brace utilization factor Ub. Default = 1.0

NOTES:
Use the command SELECT CODE-OF-PRACTICE ISO19902 to activate the present code check.

Member check:

i: New options with respect to moment reduction factor according to table13.5-1 in the standard are given by the command

```
ASSIGN STABILITY <sel-mem> MOMENT-REDUCTION-FACTOR <option>
```

where options are: ISO-1, ISO-2, ISO-3, and ISO-2-3

corresponding to Cm: 1), 2), 3), and 2) or 3)

The alternative by manually define the Cm factors may also be used.

ii: Option regarding use of commentary part “A.13.2.3.2. Column buckling" is defined by the command (common for NORSOK and ISO).

```
ASSIGN STABILITY <sel-mem> NORSOK_ISO-AXIAL-COMPRESSION <option>
```

where options are `INCLUDE-COMMENTARY` (default) or `EXCLUDE-COMMENTARY`.

The default option is to include the approach according to equations (A.13.2-1) and (A.13.2-2).

Also note that it is possible to use the member buckling length option `AUTOMATIC` (and `LATERAL-SUPPORT-AUTO`) to automatically calculate buckling lengths. See command

```
ASSIGN STABILITY <sel-mem> BUCKLING-LENGTH.
```

iii: The capped-end forces due to hydrostatic pressure are as default assumed to be included in the forces from factored actions. (Assume wave load and buoyancy calculated by use of Wajac). If this is not the case, use the command:

```
DEFINE MEMBER-CHECK-PARAMETERS CALCULATION-METHOD A
```

The two methods/options are B (default, i.e. capped-end forces included) and A. This command was introduced in connection with implementation of NORSOK N-004 code check.

iv: The partial action factor (gamma_f,G1) used when calculating the factored hydrostatic pressure is defined by use of the “old" command

```
ASSIGN LOAD-CASE <sel-loadcase> CONDITION <option>
```

where options are:

-OPERATING (default)	–>	gamma_f, G1 = 1.3
-STORM	–>	gamma_f, G1 = 1.1
-EARTHQUAKE	–>	gamma_f, G1 = 1.1
-YIELD-FACTOR + value	–>	manually define action factor

Joint check:

Note that in current version of Framework it is neither possible to give individual utilization factors (Ub) for each brace nor possible to automatically read Ub from a member check run.

Conical check:

i: One additional option (`CONE-LENGTH`) is added with respect to definition of L to be used when calculating the geometric parameter “mu" used in, ref. section 13.2.6.2 “Hoop buckling". When using the `CONE-LENGTH` option the geometric length of the cone is used (i.e. no ring stiffeners inside the cone).

```
ASSIGN STABILITY ( ) STIFFENER-SPACING CONE-LENGTH
```

The default is to use the member length (LENGTH-BETWEEN-JOINTS) and the third option is to manually specify the length to be used.

ii: he capped-end forces due to hydrostatic pressure are as default assumed to be included in the forces from factored actions. (Assume wave load buoyancy calculated by use of Wajac). If this is not the case, use the command

```
DEFINE MEMBER-CHECK-PARAMETERS CALCULATION-METHOD A
```

(The two options are B (default) and A. This command was defined in connection with implementation of NORSOK N-004 code check.)

iii: The partial action factor (gamma_f,G1) used when calculating the factored hydrostatic pressure is defined by use of the “old" command

```
ASSIGN LOAD-CASE <sel-loadcase> CONDITION <option>
```

where options are:

-OPERATING (default)	–>	gamma_f, G1 = 1.3
-STORM	–>	gamma_f, G1 = 1.1
-EARTHQUAKE	–>	gamma_f, G1 = 1.1
-YIELD-FACTOR + value	–>	manually define action factor

EXAMPLES:

```
DEFINE ISO AXIAL-TENSILE-STRENGTH-FACTOR 1.05
DEFINE ISO AXIAL-COMPRESSIVE-STRENGTH-FACTOR 1.18
DEFINE ISO BENDING-STRENGTH-FACTOR 1.05
DEFINE ISO SHEAR_TORSION-STRENGTH-FACTOR 1.05
DEFINE ISO HOOP-BUCKLING-STRENGTH-FACTOR 1.25
DEFINE ISO USE-LOCAL-BENDING-MOMENT OFF
DEFINE ISO JOINT-RESISTANCE-FACTOR 1.05
DEFINE ISO JOINT-YIELD-STRENGTH-FACTOR 1.05
DEFINE ISO JOINT-BRACE-MEMBER-FACTOR 1.17
DEFINE ISO JOINT-AXIAL-Y-C1 25.0
DEFINE ISO JOINT-AXIAL-X-C1 20.0
DEFINE ISO JOINT-AXIAL-K-C1 14.0
DEFINE ISO JOINT-BRACE-MOMENT-C1 25.0
DEFINE ISO JOINT-AXIAL-Y-C2 11.0
DEFINE ISO JOINT-AXIAL-X-C2 22.0
DEFINE ISO JOINT-AXIAL-K-C2 43.0
DEFINE ISO JOINT-BRACE-MOMENT-C2 43.0
DEFINE ISO JOINT-X-TENSION-QU-FORMULA ISO
DEFINE ISO JOINT-IDENTIFICATION NON-CRITICAL
DEFINE ISO BRACE-UTILIZATION-UB 1.0
```

DEFINE JOINT-PARAMETERS

...	JOINT-PARAMETERS	CAN-DIAMETER-FRACTION	data
		MERGE-DIAMETER-FRACTION	
		MINIMUM-FREE-CAN-LENGTH	
		MINIMUM-FREE-STUB-LENGTH	
		MINIMUM-GAP-LENGTH	
		MINIMUM-GAP-RESET	
		STUB-DIAMETER-FRACTION	
		LOADPATH-FORCE-RATIO-LIMIT	
		JOINT-IDENTIFICATION	
		GROUTED-JOINT	

PURPOSE:
To define parameters and options for a tubular joint's punch shear check.

PARAMETERS:

CAN-DIAMETER-FRACTION	Define fraction of can diameter to be used as minimum free can length.
MERGE-DIAMETER-FRACTION	Define fraction of chord / can diameter to be used as maximum search distance when merging joints.
MINIMUM-FREE-CAN-LENGTH	Define length to be used as minimum free can length.
MINIMUM-FREE-STUB-LENGTH	Define length to be used as minimum free stub length.
MINIMUM-GAP-LENGTH	Define a minimum gap length.
MINIMUM-GAP-RESET	Define for which joints this minimum value shall apply.
STUB-DIAMETER-FRACTION	Define fraction of stub diameter to be used as minimum free can length.
LOADPATH-FORCE-RATIO-LIMIT	Define a lower limit of brace axial forces ratio to skip loadpath classification on the target brace.
JOINT-IDENTIFICATION	Turn on/off critical joints check in the next punch shear check.
GROUTED-JOINT	Choose the option of grouted joints in the next punch shear check.

NOTES:
All data are fully explained subsequently as each command is described in detail.

DEFINE JOINT-PARAMETER CAN-DIAMETER-FRACTION

...	CAN-DIAMETER-FRACTION	frac

PURPOSE:

Define the fraction of can diameter to be used as minimum free can length when assigning can section in a tubular joint.

PARAMETERS:

frac Fraction of diameter to be used.

NOTES:

Default value is 0.25.

The can diameter fraction specifies the minimum free length of the can from the (outermost) brace weld toe as a fraction of the can diameter. The default values correspond to the recommended values in API and NORSOK (and NPD).

See also:

`ASSIGN CAN ...`

EXAMPLES:

```
DEFINE JOINT-PARAMETER CAN-DIAMETER-FRACTION 0.3
```

DEFINE JOINT-PARAMETER MERGE-DIAMETER-FRACTION

...	MERGE-DIAMETER-FRACTION	frac

PURPOSE:

Define the fraction of chord / can diameter to be used as maximum search distance along chord and aligned chord when merging joints.

PARAMETERS:

frac Fraction of section diameter to be used.

NOTES:

Default value is 2.0.

See also:

`CREATE JOINT ...`

EXAMPLES:

```
DEFINE JOINT-PARAMETER MERGE-DIAMETER-FRACTION 1.5
```

DEFINE JOINT-PARAMETER MINIMUM-FREE-CAN-LENGTH

...	MINIMUM-FREE-CAN-LENGTH	length

PURPOSE:

Define the length to be used as minimum free can length when assigning can section in a tubular joint.

PARAMETERS:

length Free can length to be used.

NOTES:

Default value is 0.0.

The can length specifies the minimum free length of the can from the (outermost) brace weld toe.

These values must be defined by the user in units consistent with the model length unit.

See also:
`ASSIGN CAN ...`

EXAMPLES:

```
DEFINE JOINT-PARAMETER MINIMUM-FREE-CAN-LENGTH 0.3
```

DEFINE JOINT-PARAMETER MINIMUM-FREE-STUB-LENGTH

...	MINIMUM-FREE-STUB-LENGTH	length

PURPOSE:

Define the length to be used as minimum free stub length when assigning stub section to braces in a tubular joint.

PARAMETERS:

length Free stub length to be used.

NOTES:

Default value is 0.0.

The stub length specifies the minimum free length of the stub from the brace weld toe.

These values must be defined by the user in units consistent with the model length unit.

See also:
`ASSIGN STUB ...`

EXAMPLES:

```
DEFINE JOINT-PARAMETER MINIMUM-FREE-STUB-LENGTH 0.6
```

DEFINE JOINT-PARAMETER MINIMUM-GAP-LENGTH

.. .	MINIMUM-GAP-LENGTH	gap

PURPOSE:

Define the minimum gap to be used when assigning gap between braces in tubular joints.

PARAMETERS:

gap Gap value to be used.

NOTES:

Default value is 0.0.

See also:

```
ASSIGN JOINT-GAP ...
DEFINE JOINT-PARAMETER MINIMUM-GAP-RESET
```

EXAMPLES:

```
DEFINE JOINT-PARAMETER MINIMUM-GAP-LENGTH 0.051
```

DEFINE JOINT-PARAMETER MINIMUM-GAP-RESET

.. .	MINIMUM-GAP-RESET	ALL
		GAP
		NONE

PURPOSE:

Define for which joints the minimum gap value shall apply when using the command ASSIGN JOINT-GAP brace sel-jnt AUTOMATIC.

PARAMETERS:

ALL	Use for all braces, also when actual geometry gives overlap.
GAP	If the calculated gap value is greater than minimum, the calculated value will be used. If the calculated gap is smaller than minimum, but still positive (gap), the gap will be set to the minimum gap. If there is a joint overlap, the overlap data will be used.
NONE	Neglect minimum value.

NOTES:

Default value is NONE.

See also:

```
ASSIGN JOINT-GAP ...
DEFINE JOINT-PARAMETER MINIMUM-GAP-LENGTH
PRINT JOINT PUNCH-CHECK-DATA
```

EXAMPLES:

```
DEFINE JOINT-PARAMETER MINIMUM-GAP-RESET GAP
```

DEFINE JOINT-PARAMETER STUB-DIAMETER-FRACTION

...	STUB-DIAMETER-FRACTION	frac

PURPOSE:

Define the fraction of stub diameter to be used as minimum free stub length when assigning stub section to braces in a tubular joint.

PARAMETERS:

frac Fraction of diameter to be used.

NOTES:

Default value is 1.0.

The stub diameter fraction specifies the minimum free length of the stub from the brace weld toe as a fraction of the stub diameter. The default values correspond to the recommended values in API and NORSOK (and NPD).

See also:

`ASSIGN STUB ...`

EXAMPLES:

```
DEFINE JOINT-PARAMETER STUB-DIAMETER-FRACTION 1.2
```

DEFINE JOINT-PARAMETERS LOADPATH-FORCE-RATIO-LIMIT

...	JOINT-PARAMETERS	LOADPATH-FORCE-RATIO-LIMIT	Rlmt

PURPOSE:
Define the lower limit of the brace axial force ratio for loadpath dependent joint type classification.

PARAMETERS:

Rlmt	limit of the brace axial force ratio. If the brace axial force ratio is less than the limit, the loadpath classification on the target brace will be skipped. Default limit is 0.

NOTES:
The brace axial force ratio of target brace i is defined as

$$R_i = \frac{|P_{a_i}|}{\max_{j=1}^{n} |P_{a_j}|}$$

where P_{a_i} is the axial force on the target brace i, P_{a_j} is the jth brace axial force, j runs through all the n braces in the same chord-brace plane, including target brace i. If $R_i < Rlmt$, the loadpath classification on the target brace will be skipped. The skip of loadpath balance check will not change the joint type at command ASSIGN JOINT TYPE. The joint type in listing report will still show LOADPATH but the percentage of the type according Geometry is set to 100%. The axial force ratio limit usually is a very small fraction, for example 0.001 or 1.E-6. Using scientific format to enter the ratio limit is recommended. The command is effective for both SCF calculation of fatigue analysis and joint punch shear code check.

EXAMPLES:

```
DEFINE JOINT-PARAMETERS LOADPATH-FORCE-RATIO-LIMIT 1.0E-6
```

DEFINE JOINT-PARAMETERS JOINT-IDENTIFICATION

. . .	JOINT-PARAMETERS	JOINT-IDENTIFICATION	NON-Critical
			Critical

PURPOSE:
To define the option for tubular joint's punch shear check. This option is particularly designed for checking joint *100% strength* under earthquake excitation as per API RP2A WSD 2007 edition and after.

PARAMETERS:

Non-critical	If non-critical, which is the DEFAULT, the simple tubular connection check is performed.
Critical	If critical, API *100% strength check* will be made for EARTHQUAKE load combinations.

NOTES:
This option is to activate *100% strength check* under earthquake excitation as per API RP2A WSD 2007 edition and after. The *100% strength check* will be performed if (a) **CRITICAL** joint option is on, and (b) the load case is of **Earthquake** design condition.

The option is global and active for the next code check run. If the joint identification option changes for the joint set in the next code check, this command must be issued before the next `RUN PUNCH-CHECK` command.

EXAMPLES:

```
SELECT CODE-OF-PRACTICE API-AISC-WSD
DEFINE CODE-OF-PRACTICE-VERSION API-RP2A-WSD 2007

DEFINE JOINT-PARAMETERS JOINT-IDENTIFICATION CRITICAL
SELECT JOINTS ONLY SET JTCrit
RUN PUNCH-CHECK PNCH None ( ) ( )
```

DEFINE JOINT-PARAMETERS GROUTED-JOINT

...	JOINT-PARAMETERS	GROUTED-JOINT	NOT-GROUTED	
			FULLY-GROUTED	
			DOUBLE-SKIN	Tp

PURPOSE:
To define the option for grouted tubular joints in punch shear check. This option is for *100% strength check* as per API RP2A WSD 2007 edition and after.

PARAMETERS:

NOT-GROUTED	This is the DEFAULT. The simple tubular connection check is performed.
FULLY-GROUTED	This option defines the joints as fully grouted in API *100% strength check*.
DOUBLE-SKIN	This option defines the joints as double-skin grouted joint in API *100% strength check*.
Tp	Inner pile thickness that is applied in effective thickness calculation

NOTES:
This option is particularly designed for **critical** joint's *100% strength check* under **earthquake** excitation as per API RP2A WSD 2007 edition and after.

The option is a global option and is active for the next code check run. If the grouted joint option changes for the joint set of the next code check, this command must be issued before the next `RUN PUNCH-CHECK` command.

EXAMPLES:

```
SELECT CODE-OF-PRACTICE API-AISC-WSD
DEFINE CODE-OF-PRACTICE-VERSION API-RP2A-WSD 2007
DEFINE JOINT-PARAMETERS JOINT-IDENTIFICATION CRITICAL
SELECT JOINTS ONLY SET JTFulGt
DEFINE JOINT-PARAMETERS GROUTED-JOINT FULLY-GROUTED
RUN PUNCH-CHECK PNFul None ( ) ( )

SELECT JOINTS ONLY SET JTDBGt
DEFINE JOINT-PARAMETERS GROUTED-JOINT DOUBLE-SKIN 0.016
RUN PUNCH-CHECK PNDb None ( ) ( )
```

DEFINE JOINT-TYPE-VALIDATE

...	JOINT-TYPE-VALIDATE	ON
		OFF

PURPOSE:

To switch off (on) activation of joint type validation

PARAMETERS:

ON	Turn this feature on.
OFF	Turn off this feature. (Default behaviour.)

NOTES:

EXAMPLES:

```
DEFINE JOINT-TYPE-VALIDATE ON
```

DEFINE LOAD

...	LOAD	NAMING-CONVENTION	INTERNAL-RESULT-ID
			EXTERNAL-RESULT-ID
			LOAD-CASE-NAME
			RESULT-CASE-NAME

PURPOSE:

To define naming convention to be used when establishing load case names (when reading results file).

PARAMETERS:

INTERNAL-RESULT-ID	Create name from internal (sequential) load number. Default behaviour.
EXTERNAL-RESULT-ID	Create name from external load number, e.g. result combination defined in Prepost.
LOAD-CASE-NAME	Use load case name when available. Defined on result file by use of the TDLOAD card.
RESULT-CASE-NAME	Use result case name when available. Defined on result file by use of the TDRESREF card.

NOTES:

This command option must be set prior to opening and transferring model and results from the result interface file.

See also:

```
FILE OPEN ...
FILE TRANSFER ...
```

EXAMPLES:

```
DEFINE LOAD NAMING-CONVENTION EXTERNAL-RESULT-ID
```

DEFINE LRFD-CODE-CHECK

...	LRFD-CODE-CHECK	YIELD-CHECK-COMPRESSIVE-STRENGTH	CRITICAL
			YIELD
		SECTION-H2	EXCLUDE
			INCLUDE

PURPOSE:

To define options in connection with the AISC-LRFD yield and stability code check.

PARAMETERS:

YIELD-CHECK-COMPRESSIVE-STRENGTH	Select nominal compressive strength to be used in the yield check.
CRITICAL	Use critical stress (according to Section E2).
YIELD	Use yield stress (default option).
SECTION-H2	Select how to handle Section H2. Will have effect for members with box and general profiles only.
EXCLUDE	Exclude Section H2 (default option).
INCLUDE	Include check according to Section H2.

NOTES:

None.

See also:
`PRINT ACTIVE-SETTINGS`

EXAMPLES:

```
DEFINE LRFD-CODE-CHECK YIELD-CHECK-COMPRESSIVE-STRENGTH CRITICAL
```

...	LRFD-RESISTANCE-FACTORS	PIPE-TENSION	value
		PIPE-COMPRESSION	
		PIPE-BENDING	
		PIPE-SHEAR	
		PIPE-HYDROSTATIC	
		NON-PIPE-TENSION	
		NON-PIPE-COMPRESSION	
		NON-PIPE-BENDING	
		NON-PIPE-SHEAR	
		PUNCH-YIELD-STRESS	
		PUNCH-WELD	
		PUNCH-K-TENSION	
		PUNCH-K-COMPRESSION	
		PUNCH-K-IPB	
		PUNCH-K-OPB	
		PUNCH-TY-TENSION	
		PUNCH-TY-COMPRESSION	
		PUNCH-TY-IPB	
		PUNCH-TY-OPB	
		PUNCH-X-TENSION	
		PUNCH-X-COMPRESSION	
		PUNCH-X-IPB	
		PUNCH-X-OPB	

PURPOSE:

To specify / change API / AISC LRFD resistance factors.

PARAMETERS:

PIPE-TENSION
Define the resistance factor for pipe section, axial tension stress. Default value = 0.95.

PIPE-COMPRESSION
Define the resistance factor for pipe section, axial compression stress. Default value = 0.85.

PIPE-BENDING
Define the resistance factor for pipe section, bending stress. Default value = 0.95.

PIPE-SHEAR
Define the resistance factor for pipe section, shear stress. Default value = 0.95.

PIPE-HYDROSTATIC
Define the resistance factor for pipe section, hydrostatic pressure stress. Default value = 0.8.

NON-PIPE-TENSION
Define the resistance factor for non-pipe section, axial tension stress. Default value = 0.9.

NON-PIPE-COMPRESSION
Define the resistance factor for non-pipe section, axial compression stress. Default value = 0.85.

NON-PIPE-BENDING
Define the resistance factor for non-pipe section, bending stress. Default value = 0.9.

NON-PIPE-SHEAR	Define the resistance factor for non-pipe section, shear stress. Default value = 0.9.
PUNCH-YIELD-STRESS	Define the resistance factor for punching check yield stress. Default value = 0.95.
PUNCH-WELD	Define the resistance factor for punching check overlapping joint welds. Default value = 0.54.
PUNCH-K-TENSION	Define the resistance factor for punching check connection factor, K brace, axial tension. Default value = 0.95.
PUNCH-K-COMPRESSION	Define the resistance factor for punching check connection factor, K brace, axial compression. Default value = 0.95.
PUNCH-K-IPB	Define the resistance factor for punching check connection factor, K brace, in-plane bending. Default value = 0.95.
PUNCH-K-OPB	Define the resistance factor for punching check connection factor, K brace, out-of-plane bending. Default value = 0.95.
PUNCH-TY-TENSION	Define the resistance factor for punching check connection factor, T and Y brace, axial tension. Default value = 0.9.
PUNCH-TY-COMPRESSION	Define the resistance factor for punching check connection factor, T and Y brace, axial compression. Default value = 0.95.
PUNCH-TY-IPB	Define the resistance factor for punching check connection factor, T and Y brace, in-plane bending. Default value = 0.95.
PUNCH-TY-OPB	Define the resistance factor for punching check connection factor, T and Y brace, out-of-plane bending. Default value = 0.95.
PUNCH-X-TENSION	Define the resistance factor for punching check connection factor, cross (X) brace, axial tension. Default value = 0.9.
PUNCH-X-COMPRESSION	Define the resistance factor for punching check connection factor, cross (X) brace, axial compression. Default value = 0.95.
PUNCH-X-IPB	Define the resistance factor for punching check connection factor, cross (X) brace, in-plane bending. Default value = 0.95.
PUNCH-X-OPB	Define the resistance factor for punching check connection factor, cross (X) brace, out-of-plane bending. Default value = 0.95.

NOTES:

None.

See also:

`PRINT LRFD-RESISTANCE-FACTORS`

EXAMPLES:

```
DEFINE LRFD-RESISTANCE-FACTORS NON-PIPE-TENSION 0.95
```

DEFINE MEMBER-CHECK-PARAMETERS

...	MEMBER-CHECK-PARAMETERS	CALCULATION-METHOD	data
		ELASTIC-CAPACITY-ONLY	
		REFERENCE-YOUNGS-MODULUS-KSI	
		REFERENCE-YOUNGS-MODULUS-MPA	
		SECTION-CAPACITY-CHECK	
		STABILITY-CAPACITY-CHECK	
		UNIT-LENGTH-FACTOR	
		VON-MISES-CHECK	

PURPOSE:

To define parameters used in connection with member code check.

PARAMETERS:

CALCULATION-METHOD — Define how to handle hydrostatic pressure in connection with the NORSOK code of practice.

ELASTIC-CAPACITY-ONLY — Define how to handled plastic / elastic section capacity in connection with the EUROCODE / NS3472 code of practice.

REFERENCE-YOUNGS-MODULUS-KSI — Define the reference value of Young's modulus in ksi for use in code check according to AISC and Eurocode/NS3472.

REFERENCE-YOUNGS-MODULUS-MPA — Define the reference value of Young's modulus in MPa for use in code check according to AISC and Eurocode/NS3472.

SECTION-CAPACITY-CHECK — Define how to handle the resistance of cross section check in connection with the EUROCODE / NS3472 code of practice.

STABILITY-CAPACITY-CHECK — Define how to handle the buckling check in connection with the EUROCODE / NS3472 code of practice.

UNIT-LENGTH-FACTOR — Define the factor which multiplied with the unit length used in the analysis gives 1.0 meter.

VON-MISES-CHECK — Define how the von Mises stress check criteria is handled in connection with the EUROCODE / NS3472 code of practice.

All data are fully explained subsequently as each command is described in detail.

DEFINE MEMBER-CHECK-PARAMETERS CALCULATION-METHOD

...	CALCULATION-METHOD	A
		B

PURPOSE:

To define how to the handle hydrostatic pressure in connection with the NORSOK and ISO code of practice.

PARAMETERS:

A	Capped-end compressive forces due to the external hydrostatic pressure are not included in the structural analysis.
B	Capped-end compressive forces are included in the analysis as external nodal forces.

NOTES:

For members exposed to external hydrostatic pressure, the design provisions is divided into two categories, i.e. method A and method B. In method A it is assumed that the capped-end compressive forces due to the external hydrostatic pressure are not included in the structural analysis. Alternatively, the design provisions in method B assume that such forces are included in the analysis as external nodal forces.

If Wajac has been used to calculate the sea state loads, method B should be used. The default method selected by Framework is method B.

See also:

`RUN MEMBER-CHECK ...`

EXAMPLES:

```
DEFINE MEMBER-CHECK-PARAMETER CALCULATION-METHOD B
```

DEFINE MEMBER-CHECK-PARAMETERS ELASTIC-CAPACITY-ONLY

...	ELASTIC-CAPACITY-ONLY	ON
		OFF

PURPOSE:

To define how to handled plastic / elastic section capacity in connection with the EUROCODE / NS3472 code of practice.

PARAMETERS:

ON	Lock to elastic section capacity. Hence, the section will always be classified in class 3 or 4.
OFF	Use plastic capacity if geometry allows (default option).

NOTES:

See also:

`RUN MEMBER-CHECK ...`

EXAMPLES:

```
DEFINE MEMBER-CHECK-PARAMETER VON-MISES-CHECK ONLY
```

DEFINE MEMBER-CHECK-PARAMETERS REFERENCE-YOUNGS-MODULUS-KSI

...	REFERENCE-YOUNGS-MODULUS-KSI	value

PURPOSE:

To define the value to used as reference Young's modulus for use in AISC and EUROCODE/NS3472 code checks.

PARAMETERS:

value The Youngs modulus in ksi unit.

NOTES:

Both AISC and Eurocode refer to modulus of elasticity defined in ksi and MPa respectively. In previous versions these built in reference values have been set to 30458 ksi and 2.1E5 MPa. For models using Young's modulus equal to 29000 ksi (corresponding to 2.0E5 MPa) some deviations in results could occur in code checks according to Eurocode and AISC. The user should define these two values consistent with actual modulus of elasticity used in the model. E.g. if using E = 2.0E11 Pa (N/m^2) in the model; set this value to 29000.

Default value is 30458 ksi for compatibility reasons. (this command is new in v3.5-01)

DEFINE MEMBER-CHECK-PARAMETERS REFERENCE-YOUNGS-MODULUS-MPA

...	REFERENCE-YOUNGS-MODULUS-MPa	value

PURPOSE:

To define the value to used as reference Young's modulus for use in AISC and EUROCODE/NS3472 code checks.

PARAMETERS:

value The Youngs modulus in MPa (N/mm^2) unit.

NOTES:

Both AISC and Eurocode refer to modulus of elasticity defined in ksi and MPa respectively. In previous versions these built in reference values have been set to 30458 ksi and 2.1E5 MPa. For models using Young's modulus equal to 29000 ksi (corresponding to 2.0E5 MPa) some deviations in results could occur in code checks according to Eurocode and AISC. The user should define these two values consistent with actual modulus of elasticity used in the model. E.g. if using E = 2.0E11 Pa (N/m^2) in the model; set this value to 2.0E5.

Default value is 2.1E5 MPa for compatibility reasons. (this command is new in v3.5-01)

DEFINE MEMBER-CHECK-PARAMETERS SECTION-CAPACITY-CHECK

...	SECTION-CAPACITY-CHECK	ON
		OFF
		SHEAR
		COMBINED

PURPOSE:

To define how the resistance of cross section check criteria is handled in connection with the EUROCODE / NS3472 code of practice.

PARAMETERS:

ON	Include the shear check and the combined axial + bending moment check.
OFF	Skip the resistance of cross section check.
SHEAR	Do a shear check only.
COMBINED	Do the combined axial + bending moment check only.

NOTES:

When the DEFINE MEMBER-CHECK-PARAMETERS VON-MISES-CHECK is set to ONLY the settings for the above switch is neglected.

The default is ON.

See also:

```
RUN MEMBER-CHECK ...
DEFINE MEMBER-CHECK-PARAMETERS VON-MISES-CHECK ...
DEFINE MEMBER-CHECK-PARAMETERS STABILITY-CAPACITY-CHECK ...
```

EXAMPLES:

```
DEFINE MEMBER-CHECK-PARAMETER SECTION-CAPACITY-CHECK COMBINED
```

DEFINE MEMBER-CHECK-PARAMETERS STABILITY-CAPACITY-CHECK

...	STABILITY-CAPACITY-CHECK	ON
		OFF
		AUTO

PURPOSE:

To define how the buckling check criteria is handled in connection with the EUROCODE / NS3472 code of practice.

PARAMETERS:

ON	Include the buckling check. (Default setting.)
OFF	Skip the buckling check.
AUTO	When set to AUTOmatic the code check will automatically skip the lateral buckling capacity check and axial buckling capacity check for beams having small slenderness values. See notes.

NOTES:

When the DEFINE MEMBER-CHECK-PARAMETERS VON-MISES-CHECK is set to ONLY the settings for the above switch is neglected.

When set to AUTOmatic the code check will automatically skip the lateral buckling capacity check and axial buckling capacity check for beams having small slenderness values. The axial compression buckling check is omitted when the non-dimensional slenderness (for both local y- and z-axes) are less than 0.2. The lateral buckling check is omitted when the non-dimensional slenderness for lateral buckling is less than 0.4.

See also:

```
RUN MEMBER-CHECK ...
DEFINE MEMBER-CHECK-PARAMETERS VON-MISES-CHECK ...
DEFINE MEMBER-CHECK-PARAMETERS SECTION-CAPACITY-CHECK ...
```

EXAMPLES:

```
DEFINE MEMBER-CHECK-PARAMETER STABILITY-CAPACITY-CHECK OFF
```

DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR

...	UNIT-LENGTH-FACTOR	value

PURPOSE:

To define the factor which multiplied with the unit length used in the analysis gives 1.0 meter.

PARAMETERS:

value The unit length multiplier to be used.

NOTES:

The unit length factor is used in connection with geometric requirements, e.g. to verify that the tubular to be checked has a wall thickness greater or equal to 6 mm when using NORSOK code of practice. The value to be used is the factor which multiplied with the unit length used in the analysis gives 1.0 meter. (E.g. if the unit length used is millimetres => value = 1000.0).

See also:

`RUN MEMBER-CHECK ...`

EXAMPLES:

```
DEFINE MEMBER-CHECK-PARAMETER UNIT-LENGTH-FACTOR 1000.
```

DEFINE MEMBER-CHECK-PARAMETERS VON-MISES-CHECK

...	VON-MISES-CHECK	ON
		OFF
		ONLY

PURPOSE:

To define how the von Mises stress check criteria is handled in connection with the EUROCODE / NS3472 code of practice.

PARAMETERS:

ON	Include a von Mises stress check at each check position.
OFF	Skip the von Mises check.
ONLY	Do the check based on von Mises check only (skip other checks).

NOTES:

The von Mises stress check is based on a linear elastic analysis and use of elastic section modulus.

The default is ON.

See also:

```
RUN MEMBER-CHECK ...
DEFINE MEMBER-CHECK-PARAMETERS SECTION-CAPACITY-CHECK ...
DEFINE MEMBER-CHECK-PARAMETERS STABILITY-CAPACITY-CHECK ...
```

EXAMPLES:

```
DEFINE MEMBER-CHECK-PARAMETER VON-MISES-CHECK ONLY
```

DEFINE MEMBER-CODE-CHECK-DUMP

...	MEMBER-CODE-CHECK-DUMP	ON
		OFF

PURPOSE:

To define if intermediate results from the member code check calculations shall be written to separate file.

PARAMETERS:

ON	Activate this feature.
OFF	Turn off this feature. (Default behaviour.)

NOTES:

This feature is available for EUROCODE / NS3472 code of practice only.

For each member code check run, important check parameters will be written to a separate file. The files will be named run-nameMCC.TMP.

See also:

`RUN MEMBER-CHECK ...`

EXAMPLES:

```
DEFINE MEMBER-CODE-CHECK-DUMP ON
```

DEFINE MEMBER-REDESIGN

.. .	MEMBER-REDESIGN	OPTIONS	REDESIGN-MODE	...	ON
			LOCK-SECTION-TYPE		
			ASSIGN-SECTION		OFF
			ALLOW-OPTIMIZE		
			TARGET-USAGE-FACTOR	value	
		SECTION-LIST	list		

PURPOSE:

To define parameters used in connection with member code check redesign / resize.

PARAMETERS:

OPTIONS	Set the option switches ON or OFF.
REDESIGN-MODE	Global switch used to select the redesign mode. Default = OFF.
LOCK-SECTION-TYPE	Switch used to select that the redesign process shall only use sections of equal type as originally assigned the member. Default = ON, i.e. do not try sections of other types.
ASSIGN-SECTION	Switch used to select if the proposed section automatically shall be assigned to the member. Default = OFF, i.e. do not assign.
ALLOW-OPTIMIZE	Switch used to select if the redesign process shall continue when the already assigned section satisfies the target usage factor. Default = OFF, i.e. do not try to optimise (select a smaller section) if the current section is acceptable.
TARGET-USAGE-FACTOR	Defines the target usage factor when running redesign. Default value = 1.0.
value	Give target value.
SECTION-LIST	Define the list of sections to be used in the redesign process.
list	The section list: (ONLY secnam1 secnam2 ...), see notes.

NOTES:

The global REDESIGN-MODE switch is the main switch used to select the redesign mode ON or OFF. When switched to ON, the code check runs will enter a redesign mode. The code check run will then try to find the cross section (based on the list of sections) that will satisfy the target usage factor.

A list of sections to be used in the redesign process must be defined. This list must contain the sections in a prioritised order with respect to preferred sections to use. The section on top of the list will be checked first, hence order from ‘weak’ to ‘strong’ sections.

During the redesign process the various results are reported in the message field (and written to the MLG file). The results from the ‘final selection’ may be printed by use of the ordinary code check print command.

See also:

`PRINT CODE-CHECK-RESULTS ...`

EXAMPLES:

```
DEFINE MEMBER-REDESIGN OPTIONS REDESIGN-MODE ON
DEFINE MEMBER-REDESIGN OPTIONS LOCK-SECTION-TYPE ON
DEFINE MEMBER-REDESIGN OPTIONS ASSIGN-SECTION OFF
DEFINE MEMBER-REDESIGN OPTIONS ALLOW-OPTIMIZE OFF
DEFINE MEMBER-REDESIGN OPTIONS TARGET-USAGE-FACTOR 0.95
DEFINE MEMBER-REDESIGN SECTION-LIST ( ONLY HEA120 HEA140 HEA160 HEA180 )
```

DEFINE NEAR-CHORD-RULE

. . .	NEAR-CHORD-RULE	OFF
		ON

PURPOSE:
To activate the new near chord rule to determine the chord member of a brace

PARAMETERS:

OFF	Do not use the near chord rule (default).
ON	Use the near chord rule.

NOTES:
The command MUST be used before `FILE OPEN` and `FILE TRANSFER`. When the result .SIN file is read into Framework, the program will automatically assign chord member and its align member to a brace at a tubular connection. The original method and the new rule are described in Section 2.3.4.

This new rule is not applicable in WindFat module.

DEFINE NORSOK

...	NORSOK	USE-LOCAL-BENDING-MOMENT	OFF
			ON
		USE-CONE-INTERNAL-FORCES	OFF
			ON
		GROUTED-JOINT	NOT-GROUTED
			FULLY-GROUTED
			DOUBLE-SKIN
		INNER-MEMBER-TP	thk

PURPOSE:
Define NORSOK N-004 code check parameters in connection with Rev. 3 (not available/active for Rev. 2).

PARAMETERS:

USE-LOCAL-BENDING-MOMENT	Specify if the maximum or local bending moments shall be used in the member check.
OFF	Use the maximum moments along the member (default).
ON	Use the actual/local bending moments at every code check position is used in the stabiliy check.
USE-CONE-INTERNAL-FORCES	Specify forces of conical transitions to be used in the cone check.
ON	Use forces at the conical side when calculating stresses in the cone (default).
OFF	Use forces at the adjacent tubular part when calculating stresses in the cone.
GROUTED-JOINT	Specify if the joints shall be checked as not grouted, fully grouted or double-skin joints.
NOT-GROUTED	Joints are not grouted (default).
FULLY-GROUTED	Joints are fully grouted.
DOUBLE-SKIN	Double skin is selected for the joints.
INNER-MEMBER-TP	Define wall thickness of inner member/pile.
thk	Actual wall thickness of inner member/pile.

NOTES:
Note that revision 3 from 2013 is the default option when NORSOK is selected as code of practice. Hence, the input command `DEFINE CODE-OF-PRACTICE-VERSION NORSOK-N-004 <year>` is by default set to year 2013.

Member check:

Apply the command `DEFINE NORSOK USE-LOCAL-BENDING-MOMENTS` for specification of moments to be used in the member check.

Joint check:

The joint check has been implemented as global switches by applying the command `DEFINE NORSOK GROUTED-JOINT`. The default setting is that joints are non-grouted. Hence, select relevant joints, define joint type with respect to grouting condition and run analysis.

When `DOUBLE-SKIN` is selected, the wall thickness of the inner member must also be defined by `DEFINE NORSOK INNER-MEMBER-TP <thk>`.

Note that check of grouted joints has been removed from Rev. 3 of N-004, [58]. The formulas implemented is according to N-004 Rev. 2 section1 0.8.3, see [57].

Cone check:

i: Definition of length L to be used when calculating the geometric parameter "mu" used in Ch when calculating "Hoop buckling" (ref. N-004 section 6.5.4.1 and 6.3.6.1) may be defined as:

- member length
- cone length
- a user given value

The command `ASSIGN STABILITY ( ) STIFFENER-SPACING` is used for this purpose. When using the CONE-LENGTH option the geometric length of the cone is used (i.e. no ring stiffeners inside the cone). Default is to use the member length (`LENGTH-BETWEEN-JOINTS`).

ii: For members with external hydrostatic pressure the effect of capped-end forces is included when running Wajac. A conical transition is simulated as a tubular beam with average outer diameter when running the wave and static analyses. Hence, the axial force contribution from capped-end force will be different at the cylinder/tubular side and the conical side of the junction. The default is to use the forces at the conical side when calculating stresses in the cone. Optionally the forces at the adjacent tubular parts may be used.

EXAMPLES:

```
DEFINE NORSOK USE-LOCAL-BENDING-MOMENT OFF
DEFINE NORSOK USE-CONE-INTERNAL-FORCES ON
DEFINE NORSOK GROUTED-JOINT NOT-GROUTED
DEFINE NORSOK INNER-MEMBER-TP 0.0
DEFINE NORSOK USE-LOCAL-BENDING-MOMENT OFF
DEFINE NORSOK USE-CONE-INTERNAL-FORCES ON
DEFINE NORSOK GROUTED-JOINT FULLY-GROUTED
DEFINE NORSOK INNER-MEMBER-TP 0.0
DEFINE NORSOK USE-LOCAL-BENDING-MOMENT ON
DEFINE NORSOK USE-CONE-INTERNAL-FORCES ON
DEFINE NORSOK GROUTED-JOINT DOUBLE-SKIN
DEFINE NORSOK INNER-MEMBER-TP 0.01
```

DEFINE PARAMETRIC-SCF

...	PARAMETRIC-SCF	LIMITATION-METHOD-SCF	ACTUAL	
			LIMITS	
			MAXIMUM	
		RING-STIFFENER-GEOMETRY	ACTUAL	
			LIMITS	
			NEGLECT	
		RING-STIFFENER-PARAMETER	ACTUAL	
			LIMITS	
		ACTIVE-BRACE-FOOTPRINT	value	
		UNSTIFFENED-SADDLE-SCF	ON	
			OVERRULE	
		AXIAL-USE-MAXIMUM	ON	
			OFF	
		CHORD-BRACE-SEPARATE	ON	
			OFF	
		CHORD-AXIAL-CROWN	value (default 2.5)	
		CHORD-AXIAL-SADDLE	value (default 2.5)	
		CHORD-IPB-CROWN	value (default 2.5)	
		CHORD-OPB-SADDLE	value (default 2.5)	
		BRACE-AXIAL-CROWN	value (default 2.5)	
		BRACE-AXIAL-SADDLE	value (default 2.5)	
		BRACE-IPB-CROWN	value (default 2.5)	
		BRACE-OPB-SADDLE	value (default 2.5)	
		INFLUENCE-FUNCTION-METHOD	A	
			B	
			C (default)	
		ABSOLUTE-VALUE-OF-TOTAL-SCF	OFF (default)	
			ON	
		FORCE-AND-MOMENT-RATIOS	ACTUAL (default)	
			LIMITS	Fratio
				Mratio

PURPOSE:
To define how to calculate parametric SCFs and SCF ratios for ring stiffeners regarding limitation given in the formulas.

PARAMETERS:

LIMITATION-METHOD-SCF	How to handle SCF calculation regarding geometric limitations.
ACTUAL	Calculate based on actual geometry and neglect limits.

LIMITS	Calculate based on limits when outside limits.
MAXIMUM	Calculate both alternatives and use maximum values (default).
RING-STIFFENER-GEOMETRY	How to handle SCF ratio calculation regarding geometric limitations in ring stiffeners.
NEGLECT	Ring stiffeners neglected (will give SCFs as if no ring stiffeners had been assigned).
RING-STIFFENER-PARAMETER	How to handle SCF ratio calculation regarding limitations in the chord and ring parameters, i.e. the R_{tau}, K_2, K_1 and I_{mod} ratios.
ACTIVE-BRACE-FOOTPRINT	Brace footprint length (percentage) to be used when calculating ring separation.
value	Value in percentage to be used (default value is 80).
UNSTIFFENED-SADDLE-SCF	How to handle the Lloyd's Register recommendation regarding ring-stiffening joints with $b > 0.8$.
ON	Use recommendations given by LR / NORSOK (default).
OVERRULE	Overrule LR's recommendation.
AXIAL-USE-MAXIMUM	How to handle NORSOK C.2.6.3.4 (DNV-RP-C203 3.3.4).
OFF	Do not use the recommendation in NORSOK C.2.6.3.4.
CHORD-BRACE-SEPARATE	Switch if separate minimum SCFs shall be used on chord side and brace side. When set to ON the values specified below will be used. When set to OFF the values defined from DEFINE FATIGUE-CONSTANTS will be used.
CHORD-AXIAL-CROWN	Specify minimum SCF to be used on chord side, crown position and axial load.
value	Minimum SCF to be used (default 2.5).
CHORD-AXIAL-SADDLE	Specify minimum SCF to be used on chord side, saddle position and axial load.
CHORD-IPB-CROWN	Specify minimum SCF to be used on chord side, crown position (in-plane bending moment).
CHORD-OPB-SADDLE	Specify minimum SCF to be used on chord side, saddle position (out-of-plane bending moment).
BRACE-AXIAL-CROWN	Specify minimum SCF to be used on brace side, crown position and axial load.
BRACE-AXIAL-SADDLE	Specify minimum SCF to be used on brace side, saddle position and axial load.
BRACE-IPB-CROWN	Specify minimum SCF to be used on brace side, crown position (in-plane bending moment).
BRACE-OPB-SADDLE	Specify minimum SCF to be used on brace side, saddle position (out-of-plane bending moment).
INFLUENCE-FUNCTION-METHOD	Specify the Efthymiou model to be used when calculating the SCFs, see note below and Section 2.3.34.
A	Use Efthymiou model A, i.e. use the influence function formulation including multiplanar effect, see also note below.
B	Use Efthymiou model B, i.e. use the influence function formulation excluding multiplanar effect, see also note below.
C	Use Efthymiou model C, i.e. use the conventional SCF approach. This is the default behaviour.
ABSOLUTE-VALUE-OF-TOTAL-SCF	ON/OFF switch for using/not using absolute values of the resulting SCFs, obtained from adding SCFs of the loaded brace with SCF contributions from the influence braces, see note below. Default is OFF.
FORCE-AND-MOMENT-RATIOS	How to handle axial force and OPB moment ratios in the influence function formulation of method A and B.
ACTUAL	Calculation based on actual values of force and moment ratios.

LIMITS	Calculation based on user defined limits on force and moment ratios to avoid big peak ratios when force or moment in reference brace is close to zero, that may give unrealistic high SCF contributions from the influence braces.
Fratio	Size limit on axial force ratio Fxb/Fxa. Fxa is the axial force of the reference brace and Fxb is the axial force of current influence brace. Fxb/Fxa > = 0.0. Default = 10.
Mratio	Size limit on OPB moment ratio Mob/Moa. Moa is OPB moment of the reference brace and Mob is OPB moment of current influence brace. Mob/Moa>=0.0. Default = 10.

NOTES:
Parametric SCFs according to Kuang and Wordsworth/Smedley can only be calculated according to method ACTUAL or LIMITS. (When MAXIMUM (Framework default) is selected, similar calculation as for ACTUAL is used.).

When using alternative MAXIMUM in LIMITATION-METHOD-SCF parameters described in RING-STIFFENER-GEOMETRY and RING-STIFFENER-PARAMETER will be set to ACTUAL in first calculation pass and LIMIT in second pass.

When using alternative NEGLECT in RING-STIFFENER-GEOMETRY, the option selected in RING-STIFFENER-PARAMETER is of no relevance.

The option with CHORD-BRACE-SEPARATE ON is implemented for SCFs according to Efthymiou and Lloyd's.

For the INFLUENCE-FUNCTION-METHOD option to be used for models A or B, the joint SCF assignment must be defined to be PARAMETRIC EFTHYMIOU and the joint type must be assigned to type LOADPATH, i.e. calculate the SCFs based on load path for each stress calculation step. Use the commands ASSIGN SCF JOINT brace-name jnt-name text PARAMETRIC EFTHYMIOU and ASSIGN JOINT-TYPE brace-name jnt-name LOADPATH.

For joint type LOADPATH used in combination with parametric SCFs, the print of the results will report SCFs partly according to joint geometry and partly according to the actual worst hotspot. The SCFaxC and SCFaxS are the hotspots for the Crown and Saddle positions independent of worst hotspot regarding fatigue. The SCFipb and SCFopb are the SCFs for crown position from in-plane bending and saddle position from out-of-plane bending (also independent of worst hotspot regarding fatigue). The SCFax is the actual SCF for axial force used for the hotspot reported to be governing. Hence, if the worst hotspot is a saddle point (1 or 13) the SCFaxS is reported, if a crown point (7 or 19) the SCFaxC is reported, and if any points in between (4, 10, 16 or 22) the average value SCF of crown and saddle is used.

Correction of hotspot stresses are done internally in the calculation routines taking the effect from commands DEFINE FATIGUE-CONSTANTS IN-PLANE-FACTOR and DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-FACTOR into account. These are not reflected in the reports/print, but are global settings of how to perform the calculations. The settings/values of the parameters (together with other fatigue global parameters) can be printed by the command PRINT FATIGUE-CHECK-TYPE.

Framework adds SCFs of the loaded brace with SCF contributions from the influence braces when influence functions are used. The influence contributions may turn the resulting SCFs of the loaded brace into negative. Negative SCFs means that brace stresses used to find the resulting stress range for the fatigue analysis turn direction. Prior to version 3.9-04 Framework uses the absolute value of the resulting SCFs prohibiting negative SCFs to occur. By the ABSOLUTE-VALUE-OF-TOTAL-SCF parameter the user itself may decide upon using negative resulting SCFs or not. The OFF option allows for negative resulting SCFS while the ON option does not. The ON option works according to previous versions of Framework prior to version 3.9-04. The ABSOLUTE-VALUE-OF-TOTAL-SCF parameter applies only for the influence function method A and B and classification based on load path. Note that for the OFF option minimum SCFs imposed by the user do not apply while they do apply for the ON option. Default option is OFF.

The contributions to the SCFs from the influence braces in the influence function formulation contains force and moments ratios of current influence brace relative to the reference brace. It appears that these ratios may in some cases be very big when force and moment of the reference brace are very small compared to the influence brace or close to zero and thereby give unrealistic high SCFs contributions. To control this problem the possibility of limiting these ratios within a given range have been implemented by the parameters Ratio and Mratio of the FORCE-AND-MOMENT-RATIOS LIMITS option. For details of influence function method, see Appendix B.7.

A detailed dump print of all SCF values and force and moment ratios is given by applying the command DEFINE FATIGUE-DUMP INFLUENCE-FUNCTION-SCFS ON prior to run execution. All SCF contributions to the total SCF value is printed including SCFs of the reference brace and SCFs of all inplanar and multiplanar influence braces for all load cases at all brace end positions of current member selection. The extensive dump print will generate very big files for problems with many load cases and many members in the selection and should therefore be used with care.

See also:

```
ASSIGN JOINT-RING-STIFFENER ...
PRINT JOINT PARAMETRIC-SCF ...
```

EXAMPLES:

```
DEFINE PARAMETRIC-SCF LIMITATION-METHOD-SCF ACTUAL
DEFINE PARAMETRIC-SCF FORCE-AND-MOMENT-RATIOS LIMITS 10.0 10.0
```

DEFINE POSITION-BOTH-SIDES

...	POSITION-BOTH-SIDES	ON
		OFF

PURPOSE:

To define how to assign code check positions at member intermediate joints.

PARAMETERS:

ON	Define position at both sides of intermediate joint in member even when equal cross section is assigned elements at both sides of the joint (node).
OFF	Turn off this feature. (Default behaviour.)

NOTES:

When switched ON the command has effect for all subsequent given ASSIGN POSITION commands.

If ON is wanted as default behaviour it should be set prior to executing the FILE OPEN and FILE TRANSFER commands.

See also:

```
ASSIGN POSITION CODE-CHECK ...
FILE OPEN ...
FILE TRANSFER ...
```

EXAMPLES:

```
DEFINE POSITION-BOTH-SIDES ON
```

DEFINE PREFRAME-INPUT

...	PREFRAME-INPUT	ON
		OFF

PURPOSE:

To define if a command input file to Preframe shall be generated when exiting Framework.

PARAMETERS:

ON	Activate this feature.
OFF	Turn off this feature. (Default behaviour.)

NOTES:

When set to ON, create a command input file to Preframe when exiting Framework. The input file will contain Preframe commands corresponding to geometric changes / modifications done in the Framework model from point of establishment to current status.

The file name for the Preframe input command file is prefixFW2PF.JNL, where prefix is the user defined print file prefix.

See also:

`SET PRINT FILE ...`

EXAMPLES:

```
DEFINE PREFRAME-INPUT ON
```

DEFINE PRESENTATION

...	PRESENTATION	DISPLAY	data
		FORCE	
		PRINT	
		RESULT	
		STRESS	
		SUPPORT-REACTION	

PURPOSE:

To define alternatives with respect to presentation of section stresses and analyses results.

PARAMETERS:

DISPLAY	Define settings used in connection with the display command.
FORCE	Define global parameters to be used in connection with print of forces, joint member end forces and display of force / moment diagrams.
PRINT	Define parameter to be used in connection with print.
RESULT	Define global parameters to be used in connection with analyses / check results presentation.
STRESS	Define global parameters to be used in connection with stress presentation.
SUPPORT-REACTION	Define global parameters to be used in connection with print of support reactions.

All data are fully explained subsequently as each command is described in detail.

DEFINE PRESENTATION DISPLAY

...	DISPLAY	LOADCASE-NAME	ON	
			OFF	
			SPLIT	
		TENSION-LABEL	...	ON
		LABEL-ALIGNMENT		
		SHOW-VALUES		OFF
		COLOR-CODING		
		COLOR-ONE	color	limit
		COLOR-TWO	color	limit
		COLOR-THREE	color	limit
		COLOR-FOUR	color	limit
		COLOR-FIVE	color	limit
		COLOR-SIX	color	limit
		COLOR-SEVEN	color	limit
		COLOR-EIGHT	color	limit
		COLOR-NINE	color	
		COLOR-LEVELS-ACTIVE	numlev	
		COLOR-LINE-WIDTH	linwidth	
		LEGEND-IN-CORNER	UPPER-LEFT	
			LOWER-RIGHT	

PURPOSE:

Define settings used in connection with the display command.

PARAMETERS:

LOADCASE-NAME — How to handle the loadcase name in parentheses behind the usage factor when displaying code check results for worst loadcase. Default ON.

ON — Switch option ON.

OFF — Switch option OFF.

SPLIT — The usage factor and governing loadcase are split and presented with usage factor above member line and governing loadcase below member line.

TENSION-LABEL — How to handle the 'Tens' label on stability code check result display. Default ON.

LABEL-ALIGNMENT — Labels are drawn alongside the members. Default OFF.

SHOW-VALUES — Define if result values shall be shown when colour coding is switched on. Default ON.

COLOR-CODING — Controls use of extended color coding when displaying results from code checking and fatigue calculations, i.e. when using the commands DISPLAY CODE-CHECK-RESULTS and DISPLAY FATIGUE-CHECK-RESULTS. Default OFF.

COLOR-ONE — Define the colour and limit value for 1st colour level. See notes for defaults.

color	Colour to be used. Available colours are RED, REDDISH-BROWN, ORANGE, YELLOW, ABSINTHE, DARK-GREEN, GREEN, CYAN, MAGENTA, VIOLET, BLUE, ANTI-BACKGROUND.
limit	Define the limit values regarding which colour to use when drawing the member (or part of member). The different levels (colours) are used when the result to report is greater than the limit value.
COLOR-TWO	Define the colour and limit value for 2nd colour level. See notes for defaults.
COLOR-THREE	Define the colour and limit value for 3rd colour level. See notes for defaults.
COLOR-FOUR	Define the colour and limit value for 4th colour level. See notes for defaults.
COLOR-FIVE	Define the colour and limit value for 5th colour level. See notes for defaults.
COLOR-SIX	Define the colour and limit value for 6th colour level. See notes for defaults.
COLOR-SEVEN	Define the colour and limit value for 7th colour level. See notes for defaults.
COLOR-EIGHT	Define the colour and limit value for 8th colour level. See notes for defaults.
COLOR-NINE	Define the colour for 9th colour level. All results less than limit for level eight is drawn in colour defined for level nine (hence no limit value for level nine). See notes for defaults.
COLOR-LEVELS-ACTIVE	Choose the actual number of colour levels to be used.
numlev	Number of levels in the range of 3 to 9 (default 9). When e.g. using 5 levels, all results less than limit for COLOR-FOUR will be drawn with colour selection for COLOR-FIVE.
COLOR-LINE-WIDTH	Choose line with to be used on plots.
linwidth	Line width is in the range of 1.0 to 10.0 (default 3.0). Line width 1.0 corresponds to the standard line width used when drawing members and borders.
LEGEND-IN-CORNER	Choose where to draw the colour coding legend.
UPPER-LEFT	Draw the colour coding legend in upper left corner of the display window. This is the default location.
LOWER-RIGHT	Draw the colour coding legend in lower right corner of the display window.

NOTES:

When TENSION-LABEL is switched ON all members which are in tension for all loadcases investigated in the stability run will be given the label ‘Tens’ on the code check results display.

Default colours and limit values for colour coding are as follows

```
DEFINE PRESENTATION DISPLAY COLOR-ONE RED 1.0
DEFINE PRESENTATION DISPLAY COLOR-TWO ORANGE 0.9
DEFINE PRESENTATION DISPLAY COLOR-THREE YELLOW 0.8
DEFINE PRESENTATION DISPLAY COLOR-FOUR GREEN 0.7
DEFINE PRESENTATION DISPLAY COLOR-FIVE CYAN 0.6
DEFINE PRESENTATION DISPLAY COLOR-SIX MAGENTA 0.5
DEFINE PRESENTATION DISPLAY COLOR-SEVEN VIOLET 0.4
DEFINE PRESENTATION DISPLAY COLOR-EIGHT BLUE 0.3
DEFINE PRESENTATION DISPLAY COLOR-NINE ANTI-BACKGROUND
```

When displaying fatigue life, turn color palette ‘upside down’ to get ‘critical colours’ for lower life.

EXAMPLES:

```
DEFINE PRESENTATION DISPLAY TENSION-LABEL OFF
DEFINE PRESENTATION DISPLAY COLOR-CODING ON
```

```
DEFINE PRESENTATION DISPLAY COLOR-LEVELS-ACTIVE 5
DEFINE PRESENTATION DISPLAY COLOR-LINE-WIDTH 5.0
```

DEFINE PRESENTATION FORCE

...	FORCE	SUMMARY	OFF
			EACH-LOAD-CASE
			ALL-LOAD-CASES
		COMPONENT	PX
			QY
			QZ
			MX
			MY
			MZ
		SEARCH	ABSOLUTE-MAXIMUM
			MAXIMUM
			MINIMUM
			MAX-AND-MIN
			ENVELOP
		PHASE-ANGLE	MAX
			ALL
		DIAGRAM-SPLIT	nsplit

PURPOSE:

To define global parameters to be used in connection with print of forces, joint member end forces and display of force / moment diagrams.

PARAMETERS:

SUMMARY	Alternatives regarding summary option.
OFF	Do not use any summary option.
EACH-LOAD-CASE	Print max / min value for each selected load case.
ALL-LOAD-CASES	Print max / min value among all selected load cases.
COMPONENT	Select force / bending moment component to scan.
PX	Axial force
QY	Shear force in the direction of member local y-axis.
QZ	Shear force in the direction of member local z-axis.
MX	Torsional moment.
MY	Moment about member local y-axis.
MZ	Moment about member local z-axis.
SEARCH	Define search alternative.
ABSOLUTE-MAXIMUM	Search for absolute maximum value of selected component.
MAXIMUM	Search for maximum value of selected component.
MINIMUM	Search for minimum value of selected component.
MAX-AND-MIN	Search for maximum and minimum value of each component.
ENVELOP	Search for maximum and minimum value of each component for each check position.

PHASE-ANGLE	How to handle print of member forces for complex load cases.
MAX	Print for max response only. The default option.
ALL	Print for all predefined report phase angles. The phase angles are defined through DEFINE CONSTANTS PHASE-ANGLE.
DIAGRAM-SPLIT	Used to modify default number (50) of parts each beam is split into when drawing a force / moment diagram.
nsplit	Number of divisions ($10 \leq$ nsplit ≤ 100).

NOTES:

When used in connection with PRINT FORCES it is possible to print forces at the position (among the predefined check positions) along the member giving absolute maximum, maximum or minimum value of a selected force / bending moment component. This max / min print can be printed for each of the selected load cases, or as a max / min print among all selected load cases. These options are controlled by switches set prior to using the ordinary PRINT FORCE command.

When used in connection with PRINT JOINT MEMBER-FORCES it is possible to print the member end forces for a selection of joints and load cases. The forces / bending moments at the member end entering the joint will be printed.

For complex loads the phase angle giving the max / min value for selected component with corresponding values (using the same phase) for the other components will be printed. (Note that the ordinary print force command prints the magnitude (amplitude) of each load component, hence may report forces / bending moments for different phase angles.)

The print heading shows the search alternatives made. E.g. if component MY is selected together with search alternative absolute maximum, the heading will look like this:

```
Joint/Po D      PX          PY          PZ          MX       |MY|max       MZ
-------------------------------------------------------------------------------
```

The envelop print (SEARCH ENVELOP) for summary option EACH-LOAD-CASE is nothing else but an ordinary force print, hence the ENVELOP alternative is defined to give the same result for both EACH-LOAD-CASE and ALL-LOAD-CASES with one exception; the EACH-LOAD-CASE option prints a ‘dividing line’ for each new member.

The PHASE-ANGLE option will be neglected if the SUMMARY is active.

The display diagram functionality is independent of assigned positions. Each member is as default split into 50 parts when drawing the diagram. The default number of parts may be adjusted by the above defined command.

See also:

```
PRINT FORCE ...
PRINT JOINT MEMBER-FORCES ...
```

EXAMPLES:

```
DEFINE PRESENTATION FORCE COMPONENT MY
```

DEFINE PRESENTATION PRINT

.. .	PRINT	SIMPLIFIED	ON
			OFF
		PUNCH-CHECK-DATA	BRIEF
			FULL

PURPOSE:

Define settings used in connection with print.

PARAMETERS:

SIMPLIFIED	How to format the print regarding blank lines and lines containing hyphens only.
ON	Switch on simplified format, i.e. skip “unnecessary” lines.
OFF	Normal print. (Default behaviour.)
PUNCH-CHECK-DATA	Define wanted print format for punch check data.
BRIEF	Use the brief format printing one line for each member entering the joint.
FULL	Use the full print format. (Default behaviour.)

NOTES:

When the SIMPLIFIED print option is activated each line printed will contain member name and load case name. Hence, this will give a print format more suitable for e.g. spreadsheet import.

The SIMPLIFIED option is currently implemented for PRINT FORCES, PRINT JOINT MEMBER-FORCES and PRINT STRESS FULL only. The PRINT STRESS FULL command must be used in combination with DEFINE PRESENTATION STRESS FORMAT OPTIONAL.

Regarding PUNCH-CHECK-DATA. For braces with negative gap (overlap) the detailed information about the overlap is not given for the BRIEF option. Hence, use the default (FULL) print option for selected joints when such information is of importance.

See also:

`SET PRINT PAGE-HEIGHT`

EXAMPLES:

```
DEFINE PRESENTATION PRINT SIMPLIFIED ON
```

...	RESULT	JOINT-REACTION-PHASE-ANGLE	value
		PRINT-MAXIMUM-DISPLACEMENT	MAXCOMP
			OFF
			TOTAL
		PRINT-MEMBER-RESULT	ALL
			SELECTED
		PRINT-MEMBER-SUMMARY	ALL-POSITIONS
			MAX-PER-ELEMENT
			OFF
		PRINT-ELEMENT-NUMBER	ON
			OFF
		PRINT-LOAD-CONDITION	ON
			OFF (default)
		SUPPORT-REACTIONS	JOINTWISE
			LOADCASEWISE

PURPOSE:

To define global parameters to be used in connection with analyses / check results presentation.

PARAMETERS:

JOINT-REACTION-PHASE-ANGLE — Specify the phase to be used when printing joint reactions for complex results.

value — Phase angle in degrees.

PRINT-MAXIMUM-DISPLACEMENT — Print alternatives when printing joint displacements.

MAXCOMP — The maximum displacement / rotation in each direction will be printed independent of loadcase. The text MAXCOMP will be printed instead of the loadcase name.

TOTAL — Print the displacements for the loadcase giving maximum displacement.

OFF — Use the default presentation.

PRINT-MEMBER-RESULT — Print options in connection with print of results from member code check.

ALL — To print results for all members checked when using the print alternative MEMBERS AND WORST LOADCASE.

SELECTED — To limit the print to current selected members when using the print alternative MEMBERS AND WORST LOADCASE.

PRINT-MEMBER-SUMMARY — Print options in connection with print of results from member code check (currently through member check only).

ALL-POSITIONS — To print the maximum utilisation at each code check position for selected members and load-cases/combinations. (I.e. utilisation from different load cases will be printed for the different positions).

MAX-PER-ELEMENT — To print the maximum utilisation among the code check positions within each elements being part of a member. The position (element) with the highest utilisation factor is printed first.

PRINT-ELEMENT-NUMBER — Add element numbers to the print from code check according to API-AISC (and “old” NPD-NS3472) and fatigue check.

PRINT-LOAD-CONDITION	Print load condition, load case/combination overview, member check results and conical transition code-check results according to NORSOK N-004.
ON / OFF	Switch ON or OFF (default is OFF).
SUPPORT-REACTIONS	Switch used in connection with print of support reactions.
JOINTWISE	The support reactions shall be sorted by joint.
LOADCASEWISE	The support reactions shall be sorted by loadcase (incl. print of loadsum for each loadcase). This is the default setting.

NOTES:

The PRINT-MEMBER-RESULT definition will effect the outcome of the PRINT-CODE-CHECK-RESULTS command when using the print alternative MEMBERS AND WORST LOADCASE.

The PRINT-MEMBER-SUMMARY definition will effect the outcome of the PRINT-CODE-CHECK-RESULTS command when using the print alternative SELECTED-MEMBERS-AND-LOADCASES.

The PRINT-ELEMENT-NUMBER adds element numbers to the print from code check according to API-AISC (and “old” NPD-NS3472) and fatigue check. The element number is printed right below the ‘Joint/Po’ location for each result presented. This indicates on which element being part of the member the check position is located. Note that for code check according to NORSOK and EUROCODE-NS3472 the element number will always be printed.

See also:

```
PRINT JOINT REACTION-FORCES ...
PRINT DISLACEMENT ...
PRINT SUPPORT-REACTIONS ...
PRINT CODE-CHECK-RESULTS ...
```

EXAMPLES:

```
DEFINE PRESENTATION JOINT-REACTION-PHASE-ANGLE 90.
```

DEFINE PRESENTATION STRESS

...	STRESS	COMPONENTS	ACTIVE
			HOTSPOT
			SECTION
			MAXTENSION
			MAXCOMPRESSION
		PHASE-ANGLE	ALL
			MAX
		FORMAT	DEFAULT
			OPTIONAL

PURPOSE:

To define global parameters to be used in connection with print of member stresses.

PARAMETERS:

COMPONENTS	Alternatives regarding stresses and hotspot.
ACTIVE	Print stresses for all active cross section hotspots.
HOTSPOT	The default stress presentation is to print stresses at the stress point with the highest stress.
SECTION	The maximum stress components for a static load case in the section is printed, i.e. the stresses are not related to the printed hotspot.
MAXTENSION	Print a stress summary only (worst hotspot, worst position, worst loadcase) searching maximum tensile stress.
MAXCOMPRESSION	Print a stress summary only (worst hotspot, worst position, worst loadcase) searching maximum compressive stress.
PHASE-ANGLE	Alternatives regarding complex load cases.
ALL	All phase angles and the corresponding stresses will be printed for defined phase angles as described under command DEFINE CONSTANTS PHASE-ANGLE.
MAX	Find the phase angle which gives maximum stress when the command PRINT STRESS is given. The maximum stress and its corresponding phase angle is then printed. This option is default.
FORMAT	Select which format to use when printing member stress.
DEFAULT	Default format, using two lines for each position.
OPTIONAL	Optional format, using one line for each position.

NOTES:

The command DEFINE PRESENTATION STRESS PHASE-ANGLE is relevant for dynamic load cases only.

When using PRINT STRESS ... EQUIVALENT-STRESS any of the MAXTENSION / MAXCOMPRESSION options will work. If the option DEFINE PRESENTATION STRESS PHASE-ANGLE is set to ALL, the MAXTENSION / MAXCOMPRESSION alternatives will be neglected.

Switching to the FORMAT OPTIONAL print format has no effect if using the PRINT STRESS BRIEF command. This option should also be used in combination with the command DEFINE PRESENTATION PRINT SIMPLIFIED ON to skip dividing lines, i.e. skip blank lines and lines with hyphens only.

See also:

```
PRINT STRESS ...
CHANGE HOTSPOTS ...
DEFINE CONSTANTS PHASE-ANGLE ...
```

EXAMPLES:

```
DEFINE PRESENTATION STRESS COMPONENTS ACTIVE
```

...	SUPPORT-REACTION	SUMMARY	ON
			OFF
		COMPONENT	FX
			FY
			FZ
			MX
			MY
			MZ
		SEARCH	ABSOLUTE-MAXIMUM
			MAXIMUM
			MINIMUM
		PHASE-ANGLE	MAX
			ALL

PURPOSE:

To define global parameters to be used in connection with print of support reactions.

PARAMETERS:

SUMMARY	Alternatives regarding summary option.
ON	Switch on the summary option.
OFF	Switch off the summary option. Default option.
COMPONENT	Select force / bending moment component to scan.
FX	Force in X direction. Default option.
FY	Force in Y direction.
FZ	Force in Z direction.
MX	Moment about X-axis.
MY	Moment about Y-axis.
MZ	Moment about Z-axis.
SEARCH	Define search alternative.
ABSOLUTE-MAXIMUM	Search for absolute maximum value of selected component. Default option.
MAXIMUM	Search for maximum value of selected component.
MINIMUM	Search for minimum value of selected component.
PHASE-ANGLE	How to handle print of forces for complex load cases.
MAX	Print for max response only. Default option.
ALL	Print for all predefined report phase angles. The phase angles are defined through DEFINE CONSTANTS PHASE-ANGLE.

NOTES:

When used in connection with PRINT SUPPORT-REACTIONS it is possible to print support reaction forces and moments giving absolute maximum, maximum or minimum value of a selected force / bending moment component. This max / min print can only be used when printing the support reactions joint wise, i.e. switch

to DEFINE PRESENTATION SUPPORT-REACTIONS JOINTWISE. These options are controlled by switches set prior to using the ordinary PRINT SUPPORT-REACTIONS command.

For complex loads the phase angle giving the max / min value for selected component with corresponding values (using the same phase) for the other components will be printed. The print heading shows the search alternatives made.

If the option DEFINE PRESENTATION SUPPORT-REACTION SUMMARY is ON, the PHASE-ANGLE ALL option will be neglected. The predefined phase angles for reporting are defined through the command DEFINE CONSTANTS PHASE-ANGLE.

Combined with the setting DEFINE PRESENTATION PRINT SIMPLIFIED ON the line giving the phase angles will be skipped. This is governing also when summary or ALL phase angles are switched off.

See also:

```
PRINT SUPPORT-REACTIONS
DEFINE PRESENTATION SUPPORT-REACTIONS JOINTWISE
DEFINE CONSTANTS PHSE-ANGLE ...
DEFINE PRESENTATION PRINT SIMPLIFIED ON
```

EXAMPLES:

```
DEFINE PRESENTATION SUPPORT-REACTION SUMMARY ON
DEFINE PRESENTATION SUPPORT-REACTION COMPONENT FZ
```

DEFINE READ-CONCEPTS

...	READ-CONCEPTS	ON
		OFF

PURPOSE:

To switch OFF reading the concept information from the result file.

PARAMETERS:

ON	Read conceptual information. (Default behaviour.)
OFF	Skip conceptual information.

NOTES:

When set to OFF, member information and member attribute data defined on the concept data cards will not be transferred when the model is established. In this mode, the program will also skip reading node, material and cross section names.

This switch must be set prior to opening and transferring model and results from the result interface file.

See also:

```
FILE OPEN ...
FILE TRANSFER ...
```

EXAMPLES:

```
DEFINE READ-CONCEPTS OFF
```

DEFINE READ-NAMED-SETS

...	READ-NAMED-SETS	OPTION	ALL
			ELEMENTS-ONLY
			JOINTS-ONLY
			NONE

PURPOSE:

To define how to handle named sets when reading results file.

PARAMETERS:

ALL	Read all defined named sets. (Default behaviour.)
ELEMENTS-ONLY	Read sets containing elements only.
JOINTS-ONLY	Read sets containing joints (nodes) only.
NONE	Do not read named sets.

NOTES:

This command option must be set prior to opening and transferring model and results from the result interface file.

See also:

```
FILE OPEN ...
FILE TRANSFER ...
```

EXAMPLES:

```
DEFINE READ-NAMED-SETS OPTION ELEMENTS-ONLY
```

DEFINE SECTION-OVERRULE

...	SECTION-OVERRULE	ON
		OFF

PURPOSE:

To define the possibility to overrule the CREATE SECTION command when the given section name already exist.

PARAMETERS:

ON	Activate this feature.
OFF	Turn off this feature. (Default behaviour.)

NOTES:

When switched to ON the following message will be given: * Section ‘sec-nam’ exist. Command neglected due to activation of section overrule. The execution of a command input file will continue.

When switched to OFF, the execution of a command input file will stop.

See also:

`CREATE SECTION ...`

EXAMPLES:

```
DEFINE SECTION-OVERRULE ON
```

DEFINE TIME-HISTORY-FATIGUE-TIME

.. .	TIME-HISTORY-FATIGUE-TIME	UNIT-TIME		.. .	tstart
		TIME-SERIES-DURATION			tend
		UNIT-YEAR			tintv
		TARGET-FATIGUE-LIFE			tintv
		USER-TIME	years		strslev

PURPOSE:

Define time duration of the fatigue exposure for time history fatigue damage calculation.

PARAMETERS:

UNIT-TIME	Damage is calculated for a time length of 1 second. (Default).
TIME-SERIES-DURATION	Damage is calculated for a time length equal to the duration of the fatigue load time history.
UNIT-YEAR	Damage is calculated for a time length of one year.
TARGET-FATIGUE-LIFE	Damage is calculated for a time length equal to the target fatigue life, see command DEFINE FATIGUE-CONSTANTS.
USER-TIME	Damage is calculated for the user time length years.
years	User defined fatigue exposure time in years.
tstart	Time start of selected time range in seconds.
tend	Time end of selected time range in seconds. Time end is larger than the time start value.
tintv	Time step interval given as integer 1, 2, 3 etc. Time step used = tintv * time step of time series
strslev	Stress level. Damage of a hotspot is calculated if at least one stress peak in the hotspot stress time series exceeds strslev. Applies to both tensile and compressive stresses.

NOTES:

This command is applicable for time history fatigue analysis only.

Time range start and time range end values should be within the total range of the time series. Values outside the total range will be adjusted to the start or end point of the time series. If the start or end values do not coincide with time values of the time series, they are adjusted to the times series values that are closest but not above to the input values. A message is printed when input values are adjusted.

EXAMPLES:

```
DEFINE TIME-HISTORY-FATIGUE-TIME UNIT-TIME 0.0 595.0 1 1.E1
DEFINE TIME-HISTORY-FATIGUE-TIME TIME-SERIES-DURATION 0.0 595.0 3 1.E1
DEFINE TIME-HISTORY-FATIGUE-TIME UNIT-YEAR 110.0 450.0 1
DEFINE TIME-HISTORY-FATIGUE-TIME TARGET-FATIGUE-LIFE 110.0 450.0 2 1.E1
DEFINE TIME-HISTORY-FATIGUE-TIME USER-TIME 0.5 0.0 300.0 1 1.E1
```

DEFINE WIDE-BAND-CORRECTION-FACTOR

...	WIDE-BAND-CORRECTION-FACTOR	OFF
		ON

PURPOSE:

To switch OFF/ON Wirsching correction factor for wide banded stress processes. The correction factor is given in Appendix B 5.

PARAMETERS:

OFF Switch off Wirsching correction factor (default)

ON Switch on Wirsching correction factor

NOTES:

This command is applicable for time history fatigue analysis only.

Time range start and time range end values should be within the total range of the time series. Values outside the total range will be adjusted to the start or end point of the time series. If the start or end values do not coincide with time values of the time series, they are adjusted to the times series values that are closest but not above to the input values. A message is printed when input values are adjusted.

EXAMPLES:

```
DEFINE WIDE-BAND-CORRECTION-FACTOR ON
```

DEFINE WIND-FATIGUE

. . .	WIND-FATIGUE	WIND-PARAMETERS	. . .
		COHERENCE-COEFFICIENTS	
		WIND-DIRECTIONS	
		WIND-SPEEDS	
		WIND-PROBABILITIES	
		DRAG-CORRECTION-FACTORS	
		BENT-CAN-DAMAGE	
		VORTEX-PARAMETERS	
		DEFAULT-MEMBER-FIXITIES	
		DEBUG-PRINT	

PURPOSE:
To define data for wind fatigue calculation.

PARAMETERS:

WIND-PARAMETERS	Define wind- and structural related parameters.
COHERENCE-COEFFICIENTS	Define coefficients of the GENERAL coherence model.
WIND-DIRECTIONS	Define wind directions to be considered.
WIND-SPEEDS	Define hourly wind speeds to be considered.
WIND-PROBABILITIES	Define annual probabilities associated with the wind speeds.
DRAG-CORRECTION-FACTORS	Define factors applied to the member drag coefficient for each of the associated wind speeds.
BENT-CAN-DAMAGE	On/Off switch for damage calculation of Bent Cans.
VORTEX-PARAMETERS	Define additional wind parameters required for studying vortex shedding effects.
DEFAULT-MEMBER-FIXITIES	Define default member end fixities for studying vortex shedding effects.
DEBUG-PRINT	Provide debug print for buffeting and vortex shedding damage calculation.

All data are fully explained subsequently as each command is described in detail.

DEFINE WIND-FATIGUE WIND-PARAMETERS

...	WIND-PARAMETERS	cc	kappa	xludav	xluhar	sncrv	scfrule	...

...	damp	l/d	angtol	damlim	$epsfrc$	$epscoh$

PURPOSE:
To define wind parameters for wind fatigue calculation.

PARAMETERS:

cc	Constant of the coherence function. Default = 8.0
kappa	Ground surface roughness coefficient. Default = 0.015
xludav	Along wind turbulence length Davenport spectrum Default = 1200.0
xluhar	Along wind turbulence length Harris spectrum Default = 1800.0
sncrv	Default SN-curve. Default = DOE-T
scfrule	Default SCF scheme. The options are EFTHYMIOU (default) and LLOYDS.
l/d	Ratio of chord length to chord diameter. Used as parameter in the LLOOYD and ORIGINAL SCF calculation schemes. The value is not used if SCF data are assigned by the user/Framework. (READ option in command ASSIGN WIND-FATIGUE JOINTSCF). Default = 30.0
angtol	Angular tolerance in degrees used to determine whether a given tubular element is within an analysis plane or not. Default = 15.0
damlim	Lower limit of printed damage values in the damage result table. All damage above the limit are printed (default 1.0E-10).
damp	Ratio of estimated total damping to the critical damping. It is used to represent the combined effects of both the aerodynamic and structural damping. Default = 0.01.
$epsfrc$	Limit value of minimum wind force relative to maximum wind force to account for in the wind buffeting fatigue calculation (default 1.0E–5). Valid range: $0.0 < epsfrc < 1.0$.
$epscoh$	Limit value on coherence terms to account for in the wind buffeting fatigue calculation (default 1.0E–3). Valid range: $0.0 < epscoh < 1.0$.

NOTES:

The damping ratio in Framework-WindFat is defined as the hysteretic damping ratio of complex stiffness damping. See Section 6.12.1 for more details. In brief, $\gamma \approx 2\xi$, where $\xi = \frac{c}{c_c}$ is the ratio of viscous damping coefficient over the critical damping factor.

The value of the wind force components relative to the maximum component is calculated and compared to the limit parameter $epsfrc$. All components with relative values equal to or larger than epsfrc are accounted for in the fatigue calculation.

The coherence terms that are accounted for is given by:

$$coh \geq epscoh$$

where coh is value from the coherence model applied. Available coherence models are describe in Sec.6.7. The coherence is a function of distance from the current point, wind velocity and frequency. At the current

targeting point, the coherence is $coh = 1.0$. At far distance from point the coherence approaches zero in limit. The coherence changes exponentially. It increases with increasing velocity and decreases with increasing frequency and increasing distance from the current point. For given values of velocities and frequencies the parameter $epscoh$ limits the extension of coherence to the distance from the point. The extreme case is to set $epscoh = 1.0$ to ignore the coherence which is not recommended in practice.

Calculation of the coherence matrix, which is a square by square matrix of the number of degrees of freedoms of the system, is performed in the innermost loop of about ten levels of loops and is extremely costly and time consuming to establish. All diagonal terms of the matrix have the value of 1.0 and the off-diagonal terms have values between 1.0 and 0.0 depending on the distance between the joints. Most of the off diagonal terms are zero or close to zero and will contribute insignificantly to the damage value. High values of the parameters $epsfrc$ and $epscoh$ will limit the size of matrices operating on and may improve the computation efficiency considerable for large systems, but at same time reduce the accuracy of results. The purpose of these parameters is to apply values which improves the computation time without reducing the accuracy in results significantly. The most important parameter to reduce computation time is $epscoh$.

To see how the various parameters affect the accuracy of results and the CPU time consumption of the calculatingly, a few joints should be analysed with various values of epsfrc, epscoh, velocity and various number of dynamic modes and velocities. All these parameters affects the calculated results and the CPU time of the analysis. When proper values of the parameters have been decided a more comprehensive fatigue calculation may be executed.

EXAMPLES:

```
DEFINE WIND-FATIGUE WIND-PARAMETERS
8.0 0.015 1200.0 1800.0 DOE-T EFTHYMIOU 0.01 30.0 1.0 1.E-12
```

DEFINE WIND-FATIGUE COHERENCE-COEFFICIENTS

...	COHERENCE-COEFFICIENTS	Cux	Cuy	Cuz	Cvx	Cvy	Cvz	Cwx	Cvy	Cwz

PURPOSE:

To define coefficients of the GENERAL coherence model.

PARAMETERS:

Cux Coefficient of x separation for coherence in mean wind direction. Default = 0.0

Cuy Coefficient of y separation for coherence in mean wind direction. Default = 8.0

Cuz Coefficient of z separation for coherence in mean wind direction. Default = 8.0

Cvx Coefficient of x separation for coherence lateral to mean wind direction. Default = 0.0

Cvy Coefficient of y separation for coherence lateral to mean wind direction. Default = 6.0

Cvz Coefficient of z separation for coherence lateral to mean wind direction. Default = 6.0

Cwx Coefficient of x separation for coherence vertical to mean wind direction. Default = 0.0

Cwy Coefficient of y separation for coherence vertical to mean wind direction. Default = 6.0

Cwz Coefficient of z separation for coherence vertical to mean wind direction. Default = 6.0

NOTES:

Coherence in mean wind direction by the GENERAL coherence model is applied to the HARRIS and DAVENPORT wind spectra. Coherence lateral and vertical to the mean wind direction is applied to the PANOFSKY LATERAL and PANOFSKY VERTICAL wind spectra

The GENERAL coherence model is given in Section 2.1.4

EXAMPLES:

```
DEFINE WIND-FATIGUE COHERENCE-COEFFICIENTS 16.0 16.0 8.0 16.0 16.0 8.0 16.0
       16.0 8.0
```

DEFINE WIND-FATIGUE WIND-DIRECTIONS

...	WIND-DIRECTIONS	(	ONLY	dir	)	depth

PURPOSE:

To define mean wind directions to be included in the wind fatigue calculation.

PARAMETERS:

ONLY	Mandatory attribute
( )	Mandatory parentheses
dir	Mean wind direction in degrees transferred from the SIN file. Maximum 6 directions may be selected from the list.
depth	Water depth transferred from the SIN file. Only one depth can be selected.

NOTES:

Wind directions and water depths are defined in Wajac where the static wind loads are calculated.The same wind directions apply to all water depths. Wind directions of one water depth can be processed in a same run. Up to six wind directions can handled in a wind fatigue analysis.

The wind directions of the first water depth specified in Wajac are read automatically from the Results Interface File (R#.SIN file). If another the water depth or wind directions are requested, the present command must be executed. In graphic mode wind directions and water depths are selected from given lists in the dialogue box.

EXAMPLES:

```
DEFINE WIND-FATIGUE WIND-DIRECTIONS ( ONLY 0.0 30.0 60.0 90.0 120.0 150.0 ) 0.0
```

DEFINE WIND-FATIGUE WIND-SPEEDS

...	WIND-SPEEDS	(	ONLY	speed	)

PURPOSE:

To define the hourly mean wind speeds to be included in the wind fatigue calculation. They correspond to wind speed values at a height of 10 m above the ground or sea level.

The wind speeds apply for all mean wind directions included in the wind fatigue calculation.

PARAMETERS:

ONLY	Mandatory attribute
( )	Mandatory parentheses
speed	Mean wind speed. Enter maximum 12 speeds.

EXAMPLES:

```
DEFINE WIND-FATIGUE WIND-SPEEDS ( ONLY 10.0 15.0 20.0 25.0 30.0 )
```

DEFINE WIND-FATIGUE WIND-PROBABILITIES

...	WIND-PROBABILITIES	EQUAL-PROBABILITIES	...
		VARIABEL-PROBABILITIES	...

...	prob			
...	(ONLY	$prob(1,1)$, $prob(1,2)$, ... ,	$prob(i,j)$, ... , $prob(ndir, nspd)$	)

PURPOSE:
To define annual probability distribution associated with specified wind speeds and wind directions. The probability distribution describes the ratio or percentage of time a certain wind speed is likely to occur.

PARAMETERS:

EQUAL-PROBABILITIES	The annual probabilities are equal for all wind speeds and all wind directions
prob	Annual probability
VARIABEL-PROBABILITIES	The annual probabilities vary with wind speed and wind direction.
ONLY	Mandatory attribute
( )	Mandatory parentheses
$prob(i,j)$	Annual probability associated with wind speed j in wind direction i. nspd probabilities must be repeated ndir times, where nspd is the number of wind speeds and ndir is the number of wind directions that are requested. The probabilities for direction j should sum to either 1.0 or to the total probability that is associated with that direction.

NOTES:
For any given wind direction at any site, the time averaged (hourly average) wind speed at height 10 m, has a finite probability of lying within a selected band of speeds. This probability may be expressed as an annual probability, where the probability of occurrence is:

$$\text{Wind Probability} = \frac{\text{Number of hours within selected frequency band}}{\text{Number of hours in a year}}$$

If there is only one direction in the fatigue analysis, the probabilities of the direction should sum to 1.0; If there are multiple directions, the sum of probabilities of one direction should be the probability share that is associated with that direction among all directions. The total probabilities of all directions should be 1.

EXAMPLES:
If there are 6 wind speeds, such as:

```
DEFINE WIND-FATIGUE WIND-SPEEDS ( ONLY 3.0 9.0 14.0 18.0 22.0 27.0 )
```

When using equal-probability, the command can be:

```
DEFINE WIND-FATIGUE WIND-PROBABILITIES EQUAL-PROBABILITIES 0.25
```

The corresponding messages will be printed in MLG file, for example,

```
Wind direction 1: Sum of wind speed associated probabilities = 1.5
Wind direction 2: Sum of wind speed associated probabilities = 1.5
Wind direction 3: Sum of wind speed associated probabilities = 1.5
Wind direction 4: Sum of wind speed associated probabilities = 1.5
```

```
  All directions  : Sum of wind speed associated probabilities = 6.0
*
  Warning! Sum probability for all wind directions 6.0 is not 1.0. This
  must be taken into accounted when damage values are evaluated.
```

The warning means the sum of total probability is not 1.0. Certain correction or adjustment on damage is needed.

When using variable-probability, such as

```
DEFINE WIND-FATIGUE WIND-PROBABILITIES VARIABLE-PROBABILITIES ( ONLY
    0.0972 0.0502 0.0009 0.0010 0.0006 0.0002
    0.2340 0.1035 0.0006 0.0014 0.0009 0.0007
    0.2257 0.0630 0.0010 0.0054 0.0025 0.0009
    0.1340 0.0693 0.0021 0.0026 0.0018 0.0005 )
```

The corresponding messages is

```
  Wind direction 1: Sum of wind speed associated probabilities = 0.1501
  Wind direction 2: Sum of wind speed associated probabilities = 0.3411
  Wind direction 3: Sum of wind speed associated probabilities = 0.2985
  Wind direction 4: Sum of wind speed associated probabilities = 0.2103
  All directions  : Sum of wind speed associated probabilities = 1.0
```

This is recommended for multiple directions practice.

DEFINE WIND-FATIGUE DRAG-CORRECTION-FACTORS

. . .	DRAG-CORRECTION-FACTORS	EQUAL-FACTORS	. . .
		VARIABEL-FACTORS	. . .

. . .	factor			
. . .	(ONLY	$fact(1,1)$ . . . ,	$prob(i,j)$, . . . ,	$prob(ndir,nspd)$)

PURPOSE:
To defines drag coefficient correction factors associated with specified wind speeds and wind directions. These are factors applied to the member wind forces for each associated wind speed.

PARAMETERS:

EQUAL-FACTORS	The drag coefficient correction factors are equal for all wind speeds and all wind directions.
factor	Drag coefficient correction factor
VARIABEL-FACTORS	The drag coefficient correction factors vary with wind speed and for wind direction.
ONLY	Mandatory attribute
( )	Mandatory parentheses
$fact(i,j)$	Drag coefficient correction factor associated with wind speed j in wind direction i. nspd factors must be repeated ndir times, where nspd is the number of wind speeds and ndir is the number of wind directions that is requested.

NOTES:

In Framework Wind Fatigue module, the load attracted by a member at any wind speed is based on the reference wind loads for the reference wind profiles defined in Wajac. The reference wind forces are stored in the SIN file and the reference wind profile information are passed to Framework. In Framework's input, user needs to provide the wind speeds that contribute to the wind fatigue damage.

In Wajac, the wind force acting on a member is

$$F_n = \frac{1}{2}\rho A C_a(R_e)|V_n|V_n$$

where the air drag coefficient C_a is a function of Reynold's number, R_e. Without considering the change of drag coefficient, the ratio of wind force magnitude is in the proportion of the square of wind speeds.

$$\frac{f_j}{f_0} \sim \frac{V_j^2}{V_0^2}$$

where f_j is the member wind forces applied in Framework due to j-th wind speed V_j, and f_0 is the member wind forces of reference wind speed V_0. However, to take account of variations in drag coefficients with changing Reynold's number, a drag coefficient correction factor C_{corr} is introduced.

$$f_j = f_0 \frac{V_j^2}{V_0^2} C_{corr}$$

The porper calculation of the drag coefficient correction factor requires the user to run a number of static wind load analysis in Wajac at several wind speeds, obtain the base shears, and get the ratios between the base shear of j-th wind speed over that of the reference wind speed. This does not accurately portray the drag coefficient of every individual member but does provide a means to ensure that the total wind loading is reasonable. Using the drag correction factors can avoid the overestimate of wind loading at high wind speeds.

If this command is not used, a constant factor 1.0 will be applied in the program by default.

EXAMPLES:

```
DEFINE WIND-FATIGUE DRAG-CORRECTION-FACTORS VARIABLE-FACTORS ( ONLY
    1.0 0.90 0.80 0.75 0.70
    1.0 0.91 0.81 0.76 0.71
    1.0 0.92 0.82 0.77 0.72
    1.0 0.95 0.85 0.80 0.75 )
```

DEFINE WIND-FATIGUE BENT-CAN-DAMAGE

...	BENT-CAN-DAMAGE	ON
		OFF

PURPOSE:

To switch OFF/ON damage calculation of bent cans.

PARAMETERS:

ON	Switch on (default).
OFF	Switch off.

NOTES:

None.

EXAMPLES:

```
DEFINE WIND-FATIGUE BENT-CAN-DAMAGE OFF
```

DEFINE WIND-FATIGUE VORTEX-PARAMETERS

...	VORTEX-PARAMETERS	denair	kinvis	addmas	strhal	transra	...

...	turbin	youngs	denstl	thcoat	dencoat	scfmdl

PURPOSE:

To define additional parameters for vortex shedding induced fatigue damage calculation. The parameters relate to physical properties of the air, the structure's material and the coating on the members.

The data are of relevance only when vortex shedding induced fatigue damage calculation is to be executed.

PARAMETERS:

denair — Density of air. Default = 1.225 (Kg/m^3)

kinvis — Kinematic viscosity of air. Default = $1.5*10^{-5}$ (m^2/sec)

addmas — Added mass coefficient for all members. Default = 1.0

strhal — Strouhal number for all members. Default = 0.2

transra — Transition between sub-critical and post-critical Reynolds' number ranges. Recommended values are as follows:

Material type	tranra	Reynolds' number transition
As new steel	4.0	1.18×10^5
Concrete	5.0	9.42×10^4
Old steel or chartek	7.0	6.73×10^4

Default = 4.0

turbin — Turbulence intensity ratio. Default = 0.1

youngs — Young's modulus of the structure's material. Default = $2.1*10^{11}$ (N/m^2)

denstl — Density of the structure's material. Default = 7380.0 (Kg/m^3)

thcoat — Thickness of the coating material on all members. Default = 0.0001 (m)

dencoat — Density of the coating material on all members. Default = 1245.0 (Kg/m^3)

scfmdl — SCF (stress concentration factor) to be applied at mid span of all members analysed by vortex shedding. Default = 1.6

EXAMPLES:

```
DEFINE WIND-FATIGUE VORTEX-PARAMETERS 1.225 0.000015 1.0 0.2 4.0 0.1 2.1E11 7380.
1.0E-04 1245. 1.6
```

DEFINE WIND-FATIGUE DEFAULT-MEMBER-FIXITIES

...	DEFAULT-MEMBER-FIXITIES	lowdeff	updeff	nstep

PURPOSE:

To define default lower and upper bound end fixities of all members and the number of fixity steps. The data are of relevance only when vortex shedding induced fatigue damage calculation is to be executed.

PARAMETERS:

lowdeff	Lower bound fixity. Range of valid value: 0.0 to 1.0. Default = 0.3
updeff	Upper bound fixity. Range of valid value: 0.0 to 1.0. Default = 0.3
nsteps	Number of fixity values to be investigated including the lower and upper bound values. Range of valid value: 1 to 5. Default = 1

EXAMPLES:

```
DEFINE WIND-FATIGUE DEFAULT-MEMBER-FIXITIES 0.2 0.8 5
```

DEFINE WIND-FATIGUE DEBUG-PRINT

...	DEBUG-PRINT	BUFFETING	OFF
			ON
		VORTEX	OFF
			ON

PURPOSE:
To switch OFF/ON debug print of buffeting and vortex shedding damage calculation.

PARAMETERS:

BUFFETING	Debug print of the buffeting damage calculation.
VORTEX	Debug print of vortex the shedding damage calculation.
OFF	Switch off (default).
ON	Switch on.

NOTES:
Output of the debug print is written to file `<runname>Debug.txt`.

Note that the debug print file may easily be tremendously big and the command should be used with care and mainly for small analysis cases where detailed inspection of the data is wanted.

EXAMPLES:

```
DEFINE WIND-FATIGUE DEBUG-PRINT BUFFETING-ON
DEFINE WIND-FATIGUE DEBUG-PRINT VORTEX-OFF
```

DELETE

DELETE	MATERIAL	name
	SECTION	
	CODE-CHECK-RESULTS	
	FATIGUE-CHECK-RESULTS	
	EARTHQUAKE-DAMPING-FUNCTION	
	EARTHQUAKE-SPECTRUM	
	WAVE-SPREADING-FUNCTION	
	WAVE-STATISTICS	
	FATIGUE-LOAD-SERIES	
	SN-CURVE	
	RING-STIFFENER	select
	WIND-FATIGUE	. . .

PURPOSE:
To delete data from database.

PARAMETERS:

MATERIAL	The command will delete a material from the database.
SECTION	The command will delete a section from the database.
CODE-CHECK-RESULTS	The command will delete a code check run from the database.
FATIGUE-CHECK-RESULTS	The command will delete a fatigue check run from the database.
EARTHQUAKE-DAMPING-FUNCTION	The command will delete an earthquake damping function from the database.
EARTHQUAKE-SPECTRUM	The command will delete an earthquake spectrum from the database.
WAVE-SPREADING-FUNCTION	The command will delete a wave spreading function from the database.
WAVE-STATISTICS	The command will delete wave statistics from the database.
FATIGUE-LOAD-SERIES	The command will delete fatigue load series from the database.
SN-CURVE	The command will delete a SN-curve from the database.
RING-STIFFENER	The command will delete assigned ring stiffeners from selected joints and braces.
WIND-FATIGUE	The command will delete wind fatigue data.
name	Name of the material, section or run name etc.
select	Selection of joints and braces for removal of assigned ring stiffeners.

EXAMPLE:

```
DELETE CODE-CHECK-RESULTS RUN-1
DELETE FATIGUE-LOAD-SERIES (ONLY  SR1)
```

DELETE WIND-FATIGUE

...	WIND-FATIGUE	BENT-CAN-SN-CURVE	...	ALL		
		BENT-CAN-SCF		SELECT	joint	sel-jnt
		VORTEX-DIMENSION		ALL		
				SELECT	mem-ber	sel-mem

PURPOSE:

To delete data related to the wind fatigue calculation.

PARAMETERS:

BENT-CAN-SN-CURVE	Delete bent can SN curves.
BENT-CAN-SCF	Delete bent can SCFs. All SCFs of specified joints are deleted.
VORTEX-DIMENSION	Delete vortex dimensions. All vortex dimensions of specified members are deleted.
ALL	Deletion performed for all relevant joints or members.
SELECT	Deletion performed for a selection of joints or members
joint	Name of joint that deletion shall be performed for. Valid alternatives are: ALL (for selecting all joints) or joint name (for selecting a single joint) or CURRENT (see command SELECT JOINTS).
sel-jnt	Select joints that deletion shall be performed for. For valid alternatives see command SELECT JOINTS.
member	Name of member that deletion shall be performed for. Valid alternatives are: ALL (for selecting all joints) or joint name (for selecting a single joint) or CURRENT (see command SELECT MEMBERS).
sel-mem	Select members that deletion shall be performed for. For valid alternatives see command SELECT MEMBERS.

EXAMPLES:

```
DELETE WIND-FATIGUE BENT-CAN-SN-CURVE SELECT CURRENT
DELETE WIND-FATIGUE BENT-CAN-SCF ALL
DELETE WIND-FATIGUE VORTEX-DIMENSION SELECT 4
```

DISPLAY

DISPLAY	CODE-CHECK-RESULTS	subcommands	data
	DIAGRAM		
	EARTHQUAKE-SPECTRUM		
	FATIGUE-CHECK-RESULTS		
	JOINT		
	LABEL		
	MEMBER		
	PRESENTATION		
	SHAPE		
	SN-CURVE		
	SN-CURVE-SORTED		
	STABILITY		
	SUPERELEMENT		
	WAVE-SPREADING-FUNCTION		
	Stress Transfer Function		

PURPOSE:
To present models and associated data graphically.

PARAMETERS:

CODE-CHECK-RESULTS	Displays the usage factors for a code check (punch, yield, stability or hydrostatic check) on the members for a given run name.
DIAGRAM	Display diagram of member forces.
EARTHQUAKE-SPECTRUM	Display an earthquake spectrum.
FATIGUE-CHECK-RESULTS	Displays the usage factors for a stochastic or deterministic fatigue check on the members for a given run name.
JOINT	Displays joints in the current selected set.
LABEL	Turns display of labels on members or joints on/off.
MEMBER	Displays members in the current selected set.
PRESENTATION	Switch between wireframe and hidden surface display.
SHAPE	Displays deformed shape diagram.
SN-CURVE	Display one or more SN-curves.
STABILITY	Turns labels showing stability parameters on/off.
SUPERELEMENT	Displays the finite element model for the current super element.
WAVE-SPREADING-FUNCTION	Displays a wave spreading function.
Stress Transfer Function	Displays transfer functions if set in the Define Fatigue Dump command.

All subcommands and data are fully explained subsequently as each command is described in detail.

DISPLAY CODE-CHECK-RESULTS

...	CODE-CHECK-RESULTS	run	loadcase	...	MAX-USAGE-FACTOR	...
			WORST-LOADCASE		EACH-POSITION	

...	ABOVE	limit	
	BELOW	limit	
	BETWEEN	limit1	limit2

PURPOSE:

Displays the usage factors for a code check (punch, yield, stability, member, cone or hydrostatic check) on the members for a given run name.

PARAMETERS:

run	Run name.
loadcase	Selected load case.
WORST-LOADCASE	Worst load case within run for each member.
MAX-USAGE-FACTOR	Present only the maximum UF along the member.
EACH-POSITION	Present the UF calculated at each check position.
ABOVE	Present usage factors above the given limit.
BELOW	Present usage factors below the given limit.
BETWEEN	Present usage factors between the given limits.
limit / limit1 / limit2	Limit usage factor for display of numerical values on members.

NOTES:

For alternative ABOVE and BELOW: If the value of usage factor is greater than 1.0, the member will be shown in red colour. If it is in between limit, and 1.0 it will be yellow, otherwise it will be green. Default limit is 0.8 for ABOVE and 0.5 for BELOW.

For alternative BETWEEN: If the value of usage factor is greater than limit2, the member will be shown in red colour. If it is in between limit1 and limit2 it will be yellow, otherwise it will be green. Default limits are 0.5 and 0.8.

It is also possible to use more than just three colours when displaying the results. See the command DEFINE PRESENTATION DISPLAY.

When EACH-POSITION is used in combination with WORST-LOADCASE the maximum usage factor at each position searching the investigated loadcases are given. For couples of check positions defined closer to each other than 0.05 times the member length, only the highest usage factor of the two is reported

The EACH-POSITION option is not valid when displaying results from a pure STABILITY code check.

See also:

```
PRINT CODE-CHECK-RESULTS...
DEFINE PRESENTATION DISPLAY ...
```

EXAMPLES:

```
DISPLAY CODE-CHECK-RESULTS RUN01 WORST MAX-USAGE-FACTOR
```

DISPLAY DIAGRAM

...	DIAGRAM	load-case	PX	...	rel-fac	
			QY			
			QZ			
			MX		ABSOLUTE	abs-fac
			MY			
			MZ			

PURPOSE:

Present diagram of member forces.

PARAMETERS:

load-case	Load case selected.
PX	Axial force
QY	Shear force in the direction of member local y-axis.
QZ	Shear force in the direction of member local z-axis.
MX	Torsional moment.
MY	Moment about member local y-axis.
MZ	Moment about member local z-axis.
rel-fac	Relative scale factor (multiplied with computed default).
abs-fac	Absolute scale factor (multiplied with absolute force/moment values).

NOTES:

In order to ease interpretation, intervals with a positive force or moment is shown red, and negative is blue on a colour display.

The use of an ABSOLUTE scale factor should be done after the default value is known (is printed as A-factor at the top of a display).

It is also possible to display (and plot) force diagrams showing force envelopes. The envelopes are drawn for selected members based on active selection of load cases. Use ENVELOPE as load case name. Prior to executing this command a selection of members and active load cases must be defined through the existing selection alternatives. The name ENVELOPE is hence used as a command input in DISPLAY DIAGRAM and should not be used as a load case name in a preprocessor or as a load combination name.

See also:

`DEFINE PRESENTATION FORCE...`

EXAMPLES:

```
DISPLAY DIAGRAM 1 PX 1.0
```

DISPLAY EARTHQUAKE-SPECTRUM

...	EARTHQUAKE-SPECTRUM	name

PURPOSE:

Present an earthquake spectrum

PARAMETERS:

name Earthquake spectrum selected.

NOTES:

The spectrum will always be shown in log-log scale.

EXAMPLES:

```
DISPLAY EARTHQUAKE-SPECTRUM API1
```

DISPLAY FATIGUE-CHECK-RESULTS

...	FATIGUE-CHECK-RESULTS	run	MAX-USAGE-FACTOR	...
			ACCUMULATED-DAMAGE	
			FATIGUE-LIFE	
			LIFE-EACH-POSITION	

...	ABOVE	limit	
	BELOW	limit	
	BETWEEN	limit1	limit2

PURPOSE:

Displays the usage factors for a stochastic or deterministic fatigue check on the members for a given run name.

PARAMETERS:

run	Run name
MAX-USAGE-FACTOR	Max usage factor along the member is presented. This corresponds to the accumulated fatigue damage at the worst joint of the member
ACCUMULATED-DAMAGE	Accumulated damage values are presented.
FATIGUE-LIFE	Fatigue lives are presented.
LIFE-EACH-POSITION	Fatigue lives are presented at each check position.
limit / limit1 / limit2	Limit usage factor for display of numerical values on members.

NOTES:

For alternative ABOVE and BELOW: If the value of usage factor is greater than 1.0, the member will be shown in red color. If it is in between limit, and 1.0 it will be yellow, otherwise it will be green. Default limit is 0.8 for ABOVE and 0.5 for BELOW.

For alternative BETWEEN: If the value of usage factor is greater than limit2, the member will be shown in red color. If it is in between limit1 and limit2 it will be yellow, otherwise it will be green. Default limits are 0.5 and 0.8.

The specification of limit will only affect colour display/plotting. No changes are observed when using in monochrome graphics devices.

The command will display only the elements that have results and that are within the current MEMBER selection. Use the command SELECT MEMBER ALL in advance to ensure that all results from the run is presented.

The LIFE-EACH-POSITION is only active when the color coding is switched on (see DEFINE PRESENTATION DISPLAY COLOR-CODING ON). For couples of check positions defined closer to each other than 0.05 times the member length, only the lowest fatigue life of the two is reported

See also:

```
PRINT FATIGUE-CHECK-RESULTS...
DEFINE PRESENTATION DISPLAY COLOR-CODING ON
```

EXAMPLES:

```
DISPLAY FATIGUE-CHECK-RESULTS RUN02 MAX-USAGE-FACTOR 0.8
```

DISPLAY LABEL

...	LABEL	MEMBER-NAMES	status	
		SECTION-NAMES	status	
		MATERIAL-NAMES	status	
		JOINT-NAMES	status	
		CHORD-AND-BRACE	status	
		JOINT-TYPE	status	
		JOINT-RING-STIFFENER	status	
		JOINT-SYMBOL	status	
		MEMBER-Z-AXIS	status	
		DIAGRAM-VALUES	status	limit

PURPOSE:

Turns display of labels on members or joints on/off.

PARAMETERS:

MEMBER-NAMES	Label the member names when members are displayed and element numbers when the superelement is displayed.
SECTION-NAMES	Label the section names (member display only).
MATERIAL-NAMES	Label the material names (member display only).
JOINT-NAMES	Label the joint names.
CHORD-AND-BRACE	Label the chord and brace status of each end of members (joint display only).
JOINT-TYPE	Label the joint type at each end of members (joint display only).
JOINT-RING-STIFFENER	Label assignment of ring stiffeners at each end of members (joint display only).
JOINT-SYMBOL	Draw a symbol indicating location of joints.
MEMBER-Z-AXIS	Draw a symbol indicating member local z-axis.
DIAGRAM-VALUES	Add to display the diagram values when displaying diagram of member forces and moments.
status	Turn label ON or OFF.
limit	The threshold (absolute value, i.e. sign independent) for values to be printed.

NOTES:

In CHORD-AND-BRACE display:	C= chord, B= brace, L= local chord, N=non-pipe, P= probably a pile, S= support or free end.

The z-axis indicator is positioned at one quarter of the member length measured from the member start node. Hence the label will then also indicate the positive x-direction of the members.

EXAMPLES:

```
DISPLAY LABEL MEMBER-NAMES ON
```

DISPLAY MEMBER

...	MEMBER

PURPOSE:

Displays members in the current selected set.

PARAMETERS:

None

NOTES:

See also:

```
PRINT MEMBER...
SELECT MEMBERS...
```

EXAMPLES:

```
DISPLAY MEMBER
```

DISPLAY PRESENTATION

...	PRESENTATION	WIREFRAME	
		HIDDEN-SURFACE	resolu-tion

PURPOSE:

Switch between wireframe and hidden surface display.

PARAMETERS:

WIREFRAME	Line display.
HIDDEN-SURFACE	Hidden surface display.
resolution	Numerical factor defining resolution for the hidden-surface display (default value is 1.0, a value of 0.1 will give a coarse resolution).

NOTES:

The HIDDEN-SURFACE display is only available in the DISPLAY MEMBER option.

The HIDDEN-SURFACE display requires a high performance (grayscale or colour) workstation or terminal running the X windows system.

EXAMPLES:

```
DISPLAY PRESENTATION HIDDEN-SURFACE 0.1
```

DISPLAY SHAPE

...	SHAPE	DEFORMED	load-case	rel-fac		phase-angle	CUBIC
		OVERLAY		ABSOLUTE	abs-fac		LINEAR

PURPOSE:

Present deformed shape plot.

PARAMETERS:

DEFORMED	Only the deformed shape is shown
OVERLAY	Both the original shape and the deformed shape is shown.
load-case	Load case selected.
rel-fac	Relative scale factor (multiplied with computed default).
ABSOLUTE	Absolute scale factor follows.
abs-fac	Absolute scale factor (multiplied with absolute force/moment values).
phase-angle	Phase angle for the selected load case. The value used has no effect on static / quasi-static load cases.
CUBIC	with cubic shape functions.
LINEAR	Display shape with linear shape functions.

NOTES:

The use of an ABSOLUTE scale factor should be done after the default value is known (is printed as A-factor at the top of a display).

EXAMPLES:

```
DISPLAY SHAPE DEFORMED 1 0.0 1.0
```

DISPLAY SN-CURVE

...	SN-CURVE	name *

PURPOSE:

Present one or more SN-curves.

PARAMETERS:

name Name of SN-curves selected.

NOTES:

The SN-curves will always be shown in log-log scale.

The library curves use the units Newton and meter and should only be displayed together with user defined curves having the same units.

EXAMPLES:

```
DISPLAY SN-CURVE DNV-X
```

DISPLAY SN-CURVE-SORTED

.. .	SN-CURVE-SORTED	ABS		(	ONLY	snname+)
		API				
		DNV	OLDER			
			RP-C203-2010			
		DOE				
		HSE				
		NORSOK				
		NS				
		USER				
		ALL				

PURPOSE:

To display SN-curves.

PARAMETERS:

ABS	Selection of ABS SN-curves
API	Selection of API SN-curves
DNV	Selection of DNV SN-curves
OLDER	Selection of DNV SN-curves older than 2010
RP-C203-2010	Selection of DNV SN-curves of Recommended Practice DNV-RP-C203, April 2010
DOE	Selection of DOE SN-curves
HSE	Selection of HSE SN-curves
NORSOK	Selection of NORSOK SN-curves
NS	Selection of Norwegian Standard NS 3472 SN-curves
USER	Selection of user defined SN-curves
ALL	Selection of all available SN-curves
snname+	Name of SN-curve
ONLY	Mandatory attribute
( )	Mandatory parentheses

NOTES:

This SN-curves will always be displayed in a log-log scale.

EXAMPLES:

```
DISPLAY SN-CURVE-SORTED DNV OLDER ( ONLY DNV-X DNVC-I DNVC-II )
DISPLAY SN-CURVE-SORTED ALL ( ONLY ABS-B-A DNV-X DNV2010_B1-AIR HSE-C-CP )
```

DISPLAY STABILITY

...	STABILITY	BUCKLING-LENGTH-Y	status
		BUCKLING-LENGTH-Z	
		BUCKLING-FACTOR-Y	
		BUCKLING-FACTOR-Z	
		BUCKLING-CURVE-Y	
		BUCKLING-CURVE-Z	

PURPOSE:

Turns display of labels showing buckling parameters on/off.

PARAMETERS:

BUCKLING-LENGTH-Y	Label the assigned buckling length about local y-axis.
BUCKLING-LENGTH-Z	Label the assigned buckling length about local z-axis.
BUCKLING-FACTOR-Y	Label the assigned buckling factor about local y-axis.
BUCKLING-FACTOR-Z	Label the assigned buckling factor about local z-axis.
BUCKLING-CURVE-Y	Label the assigned buckling curve about local y-axis.
BUCKLING-CURVE-Z	Label the assigned buckling curve about local z-axis.
status	Turn label ON or OFF.

NOTES:

Not more than two parameters can be switched on simultaneously.

EXAMPLES:

```
DISPLAY STABILITY BUCKLING-LENGTH-Y ON
```

DISPLAY SUPERELEMENT

...	SUPERELEMENT

PURPOSE:

Displays the finite element model for the current superelement.

PARAMETERS:

None

NOTES:

See also:
`PRINT SUPERELEMENT`

EXAMPLES:

```
DISPLAY SUPERELEMENT
```

DISPLAY Stress Transfer Function

...	Stress Transfer Function

PURPOSE:
Displays the stress transfer functions for a selected member set.

PARAMETERS:

None

NOTES:
See Also:

`DEFINE FATIGUE-DUMP`

EXAMPLES:

```
Display Stress Transfer Function
```

FILE	OPEN
	TRANSFER
	INTERROGATE
	EXIT

PURPOSE:

To open a Results Interface File, transfer the geometry of a superelement to the Framework database or to exit the program.

PARAMETERS:

OPEN	To open a Results Interface File.
TRANSFER	To transfer the geometry and loads of a superelement to the Framework database.
INTERROGATE	Allow the user to read the superelement data from a Results Interface File without opening the file.
EXIT	Ends the Framework session.

FILE OPEN

...	OPEN	format	prefix	name

PURPOSE:

To open a Results Interface File

PARAMETERS:

format	Results Interface File format. At present the only valid alternative is SIN.
prefix	Results Interface File prefix.
name	Results Interface File name.

NOTES:

It is important to note that ONLY a direct access file with an extension.SIN may be read by Framework. If your Results Interface File is of any other format, use Prepost in order to convert it to a direct access file (.SIN).

This command does not transfer any information about the model, this is done using the FILE TRANSFER command.

EXAMPLES:

```
FILE OPEN SIN X108A R1
```

FILE TRANSFER

...	TRANSFER	sup-key	sup-name	loadset-name	loadset-text

PURPOSE:

To transfer the geometry and loads of a superelement to the Framework database.

PARAMETERS:

sup-key	Superelement (identified through a key) to be transferred into the Framework database file.
sup-name	User given name of the superelement transferred.
loadset-name	User given name to the loadcases present in the Results Interface File.
loadset-text	Text associated with the loadset name.

NOTES:

This command should only be issued after a FILE OPEN command.

At present ONLY one superelement may be transferred in to the Framework database file.

See also:

```
PRINT SUPERELEMENT
PRINT LOAD-SET
```

EXAMPLES:

```
FILE TRANSFER 1 JACKET WAVE_LOADS 'Design wave load 100 year return'
```

FILE INTERROGATE

...	INTERROGATE	pre-fix	nam e	for-mat

PURPOSE:

To read the superelement name without opening the file.

PARAMETERS:

prefix	Results Interface File prefix.
name	Results Interface File name.
format	Results Interface File format. At present the only valid alternative is SIN.

EXAMPLES:

```
FILE INTERROGATE X108A FRAMEWORK SIN
```

FILE EXIT

...	EXIT

PURPOSE:

To exit the program.

PARAMETERS

None

EXAMPLES:

```
FILE EXIT
```

PLOT

PLOT

PURPOSE:

To send last display to plot file. This requires that a DISPLAY command has been used previously.

PARAMETERS:

None

NOTES:

See also:

```
DISPLAY...
SET PLOT FORMAT...
SET PLOT FILE...
```

PRINT	ACCELERATION	subcommands	data
	ACTIVE-SETTINGS		
	CHORD-AND-BRACE		
	CODE-CHECK-RESULTS		
	CODE-OF-PRACTICE		
	DATABASE-HISTORY		
	DEFLECTION		
	DISPLACEMENT		
	EARTHQUAKE-CHECK-TYPE		
	EARTHQUAKE-DAMPING-FUNCTION		
	EARTHQUAKE-SPECTRUM		
	FATIGUE-CHECK-RESULTS		
	FATIGUE-CHECK-TYPE		
	FORCE		
	HYDROSTATIC-DATA		
	JOINT		
	LOAD-CASE		
	LOAD-SET		
	LRFD-RESISTANCE-FACTORS		
	MATERIAL		
	MEMBER		
	MODE-SHAPE		
	MODAL-MASS		
	RUN		
	SECTION		
	SN-CURVE		
	SN-CURVE-SORTED		
	STRESS		
	SUPERELEMENT		
	SUPPORT-REACTIONS		
	VELOCITY		
	WAVE-DIRECTIONS		
	WAVE-LOAD-FACTOR		
PRINT	WAVE-SPREADING-FUNCTION	subcommands	data
	WAVE-STATISTICS		
	WIND-FATIGUE		

PURPOSE:

To print data and results.

PARAMETERS:

ACCELERATION To print joint accelerations.

ACTIVE-SETTINGS	To print active settings for various option switches.
CHORD-AND-BRACE	To print chord and brace data for selected joints.
CODE-CHECK-RESULTS	To print results from a code check run.
CODE-OF-PRACTICE	To print the current code of practice.
DATABASE-HISTORY	To print the database history.
DEFLECTION	To print the member deflections.
DISPLACEMENT	To print joint displacements.
EARTHQUAKE-CHECK-TYPE	To print constant settings for the earthquake check.
EARTHQUAKE-DAMPING-FUNCTION	To print earthquake damping function.
EARTHQUAKE-SPECTRUM	To print earthquake spectra.
FATIGUE-CHECK-RESULTS	To print results from a fatigue check.
FATIGUE-CHECK-TYPE	To print constant settings for fatigue analysis.
FORCE	To print members forces.
HYDROSTATIC-DATA	To print constant settings for hydrostatic collapse check.
JOINT	To print joint data.
LOAD-CASE	To print loadcase data.
LOAD-SET	To print the current loadset.
LRFD-RESISTANCE-FACTORS	To print the current setting for LRFD load resistance factors.
MATERIAL	To print material data.
MEMBER	To print members data.
MODE-SHAPE	To print mode shapes.
MODAL-MASS	To print effective modal mass.
RUN	To print information about all runs.
SECTION	To print section data.
SN-CURVE	To print data related to an SN curve.
SN-CURVE-SORTED	To print data related to an SN curve sorted in groups.
STRESS	To print members stresses.
SUPERELEMENT	To print main superelement data.
SUPPORT-REACTIONS	To print support reactions for result cases for selected joints and loadcases.
VELOCITY	To print joint velocities.
WAVE-DIRECTIONS	To print fatigue wave directions and environmental data assigned.
WAVE-LOAD-FACTORS	To print fatigue wave load factors assigned to wave directions.
WAVE-SPREADING-FUNCTION	To print data for a wave spreading function.
WAVE-STATISTICS	To print data related to a wave scatter diagram.
WIND-FATIGUE	To print data related to a wind fatigue calculations.

All subcommands and data are fully explained subsequently as each command sequence is described in detail.

PRINT ACCELERATION

...	ACCELERATION	sel-jnt	sel-lcs

PURPOSE:

To print joint accelerations for selected joints and loadcases.

PARAMETERS:

sel-jnt	Joints for which accelerations shall be printed. For valid alternatives see command SELECT JOINT.
sel-lcs	Loadcases for which acceleration shall be printed. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

See also:

```
PRINT DISPLACEMENT...
PRINT VELOCITY...
```

EXAMPLES:

```
PRINT ACCELERATION ( ONLY 200 400 ) ALL
```

PRINT ACTIVE-SETTINGS

...	ACTIVE-SETTINGS

PURPOSE:

To print the current setting for various options dependent on the selected code of practice

PARAMETERS:

None

NOTES:

The information printed is also dendent on which of the code of practice that is active. See command DEFINE CODE-OF-PRACTICE-VERSION.

EXAMPLES:

```
PRINT ACTIVE-SETTINGS
```

PRINT CHORD-AND-BRACE

...	CHORD-AND-BRACE	sel-jnt

PURPOSE:

To print chord and brace data for selected joints.

PARAMETERS:

sel-jnt — Joints for which chord and brace data to be printed. For valid alternatives see command SELECT JOINTS.

NOTES:

See also:

`ASSIGN CHORD...`

EXAMPLES:

```
PRINT CHORD-AND-BRACE ONLY 2
```

PRINT CODE-CHECK-RESULTS

...	CODE-CHECK-RESULTS	name	...

	WORST-LOADCASE			
	MEMBER-AND-WORST-LOADCASE			
	SELECTED-MEMBERS-AND-LOADCASES	sel-mem	sel-lcs	
...	JOINT-AND-WORST-LOADCASE			...
	WORST-LOADCASE-ALL-BRACES			
	BRACE-AND-WORST-LOADCASE			
	SELECTED-JOINTS-AND-LOADCASES	sel-jnt	sel-lcs	

...	FULL	...	ABOVE	limit	
	SUMMARY		BELOW	limit	
			BETWEEN	limit1	limit2

PURPOSE:

To print results from a code check run. This command must be used in order to print results from a yield, stability, punch or hydrostatic-check.

PARAMETERS:

name	Name of run for which results are to be printed.
WORST-LOADCASE	The print should contain only the worst loadcase for each member or joint. The print is sorted with decreasing usage-factors and results are printed for only the worst position.
MEMBER-AND-WORST-LOADCASE	The print should contain only the worst loadcase for each member. The print is sorted on member names and results are printed for only the worst position.
SELECTED-MEMBERS-AND-LOADCASES	The print should contain selected members and loadcases. The print is sorted on member names and results are printed for all positions checked.
JOINT-AND-WORST-LOADCASE	The print should contain only the worst loadcase for each joint. The print is sorted on joint names and results are printed for the worst brace at the joint.
WORST-LOADCASE-ALL-BRACES	Print maximum utilisation for all braces entering the joint. The results is sorted with decreasing utilisations.
BRACE-AND-WORST-LOADCASE	Print maximum utilisation for all braces entering the joint. Order the results according to joints and incoming braces.
SELECTED-JOINTS-AND-LOADCASES	The print should contain selected joints and loadcases. The print is sorted on joint names and results are printed for all braces at the joint.
sel-mem	Members to include in the print. For valid alternatives see command SELECT MEMBERS.
sel-lcs	Loadcases to include in the print. For valid alternatives see command SELECT LOAD-CASE.
sel-jnt	Joints to include in the print. For valid alternatives see command SELECT JOINT.
FULL	A full print of results is required.
SUMMARY	A summary print of results is required.

ABOVE	Results shall only be printed provided that the usage factor is above a user specified threshold value.
BELOW	Results shall only be printed provided that the usage factor is below a user specified threshold value.
BETWEEN	Results shall only be printed provided that the usage factor is between a user specified threshold values.
limit / limit1 / limit2	Threshold values for which results will be printed.

NOTES:

For a yield, stability or hydrostatic check run the valid alternatives are as follows: WORST-LOADCASE, MEMBER-AND-WORST-LOADCASE and SELECTED-MEMBERS-AND-LOADCASES.

For a punch check run the valid alternatives are as follows: WORST-LOADCASE, JOINTS-AND-WORST-LOADCASE and SELECTED-JOINTS-AND-LOADCASES

For a yield, stability or hydrostatic check, the WORST-LOADCASE option reports for a member, the worst usage factor obtained and the corresponding loadcase that produced it. In this print, code check results for a member are only printed once. Members are printed in an order of decreasing usage factors.

For a punch check, the WORST-LOADCASE option reports for a joint, the brace at that joint with the worst usage factor and the corresponding loadcase that produced it. In this print, code check results for a brace are only printed once. Braces are printed in order of decreasing usage factors.

The commands MEMBER/JOINT-AND-WORST-LOADCASE will print only the members/joints that have results and that are within the current MEMBER/JOINT selection. Use the command SELECT MEMBER/JOINT ALL in advance to ensure that all results from the run are presented.

See also:

```
DISPLAY CODE-CHECK-RESULTS
DISPLAY FATIGUE-CHECK-RESULTS
DEFINE PRESENTATION RESULTS PRINT-MEMBER-RESULT
DEFINE PRESENTATION RESULTS PRINT-MEMBER-SUMMARY
PRINT FATIGUE-CHECK-RESULTS...
PRINT RUN
RUN...
```

EXAMPLES:

```
SELECT MEMBER ONLY 33115
PRINT CODE-CHECK-RESULTS RUN01 MEMBER-AND-WORST-LOADCASE SUMMARY ABOVE 0.5
```

PRINT CODE-OF-PRACTICE

...	CODE-OF-PRACTICE

PURPOSE

To print the current code of practice which will be used when a yield, stability, punch or hydrostatic check run is performed.

PARAMETERS:

None

NOTES:

See also:

`SELECT CODE-OF-PRACTICE`

EXAMPLES:

```
PRINT CODE-OF-PRACTICE
```

PRINT DEFLECTION

...	DEFLECTION	CODE-CHECK-POSITIONS		...	TOTAL	.. .	GLOBAL	...
		EVEN-DISTRIBUTED	num-ber		RIGID		LOCAL	
					RELATIVE			

...	sel-mem	sel-lcs

PURPOSE:

To calculate and print member deflections for selected members and loadcases. The deflections are basically the same as the nodal displacements but seen from the perspective of the members rather than the nodes:

- TOTAL deflection is found by quadratic interpolation between the end joint displacements.
- RIGID deflection constitute a straight line between the displaced end joints, i.e. no bending stresses.
- RELATIVE deflection is the deformation yielding the bending stresses.

PARAMETERS:

CODE-CHECK-POSITIONS	The deflections in the code-check-positions are printed.
EVEN-DISTRIBUTED	The deflections in a number of even distributed points along the member are printed.
number	Number of points along member.
TOTAL	The total deflections are printed.
RIGID	The deflections for a member considered as a rigid body are printed.
RELATIVE	The difference between the total deflections and the rigid body deflections are printed.
GLOBAL	The deflections are with respect to the global coordinate system.
LOCAL	The deflections are with respect to the local coordinate system
sel-mem	Members for which deformation shall be printed. For valid alternatives see command SELECT MEMBER.
sel-lcs	Loadcases for which deformation shall be printed. For valid alternatives see command SELECT LOAD-CASE.

EXAMPLES:

```
PRINT DEFLECTION CODE-CHECK-POSITIONS TOTAL GLOBAL 33317 1
```

PRINT DISPLACEMENT

...	DISPLACEMENT	sel-jnt	sel-lcs

PURPOSE:

To print joint displacements for selected joints and loadcases.

PARAMETERS:

sel-jnt	Joints for which displacements shall be printed. For valid alternatives see command SELECT JOINT.
sel-lcs	Loadcases for which displacements shall be printed. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

See also:

```
PRINT ACCELERATION...
PRINT VELOCITY...
```

EXAMPLES:

```
PRINT DISPLACEMENT GROUP 10 90 10 ALL
```

PRINT EARTHQUAKE-CHECK-TYPE

...	EARTHQUAKE-CHECK-TYPE

PURPOSE:

To print constant settings for the earthquake check.

PARAMETERS:

None

NOTES:

See also:
`SELECT EARTHQUAKE-CHECK-TYPE ...`

EXAMPLES:

```
PRINT EARTHQUAKE-CHECK-TYPE
```

PRINT EARTHQUAKE-DAMPING-FUNCTION

...	EARTHQUAKE-DAMPING-FUNCTION	damp*

PURPOSE:

To print earthquake damping function

PARAMETERS:

damp A selection of damping functions.

NOTES:

See also:

```
ASSIGN EARTHQUAKE-DAMPING-FUNCTION...
CREATE EARTHQUAKE-DAMPING-FUNCTION...
```

EXAMPLES:

```
PRINT EARTHQUAKE-DAMPING-FUNCTION *
```

PRINT EARTHQUAKE-SPECTRUM

...	EARTHQUAKE-SPECTRUM	spectr *

PURPOSE:

To print earthquake spectra.

PARAMETERS:

spectr A selection of earthquake spectra.

NOTES:

See also:

```
ASSIGN EARTHQUAKE-SPECTRUM ...
CREATE EARTHQUAKE-SPECTRUM ...
```

EXAMPLES:

```
PRINT EARTHQUAKE-SPECTRUM *
```

PRINT EARTHQUAKE-BASE-LOADS

...	EARTHQUAKE-BASE-LOADS	static	modal	jointwise	ALL X Y Z	ORIGIN or (x,y,z)

PURPOSE:
To output the total modal combination of base responses to earthquake excitations.

PARAMETERS:

static	Option to include base reactions of basic static load cases. DEFAULT=OFF.
modal	Option to include base reactions of mode shape resultcases. DEFAULT=ON.
jointwise	Option to print the reactions for every joint with fixed boundary condition or spring support. DEFAULT=OFF.
X	Earthquake excitation shall be applied in the global X-direction.
Y	Earthquake excitation shall be applied in the global Y-direction.
Z	Earthquake excitation shall be applied in the global Z-direction.
ALL	Earthquake excitation shall be applied in all three global directions.
ORIGIN	The option is to sum the moments to the origin (0,0,0) of the superelement.
(x,y,z)	The coordinate of user specified point to which the moment is summed.

NOTES:
The report consists of the static and modal base reactions, the modal response to earthquake excitations, and the total modal combination of base responses.

The base reactions are summerized from all supported joints. The joints of fixed boundary condition and spring supports are considered. The reaction forces at a joint are calculated as the balancing force resultant contributed from all connected beam elements to the joint. The point loads at the node are included. The total base reaction is a summation of all joint reactions. The Beam element with 2 nodes is considered only. The forces and moments on each element end connected to the joint are transformed to the global coordinate system and then summed up. In the total moment reactions, the moments around the Global axes are accumulated from all contributing joints, with the moment contributed from shear forces included. The “Global axes” means the coordinate system at the origin of the superelement. Alternatively, a user specified point to which the moments are summed can be defined as the “Reactions Center”. User specified Local coordinate system is not supported.

The modal response to earthquake excitation is calculated according to the response spectrum analysis method. The total base response is the modal combination of the base response of all selected modes. To get the modal responses and modal combination, the earthquake spectrum, damping function for earthquake must be input in advance. The modal combination rule of the modal base reactions applies the same rule specified in command `SELECT EARTHQUAKE-CHECK-TYPE`. The default modal combination rule is the “CQC” method. See Section 3.18.2 for more details.

If the excitations from all 3 global directions are applied, the total base responses are combined as the square root of the sum of square of 3 directional results.

See also:

```
SELECT EARTHQUAKE-CHECK-TYPE
CREATE EARTHQUAKE-DAMPING-FUNCTION
```

```
CREATE EARTHQUAKE-SPECTRUM
RUN EARTHQUAKE-CHECK
```

EXAMPLE:

```
PRINT EARTHQUAKE-BASE-LOADS OFF ON OFF ALL 0. 0. 0.
PRINT EARTHQUAKE-BASE-LOADS OFF ON ON X ORIGIN
PRINT EARTHQUAKE-BASE-LOADS OFF ON OFF Y 0. 0. -55.
```

PRINT FATIGUE-CHECK-RESULTS

...	FATIGUE-CHECK-RESULTS	run-name	...

...	WORST-USAGE-FACTOR			...	FULL
	SELECTED-MEMBERS	sel-mem			SUMMARY
	JOINT	SELECTED-JOINTS	sel-jnt		

...	ABOVE	limit	
	BELOW	limit	
	BETWEEN	limit1	limit2

PURPOSE:

To print results from a fatigue check. This command must be used in order to print results from a deterministic or stochastic fatigue run.

PARAMETERS:

run-name	Name of run for which results are to be printed.
WORST-USAGE-FACTOR	Prints the position with the worst usage factor for each member, sorted in order of descending usage factors.
SELECTED-MEMBERS	Prints the usage factor for all positions checked for selected members.
sel-mem	Members to include in the print. For valid alternatives see command SELECT MEMBERS.
JOINT	Print for brace ends connected to joints.
SELECTED-JOINTS	Print for selected joints.
sel-jnt	Joints to include in the print. For valid alternatives see command SELECT JOINTS.
FULL	A full print of results is required.
SUMMARY	A summary print of results is required.
ABOVE	Results shall only be printed provided that the usage factor is above a user specified threshold value.
BELOW	Results shall only be printed provided that the usage factor is below a user specified threshold value.
BETWEEN	Results shall only be printed provided that the usage factor is between the user specified threshold values.
limit / limit1 / limit2	Threshold values for which results will be printed.

NOTES:

The JOINT alternative is available for tubular joints only.

The print table for JOINT alternative will give erroneous results if any assignments are altered after the fatigue run.

See also:

```
DISPLAY FATIGUE-CHECK-RESULTS
PRINT RUN
```

EXAMPLES:

```
PRINT FATIGUE-CHECK-RESULTS RUN01 WORST-USAGE-FACTOR SUMMARY ABOVE 0.5
```

PRINT FATIGUE-CHECK-TYPE

...	FATIGUE-CHECK-TYPE

PURPOSE:

To print constant settings for the fatigue analysis.

PARAMETERS:

None

NOTES:

See also:
`DEFINE FATIGUE-CONSTANTS ...`

EXAMPLES:

```
PRINT FATIGUE-CHECK-TYPE
```

PRINT FORCE

...	FORCE	sel-mem	sel-lcs

PURPOSE:

To print member reactive forces for selected members and loadcases.

PARAMETERS:

sel-mem	Members for which forces shall be printed. For valid alternatives see command SELECT MEMBERS.
sel-lcs	Loadcases for which forces shall be printed. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

Forces and moments are printed for positions along the members corresponding to the predefined code check positions.

See also:

```
DEFINE PRESENTATION FORCE ...
ASSIGN POSITIONS ...
PRINT STRESS ...
```

EXAMPLES:

```
PRINT FORCE ONLY WITH-SECTION 1 ALL
```

PRINT HYDROSTATIC-DATA

...	HYDROSTATIC-DATA

PURPOSE:

To print constant settings for the hydrostatic collapse check.

PARAMETERS:

None

NOTES:

See also:
`DEFINE HYDROSTATIC-DATA ...`

EXAMPLES:

```
PRINT HYDROSTATIC-DATA
```

PRINT JOINT

...	JOINT	COORDINATES	sel-jnt
		PARAMETRIC-SCF	
		PUNCH-CHECK-DATA	
		RING-STIFFENERS	
		TAKE-OFF	
		MEMBER-FORCES	...
		REACTION-FORCES	...

PURPOSE:

To print joint coordinates or data related to punch and fatigue check.

PARAMETERS:

COORDINATES	That joint coordinates shall be printed.
PARAMETRIC-SCF	Assigned SCF's shall be printed. Parametric SCFs are calculated based on given rule and actual geometry and joint type. For Efthymiou parametric SCFs it is always the GEOMETRY Efthymiou model C SCFs that are printed.
PUNCH-CHECK-DATA	Data related to a punch check shall be printed.
RING-STIFFENERS	Data related to assigned ring stiffeners shall be printed.
TAKE-OFF	Material and section take-off data will be printed.
MEMBER-FORCES	To print the member end forces for a selection of joints and load cases. See separate description.
REACTION-FORCES	To print a table of joint reaction forces. See separate description.
sel-jnt	Joints for which data shall be printed. For valid alternatives see command SELECT JOINTS.

NOTES:

The eight SCF ratios reported when printing parametric SCFs at joints with assigned ring stiffeners are the following:

```
1 => SCF ratio for axial stress in the brace, saddle position
2 => SCF ratio for axial stress in the brace, crown position
3 => SCF ratio for in-plane bending in the brace (crown)
4 => SCF ratio for out-of-plane bending in the brace (saddle)
5 => SCF ratio for axial stress in the chord, saddle position
6 => SCF ratio for axial stress in the chord, crown position
7 => SCF ratio for in-plane bending in the chord (crown)
8 => SCF ratio for out-of-plane bending in the chord (saddle)
```

See also:

```
PRINT MEMBER...
```

EXAMPLES:

```
PRINT JOINT PUNCH-DATA ONLY 2
```

PRINT JOINT MEMBER-FORCES

...	MEMBER-FORCES	sel-jnt	sel-lcs

PURPOSE:

To print the member end forces for a selection of joints and load cases. The forces / bending moments at the member end entering the joint will be printed.

PARAMETERS:

sel-jnt — Joints for which data shall be printed. For valid alternatives see command SELECT JOINTS.

sel-lcs — Load cases for which data shall be printed. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

It is also possible to print absolute maximum, maximum or minimum value of a selected force / bending moment component among all selected load cases. These options are controlled by the same switches used to control the 'member force max/min print', and must be set prior to using the PRINT JOINT MEMBER-FORCES command.

See also:

`DEFINE PRESENTATION FORCE...`

EXAMPLES:

```
PRINT JOINT MEMBER-FORCES ( ONLY 2 ) ALL
```

PRINT JOINT REACTION-FORCES

. . .	REACTION-FORCES	sel-jnt	sel-lcs	BRIEF FULL TOTAL	. . .	GLOBAL LOCAL	 . . .

. . .	XO	YO	ZO	Xx	Yx	Zx	Xz	Yz	Zz

PURPOSE:
To print a table of joint reaction forces. Forces and moments for two node beam elements and two node spring elements connected to selected joints are included.

PARAMETERS:

sel-jnt	Joints for which data shall be printed. For valid alternatives see command SELECT JOINTS.
sel-lcs	Load cases for which data shall be printed. For valid alternatives see command SELECT LOAD-CASE.
BRIEF	The BRIEF table contain sum of forces for each joint and loadcase, in addition to the Total sum.
FULL	The FULL table contain the forces from each member in the common coordinate system, in addition to the contents of the BRIEF table.
TOTAL	In the TOTAL sum table, moments around the axes of the common coordinate system is accumulated from each contributing joint.
GLOBAL	Use the GLOBAL coordinate system as reference system when printing reaction forces.
LOCAL	Use a user defined LOCAL coordinate systems reference system when printing reaction forces.
XO,YO,ZO	Coordinate for origin in local coordinate system.
Xx, Yx, Zx	A vector in the local coordinate system pointing in global X-direction.
Xz, Yz, Zz	A vector in the local coordinate system pointing in global Z-direction.

NOTES:

Reaction forces is calculated as the force resultant when contributions from all connected 2 node beam and spring elements are added. Shell, solid and membrane elements are ignored. At joints with fixed boundary conditon, Joint Reactions can be used to check the support reaction in static analysis. However, the node loads from buoyancy and BNWALO loads from Wajac (e.g. use of Soil Permeability Factor for Leg) on fixed nodes, and spring to ground elements are also ignored. It means the sum of member end forces do not balance the support reations when there are node laods on the fixed joint. User should be cautious on this situation. For static loadcases, the other command PRINT SUPPORT-REACTIONS can be used.

Forces in the end of each member connected to the Joint is transformed to a common coordinate system, and summed. Note that the effect of any eccentricities is not accounted for. If all joints being fixed, or connected by Spring to ground is selected, then base shear forces, and overturning moments may be printed. If supernodes is selected, forces transferred to other superelements is printed. In other joints, node loads and resultant from 2 node springs will appear as unbalanced forces.

It should be noted that the joint reactions are not valid in some cases. For example, the earthquake analysis generates a new loadcase that is a modal combination without the sign of forces. The summation of member end forces of an earthquake loadcase does not have physical meaning. Thus, Joint Reactions report will skip earthquake loadcase and load combinations.

See also:

```
DEFINE PRESENTATION RESULT JOINT-REACTION-PHASE-ANGLE...
PRINT SUPPORT-REACTIONS.
```

EXAMPLE:

```
PRINT JOINT REACTION-FORCES ( ONLY 2 ) ALL FULL GLOBAL
```

PRINT LOAD-CASE

...	LOAD-CASE	FULL	sel-lcs
		BRIEF	

PURPOSE:

To print data related to loadcases.

PARAMETERS:

FULL	A full print is required.
BRIEF	a brief print is required.
sel-lcs	Loadcases for which data shall be printed. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

See also:

```
ASSIGN LOAD-CASE...
CREATE LOAD-COMBINATION...
PRINT LOAD-SET
```

EXAMPLES:

```
PRINT LOAD-CASE FULL ALL
```

PRINT LOAD-SET

...	LOAD-SET

PURPOSE:

To print the current loadset from which loadcases are selected from.

PARAMETERS:

None

NOTES:

See also:
`PRINT LOAD-CASE`

EXAMPLES:

```
PRINT LOAD-SET
```

PRINT LRDF-RESISTANCE-FACTORS

...	LRFD-RESISTANCE-FACTORS

PURPOSE:

To print the current set of resistance factors used in API-AISC-LRFD code check.

PARAMETERS:

None

NOTES:

See also:
`DEFINE LRFD-RESISTANCE-FACTORS ...`

EXAMPLES:

```
PRINT LRFD-RESISTANCE-FACTORS
```

PRINT MATERIAL

...	MATERIAL	PROPERTY	mat-name
		TAKE-OFF	

PURPOSE:

To print material data.

PARAMETERS:

PROPERTY	Material property data shall be printed.
TAKE-OFF	Material take-off data shall be printed.
mat-name	Material name of which data shall be printed, or * for all.

NOTES:

See also:

```
ASSIGN MATERIAL...
CHANGE MATERIAL...
CREATE MATERIAL...
```

EXAMPLES:

```
PRINT MATERIAL PROPERTY 1
```

...	MEMBER	GEOMETRY-AND-MATERIAL	sel-mem
		ECCENTRICITY-DATA	
		YIELD-CHECK-DATA	
		STABILITY-CHECK-DATA	
		FATIGUE-CHECK-DATA	
		FATIGUE-CHECK-POSITIONS	
		TAKE-OFF	

PURPOSE:

To print various member data.

PARAMETERS:

GEOMETRY-AND-MATERIAL	That member data related to geometry and material will be printed.
ECCENTRICITY-DATA	Member eccentricities will be printed.
YIELD-CHECK-DATA	Member data related to a yield check will be printed.
STABILITY-CHECK-DATA	Member data related to a stability check will be printed.
FATIGUE-CHECK-DATA	Member data related to a fatigue check will be printed.
FATIGUE-CHECK-POSITIONS	Member fatigue check position names will be printed.
TAKE-OFF	Material and section take-off data will be printed.
sel-mem	Members for which data shall be printed. For valid alternatives see command SELECT MEMBERS.

NOTES:

The command parameter FATIGUE-CHECK-POSITIONS will print the member fatigue check position names which must be referred to in the ASSIGN SCF MEMBER and ASSIGN FATIGUE-PART-DAMAGE MEMBER commands.

See also:

`PRINT JOINT...`

EXAMPLES:

```
PRINT MEMBER STABILITY-CHECK-DATA ALL
```

PRINT MODE-SHAPE

...	MODE-SHAPE	sel-mod

PURPOSE:

To print results for selected mode shapes resulting from an eigen frequency analysis. The frequencies and the modal load factors are included in the print table.

PARAMETERS:

sel-mod	Mode shapes for which to print results. For valid alternatives see command SELECT MODE-SHAPE.

EXAMPLES:

```
PRINT MODE-SHAPE ALL
```

PRINT MODAL-MASS

. . .	MODAL-MASS	sel-mod

PURPOSE:
To print the effective modal mass (EMM) from an eigenfrequency analysis. The printed values equals the modal load factors for X, Y and Z-directions squared.

PARAMETERS:

sel-mod	Mode shapes for which to print results. For valid alternatives see command SELECT MODE-SHAPE.

NOTES:

The fraction of EMM to total mass in each direction and the accumulative fraction are printed. The sum of the effective modal masses for the selected mode shapes is printed. The total masses in 3 global directions are also printed.

If the Results Interface File read in Framework is a “merged” file from the static analysis and eigenvalue analysis, to obtain a correct total mass from two separately analyses, the eigenvalue analysis result MUST be the primary one (*.*SIN* format) when merging two Results Interface Files in Prepost.

EXAMPLE:

```
PRINT MODAL-MASS ALL
```

PRINT RUN

...	RUN

PURPOSE:

To print a summary of all runs performed.

PARAMETERS:

None

NOTES:

See also:
`RUN...`

EXAMPLES:

```
PRINT RUN
```

PRINT SECTION

...	SECTION	GEOMETRY	sec-name
		PROPERTY	
		HOTSPOTS	

PURPOSE:

To print section data.

PARAMETERS:

GEOMETRY	Section geometric data shall be printed.
PROPERTY	Section property data shall be printed.
HOTSPOTS	Section hotspot data shall be printed.
sec-name	Section name for which data are to be printed, or * for all.

NOTES:

See also:

```
ASSIGN SECTION...
CREATE SECTION...
```

EXAMPLES:

```
PRINT SECTION GEOMETRY *
```

PRINT SN-CURVE

...	SN-CURVE	sn-name

PURPOSE:

To print data related to an SN curve.

PARAMETERS:

sn-name Name of SN curves for which data shall be printed, or * for all.

NOTES:

See also:

```
ASSIGN SN-CURVE...
CREATE SN-CURVE...
```

EXAMPLES:

```
PRINT SN-CURVE *
```

PRINT SN-CURVE-SORTED

.. .	SN-CURVE-SORTED	ABS		(	ONLY	snname+)
		API				
		DNV	OLDER			
			RP-C203-2010			
		DOE				
		HSE				
		NORSOK				
		NS				
		USER				
		ALL				

PURPOSE:

To print data related the SN-curves.

PARAMETERS:

ABS	Selection of ABS SN-curves
API	Selection of API SN-curves
DNV	Selection of DNV SN-curves
OLDER	Selection of DNV SN-curves older than 2010
RP-C203-2010	Selection of DNV SN-curves of Recommended Practice DNV-RP-C203, April 2010
DOE	Selection of DOE SN-curves
HSE	Selection of HSE SN-curves
NORSOK	Selection of NORSOK SN-curves
NS	Selection of Norwegian Standard NS 3472 SN-curves
USER	Selection of user defined SN-curves
ALL	Selection of all available SN-curves
snname+	Name of SN-curve
ONLY	Mandatory attribute
( )	Mandatory parentheses

NOTES:

This SN-curves will always be displayed in a log-log scale.

EXAMPLES:

```
PRINT SN-CURVE-SORTED DNV OLDER ( ONLY DNV-X DNVC-I DNVC-II )
PRINT SN-CURVE-SORTED ALL ( ONLY ABS-B-A DNV-X DNV2010_B1-AIR HSE-C-CP )
```

PRINT STRESS

...	STRESS	FULL	.. .	NORMAL-STRESS	sel-mem	sel-lcs
		BRIEF		EQUIVALENT-STRESS		
				BOTH		

PURPOSE:

To print member stresses for selected members and loadcases.

PARAMETERS:

FULL	A full print is required.
BRIEF	A brief print is required.
NORMAL-STRESS	Normal stresses shall be printed.
EQUIVALENT-STRESS	Equivalent stresses shall be printed.
BOTH	Normal & equivalent stresses shall be printed.
sel-mem	Members for which stresses shall be printed. For valid alternatives see command SELECT MEMBERS.
sel-lcs	Loadcases for which stresses shall be printed. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

Stresses are printed for positions along the members corresponding to the predefined code check positions.

When searching maximum stress components in a cross section at a specific hotspot it is advisable to use the EQUIVALENT-STRESS alternative.

Stresses are printed for the hotspot with the highest NORMAL-STRESS/EQUIVALENT-STRESS. Use DEFINE PRESENTATION STRESS COMPONENTS ACTIVE to print for all active hotspots.

See also:

```
PRINT FORCE...
ASSIGN POSITIONS...
DEFINE PRESENTATION STRESS COMPONENTS ACTIVE
```

EXAMPLES:

```
PRINT STRESS FULL BOTH ALL ALL
```

PRINT SUPERELEMENT

...	SUPERELEMENT

PURPOSE

To print the current superelement from which members are selected.

PARAMETERS:

None

NOTES:

See also:
`DISPLAY SUPERELEMENT`

EXAMPLES:

```
PRINT SUPERELEMENT
```

PRINT SUPPORT-REACTIONS

...	SUPPORT-REACTIONS	sel-jnt	sel-lcs

PURPOSE:

To print support reactions for result cases defined on the results file and load combinations created in Framework for selected joints and loadcases.

PARAMETERS:

sel-jnt	Joints for which support reactions shall be printed. For valid alternatives see command SELECT JOINT.
sel-lcs	Loadcases for which support reactions shall be printed. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

This feature require use of Sestra version 7.5-02 or later.

The support reactions may be sorted by joint or sorted by loadcase (incl. a loadsum for each loadcase).

For complex load cases the print option ‘jointwise’ will give the load amplitudes and corresponding phase angles, while for the ‘loadcasewise’ option the user must specify which phase angle to report.

There is no default created named set of joints with boundary conditions which can be referred when selecting joints, but you may refer to ‘ALL’ joints. Framework will then just skip joints without any support reaction forces when printing. You may also select only some of the support joints, but the loadsum will then only contain sum based on the selected joints.

For options to use in connection with this command, see DEFINE PRESENTATION RESULT.

See also:

```
DEFINE PRESENTATION RESULT...
```

EXAMPLES:

```
PRINT SUPPORT-REACTIONS GROUP 10 90 10 ALL
```

PRINT VELOCITY

...	VELOCITY	sel-jnt	sel-lcs

PURPOSE:

To print joint velocities for selected joints and loadcases.

PARAMETERS:

sel-jnt	Joints for which velocities shall be printed. For valid alternatives see command SELECT JOINT.
sel-lcs	Loadcases for which velocities shall be printed. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

See also:

```
PRINT ACCELERATION...
PRINT DISPLACEMENT...
```

EXAMPLES:

```
PRINT VELOCITY 200 ( ONLY GROUP 10 80 10 )
```

PRINT WAVE-DIRECTIONS

...	WAVE-DIRECTIONS

PURPOSE:

To print wave directions for fatigue analysis and environmental data assigned.

PARAMETERS:

None

NOTES:

See also:

```
ASSIGN WAVE-DIRECTION-PROBABILITY...
ASSIGN WAVE-STATISTICS...
```

EXAMPLES:

```
PRINT WAVE-DIRECTIONS
```

PRINT WAVE-LOAD-FACTORS

...	WAVE-LOAD-FACTORS

PURPOSE:

To print wave load factors assigned to wave directions.

PARAMETERS:

None

NOTES:

See also:
`ASSIGN WAVE-LOAD-FACTOR...`

EXAMPLES:

```
PRINT WAVE-LOAD-FACTORS
```

PRINT WAVE-SPREADING-FUNCTION

...	WAVE-SPREADING-FUNCTION	name	space

PURPOSE:

To print data related to a wave spreading function.

PARAMETERS:

name	Wave spreading function name for which to print data.
space	Spacing between elementary wave directions in degrees (used for discretisation).

NOTES:

See also:

```
ASSIGN WAVE-SPREADING-FUNCTION...
CREATE WAVE-SPREADING-FUNCTION...
```

EXAMPLES:

```
PRINT WAVE-SPREADING-FUNCTION *
```

PRINT WAVE-STATISTICS

...	WAVE-STATISTICS	name +

PURPOSE:

To print data related to a wave scatter diagram.

PARAMETERS:

name Name of wave statistics (Scatter diagram).

NOTES:

See also:

```
ASSIGN WAVE-STATISTICS...
CREATE WAVE-STATISTICS...
```

EXAMPLES:

```
PRINT WAVE-STATISTICS *
```

PRINT WIND-FATIGUE

...	WIND-FATIGUE	INPUT	SELECT-MEMBERS	...	ALL	
			SELECT-JOINTS			
			SELECT-WIND-DIRECTIONS			
			SELECT-EIGENMODES		NO.	value
			SELECT-STATIC-LOAD-CASES			
			JOINT-COORDINATES	...	OFF	
			MEMBER-DATA			
			WIND-PARAMETERS			
			VORTEX-WIND-PARAMETERS			
			SN-CURVES			
			STRESS-CONCENTRATION-FACTORS			
			EIGENVALUES-AND-EIGENMODES			
			EIGENMODE-ELEMENT-FORCES		ON	
			STATIC-WIND-LOAD-CASES			
			STATIC-ELEMENT-FORCES			
			STATIC-NODAL-POINT-WIND-LOADS			
			SUM-OF-STATIC-LOADS			
			RUN-SCENARIO			

PURPOSE:

To print input data for wind fatigue calculation.

PARAMETERS:

SELECT-MEMBERS	Select members for print.
SELECT-JOINTS	Select joints for print.
SELECT-WIND-DIRECTIONS	Select wind directions for print.
SELECT-EIGENMODES	Select eigenmodes for print.
SELECT-STATIC-LOAD-CASES	Select static load cases for print.
ALL	All members, joints, wind directions, eigenmodes and static load cases are printed.
NO.	Select individual member, joint, wind direction, eigenmode and static load case for print.
value	Member, joint, wind direction, eigenmode or static load case to be printed.
JOINT-COORDINATES	Turn print of joint coordinates ON/OFF.
MEMBER-DATA	Turn print of member data ON/OFF.
WIND-PARAMETERS	Turn print of wind parameters ON/OFF.
VORTEX-WIND-PARAMETERS	Turn print of vortex wind parameters ON/OFF.
SN-CURVES	Turn print of SN curves ON/OFF. SN curves for joint-brace connections of current joint selection is printed.
STRESS-CONCENTRATION-FACTORS	Turn print of stress concentration factors (SCFs) ON/OFF. Input SCFs are printed as well as SCFs and SN curves applied in the fatigue calculations of last executed run.

EIGENVALUES-AND-EIGENMODES	Turn print of eigenvalues and eigenmodes ON/OFF.
EIGENMODE-ELEMENT-FORCES	Turn print of eigenmode element forces ON/OFF.
STATIC-WIND-LOAD-CASES	Turn print of static wind load cases ON/OFF.
STATIC-ELEMENT-FORCES	Turn print of static element forces ON/OFF.
STATIC-NODAL-POINT-WIND-LOADS	Turn print of static nodal point wind loads ON/OFF.
SUM-OF-STATIC-LOADS	Turn print of sum of static loads ON/OFF.
RUN-SCENARIO	Turn print of run scenario ON/OFF.

EXAMPLES:

```
PRINT WIND-FATIGUE INPUT SELECT-MEMBERS ALL
PRINT WIND-FATIGUE INPUT SELECT-JOINTS ALL
PRINT WIND-FATIGUE INPUT SELECT-WIND-DIRECTIONS ALL
PRINT WIND-FATIGUE INPUT SELECT-EIGENMODES NO. 1
PRINT WIND-FATIGUE INPUT SELECT-STATIC-LOAD-CASES NO. 10
PRINT WIND-FATIGUE INPUT JOINT-COORDINATES ON
PRINT WIND-FATIGUE INPUT MEMBER-DATA OFF
PRINT WIND-FATIGUE INPUT WIND-PARAMETERS OFF
PRINT WIND-FATIGUE INPUT VORTEX-WIND-PARAMETERS OFF
PRINT WIND-FATIGUE INPUT SN-CURVES ON
PRINT WIND-FATIGUE INPUT STRESS-CONCENTRATION-FACTORS OFF
PRINT WIND-FATIGUE INPUT EIGENVALUES-AND-EIGENMODES ON
PRINT WIND-FATIGUE INPUT EIGENMODE-ELEMENT-FORCES OFF
PRINT WIND-FATIGUE INPUT STATIC-WIND-LOAD-CASES OFF
PRINT WIND-FATIGUE INPUT STATIC-ELEMENT-FORCES OFF
PRINT WIND-FATIGUE INPUT STATIC-NODAL-POINT-WIND-LOADS OFF
PRINT WIND-FATIGUE INPUT SUM-OF-STATIC-WIND-LOADS OFF
PRINT WIND-FATIGUE INPUT RUN-SCENARIO OFF
```

RUN	CONE-CHECK	subcom-mands	data
	EARTHQUAKE-CHECK		
	FATIGUE-CHECK		
	HYDROSTATIC-CHECK		
	MEMBER-CHECK		
	PUNCH-CHECK		
	REDESIGN		
	STABILITY-CHECK		
	YIELD-CHECK		
	WIND-FATIGUE-CHECK		

PURPOSE:

To perform a check.

PARAMETERS:

CONE-CHECK	To perform a check of conical transitions.
EARTHQUAKE-CHECK	To perform a member earthquake check.
FATIGUE-CHECK	To perform a member fatigue check.
HYDROSTATIC-CHECK	To perform a member hydrostatic check.
MEMBER-CHECK	To perform a member check (both yield and stability).
PUNCH-CHECK	To perform a joint punch check.
REDESIGN	To perform a joint can redesign.
STABILITY-CHECK	To perform a member stability check.
YIELD-CHECK	To perform a member yield check.
WIND-FATIGUE-CHECK	To perform a wind fatigue check.

All subcommands and data are fully explained subsequently as each command sequence is described in detail.

RUN CONE-CHECK

...	CONE-CHECK	run-name	run-text	sel-mem	sel-lcs

PURPOSE:

To perform a check of conical transitions according to the pre-selected code of practice.

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with run.
sel-mem	Members to be checked. For valid alternatives see command SELECT MEMBER.
sel-lcs	Loadcases to be checked. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

The stress criteria checks are performed for cylinder and cone at both ends of the conical transition. Effect of external hydrostatic pressure is accounted for in calculation of the hoop stress (if a water plane is defined prior to the run).

The cones are checked without any ring stiffeners at the junction of cylinder and cone. Hence, if the criteria in the code of practice is not satisfied, the user must manually design ring stiffeners, or alternatively change the wall thickness of the cone and/or cylinder.

When NPD is selected as code of practice, the allowable fabrication tolerance default is set to 0.005 times R.

See also:

```
PRINT CODE-CHECK-RESULTS...
PRINT RUN
SELECT CODE-OF-PRACTICE...
DEFINE CONE-PARAMETERS...
```

EXAMPLES:

```
RUN CONE-CHECK CONECHK 'Check cones' ( ONLY WITH-CONE ALL ) ALL
```

RUN EARTHQUAKE-CHECK

...	EARTHQUAKE-CHECK	run-name	run-text	X Y Z ALL	...	sel-mem sel-jnt	sel-mod

PURPOSE:

To perform a member or joint earthquake check according to the pre-selected mode combination rule and output request.

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with run.
X	Earthquake excitation shall be applied in the global X-direction.
Y	Earthquake excitation shall be applied in the global Y-direction.
Z	Earthquake excitation shall be applied in the global Z-direction.
ALL	Earthquake excitation shall be applied in all three global directions.
sel-mem	Members to be checked (only when the requested output is FORCES). For valid alternatives see command SELECT MEMBERS.
sel-jnt	Joints to be checked (only when the requested output is DISPLACEMENT, VELOCITY or ACCELERATION). For valid alternatives see command SELECT JOINTS.
sel-mod	Mode shapes to be checked. For valid alternatives see command SELECT MODE-SHAPE.

NOTES:

Results from an earthquake check are printed through either print of forces, stresses, displacements, velocities or accelerations.

See also:

```
SELECT EARTHQUAKE-CHECK-TYPE...
PRINT FORCE...
PRINT STRESS...
PRINT DISPLACEMENT...
PRINT VELOCITY...
PRINT ACCELERATION...
PRINT RUN
```

EXAMPLES:

```
RUN EARTHQUAKE-CHECK RUNEQUX 'Check X direction' X ALL ALL
```

RUN FATIGUE-CHECK

...	FATIGUE-CHECK	run-name	run-text	ALL	sel-mem

PURPOSE:

To perform a member fatigue check according to the pre-selected type (i.e. deterministic, stochastic or time history).

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with run.
ALL	Wave directions to be checked.
sel-mem	Member to be checked. For valid alternatives see command SELECT MEMBERS.

NOTES:

See also:

```
PRINT FATIGUE-CHECK-RESULTS...
PRINT RUN
SELECT FATIGUE-CHECK-TYPE...
DEFINE FATIGUE-CONSTANTS...
```

EXAMPLES:

```
RUN FATIGUE-CHECK RUNFAT1 'Check member 1009' ALL 1009
```

RUN HYDROSTATIC-CHECK

...	HYDROSTATIC-CHECK	run-name	run-text	sel-mem	sel-lcs

PURPOSE:

To perform a member hydrostatic check according to the pre-selected code of practice.

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with run.
sel-mem	Members to be checked. For valid alternatives see command SELECT MEMBER.
sel-lcs	Loadcases to be checked. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

The hydrostatic check is only relevant for tubular members checked according to API-AISC-WSD and API-AISC-LRFD.

See also:

```
PRINT CODE-CHECK-RESULTS...
PRINT RUN
SELECT CODE-OF-PRACTICE...
```

EXAMPLES:

```
RUN HYDROSTATIC-CHECK HYDROCHK 'Check all members' ALL ALL
```

RUN MEMBER-CHECK

...	MEMBER-CHECK	run-name	run-text	sel-mem	sel-lcs

PURPOSE:

To perform a member combined yield and stability check according to the pre-selected code of practice. The member check is available for codes of practice NORSOK, API-AISC (WSD and LRFD) and EUROCODE / NS3472 (release 3).

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with run.
sel-mem	Members to be checked. For valid alternatives see command SELECT MEMBERS.
sel-lcs	Loadcases to be checked. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

For API-AISC WSD and LRFD this MEMBER-CHECK will run the three check types yield, stability and hydrostatic in sequence and report the governing usage factor (UF). The outcome column on the print will indicate which case that is governing by showing: Yld, Stab or Hydr. For utilisations above 1.0, the three first characters in the outcome column shows '*Fa' to indicate failure.

With this combined check used on API-AISC the heading on the print of results must show different type of data dependent of governing check and member cross section type. Hence note that numbers set to zero normally means that data is not calculated or not in use for governing check type and section. The NOMENCLATURE indicates Y: for specific yield related data, S: for stability and H: for hydrostatic data. Governing hot-spot names for yield check results are not reported for this combined check

See also:

```
PRINT CODE-CHECK-RESULTS...
PRINT RUN
SELECT CODE-OF-PRACTICE...
DEFINE MEMBER-CHECK-PARAMETERS...
```

EXAMPLES:

```
RUN MEMBER-CHECK MEMCHK 'Check all members' ( ONLY BRACE-MEMBERS ) ALL
```

RUN PUNCH-CHECK

...	PUNCH-CHECK	run-name	run-text	sel-jnt	sel-lcs

PURPOSE:

To perform a joint punch check according to the pre-selected code of practice.

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with run.
sel-jnt	Joints to be checked. For valid alternatives see command SELECT JOINTS.
sel-lcs	Loadcases to be checked. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

When running punching check according to the NORSOK standard, the L parameter (the least distance between crown and edge of chord can) used in equation 6.56 specified in section 6.4.3.5 “Design axial resistance for X and Y joints with joint can” will be calculated even if a can section is not defined at the end of the chord / aligned chord. The can length is detected if the chord member is modelled with more than one element and a transition in diameter / thickness occur.

Use the command PRINT CHORD-AND-BRACE to check if Framework detects any can (or stub) joint reinforcements.

See also:

```
PRINT CODE-CHECK-RESULTS...
PRINT RUN
SELECT CODE-OF-PRACTICE...
PRINT CHORD-AND-BRACE...
```

EXAMPLES:

```
RUN PUNCH-CHECK RJ200 'Check joint 200' ONLY 2 ALL
```

RUN REDESIGN

...	REDESIGN	run-name	target	{sec-nam, mat-nam}*	RESIZE

PURPOSE:

To perform a joint can redesign (after a joint punch check according to a pre-selected code of practice).

The user inputs a list of proposed pairs of section and material combinations.

PARAMETERS:

run-name	Name of an existing punching check run.
target	Target value for usage factor after redesign.
sec-nam	Name of section.
mat-nam	Name of a material.

NOTES:

The redesign feature is only available in conjunction with a joint punch check.

It is required that the user has performed a joint punch check run in advance.

See also:

```
PRINT CODE-CHECK-RESULTS...
PRINT RUN
SELECT CODE-OF-PRACTICE...
```

EXAMPLES:

```
RUN REDESIGN P1 1. (11 1  12 1  13 1) RESIZE
```

RUN STABILITY-CHECK

...	STABILITY-CHECK	run-name	run-text	sel-mem	sel-lcs

PURPOSE:

To perform a member stability check according to the pre-selected code of practice.

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with run.
sel-mem	Members to be checked. For valid alternatives see command SELECT MEMBERS.
sel-lcs	Loadcases to be checked. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

Non-pipe members having slenderness greater then 250 are skipped when running stability check according to NPD/NS3472 code of practice. Always check the MLG file to check for message with following text: Member xxxxxx has **failed** because Kl/r > 250.

See also:

```
PRINT CODE-CHECK-RESULTS...
PRINT RUN
SELECT CODE-OF-PRACTICE...
```

EXAMPLES:

```
RUN STABILITY-CHECK RUNS 'Check all members' ALL ALL
```

RUN YIELD-CHECK

...	YIELD-CHECK	run-name	run-text	sel-mem	sel-lcs

PURPOSE:

To perform a member yield check according to the pre-selected code of practice.

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with run.
sel-mem	Members to be checked. For valid alternatives see command SELECT MEMBERS.
sel-lcs	Loadcases to be checked. For valid alternatives see command SELECT LOAD-CASE.

NOTES:

See also:

```
PRINT CODE-CHECK-RESULTS...
PRINT RUN
SELECT CODE-OF-PRACTICE...
```

EXAMPLES:

```
RUN YIELD-CHECK RUNIBMS 'Check all I beams' ONLY WITH-SECTION 2 ALL
```

RUN WIND-FATIGUE-CHECK

...	WIND-FATIGUE-CHECK	run-name	run-text

PURPOSE:

To perform a wind fatigue calculation run.

PARAMETERS:

run-name	Name given to the run.
run-text	Text associated with the run.

NOTES:

When the run command is executed a test of the input is performed. All relevant commands related to wind fatigue calculation must have been accessed before the run is being started. Otherwise, or if input errors have been detected, the run is stopped and a message is printed to the screen.

EXAMPLES:

```
RUN WIND-FATIGUE-CHECK FTOW1 'Fatigue check of flare tower'
```

SELECT	CODE-OF-PRACTICE	subcom-mands	data
	EARTHQUAKE-CHECK-TYPE		
	FATIGUE-CHECK-TYPE		
	JOINTS		
	LOAD-CASE		
	LOAD-SET		
	MEMBERS		
	MODE-SHAPE		
	SET		

PURPOSE:

To perform a selection.

PARAMETERS:

CODE-OF-PRACTICE	To select a code of practice.
EARTHQUAKE-CHECK	To select the modal combination rule and type of output from an earthquake analysis.
FATIGUE-CHECK-TYPE	To select the type of fatigue check.
JOINTS	To select joints.
LOAD-CASE	To select load cases.
LOAD-SET	To select a load set.
MEMBERS	To select members.
MODE-SHAPE	To select mode shapes.
SET	To select named sets of joints or members.

NOTES:

The command SELECT SET will differ between motif mode and line mode execution of Framework. The description given above is valid for line mode. For motif mode the command SELECT SET is replaced by the commands SELECT MEMBER-SET and SELECT JOINT-SET.

All subcommands and data are fully explained subsequently as each command sequence is described in detail.

SELECT CODE-OF-PRACTICE

...	CODE-OF-PRACTICE	API-AISC-LRFD
		API-AISC-WSD
		EUROCODE-NS3472
		NORSOK
		NPD-NS3472
		ISO19902

PURPOSE:
To select the current code of practice to be used for member and joint checks.

PARAMETERS:

API-AISC-LRFD	The API draft recommended practice & AISC code of practice shall be used, based on Load and Resistance Factor Design (LRFD).
API-AISC-WSD	The API & AISC codes of practice shall be used, based on Working Strength Design (i.e. allowable stresses).
EUROCODE-NS3472	The EUROCODE / NS3472 (release 3) codes of practice shall be used.
NORSOK	The NORSOK codes of practice shall be used.
NPD-NS3472	The NPD & NS3472 (release 2) codes of practice shall be used.
ISO19902	The ISO 19902 [33] standard for check of tubular members, tubular joints and conical transitions shall be used.

NOTES:
The default code of practice is API-AISC-WSD.

When performing code check according to API-AISC-LRFD and API-AISC-WSD the limiting width thickness ratios for compression elements defined in Table I-8-1 from “Seismic Provisions for Structural Steel Buildings" [49] are accounted for. The limiting width thickness ratio for ‘lambda_p (compact)’ is modified for cross sections of type I/H, Box and Channel when checked for load cases defined as ‘earthquake’.

In connection with code check according to API-AISC-LRFD (member yield, stability, combined yield and stability) it is possible to get dump of data giving information about flange and web classification used for cross sections of type I/H, Box and Channel. See description under DEFINE BUCKLING-LENGTH-DUMP.

Installations which have licence to run API-AISC-LRFD will be able to run the implemented ISO 19902 code check. Note that members which have non-tubular cross section types must be checked in a separate run selecting an appropriate code of practice.

The 2013 edition is the default option when selecting SELECT CODE-OF-PRACTICE NORSOK, see DEFINE CODE-OF-PRACTICE-VERSION NORSOK 2013.

See Also:

```
PRINT CODE-OF-PRACTICE
RUN YIELD-CHECK...
RUN STABILITY-CHECK...
RUN MEMBER-CHECK...
RUN PUNCH-CHECK...
RUN CONE-CHECK...
RUN HYDROSTATIC-CHECK...
```

EXAMPLES:

```
SELECT CODE-OF-PRACTICE NPD-NS3742.
```

SELECT EARTHQUAKE-CHECK-TYPE

...	EARTHQUAKE-CHECK-TYPE	CQC	...	FORCE
		SRSS		DISPLACEMENT
		ABS		VELOCITY
		NRL		ACCELERATION
		APIC		

PURPOSE:

To select the type of modal combination rule to be used for an earthquake analysis and the type of desired output.

PARAMETERS:

CQC	The CQC method shall be used.
SRSS	The SRSS method shall be used.
ABS	The ABS method shall be used.
NRL	The NRL method shall be used.
APIC	The method recommended in API RP-2A shall be used.
FORCE	Member forces shall be the output from an earthquake analysis.
DISPLACEMENT	Joint displacements shall be the output from an earthquake analysis.
VELOCITY	Joint velocities shall be the output from an earthquake analysis.
ACCELERATION	Joint accelerations shall be the output from an earthquake analysis.

NOTES:

The APIC combination method, recommended in API RP-2A LRFD and - WSD, is available for earthquake response spectrum combination. The CQC, Complete Quadratic Combination, is used for combining modal responses, followed by SRSS, Square root of the sum of the squares, for the directions

See also:

```
PRINT EARTHQUAKE-CHECK...
RUN EARTHQUAKE-CHECK...
```

EXAMPLES:

```
SELECT EARTHQUAKE-CHECK-TYPE CQC FORCE
```

SELECT FATIGUE-CHECK-TYPE

...	FATIGUE-CHECK-TYPE	DETERMINISTIC
		STOCHASTIC
		TIME-HISTORY
		SPECTRAL
		DIRECT-DETERMINISTIC
		NONE

PURPOSE:
To select the type of fatigue check to be performed.

PARAMETERS:

DETERMINISTIC	Deterministic fatigue check shall be performed.
STOCHASTIC	Stochastic fatigue check shall be performed.
TIME-HISTORY	Time history fatigue check shall be performed.
SPECTRAL	Spectral fatigue check shall be performed.
DIRECT-DETERMINISTIC	Direct Deterministic fatigue check shall be performed.
NONE	No fatigue check shall be performed.

NOTES:
See Also:

```
PRINT FATIGUE-CHECK-TYPE
PRINT FATIGUE-CHECK-RESULTS...
RUN FATIGUE-CHECK...
```

EXAMPLES:

```
SELECT FATIGUE-CHECK-TYPE STOCHASTIC
SELECT FATIGUE-CHECK-TYPE DIRECT-DETERMINISTIC
```

SELECT JOINTS

...	JOINTS	ONLY	...	joint							
				ALL							
				CURRENT							
		INCLUDE		GROUP	first-jnt		last-jnt		jnt-step		
				LINE	start-jnt		end-jnt		tol		
				SET	name						
				PLANE	jnt 1	jnt 2	jnt3	tol			
		EXCLUDE		VOLUME	xl	xh	yl	yh	zl	zh	
				CONNECTED-TO-MEMBER	mem-name						
				WITH-CAN	can-name						
				WITH-STUB	stub-name						

PURPOSE:

To select joints an put them in a set called CURRENT.

PARAMETERS:

ONLY	Only the subsequently selected joints shall be placed in the CURRENT set. The last CURRENT set of joints is disregarded.
INCLUDE	The subsequently selected joints shall be included (appended) in the CURRENT set.
EXCLUDE	The subsequently selected joints shall be excluded (removed) from the CURRENT set.
joint	Joint name to be selected.
ALL	All joints in the superelement are selected.
CURRENT	The last CURRENT selection shall be selected.
GROUP	Joints shall be selected as a group.
first-jnt	Joint name to start the group selection.
last-jnt	Joint name to end the group selection.
jnt-step	Step in the group selection.
LINE	All joints lying in a straight line shall be selected.
start-jnt	Starting joint identifying the start of the line.
end-jnt	Ending joint identifying the end of the line.
tol	Tolerance (distance from line).
SET	All joints defined in named SET.
name	Name of SET.
PLANE	All joints lying on a plane shall be selected.
jnt1	First joint lying on the plane.
jnt2	Second joint lying on the plane.
jnt3	Third joint lying on the plane.
tol	Tolerance (distance from plane).

VOLUME	Joints within a volume shall be selected.
xl	Low value of x coordinate of point defining the volume.
xh	High value of x coordinate of point defining the volume.
yl	Low value of y coordinate of point defining the volume.
yh	High value of y coordinate of point defining the volume.
zl	Low value of z coordinate of point defining the volume.
zh	High value of z coordinate of point defining the volume.
CONNECTED-TO-MEMBER	The joints connected to a member shall be selected.
mem-name	Member name.
WITH-CAN	All joints with a can name shall be selected.
can-name	Name of can section.
WITH-STUB	All joints with a stub name shall be selected.
stub-name	Name of stub section.

NOTES:

Framework cannot access named SETs read from the Results File when the name includes the control character. (dot) or +.

See also:

`PRINT JOINT...`

EXAMPLES:

```
SELECT JOINTS INCLUDE ALL
SELECT JOINTS EXCLUDE WITH-CAN C70025
```

SELECT LOAD-CASE

...	LOAD-CASE	ONLY	...	loadcase			
		INCLUDE		ALL			
		EXCLUDE		CURRENT			
				GROUP	first-lcs	last-lcs	lcs-step

PURPOSE:

To select loadcases an put them in a set called CURRENT.

PARAMETERS:

ONLY	Only the subsequently selected loadcases shall be placed in the CURRENT set. The last CURRENT set of loadcases is disregarded.
INCLUDE	The subsequently selected loadcases shall be included (appended) in the CURRENT set.
EXCLUDE	The subsequently selected loadcases shall be excluded (removed) from the CURRENT set.
loadcase	Loadcase name to be selected.
ALL	All loadcases are selected.
CURRENT	The last CURRENT selection shall be selected.
GROUP	Loadcases shall be selected as a group.
first-lcs	Loadcase name to start the group selection.
last-lcs	Loadcase name to end the group selection.
lcs-step	Step in the group selection.

NOTES:

See also:

`PRINT LOAD-CASE...`

EXAMPLES:

```
SELECT LOAD-CASE ONLY GROUP 1 14 1
SELECT LOAD-CASE INCLUDE LCOM1
```

SELECT LOAD-SET

...	LOAD-SET	name

PURPOSE:

To select loadset.

PARAMETERS:

name Name of loadset to be the current loadset.

NOTES:

See also:
`PRINT LOAD-SET...`

SELECT MEMBERS

...	MEMBERS	ONLY	...	member						
				ALL						
				ALL-BUT-PILES						
				CURRENT						
				SET	name					
				GROUP	first-mem		last-mem		mem-step	
		INCLUDE		LINE	start-jnt		end-jnt		tol	
				PLANE	jnt 1	jnt 2	jnt3	tol		
				VOLUME	xl	xh	yl	yh	zl	zh
				CONNECTED-TO-JOINT	joint-name					
				WITH-MATERIAL	mat-name					
				WITH-SECTION	sec-name					
		EXCLUDE		WITH-CAN	can-name					
				WITH-CONE	cone-name					
				WITH-STUB	stub-name					
				PILE-CONCEPTS	sec-nam					
				CHORD-MEMBERS						
				BRACE-MEMBERS						

PURPOSE:

To select members an put them in a set called CURRENT.

PARAMETERS:

ONLY	Only the subsequently selected members shall be placed in the CURRENT set. The last CURRENT set of members is disregarded.
INCLUDE	The subsequently selected members shall be included (appended) in the CURRENT set.
EXCLUDE	The subsequently selected members shall be excluded (removed) from the CURRENT set.
member	Member name to be selected.
ALL	All members in the superelement are selected.
ALL-BUT-PILES	All members except the piles shall be selected.
CURRENT	The last CURRENT selection shall be selected.
SET	Member included in named SET shall be selected.
name	Name of the SET.
GROUP	Members shall be selected as a group.
first-mem	Member name to start the group selection.
last-mem	Member name to end the group selection.
mem-step	Step in the group selection.
LINE	All members lying in a straight line shall be selected.

start-jnt	Starting joint identifying the start of the line.
end-jnt	Ending joint identifying the end of the line.
tol	Tolerance (distance from line).
PLANE	That all members lying on a plane shall be selected.
jnt1	First joint lying on the plane.
jnt2	Second joint lying on the plane.
jnt3	Third joint lying on the plane.
tol	Tolerance (distance from plane).
VOLUME	Members within a volume shall be selected.
xl	Low value of x coordinate of point defining the volume.
xh	High value of x coordinate of point defining the volume.
yl	Low value of y coordinate of point defining the volume.
yh	High value of y coordinate of point defining the volume.
zl	Low value of z coordinate of point defining the volume.
zh	High value of z coordinate of point defining the volume.
CONNECTED-TO-JOINT	All members connected to a joint shall be selected.
joint-name	Name of joint.
WITH-MATERIAL	All members with a material name shall be selected.
mat-name	Material name.
WITH-SECTION	All members with a section name shall be selected.
sec-name	Section name.
WITH-CAN	All members with a can name shall be selected.
can-name	Name of can section.
WITH-CONE	All members with a cone name shall be selected.
can-name	Name of cone section.
WITH-STUB	All members with a stub name shall be selected.
stub-name	Name of stub section.
PILE-CONCEPT	All piles with specified section name shall be selected.
sec-name	Section name.
CHORD-MEMBERS	All chord members shall be selected.
BRACE-MEMBERS	All brace members shall be selected.

NOTES:

Framework cannot access named SETs read from the Results File when the name includes the control character. (dot) or +.

See also:

```
DISPLAY MEMBER
PRINT MEMBER...
```

EXAMPLES:

```
SELECT MEMBERS INCLUDE ALL
SELECT MEMBERS EXCLUDE WITH-SECTION 1
```

SELECT MODE-SHAPE

...	MODE-SHAPE	ONLY	...	modeshape			
		INCLUDE		ALL			
		EXCLUDE		CURRENT			
				GROUP	first-mod	last-mod	mod-step

PURPOSE:

To select mode shapes and put them in a set called CURRENT.

PARAMETERS:

ONLY	Only the subsequently selected mode shapes shall be placed in the CURRENT set. The last CURRENT set of mode shapes is disregarded.
INCLUDE	The subsequently selected mode shapes shall be included (appended) in the CURRENT set.
EXCLUDE	The subsequently selected mode shapes shall be excluded (removed) from the CURRENT set.
modeshape	modeshape name to be selected.
ALL	All mode shapes are selected.
CURRENT	The last CURRENT selection shall be selected.
GROUP	Mode shapes shall be selected as a group.
first-mod	Mode shape name to start the group selection.
last-mod	Mode shape name to end the group selection.
mod-step	Step in the group selection.

NOTES:

See also:

`PRINT MODE-SHAPE...`

EXAMPLES:

```
SELECT MODE-SHAPE ONLY GROUP 1 14 1
SELECT MODE-SHAPE EXCLUDE 14
```

SELECT SET

...	SET	MEMBERS	name	sel-mem
		JOINTS	name	sel-jnt

PURPOSE:

To create named sets.

PARAMETERS:

MEMBERS	To create a member set.
JOINTS	To create a joint set.
name	Name of set.
sel-mem	Members to be included in the set.
sel-jnt	Joints to be included in the set.

NOTES:

If a new set name is given, a new set is created.

If an existing set name is given, an existing set is updated.

The currently active set is the one last referred, but the user is recommended to explicitly give a set name and NOT use the reply CURRENT.

The joint and member sets named DEFAULT are also modified by the commands SELECT MEMBERS, SELECT JOINTS and also most on the fly selections.

A member set and a joint set may have the same name, but their definition is not interconnected.

EXAMPLES:

```
SELECT SET MEMBERS leg ONLY 33317
```

SET

SET	COMPANY-NAME	subcom-mands	data
	DISPLAY		
	DRAWING		
	GRAPH		
	PLOT		
	PRINT		
	TITLE		

PURPOSE:

Set or re-set global file/device environment characteristics.

PARAMETERS:

COMPANY-NAME	Set company name on display/plot
DISPLAY	Set display characteristics.
DRAWING	Set drawing characteristics.
GRAPH	Set graph characteristics.
PLOT	Set plot file characteristics.
PRINT	Set print characteristics.
TITLE	Set plot title.

All subcommands and data are fully explained subsequently as each command is described in detail.

SET COMPANY-NAME

...	COMPANY-NAME	name

PURPOSE:

To set the company name for use with result presentation

PARAMETERS:

name The name of the company.

NOTES:

The name is used at the top of a framed display/plot. It is not used with printed results.

See also:

DISPLAY
PLOT

EXAMPLES:

```
SET COMPANY-NAME 'Det Norske Veritas'
```

SET DISPLAY

...	DISPLAY	COLOUR	subcom-mands	data
		DESTINATION		
		DEVICE		
		WORKSTATION-WINDOW		

PURPOSE:

To set display characteristics.

PARAMETERS:

COLOUR	Sets the output to the display device to be in colours or monochrome.
DESTINATION	Set the destination of the graphics produced in the DISPLAY command.
DEVICE	Set the current screen display device type.
WORKSTATION-WINDOW	Set the size and position of the display window when using a workstation device.

All subcommands and data are fully explained subsequently as each command is described in detail.

SET DISPLAY COLOUR

...	COLOUR	ON
		OFF

PURPOSE:

Turn colour on/off in the display.

PARAMETERS:

ON	Screen output is in colours.
OFF	Screen output is in monochrome.

NOTES:

Note that display and plot colour options may be different.

See also:

`DISPLAY...`
`SET PLOT COLOUR...`

SET DISPLAY DESTINATION

...	DESTINATION	FILE
		SCREEN

PURPOSE:

To set the destination of the graphics produced in the DISPLAY command.

PARAMETERS:

FILE	Direct the graphics in the DISPLAY command to a plot file.
SCREEN	Direct the graphics in the DISPLAY command to the screen. This is the default.

SET DISPLAY DEVICE

...	DEVICE	device-name

PURPOSE:

To set the current screen display device type.

PARAMETERS:

device-name SESAM device name, one of:

TX4014-15-16-54	(Tektronix b/w devices)
TX4105	(Tektronix 4105)
TX4107-09-13-15	(Tektronix colour devices)
VT125	(Digital VT 125 screen)
VT240	(Digital VT 240 screen)
VT340	(Digital VT 340 screen)
WESTWARD-3219	
WESTWARD-3220	
VAXSTATION-UIS	(VAXStation UIS window system)
X-WINDOW	(X-Windows window system)
DUMMY	The Dummy device is used to do a Display command without generating a display.

NOTES:

The actual list of available devices depend on the installation. Some, but not necessarily all, may be available.

SET DISPLAY WORKSTATION-WINDOW

...	WORKSTATION-WINDOW	left	right	bottom	top

PURPOSE:

To pre-set the size and position of the graphics display window when using a workstation device.

PARAMETERS:

left	Position of left display window border.
right	Position of right display window border.
bottom	Position of bottom display window border.
top	Position of top display window border.

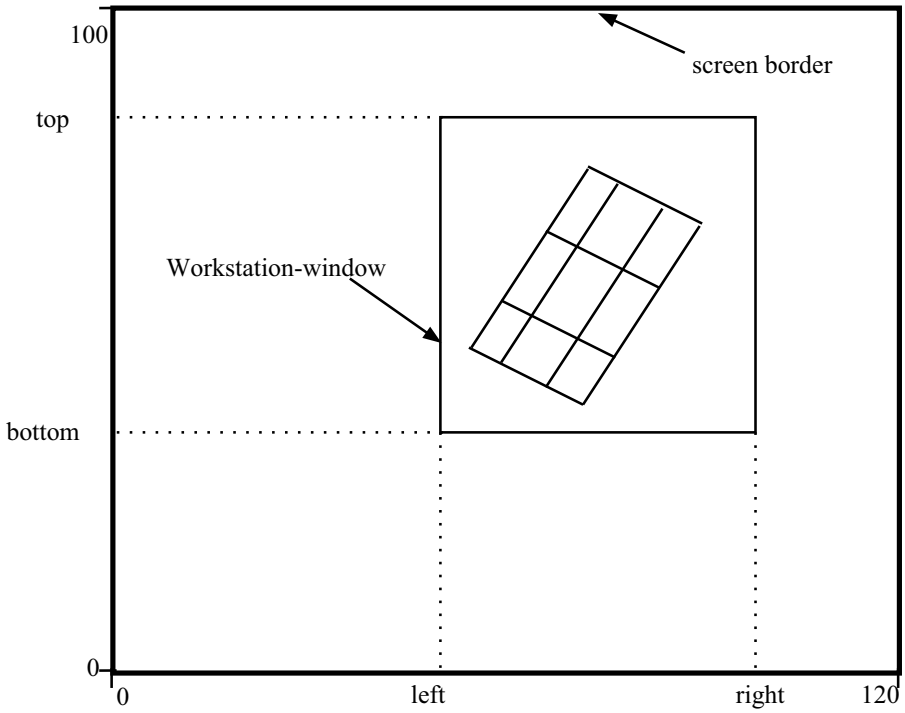


Figure 5.7 Setting workstation window

Note: This command will only be taken into account if issued prior to any DISPLAY command. Otherwise, the settings will not be valid until the user has exited from Framework and entered again.

SET DRAWING

...	DRAWING	CHARACTER-TYPE	subcom-mands	data
		FONT-SIZE		
		FONT-TYPE		
		FRAME		
		GRID		

PURPOSE:

To set drawing characteristics.

PARAMETERS:

CHARACTER-TYPE	Set the character type.
FONT-SIZE	Set the font size.
FONT-TYPE	Set the font type.
FRAME	Set frame on drawing on or off.
GRID	Set grid on drawing on or off.

All subcommands and data are fully explained subsequently as each command is described in detail.

SET DRAWING CHARACTER-TYPE

...	CHARACTER-TYPE	SOFTWARE
		HARDWARE

PURPOSE:

Set the drawing character type.

PARAMETERS:

SOFTWARE	Select software character set (default).
HARDWARE	Select hardware character set.

SET DRAWING FONT-SIZE

...	FONT-SIZE	ABSOLUTE	width
		RELATIVE	factor

PURPOSE:

To set the drawing font size.

PARAMETERS:

ABSOLUTE	Set to absolute value.
width	Set font width.
RELATIVE	Set to relative value.
factor	Set scaling factor.

NOTES:

The font size can be set to an absolute value (the width of a character in mm, with the height being twice as large), or to a relative value scalable by a factor, where 40*80 characters are fitted into the window when the factor is 1. The default (which was used previously) is SET DRAWING FONT-SIZE RELATIVE 1.0. On a typical screen display, SET DRAWING ABSOLUTE 1.8 produces approximately the same font size.

The absolute size setting may be useful when changing the size of the display window. It will ensure that the characters remain readable.

The relative size may be useful for controlling the character size on a plot, as the size of the screen display and the plot window typically differ, and the relative setting ensures that the proportions of the layout are kept.

SET DRAWING FONT-TYPE

...	FONT-TYPE	SIMPLE
		GROTESQUE
		ROMAN-NORMAL
		ROMAN-ITALIC
		ROMAN-BOLD

PURPOSE:

To set the drawing font type.

PARAMETERS:

SIMPLE	Simple font type (default).
GROTESQUE	Grotesque font type.
ROMAN-NORMAL	Roman-normal font type.
ROMAN-ITALIC	Roman-italic font type.
ROMAN-BOLD	Roman-bold font type.

SET DRAWING FRAME

...	FRAME	ON
		OFF

PURPOSE:

To set frame around drawing.

PARAMETERS:

ON	Set frame on.
OFF	Set frame off.

SET DRAWING GRID

...	GRID	ON
		OFF

PURPOSE:

To set grid on or off.

PARAMETERS:

ON	Set grid on.
OFF	Set grid off.

SET GRAPH

...	GRAPH	LINE-OPTIONS	subcom-mands	data
		XAXIS-ATTRIBUTES		
		YAXIS-ATTRIBUTES		

PURPOSE:

To set plot file characteristics.

PARAMETERS:

LINE-OPTIONS	Set the options controlling how lines are drawn and marked.
XAXIS-ATTRIBUTES	Set the options controlling the drawing and scale of the x-axis.
YAXIS-ATTRIBUTES	Set the options controlling the drawing and scale of the y-axis.

All subcommands and data are fully explained subsequently as each command is described in detail.

SET GRAPH LINE-OPTIONS

...	LINE-OPTIONS	LINE-TYPE	line	line-type
		MARKER	ON/OFF	
		MARKER-TYPE	line	marker-type
		MARKER-SIZE	size	

PURPOSE:

To set options controlling how lines are drawn and marked

PARAMETERS:

LINE-TYPE	Controls how lines are drawn. Only six lines can be controlled.
line	A line number, from 1 to 6.
line-type	BLANK,END-POINT,DASHED,DASH-DOT,DEFAULT,DOTTED or SOLID.
MARKER ON / OFF	Turn usage of markers on/off.
MARKER-TYPE	Control the marker type
marker-type	CROSS,DEFAULT,DELTA,DIAMOND,NABLA,PLUS,SQUARE or STAR
MARKER-SIZE	Set the size of the markers.

SET GRAPH XAXIS-ATTRIBUTES

...	XAXIS-ATTRIBUTES	DECIMAL-FORMAT	format		
		LIMITS	FREE/FIXED	xmin	ymin
		SPACING	LINEAR/LOGARITHMIC		
		TITLE	DEFAULT/SPECIFIED		xtitle

PURPOSE:

To set options controlling how lines are drawn and marked

PARAMETERS:

DECIMAL-FORMAT — Controls the presentation of numbers labelling the x-axis. The numbers can be presented in EXPONENTIAL format, in FIXED format, as INTEGERs or in GENERAL (free) format.

LIMITS — Controls the limits of the x-axis. These can either be FREE (i.e. determined by the data that are being presented or FIXED to the min value xmin and the max value xmax.

SPACING — Controls the spacing of numbers along the axis. The axis can have a LINEAR spacing or be LOGARITHMIC with base 10.

TITLE — The title at the x-axis can be specified by Framework or overridden with a SPECIFIED text: xtitle.

SET GRAPH YAXIS-ATTRIBUTES

...	YAXIS-ATTRIBUTES	DECIMAL-FORMAT	format		
		LIMITS	FREE/FIXED	ymin	ymax
		SPACING	LINEAR/LOGARITHMIC		
		TITLE	DEFAULT/SPECIFIED		ytitle

PURPOSE:

To set options controlling how lines are drawn and marked

PARAMETERS:

DECIMAL-FORMAT — Controls the presentation of numbers labelling the axis. The numbers can be presented in EXPONENTIAL format, in FIXED format, as INTEGERs or in GENERAL (free) format.

LIMITS — Controls the limits of the y-axis. These can either be FREE (i.e. determined by the data that are being presented or FIXED to the min value ymin and the max value ymax.

SPACING — Controls the spacing of numbers along the axis. The axis can have a LINEAR spacing or be LOGARITHMIC with base 10.

TITLE — The title at the y-axis can be specified by Framework or overridden with a SPECIFIED text: ytitle.

SET PLOT

...	PLOT	COLOUR	subcom-mands	data
		FORMAT		
		FILE		
		PAGE-SIZE		

PURPOSE:

To set plot file characteristics.

PARAMETERS:

COLOUR	Sets the output to the plot file to be in colours or monochrome.
FORMAT	Set the type of plot file to be used.
FILE	Set the prefix and name of the plot file.
PAGE-SIZE	Sets the size of the plot.

All subcommands and data are fully explained subsequently as each command is described in detail.

SET PLOT COLOUR

...	COLOUR	ON
		OFF

PURPOSE:

Turn colour on/off in the plot file.

PARAMETERS:

ON	Plot file output is in colours.
OFF	Plot file output is monochrome.

NOTES:

Note that display and plot colour options may be different.

See also:

PLOT
SET DISPLAY COLOUR...

SET PLOT FORMAT

...	FORMAT	SESAM-NEUTRAL
		POSTSCRIPT
		HPGL-7550
		HPGL-7470
		WINDOWS-PRINTER
		CGM-BINARY

PURPOSE:

To set the type of plot file format to be used in subsequent PLOT commands.

PARAMETERS:

SESAM-NEUTRAL	SESAM Neutral format. This is the default format.
POSTSCRIPT	PostScript format (PostScript is a trademark of Adobe Systems Incorporated). Note that this requires access to a printer that accepts PostScript files.
HPGL-7550	HP 7550 plotter file format.
HPGL-2	HP GL 2 plotter file format.
WINDOWS-PRINTER	Send plot directly to the default printer (defined in Windows).
CGM-BINARY	CGM binary plot file format.

NOTES:

The actual list of available devices depend on the installation. Some, but not necessarily all may be available.

SET PLOT FILE

...	FILE	prefix	name

PURPOSE:

To set the prefix and name of the plot file to be used in subsequent PLOT commands. Previous plot file (if any) will be closed.

PARAMETERS:

prefix	Prefix of the plot file.
name	Name of the plot file.

SET PLOT PAGE-SIZE

...	PAGE-SIZE	A1
		A2
		A3
		A4
		A5

PURPOSE:

Set the size of the plot written to the plot file.

PARAMETERS:

A1 A2 A3 A4 A5 Paper size.

NOTES:

Default size is A4.

SET PRINT

...	PRINT	DESTINATION	subcom-mands	data
		FILE		
		PAGE-HEIGHT		
		PAGE-ORIENTATION		
		SCREEN-HEIGHT		

PURPOSE:

To set print characteristics.

PARAMETERS:

DESTINATION	Set the print destination to screen or print file.
FILE	Set the prefix and name of the print file.
PAGE-HEIGHT	Set the number of lines between page breaks for the print file.
PAGE-ORIENTATION	Set the page orientation for the print file.
SCREEN-HEIGHT	Set number of lines in one screen page.

All subcommands and data are fully explained subsequently as each command is described in detail.

SET PRINT DESTINATION

...	DESTINATION	SCREEN
		FILE
		CSV-FILE

PURPOSE:

To set the print destination to screen or print file, ordinary text file or 'comma separated values' file.

PARAMETERS:

SCREEN	Direct print to the screen.
FILE	Direct print to the print file.
CSV-FILE	Direct print to the 'comma separated values' print file.

NOTES:

The CSV-FILE option gives the same print as the FILE destination option, but a semicolon is inserted as delimiter between each column in the print table. The print will contain the print introduction page and page break inclusive table nomenclature at top of each print table. It is therefore recommended to print each wanted data table to separate files and remove additional information above the table prior to e.g. importing the table data into Microsoft Excel. The file name will get the extension '.csv'. This print option sets the (maximum) number of lines for each print table to 100000. Use this option only in connection with PAGE-ORIENTATION LANDSCAPE.

See also:

`SET PRINT FILE...`

SET PRINT FILE

...	FILE	prefix	name

PURPOSE:

To set the prefix and name of the print file.

PARAMETERS:

prefix	Prefix of the print file.
name	Name of the print file.

NOTES:

See also:
`SET PRINT DESTINATION...`

EXAMPLES:

```
SET PRINT FILE JACKET_ JOINTS
```

SET PRINT PAGE-HEIGHT

...	PAGE-HEIGHT	n-line

PURPOSE:

To set the number of lines used between each page break when printing to file.

PARAMETERS:

n-line Number of lines.

NOTES:

E.g. by giving n-line = 100000 very long tables (e.g. member forces) are printed without page breaks. This command has the same effect as the program start-up command line argument:

/PRINT-PAGESIZE= n-line.

SET PRINT PAGE-ORIENTATION

...	PAGE-ORIENTATION	LANDSCAPE
		PORTRAIT

PURPOSE:

To set the page orientation for the print file.

PARAMETERS:

LANDSCAPE	The print page is 132 characters wide.
PORTRAIT	The print page is 80 characters wide.

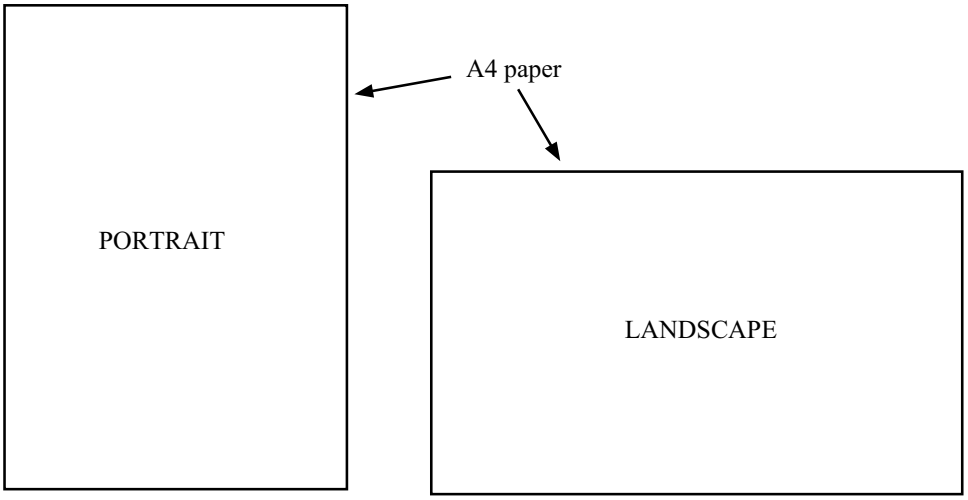


Figure 5.8 Setting print page orientation

SET PRINT SCREEN-HEIGHT

...	SCREEN-HEIGHT	n-line

PURPOSE:

To set the number of lines used in one screen page.

PARAMETERS:

n-line Number of lines.

NOTES:

See also:
`SET DISPLAY WORKSTATION-WINDOW...`

SET TITLE

...	TITLE	{text}*4

PURPOSE:

To set the title to be used on X-Y plots.

PARAMETERS:

text Give four lines defining the plot title.

TASK	CODE-CHECK
	FATIGUE-CHECK
	EARTHQUAKE-CHECK
	SHIP-ANALYSIS
	WIND-FATIGUE-CHECK
	ALL

PURPOSE:

To select a specific task. Upon selection, ONLY the commands relevant to that task shall be visible (and possible to select).

PARAMETERS:

CODE-CHECK	Only commands relevant to code checks shall be visible.
FATIGUE-CHECK	Only commands relevant to fatigue check shall be visible.
EARTHQUAKE-CHECK	Only commands relevant to an earthquake check shall be visible.
SHIP-ANALYSIS	Only commands relevant to a ship analysis shall be visible.
WIND-FATIGUE-CHECK	Only commands relevant to wind fatigue check shall be visible.
ALL	All commands shall be visible independent of the task.

EXAMPLES:

```
TASK CODE-CHECK
```

VIEW	FRAME	subcom-mands	data
	PAN		
	POSITION		
	ROTATE		
	ZOOM		
	XYPAN		
	XYZOOM		

PURPOSE:

To control the appearance of the view, by specification of view angles, zoom and pan.

PARAMETERS:

FRAME	Perform an automatic zoom to fit the current view within the frame of the display.
PAN	Pan (shift) the current view in the plane of the screen.
POSITION	Define the view angles by specifying a point in space which, together with the centre of the model's coordinate system, defines the direction of the user's observation.
ROTATE	Rotate view by specifying rotation angles.
ZOOM	Zoom in or out.
XYPAN	Pan (shift) the current view in the plane of the screen defined by relative display co-ordinates.
XYZOOM	Zoom in or out defined by relative display coordinates.

All subcommands and data are fully explained subsequently as each command is described in detail.

VIEW FRAME

...	FRAME

PURPOSE:

Perform an automatic zoom to fit the current view within the frame of the display.

PARAMETERS:

None

NOTES:

See also:

```
DISPLAY...
VIEW ZOOM
VIEW PAN
```

VIEW PAN

...	PAN	pick_from	pick_to

PURPOSE:

Pan (shift) the current view in the plane of the screen. The view is shifted by defining a vector in the plane of the screen. The vector is defined by picking the ‘from’ and the ‘to’ positions, see below.

PARAMETERS:

pick_from	Pick (using mouse or cross-hair) a point on the screen to define the ‘from’ position.
pick_to	Pick (using mouse or cross-hair) a point on the screen to define the ‘to’ position.

NOTES:

See also:

`DISPLAY...`
`VIEW ZOOM`
`VIEW FRAME`

VIEW POSITION

...	POSITION	x-model	y-model	z-model

PURPOSE:

Define the view angles by specifying a point in space. The imaginary line from this point towards the origin of the model's coordinate system defines the direction of the user's observation.

Note that this command is independent of any previously entered rotations, and can therefore be used to 'reset' the viewing direction.

PARAMETERS:

x-model	x-coordinate in the model's coordinate system.
y-model	y-coordinate in the model's coordinate system.
z-model	y-coordinate in the model's coordinate system.

NOTES:

See also:

```
DISPLAY...
VIEW ROTATE
VIEW FRAME
```

VIEW ROTATE

...	ROTATE	TO	angle-x	angle-y	angle-z
		UP	angle-x-screen		
		DOWN	angle-x-screen		
		LEFT	angle-y-screen		
		RIGHT	angle-y-screen		
		CLOCKWISE	angle-z-screen		
		X-AXIS	angle-x-model		
		Y-AXIS	angle-y-model		
		Z-AXIS	angle-z-model		

PURPOSE:

Rotate view by specifying rotation angles. Note that this command operates in two basic modes, screen mode and space mode.

Screen mode (TO, UP, DOWN, LEFT, RIGHT & CLOCKWISE alternatives): Here, all angles are relative to the screen axes, which remains fixed, no matter how many rotations are entered. The angles should be interpreted such that it is the observer (the user) that revolves around a stationary model.

The origin of the screen axis system lies in the centre of the screen. The x-axis is horizontal and points from the origin towards the right hand side of the screen. The y-axis is vertical and points from the origin towards the top of the screen. The z-axis is horizontal and points from the origin and out of the screen (towards the user).

Space mode (X-AXIS, Y-AXIS & Z-AXIS alternatives). Here, all angles are relative to the model axes, which follow the rotations. The angles should be interpreted such that it is the model coordinate system that rotates relative to the observer.

PARAMETERS:

TO — angle-x angle-y angle-z - This alternative is independent of all previously entered rotations. At the execution of this command, the program first re-initialises the rotations, such that the model and screen axes overlap. Then, the x, y and z rotations specified by the user are applied, in the same order.

UP — angle-x-screen – Rotate the view position angle-x-screen degrees UP, relative to the screen x-axis, from the current position.

DOWN — angle-x-screen - Rotate the view position angle-x-screen degrees DOWN, relative to the screen x-axis, from the current position.

LEFT — angle-y-screen - Rotate the view position angle-y-screen degrees LEFT, relative to the screen y-axis, from the current position.

RIGHT — angle-y-screen - Rotate the view position angle-y-screen degrees RIGHT, relative to the screen y-axis, from the current position.

CLOCKWISE — angle-z-screen - Rotate the view position angle-z-screen degrees CLOCKWISE, relative to the screen z-axis, from the current position.

X-AXIS — angle-x-model - Rotate the model coordinate system angle-x-model around the model x-axis.

Y-AXIS — angle-y-model - Rotate the model coordinate system angle-x-model around the model y-axis.

Z-AXIS — angle-z-model - Rotate the model coordinate system angle-x-model around the model z-axis.

NOTES:

See also:

DISPLAY...
VIEW POSITION

```
VIEW FRAME
```

VIEW ZOOM

...	ZOOM	IN OUT	pick	pick

PURPOSE:

To zoom the current view in or out.

PARAMETERS:

IN	Zoom out by pointing to two diagonal corners in a square on the screen. The part of the view within the square will then be enlarged and fitted within the whole screen, causing an illusion of movement towards the model.
OUT	Zoom out by pointing to two diagonal corners in a square on the screen. The current view will then be compressed and fitted within the smaller square, causing an illusion of movement away from the model.

NOTES:

See also:

`DISPLAY...`
`VIEW FRAME`

VIEW XYPAN

...	XYPAN	x1	y1	x2	y2

PURPOSE:

Pan (shift) the current view in the plane of the screen. The view is shifted by defining a vector in the plane of the screen. The vector is defined by relative display coordinates.

PARAMETERS:

x1	X coordinate for first point.
y1	Y coordinate for first point.
x2	X coordinate for second point.
y2	Y coordinate for second point.

NOTES:

The VIEW PAN command is logged as VIEW XYPAN both from line mode and graphical mode.

See also:

DISPLAY...
VIEW ZOOM
VIEW FRAME

VIEW XYZOOM

...	XYZOOM	IN OUT	x1	y1	x2	y2

PURPOSE:

To zoom the current view in or out.

PARAMETERS:

IN	Zoom out by pointing to two diagonal corners in a square on the screen. The part of the view within the square will then be enlarged and fitted within the whole screen, causing an illusion of movement towards the model.
OUT	Zoom out by pointing to two diagonal corners in a square on the screen. The current view will then be compressed and fitted within the smaller square, causing an illusion of movement away from the model.
x1	X coordinate for first point.
y1	Y coordinate for first point.
x2	X coordinate for second point.
y2	Y coordinate for second point.

NOTES:

The VIEW ZOOM command is logged as VIEW XYZOOM both from line mode and graphical mode.

See also:

DISPLAY...
VIEW FRAME

6 Wind fatigue design

6.1 Purpose

This section is part of the original Framework Wind Fatigue Theory Manual [24]. A few typing corrections have been made. The primary content of the old Theory Manual is still valid. Some detailed derivation still refers to the appendix of the old Theory Manual.

The purpose of this manual is to describe the theory underlying the Framework wind fatigue application. Wind fatigue of Framework is according to the wind fatigue program Gusto [2], which has been implemented into Framework for the purpose of making wind fatigue application available in Sesam.

This original theory manual [24] is a reprint of the theory manual of Gusto [1], except for matters and references related to external programs, which are not relevant for Framework applications.

6.2 Scope

This manual describes the calculation methods used in Framework for the determination of fatigue damage to frame structures subjected to wind loading. Buffeting loads due to gusting are treated by the power spectral density approach. The damage is a function of the overall structural response. The effects of vortex shedding induced fatigue due to steady winds are treated by separate evaluation of individual member responses. Framework calculates the two effects on the assumption that they are uncoupled. The resultant damages are summed to give overall fatigue lives of joints and members.

6.3 Overview and assumptions

6.3.1 Overview

The Framework wind fatigue module evaluates fatigue damage of frame structures subjected to wind loading. Buffeting loads due to wind gusts and the vortex shedding effects due to steady state wind are considered. Wind fatigue due to buffeting loads is treated by the power spectral density method (or termed energy spectrum or wave spectrum method) and the damage is a function of the overall structural response. The effects of vortex shedding induced fatigue are treated by evaluation of individual member responses. The two effects are calculated on the assumption that they are uncoupled and are summed to give the overall fatigue damages of joints and members in the structure. The Framework wind fatigue module receives input information in terms of the eigen-modes of a structure, coupled with statistical data on the annual wind distribution and associated drag factors.

The fatigue analysis is based on annual wind data. The annual wind data are characterized by a set of wind states, considered to represent the climate for the year. For each of these wind states, the response stress power spectra at local "hot spots" within a particular joint are evaluated.

For buffeting fatigue calculations the hotspot power spectrum response is divided into a quasi-static response part and a dynamic response part, see Figure 6.2. The quasi-static part of the power spectrum covers the low frequency non-resonant response. This spectrum has a broad peak at low frequencies but is treated as a narrow band at its peak frequency. The resulting damage is then multiplied by a broad band correction factor accounting for the broadness of wind spectrum, see Appendix B.5 Wide Band Correction Factor for Spectral Fatigue Analysis. An alternative to this approach has been implemented where the broad band nature of the quasi-static part of the power spectrum is accounted for by using the Wirsching correction factor for wide banded processes.

The dynamic response consists of the excited resonant modes. It is partitioned into the separate resonant modal responses; for each of these an independent damage assessment is made. This assumes that each response is narrow band and independent of the others.

Vortex shedding from brace members may induce oscillations in individual braces. These are local modes rather than overall structural modes. It is assumed that the vortex shedding effects are of significance for fatigue only if they induce oscillations in the first mode of the brace.

The quasi-static part of the power spectra covers the low frequency non-resonant response. This spectrum has a broad peak at low frequencies but is treated as a narrow band at its peak frequency with one third

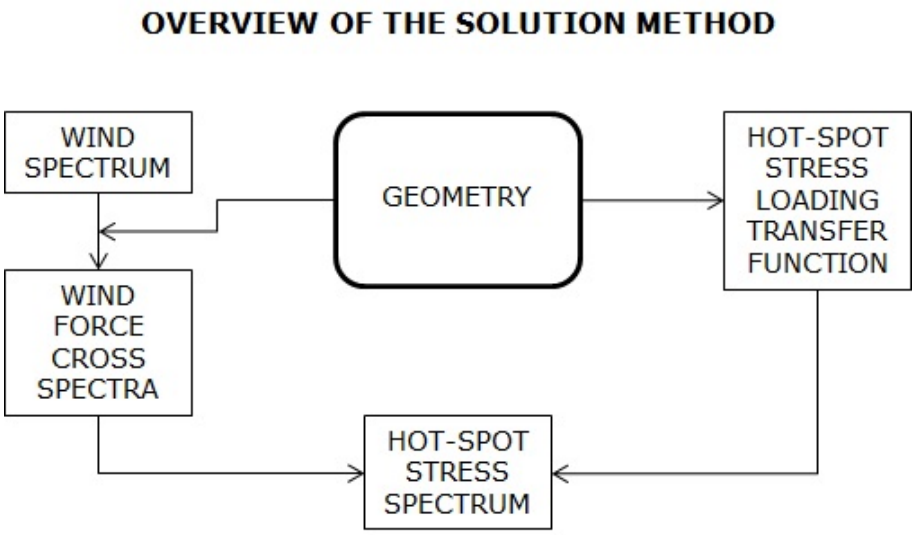


Figure 6.1: Generation of hot-spot stress spectrum

of the stress variance of the low frequency broad band stress spectrum. The resulting damage is then multiplied by 10. This approach assumes that the quasi-static contribution to the damage is small, so that a rigorous evaluation is not required.

For each of these dynamic and static partitions a Rayleigh distribution of the "hot spot" stress range versus the number of cycles is assumed. The variance is given by the integral under the power spectrum. Fatigue damage may then be evaluated by application of the Palmgren-Miner relationship and use of a recognised SN-curve (see Section 6.14).

Vortex shedding from brace members may induce oscillations in individual braces. These are local modes rather than overall structural modes. It is assumed that the vortex shedding effects are only of any significance for fatigue if they induce oscillations in the first mode of the brace.

The overview of this solution method is shown in Figures 6.1 to 6.4.

With reference to Figure 6.3 “Summary of calculation methods". For the process “USE OF HOT-SPOT STRESS SPECTRUM IN PREDICTION OF FATIGUE LIFE FOR A GIVEN WINDSTATE" reference is made to Section 6.13.2.

With reference to Figure 6.4 “Expanded derivation of hot-spot stress spectrum". For the process “DERIVATION OF CROSS-POWER SPECTRUM OF WIND FORCING" reference is made to Section 6.8. For the process “DERIVATION OF FREQUENCY DOMAIN STRUCTURE TRANSFER FUNCTION" reference is made to Sections 6.10 – 6.12.

Specifically, for the individual processes reference is made as follows

“Demonstrate the Guyan Reduction Method" see Section 6.10

“Describe Joint Stress Concentration Factors" see Section 6.11

“Describe the Hot-Spot Stress Transfer Function from Point Forcing" see Section 6.12

And finally, for the process “COMBINATION TO FORM HOT-SPOT STRESS SPECTRUM" reference is made to Section 6.13.

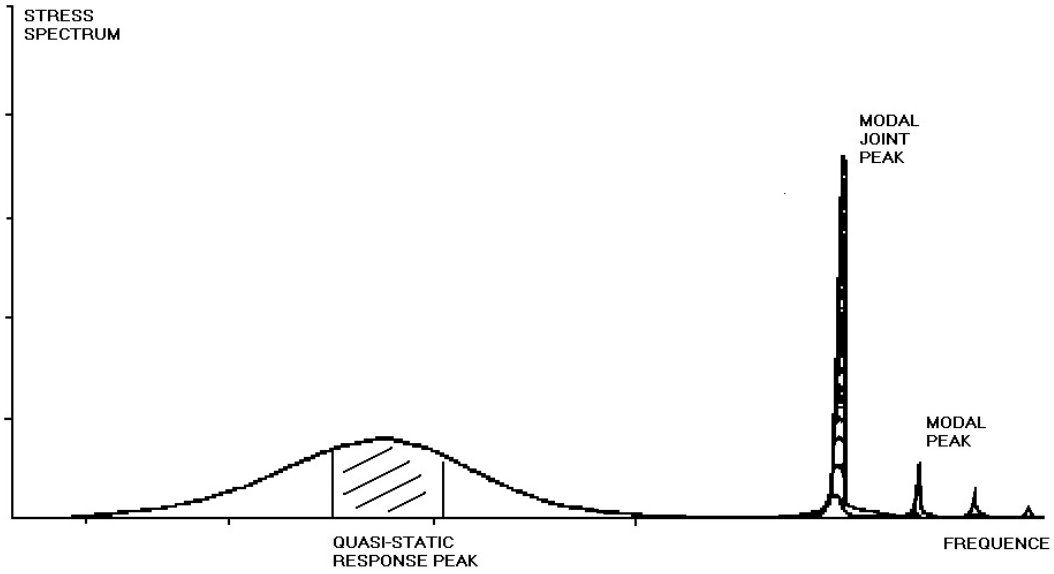


Figure 6.2: Typical hotspot stress spectrum due to wind loading

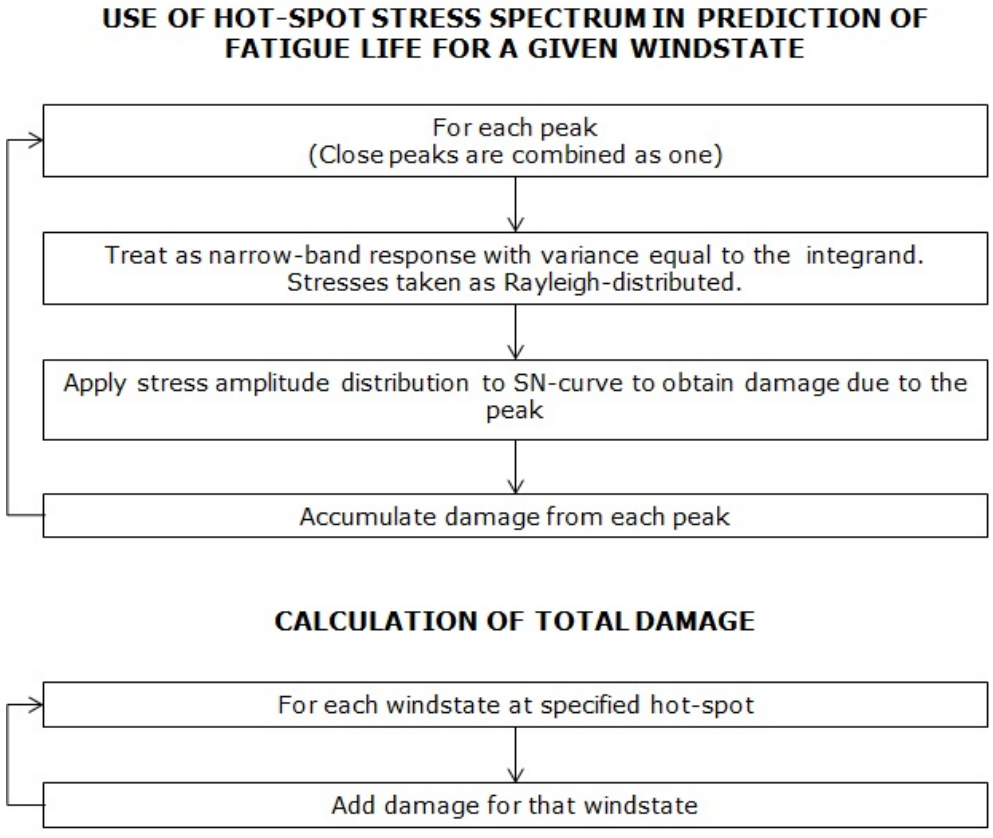


Figure 6.3: Summary of calculation methods

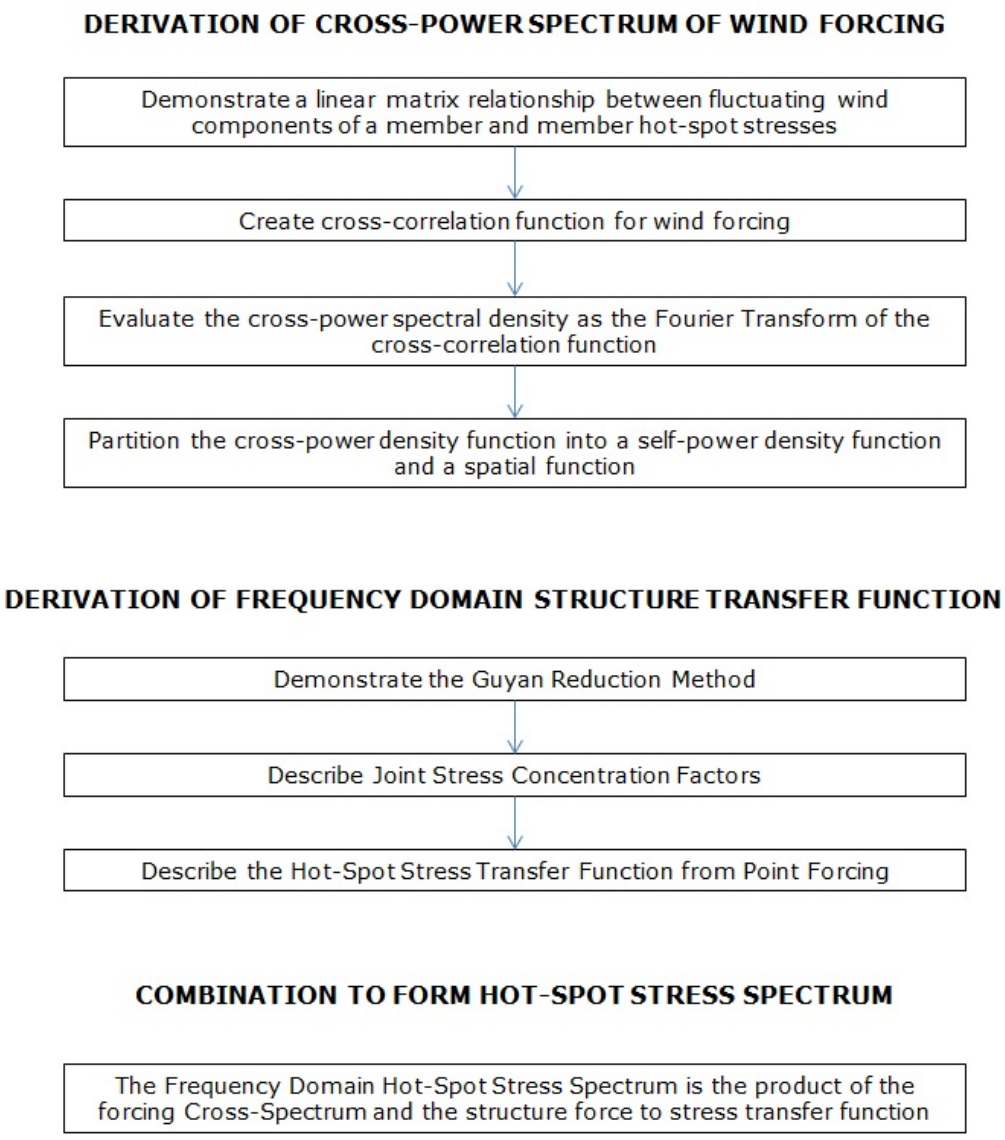


Figure 6.4: Expanded derivation of hot-spot stress spectrum

6.3.2 Assumptions

The major assumptions made for wind fatigue calculation are:

1. buffeting damage is dominated by low frequency resonant modes
   this implies:
   - separate narrow-band damage evaluation for the resonant modal responses is conservative
   - the greatest hot spot stresses within a modal response cycle occur at maximum modal amplitude
   - Guyan reduction may be used to reduce the mass and stiffness matrices without significant loss of accuracy to the low modes, see Section 6.8. (Note: The Framework wind fatigue assumes all non-fixed translational degrees of freedoms (dof) to be set to master degrees of freedoms.)
2. the greatest hotspot stresses within a modal response cycle occur at maximum modal amplitude
3. the structure is made of welded tubular members
4. parametric SCF equations or user specified SCFs are used to evaluate joint stress concentrations
5. wind forces are parameterized as linear fluctuating components super-imposed upon mean wind profiles
6. wind gust velocities in the mean wind direction and normal to the mean wind both horizontally and vertically are statistically independent
7. member drag coefficients are invariant under the fluctuating wind component and are proportional to the mean wind speed
8. vortex shedding induced member oscillations and fatigue are uncoupled from any buffeting induced vibrations and damage

6.3.3 Scope of analysis

The solution technique used by Framework requires a significant amount of input information. Eigenvalues, mass normalized eigenvectors, resultant stresses from the normalized eigendeformations, and forcing functions generated by Sestra, reference is made to [32].

6.4 The spectral approach

The most appropriate technique for determining wind-induced cyclic stresses is referred to as the frequency-domain or power-spectral density approach.

A power spectrum describes a time-dependent variable relating the energy distribution over a range of frequencies. All phase information is averaged out. Analysis methods whereby output spectra are obtained from input spectra via transfer functions are required for random processes such as wind or wave loading, where only a statistical description of the environmental forces can be given. In the spectral analysis method of fatigue due to wind, the stress spectrum is obtained from the input wind spectrum via the structure stress transfer function. Because of the nature of the fluctuating wind force, there is, to good accuracy, a direct linear relationship between the wind speed and force spectra allowing structure stress spectra to be linearly related to wind speed spectra.

6.5 The nature of the wind

The energy content of wind as a function of frequency is demonstrated in the form of a power spectrum averaged over a year, as shown in Figure 6.5, taken from [66]. Two dominant peaks occur in this figure. The lower frequency peak is associated with cycles with a period of the order 2-3 days and is due to the passage of large-scale atmospheric depressions. The higher frequency peak has significant energy in the range 10 minutes to 1 second. It is this part of the spectrum, which is of interest to structural designers and is commonly known as the gust spectrum. There is apparently a lack of wind energy with periods between 10 minutes and two hours. It can clearly be assumed that fatigue, which depends on changes in wind speed, is not significantly affected by cycles of length greater than two hours.

For the purpose of fatigue analysis, the wind speed is averaged over a suitable period and the wind is then represented in that time as having a constant mean value and direction, upon which fluctuations or gusts are superimposed. Although a period of about ten minutes would appear to be desirable as an averaging period in order to reflect the influence of the short-term storms, a period of one hour has traditionally been used. It is for this time that data are usually available, see, for example, [74]. The API and NORSOK power laws represent the variation of mean wind speed with height relationship based on the drag at the earth's

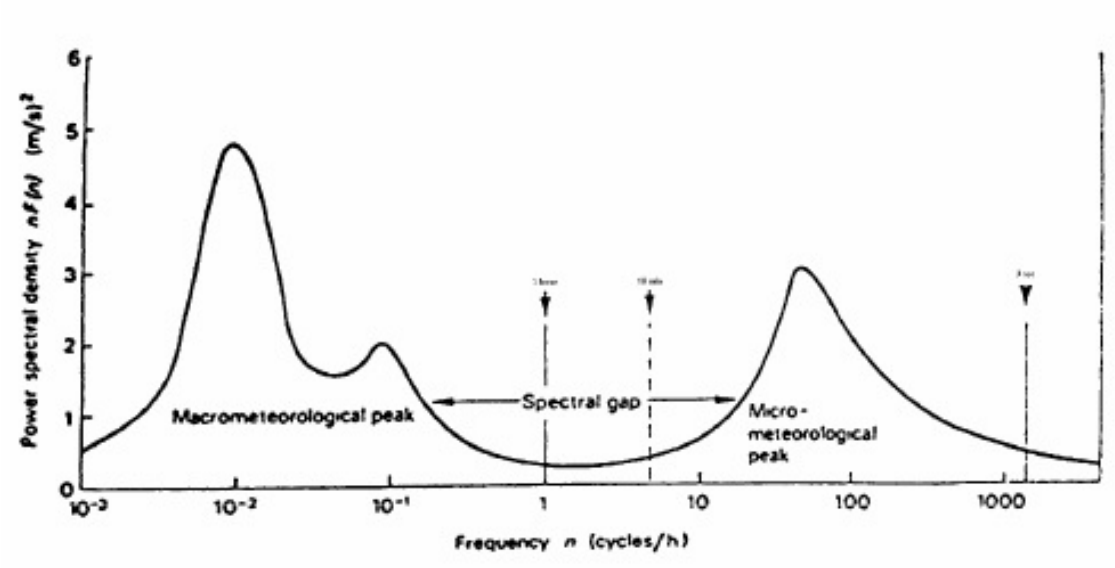


Figure 6.5: Spectrum of horizontal wind speed, from [66]

surface.

While the mean wind in any given hour is represented by speed and direction, the gust components are statistically described by three parameters: probability distribution, power spectrum (sometimes cross-power spectrum) and cross-correlation function.

The probability distribution describes the ratio or percentage of time a certain wind speed is likely to occur, the power spectra reflect the energy content of the wind as a function of frequency, and the cross-correlation function indicates the way in which the gusts are spatially correlated.

The probability distribution can be obtained from measurements; but standard formulae exist for describing this as a function of mean wind speed, ([7] and [48]). A set of wind states may, for instance be formed by taking wind measurements, over a period of one year, to show the number of hours per year the hourly mean wind is blowing for each speed and direction. The measurements are normally taken at 10m above ground or sea level. For each of these, three parameterized gust spectra are calculated, and a resultant damage assessment made. The total annual damage is obtained by adding these damage assessments in proportion to the fraction of a year in which they are generated.

6.6 Wind spectra

Framework requires the definition of a set of hourly mean wind speed (the 60-minute mean wind speed) vs. height profiles, their bearings and for what fraction of a year they exist. For each of these, three parameterized gust spectra are calculated, and a resultant damage assessment made. The total annual damage may be obtained by adding these damage assessments in proportion to the fraction of a year in which they are generated.

Obtaining a set of such hourly mean profiles may in itself be a major undertaking when the measured data are not totally adequate. Engineering judgement may be required in assessing what approximations are valid. To gain the necessary knowledge base from which to do this, the reader's attention is drawn to References [7] and [11].

In general, over a period of one year, wind measurements can be taken to show the number of hours per year the hourly mean wind is blowing for each speed and direction. These measurements are taken at 10m above ground or sea level. By applying a power law to represent the variation of mean wind speed with height relationship based on the drag at the earth's surface, ([7]), the requirements are met.

Typically the wind data are such that the easiest set of hourly mean wind speeds to find are over the eight

major compass points and the twelve/fourteen divisions of the Beaufort scale. A hypothetical table for the percentage of the year occupied by each such wind state is shown in Table 6.1 related to the Beaufort scale.

	Direction								
Beaufort scale	N	NE	E	SE	S	SW	W	NW	Total
1: 0.3-1.5 m/s	0.24	0.13	0.14	0.14	0.18	0.16	0.19	0.23	1.44
2: 1.6-3.3 m/s	0.77	0.64	0.61	0.46	0.77	0.59	0.74	0.68	5.27
3: 3.4-5.4 m/s	1.52	1.42	1.27	1.30	2.08	1.82	1.84	1.71	12.97
4: 5.5-7.9 m/s	3.14	2.59	1.67	2.22	4.77	3.64	4.01	2.94	24.98
5: 8.0-10.7 m/s	2.57	1.95	0.48	1.71	4.26	3.12	2.74	2.06	18.89
6: 10.8-13.8 m/s	2.90	1.47	0.39	1.84	4.72	2.85	2.41	1.80	18.37
7: 13.9-17.1 m/s	1.58	0.73	0.14	1.42	2.84	1.52	1.36	1.23	10.82
8: 17.2-20.7 m/s	0.67	0.20	0.04	0.75	1.57	0.62	0.82	0.58	5.26
9: 20.8-24.4 m/s	0.12	0.02	0.00	0.27	0.41	0.16	0.18	0.13	1.28
10: 24.5-28.4 m/s	0.02	0.01	0.00	0.13	0.16	0.02	0.06	0.04	0.44
11: 28.5-32.6 m/s	0.00	0.00	0.00	0.02	0.05	0.00	0.00	0.02	0.09
12: > 32.7 m/s	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
									100

Table 6.1: Probability distribution of mean wind speed expressed as % of year for which it occurs

In such a case the bearing of the normal to one of the structure faces does not usually correspond to one of the compass points. For convenience, the data may be linearly interpolated to provide wind directions meeting this criterion.

Towers, which exhibit symmetry, may allow opposing wind directions to be treated as one. Table 6.2 shows data for the 8 directions of Table 6.1 expressed as four composite directions. The annual mean wind distribution is therefore fully characterized in Table 6.2 by 48 wind states, that is 12 in each of four directions.

For each wind state, the wind speed at a height of 10m above the earth's surface is used to help compute a single-sided gust spectrum $S^s w(f)$, where f is in cycles/sec.

Beaufort scale		N/S	NE/SW	E/W	SE/NW
1: 0.3-1.5 m/s	(0.90 m/s)	0.42	0.29	0.33	0.37
2: 1.6-3.3 m/s	(1.95 m/s)	1.54	1.23	1.35	1.14
3: 3.4-5.4 m/s	(4.40 m/s)	3.60	3.24	3.11	3.01
4: 5.5-7.9 m/s	(6.70 m/s)	7.91	6.23	5.68	5.16
5: 8.0-10.7 m/s	(9.35 m/s)	6.83	5.07	3.22	3.77
6: 10.8-13.8 m/s	(12.40 m/s)	7.62	4.32	2.80	3.64
7: 13.9-17.1 m/s	(15.50 m/s)	4.42	2.25	1.50	2.65
8: 17.2-20.7 m/s	(18.80 m/s)	2.24	0.82	0.86	1.33
9: 20.8-24.4 m/s	(22.60 m/s)	0.53	0.18	0.18	0.40
10: 24.5-28.4 m/s	(26.45 m/s)	0.18	0.03	0.06	0.17
11: 28.5-32.6 m/s	(30.55 m/s)	0.05	0.00	0.00	0.04
12: > 32.7 m/s	(32.70 m/s)	0.00	0.00	0.00	0.00

Table 6.2: Probability distribution of composite wind states expressed as % of year for which it occurs

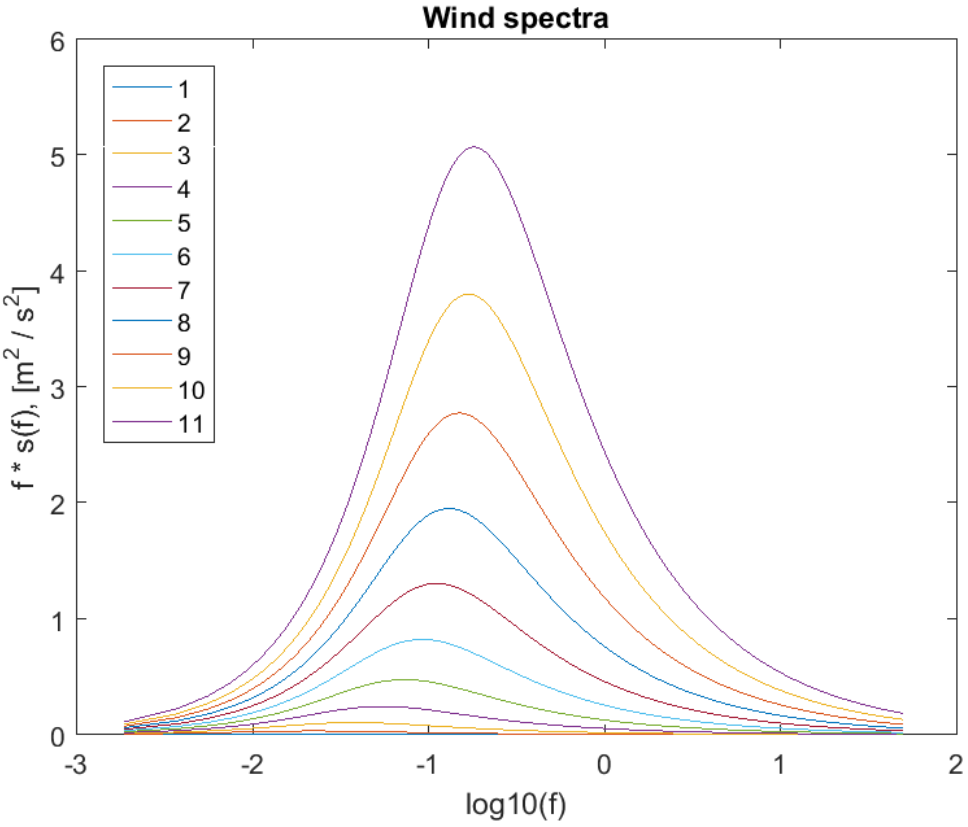


Figure 6.6: Gust spectra for wind states 1-11 in Tables 6.1 and 6.2 (SI units)

Figure 6.6 shows a plot of the HARRIS spectra ([7]), associated with wind cases 1-11 in Tables 6.1 and 6.2

with mean wind speeds as shown in parantheses in the "Beaufort scale" column of Table 6.2. In addition, the surface drag coefficient (k) is set to 0.003 and the turbulence length scale (L_u) is set to 180 meters for Beaufort scale 1 with an increase by 10 meters for each wind scale level. See for instance [22] for choices of L_u. Notice that the Harris spectrum – as defined in [22], expresses the spectral density in terms of the 10-minute mean wind speed, while in Framework it is expressed in terms of the 60-minute mean wind speed. Consult Appendix B.6 for the definition of the Harris spectrum ([7]).

The Harris spectra ([7]) – and other spectra, exhibit a number of important features:

- the eddy spectra is independent of height; simplifying the problem
- at typical tower modal frequencies ($\sim$ 1Hz) gust energy increases greatly with mean wind speed. Typically damage per unit time is proportional to the mean velocity raised to a power between 8 and 12
- the eddy spectra is linearly dependent on the drag at the earth's surface

From these single-sided spectra $S^s w(f)$ in cycles/sec, the double-sided spectra in rad/sec are then

$$S_w(\omega) = \frac{1}{4\pi} S^s w(f), \tag{6.1}$$

where

$$f = \frac{\omega}{2\pi}.$$

6.7 Wind spectra and coherence models

The cross-power spectrum $S(r, f)$ of the wind may be approximated by a frequency dependent part $S(f)$, termed spectral density or wind spectrum, and a spacial dependent part, $coh(r, s, f)$, termed wind coherence:

$$S(r, s, f) = S(f) \cdot coh(r, s, f). \tag{6.2}$$

The wind coherence describes the cross-correlation coefficients between the spectral densities of two points (r, s) in space and is a function of the separation of the points.

Five wind spectra are available in Framework:

1. the HARRIS spectrum representing gust components in the mean wind direction ([7])
2. the DAVENPORT spectrum representing gust components in the mean wind direction ([48])
3. the NPD spectrum representing gust components in the mean wind direction (Frøya in [22] and [40])
4. the PANOFSKY LATERAL spectrum representing gust components lateral across to the mean wind ([48])
5. the PANOFSKY VERTICAL spectrum representing gust components vertical across to the mean wind ([48])

The HARRIS and DAVENPORT spectra are independent of height (z) and is linearly dependent on the drag at the ground surface. The PANOFSKY and NPD spectra depend on the height (z).

The first three are spectra representing the gusts in the same direction as the mean wind, the fourth is for lateral (horizontal) gusts across the mean wind and the fifth is for vertical gusts across the mean wind.

The following coherence models are available in Framework:

1. the GUSTO 1 coherence model associated with the Harris wind spectrum
2. the GUSTO 2 coherence model associated to the Davenport and Panofsky wind spectra
3. the GENERAL coherence model associated with the Harris, Davenport and Panofsky wind spectra
4. the DAVENPORT coherence model associated with the Harris, Davenport and Panofsky wind spectra

Table 6.3: Possible combinations of wind spectrum and coherence model

Wind spectrum	**Wind component**	**Coherence options**				
		Model 1	Model 2	Model 3	Model 4	Model 5
		Gusto 1	Gusto 2	General	Davenport	NPD
Harris	u	Yes		Yes	Yes	
Davenport	u		Yes	Yes	Yes	
NPD	u					Yes
Panofsky lateral	v		Yes	Yes	Yes	
Panofsky vertical	w		Yes	Yes	Yes	

5. the NPD (Frøya in [22]) coherence model

Possible combinations of wind spectrum and coherence model implemented in Framework are given in Table 6.3. The spectra and coherence models are defined and further discussed in Appendix B.6.

6.8 A spectral forcing function

In this section, an approximation to the cross-power spectral density function of the buffeting wind loads is presented in terms of the power spectra for the fluctuating wind. This may then be used in the derivation of hot-spot stress power spectra. The linear relationship between the forcing spectra and hot-spot stress spectra forms the backbone of the spectral approach to wind fatigue analysis.

In Sections 6.8.1 and 6.8.2 a linear relationship between the fluctuating wind components and the fluctuating forcing at a given node is established. This involves first evaluating the forcing on the members, and then defining a relationship between member forces and nodal forces. Because the linear relationship exists and the wind spectra applied in the three directions may be regarded as statistically independent the cross-power spectral density function of the forcing from all three spectra is the linear sum of that from the individual spectra. In Section 6.8.3 the cross-power spectrum of forcing is found from the wind cross-power spectral density function of the wind. The wind-cross power spectral density function is then expressed in terms of the power spectrum of this wind, multiplied by a simple function. For detailed descriptions of the mathematical definitions of the various spectral functions above, see Appendix B.6.

6.8.1 Wind force on a member

The general form for the wind force on a member, as shown in Figure 6.7, is given by

$$\mathbf{F} = \frac{1}{2}\rho C_d D L |\mathbf{u}_n| \mathbf{u}_n, \tag{6.3}$$

where ρ is the mass density of the air, C_d is the member drag coefficient, D is the member diameter, L is the member length, and $\mathbf{u}_n$ is the wind velocity vector normal to the member.

The above form (the Morison formula 6.3) can be expanded by splitting the wind velocity vector into a mean velocity (u_{mean}) and three fluctuating gust components. A gust component denoted $u^g = u^d$ longitudinal to the mean wind direction, a gust component denoted $v^g = v^d$ lateral to the mean wind direction, and a gust component denoted $w^g = w^d$ vertical to the mean wind direction. Then the wind force vector may be written as

$$\mathbf{F}(t) = \mathbf{F}_{\langle u \rangle u^d} + \mathbf{F}_{\langle u \rangle v^d} + \mathbf{F}_{\langle u \rangle w^d}, \tag{6.4}$$

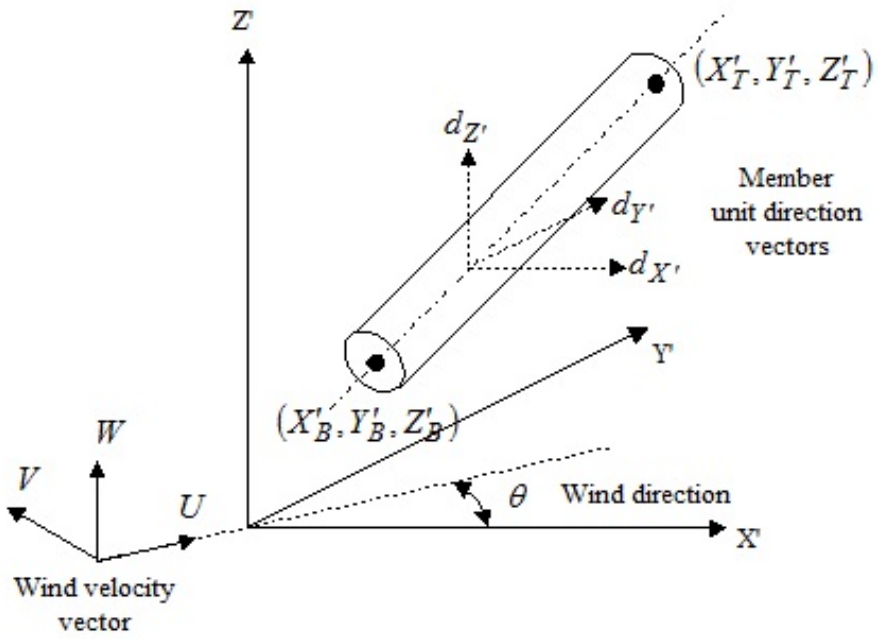


Figure 6.7: Wind forces on a member

where the resulting force vector has been divided into three separated vectors representing forces due to the three wind gust components u^d, v^d, w^d, respectively. Further notice that time dependency is indicated by setting $\mathbf{F} = \mathbf{F}(t)$.

When the formula 6.3 is expanded and the fluctuating terms – the gust components – are considered to be small compared to the time mean terms, then the wind force $\mathbf{F}(t)$ may be expressed as

$$\begin{aligned}\mathbf{F}(t) &= \frac{1}{2}\rho C_d D L a A \begin{bmatrix}\langle u\rangle^2 \\ 0 \\ 0\end{bmatrix} + \frac{1}{2}\rho C_d D L a A \begin{bmatrix}2 & b & c \\ 0 & 1 & 0 \\ 0 & 0 & 1\end{bmatrix} \begin{bmatrix}\langle u\rangle u^d \\ \langle u\rangle v^d \\ \langle u\rangle w^d\end{bmatrix} \\ &= \frac{1}{2}\rho C_d D L a A \left(\begin{bmatrix}\langle u\rangle^2 \\ 0 \\ 0\end{bmatrix} + \begin{bmatrix}2 & b & c \\ 0 & 1 & 0 \\ 0 & 0 & 1\end{bmatrix} \begin{bmatrix}\langle u\rangle u^d \\ \langle u\rangle v^d \\ \langle u\rangle w^d\end{bmatrix} \right),\end{aligned} \tag{6.5}$$

where A is a transformation matrix, and a, b, and c are constants depending on the mean wind direction and member orientation. See Appendix 9 Pre-processing of Wind Loads by Wajac of Framework Wind Fatigue Theory Manual [24]. The notation $\langle(\cdot)\rangle$ indicates that $(\cdot)$ is a time average component, see Appendix K.

In the wind force expression 6.5, the wind velocity vector over a period of time has been split into a time mean

$$\begin{bmatrix}\langle u\rangle \\ 0 \\ 0\end{bmatrix}, \tag{6.6}$$

plus fluctuation

$$\begin{bmatrix}u^d \\ v^d \\ w^d\end{bmatrix}. \tag{6.7}$$

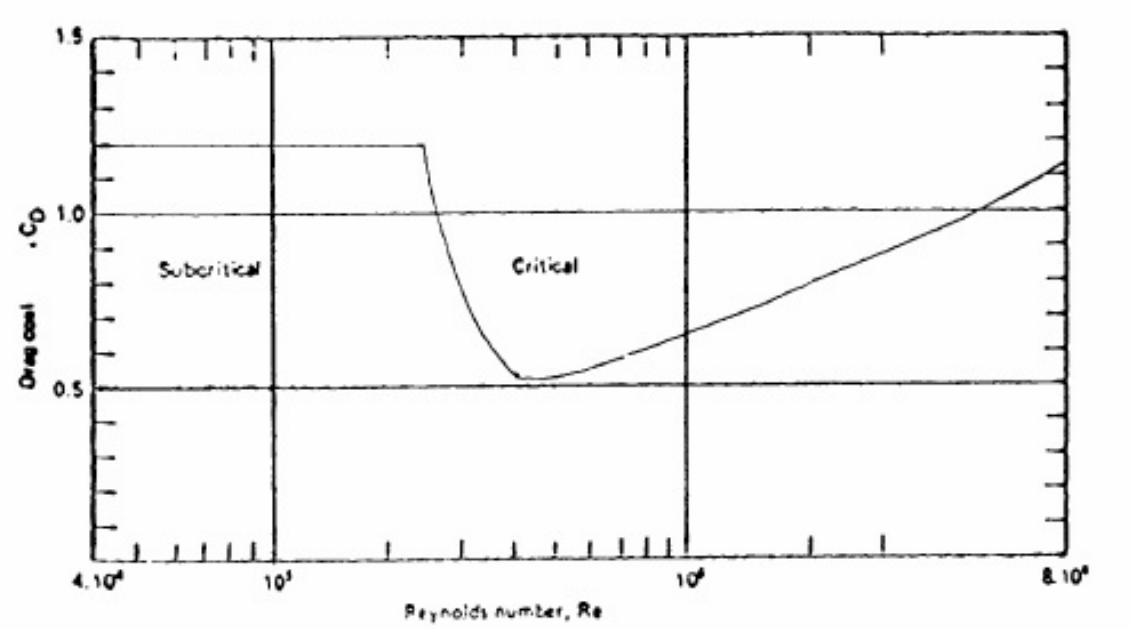


Figure 6.8: Variation of drag coefficient for a cylindrical member with Reynolds' number

All structural members are assumed to be tubular with drag coefficients of 1.2 in the sub-critical regime and varying as per Figure 6.8 in the critical and super-critical regimes. Although Reynolds' number varies with wind speed, the assumption is made that the drag coefficient is not time dependent.

The drag coefficient is dependent on the Reynolds' number as below.

In the absence of ice

$$\begin{aligned} &\mathrm{Re} \leq 2.5 \times 10^5 && C_d = 1.2 \\ &2.5 \times 10^5 < \mathrm{Re} \leq 3.85 \times 10^5 && C_d = 10^{10.8599 - 1.997199 log(\mathrm{Re})} \\ &3.85 \times 10^5 < \mathrm{Re} && C_d = 10^{0.2557 log(\mathrm{Re}) - 1.7109} \end{aligned}$$

In the presence of ice the relationship is

$$\begin{aligned} &\mathrm{Re} \leq 5 \times 10^5 && C_d = 1.2 \\ &\mathrm{Re} > 5 \times 10^5 && C_d = 0.7 \end{aligned}$$

6.8.2 The wind force on a degree of freedom

By summing these member forces and distributing them to the degrees of freedom, the fluctuating force, or time dependent force, at degree of freedom r from wind fluctuations may be expressed as

$$\begin{aligned} F_r^d(t) &= 2 \cdot E_r^{uu} \cdot \langle u(z_r,t) \rangle \cdot u^d(t) + 2 \cdot E_r^{vv} \cdot \langle u(z_r,t) \rangle \cdot v^d(t) + 2 \cdot E_r^{ww} \cdot \langle u(z_r,t) \rangle \cdot w^d(t) \\ &= 2 \cdot \left(E_r^{uu} \cdot u^d(t) + E_r^{vv} \cdot v^d(t) + E_r^{ww} \cdot w^d(t) \right) \cdot \langle u(z_r,t) \rangle . \end{aligned} \tag{8.2.1}$$

The static force, or the time mean force, at degree of freedom r may be expressed as

$$F_r^s(t) = E_r^{uu} \cdot \langle u(z_r,t) \rangle^2, \tag{8.2.2}$$

where E_r^{uu}, E_r^{vv} and E_r^{ww} are constant at each degree of freedom. They depend upon ρ and C_d and the values of D, L, A, a, b and c for each member connected to that degree of freedom. z_r is the height of the degree of freedom r. Appendix 9: Pre-processing of wind loads by Wajac of Framework Wind Fatigue Theory Manual [24] shows the derivation in details.

6.8.3 Spectral relationships

The cross-power spectral density function is the Fourier transform of the cross correlation function. The cross-power spectral density function $S_{ff}(r,s:\omega)$ of the forcing between degree of freedom r and degree of freedom s is therefore

$$S_{ff}(r,s:\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\tau\omega}\langle F_r(t)\cdot F_s(t+\tau)\rangle d\tau. \tag{8.3.1}$$

The notation $\langle(\cdot)\rangle$ indicates that $(\cdot)$ is a time average component, see Appendix K.

Using Equations 8.2.1 and 8.2.2, i.e.

$$F_r^d(t) = 2\cdot E_r^{uu}\cdot\langle u(z_r,t)\rangle\cdot u^d(t) + 2\cdot E_r^{vv}\cdot\langle u(z_r,t)\rangle\cdot v^d(t) + 2\cdot E_r^{ww}\cdot\langle u(z_r,t)\rangle\cdot w^d(t) \tag{8.2.1}$$

and

$$F_r^s(t) = E_r^{uu}\cdot\langle u(z_r,t)\rangle^2, \tag{8.2.2}$$

we arrive at (correct misprints!)

$$\langle F_r(t)\cdot F_s(t+\tau)\rangle = \langle F_r^d(t)\cdot F_s^d(t+\tau)\rangle + \langle F_r^s(t)\rangle\cdot\langle F_s^s(t+\tau)\rangle + \langle F_r^s(t)\rangle\cdot\langle F_s^d(t+\tau)\rangle + \langle F_r^d(t)\rangle\cdot\langle F_s^s(t+\tau)\rangle \tag{6.8}$$

As $\langle F_r^d(t)\rangle = \langle F_s^d(t+\tau)\rangle = 0$, and $\langle F_s^s(t+\tau)\rangle = \langle F_s^s(t)\rangle$, this becomes

$$\langle F_r(t)\cdot F_s(t+\tau)\rangle = \langle F_r^d(t)\cdot F_s^d(t+\tau)\rangle + \langle F_r^s(t)\rangle\cdot\langle F_s^s(t)\rangle \tag{6.9}$$

So the power spectra may be divided into two integrals

$$S_{ff}(r,s:\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\tau\omega}\cdot\langle F_r^d(t)\cdot F_s^d(t+\tau)\rangle d\tau + \frac{1}{2\pi}\langle F_r^s(t)\rangle\cdot\langle F_s^s(t)\rangle\int_{-\infty}^{\infty} e^{-i\tau\omega}d\tau \tag{6.10}$$

The first integral is simply $S_{f^df^d}(r,s:\omega)$, i.e. 6.10 reads

$$S_{ff}(r,s:\omega) = S_{f^df^d}(r,s:\omega) + \frac{1}{2\pi}\cdot\langle F_r^s(t)\rangle\cdot\langle F_s^s(t)\rangle\int_{-\infty}^{\infty} e^{-i\tau\omega}d\tau. \tag{6.11}$$

The Fourier transform identity

$$\delta(\omega) = \int e^{-i\tau\omega}d\tau, \tag{6.12}$$

where $\delta(\omega)$ is the Dirac delta function with the property

$$\delta(\omega)\begin{cases} = 0 & \omega = 0 \\ = 1 & \omega \neq 0 \end{cases}, \tag{6.13}$$

can be used in 6.11.

Thus, the second integral of 6.11 may be re-written to read

$$\frac{1}{2\pi}\cdot\langle F_r^s(t)\rangle\cdot\langle F_s^s(t)\rangle\int_{-\infty}^{\infty} e^{-i\tau\omega}d\tau = \frac{\delta(\omega)}{2\pi}\cdot\langle F_r^s(t)\rangle\cdot\langle F_s^s(t)\rangle. \tag{6.14}$$

Then the cross-power spectral density of the forcing can be expressed as

$$S_{ff}(r,s:\omega) = S_{f^d f^d}(r,s:\omega) + \frac{\delta(\omega)}{2\pi} \cdot \langle F_r^s(t)\rangle \cdot \langle F_s^s(t)\rangle. \tag{8.3.2}$$

The first term (the fluctuating component) and the second term (the time average component) in 8.3.2, may be further expanded in terms of wind data.

The first term $S_{f^d f^d}(r,s:\omega)$ is defined as

$$S_{f^d f^d}(r,s:\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\tau\omega} \cdot \langle F_r^d(t) \cdot F_s^d(t+\tau)\rangle d\tau \tag{6.15}$$

and by substitution from Equation 8.2.1 – see Apendix 3 for detailed derivation

$$\begin{aligned} S_{f^d f^d}(r,s:\omega) &= 4 \cdot \langle u(r,t)\rangle \cdot \langle u(s,t+\tau)\rangle \cdot \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\tau\omega} \begin{pmatrix} E_r^{uu}\cdot E_s^{uu}\cdot\langle u_r^d(t)\cdot u_s^d(t+\tau)\rangle \\ +E_r^{uv}\cdot E_s^{uv}\cdot\langle v_r^d(t)\cdot v_s^d(t+\tau)\rangle \\ +E_r^{uw}\cdot E_s^{uw}\cdot\langle w_r^d(t)\cdot w_s^d(t+\tau)\rangle \end{pmatrix} d\tau \\ &= 4 \cdot \langle u(r,t)\rangle \cdot \langle u(s,t)\rangle \cdot \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\tau\omega} \begin{pmatrix} E_r^{uu}\cdot E_s^{uu}\cdot\langle u_r^d(t)\cdot u_s^d(t+\tau)\rangle \\ +E_r^{uv}\cdot E_s^{uv}\cdot\langle v_r^d(t)\cdot v_s^d(t+\tau)\rangle \\ +E_r^{uw}\cdot E_s^{uw}\cdot\langle w_r^d(t)\cdot w_s^d(t+\tau)\rangle \end{pmatrix} d\tau, \end{aligned} \tag{6.16}$$

since $\langle u(r,t)\rangle = \langle u(s,t+\tau)\rangle$, and then

$$S_{f^d f^d}(r,s:\omega) = 4 \cdot \langle u(r,t)\rangle \cdot \langle u(s,t)\rangle \cdot \begin{bmatrix} E_r^{uu}\cdot E_s^{uu}\cdot S_{u^d u^d}(r,s:\omega) \\ E_r^{uv}\cdot E_s^{uv}\cdot S_{v^d v^d}(r,s:\omega) \\ E_r^{uw}\cdot E_s^{uw}\cdot S_{w^d w^d}(r,s:\omega) \end{bmatrix}, \tag{6.17}$$

where $S_{u^d u^d}(r,s:\omega)$, $S_{v^d v^d}(r,s:\omega)$ and $S_{w^d w^d}(r,s:\omega)$ are the cross-power spectral densities of the wind in the directions along, laterally across and vertically across the mean wind, respectively. $S_{u^d u^d}(r,s:\omega)$, $S_{v^d v^d}(r,s:\omega)$ and $S_{w^d w^d}(r,s:\omega)$ contain the fluctuating vind velocity components .... and .... the square terms are implicitly included through the cross-power spectral densities as shown in Appendix 3.

And where $\langle u(r,t)\rangle$ and $\langle u(s,t)\rangle$ are the variation of the mean wind velocity with height z (and we write $\langle u(z,t)\rangle$), i.e the wind profile law applied.

The variation of the mean wind with height, may be parameterized by the following power law identity ([7])

$$\langle u(z,t)\rangle = \langle V(10,t)\rangle \cdot \left(\frac{z}{10}\right)^{\alpha}, \tag{8.3.3}$$

which is the API wind profile power law, [25]. Please notice that the first term in 8.3.3, i.e. $\langle V(10,t)\rangle$ – does not include the height z.

The cross-power spectra of wind $S_{u^d u^d}(r,s:\omega)$ may be approximated in terms of $S_{u^d u^d}(\omega)$, the power spectral density of the wind and a coherence function (References [7] and [48]), $coh(r,s:\omega)$

$$S_{u^d u^d}(r,s:\omega) = coh(r,s:\omega) \cdot S_{u^d u^d}(\omega), \tag{6.18}$$

giving the cross-power spectral density function of the fluctuating forcing, i.e. substituting 8.3.3 into 6.17 gives

$$S_{f^d f^d}(r,s:\omega) = 4 \cdot \langle V(10,t)\rangle^2 \cdot \left(\frac{z_s}{10}\right)^{\alpha} \cdot \left(\frac{z_r}{10}\right)^{\alpha} \cdot coh(r,s:\omega) \cdot \begin{pmatrix} E_r^{uu} \cdot E_s^{uu} \cdot S_{u^d u^d}(\omega) \\ +E_r^{uv} \cdot E_s^{uv} \cdot S_{v^d v^d}(\omega) \\ +E_r^{uw} \cdot E_s^{uw} \cdot S_{w^d w^d}(\omega) \end{pmatrix}, \tag{8.3.4}$$

where all the terms on the right-hand sides (RHS) may be readily evaluated from the geometry of the structure and the basic wind data presented in Section 6.6. The forms of the coherence function used are presented in Appendix B.6.2.

As $S_{u^d u^d} = 0$ at $\omega = 0$, it is clear that $S_{f^d f^d}(r,s:\omega) = 0$ at $\omega = 0$. Hence Equation 8.3.1 may be re-written as

$$S_{ff}(r,s:\omega) \begin{cases} = S_{f^d f^d}(r,s:\omega) & \omega \neq 0 \\ = \frac{1}{2\pi} \cdot \langle F_r^s(t)\rangle \cdot \langle F_s^s(t)\rangle & \omega = 0 \end{cases}. \tag{6.19}$$

Now, substituting the values of $\langle F_r^s(t)\rangle$ and $\langle u(z,t)\rangle$ from the Equations 8.2.2 and 8.3.3.

$$\langle F_r^s(t)\rangle = E_r^{uu} \cdot \langle V(10,t)\rangle \cdot \left(\frac{z_r}{10}\right)^{\alpha}, \tag{6.20}$$

giving

$$S_{ff}(r,s:\omega) \begin{cases} = S_{f^d f^d}(r,s:\omega) & \omega \neq 0 \\ = \frac{1}{4\pi^2} \cdot E_r^{uu} \cdot E_s^{uu} \cdot \langle V(10,t)\rangle^2 \left(\frac{z_r}{10}\right)^{\alpha} \left(\frac{z_s}{10}\right)^{\alpha} & \omega = 0 \end{cases}. \tag{8.3.5}$$

6.9 Vortex shedding induced vibrations

In this section the procedures followed to determine the amplitudes of oscillation excited by vortex shedding in steady winds are described. The determination of the first natural frequency and its associated mode shape are described, followed by the estimation of the amplitude of oscillation in a given steady wind. The stress levels at the member ends and centre then follow from application of the stress concentration factors to the raw member behaviour.

It is assumed that the vortex shedding effects are only of any significance if they induce oscillations in the **first** mode of the brace. This is a reasonable assumption for tubular structural steel members that are used in typical flare towers. This assumption would not be valid if applications were to assess the vibration amplitude and stresses associated with long slender tie rods or guy ropes, where a higher mode may be excited.

The mode and frequency are highly dependent on the conditions of member end fixity. In general these are not known to any great degree of accuracy, so Framework allows the user to investigate ranges of fixity. Low end fixity reduces the natural frequency and the member end damage that occurs. In the extreme a pin-ended member suffers no end damage because the pure bending deformation induced by vortex shedding produces no end moments, stresses or damage. High end fixity produces a higher natural frequency and associated with it the possibility of higher end moments. The amplitude of excitation may, however, be much smaller because there may be no resonance between the frequency of shedding of vortices and the natural frequency of the member. For a pin-ended member the damage at the member centre will exceed that of the member ends, for fixed end members the damage needs to be checked at the member centre and at both ends.

6.9.1 Determination of mode shape and fundamental frequency of a brace

The brace may be considered as a beam element with end supports. The ends are assumed to be restrained against lateral translation. The rotational supports may be different at each end and are allowed to vary between pin-ended (i.e. no rotational resistance) and fully fixed (i.e. fully restrained against rotation). The basic theory for the solution of this class of problem is given in Timoshenko and Young ([86]).

The fundamental equation for the dynamic bending behaviour of a thin beam (i.e. one in which shear deformations are negligible) is given by

$$EI\frac{\partial^4 w}{\partial x^4} = -m\frac{\partial^2 w}{\partial t^2},$$

where E is the Young's modulus of the material; I is the second moment of area of the beam, w is the transverse deflexion of the beam, m is its mass per unit length, x is the co-ordinate along the beam's neutral axis and t is time.

This fourth-order differential equation has a general solution of the form

$$w = (A\cos kx + B\sin kx + C\cosh kx + D\sinh kx)\cos(\omega t + \phi)$$

where A, B, C and D are constants that will be determined from the boundary conditions applied at the beam ends. ω is the natural frequency of the response (in radians per second), ϕ is the phase lag and k is defined by the relationship

$$k = \sqrt[4]{\frac{m\omega^2}{EI}}.$$

For a brace member in a flare tower the displacement boundary conditions applied at both ends are that the deflexions, w, are zero. For a beam of length L this gives two equations

$$\begin{aligned} A + C &= 0, \\ A\cos kL + B\sin kL + C\cosh kL + D\sinh kL &= 0. \end{aligned}$$

In addition to the displacement boundary conditions it is necessary to apply boundary conditions to the rotations. For simple supports the conditions are that there is no curvature at either beam end. Equating the second derivative of the displacement to zero gives

$$\begin{aligned} -A + C &= 0, \\ -A\cos kL - B\sin kL + C\cosh kL + D\sinh kL &= 0. \end{aligned}$$

For fixed ends the corresponding boundary conditions, which are that the slopes are zero at either beam end, leads to

$$\begin{aligned} B + D &= 0, \\ -A\sin kL - B\cos kL + C\sinh kL + D\cosh kL &= 0. \end{aligned}$$

For more general support conditions, where there are dissimilar rotational springs at either end of the beam, the following relationships apply

$$\begin{aligned} &K_0\{B + D\} = EIk\{-A + C\} \\ &K_L\{-A\sin kL + B\cos kL + C\sinh kL + D\cosh kL\} = \\ &\qquad EIk\{-A\cos kL - B\sin kL + C\cosh kL + D\sinh kL\} \end{aligned}$$

These equations are derived from the ratios of the end moments to end rotations, which are, by definition equal to the spring stiffnesses for linear elastic spring supports. The rotational spring stiffnesses at $x = 0$ and $x = L$ are given by K_0 and K_L, respectively. The relationships for simply supported or fully fixed ends may

be derived as special cases of the last pair of equations, with zero or infinite spring stiffnesses substituted as appropriate.

From the set of four equations, i.e. two displacements and two rotational boundary conditions selected as appropriate, it is possible to solve for any three of the unknowns in terms of the fourth. This solution gives the mode shape, but not its amplitude, and the corresponding frequency. Strictly speaking the process will give an infinite number of solutions for the pairs of mode shapes and frequencies, as there is an infinite number of choices of kL that will satisfy the relationships. As noted above, the fundamental frequency, corresponding to the first mode is the only one likely to be of any significance for structural applications.

The solution of this set of four equations is carried out iteratively in Framework. The starting approximation to the value of kL is made using a simplified assumption, which is close to the value corresponding to the fundamental mode. This ensures that convergence is to the lowest frequency and not to a spurious higher mode.

The iterative scheme is based upon the Newton-Raphson approach. The determinant of the matrix of the four simultaneous equations is evaluated together with the determinant of the derivative of the matrix with respect to the variable kL. The objective is to produce a zero value for the matrix. If F_N is an approximation to the numerical value of determinant of the four homogeneous equations then

$$F_{N+1} = F_N \cdot \left\{ 1 - \frac{\partial F_N}{\partial (kL)} \right\},$$

is likely to be a better approximation. F_N and its derivative are evaluated at the current (trial) value of kL. This process is repeated until the values of F_N and F_{N+1} differ by less than a suitably small relative value. Currently this is set to 10^{-6} in Framework. The iteration limit is set to 100.

As an example consider the set of four equations for a simply supported beam. In this case the solution may be derived by inspection. The conditions are that

$$\begin{aligned} A &= 0, \\ B \sin kL &= 0, \\ C &= 0, \\ D \sinh kL &= 0. \end{aligned}$$

The only solution for kL that gives deflections that are other than zero at all times is

$$\begin{aligned} kL &= n\pi, \\ D &= 0. \end{aligned}$$

Substitution of integer values of n in the above relation and referring to the equation for k above gives the relationship for the natural frequency corresponding to mode n. This equation is valid for all positive integer values of n.

Similar procedures may be followed for other boundary condition sets. The resulting relationships for kL are more complex and generally involve the use of iterative solution techniques. [86] gives details of many more examples, including free ended beams and cantilevers.

6.9.2 Brace oscillation amplitude calculation

The frequency at which vortices are shed from opposite sides of the brace member is dependent on the Reynolds' number of the fluid flow. If the vortex shedding frequency is sufficiently removed from the natural frequency of transverse oscillations of the brace there will not be any resonance and the amplitude of any oscillations will be negligible. If the ratio of the two frequencies is close to unity, the amplitude of the oscillations will be significant, that is high stress levels and hence structural fatigue will be caused. The critical velocity of the flow is defined as that which will cause resonant vortex shedding. Wind velocities in

the range of 60 to 140 per cent of the critical velocity will excite oscillations that cause damage. Velocities outside this range do not cause appreciable damage and their effects may be ignored.

Depending on the member end fixities the damage may be higher at the brace ends or at the member centre.

For each wind attack direction the wind is resolved into components normal and tangential to each brace. The velocity used is that computed at the member centroid, it being assumed that any variation of velocity, with height, along the member length will be relatively unimportant. The normal component of the velocity is used to calculate the Reynolds' number in conjunction with the outer diameter of the brace. Note that the value used is the member total diameter, which will include any non-structural cladding or insulation material.

From the Reynolds' number the vortex shedding frequency may be estimated.

This frequency is then compared with the natural frequency of the member itself, again taking into account the effects of any non-structural mass due to cladding.

The critical velocity is defined as

$$V_{crit} = f_N \cdot \frac{D_{inc}}{\mathrm{St}},$$

where f_N is the natural frequency of the brace member, D_{inc} is the diameter of the member including any coating material and St is the Strouhal number.

For each brace member the wind velocities that occur throughout the year are resolved into normal components. This is done by decomposing the statistical data on wind speeds, directions and the proportion of the year that such winds occur, into discrete ranges at constant speeds. The effect of each wind range and its associated velocity is then considered in isolation. The total damage induced by each wind speed range from each direction is then summed to give the total structural damage. Note that the effect of wind from opposing directions will be identical so use of the composite wind data, as described in Section 6.7, will reduce the volume of data required.

If the normal component of a selected range of wind speeds lies in the range

$$0.6 \cdot V_{crit} < V_{normal} < 1.4 \cdot V_{crit},$$

then the contribution to the member end and centre damage is accumulated. If the normal velocity is outside this range there is no damage contribution. For each wind speed range the following process is used. [97] contains background information.

The stability coefficient is defined as

$$K_s = 4\pi \cdot \frac{\varepsilon \cdot m_e}{\rho \cdot D_{inc}^2},$$

where ε is the structural damping ratio, m_e is the effective mass per unit length of the brace and ρ is the density of air.

The structural damping ratio is assumed to be defined by

$$\varepsilon = 0.0014 + 0.0036 \cdot e^{-0.0855 \cdot \frac{L}{D_{ext}}},$$

where D_{ext} is the external diameter of the structural member, i.e. excluding any insulation or cladding material.

The response parameter, S_G, is given by

$$S_G = 2\pi \cdot \mathrm{St}^2 \cdot K_s.$$

The structural lift coefficient, C_L, is dependent on the Reynolds' (Re) number of the flow.

$$\begin{array}{rcccl} & \mathrm{Re} & \leq & 2.0 \cdot 10^4, & C_L = 0.42 - 0.33 \cdot e^{\frac{-2.0 \cdot 10^4 \mathrm{Re}^2}{10^{12}}}, \\ 2.0 \cdot 10^4 & < & \mathrm{Re} & \leq \frac{4.71 \cdot 10^5}{R_{tran}}, & C_L = 0.09 + 0.33 \cdot e^{-3200 \cdot (\mathrm{Re} \cdot 10^{-6} \cdot R_{tran})^{10}}, \\ & \mathrm{Re} & > & \frac{4.71 \cdot 10^5}{R_{tran}}, & C_L = 0.15, \end{array}$$

where R_{tran} is the transition ratio.

The Van der Pol coefficient for the brace is given by

$$C_{VDP} = \sqrt{\frac{\int_0^L w^2 dx}{\int_0^L w^4 dx}},$$

where $w = w(x)$ is the mode shape determined from the frequency equation described above.

The amplitude of the response, A_r, at the resonant vortex shedding frequency is then given by

$$A_r = 3.82 \cdot \left(\frac{D_{inc} \cdot C_{VDP} \cdot C_L}{\left(1 + 0.19 \cdot \frac{S_G}{C_L}\right)^{3.35}} \right).$$

At wind velocities away from the critical area, the non-resonant amplitude, A_B, for a broad band response is given by the expression

$$A_B = A_r \cdot e^{\left(\frac{-(-1-V_R)^2}{0.02 + 0.1 \cdot (0.4 - 0.32 \cdot e^{-25000 \cdot turb^5})} \right)},$$

and $turb$ is the turbulence intensity of the flow.

For narrow-band response the amplitude, A_N, is dependent on the value of the stability factor, K_S.

$$\begin{array}{rcccl} & K_S & < & 4.0\pi & A_N = A_r \cdot e^{-30 \cdot (1-V_R)^2} \\ 4.0\pi & \leq & K_S & \leq 12.0\pi \quad \text{or} \quad 0.725 < V_R < 1.0 & A_N = A_r \cdot e^{-30 \cdot (1-V_R)^2 \cdot (\frac{K_S}{4\pi})^{1.8}} \\ 12.0\pi & < & K_S & & A_N = A_r \cdot e^{-30 \cdot (1-V_R)^2 \cdot 3.0^{1.8}} \end{array}$$

Note that in all cases the amplitude of the response is given as a factor of the resonant amplitude. The factor defines a bell shaped curve between the lower and upper limits of the velocity ratio, with maximum amplitude at the resonant frequency. A broad band response gives a flatter bell shaped curve than the pronounced peak of the narrow-band response curve.

6.9.3 Member end damage calculation

The member end damage calculation closely mirrors that used in the buffeting damage calculations. From the calculated forcing frequency, as given by the vortex shedding characteristics of the brace, and the time per year that the wind blows, the total number of oscillations of the brace may be determined. The amplitude of the vibrations is determined using the approach outlined in Section 6.9.2 above. From the displacement amplitude and the mode shape the beam section properties are used to calculate the member stresses at the two ends.

The raw member stresses are then factored by the stress concentration factors (SCFs) to give the local hot-spot stresses. The evaluation of the SCFs is described in Section 6.11. Note that the stress range, which is

twice the stress amplitude, is needed for fatigue damage calculations. The damage is evaluated using the Miner's law approach in an analogous manner to the buffeting damage.

6.9.4 Member centre damage calculation

The member centre damage is calculated in a similar manner to the member end damage. The SCF for the member centre is applied as a blanket value to the entire structure. This value is supplied from the input data and there are no calculations involved to derive the value. This user specified SCF should represent the typical value that would be associated with a single-sided girth closure weld. It will depend on the quality control of the welding process, the out of roundness and the mismatch that are permissible in the fabricated tubular structure.

The approach used is conservative. The damage is evaluated at the section on the brace's length that has the maximum curvature, and hence bending moment. The member's displaced shape is examined at 100 equally spaced positions along its length to determine the greatest curvature. It is unlikely, although possible, that the position of maximum moment would coincide with a closure weld.

6.10 Condensation of forces

The transfer function linking the cross-power spectral density function of fluctuating forcing to the power spectral density function of the response depends upon knowledge of the structure's modal frequencies and shapes.

The extraction of a full set of eigenvalues and mode shapes for a structure with a large number of degrees of freedom is computationally expensive. Consequently, the technique known as static condensation, or Guyan reduction, is used [6]. This reduces the analysis to a more manageable size by retaining a set of master degrees of freedom, which are chosen to characterize the structure's kinetic energy. The degrees of freedom are reduced out are known as the slave degrees of freedom. The algebra of the reduction to the master degrees of freedom of the forcing vector is given in Appendix 3 of Framework Wind Fatigue Theory Manual [24].

The Framework wind fatigue keeps all free translational degrees of freedom as master degrees of freedom and the user can not select the master freedoms.

6.11 Stress concentration factors

6.11.1 An overview

Stress concentrations occur in the welded tubular joints. For fatigue calculations it is therefore important to take them into account. To evaluate the stress concentrations or "hot-spot stresses" (HSSs), empirically derived stress concentration factors (SCFs) based on joint geometry are used.

Using these the distribution of the hot-spot stresses around the welds is found, under loading produced by a mean wind state (static loading). When the tower is subject to buffeting, i.e., dynamic eddy loading, the maximum hot-spot stresses at a joint, for each mode of response, is assumed to occur in the same place as for the static loading. This is a reasonable assumption, in that buffeting fatigue effects on flare towers are normally dominated by the cantilever modes of response. These strongly resemble the tower's static response.

At each joint, connected members may be either braces or chords. The chord is taken as the pair of elements of greatest diameter which are collinear. (If there is more than one pair of collinear elements of the same maximum diameter, the chord is assumed to be the pair with the greatest thickness.) All other members are assumed to be braces. Hot-spot stresses are found for each brace/chord intersection separately, for both chordside and braceside of the weld.

If collinear elements are not found, the joint classification of Framework is tried. A chord may be identified in Framework without the presence of collinear elements at the joint.

6.11.2 Components of the hot-spot stresses

For each brace the axial, in-plane bending (IPB) and out-of-plane bending (OPB) stresses (σ_{AX}, σ_{IPB} and σ_{OPB}, respectively) are all deemed to contribute to both the chordside and braceside HSS distribution around the

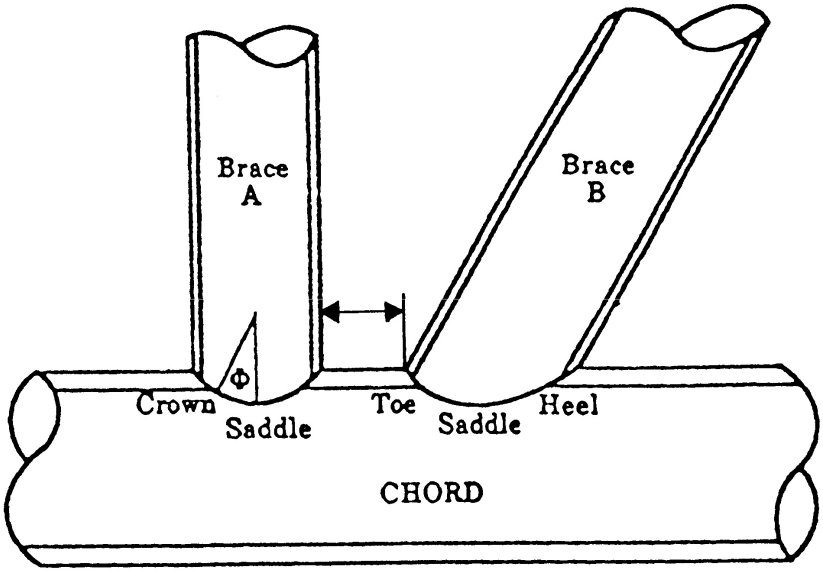


Figure 6.9: Tubular joint - chord, brace, saddle, toe, heel and ϕ

weld. Chordside and braceside IPB and OPB components are approximated by

$$\mathrm{HSS}_{\mathrm{IPB}}(\phi) = \mathrm{SCF}_{\mathrm{IPB}}\sigma_{\mathrm{IPB}}\sin(\phi), \tag{6.21}$$

$$\mathrm{HSS}_{\mathrm{OPB}}(\phi) = \mathrm{SCF}_{\mathrm{OPB}}\sigma_{\mathrm{OPB}}\cos(\phi), \tag{6.22}$$

where $\mathrm{SCF}_{\mathrm{IPB}}$ and $\mathrm{SCF}_{\mathrm{OPB}}$ are the IPB (crown) and OPB (saddle) SCFs respectively and ϕ is the angle around the weld, measured from the saddle point (see Figure 6.9). The axial components are approximated by

$$\mathrm{HSS}_{\mathrm{A}}(\phi) = \sigma_{\mathrm{AX}} \cdot \left(\frac{\mathrm{SCF}_{\mathrm{AS}} + \mathrm{SCF}_{\mathrm{AC}}}{2} + \frac{\mathrm{SCF}_{\mathrm{AS}} - \mathrm{SCF}_{\mathrm{AC}}}{2} \cdot \cos(2\phi) \right), \tag{6.23}$$

where $\mathrm{SCF}_{\mathrm{AS}}$ and $\mathrm{SCF}_{\mathrm{AS}}$ are the axial saddle and crown SCFs respectively.

6.11.3 The stress concentration factor (SCF) Schemes

The wind fatigue module of Framework has three schemes by which the hot-spot stresses may be evaluated, the "I", "E" and "O" schemes. They use different SCF formulae, and combine the component hot-spot stresses in slightly different manners. Details of the equations used to derive the SCFs may be found in Appendix 4 Parametric SCF Schemes of the wind fatigue module of Framework Wind Fatigue Theory Manual [24].

These schemes classify joints as either:

- T–joints
- K–joints
- KT–joints
- X–joints
- or non-standard joints (see Section 6.11.4)

The "I" and "O" schemes will not recognise an X–joint, which is classified as a non-standard joint for these schemes. Under the "E" scheme, X–joints may be included.

The "I" scheme:

- treats a KT–joint as a K–joint plus a T–joint. The K–joint makes up the outer braces, while the T–joint makes up the middle brace.
- sets saddle SCFs = 0 (i.e. $\mathrm{SCF}_{\mathrm{OPB}} = \mathrm{SCF}_{\mathrm{AS}} = 0$).
- evaluates the HSS distribution around the weld as

$$ {}_{\mathrm{B}}\mathrm{HSS}(\phi) =_{\mathrm{B}} \mathrm{HSS}_{\mathrm{IPB}}(\phi) + \underset{(\equiv 0)}{\lfloor {}_{\mathrm{B}}\mathrm{HSS}_{\mathrm{OPB}}(\phi) \rfloor} +_{\mathrm{B}} \mathrm{HSS}_{\mathrm{A}}(\phi), \tag{6.24} $$

$$ {}_{\mathrm{C}}\mathrm{HSS}(\phi) =_{\mathrm{C}} \mathrm{HSS}_{\mathrm{IPB}}(\phi) + \underset{(\equiv 0)}{\lfloor {}_{\mathrm{C}}\mathrm{HSS}_{\mathrm{OPB}}(\phi) \rfloor} +_{\mathrm{C}} \mathrm{HSS}_{\mathrm{A}}(\phi) +^{\star}_{\sigma_{\mathrm{CHORD}}}, \tag{6.25} $$

  where the new $_{\mathrm{B}}$ subscript denotes brace side of the weld and the $_{\mathrm{C}}$ subscript denotes chord side. $^{\star}_{\sigma_{\mathrm{CHORD}}}$ is the chord stress, with sign. ${}_{\mathrm{C}}\mathrm{HSS}(\phi)$is the locally enhanced stress.

The "O" scheme:

- evaluates the HSS distribution around the weld, both chordside and braceside as

$$ \mathrm{HSS}(\phi) = \mathrm{HSS}_{\mathrm{IPB}}(\phi) + \mathrm{HSS}_{\mathrm{OPB}}(\phi) +_{\mathrm{B}} \mathrm{HSS}_{\mathrm{A}}(\phi), \tag{6.26} $$

The "E" scheme is described in Appendix 4 Parametric SCF Schemes of the wind fatigue module of Framework Wind Fatigue Theory Manual [24].

6.11.4 Non-standard joints

The wind fatigue module of Framework recognizes joints for which

- there is a chord and more than three braces
- the gap between braces is either zero or negative (Figure 6.9 shows a positive gap, i.e. the left-right arrow $\leftrightarrow$). This is called an OVERLAPPING joint.

For both of these joint types each brace will be treated as a T–joint, and then take the maximum hot-spot stresses over all joints.

To consider overlapping joints it is recommended that the facilities available in Framework basic are applied.

6.11.5 Efthymiou scheme

The Efthymiou equations which allows X–joints as well as K–, KT–, and T–joints are made available in Framework. This is the "E" scheme. Details are given in Appendix 4 of [24]. Note that there are some differences in the implementation of the Efthymiou equations and treatment of valid ranges of geometric parameters of the equations in Framework basic and the wind fatigue module. In particular overlapping braces of K–joints are not handled by the wind fatigue application implementation.

6.12 The hot-spot stress transfer function from point forcing

6.12.1 The dynamic equation

A finite element model of a structure is characterized by its mass and stiffness matrices M and K. The structural damping may be modelled as an imaginary component of the stiffness matrix. The damping is assumed as the “COMPLEX STIFFNESS DAMPING” in [63].

The forced response of a structure subjected to a force vector $F(\omega)$ at frequency ω, where ω is in radians/sec, is given by

$$ \begin{aligned} \left((1+\mathrm{i}\gamma)\,K - \omega^2 M\right) \cdot u(\omega) \cdot \mathrm{e}^{\mathrm{i}\omega t} &= F(\omega) \cdot \mathrm{e}^{\mathrm{i}\omega t} \\ \left[\left((1+\mathrm{i}\gamma)\,K - \omega^2 M\right) \cdot u(\omega) \;=\; F(\omega)\right] \cdot \mathrm{e}^{\mathrm{i}\omega t}, & \end{aligned} \tag{6.27} $$

where $u(\omega)$ is the displacement vector, and γ is the “hysteretic” (structural) damping factor which defines the damping force as a function of the elastic stiffness force.

Hysteretic damping may be defined as a damping force f_D proportional to the displacement amplitude but in phase with the velocity, for the case of harmonic motion the damping force may be expressed as $f_D = i\gamma ku$. The imaginary constant i puts the force in phase with the velocity. Then, the equation of motion of a single-degree-of-freedom (SDOF) system under free vibration is

$$m\ddot{u} + i\gamma ku + ku = 0.$$

The complex stiffness can be defined as

$$\hat{k} = (1 + i\gamma)k$$

Recall the classic SDOF system with a viscous damper,

$$m\ddot{u} + c\dot{u} + ku = 0.$$

The critical damping coefficient is

$$c_c = 2\sqrt{mk}.$$

The “viscous” damping factor or ratio is defined as

$$\xi = \frac{c}{c_c} = \frac{c}{2\sqrt{mk}}.$$

It is necessary to compare the “hysteretic” damping factor with the commonly used “viscous” damping factor above. It has been shown in **??** [63] defining

$$\gamma = 2\xi\frac{\omega}{\omega_0},$$

where $\omega_0 = \sqrt{k/m}$ is the natural angular frequency, will let the hysteretic damping yields the same response as the viscous damping response.

For the dynamic resonant responses considered in Framework’s wind fatigue analysis, the system is excited at resonance $\omega \approx \omega_s$ of each eigen-mode. In this case, the hysteretic damping factor is

$$\gamma \approx 2\xi.$$

The damping ratio γ is assumed to be a constant for all vibration modes.

When Guyan reduction [6] is employed to give reduced mass and stiffness matrices M_M and K_M with an equivalent force vector F_M applied at the master degrees of freedom to produce a displacement vector $u_M(\omega)$ at these degrees of freedom, and the $\mathrm{e}^{\mathrm{i}\omega t}$ term is dropped then

$$\left[(1 + \mathrm{i}\gamma)\, K_M - \omega^2 M_M\right] \cdot u_M(\omega) = F_M(\omega). \tag{12.1}$$

Note: The index of equation, e.g. 12.1, is kept identical to the Equations in the old Sesam Theory Manual - Framework Wind Fatigue Design for comparison and search.

6.12.2 Results from the eigenvalue problem

The homogeneous part of equation 12.1 may be written as

$$\left[M_M^{-1}K_M - \frac{\omega^2}{(1 + \mathrm{i}\gamma)} \cdot I\right] \cdot u_M(\omega) = 0, \tag{12.2.1}$$

which is the classic eigenvalue problem for the values

$$\lambda_s = \frac{\omega_s^2}{(1 + \mathrm{i}\gamma)}. \tag{6.28}$$

Let ϕ be a matrix of eigenvectors ϕ_s. This set of vectors is not unique because any linear multiple of an eigenvector is also an eigenvector. If there are coincident eigenvalues the situation is more complicated.

Any linear combination of the eigenvectors corresponding to the coincident modes is also an eigenvector. To establish a unique matrix ϕ of vectors ϕ_s, ϕ is constrained to follow the relationship

$$\phi^T M_M \phi = I. \tag{12.2.2a}$$

This is called "normalizing on the (reduced) mass matrix".

Additionally the eigenvectors are mass orthogonal, that is,

$$\phi_r^T M_M \phi_s = 0 \qquad \text{for} \qquad r \neq s. \tag{12.2.2b}$$

Expression 12.2.1 holds for each eigensolution, and may therefore be written as a set of simultaneous eigensolutions

$$K_M \cdot \phi - \text{diag}(\lambda_s) \cdot M_M \cdot \phi = 0. \tag{6.29}$$

Premultiplying 6.29 by ϕ^T gives

$$\phi^T \cdot K_M \cdot \phi - \text{diag}(\lambda_s) \cdot \phi^T \cdot M_M \cdot \phi = 0. \tag{6.30}$$

Since, from 12.2.2a, $\phi^T M_M \phi = I$ – the expression 6.30 can be written

$$\phi^T \cdot K_M \cdot \phi = \text{diag}(\lambda_s) \cdot I. \tag{6.31}$$

Left multiplication of 6.31 by ϕ^{-T} and right multiplication by ϕ^{-1} gives

$$K_M = \phi^{-T} \cdot \text{diag}(\lambda_s) \cdot \phi^{-1}. \tag{12.2.3a}$$

Since, by 12.2.2a, the eigenmode ϕ is orthogonal with respect to the mass matrix, then 12.2.3a can alternatively be written

$$K_M = M_M \phi \cdot \text{diag}(\lambda_s) \cdot \phi^T M_M. \tag{6.32}$$

Similarly, 12.2.2a can be written

$$M_M = \phi^{-T} \cdot I \cdot \phi^{-1}, \tag{12.2.3b}$$

and then 12.2.3b becomes

$$M_M = M_M \phi \cdot I \cdot \phi^T M_M. \tag{6.33}$$

6.12.3 The structure displacement vector from a point force

The eigensolutions, i.e. 12.2.3a and 12.2.3b, can be inserted in 12.1, i.e. in

$$\left[(1 + \mathrm{i}\gamma) K_M - \omega^2 M_M\right] \cdot u_M(\omega) = F_M(\omega). \tag{12.1}$$

to give

$$\left[(1 + \mathrm{i}\gamma) \phi^{-T} \cdot \text{diag}(\lambda_s) \cdot \phi^{-1} - \omega^2 \phi^{-T} \cdot I \cdot \phi^{-1}\right] \cdot u_M(\omega) = F_M(\omega). \tag{6.34}$$

i.e.

$$\left[\phi^{-T} \cdot \text{diag}\left((1 + \mathrm{i}\gamma) \lambda_s - \omega^2\right) \cdot \phi^{-1}\right] \cdot u_M(\omega) = F_M(\omega). \tag{6.35}$$

Thus $u_M(\omega)$ is given as

$$u_M(\omega) = \left[\phi^{-T} \cdot \text{diag}\left((1 + \mathrm{i}\gamma) \lambda_s - \omega^2\right) \cdot \phi^{-1}\right]^{-1} \cdot F_M(\omega) = \left[\phi \cdot \text{diag}\left(\frac{1}{(1 + \mathrm{i}\gamma) \lambda_s - \omega^2}\right) \cdot \phi^T\right] \cdot F_M(\omega). \tag{6.36}$$

The final form of 6.36 is obtained as follows. Let the matrix Q and the vector S be

$$Q = \phi \cdot \mathrm{diag}\left(\frac{1}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2}\right), \tag{6.37}$$

$$S = \phi^T \cdot F_M(\omega). \tag{6.38}$$

The corresponding matrix (Q_{rs}) and vector (S_s) components are

$$Q_{rs} = \frac{\phi_{rs}}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2}, \tag{6.39}$$

$$S_s = \sum_k \phi_{ks} \cdot F_{M_k}(\omega), \tag{6.40}$$

where the r and s subscripts refer to the rth row and sth column of their respective matrices. Hence 6.36 may be expressed as

$$u_M(\omega) = Q \cdot S, \tag{6.41}$$

$$u_{M_r}(\omega) = \sum_s Q_{rs} \cdot S_s = \sum_s \frac{\phi_{rs}}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2} \cdot \sum_k \phi_{ks} \cdot F_{M_k}(\omega) = \sum_k \sum_s \frac{\phi_{rs} \cdot \phi_{ks} \cdot F_{M_k}(\omega)}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2}, \tag{6.42}$$

i.e. gives the displacement at the rth degree of freedom as a summation of the displacements from a force at each degree of freedom k. Hence if $u_{M_r}(k,\omega)$ is the displacement at master freedom r from an equivalent force $F_{M_k}(\omega)$at master freedom s then

$$u_{M_r}(k,\omega) = \sum_s \frac{\phi_{rs} \cdot \phi_{ks} \cdot F_{M_k}(\omega)}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2}. \tag{6.43}$$

6.43 may be extended to include the displacement vector for all n_M master freedoms $u_M(k,\omega)$ resulting from an equivalent force $F_{M_k}(\omega)$ at master freedom k

$$u_M(k,\omega) = \begin{bmatrix} \sum_s \frac{\phi_{ks}\cdot\phi_{1s}}{(1+\mathrm{i}\gamma)\lambda_s-\omega^2} \\ \sum_s \frac{\phi_{ks}\cdot\phi_{2s}}{(1+\mathrm{i}\gamma)\lambda_s-\omega^2} \\ \vdots \\ \sum_s \frac{\phi_{ks}\cdot\phi_{n_M s}}{(1+\mathrm{i}\gamma)\lambda_s-\omega^2} \end{bmatrix} \cdot F_{M_k}(\omega). \tag{6.44}$$

Finally, 6.44 may be expressed in terms of the normalized eigenvectors ϕ_s

$$u_M(k,\omega) = \sum_s \frac{\phi_{ks} \cdot F_{M_k}(\omega)}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2} \cdot \phi_s. \tag{12.3.2}$$

6.12.4 Hot-spot stresses from a point force

The displacement vector of the structure's master degrees of freedom, $u_M(k,\omega)$, from an equivalent force at master freedom k may be directly translated into the member stresses of member n by substituting the member stresses for the normalized eigenvectors into 12.3.2.

$$\sigma\left(u_M(k,\omega)\right) = \sum_s \frac{\phi_{ks} \cdot F_{M_k}(\omega)}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2} \cdot N^\sigma\left(\phi_s\right). \tag{12.4.1a}$$

The stress function N^σ is linear, i.e. it satisfies

$$N^\sigma(k \cdot \phi_s) = k \cdot N^\sigma(\phi_s). \tag{6.45}$$

In the Sesam system – after the finite element solution[2], the stress function N^{σ} is available as stresses are derived from nodal deformations and computed at the hot-spots points around the tube sections, see further comments in Section 6.13.2.

The stresses given by 12.4.1a are the stresses derived from the eigenvector displacements factored by the appropriate stimulated amplitudes $F_{M_k}(\omega)$. To find the hot-spot stresses (HSS) at a joint requires application of the appropriate stress concentration factors (SCFs) to these stresses. This then allows $\mathrm{HSS}_{pk}(\omega)$, the hot-spot stress at joint p from point forcing at degree of freedom k, to be written in terms of a function and the value of the point forcing. I.e

$$\mathrm{HSS}_{pk}(\omega) = H_{pk}(\omega) \cdot F_{M_k}(\omega). \tag{12.4.1b}$$

If the SCF effects are neglected, then 12.4.1a can be written

$$\sigma\left(u_M(k,\omega)\right) = \sum_s \frac{\phi_{ks}}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2} \cdot N^{\sigma}\left(\phi_s\right) \cdot F_{M_k}(\omega) = H_{pk}(\omega) \cdot F_{M_k}(\omega). \tag{6.46}$$

See also Section 6.13.2 where 6.46 is used.

6.13 Hot-spot stress power spectrum

6.13.1 The hot-spot stress power spectra

Section 6.12 established a transfer function between a forcing point load and the hot-spot stress at a selected joint. In this section the resultant hot-spot stress power spectrum at a joint from the ensemble of forcing point loads will be described.

To derive the power spectra, the hot-spot stress given by 12.4.1a and 12.4.1b needs to be re-expressed in the time domain. This is achieved by Fourier transform inversion using the convolution theorem

$$\mathrm{hss}_{pk}(t) = \int_{-\infty}^{\infty} h_{pk}(\tau) \cdot f_{M_k}(t-\tau)\mathrm{d}\tau, \tag{13.1.1}$$

where $h_{pk}(\tau)$ is the transform of $H_{pk}(\omega)$ and $f_{M_k}(t-\tau)$ is the transform of $F_{M_k}(\omega)$. $f_{M_k}(t)$ is the time series of the equivalent forcing at one master degree of freedom.

By summing this equation over all the forcings at each master degree of freedom, the total hot-spot stress $\sum_k \mathrm{hss}_{pk}(t)$ at any joint p from the ensemble of equivalent point forces in the time domain may be found. The auto-correlation function of the joint's hot-spot stress is then given by

$$C_{\mathrm{hss}_p\mathrm{hss}_p}(\tau) = \Big\langle \sum_r \sum_s \mathrm{hss}_{pr} \cdot \mathrm{hss}_{ps} \Big\rangle, \tag{13.1.1a}$$

From 13.1.1a, and by taking the summations outside the integrals

$$C_{\mathrm{hss}_p\mathrm{hss}_p}(\tau) = \Big\langle \sum_r \sum_s \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h_{pr}(\varepsilon) \cdot h_{ps}(\varepsilon^1) \cdot f_{M_r}(t-\varepsilon) \cdot f_{M_s}(t+\tau-\varepsilon^1) \cdot \mathrm{d}\varepsilon \cdot \mathrm{d}\varepsilon^1 \Big\rangle, \tag{6.47}$$

and noting that the time averaging operator, $\langle(\cdot)\rangle$, only applies to functions of time

$$C_{\mathrm{hss}_p\mathrm{hss}_p}(\tau) = \sum_r \sum_s \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} h_{pr}(\varepsilon) \cdot h_{ps}(\varepsilon^1) \cdot \left\langle f_{M_r}(t-\varepsilon) \cdot f_{M_s}(t+\tau-\varepsilon^1) \right\rangle \cdot \mathrm{d}\varepsilon \cdot \mathrm{d}\varepsilon^1. \tag{6.48}$$

[2] A linear FE-Analysis, that is

By means of 6.48, the power spectra

$$S_{\mathrm{hss}_p\mathrm{hss}_p}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \mathrm{e}^{-i\omega\tau}\cdot C_{\mathrm{hss}_p\mathrm{hss}_p}(\tau)\cdot \mathrm{d}\tau, \tag{6.49}$$

may be expressed as

$$S_{\mathrm{hss}_p\mathrm{hss}_p}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \mathrm{e}^{-i\omega\tau}\left[\sum_r\sum_s\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} h_{pr}(\varepsilon)h_{ps}(\varepsilon^1)\big\langle f_{M_r}(t-\varepsilon)\cdot f_{M_s}(t+\tau-\varepsilon^1)\big\rangle \mathrm{d}\varepsilon\mathrm{d}\varepsilon^1\right]\mathrm{d}\tau. \tag{6.50}$$

By exchanging the order of integration and summation this becomes

$$S_{\mathrm{hss}_p\mathrm{hss}_p}(\omega) = \sum_r\sum_s\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} h_{pr}(\varepsilon)h_{ps}(\varepsilon^1)\left[\frac{1}{2\pi}\int_{-\infty}^{\infty} \mathrm{e}^{-i\omega\tau}\big\langle f_{M_r}(t-\varepsilon)\cdot f_{M_s}(t+\tau-\varepsilon^1)\big\rangle \mathrm{d}\tau\right]\mathrm{d}\varepsilon\mathrm{d}\varepsilon^1. \tag{6.51}$$

The substitution $\tau^1 = \tau - \varepsilon^1 + \varepsilon$ then gives

$$\mathrm{d}\tau^1 = \mathrm{d}(\tau-\varepsilon^1+\varepsilon) = \mathrm{d}\tau, \tag{6.52}$$

$$\mathrm{e}^{-i\omega\tau} = \mathrm{e}^{-i\omega(\tau^1+\varepsilon^1-\varepsilon)} = \mathrm{e}^{-i\omega\tau^1}\mathrm{e}^{-i\omega\varepsilon^1}\mathrm{e}^{i\omega\varepsilon}, \tag{6.53}$$

$$t+\tau-\varepsilon^1 = t+(\tau^1+\varepsilon^1-\varepsilon)-\varepsilon^1 = t+\tau^1-\varepsilon, \tag{6.54}$$

so that 6.51 becomes

$$S_{\mathrm{hss}_p\mathrm{hss}_p}(\omega) = \sum_r\sum_s\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} h_{pr}(\varepsilon)h_{ps}(\varepsilon^1)\left[\frac{1}{2\pi}\int_{-\infty}^{\infty} \mathrm{e}^{-i\omega\tau^1}\mathrm{e}^{-i\omega\varepsilon^1}\mathrm{e}^{i\omega\varepsilon}\big\langle f_{M_r}(t-\varepsilon)\cdot f_{M_s}(t+\tau^1-\varepsilon)\big\rangle \mathrm{d}\tau^1\right]\mathrm{d}\varepsilon\mathrm{d}\varepsilon^1. \tag{6.55}$$

and then exchanging the order of integration(s) leads to

$$S_{\mathrm{hss}_p\mathrm{hss}_p}(\omega) = \sum_r\sum_s\int_{-\infty}^{\infty} h_{ps}(\varepsilon^1)\mathrm{e}^{-i\omega\varepsilon^1}\int_{-\infty}^{\infty} h_{pr}(\varepsilon)\mathrm{e}^{i\omega\varepsilon}\int_{-\infty}^{\infty}\frac{\mathrm{e}^{-i\omega\tau^1}}{2\pi}\big\langle f_{M_r}(t-\varepsilon)\cdot f_{M_s}(t+\tau^1-\varepsilon)\big\rangle \mathrm{d}\tau^1\mathrm{d}\varepsilon\mathrm{d}\varepsilon^1. \tag{6.56}$$

For a stationary random process the time average with respect to $t-\varepsilon$ should be the same as a time average with respect to t, so that

$$\big\langle f_{M_r}(t-\varepsilon)\cdot f_{M_s}(t+\tau^1-\varepsilon)\big\rangle = \big\langle f_{M_r}(t)\cdot f_{M_s}(t+\tau^1)\big\rangle. \tag{6.57}$$

Then by definition

$$S_{ff}(r,s:\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \mathrm{e}^{-i\omega\tau^1}\cdot\big\langle f_{M_r}(t)\cdot f_{M_s}(t+\tau^1)\big\rangle \mathrm{d}\tau^1, \tag{13.1.2}$$

where $S_{ff}(r,s:\omega)$ is the cross-power spectral density function of the reduced force, see Section 6.8.3.

Then, using 13.1.2, the hot-spot stress power spectra may be written

$$S_{\mathrm{hss}_p\mathrm{hss}_p}(\omega) = \sum_r\sum_s\int_{-\infty}^{\infty} h_{ps}(\varepsilon^1)\mathrm{e}^{-i\omega\varepsilon^1}\int_{-\infty}^{\infty} h_{pr}(\varepsilon)\mathrm{e}^{i\omega\varepsilon}\cdot S_{ff}(r,s:\omega)\cdot \mathrm{d}\varepsilon\mathrm{d}\varepsilon^1. \tag{6.58}$$

Since $S_{ff}(r,s:\omega)$ of 13.1.2 is not a function of ε or of ε^1. In addition the two integrals are independent and can be evaluated in any order. Thus, 6.58 can be written

$$S_{\mathsf{hss}_p\mathsf{hss}_p}(\omega) = \sum_r \sum_s S_{ff}(r,s:\omega) \cdot \int_{-\infty}^{\infty} h_{ps}(\varepsilon^1) \mathrm{e}^{-i\omega\varepsilon^1} \mathrm{d}\varepsilon^1 \cdot \int_{-\infty}^{\infty} h_{pr}(\varepsilon) \mathrm{e}^{i\omega\varepsilon} \cdot \mathrm{d}\varepsilon. \tag{6.59}$$

The following two identities may now be used

$$H_{ps}(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} h_{ps}(\varepsilon^1) \mathrm{e}^{-i\omega\varepsilon^1} \mathrm{d}\varepsilon^1, \tag{6.60}$$

because $H_{ps}(\omega)$ is the Fourier transform of $h_{ps}(t)$, and

$$H^{\star}_{pr}(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} h_{pr}(\varepsilon) \mathrm{e}^{i\omega\varepsilon} \mathrm{d}\varepsilon. \tag{6.61}$$

where $H^{\star}_{pr}(\omega)$ is the complex conjugate of $H_{pr}(\omega)$. This second identity, i.e. 6.61, may be easily verified by expressing the exponent as cosine plus imaginary sine terms. Hence 13.1.2 may be written

$$S_{\mathsf{hss}_p\mathsf{hss}_p}(\omega) = 4\pi^2 \sum_r \sum_s S_{ff}(r,s:\omega) \cdot H_{ps}(\omega) \cdot H^{\star}_{pr}(\omega), \tag{13.1.3}$$

where $S_{ff}(r,s:\omega)$ was evaluated in 8.3.5.

6.13.2 Integrating the hot-spot stress power spectra

The hot-spot stress power spectrum shown in 13.1.3 is frequency dependent in the cross power spectra of the forcing and in the functions $H_{pr}(\omega)$, $H^{\star}_{pr}(\omega)$.

At frequencies far below the modal frequencies the structure behaves in a quasi-static manner and $H_{pr}(\omega)$ may be approximated by $H_{pr}(0)$. If corrections are made for the variation in drag coefficient with wind speed, the integral of the hot-spot stress power spectrum may then be evaluated by simple numerical integration.

For frequencies near the modal frequency, the variation of the forcing cross power spectra with frequency is small compared to the variation in $H_{pr}(\omega)$. Hence near a modal frequency $\lambda_q^{\frac{1}{2}}$ the integral may be expressed as

$$\int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} S_{\mathsf{hss}_p\mathsf{hss}_p}(\omega)\mathrm{d}\omega = 4\pi^2 \sum_r \sum_s S_{ff}(r,s:\omega) \int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} H_{ps}(\omega) \cdot H^{\star}_{pr}(\omega)\mathrm{d}\omega, \tag{13.2.1}$$

where $H^{\star}_{pr}(\omega)$ is the complex conjugate of $H_{pr}(\omega)$.

Neglecting the effects of the SCFs, and using 12.4.1a,

$$\sigma\left(u_M(k,\omega)\right) = \sum_s \frac{\phi_{ks} \cdot F_{M_k}(\omega)}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2} \cdot N^{\sigma}\left(\phi_s\right), \tag{12.4.1a}$$

12.4.1b,

$$\mathsf{HSS}_{pk}(\omega) = H_{pk}(\omega) \cdot F_{M_k}(\omega), \tag{12.4.1b}$$

and 6.46

$$\sigma\left(u_M(k,\omega)\right) = \sum_s \frac{\phi_{ks}}{(1+\mathrm{i}\gamma)\,\lambda_s - \omega^2} \cdot N^{\sigma}\left(\phi_s\right) \cdot F_{M_k}(\omega) = H_{pk}(\omega) \cdot F_{M_k}(\omega), \tag{6.46}$$

we get – noting that $H_{ps}(\omega)$, $H_{pr}(\omega)$ and the complex conjugate $H^{\star}_{pr}(\omega)$ are

$$\begin{aligned} H_{ps}(\omega) &= \frac{\phi_{sm}}{(1+\mathrm{i}\gamma)\,\lambda_m - \omega^2} \cdot N^{\sigma}\left(\phi_m\right), \\ H_{pr}(\omega) &= \frac{\phi_{rn}}{(1+\mathrm{i}\gamma)\,\lambda_n - \omega^2} \cdot N^{\sigma}\left(\phi_n\right), \\ H^{\star}_{pr}(\omega) &= \frac{\phi_{rn}}{(1-\mathrm{i}\gamma)\,\lambda_n - \omega^2} \cdot N^{\sigma}\left(\phi_n\right), \end{aligned} \tag{6.62}$$

i.e.

$$\begin{aligned} &\int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} H_{ps}(\omega)\cdot H^{\star}_{pr}(\omega)\mathrm{d}\omega \\ &= \int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} \sum_m \frac{\phi_{sm}}{(1+\mathrm{i}\gamma)\,\lambda_m - \omega^2} \cdot N^{\sigma}\left(\phi_m\right) \cdot \sum_n \frac{\phi_{rn}}{(1-\mathrm{i}\gamma)\,\lambda_n - \omega^2} \cdot N^{\sigma}\left(\phi_n\right)\mathrm{d}\omega \\ &= \sum_m \sum_n \phi_{sm}\cdot N^{\sigma}\left(\phi_m\right)\cdot \phi_{rn}\cdot N^{\sigma}\left(\phi_n\right) \int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} \frac{1}{\left((1+\mathrm{i}\gamma)\,\lambda_m - \omega^2\right)\left((1-\mathrm{i}\gamma)\,\lambda_n - \omega^2\right)}\cdot \mathrm{d}\omega \\ &= \sum_m \sum_n \phi_{sm}\cdot N^{\sigma}\left(\phi_m\right)\cdot \phi_{rn}\cdot N^{\sigma}\left(\phi_n\right)\cdot G_{mn}, \end{aligned} \tag{13.2.2}$$

where

$$G_{mn} = \int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} \frac{1}{\left((1+\mathrm{i}\gamma)\,\lambda_m - \omega^2\right)\left((1-\mathrm{i}\gamma)\,\lambda_n - \omega^2\right)}\cdot \mathrm{d}\omega. \tag{6.63}$$

The stress functions $N^{\sigma}\left(\phi_m\right)$ and $N^{\sigma}\left(\phi_n\right)$ give the stresses of the joint connection at each hot-spot for eigenmodes m and n, respectively.

The G_{mn}-integral of 6.63 may be re-expressed as

$$G_{mn} = \int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} \frac{1}{\left((1+\mathrm{i}\gamma)\,\lambda_m - \omega^2\right)\left((1-\mathrm{i}\gamma)\,\lambda_n - \omega^2\right)}\cdot \mathrm{d}\omega = \int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} \frac{1}{\left(C_m^2 - \omega^2\right)\left(D_n^2 - \omega^2\right)}\cdot \mathrm{d}\omega, \tag{6.64}$$

where

$$\begin{aligned} C_m &= \left(\frac{1+\left(1+\gamma^2\right)^{\frac{1}{2}}}{2}\right)^{\frac{1}{2}}\cdot \lambda_m^{\frac{1}{2}} + \mathrm{i}\left(\frac{\left(1+\gamma^2\right)^{\frac{1}{2}}-1}{2}\right)^{\frac{1}{2}}\cdot \lambda_m^{\frac{1}{2}}, \\ D_n &= \left(\frac{1+\left(1+\gamma^2\right)^{\frac{1}{2}}}{2}\right)^{\frac{1}{2}}\cdot \lambda_n^{\frac{1}{2}} - \mathrm{i}\left(\frac{\left(1+\gamma^2\right)^{\frac{1}{2}}-1}{2}\right)^{\frac{1}{2}}\cdot \lambda_n^{\frac{1}{2}}. \end{aligned} \tag{6.65}$$

The G_{mn}-integral of 6.64 is then evaluated to

$$G_{mn} = \int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} \frac{1}{\left(C_m^2 - \omega^2\right)\left(D_n^2 - \omega^2\right)}\cdot \mathrm{d}\omega = \frac{0.5}{C_m^2 - D_n^2}\left[\frac{\ln\left(\frac{\omega - C_m}{\omega + C_m}\right)}{C_m} - \frac{\ln\left(\frac{\omega - D_n}{\omega + D_n}\right)}{D_n}\right]_{\omega=\lambda_q^{\frac{1}{2}}-\Delta_1}^{\omega=\lambda_q^{\frac{1}{2}}+\Delta_2}, \tag{6.66}$$

where $\ln(\cdot) = \log_e(\cdot)$.

Substituting the right-hand side of 6.66 into 13.2.2 then gives

$$\begin{aligned}
&\int_{\lambda_q^{\frac{1}{2}}-\Delta_1}^{\lambda_q^{\frac{1}{2}}+\Delta_2} H_{ps}(\omega)\cdot H_{pr}^{\star}(\omega)\mathrm{d}\omega \\
&= \sum_m \sum_n \phi_{sm}\cdot N^{\sigma}(\phi_m)\cdot\phi_{rn}\cdot N^{\sigma}(\phi_n)\,\frac{0.5}{C_m^2-D_n^2}\left[\frac{\ln\left(\frac{\omega-C_m}{\omega+C_m}\right)}{C_m}-\frac{\ln\left(\frac{\omega-D_n}{\omega+D_n}\right)}{D_n}\right]_{\omega=\lambda_q^{\frac{1}{2}}-\Delta_1}^{\omega=\lambda_q^{\frac{1}{2}}+\Delta_2} \\
&= \sum_m \sum_n \phi_{sm}\cdot N^{\sigma}(\phi_m)\cdot\phi_{rn}\cdot N^{\sigma}(\phi_n)\cdot G_{mn},
\end{aligned} \tag{6.67}$$

where

$$G_{mn} = \frac{0.5}{C_m^2-D_n^2}\left[\frac{\ln\left(\frac{\omega-C_m}{\omega+C_m}\right)}{C_m}-\frac{\ln\left(\frac{\omega-D_n}{\omega+D_n}\right)}{D_n}\right]_{\omega=\lambda_q^{\frac{1}{2}}-\Delta_1}^{\omega=\lambda_q^{\frac{1}{2}}+\Delta_2}. \tag{6.68}$$

Substitution of 6.67 into 13.2.1 with SCFs added gives the integral of the hot-spot stress power spectrum. Notice that according to 13.2.1, only the value of the stress spectrum $S_{ff}(r,s:\omega)$ at the modal frequency $\omega_q = \lambda_q^{\frac{1}{2}}$ is required.

6.14 Calculation of fatigue life

6.14.1 Assumptions

The following assumptions are made:

- The hot spot stress power spectrum is characterized by a quasi-static response with several separated sharp peaks at the structure resonances. The stress spectrum is discretized into a finite number of frequency bands covering the sub-modal and modal peaks.
- The integral under these peaks (or frequency bands) is the variance of the stress amplitude at the frequency associated with the peaks.
- The stress amplitude within each frequency band has a Rayleigh distribution. This is true for narrow band processes (Reference [8]). The sub-modal section is split into three portions, each of which is treated as having a Rayleigh distribution.
- For each frequency band fatigue is directly related to the number of cycles experienced in each stress range through the Palmgren-Miner relationship (Reference [5]).
- The number of cycles to failure at any stress range (amplitude) may be found from standard SN curves (Reference [18]).

6.14.2 Damage evaluation

The Palmgren-Miner relationship ([5]), for the damage sustained due to stress cycles, may be written in terms of the stress amplitude

$$D(A) = \frac{n_c(A)}{N_c(A)}, \tag{6.69}$$

where $D(A)$ is the cumulative damage at stress amplitude A, $n_c(A)$ is the number of cycles experienced at the stress amplitude A, and $N_c(A)$ is the number of cycles to cause failure at stress amplitude A.

The damage evaluated over all stress ranges is then obtained by integrating over all the possible stress amplitudes, i.e.

$$D = \int_{-\infty}^{\infty} \frac{n_c(A)}{N_c(A)} \cdot \mathrm{d}A. \tag{6.70}$$

With an SN curve of the following form (θ is to allow for thickness corrections, where appropriate)

$$N_c(A) = \begin{cases} \theta^{\frac{m}{4}} \cdot K_2 \left[2A\right]^{-m} & \text{for} \quad N_c(A) \leq 10^7, \quad \text{where} \quad A = A_0 \quad \text{at} \quad N_c(A) = 10^7, \\ \theta^{\frac{m+2}{4}} \cdot K_L \left[2A\right]^{-(m+2)} & \text{for} \quad N_c(A) > 10^7, \end{cases} \tag{6.71}$$

the annual damage for any frequency band is found in Appendix 8 Framework Wind Fatigue Theory Manual [24]. It is

$$D = N_\omega \cdot f_n \cdot \left\{ 2^{\frac{3(m+2)}{2}} \cdot \theta^{\frac{m+2}{4}} \cdot K_L \left[2A\right]^{-(m+2)} \cdot \left[\sigma^2_{\mathsf{hss}}\right]^{\frac{m+2}{2}} \cdot \Psi_{m+4} + \theta^{\frac{m}{4}} \cdot K_2 \left[2A\right]^{-m} \cdot \left[\sigma^2_{\mathsf{hss}}\right]^{\frac{m}{2}} \cdot \Psi_{m+2} \right\}, \tag{6.72}$$

where

$$\begin{aligned} \Psi_{m+4} &= \Gamma\left(\frac{m+4}{2}\right) \cdot \Gamma_p\left(\frac{m+4}{2}, \frac{A_0}{2\sigma^2_{\mathsf{hss}}}\right), \\ \Psi_{m+2} &= \Gamma\left(\frac{m+2}{2}\right) \cdot \left[1 - \Gamma_p\left(\frac{m+2}{2}, \frac{A_0}{2\sigma^2_{\mathsf{hss}}}\right)\right], \end{aligned} \tag{6.73}$$

and where

$$\begin{aligned} \Gamma(a) &= \int_{-\infty}^{\infty} t^{a-1} \cdot \mathrm{e}^{-t} \cdot \mathrm{d}t, \\ \Gamma(a,x) &= \frac{1}{\Gamma(a)} \int_0^x t^{a-1} \cdot \mathrm{e}^{-t} \cdot \mathrm{d}t. \end{aligned} \tag{6.74}$$

Further, σ^2_{hss} is the variance of the stress amplitude, N_ω is the number of seconds for which the parameterized wind-state forcing the tower is deemed to last within each year, and f_n is the frequency associated with the peak in the hot-spot stress power spectrum.

The total annual damage is therefore the sum of the damages over all the frequency bands and all the wind states. The estimated life is then the reciprocal of the total annual damage.

See Appendix 8 of Framework Wind Fatigue Theory Manual [24] for supporting mathematical background.

A Tutorial examples

A.1 Example 1 – Code check, deterministic-, stochastic-, and spectral fatigue

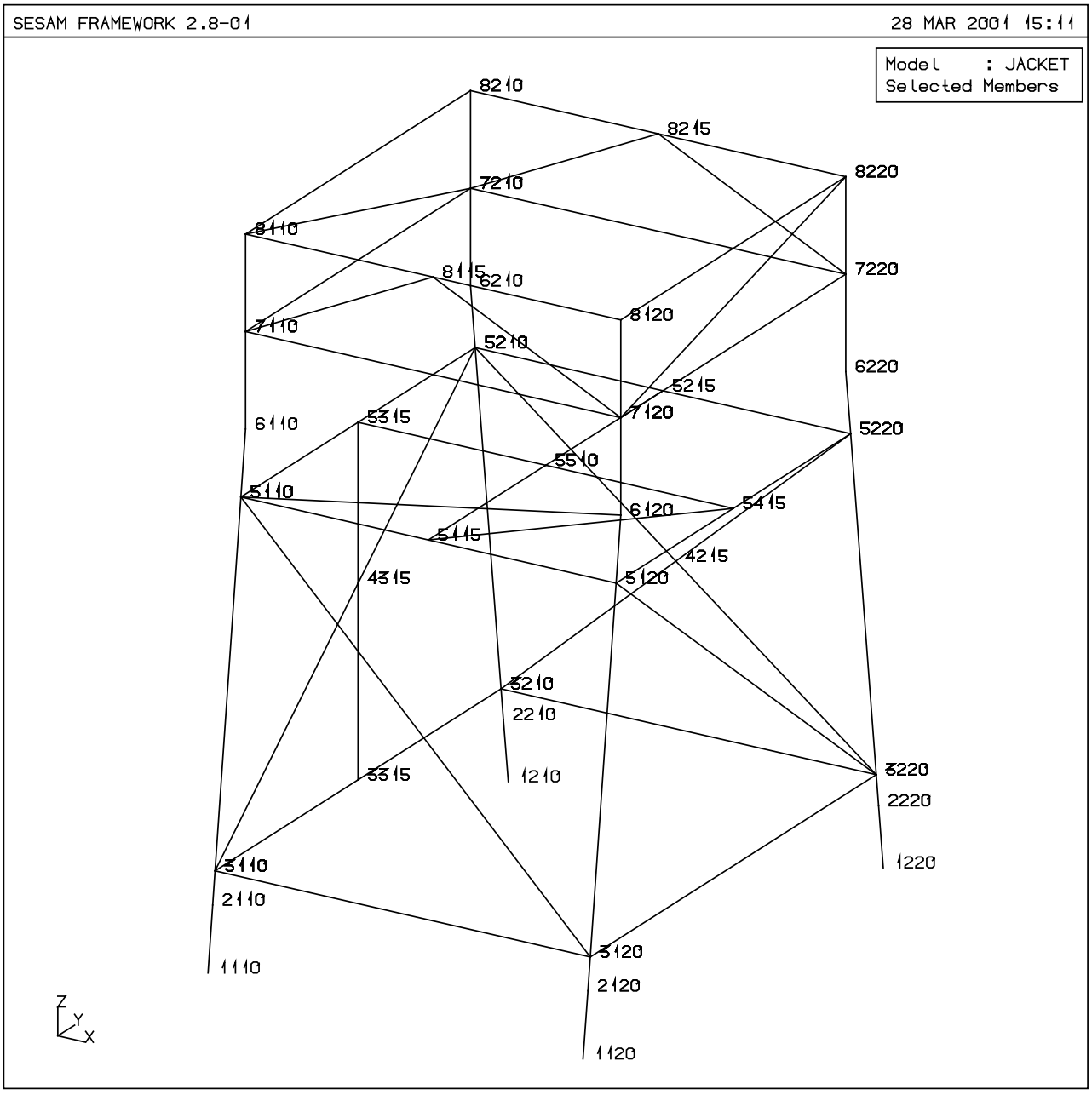
In this example a 3 dimensional jacket structure is used to show code checks, deterministic fatigue, stochastic fatigue, and spectral fatigue analyses in Framework.

The example is denoted `X108` in the Sesam regression test data base from which tests X108B, X108C, and X108D are used in the current appendix.

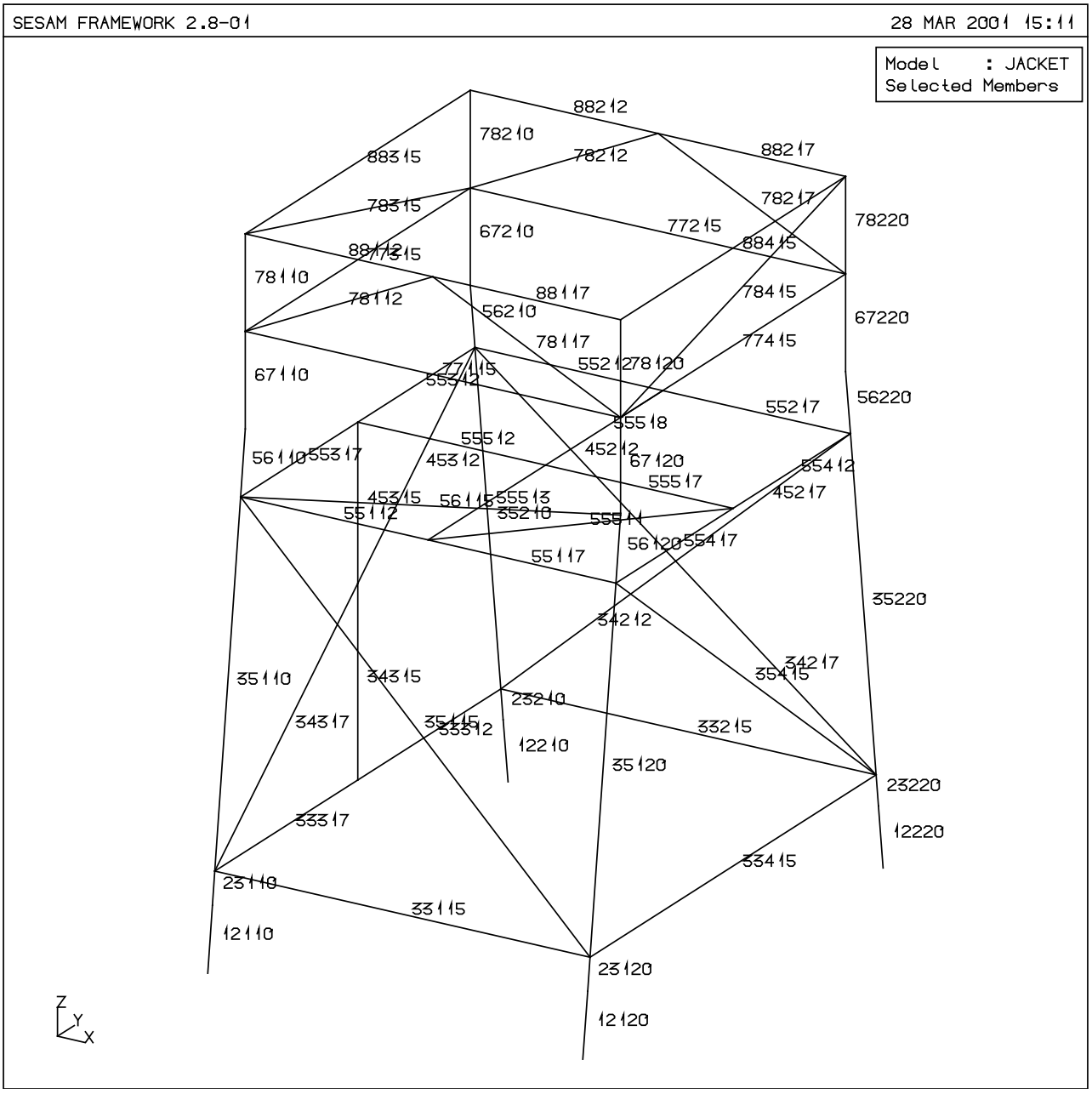
The following sets of wave loads are computed by Wajac:

- Deterministic analysis accounting for fatigue waves
- Stochastic analysis accounting for fatigue waves
- Spectral analysis accounting for fatigue waves

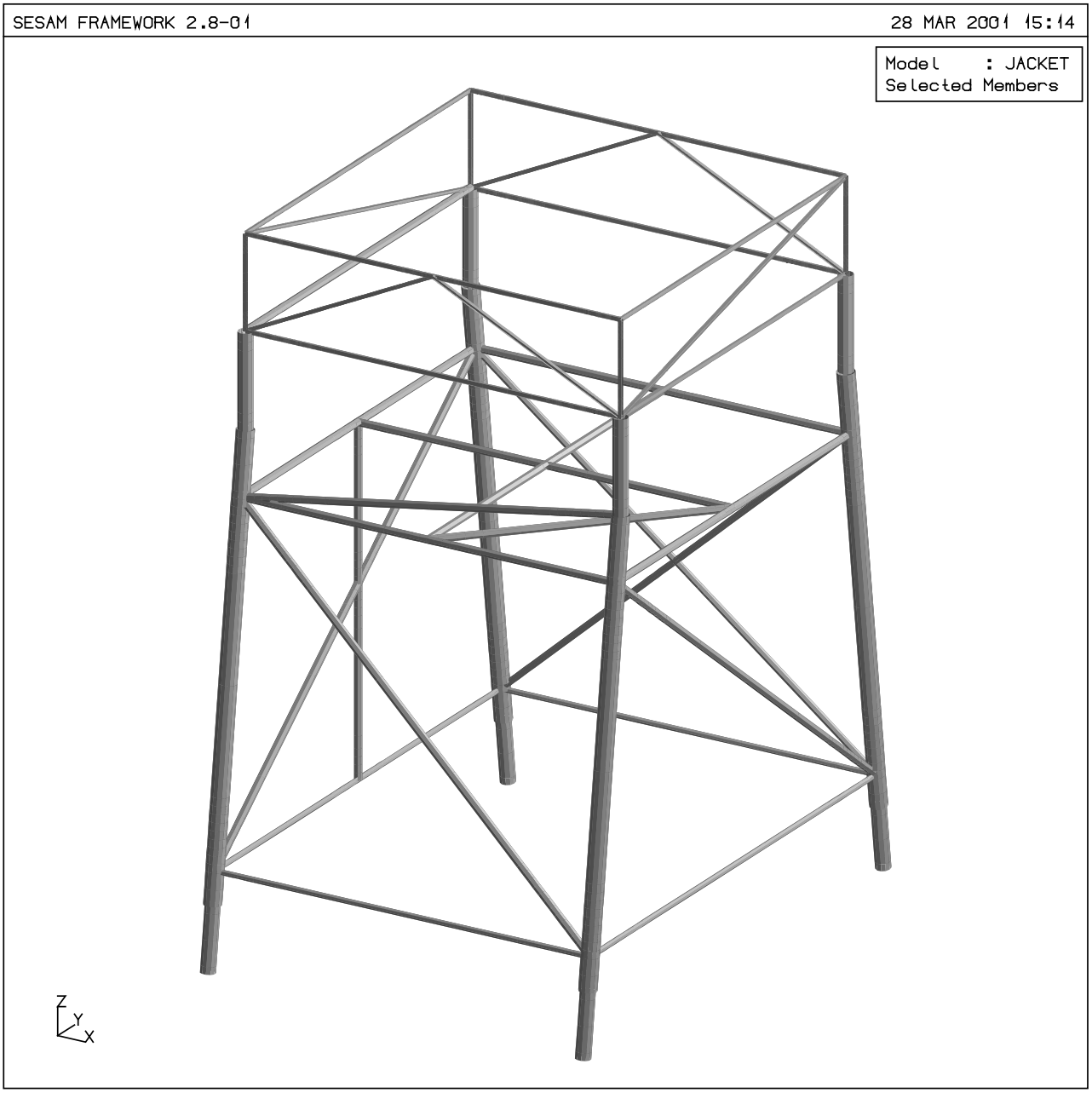
A.1.1 Joint numbers



A.1.2 Member numbers



A.1.3 Shaded view



A.1.4 Preframe journal file – X108APREFRAME1_IN.JNL

```
%    Preframe journal file for a 4-leg jacket structure
%
%    Note :   Units of length are in mm
%             Units of force are Newtons
%
%     Define nodal coordinates
%
%LEG A1
NODE 1110 -18000. -24000. -6000.
2110 -18000.0 -23250. 0.
3110 -18000.0 -22875. 3000.
5110 -18000.0 -18750.0 36000.
6110 -18000.0 -18000.0 42000.0
7110 -18000.0 -18000.0 51000.0
8110 -18000.0 -18000.0 60000.0
%LINE 1
5115 0.0 -18750.0 36000.0
8115 0.0 -18000.0 60000.0
%LEG B1
1120 18000.0 -24000.0 -6000.0
2120 18000.0 -23250.0 0.0
3120 18000.0 -22875.0 3000.0
5120 18000.0 -18750.0 36000.0
6120 18000.0 -18000.0 42000.0
7120 18000.0 -18000.0 51000.0
8120 18000.0 -18000.0 60000.0
%LEG A2
1210 -18000.0 24000.0 -6000.0
2210 -18000.0 23250.0 0.0
3210 -18000.0 22875.0 3000.0
5210 -18000.0 18750.0 36000.0
6210 -18000.0 18000.0 42000.0
7210 -18000.0 18000.0 51000.0
8210 -18000.0 18000.0 60000.0
%LINE 2
4215 0.0 20811.0 19500.0
5215 0.0 18750.0 36000.0
8215 0.0 18000.0 60000.0
%LEG B2
1220 18000.0 24000.0 -6000.0
2220 18000.0 23250.0 0.0
3220 18000.0 22875.0 3000.0
5220 18000.0 18750.0 36000.0
6220 18000.0 18000.0 42000.0
7220 18000.0 18000.0 51000.0
8220 18000.0 18000.0 60000.0
%LINE A
3315 -18000.0 0.0 3000.0
4315 -18000.0 0.0 21135.0
5315 -18000.0 0.0 36000.0
%LINE B
5415 18000.0 0.0 36000.0
%LEVEL 36M
5510 0.0 0.0 36000.0
..
%
% Define element connectivity
%
```

```
ELEMENT BEAM-(BEAS) 12110 1110 2110
23110 2110 3110
35110 3110 5110
56110 5110 6110
67110 6110 7110
78110 7110 8110
%LEG B1
12120 1120 2120
23120 2120 3120
35120 3120 5120
56120 5120 6120
67120 6120 7120
78120 7120 8120
%LINE 1
33115 3110 3120
35115 3120 5110
55112 5110 5115
55117 5115 5120
56115 5110 6120
77115 7110 7120
78112 7110 8115
78117 7120 8115
88112 8110 8115
88117 8115 8120
%LEG A2
12210 1210 2210
23210 2210 3210
35210 3210 5210
56210 5210 6210
67210 6210 7210
78210 7210 8210
%LEG B2
12220 1220 2220
23220 2220 3220
35220 3220 5220
56220 5220 6220
67220 6220 7220
78220 7220 8220
%LINE 2
33215 3210 3220
34212 3210 4215
34217 3220 4215
45212 4215 5210
45217 4215 5220
55212 5210 5215
55217 5215 5220
77215 7210 7220
78212 7210 8215
78217 7220 8215
88212 8210 8215
88217 8215 8220
%LINE A
33312 3210 3315
33317 3315 3110
34315 3315 4315
45315 4315 5315
34317 3110 4315
45312 4315 5210
55312 5210 5315
```

```
55317 5315 5110
77315 7210 7110
78315 7210 8110
88315 8210 8110
%LINE B
33415 3220 3120
35415 3220 5120
55412 5220 5415
55417 5415 5120
77415 7220 7120
78415 7120 8220
88415 8220 8120
%LEVEL 36M
55511 5115 5415
55513 5115 5510
55512 5315 5510
55517 5510 5415
55518 5510 5215
..
%
% Specify boundary conditions
%
BOUNDARY FIXED FIXED FIXED FREE FREE FREE GLOBAL 1110 1120 1210 1220 NO
%
% Specify material properties
%
PROPERTY MATERIAL 1 LINEAR-ELASTIC 2.E05 0.25 7.7E-9 0.0 0.12E-04
..
%
% Specify section types
%
PROPERTY SECTION 135050 PIPE 1350.0 50.0 1.0 1.0
160060 PIPE 1600.0 60.0 1.0 1.0
50025 PIPE 500.0 25.0 1.0 1.0
70020 PIPE 700.0 20.0 1.0 1.0
70025 PIPE 700.0 25.0 1.0 1.0
60025 PIPE 600.0 25.0 1.0 1.0
1414103 I 300.0 300.0 20.0 24.0 300.0 20.0 1.0 1.0
16750 I 413.0 180.0 16.0 10.0 180.0 16.0 1.0 1.0
1212 I 305.0 305.0 20.0 24.0 305.0 20.0 1.0 1.0
..
%
% Connect materials to elements
%
PROPERTY CONNECT MATERIAL 1 ALL
END
END
%
% Connect section numbers to elements
%
PROPERTY CONNECT SECTION 135050 12110 67110 12120 67120 12210 67210
 12220 67220 NO
160060 23110 35110 56110 23120 35120 56120 23210 35210 56210 23220
 35220 56220 NO
1414103 78110 78120 78210 78220 NO
50025 33115 33215 33312 33317 33415 NO
70020 35115 34315 45315 34317 45312 55312 55317 77315 35415 55412 55417
 55511 55512 55513 55517 55518 NO
70025 55112 55117 56115 55212 55217 NO
```

```
 16750 77115 77215 88112 88117 88212 88217 88315 77415 88415 NO
 1212 78112 78117 78212 78217 78315 78415 NO
 60025 34212 34217 45212 45217 NO
 END
 END
 %
 %  Write interface file
 %
 WRITE
 BANDWIDTH-OPTIMIZATION
 1
%%
%%  End of journal file
%%
```

Run the Preframe module and create the finite element model.

Alternatively, user now can use the GUI supported package GeniE to create the concept (geometric) model and then output the finite element model to be used by Wajac.

The hydrodynamic wave loads are acting on the finite element model.

A.1.5 Finite element model

There are three finite element model files in the analysis, `X108BT1.FEM`, `X108CT1.FEM`, and `X108DT1.FEM`. These are essentially the same and we show only `X108BT1.FEM`.

```
IDENT     1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
DATE      1.00000000E+00  0.00000000E+00  4.00000000E+00  7.20000000E+01
        DATE:     13-AUG-2015         TIME:         09:30:01
        PROGRAM:  SESAM PREFRAME      VERSION:      7.0-04 18-JAN-2011
        COMPUTER: 586 WIN NT 6.1 [7601INSTALLATION: , OSLL400284
        USER:     ACD                 ACCOUNT:
GNODE     1.11000000E+03  1.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     1.12000000E+03  2.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     1.22000000E+03  3.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     2.11000000E+03  4.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     2.12000000E+03  5.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     2.22000000E+03  6.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     1.21000000E+03  7.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     3.11000000E+03  8.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     3.12000000E+03  9.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     3.22000000E+03  1.00000000E+01  6.00000000E+00  1.23456000E+05
GNODE     2.21000000E+03  1.10000000E+01  6.00000000E+00  1.23456000E+05
GNODE     3.31500000E+03  1.20000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.12000000E+03  1.30000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.11500000E+03  1.40000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.41500000E+03  1.50000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.51000000E+03  1.60000000E+01  6.00000000E+00  1.23456000E+05
GNODE     4.31500000E+03  1.70000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.11000000E+03  1.80000000E+01  6.00000000E+00  1.23456000E+05
GNODE     4.21500000E+03  1.90000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.22000000E+03  2.00000000E+01  6.00000000E+00  1.23456000E+05
GNODE     3.21000000E+03  2.10000000E+01  6.00000000E+00  1.23456000E+05
GNODE     6.12000000E+03  2.20000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.21500000E+03  2.30000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.31500000E+03  2.40000000E+01  6.00000000E+00  1.23456000E+05
GNODE     5.21000000E+03  2.50000000E+01  6.00000000E+00  1.23456000E+05
GNODE     6.11000000E+03  2.60000000E+01  6.00000000E+00  1.23456000E+05
GNODE     6.22000000E+03  2.70000000E+01  6.00000000E+00  1.23456000E+05
GNODE     7.12000000E+03  2.80000000E+01  6.00000000E+00  1.23456000E+05
```

```
GNODE     8.12000000E+03  2.90000000E+01  6.00000000E+00  1.23456000E+05
GNODE     6.21000000E+03  3.00000000E+01  6.00000000E+00  1.23456000E+05
GNODE     7.11000000E+03  3.10000000E+01  6.00000000E+00  1.23456000E+05
GNODE     7.22000000E+03  3.20000000E+01  6.00000000E+00  1.23456000E+05
GNODE     8.11500000E+03  3.30000000E+01  6.00000000E+00  1.23456000E+05
GNODE     8.22000000E+03  3.40000000E+01  6.00000000E+00  1.23456000E+05
GNODE     7.21000000E+03  3.50000000E+01  6.00000000E+00  1.23456000E+05
GNODE     8.11000000E+03  3.60000000E+01  6.00000000E+00  1.23456000E+05
GNODE     8.21500000E+03  3.70000000E+01  6.00000000E+00  1.23456000E+05
GNODE     8.21000000E+03  3.80000000E+01  6.00000000E+00  1.23456000E+05
GCOORD    1.00000000E+00 -1.80000000E+04 -2.40000000E+04 -6.00000000E+03
GCOORD    2.00000000E+00  1.80000000E+04 -2.40000000E+04 -6.00000000E+03
GCOORD    3.00000000E+00  1.80000000E+04  2.40000000E+04 -6.00000000E+03
GCOORD    4.00000000E+00 -1.80000000E+04 -2.32500000E+04  0.00000000E+00
GCOORD    5.00000000E+00  1.80000000E+04 -2.32500000E+04  0.00000000E+00
GCOORD    6.00000000E+00  1.80000000E+04  2.32500000E+04  0.00000000E+00
GCOORD    7.00000000E+00 -1.80000000E+04  2.40000000E+04 -6.00000000E+03
GCOORD    8.00000000E+00 -1.80000000E+04 -2.28750000E+04  3.00000000E+03
GCOORD    9.00000000E+00  1.80000000E+04 -2.28750000E+04  3.00000000E+03
GCOORD    1.00000000E+01  1.80000000E+04  2.28750000E+04  3.00000000E+03
GCOORD    1.10000000E+01 -1.80000000E+04  2.32500000E+04  0.00000000E+00
GCOORD    1.20000000E+01 -1.80000000E+04  0.00000000E+00  3.00000000E+03
GCOORD    1.30000000E+01  1.80000000E+04 -1.87500000E+04  3.60000000E+04
GCOORD    1.40000000E+01  0.00000000E+00 -1.87500000E+04  3.60000000E+04
GCOORD    1.50000000E+01  1.80000000E+04  0.00000000E+00  3.60000000E+04
GCOORD    1.60000000E+01  0.00000000E+00  0.00000000E+00  3.60000000E+04
GCOORD    1.70000000E+01 -1.80000000E+04  0.00000000E+00  2.11350000E+04
GCOORD    1.80000000E+01 -1.80000000E+04 -1.87500000E+04  3.60000000E+04
GCOORD    1.90000000E+01  0.00000000E+00  2.08110000E+04  1.95000000E+04
GCOORD    2.00000000E+01  1.80000000E+04  1.87500000E+04  3.60000000E+04
GCOORD    2.10000000E+01 -1.80000000E+04  2.28750000E+04  3.00000000E+03
GCOORD    2.20000000E+01  1.80000000E+04 -1.80000000E+04  4.20000000E+04
GCOORD    2.30000000E+01  0.00000000E+00  1.87500000E+04  3.60000000E+04
GCOORD    2.40000000E+01 -1.80000000E+04  0.00000000E+00  3.60000000E+04
GCOORD    2.50000000E+01 -1.80000000E+04  1.87500000E+04  3.60000000E+04
GCOORD    2.60000000E+01 -1.80000000E+04 -1.80000000E+04  4.20000000E+04
GCOORD    2.70000000E+01  1.80000000E+04  1.80000000E+04  4.20000000E+04
GCOORD    2.80000000E+01  1.80000000E+04 -1.80000000E+04  5.10000000E+04
GCOORD    2.90000000E+01  1.80000000E+04 -1.80000000E+04  6.00000000E+04
GCOORD    3.00000000E+01 -1.80000000E+04  1.80000000E+04  4.20000000E+04
GCOORD    3.10000000E+01 -1.80000000E+04 -1.80000000E+04  5.10000000E+04
GCOORD    3.20000000E+01  1.80000000E+04  1.80000000E+04  5.10000000E+04
GCOORD    3.30000000E+01  0.00000000E+00 -1.80000000E+04  6.00000000E+04
GCOORD    3.40000000E+01  1.80000000E+04  1.80000000E+04  6.00000000E+04
GCOORD    3.50000000E+01 -1.80000000E+04  1.80000000E+04  5.10000000E+04
GCOORD    3.60000000E+01 -1.80000000E+04 -1.80000000E+04  6.00000000E+04
GCOORD    3.70000000E+01  0.00000000E+00  1.80000000E+04  6.00000000E+04
GCOORD    3.80000000E+01 -1.80000000E+04  1.80000000E+04  6.00000000E+04
BNBCD     1.00000000E+00  6.00000000E+00  1.00000000E+00  1.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
BNBCD     2.00000000E+00  6.00000000E+00  1.00000000E+00  1.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
BNBCD     3.00000000E+00  6.00000000E+00  1.00000000E+00  1.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
BNBCD     7.00000000E+00  6.00000000E+00  1.00000000E+00  1.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   1.21100000E+04  1.00000000E+00  1.50000000E+01  0.00000000E+00
          1.00000000E+00  4.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   2.31100000E+04  2.00000000E+00  1.50000000E+01  0.00000000E+00
```

```
          4.00000000E+00  8.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   3.51100000E+04  3.00000000E+00  1.50000000E+01  0.00000000E+00
          8.00000000E+00  1.80000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.61100000E+04  4.00000000E+00  1.50000000E+01  0.00000000E+00
          1.80000000E+01  2.60000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   6.71100000E+04  5.00000000E+00  1.50000000E+01  0.00000000E+00
          2.60000000E+01  3.10000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.81100000E+04  6.00000000E+00  1.50000000E+01  0.00000000E+00
          3.10000000E+01  3.60000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   1.21200000E+04  7.00000000E+00  1.50000000E+01  0.00000000E+00
          2.00000000E+00  5.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   2.31200000E+04  8.00000000E+00  1.50000000E+01  0.00000000E+00
          5.00000000E+00  9.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   3.51200000E+04  9.00000000E+00  1.50000000E+01  0.00000000E+00
          9.00000000E+00  1.30000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.61200000E+04  1.00000000E+01  1.50000000E+01  0.00000000E+00
          1.30000000E+01  2.20000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   6.71200000E+04  1.10000000E+01  1.50000000E+01  0.00000000E+00
          2.20000000E+01  2.80000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.81200000E+04  1.20000000E+01  1.50000000E+01  0.00000000E+00
          2.80000000E+01  2.90000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.31150000E+04  1.30000000E+01  1.50000000E+01  0.00000000E+00
          8.00000000E+00  9.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   3.51150000E+04  1.40000000E+01  1.50000000E+01  0.00000000E+00
          9.00000000E+00  1.80000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.51120000E+04  1.50000000E+01  1.50000000E+01  0.00000000E+00
          1.80000000E+01  1.40000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.51170000E+04  1.60000000E+01  1.50000000E+01  0.00000000E+00
          1.40000000E+01  1.30000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.61150000E+04  1.70000000E+01  1.50000000E+01  0.00000000E+00
          1.80000000E+01  2.20000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.71150000E+04  1.80000000E+01  1.50000000E+01  0.00000000E+00
          3.10000000E+01  2.80000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.81120000E+04  1.90000000E+01  1.50000000E+01  0.00000000E+00
          3.10000000E+01  3.30000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.81170000E+04  2.00000000E+01  1.50000000E+01  0.00000000E+00
          2.80000000E+01  3.30000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   8.81120000E+04  2.10000000E+01  1.50000000E+01  0.00000000E+00
          3.60000000E+01  3.30000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   8.81170000E+04  2.20000000E+01  1.50000000E+01  0.00000000E+00
          3.30000000E+01  2.90000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   1.22100000E+04  2.30000000E+01  1.50000000E+01  0.00000000E+00
          7.00000000E+00  1.10000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   2.32100000E+04  2.40000000E+01  1.50000000E+01  0.00000000E+00
          1.10000000E+01  2.10000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.52100000E+04  2.50000000E+01  1.50000000E+01  0.00000000E+00
          2.10000000E+01  2.50000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.62100000E+04  2.60000000E+01  1.50000000E+01  0.00000000E+00
          2.50000000E+01  3.00000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   6.72100000E+04  2.70000000E+01  1.50000000E+01  0.00000000E+00
          3.00000000E+01  3.50000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.82100000E+04  2.80000000E+01  1.50000000E+01  0.00000000E+00
          3.50000000E+01  3.80000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   1.22200000E+04  2.90000000E+01  1.50000000E+01  0.00000000E+00
          3.00000000E+00  6.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   2.32200000E+04  3.00000000E+01  1.50000000E+01  0.00000000E+00
          6.00000000E+00  1.00000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.52200000E+04  3.10000000E+01  1.50000000E+01  0.00000000E+00
          1.00000000E+01  2.00000000E+01  0.00000000E+00  0.00000000E+00
```

```
GELMNT1   5.62200000E+04  3.20000000E+01  1.50000000E+01  0.00000000E+00
          2.00000000E+01  2.70000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   6.72200000E+04  3.30000000E+01  1.50000000E+01  0.00000000E+00
          2.70000000E+01  3.20000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.82200000E+04  3.40000000E+01  1.50000000E+01  0.00000000E+00
          3.20000000E+01  3.40000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.32150000E+04  3.50000000E+01  1.50000000E+01  0.00000000E+00
          2.10000000E+01  1.00000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.42120000E+04  3.60000000E+01  1.50000000E+01  0.00000000E+00
          2.10000000E+01  1.90000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.42170000E+04  3.70000000E+01  1.50000000E+01  0.00000000E+00
          1.00000000E+01  1.90000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   4.52120000E+04  3.80000000E+01  1.50000000E+01  0.00000000E+00
          1.90000000E+01  2.50000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   4.52170000E+04  3.90000000E+01  1.50000000E+01  0.00000000E+00
          1.90000000E+01  2.00000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.52120000E+04  4.00000000E+01  1.50000000E+01  0.00000000E+00
          2.50000000E+01  2.30000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.52170000E+04  4.10000000E+01  1.50000000E+01  0.00000000E+00
          2.30000000E+01  2.00000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.72150000E+04  4.20000000E+01  1.50000000E+01  0.00000000E+00
          3.50000000E+01  3.20000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.82120000E+04  4.30000000E+01  1.50000000E+01  0.00000000E+00
          3.50000000E+01  3.70000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.82170000E+04  4.40000000E+01  1.50000000E+01  0.00000000E+00
          3.20000000E+01  3.70000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   8.82120000E+04  4.50000000E+01  1.50000000E+01  0.00000000E+00
          3.80000000E+01  3.70000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   8.82170000E+04  4.60000000E+01  1.50000000E+01  0.00000000E+00
          3.70000000E+01  3.40000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.33120000E+04  4.70000000E+01  1.50000000E+01  0.00000000E+00
          2.10000000E+01  1.20000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.33170000E+04  4.80000000E+01  1.50000000E+01  0.00000000E+00
          1.20000000E+01  8.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   3.43150000E+04  4.90000000E+01  1.50000000E+01  0.00000000E+00
          1.20000000E+01  1.70000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   4.53150000E+04  5.00000000E+01  1.50000000E+01  0.00000000E+00
          1.70000000E+01  2.40000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.43170000E+04  5.10000000E+01  1.50000000E+01  0.00000000E+00
          8.00000000E+00  1.70000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   4.53120000E+04  5.20000000E+01  1.50000000E+01  0.00000000E+00
          1.70000000E+01  2.50000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.53120000E+04  5.30000000E+01  1.50000000E+01  0.00000000E+00
          2.50000000E+01  2.40000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.53170000E+04  5.40000000E+01  1.50000000E+01  0.00000000E+00
          2.40000000E+01  1.80000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.73150000E+04  5.50000000E+01  1.50000000E+01  0.00000000E+00
          3.50000000E+01  3.10000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.83150000E+04  5.60000000E+01  1.50000000E+01  0.00000000E+00
          3.50000000E+01  3.60000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   8.83150000E+04  5.70000000E+01  1.50000000E+01  0.00000000E+00
          3.80000000E+01  3.60000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   3.34150000E+04  5.80000000E+01  1.50000000E+01  0.00000000E+00
          1.00000000E+01  9.00000000E+00  0.00000000E+00  0.00000000E+00
GELMNT1   3.54150000E+04  5.90000000E+01  1.50000000E+01  0.00000000E+00
          1.00000000E+01  1.30000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.54120000E+04  6.00000000E+01  1.50000000E+01  0.00000000E+00
          2.00000000E+01  1.50000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.54170000E+04  6.10000000E+01  1.50000000E+01  0.00000000E+00
```

```
          1.50000000E+01  1.30000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.74150000E+04  6.20000000E+01  1.50000000E+01  0.00000000E+00
          3.20000000E+01  2.80000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   7.84150000E+04  6.30000000E+01  1.50000000E+01  0.00000000E+00
          2.80000000E+01  3.40000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   8.84150000E+04  6.40000000E+01  1.50000000E+01  0.00000000E+00
          3.40000000E+01  2.90000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.55110000E+04  6.50000000E+01  1.50000000E+01  0.00000000E+00
          1.40000000E+01  1.50000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.55130000E+04  6.60000000E+01  1.50000000E+01  0.00000000E+00
          1.40000000E+01  1.60000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.55120000E+04  6.70000000E+01  1.50000000E+01  0.00000000E+00
          2.40000000E+01  1.60000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.55170000E+04  6.80000000E+01  1.50000000E+01  0.00000000E+00
          1.60000000E+01  1.50000000E+01  0.00000000E+00  0.00000000E+00
GELMNT1   5.55180000E+04  6.90000000E+01  1.50000000E+01  0.00000000E+00
          1.60000000E+01  2.30000000E+01  0.00000000E+00  0.00000000E+00
GIORH     1.21200000E+03  3.05000000E+02  2.40000000E+01  3.05000000E+02
          2.00000000E+01  3.05000000E+02  2.00000000E+01  1.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    1.21200000E+03  0.00000000E+00  1.85600000E+04  3.70212250E+06
          2.85362176E+08  9.48806960E+07  0.00000000E+00  1.54255109E+05
          1.87122738E+06  6.22168500E+05  7.83806006E+03  6.34182227E+03
          0.00000000E+00  1.76226223E-07  1.07992500E+06  4.84205000E+05
GIORH     1.67500000E+04  4.13000000E+02  1.00000000E+01  1.80000000E+02
          1.60000000E+01  1.80000000E+02  1.60000000E+01  1.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    1.67500000E+04  0.00000000E+00  9.57000000E+03  8.04076000E+05
          2.73168448E+08  1.55837500E+07  0.00000000E+00  5.02547500E+04
          1.32284962E+06  1.73152781E+05  3.71145215E+03  3.62710278E+03
          0.00000000E+00  0.00000000E+00  7.53131250E+05  1.34362500E+05
GPIPE     5.00250000E+04  4.50000000E+02  5.00000000E+02  2.50000000E+01
          1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    5.00250000E+04  0.00000000E+00  3.73064141E+04  2.11014400E+09
          1.05507200E+09  1.05507200E+09  0.00000000E+00  8.44057600E+06
          4.22028800E+06  4.22028800E+06  1.86876211E+04  1.86876211E+04
          0.00000000E+00  0.00000000E+00  2.82291675E+06  2.82291675E+06
GPIPE     6.00250000E+04  5.50000000E+02  6.00000000E+02  2.50000000E+01
          1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    6.00250000E+04  0.00000000E+00  4.51603945E+04  3.73984538E+09
          1.86992269E+09  1.86992269E+09  0.00000000E+00  1.24661510E+07
          6.23307550E+06  6.23307550E+06  2.26086367E+04  2.26086367E+04
          0.00000000E+00  0.00000000E+00  4.13541675E+06  4.13541675E+06
GPIPE     7.00200000E+04  6.60000000E+02  7.00000000E+02  2.00000000E+01
          1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    7.00200000E+04  0.00000000E+00  4.27256602E+04  4.94335898E+09
          2.47167949E+09  2.47167949E+09  0.00000000E+00  1.41238830E+07
          7.06194150E+06  7.06194150E+06  2.13751465E+04  2.13751465E+04
          0.00000000E+00  0.00000000E+00  4.62533350E+06  4.62533350E+06
GPIPE     7.00250000E+04  6.50000000E+02  7.00000000E+02  2.50000000E+01
          1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    7.00250000E+04  0.00000000E+00  5.30143789E+04  6.04695245E+09
          3.02347622E+09  3.02347622E+09  0.00000000E+00  1.72770060E+07
          8.63850300E+06  8.63850300E+06  2.65314199E+04  2.65314199E+04
          0.00000000E+00  0.00000000E+00  5.69791650E+06  5.69791650E+06
GPIPE     1.35050000E+05  1.25000000E+03  1.35000000E+03  5.00000000E+01
          1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    1.35050000E+05  0.00000000E+00  2.04203531E+05  8.64036209E+10
          4.32018104E+10  4.32018104E+10  0.00000000E+00  1.28005368E+08
```

```
          6.40026840E+07  6.40026840E+07  1.02202414E+05  1.02202414E+05
          0.00000000E+00  0.00000000E+00  4.22708320E+07  4.22708320E+07
GPIPE     1.60060000E+05  1.48000000E+03  1.60000000E+03  6.00000000E+01
          1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    1.60060000E+05  0.00000000E+00  2.90283156E+05  1.72370149E+11
          8.61850747E+10  8.61850747E+10  0.00000000E+00  2.15462688E+08
          1.07731344E+08  1.07731344E+08  1.45288391E+05  1.45288391E+05
          0.00000000E+00  0.00000000E+00  7.11840000E+07  7.11840000E+07
GIORH     1.41410300E+06  3.00000000E+02  2.40000000E+01  3.00000000E+02
          2.00000000E+01  3.00000000E+02  2.00000000E+01  1.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
GBEAMG    1.41410300E+06  0.00000000E+00  1.82400000E+04  3.63750375E+06
          2.70752000E+08  9.02995200E+07  0.00000000E+00  1.51562656E+05
          1.80501338E+06  6.01996812E+05  7.70605225E+03  6.23134619E+03
          0.00000000E+00  0.00000000E+00  1.04280000E+06  4.68720000E+05
MISOSEL   1.00000000E+00  2.00000000E+05  2.50000000E-01  7.69999975E-09
          0.00000000E+00  1.20000004E-05  0.00000000E+00  0.00000000E+00
GUNIVEC   1.00000000E+00  0.00000000E+00 -9.92277920E-01  1.24034740E-01
GUNIVEC   2.00000000E+00  0.00000000E+00 -9.92277920E-01  1.24034740E-01
GUNIVEC   3.00000000E+00  0.00000000E+00 -9.92277920E-01  1.24034740E-01
GUNIVEC   4.00000000E+00  0.00000000E+00 -9.92277920E-01  1.24034740E-01
GUNIVEC   5.00000000E+00  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   6.00000000E+00  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   7.00000000E+00  0.00000000E+00 -9.92277920E-01  1.24034740E-01
GUNIVEC   8.00000000E+00  0.00000000E+00 -9.92277920E-01  1.24034740E-01
GUNIVEC   9.00000000E+00  0.00000000E+00 -9.92277920E-01  1.24034740E-01
GUNIVEC   1.00000000E+01  0.00000000E+00 -9.92277920E-01  1.24034740E-01
GUNIVEC   1.10000000E+01  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   1.20000000E+01  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   1.30000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   1.40000000E+01  6.68949902E-01 -7.66505077E-02  7.39344895E-01
GUNIVEC   1.50000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   1.60000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   1.70000000E+01 -1.64328620E-01 -3.42351315E-03  9.86399710E-01
GUNIVEC   1.80000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   1.90000000E+01 -4.47213620E-01  0.00000000E+00  8.94427240E-01
GUNIVEC   2.00000000E+01  4.47213620E-01  0.00000000E+00  8.94427240E-01
GUNIVEC   2.10000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   2.20000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   2.30000000E+01  0.00000000E+00  9.92277920E-01  1.24034740E-01
GUNIVEC   2.40000000E+01  0.00000000E+00  9.92277920E-01  1.24034740E-01
GUNIVEC   2.50000000E+01  0.00000000E+00  9.92277920E-01  1.24034740E-01
GUNIVEC   2.60000000E+01  0.00000000E+00  9.92277920E-01  1.24034740E-01
GUNIVEC   2.70000000E+01  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   2.80000000E+01  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   2.90000000E+01  0.00000000E+00  9.92277920E-01  1.24034740E-01
GUNIVEC   3.00000000E+01  0.00000000E+00  9.92277920E-01  1.24034740E-01
GUNIVEC   3.10000000E+01  0.00000000E+00  9.92277920E-01  1.24034740E-01
GUNIVEC   3.20000000E+01  0.00000000E+00  9.92277920E-01  1.24034740E-01
GUNIVEC   3.30000000E+01  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   3.40000000E+01  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   3.50000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   3.60000000E+01 -6.68940127E-01  7.67051280E-02  7.39347994E-01
GUNIVEC   3.70000000E+01  6.68940127E-01  7.67051280E-02  7.39347994E-01
GUNIVEC   3.80000000E+01  6.68959677E-01  7.65958875E-02  7.39341676E-01
GUNIVEC   3.90000000E+01 -6.68959677E-01  7.65958875E-02  7.39341676E-01
GUNIVEC   4.00000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   4.10000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   4.20000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
```

```
GUNIVEC   4.30000000E+01 -4.47213620E-01  0.00000000E+00  8.94427240E-01
GUNIVEC   4.40000000E+01  4.47213620E-01  0.00000000E+00  8.94427240E-01
GUNIVEC   4.50000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   4.60000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   4.70000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   4.80000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   4.90000000E+01  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   5.00000000E+01  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   5.10000000E+01  0.00000000E+00 -6.21242464E-01  7.83618450E-01
GUNIVEC   5.20000000E+01  0.00000000E+00 -6.21248782E-01  7.83613443E-01
GUNIVEC   5.30000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   5.40000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   5.50000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   5.60000000E+01  0.00000000E+00  2.42535636E-01  9.70142543E-01
GUNIVEC   5.70000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   5.80000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   5.90000000E+01  0.00000000E+00  6.21245265E-01  7.83616185E-01
GUNIVEC   6.00000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   6.10000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   6.20000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   6.30000000E+01  0.00000000E+00 -2.42535636E-01  9.70142543E-01
GUNIVEC   6.40000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   6.50000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   6.60000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   6.70000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   6.80000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   6.90000000E+01  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.35050000E+05  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   2.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  2.00000000E+00
GELREF1   3.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  3.00000000E+00
GELREF1   4.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  4.00000000E+00
GELREF1   5.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.35050000E+05  0.00000000E+00  0.00000000E+00  5.00000000E+00
GELREF1   6.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.41410300E+06  0.00000000E+00  0.00000000E+00  6.00000000E+00
GELREF1   7.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.35050000E+05  0.00000000E+00  0.00000000E+00  7.00000000E+00
GELREF1   8.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  8.00000000E+00
GELREF1   9.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  9.00000000E+00
GELREF1   1.00000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  1.00000000E+01
GELREF1   1.10000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
```

```
          1.35050000E+05  0.00000000E+00  0.00000000E+00  1.10000000E+01
GELREF1   1.20000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.41410300E+06  0.00000000E+00  0.00000000E+00  1.20000000E+01
GELREF1   1.30000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          5.00250000E+04  0.00000000E+00  0.00000000E+00  1.30000000E+01
GELREF1   1.40000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  1.40000000E+01
GELREF1   1.50000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00250000E+04  0.00000000E+00  0.00000000E+00  1.50000000E+01
GELREF1   1.60000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00250000E+04  0.00000000E+00  0.00000000E+00  1.60000000E+01
GELREF1   1.70000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00250000E+04  0.00000000E+00  0.00000000E+00  1.70000000E+01
GELREF1   1.80000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  1.80000000E+01
GELREF1   1.90000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.21200000E+03  0.00000000E+00  0.00000000E+00  1.90000000E+01
GELREF1   2.00000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.21200000E+03  0.00000000E+00  0.00000000E+00  2.00000000E+01
GELREF1   2.10000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  2.10000000E+01
GELREF1   2.20000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  2.20000000E+01
GELREF1   2.30000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.35050000E+05  0.00000000E+00  0.00000000E+00  2.30000000E+01
GELREF1   2.40000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  2.40000000E+01
GELREF1   2.50000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  2.50000000E+01
GELREF1   2.60000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  2.60000000E+01
GELREF1   2.70000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.35050000E+05  0.00000000E+00  0.00000000E+00  2.70000000E+01
GELREF1   2.80000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.41410300E+06  0.00000000E+00  0.00000000E+00  2.80000000E+01
GELREF1   2.90000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.35050000E+05  0.00000000E+00  0.00000000E+00  2.90000000E+01
GELREF1   3.00000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  3.00000000E+01
GELREF1   3.10000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
```

```
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  3.10000000E+01
GELREF1   3.20000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.60060000E+05  0.00000000E+00  0.00000000E+00  3.20000000E+01
GELREF1   3.30000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.35050000E+05  0.00000000E+00  0.00000000E+00  3.30000000E+01
GELREF1   3.40000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.41410300E+06  0.00000000E+00  0.00000000E+00  3.40000000E+01
GELREF1   3.50000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          5.00250000E+04  0.00000000E+00  0.00000000E+00  3.50000000E+01
GELREF1   3.60000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          6.00250000E+04  0.00000000E+00  0.00000000E+00  3.60000000E+01
GELREF1   3.70000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          6.00250000E+04  0.00000000E+00  0.00000000E+00  3.70000000E+01
GELREF1   3.80000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          6.00250000E+04  0.00000000E+00  0.00000000E+00  3.80000000E+01
GELREF1   3.90000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          6.00250000E+04  0.00000000E+00  0.00000000E+00  3.90000000E+01
GELREF1   4.00000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00250000E+04  0.00000000E+00  0.00000000E+00  4.00000000E+01
GELREF1   4.10000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00250000E+04  0.00000000E+00  0.00000000E+00  4.10000000E+01
GELREF1   4.20000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  4.20000000E+01
GELREF1   4.30000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.21200000E+03  0.00000000E+00  0.00000000E+00  4.30000000E+01
GELREF1   4.40000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.21200000E+03  0.00000000E+00  0.00000000E+00  4.40000000E+01
GELREF1   4.50000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  4.50000000E+01
GELREF1   4.60000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  4.60000000E+01
GELREF1   4.70000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          5.00250000E+04  0.00000000E+00  0.00000000E+00  4.70000000E+01
GELREF1   4.80000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          5.00250000E+04  0.00000000E+00  0.00000000E+00  4.80000000E+01
GELREF1   4.90000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  4.90000000E+01
GELREF1   5.00000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  5.00000000E+01
```

```
GELREF1   5.10000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  5.10000000E+01
GELREF1   5.20000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  5.20000000E+01
GELREF1   5.30000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  5.30000000E+01
GELREF1   5.40000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  5.40000000E+01
GELREF1   5.50000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  5.50000000E+01
GELREF1   5.60000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.21200000E+03  0.00000000E+00  0.00000000E+00  5.60000000E+01
GELREF1   5.70000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  5.70000000E+01
GELREF1   5.80000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          5.00250000E+04  0.00000000E+00  0.00000000E+00  5.80000000E+01
GELREF1   5.90000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  5.90000000E+01
GELREF1   6.00000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  6.00000000E+01
GELREF1   6.10000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  6.10000000E+01
GELREF1   6.20000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  6.20000000E+01
GELREF1   6.30000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.21200000E+03  0.00000000E+00  0.00000000E+00  6.30000000E+01
GELREF1   6.40000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.67500000E+04  0.00000000E+00  0.00000000E+00  6.40000000E+01
GELREF1   6.50000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  6.50000000E+01
GELREF1   6.60000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  6.60000000E+01
GELREF1   6.70000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  6.70000000E+01
GELREF1   6.80000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  6.80000000E+01
GELREF1   6.90000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          7.00200000E+04  0.00000000E+00  0.00000000E+00  6.90000000E+01
IEND      0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
```

A.1.6 Wajac data file for deterministic wave load – X108BWAJAC.INP

```
WAJAC
TITL DETERMINISTC FATIGUE ANALYSIS
TITL TUTORIAL EXAMPLE FOR A 4-LEG JACKET
MODE                  1.       1.
FMOD      X108B
FWAVE     X108B                                    FORMATTED
C    56789.123456789.123456789.123456789.123456789.123456789.
CONS      1.0       9806.6      1.025E-9
HYDR
COEF        0.        100000.      1.0              2.0
LOAD
DPTH       43500.
SEA  1.1       4000. 8.0         0.0     0.0      45.0        -8.0     0.0
SEA  1.1       3000. 5.0         0.0     0.0      45.0        -8.0     0.0
SEA  1.1       6000. 8.0         0.0     0.0      45.0        -8.0     45.0
SEA  1.1       5000. 7.0         0.0     0.0      45.0        -8.0     45.0
SEA  1.1       6000. 9.0         0.0     0.0      45.0        -8.0     90.0
SEA  1.1       5000. 8.0         0.0     0.0      45.0        -8.0     90.0
SEA  1.1       4000. 7.0         0.0     0.0      45.0        -8.0     90.0
SEA  1.1       3000. 6.0         0.0     0.0      45.0        -8.0     90.0
SEA  1.1       2000. 5.0         0.0     0.0      45.0        -8.0     90.0
END
```

A.1.7 Wajac data file for stochastic wave load – X108CWAJAC.INP

```
WAJAC
TITL STOCHASTIC FATIGUE ANALYSIS
TITL TUTORIAL EXAMPLE FOR A 4-LEG JACKET
FMOD      X108C
FWAVE     X108C                                    FORMATTED
C    56789.123456789.123456789.123456789.123456789.123456789.
MODE                  1.       1.
CONS      1.0       9806.6      1.025E-9
HYDR
COEF        0.        100000.      0.7              2.0
LOAD
DPTH       43500.
SEAFRQ 2.             -45.
SEAFRQ 2.             0.
SEAFRQ 2.             45.
SEAFRQ 2.             90.
SEAFRQ 2.             135.
FRQ        4.
FRQ        2.0        3.0        5.0        12.5
AMP        500.       1000.      2300.      8500.
MPRT          67210.                  1.       1.         1.        0.        0.
MPRT          55000.    57000.        1.       1.         1.        2.        3.
END
```

A.1.8 Wajac data file for spectral fatigue wave loads – X108DWAJAC.INP

```
WAJAC
TITL SPECTRAL FATIGUE WAVE LOADS
TITL TUTORIAL EXAMPLE FOR A 4-LEG JACKET
FMOD      X108D
FWAVE     X108D                                    FORMATTED
C    56789.123456789.123456789.123456789.123456789.123456789.
MODE                  1.       1.
CONS      1.0       9806.6      1.025E-9
```

```
HYDR
COEF        0.         100000.      1.0              2.0
LOAD
DPTH       43500.
C
C          ISEA THEO    HEIGHT    PERIOD      PHIO        TO      STEP     NSTEP
SEA          1.  1.0       800        3.        0.        0.       20.      -18.
SEA          2.  1.0      3000       6.5        0.        0.       20.      -18.
SEA          3.  1.0      6000       8.0        0.        0.       20.      -18.
SEA          4.  1.0      8000       9.2        0.        0.       20.      -18.
SEA          5.  1.0     12000      11.3        0.        0.       20.      -18.
SEA          6.  1.0     15000      12.6        0.        0.       20.      -18.
SEA          7.  1.0       800        3.        0.        0.       20.      -18.
SEA          8.  1.0      3000       6.5        0.        0.       20.      -18.
SEA          9.  1.0      6000       8.0        0.        0.       20.      -18.
SEA         10.  1.0      8000       9.2        0.        0.       20.      -18.
SEA         11.  1.0     12000      11.3        0.        0.       20.      -18.
SEA         12.  1.0     15000      12.6        0.        0.       20.      -18.
SEA         13.  1.0       800        3.        0.        0.       20.      -18.
SEA         14.  1.0      3000       6.5        0.        0.       20.      -18.
SEA         15.  1.0      6000       8.0        0.        0.       20.      -18.
SEA         16.  1.0      8000       9.2        0.        0.       20.      -18.
SEA         17.  1.0     12000      11.3        0.        0.       20.      -18.
SEA         18.  1.0     15000      12.6        0.        0.       20.      -18.
C
C          ISEA BETA WKFA CTNO CBFA CSTR LOAD DLOA  WID WIME
SEAOPT       1.   0.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT       2.   0.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT       3.   0.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT       4.   0.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT       5.   0.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT       6.   0.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT       7.  45.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT       8.  45.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT       9.  45.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      10.  45.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      11.  45.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      12.  45.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      13.  90.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      14.  90.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      15.  90.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      16.  90.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      17.  90.   1.   0.   1.  -1.   1.   0.   0.   0.
SEAOPT      18.  90.   1.   0.   1.  -1.   1.   0.   0.   0.
END
```

A.1.9 Sestra data file for deterministic wave analysis – X108BSESTRA.INP

Results file name is X108BR1.SIN.

```
CMAS
INAM X108B
LNAM X108B          FORMATTED
ITOP   1.
RETR   3.   2.
RSEL    1.   0.   0.   0.   0.   0.   1.   0.
COMM RNAM X108B          FORMATTED
RNAM X108B          NORSAM
Z
```

A.1.10 Sestra data file for stochastic wave analysis – X108CSESTRA.INP

Results file name is X108CR1.SIN.

Notice that the Sestra input data file is for a quasi-static analysis in frequency domain. The modal analysis and the calculation of dynamic forced response are not performed. Refer to Sestra User's Manual for more details on dynamic analysis.

This example shows a static analysis.

```
CMAS
INAM X108C
LNAM X108C          FORMATTED
ITOP   1.
RETR   3.   2.
RSEL    1.   0.   0.   0.   0.   0.   1.   0.
COMM RNAM X108C          FORMATTED
RNAM X108C          NORSAM
Z
```

A.1.11 Sestra data file for the analysis of the spectral fatigue waves – X108DSESTRA.INP

Results file name is X108DR1.SIN. This example is a static analysis.

```
HEAD SPECTRAL FATIGUE ANALYSIS WAVE LOAD CALCULATION
COMM Superelement: 1
COMM Static analysis
COMM ------------------------------------------------------------------------
COMM CHECK ANTP MSUM MOLO STIF RTOP LBCK      PILE     CSIGN      SIGM
CMAS    0.   1.   1.   0.   0.   0.   0.        0.        0.        0.
INAM X108D
LNAM X108D          FORMATTED
RNAM X108D          NORSAM
ITOP    1.
ELOP                   1.
COMM ------------------------------------------------------------------------
COMM SOLVE     ORDER           COND INFO     CACHE   MFRWORK
SOLM     0        0.             0.   0.        0.        0.
COMM ------------------------------------------------------------------------
COMM  RTRA PRNT STOR EQUI
RETR   3.   2.
COMM ------------------------------------------------------------------------
COMM  ISE1 ISE2 ISE3 ISE4 ISE5 ISE6 ISE7 ISE8
RSEL    1.   0.   0.   0.   0.   0.   1.   0.
COMM ------------------------------------------------------------------------
COMM  ZPRI PREA
CPRI    0.   1.
COMM ------------------------------------------------------------------------
Z
```

A.1.12 Framework journal file for deterministic fatigue – X108BFRAMEWORK_IN.JNL

```
%=========================================================================
% X108B : This is the FRAMEWORK journal file for a deterministic fatigue.
%=========================================================================
%
% Local and parametric SCFs are used.
%
% Only a subset of elements are checked
%
% Remember that working units are Newtons and mm
%
% In this example no CAN or STUB sections are used. For all calculations
% nominal section properties are used.
%
%=========================================================================
%
% Let us start by opening a Results Interface file called X108BR1.SIN
%
 FILE OPEN SIN X108B R1
%
% Where X108B.......... is the Results file prefix
%       R1.............. is the Results file name
%
% Transfer superelement number 1
%
 FILE TRANSFER 1 JACKET WAVE_LOADS 'loads for deterministic fatigue'
%%
%% after new default values in May-05
DEFINE FATIGUE-CONSTANTS IN-PLANE-FACTOR 1.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-FACTOR 1.0
%%
%
% Where 1............... is the key identifying the superelement read
%       JACKET.........  is the name given to the superelemnt
%       WAVE_LOADS..... is the loadset name
%
% Youngs modulus is now read from the Results Interface File and does
% not need to be assigned. Its value is 200000 N/mm**2
%
%
% The FE model is built in the unit of mm. But the default built-in length unit is meter.
% Define a unit length factor to let the built-in length match what is being used in model.
%
DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR 1000.0
%
% Assign individual wave data.
%
% For each wave direction the waves follow a linear H-logN distribution.
%
 ASSIGN INDIVIDUAL-WAVE
  LOOP
    0 LINEAR 1.03E+8
   45 LINEAR 1.88E+7
   90 LINEAR 2.53E+8
 END
%
%
% Create a modified SN-curve
%
```

```
 CREATE SN-CURVE USE-X USER 'User defined X test curve'
   4.1 34.0 8.301 HORISONTAL-TAIL
%
%
% Assign SN-CURVE for element 33115
%
 ASSIGN SN-CURVE JOINT 33115 CONNECTED-TO-MEMBER 33115 USE-X
%
% Assign LOCAL SCF's for elements 33115
%
 ASSIGN SCF JOINT 33115 ONLY 3110 ' ' LOCAL BOTH-SIDES
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
   ( 1  1.00 0.00 1.00
     4  0.00 0.00 0.00
     7  1.00 1.00 0.00
    10  0.00 0.00 0.00
    13  1.00 0.00 1.00
    16  0.00 0.00 0.00
    19  1.00 1.00 0.00
    22  0.00 0.00 0.00 )
%
 ASSIGN SCF JOINT 33115 ONLY 3120 ' ' LOCAL BOTH-SIDES
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
   ( 1  1.00 0.00 1.00
     4  0.00 0.00 0.00
     7  1.00 1.00 0.00
    10  0.00 0.00 0.00
    13  1.00 0.00 1.00
    16  0.00 0.00 0.00
    19  1.00 1.00 0.00
    22  0.00 0.00 0.00 )
%
% Assign LOCAL SCF's for elements  56115, 55112, 35115, 33115, 55117
%
 ASSIGN SN-CURVE JOINT 56115 CONNECTED-TO-MEMBER 56115 USE-X
%
 ASSIGN SCF JOINT 56115 5110 ' ' LOCAL BOTH-SIDES
    UNIFORM
      6.0  6.0  6.0
%
 ASSIGN SCF JOINT 56115 6120 ' ' LOCAL BOTH-SIDES
    NON-SYMMETRIC
   ( 7  4.97 2.57 0.00
    10  0.0  0.0  0.0
    13  4.85 0.00 2.57
    16  0.0  0.0  0.0
    19  4.97 2.57 0.00
    22  0.0  0.0  0.0
     1  4.85 0.00 2.57
     4  0.0  0.0  0.0 )
%
 ASSIGN SN-CURVE JOINT 55112 CONNECTED-TO-MEMBER 55112 USE-X
%
 ASSIGN SCF JOINT 55112 5110 ' ' LOCAL BOTH-SIDES
    NON-SYMMETRIC
  ( 7  2.57 2.57 0.00
   10  0.0  0.0  0.0
```

```
   13  6.52 0.00 2.57
   16  0.0  0.0  0.0
   19  2.57 2.57 0.00
   22  0.0  0.0  0.0
    1  6.52 0.00 2.57
    4  0.0  0.0  0.0 )
%
 ASSIGN SN-CURVE JOINT 35115 CONNECTED-TO-MEMBER 35115 USE-X
%
 ASSIGN SCF JOINT 35115 3120 ' ' LOCAL BOTH-SIDES
    NON-SYMMETRIC
  ( 7  2.57 2.57 0.00
   10  0.0  0.0  0.0
   13  2.57 0.00 2.57
   16  0.0  0.0  0.0
   19  2.57 2.57 0.00
   22  0.0  0.0  0.0
    1  2.57 0.00 2.57
    4  0.0  0.0  0.0 )
%
 ASSIGN SCF JOINT 35115 5110 ' ' LOCAL BOTH-SIDES
    NON-SYMMETRIC
  ( 7  2.57 2.57 0.00
   10  0.0  0.0  0.0
   13  2.57 0.00 2.57
   16  0.0  0.0  0.0
   19  2.57 2.57 0.00
   22  0.0  0.0  0.0
    1  2.57 0.00 2.57
    4  0.0  0.0  0.0 )
%
 ASSIGN SN-CURVE JOINT 33115 CONNECTED-TO-MEMBER 33115 USE-X
%
 ASSIGN SCF JOINT 33115 3110 ' ' LOCAL BOTH-SIDES
    NON-SYMMETRIC
 (  7  4.97 2.57 0.00
   10  0.0  0.0  0.0
   13  4.95 0.00 2.57
   16  0.0  0.0  0.0
   19  4.97 2.57 0.00
   22  0.0  0.0  0.0
    1  4.95 0.00 2.57
    4  0.0  0.0  0.0 )
%
 ASSIGN SCF JOINT 33115 3120 ' ' LOCAL BOTH-SIDES
    NON-SYMMETRIC
  ( 7  2.57 2.57 0.00
   10  0.0  0.0  0.0
   13  6.52 0.00 2.57
   16  0.0  0.0  0.0
   19  2.57 2.57 0.00
   22  0.0  0.0  0.0
    1  6.52 0.00 4.03
    4  0.0  0.0  0.0 )
%
 ASSIGN SN-CURVE JOINT 55117 CONNECTED-TO-MEMBER 55117 USE-X
%
 ASSIGN SCF JOINT 55117 5120 ' ' LOCAL BOTH-SIDES
    NON-SYMMETRIC
```

```
 (  7  4.97 2.57 0.00
   10  0.0 0.0 0.0
   13  4.95 0.00 2.57
   16  0.0 0.0 0.0
   19  4.97 2.57 0.00
   22  0.0 0.0 0.0
    1  4.95 0.00 2.57
    4  0.0 0.0 0.0 )
%
% Assign SN-CURVE and SCFs for element 33215
%
 ASSIGN SN-CURVE JOINT 33215 CONNECTED-TO-MEMBER 33215 USE-X
 ASSIGN SCF JOINT 33215 CONNECTED-TO-MEMBER 33215 None PARAMETRIC WORDSWORTH
 ASSIGN JOINT-TYPE 33215 CONNECTED-TO-MEMBER 33215 X
%
% Assign SN-CURVE and SCFs for element 33415
%
 ASSIGN SN-CURVE JOINT 33415 CONNECTED-TO-MEMBER 33415 USE-X
 ASSIGN SCF JOINT 33415 CONNECTED-TO-MEMBER 33415 None PARAMETRIC KUANG
 ASSIGN JOINT-TYPE 33415 CONNECTED-TO-MEMBER 33415 KTT
 ASSIGN JOINT-GAP 33415 CONNECTED-TO-MEMBER 33415 1.
%
% Assign SN-CURVE and SCFs for element 35415
%
 ASSIGN SN-CURVE JOINT 35415 CONNECTED-TO-MEMBER 35415 USE-X
 ASSIGN SCF JOINT 35415 CONNECTED-TO-MEMBER 35415 None PARAMETRIC KUANG
 ASSIGN JOINT-TYPE 35415 CONNECTED-TO-MEMBER 35415 KTK
 ASSIGN JOINT-GAP 35415 CONNECTED-TO-MEMBER 35415 1.
%
%
% Define the target fatigue life
%
 DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
%
% Perform fatigue check
%
 RUN FATIGUE-CHECK DETFAT 'DETERMINISTIC FATIGUE ANALYSIS' ALL
    ( ONLY 33115 33215 33415 35415 ) %%% 35115 55112 55117 )
%
% Print the results

 SET PRINT DESTINATION FILE
 SET PRINT FILE X108B DETFAT
 SET PRINT PAGE-ORIENTATION LANDSCAPE
%
 PRINT FATIGUE-CHECK-RESULTS DETFAT
     SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
%=============================================================================
% End of fatigue checks. The following shall not be included in the
% User's Manual.
%=============================================================================
%
% Test PCR 93-2895, Report the worst results for weldside='BOTH-SIDES'
%                   Include thickness effect.
%
 CREATE SN-CURVE TEST USER 'User defined X test curve'
   4.1 34.0 8.301 HORISONTAL-TAIL
 ASSIGN THICKNESS-CORRECTION TEST ARBITRARY 32. 22. 0.25
```

```
 ASSIGN SN-CURVE JOINT 33115 CONNECTED-TO-MEMBER 33115 TEST
%
%
 RUN FATIGUE-CHECK F1 'DETERMINISTIC FATIGUE ANALYSIS' ALL
    ( ONLY 33115 )
 PRINT FATIGUE-CHECK-RESULTS F1
     SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
% Assign LOCAL SCF's for elements 33115
%
 ASSIGN SCF JOINT 33115 ONLY 3110 ' ' LOCAL CHORD-SIDE
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
 (  7  4.97 2.57 0.00
   10  0.0  0.0  0.0
   13  4.95 0.00 2.57
   16  0.0  0.0  0.0
   19  4.97 2.57 0.00
   22  0.0  0.0  0.0
    1  4.95 0.00 2.57
    4  0.0  0.0  0.0 )
%
 ASSIGN SCF JOINT 33115 ONLY 3110 ' ' LOCAL BRACE-SIDE
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
 (  7  4.97 2.57 0.00
   10  0.0  0.0  0.0
   13  4.95 0.00 2.57
   16  0.0  0.0  0.0
   19  4.97 2.57 0.00
   22  0.0  0.0  0.0
    1  4.95 0.00 2.57
    4  0.0  0.0  0.0 )
%
 ASSIGN SCF JOINT 33115 ONLY 3120 ' ' LOCAL CHORD-SIDE
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
  ( 7  2.57 2.57 0.00
   10  0.0  0.0  0.0
   13  6.52 0.00 2.57
   16  0.0  0.0  0.0
   19  2.57 2.57 0.00
   22  0.0  0.0  0.0
    1  6.52 0.00 4.03
    4  0.0  0.0  0.0 )
%
 ASSIGN SCF JOINT 33115 ONLY 3120 ' ' LOCAL BRACE-SIDE
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
  ( 7  2.57 2.57 0.00
   10  0.0  0.0  0.0
   13  6.52 0.00 2.57
   16  0.0  0.0  0.0
   19  2.57 2.57 0.00
   22  0.0  0.0  0.0
    1  6.52 0.00 4.03
    4  0.0  0.0  0.0 )
%
RUN FATIGUE-CHECK F2 'DETERMINISTIC FATIGUE ANALYSIS' ALL
```

```
    ( ONLY 33115 )
PRINT FATIGUE-CHECK-RESULTS F2
     SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
%
% Test PCR 93-2836, Error in ASSIGN SCF JOINT command
%
SELECT MEMBERS EXCLUDE ALL
SELECT MEMBERS CONNECTED-TO-JOINT 5220
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
ASSIGN SCF JOINT ALL 5220 None PARAMETRIC EFTHYMIOU
%
% Test PCR 93-2861, Error in ASSIGN SCF MEMBER command
%
ASSIGN POSITIONS CURRENT FATIGUE-CHECK RELATIVE INCLUDE QUA    0.25
ASSIGN POSITIONS CURRENT FATIGUE-CHECK RELATIVE INCLUDE MID    0.5
ASSIGN POSITIONS CURRENT FATIGUE-CHECK RELATIVE INCLUDE 3QUART 0.75
%% ASSIGN SCF MEMBER CURRENT INCLUDE Mid-0.5000 None LOCAL UNIFORM 1.6 1.6 1.6
%
% Is SN-curve assigned properly ? Check also interactive print messages !
%
ASSIGN SN-CURVE MEMBER 55217 API-X
ASSIGN CHORD GLOBAL 5220 55217
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
%
RUN FATIGUE-CHECK F3 'DETERMINISTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT FATIGUE-CHECK-RESULTS F3
     SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
% Test PCR 93-2877, Error in ASSIGN CHORD GLOBAL command
% Is this really an error ?
% Remember, 34217 & 45212 are braces, 34212 is chord and 45217 is aligned
% chord.
%
SELECT MEMBERS EXCLUDE ALL
SELECT MEMBERS CONNECTED-TO-JOINT 4215
SELECT JOINTS ONLY 4215
PRINT JOINT PUNCH-CHECK-DATA CURRENT
ASSIGN SN-CURVE JOINT ALL CURRENT API-X
ASSIGN CHORD GLOBAL 4215 34217
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT JOINT PUNCH-CHECK-DATA CURRENT
%
RUN FATIGUE-CHECK F4 'DETERMINISTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT FATIGUE-CHECK-RESULTS F4
     SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
% ------------------------------------------------------------------------
%
% TEST OF NEW FEATURES IN FRAMEWORK: FATIGUE PART DAMAGE
%                                    FATIGUE SAFETY (DESIGN) FACTORS
%                                    FATIGUE EXPOSURE TIME
%                                    MODIFIED PRINT MEMBER FATIGUE DATA
%                  CALC OF SCFS BASED ON AUTOMATIC GAPS TESTED ELSEWHERE
%           P. Dahlberg        DNV Sesam A.S.     October 1996
% ------------------------------------------------------------------------
%
SET PRINT DESTINATION FILE
SET PRINT FILE X108B FATADD
```

```
%
SELECT MEMBERS ONLY 45217
%
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
%
DEFINE FATIGUE-CONSTANTS FATIG-EXPOSURE-TIME 20.0
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
%
ASSIGN FATIGUE-SAFETY-FACTOR MEMBER CURRENT INDIVIDUAL 3.0 3.0 1. 2. 3. 10. 10.
%
RUN FATIGUE-CHECK F41 'DETERMINISTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS F41 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 40.0
RUN FATIGUE-CHECK F41B 'DETERMINISTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS F41B SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
ASSI FAT-PA-DAM MEMB CURRENT ONLY BRACE-SIDE-1.0000 None LOCAL UNIFORM .2
ASSI FAT-PA-DAM MEMB CURRENT ONLY CHORD-SIDE-1.0000 None LOCAL UNIFORM .1
%
RUN FATIGUE-CHECK F42 'DETERMINISTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS F42 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
DEFINE FATIGUE-CONSTANTS ACCUMULATE-FATIGUE-RUN F4
%
RUN FATIGUE-CHECK F43 'DETERMINISTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS F43 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
SELECT MEMBER ONLY 33115
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
ASSIGN FATIGUE-SAFETY-FACTOR MEMBER CURRENT 3.
DEFINE FATIGUE-CONSTANTS ACCUMULATE-FATIGUE-RUN F2
PRINT MEMBER FATIGUE-CHECK-DATA ONLY 33115
%
RUN FATIGUE-CHECK F21 'DETERMINISTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS F21 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
%
 SELECT JOINTS ONLY 3220
 SELECT MEMBER ONLY CONNECTED-TO-JOINT 3220
 ASSIGN JOINT-TYPE ALL ONLY 3220 GEOMETRY
 %
 ASSIGN SCF JOINT 34217 3220 None PARAMETRIC EFTHYMIOU
 % PRINT JOINT PARAMETRIC-SCF CURRENT
 %
 CREATE SECTION STU32 None PIPE 720 30
 DEFINE JOINT-PARAMETERS MINIMUM-FREE-STUB-LENGTH 600.
 ASSIGN STUB JOINT 3220 STU32 1 AUTOMATIC
 % ASSIGN STUB JOINT 3220 STU32 1 1600.
 PRINT CHORD-AND-BRACE 3220
%
 ASSIGN POSITIONS ONLY CON-TO-JOI 3220 FATIGUE-CHECK OPTIONS ON ON ON ON ON OFF
 ASSIGN SCF MEMBER 34217 ONLY Section-60025 None LOCAL UNIFORM 2.2 3.3 4.4
 PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
```

```
 RUN FATIGUE-CHECK F22 None ALL ONLY 34217
 PRINT FATIGUE-CHECK-RESULTS F22 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
 SELECT MEMBER ONLY CONNECTED-TO-JOINT 3220
 ASSIGN FATIGUE-SAFETY-FACTOR MEMBER CURRENT 10.
 ASSIGN FATIGUE-SAFETY-FACTOR JOINT ALL 3220 3.0
 ASSIGN FATIGUE-SAFETY-FACTOR MEMBER 34217 INDIVIDUAL 2. 2. 3. 1. 1. 1.
 ASSIGN SN-CURVE JOINT ALL 3220 NS-F2-SE
 SELECT MEMBER ONLY CONNECTED-TO-JOINT 3220
 PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
%
% Check alternative chord length definition
SELECT JOINTS ONLY 3220
ASSIGN JOINT-CHORD-LENGTH ALL ( ) 1200
SET PRINT FILE X108B CHOLEN
PRINT JOINT PARAMETRIC-SCF ( )
%%
%% ---------------------
%% TEST WAVE LOAD FACTOR
%%
DEFINE FATIGUE-DUMP FILE-NAME X108BDAF
DEFINE FATIGUE-DUMP HOTSPOT-STRESS-RANGE ON
ASSIGN WAVE-LOAD-FACTOR 45.0 1.2
ASSIGN WAVE-LOAD-FACTOR 90.0 INDIV 1.1 1.2 1.3 1.4 1.5
SELECT MEMBERS ONLY 34217
RUN FATIGUE-CHECK DAF-TST None ALL ( )
DEFINE FATIGUE-DUMP HOTSPOT-STRESS-RANGE OFF
%%
%% ---------------------
%% TEST RING STIFFENERS
%%
SELECT MEMBERS ONLY 34317
SELECT MEMBERS INCLUDE 45312
ASSIGN SECTION 60025 ( )
SELECT MEMBERS ONLY 34315
SELECT MEMBERS INCLUDE 45315
ASSIGN SECTION 70025 ( )
SELECT MEMBERS INCLUDE ALL
%
SELECT JOINTS INCLUDE ALL
ASSIGN JOINT-TYPE ALL ( ) GEOMETRY
ASSIGN JOINT-GAP ALL ( ) 0.0
ASSIGN JOINT-CHORD-LENGTH ALL ( ) 10000
ASSIGN SCF JOINT ALL ( ) None GLOBAL
CREATE SECTION RSTF-T None RING-STIFFENER-T 180 160 20 16
CREATE SECTION RSTF-F None RING-STIFFENER-FLAT 180 22
%
SELECT JOINTS ONLY 3220
SELECT JOINTS INCLUDE 4315
ASSIGN SCF JOINT ALL ( ) None PARAMETRIC EFTHYMIOU
ASSIGN JOINT-RING-STIFFENER ALL ( ) 2 RSTF-T AUTOMATIC
%
SET PRI DES FIL
SET PRINT FILE X108B RINGS
SET PRINT P-O LAND
%
DEFINE FATIGUE-CONSTANTS AXIAL-MINIMUM-SCF 1.5
DEFINE FATIGUE-CONSTANTS IN-PLANE-MINIMUM-SCF 1.5
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-MINIMUM 1.5
```

```
%
% No rings active
DEFINE PARAMETRIC-SCF LIMITATION-METHOD-SCF LIMITS
DEFINE PARAMETRIC-SCF RING-STIFFENER-GEOMETRY NEGLECT
DEFINE PARAMETRIC-SCF RING-STIFFENER-PARAMETER LIMITS
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF ON
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM ON
PRINT JOINT PARAMETRIC-SCF ( )
%
DEFINE PARAMETRIC-SCF LIMITATION-METHOD-SCF LIMITS
DEFINE PARAMETRIC-SCF RING-STIFFENER-GEOMETRY LIMITS
DEFINE PARAMETRIC-SCF RING-STIFFENER-PARAMETER LIMITS
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF ON
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM ON
PRINT JOINT PARAMETRIC-SCF ( )
%
DEFINE PARAMETRIC-SCF LIMITATION-METHOD-SCF ACTUAL
DEFINE PARAMETRIC-SCF RING-STIFFENER-GEOMETRY ACTUAL
DEFINE PARAMETRIC-SCF RING-STIFFENER-PARAMETER ACTUAL
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF ON
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM OFF
PRINT JOINT PARAMETRIC-SCF ( )
%
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF OVERRULE
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM ON
PRINT JOINT PARAMETRIC-SCF ( )
%
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF OVERRULE
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM OFF
PRINT JOINT PARAMETRIC-SCF ( )
%
ASSIGN JOINT-TYPE ALL ( ) YT
%
% No rings active
DEFINE PARAMETRIC-SCF LIMITATION-METHOD-SCF LIMITS
DEFINE PARAMETRIC-SCF RING-STIFFENER-GEOMETRY NEGLECT
DEFINE PARAMETRIC-SCF RING-STIFFENER-PARAMETER LIMITS
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF ON
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM ON
PRINT JOINT PARAMETRIC-SCF ( )
%
DEFINE PARAMETRIC-SCF LIMITATION-METHOD-SCF LIMITS
DEFINE PARAMETRIC-SCF RING-STIFFENER-GEOMETRY LIMITS
DEFINE PARAMETRIC-SCF RING-STIFFENER-PARAMETER LIMITS
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF ON
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM ON
PRINT JOINT PARAMETRIC-SCF ( )
%
DEFINE PARAMETRIC-SCF LIMITATION-METHOD-SCF ACTUAL
DEFINE PARAMETRIC-SCF RING-STIFFENER-GEOMETRY ACTUAL
DEFINE PARAMETRIC-SCF RING-STIFFENER-PARAMETER ACTUAL
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
```

```
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF ON
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM OFF
PRINT JOINT PARAMETRIC-SCF ( )
%
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF OVERRULE
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM ON
PRINT JOINT PARAMETRIC-SCF ( )
%
DEFINE PARAMETRIC-SCF ACTIVE-BRACE-FOOTPRINT 80.0
DEFINE PARAMETRIC-SCF UNSTIFFENED-SADDLE-SCF OVERRULE
DEFINE PARAMETRIC-SCF AXIAL-USE-MAXIMUM OFF
PRINT JOINT PARAMETRIC-SCF ( )
%%
%% ---------------------
%% TEST BUTT SCF
%%
SET PRINT FILE X108B BUTT
SELECT SET MEMBERS DEFAULT ONLY 33415
PRINT MEMBER FATIGUE-CHECK-DATA ( )
%
% Butt weld with slope 4
ASSIGN SCF MEMBER CURRENT ( ONLY Section-STU32-0.0343 Section-50025-0.0344 )
    None BUTT-WELD WITH-SLOPE 4.0
PRINT MEMBER FATIGUE-CHECK-DATA ( )
RUN FATIGUE-CHECK BUTT-1 None ALL ( )
PRINT FATIGUE-CHECK-RESULTS BUTT-1 SELECTED-MEMBERS ( ) FULL ABOVE 0.
%
% Butt weld manually, use 0.0 , i.e. program to calculate
ASSIGN SCF MEMBER CURRENT ( ONLY Section-STU32-0.0343 Section-50025-0.0344 )
    None BUTT-WELD MANUAL 0.0 0.0
PRINT MEMBER FATIGUE-CHECK-DATA ( )
RUN FATIGUE-CHECK BUTT-1A None ALL ( )
PRINT FATIGUE-CHECK-RESULTS BUTT-1A SELECTED-MEMBERS ( ) FULL ABOVE 0.
%
% Butt weld manually, use delta=5 and L=30
ASSIGN SCF MEMBER CURRENT ( ONLY Section-STU32-0.0343 Section-50025-0.0344 )
    None BUTT-WELD MANUAL 5 30
PRINT MEMBER FATIGUE-CHECK-DATA ( )
RUN FATIGUE-CHECK BUTT-1B None ALL ( )
PRINT FATIGUE-CHECK-RESULTS BUTT-1B SELECTED-MEMBERS ( ) FULL ABOVE 0.
%
% Set default global fabrication out-of-roundness to 4 mm
% Butt weld manually, use delta=5 and L=30
DEFINE FATIGUE-CONSTANTS DEFAULT-FABRICATION-TOLERANCE 4.
RUN FATIGUE-CHECK BUTT-1C None ALL ( )
PRINT FATIGUE-CHECK-RESULTS BUTT-1C SELECTED-MEMBERS ( ) FULL ABOVE 0.
%
%
%=============================================================================
% Test of correct thickness correction for SN curve group DNV PR-C203-210.
%
% Two runs are executed:
% Run 1): Use library SN cuve DNV2010_W3-SEACP
% Run 2): Establish user defined SN curve, USER_W3-SEACP in length unit mm
%         identical to DNV2010_W3-SEACP with standard T thickness correction
% RUN 3): Same user defined SN curve as in Run 2) with thickness correction
%         defined by ref. thickness, cut thickness.
%
```

```
% The two runs shall give identical fatigue results. Results are printed
% in to file X108B_SNTEST. SN curve data are also printed.
%=========================================================================
%
% Set Print file
%
 SET PRINT DESTINATION FILE
 SET PRINT FILE X108B _SNTEST
 SET PRINT PAGE-ORIENTATION LANDSCAPE
%
% Define unit length factor
%
DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR 1000.0
%
% Define user SN curve in length unit mm identical to DNV2010_W3-SEACP
%
CREATE SN-CURVE USER_W3-SEACP LOGA NONE 3.0 10.570 6.0 ARBITRARY-TAIL 5.0
    ALIGNED-WITH-SECOND
%
% Run 1: Library SN curve with standard T thickness correction. Tref = 0.025m
%
CHANGE MATERIAL 1 YOUNGS-MODULUS 2.1E5
ASSIGN SN-CURVE JOINT DEFAULT ( ) DNV2010_W3-SEACP
ASSIGN SN-CURVE MEMBER CURRENT DNV2010_W3-SEACP
%
RUN FATIGUE-CHECK SN1 None ALL ( )
PRINT FATIGUE-CHECK-RESULTS SN1 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
PRINT SN-CURVE ( ONLY DNV2010_W2-SEACP )
%
%
% Run 2: User defined SN equivalent to DNV2010_W3-SEACP.
%        Standard T thickness correction
%
ASSIGN THICKNESS-CORRECTION USER_W3-SEACP STANDARD-T-CURVE 25.0
ASSIGN SN-CURVE JOINT DEFAULT ( ) USER_W3-SEACP
ASSIGN SN-CURVE MEMBER CURRENT USER_W3-SEACP
%
RUN FATIGUE-CHECK SN2 None ALL ( )
PRINT FATIGUE-CHECK-RESULTS SN2 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
PRINT SN-CURVE ( ONLY USER_W3-SEACP )
%
% Run 3: User defined SN equivalent to DNV2010_W3-SEACP.
%        Arbitary thickness correctionequivalent to standard T curve
%
ASSIGN THICKNESS-CORRECTION USER_W3-SEACP ARBITRARY 25.0 25.0 0.25
ASSIGN SN-CURVE JOINT DEFAULT ( ) USER_W3-SEACP
ASSIGN SN-CURVE MEMBER CURRENT USER_W3-SEACP
RUN FATIGUE-CHECK SN3 None ALL ( )
PRINT FATIGUE-CHECK-RESULTS SN3 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
PRINT SN-CURVE ( ONLY USER_W3-SEACP )
%%
% Exit FRAMEWORK
%
EXIT
```

A.1.13 Framework journal file for stochastic fatigue – X108CFRAMEWORK_IN.JNL

```
%=============================================================================
% X108C : This is the FRAMEWORK journal file for a stochastic fatigue.
%=============================================================================
%
% Local and parametric SCFs are used.
%
% Only a subset of elements are checked
%
% Remember that working units are Newtons and mm
%
% In this example no CAN or STUB sections are used. For all calculations
% nominal section properties are used.
%
%=============================================================================
%
% Let us start by opening a Results Interface file called X108CR1.SIN
%
 FILE OPEN SIN X108C R1
%
% Where X108C.......... is the Results file prefix
%       R1.............. is the Results file name
%
% Transfer superelement number 1
%
 FILE TRANSFER 1 JACKET WAVE_LOADS 'loads for stochastic fatigue'
%%
%% after new default values in May-05
DEFINE FATIGUE-CONSTANTS IN-PLANE-FACTOR 1.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-FACTOR 1.0
%%
%
% Where 1............... is the key identifying the superelement read
%       JACKET.........  is the name given to the superelemnt
%       WAVE_LOADS..... is the loadset name
%
%
% Youngs modulus is now read from the Results Interface File and does
% not need to be assigned. Its value is 200000 N/mm**2
%
%
% Assign environmental data
%
% Create scatter diagram with 6 seastates
%
 CREATE WAVE-STATISTICS SCATTER 'ARBITRARY DATA'
     SCATTER-DIAGRAM PROBABILITY
     (
%%%    Hs      Tz      Prob
       1750.0  4.75    0.249
       1750.0  7.75    0.086
       1250.0  6.25    0.236
       3250.0  6.25    0.206
       4750.0  7.75    0.117
       4750.0  7.75    0.106
     )
%
% Create a wave spreading function
%
```

```
 CREATE WAVE-SPREADING-FUNCTION DIS2 'DISCRETIZED COS**2'
    USER-DEFINED
     (
%%%  Dir  Weigth
     -45  0.25
       0  0.50
      45  0.25
     )
%
% Assign the wave spreading function.
%
 ASSIGN WAVE-SPREADING-FUNCTION SCATTER DIS2 ALL
%
% Assign a Pierson-Moskowitz spectrum for all seastates.
%
 ASSIGN WAVE-SPECTRUM-SHAPE SCATTER PIERSON-MOSKOWITZ ALL
%
%
% Assign scatter diagrams for each of the main wave directions.
%
 ASSIGN WAVE-STATISTICS
   LOOP
%%%   Dir   Name
      -45   SCATTER
        0   SCATTER
       45   SCATTER
       90   SCATTER
      135   SCATTER
   END
%
% Assign the probability of ocurrence for each of the main wave directions.
%
 ASSIGN WAVE-DIRECTION-PROBABILITY
   LOOP
%%%   Dir   Prob
      -45   0.0
        0   0.9
       45   0.0
       90   0.1
      135   0.0
   END
%
%
%
% Create a modified SN-curve
%
 CREATE SN-CURVE USE-X USER 'User defined X test curve'
   4.1 34.0 8.301 HORISONTAL-TAIL
%
%
% Assign SN-CURVE for element 33115
%
 ASSIGN SN-CURVE JOINT 33115 CONNECTED-TO-MEMBER 33115 USE-X
%
% Assign LOCAL SCF's for elements 33115
%
 ASSIGN SCF JOINT 33115 ONLY 3110 ' ' LOCAL BOTH-SIDES
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
```

```
   ( 1  1.00 0.00 1.00
     4  0.00 0.00 0.00
     7  1.00 1.00 0.00
    10  0.00 0.00 0.00
    13  1.00 0.00 1.00
    16  0.00 0.00 0.00
    19  1.00 1.00 0.00
    22  0.00 0.00 0.00 )
%
 ASSIGN SCF JOINT 33115 ONLY 3120 ' ' LOCAL BOTH-SIDES
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
   ( 1  1.00 0.00 1.00
     4  0.00 0.00 0.00
     7  1.00 1.00 0.00
    10  0.00 0.00 0.00
    13  1.00 0.00 1.00
    16  0.00 0.00 0.00
    19  1.00 1.00 0.00
    22  0.00 0.00 0.00 )
%
%
% Assign SN-CURVE and SCFs for element 33215
%
 ASSIGN SN-CURVE JOINT 33215 CONNECTED-TO-MEMBER 33215 USE-X
 ASSIGN SCF JOINT 33215 CONNECTED-TO-MEMBER 33215 None PARAMETRIC WORDSWORTH
 ASSIGN JOINT-TYPE 33215 CONNECTED-TO-MEMBER 33215 X
%
% Assign SN-CURVE and SCFs for element 33415
%
 ASSIGN SN-CURVE JOINT 33415 CONNECTED-TO-MEMBER 33415 USE-X
 ASSIGN SCF JOINT 33415 CONNECTED-TO-MEMBER 33415 None PARAMETRIC KUANG
 ASSIGN JOINT-TYPE 33415 CONNECTED-TO-MEMBER 33415 KTT
 ASSIGN JOINT-GAP 33415 CONNECTED-TO-MEMBER 33415 1.
%
% Assign SN-CURVE and SCFs for element 35415
%
 ASSIGN SN-CURVE JOINT 35415 CONNECTED-TO-MEMBER 35415 USE-X
 ASSIGN SCF JOINT 35415 CONNECTED-TO-MEMBER 35415 None PARAMETRIC KUANG
 ASSIGN JOINT-TYPE 35415 CONNECTED-TO-MEMBER 35415 KTK
 ASSIGN JOINT-GAP 35415 CONNECTED-TO-MEMBER 35415 1.
%
%
% Define the target fatigue life
%
 DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
%
% Perform fatigue check
%
 RUN FATIGUE-CHECK STOFAT 'STOCHASTIC FATIGUE ANALYSIS' ALL
    ( ONLY 33115 33215 33415 35415 )
%
% Print the results
%
 SET PRINT DESTINATION FILE
 SET PRINT FILE X108C FRAMEWORK
 SET PRINT PAGE-ORIENTATION LANDSCAPE
%
 PRINT FATIGUE-CHECK-RESULTS STOFAT
```

```
     SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
SET PRINT DESTINATION FILE
SET PRINT FILE X108C FATADD
%
SELECT MEMBERS ONLY 33415
%
ASSIGN FATIGUE-SAFETY-FACTOR MEMBER CURRENT 3.0
%
RUN FATIGUE-CHECK S2 'STOCHASTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS S2 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 40.0
RUN FATIGUE-CHECK S3 'STOCHASTIC FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS S3 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
ASSI FAT-PA-DAM MEMB CURRENT ONLY BRACE-SIDE-1.0000 None LOCAL UNIFORM .2
ASSI FAT-PA-DAM MEMB CURRENT ONLY CHORD-SIDE-1.0000 None LOCAL UNIFORM .1
%
RUN FATIGUE-CHECK S4 'FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS S4 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
DEFINE FATIGUE-CONSTANTS ACCUMULATE-FATIGUE-RUN STOFAT
%
RUN FATIGUE-CHECK S5 'FATIGUE ANALYSIS' ALL CURRENT
PRINT MEMBER FATIGUE-CHECK-DATA CURRENT
PRINT FATIGUE-CHECK-RESULTS S5 SELECTED-MEMBERS CURRENT FULL ABOVE 0.0
%
% End of fatigue checks.
%
% Exit FRAMEWORK by command FILE EXIT
EXIT
%
```

A.1.14 Framework journal file for spectral fatigue – X108DFRAMEWORK_IN.JNL

```
%=====================================================================
% X108D : This is the FRAMEWORK journal file for a spectral fatigue.
%=====================================================================
%
% Local and parametric SCFs are used.
%
% Only a subset of elements are checked
%
% Remember that working units are Newtons and mm
%
% In this example no CAN or STUB sections are used. For all calculations
% nominal section properties are used.
%
%=====================================================================
%
% Let us start by opening a Results Interface file called X108DR1.SIN
%
 FILE OPEN SIN 'X108D' R1
%
% Where 'X108D' ....... is the Results file prefix
%       R1............. is the Results file name
%
% Transfer superelement number 1
%
 FILE TRANSFER 1 JACKET WAVE_LOADS 'loads for spectral fatigue'
%
% Where 1.............. is the key identifying the superelement read
%       JACKET........  is the name given to the superelemnt
%       WAVE_LOADS..... is the loadset name
%
%
% Youngs modulus is now read from the Results Interface File and does
% not need to be assigned. Its value is 200000 N/mm**2
%
SELECT FATIGUE-CHECK-TYPE SPECTRAL
%
% SET UP BASIC FATIGUE OPTIONS:
% IT IS RECOMMENDED TO USE DEFINE FATIGUE CONSTANTS BEFORE RUNNING FATIGUE ANALYSIS.
%
% CHOOSE AUTOMATIC EVELVATION DEPENDENT SN CURVE
%
DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE API-WJ
%
DEFINE FATIGUE-CONSTANTS MARSHALL-REDUCTION 0.8
%
DEFINE FATIGUE-CONSTANTS SHORT-CHORD-FIXITY-PARAMETER 0.7
DEFINE FATIGUE-CONSTANTS SHORT-CHORD-FIXITY-OPTION GLOBAL
%
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
DEFINE FATIGUE-CONSTANTS FATIGUE-EXPOSURE-TIME -1.0
DEFINE FATIGUE-CONSTANTS DEFAULT-FATIGUE-SAFETY-FACTOR 1.0
DEFINE FATIGUE-CONSTANTS GLOBAL-FATIGUE-PART-DAMAGE 0.0
DEFINE FATIGUE-CONSTANTS DEFAULT-FABRICATION-TOLERANCE 0.0
%
% Length unit is mm. Enter elevation in mm.
DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-UPPER-LIMIT-ELEVATION 45000.
DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-LOWER-LIMIT-ELEVATION 40000.
%
```

```
% The FE model is built in the unit of mm. But the default built-in length unit is meter.
% Define a unit length factor to let the built-in length match what is being used in model.
%
DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR 1000.0
%
DEFINE FATIGUE-CONSTANTS ACCUMULATE-FATIGUE-RUN NONE
DEFINE FATIGUE-CONSTANTS AXIAL-MINIMUM-SCF 2.5
DEFINE FATIGUE-CONSTANTS IN-PLANE-MINIMUM-SCF 2.5
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-MINIMUM 2.5
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 1.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-FACTOR 0.7071
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-FACTOR 0.7071
%
% Assign environmental data
%
% Create scatter diagram with 6 seastates
%
 CREATE WAVE-STATISTICS SCATTER 'ARBITRARY DATA'
     SCATTER-DIAGRAM PROBABILITY
     (
%%%    Hs     Tz     Prob
      1750.0  4.75   0.2
      1750.0  7.75   0.18
      1250.0  6.25   0.12
      3250.0  6.25   0.26
      4750.0  7.75   0.13
      4750.0  7.75   0.11
     )
%
% Create wave spreading functions
%
 CREATE WAVE-SPREADING-FUNCTION SP1 cos2 COSINE-POWER 2
 CREATE WAVE-SPREADING-FUNCTION DIS2 'DISCRETIZED COS**2'
    USER-DEFINED
     (
%%%  Dir  Weight
       0  0.50
      45  0.25
      90  0.25
     )
%
% Assign the wave spreading function.
%
 ASSIGN WAVE-SPREADING-FUNCTION SCATTER SP1 ALL
%
% Assign a Pierson-Moskowitz spectrum for all seastates.
%
 ASSIGN WAVE-SPECTRUM-SHAPE SCATTER PIERSON-MOSKOWITZ ALL
%
%
% Assign scatter diagrams for each of the main wave directions.
%
 ASSIGN WAVE-STATISTICS
   LOOP
%%%   Dir   Name
        0   SCATTER
       45   SCATTER
```

```
       90   SCATTER
   END
%
% Assign the probability of ocurrence for each of the main wave directions.
%
 ASSIGN WAVE-DIRECTION-PROBABILITY
   LOOP
%%%   Dir   Prob
        0   0.3
       45   0.3
       90   0.4
   END
%////////////////////////////////////////////////////////////////////
%
% ASSIGN SN curve and SCF for ALL joints
%
SELECT JOINTS INCLUDE ALL
SELECT MEMBERS ONLY CONNECTED-TO-JOINT CURRENT
ASSIGN SN-CURVE JOINT ALL ( ) API-WJ
ASSIGN SCF JOINT ALL ( ) ' ' PARAMETRIC EFTHYMIOU
%
% ASSIGN joint type and gap option
%
ASSIGN JOINT-TYPE DEFAULT ( ) GEOMETRY
SELECT JOINTS ONLY CURRENT
SELECT MEMBERS ONLY CURRENT
ASSIGN JOINT-GAP DEFAULT ( ) AUTOMATIC
%
% Set the format to print the results
%
SET PRINT DESTINATION FILE
SET PRINT PAGE-HEIGHT 200
SET PRINT SCREEN-HEIGHT 24
SET PRINT FILE X108D FRAMEWORK
SET PRINT PAGE-ORIENTATION LANDSCAPE
%
% SELECT CRITICAL JOINTS TO RUN FATIGUE
%
SELECT JOINTS ONLY 5110
SELECT JOINTS INCLUDE 5120
SELECT JOINTS INCLUDE 5220
SELECT JOINTS INCLUDE 5210
SELECT MEMBERS ONLY CONNECTED-TO-JOINT CURRENT
%
RUN FATIGUE-CHECK SPECFAT1 'CRITICAL JOINTS' ALL ( )
PRINT FATIGUE-CHECK-RESULTS SPECFAT1 JOINT SELECTED-JOINTS ( ) FULL ABOVE 0.8
%
%
% SELECT JOINTS TO USE SPECIFIC REGULAR SN CURVE Free Corrosion to be conservative
%
ASSIGN SN-CURVE JOINT DEFAULT ( ) API-WJ-FC
%
RUN FATIGUE-CHECK SPECFAT2 'CONSERVATIVE JOINTS' ALL ( )
PRINT FATIGUE-CHECK-RESULTS SPECFAT2 JOINT SELECTED-JOINTS ( ) FULL ABOVE 0.0
%
% ////////////////////////////////////////////////////////////////////
%
% Create a user defined SN-curve and assign special SCF to certain elements
%
```

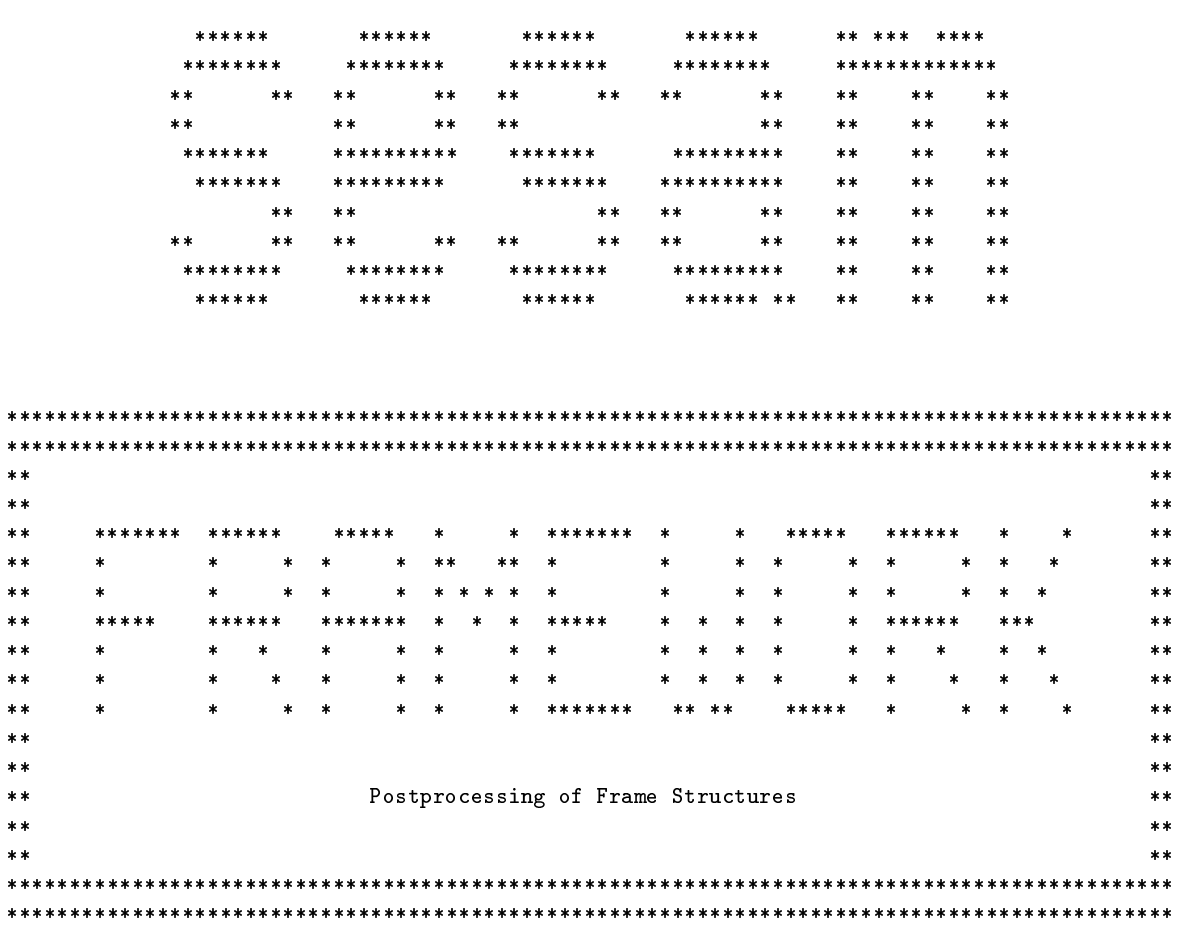
```
 CREATE SN-CURVE USE-X USER 'User defined X test curve'
   4.1 34.0 8.301 HORISONTAL-TAIL
%
% Assign SN-CURVE for element 33115
%
 ASSIGN SN-CURVE JOINT 33115 CONNECTED-TO-MEMBER 33115 USE-X
%
% Assign LOCAL SCF's for elements 33115
%
 ASSIGN SCF JOINT 33115 ONLY 3110 ' ' LOCAL BOTH-SIDES
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
   ( 1  1.00 0.00 1.00
     4  0.00 0.00 0.00
     7  1.00 1.00 0.00
    10  0.00 0.00 0.00
    13  1.00 0.00 1.00
    16  0.00 0.00 0.00
    19  1.00 1.00 0.00
    22  0.00 0.00 0.00 )
%
 ASSIGN SCF JOINT 33115 ONLY 3120 ' ' LOCAL BOTH-SIDES
     NON-SYMMETRIC
%%% Hot Ax   Ipb  Opb
   ( 1  1.00 0.00 1.00
     4  0.00 0.00 0.00
     7  1.00 1.00 0.00
    10  0.00 0.00 0.00
    13  1.00 0.00 1.00
    16  0.00 0.00 0.00
    19  1.00 1.00 0.00
    22  0.00 0.00 0.00 )
%
%
% Assign SN-CURVE and SCFs for element 33215
%
 ASSIGN SN-CURVE JOINT 33215 CONNECTED-TO-MEMBER 33215 USE-X
 ASSIGN SCF JOINT 33215 CONNECTED-TO-MEMBER 33215 None PARAMETRIC WORDSWORTH
 ASSIGN JOINT-TYPE 33215 CONNECTED-TO-MEMBER 33215 X
%
% Assign SN-CURVE and SCFs for element 33415
%
 ASSIGN SN-CURVE JOINT 33415 CONNECTED-TO-MEMBER 33415 USE-X
 ASSIGN SCF JOINT 33415 CONNECTED-TO-MEMBER 33415 None PARAMETRIC KUANG
 ASSIGN JOINT-TYPE 33415 CONNECTED-TO-MEMBER 33415 KTT
 ASSIGN JOINT-GAP 33415 CONNECTED-TO-MEMBER 33415 1.
%
% Assign SN-CURVE and SCFs for element 35415
%
 ASSIGN SN-CURVE JOINT 35415 CONNECTED-TO-MEMBER 35415 USE-X
 ASSIGN SCF JOINT 35415 CONNECTED-TO-MEMBER 35415 None PARAMETRIC KUANG
 ASSIGN JOINT-TYPE 35415 CONNECTED-TO-MEMBER 35415 KTK
 ASSIGN JOINT-GAP 35415 CONNECTED-TO-MEMBER 35415 1.
%
%
% Perform fatigue check
%
 RUN FATIGUE-CHECK SPECFAT3 'SPECIAL MEMBERS' ALL
    ( ONLY 33115 33215 33415 35415 )
```

```
%
PRINT FATIGUE-CHECK-RESULTS SPECFAT3 SELECTED-MEMBERS ( ) FULL ABOVE 0.0
%
% End of fatigue checks.
%
% Exit FRAMEWORK by command FILE EXIT
EXIT
%
```

A.1.15 Results from deterministic fatigue analysis

A.1.15.1 X108B_SNTEST.LIS

1



```
             Program id    : 3.13-00                                  Computer         : 586
             Release date  : 11-MAY-2016                              Impl. update     :
             Access time   : 12-MAY-2016 10:00:08                     Operating system : Win NT 6.1 [7601]
             User id       : acd                                      CPU id           : 0112953272
                                                                      Installation     : , OSLL400284


             Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway



DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                          PAGE:     1

                                   DETERMINISTIC    fatigue check results
                                   Run:      Superelement:     Loadset:
                                   SN1       JACKET            WAVE_LOADS
                                   Priority....: Selected Members
                                   Usage factor: Above   0.00                                    SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
```

```
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                PAGE:     2
```

```
                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                SN1       JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                                  SUB PAGE:     2
```

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33415	PIPE STU32	3220		3.04E-01	1.97E+02	CHORD-SID	10	EFTHY+RST	3.449	1.966	2.519	DNV2010_W3-SEACP
					0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.245	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	3.137	3.760
		3220		3.29E-01	1.83E+02	BRACE-SID	10	EFTHY+RST	3.994	2.626	2.875	DNV2010_W3-SEACP
					0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.047	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	4.005	3.983
		0.03		1.02E-03	1.97E+05	STU32	7	*ILLEGAL*	1.000	1.000	1.000	DNV2010_W3-SEACP
					0.000	MANUAL	7.20E+02	30.000	0.00E+00	1.047	1.000	3.75E+08
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
	PIPE 50025	0.03		3.47E-02	5.76E+03	50025	7	*ILLEGAL*	1.000	1.000	1.000	DNV2010_W3-SEACP
					0.000	MANUAL	5.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		3120		6.27E-02	3.19E+03	BRACE-SID	22	GLOBAL	1.000	1.000	1.000	DNV2010_W3-SEACP

```
                                          0.000  UNIFORM    5.00E+02  25.000    0.00E+00  1.000  1.000      3.75E+08
                                         82.875             1.60E+03  60.000    1.00E+04  1.000  1.000        1.000
                    3120              1.87E-01  1.07E+03 CHORD-SID        22 GLOBAL      1.000    1.000  1.000 DNV2010_W3-SEACP
                                          0.000  UNIFORM    5.00E+02  25.000    0.00E+00  1.245  1.000      3.75E+08
                                         82.875             1.60E+03  60.000    1.00E+04  1.000  1.000        1.000
```


NOMENCLATURE:

Name	Name of the SN curve
Branch	Current branch of the curve
m	Inverse slope of the current branch of the curve
S	Stress range at intersection with next branch
LogN	Logarithm of number of cycles at branch intersection
LogA	Logarithm of number of cycles for stress range = 1.0
logK	Mean of log capacity (log(K0))
Std(lK)	Stdv of log capacity (log(K0))

Name	Branch	m	S	LogN	LogA	logK	Std(lK)
DNV2010_W2-SEACP	W2-curve sea cathodic protection				DNV-RP-C203-2010 (N/m^2)		
	First	3.000	3.707E+07	6.000	28.707	28.707	None
	Second	5.000			43.845		

Thickness correction: Standard T curve ThickRef 2.5E-02

Run: Superelement: Loadset:
SN2 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees
Jtype	Joint type
DiaCho	Chord diameter
ThiCho	Chord thickness
LenCho	Chord length
FixCho	Chord end fixity parameter
SCFaxC	SCF for axial force at Crown (Hotspot 7)
SCFaxS	SCF for axial force at Saddle (Hotspot 1)

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 5

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
SN2 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33415	PIPE	3220		3.04E-01	1.97E+02	CHORD-SID	10	EFTHY+RST	3.449	1.966	2.519	USER_W3-SEACP
	STU32				0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.245	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	3.137	3.760
		3220		3.29E-01	1.83E+02	BRACE-SID	10	EFTHY+RST	3.994	2.626	2.875	USER_W3-SEACP
					0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.047	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	4.005	3.983
		0.03		1.02E-03	1.97E+05	STU32	7	*ILLEGAL*	1.000	1.000	1.000	USER_W3-SEACP
					0.000	MANUAL	7.20E+02	30.000	0.00E+00	1.047	1.000	3.75E+08
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
	PIPE	0.03		3.47E-02	5.76E+03	50025	7	*ILLEGAL*	1.000	1.000	1.000	USER_W3-SEACP
	50025				0.000	MANUAL	5.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		3120		6.27E-02	3.19E+03	BRACE-SID	22	GLOBAL	1.000	1.000	1.000	USER_W3-SEACP
					0.000	UNIFORM	5.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					82.875		1.60E+03	60.000	1.00E+04	1.000	1.000	1.000
		3120		1.87E-01	1.07E+03	CHORD-SID	22	GLOBAL	1.000	1.000	1.000	USER_W3-SEACP
					0.000	UNIFORM	5.00E+02	25.000	0.00E+00	1.245	1.000	3.75E+08
					82.875		1.60E+03	60.000	1.00E+04	1.000	1.000	1.000

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 6

SN Curve SUB PAGE: 1

NOMENCLATURE:

Name Name of the SN curve
Branch Current branch of the curve

```
m           Inverse slope of the current branch of the curve
S           Stress range at intersection with next branch
 LogN       Logarithm of number of cycles at branch intersection
LogA        Logarithm of number of cycles for stress range = 1.0
logK        Mean of log capacity (log(K0))
 Std(lK)    Stdv of log capacity (log(K0))


Name             Branch      m        S        LogN   LogA    logK    Std(lK)
-------------------------------------------------------------------------------
USER_W3-SEACP    NONE

                 First      3.000  3.337E+01   6.000  10.570  10.570  None
                 Second     5.000                     13.617

                 Thickness correction: Standard T curve ThickRef 25.0




DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                    PAGE:     7


                                   DETERMINISTIC    fatigue check results
                                   Run:      Superelement:     Loadset:
                                   SN3       JACKET            WAVE_LOADS
                                   Priority....: Selected Members
                                   Usage factor: Above   0.00                                  SUB PAGE:     1



NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
```

SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees
Jtype	Joint type
DiaCho	Chord diameter
ThiCho	Chord thickness
LenCho	Chord length
FixCho	Chord end fixity parameter
SCFaxC	SCF for axial force at Crown (Hotspot 7)
SCFaxS	SCF for axial force at Saddle (Hotspot 1)

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 8

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
SN3 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33415	PIPE	3220		3.04E-01	1.97E+02	CHORD-SID	10	EFTHY+RST	3.449	1.966	2.519	USER_W3-SEACP
	STU32				0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.245	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	3.137	3.760
		3220		3.29E-01	1.83E+02	BRACE-SID	10	EFTHY+RST	3.994	2.626	2.875	USER_W3-SEACP
					0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.047	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	4.005	3.983
		0.03		1.02E-03	1.97E+05	STU32	7	*ILLEGAL*	1.000	1.000	1.000	USER_W3-SEACP
					0.000	MANUAL	7.20E+02	30.000	0.00E+00	1.047	1.000	3.75E+08
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000

```
             PIPE     0.03              3.47E-02  5.76E+03 50025            7 *ILLEGAL*   1.000    1.000  1.000 USER_W3-SEACP
             50025                                 0.000  MANUAL     5.00E+02  25.000    0.00E+00  1.000  1.000     3.75E+08
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                      3120              6.27E-02  3.19E+03 BRACE-SID       22 GLOBAL      1.000    1.000  1.000 USER_W3-SEACP
                                                   0.000  UNIFORM    5.00E+02  25.000    0.00E+00  1.000  1.000     3.75E+08
                                                  82.875             1.60E+03  60.000    1.00E+04  1.000  1.000       1.000
                      3120              1.87E-01  1.07E+03 CHORD-SID       22 GLOBAL      1.000    1.000  1.000 USER_W3-SEACP
                                                   0.000  UNIFORM    5.00E+02  25.000    0.00E+00  1.245  1.000     3.75E+08
                                                  82.875             1.60E+03  60.000    1.00E+04  1.000  1.000       1.000
```


NOMENCLATURE:

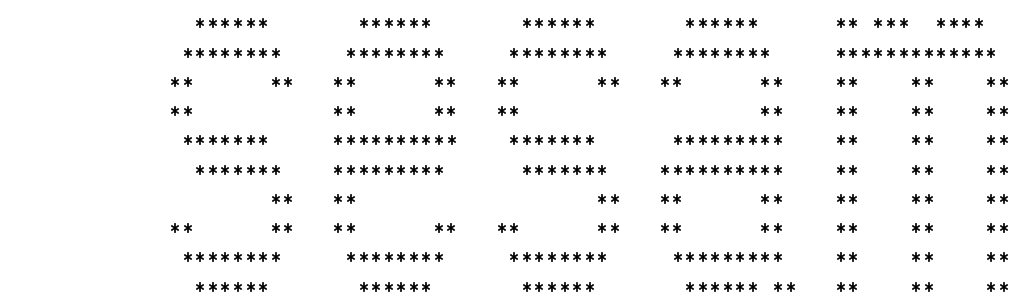
Name	Name of the SN curve
Branch	Current branch of the curve
m	Inverse slope of the current branch of the curve
S	Stress range at intersection with next branch
LogN	Logarithm of number of cycles at branch intersection
LogA	Logarithm of number of cycles for stress range = 1.0
logK	Mean of log capacity (log(K0))
Std(lK)	Stdv of log capacity (log(K0))

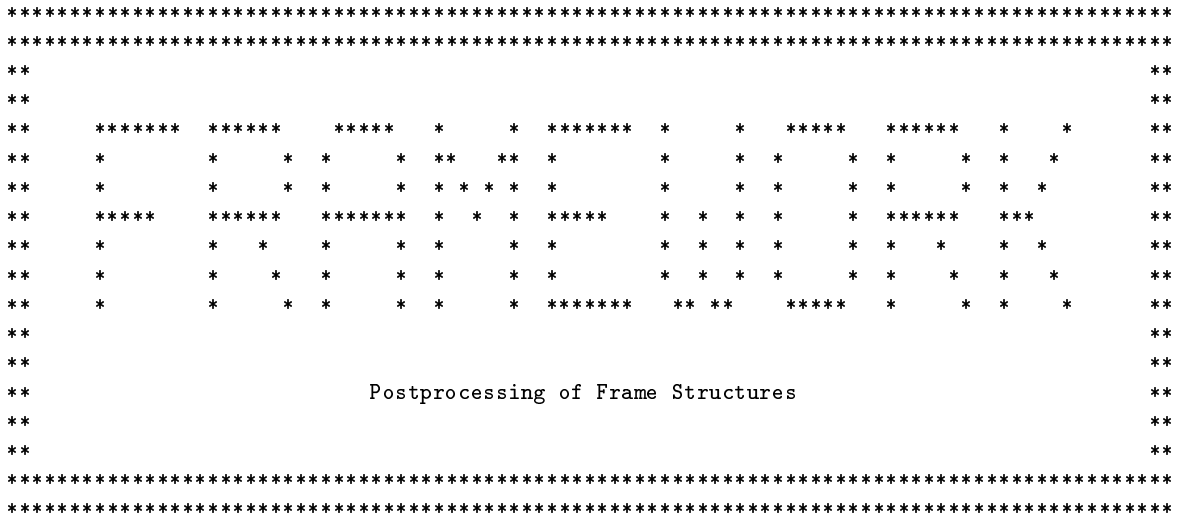
Name	Branch	m	S	LogN	LogA	logK	Std(lK)
USER_W3-SEACP	NONE						
	First	3.000	3.337E+01	6.000	10.570	10.570	None
	Second	5.000			13.617		

Thickness correction: Standard T curve ThickRef 25.0

A.1.15.2 X108BBUTT.LIS

1





Postprocessing of Frame Structures

Marketing and Support by DNV GL - Software

```
              Program id   : 3.13-00                                  Computer         : 586
              Release date : 11-MAY-2016                              Impl. update     :
              Access time  : 12-MAY-2016 10:00:08                     Operating system : Win NT 6.1 [7601]
              User id      : acd                                      CPU id           : 0112953272
                                                                      Installation     : , OSLL400284


              Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway
```


Member fatigue check data

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
33415	3220	PIPE	CHORD-SIDE	NS-F2-SE	3.0	60.0	EFTHYMIO						F2	0.000E+00
	3220	PIPE	BRACE-SIDE	NS-F2-SE	3.0	60.0	EFTHYMIO						F2	0.000E+00
	0.03	PIPE	STU32	DNV-X	10.0	200.0	BUTT-DNV	0.15TS		1.000	0.000	0.000	F2	0.000E+00

0.03	PIPE	50025	DNV-X	10.0	200.0	BUTT-DNV 0.15TS	1.000	0.000	0.000	F2		0.000E+00
3120	PIPE	BOTH-SIDES	USE-X	10.0	200.0	GLOBAL				F2		0.000E+00

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 2

Member fatigue check data SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
33415	3220	PIPE	CHORD-SIDE	NS-F2-SE	3.0	60.0	EFTHYMIO						F2	0.000E+00
	3220	PIPE	BRACE-SIDE	NS-F2-SE	3.0	60.0	EFTHYMIO						F2	0.000E+00
	0.03	PIPE	STU32	DNV-X	10.0	200.0	BUTT-NOR SLOPE			1.000	0.000	0.000	F2	0.000E+00
	0.03	PIPE	50025	DNV-X	10.0	200.0	BUTT-NOR SLOPE			1.000	0.000	0.000	F2	0.000E+00
	3120	PIPE	BOTH-SIDES	USE-X	10.0	200.0	GLOBAL						F2	0.000E+00

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 3

```
                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                BUTT-1    JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                    SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 4

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
BUTT-1 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33415	PIPE	3220		2.02E-02	2.97E+03	CHORD-SID	10	EFTHY+RST	3.449	1.966	2.519	NS-F2-SE
	STU32				0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.000	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	3.137	3.760
		3220		7.44E-02	8.06E+02	BRACE-SID	10	EFTHY+RST	3.994	2.626	2.875	NS-F2-SE
					0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.000	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	4.005	3.983
		0.03		1.00E-10	2.00E+12	STU32	1	*ILLEGAL*	1.000	1.000	1.000	DNV-X
					0.000	WITH-SLOP	7.20E+02	30.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
	PIPE	0.03		1.00E-10	2.00E+12	50025	1	*ILLEGAL*	1.000	1.000	1.000	DNV-X
	50025				0.000	WITH-SLOP	5.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		3120		1.00E-10	2.00E+12	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	USE-X
					0.000	UNIFORM	5.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					82.875		1.60E+03	60.000	1.00E+04	1.000	1.000	1.000

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 5

Member fatigue check data SUB PAGE: 1

NOMENCLATURE:

Member Name of member
Joint/Po Joint name or position within the member

```
SecTy        Section type
WeldSide     Side of weld
SNcurve      Name of SN curve
  FSF        Fatigue Safety (Design) Factor
DFLif        Design Fatigue Life
SCFrule      Method used for SCF calculation
Symmet       Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot          Hotspot (stress point) name
  SCF        SCFax when Local rule
 Para1       Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
 Para2       Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
 OrgFPD      Origin of Fatigue Part Damage (RUN Name or specified
 FPDamage    Fatigue Part Damage in current hotspot
```

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
33415	3220	PIPE	CHORD-SIDE	NS-F2-SE	3.0	60.0	EFTHYMIO						F2	0.000E+00
	3220	PIPE	BRACE-SIDE	NS-F2-SE	3.0	60.0	EFTHYMIO						F2	0.000E+00
	0.03	PIPE	STU32	DNV-X	10.0	200.0	BUTT-NOR	MANUAL		1.000	0.000	0.000	F2	0.000E+00
	0.03	PIPE	50025	DNV-X	10.0	200.0	BUTT-NOR	MANUAL		1.000	0.000	0.000	F2	0.000E+00
	3120	PIPE	BOTH-SIDES	USE-X	10.0	200.0	GLOBAL						F2	0.000E+00

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                    PAGE:     6

                                   DETERMINISTIC    fatigue check results
                                   Run:      Superelement:     Loadset:
                                   BUTT-1A   JACKET            WAVE_LOADS
                                   Priority....: Selected Members
                                   Usage factor: Above   0.00                                  SUB PAGE:     1
```

```
NOMENCLATURE:

Member       Name of member
Type         Section type
Joint/Po     Joint name or position within the member
Outcome      Outcome message from the code check
Damage       Accumulated damage
```

```
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                  PAGE:     7

                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                BUTT-1A   JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                                  SUB PAGE:     2

Member       Type     Joint/Po Outcome   Damage     Life    WeldSide        Hot SCFrule    SCFax    SCFipb SCFopb SNcurve
             SctNam                               Alpha    Symmet     DiaBra    ThiBra      Gap    ThiFac   QR       Cycles
                                                  Theta    Jtype      DiaCho    ThiCho    LenCho   FixCho SCFaxC      SCFaxS
-------------------------------------------------------------------------------------------------------------------------------
33415        PIPE     3220               2.02E-02  2.97E+03 CHORD-SID        10 EFTHY+RST   3.449    1.966  2.519 NS-F2-SE
             STU32                                  0.000  CROWN-SAD  7.20E+02  30.000    0.00E+00  1.000  1.000     3.75E+08
                                                   82.875  YT         1.60E+03  60.000    1.00E+04  1.000  3.137       3.760
```

```
                    3220              7.44E-02  8.06E+02 BRACE-SID        10 EFTHY+RST   3.994    2.626  2.875 NS-F2-SE
                                                  0.000  CROWN-SAD  7.20E+02  30.000    0.00E+00  1.000  1.000      3.75E+08
                                                 82.875  YT         1.60E+03  60.000    1.00E+04  1.000  4.005        3.983
                    0.03              1.00E-10  2.00E+12 STU32             1 *ILLEGAL*   1.000    1.000  1.000 DNV-X
                                                  0.000  MANUAL     7.20E+02  30.000    0.00E+00  1.000  1.000      0.00E+00
                                                  0.000             0.00E+00   0.000    0.00E+00  1.000  1.000        1.000
          PIPE      0.03              1.00E-10  2.00E+12 50025             1 *ILLEGAL*   1.000    1.000  1.000 DNV-X
          50025                                   0.000  MANUAL     5.00E+02  25.000    0.00E+00  1.000  1.000      0.00E+00
                                                  0.000             0.00E+00   0.000    0.00E+00  1.000  1.000        1.000
                    3120              1.00E-10  2.00E+12 BOTH-SIDE         1 GLOBAL      1.000    1.000  1.000 USE-X
                                                  0.000  UNIFORM    5.00E+02  25.000    0.00E+00  1.000  1.000      0.00E+00
                                                 82.875             1.60E+03  60.000    1.00E+04  1.000  1.000        1.000
```


Member fatigue check data

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage

```
33415    3220     PIPE  CHORD-SIDE  NS-F2-SE          3.0  60.0 EFTHYMIO                                    F2        0.000E+00
         3220     PIPE  BRACE-SIDE  NS-F2-SE          3.0  60.0 EFTHYMIO                                    F2        0.000E+00
         0.03     PIPE  STU32       DNV-X            10.0 200.0 BUTT-NOR MANUAL        1.000   0.000   0.000 F2        0.000E+00
         0.03     PIPE  50025       DNV-X            10.0 200.0 BUTT-NOR MANUAL        1.000   0.000   0.000 F2        0.000E+00
         3120     PIPE  BOTH-SIDES  USE-X            10.0 200.0 GLOBAL                                        F2        0.000E+00
```


DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
BUTT-1B JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles

```
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:    10

                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                BUTT-1B   JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                                      SUB PAGE:     2
```

Member	Type SctNam	Joint/Po	Outcome	Damage	Life Alpha Theta	WeldSide Symmet Jtype	Hot DiaBra DiaCho	SCFrule ThiBra ThiCho	SCFax Gap LenCho	SCFipb ThiFac FixCho	SCFopb QR SCFaxC	SNcurve Cycles SCFaxS
33415	PIPE	3220		2.02E-02	2.97E+03	CHORD-SID	10	EFTHY+RST	3.449	1.966	2.519	NS-F2-SE
	STU32				0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.000	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	3.137	3.760
		3220		7.44E-02	8.06E+02	BRACE-SID	10	EFTHY+RST	3.994	2.626	2.875	NS-F2-SE
					0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.000	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	4.005	3.983
		0.03		1.00E-10	2.00E+12	STU32	1	*ILLEGAL*	1.000	1.000	1.000	DNV-X
					0.000	MANUAL	7.20E+02	30.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
	PIPE	0.03		1.00E-10	2.00E+12	50025	1	*ILLEGAL*	1.000	1.000	1.000	DNV-X
	50025				0.000	MANUAL	5.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		3120		1.00E-10	2.00E+12	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	USE-X
					0.000	UNIFORM	5.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					82.875		1.60E+03	60.000	1.00E+04	1.000	1.000	1.000

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:    11
```

```
                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                BUTT-1C   JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                    SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

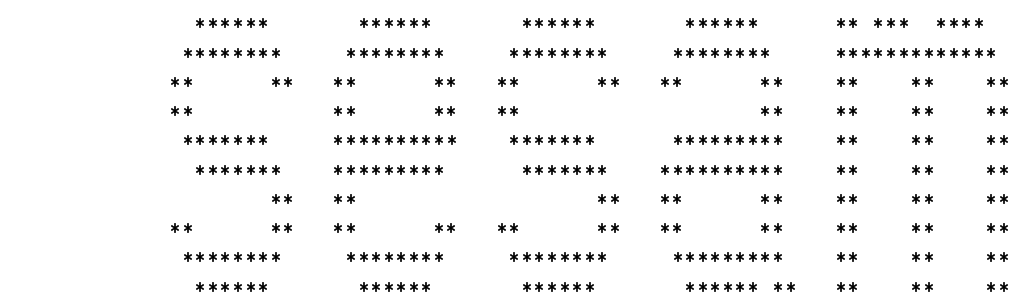
DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 12

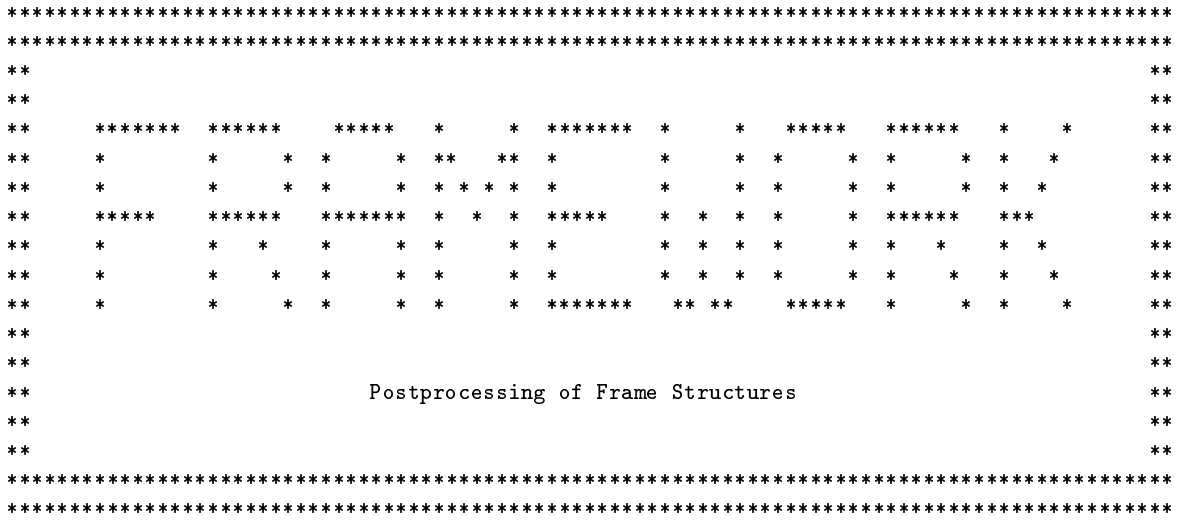
DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
BUTT-1C JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33415	PIPE	3220		2.02E-02	2.97E+03	CHORD-SID	10	EFTHY+RST	3.449	1.966	2.519	NS-F2-SE
	STU32				0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.000	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	3.137	3.760
		3220		7.44E-02	8.06E+02	BRACE-SID	10	EFTHY+RST	3.994	2.626	2.875	NS-F2-SE
					0.000	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.000	1.000	3.75E+08
					82.875	YT	1.60E+03	60.000	1.00E+04	1.000	4.005	3.983
		0.03		1.00E-10	2.00E+12	STU32	1	*ILLEGAL*	1.000	1.000	1.000	DNV-X
					0.000	MANUAL	7.20E+02	30.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
	PIPE	0.03		1.00E-10	2.00E+12	50025	1	*ILLEGAL*	1.000	1.000	1.000	DNV-X
	50025				0.000	MANUAL	5.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		3120		1.00E-10	2.00E+12	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	USE-X
					0.000	UNIFORM	5.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					82.875		1.60E+03	60.000	1.00E+04	1.000	1.000	1.000

A.1.15.3 X108BDETFAT.LIS

1





Marketing and Support by DNV GL - Software

```
              Program id    : 3.13-00                          Computer         : 586
              Release date  : 11-MAY-2016                      Impl. update     :
              Access time   : 12-MAY-2016 10:00:08             Operating system : Win NT 6.1 [7601]
              User id       : acd                              CPU id           : 0112953272
                                                               Installation     : , OSLL400284


              Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway



DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                          PAGE:     1


                                   DETERMINISTIC    fatigue check results
                                   Run:      Superelement:     Loadset:
                                   DETFAT    JACKET            WAVE_LOADS
                                   Priority....: Selected Members
                                   Usage factor: Above   0.00                                    SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
```

```
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```


DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
DETFAT JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33115	PIPE	3110		3.00E-05	6.68E+05	BOTH-SIDE	19	LOCAL	4.970	2.570	0.000	USE-X
	50025				7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	4.970	4.950
		3120		1.06E-05	1.89E+06	BOTH-SIDE	1	LOCAL	6.520	0.000	4.030	USE-X
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	2.570	6.520
33215	PIPE	3210		2.47E-08	8.09E+08	CHORD-SID	10	WORDSWORT	5.991	2.500	2.602	USE-X
	50025				352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	5.991	5.991
		3210		5.98E-08	3.34E+08	BRACE-SID	10	WORDSWORT	8.081	2.500	2.909	USE-X
					352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	8.081	8.081
		3220		1.00E-10	2.00E+11	BRACE-SID	1	WORDSWORT	8.081	2.500	2.909	USE-X
					352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	0.00E+00
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	8.081	8.081

		3220	1.00E-10	2.00E+11	CHORD-SID	1	WORDSWORT	5.991	2.500	2.602	USE-X		
				352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00		
				90.000	YT	1.60E+03	60.000	3.63E+04	1.000	5.991	5.991		
33415	PIPE 50025	3220	6.43E-07	3.11E+07	CHORD-SID	10	KUANG	2.500	2.500	2.571	USE-X		
				0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	1.000	3.75E+08		
				82.875	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500		
		3220	1.35E-06	1.48E+07	BRACE-SID	10	KUANG	3.182	2.692	2.866	USE-X		
				0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	0.800	3.75E+08		
				82.875	K	1.60E+03	60.000	3.63E+04	1.000	3.182	3.182		
		3120	3.65E-03	5.47E+03	BRACE-SID	22	KUANG	7.964	2.500	2.866	USE-X		
				0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	3.75E+08		
				82.875	YT	1.60E+03	60.000	3.63E+04	1.000	7.964	7.964		
		3120	2.83E-06	7.08E+06	CHORD-SID	22	KUANG	5.913	2.500	2.571	USE-X		
				0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08		
				82.875	YT	1.60E+03	60.000	3.63E+04	1.000	5.913	5.913		
35415	PIPE 70020	3220	4.04E-05	4.95E+05	CHORD-SID	4	KUANG	2.500	2.500	2.500	USE-X		
				0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	1.000	3.75E+08		
				44.468	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500		
		3220	4.04E-05	4.95E+05	BRACE-SID	4	KUANG	2.500	2.500	2.500	USE-X		
				0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	0.800	3.75E+08		
				44.468	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500		
		5120	5.69E-03	3.52E+03	BRACE-SID	10	KUANG	2.500	2.500	2.500	USE-X		
				0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	0.800	3.75E+08		
				58.718	K	1.60E+03	60.000	3.93E+04	1.000	2.500	2.500		
		5120	5.69E-03	3.52E+03	CHORD-SID	10	KUANG	2.500	2.500	2.500	USE-X		
				0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	1.000	3.75E+08		
				58.718	K	1.60E+03	60.000	3.93E+04	1.000	2.500	2.500		

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 3

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F1 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees
Jtype	Joint type
DiaCho	Chord diameter
ThiCho	Chord thickness
LenCho	Chord length
FixCho	Chord end fixity parameter
SCFaxC	SCF for axial force at Crown (Hotspot 7)
SCFaxS	SCF for axial force at Saddle (Hotspot 1)

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 4

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F1 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type SctNam	Joint/Po	Outcome	Damage	Life Alpha Theta	WeldSide Symmet Jtype	Hot DiaBra DiaCho	SCFrule ThiBra ThiCho	SCFax Gap LenCho	SCFipb ThiFac FixCho	SCFopb QR SCFaxC	SNcurve Cycles SCFaxS
33115	PIPE	3110		1.45E-04	1.38E+05	CHORD-SID	19	LOCAL	4.970	2.570	0.000	TEST
	50025				7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.170	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	4.970	4.950
		3110		1.41E-05	1.42E+06	BRACE-SID	19	LOCAL	4.970	2.570	0.000	TEST
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	0.940	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	4.970	4.950
		3120		5.52E-06	3.62E+06	BRACE-SID	1	LOCAL	6.520	0.000	4.030	TEST
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	0.940	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	2.570	6.520
		3120		6.11E-05	3.27E+05	CHORD-SID	1	LOCAL	6.520	0.000	4.030	TEST
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.170	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	2.570	6.520

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F2 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending

SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees
Jtype	Joint type
DiaCho	Chord diameter
ThiCho	Chord thickness
LenCho	Chord length
FixCho	Chord end fixity parameter
SCFaxC	SCF for axial force at Crown (Hotspot 7)
SCFaxS	SCF for axial force at Saddle (Hotspot 1)

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 6

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F2 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33115	PIPE	3110		1.45E-04	1.38E+05	CHORD-SID	19	LOCAL	4.970	2.570	0.000	TEST
	50025				7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.170	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	4.970	4.950
		3110		1.41E-05	1.42E+06	BRACE-SID	19	LOCAL	4.970	2.570	0.000	TEST
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	0.940	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	4.970	4.950
		3120		5.52E-06	3.62E+06	BRACE-SID	1	LOCAL	6.520	0.000	4.030	TEST
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	0.940	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	2.570	6.520

```
                    3120              6.11E-05  3.27E+05 CHORD-SID         1 LOCAL       6.520    0.000  4.030 TEST
                                                  7.125  NON-SYMME  5.00E+02  25.000    0.00E+00  1.170  1.000     3.75E+08
                                                 90.000  YT         1.60E+03  60.000    3.63E+04  1.000  2.570       6.520



DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:     7

                                   Member fatigue check data                                                      SUB PAGE:     1


NOMENCLATURE:

Member       Name of member
Joint/Po     Joint name or position within the member
SecTy        Section type
WeldSide     Side of weld
SNcurve      Name of SN curve
  FSF        Fatigue Safety (Design) Factor
DFLif        Design Fatigue Life
SCFrule      Method used for SCF calculation
Symmet       Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot          Hotspot (stress point) name
  SCF        SCFax when Local rule
 Para1       Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
 Para2       Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
 OrgFPD      Origin of Fatigue Part Damage (RUN Name or specified
 FPDamage    Fatigue Part Damage in current hotspot

Member   Joint/Po SecTy WeldSide    SNcurve            FSF DFLif SCFrule  Symmet   Hot    SCF   Para1   Para2   OrgFPD    FPDamage
-------------------------------------------------------------------------------------------------------------------------------------
35220    3220     PIPE  CHORD-SIDE  DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00
         3220     PIPE  BRACE-SIDE  DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00
         5220     PIPE  BRACE-SIDE  DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00
         5220     PIPE  CHORD-SIDE  DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00

45217    4215     PIPE  CHORD-SIDE  DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00
         4215     PIPE  BRACE-SIDE  DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00
         5220     PIPE  BRACE-SIDE  DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00
         5220     PIPE  CHORD-SIDE  DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00
```

55217	5215	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	5215	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	5220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
55412	5220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	5415	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	5415	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
56220	5220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	6220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00
	6220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL			Specif.	0.000E+00

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
35220	3220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	3220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.25	PIPE	QUA	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.50	PIPE	MID	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.75	PIPE	3QUART	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	5220	PIPE	BOTH-SIDES	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
45217	4215	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	4215	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.25	PIPE	QUA	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.50	PIPE	MID	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.75	PIPE	3QUART	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	EFTHYMIO						Specif.	0.000E+00
	5220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	EFTHYMIO						Specif.	0.000E+00
55217	5215	PIPE	CHORD-SIDE	API-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	5215	PIPE	BRACE-SIDE	API-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.25	PIPE	QUA	API-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.50	PIPE	MID	API-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.75	PIPE	3QUART	API-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	API-X	1.0	20.0	EFTHYMIO						Specif.	0.000E+00
	5220	PIPE	CHORD-SIDE	API-X	1.0	20.0	EFTHYMIO						Specif.	0.000E+00
55412	5220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	EFTHYMIO						Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	EFTHYMIO						Specif.	0.000E+00
	0.25	PIPE	QUA	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.50	PIPE	MID	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.75	PIPE	3QUART	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	5415	PIPE	BOTH-SIDES	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00

Member fatigue check data

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
56220	5220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00

```
         5220     PIPE  BRACE-SIDE  DNV-X             1.0  20.0 GLOBAL                    Specif.   0.000E+00
         0.25     PIPE  QUA         DNV-X             1.0  20.0 GLOBAL                    Specif.   0.000E+00
         0.50     PIPE  MID         DNV-X             1.0  20.0 GLOBAL                    Specif.   0.000E+00
         0.75     PIPE  3QUART      DNV-X             1.0  20.0 GLOBAL                    Specif.   0.000E+00
         6220     PIPE  BOTH-SIDES  DNV-X             1.0  20.0 GLOBAL                    Specif.   0.000E+00
```


DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F3 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles

```
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:    11

                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                F3        JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                                      SUB PAGE:     2
```

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
35220	PIPE	3220		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
	160060				0.000	UNIFORM	1.60E+03	60.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.25		1.00E-10	2.00E+11	QUA	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	1.60E+03	60.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.50		1.00E-10	2.00E+11	MID	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	1.60E+03	60.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.75		1.00E-10	2.00E+11	3QUART	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	1.60E+03	60.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		5220		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
					90.000	UNIFORM	1.60E+03	60.000	0.00E+00	1.000	1.000	0.00E+00
					90.000		7.00E+02	25.000	1.80E+04	1.000	1.000	1.000
45217	PIPE	4215		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
	60025				0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.25		1.00E-10	2.00E+11	QUA	1	GLOBAL	1.000	1.000	1.000	DNV-X

```
                                          0.000  UNIFORM    6.00E+02  25.000    0.00E+00  1.000  1.000      0.00E+00
                                          0.000             0.00E+00   0.000    0.00E+00  1.000  1.000         1.000
                  0.50             1.00E-10  2.00E+11 MID              1 GLOBAL      1.000    1.000  1.000 DNV-X
                                          0.000  UNIFORM    6.00E+02  25.000    0.00E+00  1.000  1.000      0.00E+00
                                          0.000             0.00E+00   0.000    0.00E+00  1.000  1.000         1.000
                  0.75             1.00E-10  2.00E+11 3QUART           1 GLOBAL      1.000    1.000  1.000 DNV-X
                                          0.000  UNIFORM    6.00E+02  25.000    0.00E+00  1.000  1.000      0.00E+00
                                          0.000             0.00E+00   0.000    0.00E+00  1.000  1.000         1.000
                  5220             5.85E-04  3.42E+04 BRACE-SID        7 EFTHYMIOU  10.004    2.962  3.703 DNV-X
                                        170.349  CROWN-SAD  6.00E+02  25.000    0.00E+00  1.000  1.000      3.75E+08
                                         42.731  YT         7.00E+02  25.000    1.80E+04  1.000 10.004        3.929
                  5220             5.44E-02  3.68E+02 CHORD-SID        4 EFTHYMIOU  18.536    2.849  6.703 DNV-X
                                        170.349  CROWN-SAD  6.00E+02  25.000    0.00E+00  1.000  1.000      3.75E+08
                                         42.731  YT         7.00E+02  25.000    1.80E+04  1.000 18.067       19.005

55217      PIPE  5215             1.00E-10  2.00E+11 BOTH-SIDE        1 GLOBAL      1.000    1.000  1.000 API-X
           70025                          0.000  UNIFORM    7.00E+02  25.000    0.00E+00  1.118  1.000      0.00E+00
                                          0.000             0.00E+00   0.000    0.00E+00  1.000  1.000         1.000
                  0.25             1.00E-10  2.00E+11 QUA              1 GLOBAL      1.000    1.000  1.000 API-X
                                          0.000  UNIFORM    7.00E+02  25.000    0.00E+00  1.118  1.000      0.00E+00
                                          0.000             0.00E+00   0.000    0.00E+00  1.000  1.000         1.000
                  0.50             1.00E-10  2.00E+11 MID              1 GLOBAL      1.000    1.000  1.000 API-X
                                          0.000  UNIFORM    7.00E+02  25.000    0.00E+00  1.118  1.000      0.00E+00
                                          0.000             0.00E+00   0.000    0.00E+00  1.000  1.000         1.000


DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                          PAGE:    12

                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                F3        JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                          SUB PAGE:     3

Member       Type     Joint/Po Outcome   Damage     Life    WeldSide        Hot SCFrule    SCFax    SCFipb SCFopb SNcurve
             SctNam                                Alpha    Symmet     DiaBra    ThiBra      Gap    ThiFac   QR       Cycles
                                                   Theta    Jtype      DiaCho    ThiCho    LenCho   FixCho SCFaxC      SCFaxS
-------------------------------------------------------------------------------------------------------------------------------
                  0.75             1.00E-10  2.00E+11 3QUART           1 GLOBAL      1.000    1.000  1.000 API-X
                                          0.000  UNIFORM    7.00E+02  25.000    0.00E+00  1.118  1.000      0.00E+00
                                          0.000             0.00E+00   0.000    0.00E+00  1.000  1.000         1.000
                  5220             1.00E-10  2.00E+11 BRACE-SID        1 $NONE       0.000    0.000  0.000 API-X
```

```
                                                 170.349  CROWN-SAD  6.00E+02  25.000    0.00E+00  1.118  1.000     0.00E+00
                                                  42.731  YT         7.00E+02  25.000    1.80E+04  1.000  0.000       0.000
                  5220              1.00E-10  2.00E+11  CHORD-SID         1  $NONE       0.000    0.000  0.000  API-X
                                                 170.349  CROWN-SAD  6.00E+02  25.000    0.00E+00  1.118  1.000     0.00E+00
                                                  42.731  YT         7.00E+02  25.000    1.80E+04  1.000  0.000       0.000

55412     PIPE    5220     **Fail**  3.81E+00  5.24E+00  CHORD-SID        10  EFTHYMIOU  13.591    2.791  7.280  DNV-X
          70020                                   90.000  CROWN-SAD  7.00E+02  20.000    0.00E+00  1.000  1.000     3.75E+08
                                                  90.000  YT         7.00E+02  25.000    1.80E+04  1.000 22.596       4.587
                  5220              4.44E-01  4.50E+01  BRACE-SID        10  EFTHYMIOU   6.673    2.500  4.318  DNV-X
                                                  90.000  CROWN-SAD  7.00E+02  20.000    0.00E+00  1.000  1.000     3.75E+08
                                                  90.000  YT         7.00E+02  25.000    1.80E+04  1.000  9.514       3.833
                  0.25              1.00E-10  2.00E+11  QUA               1  GLOBAL      1.000    1.000  1.000  DNV-X
                                                   0.000  UNIFORM    7.00E+02  20.000    0.00E+00  1.000  1.000     0.00E+00
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                  0.50              1.00E-10  2.00E+11  MID               1  GLOBAL      1.000    1.000  1.000  DNV-X
                                                   0.000  UNIFORM    7.00E+02  20.000    0.00E+00  1.000  1.000     0.00E+00
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                  0.75              5.03E-09  3.97E+09  3QUART           19  GLOBAL      1.000    1.000  1.000  DNV-X
                                                   0.000  UNIFORM    7.00E+02  20.000    0.00E+00  1.000  1.000     3.75E+08
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                  5415              2.35E-05  8.51E+05  BOTH-SIDE        19  GLOBAL      1.000    1.000  1.000  DNV-X
                                                   0.000  UNIFORM    7.00E+02  20.000    0.00E+00  1.000  1.000     3.75E+08
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000

56220     PIPE    5220              1.00E-10  2.00E+11  BOTH-SIDE         1  GLOBAL      1.000    1.000  1.000  DNV-X
          160060                                  90.000  UNIFORM    1.60E+03  60.000    0.00E+00  1.000  1.000     0.00E+00
                                                  90.000             7.00E+02  25.000    1.80E+04  1.000  1.000       1.000
                  0.25              1.00E-10  2.00E+11  QUA               1  GLOBAL      1.000    1.000  1.000  DNV-X
                                                   0.000  UNIFORM    1.60E+03  60.000    0.00E+00  1.000  1.000     0.00E+00
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                  0.50              1.00E-10  2.00E+11  MID               1  GLOBAL      1.000    1.000  1.000  DNV-X
                                                   0.000  UNIFORM    1.60E+03  60.000    0.00E+00  1.000  1.000     0.00E+00
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                  0.75              1.00E-10  2.00E+11  3QUART            1  GLOBAL      1.000    1.000  1.000  DNV-X
                                                   0.000  UNIFORM    1.60E+03  60.000    0.00E+00  1.000  1.000     0.00E+00
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                  6220              1.00E-10  2.00E+11  BOTH-SIDE         1  GLOBAL      1.000    1.000  1.000  DNV-X
                                                   0.000  UNIFORM    1.60E+03  60.000    0.00E+00  1.000  1.000     0.00E+00
                                                   0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
```

Joint punch check data SUB PAGE: 1

Joint ..: 4215

Member ..: 34212
Status ..: CHORD

Diameter ......: 6.000E+02
Thickness .....: 2.500E+01
Yield ....: 1.905E+02
No. of braces .: 2

Member ..: 34217
Status ..: BRACE

Diameter ......: 6.000E+02
Thickness .....: 2.500E+01
Yield ....: 1.905E+02
Joint type ....: YT /MANU
Gap ....: 0.000E+00
Chord angle ...: 85.46
Brace/Chord dia: 1.00
I/O angle .....: 9.66
Chord member ..: 34212
Diameter ......: 6.000E+02
Thickness .....: 2.500E+01
Yield ....: 1.905E+02
Tensile ....: 2.114E+02

Member ..: 45212
Status ..: BRACE

Diameter ......: 6.000E+02
Thickness .....: 2.500E+01
Yield ....: 1.905E+02
Joint type ....: YT /MANU
Gap ....: 0.000E+00
Chord angle ...: 85.46
Brace/Chord dia: 1.00

```
                    I/O angle .....:  9.66
                    Chord member ..:  34212
                    Diameter ......:  6.000E+02
                    Thickness .....:  2.500E+01
                    Yield .........:  1.905E+02
                    Tensile .......:  2.114E+02

          Member ..: 45217
          Status ..: ALIGN

                    Diameter ......:  6.000E+02
                    Thickness .....:  2.500E+01
                    Yield .........:  1.905E+02
                    No. of braces .:  0
```


NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
34212	3210	PIPE	BOTH-SIDES	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	4215	PIPE	BOTH-SIDES	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
34217	3220	PIPE	BOTH-SIDES	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	4215	PIPE	BOTH-SIDES	API-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
45212	4215	PIPE	BOTH-SIDES	API-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	5210	PIPE	BOTH-SIDES	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
45217	4215	PIPE	BOTH-SIDES	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.25	PIPE	QUA	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.50	PIPE	MID	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.75	PIPE	3QUART	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	EFTHYMIO						Specif.	0.000E+00
	5220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	EFTHYMIO						Specif.	0.000E+00

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 15

Joint punch check data SUB PAGE: 1

Joint ..: 4215

Member ..: 34212
Status ..: BRACE

Diameter ......: 6.000E+02
Thickness .....: 2.500E+01
Yield ....: 1.905E+02
Joint type ....: YT /MANU
Gap ....: 0.000E+00
Chord angle ...: 85.46
Brace/Chord dia: 1.00
I/O angle .....: 350.34
Chord member ..: 34217
Diameter ......: 6.000E+02
Thickness .....: 2.500E+01

```
                Yield .........:  1.905E+02
                Tensile .......:  2.114E+02

          Member ..: 34217
          Status ..: CHORD

                Diameter ......:  6.000E+02
                Thickness .....:  2.500E+01
                Yield .........:  1.905E+02
                No. of braces .:  2

          Member ..: 45212
          Status ..: ALIGN

                Diameter ......:  6.000E+02
                Thickness .....:  2.500E+01
                Yield .........:  1.905E+02
                No. of braces .:  0

          Member ..: 45217
          Status ..: BRACE

                Diameter ......:  6.000E+02
                Thickness .....:  2.500E+01
                Yield .........:  1.905E+02
                Joint type ....:  YT /MANU
                Gap ...........:  0.000E+00
                Chord angle ...:  85.46
                Brace/Chord dia:  1.00
                I/O angle .....:  350.34
                Chord member ..:  34217
                Diameter ......:  6.000E+02
                Thickness .....:  2.500E+01
                Yield .........:  1.905E+02
                Tensile .......:  2.114E+02
```



```
                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
```

F4 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees
Jtype	Joint type
DiaCho	Chord diameter
ThiCho	Chord thickness
LenCho	Chord length
FixCho	Chord end fixity parameter
SCFaxC	SCF for axial force at Crown (Hotspot 7)
SCFaxS	SCF for axial force at Saddle (Hotspot 1)

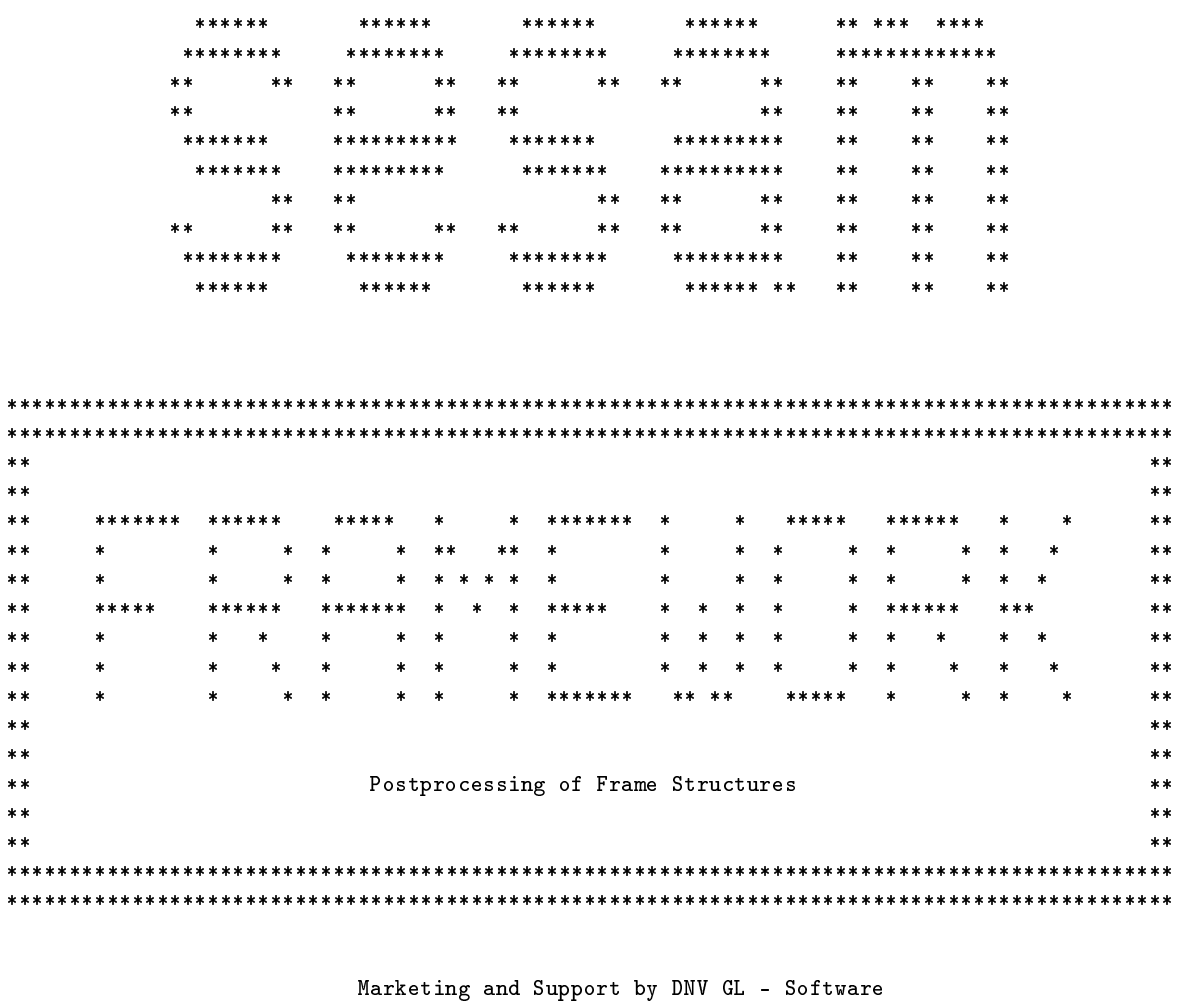
DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F4 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
34212	PIPE	3210		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
	60025				350.342	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					47.268		1.60E+03	60.000	3.63E+04	1.000	1.000	1.000
		4215		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
					350.335	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					85.464		6.00E+02	25.000	4.90E+04	1.000	1.000	1.000
34217	PIPE	3220		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
	60025				9.658	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					47.268		1.60E+03	60.000	3.63E+04	1.000	1.000	1.000
		4215		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	API-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.118	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
45212	PIPE	4215		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	API-X
	60025				0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.118	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		5210		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
					9.658	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					47.269		1.60E+03	60.000	3.93E+04	1.000	1.000	1.000
45217	PIPE	4215		1.00E-10	2.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
	60025				350.342	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					85.464		6.00E+02	25.000	4.90E+04	1.000	1.000	1.000
		0.25		1.00E-10	2.00E+11	QUA	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.50		1.00E-10	2.00E+11	MID	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.75		1.00E-10	2.00E+11	3QUART	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		5220		5.85E-04	3.42E+04	BRACE-SID	7	EFTHYMIOU	10.004	2.962	3.703	DNV-X

```
                                  170.349  CROWN-SAD  6.00E+02  25.000    0.00E+00  1.000  1.000      3.75E+08
                                   42.731  YT         7.00E+02  25.000    1.80E+04  1.000 10.004        3.929
5220                5.44E-02   3.68E+02 CHORD-SID          4 EFTHYMIOU 18.536    2.849  6.703 DNV-X
                                  170.349  CROWN-SAD  6.00E+02  25.000    0.00E+00  1.000  1.000      3.75E+08
                                   42.731  YT         7.00E+02  25.000    1.80E+04  1.000 18.067       19.005
```

A.1.15.4 X108BFATADD.LIS

1



```
              Program id   : 3.13-00                                  Computer         : 586
              Release date : 11-MAY-2016                              Impl. update     :
              Access time  : 12-MAY-2016 10:00:08                     Operating system : Win NT 6.1 [7601]
              User id      : acd                                      CPU id           : 0112953272
                                                                      Installation     : , OSLL400284


              Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway
```


Member fatigue check data

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
45217	4215	PIPE	BOTH-SIDES	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.25	PIPE	QUA	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.50	PIPE	MID	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00

```
         0.75     PIPE  3QUART      DNV-X              1.0  20.0 GLOBAL                                          Specif.   0.000E+00
         5220     PIPE  BRACE-SIDE  DNV-X              1.0  20.0 EFTHYMIO                                        Specif.   0.000E+00
         5220     PIPE  CHORD-SIDE  DNV-X              1.0  20.0 EFTHYMIO                                        Specif.   0.000E+00
```


Member fatigue check data

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
45217	4215	PIPE	BOTH-SIDES	DNV-X	3.0	60.0	GLOBAL						Specif.	0.000E+00
	0.25	PIPE	QUA	DNV-X	1.0	20.0	GLOBAL						Specif.	0.000E+00
	0.50	PIPE	MID	DNV-X	2.0	40.0	GLOBAL						Specif.	0.000E+00
	0.75	PIPE	3QUART	DNV-X	3.0	60.0	GLOBAL						Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	DNV-X	10.0	200.0	EFTHYMIO						Specif.	0.000E+00
	5220	PIPE	CHORD-SIDE	DNV-X	10.0	200.0	EFTHYMIO						Specif.	0.000E+00

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 3

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F41 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees
Jtype	Joint type
DiaCho	Chord diameter
ThiCho	Chord thickness
LenCho	Chord length
FixCho	Chord end fixity parameter
SCFaxC	SCF for axial force at Crown (Hotspot 7)
SCFaxS	SCF for axial force at Saddle (Hotspot 1)

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 4

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F41 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type SctNam	Joint/Po	Outcome	Damage	Life Alpha Theta	WeldSide Symmet Jtype	Hot DiaBra DiaCho	SCFrule ThiBra ThiCho	SCFax Gap LenCho	SCFipb ThiFac FixCho	SCFopb QR SCFaxC	SNcurve Cycles SCFaxS
45217	PIPE	4215		1.00E-10	6.00E+11	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
	60025				350.342	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					85.464		6.00E+02	25.000	4.90E+04	1.000	1.000	1.000
		0.25		1.00E-10	2.00E+11	QUA	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.50		1.00E-10	4.00E+11	MID	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.75		1.00E-10	6.00E+11	3QUART	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		5220		5.85E-03	3.42E+04	BRACE-SID	7	EFTHYMIOU	10.004	2.962	3.703	DNV-X
					170.349	CROWN-SAD	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					42.731	YT	7.00E+02	25.000	1.80E+04	1.000	10.004	3.929
		5220		5.44E-01	3.68E+02	CHORD-SID	4	EFTHYMIOU	18.536	2.849	6.703	DNV-X
					170.349	CROWN-SAD	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					42.731	YT	7.00E+02	25.000	1.80E+04	1.000	18.067	19.005

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 5

Member fatigue check data SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
45217	4215	PIPE	BOTH-SIDES	DNV-X	3.0	120.0	GLOBAL						Specif.	0.000E+00
	0.25	PIPE	QUA	DNV-X	1.0	40.0	GLOBAL						Specif.	0.000E+00
	0.50	PIPE	MID	DNV-X	2.0	80.0	GLOBAL						Specif.	0.000E+00
	0.75	PIPE	3QUART	DNV-X	3.0	120.0	GLOBAL						Specif.	0.000E+00
	5220	PIPE	BRACE-SIDE	DNV-X	10.0	400.0	EFTHYMIO						Specif.	0.000E+00
	5220	PIPE	CHORD-SIDE	DNV-X	10.0	400.0	EFTHYMIO						Specif.	0.000E+00

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 6

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F41B JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

```
Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                PAGE:     7

                                   DETERMINISTIC    fatigue check results
                                   Run:      Superelement:     Loadset:
                                   F41B      JACKET            WAVE_LOADS
                                   Priority....: Selected Members
                                   Usage factor: Above   0.00                                                SUB PAGE:     2

Member       Type     Joint/Po Outcome   Damage     Life     WeldSide        Hot SCFrule    SCFax    SCFipb SCFopb SNcurve
```

	SctNam			Alpha	Symmet	DiaBra	ThiBra	Gap	ThiFac	QR	Cycles
				Theta	Jtype	DiaCho	ThiCho	LenCho	FixCho	SCFaxC	SCFaxS
45217	PIPE	4215	1.00E-10	1.20E+12	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
	60025			350.342	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
				85.464		6.00E+02	25.000	4.90E+04	1.000	1.000	1.000
		0.25	1.00E-10	4.00E+11	QUA	1	GLOBAL	1.000	1.000	1.000	DNV-X
				0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
				0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.50	1.00E-10	8.00E+11	MID	1	GLOBAL	1.000	1.000	1.000	DNV-X
				0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
				0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.75	1.00E-10	1.20E+12	3QUART	1	GLOBAL	1.000	1.000	1.000	DNV-X
				0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	0.00E+00
				0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		5220	1.17E-02	3.42E+04	BRACE-SID	7	EFTHYMIOU	10.004	2.962	3.703	DNV-X
				170.349	CROWN-SAD	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
				42.731	YT	7.00E+02	25.000	1.80E+04	1.000	10.004	3.929
		5220	**Fail** 1.09E+00	3.68E+02	CHORD-SID	4	EFTHYMIOU	18.536	2.849	6.703	DNV-X
				170.349	CROWN-SAD	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
				42.731	YT	7.00E+02	25.000	1.80E+04	1.000	18.067	19.005

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name

```
  SCF        SCFax when Local rule
 Para1       Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
 Para2       Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
 OrgFPD      Origin of Fatigue Part Damage (RUN Name or specified
 FPDamage    Fatigue Part Damage in current hotspot


Member   Joint/Po SecTy WeldSide    SNcurve            FSF DFLif SCFrule  Symmet   Hot    SCF   Para1   Para2   OrgFPD    FPDamage
-------------------------------------------------------------------------------------------------------------------------------------
45217    4215     PIPE  BOTH-SIDES  DNV-X             3.0 120.0 GLOBAL                                        Specif.   0.000E+00
         0.25     PIPE  QUA         DNV-X             1.0  40.0 GLOBAL                                        Specif.   0.000E+00
         0.50     PIPE  MID         DNV-X             2.0  80.0 GLOBAL                                        Specif.   0.000E+00
         0.75     PIPE  3QUART      DNV-X             3.0 120.0 GLOBAL                                        Specif.   0.000E+00
         5220     PIPE  BRACE-SIDE  DNV-X            10.0 400.0 EFTHYMIO                                      Specif.   2.000E-01
         5220     PIPE  CHORD-SIDE  DNV-X            10.0 400.0 EFTHYMIO                                      Specif.   1.000E-01



DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                PAGE:     9


                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                F42       JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                          SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
```

```
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                  PAGE:    10

                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                F42       JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                                    SUB PAGE:     2

Member       Type     Joint/Po Outcome   Damage     Life    WeldSide        Hot SCFrule    SCFax    SCFipb SCFopb SNcurve
             SctNam                                Alpha    Symmet     DiaBra    ThiBra      Gap    ThiFac   QR       Cycles
                                                   Theta    Jtype      DiaCho    ThiCho    LenCho   FixCho SCFaxC      SCFaxS
-------------------------------------------------------------------------------------------------------------------------------
45217        PIPE     4215               1.00E-10  1.20E+12 BOTH-SIDE         1 GLOBAL      1.000    1.000  1.000 DNV-X
             60025                                  350.342  UNIFORM    6.00E+02  25.000    0.00E+00 1.000  1.000      0.00E+00
                                                     85.464           6.00E+02  25.000    4.90E+04 1.000  1.000        1.000
                      0.25               1.00E-10  4.00E+11 QUA               1 GLOBAL      1.000    1.000  1.000 DNV-X
                                                       0.000  UNIFORM    6.00E+02  25.000    0.00E+00 1.000  1.000      0.00E+00
                                                       0.000           0.00E+00   0.000    0.00E+00 1.000  1.000        1.000
                      0.50               1.00E-10  8.00E+11 MID               1 GLOBAL      1.000    1.000  1.000 DNV-X
                                                       0.000  UNIFORM    6.00E+02  25.000    0.00E+00 1.000  1.000      0.00E+00
                                                       0.000           0.00E+00   0.000    0.00E+00 1.000  1.000        1.000
                      0.75               1.00E-10  1.20E+12 3QUART            1 GLOBAL      1.000    1.000  1.000 DNV-X
```

```
                                          0.000  UNIFORM    6.00E+02  25.000    0.00E+00  1.000  1.000      0.00E+00
                                          0.000             0.00E+00   0.000    0.00E+00  1.000  1.000         1.000
                    5220              2.12E-01  1.89E+03 BRACE-SID         7 EFTHYMIOU  10.004    2.962  3.703 DNV-X
                                                170.349  CROWN-SAD  6.00E+02  25.000    0.00E+00  1.000  1.000      3.75E+08
                                                 42.731  YT         7.00E+02  25.000    1.80E+04  1.000 10.004        3.929
                    5220     **Fail**  1.19E+00  3.37E+02 CHORD-SID         4 EFTHYMIOU  18.536    2.849  6.703 DNV-X
                                                170.349  CROWN-SAD  6.00E+02  25.000    0.00E+00  1.000  1.000      3.75E+08
                                                 42.731  YT         7.00E+02  25.000    1.80E+04  1.000 18.067       19.005
```


Member fatigue check data SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
45217	4215	PIPE	BOTH-SIDES	DNV-X	3.0	120.0	GLOBAL						F4	1.000E-10
	0.25	PIPE	QUA	DNV-X	1.0	40.0	GLOBAL						F4	1.000E-10
	0.50	PIPE	MID	DNV-X	2.0	80.0	GLOBAL						F4	1.000E-10
	0.75	PIPE	3QUART	DNV-X	3.0	120.0	GLOBAL						F4	1.000E-10

```
         5220     PIPE  BRACE-SIDE  DNV-X            10.0 400.0 EFTHYMIO                                F4        5.853E-04
         5220     PIPE  CHORD-SIDE  DNV-X            10.0 400.0 EFTHYMIO                                F4        5.438E-02



DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                          PAGE:    12

                                   DETERMINISTIC    fatigue check results
                                   Run:      Superelement:     Loadset:
                                   F43       JACKET            WAVE_LOADS
                                   Priority....: Selected Members
                                   Usage factor: Above   0.00                                        SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
```

```
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:    13
```

```
                              DETERMINISTIC    fatigue check results
                              Run:      Superelement:     Loadset:
                              F43       JACKET            WAVE_LOADS
                              Priority....: Selected Members
                              Usage factor: Above   0.00                                                    SUB PAGE:     2
```

Member	Type SctNam	Joint/Po	Outcome	Damage	Life Alpha Theta	WeldSide Symmet Jtype	Hot DiaBra DiaCho	SCFrule ThiBra ThiCho	SCFax Gap LenCho	SCFipb ThiFac FixCho	SCFopb QR SCFaxC	SNcurve Cycles SCFaxS
45217	PIPE	4215		1.00E-10	1.20E+12	BOTH-SIDE	1	GLOBAL	1.000	1.000	1.000	DNV-X
	60025				350.342	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					85.464		6.00E+02	25.000	4.90E+04	1.000	1.000	1.000
		0.25		1.00E-10	4.00E+11	QUA	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.50		1.00E-10	8.00E+11	MID	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		0.75		1.00E-10	1.20E+12	3QUART	1	GLOBAL	1.000	1.000	1.000	DNV-X
					0.000	UNIFORM	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000
		5220		1.23E-02	3.25E+04	BRACE-SID	7	EFTHYMIOU	10.004	2.962	3.703	DNV-X
					170.349	CROWN-SAD	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					42.731	YT	7.00E+02	25.000	1.80E+04	1.000	10.004	3.929
		5220	**Fail**	1.14E+00	3.50E+02	CHORD-SID	4	EFTHYMIOU	18.536	2.849	6.703	DNV-X
					170.349	CROWN-SAD	6.00E+02	25.000	0.00E+00	1.000	1.000	3.75E+08
					42.731	YT	7.00E+02	25.000	1.80E+04	1.000	18.067	19.005

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:    14
```

Member fatigue check data SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
33115	3110	PIPE	CHORD-SIDE	TEST	3.0	60.0	LOCAL	NON-SYMM	7	4.970	2.570	0.000	F2	1.448E-04
									10	0.000	0.000	0.000		1.448E-04
									13	4.950	0.000	2.570		1.448E-04
									16	0.000	0.000	0.000		1.448E-04
									19	4.970	2.570	0.000		1.448E-04
									22	0.000	0.000	0.000		1.448E-04
									1	4.950	0.000	2.570		1.448E-04
									4	0.000	0.000	0.000		1.448E-04
	3110	PIPE	BRACE-SIDE	TEST	3.0	60.0	LOCAL	NON-SYMM	7	4.970	2.570	0.000	F2	1.406E-05
									10	0.000	0.000	0.000		1.406E-05
									13	4.950	0.000	2.570		1.406E-05
									16	0.000	0.000	0.000		1.406E-05
									19	4.970	2.570	0.000		1.406E-05
									22	0.000	0.000	0.000		1.406E-05
									1	4.950	0.000	2.570		1.406E-05
									4	0.000	0.000	0.000		1.406E-05
	3120	PIPE	BRACE-SIDE	TEST	3.0	60.0	LOCAL	NON-SYMM	7	2.570	2.570	0.000	F2	5.518E-06

									10	0.000	0.000	0.000		5.518E-06
									13	6.520	0.000	2.570		5.518E-06
									16	0.000	0.000	0.000		5.518E-06
									19	2.570	2.570	0.000		5.518E-06
									22	0.000	0.000	0.000		5.518E-06
									1	6.520	0.000	4.030		5.518E-06
									4	0.000	0.000	0.000		5.518E-06
	3120	PIPE	CHORD-SIDE	TEST	3.0	60.0	LOCAL	NON-SYMM	7	2.570	2.570	0.000	F2	6.110E-05
									10	0.000	0.000	0.000		6.110E-05
									13	6.520	0.000	2.570		6.110E-05
									16	0.000	0.000	0.000		6.110E-05
									19	2.570	2.570	0.000		6.110E-05
									22	0.000	0.000	0.000		6.110E-05
									1	6.520	0.000	4.030		6.110E-05

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 15

Member fatigue check data SUB PAGE: 2

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
									4	0.000	0.000	0.000		6.110E-05

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 16

Member fatigue check data SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor

DFLif Design Fatigue Life
SCFrule Method used for SCF calculation
Symmet Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot Hotspot (stress point) name
SCF SCFax when Local rule
Para1 Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2 Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD Origin of Fatigue Part Damage (RUN Name or specified
FPDamage Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
33115	3110	PIPE	CHORD-SIDE	TEST	3.0	60.0	LOCAL	NON-SYMM	7	4.970	2.570	0.000	F2	1.448E-04
									10	0.000	0.000	0.000		1.448E-04
									13	4.950	0.000	2.570		1.448E-04
									16	0.000	0.000	0.000		1.448E-04
									19	4.970	2.570	0.000		1.448E-04
									22	0.000	0.000	0.000		1.448E-04
									1	4.950	0.000	2.570		1.448E-04
									4	0.000	0.000	0.000		1.448E-04
	3110	PIPE	BRACE-SIDE	TEST	3.0	60.0	LOCAL	NON-SYMM	7	4.970	2.570	0.000	F2	1.406E-05
									10	0.000	0.000	0.000		1.406E-05
									13	4.950	0.000	2.570		1.406E-05
									16	0.000	0.000	0.000		1.406E-05
									19	4.970	2.570	0.000		1.406E-05
									22	0.000	0.000	0.000		1.406E-05
									1	4.950	0.000	2.570		1.406E-05
									4	0.000	0.000	0.000		1.406E-05
	3120	PIPE	BRACE-SIDE	TEST	3.0	60.0	LOCAL	NON-SYMM	7	2.570	2.570	0.000	F2	5.518E-06
									10	0.000	0.000	0.000		5.518E-06
									13	6.520	0.000	2.570		5.518E-06
									16	0.000	0.000	0.000		5.518E-06
									19	2.570	2.570	0.000		5.518E-06
									22	0.000	0.000	0.000		5.518E-06
									1	6.520	0.000	4.030		5.518E-06
									4	0.000	0.000	0.000		5.518E-06
	3120	PIPE	CHORD-SIDE	TEST	3.0	60.0	LOCAL	NON-SYMM	7	2.570	2.570	0.000	F2	6.110E-05
									10	0.000	0.000	0.000		6.110E-05
									13	6.520	0.000	2.570		6.110E-05
									16	0.000	0.000	0.000		6.110E-05
									19	2.570	2.570	0.000		6.110E-05
									22	0.000	0.000	0.000		6.110E-05
									1	6.520	0.000	4.030		6.110E-05

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 17

Member fatigue check data SUB PAGE: 2

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
									4	0.000	0.000	0.000		6.110E-05

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 18

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F21 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation

```
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:    19
```

```
                                DETERMINISTIC    fatigue check results
                                Run:      Superelement:     Loadset:
                                F21       JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                                    SUB PAGE:     2
```

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33115	PIPE	3110		5.79E-04	1.04E+05	CHORD-SID	19	LOCAL	4.970	2.570	0.000	TEST
	50025				7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.170	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	4.970	4.950
		3110		5.63E-05	1.07E+06	BRACE-SID	19	LOCAL	4.970	2.570	0.000	TEST
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	0.940	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	4.970	4.950
		3120		2.21E-05	2.72E+06	BRACE-SID	1	LOCAL	6.520	0.000	4.030	TEST
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	0.940	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	2.570	6.520
		3120		2.44E-04	2.46E+05	CHORD-SID	1	LOCAL	6.520	0.000	4.030	TEST
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.170	1.000	3.75E+08
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	2.570	6.520

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 20

Chord and braces SUB PAGE: 1

NOMENCLATURE:

Joint Name of joint
Member Name of member connected
Type Type of the member
Diameter Diameter of the member or can if assigned
Thick Thickness of the member or can/stub if assigned
Yield Yield strength of the member or can/stub if assigned
Chord Name of the chord member associated with the brace
Can/Stub Name of the can/stub assign to the member
Length Length of the can/stub

Joint	Member	Type	Diameter	Thick	Yield	Chord	Can/Stub	Length
3220	23220	CHORD	1.600E+03	6.00E+01	1.90E+02			
	35220	ALIGN	1.600E+03	6.00E+01	1.90E+02			
	33215	BRACE	7.200E+02	3.00E+01	1.90E+02	23220	STU32	1.520E+03
	34217	BRACE	7.200E+02	3.00E+01	1.90E+02	23220	STU32	2.142E+03
	33415	BRACE	7.200E+02	3.00E+01	1.90E+02	23220	STU32	1.571E+03
	35415	BRACE	7.200E+02	3.00E+01	1.90E+02	23220	STU32	2.229E+03

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 21

Member fatigue check data SUB PAGE: 1

NOMENCLATURE:

Member Name of member

Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
23220	2220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL						F2	0.000E+00
	2220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL						F2	0.000E+00
	3220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	GLOBAL						F2	0.000E+00
	3220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL						F2	0.000E+00
33215	3210	PIPE	CHORD-SIDE	USE-X	1.0	20.0	WORDSWOR						F2	0.000E+00
	3210	PIPE	BRACE-SIDE	USE-X	1.0	20.0	WORDSWOR						F2	0.000E+00
	0.96	PIPE	50025	DNV-X	1.0	20.0	BUTT-DNV	0.15TS		1.000	0.000	0.000	F2	0.000E+00
	0.96	PIPE	STU32	DNV-X	1.0	20.0	BUTT-DNV	0.15TS		1.000	0.000	0.000	F2	0.000E+00
	3220	PIPE	BRACE-SIDE	USE-X	1.0	20.0	WORDSWOR						F2	0.000E+00
	3220	PIPE	CHORD-SIDE	USE-X	1.0	20.0	WORDSWOR						F2	0.000E+00
33415	3220	PIPE	CHORD-SIDE	USE-X	1.0	20.0	KUANG						F2	0.000E+00
	3220	PIPE	BRACE-SIDE	USE-X	1.0	20.0	KUANG						F2	0.000E+00
	0.03	PIPE	STU32	DNV-X	1.0	20.0	BUTT-DNV	0.15TS		1.000	0.000	0.000	F2	0.000E+00
	0.03	PIPE	50025	DNV-X	1.0	20.0	BUTT-DNV	0.15TS		1.000	0.000	0.000	F2	0.000E+00
	3120	PIPE	BRACE-SIDE	USE-X	1.0	20.0	KUANG						F2	0.000E+00
	3120	PIPE	CHORD-SIDE	USE-X	1.0	20.0	KUANG						F2	0.000E+00
34217	3220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	EFTHYMIO						F2	0.000E+00
	3220	PIPE	BRACE-SIDE	DNV-X	1.0	20.0	EFTHYMIO						F2	0.000E+00
	0.09	PIPE	STU32	DNV-X	1.0	20.0	BUTT-DNV	0.15TS		1.000	0.000	0.000	F2	0.000E+00
	0.09	PIPE	60025	DNV-X	1.0	20.0	LOCAL	UNIFORM	1	2.200	3.300	4.400	F2	0.000E+00
	4215	PIPE	BOTH-SIDES	API-X	1.0	20.0	GLOBAL						F2	0.000E+00
35220	3220	PIPE	CHORD-SIDE	DNV-X	1.0	20.0	GLOBAL						F2	0.000E+00

```
         3220     PIPE  BRACE-SIDE  DNV-X              1.0  20.0 GLOBAL                                                F2         0.000E+00
         5220     PIPE  BRACE-SIDE  DNV-X              1.0  20.0 GLOBAL                                                F2         0.000E+00
         5220     PIPE  CHORD-SIDE  DNV-X              1.0  20.0 GLOBAL                                                F2         0.000E+00



DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                  PAGE:    22


                                   Member fatigue check data                                                  SUB PAGE:     2

Member   Joint/Po SecTy WeldSide    SNcurve            FSF DFLif SCFrule  Symmet   Hot    SCF   Para1   Para2   OrgFPD    FPDamage
-------------------------------------------------------------------------------------------------------------------------------------
35415    3220     PIPE  CHORD-SIDE  USE-X              1.0  20.0 KUANG                                                 F2         0.000E+00
         3220     PIPE  BRACE-SIDE  USE-X              1.0  20.0 KUANG                                                 F2         0.000E+00
         0.04     PIPE  STU32       DNV-X              1.0  20.0 BUTT-DNV 0.15TS         1.449   6.000  40.000 F2         0.000E+00
         0.04     PIPE  70020       DNV-X              1.0  20.0 BUTT-DNV 0.15TS         1.449   6.000  40.000 F2         0.000E+00
         5120     PIPE  BRACE-SIDE  USE-X              1.0  20.0 KUANG                                                 F2         0.000E+00
         5120     PIPE  CHORD-SIDE  USE-X              1.0  20.0 KUANG                                                 F2         0.000E+00



DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                  PAGE:    23


                                   DETERMINISTIC    fatigue check results
                                   Run:      Superelement:     Loadset:
                                   F22       JACKET            WAVE_LOADS
                                   Priority....: Selected Members
                                   Usage factor: Above   0.00                                                 SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
```

Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees
Jtype	Joint type
DiaCho	Chord diameter
ThiCho	Chord thickness
LenCho	Chord length
FixCho	Chord end fixity parameter
SCFaxC	SCF for axial force at Crown (Hotspot 7)
SCFaxS	SCF for axial force at Saddle (Hotspot 1)

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 24

DETERMINISTIC fatigue check results
Run: Superelement: Loadset:
F22 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
34217	PIPE	3220		2.02E-07	9.89E+07	CHORD-SID	16	EFTHYMIOU	2.559	2.500	4.324	DNV-X
	STU32				9.658	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.000	1.000	3.75E+08
					47.268	K	1.60E+03	60.000	3.63E+04	1.000	2.559	2.559
		3220		2.08E-07	9.62E+07	BRACE-SID	16	EFTHYMIOU	2.554	2.700	4.318	DNV-X
					9.658	CROWN-SAD	7.20E+02	30.000	0.00E+00	1.000	1.000	3.75E+08

```
                                                47.268  K          1.60E+03  60.000    3.63E+04  1.000  2.554       2.554
                    0.09                1.00E-10  2.00E+11 STU32            1 *ILLEGAL*   1.000    1.000  1.000 DNV-X
                                                  0.000  0.15TS     7.20E+02  30.000    0.00E+00  1.000  1.000     0.00E+00
                                                  0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
              PIPE      0.09                4.16E-06  4.80E+06 60025           16 LOCAL       2.200    3.300  4.400 DNV-X
              60025                               0.000  UNIFORM    6.00E+02  25.000    0.00E+00  1.000  1.000     3.75E+08
                                                  0.000             0.00E+00   0.000    0.00E+00  1.000  2.200       2.200
                    4215                1.00E-10  2.00E+11 BOTH-SIDE        1 GLOBAL      1.000    1.000  1.000 API-X
                                                  0.000  UNIFORM    6.00E+02  25.000    0.00E+00  1.118  1.000     0.00E+00
                                                  0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000



DATE: 12-MAY-2016 TIME: 10:00:08   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:    25


                                   Member fatigue check data                                                  SUB PAGE:     1


NOMENCLATURE:

Member       Name of member
Joint/Po     Joint name or position within the member
SecTy        Section type
WeldSide     Side of weld
SNcurve      Name of SN curve
  FSF        Fatigue Safety (Design) Factor
DFLif        Design Fatigue Life
SCFrule      Method used for SCF calculation
Symmet       Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot          Hotspot (stress point) name
  SCF        SCFax when Local rule
 Para1       Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
 Para2       Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
 OrgFPD      Origin of Fatigue Part Damage (RUN Name or specified
 FPDamage    Fatigue Part Damage in current hotspot


Member   Joint/Po SecTy WeldSide    SNcurve            FSF DFLif SCFrule  Symmet   Hot    SCF   Para1   Para2   OrgFPD    FPDamage
-------------------------------------------------------------------------------------------------------------------------------------
23220    2220     PIPE  BOTH-SIDES  DNV-X             10.0 200.0 GLOBAL                                        F2        0.000E+00
         3220     PIPE  BOTH-SIDES  DNV-X             10.0 200.0 GLOBAL                                        F2        0.000E+00
```

33215	3210	PIPE	CHORD-SIDE	USE-X	10.0	200.0	WORDSWOR					F2	0.000E+00
	3210	PIPE	BRACE-SIDE	USE-X	10.0	200.0	WORDSWOR					F2	0.000E+00
	0.96	PIPE	50025	DNV-X	10.0	200.0	BUTT-DNV	0.15TS		1.000	0.000	0.000 F2	0.000E+00
	0.96	PIPE	STU32	DNV-X	10.0	200.0	BUTT-DNV	0.15TS		1.000	0.000	0.000 F2	0.000E+00
	3220	PIPE	BRACE-SIDE	NS-F2-SE	3.0	60.0	WORDSWOR					F2	0.000E+00
	3220	PIPE	CHORD-SIDE	NS-F2-SE	3.0	60.0	WORDSWOR					F2	0.000E+00
33415	3220	PIPE	CHORD-SIDE	NS-F2-SE	3.0	60.0	KUANG					F2	0.000E+00
	3220	PIPE	BRACE-SIDE	NS-F2-SE	3.0	60.0	KUANG					F2	0.000E+00
	0.03	PIPE	STU32	DNV-X	10.0	200.0	BUTT-DNV	0.15TS		1.000	0.000	0.000 F2	0.000E+00
	0.03	PIPE	50025	DNV-X	10.0	200.0	BUTT-DNV	0.15TS		1.000	0.000	0.000 F2	0.000E+00
	3120	PIPE	BRACE-SIDE	USE-X	10.0	200.0	KUANG					F2	0.000E+00
	3120	PIPE	CHORD-SIDE	USE-X	10.0	200.0	KUANG					F2	0.000E+00
34217	3220	PIPE	CHORD-SIDE	NS-F2-SE	2.0	40.0	EFTHYMIO					F2	0.000E+00
	3220	PIPE	BRACE-SIDE	NS-F2-SE	2.0	40.0	EFTHYMIO					F2	0.000E+00
	0.09	PIPE	STU32	DNV-X	3.0	60.0	BUTT-DNV	0.15TS		1.000	0.000	0.000 F2	0.000E+00
	0.09	PIPE	60025	DNV-X	1.0	20.0	LOCAL	UNIFORM	1	2.200	3.300	4.400 F2	0.000E+00
	4215	PIPE	BOTH-SIDES	API-X	1.0	20.0	GLOBAL					F2	0.000E+00
35220	3220	PIPE	BOTH-SIDES	DNV-X	10.0	200.0	GLOBAL					F2	0.000E+00
	5220	PIPE	BOTH-SIDES	DNV-X	10.0	200.0	GLOBAL					F2	0.000E+00

DATE: 12-MAY-2016 TIME: 10:00:08 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 26

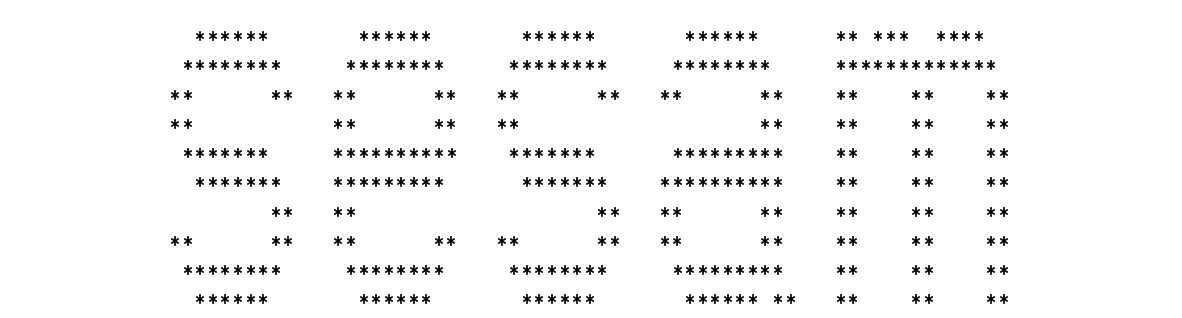
Member fatigue check data SUB PAGE: 2

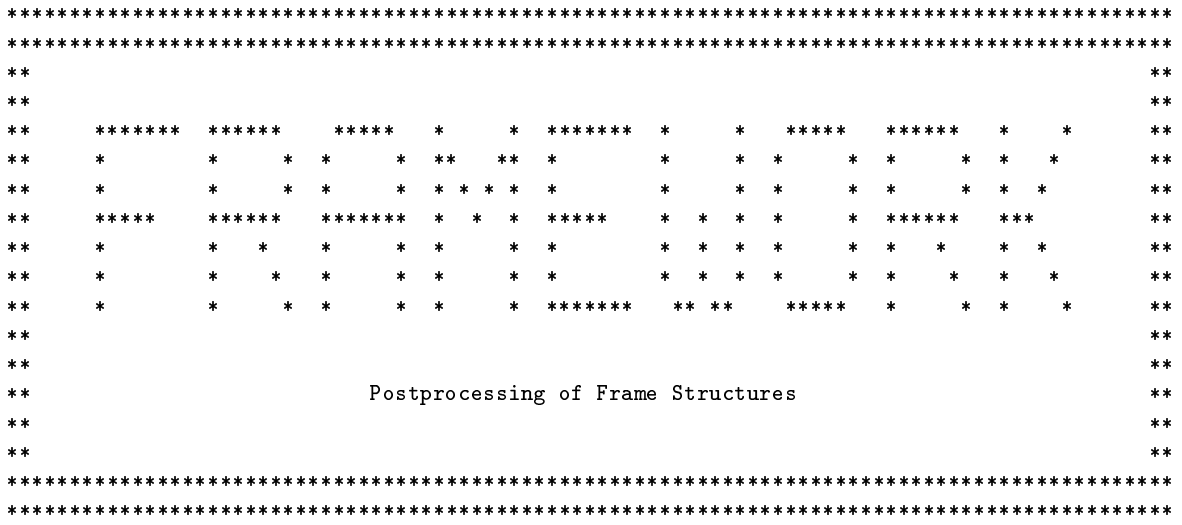
Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
35415	3220	PIPE	CHORD-SIDE	NS-F2-SE	3.0	60.0	KUANG						F2	0.000E+00
	3220	PIPE	BRACE-SIDE	NS-F2-SE	3.0	60.0	KUANG						F2	0.000E+00
	0.04	PIPE	STU32	DNV-X	10.0	200.0	BUTT-DNV	0.15TS		1.449	6.000	40.000	F2	0.000E+00
	0.04	PIPE	70020	DNV-X	10.0	200.0	BUTT-DNV	0.15TS		1.449	6.000	40.000	F2	0.000E+00
	5120	PIPE	BRACE-SIDE	USE-X	10.0	200.0	KUANG						F2	0.000E+00
	5120	PIPE	CHORD-SIDE	USE-X	10.0	200.0	KUANG						F2	0.000E+00

A.1.16 Results from stochastic fatigue analysis

A.1.16.1 X108CFATADD.LIS

1





Marketing and Support by DNV GL - Software

```
              Program id    : 3.13-00                                  Computer         : 586
              Release date  : 11-MAY-2016                              Impl. update     :
              Access time   : 12-MAY-2016 10:00:21                     Operating system : Win NT 6.1 [7601]
              User id       : acd                                      CPU id           : 0112953272
                                                                       Installation     : , OSLL400284


              Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway



DATE: 12-MAY-2016 TIME: 10:00:21   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                PAGE:     1

                                   Member fatigue check data                                                  SUB PAGE:     1


NOMENCLATURE:

Member       Name of member
Joint/Po     Joint name or position within the member
SecTy        Section type
WeldSide     Side of weld
SNcurve      Name of SN curve
  FSF        Fatigue Safety (Design) Factor
DFLif        Design Fatigue Life
SCFrule      Method used for SCF calculation
Symmet       Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot          Hotspot (stress point) name
  SCF        SCFax when Local rule
 Para1       Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
 Para2       Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
 OrgFPD      Origin of Fatigue Part Damage (RUN Name or specified
 FPDamage    Fatigue Part Damage in current hotspot


Member    Joint/Po SecTy WeldSide    SNcurve            FSF DFLif SCFrule  Symmet   Hot    SCF   Para1   Para2   OrgFPD    FPDamage
-------------------------------------------------------------------------------------------------------------------------------------
```

```
33415    3220     PIPE  CHORD-SIDE  USE-X            3.0  60.0 KUANG                    Specif.   0.000E+00
         3220     PIPE  BRACE-SIDE  USE-X            3.0  60.0 KUANG                    Specif.   0.000E+00
         3120     PIPE  BRACE-SIDE  USE-X            3.0  60.0 KUANG                    Specif.   0.000E+00
         3120     PIPE  CHORD-SIDE  USE-X            3.0  60.0 KUANG                    Specif.   0.000E+00
```


STOCHASTIC fatigue check results

Run:	Superelement:	Loadset:
S2	JACKET	WAVE_LOADS

Priority....: Selected Members

Usage factor: Above 0.00

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees

```
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:21   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                    PAGE:     3

                                STOCHASTIC       fatigue check results
                                Run:      Superelement:     Loadset:
                                S2        JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                          SUB PAGE:     2
```

Member	Type	Joint/Po	Outcome	Damage	Life	WeldSide	Hot	SCFrule	SCFax	SCFipb	SCFopb	SNcurve
	SctNam				Alpha	Symmet	DiaBra	ThiBra	Gap	ThiFac	QR	Cycles
					Theta	Jtype	DiaCho	ThiCho	LenCho	FixCho	SCFaxC	SCFaxS
33415	PIPE	3220		1.82E-01	3.30E+02	CHORD-SID	10	KUANG	2.500	2.500	2.571	USE-X
	50025				0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	1.000	2.45E+08
					82.875	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500
		3220		3.28E-01	1.83E+02	BRACE-SID	10	KUANG	3.182	2.692	2.866	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	0.800	2.46E+08
					82.875	K	1.60E+03	60.000	3.63E+04	1.000	3.182	3.182
		3120	**Fail**	1.03E+00	5.82E+01	BRACE-SID	22	KUANG	7.964	2.500	2.866	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	2.62E+08
					82.875	YT	1.60E+03	60.000	3.63E+04	1.000	7.964	7.964
		3120		5.11E-01	1.17E+02	CHORD-SID	22	KUANG	5.913	2.500	2.571	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	2.59E+08
					82.875	YT	1.60E+03	60.000	3.63E+04	1.000	5.913	5.913

```
DATE: 12-MAY-2016 TIME: 10:00:21   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                    PAGE:     4

                                Member fatigue check data                                           SUB PAGE:     1
```

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
33415	3220	PIPE	CHORD-SIDE	USE-X	3.0	120.0	KUANG						Specif.	0.000E+00
	3220	PIPE	BRACE-SIDE	USE-X	3.0	120.0	KUANG						Specif.	0.000E+00
	3120	PIPE	BRACE-SIDE	USE-X	3.0	120.0	KUANG						Specif.	0.000E+00
	3120	PIPE	CHORD-SIDE	USE-X	3.0	120.0	KUANG						Specif.	0.000E+00

DATE: 12-MAY-2016 TIME: 10:00:21 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 5

STOCHASTIC fatigue check results
Run: Superelement: Loadset:
S3 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

```
Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:21   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                    PAGE:     6

                                STOCHASTIC       fatigue check results
                                Run:      Superelement:     Loadset:
                                S3        JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                    SUB PAGE:     2

Member       Type     Joint/Po Outcome   Damage     Life    WeldSide        Hot SCFrule    SCFax    SCFipb SCFopb SNcurve
             SctNam                              Alpha    Symmet     DiaBra    ThiBra      Gap    ThiFac   QR       Cycles
```

				Theta	Jtype	DiaCho	ThiCho	LenCho	FixCho	SCFaxC	SCFaxS
33415	PIPE	3220	3.64E-01	3.30E+02	CHORD-SID	10	KUANG	2.500	2.500	2.571	USE-X
	50025			0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	1.000	4.90E+08
				82.875	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500
		3220	6.57E-01	1.83E+02	BRACE-SID	10	KUANG	3.182	2.692	2.866	USE-X
				0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	0.800	4.92E+08
				82.875	K	1.60E+03	60.000	3.63E+04	1.000	3.182	3.182
		3120	**Fail** 2.06E+00	5.82E+01	BRACE-SID	22	KUANG	7.964	2.500	2.866	USE-X
				0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	5.24E+08
				82.875	YT	1.60E+03	60.000	3.63E+04	1.000	7.964	7.964
		3120	**Fail** 1.02E+00	1.17E+02	CHORD-SID	22	KUANG	5.913	2.500	2.571	USE-X
				0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	5.18E+08
				82.875	YT	1.60E+03	60.000	3.63E+04	1.000	5.913	5.913

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
33415	3220	PIPE	CHORD-SIDE	USE-X	3.0	120.0	KUANG						Specif.	0.000E+00
	3220	PIPE	BRACE-SIDE	USE-X	3.0	120.0	KUANG						Specif.	0.000E+00
	3120	PIPE	BRACE-SIDE	USE-X	3.0	120.0	KUANG						Specif.	2.000E-01
	3120	PIPE	CHORD-SIDE	USE-X	3.0	120.0	KUANG						Specif.	1.000E-01

DATE: 12-MAY-2016 TIME: 10:00:21 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 8

STOCHASTIC fatigue check results
Run: Superelement: Loadset:
S4 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs

```
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:21   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                    PAGE:     9

                                STOCHASTIC       fatigue check results
                                Run:      Superelement:     Loadset:
                                S4        JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                        SUB PAGE:     2
```

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33415	PIPE	3220		3.64E-01	3.30E+02	CHORD-SID	10	KUANG	2.500	2.500	2.571	USE-X
	50025				0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	1.000	4.90E+08
					82.875	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500
		3220		6.57E-01	1.83E+02	BRACE-SID	10	KUANG	3.182	2.692	2.866	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	0.800	4.92E+08
					82.875	K	1.60E+03	60.000	3.63E+04	1.000	3.182	3.182
		3120	**Fail**	2.26E+00	5.31E+01	BRACE-SID	22	KUANG	7.964	2.500	2.866	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	5.24E+08
					82.875	YT	1.60E+03	60.000	3.63E+04	1.000	7.964	7.964
		3120	**Fail**	1.12E+00	1.07E+02	CHORD-SID	22	KUANG	5.913	2.500	2.571	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	5.18E+08
					82.875	YT	1.60E+03	60.000	3.63E+04	1.000	5.913	5.913

```
DATE: 12-MAY-2016 TIME: 10:00:21   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                    PAGE:    10
```

Member fatigue check data SUB PAGE: 1

NOMENCLATURE:

Member	Name of member
Joint/Po	Joint name or position within the member
SecTy	Section type
WeldSide	Side of weld
SNcurve	Name of SN curve
FSF	Fatigue Safety (Design) Factor
DFLif	Design Fatigue Life
SCFrule	Method used for SCF calculation
Symmet	Symmetry in SCF specifiation/SCF attachment when LOTSBERG SCF rule
Hot	Hotspot (stress point) name
SCF	SCFax when Local rule
Para1	Total misalignment for Butt-weld / TC for unstiff Cone or SCFadd for stiff. Cone / SCFipb for Local
Para2	Transition length L for Butt-weld / TAN(ALPHA) for CONE-DNV, A_stiff for CONE-NOR / SCFopb for Local
OrgFPD	Origin of Fatigue Part Damage (RUN Name or specified
FPDamage	Fatigue Part Damage in current hotspot

Member	Joint/Po	SecTy	WeldSide	SNcurve	FSF	DFLif	SCFrule	Symmet	Hot	SCF	Para1	Para2	OrgFPD	FPDamage
33415	3220	PIPE	CHORD-SIDE	USE-X	3.0	120.0	KUANG						STOFAT	6.059E-02
	3220	PIPE	BRACE-SIDE	USE-X	3.0	120.0	KUANG						STOFAT	1.094E-01
	3120	PIPE	BRACE-SIDE	USE-X	3.0	120.0	KUANG						STOFAT	3.434E-01
	3120	PIPE	CHORD-SIDE	USE-X	3.0	120.0	KUANG						STOFAT	1.703E-01

DATE: 12-MAY-2016 TIME: 10:00:21 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 11

STOCHASTIC fatigue check results

Run:	Superelement:	Loadset:
S5	JACKET	WAVE_LOADS

Priority....: Selected Members

Usage factor: Above 0.00 SUB PAGE: 1

NOMENCLATURE:

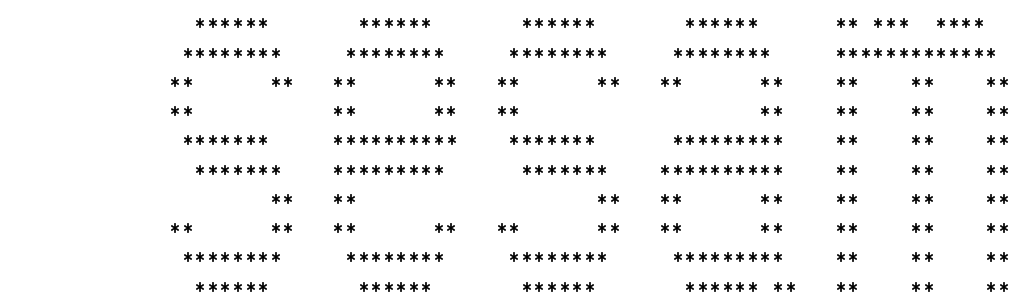
Member	Name of member
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage
SCFrule	Method used for SCF calculation
SCFax	SCF for axial force
SCFipb	SCF for in plane bending
SCFopb	SCF for out of plane bending
SNcurve	SN curve name
SctNam	Section name
Alpha	Moment transformation angle from local to in/out-of-plane co. system
Symmet	Symmetry in SCF specifiation
DiaBra	Brace diameter
ThiBra	Brace thickness
Gap	Gap between braces
ThiFac	Thickness correction factor on SN-curve
QR	Marchall reduction factor applied on SCFs
Cycles	Total number of stress cycles
Theta	Angle between brace and chord in degrees
Jtype	Joint type
DiaCho	Chord diameter
ThiCho	Chord thickness
LenCho	Chord length
FixCho	Chord end fixity parameter
SCFaxC	SCF for axial force at Crown (Hotspot 7)
SCFaxS	SCF for axial force at Saddle (Hotspot 1)

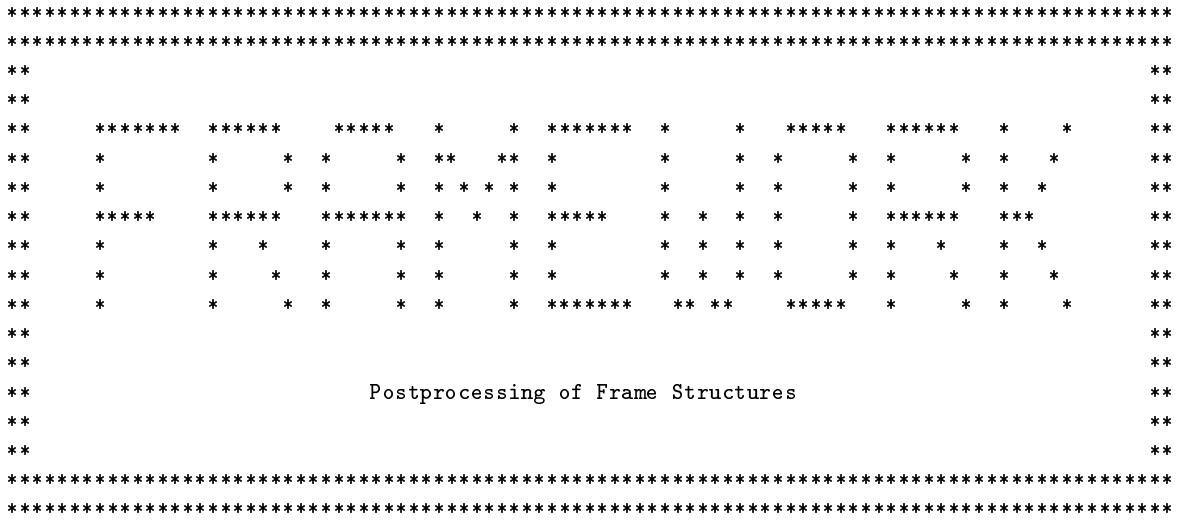
STOCHASTIC fatigue check results
Run: Superelement: Loadset:
S5 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00

Member	Type SctNam	Joint/Po	Outcome	Damage	Life Alpha Theta	WeldSide Symmet Jtype	Hot DiaBra DiaCho	SCFrule ThiBra ThiCho	SCFax Gap LenCho	SCFipb ThiFac FixCho	SCFopb QR SCFaxC	SNcurve Cycles SCFaxS
33415	PIPE	3220		4.24E-01	2.83E+02	CHORD-SID	10	KUANG	2.500	2.500	2.571	USE-X
	50025				0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	1.000	4.90E+08
					82.875	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500
		3220		7.66E-01	1.57E+02	BRACE-SID	10	KUANG	3.182	2.692	2.866	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	0.800	4.92E+08
					82.875	K	1.60E+03	60.000	3.63E+04	1.000	3.182	3.182
		3120	**Fail**	2.40E+00	4.99E+01	BRACE-SID	22	KUANG	7.964	2.500	2.866	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	5.24E+08
					82.875	YT	1.60E+03	60.000	3.63E+04	1.000	7.964	7.964
		3120	**Fail**	1.19E+00	1.01E+02	CHORD-SID	22	KUANG	5.913	2.500	2.571	USE-X
					0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	5.18E+08
					82.875	YT	1.60E+03	60.000	3.63E+04	1.000	5.913	5.913

A.1.16.2 X108CFRAMEWORK.LIS

1





Marketing and Support by DNV GL - Software

```
               Program id   : 3.13-00                          Computer         : 586
               Release date : 11-MAY-2016                      Impl. update     :
               Access time  : 12-MAY-2016 10:00:21             Operating system : Win NT 6.1 [7601]
               User id      : acd                              CPU id           : 0112953272
                                                               Installation     : , OSLL400284


               Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway



DATE: 12-MAY-2016 TIME: 10:00:21   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                          PAGE:     1


                                   STOCHASTIC       fatigue check results
                                   Run:      Superelement:     Loadset:
                                   STOFAT    JACKET            WAVE_LOADS
                                   Priority....: Selected Members
                                   Usage factor: Above   0.00                                    SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
```

```
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

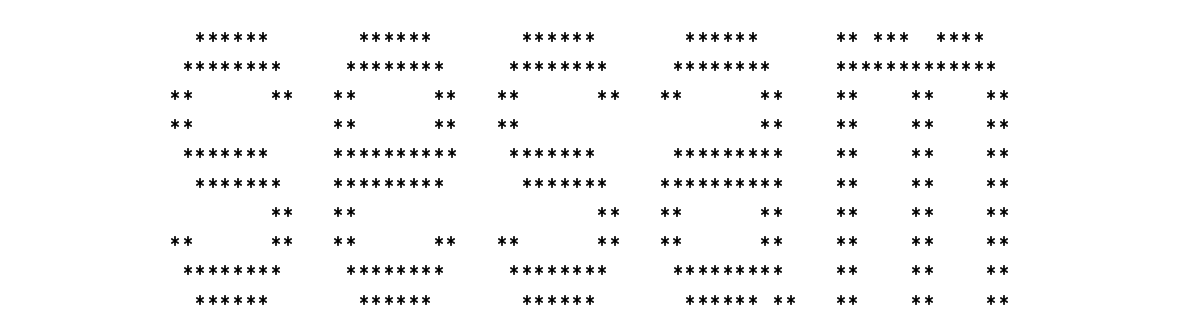

STOCHASTIC fatigue check results
Run: Superelement: Loadset:
STOFAT JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00

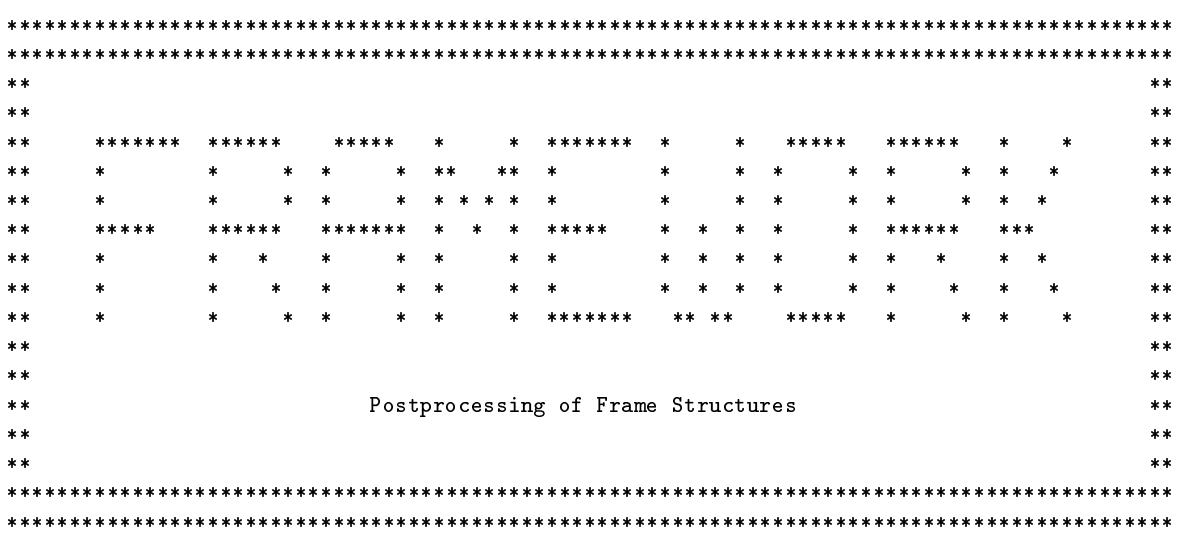
Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33115	PIPE	3110		1.12E-04	1.78E+05	BOTH-SIDE	19	LOCAL	1.000	1.000	0.000	USE-X
	50025				7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.000	1.000	9.21E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	1.000	1.000
		3120		1.86E-04	1.07E+05	BOTH-SIDE	7	LOCAL	1.000	1.000	0.000	USE-X
					7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.000	1.000	9.18E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	1.000	1.000
33215	PIPE	3210		1.51E-01	1.33E+02	CHORD-SID	22	WORDSWORT	5.991	2.500	2.602	USE-X
	50025				352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	8.47E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	5.991	5.991
		3210		1.97E-01	1.01E+02	BRACE-SID	22	WORDSWORT	8.081	2.500	2.909	USE-X
					352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	8.45E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	8.081	8.081
		3220		1.80E-01	1.11E+02	BRACE-SID	10	WORDSWORT	8.081	2.500	2.909	USE-X
					352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	8.41E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	8.081	8.081

		3220		1.34E-01	1.49E+02	CHORD-SID	10	WORDSWORT	5.991	2.500	2.602	USE-X	
					352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	8.44E+07	
					90.000	YT	1.60E+03	60.000	3.63E+04	1.000	5.991	5.991	
33415	PIPE 50025	3220		6.06E-02	3.30E+02	CHORD-SID	10	KUANG	2.500	2.500	2.571	USE-X	
					0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	1.000	8.17E+07	
					82.875	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500	
		3220		1.09E-01	1.83E+02	BRACE-SID	10	KUANG	3.182	2.692	2.866	USE-X	
					0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	0.800	8.21E+07	
					82.875	K	1.60E+03	60.000	3.63E+04	1.000	3.182	3.182	
		3120		3.43E-01	5.82E+01	BRACE-SID	22	KUANG	7.964	2.500	2.866	USE-X	
					0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	8.73E+07	
					82.875	YT	1.60E+03	60.000	3.63E+04	1.000	7.964	7.964	
		3120		1.70E-01	1.17E+02	CHORD-SID	22	KUANG	5.913	2.500	2.571	USE-X	
					0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	8.63E+07	
					82.875	YT	1.60E+03	60.000	3.63E+04	1.000	5.913	5.913	
35415	PIPE 70020	3220		3.65E-01	5.47E+01	CHORD-SID	10	KUANG	2.500	2.500	2.500	USE-X	
					0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	1.000	8.06E+07	
					44.468	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500	
		3220		3.65E-01	5.47E+01	BRACE-SID	10	KUANG	2.500	2.500	2.500	USE-X	
					0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	0.800	8.06E+07	
					44.468	K	1.60E+03	60.000	3.63E+04	1.000	2.500	2.500	
		5120	**Fail**	1.76E+00	1.14E+01	BRACE-SID	10	KUANG	2.500	2.500	2.500	USE-X	
					0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	0.800	8.65E+07	
					58.718	K	1.60E+03	60.000	3.93E+04	1.000	2.500	2.500	
		5120	**Fail**	1.76E+00	1.14E+01	CHORD-SID	10	KUANG	2.500	2.500	2.500	USE-X	
					0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	1.000	8.65E+07	
					58.718	K	1.60E+03	60.000	3.93E+04	1.000	2.500	2.500	

A.1.17 Results from spectral fatigue analysis – X108DFRAMEWORK.LIS

1





Marketing and Support by DNV GL - Software

```
              Program id   : 3.13-00                                  Computer         : 586
              Release date : 11-MAY-2016                              Impl. update     :
              Access time  : 12-MAY-2016 10:00:35                     Operating system : Win NT 6.1 [7601]
              User id      : acd                                      CPU id           : 0112953272
                                                                      Installation     : , OSLL400284


              Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway



DATE: 12-MAY-2016 TIME: 10:00:35   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                          PAGE:     1


                                   SPECTRAL         fatigue check results
                                   Run:      Superelement:     Loadset:
                                   SPECFAT1  JACKET            WAVE_LOADS
                                   Priority....: Selected Joints
                                   Usage factor: Above   0.80                                    SUB PAGE:     1


NOMENCLATURE:

Joint       Name of joint
Brace       Member name of the brace
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
Chord       Member name of the corresponding chord
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
```

```
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:35   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                    PAGE:     2
```

```
                                SPECTRAL         fatigue check results
                                Run:      Superelement:     Loadset:
                                SPECFAT1  JACKET            WAVE_LOADS
                                Priority....: Selected Joints
                                Usage factor: Above   0.80                                                  SUB PAGE:     2
```

Joint	Brace / Chord	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
5110	35115	**Fail**	5.03E+00	3.98E+00	BRACE-SID	13	EFTHYMIOU	2.500	2.500	5.374	API-WJ
	35110			350.342	CROWN-SAD	7.00E+02	20.000	-8.74E+01	1.057	1.000	8.19E+07
				47.268	KTK	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
		Fail	6.54E+00	3.06E+00	CHORD-SID	13	EFTHYMIOU	2.500	2.500	4.293	API-WJ
				350.342	CROWN-SAD	7.00E+02	20.000	-8.74E+01	1.392	1.000	8.17E+07
				47.268	KTK	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
	55112	**Fail**	2.51E+01	7.96E-01	CHORD-SID	10	EFTHYMIOU	2.652	2.500	7.109	API-WJ
	35110			7.125	CROWN-SAD	7.00E+02	25.000	-8.74E+01	1.392	1.000	8.74E+07
				90.000	KTT	1.60E+03	60.000	3.93E+04	0.700	2.652	2.652
		Fail	1.51E+01	1.32E+00	BRACE-SID	10	EFTHYMIOU	3.125	2.500	7.889	API-WJ
				7.125	CROWN-SAD	7.00E+02	25.000	-8.74E+01	1.118	1.000	8.72E+07
				90.000	KTT	1.60E+03	60.000	3.93E+04	0.700	3.125	3.125
	56115	**Fail**	3.19E+01	6.28E-01	CHORD-SID	13	EFTHYMIOU	3.419	2.500	6.972	API-WJ
	35110			7.224	CROWN-SAD	7.00E+02	25.000	-5.71E+02	1.392	1.000	1.05E+08

				80.465	KTK	1.60E+03	60.000	3.93E+04	0.700	3.419	3.419
		Fail	2.18E+01	9.18E-01	BRACE-SID	13	EFTHYMIOU	3.653	2.500	7.736	API-WJ
				7.224	CROWN-SAD	7.00E+02	25.000	-5.71E+02	1.118	1.000	1.05E+08
				80.465	KTK	1.60E+03	60.000	3.93E+04	0.700	3.653	3.653
	55317	**Fail**	4.77E+00	4.19E+00	BRACE-SID	1	EFTHYMIOU	6.218	2.500	3.876	API-WJ
	35110			0.000	CROWN-SAD	7.00E+02	20.000	0.00E+00	1.057	1.000	8.55E+07
				82.875	YT	1.60E+03	60.000	3.93E+04	0.700	3.335	6.218
		Fail	6.95E+00	2.88E+00	CHORD-SID	22	EFTHYMIOU	3.997	2.500	3.096	API-WJ
				0.000	CROWN-SAD	7.00E+02	20.000	0.00E+00	1.392	1.000	8.19E+07
				82.875	YT	1.60E+03	60.000	3.93E+04	0.700	3.663	4.332
5120	55117	**Fail**	5.68E+00	3.52E+00	BRACE-SID	7	EFTHYMIOU	3.542	2.500	4.348	API-WJ
	35120			7.125	CROWN-SAD	7.00E+02	25.000	0.00E+00	1.118	1.000	9.10E+07
				90.000	YT	1.60E+03	60.000	3.93E+04	0.700	3.542	6.919
		Fail	1.36E+01	1.47E+00	CHORD-SID	7	EFTHYMIOU	4.599	2.500	3.918	API-WJ
				7.125	CROWN-SAD	7.00E+02	25.000	0.00E+00	1.392	1.000	9.12E+07
				90.000	YT	1.60E+03	60.000	3.93E+04	0.700	4.599	5.546
	35415	**Fail**	2.53E+00	7.92E+00	BRACE-SID	1	EFTHYMIOU	2.500	2.541	4.436	API-WJ
	35120			0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.057	1.000	8.55E+07
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
		Fail	3.26E+00	6.14E+00	CHORD-SID	1	EFTHYMIOU	2.500	2.500	3.544	API-WJ
				0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.392	1.000	8.53E+07
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
	55417	**Fail**	9.31E+00	2.15E+00	BRACE-SID	7	EFTHYMIOU	2.604	2.500	4.860	API-WJ
	35120			0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.057	1.000	9.04E+07
				82.875	K	1.60E+03	60.000	3.93E+04	0.700	2.604	2.604
		Fail	2.40E+01	8.33E-01	CHORD-SID	7	EFTHYMIOU	2.500	2.500	3.882	API-WJ
				0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.392	1.000	9.04E+07
				82.875	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
5210	55212	**Fail**	4.33E+00	4.62E+00	CHORD-SID	7	EFTHYMIOU	3.013	2.500	4.326	API-WJ
	35210			352.875	CROWN-SAD	7.00E+02	25.000	-1.94E+01	1.392	1.000	9.10E+07
				90.000	K	1.60E+03	60.000	3.93E+04	0.700	3.013	3.013
		Fail	2.05E+00	9.73E+00	BRACE-SID	7	EFTHYMIOU	3.429	2.590	4.801	API-WJ
				352.875	CROWN-SAD	7.00E+02	25.000	-1.94E+01	1.118	1.000	9.10E+07
				90.000	K	1.60E+03	60.000	3.93E+04	0.700	3.429	3.429
	45312	**Fail**	2.17E+00	9.21E+00	BRACE-SID	1	EFTHYMIOU	2.500	2.541	4.436	API-WJ
	35210			0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.057	1.000	8.66E+07
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
		Fail	2.96E+00	6.76E+00	CHORD-SID	1	EFTHYMIOU	2.500	2.500	3.544	API-WJ

```
                                        0.000  CROWN-SAD  7.00E+02  20.000   -1.76E+02  1.392  1.000     8.65E+07
                                       58.718  K          1.60E+03  60.000    3.93E+04  0.700  2.500       2.500

        55312          **Fail**  1.16E+00  1.73E+01 CHORD-SID         4 EFTHYMIOU   2.500    2.500  3.882 API-WJ
        35210                                  0.000  CROWN-SAD  7.00E+02  20.000   -1.76E+02  1.392  1.000     9.18E+07
                                              82.875  K          1.60E+03  60.000    3.93E+04  0.700  2.500       2.500

5220    55217          **Fail**  3.99E+00  5.01E+00 BRACE-SID         4 EFTHYMIOU   3.429    2.590  4.801 API-WJ
        35220                                352.875  CROWN-SAD  7.00E+02  25.000   -1.94E+01  1.118  1.000     8.62E+07
                                              90.000  K          1.60E+03  60.000    3.93E+04  0.700  3.429       3.429
                       **Fail**  7.11E+00  2.81E+00 CHORD-SID         4 EFTHYMIOU   3.013    2.500  4.326 API-WJ
                                            352.875  CROWN-SAD  7.00E+02  25.000   -1.94E+01  1.392  1.000     8.63E+07
                                              90.000  K          1.60E+03  60.000    3.93E+04  0.700  3.013       3.013

        55412          **Fail**  2.38E+01  8.41E-01 CHORD-SID         7 EFTHYMIOU   3.663    2.500  3.096 API-WJ
        35220                                  0.000  CROWN-SAD  7.00E+02  20.000    0.00E+00  1.392  1.000     9.09E+07
                                              82.875  YT         1.60E+03  60.000    3.93E+04  0.700  3.663       4.332
                       **Fail**  8.95E+00  2.23E+00 BRACE-SID         7 EFTHYMIOU   3.335    2.500  3.876 API-WJ
                                              0.000  CROWN-SAD  7.00E+02  20.000    0.00E+00  1.057  1.000     9.08E+07
                                              82.875  YT         1.60E+03  60.000    3.93E+04  0.700  3.335       6.218
```


SPECTRAL fatigue check results

Run: SPECFAT2 | Superelement: JACKET | Loadset: WAVE_LOADS

Priority....: Selected Joints

Usage factor: Above 0.00

NOMENCLATURE:

Joint	Name of joint
Brace	Member name of the brace
Outcome	Outcome message from the code check
Damage	Accumulated damage
Life	Fatigue life
WeldSide	Side of weld
Hot	Hotspot (stress point) with maximum damage

```
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
Chord       Member name of the corresponding chord
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)
```

```
DATE: 12-MAY-2016 TIME: 10:00:36   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                                PAGE:     4

                                SPECTRAL         fatigue check results
                                Run:      Superelement:     Loadset:
                                SPECFAT2  JACKET            WAVE_LOADS
                                Priority....: Selected Joints
                                Usage factor: Above   0.00                                                  SUB PAGE:     2

Joint    Brace          Outcome   Damage     Life    WeldSide        Hot SCFrule    SCFax    SCFipb SCFopb SNcurve
         Chord                              Alpha    Symmet     DiaBra    ThiBra      Gap    ThiFac   QR       Cycles
                                            Theta    Jtype      DiaCho    ThiCho    LenCho   FixCho SCFaxC      SCFaxS
-------------------------------------------------------------------------------------------------------------------------
5110     35115          **Fail**  1.01E+01  1.98E+00 BRACE-SID        13 EFTHYMIOU   2.500    2.500  5.374 API-WJ-FC
         35110                              350.342  CROWN-SAD  7.00E+02  20.000   -8.74E+01  1.057  1.000     8.19E+07
                                             47.268  KTK        1.60E+03  60.000    3.93E+04  0.700  2.500       2.500
                         **Fail**  1.26E+01  1.59E+00 CHORD-SID        13 EFTHYMIOU   2.500    2.500  4.293 API-WJ-FC
                                            350.342  CROWN-SAD  7.00E+02  20.000   -8.74E+01  1.392  1.000     8.17E+07
                                             47.268  KTK        1.60E+03  60.000    3.93E+04  0.700  2.500       2.500
```

	55112	**Fail**	4.19E+01	4.78E-01	CHORD-SID	10	EFTHYMIOU	2.652	2.500	7.109	API-WJ-FC	
	35110			7.125	CROWN-SAD	7.00E+02	25.000	-8.74E+01	1.392	1.000	8.74E+07	
				90.000	KTT	1.60E+03	60.000	3.93E+04	0.700	2.652	2.652	
		Fail	2.65E+01	7.53E-01	BRACE-SID	10	EFTHYMIOU	3.125	2.500	7.889	API-WJ-FC	
				7.125	CROWN-SAD	7.00E+02	25.000	-8.74E+01	1.118	1.000	8.72E+07	
				90.000	KTT	1.60E+03	60.000	3.93E+04	0.700	3.125	3.125	
	56115	**Fail**	5.27E+01	3.80E-01	CHORD-SID	13	EFTHYMIOU	3.419	2.500	6.972	API-WJ-FC	
	35110			7.224	CROWN-SAD	7.00E+02	25.000	-5.71E+02	1.392	1.000	1.05E+08	
				80.465	KTK	1.60E+03	60.000	3.93E+04	0.700	3.419	3.419	
		Fail	3.73E+01	5.36E-01	BRACE-SID	13	EFTHYMIOU	3.653	2.500	7.736	API-WJ-FC	
				7.224	CROWN-SAD	7.00E+02	25.000	-5.71E+02	1.118	1.000	1.05E+08	
				80.465	KTK	1.60E+03	60.000	3.93E+04	0.700	3.653	3.653	
	55317	**Fail**	9.88E+00	2.02E+00	BRACE-SID	1	EFTHYMIOU	6.218	2.500	3.876	API-WJ-FC	
	35110			0.000	CROWN-SAD	7.00E+02	20.000	0.00E+00	1.057	1.000	8.55E+07	
				82.875	YT	1.60E+03	60.000	3.93E+04	0.700	3.335	6.218	
		Fail	1.34E+01	1.50E+00	CHORD-SID	22	EFTHYMIOU	3.997	2.500	3.096	API-WJ-FC	
				0.000	CROWN-SAD	7.00E+02	20.000	0.00E+00	1.392	1.000	8.19E+07	
				82.875	YT	1.60E+03	60.000	3.93E+04	0.700	3.663	4.332	
5120	55117	**Fail**	1.21E+01	1.65E+00	BRACE-SID	7	EFTHYMIOU	3.542	2.500	4.348	API-WJ-FC	
	35120			7.125	CROWN-SAD	7.00E+02	25.000	0.00E+00	1.118	1.000	9.10E+07	
				90.000	YT	1.60E+03	60.000	3.93E+04	0.700	3.542	6.919	
		Fail	2.47E+01	8.11E-01	CHORD-SID	7	EFTHYMIOU	4.599	2.500	3.918	API-WJ-FC	
				7.125	CROWN-SAD	7.00E+02	25.000	0.00E+00	1.392	1.000	9.12E+07	
				90.000	YT	1.60E+03	60.000	3.93E+04	0.700	4.599	5.546	
	35415	**Fail**	5.75E+00	3.48E+00	BRACE-SID	1	EFTHYMIOU	2.500	2.541	4.436	API-WJ-FC	
	35120			0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.057	1.000	8.55E+07	
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500	
		Fail	7.05E+00	2.84E+00	CHORD-SID	1	EFTHYMIOU	2.500	2.500	3.544	API-WJ-FC	
				0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.392	1.000	8.53E+07	
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500	
	55417	**Fail**	1.79E+01	1.12E+00	BRACE-SID	7	EFTHYMIOU	2.604	2.500	4.860	API-WJ-FC	
	35120			0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.057	1.000	9.04E+07	
				82.875	K	1.60E+03	60.000	3.93E+04	0.700	2.604	2.604	
		Fail	4.05E+01	4.94E-01	CHORD-SID	7	EFTHYMIOU	2.500	2.500	3.882	API-WJ-FC	
				0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.392	1.000	9.04E+07	
				82.875	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500	
5210	45212	**Fail**	1.74E+00	1.15E+01	BRACE-SID	13	EFTHYMIOU	2.500	2.656	3.766	API-WJ-FC	

	35210			9.658	CROWN-SAD	6.00E+02	25.000	-1.94E+01	1.118	1.000	8.48E+07
				47.269	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
		Fail	2.26E+00	8.83E+00	CHORD-SID	13	EFTHYMIOU	2.500	2.500	3.277	API-WJ-FC
				9.658	CROWN-SAD	6.00E+02	25.000	-1.94E+01	1.392	1.000	8.49E+07
				47.269	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
	55212	**Fail**	9.82E+00	2.04E+00	CHORD-SID	7	EFTHYMIOU	3.013	2.500	4.326	API-WJ-FC
	35210			352.875	CROWN-SAD	7.00E+02	25.000	-1.94E+01	1.392	1.000	9.10E+07
				90.000	K	1.60E+03	60.000	3.93E+04	0.700	3.013	3.013
		Fail	5.76E+00	3.47E+00	BRACE-SID	7	EFTHYMIOU	3.429	2.590	4.801	API-WJ-FC
				352.875	CROWN-SAD	7.00E+02	25.000	-1.94E+01	1.118	1.000	9.10E+07
				90.000	K	1.60E+03	60.000	3.93E+04	0.700	3.429	3.429
	45312	**Fail**	5.46E+00	3.66E+00	BRACE-SID	1	EFTHYMIOU	2.500	2.541	4.436	API-WJ-FC
	35210			0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.057	1.000	8.66E+07
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
		Fail	6.90E+00	2.90E+00	CHORD-SID	1	EFTHYMIOU	2.500	2.500	3.544	API-WJ-FC
				0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.392	1.000	8.65E+07
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
	55312	**Fail**	3.80E+00	5.26E+00	CHORD-SID	4	EFTHYMIOU	2.500	2.500	3.882	API-WJ-FC
	35210			0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.392	1.000	9.18E+07
				82.875	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
		Fail	2.21E+00	9.06E+00	BRACE-SID	4	EFTHYMIOU	2.604	2.500	4.860	API-WJ-FC
				0.000	CROWN-SAD	7.00E+02	20.000	-1.76E+02	1.057	1.000	9.17E+07
				82.875	K	1.60E+03	60.000	3.93E+04	0.700	2.604	2.604
5220	45217	**Fail**	1.82E+00	1.10E+01	BRACE-SID	13	EFTHYMIOU	2.500	2.656	3.766	API-WJ-FC
	35220			350.342	CROWN-SAD	6.00E+02	25.000	-1.94E+01	1.118	1.000	7.95E+07
				47.269	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
		Fail	2.39E+00	8.36E+00	CHORD-SID	13	EFTHYMIOU	2.500	2.500	3.277	API-WJ-FC
				350.342	CROWN-SAD	6.00E+02	25.000	-1.94E+01	1.392	1.000	7.96E+07
				47.269	K	1.60E+03	60.000	3.93E+04	0.700	2.500	2.500
	55217	**Fail**	8.94E+00	2.24E+00	BRACE-SID	4	EFTHYMIOU	3.429	2.590	4.801	API-WJ-FC
	35220			352.875	CROWN-SAD	7.00E+02	25.000	-1.94E+01	1.118	1.000	8.62E+07
				90.000	K	1.60E+03	60.000	3.93E+04	0.700	3.429	3.429
		Fail	1.40E+01	1.42E+00	CHORD-SID	4	EFTHYMIOU	3.013	2.500	4.326	API-WJ-FC
				352.875	CROWN-SAD	7.00E+02	25.000	-1.94E+01	1.392	1.000	8.63E+07
				90.000	K	1.60E+03	60.000	3.93E+04	0.700	3.013	3.013
	55412	**Fail**	4.02E+01	4.98E-01	CHORD-SID	7	EFTHYMIOU	3.663	2.500	3.096	API-WJ-FC
	35220			0.000	CROWN-SAD	7.00E+02	20.000	0.00E+00	1.392	1.000	9.09E+07
				82.875	YT	1.60E+03	60.000	3.93E+04	0.700	3.663	4.332

```
                    **Fail**  1.73E+01  1.15E+00 BRACE-SID         7 EFTHYMIOU   3.335    2.500  3.876 API-WJ-FC
                                0.000  CROWN-SAD  7.00E+02  20.000    0.00E+00  1.057  1.000     9.08E+07
                               82.875  YT         1.60E+03  60.000    3.93E+04  0.700  3.335       6.218



DATE: 12-MAY-2016 TIME: 10:00:36   PROGRAM: SESAM    FRAMEWORK 3.13-00 11-MAY-2016                              PAGE:     5


                                SPECTRAL         fatigue check results
                                Run:      Superelement:     Loadset:
                                SPECFAT3  JACKET            WAVE_LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                              SUB PAGE:     1


NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
```

DiaCho Chord diameter
ThiCho Chord thickness
LenCho Chord length
FixCho Chord end fixity parameter
SCFaxC SCF for axial force at Crown (Hotspot 7)
SCFaxS SCF for axial force at Saddle (Hotspot 1)

DATE: 12-MAY-2016 TIME: 10:00:36 PROGRAM: SESAM FRAMEWORK 3.13-00 11-MAY-2016 PAGE: 6

SPECTRAL fatigue check results
Run: Superelement: Loadset:
SPECFAT3 JACKET WAVE_LOADS
Priority....: Selected Members
Usage factor: Above 0.00 SUB PAGE: 2

Member	Type / SctNam	Joint/Po	Outcome	Damage	Life / Alpha / Theta	WeldSide / Symmet / Jtype	Hot / DiaBra / DiaCho	SCFrule / ThiBra / ThiCho	SCFax / Gap / LenCho	SCFipb / ThiFac / FixCho	SCFopb / QR / SCFaxC	SNcurve / Cycles / SCFaxS
33115	PIPE	3110		3.24E-08	6.17E+08	BOTH-SIDE	19	LOCAL	1.000	1.000	0.000	USE-X
	50025				7.125	NON-SYMME	5.00E+02	25.000	0.00E+00	1.000	1.000	8.18E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	0.700	1.000	1.000
		3120		5.60E-08	3.57E+08	BOTH-SIDE	7	LOCAL	1.000	1.000	0.000	USE-X
					7.125	NON-SYMME	5.00E+02	25.000	1.26E+01	1.000	1.000	8.23E+07
					90.000	K	1.60E+03	60.000	3.63E+04	0.700	1.000	1.000
33215	PIPE	3210		1.22E-03	1.64E+04	CHORD-SID	10	WORDSWORT	5.991	2.500	2.602	USE-X
	50025				352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	7.80E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	0.700	5.991	5.991
		3210		2.56E-03	7.82E+03	BRACE-SID	10	WORDSWORT	8.081	2.500	2.909	USE-X
					352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	7.85E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	0.700	8.081	8.081
		3220		2.72E-03	7.36E+03	BRACE-SID	10	WORDSWORT	8.081	2.500	2.909	USE-X
					352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800	7.43E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	0.700	8.081	8.081
		3220		1.33E-03	1.50E+04	CHORD-SID	10	WORDSWORT	5.991	2.500	2.602	USE-X
					352.875	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000	7.39E+07
					90.000	YT	1.60E+03	60.000	3.63E+04	0.700	5.991	5.991
33415	PIPE	3220		4.59E-03	4.35E+03	CHORD-SID	10	KUANG	2.500	2.500	2.571	USE-X
	50025				0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	1.000	7.67E+07

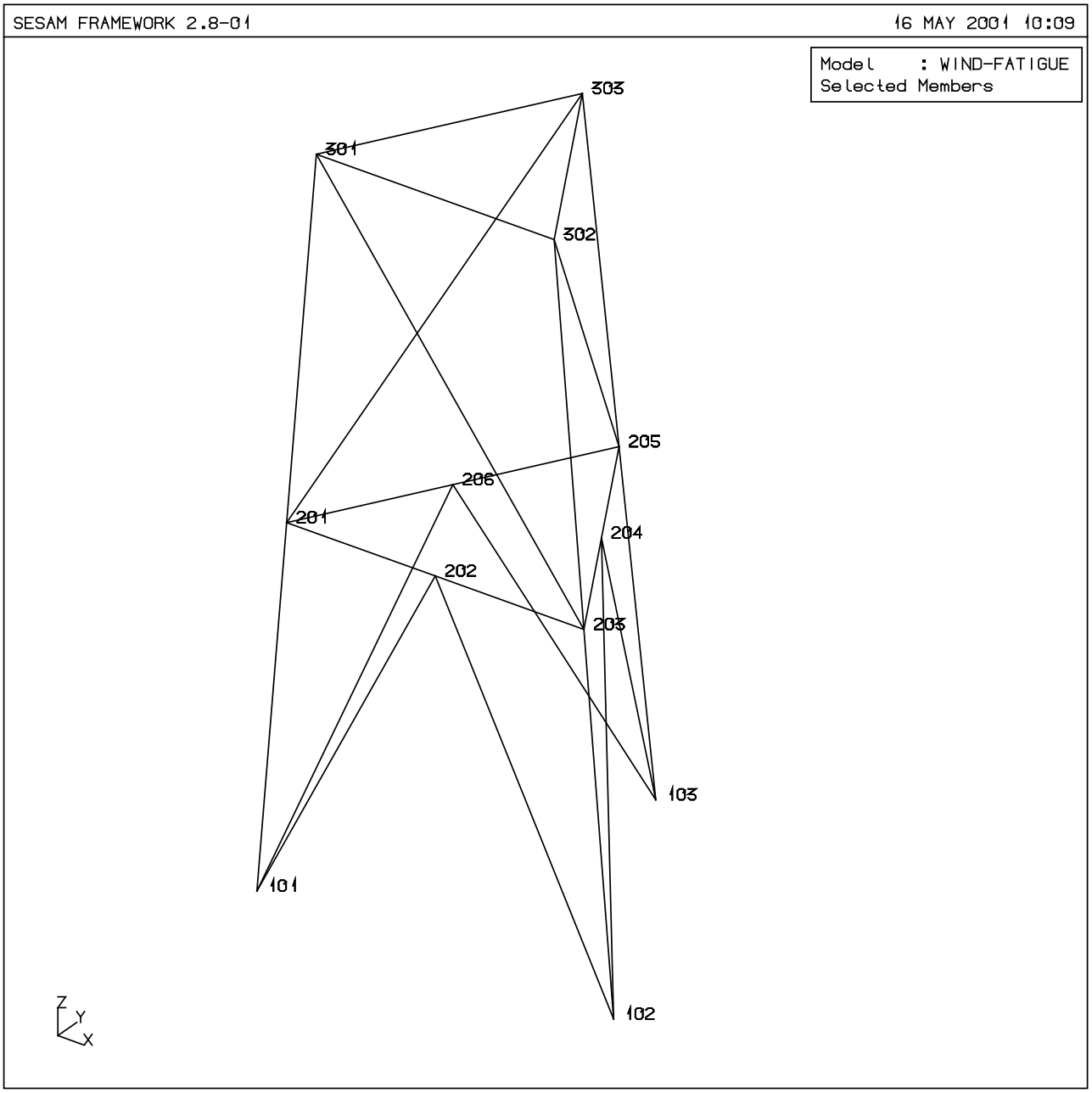
				82.875	K	1.60E+03	60.000	3.63E+04	0.700	2.500		2.500	
		3220	1.17E-02	1.71E+03	BRACE-SID	10	KUANG	3.182	2.692	2.866	USE-X		
				0.000	CROWN-SAD	5.00E+02	25.000	1.00E+00	1.000	0.800		7.71E+07	
				82.875	K	1.60E+03	60.000	3.63E+04	0.700	3.182		3.182	
		3120	5.59E-02	3.58E+02	BRACE-SID	22	KUANG	7.964	2.500	2.866	USE-X		
				0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	0.800		8.52E+07	
				82.875	YT	1.60E+03	60.000	3.63E+04	0.700	7.964		7.964	
		3120	2.05E-02	9.76E+02	CHORD-SID	22	KUANG	5.913	2.500	2.571	USE-X		
				0.000	CROWN-SAD	5.00E+02	25.000	0.00E+00	1.000	1.000		8.45E+07	
				82.875	YT	1.60E+03	60.000	3.63E+04	0.700	5.913		5.913	
35415	PIPE	3220	7.47E-02	2.68E+02	CHORD-SID	4	KUANG	2.500	2.500	2.500	USE-X		
	70020			0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	1.000		8.05E+07	
				44.468	K	1.60E+03	60.000	3.63E+04	0.700	2.500		2.500	
		3220	7.47E-02	2.68E+02	BRACE-SID	4	KUANG	2.500	2.500	2.500	USE-X		
				0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	0.800		8.05E+07	
				44.468	K	1.60E+03	60.000	3.63E+04	0.700	2.500		2.500	
		5120	2.46E-01	8.13E+01	BRACE-SID	7	KUANG	2.500	2.500	2.500	USE-X		
				0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	0.800		8.55E+07	
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500		2.500	
		5120	2.46E-01	8.13E+01	CHORD-SID	7	KUANG	2.500	2.500	2.500	USE-X		
				0.000	CROWN-SAD	7.00E+02	20.000	1.00E+00	1.000	1.000		8.55E+07	
				58.718	K	1.60E+03	60.000	3.93E+04	0.700	2.500		2.500	

A.2 Example 2 – Wind induced fatigue

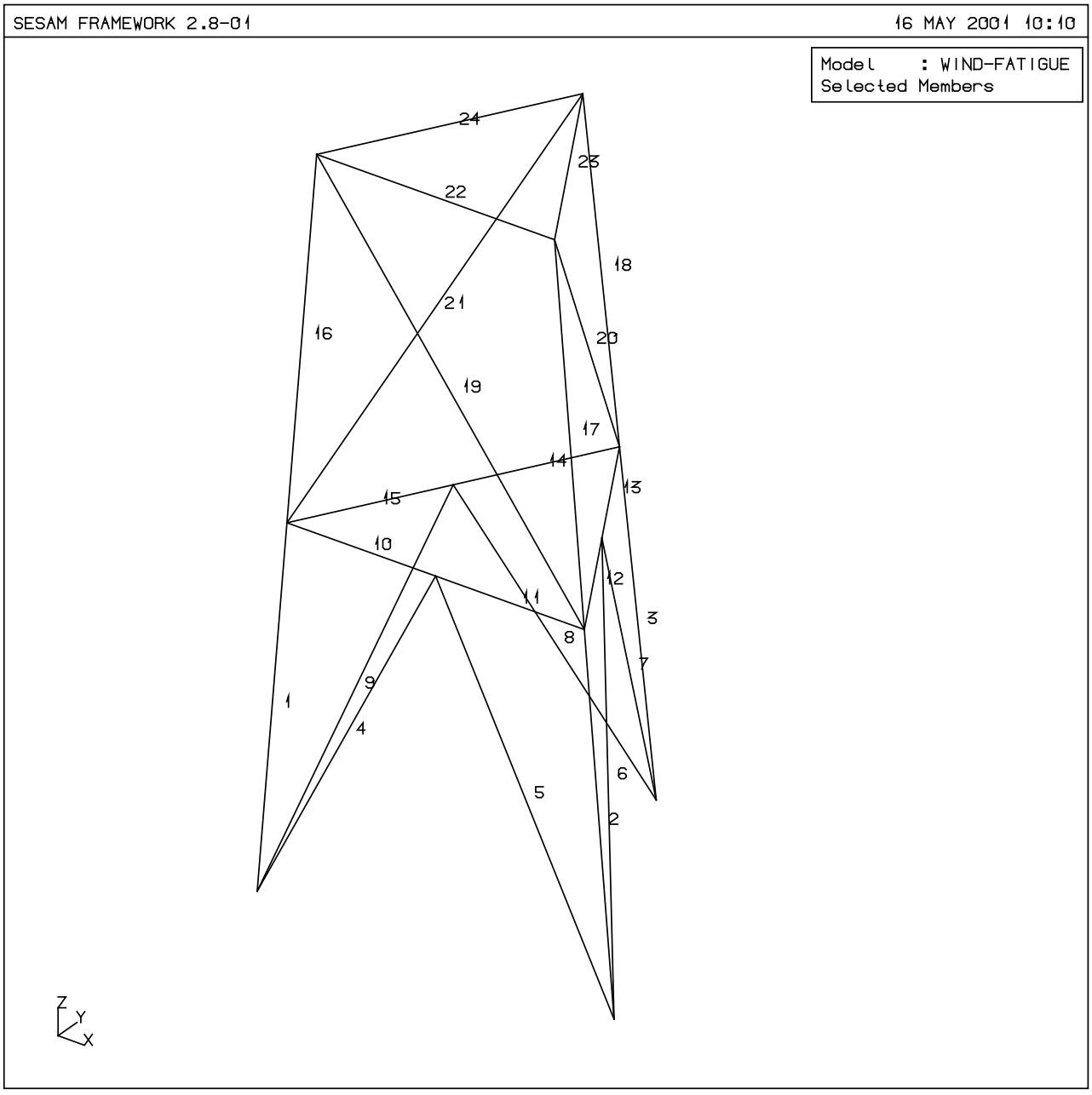
In this example a 3 dimensional jacket structure is used to show a wind fatigue analysis.

The example is denoted `X505` in the Sesam regression test data base from which test `X505B` is added to the current appendix.

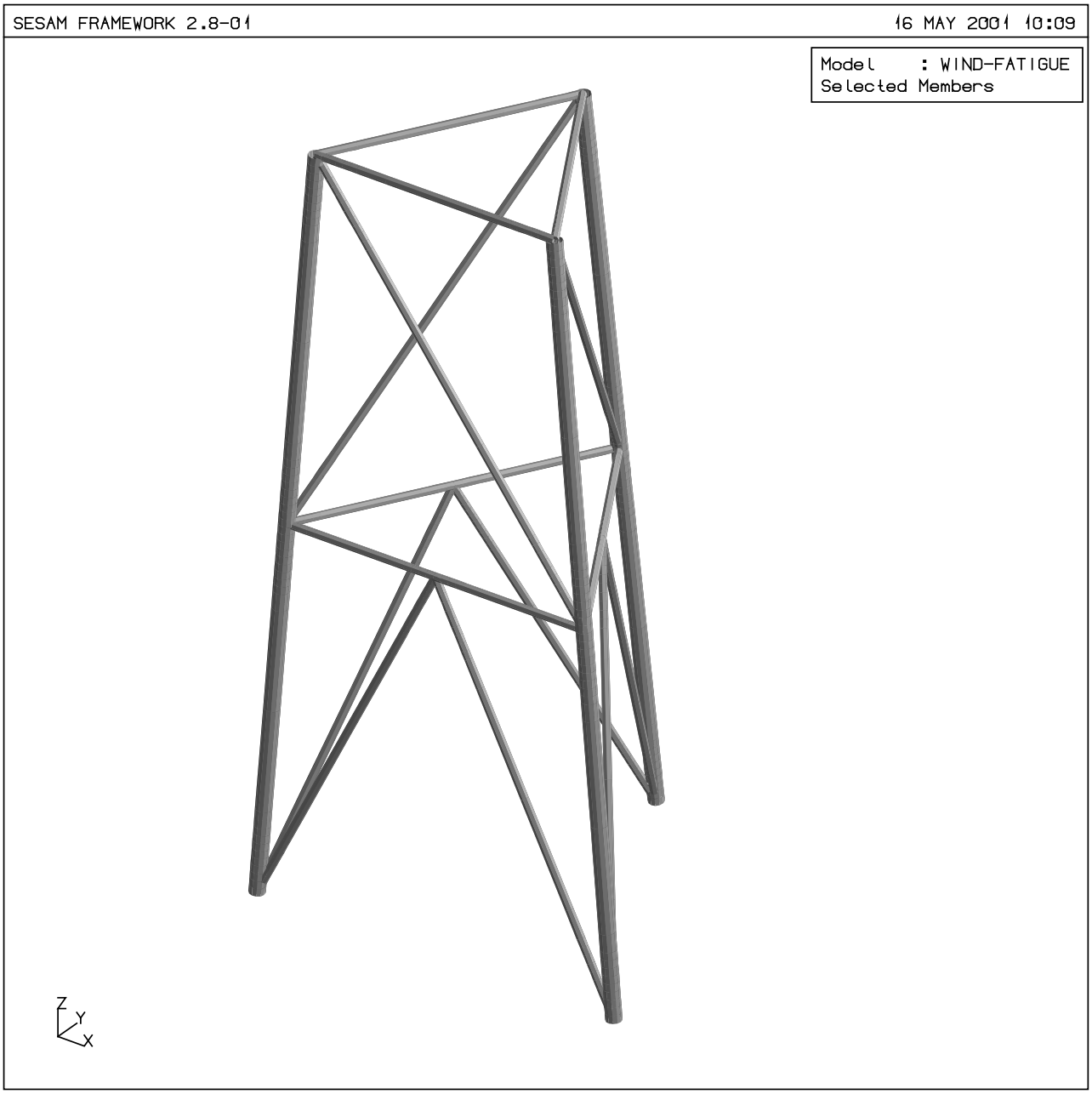
A.2.1 Joint numbers



A.2.2 Member numbers



A.2.3 Shaded view



A.2.4 Prepost journal file for converting SIF to SIN – X505BREPOST_IN.JNL

```
%%
%% OPENED DATE: 04-SEP-2000  12:29:29
%%
%% PROGRAM:  SESAM PREPOST       VERSION:      6.3-01 21-JAN-2000
%% COMPUTER: 586 WIN NT 4.0 [1381INSTALLATION: DNVS OSLPCN20
%% USER:     TTAN                ACCOUNT:
%%
 SET PERMANENT-WORKING-FILE X505B R1
 END
 READ SIF-FORMATTED X505B R1 ALL
%%
%% CLOSED DATE: 04-SEP-2000  12:29:29
%%
```

A.2.5 Framework journal file for wind fatigue – X505BFRAMEWORK_IN.JNL

```
%%
%% X505B - Framework wind induced fatigue.
%%
%% Reduced in number of analyses compared to X505A
%% for the Framework wind example in the user manual.
%% That is, only test 3 is run for the UM data.
%%
DEFINE READ-CONCEPTS OFF
FILE OPEN SIN-DIRECT-ACCESS X505B R1
FILE TRANSFER 1 JACKET LOADS None
DEFINE FATIGUE-CONSTANTS AXIAL-MINIMUM-SCF 1.6
DEFINE FATIGUE-CONSTANTS IN-PLANE-MINIMUM-SCF 1.6
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-MINIMUM 1.6
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 1.6
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 1.6
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 1.6
DEFINE WIND-FATIGUE WIND-DIRECTIONS ( ONLY 0.0  30.0  60.0  90.0  120.0 150.0 ) 10.0
%%CREATE WIND-FATIGUE STATIC-WIND-LOADS FEM-SEQUENTIAL X505B L1
DEFINE WIND-FATIGUE WIND-SPEEDS ( ONLY
    10.0 15.0 20.0 25.0 30.0 )
DEFINE WIND-FATIGUE WIND-PROBABILITIES VARIABLE-PROBABILITIES ( ONLY
    0.30 0.25 0.20 0.15 0.10
    0.35 0.20 0.20 0.15 0.10
    0.40 0.20 0.15 0.15 0.10
    0.20 0.20 0.20 0.20 0.20
    0.30 0.25 0.20 0.15 0.10
    0.36 0.22 0.21 0.11 0.10 )
DEFINE WIND-FATIGUE DRAG-CORRECTION-FACTORS VARIABLE-FACTORS ( ONLY
    1.00 0.90 0.80 0.75 0.70
    1.01 0.91 0.81 0.76 0.71
    1.02 0.92 0.82 0.77 0.72
    1.03 0.93 0.83 0.78 0.73
    1.04 0.94 0.84 0.79 0.74
    1.05 0.95 0.85 0.80 0.75 )
DEFINE WIND-FATIGUE DEFAULT-MEMBER-FIXITIES 0.2 0.8 5
DEFINE WIND-FATIGUE VORTEX-PARAMETERS 1.225 0.000015 1.0 0.2 4.0 0.1 2.0E11 7380.
    1.0E-04 1245. 1.6
CREATE WIND-FATIGUE ANALYSIS-PLANES ( ONLY
    101   203   301
    102   205   302
    103   201   303
    201   203   205)
%%ASSIGN WIND-FATIGUE WIND-PROFILE API 1.0
%%ASSIGN WIND-FATIGUE WIND-PROFILE NORSOK-NORMAL-WIND 1.0
%%ASSIGN WIND-FATIGUE WIND-PROFILE NORSOK-EXTREME-WIND 1.0
ASSIGN WIND-FATIGUE VORTEX-FIXITY MEMBER-ENDS ( ONLY
    201   202   4   0.1   0.9   0.3   0.7
    202   203   3   0.0   1.0   0.0   1.0
    203   202   5   0.1   0.95  0.1   0.95
    205   302   2   0.4   0.6   0.4   0.6 )
SELECT JOINTS INCLUDE ALL
SELECT MEMBERS INCLUDE ALL
ASSIGN WIND-FATIGUE SN-CURVE JOINT CURRENT ( ) DOE-T
%%ASSIGN WIND-FATIGUE JOINT-SCF EFTHYMIOU
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 201
SELECT MEMBERS EXCLUDE ALL
SELECT MEMBERS INCLUDE 10
```

```
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 8.09 11.55 3.31 8.32
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 4.18  9.05 2.85 6.27
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 15
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 6.95 6.95 3.31 8.55
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 5.66 5.66 2.85 6.44
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 21
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 3.78 3.78 2.16 5.41
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.65 2.65 3.30 4.08
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 202
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 4
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 4.21 4.21 2.64 5.86
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.56 2.56 2.38 3.16
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 5
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 4.21 4.21 2.64 5.86
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.56 2.56 2.38 3.16
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 203
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 11
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 6.97 6.97 3.31 8.49
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 5.66 5.66 2.85 6.39
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 12
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 3.00 3.00 4.24 4.24
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 3.00 3.00 4.24 4.24
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 19
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 3.72 3.72 2.13 5.32
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.60 2.60 3.32 4.01
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 204
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 6
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 4.32 4.32 2.67 5.92
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.62 2.62 2.36 3.20
SELECT MEMBERS EXCLUDE CURRENT
```

```
SELECT MEMBERS INCLUDE 7
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 4.18 4.18 2.61 5.81
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.53 2.53 2.39 3.13
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 205
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 13
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 6.99 6.99 3.30 8.41
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 5.66 5.66 2.85 6.33
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 14
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 8.08 11.53 3.30 8.26
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 4.18  8.98 2.85 6.22
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 20
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 3.65 3.65 2.09 5.20
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.54 2.54 3.34 3.91
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 206
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 9
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( )  LOCAL CHORD-SIDE
    CROWN-SADDLE 4.32 4.32 2.67 5.92
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.62 2.62 2.36 3.20
SELECT MEMBERS EXCLUDE CURRENT
SELECT MEMBERS INCLUDE 8
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL CHORD-SIDE
    CROWN-SADDLE 4.18 4.18 2.61 5.81
ASSIGN WIND-FATIGUE JOINT-SCF READ CURRENT ( ) LOCAL BRACE-SIDE
    CROWN-SADDLE 2.53 2.53 2.39 3.13
%
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 301
SELECT JOINTS INCLUDE 302
SELECT JOINTS INCLUDE 303
SELECT MEMBERS INCLUDE ALL
ASSIGN WIND-FATIGUE JOINT-SCF READ DEFAULT ( ) PARAMETRIC EFTHYMIOU
%
SELECT JOINTS EXCLUDE CURRENT
SELECT JOINTS INCLUDE 201
SELECT JOINTS INCLUDE 203
SELECT JOINTS INCLUDE 205
ASSIGN WIND-FATIGUE BENT-CAN-SCF ( ) LOCAL 5.0 5.0 5.0 5.0 ALL
%
%
DEFINE WIND-FATIGUE COHERENCE-COEFFICIENTS 16.0 16.0 8.0 16.0 16.0 8.0 16.0
    16.0 8.0
DEFINE WIND-FATIGUE WIND-PARAMETERS
    8.0 0.015 1200.0 1800.0 DOE-T EFTHYMIOU 0.01 30.0 1.0 1.E-12 1.0E-5 1.0
ASSIGN WIND-FATIGUE RUN-SCENARIO MULTI-BRACE-CASE 1 6 101 303 1 4 2 OFF
```

```
ASSIGN WIND-FATIGUE WIND-TYPE WIND-BUFFETING
%
%*************************** RUN TESTS 0 *********************************
% 1) DO NOT USE ANY COMMAND ASSIGN WIND-FATIGUE WIND-SPECTRUM
%    FOR ALONG, LATERAL, VERTICAL. Use default.
% 2) NO COHERENCE EFFECT COH LIM = 1.0
RUN WIND-FATIGUE-CHECK X505B None
%
%*************************** RUN TESTS 1 *********************************
% 1) HARRIS, DAVENPORT AND NPD SPECTRA
% 2) ALONG WIND ONLY. NO LATRAL AND VERTICAL WIND EFFECT
% 3) NO COHERENCE EFFECT  COH LIM = 1.0
% 4) BUFFET WIND ONLY
%
%  WIND SPECTRUM LATERAL TO  WIND DIRECTION (OFF): PANOFSKY LATERAL
%  WIND SPECTRUM VERTICAL TO WIND DIRECTION (OFF): PANOFSKY VERTICAL
%  COHERENCE MODEL ALL DIRECTIONS           (OFF): GUSTO
%
%  WIND SPECTRUM ALONG       WIND DIRECTION      : HARRIS
%%ASSIGN WIND-FATIGUE WIND-SPECTRUM HARRIS OFF OFF
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U HARRIS COHERENCE-GUSTO1
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V LATERAL-OFF
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W VERTICAL-OFF
%%
RUN WIND-FATIGUE-CHECK X505B None
%
%  WIND SPECTRUM ALONG       WIND DIRECTION      : DAVENPORT (Default)
%%ASSIGN WIND-FATIGUE WIND-SPECTRUM DAVENPORT OFF OFF
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U DAVENPORT COHERENCE-GUSTO2
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V LATERAL-OFF
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W VERTICAL-OFF
%%
RUN WIND-FATIGUE-CHECK X505B None
%
%  WIND SPECTRUM ALONG       WIND DIRECTION      : NPD
%%ASSIGN WIND-FATIGUE WIND-SPECTRUM NPD OFF OFF
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U NPD COHERENCE-NPD
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V LATERAL-OFF
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W VERTICAL-OFF
%%
RUN WIND-FATIGUE-CHECK X505B None
%
%
%*************************** RUN TESTS 3 *********************************
%
% 1) HARRIS, DAVENPORT AND NPD SPECTRA
% 2) ALONG, LATERAL AND VERTICAL WIND DIRECTIONS
% 3) COHERENCE EFFECT INCLUDED. COH. LIMIT = 1.0E-3. GUSTO COHERENCE MODEL
% 4) BUFFET WIND ONLY
%
DEFINE WIND-FATIGUE WIND-PARAMETERS
    8.0 0.015 1200.0 1800.0 DOE-T EFTHYMIOU 0.01 30.0 1.0 1.E-12 1.0E-5 1.0E-3
%%ASSIGN WIND-FATIGUE COHERENCE-MODEL GUSTO
%
%  WIND SPECTRUM ALONG       WIND DIRECTION      : DAVENPORT (Default)
%  WIND SPECTRUM LATERAL TO  WIND DIRECTION (ON ): PANOFSKY LATERAL
%  WIND SPECTRUM VERTICAL TO WIND DIRECTION (ON ): PANOFSKY VERTICAL
%  COHERENCE MODEL ALL DIRECTIONS           (ON ): GUSTO
%
```

```
%  WIND SPECTRUM ALONG       WIND DIRECTION      : HARRIS
%%ASSIGN WIND-FATIGUE WIND-SPECTRUM HARRIS ON ON
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U HARRIS COHERENCE-GUST01
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V PANOFSKY-LATERAL COHERENCE-GUST02
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W PANOFSKY-VERTICAL COHERENCE-GUST02
%%
RUN WIND-FATIGUE-CHECK X505B None
%
%  WIND SPECTRUM ALONG       WIND DIRECTION      : DAVENPORT (Default)
%%ASSIGN WIND-FATIGUE WIND-SPECTRUM DAVENPORT ON ON
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U DAVENPORT COHERENCE-GUST02
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V PANOFSKY-LATERAL COHERENCE-GUST02
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W PANOFSKY-VERTICAL COHERENCE-GUST02
%%
RUN WIND-FATIGUE-CHECK X505B None
%
%  WIND SPECTRUM ALONG       WIND DIRECTION      : NPD
%%ASSIGN WIND-FATIGUE WIND-SPECTRUM NPD ON ON
ASSIGN WIND-FATIGUE WIND-SPECTRUM-U NPD COHERENCE-NPD
ASSIGN WIND-FATIGUE WIND-SPECTRUM-V PANOFSKY-LATERAL COHERENCE-GUST02
ASSIGN WIND-FATIGUE WIND-SPECTRUM-W PANOFSKY-VERTICAL COHERENCE-GUST02
%%
RUN WIND-FATIGUE-CHECK X505B None
%
%
EXIT
```

A.2.6 Framework results from wind fatigue

A.2.6.1 Listing file – X505BFrameworkWind.Lis

```
  ******      ******       ******       ******      ** ***  ****
 ********    ********     ********     ********     **************
**      **  **      **   **      **   **      **    **    **    **
**          **      **   **                  **    **    **    **
 *******    **********    *******      *********    **    **    **
  *******   *********      *******    **********    **    **    **
        **  **                    **   **      **    **    **    **
**      **  **      **   **      **   **      **    **    **    **
 ********    ********     ********     *********    **    **    **
  ******      ******       ******       ****** **   **    **    **


              ******************************************
              *                                        *
              *            F R A M E W O R K           *
              *                                        *
              *    Postprocessing of Frame Structures  *
              *                                        *
              ******************************************

                  Marketing and Support by DNV GL - Software

 Program id   : D3.14-03                Computer         : 586
 Release date : 17-MAR-2017             Impl. update     :
 Access time  : 24-MAR-2017 15:44:58    Operating system : Win NT 6.1 [7601]
 User id      : lzhan                   CPU id           : 0405880964
                                        Installation     : , HOUL130304

 Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway



************************************************************************

PRINT OF                : WIND FATIGUE RESULTS

RUN NAME                : X505B
RUN DESCRIPTION         : None
```

```
RESULTS INTERFACE FILE  : X505BR1.SIN
PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  15:44:58

************************************************************************

RUN SCENARIO:
=============
ANALYSIS CASE              : MULTI BRACE FATIGUE CHECK
FIRST WIND DIRECTION       : 1
LAST  WIND DIRECTION       : 6
FIRST NODE CHECKED         : 101
LAST  NODE CHECKED         : 303
FIRST ANALYSIS PLANE       : 1
LAST  ANALYSIS PLANE       : 4
NUMBER OF EIGENMODES       : 2
SHOW PROGRESS OF EXECUTION : OFF

WIND LOAD MODELLING:
====================
WIND LOAD TYPE             : WIND BUFFETING
WIDE BAND CORRECTION       : NONE
WIND PROFILE               : API (WIND PROFILE TYPE READ FROM SIN FILE)
GUST COMPONENTS CONSIDERED : ALL (ALONG + ACROSS WIND COMPONENTS)
GUST DIRECTION MOMENT      : DAMAGE BY ADD OF GUST SPECTRUM MOMENTS
WIND SPECTRA :
    LONGITUDINAL DIRECTION : DAVENPORT
    LATERAL      DIRECTION : PANOFSKY LATERAL
    VERTICAL     DIRECTION : PANOFSKY VERTICAL
COHERENCE FUNCTIONS :
    LONGITUDINAL DIRECTION : GUST02
    LATERAL      DIRECTION : GUST02
    VERTICAL     DIRECTION : GUST02

INPUT DATA:
===========

PARAMETERS READ FROM SIN FILE :
(l = current length unit)
------------------------------

WATER DEPTH - WD  (l)                          : 10.0
Z-COORDINATE OF MUDLINE - ZMUD  (l)            : -10.0
Z-COORDINATE OF STILL WATER LEVEL/GROUND  (l)   : 0.0
                       (Z0 = ZMUD + WD)
```

```
WIND DIRECTIONS (RELATIVE TO GLOBAL X-AXIS)       : DIR  ANGLE (deg)
                                                    1    0.0
                                                    2    30.0
                                                    3    60.0
                                                    4    90.0
                                                    5    120.0
                                                    6    150.0
MEAN WIND VELOCITY  (l/sec)                       : 30.0
MEAN WIND VELOCITY LEVEL  (l)                     : 10.0
HEIGHT EXPONENT, API WIND PROFILE                 : .125
GUST FACTOR, API WIND PROFILE                     : 1.0
ACCELERATION OF GRAVITY (g)  (l/sec^2)            : 9.81
UNIT LENGTH ADJUSTMENT FACTOR (9.81/g)            : 1.0

DIRECT INPUT PARAMETERS :
(l = current length unit)
-------------------------

DAMAGE CALCULATION OF BENT CAN JOINTS             : ON
COHERENCE FUNCTION CONSTANT (GUSTO, DAVENPORT)    : 8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz ALONG DIR.  : 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz LATERAL DIR.: 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz VERTICAL DIR: 16.0   16.0   8.0
GROUND ROUGNESS COEFFICIENT                       : 1.5E-02
TURBULENCE LENGTH SCALE DAVENPORT SPECTRUM  (l)   : 1200.0
TURBULENCE LENGTH SCALE HARRIS SPECTRUM  (l)      : 1800.0
DEFAULT SN CURVE                                  : DOE-T
MINIMUM PARAMETRIC SCFS                           : 1.6    1.6    1.6
DEFAULT GLOBAL SCFS                               : 1.6    1.6    1.6
DEFAULT SCF SCHEME, Alt.: EFTHYMIOU, LLOYDS       : EFTHYMIOU
(New default overrules previously assigned SCFs)
DAMPING RATIO                                     : 1.0E-02
CHORD LENGTH/DIAMETER RATIO (L/D)                 : 30.0
ANGULAR TOLERANCE ANALYSIS PLANES (DEG)           : 1.0
LIMIT FOR PRINTING DAMAGE VALUES                  : 1.0E-12
MIN. WIND FORCE USED RELATIVE TO MAX.             : 1.000E-05
LIMIT VALUE ON COHERENCE EFFECT                   : 1.000E+00
(NO COHERENCE = 1.0, FULL COHERENCE = 0 in limit)
NUMBER OF WIND SPEEDS                             : 5

WIND PROBABILITIES AND DRAG CORRECTION COEFFICIENT
-------------------------------------------------------
   DIR    WIND          WIND          WIND    DRAG COEFF
    NO   SPEED         SPEED   PROBABILITY    CORRECTION
```

	NO			FACTORS
1	1	10.0000	0.3000	1.0000
1	2	15.0000	0.2500	0.9000
1	3	20.0000	0.2000	0.8000
1	4	25.0000	0.1500	0.7500
1	5	30.0000	0.1000	0.7000
2	1	10.0000	0.3500	1.0100
2	2	15.0000	0.2000	0.9100
2	3	20.0000	0.2000	0.8100
2	4	25.0000	0.1500	0.7600
2	5	30.0000	0.1000	0.7100
3	1	10.0000	0.4000	1.0200
3	2	15.0000	0.2000	0.9200
3	3	20.0000	0.1500	0.8200
3	4	25.0000	0.1500	0.7700
3	5	30.0000	0.1000	0.7200
4	1	10.0000	0.2000	1.0300
4	2	15.0000	0.2000	0.9300
4	3	20.0000	0.2000	0.8300
4	4	25.0000	0.2000	0.7800
4	5	30.0000	0.2000	0.7300
5	1	10.0000	0.3000	1.0400
5	2	15.0000	0.2500	0.9400
5	3	20.0000	0.2000	0.8400
5	4	25.0000	0.1500	0.7900
5	5	30.0000	0.1000	0.7400
6	1	10.0000	0.3600	1.0500
6	2	15.0000	0.2200	0.9500
6	3	20.0000	0.2100	0.8500
6	4	25.0000	0.1100	0.8000
6	5	30.0000	0.1000	0.7500

NODES DEFINING THE ANALYSIS PLANES:

1	101	203	301
2	102	205	302
3	103	201	303
4	201	203	205

NUMBER OF COHERENCE MATRICES FOR THE U, V AND W WIND GUST DIRECTIONS : 1
Note! 1,2 or 3 coherence matrices are formed depending on the choice of
wind spectrum and coherence models. Theexecution time increases
with the number of coherence matrices applied in the run.

****

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
201	202	1	1 1	5.0537E-02	100.0	18.3	0.0	16.0	93.6	17.1	0.0	17.5	24.3	4.4	0.0	3.9	22.7	4.2	0.0	4.2
201	206	3	5 1	2.3718E-01	93.4	16.4	0.0	18.5	100.0	18.2	0.0	16.8	23.0	4.0	0.0	4.5	24.8	4.4	0.0	4.1
201	303	3	1 1	9.6645E-05	100.0	41.5	0.2	3.3	46.8	16.2	0.0	9.1	23.8	18.7	0.9	1.0	11.6	8.6	0.2	1.0
201	202	4	3 1	3.9054E-03	0.0	16.9	100.0	19.1	0.0	15.5	95.3	18.2	0.0	16.9	100.0	19.1	0.0	15.5	95.3	18.2
201	206	4	3 1	1.6104E-02	0.0	24.9	100.0	12.8	0.0	22.0	91.4	11.3	0.0	24.9	100.0	12.8	0.0	22.0	91.4	11.3
202	101	1	7 1	9.5878E-04	0.0	1.1	21.9	1.9	0.0	10.5	100.0	7.5	0.0	0.0	0.2	0.0	0.0	0.8	4.3	0.6
202	102	1	3 1	9.5702E-04	0.0	7.6	100.0	10.4	0.0	1.9	21.9	1.1	0.0	0.6	4.3	0.8	0.0	0.0	0.2	0.0
202	201	4	7 1	4.2776E-05	0.0	14.2	82.9	14.1	0.0	18.5	100.0	18.3	0.0	14.2	82.9	14.1	0.0	18.5	100.0	18.3
202	203	4	7 1	4.2881E-05	0.1	14.2	82.6	14.0	0.0	18.7	100.0	18.2	0.1	14.2	82.6	14.0	0.0	18.7	100.0	18.2
203	202	1	5 1	5.4343E-02	98.6	17.1	0.0	18.1	100.0	17.6	0.0	17.9	23.9	4.1	0.0	4.4	24.3	4.3	0.0	4.4
203	301	1	3 2	1.1936E-05	66.3	46.0	25.3	18.1	62.7	17.4	1.1	16.0	16.0	63.1	100.0	19.6	15.2	17.1	21.4	10.7
203	204	2	1 1	2.1552E-01	100.0	18.6	0.0	14.7	85.4	15.4	0.0	18.0	24.7	4.5	0.0	3.6	20.9	3.8	0.0	4.3
203	202	4	3 1	3.8476E-03	0.0	17.2	100.0	18.6	0.0	16.4	98.3	18.8	0.0	17.2	100.0	18.6	0.0	16.4	98.3	18.8
203	204	4	3 1	1.6266E-02	0.0	24.5	100.0	13.2	0.0	20.9	89.0	11.1	0.0	24.5	100.0	13.2	0.0	20.9	89.0	11.1
204	102	2	7 1	5.7101E-05	0.3	2.8	33.1	5.1	0.6	16.0	100.0	7.0	0.0	0.1	0.5	0.2	0.1	1.0	3.7	0.5
204	103	2	3 1	6.6348E-05	0.4	14.3	100.0	9.6	0.5	3.5	23.9	2.9	0.1	1.1	4.5	0.7	0.1	0.1	0.3	0.1
204	203	4	7 1	1.6942E-04	0.0	21.4	86.9	10.2	0.0	25.7	100.0	12.6	0.0	21.4	86.9	10.2	0.0	25.7	100.0	12.6
204	205	4	7 1	1.6992E-04	0.0	18.9	76.7	8.5	0.0	26.7	100.0	12.7	0.0	18.9	76.7	8.5	0.0	26.7	100.0	12.7
205	204	2	5 1	1.0432E-01	79.8	13.7	0.0	18.3	100.0	19.0	0.0	13.3	19.2	3.3	0.0	4.5	24.5	4.7	0.0	3.2
205	302	2	5 1	5.0356E-05	46.8	8.2	0.6	53.1	100.0	7.8	0.0	18.4	11.6	5.8	2.9	30.0	23.4	2.1	0.7	13.1
205	206	3	1 1	1.0360E-01	100.0	18.3	0.0	11.9	69.3	11.8	0.0	18.6	24.5	4.3	0.0	2.9	16.7	2.9	0.0	4.4
205	204	4	3 1	7.9401E-03	0.0	27.6	100.0	12.4	0.0	19.1	76.5	8.5	0.0	27.6	100.0	12.4	0.0	19.1	76.5	8.5
205	206	4	3 1	7.8717E-03	0.0	26.7	100.0	12.8	0.0	18.6	76.8	8.7	0.0	26.7	100.0	12.8	0.0	18.6	76.8	8.7
206	103	3	7 1	6.2782E-05	0.4	3.0	25.9	4.0	0.6	9.9	100.0	14.4	0.1	0.1	0.4	0.2	0.1	0.7	4.5	1.1
206	101	3	3 1	5.7280E-05	0.3	7.0	100.0	15.8	0.6	4.6	29.3	2.3	0.0	0.5	3.8	1.0	0.1	0.1	0.4	0.1
206	205	4	7 1	1.6841E-04	0.0	19.1	78.0	8.7	0.0	26.5	100.0	12.7	0.0	19.1	78.0	8.7	0.0	26.5	100.0	12.7
206	201	4	7 1	1.6863E-04	0.0	21.8	88.0	10.3	0.0	25.8	100.0	12.5	0.0	21.8	88.0	10.3	0.0	25.8	100.0	12.5
301	203	1	3 2	4.2609E-06	11.1	57.9	60.7	11.2	7.2	4.8	3.5	4.4	2.3	51.6	100.0	14.5	1.8	8.3	20.3	4.4
301	302	1	1 1	5.2058E-05	100.0	7.5	0.3	26.4	47.6	5.7	1.3	64.7	22.8	1.7	0.2	8.2	12.0	1.4	0.5	17.9
301	303	3	1 1	7.1598E-06	100.0	38.9	0.4	9.6	86.5	33.7	0.2	11.2	24.0	10.6	0.2	2.2	21.2	9.3	0.1	2.6
301	302	4	2 1	8.0667E-08	22.8	100.0	33.6	2.1	5.3	36.7	16.7	1.6	22.8	100.0	33.6	2.1	5.3	36.7	16.7	1.6
301	303	4	6 1	4.7770E-09	11.1	82.0	60.9	4.2	22.6	100.0	70.0	4.7	11.1	82.0	60.9	4.2	22.6	100.0	70.0	4.7
302	301	1	1 1	8.3114E-05	100.0	65.5	0.9	3.7	41.9	27.8	0.2	5.6	22.7	18.0	0.4	0.9	10.7	8.6	0.1	1.2
302	205	2	1 1	1.5161E-05	100.0	77.3	1.9	1.8	28.2	21.9	0.1	3.8	21.3	36.3	3.7	1.3	8.0	15.1	0.9	0.4

302	303	2	1	1	5.5888E-06	100.0	14.4	0.1	17.3	77.3	11.9	0.6	28.5	23.6	3.4	0.1	4.5	19.0	2.9	0.3	7.3
302	301	4	6	1	1.2056E-07	4.0	39.6	15.8	1.1	16.5	100.0	35.8	1.4	4.0	39.6	15.8	1.1	16.5	100.0	35.8	1.4
302	303	4	3	1	2.7332E-09	43.8	97.6	100.0	8.9	9.5	39.8	80.1	7.5	43.8	97.6	100.0	8.9	9.5	39.8	80.1	7.5
303	302	2	1	1	2.5945E-05	100.0	29.9	0.2	11.0	76.6	19.7	0.0	13.2	23.7	7.7	0.1	2.6	18.9	5.3	0.0	3.1
303	201	3	5	1	3.6364E-06	28.5	13.9	3.5	72.1	100.0	6.1	0.3	13.6	7.4	7.8	6.0	30.1	20.5	2.3	1.6	9.1
303	301	3	1	1	2.4437E-05	100.0	14.0	0.1	22.6	82.6	11.7	0.1	27.7	23.9	3.3	0.1	6.1	20.3	2.8	0.1	7.2
303	302	4	7	1	1.3215E-08	3.2	47.3	79.2	6.5	17.8	91.3	100.0	8.0	3.2	47.3	79.2	6.5	17.8	91.3	100.0	8.0
303	301	4	3	1	1.2635E-08	10.9	77.1	100.0	8.3	7.6	60.3	83.7	6.5	10.9	77.1	100.0	8.3	7.6	60.3	83.7	6.5

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 2, 30.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points -->								| <-- Side 2: Brace side points --> |						
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	2.5133E-01	100.0	18.7	0.0	14.2	82.3	14.8	0.0	18.3	24.9	4.5	0.0	3.5	20.2	3.6	0.0	4.4
201	206	3	5	1	2.9107E-01	91.1	16.1	0.0	18.6	100.0	18.6	0.0	16.4	22.5	3.9	0.0	4.6	25.0	4.5	0.0	4.0
201	303	3	1	1	3.0649E-05	100.0	96.4	4.0	4.8	29.2	17.2	0.1	5.3	23.3	71.4	13.8	2.4	7.2	18.9	2.4	1.2
201	202	4	3	1	1.9521E-02	0.0	17.7	100.0	18.9	0.0	14.2	86.5	15.6	0.0	17.7	100.0	18.9	0.0	14.2	86.5	15.6
201	206	4	3	1	2.0011E-02	0.0	25.5	100.0	12.7	0.0	21.4	88.3	10.8	0.0	25.5	100.0	12.7	0.0	21.4	88.3	10.8
202	101	1	7	1	5.3552E-04	0.0	0.8	24.2	3.4	0.2	14.6	100.0	5.0	0.0	0.0	0.3	0.1	0.0	1.0	4.1	0.4
202	102	1	3	1	5.3312E-04	0.1	10.6	100.0	7.3	0.1	1.5	24.0	2.1	0.0	0.8	4.1	0.5	0.0	0.0	0.3	0.0
202	201	4	7	1	2.6757E-04	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3
202	203	4	7	1	2.6817E-04	0.0	14.1	82.3	13.9	0.0	18.6	100.0	18.3	0.0	14.1	82.3	13.9	0.0	18.6	100.0	18.3
203	202	1	5	1	2.6861E-01	90.2	15.8	0.0	18.6	100.0	18.5	0.0	16.1	22.2	3.8	0.0	4.5	24.9	4.5	0.0	3.9
203	301	1	1	1	1.4801E-05	100.0	28.8	9.0	46.3	59.2	9.5	0.3	23.6	23.6	13.9	32.6	47.5	14.3	5.5	5.5	14.5
203	204	2	1	1	2.6421E-01	100.0	18.7	0.0	14.2	82.1	14.7	0.0	18.3	24.9	4.5	0.0	3.5	20.1	3.6	0.0	4.4
203	202	4	3	1	1.9664E-02	0.0	18.1	100.0	18.4	0.0	14.8	87.7	15.5	0.0	18.1	100.0	18.4	0.0	14.8	87.7	15.5
203	204	4	3	1	1.9928E-02	0.0	25.0	100.0	13.1	0.0	20.3	86.2	10.6	0.0	25.0	100.0	13.1	0.0	20.3	86.2	10.6
204	102	2	7	1	1.4152E-04	0.2	2.6	39.6	4.4	0.4	10.6	100.0	7.4	0.0	0.1	0.6	0.2	0.0	0.7	3.4	0.5
204	103	2	3	1	1.5940E-04	0.1	7.0	100.0	10.8	0.3	3.6	31.8	1.7	0.0	0.5	4.1	0.8	0.0	0.1	0.5	0.1
204	203	4	7	1	2.7264E-04	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	2.7024E-04	0.0	20.2	82.1	9.4	0.0	26.2	100.0	12.6	0.0	20.2	82.1	9.4	0.0	26.2	100.0	12.6
205	204	2	5	1	2.5807E-01	89.8	15.7	0.0	18.6	100.0	18.5	0.0	16.0	22.1	3.8	0.0	4.5	24.9	4.5	0.0	3.9
205	302	2	1	1	1.3692E-04	100.0	17.0	0.5	18.9	99.1	16.2	0.0	19.2	24.2	4.9	2.0	5.1	24.0	3.8	0.4	5.1
205	206	3	1	1	2.5707E-01	100.0	18.7	0.0	14.2	82.0	14.7	0.0	18.3	24.9	4.5	0.0	3.5	20.1	3.6	0.0	4.4
205	204	4	3	1	1.9916E-02	0.0	25.5	100.0	12.8	0.0	21.1	87.8	10.8	0.0	25.5	100.0	12.8	0.0	21.1	87.8	10.8
205	206	4	3	1	2.0444E-02	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.7	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.7
206	103	3	7	1	5.7236E-04	0.1	1.9	22.2	1.4	0.1	7.1	100.0	10.9	0.0	0.0	0.3	0.0	0.0	0.6	4.5	0.8
206	101	3	3	1	5.2211E-04	0.0	5.4	100.0	13.8	0.2	3.4	26.1	1.0	0.0	0.4	3.7	0.9	0.0	0.1	0.3	0.0
206	205	4	7	1	2.7457E-04	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7
206	201	4	7	1	2.7834E-04	0.0	20.4	82.6	9.4	0.0	26.2	100.0	12.6	0.0	20.4	82.6	9.4	0.0	26.2	100.0	12.6

301	203	1	2	1	8.2556E-06	49.6	100.0	14.3	1.1	3.0	7.2	0.5	0.5	8.8	57.5	22.0	0.8	0.9	10.6	3.4	0.2
301	302	1	1	1	5.6970E-05	100.0	8.7	0.1	18.0	48.1	6.5	0.6	49.5	22.7	2.0	0.1	5.3	12.1	1.6	0.3	13.2
301	303	3	1	1	8.4379E-05	100.0	51.3	0.3	4.9	57.9	30.2	0.1	7.0	23.3	14.0	0.1	1.1	14.6	8.8	0.1	1.5
301	302	4	2	1	5.7343E-08	17.5	100.0	51.6	3.6	2.2	28.0	25.9	2.9	17.5	100.0	51.6	3.6	2.2	28.0	25.9	2.9
301	303	4	6	1	8.0353E-08	4.8	55.7	27.4	1.3	12.5	100.0	45.2	1.6	4.8	55.7	27.4	1.3	12.5	100.0	45.2	1.6
302	301	1	1	1	7.4930E-05	100.0	48.0	0.6	7.3	55.8	20.3	0.1	9.2	23.0	12.8	0.3	1.7	13.9	5.9	0.1	2.1
302	205	2	5	1	1.3970E-05	99.5	25.0	2.8	14.1	100.0	22.5	0.1	13.7	24.1	8.9	5.0	3.4	24.2	6.7	0.9	2.8
302	303	2	1	1	4.3755E-05	100.0	12.1	0.0	18.0	66.3	9.1	0.1	30.3	23.5	2.8	0.0	4.8	16.5	2.2	0.0	7.8
302	301	4	6	1	7.1976E-08	2.6	32.3	31.4	3.3	17.8	100.0	54.3	4.0	2.6	32.3	31.4	3.3	17.8	100.0	54.3	4.0
302	303	4	3	1	2.0768E-08	7.3	88.6	100.0	6.9	1.7	43.8	69.3	5.2	7.3	88.6	100.0	6.9	1.7	43.8	69.3	5.2
303	302	2	1	1	4.7494E-05	100.0	34.6	0.1	7.7	61.9	19.5	0.0	10.6	23.4	9.0	0.0	1.8	15.5	5.4	0.0	2.4
303	201	3	4	1	1.4231E-06	47.3	23.7	61.3	100.0	25.0	3.6	2.3	17.5	9.8	15.2	88.0	70.8	5.0	3.5	13.4	13.1
303	301	3	1	1	5.5832E-05	100.0	10.6	0.3	27.0	64.8	8.2	0.6	46.2	23.4	2.4	0.1	7.9	16.1	2.0	0.3	12.7
303	302	4	6	1	2.5821E-08	2.2	48.4	58.6	3.9	8.6	100.0	90.1	5.1	2.2	48.4	58.6	3.9	8.6	100.0	90.1	5.1
303	301	4	2	1	5.4148E-08	24.1	100.0	49.5	3.3	9.8	53.4	33.9	2.4	24.1	100.0	49.5	3.3	9.8	53.4	33.9	2.4

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 3, 60.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S N	S I D E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	2.3001E-01	100.0	18.7	0.0	14.7	85.0	15.3	0.0	18.0	24.8	4.5	0.0	3.6	20.8	3.8	0.0	4.3
201	206	3	5	1	6.8729E-02	98.3	17.0	0.0	18.1	100.0	17.6	0.0	17.9	23.9	4.1	0.0	4.4	24.3	4.3	0.0	4.3
201	303	3	3	2	1.0898E-05	78.7	53.7	27.4	20.1	72.8	18.6	1.1	19.4	18.9	68.9	100.0	18.7	17.7	16.8	19.2	11.4
201	202	4	3	1	1.7928E-02	0.0	17.4	100.0	19.0	0.0	14.5	88.6	16.1	0.0	17.4	100.0	19.0	0.0	14.5	88.6	16.1
201	206	4	3	1	4.5612E-03	0.0	24.5	100.0	12.9	0.0	23.3	98.0	13.0	0.0	24.5	100.0	12.9	0.0	23.3	98.0	13.0
202	101	1	7	1	6.4750E-05	0.2	2.4	29.5	5.0	0.7	17.8	100.0	6.7	0.0	0.1	0.4	0.1	0.1	1.2	4.0	0.5
202	102	1	3	1	6.6814E-05	0.4	13.1	100.0	9.9	0.7	3.7	25.7	3.0	0.0	0.9	4.2	0.7	0.1	0.1	0.3	0.1
202	201	4	7	1	1.8785E-04	0.0	14.9	86.6	14.9	0.0	18.3	100.0	18.2	0.0	14.9	86.6	14.9	0.0	18.3	100.0	18.2
202	203	4	7	1	1.9043E-04	0.0	13.2	77.1	12.7	0.0	19.0	100.0	18.4	0.0	13.2	77.1	12.7	0.0	19.0	100.0	18.4
203	202	1	5	1	1.2277E-01	80.9	13.9	0.0	18.4	100.0	18.9	0.0	13.6	19.5	3.3	0.0	4.5	24.6	4.6	0.0	3.3
203	301	1	5	1	4.9983E-05	50.2	9.5	0.5	48.7	100.0	8.7	0.0	17.5	12.4	6.0	2.4	25.2	23.6	2.2	0.6	10.9
203	204	2	1	1	1.2254E-01	100.0	18.4	0.0	12.0	70.2	12.0	0.0	18.5	24.6	4.4	0.0	3.0	16.9	3.0	0.0	4.4
203	202	4	3	1	8.9201E-03	0.0	19.4	100.0	18.1	0.0	13.2	76.9	12.7	0.0	19.4	100.0	18.1	0.0	13.2	76.9	12.7
203	204	4	3	1	8.8628E-03	0.0	26.3	100.0	13.0	0.0	18.5	77.2	8.9	0.0	26.3	100.0	13.0	0.0	18.5	77.2	8.9
204	102	2	7	1	6.4364E-05	0.3	2.7	30.0	4.5	0.8	9.8	100.0	12.1	0.0	0.1	0.4	0.2	0.1	0.6	3.8	0.8
204	103	2	3	1	7.0814E-05	0.2	7.0	100.0	18.5	0.8	5.3	25.8	1.9	0.0	0.6	4.5	1.3	0.1	0.2	0.4	0.1
204	203	4	7	1	1.9021E-04	0.0	19.1	78.3	8.8	0.0	26.3	100.0	12.8	0.0	19.1	78.3	8.8	0.0	26.3	100.0	12.8
204	205	4	7	1	1.8631E-04	0.0	21.6	87.6	10.3	0.0	25.7	100.0	12.6	0.0	21.6	87.6	10.3	0.0	25.7	100.0	12.6
205	204	2	5	1	2.3582E-01	92.8	16.2	0.0	18.6	100.0	18.2	0.0	16.7	22.8	3.9	0.0	4.5	24.8	4.4	0.0	4.0
205	302	2	1	1	1.0250E-04	100.0	41.8	0.3	3.4	44.8	15.4	0.0	9.2	23.5	19.7	1.3	1.3	11.2	8.9	0.4	1.0

205	206	3	1	1	6.0415E-02	100.0	18.4	0.0	15.8	93.0	17.1	0.0	17.5	24.3	4.4	0.0	3.8	22.5	4.2	0.0	4.2
205	204	4	3	1	1.8104E-02	0.0	24.8	100.0	12.9	0.0	21.8	91.3	11.4	0.0	24.8	100.0	12.9	0.0	21.8	91.3	11.4
205	206	4	3	1	4.7898E-03	0.0	23.9	100.0	13.4	0.0	21.8	95.0	12.8	0.0	23.9	100.0	13.4	0.0	21.8	95.0	12.8
206	103	3	7	1	1.1638E-03	0.0	1.0	20.3	1.7	0.0	10.7	100.0	7.5	0.0	0.0	0.2	0.0	0.0	0.8	4.7	0.6
206	101	3	3	1	1.0501E-03	0.0	7.8	100.0	10.4	0.0	2.0	23.9	1.3	0.0	0.5	3.9	0.7	0.0	0.0	0.2	0.0
206	205	4	7	1	5.2012E-05	0.0	20.3	83.1	9.6	0.0	26.1	100.0	12.6	0.0	20.3	83.1	9.6	0.0	26.1	100.0	12.6
206	201	4	7	1	5.2740E-05	0.1	20.4	82.8	9.5	0.0	26.2	100.0	12.6	0.1	20.4	82.8	9.5	0.0	26.2	100.0	12.6
301	203	1	1	1	1.4692E-05	100.0	68.7	1.5	1.9	27.6	18.7	0.1	4.5	21.2	29.7	2.8	1.2	7.8	11.8	0.7	0.4
301	302	1	1	1	6.4765E-06	100.0	14.2	0.1	17.0	77.0	12.0	0.7	29.7	23.6	3.3	0.1	4.5	18.9	2.9	0.3	7.6
301	303	3	1	1	9.6717E-05	100.0	64.1	0.8	3.6	41.5	27.2	0.2	5.6	22.8	17.6	0.3	0.9	10.6	8.4	0.1	1.2
301	302	4	3	1	3.4167E-09	35.8	96.6	100.0	12.7	6.7	31.7	78.4	10.4	35.8	96.6	100.0	12.7	6.7	31.7	78.4	10.4
301	303	4	6	1	1.3490E-07	5.7	39.8	13.3	0.6	21.6	100.0	29.3	0.9	5.7	39.8	13.3	0.6	21.6	100.0	29.3	0.9
302	301	1	1	1	3.0476E-05	100.0	29.7	0.2	11.6	77.8	19.7	0.0	13.5	23.7	7.7	0.1	2.8	19.1	5.2	0.0	3.2
302	205	2	5	1	5.8234E-06	29.4	11.6	3.1	68.7	100.0	6.4	0.3	14.3	7.8	7.2	6.2	29.6	20.8	2.2	1.7	9.7
302	303	2	1	1	3.2459E-05	100.0	14.1	0.1	22.9	83.6	11.9	0.1	27.4	23.9	3.3	0.0	6.1	20.5	2.9	0.0	7.1
302	301	4	7	1	1.6123E-08	2.0	38.1	79.0	10.1	11.2	77.9	100.0	12.0	2.0	38.1	79.0	10.1	11.2	77.9	100.0	12.0
302	303	4	3	1	1.5903E-08	8.7	74.8	100.0	8.6	6.2	60.4	84.6	6.8	8.7	74.8	100.0	8.6	6.2	60.4	84.6	6.8
303	302	2	1	1	9.1620E-06	100.0	39.2	0.4	8.8	86.4	34.2	0.2	10.5	24.0	10.7	0.2	2.0	21.2	9.5	0.1	2.4
303	201	3	3	2	3.8366E-06	12.8	70.6	65.3	10.1	6.7	4.8	3.3	4.1	2.5	57.7	100.0	12.8	1.6	8.2	18.4	3.7
303	301	3	1	1	5.7975E-05	100.0	6.9	0.3	26.6	45.3	5.1	1.2	65.7	22.8	1.5	0.2	8.3	11.5	1.2	0.5	18.3
303	302	4	6	1	6.2377E-09	9.8	83.0	62.4	3.8	21.2	100.0	71.9	4.3	9.8	83.0	62.4	3.8	21.2	100.0	71.9	4.3
303	301	4	2	1	9.2537E-08	29.0	100.0	27.5	1.2	7.4	37.2	13.9	0.9	29.0	100.0	27.5	1.2	7.4	37.2	13.9	0.9

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 4, 90.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points -->								| <-- Side 2: Brace side points --> |						
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	5.4241E-01	100.0	18.9	0.0	14.3	82.0	14.8	0.0	18.4	25.1	4.5	0.0	3.5	20.2	3.6	0.0	4.4
201	206	3	5	1	6.1912E-01	91.1	16.2	0.0	18.8	100.0	18.7	0.0	16.5	22.7	3.9	0.0	4.6	25.3	4.6	0.0	4.0
201	303	3	1	1	2.8858E-05	100.0	28.0	9.1	40.5	56.4	9.8	0.2	22.1	23.8	12.5	30.8	41.3	13.7	5.1	4.6	11.9
201	202	4	3	1	4.2520E-02	0.0	17.7	100.0	18.9	0.0	14.1	86.1	15.5	0.0	17.7	100.0	18.9	0.0	14.1	86.1	15.5
201	206	4	3	1	4.3034E-02	0.0	25.5	100.0	12.7	0.0	21.3	88.1	10.7	0.0	25.5	100.0	12.7	0.0	21.3	88.1	10.7
202	101	1	7	1	2.9510E-04	0.1	2.1	36.8	4.3	0.4	11.2	100.0	6.9	0.0	0.1	0.6	0.2	0.0	0.7	3.7	0.5
202	102	1	3	1	3.0340E-04	0.1	6.9	100.0	11.3	0.4	4.0	33.2	1.8	0.0	0.5	3.8	0.7	0.0	0.1	0.5	0.1
202	201	4	7	1	5.7975E-04	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3
202	203	4	7	1	5.8109E-04	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2
203	202	1	5	1	5.7020E-01	90.1	15.9	0.0	18.8	100.0	18.7	0.0	16.2	22.4	3.8	0.0	4.6	25.2	4.6	0.0	3.9
203	301	1	1	1	2.8491E-04	100.0	18.7	0.4	17.0	98.2	17.6	0.0	17.4	24.2	5.5	1.6	4.2	23.8	4.5	0.3	4.1
203	204	2	1	1	5.6719E-01	100.0	18.9	0.0	14.4	82.3	14.9	0.0	18.5	25.2	4.5	0.0	3.5	20.3	3.7	0.0	4.4
203	202	4	3	1	4.2189E-02	0.0	18.2	100.0	18.4	0.0	14.8	87.3	15.5	0.0	18.2	100.0	18.4	0.0	14.8	87.3	15.5

203	204	4	3	1	4.3228E-02	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.6	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.6
204	102	2	7	1	1.0929E-03	0.1	2.0	25.2	1.8	0.1	8.0	100.0	10.0	0.0	0.0	0.3	0.1	0.0	0.5	3.8	0.7
204	103	2	3	1	1.1923E-03	0.0	4.6	100.0	15.7	0.2	3.5	23.1	0.7	0.0	0.4	4.4	1.2	0.0	0.1	0.3	0.0
204	203	4	7	1	5.9326E-04	0.0	20.2	82.7	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.7	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	5.8770E-04	0.0	20.3	82.3	9.4	0.0	26.2	100.0	12.6	0.0	20.3	82.3	9.4	0.0	26.2	100.0	12.6
205	204	2	5	1	5.5766E-01	90.5	16.0	0.0	18.8	100.0	18.7	0.0	16.3	22.5	3.9	0.0	4.6	25.1	4.6	0.0	4.0
205	302	2	2	1	6.6381E-05	97.4	100.0	4.9	5.9	31.3	18.1	0.2	4.7	22.2	82.2	20.1	3.5	7.7	23.0	4.1	1.4
205	206	3	1	1	5.4289E-01	100.0	18.9	0.0	14.4	82.5	15.0	0.0	18.5	25.1	4.5	0.0	3.5	20.4	3.7	0.0	4.4
205	204	4	3	1	4.3470E-02	0.0	25.5	100.0	12.8	0.0	21.3	88.4	10.9	0.0	25.5	100.0	12.8	0.0	21.3	88.4	10.9
205	206	4	3	1	4.3588E-02	0.0	25.0	100.0	13.1	0.0	20.4	86.6	10.8	0.0	25.0	100.0	13.1	0.0	20.4	86.6	10.8
206	103	3	7	1	1.2054E-03	0.0	0.7	23.3	3.6	0.2	15.9	100.0	4.5	0.0	0.0	0.3	0.1	0.0	1.2	4.4	0.4
206	101	3	3	1	1.1101E-03	0.1	10.1	100.0	7.9	0.1	1.8	25.1	2.0	0.0	0.7	3.8	0.5	0.0	0.1	0.3	0.0
206	205	4	7	1	5.8671E-04	0.0	20.3	82.5	9.5	0.0	26.1	100.0	12.6	0.0	20.3	82.5	9.5	0.0	26.1	100.0	12.6
206	201	4	7	1	5.9470E-04	0.0	20.3	82.7	9.5	0.0	26.1	100.0	12.7	0.0	20.3	82.7	9.5	0.0	26.1	100.0	12.7
301	203	1	5	1	2.6076E-05	98.1	21.2	2.7	16.9	100.0	18.9	0.1	16.2	23.8	7.1	4.4	4.3	24.2	5.1	0.8	3.8
301	302	1	1	1	8.7307E-05	100.0	12.1	0.0	18.6	67.5	9.4	0.1	31.1	23.5	2.8	0.0	5.0	16.7	2.2	0.0	8.0
301	303	3	1	1	1.6940E-04	100.0	48.0	0.6	7.2	54.6	20.0	0.1	9.1	23.0	12.8	0.2	1.7	13.6	5.8	0.1	2.1
301	302	4	3	1	4.6010E-08	5.2	76.4	100.0	9.9	1.2	36.3	69.1	7.7	5.2	76.4	100.0	9.9	1.2	36.3	69.1	7.7
301	303	4	6	1	1.6398E-07	3.9	33.3	27.4	2.0	23.3	100.0	45.5	2.5	3.9	33.3	27.4	2.0	23.3	100.0	45.5	2.5
302	301	1	1	1	1.0486E-04	100.0	34.6	0.1	8.1	63.2	19.7	0.0	10.8	23.4	9.0	0.0	1.9	15.8	5.4	0.0	2.4
302	205	2	4	1	5.0839E-06	40.1	19.2	48.9	100.0	28.5	3.3	2.1	16.7	8.5	13.0	81.8	75.7	5.8	3.5	14.5	15.9
302	303	2	1	1	1.4180E-04	100.0	10.7	0.2	26.5	65.4	8.3	0.5	44.8	23.5	2.5	0.1	7.7	16.3	2.0	0.2	12.2
302	301	4	7	1	5.5161E-08	1.3	42.7	65.0	6.7	5.8	91.2	100.0	8.4	1.3	42.7	65.0	6.7	5.8	91.2	100.0	8.4
302	303	4	2	1	1.2388E-07	21.6	100.0	52.1	3.5	8.7	54.0	35.9	2.6	21.6	100.0	52.1	3.5	8.7	54.0	35.9	2.6
303	302	2	1	1	1.8370E-04	100.0	50.7	0.3	4.6	57.1	29.8	0.1	6.8	23.3	13.8	0.1	1.0	14.4	8.7	0.1	1.4
303	201	3	2	1	1.7237E-05	48.7	100.0	14.5	0.8	2.1	6.6	0.4	0.5	8.6	56.2	21.2	0.6	0.7	9.9	3.0	0.2
303	301	3	1	1	1.2121E-04	100.0	8.3	0.1	17.5	45.2	5.8	0.5	48.8	22.6	1.8	0.0	5.2	11.4	1.4	0.2	12.9
303	302	4	6	1	1.7757E-07	4.3	55.6	28.0	1.2	11.6	100.0	47.1	1.5	4.3	55.6	28.0	1.2	11.6	100.0	47.1	1.5
303	301	4	2	1	1.2269E-07	20.4	100.0	45.3	2.1	2.9	29.1	22.9	1.6	20.4	100.0	45.3	2.1	2.9	29.1	22.9	1.6

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 5, 120.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N	N	P	P	S																
O	O	L	O	I									<==RELATIVE DAMAGES AROUND THE WELD ====>							
D	D	A	S	D		<-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->						
E	E	N	N	E																
1	2	E			DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.3972E-01	100.0	18.5	0.0	11.9	70.0	12.0	0.0	18.5	24.6	4.4	0.0	3.0	16.9	3.0	0.0	4.4
201	206	3	5	1	1.4800E-01	81.9	14.1	0.0	18.3	100.0	18.9	0.0	13.8	19.8	3.4	0.0	4.5	24.6	4.7	0.0	3.3
201	303	3	5	1	6.1219E-05	50.5	9.0	0.5	52.4	100.0	8.0	0.0	19.4	12.4	5.6	2.2	28.1	23.7	2.1	0.5	12.4
201	202	4	3	1	1.0463E-02	0.0	18.7	100.0	18.7	0.0	12.8	77.1	13.1	0.0	18.7	100.0	18.7	0.0	12.8	77.1	13.1
201	206	4	3	1	1.0082E-02	0.0	27.2	100.0	12.5	0.0	19.0	77.1	8.6	0.0	27.2	100.0	12.5	0.0	19.0	77.1	8.6
202	101	1	7	1	7.4730E-05	0.4	3.1	28.1	4.2	0.7	10.0	100.0	13.1	0.0	0.1	0.4	0.2	0.1	0.7	4.1	0.9

202	102	1	3	1	7.6609E-05	0.2	6.6	100.0	17.4	0.7	4.6	26.2	1.9	0.0	0.5	4.1	1.2	0.1	0.1	0.4	0.1
202	201	4	7	1	2.2206E-04	0.0	13.3	78.3	13.0	0.0	18.8	100.0	18.4	0.0	13.3	78.3	13.0	0.0	18.8	100.0	18.4
202	203	4	7	1	2.2015E-04	0.0	15.1	87.1	14.9	0.0	18.3	100.0	18.1	0.0	15.1	87.1	14.9	0.0	18.3	100.0	18.1
203	202	1	5	1	2.8307E-01	92.4	16.3	0.0	18.7	100.0	18.4	0.0	16.6	22.8	3.9	0.0	4.6	25.0	4.5	0.0	4.0
203	301	1	1	1	1.3450E-04	100.0	44.4	0.2	3.0	46.0	17.3	0.0	8.4	23.6	21.5	1.1	1.0	11.5	10.1	0.3	0.8
203	204	2	1	1	6.9106E-02	100.0	18.3	0.0	15.8	92.4	16.8	0.0	17.5	24.3	4.4	0.0	3.8	22.4	4.1	0.0	4.2
203	202	4	3	1	2.0713E-02	0.0	17.7	100.0	18.5	0.0	15.2	90.3	16.1	0.0	17.7	100.0	18.5	0.0	15.2	90.3	16.1
203	204	4	3	1	5.1810E-03	0.0	24.1	100.0	13.2	0.0	21.9	94.5	12.5	0.0	24.1	100.0	13.2	0.0	21.9	94.5	12.5
204	102	2	7	1	1.2287E-03	0.0	1.3	24.5	2.1	0.1	10.6	100.0	7.7	0.0	0.0	0.3	0.1	0.0	0.7	3.9	0.5
204	103	2	3	1	1.3593E-03	0.0	7.6	100.0	10.6	0.0	1.8	20.8	1.0	0.0	0.6	4.7	0.8	0.0	0.0	0.2	0.0
204	203	4	7	1	5.9739E-05	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7
204	205	4	7	1	5.9129E-05	0.1	20.5	83.2	9.6	0.0	26.2	100.0	12.6	0.1	20.5	83.2	9.6	0.0	26.2	100.0	12.6
205	204	2	5	1	7.3143E-02	99.0	17.1	0.0	18.2	100.0	17.5	0.0	18.2	24.0	4.1	0.0	4.4	24.3	4.2	0.0	4.4
205	302	2	3	2	2.0411E-05	56.0	38.6	22.8	17.3	53.6	14.7	1.1	14.4	13.5	57.6	100.0	21.5	13.0	16.1	23.4	11.3
205	206	3	1	1	2.6203E-01	100.0	18.8	0.0	14.8	85.7	15.6	0.0	18.1	24.9	4.5	0.0	3.6	21.1	3.8	0.0	4.3
205	204	4	3	1	5.4962E-03	0.0	24.1	100.0	13.1	0.0	23.1	99.1	13.5	0.0	24.1	100.0	13.1	0.0	23.1	99.1	13.5
205	206	4	3	1	2.1051E-02	0.0	24.4	100.0	13.2	0.0	20.8	89.2	11.3	0.0	24.4	100.0	13.2	0.0	20.8	89.2	11.3
206	103	3	7	1	8.0923E-05	0.2	2.3	28.9	5.9	0.9	19.2	100.0	7.0	0.0	0.1	0.4	0.2	0.1	1.3	4.3	0.5
206	101	3	3	1	7.8207E-05	0.3	12.2	100.0	9.5	0.8	3.9	27.1	2.6	0.0	0.8	3.8	0.6	0.1	0.2	0.4	0.1
206	205	4	7	1	2.1369E-04	0.0	21.3	86.9	10.2	0.0	25.7	100.0	12.6	0.0	21.3	86.9	10.2	0.0	25.7	100.0	12.6
206	201	4	7	1	2.1911E-04	0.0	18.9	77.2	8.6	0.0	26.5	100.0	12.8	0.0	18.9	77.2	8.6	0.0	26.5	100.0	12.8
301	203	1	5	1	6.7128E-06	27.1	10.7	3.3	78.9	100.0	5.1	0.3	16.7	7.3	6.5	6.0	35.2	20.7	2.0	1.6	11.8
301	302	1	1	1	3.2167E-05	100.0	14.3	0.1	22.5	84.7	12.4	0.1	27.1	23.9	3.4	0.0	6.0	20.8	3.0	0.1	7.1
301	303	3	1	1	3.7826E-05	100.0	29.4	0.2	11.4	77.0	19.2	0.0	13.4	23.7	7.6	0.1	2.7	18.9	5.1	0.0	3.1
301	302	4	3	1	1.7090E-08	6.9	63.0	100.0	12.7	4.3	48.6	85.6	10.5	6.9	63.0	100.0	12.7	4.3	48.6	85.6	10.5
301	303	4	7	1	1.8272E-08	2.7	44.9	79.9	6.8	16.0	89.4	100.0	8.3	2.7	44.9	79.9	6.8	16.0	89.4	100.0	8.3
302	301	1	1	1	9.8176E-06	100.0	41.0	0.5	9.6	87.5	36.1	0.2	11.2	24.0	11.3	0.2	2.3	21.4	10.1	0.1	2.6
302	205	2	3	2	7.4831E-06	9.5	48.6	55.7	10.9	6.9	4.9	3.4	3.9	2.0	47.6	100.0	15.2	1.7	8.7	21.9	4.4
302	303	2	1	1	7.6575E-05	100.0	7.3	0.3	25.8	46.4	5.4	1.1	63.4	22.8	1.6	0.2	8.0	11.8	1.3	0.5	17.4
302	301	4	6	1	6.9575E-09	8.9	83.3	66.2	6.0	18.0	100.0	75.1	7.1	8.9	83.3	66.2	6.0	18.0	100.0	75.1	7.1
302	303	4	2	1	1.1177E-07	28.9	100.0	28.7	1.4	7.3	37.2	14.9	1.0	28.9	100.0	28.7	1.4	7.3	37.2	14.9	1.0
303	302	2	1	1	1.0925E-04	100.0	65.1	0.8	3.3	40.1	27.2	0.2	5.3	22.7	18.0	0.3	0.8	10.3	8.5	0.1	1.1
303	201	3	1	1	1.7004E-05	100.0	77.1	1.8	1.5	26.3	21.2	0.1	3.7	21.2	34.4	3.0	1.0	7.5	13.9	0.8	0.3
303	301	3	1	1	7.0885E-06	100.0	13.6	0.2	17.0	73.3	11.1	0.7	30.9	23.4	3.2	0.1	4.5	18.0	2.7	0.3	8.0
303	302	4	6	1	1.6183E-07	5.5	39.5	12.6	0.6	21.3	100.0	29.0	0.8	5.5	39.5	12.6	0.6	21.3	100.0	29.0	0.8
303	301	4	2	1	4.0342E-09	42.3	100.0	89.5	7.4	10.2	37.0	68.8	6.0	42.3	100.0	89.5	7.4	10.2	37.0	68.8	6.0

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 6, 150.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N	N	P	P	S																
O	O	L	O	I									<==RELATIVE DAMAGES AROUND THE WELD ====>							
D	D	A	S	D		<-- Side 1: Chord side points -->							<-- Side 2: Brace side points -->							
E	E	N	N	E																
1	2	E		DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8

201	202	1	1	1	3.1438E-01	100.0	19.0	0.0	14.4	82.4	15.0	0.0	18.5	25.2	4.6	0.0	3.5	20.4	3.7	0.0	4.4
201	206	3	5	1	3.5031E-01	91.0	16.3	0.0	19.0	100.0	18.9	0.0	16.5	22.8	3.9	0.0	4.6	25.4	4.6	0.0	4.0
201	303	3	1	1	1.6653E-04	100.0	17.3	0.4	18.5	98.2	16.2	0.0	19.0	24.2	4.8	1.4	4.9	23.8	3.8	0.2	4.9
201	202	4	3	1	2.4799E-02	0.0	17.7	100.0	18.9	0.0	14.2	86.3	15.6	0.0	17.7	100.0	18.9	0.0	14.2	86.3	15.6
201	206	4	3	1	2.4485E-02	0.0	25.5	100.0	12.7	0.0	21.2	88.0	10.7	0.0	25.5	100.0	12.7	0.0	21.2	88.0	10.7
202	101	1	7	1	6.4372E-04	0.1	2.1	24.0	1.6	0.1	7.4	100.0	10.6	0.0	0.0	0.3	0.0	0.0	0.5	4.1	0.8
202	102	1	3	1	6.4728E-04	0.0	5.1	100.0	14.6	0.2	3.4	24.0	0.8	0.0	0.4	4.1	1.0	0.0	0.1	0.3	0.0
202	201	4	7	1	3.3520E-04	0.0	14.1	82.6	14.0	0.0	18.5	100.0	18.3	0.0	14.1	82.6	14.0	0.0	18.5	100.0	18.3
202	203	4	7	1	3.3609E-04	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2
203	202	1	5	1	3.2578E-01	90.5	16.1	0.0	18.9	100.0	18.8	0.0	16.4	22.6	3.9	0.0	4.6	25.3	4.6	0.0	4.0
203	301	1	2	1	3.5634E-05	96.2	100.0	4.8	5.0	27.8	16.9	0.1	4.6	22.1	79.0	17.7	2.7	6.9	20.8	3.1	1.2
203	204	2	1	1	3.2401E-01	100.0	19.0	0.0	14.5	82.6	15.0	0.0	18.6	25.3	4.6	0.0	3.5	20.5	3.7	0.0	4.4
203	202	4	3	1	2.4225E-02	0.0	18.2	100.0	18.4	0.0	14.9	87.8	15.6	0.0	18.2	100.0	18.4	0.0	14.9	87.8	15.6
203	204	4	3	1	2.4824E-02	0.0	25.0	100.0	13.1	0.0	20.4	86.4	10.7	0.0	25.0	100.0	13.1	0.0	20.4	86.4	10.7
204	102	2	7	1	6.5242E-04	0.0	1.0	26.8	3.6	0.2	14.0	100.0	5.4	0.0	0.0	0.3	0.1	0.0	0.9	3.7	0.4
204	103	2	3	1	7.1707E-04	0.1	11.0	100.0	7.1	0.1	1.4	22.6	2.0	0.0	0.8	4.5	0.6	0.0	0.0	0.3	0.0
204	203	4	7	1	3.4401E-04	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	3.4071E-04	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7
205	204	2	5	1	3.2377E-01	90.3	16.0	0.0	18.9	100.0	18.8	0.0	16.3	22.5	3.9	0.0	4.6	25.3	4.6	0.0	4.0
205	302	2	1	1	1.7503E-05	100.0	29.1	11.0	54.4	59.4	9.0	0.3	24.2	23.5	14.8	43.4	60.4	14.3	5.7	7.4	17.1
205	206	3	1	1	3.0806E-01	100.0	19.0	0.0	14.4	82.2	14.9	0.0	18.5	25.2	4.5	0.0	3.5	20.4	3.7	0.0	4.4
205	204	4	3	1	2.5386E-02	0.0	25.5	100.0	12.8	0.0	21.2	88.1	10.8	0.0	25.5	100.0	12.8	0.0	21.2	88.1	10.8
205	206	4	3	1	2.4828E-02	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.7	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.7
206	103	3	7	1	1.8946E-04	0.1	2.0	34.9	3.9	0.3	10.8	100.0	7.0	0.0	0.1	0.6	0.1	0.0	0.8	4.0	0.5
206	101	3	3	1	1.7809E-04	0.2	7.4	100.0	10.7	0.4	4.0	35.6	2.3	0.0	0.5	3.5	0.7	0.0	0.1	0.5	0.1
206	205	4	7	1	3.3401E-04	0.0	20.2	82.4	9.4	0.0	26.1	100.0	12.6	0.0	20.2	82.4	9.4	0.0	26.1	100.0	12.6
206	201	4	7	1	3.3831E-04	0.0	20.3	82.5	9.4	0.0	26.2	100.0	12.6	0.0	20.3	82.5	9.4	0.0	26.2	100.0	12.6
301	203	1	4	1	2.2841E-06	39.3	18.9	55.9	100.0	24.5	3.1	2.0	15.2	8.2	12.6	85.8	73.6	4.8	3.0	13.4	13.4
301	302	1	1	1	7.0566E-05	100.0	11.1	0.2	25.9	66.9	8.8	0.5	43.9	23.5	2.6	0.1	7.5	16.6	2.1	0.2	12.0
301	303	3	1	1	6.2157E-05	100.0	33.7	0.1	8.0	62.9	19.3	0.0	10.8	23.4	8.7	0.0	1.9	15.7	5.3	0.0	2.4
301	302	4	2	1	6.0120E-08	17.4	100.0	61.8	5.9	6.4	52.2	42.4	4.6	17.4	100.0	61.8	5.9	6.4	52.2	42.4	4.6
301	303	4	6	1	3.0840E-08	2.0	49.1	61.9	4.3	8.0	100.0	93.8	5.5	2.0	49.1	61.9	4.3	8.0	100.0	93.8	5.5
302	301	1	1	1	1.0305E-04	100.0	53.2	0.3	5.0	58.6	31.5	0.1	7.0	23.3	14.6	0.2	1.2	14.7	9.3	0.1	1.5
302	205	2	2	1	1.1410E-05	44.9	100.0	16.0	1.2	3.1	7.3	0.5	0.4	8.0	61.9	26.7	0.9	0.8	11.9	4.2	0.3
302	303	2	1	1	7.1718E-05	100.0	9.1	0.1	17.1	48.7	6.6	0.5	46.7	22.8	2.0	0.0	5.0	12.2	1.6	0.2	12.3
302	301	4	6	1	1.0142E-07	3.5	55.5	32.3	2.1	9.7	100.0	53.4	2.6	3.5	55.5	32.3	2.1	9.7	100.0	53.4	2.6
302	303	4	2	1	6.6574E-08	22.1	100.0	47.4	2.6	3.0	28.7	25.8	2.0	22.1	100.0	47.4	2.6	3.0	28.7	25.8	2.0
303	302	2	1	1	8.7747E-05	100.0	48.5	0.7	7.3	55.8	20.3	0.1	9.2	23.0	13.0	0.3	1.7	13.9	5.9	0.1	2.1
303	201	3	5	1	1.2417E-05	98.5	25.7	2.9	14.0	100.0	22.6	0.1	13.4	23.9	9.1	4.5	3.2	24.2	6.6	0.8	2.8
303	301	3	1	1	4.9185E-05	100.0	11.7	0.0	18.6	65.9	8.8	0.1	31.5	23.4	2.7	0.0	5.1	16.4	2.1	0.0	8.1
303	302	4	6	1	9.0782E-08	4.1	33.2	27.7	2.0	24.9	100.0	45.1	2.5	4.1	33.2	27.7	2.0	24.9	100.0	45.1	2.5
303	301	4	3	1	2.4538E-08	8.7	94.8	100.0	6.6	2.2	46.9	68.9	4.9	8.7	94.8	100.0	6.6	2.2	46.9	68.9	4.9

BUFFETING DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

NODE 1	NODE 2	PLANE	LOAD	SIDE	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ==== Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.5284E+00	100.0	18.8	0.0	14.2	81.9	14.7	0.0	18.3	25.0	4.5	0.0	3.5	20.1	3.6	0.0	4.4
201	206	3	5	1	1.7144E+00	90.9	16.1	0.0	18.7	100.0	18.6	0.0	16.3	22.5	3.9	0.0	4.6	25.1	4.5	0.0	3.9
201	303	3	1	1	3.6215E-04	100.0	32.5	2.2	22.5	83.7	15.9	0.1	17.2	24.0	17.2	7.9	11.3	20.3	6.9	1.4	6.0
201	202	4	3	1	1.1914E-01	0.0	17.7	100.0	18.9	0.0	14.2	86.1	15.5	0.0	17.7	100.0	18.9	0.0	14.2	86.1	15.5
201	206	4	3	1	1.1828E-01	0.0	25.6	100.0	12.7	0.0	21.3	88.0	10.7	0.0	25.6	100.0	12.7	0.0	21.3	88.0	10.7
202	101	1	7	1	2.5726E-03	0.1	1.5	25.0	2.5	0.2	10.8	100.0	7.8	0.0	0.0	0.3	0.1	0.0	0.8	4.1	0.6
202	102	1	3	1	2.5842E-03	0.1	7.6	100.0	11.1	0.2	2.5	24.4	1.4	0.0	0.6	4.1	0.8	0.0	0.1	0.3	0.0
202	201	4	7	1	1.6352E-03	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3
202	203	4	7	1	1.6388E-03	0.0	14.1	82.2	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.2	13.8	0.0	18.6	100.0	18.2
203	202	1	5	1	1.6248E+00	90.2	15.9	0.0	18.7	100.0	18.6	0.0	16.2	22.3	3.8	0.0	4.6	25.1	4.5	0.0	3.9
203	301	1	1	1	5.0149E-04	100.0	32.6	1.6	17.5	83.3	17.4	0.1	15.3	24.0	17.0	6.0	7.2	20.2	7.5	1.2	4.4
203	204	2	1	1	1.5626E+00	100.0	18.8	0.0	14.3	82.3	14.8	0.0	18.4	25.0	4.5	0.0	3.5	20.2	3.6	0.0	4.4
203	202	4	3	1	1.1956E-01	0.0	18.1	100.0	18.4	0.0	14.8	87.6	15.5	0.0	18.1	100.0	18.4	0.0	14.8	87.6	15.5
203	204	4	3	1	1.1829E-01	0.0	25.0	100.0	13.1	0.0	20.3	86.4	10.7	0.0	25.0	100.0	13.1	0.0	20.3	86.4	10.7
204	102	2	7	1	3.2370E-03	0.1	1.6	26.1	2.5	0.1	10.5	100.0	8.1	0.0	0.0	0.3	0.1	0.0	0.7	3.8	0.6
204	103	2	3	1	3.5652E-03	0.0	7.4	100.0	11.7	0.1	2.5	22.6	1.2	0.0	0.6	4.5	0.9	0.0	0.1	0.3	0.0
204	203	4	7	1	1.6293E-03	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	1.6140E-03	0.0	20.3	82.3	9.4	0.0	26.2	100.0	12.6	0.0	20.3	82.3	9.4	0.0	26.2	100.0	12.6
205	204	2	5	1	1.5528E+00	90.3	15.9	0.0	18.7	100.0	18.6	0.0	16.2	22.3	3.8	0.0	4.6	25.0	4.5	0.0	3.9
205	302	2	1	1	3.5657E-04	100.0	42.0	3.1	20.5	76.9	16.4	0.1	15.5	23.8	27.7	13.1	11.4	18.6	9.8	2.8	5.8
205	206	3	1	1	1.5341E+00	100.0	18.8	0.0	14.3	82.4	14.9	0.0	18.4	25.0	4.5	0.0	3.5	20.3	3.7	0.0	4.4
205	204	4	3	1	1.2031E-01	0.0	25.5	100.0	12.8	0.0	21.2	88.4	10.9	0.0	25.5	100.0	12.8	0.0	21.2	88.4	10.9
205	206	4	3	1	1.2257E-01	0.0	25.0	100.0	13.1	0.0	20.3	86.6	10.8	0.0	25.0	100.0	13.1	0.0	20.3	86.6	10.8
206	103	3	7	1	3.2747E-03	0.0	1.2	22.9	2.6	0.2	12.2	100.0	7.1	0.0	0.0	0.3	0.1	0.0	0.9	4.5	0.6
206	101	3	3	1	2.9959E-03	0.1	8.3	100.0	10.2	0.1	2.4	25.6	1.6	0.0	0.6	3.8	0.7	0.0	0.1	0.3	0.0
206	205	4	7	1	1.6294E-03	0.0	20.3	82.6	9.5	0.0	26.1	100.0	12.7	0.0	20.3	82.6	9.5	0.0	26.1	100.0	12.7
206	201	4	7	1	1.6518E-03	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7
301	203	1	1	1	4.7572E-05	100.0	57.8	13.0	27.0	79.8	18.7	0.6	13.8	22.8	29.2	21.0	12.6	19.1	9.4	4.0	5.0
301	302	1	1	1	3.0555E-04	100.0	10.7	0.1	21.9	62.4	8.4	0.5	42.8	23.3	2.5	0.1	6.3	15.5	2.0	0.2	11.5
301	303	3	1	1	4.5763E-04	100.0	48.4	0.5	6.5	55.9	23.4	0.1	8.6	23.1	13.0	0.2	1.5	14.0	6.8	0.1	1.9
301	302	4	2	1	2.4734E-07	17.6	100.0	64.8	5.9	4.4	41.7	41.6	4.6	17.6	100.0	64.8	5.9	4.4	41.7	41.6	4.6
301	303	4	6	1	4.3117E-07	4.5	41.8	28.2	1.8	19.5	100.0	46.6	2.3	4.5	41.8	28.2	1.8	19.5	100.0	46.6	2.3
302	301	1	1	1	4.0625E-04	100.0	47.9	0.4	6.6	58.0	24.9	0.1	8.7	23.2	12.9	0.2	1.6	14.5	7.2	0.1	1.9
302	205	2	1	1	3.8651E-05	100.0	82.6	24.2	31.8	68.3	21.2	1.2	11.7	22.1	47.7	42.2	19.4	16.4	14.3	8.4	5.7
302	303	2	1	1	3.7190E-04	100.0	10.2	0.2	23.1	60.1	7.8	0.6	45.5	23.2	2.3	0.1	6.7	15.0	1.9	0.2	12.3
302	301	4	6	1	3.6379E-07	3.2	44.7	35.1	3.2	13.4	100.0	58.5	3.9	3.2	44.7	35.1	3.2	13.4	100.0	58.5	3.9

302	303	4	2	1	3.3519E-07	23.2	100.0	50.0	3.2	6.7	43.9	32.3	2.4	23.2	100.0	50.0	3.2	6.7	43.9	32.3	2.4
303	302	2	1	1	4.6330E-04	100.0	50.6	0.5	5.5	55.0	25.8	0.1	7.7	23.1	13.8	0.2	1.3	13.8	7.6	0.1	1.7
303	201	3	1	1	3.9826E-05	100.0	93.1	16.7	16.5	54.0	20.1	0.7	8.2	21.5	48.7	25.2	8.2	13.2	13.4	4.3	2.7
303	301	3	1	1	3.1573E-04	100.0	9.5	0.1	21.4	55.5	7.1	0.6	46.7	23.0	2.2	0.1	6.3	13.9	1.7	0.2	12.6
303	302	4	6	1	4.7431E-07	4.6	45.7	26.3	1.5	17.6	100.0	44.8	1.9	4.6	45.7	26.3	1.5	17.6	100.0	44.8	1.9
303	301	4	2	1	3.0642E-07	22.9	100.0	48.5	2.8	5.7	39.1	29.2	2.1	22.9	100.0	48.5	2.8	5.7	39.1	29.2	2.1

20 WORST BUFFETING DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	206	3	5	1	1.7144E+00	90.9	16.1	0.0	18.7	100.0	18.6	0.0	16.3	22.5	3.9	0.0	4.6	25.1	4.5	0.0	3.9
203	202	1	5	1	1.6248E+00	90.2	15.9	0.0	18.7	100.0	18.6	0.0	16.2	22.3	3.8	0.0	4.6	25.1	4.5	0.0	3.9
203	204	2	1	1	1.5626E+00	100.0	18.8	0.0	14.3	82.3	14.8	0.0	18.4	25.0	4.5	0.0	3.5	20.2	3.6	0.0	4.4
205	204	2	5	1	1.5528E+00	90.3	15.9	0.0	18.7	100.0	18.6	0.0	16.2	22.3	3.8	0.0	4.6	25.0	4.5	0.0	3.9
205	206	3	1	1	1.5341E+00	100.0	18.8	0.0	14.3	82.4	14.9	0.0	18.4	25.0	4.5	0.0	3.5	20.3	3.7	0.0	4.4
201	202	1	1	1	1.5284E+00	100.0	18.8	0.0	14.2	81.9	14.7	0.0	18.3	25.0	4.5	0.0	3.5	20.1	3.6	0.0	4.4
205	206	4	3	1	1.2257E-01	0.0	25.0	100.0	13.1	0.0	20.3	86.6	10.8	0.0	25.0	100.0	13.1	0.0	20.3	86.6	10.8
205	204	4	3	1	1.2031E-01	0.0	25.5	100.0	12.8	0.0	21.2	88.4	10.9	0.0	25.5	100.0	12.8	0.0	21.2	88.4	10.9
203	202	4	3	1	1.1956E-01	0.0	18.1	100.0	18.4	0.0	14.8	87.6	15.5	0.0	18.1	100.0	18.4	0.0	14.8	87.6	15.5
201	202	4	3	1	1.1914E-01	0.0	17.7	100.0	18.9	0.0	14.2	86.1	15.5	0.0	17.7	100.0	18.9	0.0	14.2	86.1	15.5
203	204	4	3	1	1.1829E-01	0.0	25.0	100.0	13.1	0.0	20.3	86.4	10.7	0.0	25.0	100.0	13.1	0.0	20.3	86.4	10.7
201	206	4	3	1	1.1828E-01	0.0	25.6	100.0	12.7	0.0	21.3	88.0	10.7	0.0	25.6	100.0	12.7	0.0	21.3	88.0	10.7
204	103	2	3	1	3.5652E-03	0.0	7.4	100.0	11.7	0.1	2.5	22.6	1.2	0.0	0.6	4.5	0.9	0.0	0.1	0.3	0.0
206	103	3	7	1	3.2747E-03	0.0	1.2	22.9	2.6	0.2	12.2	100.0	7.1	0.0	0.0	0.3	0.1	0.0	0.9	4.5	0.6
204	102	2	7	1	3.2370E-03	0.1	1.6	26.1	2.5	0.1	10.5	100.0	8.1	0.0	0.0	0.3	0.1	0.0	0.7	3.8	0.6
206	101	3	3	1	2.9959E-03	0.1	8.3	100.0	10.2	0.1	2.4	25.6	1.6	0.0	0.6	3.8	0.7	0.0	0.1	0.3	0.0
202	102	1	3	1	2.5842E-03	0.1	7.6	100.0	11.1	0.2	2.5	24.4	1.4	0.0	0.6	4.1	0.8	0.0	0.1	0.3	0.0
202	101	1	7	1	2.5726E-03	0.1	1.5	25.0	2.5	0.2	10.8	100.0	7.8	0.0	0.0	0.3	0.1	0.0	0.8	4.1	0.6
206	201	4	7	1	1.6518E-03	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7
202	203	4	7	1	1.6388E-03	0.0	14.1	82.2	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.2	13.8	0.0	18.6	100.0	18.2

BUFFETING DAMAGE EVALUATED FOR 42 JOINT CONNECTIONS OVER ALL ANALYSIS PLANES

****

PRINT OF : WIND FATIGUE RESULTS

```
RUN NAME                : X505B
RUN DESCRIPTION         : None
RESULTS INTERFACE FILE  : X505BR1.SIN
PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  15:44:58

************************************************************************

RUN SCENARIO:
=============
ANALYSIS CASE              : MULTI BRACE FATIGUE CHECK
FIRST WIND DIRECTION       : 1
LAST  WIND DIRECTION       : 6
FIRST NODE CHECKED         : 101
LAST  NODE CHECKED         : 303
FIRST ANALYSIS PLANE       : 1
LAST  ANALYSIS PLANE       : 4
NUMBER OF EIGENMODES       : 2
SHOW PROGRESS OF EXECUTION : OFF

WIND LOAD MODELLING:
====================
WIND LOAD TYPE             : WIND BUFFETING
WIDE BAND CORRECTION       : NONE
WIND PROFILE               : API (WIND PROFILE TYPE READ FROM SIN FILE)
GUST COMPONENTS CONSIDERED : ALONG WIND COMPONENT ONLY
GUST DIRECTION MOMENT      : DAMAGE BY ADD OF GUST SPECTRUM MOMENTS
WIND SPECTRA :
    LONGITUDINAL DIRECTION : HARRIS
    LATERAL      DIRECTION : NOT ACTIVE
    VERTICAL     DIRECTION : NOT ACTIVE
COHERENCE FUNCTIONS :
    LONGITUDINAL DIRECTION : GUSTO1
    LATERAL      DIRECTION : NOT APPLICABLE
    VERTICAL     DIRECTION : NOT APPLICABLE

INPUT DATA:
===========

PARAMETERS READ FROM SIN FILE :
(l = current length unit)
------------------------------

WATER DEPTH - WD  (l)                          : 10.0
Z-COORDINATE OF MUDLINE - ZMUD  (l)            : -10.0
```

```
Z-COORDINATE OF STILL WATER LEVEL/GROUND  (l)     : 0.0
                        (Z0 = ZMUD + WD)
WIND DIRECTIONS (RELATIVE TO GLOBAL X-AXIS)       : DIR  ANGLE (deg)
                                                    1    0.0
                                                    2    30.0
                                                    3    60.0
                                                    4    90.0
                                                    5    120.0
                                                    6    150.0
MEAN WIND VELOCITY  (l/sec)                       : 30.0
MEAN WIND VELOCITY LEVEL  (l)                     : 10.0
HEIGHT EXPONENT, API WIND PROFILE                 : .125
GUST FACTOR, API WIND PROFILE                     : 1.0
ACCELERATION OF GRAVITY (g)  (l/sec^2)            : 9.81
UNIT LENGTH ADJUSTMENT FACTOR (9.81/g)            : 1.0

DIRECT INPUT PARAMETERS :
(l = current length unit)
-------------------------

DAMAGE CALCULATION OF BENT CAN JOINTS             : ON
COHERENCE FUNCTION CONSTANT (GUSTO, DAVENPORT)    : 8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz ALONG DIR.  : 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz LATERAL DIR.: 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz VERTICAL DIR: 16.0   16.0   8.0
GROUND ROUGNESS COEFFICIENT                       : 1.5E-02
TURBULENCE LENGTH SCALE DAVENPORT SPECTRUM  (l)   : 1200.0
TURBULENCE LENGTH SCALE HARRIS SPECTRUM  (l)      : 1800.0
DEFAULT SN CURVE                                  : DOE-T
MINIMUM PARAMETRIC SCFS                           : 1.6    1.6    1.6
DEFAULT GLOBAL SCFS                               : 1.6    1.6    1.6
DEFAULT SCF SCHEME, Alt.: EFTHYMIOU, LLOYDS       : EFTHYMIOU
(New default overrules previously assigned SCFs)
DAMPING RATIO                                     : 1.0E-02
CHORD LENGTH/DIAMETER RATIO (L/D)                 : 30.0
ANGULAR TOLERANCE ANALYSIS PLANES (DEG)           : 1.0
LIMIT FOR PRINTING DAMAGE VALUES                  : 1.0E-12
MIN. WIND FORCE USED RELATIVE TO MAX.             : 1.000E-05
LIMIT VALUE ON COHERENCE EFFECT                   : 1.000E+00
(NO COHERENCE = 1.0, FULL COHERENCE = 0 in limit)
NUMBER OF WIND SPEEDS                             : 5

WIND PROBABILITIES AND DRAG CORRECTION COEFFICIENT
-------------------------------------------------------
```

DIR NO	WIND SPEED NO	WIND SPEED	WIND PROBABILITY	DRAG COEFF CORRECTION FACTORS
1	1	10.0000	0.3000	1.0000
1	2	15.0000	0.2500	0.9000
1	3	20.0000	0.2000	0.8000
1	4	25.0000	0.1500	0.7500
1	5	30.0000	0.1000	0.7000
2	1	10.0000	0.3500	1.0100
2	2	15.0000	0.2000	0.9100
2	3	20.0000	0.2000	0.8100
2	4	25.0000	0.1500	0.7600
2	5	30.0000	0.1000	0.7100
3	1	10.0000	0.4000	1.0200
3	2	15.0000	0.2000	0.9200
3	3	20.0000	0.1500	0.8200
3	4	25.0000	0.1500	0.7700
3	5	30.0000	0.1000	0.7200
4	1	10.0000	0.2000	1.0300
4	2	15.0000	0.2000	0.9300
4	3	20.0000	0.2000	0.8300
4	4	25.0000	0.2000	0.7800
4	5	30.0000	0.2000	0.7300
5	1	10.0000	0.3000	1.0400
5	2	15.0000	0.2500	0.9400
5	3	20.0000	0.2000	0.8400
5	4	25.0000	0.1500	0.7900
5	5	30.0000	0.1000	0.7400
6	1	10.0000	0.3600	1.0500
6	2	15.0000	0.2200	0.9500
6	3	20.0000	0.2100	0.8500
6	4	25.0000	0.1100	0.8000
6	5	30.0000	0.1000	0.7500

NODES DEFINING THE ANALYSIS PLANES:

1	101	203	301
2	102	205	302
3	103	201	303
4	201	203	205

NUMBER OF COHERENCE MATRICES FOR THE U, V AND W WIND GUST DIRECTIONS : 1

Note! 1,2 or 3 coherence matrices are formed depending on the choice of
wind spectrum and coherence models. Theexecution time increases

with the number of coherence matrices applied in the run.

****

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N	P O S E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
201	202	1	5	1	5.4393E-03	90.2	16.5	0.0	17.2	100.0	19.0	0.0	15.4	21.9	4.0	0.0	4.1	24.3	4.6	0.0	3.7
201	206	3	5	1	6.1730E-02	94.7	16.4	0.0	18.1	100.0	17.7	0.0	16.8	22.9	3.9	0.0	4.4	24.3	4.3	0.0	4.1
201	303	3	1	1	8.3543E-05	100.0	41.6	0.1	2.4	45.7	16.1	0.0	9.0	23.8	18.7	0.2	0.2	11.3	8.5	0.0	0.8
201	202	4	7	1	4.1494E-04	0.0	15.0	93.1	18.0	0.0	16.1	100.0	20.6	0.0	15.0	93.1	18.0	0.0	16.1	100.0	20.6
201	206	4	3	1	4.1063E-03	0.0	24.7	100.0	12.8	0.0	22.4	93.3	11.6	0.0	24.7	100.0	12.8	0.0	22.4	93.3	11.6
202	101	1	7	1	8.2014E-04	0.0	1.1	21.7	1.8	0.0	10.6	100.0	7.6	0.0	0.0	0.2	0.0	0.0	0.8	4.3	0.6
202	102	1	3	1	8.1864E-04	0.0	7.7	100.0	10.5	0.0	1.8	21.7	1.1	0.0	0.6	4.3	0.8	0.0	0.0	0.2	0.0
202	201	4	7	1	3.2647E-06	0.4	14.4	83.3	14.2	0.0	18.6	100.0	18.4	0.4	14.4	83.3	14.2	0.0	18.6	100.0	18.4
202	203	4	7	1	3.2732E-06	1.0	14.8	83.2	14.2	0.0	18.7	100.0	18.5	1.0	14.8	83.2	14.2	0.0	18.7	100.0	18.5
203	202	1	1	1	5.9721E-03	100.0	17.6	0.0	16.2	90.0	15.3	0.0	19.4	24.4	4.3	0.0	3.9	21.8	3.7	0.0	4.8
203	301	1	3	2	9.4095E-06	4.1	31.0	26.7	1.6	0.8	0.5	0.3	0.3	0.9	55.8	100.0	9.1	0.2	5.9	14.4	0.3
203	204	2	1	1	5.6024E-02	100.0	18.3	0.0	14.8	86.6	15.5	0.0	17.6	24.4	4.4	0.0	3.6	20.9	3.8	0.0	4.2
203	202	4	7	1	4.3038E-04	0.1	14.3	87.5	16.5	0.0	16.6	100.0	21.5	0.1	14.3	87.5	16.5	0.0	16.6	100.0	21.5
203	204	4	3	1	4.1806E-03	0.0	24.3	100.0	13.2	0.0	21.1	90.1	11.3	0.0	24.3	100.0	13.2	0.0	21.1	90.1	11.3
204	102	2	7	1	2.5778E-05	0.1	0.8	29.6	7.5	0.8	23.8	100.0	2.7	0.0	0.0	0.4	0.2	0.1	1.5	3.5	0.2
204	103	2	3	1	3.0150E-05	0.6	23.0	100.0	3.2	0.3	1.0	20.3	4.9	0.1	1.7	4.5	0.3	0.0	0.0	0.2	0.1
204	203	4	7	1	3.8128E-05	0.0	22.1	89.1	10.5	0.0	25.8	100.0	12.5	0.0	22.1	89.1	10.5	0.0	25.8	100.0	12.5
204	205	4	7	1	3.8780E-05	0.0	18.0	73.3	8.0	0.0	26.9	100.0	13.1	0.0	18.0	73.3	8.0	0.0	26.9	100.0	13.1
205	204	2	5	1	1.8224E-02	73.1	12.5	0.0	18.2	100.0	19.6	0.0	11.8	17.5	3.0	0.0	4.5	24.5	4.9	0.0	2.8
205	302	2	5	1	4.2697E-05	38.2	1.2	0.3	54.2	100.0	6.6	0.0	17.9	9.7	0.0	1.1	30.6	23.4	0.3	0.2	13.2
205	206	3	1	1	1.8358E-02	100.0	18.2	0.0	10.5	61.3	10.1	0.0	19.0	24.4	4.3	0.0	2.6	14.7	2.5	0.0	4.5
205	204	4	3	1	1.3895E-03	0.0	29.1	100.0	12.2	0.0	17.6	69.1	7.0	0.0	29.1	100.0	12.2	0.0	17.6	69.1	7.0
205	206	4	3	1	1.3644E-03	0.0	28.0	100.0	12.6	0.0	17.5	70.4	7.5	0.0	28.0	100.0	12.6	0.0	17.5	70.4	7.5
206	103	3	7	1	2.8864E-05	0.6	4.8	19.5	1.0	0.3	3.1	100.0	23.3	0.1	0.1	0.2	0.0	0.0	0.3	4.6	1.7
206	101	3	3	1	2.4693E-05	0.1	2.8	100.0	23.5	0.8	7.1	28.5	0.8	0.0	0.2	3.6	1.5	0.1	0.2	0.3	0.0
206	205	4	7	1	3.8207E-05	0.0	18.4	75.2	8.3	0.0	26.6	100.0	13.0	0.0	18.4	75.2	8.3	0.0	26.6	100.0	13.0
206	201	4	7	1	3.7764E-05	0.0	22.8	90.9	10.7	0.0	25.7	100.0	12.4	0.0	22.8	90.9	10.7	0.0	25.7	100.0	12.4
301	203	1	3	2	3.3781E-06	3.8	58.0	63.4	7.0	0.0	0.5	1.2	0.0	0.5	51.6	100.0	11.0	0.0	4.5	13.5	0.3
301	302	1	1	1	3.1930E-05	100.0	4.1	0.5	30.3	32.2	2.6	1.8	83.4	22.4	0.8	0.3	9.9	8.4	0.6	0.8	23.3
301	303	3	1	1	2.5127E-06	100.0	60.7	0.3	4.7	91.3	57.1	0.3	5.4	24.1	17.2	0.1	1.0	22.3	16.3	0.1	1.2
301	302	4	2	1	6.8495E-08	23.3	100.0	24.1	0.7	5.5	35.6	8.3	0.5	23.3	100.0	24.1	0.7	5.5	35.6	8.3	0.5
301	303	4	6	1	2.9040E-09	10.0	94.3	33.1	0.7	10.9	100.0	36.3	0.9	10.0	94.3	33.1	0.7	10.9	100.0	36.3	0.9

302	301	1	1	1	5.8435E-05	100.0	76.2	1.1	1.6	31.9	30.3	0.3	3.3	22.5	21.1	0.5	0.4	8.4	9.6	0.2	0.6
302	205	2	1	1	1.3185E-05	100.0	77.3	1.1	0.3	27.6	21.8	0.0	3.7	21.3	36.1	2.0	0.0	7.9	15.0	0.4	0.1
302	303	2	1	1	8.8467E-07	100.0	11.1	0.1	13.1	58.4	9.1	1.9	46.6	22.5	2.6	0.1	3.6	14.3	2.2	0.7	12.0
302	301	4	6	1	1.0306E-07	4.0	38.8	10.0	0.3	16.8	100.0	29.3	0.4	4.0	38.8	10.0	0.3	16.8	100.0	29.3	0.4
302	303	4	2	1	9.9563E-10	57.5	100.0	39.9	2.9	2.2	13.4	26.4	3.4	57.5	100.0	39.9	2.9	2.2	13.4	26.4	3.4
303	302	2	1	1	6.5874E-06	100.0	30.9	0.6	12.0	76.3	16.4	0.0	13.9	23.5	7.9	0.2	2.9	18.7	4.3	0.0	3.3
303	201	3	5	1	3.1160E-06	16.0	0.1	1.1	72.8	100.0	4.5	0.0	12.4	4.9	0.0	1.6	30.0	20.3	0.2	0.1	8.6
303	301	3	1	1	7.4420E-06	100.0	12.9	0.3	31.8	86.7	11.0	0.3	35.1	24.0	3.0	0.1	8.9	21.2	2.6	0.1	9.6
303	302	4	6	1	3.7262E-09	3.0	30.8	72.4	6.8	38.1	100.0	90.3	8.0	3.0	30.8	72.4	6.8	38.1	100.0	90.3	8.0
303	301	4	2	1	4.5794E-09	17.4	100.0	82.3	6.5	16.2	92.1	71.6	5.1	17.4	100.0	82.3	6.5	16.2	92.1	71.6	5.1

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 2, 30.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O I D		<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
				DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	5	1	2.5945E-02	96.1	17.6	0.0	17.2	100.0	18.6	0.0	16.4	23.3	4.3	0.0	4.1	24.4	4.5	0.0	4.0
201	206	3	1	1	3.5361E-02	100.0	17.5	0.0	17.0	94.4	16.1	0.0	18.7	24.4	4.2	0.0	4.1	22.9	3.9	0.0	4.6
201	303	3	2	1	2.4945E-05	93.9	100.0	4.0	0.0	12.2	13.3	0.0	3.0	21.7	74.4	13.1	0.0	3.2	17.5	1.5	0.0
201	202	4	7	1	2.0200E-03	0.0	15.7	97.0	18.7	0.0	16.2	100.0	19.8	0.0	15.7	97.0	18.7	0.0	16.2	100.0	19.8
201	206	4	7	1	2.3763E-03	0.0	21.6	92.4	12.0	0.0	23.6	100.0	13.8	0.0	21.6	92.4	12.0	0.0	23.6	100.0	13.8
202	101	1	7	1	4.5617E-04	0.0	0.7	23.1	3.1	0.1	14.6	100.0	4.9	0.0	0.0	0.2	0.1	0.0	1.0	4.1	0.4
202	102	1	3	1	4.5333E-04	0.0	10.7	100.0	7.1	0.0	1.2	23.1	2.0	0.0	0.8	4.1	0.5	0.0	0.0	0.2	0.0
202	201	4	7	1	1.1833E-05	0.0	16.5	92.7	16.3	0.0	18.0	100.0	18.2	0.0	16.5	92.7	16.3	0.0	18.0	100.0	18.2
202	203	4	7	1	1.2207E-05	0.2	12.1	71.3	11.5	0.0	19.4	100.0	19.6	0.2	12.1	71.3	11.5	0.0	19.4	100.0	19.6
203	202	1	5	1	6.0888E-03	83.0	14.2	0.0	18.3	100.0	18.7	0.0	14.2	20.0	3.4	0.0	4.5	24.4	4.6	0.0	3.4
203	301	1	4	2	5.4648E-06	7.1	1.2	19.8	88.1	35.2	0.8	0.1	4.7	1.7	1.4	68.3	100.0	7.8	0.1	7.7	14.0
203	204	2	1	1	5.9731E-02	100.0	18.4	0.0	12.5	73.3	12.7	0.0	18.2	24.4	4.4	0.0	3.1	17.7	3.1	0.0	4.3
203	202	4	3	1	4.3969E-04	0.1	19.5	100.0	18.1	0.0	13.6	79.5	13.7	0.1	19.5	100.0	18.1	0.0	13.6	79.5	13.7
203	204	4	3	1	4.3423E-03	0.0	25.7	100.0	13.1	0.0	19.0	79.8	9.3	0.0	25.7	100.0	13.1	0.0	19.0	79.8	9.3
204	102	2	3	1	1.7808E-07	31.6	27.8	100.0	46.2	39.9	38.7	75.4	23.3	1.7	1.3	2.5	2.2	2.4	1.6	1.5	1.0
204	103	2	7	1	1.8256E-07	29.8	15.4	77.5	42.5	41.5	52.3	100.0	15.6	1.4	0.7	1.7	1.9	2.5	2.6	2.8	0.7
204	203	4	7	1	6.7271E-05	0.0	20.1	82.3	9.4	0.0	26.1	100.0	12.7	0.0	20.1	82.3	9.4	0.0	26.1	100.0	12.7
204	205	4	7	1	6.6849E-05	0.0	19.9	80.9	9.2	0.0	26.3	100.0	12.6	0.0	19.9	80.9	9.2	0.0	26.3	100.0	12.6
205	204	2	5	1	5.4143E-02	81.9	14.0	0.0	18.2	100.0	18.7	0.0	13.8	19.7	3.4	0.0	4.5	24.4	4.6	0.0	3.3
205	302	2	1	1	1.1803E-04	100.0	16.4	0.0	19.0	99.5	16.2	0.0	19.1	24.2	3.6	0.0	5.0	24.1	3.6	0.0	5.1
205	206	3	1	1	6.6185E-03	100.0	18.2	0.0	11.9	69.5	12.0	0.0	18.7	24.4	4.3	0.0	2.9	16.8	3.0	0.0	4.4
205	204	4	3	1	4.1042E-03	0.0	26.8	100.0	12.5	0.0	19.5	79.0	8.8	0.0	26.8	100.0	12.5	0.0	19.5	79.0	8.8
205	206	4	3	1	4.9985E-04	0.0	27.0	100.0	12.8	0.0	18.6	77.1	9.0	0.0	27.0	100.0	12.8	0.0	18.6	77.1	9.0
206	103	3	7	1	4.8681E-04	0.0	1.9	21.1	1.0	0.0	6.8	100.0	11.0	0.0	0.0	0.2	0.0	0.0	0.6	4.5	0.9
206	101	3	3	1	4.4385E-04	0.0	5.4	100.0	13.7	0.1	3.1	25.1	0.9	0.0	0.4	3.8	0.9	0.0	0.1	0.3	0.0

206	205	4	7	1	1.4279E-05	0.0	18.0	73.3	8.0	0.0	27.0	100.0	13.3	0.0	18.0	73.3	8.0	0.0	27.0	100.0	13.3
206	201	4	7	1	1.4094E-05	0.1	24.6	95.3	11.5	0.0	25.3	100.0	12.4	0.1	24.6	95.3	11.5	0.0	25.3	100.0	12.4
301	203	1	2	1	7.1395E-06	49.5	100.0	13.7	0.0	1.0	5.9	0.2	0.4	8.8	57.1	20.5	0.0	0.5	9.8	2.2	0.0
301	302	1	1	1	2.7618E-05	100.0	3.2	0.2	18.7	18.9	1.1	1.1	73.0	21.7	0.6	0.1	6.2	5.1	0.3	0.5	19.7
301	303	3	1	1	5.1224E-05	100.0	64.7	0.4	1.3	46.3	35.9	0.2	3.4	23.1	17.8	0.2	0.3	11.9	10.8	0.1	0.6
301	302	4	2	1	4.7055E-08	18.5	100.0	29.9	0.4	2.2	24.7	6.2	0.3	18.5	100.0	29.9	0.4	2.2	24.7	6.2	0.3
301	303	4	6	1	6.5974E-08	5.0	54.3	14.6	0.1	12.9	100.0	31.0	0.1	5.0	54.3	14.6	0.1	12.9	100.0	31.0	0.1
302	301	1	1	1	3.9541E-05	100.0	64.0	1.0	3.8	34.2	19.8	0.2	5.8	22.3	17.3	0.4	0.9	8.8	6.2	0.1	1.2
302	205	2	5	1	1.2152E-05	99.2	22.2	0.0	13.8	100.0	22.4	0.0	13.6	24.1	6.3	0.0	2.8	24.2	6.4	0.0	2.8
302	303	2	1	1	2.3298E-06	100.0	15.8	0.0	17.6	88.4	13.9	0.0	19.7	24.0	3.7	0.0	4.4	21.6	3.3	0.0	4.8
302	301	4	6	1	5.7520E-08	2.6	27.2	12.9	1.2	19.1	100.0	35.4	1.5	2.6	27.2	12.9	1.2	19.1	100.0	35.4	1.5
302	303	4	3	1	1.1779E-09	0.0	31.9	100.0	9.6	0.2	28.3	88.9	7.9	0.0	31.9	100.0	9.6	0.2	28.3	88.9	7.9
303	302	2	1	1	2.1131E-06	100.0	19.5	0.0	15.0	91.7	17.6	0.0	16.1	24.0	4.8	0.0	3.6	22.3	4.3	0.0	3.8
303	201	3	4	1	1.1639E-06	0.6	3.4	61.2	100.0	15.5	0.0	0.5	1.0	0.1	5.4	84.1	69.6	2.1	0.0	7.8	5.1
303	301	3	1	1	2.5751E-05	100.0	7.0	0.5	36.8	55.4	5.3	1.2	68.0	23.2	1.6	0.3	11.4	14.0	1.3	0.5	19.3
303	302	4	7	1	1.1317E-09	0.0	27.3	92.3	9.8	0.0	31.1	100.0	10.0	0.0	27.3	92.3	9.8	0.0	31.1	100.0	10.0
303	301	4	2	1	4.2213E-08	26.7	100.0	26.9	1.2	10.9	52.0	16.0	0.9	26.7	100.0	26.9	1.2	10.9	52.0	16.0	0.9

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 3, 60.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	S I D		<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
					DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	5.8014E-02	100.0	18.4	0.0	14.6	85.6	15.3	0.0	17.7	24.4	4.4	0.0	3.6	20.7	3.7	0.0	4.2
201	206	3	1	1	7.7963E-03	100.0	17.6	0.0	16.8	92.8	15.9	0.0	19.1	24.4	4.3	0.0	4.1	22.5	3.8	0.0	4.7
201	303	3	3	2	8.8411E-06	6.5	38.2	28.5	1.5	1.6	0.8	0.3	0.6	1.5	62.4	100.0	7.9	0.4	6.6	13.5	0.3
201	202	4	3	1	4.4541E-03	0.0	17.2	100.0	19.0	0.0	14.6	89.4	16.3	0.0	17.2	100.0	19.0	0.0	14.6	89.4	16.3
201	206	4	7	1	5.2821E-04	0.0	21.2	90.2	11.7	0.0	23.6	100.0	14.9	0.0	21.2	90.2	11.7	0.0	23.6	100.0	14.9
202	101	1	7	1	2.9535E-05	0.1	0.5	24.0	7.4	1.0	27.3	100.0	2.1	0.0	0.0	0.3	0.2	0.2	1.8	4.0	0.2
202	102	1	3	1	2.9114E-05	0.5	20.8	100.0	3.6	0.3	1.2	23.9	5.1	0.1	1.4	4.0	0.3	0.0	0.0	0.3	0.1
202	201	4	7	1	4.1947E-05	0.0	15.4	88.3	15.2	0.0	18.3	100.0	18.1	0.0	15.4	88.3	15.2	0.0	18.3	100.0	18.1
202	203	4	7	1	4.2969E-05	0.0	12.6	74.3	12.1	0.0	19.0	100.0	18.8	0.0	12.6	74.3	12.1	0.0	19.0	100.0	18.8
203	202	1	5	1	2.2157E-02	75.4	12.8	0.0	18.4	100.0	19.2	0.0	12.4	18.1	3.1	0.0	4.5	24.5	4.8	0.0	2.9
203	301	1	5	1	4.1767E-05	39.2	1.4	0.2	50.3	100.0	7.4	0.0	16.7	9.8	0.1	0.7	26.0	23.5	0.4	0.1	11.0
203	204	2	1	1	2.1226E-02	100.0	18.3	0.0	10.7	63.0	10.6	0.0	18.8	24.5	4.3	0.0	2.7	15.1	2.6	0.0	4.4
203	202	4	3	1	1.6147E-03	0.0	20.3	100.0	18.0	0.0	12.3	70.6	11.1	0.0	20.3	100.0	18.0	0.0	12.3	70.6	11.1
203	204	4	3	1	1.5032E-03	0.0	27.3	100.0	12.9	0.0	17.4	71.6	7.8	0.0	27.3	100.0	12.9	0.0	17.4	71.6	7.8
204	102	2	7	1	2.8866E-05	0.4	3.7	21.1	1.4	0.4	4.5	100.0	18.3	0.1	0.1	0.2	0.1	0.0	0.3	3.9	1.2
204	103	2	3	1	2.8645E-05	0.1	1.6	100.0	31.3	1.5	9.4	26.3	0.4	0.0	0.1	4.2	2.1	0.2	0.3	0.3	0.0
204	203	4	7	1	4.1119E-05	0.0	18.4	75.8	8.4	0.0	26.4	100.0	13.1	0.0	18.4	75.8	8.4	0.0	26.4	100.0	13.1
204	205	4	7	1	3.9866E-05	0.0	22.6	90.5	10.7	0.0	25.7	100.0	12.5	0.0	22.6	90.5	10.7	0.0	25.7	100.0	12.5

205	204	2	5	1	5.8354E-02	94.2	16.2	0.0	18.2	100.0	17.7	0.0	16.8	22.8	3.9	0.0	4.4	24.3	4.3	0.0	4.1
205	302	2	1	1	8.8629E-05	100.0	41.9	0.1	2.2	43.3	15.2	0.0	9.1	23.5	19.6	0.3	0.1	10.9	8.8	0.0	0.7
205	206	3	5	1	7.1760E-03	93.2	17.2	0.0	17.0	100.0	19.1	0.0	15.9	22.6	4.2	0.0	4.0	24.3	4.6	0.0	3.8
205	204	4	3	1	4.3909E-03	0.0	24.5	100.0	12.9	0.0	22.2	93.3	11.8	0.0	24.5	100.0	12.9	0.0	22.2	93.3	11.8
205	206	4	7	1	5.6771E-04	0.0	21.7	95.1	12.9	0.0	22.4	100.0	14.8	0.0	21.7	95.1	12.9	0.0	22.4	100.0	14.8
206	103	3	7	1	9.9170E-04	0.0	1.0	20.2	1.7	0.0	10.8	100.0	7.6	0.0	0.0	0.2	0.0	0.0	0.9	4.8	0.6
206	101	3	3	1	8.9622E-04	0.0	7.9	100.0	10.5	0.0	2.0	23.8	1.3	0.0	0.6	4.0	0.7	0.0	0.0	0.2	0.0
206	205	4	7	1	4.6350E-06	0.3	20.6	83.9	9.8	0.0	26.1	100.0	12.7	0.3	20.6	83.9	9.8	0.0	26.1	100.0	12.7
206	201	4	7	1	4.7064E-06	0.9	20.7	82.6	9.5	0.0	26.3	100.0	12.9	0.9	20.7	82.6	9.5	0.0	26.3	100.0	12.9
301	203	1	1	1	1.2775E-05	100.0	68.6	0.7	0.4	26.8	18.6	0.0	4.4	21.2	29.5	1.2	0.0	7.7	11.7	0.2	0.2
301	302	1	1	1	1.2737E-06	100.0	10.2	0.1	13.1	53.5	8.3	1.8	51.2	22.3	2.3	0.1	3.7	13.2	2.0	0.7	13.3
301	303	3	1	1	6.8048E-05	100.0	74.4	1.0	1.5	31.7	29.5	0.3	3.4	22.5	20.5	0.4	0.4	8.3	9.3	0.1	0.6
301	302	4	2	1	1.6535E-09	40.5	100.0	39.7	3.6	1.7	12.4	22.2	3.2	40.5	100.0	39.7	3.6	1.7	12.4	22.2	3.2
301	303	4	6	1	1.1451E-07	5.8	38.8	7.7	0.2	22.2	100.0	23.0	0.3	5.8	38.8	7.7	0.2	22.2	100.0	23.0	0.3
302	301	1	1	1	7.8357E-06	100.0	30.6	0.4	12.1	75.1	16.0	0.0	13.9	23.4	7.8	0.2	2.9	18.4	4.2	0.0	3.3
302	205	2	5	1	4.9920E-06	19.6	0.2	0.9	69.2	100.0	5.0	0.0	13.3	5.9	0.0	1.4	29.4	20.7	0.2	0.1	9.3
302	303	2	1	1	1.0385E-05	100.0	12.5	0.2	32.7	87.4	10.7	0.2	35.8	24.0	2.9	0.1	9.0	21.4	2.6	0.1	9.7
302	301	4	7	1	4.1245E-09	1.4	25.1	76.5	10.9	23.9	95.3	100.0	12.8	1.4	25.1	76.5	10.9	23.9	95.3	100.0	12.8
302	303	4	2	1	6.0799E-09	13.6	100.0	81.3	6.4	12.6	92.5	71.2	5.0	13.6	100.0	81.3	6.4	12.6	92.5	71.2	5.0
303	302	2	1	1	3.7792E-06	100.0	55.7	0.2	4.8	91.4	52.4	0.2	5.5	24.1	15.7	0.1	1.0	22.3	14.9	0.1	1.1
303	201	3	3	2	3.1087E-06	5.9	70.8	67.7	6.6	0.1	0.6	1.1	0.1	0.8	57.7	100.0	10.0	0.0	4.7	12.5	0.2
303	301	3	1	1	3.6270E-05	100.0	3.7	0.4	30.3	30.9	2.2	1.7	83.4	22.3	0.7	0.2	9.9	8.1	0.5	0.7	23.5
303	302	4	6	1	3.9308E-09	7.5	94.3	39.4	0.7	8.2	100.0	43.2	0.9	7.5	94.3	39.4	0.7	8.2	100.0	43.2	0.9
303	301	4	2	1	7.7907E-08	30.0	100.0	18.8	0.4	7.6	35.8	6.4	0.3	30.0	100.0	18.8	0.4	7.6	35.8	6.4	0.3

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 4, 90.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points --> |							<-- Side 2: Brace side points --> |						
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.2378E-01	100.0	18.4	0.0	12.2	72.0	12.4	0.0	18.3	24.5	4.4	0.0	3.0	17.3	3.1	0.0	4.3
201	206	3	5	1	1.3107E-02	81.5	14.0	0.0	18.2	100.0	18.9	0.0	13.8	19.6	3.4	0.0	4.5	24.5	4.7	0.0	3.3
201	303	3	4	2	9.5289E-06	12.8	2.2	23.1	87.1	34.3	1.3	0.1	5.7	3.1	2.1	76.0	100.0	7.8	0.3	8.4	13.4
201	202	4	3	1	9.2767E-03	0.0	18.4	100.0	18.8	0.0	13.1	78.8	13.5	0.0	18.4	100.0	18.8	0.0	13.1	78.8	13.5
201	206	4	3	1	8.8792E-04	0.1	27.7	100.0	12.5	0.0	18.9	77.0	8.9	0.1	27.7	100.0	12.5	0.0	18.9	77.0	8.9
202	101	1	3	1	2.8332E-07	39.5	25.9	100.0	54.5	52.5	47.5	78.1	22.2	2.0	1.2	2.6	2.6	3.1	2.1	1.6	1.0
202	102	1	7	1	2.8218E-07	37.8	20.6	78.1	50.1	52.6	58.6	100.0	23.5	1.9	0.9	1.6	2.2	3.2	2.8	2.6	1.1
202	201	4	7	1	1.4892E-04	0.0	14.0	81.8	13.8	0.0	18.6	100.0	18.3	0.0	14.0	81.8	13.8	0.0	18.6	100.0	18.3
202	203	4	7	1	1.4924E-04	0.0	13.9	81.4	13.6	0.0	18.7	100.0	18.2	0.0	13.9	81.4	13.6	0.0	18.7	100.0	18.2
203	202	1	5	1	1.2799E-01	82.7	14.1	0.0	18.3	100.0	18.6	0.0	14.0	19.9	3.4	0.0	4.5	24.5	4.6	0.0	3.4
203	301	1	1	1	2.4462E-04	100.0	18.1	0.0	17.1	98.7	17.7	0.0	17.4	24.2	4.5	0.0	4.1	23.9	4.4	0.0	4.1

203	204	2	1	1	1.2253E-02	100.0	18.3	0.0	11.9	69.7	12.0	0.0	18.6	24.5	4.3	0.0	2.9	16.8	3.0	0.0	4.4
203	202	4	3	1	9.2349E-03	0.0	19.0	100.0	18.2	0.0	13.5	79.1	13.1	0.0	19.0	100.0	18.2	0.0	13.5	79.1	13.1
203	204	4	3	1	8.7767E-04	0.0	26.7	100.0	12.9	0.0	18.4	77.0	9.0	0.0	26.7	100.0	12.9	0.0	18.4	77.0	9.0
204	102	2	7	1	9.2770E-04	0.0	1.9	23.7	1.4	0.0	7.8	100.0	10.1	0.0	0.0	0.2	0.0	0.0	0.5	3.9	0.7
204	103	2	3	1	1.0068E-03	0.0	4.5	100.0	15.7	0.2	3.2	22.2	0.5	0.0	0.4	4.5	1.2	0.0	0.1	0.2	0.0
204	203	4	7	1	2.7157E-05	0.1	17.7	72.7	8.0	0.0	26.7	100.0	13.6	0.1	17.7	72.7	8.0	0.0	26.7	100.0	13.6
204	205	4	7	1	2.6134E-05	0.1	25.0	96.8	11.8	0.0	25.0	100.0	12.5	0.1	25.0	96.8	11.8	0.0	25.0	100.0	12.5
205	204	2	1	1	6.5509E-02	100.0	17.4	0.0	16.8	92.4	15.6	0.0	19.0	24.4	4.2	0.0	4.1	22.4	3.7	0.0	4.7
205	302	2	2	1	5.5430E-05	88.9	100.0	4.6	0.0	9.9	11.8	0.0	2.7	20.0	81.8	17.3	0.0	2.7	19.3	2.1	0.0
205	206	3	5	1	5.9981E-02	95.7	17.6	0.0	17.0	100.0	18.8	0.0	16.2	23.2	4.3	0.0	4.1	24.4	4.6	0.0	3.9
205	204	4	7	1	4.9928E-03	0.0	20.6	90.5	12.0	0.0	23.0	100.0	14.4	0.0	20.6	90.5	12.0	0.0	23.0	100.0	14.4
205	206	4	7	1	4.8135E-03	0.0	21.8	96.5	13.2	0.0	22.5	100.0	14.2	0.0	21.8	96.5	13.2	0.0	22.5	100.0	14.2
206	103	3	7	1	1.0210E-03	0.0	0.5	22.3	3.3	0.2	16.0	100.0	4.4	0.0	0.0	0.2	0.1	0.0	1.2	4.5	0.4
206	101	3	3	1	9.4248E-04	0.0	10.2	100.0	7.7	0.0	1.4	23.9	1.9	0.0	0.7	3.9	0.5	0.0	0.0	0.2	0.0
206	205	4	7	1	2.6536E-05	0.1	23.5	93.8	11.4	0.0	25.2	100.0	12.6	0.1	23.5	93.8	11.4	0.0	25.2	100.0	12.6
206	201	4	7	1	2.7738E-05	0.1	17.2	70.5	7.6	0.0	27.0	100.0	13.9	0.1	17.2	70.5	7.6	0.0	27.0	100.0	13.9
301	203	1	5	1	2.2681E-05	97.8	18.3	0.0	16.7	100.0	18.9	0.0	16.2	23.8	4.6	0.0	3.9	24.2	4.8	0.0	3.8
301	302	1	1	1	4.5953E-06	100.0	15.9	0.0	17.6	89.6	14.2	0.0	19.6	24.0	3.8	0.0	4.4	21.9	3.4	0.0	4.8
301	303	3	1	1	9.1582E-05	100.0	63.7	1.0	3.8	34.3	20.0	0.2	5.8	22.3	17.2	0.4	0.9	8.8	6.3	0.1	1.2
301	302	4	3	1	2.4467E-09	0.0	22.5	100.0	14.3	0.0	19.7	90.2	12.3	0.0	22.5	100.0	14.3	0.0	19.7	90.2	12.3
301	303	4	6	1	1.3078E-07	4.1	28.2	11.1	0.7	25.3	100.0	28.4	0.9	4.1	28.2	11.1	0.7	25.3	100.0	28.4	0.9
302	301	1	1	1	4.2588E-06	100.0	18.8	0.0	15.4	92.4	17.3	0.0	16.6	24.1	4.6	0.0	3.7	22.5	4.3	0.0	4.0
302	205	2	4	1	4.0806E-06	0.2	1.2	48.3	100.0	18.5	0.0	0.5	1.7	0.0	3.1	76.1	74.2	2.7	0.0	8.1	7.7
302	303	2	1	1	6.8690E-05	100.0	7.1	0.4	35.0	55.6	5.3	0.9	64.0	23.2	1.6	0.2	10.6	14.0	1.3	0.4	17.9
302	301	4	7	1	2.2687E-09	0.0	18.6	92.8	14.4	0.0	20.7	100.0	15.9	0.0	18.6	92.8	14.4	0.0	20.7	100.0	15.9
302	303	4	2	1	9.7589E-08	23.8	100.0	29.5	1.3	9.6	52.4	17.6	1.0	23.8	100.0	29.5	1.3	9.6	52.4	17.6	1.0
303	302	2	1	1	1.1468E-04	100.0	62.5	0.3	1.4	46.8	34.8	0.1	3.5	23.0	17.3	0.2	0.3	12.0	10.5	0.1	0.6
303	201	3	2	1	1.4960E-05	48.4	100.0	14.2	0.0	0.9	5.8	0.2	0.4	8.5	56.0	20.3	0.1	0.4	9.4	2.3	0.0
303	301	3	1	1	6.1256E-05	100.0	3.3	0.1	17.6	18.1	0.9	0.9	69.1	21.7	0.6	0.1	5.8	5.0	0.2	0.4	18.6
303	302	4	6	1	1.4576E-07	4.4	54.3	15.9	0.1	11.7	100.0	33.5	0.1	4.4	54.3	15.9	0.1	11.7	100.0	33.5	0.1
303	301	4	2	1	9.8348E-08	21.9	100.0	25.4	0.2	2.9	24.7	4.9	0.1	21.9	100.0	25.4	0.2	2.9	24.7	4.9	0.1

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 5, 120.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points --> 1	2	3	4	5	6	7	8	<-- Side 2: Brace side points --> 1	2	3	4	5	6	7	8
201	202	1	1	1	2.6316E-02	100.0	18.4	0.0	10.7	62.9	10.6	0.0	18.7	24.5	4.3	0.0	2.7	15.1	2.6	0.0	4.4
201	206	3	5	1	2.4505E-02	75.9	13.0	0.0	18.3	100.0	19.3	0.0	12.4	18.2	3.1	0.0	4.5	24.5	4.8	0.0	2.9
201	303	3	5	1	5.1132E-05	40.5	1.3	0.2	54.1	100.0	6.5	0.0	19.0	10.1	0.1	0.9	29.1	23.7	0.3	0.1	12.7
201	202	4	3	1	1.9304E-03	0.0	19.4	100.0	18.6	0.0	12.0	71.7	11.7	0.0	19.4	100.0	18.6	0.0	12.0	71.7	11.7

201	206	4	3	1	1.6714E-03	0.0	28.5	100.0	12.4	0.0	17.6	70.1	7.3	0.0	28.5	100.0	12.4	0.0	17.6	70.1	7.3
202	101	1	7	1	3.3341E-05	0.5	5.0	23.4	1.1	0.3	3.6	100.0	21.0	0.1	0.1	0.2	0.0	0.0	0.3	4.1	1.4
202	102	1	3	1	3.3761E-05	0.1	2.2	100.0	26.9	1.0	7.1	23.5	0.4	0.0	0.2	4.0	1.8	0.1	0.2	0.3	0.0
202	201	4	7	1	5.1086E-05	0.0	12.9	76.1	12.6	0.0	18.8	100.0	18.7	0.0	12.9	76.1	12.6	0.0	18.8	100.0	18.7
202	203	4	7	1	5.0167E-05	0.0	15.7	89.4	15.4	0.0	18.3	100.0	18.0	0.0	15.7	89.4	15.4	0.0	18.3	100.0	18.0
203	202	1	5	1	7.2900E-02	93.0	16.1	0.0	18.2	100.0	17.8	0.0	16.5	22.5	3.9	0.0	4.4	24.4	4.3	0.0	4.0
203	301	1	1	1	1.1648E-04	100.0	44.6	0.1	2.0	45.0	17.2	0.0	8.2	23.6	21.5	0.3	0.1	11.2	10.0	0.0	0.6
203	204	2	5	1	7.2022E-03	94.0	17.2	0.0	17.2	100.0	18.9	0.0	16.2	22.8	4.2	0.0	4.1	24.3	4.6	0.0	3.9
203	202	4	3	1	5.1917E-03	0.0	17.6	100.0	18.5	0.0	15.4	91.5	16.4	0.0	17.6	100.0	18.5	0.0	15.4	91.5	16.4
203	204	4	7	1	5.3845E-04	0.0	22.3	95.7	12.8	0.0	22.9	100.0	14.4	0.0	22.3	95.7	12.8	0.0	22.9	100.0	14.4
204	102	2	7	1	1.0459E-03	0.0	1.3	24.4	2.0	0.0	10.7	100.0	7.9	0.0	0.0	0.2	0.0	0.0	0.7	4.0	0.6
204	103	2	3	1	1.1550E-03	0.0	7.8	100.0	10.8	0.0	1.7	20.7	1.0	0.0	0.6	4.8	0.9	0.0	0.0	0.2	0.0
204	203	4	7	1	5.1294E-06	0.4	20.2	82.1	9.4	0.0	26.2	100.0	12.8	0.4	20.2	82.1	9.4	0.0	26.2	100.0	12.8
204	205	4	7	1	5.0659E-06	0.8	21.2	84.9	10.0	0.0	26.1	100.0	12.8	0.8	21.2	84.9	10.0	0.0	26.1	100.0	12.8
205	204	2	1	1	9.1567E-03	100.0	17.4	0.0	16.4	90.2	15.2	0.0	19.6	24.4	4.2	0.0	4.0	21.8	3.7	0.0	4.8
205	302	2	3	2	1.5550E-05	2.7	25.7	24.5	1.7	0.4	0.3	0.2	0.2	0.6	51.1	100.0	10.1	0.1	5.5	15.1	0.4
205	206	3	1	1	6.5337E-02	100.0	18.4	0.0	14.8	87.3	15.7	0.0	17.6	24.3	4.4	0.0	3.6	21.1	3.8	0.0	4.2
205	204	4	7	1	7.0131E-04	0.0	20.1	88.0	11.7	0.0	22.7	100.0	15.7	0.0	20.1	88.0	11.7	0.0	22.7	100.0	15.7
205	206	4	3	1	5.1597E-03	0.0	24.1	100.0	13.3	0.0	21.0	90.7	11.6	0.0	24.1	100.0	13.3	0.0	21.0	90.7	11.6
206	103	3	7	1	3.5261E-05	0.1	0.4	27.3	9.9	1.5	31.5	100.0	1.6	0.0	0.0	0.3	0.3	0.2	2.1	4.1	0.1
206	101	3	3	1	3.5516E-05	0.4	18.1	100.0	4.5	0.4	1.4	22.1	3.9	0.1	1.2	3.9	0.3	0.0	0.1	0.2	0.1
206	205	4	7	1	4.5370E-05	0.0	22.1	89.1	10.5	0.0	25.7	100.0	12.5	0.0	22.1	89.1	10.5	0.0	25.7	100.0	12.5
206	201	4	7	1	4.7050E-05	0.0	18.0	73.8	8.1	0.0	26.6	100.0	13.2	0.0	18.0	73.8	8.1	0.0	26.6	100.0	13.2
301	203	1	5	1	5.7873E-06	18.9	0.1	1.4	79.4	100.0	3.8	0.0	16.0	5.7	0.0	2.2	35.2	20.6	0.1	0.3	11.6
301	302	1	1	1	9.5625E-06	100.0	13.1	0.2	31.7	88.7	11.4	0.2	34.6	24.0	3.1	0.1	8.8	21.7	2.7	0.1	9.4
301	303	3	1	1	1.0507E-05	100.0	32.4	0.5	11.6	73.0	16.2	0.0	13.4	23.4	8.3	0.2	2.8	17.9	4.3	0.0	3.1
301	302	4	2	1	5.1257E-09	11.1	100.0	99.3	11.4	10.2	92.9	88.7	9.5	11.1	100.0	99.3	11.4	10.2	92.9	88.7	9.5
301	303	4	6	1	5.9860E-09	2.5	29.9	65.1	6.1	31.0	100.0	83.9	7.2	2.5	29.9	65.1	6.1	31.0	100.0	83.9	7.2
302	301	1	1	1	3.5891E-06	100.0	65.2	0.4	4.7	91.6	61.5	0.4	5.3	24.1	18.7	0.2	1.0	22.3	17.8	0.2	1.1
302	205	2	3	2	5.7858E-06	2.6	48.2	58.7	7.0	0.0	0.4	1.1	0.0	0.3	47.1	100.0	11.7	0.0	4.4	14.3	0.4
302	303	2	1	1	4.7370E-05	100.0	4.1	0.4	29.5	31.9	2.4	1.6	80.9	22.4	0.8	0.2	9.5	8.3	0.6	0.7	22.5
302	301	4	6	1	4.5656E-09	8.1	94.6	38.6	1.2	8.8	100.0	41.9	1.4	8.1	94.6	38.6	1.2	8.8	100.0	41.9	1.4
302	303	4	2	1	9.3970E-08	29.9	100.0	19.4	0.5	7.6	35.7	6.8	0.3	29.9	100.0	19.4	0.5	7.6	35.7	6.8	0.3
303	302	2	1	1	7.7790E-05	100.0	74.9	1.0	1.4	30.9	29.5	0.3	3.2	22.4	20.8	0.4	0.3	8.2	9.4	0.1	0.6
303	201	3	1	1	1.4788E-05	100.0	77.1	1.1	0.2	25.8	21.2	0.0	3.6	21.2	34.3	1.8	0.0	7.4	13.9	0.3	0.1
303	301	3	1	1	1.4629E-06	100.0	9.2	0.1	12.0	46.8	7.0	1.4	50.4	22.0	2.1	0.0	3.4	11.6	1.7	0.5	13.0
303	302	4	6	1	1.3750E-07	5.6	38.6	7.5	0.2	21.8	100.0	23.1	0.2	5.6	38.6	7.5	0.2	21.8	100.0	23.1	0.2
303	301	4	2	1	1.7762E-09	41.6	100.0	37.7	2.2	1.6	13.4	20.6	2.0	41.6	100.0	37.7	2.2	1.6	13.4	20.6	2.0

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 6, 150.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N	N	P	P	S																	
O	O	L	O	I	<==RELATIVE DAMAGES AROUND THE WELD ====>																
D	D	A	S	D	| <-- Side 1: Chord side points -->									| <-- Side 2: Brace side points -->							|

E 1	E 2	N E	N 1	E 1	DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	7.9125E-03	100.0	18.3	0.0	12.3	72.2	12.6	0.0	18.4	24.4	4.3	0.0	3.0	17.4	3.1	0.0	4.4
201	206	3	5	1	7.7262E-02	84.5	14.5	0.0	18.2	100.0	18.5	0.0	14.4	20.3	3.5	0.0	4.5	24.5	4.5	0.0	3.4
201	303	3	1	1	1.4230E-04	100.0	16.6	0.0	18.6	98.7	16.3	0.0	19.0	24.2	3.7	0.0	4.8	24.0	3.7	0.0	4.9
201	202	4	3	1	5.8922E-04	0.0	18.7	100.0	18.7	0.0	13.1	79.0	13.8	0.0	18.7	100.0	18.7	0.0	13.1	79.0	13.8
201	206	4	3	1	5.2135E-03	0.0	26.5	100.0	12.6	0.0	19.7	80.3	9.1	0.0	26.5	100.0	12.6	0.0	19.7	80.3	9.1
202	101	1	7	1	5.4607E-04	0.0	2.0	23.0	1.2	0.0	7.2	100.0	10.8	0.0	0.0	0.2	0.0	0.0	0.5	4.2	0.8
202	102	1	3	1	5.4867E-04	0.0	5.0	100.0	14.6	0.1	3.0	23.0	0.7	0.0	0.4	4.2	1.0	0.0	0.1	0.2	0.0
202	201	4	7	1	1.6005E-05	0.1	12.5	73.7	12.0	0.0	19.1	100.0	19.1	0.1	12.5	73.7	12.0	0.0	19.1	100.0	19.1
202	203	4	7	1	1.5643E-05	0.1	17.4	94.5	16.6	0.0	17.9	100.0	18.1	0.1	17.4	94.5	16.6	0.0	17.9	100.0	18.1
203	202	1	1	1	3.7224E-02	100.0	17.5	0.0	17.0	94.2	16.1	0.0	18.7	24.4	4.3	0.0	4.1	22.8	3.9	0.0	4.6
203	301	1	2	1	3.0181E-05	87.8	100.0	4.6	0.0	10.2	12.4	0.0	2.5	20.0	79.3	16.3	0.0	2.7	18.7	2.0	0.0
203	204	2	5	1	3.5998E-02	98.0	17.9	0.0	17.2	100.0	18.6	0.0	16.8	23.8	4.4	0.0	4.1	24.4	4.5	0.0	4.0
203	202	4	7	1	2.6648E-03	0.0	15.2	92.3	17.3	0.0	16.7	100.0	19.9	0.0	15.2	92.3	17.3	0.0	16.7	100.0	19.9
203	204	4	7	1	2.7400E-03	0.0	22.7	98.2	13.1	0.0	23.0	100.0	13.7	0.0	22.7	98.2	13.1	0.0	23.0	100.0	13.7
204	102	2	7	1	5.5322E-04	0.0	0.9	25.7	3.2	0.1	14.0	100.0	5.4	0.0	0.0	0.3	0.1	0.0	0.9	3.8	0.4
204	103	2	3	1	6.0665E-04	0.0	11.2	100.0	6.9	0.0	1.0	21.6	1.9	0.0	0.9	4.5	0.6	0.0	0.0	0.2	0.0
204	203	4	7	1	1.7177E-05	0.1	23.3	92.4	11.1	0.0	25.5	100.0	12.5	0.1	23.3	92.4	11.1	0.0	25.5	100.0	12.5
204	205	4	7	1	1.7514E-05	0.1	17.6	71.2	7.6	0.0	27.2	100.0	13.6	0.1	17.6	71.2	7.6	0.0	27.2	100.0	13.6
205	204	2	5	1	8.3628E-03	81.0	13.9	0.0	18.2	100.0	19.0	0.0	13.8	19.5	3.3	0.0	4.5	24.4	4.7	0.0	3.3
205	302	2	4	2	8.3888E-06	4.4	0.7	18.9	83.2	31.5	0.5	0.1	4.0	1.1	1.4	71.1	100.0	6.8	0.1	8.5	14.5
205	206	3	1	1	6.6859E-02	100.0	18.3	0.0	12.3	72.2	12.4	0.0	18.3	24.4	4.3	0.0	3.1	17.4	3.1	0.0	4.3
205	204	4	3	1	6.3446E-04	0.1	27.8	100.0	12.4	0.0	19.3	78.2	9.1	0.1	27.8	100.0	12.4	0.0	19.3	78.2	9.1
205	206	4	3	1	5.1179E-03	0.0	26.0	100.0	12.9	0.0	19.0	79.1	9.1	0.0	26.0	100.0	12.9	0.0	19.0	79.1	9.1
206	103	3	3	1	2.3152E-07	30.2	16.9	100.0	48.6	41.3	39.6	77.6	16.1	1.5	0.8	2.8	2.4	2.4	1.7	1.7	0.8
206	101	3	7	1	2.2396E-07	29.5	20.9	75.6	41.7	40.3	50.3	100.0	24.2	1.5	0.9	1.5	1.8	2.5	2.4	2.5	1.1
206	205	4	7	1	8.1469E-05	0.0	20.0	81.6	9.3	0.0	26.2	100.0	12.6	0.0	20.0	81.6	9.3	0.0	26.2	100.0	12.6
206	201	4	7	1	8.2313E-05	0.0	20.2	82.0	9.3	0.0	26.2	100.0	12.6	0.0	20.2	82.0	9.3	0.0	26.2	100.0	12.6
301	203	1	4	1	1.8872E-06	0.3	2.2	55.8	100.0	16.2	0.0	0.6	1.4	0.1	4.3	82.5	72.7	2.3	0.0	8.7	6.6
301	302	1	1	1	3.1889E-05	100.0	7.4	0.4	35.0	56.6	5.8	1.0	64.8	23.2	1.7	0.2	10.7	14.2	1.4	0.5	18.2
301	303	3	1	1	2.6636E-06	100.0	19.1	0.0	15.1	91.4	17.4	0.0	16.4	24.1	4.7	0.0	3.6	22.2	4.3	0.0	3.9
301	302	4	2	1	4.7495E-08	19.0	100.0	35.2	2.1	7.1	51.1	20.6	1.7	19.0	100.0	35.2	2.1	7.1	51.1	20.6	1.7
301	303	4	7	1	1.3547E-09	0.0	26.5	91.9	9.6	0.0	30.0	100.0	10.4	0.0	26.5	91.9	9.6	0.0	30.0	100.0	10.4
302	301	1	1	1	6.2219E-05	100.0	67.8	0.5	1.3	46.6	37.9	0.2	3.2	23.1	18.9	0.2	0.3	12.0	11.5	0.1	0.6
302	205	2	2	1	9.8704E-06	44.7	100.0	15.5	0.0	0.9	6.1	0.2	0.3	7.9	61.5	25.1	0.1	0.4	11.0	3.0	0.0
302	303	2	1	1	3.2925E-05	100.0	3.4	0.1	17.3	18.0	1.1	1.0	70.5	21.7	0.6	0.1	5.7	4.9	0.3	0.4	18.9
302	301	4	6	1	8.4595E-08	3.6	54.5	18.8	0.2	9.8	100.0	38.5	0.3	3.6	54.5	18.8	0.2	9.8	100.0	38.5	0.3
302	303	4	2	1	5.2818E-08	24.1	100.0	23.9	0.2	3.1	23.7	4.7	0.2	24.1	100.0	23.9	0.2	3.1	23.7	4.7	0.2
303	302	2	1	1	4.4843E-05	100.0	66.1	1.1	3.7	33.6	19.9	0.2	5.7	22.2	18.0	0.5	0.9	8.6	6.4	0.1	1.2
303	201	3	5	1	1.0798E-05	97.7	21.9	0.0	13.8	100.0	22.5	0.0	13.4	23.8	6.2	0.0	2.8	24.2	6.3	0.0	2.7
303	301	3	1	1	2.8330E-06	100.0	15.4	0.0	17.6	86.8	13.3	0.0	20.2	24.0	3.6	0.0	4.4	21.2	3.2	0.0	4.9
303	302	4	6	1	7.1149E-08	4.3	27.2	10.4	0.7	27.4	100.0	26.9	0.9	4.3	27.2	10.4	0.7	27.4	100.0	26.9	0.9

303	301	4	3	1	1.5070E-09	0.0	33.4	100.0	9.1	0.2	28.6	87.5	7.3	0.0	33.4	100.0	9.1	0.2	28.6	87.5	7.3

BUFFETING DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points --> |								<-- Side 2: Brace side points --> |						
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	2.4586E-01	100.0	18.4	0.0	13.3	78.3	13.8	0.0	18.0	24.4	4.4	0.0	3.3	18.9	3.4	0.0	4.3
201	206	3	5	1	2.1723E-01	90.3	15.6	0.0	18.2	100.0	18.1	0.0	15.8	21.8	3.8	0.0	4.4	24.4	4.4	0.0	3.8
201	303	3	1	1	2.7177E-04	100.0	32.2	2.2	23.8	86.9	16.0	0.0	16.8	24.1	16.6	7.4	11.8	21.1	6.4	0.9	5.7
201	202	4	3	1	1.8595E-02	0.0	18.0	100.0	18.9	0.0	13.8	83.8	14.9	0.0	18.0	100.0	18.9	0.0	13.8	83.8	14.9
201	206	4	3	1	1.4550E-02	0.0	25.7	100.0	12.7	0.0	21.3	87.8	10.7	0.0	25.7	100.0	12.7	0.0	21.3	87.8	10.7
202	101	1	7	1	1.8855E-03	0.0	1.3	22.5	2.0	0.1	10.7	100.0	8.0	0.0	0.0	0.2	0.0	0.0	0.8	4.2	0.6
202	102	1	3	1	1.8837E-03	0.0	7.8	100.0	11.1	0.1	2.1	22.5	1.3	0.0	0.6	4.2	0.8	0.0	0.0	0.2	0.0
202	201	4	7	1	2.7306E-04	0.0	14.0	81.7	13.8	0.0	18.6	100.0	18.4	0.0	14.0	81.7	13.8	0.0	18.6	100.0	18.4
202	203	4	7	1	2.7350E-04	0.0	14.2	82.1	13.8	0.0	18.6	100.0	18.3	0.0	14.2	82.1	13.8	0.0	18.6	100.0	18.3
203	202	1	5	1	2.6956E-01	88.5	15.2	0.0	18.2	100.0	18.2	0.0	15.4	21.4	3.7	0.0	4.5	24.4	4.4	0.0	3.7
203	301	1	1	1	4.0477E-04	100.0	32.1	1.3	17.3	84.2	17.4	0.0	14.9	24.0	16.1	4.6	6.7	20.4	7.1	0.6	4.0
203	204	2	1	1	1.9127E-01	100.0	18.3	0.0	14.1	82.3	14.6	0.0	17.9	24.4	4.4	0.0	3.4	19.9	3.6	0.0	4.3
203	202	4	3	1	1.9318E-02	0.0	18.3	100.0	18.4	0.0	14.6	86.1	15.2	0.0	18.3	100.0	18.4	0.0	14.6	86.1	15.2
203	204	4	3	1	1.4109E-02	0.0	24.9	100.0	13.1	0.0	20.4	86.9	10.8	0.0	24.9	100.0	13.1	0.0	20.4	86.9	10.8
204	102	2	7	1	2.5816E-03	0.0	1.4	24.4	2.1	0.1	10.4	100.0	8.2	0.0	0.0	0.2	0.1	0.0	0.7	3.9	0.6
204	103	2	3	1	2.8274E-03	0.0	7.4	100.0	11.8	0.1	2.2	21.5	1.1	0.0	0.6	4.6	0.9	0.0	0.1	0.2	0.0
204	203	4	7	1	1.9598E-04	0.0	20.1	81.8	9.4	0.0	26.1	100.0	12.8	0.0	20.1	81.8	9.4	0.0	26.1	100.0	12.8
204	205	4	7	1	1.9421E-04	0.0	20.6	82.7	9.5	0.0	26.2	100.0	12.8	0.0	20.6	82.7	9.5	0.0	26.2	100.0	12.8
205	204	2	5	1	2.0788E-01	93.4	16.1	0.0	18.2	100.0	17.9	0.0	16.8	22.6	3.9	0.0	4.4	24.3	4.4	0.0	4.1
205	302	2	1	1	2.7305E-04	100.0	42.6	3.0	20.0	75.7	15.4	0.0	14.7	23.7	27.5	11.6	10.6	18.4	8.7	1.6	4.9
205	206	3	1	1	2.2125E-01	100.0	18.4	0.0	14.5	85.1	15.3	0.0	17.8	24.4	4.4	0.0	3.5	20.6	3.8	0.0	4.2
205	204	4	3	1	1.5657E-02	0.0	25.1	100.0	12.9	0.0	22.0	92.5	11.9	0.0	25.1	100.0	12.9	0.0	22.0	92.5	11.9
205	206	4	3	1	1.7328E-02	0.0	24.6	100.0	13.2	0.0	20.8	89.2	11.4	0.0	24.6	100.0	13.2	0.0	20.8	89.2	11.4
206	103	3	7	1	2.5638E-03	0.0	1.0	21.3	2.3	0.1	12.3	100.0	7.1	0.0	0.0	0.2	0.1	0.0	0.9	4.6	0.6
206	101	3	3	1	2.3429E-03	0.0	8.4	100.0	10.0	0.1	2.0	24.1	1.5	0.0	0.6	3.9	0.7	0.0	0.0	0.2	0.0
206	205	4	7	1	2.1050E-04	0.0	20.5	83.1	9.6	0.0	26.1	100.0	12.7	0.0	20.5	83.1	9.6	0.0	26.1	100.0	12.7
206	201	4	7	1	2.1366E-04	0.0	20.1	81.2	9.2	0.0	26.2	100.0	12.9	0.0	20.1	81.2	9.2	0.0	26.2	100.0	12.9
301	203	1	1	1	3.9712E-05	100.0	55.6	10.9	26.5	81.3	18.4	0.2	13.1	22.8	27.0	16.8	11.7	19.5	8.7	2.1	4.2
301	302	1	1	1	1.0687E-04	100.0	6.2	0.3	28.1	43.8	4.5	1.2	67.6	22.7	1.4	0.2	8.7	11.1	1.1	0.5	18.7
301	303	3	1	1	2.2654E-04	100.0	65.1	0.8	3.1	39.3	26.6	0.2	5.0	22.6	17.8	0.3	0.7	10.1	8.2	0.1	1.0
301	302	4	2	1	1.7037E-07	20.5	100.0	32.6	1.6	5.1	38.6	15.0	1.3	20.5	100.0	32.6	1.6	5.1	38.6	15.0	1.3
301	303	4	6	1	3.2055E-07	4.9	38.1	12.2	0.6	21.6	100.0	28.5	0.7	4.9	38.1	12.2	0.6	21.6	100.0	28.5	0.7
302	301	1	1	1	1.7588E-04	100.0	66.9	0.8	2.9	42.3	30.3	0.2	4.7	22.7	18.4	0.3	0.7	10.8	9.3	0.1	0.9
302	205	2	1	1	3.0785E-05	100.0	83.2	23.0	31.3	70.3	21.0	0.4	9.4	22.2	47.0	38.0	17.9	16.8	13.3	4.9	3.7

302	303	2	1	1	1.6258E-04	100.0	5.9	0.3	29.3	43.6	4.1	1.1	67.7	22.7	1.3	0.2	9.1	11.1	1.0	0.5	18.7
302	301	4	6	1	2.5414E-07	3.6	42.3	16.0	0.8	14.9	100.0	36.0	1.0	3.6	42.3	16.0	0.8	14.9	100.0	36.0	1.0
302	303	4	2	1	2.5183E-07	26.0	100.0	26.3	0.9	7.5	41.0	12.6	0.7	26.0	100.0	26.3	0.9	7.5	41.0	12.6	0.7
303	302	2	1	1	2.4980E-04	100.0	65.7	0.7	2.3	41.3	30.1	0.2	4.2	22.7	18.1	0.3	0.5	10.6	9.3	0.1	0.8
303	201	3	1	1	3.3275E-05	100.0	93.1	15.4	15.5	54.3	19.8	0.2	7.3	21.5	48.0	22.4	7.1	13.3	12.9	2.6	2.0
303	301	3	1	1	1.3501E-04	100.0	4.9	0.3	25.4	34.2	3.0	1.1	69.6	22.3	1.0	0.2	8.1	8.8	0.7	0.5	19.2
303	302	4	6	1	3.6242E-07	4.9	43.2	12.7	0.3	18.8	100.0	29.2	0.4	4.9	43.2	12.7	0.3	18.8	100.0	29.2	0.4
303	301	4	2	1	2.2533E-07	25.6	100.0	25.2	0.7	6.3	35.1	9.5	0.5	25.6	100.0	25.2	0.7	6.3	35.1	9.5	0.5

20 WORST BUFFETING DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
203	202	1	5	1	2.6956E-01	88.5	15.2	0.0	18.2	100.0	18.2	0.0	15.4	21.4	3.7	0.0	4.5	24.4	4.4	0.0	3.7
201	202	1	1	1	2.4586E-01	100.0	18.4	0.0	13.3	78.3	13.8	0.0	18.0	24.4	4.4	0.0	3.3	18.9	3.4	0.0	4.3
205	206	3	1	1	2.2125E-01	100.0	18.4	0.0	14.5	85.1	15.3	0.0	17.8	24.4	4.4	0.0	3.5	20.6	3.8	0.0	4.2
201	206	3	5	1	2.1723E-01	90.3	15.6	0.0	18.2	100.0	18.1	0.0	15.8	21.8	3.8	0.0	4.4	24.4	4.4	0.0	3.8
205	204	2	5	1	2.0788E-01	93.4	16.1	0.0	18.2	100.0	17.9	0.0	16.8	22.6	3.9	0.0	4.4	24.3	4.4	0.0	4.1
203	204	2	1	1	1.9127E-01	100.0	18.3	0.0	14.1	82.3	14.6	0.0	17.9	24.4	4.4	0.0	3.4	19.9	3.6	0.0	4.3
203	202	4	3	1	1.9318E-02	0.0	18.3	100.0	18.4	0.0	14.6	86.1	15.2	0.0	18.3	100.0	18.4	0.0	14.6	86.1	15.2
201	202	4	3	1	1.8595E-02	0.0	18.0	100.0	18.9	0.0	13.8	83.8	14.9	0.0	18.0	100.0	18.9	0.0	13.8	83.8	14.9
205	206	4	3	1	1.7328E-02	0.0	24.6	100.0	13.2	0.0	20.8	89.2	11.4	0.0	24.6	100.0	13.2	0.0	20.8	89.2	11.4
205	204	4	3	1	1.5657E-02	0.0	25.1	100.0	12.9	0.0	22.0	92.5	11.9	0.0	25.1	100.0	12.9	0.0	22.0	92.5	11.9
201	206	4	3	1	1.4550E-02	0.0	25.7	100.0	12.7	0.0	21.3	87.8	10.7	0.0	25.7	100.0	12.7	0.0	21.3	87.8	10.7
203	204	4	3	1	1.4109E-02	0.0	24.9	100.0	13.1	0.0	20.4	86.9	10.8	0.0	24.9	100.0	13.1	0.0	20.4	86.9	10.8
204	103	2	3	1	2.8274E-03	0.0	7.4	100.0	11.8	0.1	2.2	21.5	1.1	0.0	0.6	4.6	0.9	0.0	0.1	0.2	0.0
204	102	2	7	1	2.5816E-03	0.0	1.4	24.4	2.1	0.1	10.4	100.0	8.2	0.0	0.0	0.2	0.1	0.0	0.7	3.9	0.6
206	103	3	7	1	2.5638E-03	0.0	1.0	21.3	2.3	0.1	12.3	100.0	7.1	0.0	0.0	0.2	0.1	0.0	0.9	4.6	0.6
206	101	3	3	1	2.3429E-03	0.0	8.4	100.0	10.0	0.1	2.0	24.1	1.5	0.0	0.6	3.9	0.7	0.0	0.0	0.2	0.0
202	101	1	7	1	1.8855E-03	0.0	1.3	22.5	2.0	0.1	10.7	100.0	8.0	0.0	0.0	0.2	0.0	0.0	0.8	4.2	0.6
202	102	1	3	1	1.8837E-03	0.0	7.8	100.0	11.1	0.1	2.1	22.5	1.3	0.0	0.6	4.2	0.8	0.0	0.0	0.2	0.0
203	301	1	1	1	4.0477E-04	100.0	32.1	1.3	17.3	84.2	17.4	0.0	14.9	24.0	16.1	4.6	6.7	20.4	7.1	0.6	4.0
202	203	4	7	1	2.7350E-04	0.0	14.2	82.1	13.8	0.0	18.6	100.0	18.3	0.0	14.2	82.1	13.8	0.0	18.6	100.0	18.3

BUFFETING DAMAGE EVALUATED FOR 42 JOINT CONNECTIONS OVER ALL ANALYSIS PLANES

****

```
PRINT OF                : WIND FATIGUE RESULTS

RUN NAME                : X505B
RUN DESCRIPTION         : None
RESULTS INTERFACE FILE  : X505BR1.SIN
PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  15:44:58

************************************************************************

RUN SCENARIO:
=============
ANALYSIS CASE              : MULTI BRACE FATIGUE CHECK
FIRST WIND DIRECTION       : 1
LAST  WIND DIRECTION       : 6
FIRST NODE CHECKED         : 101
LAST  NODE CHECKED         : 303
FIRST ANALYSIS PLANE       : 1
LAST  ANALYSIS PLANE       : 4
NUMBER OF EIGENMODES       : 2
SHOW PROGRESS OF EXECUTION : OFF

WIND LOAD MODELLING:
====================
WIND LOAD TYPE             : WIND BUFFETING
WIDE BAND CORRECTION       : NONE
WIND PROFILE               : API (WIND PROFILE TYPE READ FROM SIN FILE)
GUST COMPONENTS CONSIDERED : ALONG WIND COMPONENT ONLY
GUST DIRECTION MOMENT      : DAMAGE BY ADD OF GUST SPECTRUM MOMENTS
WIND SPECTRA :
    LONGITUDINAL DIRECTION : DAVENPORT
    LATERAL      DIRECTION : NOT ACTIVE
    VERTICAL     DIRECTION : NOT ACTIVE
COHERENCE FUNCTIONS :
    LONGITUDINAL DIRECTION : GUST02
    LATERAL      DIRECTION : NOT APPLICABLE
    VERTICAL     DIRECTION : NOT APPLICABLE

INPUT DATA:
===========

PARAMETERS READ FROM SIN FILE :
(l = current length unit)
-------------------------------
```

```
WATER DEPTH - WD  (l)                              : 10.0
Z-COORDINATE OF MUDLINE - ZMUD  (l)                : -10.0
Z-COORDINATE OF STILL WATER LEVEL/GROUND  (l)       : 0.0
                        (Z0 = ZMUD + WD)
WIND DIRECTIONS (RELATIVE TO GLOBAL X-AXIS)        : DIR  ANGLE (deg)
                                                       1    0.0
                                                       2    30.0
                                                       3    60.0
                                                       4    90.0
                                                       5    120.0
                                                       6    150.0
MEAN WIND VELOCITY  (l/sec)                        : 30.0
MEAN WIND VELOCITY LEVEL  (l)                      : 10.0
HEIGHT EXPONENT, API WIND PROFILE                  : .125
GUST FACTOR, API WIND PROFILE                      : 1.0
ACCELERATION OF GRAVITY (g)  (l/sec^2)             : 9.81
UNIT LENGTH ADJUSTMENT FACTOR (9.81/g)             : 1.0

DIRECT INPUT PARAMETERS :
(l = current length unit)
-------------------------

DAMAGE CALCULATION OF BENT CAN JOINTS              : ON
COHERENCE FUNCTION CONSTANT (GUSTO, DAVENPORT)     : 8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz ALONG DIR.   : 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz LATERAL DIR.: 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz VERTICAL DIR: 16.0   16.0   8.0
GROUND ROUGNESS COEFFICIENT                        : 1.5E-02
TURBULENCE LENGTH SCALE DAVENPORT SPECTRUM  (l)    : 1200.0
TURBULENCE LENGTH SCALE HARRIS SPECTRUM  (l)       : 1800.0
DEFAULT SN CURVE                                   : DOE-T
MINIMUM PARAMETRIC SCFS                            : 1.6    1.6    1.6
DEFAULT GLOBAL SCFS                                : 1.6    1.6    1.6
DEFAULT SCF SCHEME, Alt.: EFTHYMIOU, LLOYDS        : EFTHYMIOU
(New default overrules previously assigned SCFs)
DAMPING RATIO                                      : 1.0E-02
CHORD LENGTH/DIAMETER RATIO (L/D)                  : 30.0
ANGULAR TOLERANCE ANALYSIS PLANES (DEG)            : 1.0
LIMIT FOR PRINTING DAMAGE VALUES                   : 1.0E-12
MIN. WIND FORCE USED RELATIVE TO MAX.              : 1.000E-05
LIMIT VALUE ON COHERENCE EFFECT                    : 1.000E+00
(NO COHERENCE = 1.0, FULL COHERENCE = 0 in limit)
NUMBER OF WIND SPEEDS                              : 5
```

WIND PROBABILITIES AND DRAG CORRECTION COEFFICIENT

DIR NO	WIND SPEED NO	WIND SPEED	WIND PROBABILITY	DRAG COEFF CORRECTION FACTORS
1	1	10.0000	0.3000	1.0000
1	2	15.0000	0.2500	0.9000
1	3	20.0000	0.2000	0.8000
1	4	25.0000	0.1500	0.7500
1	5	30.0000	0.1000	0.7000
2	1	10.0000	0.3500	1.0100
2	2	15.0000	0.2000	0.9100
2	3	20.0000	0.2000	0.8100
2	4	25.0000	0.1500	0.7600
2	5	30.0000	0.1000	0.7100
3	1	10.0000	0.4000	1.0200
3	2	15.0000	0.2000	0.9200
3	3	20.0000	0.1500	0.8200
3	4	25.0000	0.1500	0.7700
3	5	30.0000	0.1000	0.7200
4	1	10.0000	0.2000	1.0300
4	2	15.0000	0.2000	0.9300
4	3	20.0000	0.2000	0.8300
4	4	25.0000	0.2000	0.7800
4	5	30.0000	0.2000	0.7300
5	1	10.0000	0.3000	1.0400
5	2	15.0000	0.2500	0.9400
5	3	20.0000	0.2000	0.8400
5	4	25.0000	0.1500	0.7900
5	5	30.0000	0.1000	0.7400
6	1	10.0000	0.3600	1.0500
6	2	15.0000	0.2200	0.9500
6	3	20.0000	0.2100	0.8500
6	4	25.0000	0.1100	0.8000
6	5	30.0000	0.1000	0.7500

NODES DEFINING THE ANALYSIS PLANES:

1	101	203	301
2	102	205	302
3	103	201	303
4	201	203	205

NUMBER OF COHERENCE MATRICES FOR THE U, V AND W WIND GUST DIRECTIONS : 1

Note! 1,2 or 3 coherence matrices are formed depending on the choice of
wind spectrum and coherence models. Theexecution time increases
with the number of coherence matrices applied in the run.

****

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I T	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
201	202	1	5	1.0524E-02	91.6	16.7	0.0	17.2	100.0	18.9	0.0	15.6	22.2	4.1	0.0	4.1	24.3	4.6	0.0	3.8
201	206	3	5	1.2024E-01	94.5	16.4	0.0	18.2	100.0	17.8	0.0	16.8	23.0	4.0	0.0	4.4	24.4	4.3	0.0	4.1
201	303	3	1	9.6060E-05	100.0	41.6	0.1	2.4	45.7	16.1	0.0	9.0	23.8	18.7	0.2	0.2	11.3	8.5	0.0	0.8
201	202	4	7	8.0683E-04	0.0	15.2	94.0	18.1	0.0	16.1	100.0	20.4	0.0	15.2	94.0	18.1	0.0	16.1	100.0	20.4
201	206	4	3	8.0290E-03	0.0	24.7	100.0	12.8	0.0	22.3	93.0	11.6	0.0	24.7	100.0	12.8	0.0	22.3	93.0	11.6
202	101	1	7	9.5616E-04	0.0	1.1	21.6	1.8	0.0	10.4	100.0	7.5	0.0	0.0	0.2	0.0	0.0	0.8	4.3	0.6
202	102	1	3	9.5437E-04	0.0	7.6	100.0	10.4	0.0	1.8	21.6	1.1	0.0	0.6	4.3	0.8	0.0	0.0	0.2	0.0
202	201	4	7	6.4167E-06	0.3	14.3	83.3	14.2	0.0	18.6	100.0	18.3	0.3	14.3	83.3	14.2	0.0	18.6	100.0	18.3
202	203	4	7	6.4334E-06	0.6	14.6	83.1	14.2	0.0	18.7	100.0	18.4	0.6	14.6	83.1	14.2	0.0	18.7	100.0	18.4
203	202	1	1	1.1588E-02	100.0	17.5	0.0	16.4	91.1	15.5	0.0	19.1	24.4	4.3	0.0	4.0	22.0	3.7	0.0	4.7
203	301	1	3	1.0815E-05	5.1	31.2	26.7	1.7	1.4	0.6	0.3	0.6	1.1	55.8	100.0	9.1	0.4	6.0	14.4	0.4
203	204	2	1	1.0893E-01	100.0	18.4	0.0	14.8	86.6	15.5	0.0	17.7	24.4	4.4	0.0	3.6	21.0	3.8	0.0	4.2
203	202	4	7	8.3133E-04	0.0	14.5	89.0	16.8	0.0	16.5	100.0	21.0	0.0	14.5	89.0	16.8	0.0	16.5	100.0	21.0
203	204	4	3	8.1462E-03	0.0	24.3	100.0	13.2	0.0	21.1	90.1	11.3	0.0	24.3	100.0	13.2	0.0	21.1	90.1	11.3
204	102	2	7	2.9838E-05	0.2	1.1	30.4	7.5	0.8	23.7	100.0	3.0	0.0	0.0	0.4	0.2	0.1	1.5	3.5	0.2
204	103	2	3	3.4873E-05	0.6	22.9	100.0	3.6	0.4	1.6	21.0	4.9	0.1	1.7	4.5	0.3	0.0	0.1	0.2	0.1
204	203	4	7	7.4705E-05	0.0	22.0	89.1	10.5	0.0	25.7	100.0	12.5	0.0	22.0	89.1	10.5	0.0	25.7	100.0	12.5
204	205	4	7	7.5590E-05	0.0	18.2	73.8	8.0	0.0	26.9	100.0	12.9	0.0	18.2	73.8	8.0	0.0	26.9	100.0	12.9
205	204	2	5	3.5735E-02	73.3	12.5	0.0	18.2	100.0	19.6	0.0	11.8	17.6	3.0	0.0	4.5	24.5	4.8	0.0	2.8
205	302	2	5	4.9210E-05	38.5	1.2	0.3	54.1	100.0	6.7	0.0	17.9	9.7	0.1	1.1	30.5	23.4	0.3	0.2	13.2
205	206	3	1	3.5958E-02	100.0	18.2	0.0	10.5	61.5	10.2	0.0	19.0	24.4	4.3	0.0	2.6	14.8	2.5	0.0	4.5
205	204	4	3	2.7235E-03	0.0	29.0	100.0	12.2	0.0	17.7	69.3	7.1	0.0	29.0	100.0	12.2	0.0	17.7	69.3	7.1
205	206	4	3	2.6758E-03	0.0	27.9	100.0	12.6	0.0	17.5	70.6	7.5	0.0	27.9	100.0	12.6	0.0	17.5	70.6	7.5
206	103	3	7	3.3383E-05	0.6	4.8	20.1	1.6	0.5	3.6	100.0	23.2	0.1	0.1	0.2	0.1	0.0	0.3	4.6	1.7
206	101	3	3	2.8580E-05	0.2	3.0	100.0	23.4	0.8	7.2	29.2	1.1	0.0	0.2	3.6	1.4	0.1	0.2	0.4	0.0
206	205	4	7	7.4554E-05	0.0	18.6	75.6	8.3	0.0	26.7	100.0	12.9	0.0	18.6	75.6	8.3	0.0	26.7	100.0	12.9
206	201	4	7	7.4031E-05	0.0	22.6	90.7	10.7	0.0	25.6	100.0	12.4	0.0	22.6	90.7	10.7	0.0	25.6	100.0	12.4
301	203	1	3	3.8827E-06	3.9	58.0	63.4	7.0	0.1	0.5	1.2	0.1	0.5	51.6	100.0	11.0	0.0	4.5	13.5	0.3
301	302	1	1	4.1867E-05	100.0	5.5	0.4	28.6	38.5	3.8	1.6	75.6	22.6	1.2	0.2	9.1	9.9	0.9	0.7	21.1
301	303	3	1	3.3627E-06	100.0	55.0	0.3	5.9	90.4	51.5	0.2	6.8	24.1	15.5	0.1	1.3	22.1	14.6	0.1	1.5

301	302	4	2	1	7.9385E-08	23.2	100.0	27.3	1.1	5.4	36.0	11.1	0.9	23.2	100.0	27.3	1.1	5.4	36.0	11.1	0.9
301	303	4	6	1	3.4201E-09	9.8	94.0	38.3	1.2	10.6	100.0	42.5	1.5	9.8	94.0	38.3	1.2	10.6	100.0	42.5	1.5
302	301	1	1	1	7.2637E-05	100.0	72.0	1.0	2.4	35.8	29.3	0.3	4.2	22.6	19.9	0.4	0.6	9.3	9.2	0.1	0.8
302	205	2	1	1	1.5155E-05	100.0	77.3	1.1	0.3	27.6	21.8	0.0	3.7	21.3	36.1	2.0	0.0	7.9	15.0	0.4	0.1
302	303	2	1	1	1.5197E-06	100.0	12.6	0.1	14.4	66.7	10.4	1.3	37.8	23.0	2.9	0.0	3.8	16.4	2.5	0.5	9.6
302	301	4	6	1	1.1920E-07	4.0	39.1	12.0	0.6	16.7	100.0	31.6	0.8	4.0	39.1	12.0	0.6	16.7	100.0	31.6	0.8
302	303	4	2	1	1.2283E-09	53.5	100.0	57.8	4.6	2.1	17.9	42.0	4.7	53.5	100.0	57.8	4.6	2.1	17.9	42.0	4.7
303	302	2	1	1	1.2263E-05	100.0	26.6	0.4	12.7	80.4	16.7	0.0	14.6	23.7	6.7	0.2	3.0	19.7	4.3	0.0	3.4
303	201	3	5	1	3.5819E-06	16.0	0.1	1.1	72.8	100.0	4.5	0.0	12.4	5.0	0.0	1.6	30.0	20.3	0.2	0.1	8.6
303	301	3	1	1	1.3606E-05	100.0	13.8	0.2	26.5	86.3	11.8	0.2	29.6	24.0	3.2	0.1	7.2	21.1	2.8	0.1	7.9
303	302	4	7	1	6.3733E-09	2.0	31.3	83.2	7.7	25.6	79.8	100.0	9.1	2.0	31.3	83.2	7.7	25.6	79.8	100.0	9.1
303	301	4	3	1	7.0155E-09	13.0	87.9	100.0	8.3	12.2	79.8	86.7	6.6	13.0	87.9	100.0	8.3	12.2	79.8	86.7	6.6

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 2, 30.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points -->								| <-- Side 2: Brace side points --> |						
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	5	1	4.9990E-02	97.3	17.8	0.0	17.1	100.0	18.5	0.0	16.6	23.6	4.3	0.0	4.1	24.3	4.5	0.0	4.0
201	206	3	1	1	6.8413E-02	100.0	17.4	0.0	17.2	95.5	16.4	0.0	18.5	24.4	4.2	0.0	4.2	23.1	3.9	0.0	4.5
201	303	3	2	1	2.8680E-05	94.0	100.0	4.0	0.1	12.3	13.3	0.0	3.0	21.8	74.4	13.1	0.0	3.2	17.5	1.5	0.0
201	202	4	7	1	3.8962E-03	0.0	15.9	98.0	18.9	0.0	16.2	100.0	19.6	0.0	15.9	98.0	18.9	0.0	16.2	100.0	19.6
201	206	4	7	1	4.5781E-03	0.0	22.0	93.9	12.2	0.0	23.6	100.0	13.7	0.0	22.0	93.9	12.2	0.0	23.6	100.0	13.7
202	101	1	7	1	5.2811E-04	0.0	0.7	23.2	3.1	0.1	14.5	100.0	4.9	0.0	0.0	0.2	0.1	0.0	1.0	4.1	0.4
202	102	1	3	1	5.2480E-04	0.0	10.7	100.0	7.1	0.0	1.3	23.1	2.0	0.0	0.8	4.1	0.5	0.0	0.0	0.2	0.0
202	201	4	7	1	2.3246E-05	0.0	16.3	92.5	16.3	0.0	17.9	100.0	18.2	0.0	16.3	92.5	16.3	0.0	17.9	100.0	18.2
202	203	4	7	1	2.3899E-05	0.1	12.2	71.6	11.5	0.0	19.4	100.0	19.0	0.1	12.2	71.6	11.5	0.0	19.4	100.0	19.0
203	202	1	5	1	1.1967E-02	83.0	14.2	0.0	18.3	100.0	18.7	0.0	14.2	20.0	3.4	0.0	4.5	24.4	4.6	0.0	3.4
203	301	1	4	2	6.2909E-06	11.8	2.0	19.8	88.6	38.2	1.3	0.1	5.7	2.9	1.5	68.2	100.0	8.6	0.2	7.7	14.3
203	204	2	1	1	1.1616E-01	100.0	18.4	0.0	12.6	73.8	12.8	0.0	18.3	24.5	4.4	0.0	3.1	17.8	3.2	0.0	4.3
203	202	4	3	1	8.6413E-04	0.1	19.5	100.0	18.1	0.0	13.6	79.5	13.7	0.1	19.5	100.0	18.1	0.0	13.6	79.5	13.7
203	204	4	3	1	8.4782E-03	0.0	25.7	100.0	13.0	0.0	19.1	80.1	9.4	0.0	25.7	100.0	13.0	0.0	19.1	80.1	9.4
204	102	2	3	1	3.5001E-07	30.2	27.7	100.0	45.6	38.2	38.5	75.4	23.0	1.6	1.3	2.5	2.2	2.3	1.6	1.5	1.0
204	103	2	7	1	3.5883E-07	23.0	13.7	77.5	41.7	34.9	50.8	100.0	14.6	1.1	0.6	1.7	1.8	2.2	2.5	2.8	0.7
204	203	4	7	1	1.3142E-04	0.0	20.2	82.5	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.5	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	1.3045E-04	0.0	20.0	81.2	9.2	0.0	26.3	100.0	12.6	0.0	20.0	81.2	9.2	0.0	26.3	100.0	12.6
205	204	2	5	1	1.0563E-01	82.2	14.1	0.0	18.3	100.0	18.7	0.0	13.9	19.8	3.4	0.0	4.5	24.5	4.6	0.0	3.3
205	302	2	1	1	1.3579E-04	100.0	16.3	0.0	19.0	99.4	16.2	0.0	19.1	24.2	3.6	0.0	5.0	24.1	3.6	0.0	5.1
205	206	3	1	1	1.3008E-02	100.0	18.2	0.0	11.9	69.5	12.0	0.0	18.7	24.4	4.3	0.0	2.9	16.8	3.0	0.0	4.4
205	204	4	3	1	8.0263E-03	0.0	26.8	100.0	12.5	0.0	19.6	79.2	8.9	0.0	26.8	100.0	12.5	0.0	19.6	79.2	8.9
205	206	4	3	1	9.8246E-04	0.0	27.0	100.0	12.8	0.0	18.6	77.1	9.0	0.0	27.0	100.0	12.8	0.0	18.6	77.1	9.0

206	103	3	7	1	5.6388E-04	0.0	1.9	21.1	1.1	0.0	6.9	100.0	11.0	0.0	0.0	0.2	0.0	0.0	0.6	4.5	0.8
206	101	3	3	1	5.1369E-04	0.0	5.4	100.0	13.6	0.1	3.1	25.1	0.9	0.0	0.4	3.7	0.9	0.0	0.1	0.3	0.0
206	205	4	7	1	2.7988E-05	0.0	18.1	73.5	8.0	0.0	27.1	100.0	13.0	0.0	18.1	73.5	8.0	0.0	27.1	100.0	13.0
206	201	4	7	1	2.7697E-05	0.1	24.1	95.1	11.5	0.0	25.3	100.0	12.4	0.1	24.1	95.1	11.5	0.0	25.3	100.0	12.4
301	203	1	2	1	8.2066E-06	49.5	100.0	13.7	0.0	1.1	5.9	0.2	0.4	8.8	57.1	20.5	0.0	0.5	9.8	2.2	0.0
301	302	1	1	1	3.3686E-05	100.0	3.9	0.1	18.6	22.5	1.8	1.1	69.9	21.9	0.7	0.1	6.1	6.0	0.4	0.4	18.9
301	303	3	1	1	6.0698E-05	100.0	63.4	0.4	1.6	47.3	35.3	0.1	3.7	23.1	17.5	0.2	0.3	12.1	10.6	0.1	0.7
301	302	4	2	1	5.4334E-08	18.4	100.0	31.7	0.6	2.2	25.0	7.8	0.5	18.4	100.0	31.7	0.6	2.2	25.0	7.8	0.5
301	303	4	6	1	7.6176E-08	4.9	54.4	15.4	0.2	12.8	100.0	32.0	0.2	4.9	54.4	15.4	0.2	12.8	100.0	32.0	0.2
302	301	1	1	1	5.4639E-05	100.0	56.6	0.8	5.5	42.9	19.3	0.1	7.4	22.6	15.2	0.3	1.3	10.9	5.9	0.1	1.6
302	205	2	5	1	1.3968E-05	99.2	22.2	0.0	13.8	100.0	22.4	0.0	13.6	24.1	6.3	0.0	2.8	24.2	6.4	0.0	2.8
302	303	2	1	1	4.5792E-06	100.0	15.8	0.0	17.5	88.1	13.9	0.0	19.7	24.0	3.7	0.0	4.3	21.5	3.3	0.0	4.8
302	301	4	6	1	6.7267E-08	2.6	28.2	19.0	2.0	18.8	100.0	42.1	2.4	2.6	28.2	19.0	2.0	18.8	100.0	42.1	2.4
302	303	4	3	1	2.3152E-09	0.0	31.9	100.0	9.6	0.1	27.8	88.6	7.9	0.0	31.9	100.0	9.6	0.1	27.8	88.6	7.9
303	302	2	1	1	4.1520E-06	100.0	19.5	0.0	14.7	90.3	17.5	0.0	16.0	24.0	4.8	0.0	3.5	22.0	4.3	0.0	3.8
303	201	3	4	1	1.3380E-06	1.0	3.4	61.2	100.0	15.6	0.0	0.5	1.1	0.2	5.4	84.1	69.6	2.1	0.0	7.8	5.1
303	301	3	1	1	3.8272E-05	100.0	8.9	0.4	32.3	61.7	7.0	0.9	57.2	23.4	2.0	0.2	9.8	15.4	1.7	0.4	16.0
303	302	4	7	1	2.2234E-09	0.0	27.1	91.0	9.2	0.0	31.1	100.0	10.0	0.0	27.1	91.0	9.2	0.0	31.1	100.0	10.0
303	301	4	2	1	5.0095E-08	25.8	100.0	35.2	2.0	10.5	52.9	23.2	1.5	25.8	100.0	35.2	2.0	10.5	52.9	23.2	1.5

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 3, 60.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I D		<==RELATIVE DAMAGES AROUND THE WELD ====>														
					<-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->						
				DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1.1270E-01	100.0	18.4	0.0	14.6	85.7	15.3	0.0	17.7	24.4	4.4	0.0	3.6	20.8	3.8	0.0	4.2
201	206	3	1	1.5153E-02	100.0	17.5	0.0	17.0	93.9	16.1	0.0	18.9	24.4	4.2	0.0	4.1	22.7	3.9	0.0	4.6
201	303	3	3	1.0162E-05	8.4	38.5	28.5	1.7	2.7	1.0	0.3	1.0	1.9	62.5	100.0	8.0	0.7	6.6	13.5	0.4
201	202	4	3	8.6744E-03	0.0	17.2	100.0	19.0	0.0	14.6	89.4	16.3	0.0	17.2	100.0	19.0	0.0	14.6	89.4	16.3
201	206	4	7	1.0211E-03	0.0	21.6	91.7	11.9	0.0	23.5	100.0	14.5	0.0	21.6	91.7	11.9	0.0	23.5	100.0	14.5
202	101	1	7	3.4167E-05	0.2	0.7	24.7	7.4	1.1	27.2	100.0	2.3	0.0	0.0	0.3	0.2	0.2	1.8	4.0	0.2
202	102	1	3	3.3680E-05	0.6	20.7	100.0	4.2	0.6	1.8	24.6	5.1	0.1	1.4	4.0	0.3	0.0	0.1	0.3	0.1
202	201	4	7	8.2131E-05	0.0	15.3	88.3	15.2	0.0	18.2	100.0	18.2	0.0	15.3	88.3	15.2	0.0	18.2	100.0	18.2
202	203	4	7	8.3821E-05	0.0	12.7	74.8	12.2	0.0	19.1	100.0	18.6	0.0	12.7	74.8	12.2	0.0	19.1	100.0	18.6
203	202	1	5	4.3442E-02	75.6	12.9	0.0	18.3	100.0	19.2	0.0	12.4	18.1	3.1	0.0	4.5	24.5	4.7	0.0	2.9
203	301	1	5	4.8221E-05	39.7	1.5	0.2	50.1	100.0	7.4	0.0	16.8	9.9	0.1	0.7	25.9	23.5	0.4	0.1	11.0
203	204	2	1	4.1558E-02	100.0	18.3	0.0	10.8	63.2	10.6	0.0	18.8	24.5	4.3	0.0	2.7	15.2	2.6	0.0	4.4
203	202	4	3	3.1643E-03	0.0	20.2	100.0	18.0	0.0	12.3	70.9	11.1	0.0	20.2	100.0	18.0	0.0	12.3	70.9	11.1
203	204	4	3	2.9472E-03	0.0	27.2	100.0	12.9	0.0	17.4	71.8	7.8	0.0	27.2	100.0	12.9	0.0	17.4	71.8	7.8
204	102	2	7	3.3427E-05	0.4	3.8	22.0	2.1	0.7	5.1	100.0	18.2	0.1	0.1	0.2	0.1	0.1	0.3	3.9	1.2
204	103	2	3	3.3189E-05	0.1	1.8	100.0	31.2	1.5	9.5	27.1	0.6	0.0	0.1	4.1	2.1	0.2	0.3	0.3	0.0

204	203	4	7	1	8.0291E-05	0.0	18.5	76.1	8.5	0.0	26.4	100.0	13.0	0.0	18.5	76.1	8.5	0.0	26.4	100.0	13.0
204	205	4	7	1	7.8087E-05	0.0	22.4	90.3	10.7	0.0	25.6	100.0	12.5	0.0	22.4	90.3	10.7	0.0	25.6	100.0	12.5
205	204	2	5	1	1.1370E-01	94.0	16.2	0.0	18.3	100.0	17.7	0.0	16.8	22.8	3.9	0.0	4.5	24.4	4.3	0.0	4.1
205	302	2	1	1	1.0190E-04	100.0	41.9	0.1	2.2	43.3	15.2	0.0	9.1	23.5	19.6	0.3	0.1	10.9	8.8	0.0	0.7
205	206	3	5	1	1.3911E-02	94.5	17.4	0.0	17.0	100.0	19.0	0.0	16.1	22.9	4.2	0.0	4.0	24.3	4.6	0.0	3.9
205	204	4	3	1	8.5845E-03	0.0	24.5	100.0	12.9	0.0	22.1	93.0	11.7	0.0	24.5	100.0	12.9	0.0	22.1	93.0	11.7
205	206	4	7	1	1.1049E-03	0.0	21.9	95.9	13.1	0.0	22.4	100.0	14.6	0.0	21.9	95.9	13.1	0.0	22.4	100.0	14.6
206	103	3	7	1	1.1604E-03	0.0	1.0	20.0	1.7	0.0	10.6	100.0	7.5	0.0	0.0	0.2	0.0	0.0	0.8	4.7	0.6
206	101	3	3	1	1.0469E-03	0.0	7.8	100.0	10.3	0.0	2.0	23.6	1.3	0.0	0.5	3.9	0.7	0.0	0.0	0.2	0.0
206	205	4	7	1	9.1102E-06	0.2	20.6	83.9	9.8	0.0	26.1	100.0	12.7	0.2	20.6	83.9	9.8	0.0	26.1	100.0	12.7
206	201	4	7	1	9.2504E-06	0.5	20.5	82.6	9.5	0.0	26.3	100.0	12.8	0.5	20.5	82.6	9.5	0.0	26.3	100.0	12.8
301	203	1	1	1	1.4684E-05	100.0	68.6	0.7	0.4	26.8	18.6	0.0	4.4	21.2	29.5	1.2	0.0	7.7	11.7	0.2	0.2
301	302	1	1	1	2.1095E-06	100.0	11.9	0.1	14.3	63.4	9.9	1.3	41.6	22.8	2.8	0.0	3.9	15.6	2.4	0.5	10.7
301	303	3	1	1	8.4471E-05	100.0	70.4	0.9	2.3	35.5	28.6	0.2	4.2	22.6	19.4	0.4	0.5	9.2	9.0	0.1	0.8
301	302	4	2	1	1.9807E-09	38.9	100.0	55.4	5.9	1.6	15.2	36.3	5.0	38.9	100.0	55.4	5.9	1.6	15.2	36.3	5.0
301	303	4	6	1	1.3275E-07	5.7	39.2	9.6	0.4	22.0	100.0	25.1	0.5	5.7	39.2	9.6	0.4	22.0	100.0	25.1	0.5
302	301	1	1	1	1.4367E-05	100.0	26.4	0.3	13.0	80.2	16.4	0.0	14.8	23.7	6.6	0.1	3.1	19.6	4.2	0.0	3.5
302	205	2	5	1	5.7379E-06	19.6	0.2	0.9	69.2	100.0	5.0	0.0	13.3	5.9	0.0	1.4	29.4	20.7	0.2	0.1	9.3
302	303	2	1	1	1.8509E-05	100.0	13.6	0.1	27.1	86.8	11.7	0.1	30.1	24.0	3.2	0.1	7.3	21.3	2.8	0.1	8.0
302	301	4	7	1	7.5944E-09	0.9	22.7	81.4	11.7	14.9	67.6	100.0	13.6	0.9	22.7	81.4	11.7	14.9	67.6	100.0	13.6
302	303	4	3	1	8.9964E-09	10.6	89.6	100.0	8.4	9.8	81.8	87.2	6.7	10.6	89.6	100.0	8.4	9.8	81.8	87.2	6.7
303	302	2	1	1	4.9725E-06	100.0	51.3	0.2	5.7	90.3	48.0	0.2	6.7	24.1	14.4	0.1	1.3	22.0	13.6	0.1	1.4
303	201	3	3	2	3.5731E-06	6.1	70.9	67.7	6.6	0.1	0.6	1.1	0.1	0.8	57.7	100.0	10.0	0.0	4.7	12.5	0.2
303	301	3	1	1	4.6870E-05	100.0	5.0	0.4	28.8	36.4	3.3	1.5	76.5	22.5	1.1	0.2	9.3	9.4	0.8	0.7	21.4
303	302	4	6	1	4.6364E-09	7.3	93.9	44.4	1.2	8.0	100.0	49.3	1.5	7.3	93.9	44.4	1.2	8.0	100.0	49.3	1.5
303	301	4	2	1	9.0502E-08	29.6	100.0	21.6	0.6	7.6	36.3	8.8	0.5	29.6	100.0	21.6	0.6	7.6	36.3	8.8	0.5

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 4, 90.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I D		<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->						
				DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	2.4036E-01	100.0	18.5	0.0	12.4	72.5	12.5	0.0	18.3	24.6	4.4	0.0	3.1	17.5	3.1	0.0	4.3
201	206	3	5	1	2.5762E-02	81.5	14.0	0.0	18.2	100.0	18.9	0.0	13.8	19.6	3.4	0.0	4.5	24.5	4.7	0.0	3.3
201	303	3	4	2	1.0986E-05	21.8	3.7	23.0	87.9	40.1	2.1	0.1	7.6	5.2	2.4	75.8	100.0	9.3	0.4	8.3	13.9
201	202	4	3	1	1.8112E-02	0.0	18.4	100.0	18.8	0.0	13.1	79.1	13.6	0.0	18.4	100.0	18.8	0.0	13.1	79.1	13.6
201	206	4	3	1	1.7451E-03	0.1	27.7	100.0	12.5	0.0	18.9	76.9	8.9	0.1	27.7	100.0	12.5	0.0	18.9	76.9	8.9
202	101	1	3	1	5.5686E-07	34.9	25.2	100.0	53.5	47.7	46.6	78.1	21.5	1.8	1.2	2.6	2.6	2.9	2.0	1.6	0.9
202	102	1	7	1	5.5464E-07	33.5	19.8	78.1	49.4	48.5	57.9	100.0	22.7	1.7	0.9	1.6	2.1	3.0	2.8	2.6	1.1
202	201	4	7	1	2.9086E-04	0.0	14.0	82.0	13.8	0.0	18.5	100.0	18.3	0.0	14.0	82.0	13.8	0.0	18.5	100.0	18.3
202	203	4	7	1	2.9150E-04	0.0	14.0	81.7	13.7	0.0	18.6	100.0	18.2	0.0	14.0	81.7	13.7	0.0	18.6	100.0	18.2

203	202	1	5	1	2.4908E-01	83.0	14.3	0.0	18.4	100.0	18.7	0.0	14.1	20.1	3.4	0.0	4.5	24.6	4.6	0.0	3.4
203	301	1	1	1	2.8154E-04	100.0	18.1	0.0	17.1	98.7	17.7	0.0	17.4	24.2	4.5	0.0	4.1	23.9	4.4	0.0	4.1
203	204	2	1	1	2.4082E-02	100.0	18.3	0.0	11.9	69.7	12.0	0.0	18.6	24.5	4.3	0.0	2.9	16.8	3.0	0.0	4.4
203	202	4	3	1	1.8063E-02	0.0	18.9	100.0	18.2	0.0	13.6	79.3	13.2	0.0	18.9	100.0	18.2	0.0	13.6	79.3	13.2
203	204	4	3	1	1.7251E-03	0.0	26.7	100.0	12.9	0.0	18.4	77.0	9.0	0.0	26.7	100.0	12.9	0.0	18.4	77.0	9.0
204	102	2	7	1	1.0761E-03	0.0	1.9	23.7	1.5	0.0	7.8	100.0	10.0	0.0	0.0	0.2	0.0	0.0	0.5	3.8	0.7
204	103	2	3	1	1.1690E-03	0.0	4.5	100.0	15.6	0.2	3.2	22.2	0.6	0.0	0.4	4.4	1.2	0.0	0.1	0.2	0.0
204	203	4	7	1	5.3228E-05	0.0	17.8	72.9	8.0	0.0	26.8	100.0	13.3	0.0	17.8	72.9	8.0	0.0	26.8	100.0	13.3
204	205	4	7	1	5.1353E-05	0.1	24.3	96.5	11.8	0.0	25.0	100.0	12.5	0.1	24.3	96.5	11.8	0.0	25.0	100.0	12.5
205	204	2	1	1	1.2666E-01	100.0	17.3	0.0	17.0	93.5	15.8	0.0	18.9	24.4	4.2	0.0	4.1	22.6	3.8	0.0	4.6
205	302	2	2	1	6.3719E-05	89.0	100.0	4.6	0.0	9.9	11.8	0.0	2.7	20.1	81.8	17.3	0.0	2.7	19.3	2.1	0.0
205	206	3	5	1	1.1576E-01	96.8	17.8	0.0	17.0	100.0	18.7	0.0	16.4	23.5	4.4	0.0	4.1	24.3	4.6	0.0	4.0
205	204	4	7	1	9.6179E-03	0.0	21.0	92.1	12.2	0.0	23.0	100.0	14.2	0.0	21.0	92.1	12.2	0.0	23.0	100.0	14.2
205	206	4	7	1	9.2950E-03	0.0	22.1	97.5	13.3	0.0	22.5	100.0	14.0	0.0	22.1	97.5	13.3	0.0	22.5	100.0	14.0
206	103	3	7	1	1.1856E-03	0.0	0.6	22.3	3.3	0.2	15.8	100.0	4.4	0.0	0.0	0.2	0.1	0.0	1.2	4.4	0.4
206	101	3	3	1	1.0934E-03	0.0	10.1	100.0	7.7	0.0	1.5	23.9	1.9	0.0	0.7	3.8	0.5	0.0	0.0	0.2	0.0
206	205	4	7	1	5.2131E-05	0.0	23.2	93.7	11.4	0.0	25.1	100.0	12.6	0.0	23.2	93.7	11.4	0.0	25.1	100.0	12.6
206	201	4	7	1	5.4305E-05	0.1	17.3	70.8	7.6	0.0	27.1	100.0	13.5	0.1	17.3	70.8	7.6	0.0	27.1	100.0	13.5
301	203	1	5	1	2.6069E-05	97.8	18.3	0.0	16.7	100.0	18.9	0.0	16.2	23.8	4.6	0.0	3.9	24.2	4.8	0.0	3.8
301	302	1	1	1	9.0322E-06	100.0	15.9	0.0	17.6	89.5	14.2	0.0	19.6	24.0	3.8	0.0	4.4	21.9	3.4	0.0	4.8
301	303	3	1	1	1.2651E-04	100.0	56.4	0.8	5.3	42.8	19.5	0.1	7.4	22.6	15.1	0.3	1.3	10.8	5.9	0.1	1.6
301	302	4	3	1	4.8090E-09	0.0	22.5	100.0	14.3	0.0	19.6	90.1	12.3	0.0	22.5	100.0	14.3	0.0	19.6	90.1	12.3
301	303	4	6	1	1.5390E-07	4.0	29.5	16.8	1.2	24.7	100.0	34.7	1.5	4.0	29.5	16.8	1.2	24.7	100.0	34.7	1.5
302	301	1	1	1	8.3703E-06	100.0	18.8	0.0	15.3	91.7	17.2	0.0	16.6	24.1	4.6	0.0	3.7	22.3	4.2	0.0	4.0
302	205	2	4	1	4.6904E-06	0.3	1.3	48.3	100.0	18.5	0.0	0.5	1.8	0.1	3.1	76.1	74.2	2.7	0.0	8.1	7.7
302	303	2	1	1	1.0150E-04	100.0	9.0	0.3	31.0	61.7	7.0	0.7	54.2	23.4	2.0	0.1	9.2	15.4	1.7	0.3	15.0
302	301	4	7	1	4.4588E-09	0.0	18.4	92.2	14.3	0.0	20.7	100.0	15.9	0.0	18.4	92.2	14.3	0.0	20.7	100.0	15.9
302	303	4	2	1	1.1594E-07	23.0	100.0	38.4	2.2	9.3	53.3	25.2	1.7	23.0	100.0	38.4	2.2	9.3	53.3	25.2	1.7
303	302	2	1	1	1.3577E-04	100.0	61.3	0.3	1.7	47.7	34.2	0.1	3.9	23.1	16.9	0.1	0.3	12.2	10.3	0.1	0.7
303	201	3	2	1	1.7197E-05	48.5	100.0	14.1	0.0	0.9	5.8	0.2	0.4	8.5	56.0	20.3	0.1	0.4	9.4	2.3	0.0
303	301	3	1	1	7.3814E-05	100.0	3.8	0.1	17.6	20.9	1.4	0.8	66.9	21.8	0.7	0.1	5.8	5.6	0.3	0.3	18.0
303	302	4	6	1	1.6834E-07	4.4	54.4	16.8	0.2	11.7	100.0	34.5	0.2	4.4	54.4	16.8	0.2	11.7	100.0	34.5	0.2
303	301	4	2	1	1.1367E-07	21.8	100.0	26.8	0.3	2.9	24.9	6.2	0.2	21.8	100.0	26.8	0.3	2.9	24.9	6.2	0.2

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 5, 120.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N	N	P	P	S																
O	O	L	O	I									<==RELATIVE DAMAGES AROUND THE WELD ====>							
D	D	A	S	D		<-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->						
E	E	N	N	E																
1	2	E			DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	5.1530E-02	100.0	18.4	0.0	10.7	63.2	10.6	0.0	18.7	24.5	4.3	0.0	2.7	15.2	2.6	0.0	4.4
201	206	3	5	1	4.8038E-02	76.1	13.0	0.0	18.3	100.0	19.3	0.0	12.4	18.2	3.1	0.0	4.5	24.5	4.8	0.0	3.0

201	303	3	5	1	5.9139E-05	41.1	1.5	0.2	53.8	100.0	6.6	0.0	19.0	10.2	0.1	0.9	28.9	23.7	0.3	0.1	12.6
201	202	4	3	1	3.7854E-03	0.0	19.4	100.0	18.6	0.0	12.0	71.8	11.7	0.0	19.4	100.0	18.6	0.0	12.0	71.8	11.7
201	206	4	3	1	3.2747E-03	0.0	28.4	100.0	12.4	0.0	17.6	70.3	7.4	0.0	28.4	100.0	12.4	0.0	17.6	70.3	7.4
202	101	1	7	1	3.8544E-05	0.6	5.0	24.0	1.7	0.6	4.0	100.0	20.9	0.1	0.1	0.3	0.1	0.0	0.3	4.0	1.4
202	102	1	3	1	3.9028E-05	0.2	2.4	100.0	26.8	1.0	7.1	24.1	0.7	0.0	0.2	4.0	1.8	0.2	0.2	0.3	0.0
202	201	4	7	1	9.9774E-05	0.0	13.0	76.4	12.6	0.0	18.9	100.0	18.6	0.0	13.0	76.4	12.6	0.0	18.9	100.0	18.6
202	203	4	7	1	9.8297E-05	0.0	15.6	89.3	15.4	0.0	18.2	100.0	18.1	0.0	15.6	89.3	15.4	0.0	18.2	100.0	18.1
203	202	1	5	1	1.4174E-01	92.9	16.1	0.0	18.3	100.0	17.9	0.0	16.5	22.6	3.9	0.0	4.5	24.5	4.4	0.0	4.0
203	301	1	1	1	1.3395E-04	100.0	44.5	0.1	2.0	45.0	17.2	0.0	8.2	23.6	21.4	0.3	0.1	11.2	10.0	0.0	0.6
203	204	2	5	1	1.3926E-02	95.5	17.5	0.0	17.1	100.0	18.8	0.0	16.4	23.2	4.3	0.0	4.1	24.3	4.5	0.0	4.0
203	202	4	3	1	1.0151E-02	0.0	17.6	100.0	18.5	0.0	15.4	91.2	16.4	0.0	17.6	100.0	18.5	0.0	15.4	91.2	16.4
203	204	4	7	1	1.0461E-03	0.0	22.5	96.7	12.9	0.0	22.9	100.0	14.2	0.0	22.5	96.7	12.9	0.0	22.9	100.0	14.2
204	102	2	7	1	1.2249E-03	0.0	1.3	24.1	2.0	0.0	10.5	100.0	7.7	0.0	0.0	0.2	0.0	0.0	0.7	3.9	0.5
204	103	2	3	1	1.3551E-03	0.0	7.6	100.0	10.6	0.0	1.7	20.5	1.0	0.0	0.6	4.7	0.8	0.0	0.0	0.2	0.0
204	203	4	7	1	1.0082E-05	0.2	20.2	82.1	9.4	0.0	26.2	100.0	12.8	0.2	20.2	82.1	9.4	0.0	26.2	100.0	12.8
204	205	4	7	1	9.9569E-06	0.5	21.0	84.9	10.0	0.0	26.1	100.0	12.7	0.5	21.0	84.9	10.0	0.0	26.1	100.0	12.7
205	204	2	1	1	1.7794E-02	100.0	17.3	0.0	16.6	91.2	15.4	0.0	19.3	24.4	4.2	0.0	4.0	22.1	3.7	0.0	4.8
205	302	2	3	2	1.7872E-05	3.3	25.8	24.5	1.8	0.7	0.4	0.2	0.3	0.7	51.1	100.0	10.1	0.2	5.5	15.1	0.4
205	206	3	1	1	1.2684E-01	100.0	18.5	0.0	14.9	87.3	15.7	0.0	17.6	24.4	4.4	0.0	3.6	21.2	3.9	0.0	4.2
205	204	4	7	1	1.3576E-03	0.0	20.4	89.3	11.9	0.0	22.7	100.0	15.3	0.0	20.4	89.3	11.9	0.0	22.7	100.0	15.3
205	206	4	3	1	1.0050E-02	0.0	24.1	100.0	13.3	0.0	21.0	90.7	11.6	0.0	24.1	100.0	13.3	0.0	21.0	90.7	11.6
206	103	3	7	1	4.0844E-05	0.1	0.6	28.1	9.9	1.5	31.4	100.0	1.8	0.0	0.0	0.4	0.3	0.2	2.1	4.1	0.1
206	101	3	3	1	4.1116E-05	0.4	18.0	100.0	5.1	0.7	2.2	22.9	3.9	0.1	1.2	3.9	0.3	0.1	0.1	0.2	0.1
206	205	4	7	1	8.8804E-05	0.0	21.9	89.1	10.6	0.0	25.6	100.0	12.6	0.0	21.9	89.1	10.6	0.0	25.6	100.0	12.6
206	201	4	7	1	9.1764E-05	0.0	18.1	74.3	8.1	0.0	26.7	100.0	13.0	0.0	18.1	74.3	8.1	0.0	26.7	100.0	13.0
301	203	1	5	1	6.6521E-06	18.9	0.1	1.4	79.4	100.0	3.8	0.0	16.0	5.7	0.0	2.2	35.2	20.6	0.1	0.3	11.6
301	302	1	1	1	1.7307E-05	100.0	14.1	0.1	26.5	88.3	12.3	0.1	29.1	24.0	3.3	0.1	7.1	21.6	2.9	0.1	7.7
301	303	3	1	1	1.9096E-05	100.0	27.7	0.3	12.5	78.6	16.6	0.0	14.3	23.6	7.0	0.1	3.0	19.3	4.3	0.0	3.4
301	302	4	3	1	9.2116E-09	7.1	72.3	100.0	12.5	6.5	66.5	89.0	10.4	7.1	72.3	100.0	12.5	6.5	66.5	89.0	10.4
301	303	4	7	1	9.3303E-09	1.8	32.2	81.9	7.7	22.8	85.6	100.0	9.1	1.8	32.2	81.9	7.7	22.8	85.6	100.0	9.1
302	301	1	1	1	4.8304E-06	100.0	58.6	0.4	6.0	90.8	55.0	0.3	6.8	24.1	16.7	0.2	1.3	22.2	15.8	0.2	1.5
302	205	2	3	2	6.6501E-06	2.6	48.2	58.7	7.0	0.0	0.4	1.1	0.0	0.3	47.1	100.0	11.7	0.0	4.4	14.3	0.4
302	303	2	1	1	6.1972E-05	100.0	5.4	0.4	27.9	37.8	3.6	1.4	73.5	22.6	1.2	0.2	8.8	9.7	0.9	0.6	20.4
302	301	4	6	1	5.3367E-09	7.9	94.3	44.0	2.0	8.7	100.0	48.2	2.4	7.9	94.3	44.0	2.0	8.7	100.0	48.2	2.4
302	303	4	2	1	1.0929E-07	29.6	100.0	22.6	0.8	7.5	36.2	9.6	0.6	29.6	100.0	22.6	0.8	7.5	36.2	9.6	0.6
303	302	2	1	1	9.5836E-05	100.0	71.3	0.9	2.1	34.2	28.6	0.2	4.0	22.5	19.8	0.4	0.5	8.9	9.1	0.1	0.8
303	201	3	1	1	1.6998E-05	100.0	77.1	1.1	0.2	25.8	21.2	0.0	3.6	21.2	34.3	1.8	0.0	7.4	13.9	0.3	0.1
303	301	3	1	1	2.3493E-06	100.0	10.9	0.0	13.4	57.1	8.6	1.0	41.9	22.6	2.5	0.0	3.7	14.1	2.1	0.4	10.7
303	302	4	6	1	1.5930E-07	5.6	38.9	9.2	0.3	21.6	100.0	25.0	0.4	5.6	38.9	9.2	0.3	21.6	100.0	25.0	0.4
303	301	4	2	1	2.1634E-09	39.3	100.0	52.0	3.5	1.5	17.1	33.1	3.0	39.3	100.0	52.0	3.5	1.5	17.1	33.1	3.0

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 6, 150.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N	N	P	P	S

O D E 1	O D E 2	L A N E	O S N	I D E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.5551E-02	100.0	18.3	0.0	12.3	72.2	12.6	0.0	18.4	24.4	4.3	0.0	3.0	17.4	3.1	0.0	4.4
201	206	3	5	1	1.5006E-01	84.8	14.7	0.0	18.4	100.0	18.6	0.0	14.5	20.5	3.5	0.0	4.5	24.6	4.6	0.0	3.5
201	303	3	1	1	1.6385E-04	100.0	16.6	0.0	18.6	98.7	16.3	0.0	19.0	24.2	3.7	0.0	4.8	23.9	3.7	0.0	4.9
201	202	4	3	1	1.1581E-03	0.0	18.7	100.0	18.7	0.0	13.1	79.0	13.8	0.0	18.7	100.0	18.7	0.0	13.1	79.0	13.8
201	206	4	3	1	1.0194E-02	0.0	26.4	100.0	12.6	0.0	19.8	80.6	9.2	0.0	26.4	100.0	12.6	0.0	19.8	80.6	9.2
202	101	1	7	1	6.3412E-04	0.0	2.0	23.0	1.3	0.0	7.2	100.0	10.7	0.0	0.0	0.2	0.0	0.0	0.5	4.1	0.8
202	102	1	3	1	6.3718E-04	0.0	5.0	100.0	14.5	0.1	3.0	23.0	0.7	0.0	0.4	4.1	1.0	0.0	0.1	0.2	0.0
202	201	4	7	1	3.1380E-05	0.0	12.6	73.9	12.0	0.0	19.2	100.0	18.8	0.0	12.6	73.9	12.0	0.0	19.2	100.0	18.8
202	203	4	7	1	3.0738E-05	0.1	16.9	94.2	16.6	0.0	17.9	100.0	18.1	0.1	16.9	94.2	16.6	0.0	17.9	100.0	18.1
203	202	1	1	1	7.1905E-02	100.0	17.5	0.0	17.2	95.3	16.3	0.0	18.6	24.4	4.2	0.0	4.2	23.1	3.9	0.0	4.5
203	301	1	2	1	3.4698E-05	87.9	100.0	4.6	0.0	10.3	12.4	0.0	2.6	20.1	79.3	16.3	0.0	2.7	18.7	2.0	0.0
203	204	2	5	1	6.9484E-02	99.1	18.1	0.0	17.1	100.0	18.5	0.0	17.0	24.0	4.4	0.0	4.1	24.3	4.5	0.0	4.1
203	202	4	7	1	5.1265E-03	0.0	15.5	94.0	17.7	0.0	16.6	100.0	19.6	0.0	15.5	94.0	17.7	0.0	16.6	100.0	19.6
203	204	4	7	1	5.2928E-03	0.0	23.0	99.1	13.2	0.0	23.0	100.0	13.6	0.0	23.0	99.1	13.2	0.0	23.0	100.0	13.6
204	102	2	7	1	6.4260E-04	0.0	0.9	25.6	3.2	0.1	13.9	100.0	5.3	0.0	0.0	0.3	0.1	0.0	0.9	3.8	0.4
204	103	2	3	1	7.0549E-04	0.0	11.1	100.0	6.9	0.0	1.1	21.6	1.9	0.0	0.9	4.5	0.6	0.0	0.0	0.2	0.0
204	203	4	7	1	3.3751E-05	0.0	23.0	92.3	11.1	0.0	25.4	100.0	12.5	0.0	23.0	92.3	11.1	0.0	25.4	100.0	12.5
204	205	4	7	1	3.4283E-05	0.1	17.6	71.5	7.7	0.0	27.3	100.0	13.2	0.1	17.6	71.5	7.7	0.0	27.3	100.0	13.2
205	204	2	5	1	1.6437E-02	81.0	13.9	0.0	18.2	100.0	19.0	0.0	13.7	19.5	3.3	0.0	4.5	24.4	4.7	0.0	3.3
205	302	2	4	2	9.6508E-06	7.2	1.2	18.9	83.4	33.1	0.7	0.1	4.6	1.7	1.5	71.0	100.0	7.2	0.1	8.5	14.7
205	206	3	1	1	1.2978E-01	100.0	18.4	0.0	12.5	72.8	12.5	0.0	18.4	24.5	4.4	0.0	3.1	17.6	3.1	0.0	4.4
205	204	4	3	1	1.2470E-03	0.1	27.8	100.0	12.4	0.0	19.3	78.2	9.1	0.1	27.8	100.0	12.4	0.0	19.3	78.2	9.1
205	206	4	3	1	9.9921E-03	0.0	26.0	100.0	12.9	0.0	19.1	79.4	9.2	0.0	26.0	100.0	12.9	0.0	19.1	79.4	9.2
206	103	3	3	1	4.5505E-07	23.2	16.1	100.0	46.7	33.9	38.6	77.6	14.6	1.1	0.8	2.8	2.3	2.1	1.7	1.7	0.7
206	101	3	7	1	4.4019E-07	28.1	20.5	75.6	41.5	38.9	49.9	100.0	24.0	1.5	0.9	1.5	1.7	2.4	2.4	2.5	1.1
206	205	4	7	1	1.5897E-04	0.0	20.1	81.8	9.3	0.0	26.1	100.0	12.6	0.0	20.1	81.8	9.3	0.0	26.1	100.0	12.6
206	201	4	7	1	1.6080E-04	0.0	20.2	82.3	9.4	0.0	26.2	100.0	12.6	0.0	20.2	82.3	9.4	0.0	26.2	100.0	12.6
301	203	1	4	1	2.1693E-06	0.5	2.2	55.8	100.0	16.2	0.0	0.6	1.4	0.1	4.3	82.5	72.7	2.3	0.0	8.7	6.7
301	302	1	1	1	4.7784E-05	100.0	9.3	0.3	30.8	63.2	7.5	0.8	54.3	23.4	2.1	0.2	9.2	15.8	1.8	0.3	15.1
301	303	3	1	1	5.2352E-06	100.0	19.1	0.0	15.0	90.9	17.3	0.0	16.4	24.1	4.7	0.0	3.6	22.1	4.3	0.0	3.9
301	302	4	2	1	5.5976E-08	18.5	100.0	44.9	3.6	6.9	51.9	29.2	2.8	18.5	100.0	44.9	3.6	6.9	51.9	29.2	2.8
301	303	4	7	1	2.6626E-09	0.0	26.4	91.4	9.4	0.0	30.0	100.0	10.4	0.0	26.4	91.4	9.4	0.0	30.0	100.0	10.4
302	301	1	1	1	7.4046E-05	100.0	66.2	0.5	1.7	47.8	37.2	0.2	3.6	23.1	18.4	0.2	0.4	12.2	11.2	0.1	0.7
302	205	2	2	1	1.1345E-05	44.7	100.0	15.5	0.0	1.0	6.1	0.2	0.3	7.9	61.5	25.1	0.1	0.4	11.0	3.0	0.0
302	303	2	1	1	4.0187E-05	100.0	4.0	0.1	17.2	21.6	1.7	1.0	67.5	21.8	0.8	0.1	5.6	5.8	0.4	0.4	18.1
302	301	4	6	1	9.7590E-08	3.6	54.6	19.9	0.3	9.8	100.0	39.7	0.4	3.6	54.6	19.9	0.3	9.8	100.0	39.7	0.4
302	303	4	2	1	6.1113E-08	24.0	100.0	25.7	0.4	3.1	24.0	6.2	0.3	24.0	100.0	25.7	0.4	3.1	24.0	6.2	0.3
303	302	2	1	1	6.2221E-05	100.0	58.3	0.9	5.3	42.2	19.5	0.1	7.3	22.5	15.8	0.4	1.3	10.7	6.0	0.1	1.6
303	201	3	5	1	1.2412E-05	97.7	21.9	0.0	13.8	100.0	22.5	0.0	13.4	23.8	6.2	0.0	2.8	24.2	6.3	0.0	2.7

303	301	3	1	1	5.5682E-06	100.0	15.4	0.0	17.6	86.8	13.3	0.0	20.2	24.0	3.6	0.0	4.4	21.2	3.2	0.0	4.9
303	302	4	6	1	8.3723E-08	4.2	28.4	15.9	1.1	26.7	100.0	33.0	1.5	4.2	28.4	15.9	1.1	26.7	100.0	33.0	1.5
303	301	4	3	1	2.9621E-09	0.0	33.4	100.0	9.1	0.1	28.4	87.4	7.3	0.0	33.4	100.0	9.1	0.1	28.4	87.4	7.3

BUFFETING DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S E	I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	4.7845E-01	100.0	18.4	0.0	13.4	78.4	13.8	0.0	18.1	24.5	4.4	0.0	3.3	19.0	3.4	0.0	4.3
201	206	3	5	1	4.2364E-01	90.2	15.6	0.0	18.2	100.0	18.2	0.0	15.8	21.9	3.8	0.0	4.5	24.5	4.4	0.0	3.8
201	303	3	1	1	3.1442E-04	100.0	32.1	2.2	23.7	86.8	16.0	0.0	16.8	24.0	16.6	7.3	11.8	21.0	6.4	0.9	5.7
201	202	4	3	1	3.6306E-02	0.0	17.9	100.0	18.9	0.0	13.8	83.8	14.9	0.0	17.9	100.0	18.9	0.0	13.8	83.8	14.9
201	206	4	3	1	2.8479E-02	0.0	25.7	100.0	12.7	0.0	21.2	87.5	10.6	0.0	25.7	100.0	12.7	0.0	21.2	87.5	10.6
202	101	1	7	1	2.1915E-03	0.0	1.3	22.5	2.1	0.1	10.7	100.0	8.0	0.0	0.0	0.2	0.0	0.0	0.8	4.2	0.6
202	102	1	3	1	2.1895E-03	0.0	7.7	100.0	11.0	0.1	2.1	22.5	1.3	0.0	0.6	4.2	0.8	0.0	0.1	0.2	0.0
202	201	4	7	1	5.3380E-04	0.0	14.0	81.9	13.8	0.0	18.6	100.0	18.3	0.0	14.0	81.9	13.8	0.0	18.6	100.0	18.3
202	203	4	7	1	5.3469E-04	0.0	14.2	82.3	13.8	0.0	18.6	100.0	18.3	0.0	14.2	82.3	13.8	0.0	18.6	100.0	18.3
203	202	1	5	1	5.2534E-01	88.4	15.3	0.0	18.3	100.0	18.3	0.0	15.4	21.4	3.7	0.0	4.5	24.5	4.5	0.0	3.7
203	301	1	1	1	4.6642E-04	100.0	32.1	1.3	17.3	84.1	17.4	0.0	14.9	24.0	16.1	4.6	6.7	20.4	7.1	0.6	4.0
203	204	2	1	1	3.7286E-01	100.0	18.4	0.0	14.1	82.2	14.6	0.0	17.9	24.4	4.4	0.0	3.4	19.9	3.6	0.0	4.3
203	202	4	3	1	3.7802E-02	0.0	18.3	100.0	18.4	0.0	14.6	85.9	15.1	0.0	18.3	100.0	18.4	0.0	14.6	85.9	15.1
203	204	4	3	1	2.7556E-02	0.0	24.9	100.0	13.1	0.0	20.4	86.8	10.8	0.0	24.9	100.0	13.1	0.0	20.4	86.8	10.8
204	102	2	7	1	3.0071E-03	0.0	1.4	24.4	2.2	0.1	10.4	100.0	8.1	0.0	0.0	0.2	0.1	0.0	0.7	3.9	0.6
204	103	2	3	1	3.2979E-03	0.0	7.4	100.0	11.7	0.1	2.2	21.4	1.1	0.0	0.6	4.6	0.9	0.0	0.1	0.2	0.0
204	203	4	7	1	3.8347E-04	0.0	20.1	82.0	9.4	0.0	26.1	100.0	12.8	0.0	20.1	82.0	9.4	0.0	26.1	100.0	12.8
204	205	4	7	1	3.7972E-04	0.0	20.5	82.9	9.5	0.0	26.2	100.0	12.7	0.0	20.5	82.9	9.5	0.0	26.2	100.0	12.7
205	204	2	5	1	4.0619E-01	93.0	16.0	0.0	18.2	100.0	17.9	0.0	16.6	22.5	3.9	0.0	4.4	24.4	4.4	0.0	4.0
205	302	2	1	1	3.1462E-04	100.0	42.6	3.0	20.0	75.6	15.4	0.0	14.7	23.7	27.4	11.6	10.6	18.4	8.7	1.6	4.9
205	206	3	1	1	4.3076E-01	100.0	18.4	0.0	14.5	85.0	15.3	0.0	17.8	24.4	4.4	0.0	3.5	20.6	3.7	0.0	4.3
205	204	4	3	1	3.0651E-02	0.0	25.1	100.0	12.9	0.0	21.9	91.9	11.7	0.0	25.1	100.0	12.9	0.0	21.9	91.9	11.7
205	206	4	3	1	3.3823E-02	0.0	24.6	100.0	13.2	0.0	20.7	89.0	11.3	0.0	24.6	100.0	13.2	0.0	20.7	89.0	11.3
206	103	3	7	1	2.9845E-03	0.0	1.0	21.3	2.3	0.1	12.2	100.0	7.0	0.0	0.0	0.2	0.1	0.0	0.9	4.5	0.6
206	101	3	3	1	2.7240E-03	0.0	8.4	100.0	10.0	0.1	2.0	24.1	1.5	0.0	0.6	3.8	0.7	0.0	0.0	0.2	0.0
206	205	4	7	1	4.1155E-04	0.0	20.5	83.3	9.6	0.0	26.1	100.0	12.7	0.0	20.5	83.3	9.6	0.0	26.1	100.0	12.7
206	201	4	7	1	4.1785E-04	0.0	20.1	81.4	9.3	0.0	26.2	100.0	12.8	0.0	20.1	81.4	9.3	0.0	26.2	100.0	12.8
301	203	1	1	1	4.5659E-05	100.0	55.6	10.9	26.5	81.3	18.4	0.2	13.1	22.8	27.0	16.8	11.7	19.5	8.6	2.1	4.2
301	302	1	1	1	1.5179E-04	100.0	8.0	0.3	26.0	51.8	6.2	1.0	58.5	22.9	1.8	0.1	7.9	13.0	1.5	0.4	16.1
301	303	3	1	1	2.9937E-04	100.0	59.3	0.7	4.4	45.3	25.4	0.2	6.3	22.8	16.1	0.3	1.0	11.5	7.7	0.1	1.4
301	302	4	2	1	1.9942E-07	20.1	100.0	39.7	2.6	5.0	39.4	21.4	2.1	20.1	100.0	39.7	2.6	5.0	39.4	21.4	2.1
301	303	4	6	1	3.7503E-07	4.8	38.8	16.5	0.9	21.2	100.0	33.2	1.2	4.8	38.8	16.5	0.9	21.2	100.0	33.2	1.2

302	301	1	1	1	2.2889E-04	100.0	61.4	0.7	4.1	47.4	28.8	0.2	6.0	22.9	16.8	0.3	1.0	12.0	8.7	0.1	1.3
302	205	2	1	1	3.5400E-05	100.0	83.1	23.0	31.3	70.3	21.0	0.4	9.5	22.2	46.9	38.0	17.9	16.8	13.3	4.9	3.7
302	303	2	1	1	2.2827E-04	100.0	7.7	0.3	27.0	50.7	5.7	0.9	59.0	23.0	1.7	0.1	8.2	12.8	1.4	0.4	16.2
302	301	4	6	1	2.9545E-07	3.5	42.8	20.0	1.3	14.8	100.0	40.4	1.6	3.5	42.8	20.0	1.3	14.8	100.0	40.4	1.6
302	303	4	2	1	2.9638E-07	25.4	100.0	32.7	1.6	7.3	41.9	18.2	1.2	25.4	100.0	32.7	1.6	7.3	41.9	18.2	1.2
303	302	2	1	1	3.1521E-04	100.0	61.7	0.6	3.2	45.0	28.9	0.2	5.2	22.8	17.0	0.3	0.7	11.5	8.8	0.1	1.1
303	201	3	1	1	3.8269E-05	100.0	93.0	15.4	15.5	54.2	19.8	0.2	7.3	21.5	48.0	22.4	7.1	13.3	12.9	2.6	2.0
303	301	3	1	1	1.8048E-04	100.0	6.4	0.2	24.2	41.0	4.3	1.0	62.7	22.6	1.4	0.1	7.6	10.5	1.0	0.4	17.2
303	302	4	6	1	4.2177E-07	4.8	43.7	15.5	0.6	18.6	100.0	32.4	0.8	4.8	43.7	15.5	0.6	18.6	100.0	32.4	0.8
303	301	4	2	1	2.6359E-07	25.1	100.0	29.9	1.1	6.2	35.8	13.6	0.8	25.1	100.0	29.9	1.1	6.2	35.8	13.6	0.8

20 WORST BUFFETING DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
203	202	1	5	1	5.2534E-01	88.4	15.3	0.0	18.3	100.0	18.3	0.0	15.4	21.4	3.7	0.0	4.5	24.5	4.5	0.0	3.7
201	202	1	1	1	4.7845E-01	100.0	18.4	0.0	13.4	78.4	13.8	0.0	18.1	24.5	4.4	0.0	3.3	19.0	3.4	0.0	4.3
205	206	3	1	1	4.3076E-01	100.0	18.4	0.0	14.5	85.0	15.3	0.0	17.8	24.4	4.4	0.0	3.5	20.6	3.7	0.0	4.3
201	206	3	5	1	4.2364E-01	90.2	15.6	0.0	18.2	100.0	18.2	0.0	15.8	21.9	3.8	0.0	4.5	24.5	4.4	0.0	3.8
205	204	2	5	1	4.0619E-01	93.0	16.0	0.0	18.2	100.0	17.9	0.0	16.6	22.5	3.9	0.0	4.4	24.4	4.4	0.0	4.0
203	204	2	1	1	3.7286E-01	100.0	18.4	0.0	14.1	82.2	14.6	0.0	17.9	24.4	4.4	0.0	3.4	19.9	3.6	0.0	4.3
203	202	4	3	1	3.7802E-02	0.0	18.3	100.0	18.4	0.0	14.6	85.9	15.1	0.0	18.3	100.0	18.4	0.0	14.6	85.9	15.1
201	202	4	3	1	3.6306E-02	0.0	17.9	100.0	18.9	0.0	13.8	83.8	14.9	0.0	17.9	100.0	18.9	0.0	13.8	83.8	14.9
205	206	4	3	1	3.3823E-02	0.0	24.6	100.0	13.2	0.0	20.7	89.0	11.3	0.0	24.6	100.0	13.2	0.0	20.7	89.0	11.3
205	204	4	3	1	3.0651E-02	0.0	25.1	100.0	12.9	0.0	21.9	91.9	11.7	0.0	25.1	100.0	12.9	0.0	21.9	91.9	11.7
201	206	4	3	1	2.8479E-02	0.0	25.7	100.0	12.7	0.0	21.2	87.5	10.6	0.0	25.7	100.0	12.7	0.0	21.2	87.5	10.6
203	204	4	3	1	2.7556E-02	0.0	24.9	100.0	13.1	0.0	20.4	86.8	10.8	0.0	24.9	100.0	13.1	0.0	20.4	86.8	10.8
204	103	2	3	1	3.2979E-03	0.0	7.4	100.0	11.7	0.1	2.2	21.4	1.1	0.0	0.6	4.6	0.9	0.0	0.1	0.2	0.0
204	102	2	7	1	3.0071E-03	0.0	1.4	24.4	2.2	0.1	10.4	100.0	8.1	0.0	0.0	0.2	0.1	0.0	0.7	3.9	0.6
206	103	3	7	1	2.9845E-03	0.0	1.0	21.3	2.3	0.1	12.2	100.0	7.0	0.0	0.0	0.2	0.1	0.0	0.9	4.5	0.6
206	101	3	3	1	2.7240E-03	0.0	8.4	100.0	10.0	0.1	2.0	24.1	1.5	0.0	0.6	3.8	0.7	0.0	0.0	0.2	0.0
202	101	1	7	1	2.1915E-03	0.0	1.3	22.5	2.1	0.1	10.7	100.0	8.0	0.0	0.0	0.2	0.0	0.0	0.8	4.2	0.6
202	102	1	3	1	2.1895E-03	0.0	7.7	100.0	11.0	0.1	2.1	22.5	1.3	0.0	0.6	4.2	0.8	0.0	0.1	0.2	0.0
202	203	4	7	1	5.3469E-04	0.0	14.2	82.3	13.8	0.0	18.6	100.0	18.3	0.0	14.2	82.3	13.8	0.0	18.6	100.0	18.3
202	201	4	7	1	5.3380E-04	0.0	14.0	81.9	13.8	0.0	18.6	100.0	18.3	0.0	14.0	81.9	13.8	0.0	18.6	100.0	18.3

BUFFETING DAMAGE EVALUATED FOR 42 JOINT CONNECTIONS OVER ALL ANALYSIS PLANES

```
************************************************************************

PRINT OF                : WIND FATIGUE RESULTS

RUN NAME                : X505B
RUN DESCRIPTION         : None
RESULTS INTERFACE FILE  : X505BR1.SIN
PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  15:44:58

************************************************************************

RUN SCENARIO:
=============
ANALYSIS CASE               : MULTI BRACE FATIGUE CHECK
FIRST WIND DIRECTION        : 1
LAST  WIND DIRECTION        : 6
FIRST NODE CHECKED          : 101
LAST  NODE CHECKED          : 303
FIRST ANALYSIS PLANE        : 1
LAST  ANALYSIS PLANE        : 4
NUMBER OF EIGENMODES        : 2
SHOW PROGRESS OF EXECUTION : OFF

WIND LOAD MODELLING:
====================
WIND LOAD TYPE              : WIND BUFFETING
WIDE BAND CORRECTION        : NONE
WIND PROFILE                : API (WIND PROFILE TYPE READ FROM SIN FILE)
GUST COMPONENTS CONSIDERED : ALONG WIND COMPONENT ONLY
GUST DIRECTION MOMENT       : DAMAGE BY ADD OF GUST SPECTRUM MOMENTS
WIND SPECTRA :
    LONGITUDINAL DIRECTION : NPD
    LATERAL      DIRECTION : NOT ACTIVE
    VERTICAL     DIRECTION : NOT ACTIVE
COHERENCE FUNCTIONS :
    LONGITUDINAL DIRECTION : NPD
    LATERAL      DIRECTION : NOT APPLICABLE
    VERTICAL     DIRECTION : NOT APPLICABLE

INPUT DATA:
===========

PARAMETERS READ FROM SIN FILE :
(l = current length unit)
```

```
------------------------------

WATER DEPTH - WD  (l)                              : 10.0
Z-COORDINATE OF MUDLINE - ZMUD  (l)                : -10.0
Z-COORDINATE OF STILL WATER LEVEL/GROUND  (l)       : 0.0
                        (Z0 = ZMUD + WD)
WIND DIRECTIONS (RELATIVE TO GLOBAL X-AXIS)        : DIR  ANGLE (deg)
                                                     1    0.0
                                                     2    30.0
                                                     3    60.0
                                                     4    90.0
                                                     5    120.0
                                                     6    150.0
MEAN WIND VELOCITY  (l/sec)                        : 30.0
MEAN WIND VELOCITY LEVEL  (l)                      : 10.0
HEIGHT EXPONENT, API WIND PROFILE                  : .125
GUST FACTOR, API WIND PROFILE                      : 1.0
ACCELERATION OF GRAVITY (g)  (l/sec^2)             : 9.81
UNIT LENGTH ADJUSTMENT FACTOR (9.81/g)             : 1.0

DIRECT INPUT PARAMETERS :
(l = current length unit)
-------------------------

DAMAGE CALCULATION OF BENT CAN JOINTS              : ON
COHERENCE FUNCTION CONSTANT (GUSTO, DAVENPORT)     : 8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz ALONG DIR.   : 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz LATERAL DIR.: 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz VERTICAL DIR: 16.0   16.0   8.0
GROUND ROUGNESS COEFFICIENT                        : 1.5E-02
TURBULENCE LENGTH SCALE DAVENPORT SPECTRUM  (l)    : 1200.0
TURBULENCE LENGTH SCALE HARRIS SPECTRUM  (l)       : 1800.0
DEFAULT SN CURVE                                   : DOE-T
MINIMUM PARAMETRIC SCFS                            : 1.6    1.6    1.6
DEFAULT GLOBAL SCFS                                : 1.6    1.6    1.6
DEFAULT SCF SCHEME, Alt.: EFTHYMIOU, LLOYDS        : EFTHYMIOU
(New default overrules previously assigned SCFs)
DAMPING RATIO                                      : 1.0E-02
CHORD LENGTH/DIAMETER RATIO (L/D)                  : 30.0
ANGULAR TOLERANCE ANALYSIS PLANES (DEG)            : 1.0
LIMIT FOR PRINTING DAMAGE VALUES                   : 1.0E-12
MIN. WIND FORCE USED RELATIVE TO MAX.              : 1.000E-05
LIMIT VALUE ON COHERENCE EFFECT                    : 1.000E+00
(NO COHERENCE = 1.0, FULL COHERENCE = 0 in limit)
```

NUMBER OF WIND SPEEDS : 5

WIND PROBABILITIES AND DRAG CORRECTION COEFFICIENT

DIR NO	WIND SPEED NO	WIND SPEED	WIND PROBABILITY	DRAG COEFF CORRECTION FACTORS
1	1	10.0000	0.3000	1.0000
1	2	15.0000	0.2500	0.9000
1	3	20.0000	0.2000	0.8000
1	4	25.0000	0.1500	0.7500
1	5	30.0000	0.1000	0.7000
2	1	10.0000	0.3500	1.0100
2	2	15.0000	0.2000	0.9100
2	3	20.0000	0.2000	0.8100
2	4	25.0000	0.1500	0.7600
2	5	30.0000	0.1000	0.7100
3	1	10.0000	0.4000	1.0200
3	2	15.0000	0.2000	0.9200
3	3	20.0000	0.1500	0.8200
3	4	25.0000	0.1500	0.7700
3	5	30.0000	0.1000	0.7200
4	1	10.0000	0.2000	1.0300
4	2	15.0000	0.2000	0.9300
4	3	20.0000	0.2000	0.8300
4	4	25.0000	0.2000	0.7800
4	5	30.0000	0.2000	0.7300
5	1	10.0000	0.3000	1.0400
5	2	15.0000	0.2500	0.9400
5	3	20.0000	0.2000	0.8400
5	4	25.0000	0.1500	0.7900
5	5	30.0000	0.1000	0.7400
6	1	10.0000	0.3600	1.0500
6	2	15.0000	0.2200	0.9500
6	3	20.0000	0.2100	0.8500
6	4	25.0000	0.1100	0.8000
6	5	30.0000	0.1000	0.7500

NODES DEFINING THE ANALYSIS PLANES:

1	101	203	301
2	102	205	302
3	103	201	303
4	201	203	205

NUMBER OF COHERENCE MATRICES FOR THE U, V AND W WIND GUST DIRECTIONS : 1
Note! 1,2 or 3 coherence matrices are formed depending on the choice of
wind spectrum and coherence models. Theexecution time increases
with the number of coherence matrices applied in the run.

****

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N	P O S E	I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	5	1	8.8439E-04	93.1	17.0	0.0	17.1	100.0	18.8	0.0	15.9	22.5	4.2	0.0	4.1	24.3	4.5	0.0	3.8
201	206	3	5	1	1.0257E-02	94.2	16.3	0.0	18.1	100.0	17.7	0.0	16.7	22.8	3.9	0.0	4.4	24.3	4.3	0.0	4.0
201	303	3	1	1	2.4112E-06	100.0	41.5	0.1	2.4	45.8	16.1	0.0	9.0	23.8	18.6	0.2	0.2	11.3	8.5	0.0	0.8
201	202	4	7	1	6.8144E-05	0.0	15.3	95.0	18.3	0.0	16.1	100.0	20.2	0.0	15.3	95.0	18.3	0.0	16.1	100.0	20.2
201	206	4	3	1	6.8195E-04	0.0	24.7	100.0	12.8	0.0	22.2	92.7	11.5	0.0	24.7	100.0	12.8	0.0	22.2	92.7	11.5
202	101	1	7	1	2.4713E-05	0.0	1.1	21.8	1.9	0.0	10.3	100.0	7.3	0.0	0.0	0.2	0.0	0.0	0.8	4.1	0.6
202	102	1	3	1	2.4665E-05	0.0	7.4	100.0	10.2	0.0	1.9	21.8	1.1	0.0	0.6	4.1	0.7	0.0	0.0	0.2	0.0
202	201	4	7	1	5.4786E-07	0.1	14.3	83.3	14.2	0.0	18.6	100.0	18.3	0.1	14.3	83.3	14.2	0.0	18.6	100.0	18.3
202	203	4	7	1	5.4928E-07	0.2	14.4	83.1	14.2	0.0	18.7	100.0	18.3	0.2	14.4	83.1	14.2	0.0	18.7	100.0	18.3
203	202	1	1	1	9.7666E-04	100.0	17.4	0.0	16.7	92.3	15.7	0.0	18.9	24.3	4.2	0.0	4.0	22.3	3.8	0.0	4.6
203	301	1	3	2	2.7094E-07	11.2	32.2	26.7	2.4	4.9	1.1	0.3	1.9	2.6	56.0	100.0	9.3	1.2	6.1	14.4	0.7
203	204	2	1	1	9.2569E-03	100.0	18.3	0.0	14.8	86.5	15.4	0.0	17.6	24.3	4.4	0.0	3.6	20.9	3.8	0.0	4.2
203	202	4	7	1	6.9740E-05	0.0	14.8	90.6	17.1	0.0	16.5	100.0	20.4	0.0	14.8	90.6	17.1	0.0	16.5	100.0	20.4
203	204	4	3	1	6.8951E-04	0.0	24.3	100.0	13.2	0.0	21.1	90.1	11.3	0.0	24.3	100.0	13.2	0.0	21.1	90.1	11.3
204	102	2	7	1	7.7795E-07	0.8	3.0	34.4	7.7	1.0	23.1	100.0	4.3	0.1	0.1	0.5	0.2	0.1	1.4	3.5	0.2
204	103	2	3	1	9.0547E-07	0.8	22.1	100.0	6.3	1.5	4.9	24.8	4.8	0.1	1.6	4.4	0.4	0.1	0.2	0.3	0.1
204	203	4	7	1	6.3583E-06	0.0	21.9	89.0	10.5	0.0	25.5	100.0	12.5	0.0	21.9	89.0	10.5	0.0	25.5	100.0	12.5
204	205	4	7	1	6.4002E-06	0.0	18.3	74.3	8.1	0.0	27.0	100.0	12.7	0.0	18.3	74.3	8.1	0.0	27.0	100.0	12.7
205	204	2	5	1	3.0444E-03	73.4	12.6	0.0	18.2	100.0	19.5	0.0	11.8	17.6	3.0	0.0	4.5	24.5	4.8	0.0	2.8
205	302	2	5	1	1.2524E-06	40.2	1.6	0.3	53.5	100.0	6.8	0.0	18.1	10.1	0.1	1.1	30.1	23.4	0.3	0.2	13.1
205	206	3	1	1	3.0599E-03	100.0	18.2	0.0	10.6	61.7	10.2	0.0	19.0	24.4	4.3	0.0	2.7	14.8	2.5	0.0	4.5
205	204	4	3	1	2.3189E-04	0.0	28.9	100.0	12.2	0.0	17.7	69.5	7.1	0.0	28.9	100.0	12.2	0.0	17.7	69.5	7.1
205	206	4	3	1	2.2796E-04	0.0	27.9	100.0	12.6	0.0	17.5	70.7	7.5	0.0	27.9	100.0	12.6	0.0	17.5	70.7	7.5
206	103	3	7	1	8.6651E-07	0.8	4.7	23.9	4.8	1.5	6.2	100.0	22.4	0.1	0.1	0.3	0.2	0.1	0.4	4.5	1.7
206	101	3	3	1	7.4466E-07	0.8	4.3	100.0	22.9	1.0	7.3	33.2	2.8	0.1	0.3	3.5	1.4	0.1	0.2	0.5	0.1
206	205	4	7	1	6.3193E-06	0.0	18.7	76.0	8.3	0.0	26.8	100.0	12.7	0.0	18.7	76.0	8.3	0.0	26.8	100.0	12.7
206	201	4	7	1	6.3042E-06	0.0	22.4	90.6	10.7	0.0	25.5	100.0	12.5	0.0	22.4	90.6	10.7	0.0	25.5	100.0	12.5
301	203	1	3	2	4.2095E-08	4.4	58.1	63.4	7.0	0.2	0.6	1.2	0.2	0.6	51.6	100.0	11.0	0.1	4.5	13.5	0.3

301	302	1	1	1	6.8883E-07	100.0	8.9	0.3	24.5	53.5	6.9	1.0	56.6	23.0	2.0	0.1	7.4	13.4	1.7	0.4	15.5
301	303	3	1	1	5.8040E-08	100.0	42.1	0.2	8.6	88.3	38.8	0.1	10.0	24.0	11.6	0.1	2.0	21.6	10.8	0.1	2.3
301	302	4	2	1	8.9059E-10	22.4	100.0	40.4	3.0	5.2	37.4	22.4	2.3	22.4	100.0	40.4	3.0	5.2	37.4	22.4	2.3
301	303	4	6	1	4.0825E-11	8.9	92.8	57.5	3.1	9.7	100.0	65.1	3.8	8.9	92.8	57.5	3.1	9.7	100.0	65.1	3.8
302	301	1	1	1	1.0363E-06	100.0	59.7	0.7	4.8	47.1	26.4	0.2	6.8	22.9	16.4	0.3	1.1	12.0	8.1	0.1	1.5
302	205	2	1	1	1.6433E-07	100.0	77.3	1.1	0.3	27.6	21.8	0.0	3.7	21.3	36.1	2.0	0.0	7.9	15.0	0.4	0.1
302	303	2	1	1	3.9343E-08	100.0	14.3	0.0	15.8	76.5	11.9	0.5	27.5	23.5	3.4	0.0	4.0	18.8	2.9	0.2	6.9
302	301	4	6	1	1.3261E-09	3.9	40.1	20.1	1.6	16.2	100.0	40.7	2.0	3.9	40.1	20.1	1.6	16.2	100.0	40.7	2.0
302	303	4	3	1	1.9214E-11	37.1	89.2	100.0	8.8	1.4	28.4	79.7	7.5	37.1	89.2	100.0	8.8	1.4	28.4	79.7	7.5
303	302	2	1	1	3.4626E-07	100.0	22.4	0.1	13.3	84.5	17.0	0.0	15.4	23.9	5.6	0.1	3.2	20.7	4.3	0.0	3.6
303	201	3	5	1	3.8852E-08	16.2	0.2	1.1	72.8	100.0	4.5	0.0	12.4	5.0	0.0	1.6	30.0	20.3	0.2	0.1	8.7
303	301	3	1	1	3.7721E-07	100.0	14.8	0.1	20.9	85.8	12.6	0.1	23.9	24.0	3.5	0.0	5.5	21.0	3.0	0.0	6.1
303	302	4	7	1	1.8301E-10	0.8	28.6	86.0	7.8	9.7	50.0	100.0	9.5	0.8	28.6	86.0	7.8	9.7	50.0	100.0	9.5
303	301	4	3	1	1.9815E-10	5.0	54.5	100.0	8.8	4.7	47.9	86.4	6.9	5.0	54.5	100.0	8.8	4.7	47.9	86.4	6.9

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 2, 30.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S D	I E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points -->								| <-- Side 2: Brace side points --> |						
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	5	1	4.1846E-03	98.7	18.0	0.0	17.1	100.0	18.4	0.0	16.9	23.9	4.4	0.0	4.1	24.3	4.5	0.0	4.1
201	206	3	1	1	5.7582E-03	100.0	17.3	0.0	17.4	96.6	16.6	0.0	18.4	24.3	4.2	0.0	4.2	23.4	4.0	0.0	4.5
201	303	3	2	1	7.2029E-07	94.9	100.0	4.0	0.2	12.9	13.4	0.0	3.2	22.0	74.3	13.0	0.0	3.3	17.5	1.5	0.1
201	202	4	7	1	3.2653E-04	0.0	16.1	99.1	19.1	0.0	16.2	100.0	19.5	0.0	16.1	99.1	19.1	0.0	16.2	100.0	19.5
201	206	4	7	1	3.8319E-04	0.0	22.4	95.6	12.4	0.0	23.5	100.0	13.5	0.0	22.4	95.6	12.4	0.0	23.5	100.0	13.5
202	101	1	7	1	1.3464E-05	0.0	0.8	24.0	3.2	0.1	14.4	100.0	4.9	0.0	0.0	0.3	0.1	0.0	1.0	4.0	0.4
202	102	1	3	1	1.3378E-05	0.0	10.5	100.0	7.4	0.1	1.7	23.9	2.0	0.0	0.8	4.0	0.5	0.0	0.1	0.3	0.0
202	201	4	7	1	1.9846E-06	0.0	16.0	92.4	16.3	0.0	17.9	100.0	18.2	0.0	16.0	92.4	16.3	0.0	17.9	100.0	18.2
202	203	4	7	1	2.0334E-06	0.0	12.2	71.9	11.5	0.0	19.5	100.0	18.5	0.0	12.2	71.9	11.5	0.0	19.5	100.0	18.5
203	202	1	5	1	1.0222E-03	83.0	14.2	0.0	18.3	100.0	18.7	0.0	14.2	20.0	3.4	0.0	4.5	24.4	4.6	0.0	3.4
203	301	1	4	2	1.5915E-07	39.1	6.8	19.6	91.0	55.8	3.8	0.1	11.5	9.4	2.5	67.6	100.0	12.9	0.8	7.6	15.7
203	204	2	1	1	9.8906E-03	100.0	18.3	0.0	12.6	74.1	12.8	0.0	18.2	24.4	4.4	0.0	3.1	17.8	3.2	0.0	4.3
203	202	4	3	1	7.3809E-05	0.0	19.4	100.0	18.1	0.0	13.6	79.5	13.7	0.0	19.4	100.0	18.1	0.0	13.6	79.5	13.7
203	204	4	3	1	7.1942E-04	0.0	25.7	100.0	13.0	0.0	19.2	80.5	9.4	0.0	25.7	100.0	13.0	0.0	19.2	80.5	9.4
204	102	2	3	1	2.9899E-08	28.8	27.6	100.0	45.1	36.5	38.2	75.4	22.8	1.6	1.3	2.5	2.1	2.2	1.6	1.5	1.0
204	103	2	7	1	3.0652E-08	16.1	12.0	77.5	41.0	28.4	49.4	100.0	13.7	0.8	0.5	1.7	1.8	1.9	2.5	2.8	0.7
204	203	4	7	1	1.1157E-05	0.0	20.3	82.8	9.5	0.0	26.0	100.0	12.7	0.0	20.3	82.8	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	1.1063E-05	0.0	20.0	81.5	9.2	0.0	26.3	100.0	12.6	0.0	20.0	81.5	9.2	0.0	26.3	100.0	12.6
205	204	2	5	1	9.0104E-03	82.3	14.1	0.0	18.2	100.0	18.6	0.0	13.9	19.8	3.4	0.0	4.4	24.4	4.6	0.0	3.3
205	302	2	1	1	3.4191E-06	100.0	16.3	0.0	19.0	99.3	16.2	0.0	19.1	24.2	3.6	0.0	5.0	24.1	3.6	0.0	5.1
205	206	3	1	1	1.1112E-03	100.0	18.2	0.0	11.9	69.5	12.0	0.0	18.7	24.4	4.3	0.0	2.9	16.8	3.0	0.0	4.4

205	204	4	3	1	6.8217E-04	0.0	26.7	100.0	12.5	0.0	19.6	79.5	8.9	0.0	26.7	100.0	12.5	0.0	19.6	79.5	8.9
205	206	4	3	1	8.3923E-05	0.0	27.0	100.0	12.8	0.0	18.6	77.1	9.0	0.0	27.0	100.0	12.8	0.0	18.6	77.1	9.0
206	103	3	7	1	1.4384E-05	0.0	1.9	21.8	1.5	0.1	7.1	100.0	10.8	0.0	0.0	0.2	0.0	0.0	0.6	4.4	0.8
206	101	3	3	1	1.3087E-05	0.0	5.4	100.0	13.5	0.1	3.2	25.9	1.0	0.0	0.4	3.7	0.9	0.0	0.1	0.3	0.0
206	205	4	7	1	2.3841E-06	0.0	18.1	73.7	8.0	0.0	27.1	100.0	12.8	0.0	18.1	73.7	8.0	0.0	27.1	100.0	12.8
206	201	4	7	1	2.3656E-06	0.0	23.6	94.8	11.5	0.0	25.2	100.0	12.4	0.0	23.6	94.8	11.5	0.0	25.2	100.0	12.4
301	203	1	2	1	8.9072E-08	49.7	100.0	13.7	0.0	1.1	6.0	0.2	0.4	8.8	57.1	20.4	0.1	0.5	9.8	2.2	0.0
301	302	1	1	1	4.5385E-07	100.0	6.2	0.1	18.2	34.0	3.9	0.8	60.2	22.3	1.3	0.1	5.7	8.7	0.9	0.3	16.1
301	303	3	1	1	7.4146E-07	100.0	58.7	0.3	2.8	51.0	33.3	0.1	4.9	23.2	16.1	0.1	0.6	13.0	9.9	0.1	1.0
301	302	4	2	1	6.0090E-10	18.0	100.0	38.9	1.7	2.2	26.0	14.1	1.3	18.0	100.0	38.9	1.7	2.2	26.0	14.1	1.3
301	303	4	6	1	8.4228E-10	4.9	54.8	19.1	0.4	12.6	100.0	36.3	0.6	4.9	54.8	19.1	0.4	12.6	100.0	36.3	0.6
302	301	1	1	1	1.0109E-06	100.0	41.4	0.5	8.7	60.7	18.4	0.1	10.8	23.1	10.9	0.2	2.1	15.1	5.2	0.0	2.5
302	205	2	5	1	1.5155E-07	99.2	22.2	0.0	13.8	100.0	22.4	0.0	13.6	24.1	6.3	0.0	2.8	24.2	6.4	0.0	2.8
302	303	2	1	1	1.3616E-07	100.0	15.8	0.0	17.4	87.8	13.8	0.0	19.7	24.0	3.7	0.0	4.3	21.5	3.3	0.0	4.8
302	301	4	6	1	7.8236E-10	2.4	31.8	42.3	5.0	17.6	100.0	67.7	6.2	2.4	31.8	42.3	5.0	17.6	100.0	67.7	6.2
302	303	4	3	1	6.8844E-11	0.0	31.9	100.0	9.6	0.0	27.4	88.4	7.9	0.0	31.9	100.0	9.6	0.0	27.4	88.4	7.9
303	302	2	1	1	1.2343E-07	100.0	19.5	0.0	14.4	89.2	17.3	0.0	16.0	24.0	4.8	0.0	3.5	21.8	4.3	0.0	3.8
303	201	3	4	1	1.4526E-08	2.6	3.8	61.2	100.0	16.0	0.1	0.5	1.4	0.6	5.4	84.1	69.6	2.3	0.0	7.8	5.2
303	301	3	1	1	8.0977E-07	100.0	12.0	0.2	24.9	72.1	9.7	0.5	39.2	23.6	2.8	0.1	7.1	17.9	2.3	0.2	10.7
303	302	4	7	1	6.6088E-11	0.0	26.8	89.8	8.7	0.0	31.1	100.0	10.0	0.0	26.8	89.8	8.7	0.0	31.1	100.0	10.0
303	301	4	2	1	6.1524E-10	22.8	100.0	65.1	4.8	9.3	56.1	49.1	3.6	22.8	100.0	65.1	4.8	9.3	56.1	49.1	3.6

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 3, 60.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	I S D E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points --> 1	2	3	4	5	6	7	8	<-- Side 2: Brace side points --> 1	2	3	4	5	6	7	8
201	202	1	1	1	9.6087E-03	100.0	18.3	0.0	14.6	85.6	15.2	0.0	17.6	24.3	4.4	0.0	3.6	20.7	3.7	0.0	4.2
201	206	3	1	1	1.2834E-03	100.0	17.4	0.0	17.1	94.9	16.3	0.0	18.7	24.3	4.2	0.0	4.2	23.0	3.9	0.0	4.6
201	303	3	3	2	2.5580E-07	19.3	40.4	28.5	2.9	9.2	1.9	0.3	3.4	4.5	62.9	100.0	8.3	2.3	6.8	13.5	1.1
201	202	4	3	1	7.3618E-04	0.0	17.3	100.0	19.0	0.0	14.6	89.4	16.3	0.0	17.3	100.0	19.0	0.0	14.6	89.4	16.3
201	206	4	7	1	8.6000E-05	0.0	22.0	93.2	12.1	0.0	23.4	100.0	14.1	0.0	22.0	93.2	12.1	0.0	23.4	100.0	14.1
202	101	1	7	1	8.9211E-07	0.5	2.0	28.5	7.6	1.2	26.6	100.0	3.3	0.0	0.1	0.4	0.2	0.2	1.8	3.9	0.2
202	102	1	3	1	8.7956E-07	0.8	20.1	100.0	7.0	1.9	5.4	28.4	5.0	0.1	1.4	3.9	0.4	0.2	0.2	0.4	0.1
202	201	4	7	1	7.0080E-06	0.0	15.2	88.3	15.3	0.0	18.1	100.0	18.2	0.0	15.2	88.3	15.3	0.0	18.1	100.0	18.2
202	203	4	7	1	7.1258E-06	0.0	12.8	75.2	12.2	0.0	19.1	100.0	18.4	0.0	12.8	75.2	12.2	0.0	19.1	100.0	18.4
203	202	1	5	1	3.7133E-03	75.7	12.9	0.0	18.3	100.0	19.2	0.0	12.4	18.2	3.1	0.0	4.5	24.5	4.7	0.0	3.0
203	301	1	5	1	1.2452E-06	42.1	2.1	0.2	49.3	100.0	7.6	0.0	17.1	10.5	0.2	0.7	25.4	23.6	0.5	0.1	10.9
203	204	2	1	1	3.5471E-03	100.0	18.3	0.0	10.8	63.5	10.6	0.0	18.7	24.5	4.3	0.0	2.7	15.2	2.6	0.0	4.4
203	202	4	3	1	2.7024E-04	0.0	20.1	100.0	17.9	0.0	12.3	71.1	11.2	0.0	20.1	100.0	17.9	0.0	12.3	71.1	11.2
203	204	4	3	1	2.5182E-04	0.0	27.2	100.0	12.9	0.0	17.5	71.9	7.9	0.0	27.2	100.0	12.9	0.0	17.5	71.9	7.9

204	102	2	7	1	8.7773E-07	0.7	3.8	26.5	6.1	2.2	8.3	100.0	17.6	0.1	0.1	0.4	0.3	0.2	0.5	3.8	1.2
204	103	2	3	1	8.7395E-07	0.4	2.7	100.0	30.2	1.6	9.7	31.5	1.8	0.0	0.2	4.1	2.0	0.2	0.3	0.5	0.1
204	203	4	7	1	6.8324E-06	0.0	18.7	76.5	8.5	0.0	26.5	100.0	12.8	0.0	18.7	76.5	8.5	0.0	26.5	100.0	12.8
204	205	4	7	1	6.6658E-06	0.0	22.2	90.1	10.7	0.0	25.4	100.0	12.5	0.0	22.2	90.1	10.7	0.0	25.4	100.0	12.5
205	204	2	5	1	9.7270E-03	93.7	16.1	0.0	18.2	100.0	17.7	0.0	16.7	22.7	3.9	0.0	4.4	24.3	4.3	0.0	4.0
205	302	2	1	1	2.5683E-06	100.0	41.9	0.1	2.2	43.3	15.2	0.0	9.1	23.5	19.5	0.3	0.1	10.9	8.8	0.0	0.7
205	206	3	5	1	1.1749E-03	95.8	17.6	0.0	16.9	100.0	18.9	0.0	16.3	23.2	4.3	0.0	4.0	24.3	4.6	0.0	3.9
205	204	4	3	1	7.3143E-04	0.0	24.6	100.0	12.9	0.0	22.0	92.7	11.6	0.0	24.6	100.0	12.9	0.0	22.0	92.7	11.6
205	206	4	7	1	9.3717E-05	0.0	22.1	96.8	13.2	0.0	22.4	100.0	14.3	0.0	22.1	96.8	13.2	0.0	22.4	100.0	14.3
206	103	3	7	1	3.0452E-05	0.0	1.0	20.0	1.8	0.0	10.3	100.0	7.2	0.0	0.0	0.2	0.0	0.0	0.8	4.5	0.6
206	101	3	3	1	2.7328E-05	0.0	7.5	100.0	10.1	0.0	2.1	23.7	1.3	0.0	0.5	3.8	0.7	0.0	0.1	0.2	0.0
206	205	4	7	1	7.8035E-07	0.1	20.6	83.9	9.8	0.0	26.1	100.0	12.7	0.1	20.6	83.9	9.8	0.0	26.1	100.0	12.7
206	201	4	7	1	7.9235E-07	0.2	20.4	82.6	9.5	0.0	26.3	100.0	12.7	0.2	20.4	82.6	9.5	0.0	26.3	100.0	12.7
301	203	1	1	1	1.5999E-07	100.0	68.6	0.7	0.4	26.8	18.6	0.0	4.5	21.2	29.4	1.2	0.0	7.7	11.7	0.2	0.2
301	302	1	1	1	5.2403E-08	100.0	14.0	0.0	15.8	75.9	11.9	0.6	29.4	23.5	3.3	0.0	4.1	18.6	2.9	0.2	7.4
301	303	3	1	1	1.2054E-06	100.0	58.7	0.7	4.6	46.4	25.9	0.2	6.7	22.9	16.0	0.3	1.1	11.8	7.9	0.1	1.5
301	302	4	3	1	2.7596E-11	30.4	91.4	100.0	12.5	1.3	22.7	77.3	10.3	30.4	91.4	100.0	12.5	1.3	22.7	77.3	10.3
301	303	4	6	1	1.4978E-09	5.5	40.5	17.1	0.9	21.2	100.0	33.8	1.3	5.5	40.5	17.1	0.9	21.2	100.0	33.8	1.3
302	301	1	1	1	4.0084E-07	100.0	22.0	0.1	13.9	85.5	16.8	0.0	15.7	23.9	5.4	0.0	3.3	20.9	4.2	0.0	3.7
302	205	2	5	1	6.2518E-08	19.7	0.2	0.9	69.2	100.0	5.0	0.0	13.3	5.9	0.0	1.4	29.4	20.7	0.2	0.1	9.3
302	303	2	1	1	5.0117E-07	100.0	14.9	0.0	21.1	86.2	12.7	0.1	24.0	24.0	3.5	0.0	5.5	21.1	3.1	0.0	6.1
302	301	4	7	1	2.1280E-10	0.3	20.2	86.4	12.4	5.8	39.5	100.0	14.5	0.3	20.2	86.4	12.4	5.8	39.5	100.0	14.5
302	303	4	3	1	2.4920E-10	4.2	54.9	100.0	9.1	3.9	48.5	86.8	7.2	4.2	54.9	100.0	9.1	3.9	48.5	86.8	7.2
303	302	2	1	1	8.2827E-08	100.0	40.7	0.1	8.1	87.7	37.3	0.1	9.6	24.0	11.2	0.1	1.9	21.4	10.4	0.0	2.2
303	201	3	3	2	3.8925E-08	6.9	71.1	67.7	6.7	0.3	0.7	1.1	0.3	1.0	57.7	100.0	10.0	0.1	4.8	12.5	0.2
303	301	3	1	1	7.4678E-07	100.0	8.2	0.3	25.0	50.4	6.1	1.0	58.8	22.9	1.8	0.1	7.7	12.7	1.5	0.5	16.2
303	302	4	6	1	5.5909E-11	6.6	92.5	62.8	2.9	7.2	100.0	71.7	3.8	6.6	92.5	62.8	2.9	7.2	100.0	71.7	3.8
303	301	4	2	1	1.0296E-09	28.4	100.0	32.8	1.7	7.2	38.0	18.3	1.2	28.4	100.0	32.8	1.7	7.2	38.0	18.3	1.2

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 4, 90.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S D		<==RELATIVE DAMAGES AROUND THE WELD ====>														
					| <-- Side 1: Chord side points --> | <-- Side 2: Brace side points --> |														
				DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	2.0881E-02	100.0	18.3	0.0	12.3	72.6	12.5	0.0	18.2	24.4	4.4	0.0	3.1	17.5	3.1	0.0	4.3
201	206	3	5	1	2.2404E-03	81.5	14.0	0.0	18.2	100.0	18.9	0.0	13.8	19.6	3.4	0.0	4.5	24.5	4.7	0.0	3.3
201	303	3	4	2	2.8728E-07	71.9	12.3	22.6	92.5	72.9	6.8	0.1	18.4	17.2	4.2	74.4	100.0	17.3	1.4	8.2	16.6
201	202	4	3	1	1.5647E-03	0.0	18.3	100.0	18.8	0.0	13.2	79.4	13.6	0.0	18.3	100.0	18.8	0.0	13.2	79.4	13.6
201	206	4	3	1	1.5175E-04	0.0	27.7	100.0	12.5	0.0	18.9	76.9	8.8	0.0	27.7	100.0	12.5	0.0	18.9	76.9	8.8
202	101	1	3	1	4.8429E-08	30.4	24.5	100.0	52.6	42.9	45.7	78.1	20.8	1.6	1.2	2.6	2.5	2.6	2.0	1.6	0.9
202	102	1	7	1	4.8235E-08	29.3	19.1	78.1	48.7	44.4	57.2	100.0	21.9	1.5	0.8	1.6	2.1	2.8	2.8	2.6	1.0

202	201	4	7	1	2.5136E-05	0.0	14.0	82.2	13.9	0.0	18.5	100.0	18.3	0.0	14.0	82.2	13.9	0.0	18.5	100.0	18.3
202	203	4	7	1	2.5192E-05	0.0	14.0	81.9	13.7	0.0	18.6	100.0	18.2	0.0	14.0	81.9	13.7	0.0	18.6	100.0	18.2
203	202	1	5	1	2.1713E-02	83.0	14.2	0.0	18.2	100.0	18.5	0.0	14.0	20.0	3.4	0.0	4.5	24.4	4.5	0.0	3.4
203	301	1	1	1	7.2772E-06	100.0	18.1	0.0	17.0	98.6	17.7	0.0	17.4	24.2	4.5	0.0	4.0	23.9	4.4	0.0	4.1
203	204	2	1	1	2.0943E-03	100.0	18.3	0.0	11.9	69.7	12.0	0.0	18.6	24.5	4.3	0.0	2.9	16.8	3.0	0.0	4.4
203	202	4	3	1	1.5633E-03	0.0	18.9	100.0	18.2	0.0	13.6	79.5	13.2	0.0	18.9	100.0	18.2	0.0	13.6	79.5	13.2
203	204	4	3	1	1.5002E-04	0.0	26.7	100.0	12.9	0.0	18.4	77.0	9.0	0.0	26.7	100.0	12.9	0.0	18.4	77.0	9.0
204	102	2	7	1	2.8228E-05	0.0	1.9	24.5	2.0	0.1	8.1	100.0	9.8	0.0	0.0	0.3	0.1	0.0	0.5	3.8	0.7
204	103	2	3	1	3.0719E-05	0.0	4.5	100.0	15.3	0.2	3.3	22.9	0.7	0.0	0.4	4.4	1.1	0.0	0.1	0.3	0.0
204	203	4	7	1	4.6163E-06	0.0	17.8	73.1	8.0	0.0	26.9	100.0	13.0	0.0	17.8	73.1	8.0	0.0	26.9	100.0	13.0
204	205	4	7	1	4.4649E-06	0.0	23.7	96.1	11.8	0.0	24.9	100.0	12.5	0.0	23.7	96.1	11.8	0.0	24.9	100.0	12.5
205	204	2	1	1	1.0848E-02	100.0	17.2	0.0	17.2	94.7	16.0	0.0	18.7	24.3	4.2	0.0	4.2	22.9	3.8	0.0	4.6
205	302	2	2	1	1.6388E-06	89.4	100.0	4.6	0.1	10.1	11.8	0.0	2.8	20.2	81.8	17.3	0.0	2.7	19.3	2.1	0.0
205	206	3	5	1	9.8911E-03	98.0	18.0	0.0	16.9	100.0	18.6	0.0	16.6	23.7	4.4	0.0	4.1	24.3	4.5	0.0	4.0
205	204	4	7	1	8.1958E-04	0.0	21.4	93.7	12.5	0.0	23.0	100.0	14.0	0.0	21.4	93.7	12.5	0.0	23.0	100.0	14.0
205	206	4	7	1	7.9405E-04	0.0	22.4	98.5	13.4	0.0	22.6	100.0	13.9	0.0	22.4	98.5	13.4	0.0	22.6	100.0	13.9
206	103	3	7	1	3.1160E-05	0.0	0.7	23.0	3.4	0.2	15.6	100.0	4.4	0.0	0.0	0.3	0.1	0.0	1.1	4.4	0.4
206	101	3	3	1	2.8682E-05	0.0	9.9	100.0	8.0	0.1	2.0	24.7	1.9	0.0	0.7	3.8	0.5	0.0	0.1	0.3	0.0
206	205	4	7	1	4.5316E-06	0.0	22.9	93.6	11.4	0.0	25.0	100.0	12.6	0.0	22.9	93.6	11.4	0.0	25.0	100.0	12.6
206	201	4	7	1	4.7042E-06	0.0	17.3	71.1	7.6	0.0	27.2	100.0	13.0	0.0	17.3	71.1	7.6	0.0	27.2	100.0	13.0
301	203	1	5	1	2.8994E-07	97.8	18.3	0.0	16.7	100.0	18.9	0.0	16.2	23.8	4.6	0.0	3.9	24.2	4.8	0.0	3.8
301	302	1	1	1	2.7353E-07	100.0	15.9	0.0	17.6	89.4	14.2	0.0	19.6	24.0	3.8	0.0	4.3	21.8	3.4	0.0	4.8
301	303	3	1	1	2.3876E-06	100.0	41.5	0.5	8.5	60.1	18.6	0.1	10.7	23.2	10.9	0.2	2.0	14.9	5.3	0.0	2.5
301	302	4	3	1	1.4564E-10	0.0	22.5	100.0	14.3	0.0	19.6	90.0	12.3	0.0	22.5	100.0	14.3	0.0	19.6	90.0	12.3
301	303	4	6	1	1.8773E-09	3.6	34.1	37.9	3.0	22.6	100.0	57.9	3.8	3.6	34.1	37.9	3.0	22.6	100.0	57.9	3.8
302	301	1	1	1	2.5348E-07	100.0	18.8	0.0	15.2	91.2	17.1	0.0	16.6	24.1	4.6	0.0	3.7	22.2	4.2	0.0	4.0
302	205	2	4	1	5.2172E-08	0.9	1.4	48.3	100.0	18.6	0.0	0.5	1.9	0.2	3.2	76.1	74.2	2.8	0.0	8.1	7.7
302	303	2	1	1	2.1696E-06	100.0	12.1	0.1	24.1	71.9	9.8	0.4	37.8	23.7	2.8	0.1	6.8	17.8	2.4	0.2	10.1
302	301	4	7	1	1.3503E-10	0.0	18.2	91.7	14.1	0.0	20.7	100.0	15.9	0.0	18.2	91.7	14.1	0.0	20.7	100.0	15.9
302	303	4	2	1	1.4636E-09	20.3	100.0	69.6	5.3	8.2	56.5	52.2	4.0	20.3	100.0	69.6	5.3	8.2	56.5	52.2	4.0
303	302	2	1	1	1.6922E-06	100.0	57.0	0.3	2.7	51.0	32.4	0.1	5.0	23.2	15.7	0.1	0.6	13.0	9.7	0.1	1.0
303	201	3	2	1	1.9134E-07	48.6	100.0	14.1	0.0	1.0	5.8	0.2	0.4	8.6	56.0	20.3	0.1	0.4	9.4	2.3	0.0
303	301	3	1	1	9.7821E-07	100.0	5.6	0.1	17.4	30.3	3.1	0.7	59.4	22.1	1.1	0.1	5.5	7.9	0.7	0.3	15.9
303	302	4	6	1	1.9094E-09	4.3	54.8	20.4	0.4	11.4	100.0	38.9	0.6	4.3	54.8	20.4	0.4	11.4	100.0	38.9	0.6
303	301	4	2	1	1.2936E-09	21.3	100.0	32.6	0.9	2.8	26.1	11.2	0.6	21.3	100.0	32.6	0.9	2.8	26.1	11.2	0.6

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 5, 120.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N	N	P	P	S																
O	O	L	O	I									<==RELATIVE DAMAGES AROUND THE WELD ====>							
D	D	A	S	D		<-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->						
E	E	N	N	E																
1	2	E		DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8

201	202	1	1	1	4.3906E-03	100.0	18.4	0.0	10.8	63.4	10.6	0.0	18.7	24.5	4.3	0.0	2.7	15.2	2.7	0.0	4.4
201	206	3	5	1	4.0970E-03	76.2	13.1	0.0	18.2	100.0	19.2	0.0	12.5	18.3	3.1	0.0	4.5	24.5	4.8	0.0	3.0
201	303	3	5	1	1.5373E-06	44.3	2.2	0.2	52.6	100.0	6.9	0.0	19.3	11.0	0.3	0.9	28.1	23.7	0.4	0.1	12.4
201	202	4	3	1	3.2277E-04	0.0	19.3	100.0	18.6	0.0	12.1	72.0	11.8	0.0	19.3	100.0	18.6	0.0	12.1	72.0	11.8
201	206	4	3	1	2.7898E-04	0.0	28.3	100.0	12.4	0.0	17.7	70.5	7.4	0.0	28.3	100.0	12.4	0.0	17.7	70.5	7.4
202	101	1	7	1	9.9941E-07	0.8	5.0	27.3	4.9	1.8	6.7	100.0	20.3	0.1	0.1	0.4	0.2	0.1	0.4	4.0	1.4
202	102	1	3	1	1.0116E-06	0.5	3.3	100.0	26.3	1.2	7.4	27.4	1.8	0.0	0.2	4.0	1.7	0.2	0.2	0.4	0.1
202	201	4	7	1	8.4731E-06	0.0	13.1	76.8	12.6	0.0	18.9	100.0	18.4	0.0	13.1	76.8	12.6	0.0	18.9	100.0	18.4
202	203	4	7	1	8.3749E-06	0.0	15.4	89.1	15.4	0.0	18.1	100.0	18.1	0.0	15.4	89.1	15.4	0.0	18.1	100.0	18.1
203	202	1	5	1	1.2133E-02	92.5	15.9	0.0	18.2	100.0	17.8	0.0	16.3	22.4	3.8	0.0	4.4	24.3	4.3	0.0	3.9
203	301	1	1	1	3.3662E-06	100.0	44.5	0.1	2.1	45.1	17.2	0.0	8.3	23.6	21.4	0.3	0.1	11.2	10.0	0.0	0.6
203	204	2	5	1	1.1705E-03	97.1	17.8	0.0	17.1	100.0	18.7	0.0	16.7	23.6	4.3	0.0	4.1	24.3	4.5	0.0	4.0
203	202	4	3	1	8.6302E-04	0.0	17.6	100.0	18.5	0.0	15.3	90.9	16.3	0.0	17.6	100.0	18.5	0.0	15.3	90.9	16.3
203	204	4	7	1	8.8357E-05	0.0	22.8	97.8	13.0	0.0	22.9	100.0	13.9	0.0	22.8	97.8	13.0	0.0	22.9	100.0	13.9
204	102	2	7	1	3.2132E-05	0.0	1.3	24.0	2.1	0.1	10.2	100.0	7.4	0.0	0.0	0.3	0.1	0.0	0.7	3.8	0.5
204	103	2	3	1	3.5766E-05	0.0	7.3	100.0	10.2	0.0	1.8	20.3	1.0	0.0	0.6	4.5	0.8	0.0	0.0	0.2	0.0
204	203	4	7	1	8.6165E-07	0.1	20.1	82.1	9.4	0.0	26.2	100.0	12.7	0.1	20.1	82.1	9.4	0.0	26.2	100.0	12.7
204	205	4	7	1	8.5096E-07	0.1	20.9	84.9	10.0	0.0	26.1	100.0	12.6	0.1	20.9	84.9	10.0	0.0	26.1	100.0	12.6
205	204	2	1	1	1.5033E-03	100.0	17.2	0.0	16.8	92.3	15.6	0.0	19.1	24.3	4.2	0.0	4.1	22.3	3.7	0.0	4.7
205	302	2	3	2	4.4835E-07	6.5	26.3	24.5	2.1	2.3	0.6	0.2	1.1	1.5	51.2	100.0	10.2	0.6	5.5	15.1	0.6
205	206	3	1	1	1.0806E-02	100.0	18.3	0.0	14.8	87.2	15.6	0.0	17.5	24.3	4.4	0.0	3.6	21.1	3.8	0.0	4.2
205	204	4	7	1	1.1425E-04	0.0	20.7	90.7	12.1	0.0	22.7	100.0	14.8	0.0	20.7	90.7	12.1	0.0	22.7	100.0	14.8
205	206	4	3	1	8.5115E-04	0.0	24.1	100.0	13.3	0.0	21.1	90.7	11.5	0.0	24.1	100.0	13.3	0.0	21.1	90.7	11.5
206	103	3	7	1	1.0705E-06	0.3	1.8	32.4	10.0	1.6	30.4	100.0	2.7	0.0	0.1	0.5	0.3	0.2	2.0	4.0	0.2
206	101	3	3	1	1.0743E-06	0.7	17.4	100.0	8.3	2.2	6.2	27.3	3.9	0.1	1.2	3.8	0.5	0.2	0.3	0.4	0.1
206	205	4	7	1	7.5581E-06	0.0	21.8	89.1	10.6	0.0	25.4	100.0	12.6	0.0	21.8	89.1	10.6	0.0	25.4	100.0	12.6
206	201	4	7	1	7.7820E-06	0.0	18.3	74.7	8.2	0.0	26.8	100.0	12.8	0.0	18.3	74.7	8.2	0.0	26.8	100.0	12.8
301	203	1	5	1	7.2237E-08	18.9	0.1	1.4	79.3	100.0	3.8	0.0	16.0	5.7	0.0	2.2	35.2	20.6	0.1	0.3	11.6
301	302	1	1	1	4.7527E-07	100.0	15.1	0.1	20.9	88.0	13.3	0.1	23.4	24.0	3.6	0.0	5.4	21.5	3.2	0.0	6.0
301	303	3	1	1	5.2672E-07	100.0	22.7	0.1	13.5	84.5	17.0	0.0	15.4	23.9	5.6	0.0	3.3	20.7	4.3	0.0	3.6
301	302	4	3	1	2.5294E-10	2.8	42.4	100.0	13.5	2.6	38.0	88.7	11.3	2.8	42.4	100.0	13.5	2.6	38.0	88.7	11.3
301	303	4	7	1	2.6315E-10	0.7	28.9	86.2	8.0	8.8	52.1	100.0	9.6	0.7	28.9	86.2	8.0	8.8	52.1	100.0	9.6
302	301	1	1	1	8.4530E-08	100.0	43.9	0.2	8.9	89.1	40.7	0.2	10.2	24.0	12.2	0.1	2.1	21.8	11.4	0.1	2.4
302	205	2	3	2	7.2197E-08	2.9	48.3	58.7	7.0	0.1	0.4	1.1	0.1	0.4	47.1	100.0	11.7	0.0	4.4	14.3	0.4
302	303	2	1	1	1.0153E-06	100.0	8.8	0.2	24.0	52.2	6.6	0.9	55.6	23.0	2.0	0.1	7.2	13.1	1.6	0.4	15.2
302	301	4	6	1	6.1993E-11	7.4	93.5	65.1	5.1	8.1	100.0	72.6	6.2	7.4	93.5	65.1	5.1	8.1	100.0	72.6	6.2
302	303	4	2	1	1.2452E-09	28.2	100.0	35.4	2.0	7.1	38.1	20.4	1.4	28.2	100.0	35.4	2.0	7.1	38.1	20.4	1.4
303	302	2	1	1	1.3328E-06	100.0	60.3	0.7	4.2	44.3	26.1	0.2	6.3	22.8	16.6	0.3	1.0	11.3	8.0	0.1	1.4
303	201	3	1	1	1.8459E-07	100.0	77.1	1.1	0.2	25.8	21.2	0.0	3.6	21.2	34.3	1.8	0.0	7.4	13.9	0.3	0.1
303	301	3	1	1	5.5895E-08	100.0	13.3	0.0	15.4	71.1	10.8	0.5	30.2	23.3	3.1	0.0	4.0	17.5	2.6	0.2	7.6
303	302	4	6	1	1.7865E-09	5.4	40.1	15.9	0.8	20.9	100.0	32.8	1.1	5.4	40.1	15.9	0.8	20.9	100.0	32.8	1.1
303	301	4	2	1	2.9031E-11	31.8	100.0	97.5	7.8	1.2	29.1	73.2	6.1	31.8	100.0	97.5	7.8	1.2	29.1	73.2	6.1

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 6, 150.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O I D E	DAMAGE	<-- Side 1: Chord side points --> 1	2	3	4	5	6	7	8	<-- Side 2: Brace side points --> 1	2	3	4	5	6	7	8
201	202	1	1 1	1.3409E-03	100.0	18.3	0.0	12.3	72.2	12.6	0.0	18.4	24.4	4.3	0.0	3.0	17.4	3.1	0.0	4.4
201	206	3	5 1	1.2998E-02	84.8	14.6	0.0	18.2	100.0	18.4	0.0	14.4	20.4	3.5	0.0	4.4	24.4	4.5	0.0	3.5
201	303	3	1 1	4.1905E-06	100.0	16.6	0.0	18.6	98.6	16.2	0.0	19.0	24.2	3.7	0.0	4.8	23.9	3.7	0.0	4.9
201	202	4	3 1	9.9857E-05	0.0	18.7	100.0	18.7	0.0	13.1	79.0	13.8	0.0	18.7	100.0	18.7	0.0	13.1	79.0	13.8
201	206	4	3 1	8.7441E-04	0.0	26.4	100.0	12.6	0.0	19.8	80.9	9.2	0.0	26.4	100.0	12.6	0.0	19.8	80.9	9.2
202	101	1	7 1	1.6456E-05	0.0	1.9	23.6	1.7	0.1	7.4	100.0	10.5	0.0	0.0	0.3	0.1	0.0	0.5	4.1	0.8
202	102	1	3 1	1.6536E-05	0.0	5.0	100.0	14.2	0.1	3.1	23.6	0.8	0.0	0.4	4.1	1.0	0.0	0.1	0.3	0.0
202	201	4	7 1	2.6991E-06	0.0	12.6	74.1	12.0	0.0	19.2	100.0	18.5	0.0	12.6	74.1	12.0	0.0	19.2	100.0	18.5
202	203	4	7 1	2.6497E-06	0.0	16.4	93.8	16.6	0.0	17.8	100.0	18.1	0.0	16.4	93.8	16.6	0.0	17.8	100.0	18.1
203	202	1	1 1	6.1037E-03	100.0	17.3	0.0	17.4	96.6	16.6	0.0	18.4	24.3	4.2	0.0	4.2	23.4	4.0	0.0	4.5
203	301	1	2 1	8.8181E-07	88.6	100.0	4.6	0.1	10.8	12.4	0.0	2.7	20.2	79.2	16.2	0.0	2.9	18.7	2.0	0.1
203	204	2	1 1	5.9059E-03	100.0	18.3	0.0	17.0	99.8	18.3	0.0	17.2	24.2	4.5	0.0	4.1	24.2	4.5	0.0	4.1
203	202	4	7 1	4.3251E-04	0.0	15.8	95.8	18.0	0.0	16.6	100.0	19.4	0.0	15.8	95.8	18.0	0.0	16.6	100.0	19.4
203	204	4	3 1	4.4903E-04	0.0	23.2	100.0	13.3	0.0	23.0	99.9	13.4	0.0	23.2	100.0	13.3	0.0	23.0	99.9	13.4
204	102	2	7 1	1.6692E-05	0.0	1.0	26.3	3.3	0.1	13.6	100.0	5.3	0.0	0.0	0.3	0.1	0.0	0.9	3.7	0.4
204	103	2	3 1	1.8370E-05	0.0	10.8	100.0	7.0	0.1	1.5	22.2	1.9	0.0	0.8	4.4	0.6	0.0	0.0	0.2	0.0
204	203	4	7 1	2.9093E-06	0.0	22.8	92.2	11.1	0.0	25.3	100.0	12.5	0.0	22.8	92.2	11.1	0.0	25.3	100.0	12.5
204	205	4	7 1	2.9439E-06	0.0	17.7	71.8	7.7	0.0	27.4	100.0	12.8	0.0	17.7	71.8	7.7	0.0	27.4	100.0	12.8
205	204	2	5 1	1.4172E-03	81.0	13.9	0.0	18.2	100.0	19.0	0.0	13.7	19.5	3.3	0.0	4.5	24.4	4.7	0.0	3.3
205	302	2	4 2	2.4622E-07	23.7	4.0	18.8	84.8	42.6	2.0	0.1	8.3	5.7	2.0	70.6	100.0	9.6	0.4	8.5	15.6
205	206	3	1 1	1.1182E-02	100.0	18.3	0.0	12.4	72.9	12.5	0.0	18.3	24.4	4.3	0.0	3.1	17.6	3.1	0.0	4.3
205	204	4	3 1	1.0751E-04	0.0	27.7	100.0	12.4	0.0	19.3	78.1	9.1	0.0	27.7	100.0	12.4	0.0	19.3	78.1	9.1
205	206	4	3 1	8.5581E-04	0.0	26.0	100.0	12.9	0.0	19.1	79.7	9.2	0.0	26.0	100.0	12.9	0.0	19.1	79.7	9.2
206	103	3	3 1	3.9237E-08	16.3	15.3	100.0	44.8	26.6	37.6	77.6	13.0	0.8	0.8	2.8	2.2	1.8	1.7	1.7	0.6
206	101	3	7 1	3.7956E-08	26.7	20.2	75.6	41.3	37.5	49.5	100.0	23.9	1.4	0.9	1.5	1.7	2.3	2.3	2.5	1.1
206	205	4	7 1	1.3607E-05	0.0	20.1	82.1	9.4	0.0	26.1	100.0	12.6	0.0	20.1	82.1	9.4	0.0	26.1	100.0	12.6
206	201	4	7 1	1.3781E-05	0.0	20.3	82.5	9.4	0.0	26.1	100.0	12.6	0.0	20.3	82.5	9.4	0.0	26.1	100.0	12.6
301	203	1	4 1	2.3833E-08	1.4	2.4	55.8	100.0	16.5	0.1	0.6	1.6	0.3	4.4	82.5	72.7	2.4	0.0	8.7	6.7
301	302	1	1 1	1.0352E-06	100.0	12.5	0.2	24.0	74.0	10.4	0.4	37.3	23.7	2.9	0.1	6.7	18.3	2.5	0.2	10.0
301	303	3	1 1	1.5716E-07	100.0	19.1	0.0	14.9	90.4	17.3	0.0	16.4	24.1	4.7	0.0	3.6	22.1	4.3	0.0	3.9
301	302	4	2 1	6.7834E-10	16.8	100.0	80.7	8.8	6.2	54.7	60.8	7.0	16.8	100.0	80.7	8.8	6.2	54.7	60.8	7.0
301	303	4	7 1	7.9930E-11	0.0	26.3	91.0	9.2	0.0	30.0	100.0	10.4	0.0	26.3	91.0	9.2	0.0	30.0	100.0	10.4
302	301	1	1 1	9.2926E-07	100.0	60.6	0.4	3.0	52.1	34.7	0.2	5.0	23.2	16.7	0.2	0.7	13.2	10.4	0.1	1.0
302	205	2	2 1	1.2463E-07	44.8	100.0	15.5	0.0	1.0	6.1	0.2	0.3	7.9	61.5	25.1	0.1	0.4	11.0	3.0	0.0
302	303	2	1 1	5.4881E-07	100.0	6.2	0.1	17.0	32.9	3.8	0.8	58.3	22.2	1.3	0.1	5.3	8.5	0.9	0.3	15.5
302	301	4	6 1	1.0882E-09	3.5	55.0	24.2	0.8	9.6	100.0	44.8	1.1	3.5	55.0	24.2	0.8	9.6	100.0	44.8	1.1
302	303	4	2 1	6.8980E-10	23.3	100.0	32.8	1.1	3.0	25.4	12.3	0.8	23.3	100.0	32.8	1.1	3.0	25.4	12.3	0.8

303	302	2	1	1	1.1730E-06	100.0	42.5	0.5	8.4	59.5	18.5	0.1	10.6	23.1	11.3	0.2	2.0	14.8	5.3	0.1	2.4
303	201	3	5	1	1.3632E-07	97.8	21.9	0.0	13.8	100.0	22.5	0.0	13.4	23.8	6.2	0.0	2.8	24.2	6.3	0.0	2.7
303	301	3	1	1	1.6717E-07	100.0	15.4	0.0	17.6	86.7	13.3	0.0	20.2	24.0	3.6	0.0	4.4	21.2	3.2	0.0	4.9
303	302	4	6	1	1.0087E-09	3.8	33.1	36.2	2.8	24.4	100.0	55.9	3.6	3.8	33.1	36.2	2.8	24.4	100.0	55.9	3.6
303	301	4	3	1	8.8926E-11	0.0	33.4	100.0	9.1	0.0	28.3	87.4	7.3	0.0	33.4	100.0	9.1	0.0	28.3	87.4	7.3

BUFFETING DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points -->								| <-- Side 2: Brace side points --> |						
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	4.1173E-02	100.0	18.3	0.0	13.3	78.2	13.7	0.0	18.0	24.4	4.4	0.0	3.3	18.9	3.4	0.0	4.3
201	206	3	5	1	3.6373E-02	89.8	15.5	0.0	18.1	100.0	18.1	0.0	15.7	21.7	3.7	0.0	4.4	24.4	4.4	0.0	3.8
201	303	3	1	1	8.2223E-06	100.0	31.5	2.1	23.3	86.3	15.8	0.0	16.9	24.0	16.0	7.1	11.5	20.9	6.3	0.9	5.7
201	202	4	3	1	3.1117E-03	0.0	17.9	100.0	18.9	0.0	13.8	83.8	14.8	0.0	17.9	100.0	18.9	0.0	13.8	83.8	14.8
201	206	4	3	1	2.4335E-03	0.0	25.7	100.0	12.7	0.0	21.1	87.2	10.5	0.0	25.7	100.0	12.7	0.0	21.1	87.2	10.5
202	101	1	7	1	5.6563E-05	0.1	1.4	23.1	2.3	0.2	10.6	100.0	7.8	0.0	0.0	0.3	0.1	0.0	0.8	4.1	0.6
202	102	1	3	1	5.6508E-05	0.1	7.6	100.0	11.0	0.2	2.4	23.1	1.3	0.0	0.6	4.1	0.8	0.0	0.1	0.3	0.0
202	201	4	7	1	4.5848E-05	0.0	14.0	82.1	13.9	0.0	18.6	100.0	18.3	0.0	14.0	82.1	13.9	0.0	18.6	100.0	18.3
202	203	4	7	1	4.5925E-05	0.0	14.2	82.4	13.9	0.0	18.6	100.0	18.2	0.0	14.2	82.4	13.9	0.0	18.6	100.0	18.2
203	202	1	5	1	4.5376E-02	88.1	15.1	0.0	18.2	100.0	18.2	0.0	15.3	21.3	3.6	0.0	4.4	24.4	4.4	0.0	3.7
203	301	1	1	1	1.2041E-05	100.0	31.7	1.2	17.2	84.1	17.3	0.0	15.0	24.0	15.8	4.5	6.6	20.4	7.0	0.6	4.0
203	204	2	1	1	3.1831E-02	100.0	18.3	0.0	14.0	82.0	14.5	0.0	17.9	24.4	4.4	0.0	3.4	19.8	3.6	0.0	4.3
203	202	4	3	1	3.2477E-03	0.0	18.3	100.0	18.4	0.0	14.5	85.6	15.0	0.0	18.3	100.0	18.4	0.0	14.5	85.6	15.0
203	204	4	3	1	2.3462E-03	0.0	25.0	100.0	13.1	0.0	20.4	86.7	10.7	0.0	25.0	100.0	13.1	0.0	20.4	86.7	10.7
204	102	2	7	1	7.8730E-05	0.0	1.5	24.9	2.4	0.1	10.3	100.0	7.9	0.0	0.0	0.3	0.1	0.0	0.7	3.8	0.5
204	103	2	3	1	8.6658E-05	0.0	7.1	100.0	11.5	0.1	2.4	21.8	1.1	0.0	0.6	4.4	0.9	0.0	0.1	0.2	0.0
204	203	4	7	1	3.2735E-05	0.0	20.1	82.1	9.4	0.0	26.1	100.0	12.7	0.0	20.1	82.1	9.4	0.0	26.1	100.0	12.7
204	205	4	7	1	3.2389E-05	0.0	20.4	83.1	9.5	0.0	26.2	100.0	12.6	0.0	20.4	83.1	9.5	0.0	26.2	100.0	12.6
205	204	2	5	1	3.4858E-02	92.6	15.9	0.0	18.2	100.0	17.9	0.0	16.5	22.4	3.8	0.0	4.4	24.3	4.4	0.0	4.0
205	302	2	1	1	8.0435E-06	100.0	42.5	2.9	19.8	75.1	15.3	0.0	14.8	23.7	27.4	11.5	10.5	18.2	8.6	1.6	4.9
205	206	3	1	1	3.6975E-02	100.0	18.3	0.0	14.4	84.7	15.1	0.0	17.7	24.3	4.4	0.0	3.5	20.5	3.7	0.0	4.2
205	204	4	3	1	2.6245E-03	0.0	25.1	100.0	12.9	0.0	21.8	91.4	11.6	0.0	25.1	100.0	12.9	0.0	21.8	91.4	11.6
205	206	4	3	1	2.8916E-03	0.0	24.6	100.0	13.2	0.0	20.7	88.8	11.3	0.0	24.6	100.0	13.2	0.0	20.7	88.8	11.3
206	103	3	7	1	7.7964E-05	0.0	1.1	21.8	2.5	0.2	12.1	100.0	6.8	0.0	0.0	0.2	0.1	0.0	0.9	4.4	0.6
206	101	3	3	1	7.0945E-05	0.1	8.2	100.0	10.0	0.2	2.4	24.7	1.6	0.0	0.6	3.8	0.7	0.0	0.1	0.3	0.0
206	205	4	7	1	3.5181E-05	0.0	20.5	83.5	9.6	0.0	26.0	100.0	12.6	0.0	20.5	83.5	9.6	0.0	26.0	100.0	12.6
206	201	4	7	1	3.5729E-05	0.0	20.0	81.5	9.3	0.0	26.2	100.0	12.7	0.0	20.0	81.5	9.3	0.0	26.2	100.0	12.7
301	203	1	1	1	5.0366E-07	100.0	55.0	10.8	26.4	81.4	18.4	0.2	13.2	22.9	26.7	16.6	11.6	19.5	8.6	2.0	4.2
301	302	1	1	1	2.9791E-06	100.0	11.4	0.1	22.0	66.8	9.4	0.5	41.3	23.4	2.7	0.1	6.3	16.6	2.3	0.2	11.1
301	303	3	1	1	5.0764E-06	100.0	45.5	0.4	7.5	59.3	22.5	0.1	9.6	23.2	12.1	0.2	1.8	14.8	6.5	0.1	2.2

301	302	4	2	1	2.3351E-09	18.7	100.0	67.1	6.7	4.7	42.4	46.0	5.4	18.7	100.0	67.1	6.7	4.7	42.4	46.0	5.4
301	303	4	6	1	4.4193E-09	4.5	41.7	32.9	2.3	19.8	100.0	51.3	3.0	4.5	41.7	32.9	2.3	19.8	100.0	51.3	3.0
302	301	1	1	1	3.7153E-06	100.0	47.7	0.5	7.2	60.2	25.0	0.1	9.2	23.3	12.9	0.2	1.7	15.0	7.3	0.1	2.1
302	205	2	1	1	3.8542E-07	100.0	83.3	23.2	31.6	70.2	21.0	0.4	9.5	22.2	47.0	38.2	18.1	16.8	13.3	4.9	3.8
302	303	2	1	1	4.4104E-06	100.0	11.1	0.1	22.6	64.7	8.8	0.5	42.2	23.4	2.6	0.1	6.5	16.1	2.1	0.2	11.3
302	301	4	6	1	3.3708E-09	3.4	44.6	35.9	3.5	14.1	100.0	57.8	4.3	3.4	44.6	35.9	3.5	14.1	100.0	57.8	4.3
302	303	4	2	1	3.5744E-09	23.1	100.0	56.6	3.9	6.7	45.4	39.0	3.0	23.1	100.0	56.6	3.9	6.7	45.4	39.0	3.0
303	302	2	1	1	4.7505E-06	100.0	50.6	0.5	5.7	55.3	25.8	0.1	7.9	23.1	13.7	0.2	1.3	13.9	7.6	0.1	1.7
303	201	3	1	1	4.2031E-07	100.0	93.2	15.4	15.4	54.0	19.7	0.2	7.3	21.5	48.1	22.3	7.0	13.3	12.9	2.6	2.0
303	301	3	1	1	3.1350E-06	100.0	9.6	0.1	21.5	56.3	7.3	0.6	47.2	23.1	2.2	0.1	6.3	14.1	1.8	0.3	12.7
303	302	4	6	1	4.8727E-09	4.6	45.5	26.5	1.5	17.6	100.0	44.8	1.9	4.6	45.5	26.5	1.5	17.6	100.0	44.8	1.9
303	301	4	2	1	3.1052E-09	23.4	100.0	47.5	2.8	5.7	38.7	29.2	2.1	23.4	100.0	47.5	2.8	5.7	38.7	29.2	2.1

20 WORST BUFFETING DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	S I D E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
203	202	1	5	1	4.5376E-02	88.1	15.1	0.0	18.2	100.0	18.2	0.0	15.3	21.3	3.6	0.0	4.4	24.4	4.4	0.0	3.7
201	202	1	1	1	4.1173E-02	100.0	18.3	0.0	13.3	78.2	13.7	0.0	18.0	24.4	4.4	0.0	3.3	18.9	3.4	0.0	4.3
205	206	3	1	1	3.6975E-02	100.0	18.3	0.0	14.4	84.7	15.1	0.0	17.7	24.3	4.4	0.0	3.5	20.5	3.7	0.0	4.2
201	206	3	5	1	3.6373E-02	89.8	15.5	0.0	18.1	100.0	18.1	0.0	15.7	21.7	3.7	0.0	4.4	24.4	4.4	0.0	3.8
205	204	2	5	1	3.4858E-02	92.6	15.9	0.0	18.2	100.0	17.9	0.0	16.5	22.4	3.8	0.0	4.4	24.3	4.4	0.0	4.0
203	204	2	1	1	3.1831E-02	100.0	18.3	0.0	14.0	82.0	14.5	0.0	17.9	24.4	4.4	0.0	3.4	19.8	3.6	0.0	4.3
203	202	4	3	1	3.2477E-03	0.0	18.3	100.0	18.4	0.0	14.5	85.6	15.0	0.0	18.3	100.0	18.4	0.0	14.5	85.6	15.0
201	202	4	3	1	3.1117E-03	0.0	17.9	100.0	18.9	0.0	13.8	83.8	14.8	0.0	17.9	100.0	18.9	0.0	13.8	83.8	14.8
205	206	4	3	1	2.8916E-03	0.0	24.6	100.0	13.2	0.0	20.7	88.8	11.3	0.0	24.6	100.0	13.2	0.0	20.7	88.8	11.3
205	204	4	3	1	2.6245E-03	0.0	25.1	100.0	12.9	0.0	21.8	91.4	11.6	0.0	25.1	100.0	12.9	0.0	21.8	91.4	11.6
201	206	4	3	1	2.4335E-03	0.0	25.7	100.0	12.7	0.0	21.1	87.2	10.5	0.0	25.7	100.0	12.7	0.0	21.1	87.2	10.5
203	204	4	3	1	2.3462E-03	0.0	25.0	100.0	13.1	0.0	20.4	86.7	10.7	0.0	25.0	100.0	13.1	0.0	20.4	86.7	10.7
204	103	2	3	1	8.6658E-05	0.0	7.1	100.0	11.5	0.1	2.4	21.8	1.1	0.0	0.6	4.4	0.9	0.0	0.1	0.2	0.0
204	102	2	7	1	7.8730E-05	0.0	1.5	24.9	2.4	0.1	10.3	100.0	7.9	0.0	0.0	0.3	0.1	0.0	0.7	3.8	0.5
206	103	3	7	1	7.7964E-05	0.0	1.1	21.8	2.5	0.2	12.1	100.0	6.8	0.0	0.0	0.2	0.1	0.0	0.9	4.4	0.6
206	101	3	3	1	7.0945E-05	0.1	8.2	100.0	10.0	0.2	2.4	24.7	1.6	0.0	0.6	3.8	0.7	0.0	0.1	0.3	0.0
202	101	1	7	1	5.6563E-05	0.1	1.4	23.1	2.3	0.2	10.6	100.0	7.8	0.0	0.0	0.3	0.1	0.0	0.8	4.1	0.6
202	102	1	3	1	5.6508E-05	0.1	7.6	100.0	11.0	0.2	2.4	23.1	1.3	0.0	0.6	4.1	0.8	0.0	0.1	0.3	0.0
202	203	4	7	1	4.5925E-05	0.0	14.2	82.4	13.9	0.0	18.6	100.0	18.2	0.0	14.2	82.4	13.9	0.0	18.6	100.0	18.2
202	201	4	7	1	4.5848E-05	0.0	14.0	82.1	13.9	0.0	18.6	100.0	18.3	0.0	14.0	82.1	13.9	0.0	18.6	100.0	18.3

BUFFETING DAMAGE EVALUATED FOR 42 JOINT CONNECTIONS OVER ALL ANALYSIS PLANES

```
************************************************************************

PRINT OF                : WIND FATIGUE RESULTS

RUN NAME                : X505B
RUN DESCRIPTION         : None
RESULTS INTERFACE FILE  : X505BR1.SIN
PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  15:44:59

************************************************************************

RUN SCENARIO:
=============
ANALYSIS CASE              : MULTI BRACE FATIGUE CHECK
FIRST WIND DIRECTION       : 1
LAST  WIND DIRECTION       : 6
FIRST NODE CHECKED         : 101
LAST  NODE CHECKED         : 303
FIRST ANALYSIS PLANE       : 1
LAST  ANALYSIS PLANE       : 4
NUMBER OF EIGENMODES       : 2
SHOW PROGRESS OF EXECUTION : OFF

WIND LOAD MODELLING:
====================
WIND LOAD TYPE             : WIND BUFFETING
WIDE BAND CORRECTION       : NONE
WIND PROFILE               : API (WIND PROFILE TYPE READ FROM SIN FILE)
GUST COMPONENTS CONSIDERED : ALL (ALONG + ACROSS WIND COMPONENTS)
GUST DIRECTION MOMENT      : DAMAGE BY ADD OF GUST SPECTRUM MOMENTS
WIND SPECTRA :
    LONGITUDINAL DIRECTION : HARRIS
    LATERAL      DIRECTION : PANOFSKY LATERAL
    VERTICAL     DIRECTION : PANOFSKY VERTICAL
COHERENCE FUNCTIONS :
    LONGITUDINAL DIRECTION : GUST01
    LATERAL      DIRECTION : GUST02
    VERTICAL     DIRECTION : GUST02

INPUT DATA:
===========
```

```
PARAMETERS READ FROM SIN FILE :
(l = current length unit)
------------------------------

WATER DEPTH - WD  (l)                            : 10.0
Z-COORDINATE OF MUDLINE - ZMUD  (l)              : -10.0
Z-COORDINATE OF STILL WATER LEVEL/GROUND  (l)     : 0.0
                       (Z0 = ZMUD + WD)
WIND DIRECTIONS (RELATIVE TO GLOBAL X-AXIS)      : DIR  ANGLE (deg)
                                                   1    0.0
                                                   2    30.0
                                                   3    60.0
                                                   4    90.0
                                                   5    120.0
                                                   6    150.0
MEAN WIND VELOCITY  (l/sec)                      : 30.0
MEAN WIND VELOCITY LEVEL  (l)                    : 10.0
HEIGHT EXPONENT, API WIND PROFILE                : .125
GUST FACTOR, API WIND PROFILE                    : 1.0
ACCELERATION OF GRAVITY (g)  (l/sec^2)           : 9.81
UNIT LENGTH ADJUSTMENT FACTOR (9.81/g)           : 1.0

DIRECT INPUT PARAMETERS :
(l = current length unit)
-------------------------

DAMAGE CALCULATION OF BENT CAN JOINTS            : ON
COHERENCE FUNCTION CONSTANT (GUSTO, DAVENPORT)   : 8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz ALONG DIR. : 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz LATERAL DIR.: 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz VERTICAL DIR: 16.0   16.0   8.0
GROUND ROUGNESS COEFFICIENT                      : 1.5E-02
TURBULENCE LENGTH SCALE DAVENPORT SPECTRUM  (l)  : 1200.0
TURBULENCE LENGTH SCALE HARRIS SPECTRUM  (l)     : 1800.0
DEFAULT SN CURVE                                 : DOE-T
MINIMUM PARAMETRIC SCFS                          : 1.6    1.6    1.6
DEFAULT GLOBAL SCFS                              : 1.6    1.6    1.6
DEFAULT SCF SCHEME, Alt.: EFTHYMIOU, LLOYDS      : EFTHYMIOU
(New default overrules previously assigned SCFs)
DAMPING RATIO                                    : 1.0E-02
CHORD LENGTH/DIAMETER RATIO (L/D)                : 30.0
ANGULAR TOLERANCE ANALYSIS PLANES (DEG)          : 1.0
LIMIT FOR PRINTING DAMAGE VALUES                 : 1.0E-12
MIN. WIND FORCE USED RELATIVE TO MAX.            : 1.000E-05
```

```
LIMIT VALUE ON COHERENCE EFFECT                    : 1.000E-03
(NO COHERENCE = 1.0, FULL COHERENCE = 0 in limit)
NUMBER OF WIND SPEEDS                              : 5

WIND PROBABILITIES AND DRAG CORRECTION COEFFICIENT
-------------------------------------------------------
   DIR    WIND          WIND          WIND    DRAG COEFF
    NO   SPEED         SPEED   PROBABILITY    CORRECTION
           NO                                    FACTORS
     1      1        10.0000        0.3000        1.0000
     1      2        15.0000        0.2500        0.9000
     1      3        20.0000        0.2000        0.8000
     1      4        25.0000        0.1500        0.7500
     1      5        30.0000        0.1000        0.7000
     2      1        10.0000        0.3500        1.0100
     2      2        15.0000        0.2000        0.9100
     2      3        20.0000        0.2000        0.8100
     2      4        25.0000        0.1500        0.7600
     2      5        30.0000        0.1000        0.7100
     3      1        10.0000        0.4000        1.0200
     3      2        15.0000        0.2000        0.9200
     3      3        20.0000        0.1500        0.8200
     3      4        25.0000        0.1500        0.7700
     3      5        30.0000        0.1000        0.7200
     4      1        10.0000        0.2000        1.0300
     4      2        15.0000        0.2000        0.9300
     4      3        20.0000        0.2000        0.8300
     4      4        25.0000        0.2000        0.7800
     4      5        30.0000        0.2000        0.7300
     5      1        10.0000        0.3000        1.0400
     5      2        15.0000        0.2500        0.9400
     5      3        20.0000        0.2000        0.8400
     5      4        25.0000        0.1500        0.7900
     5      5        30.0000        0.1000        0.7400
     6      1        10.0000        0.3600        1.0500
     6      2        15.0000        0.2200        0.9500
     6      3        20.0000        0.2100        0.8500
     6      4        25.0000        0.1100        0.8000
     6      5        30.0000        0.1000        0.7500

NODES DEFINING THE ANALYSIS PLANES:
 1    101    203    301
 2    102    205    302
 3    103    201    303
```

```
  4    201    203    205


 NUMBER OF COHERENCE MATRICES FOR THE U, V AND W  WIND GUST DIRECTIONS :   2
 Note! 1,2 or 3 coherence matrices are formed depending on the choice of
       wind spectrum and coherence models. Theexecution time increases
       with the number of coherence matrices applied in the run.

 ************************************************************************

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-12)
========================================================================================
```

NODE 1	NODE 2	PLANE	LOAD CASE	SIDE	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
201	202	1	1	1	8.2726E-03	100.0	18.3	0.0	14.1	82.2	14.7	0.0	17.9	24.4	4.4	0.0	3.4	19.9	3.6	0.0	4.3
201	206	3	5	1	1.1922E+00	91.2	18.3	0.0	21.3	100.0	21.2	0.0	18.4	25.2	4.5	0.0	5.3	28.2	5.3	0.0	4.5
201	303	3	1	1	8.4028E-05	100.0	41.5	0.2	3.5	47.1	16.3	0.0	9.1	23.8	18.7	1.0	1.1	11.7	8.6	0.3	1.0
201	202	4	3	1	6.2720E-04	0.0	17.8	100.0	18.9	0.0	14.3	86.6	15.9	0.0	17.8	100.0	18.9	0.0	14.3	86.6	15.9
201	206	4	3	1	9.5578E-02	0.0	25.5	100.0	12.8	0.0	21.1	87.0	10.3	0.0	25.5	100.0	12.8	0.0	21.1	87.0	10.3
202	101	1	7	1	8.4543E-04	0.0	1.1	24.9	2.8	0.1	11.1	100.0	7.4	0.0	0.0	0.3	0.1	0.0	0.8	4.3	0.6
202	102	1	3	1	8.4392E-04	0.0	7.6	100.0	10.5	0.0	2.1	24.9	1.3	0.0	0.6	4.3	0.8	0.0	0.1	0.3	0.0
202	201	4	7	1	8.8404E-06	0.2	14.1	82.3	13.9	0.0	18.5	100.0	18.3	0.2	14.1	82.3	13.9	0.0	18.5	100.0	18.3
202	203	4	7	1	8.8610E-06	0.4	14.2	82.1	13.8	0.0	18.6	100.0	18.3	0.4	14.2	82.1	13.8	0.0	18.6	100.0	18.3
203	202	1	1	1	8.4541E-02	100.0	17.6	0.0	12.8	71.7	10.9	0.0	20.4	24.6	4.3	0.0	3.1	17.2	2.6	0.0	5.1
203	301	1	3	2	1.0530E-05	72.8	47.7	25.1	19.9	68.9	19.3	1.2	17.9	17.5	64.0	100.0	20.9	16.7	18.5	22.3	12.1
203	204	2	1	1	7.2804E-01	100.0	20.2	0.0	18.6	98.5	19.8	0.0	18.9	26.6	5.0	0.0	4.5	26.2	4.9	0.0	4.6
203	202	4	7	1	6.1990E-03	0.0	8.8	66.3	13.1	0.0	15.9	100.0	23.1	0.0	8.8	66.3	13.1	0.0	15.9	100.0	23.1
203	204	4	3	1	6.1527E-02	0.0	23.2	100.0	13.3	0.0	22.8	98.8	13.1	0.0	23.2	100.0	13.3	0.0	22.8	98.8	13.1
204	102	2	7	1	5.6936E-05	0.8	7.7	40.0	4.1	0.4	14.1	100.0	10.7	0.1	0.3	0.7	0.1	0.1	0.9	3.5	0.6
204	103	2	3	1	6.5663E-05	0.4	12.8	100.0	17.0	2.8	12.5	30.4	2.5	0.0	1.0	4.4	1.0	0.3	0.6	0.5	0.1
204	203	4	7	1	3.2080E-04	0.0	24.2	98.1	12.0	0.0	24.8	100.0	12.4	0.0	24.2	98.1	12.0	0.0	24.8	100.0	12.4
204	205	4	7	1	3.2868E-04	0.0	16.1	65.3	6.6	0.0	28.2	100.0	12.8	0.0	16.1	65.3	6.6	0.0	28.2	100.0	12.8
205	204	2	5	1	5.6336E-02	52.8	9.0	0.0	18.2	100.0	22.1	0.0	7.3	12.5	2.1	0.0	4.5	24.8	5.6	0.0	1.7
205	302	2	5	1	4.7162E-05	55.5	10.5	0.6	50.6	100.0	8.4	0.0	19.5	13.7	6.5	2.9	28.2	23.5	2.4	0.8	12.8
205	206	3	1	1	4.6485E-01	100.0	19.2	0.0	10.5	59.5	9.9	0.0	20.3	25.8	4.5	0.0	2.7	14.6	2.5	0.0	4.8
205	204	4	3	1	4.3623E-03	0.0	35.1	100.0	11.3	0.0	13.3	46.9	3.5	0.0	35.1	100.0	11.3	0.0	13.3	46.9	3.5
205	206	4	3	1	3.6441E-02	0.0	28.4	100.0	12.5	0.0	16.9	67.2	6.8	0.0	28.4	100.0	12.5	0.0	16.9	67.2	6.8
206	103	3	7	1	5.6840E-05	0.9	2.8	23.4	4.9	2.3	11.3	100.0	14.0	0.1	0.1	0.3	0.2	0.2	0.8	4.5	1.1
206	101	3	3	1	5.2054E-05	1.8	8.5	100.0	15.3	0.8	4.0	26.3	3.6	0.1	0.6	3.8	1.0	0.1	0.1	0.3	0.1
206	205	4	7	1	1.0369E-03	0.0	18.9	76.9	8.5	0.0	26.7	100.0	12.7	0.0	18.9	76.9	8.5	0.0	26.7	100.0	12.7

206	201	4	7	1	1.0382E-03	0.0	22.0	89.0	10.5	0.0	25.6	100.0	12.5	0.0	22.0	89.0	10.5	0.0	25.6	100.0	12.5
301	203	1	3	2	3.7563E-06	14.5	58.4	60.3	11.8	8.9	5.5	3.8	5.5	3.0	51.8	100.0	15.0	2.2	8.8	21.2	5.0
301	302	1	1	1	1.8288E-04	100.0	13.5	0.1	19.1	74.1	11.1	0.3	31.1	23.7	3.2	0.0	5.2	18.3	2.7	0.1	8.1
301	303	3	1	1	2.6376E-06	100.0	65.1	1.1	4.7	88.4	56.1	0.5	5.4	24.0	18.5	0.5	1.0	21.6	16.2	0.3	1.2
301	302	4	3	1	9.6674E-08	16.5	90.7	100.0	12.0	3.9	40.9	75.4	9.2	16.5	90.7	100.0	12.0	3.9	40.9	75.4	9.2
301	303	4	6	1	3.6294E-09	13.4	80.7	27.0	1.2	28.5	100.0	30.3	0.8	13.4	80.7	27.0	1.2	28.5	100.0	30.3	0.8
302	301	1	1	1	1.0273E-04	100.0	52.8	0.6	5.6	51.9	24.7	0.2	8.0	23.1	14.4	0.3	1.3	13.1	7.4	0.1	1.8
302	205	2	1	1	1.3196E-05	100.0	77.3	2.0	2.1	28.3	21.9	0.1	3.8	21.3	36.3	3.9	1.5	8.0	15.1	1.0	0.5
302	303	2	1	1	1.0608E-06	100.0	9.9	0.8	20.1	54.0	8.0	3.1	61.4	22.5	2.3	0.4	6.1	13.4	1.9	1.3	16.7
302	301	4	6	1	1.0991E-07	3.8	41.0	26.4	2.0	15.7	100.0	48.9	2.8	3.8	41.0	26.4	2.0	15.7	100.0	48.9	2.8
302	303	4	2	1	1.7849E-09	62.3	100.0	25.8	1.8	14.3	26.7	16.0	2.3	62.3	100.0	25.8	1.8	14.3	26.7	16.0	2.3
303	302	2	1	1	1.4847E-04	100.0	21.4	0.0	13.2	85.2	17.7	0.0	15.3	23.9	5.3	0.0	3.2	20.9	4.5	0.0	3.6
303	201	3	5	1	3.1695E-06	30.1	15.9	3.8	72.1	100.0	6.4	0.4	13.8	7.7	9.0	6.6	30.1	20.5	2.6	1.9	9.1
303	301	3	1	1	4.7799E-05	100.0	14.9	0.0	20.3	87.9	13.2	0.1	23.5	24.0	3.5	0.0	5.2	21.5	3.2	0.0	6.0
303	302	4	7	1	7.8652E-08	0.5	30.4	86.2	7.5	2.7	41.4	100.0	9.3	0.5	30.4	86.2	7.5	2.7	41.4	100.0	9.3
303	301	4	3	1	2.5156E-08	5.0	52.6	100.0	8.9	3.4	43.1	88.7	7.4	5.0	52.6	100.0	8.9	3.4	43.1	88.7	7.4

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 2, 30.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S N	S I D E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points --> |								<-- Side 2: Brace side points --> |						
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	5.7727E-01	100.0	19.7	0.0	18.3	99.5	19.7	0.0	18.5	26.1	4.8	0.0	4.4	25.9	4.8	0.0	4.5
201	206	3	1	1	5.3311E-01	100.0	18.6	0.0	18.3	95.1	17.3	0.0	19.8	25.9	4.5	0.0	4.5	24.5	4.2	0.0	4.9
201	303	3	1	1	2.6127E-05	100.0	98.2	4.1	5.0	29.1	17.7	0.2	5.0	23.3	73.0	14.3	2.7	7.2	19.5	2.6	1.2
201	202	4	3	1	4.8854E-02	0.0	16.4	100.0	19.2	0.0	16.2	99.6	19.2	0.0	16.4	100.0	19.2	0.0	16.2	99.6	19.2
201	206	4	7	1	3.8223E-02	0.0	21.5	93.2	12.1	0.0	23.4	100.0	13.7	0.0	21.5	93.2	12.1	0.0	23.4	100.0	13.7
202	101	1	7	1	4.7699E-04	0.1	1.4	27.3	3.4	0.2	14.3	100.0	5.3	0.0	0.1	0.4	0.1	0.0	1.0	4.0	0.4
202	102	1	3	1	4.7494E-04	0.1	10.3	100.0	8.7	0.4	3.4	27.0	2.0	0.0	0.7	4.1	0.6	0.0	0.1	0.4	0.0
202	201	4	7	1	2.9895E-04	0.0	16.0	93.0	16.4	0.0	17.8	100.0	18.2	0.0	16.0	93.0	16.4	0.0	17.8	100.0	18.2
202	203	4	7	1	3.0636E-04	0.0	12.1	71.1	11.3	0.0	19.6	100.0	18.4	0.0	12.1	71.1	11.3	0.0	19.6	100.0	18.4
203	202	1	5	1	1.3151E-01	83.7	14.5	0.0	18.4	100.0	19.2	0.0	14.8	20.3	3.5	0.0	4.5	24.6	4.7	0.0	3.6
203	301	1	1	1	2.1526E-05	100.0	25.2	5.4	32.2	60.0	9.5	0.2	22.7	23.7	10.7	19.8	29.9	14.7	4.5	3.5	11.2
203	204	2	1	1	9.7669E-01	100.0	20.9	0.0	14.1	74.8	14.2	0.0	20.9	27.7	5.0	0.0	3.5	19.8	3.5	0.0	5.0
203	202	4	3	1	9.6017E-03	0.0	20.0	100.0	18.0	0.0	13.6	80.5	14.4	0.0	20.0	100.0	18.0	0.0	13.6	80.5	14.4
203	204	4	3	1	8.1999E-02	0.0	26.0	100.0	13.0	0.0	18.9	78.7	9.1	0.0	26.0	100.0	13.0	0.0	18.9	78.7	9.1
204	102	2	7	1	1.3776E-04	0.8	2.6	37.1	4.3	1.2	10.8	100.0	7.6	0.0	0.1	0.6	0.2	0.1	0.7	3.4	0.5
204	103	2	3	1	1.5544E-04	0.4	7.2	100.0	10.6	0.6	3.1	29.4	1.8	0.0	0.5	4.1	0.8	0.0	0.1	0.4	0.1
204	203	4	7	1	1.4134E-03	0.0	20.0	81.7	9.3	0.0	26.1	100.0	12.7	0.0	20.0	81.7	9.3	0.0	26.1	100.0	12.7
204	205	4	7	1	1.3976E-03	0.0	20.4	82.9	9.5	0.0	26.1	100.0	12.6	0.0	20.4	82.9	9.5	0.0	26.1	100.0	12.6
205	204	2	5	1	1.0598E+00	86.0	16.8	0.0	21.1	100.0	21.4	0.0	16.6	23.3	4.1	0.0	5.2	27.9	5.3	0.0	4.0

205	302	2	1	1	1.1996E-04	100.0	17.1	0.5	18.9	99.1	16.2	0.0	19.1	24.2	5.0	2.2	5.2	24.0	3.8	0.4	5.1
205	206	3	1	1	1.0761E-01	100.0	18.4	0.0	14.8	86.9	15.6	0.0	17.7	24.4	4.4	0.0	3.6	21.1	3.8	0.0	4.2
205	204	4	3	1	9.4190E-02	0.0	26.5	100.0	12.6	0.0	20.0	81.4	9.3	0.0	26.5	100.0	12.6	0.0	20.0	81.4	9.3
205	206	4	3	1	8.4982E-03	0.0	24.4	100.0	13.3	0.0	21.0	90.4	11.5	0.0	24.4	100.0	13.3	0.0	21.0	90.4	11.5
206	103	3	7	1	5.1492E-04	0.1	1.9	26.4	3.2	0.3	8.4	100.0	10.5	0.0	0.0	0.4	0.1	0.0	0.6	4.4	0.8
206	101	3	3	1	4.7086E-04	0.1	5.8	100.0	13.4	0.2	3.6	30.4	1.6	0.0	0.4	3.7	0.9	0.0	0.1	0.4	0.1
206	205	4	7	1	2.1182E-04	0.0	18.1	73.3	7.9	0.0	27.2	100.0	12.7	0.0	18.1	73.3	7.9	0.0	27.2	100.0	12.7
206	201	4	7	1	2.1013E-04	0.0	23.7	95.7	11.6	0.0	25.2	100.0	12.4	0.0	23.7	95.7	11.6	0.0	25.2	100.0	12.4
301	203	1	2	1	7.1966E-06	50.0	100.0	14.3	1.3	3.4	7.4	0.5	0.6	8.9	57.6	22.2	0.9	0.9	10.8	3.5	0.3
301	302	1	1	1	4.5069E-05	100.0	7.9	0.1	17.8	42.3	5.4	0.7	52.6	22.6	1.7	0.1	5.4	10.7	1.3	0.3	14.0
301	303	3	1	1	8.3876E-05	100.0	48.1	0.3	5.0	58.4	28.6	0.1	7.5	23.4	13.0	0.1	1.2	14.7	8.3	0.0	1.6
301	302	4	2	1	4.9459E-08	17.7	100.0	47.2	2.9	2.3	27.3	21.0	2.1	17.7	100.0	47.2	2.9	2.3	27.3	21.0	2.1
301	303	4	6	1	7.2664E-08	4.6	56.0	30.7	1.3	12.1	100.0	50.4	1.8	4.6	56.0	30.7	1.3	12.1	100.0	50.4	1.8
302	301	1	1	1	2.4776E-04	100.0	27.3	0.2	11.9	78.4	18.1	0.0	14.0	23.7	6.9	0.1	2.9	19.3	4.7	0.0	3.3
302	205	2	5	1	1.2153E-05	99.5	25.4	3.2	14.1	100.0	22.5	0.1	13.7	24.1	9.3	5.7	3.4	24.2	6.7	1.1	2.8
302	303	2	1	1	5.0175E-05	100.0	12.8	0.0	18.4	72.7	10.5	0.1	28.7	23.6	3.0	0.0	4.9	17.9	2.5	0.0	7.3
302	301	4	7	1	1.3113E-07	1.2	29.9	79.6	10.1	8.5	65.1	100.0	12.3	1.2	29.9	79.6	10.1	8.5	65.1	100.0	12.3
302	303	4	3	1	2.4102E-08	6.3	79.6	100.0	7.6	1.5	41.9	75.6	6.3	6.3	79.6	100.0	7.6	1.5	41.9	75.6	6.3
303	302	2	1	1	3.7753E-05	100.0	37.7	0.1	7.4	59.2	20.1	0.0	9.9	23.3	9.9	0.1	1.8	14.8	5.7	0.0	2.2
303	201	3	4	1	1.2532E-06	62.2	28.2	61.1	100.0	28.4	4.4	2.6	21.5	13.0	17.0	88.3	70.8	6.1	4.1	14.1	14.5
303	301	3	1	1	2.2150E-04	100.0	14.2	0.1	19.1	78.6	11.6	0.1	26.1	23.8	3.3	0.0	5.0	19.4	2.8	0.1	6.7
303	302	4	6	1	2.3674E-08	2.3	46.3	48.3	3.7	9.3	100.0	76.9	4.3	2.3	46.3	48.3	3.7	9.3	100.0	76.9	4.3
303	301	4	3	1	1.1501E-07	9.9	68.5	100.0	8.5	4.0	43.7	80.3	6.3	9.9	68.5	100.0	8.5	4.0	43.7	80.3	6.3

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 3, 60.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
201	202	1	1	1	1.2473E+00	100.0	21.7	0.0	18.7	92.8	19.6	0.0	20.7	28.4	5.4	0.0	4.6	26.0	4.9	0.0	5.1
201	206	3	1	1	1.1009E-02	100.0	18.0	0.0	17.0	93.5	16.9	0.0	25.3	25.3	4.5	0.0	4.1	22.8	4.1	0.0	6.6
201	303	3	1	1	9.5805E-06	100.0	57.9	27.3	23.0	85.2	21.2	1.2	25.0	24.0	70.1	100.0	20.3	20.7	18.2	20.0	13.8
201	202	4	3	1	1.1714E-01	0.0	16.8	100.0	19.2	0.0	15.4	93.9	17.5	0.0	16.8	100.0	19.2	0.0	15.4	93.9	17.5
201	206	4	7	1	8.5584E-04	0.0	20.5	80.4	10.2	0.0	19.8	100.0	25.0	0.0	20.5	80.4	10.2	0.0	19.8	100.0	25.0
202	101	1	7	1	6.0058E-05	1.1	6.3	29.5	4.3	0.5	16.7	100.0	10.2	0.1	0.3	0.4	0.1	0.1	1.2	4.1	0.6
202	102	1	3	1	6.2163E-05	0.6	12.5	100.0	17.3	5.0	12.0	25.4	2.7	0.0	0.9	4.2	1.0	0.4	0.5	0.3	0.1
202	201	4	7	1	7.5526E-04	0.0	16.4	95.1	16.9	0.0	17.6	100.0	18.2	0.0	16.4	95.1	16.9	0.0	17.6	100.0	18.2
202	203	4	7	1	7.7829E-04	0.0	11.6	68.2	10.6	0.0	19.8	100.0	18.4	0.0	11.6	68.2	10.6	0.0	19.8	100.0	18.4
203	202	1	5	1	1.5724E-01	54.8	9.2	0.0	18.7	100.0	21.4	0.0	7.8	13.0	2.2	0.0	4.6	25.0	5.4	0.0	1.8
203	301	1	5	1	5.0856E-05	63.1	12.3	0.5	44.3	100.0	9.8	0.0	18.9	15.4	6.6	2.3	22.3	23.7	2.6	0.6	10.3
203	204	2	1	1	3.2006E-01	100.0	18.9	0.0	8.1	47.5	7.4	0.0	20.4	25.4	4.4	0.0	2.1	11.4	1.9	0.0	4.8

203	202	4	3	1	1.1930E-02	0.0	24.0	100.0	17.2	0.0	8.7	47.3	5.7	0.0	24.0	100.0	17.2	0.0	8.7	47.3	5.7
203	204	4	3	1	2.2564E-02	0.0	29.8	100.0	12.6	0.0	14.5	57.2	5.2	0.0	29.8	100.0	12.6	0.0	14.5	57.2	5.2
204	102	2	7	1	5.8425E-05	1.0	2.4	27.8	10.3	5.9	15.5	100.0	11.8	0.0	0.1	0.4	0.4	0.4	0.9	3.8	0.8
204	103	2	3	1	6.4829E-05	0.9	9.2	100.0	17.7	0.7	4.6	23.0	3.8	0.1	0.7	4.5	1.3	0.1	0.1	0.3	0.2
204	203	4	7	1	1.0738E-03	0.0	17.8	73.2	8.0	0.0	26.8	100.0	12.8	0.0	17.8	73.2	8.0	0.0	26.8	100.0	12.8
204	205	4	7	1	1.0406E-03	0.0	23.1	94.5	11.5	0.0	24.9	100.0	12.5	0.0	23.1	94.5	11.5	0.0	24.9	100.0	12.5
205	204	2	5	1	1.4251E+00	94.9	19.6	0.0	22.1	100.0	21.4	0.0	20.3	27.2	4.9	0.0	5.5	28.9	5.3	0.0	5.0
205	302	2	1	1	8.9029E-05	100.0	41.9	0.3	3.6	45.0	15.4	0.0	9.2	23.5	19.7	1.5	1.5	11.3	8.9	0.4	1.0
205	206	3	1	1	8.5426E-03	100.0	18.3	0.0	14.2	82.9	14.9	0.0	17.9	24.3	4.4	0.0	3.4	20.1	3.6	0.0	4.3
205	204	4	3	1	1.3338E-01	0.0	24.5	100.0	13.0	0.0	22.2	92.9	11.6	0.0	24.5	100.0	13.0	0.0	22.2	92.9	11.6
205	206	4	3	1	6.6299E-04	0.0	25.1	100.0	13.1	0.0	20.5	87.3	11.2	0.0	25.1	100.0	13.1	0.0	20.5	87.3	11.2
206	103	3	7	1	1.0398E-03	0.0	1.1	25.2	2.7	0.1	11.1	100.0	7.3	0.0	0.0	0.3	0.1	0.0	0.9	4.7	0.6
206	101	3	3	1	9.4148E-04	0.0	7.7	100.0	10.6	0.0	2.7	29.0	1.5	0.0	0.5	3.9	0.7	0.0	0.1	0.4	0.0
206	205	4	7	1	9.3049E-06	0.2	20.2	82.1	9.4	0.0	26.2	100.0	12.7	0.2	20.2	82.1	9.4	0.0	26.2	100.0	12.7
206	201	4	7	1	9.4166E-06	0.4	20.5	82.9	9.5	0.0	26.1	100.0	12.7	0.4	20.5	82.9	9.5	0.0	26.1	100.0	12.7
301	203	1	1	1	1.2780E-05	100.0	68.7	1.6	2.1	27.7	18.7	0.1	4.6	21.2	29.7	3.0	1.3	7.8	11.9	0.8	0.5
301	302	1	1	1	1.2152E-06	100.0	8.5	0.7	17.8	45.7	6.9	3.3	67.5	22.0	2.0	0.4	5.6	11.3	1.6	1.3	18.3
301	303	3	1	1	1.8875E-04	100.0	40.8	0.4	7.5	61.2	21.6	0.1	10.3	23.3	10.8	0.1	1.8	15.3	6.1	0.0	2.3
301	302	4	2	1	2.4241E-09	46.4	100.0	25.7	2.0	9.2	22.1	12.3	1.8	46.4	100.0	25.7	2.0	9.2	22.1	12.3	1.8
301	303	4	6	1	1.3827E-07	4.8	45.1	40.4	2.3	18.4	100.0	62.3	3.5	4.8	45.1	40.4	2.3	18.4	100.0	62.3	3.5
302	301	1	1	1	1.5643E-04	100.0	20.7	0.0	14.6	89.0	17.6	0.0	16.2	24.0	5.1	0.0	3.5	21.7	4.4	0.0	3.9
302	205	2	5	1	5.0776E-06	30.8	13.3	3.4	68.6	100.0	6.6	0.3	14.5	8.1	8.3	6.9	29.6	20.8	2.5	2.0	9.8
302	303	2	1	1	1.3653E-04	100.0	15.6	0.0	18.7	88.5	13.8	0.0	21.2	24.0	3.7	0.0	4.7	21.6	3.3	0.0	5.3
302	301	4	7	1	8.3244E-08	0.4	21.8	89.6	13.4	2.0	30.7	100.0	15.3	0.4	21.8	89.6	13.4	2.0	30.7	100.0	15.3
302	303	4	3	1	6.8698E-08	1.8	40.2	100.0	9.5	1.3	34.2	89.2	8.0	1.8	40.2	100.0	9.5	1.3	34.2	89.2	8.0
303	302	2	1	1	3.6831E-06	100.0	61.4	1.0	4.4	90.2	54.1	0.4	5.0	24.0	17.5	0.4	0.9	22.0	15.6	0.2	1.0
303	201	3	3	2	3.3723E-06	20.0	71.9	65.0	10.8	9.1	5.6	3.6	5.9	4.0	58.0	100.0	13.2	2.3	8.7	19.2	4.4
303	301	3	1	1	1.7788E-04	100.0	12.8	0.1	19.3	69.2	9.9	0.4	33.4	23.5	3.0	0.1	5.3	17.2	2.4	0.2	8.8
303	302	4	6	1	4.7338E-09	11.9	82.3	31.3	1.2	26.9	100.0	34.4	0.7	11.9	82.3	31.3	1.2	26.9	100.0	34.4	0.7
303	301	4	2	1	1.0436E-07	22.4	100.0	85.8	6.6	5.7	46.0	62.2	4.6	22.4	100.0	85.8	6.6	5.7	46.0	62.2	4.6

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 4, 90.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S D		<==RELATIVE DAMAGES AROUND THE WELD ====>														
					<-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->						
				DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	2.2507E+00	100.0	22.0	0.0	15.9	80.1	16.2	0.0	21.6	28.8	5.4	0.0	4.0	22.2	4.1	0.0	5.3
201	206	3	5	1	2.8525E-01	94.3	16.4	0.0	18.3	100.0	17.9	0.0	16.8	23.0	4.0	0.0	4.5	24.5	4.3	0.0	4.1
201	303	3	1	1	4.4330E-05	100.0	24.2	5.2	27.5	57.4	9.3	0.1	22.0	23.8	9.3	17.6	24.8	14.0	4.0	2.7	9.4
201	202	4	3	1	2.0877E-01	0.0	18.1	100.0	18.9	0.0	13.7	82.7	14.5	0.0	18.1	100.0	18.9	0.0	13.7	82.7	14.5
201	206	4	3	1	1.9134E-02	0.0	24.7	100.0	12.8	0.0	22.2	92.6	11.5	0.0	24.7	100.0	12.8	0.0	22.2	92.6	11.5

202	101	1	7	1	2.8812E-04	0.6	2.4	34.6	3.6	0.6	10.9	100.0	7.3	0.0	0.1	0.5	0.1	0.1	0.7	3.7	0.5
202	102	1	3	1	2.9645E-04	0.5	7.0	100.0	11.8	1.2	4.3	31.0	1.7	0.0	0.5	3.8	0.8	0.1	0.2	0.4	0.1
202	201	4	7	1	2.8474E-03	0.0	14.4	84.2	14.3	0.0	18.4	100.0	18.3	0.0	14.4	84.2	14.3	0.0	18.4	100.0	18.3
202	203	4	7	1	2.8656E-03	0.0	13.7	79.8	13.3	0.0	18.8	100.0	18.2	0.0	13.7	79.8	13.3	0.0	18.8	100.0	18.2
203	202	1	5	1	1.7809E+00	83.0	16.1	0.0	21.2	100.0	21.7	0.0	15.7	22.4	3.9	0.0	5.3	28.0	5.4	0.0	3.8
203	301	1	1	1	2.5460E-04	100.0	18.8	0.5	17.0	97.8	17.5	0.0	17.5	24.2	5.7	1.8	4.2	23.7	4.5	0.3	4.2
203	204	2	1	1	3.8662E-01	100.0	18.6	0.0	11.2	65.4	11.2	0.0	19.1	24.9	4.4	0.0	2.8	15.8	2.8	0.0	4.5
203	202	4	3	1	1.5139E-01	0.0	19.3	100.0	18.2	0.0	13.2	76.7	12.5	0.0	19.3	100.0	18.2	0.0	13.2	76.7	12.5
203	204	4	3	1	2.7923E-02	0.0	27.2	100.0	12.9	0.0	17.6	73.0	8.2	0.0	27.2	100.0	12.9	0.0	17.6	73.0	8.2
204	102	2	7	1	9.6667E-04	0.1	1.9	27.8	3.7	0.5	9.4	100.0	9.8	0.0	0.0	0.4	0.1	0.1	0.6	3.8	0.7
204	103	2	3	1	1.0537E-03	0.0	4.9	100.0	15.4	0.2	3.5	25.6	1.1	0.0	0.4	4.4	1.1	0.0	0.1	0.3	0.0
204	203	4	7	1	8.8911E-04	0.0	18.0	73.9	8.1	0.0	26.8	100.0	12.8	0.0	18.0	73.9	8.1	0.0	26.8	100.0	12.8
204	205	4	7	1	8.6276E-04	0.0	23.2	94.5	11.5	0.0	25.0	100.0	12.5	0.0	23.2	94.5	11.5	0.0	25.0	100.0	12.5
205	204	2	1	1	1.5291E+00	100.0	19.5	0.0	20.4	98.9	19.3	0.0	20.8	27.3	4.8	0.0	5.0	26.9	4.7	0.0	5.1
205	302	2	2	1	5.7837E-05	96.4	100.0	4.9	6.5	32.9	18.9	0.2	4.4	22.0	82.6	20.6	3.9	8.1	23.6	4.4	1.4
205	206	3	5	1	7.7788E-01	95.8	18.6	0.0	17.9	100.0	19.8	0.0	17.0	24.4	4.6	0.0	4.3	25.6	4.8	0.0	4.1
205	204	4	7	1	1.3168E-01	0.0	23.0	98.5	13.0	0.0	23.3	100.0	13.5	0.0	23.0	98.5	13.0	0.0	23.3	100.0	13.5
205	206	4	7	1	6.5867E-02	0.0	21.7	96.7	13.2	0.0	22.5	100.0	14.1	0.0	21.7	96.7	13.2	0.0	22.5	100.0	14.1
206	103	3	7	1	1.0904E-03	0.0	1.1	28.3	4.0	0.2	15.7	100.0	4.7	0.0	0.0	0.4	0.1	0.0	1.1	4.4	0.4
206	101	3	3	1	1.0058E-03	0.1	9.7	100.0	9.2	0.3	3.8	30.2	2.0	0.0	0.7	3.7	0.6	0.0	0.1	0.4	0.1
206	205	4	7	1	3.6926E-04	0.0	22.5	92.2	11.2	0.0	25.1	100.0	12.6	0.0	22.5	92.2	11.2	0.0	25.1	100.0	12.6
206	201	4	7	1	3.8163E-04	0.0	17.8	72.8	7.9	0.0	27.1	100.0	12.9	0.0	17.8	72.8	7.9	0.0	27.1	100.0	12.9
301	203	1	5	1	2.2683E-05	98.1	21.6	3.1	16.9	100.0	18.9	0.1	16.2	23.8	7.5	5.1	4.3	24.2	5.1	0.9	3.8
301	302	1	1	1	6.1828E-05	100.0	10.7	0.0	19.5	62.7	8.2	0.1	35.5	23.3	2.4	0.0	5.4	15.6	2.0	0.1	9.2
301	303	3	1	1	5.3765E-04	100.0	28.0	0.2	11.2	75.8	18.0	0.0	13.5	23.7	7.1	0.1	2.7	18.7	4.7	0.0	3.2
301	302	4	3	1	3.2490E-08	7.3	97.9	100.0	8.4	1.7	43.7	64.4	7.0	7.3	97.9	100.0	8.4	1.7	43.7	64.4	7.0
301	303	4	7	1	2.6083E-07	2.1	39.4	78.5	6.2	12.8	80.8	100.0	8.0	2.1	39.4	78.5	6.2	12.8	80.8	100.0	8.0
302	301	1	1	1	1.3493E-04	100.0	30.4	0.1	10.6	72.0	19.0	0.0	12.6	23.6	7.8	0.0	2.5	17.8	5.1	0.0	2.9
302	205	2	4	1	4.4766E-06	47.2	22.0	49.0	100.0	30.3	3.8	2.3	19.1	10.0	14.4	82.5	75.9	6.3	4.0	15.4	17.1
302	303	2	1	1	5.3526E-04	100.0	14.4	0.0	19.1	79.6	11.9	0.1	25.7	23.8	3.4	0.0	5.0	19.6	2.9	0.1	6.6
302	301	4	7	1	7.1243E-08	1.0	36.5	73.4	9.7	4.5	73.7	100.0	11.1	1.0	36.5	73.4	9.7	4.5	73.7	100.0	11.1
302	303	4	3	1	2.6369E-07	8.8	66.8	100.0	8.8	3.5	43.1	81.4	6.7	8.8	66.8	100.0	8.8	3.5	43.1	81.4	6.7
303	302	2	1	1	1.4609E-04	100.0	53.9	0.3	3.4	53.2	30.9	0.1	5.8	23.2	14.8	0.1	0.8	13.5	9.2	0.1	1.2
303	201	3	2	1	1.5043E-05	49.7	100.0	14.5	0.9	2.6	6.7	0.5	0.7	8.8	56.1	21.2	0.7	0.8	9.9	3.1	0.3
303	301	3	1	1	1.4474E-04	100.0	10.0	0.1	16.9	52.8	7.1	0.4	41.2	22.9	2.3	0.0	4.9	13.2	1.7	0.2	10.8
303	302	4	6	1	1.5291E-07	4.4	55.0	23.4	0.7	11.8	100.0	42.6	1.0	4.4	55.0	23.4	0.7	11.8	100.0	42.6	1.0
303	301	4	2	1	1.1442E-07	19.1	100.0	60.4	3.6	2.8	31.9	34.8	2.4	19.1	100.0	60.4	3.6	2.8	31.9	34.8	2.4

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 5, 120.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N	N	P	P	S																	
O	O	L	O	I							<==RELATIVE DAMAGES AROUND THE WELD ====>										
D	D	A	S	D	| <-- Side 1: Chord side points -->								| <-- Side 2: Brace side points -->								|
E	E	N	N	E																	

1	2	E			DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.4944E-01	100.0	18.6	0.0	6.9	41.3	6.3	0.0	20.2	24.8	4.2	0.0	1.8	9.8	1.6	0.0	4.7
201	206	3	5	1	4.6348E-01	69.2	12.2	0.0	19.4	100.0	21.1	0.0	11.1	17.0	2.9	0.0	4.8	26.0	5.3	0.0	2.6
201	303	3	5	1	6.1365E-05	60.6	11.4	0.5	47.9	100.0	9.1	0.0	20.1	14.8	6.1	2.1	25.0	23.8	2.5	0.5	11.6
201	202	4	3	1	1.0505E-02	0.0	22.2	100.0	18.0	0.0	9.1	52.6	7.1	0.0	22.2	100.0	18.0	0.0	9.1	52.6	7.1
201	206	4	3	1	3.3885E-02	0.0	30.0	100.0	12.2	0.0	15.5	60.1	5.5	0.0	30.0	100.0	12.2	0.0	15.5	60.1	5.5
202	101	1	7	1	7.0610E-05	0.5	2.7	29.6	12.4	4.2	17.4	100.0	12.3	0.0	0.1	0.5	0.6	0.4	1.0	4.1	0.9
202	102	1	3	1	7.2456E-05	0.8	9.5	100.0	16.1	0.5	3.9	27.5	5.2	0.1	0.6	4.1	1.1	0.1	0.1	0.4	0.2
202	201	4	7	1	6.7936E-04	0.0	11.9	70.4	11.2	0.0	19.5	100.0	18.4	0.0	11.9	70.4	11.2	0.0	19.5	100.0	18.4
202	203	4	7	1	6.6171E-04	0.0	17.0	98.0	17.5	0.0	17.5	100.0	18.0	0.0	17.0	98.0	17.5	0.0	17.5	100.0	18.0
203	202	1	5	1	1.2516E+00	98.6	20.2	0.0	21.5	100.0	20.7	0.0	21.0	27.9	5.0	0.0	5.4	28.3	5.1	0.0	5.2
203	301	1	1	1	1.1671E-04	100.0	44.5	0.3	3.1	46.0	17.3	0.0	8.3	23.6	21.5	1.2	1.2	11.5	10.1	0.3	0.8
203	204	2	5	1	4.0329E-02	46.9	8.6	0.0	17.2	100.0	21.0	0.0	6.8	11.2	2.2	0.0	3.9	24.6	4.9	0.0	1.7
203	202	4	3	1	1.0714E-01	0.0	16.9	100.0	18.8	0.0	16.4	98.0	18.2	0.0	16.9	100.0	18.8	0.0	16.4	98.0	18.2
203	204	4	7	1	2.8192E-03	0.0	10.0	57.9	8.3	0.0	21.3	100.0	18.2	0.0	10.0	57.9	8.3	0.0	21.3	100.0	18.2
204	102	2	7	1	1.0913E-03	0.0	1.5	28.9	2.6	0.0	10.8	100.0	7.7	0.0	0.0	0.4	0.1	0.0	0.7	3.9	0.5
204	103	2	3	1	1.2030E-03	0.0	7.5	100.0	11.2	0.1	2.7	25.0	1.1	0.0	0.6	4.7	0.9	0.0	0.1	0.3	0.0
204	203	4	7	1	1.1076E-05	0.2	20.4	83.1	9.6	0.0	26.0	100.0	12.7	0.2	20.4	83.1	9.6	0.0	26.0	100.0	12.7
204	205	4	7	1	1.0993E-05	0.4	20.2	81.4	9.3	0.0	26.3	100.0	12.7	0.4	20.2	81.4	9.3	0.0	26.3	100.0	12.7
205	204	2	5	1	1.0101E-02	90.5	15.7	0.0	18.2	100.0	18.2	0.0	16.3	21.9	3.8	0.0	4.4	24.4	4.4	0.0	4.0
205	302	2	3	2	1.8088E-05	73.9	42.2	22.6	20.1	64.8	17.0	1.2	19.0	17.7	58.8	100.0	23.2	15.7	17.6	24.5	13.5
205	206	3	1	1	1.4180E+00	100.0	22.1	0.0	17.5	86.9	18.2	0.0	21.3	28.9	5.5	0.0	4.4	24.5	4.6	0.0	5.3
205	204	4	3	1	7.6225E-04	0.1	25.8	100.0	12.7	0.0	21.6	89.5	13.3	0.1	25.8	100.0	12.7	0.0	21.6	89.5	13.3
205	206	4	3	1	1.3791E-01	0.0	24.5	100.0	13.3	0.0	20.9	88.7	11.1	0.0	24.5	100.0	13.3	0.0	20.9	88.7	11.1
206	103	3	7	1	7.3729E-05	0.9	3.9	26.4	5.2	0.8	18.4	100.0	8.8	0.1	0.2	0.4	0.2	0.1	1.3	4.4	0.6
206	101	3	3	1	7.1081E-05	1.0	12.0	100.0	13.4	4.7	7.8	24.8	2.4	0.1	0.8	3.9	0.8	0.3	0.3	0.3	0.1
206	205	4	7	1	1.2239E-03	0.0	22.1	90.4	10.8	0.0	25.2	100.0	12.6	0.0	22.1	90.4	10.8	0.0	25.2	100.0	12.6
206	201	4	7	1	1.2623E-03	0.0	17.9	73.2	7.9	0.0	26.9	100.0	12.8	0.0	17.9	73.2	7.9	0.0	26.9	100.0	12.8
301	203	1	5	1	5.8527E-06	28.5	12.3	3.6	78.8	100.0	5.3	0.3	16.8	7.6	7.5	6.6	35.2	20.7	2.2	1.8	11.9
301	302	1	1	1	1.9119E-04	100.0	15.6	0.0	18.2	88.0	13.8	0.0	20.8	24.0	3.7	0.0	4.6	21.5	3.3	0.0	5.1
301	303	3	1	1	1.0276E-04	100.0	22.0	0.1	14.7	89.1	18.0	0.0	15.9	24.0	5.5	0.0	3.5	21.7	4.5	0.0	3.8
301	302	4	3	1	1.0174E-07	1.1	28.9	100.0	14.1	0.6	23.8	88.7	11.8	1.1	28.9	100.0	14.1	0.6	23.8	88.7	11.8
301	303	4	7	1	5.1714E-08	0.9	31.8	90.4	9.4	5.1	47.1	100.0	10.5	0.9	31.8	90.4	9.4	5.1	47.1	100.0	10.5
302	301	1	1	1	3.5731E-06	100.0	71.1	1.2	4.2	89.1	62.4	0.6	4.8	24.0	20.5	0.5	0.9	21.7	18.2	0.3	1.0
302	205	2	3	2	6.6188E-06	12.0	49.1	55.3	11.4	8.1	5.6	3.7	4.7	2.6	47.8	100.0	15.7	2.0	9.3	22.9	5.0
302	303	2	1	1	1.4238E-04	100.0	11.4	0.1	20.4	61.8	8.5	0.5	40.6	23.3	2.6	0.1	5.8	15.4	2.0	0.2	10.8
302	301	4	6	1	5.5537E-09	10.2	82.1	30.7	1.1	21.4	100.0	34.2	1.0	10.2	82.1	30.7	1.1	21.4	100.0	34.2	1.0
302	303	4	2	1	1.1078E-07	25.4	100.0	59.3	4.2	6.4	41.4	39.2	2.8	25.4	100.0	59.3	4.2	6.4	41.4	39.2	2.8
303	302	2	1	1	2.6386E-04	100.0	37.1	0.3	8.5	65.2	20.7	0.1	11.2	23.4	9.8	0.1	2.0	16.2	5.8	0.0	2.6
303	201	3	1	1	1.4788E-05	100.0	77.1	1.9	1.7	26.3	21.2	0.1	3.7	21.2	34.4	3.2	1.1	7.5	14.0	0.8	0.4
303	301	3	1	1	1.4728E-06	100.0	8.0	0.9	17.7	41.7	6.0	3.2	66.7	21.9	1.8	0.5	5.7	10.4	1.4	1.3	18.2
303	302	4	6	1	1.7433E-07	4.4	46.6	51.1	3.3	17.2	100.0	74.3	4.7	4.4	46.6	51.1	3.3	17.2	100.0	74.3	4.7
303	301	4	2	1	2.7857E-09	57.3	100.0	23.2	1.3	14.7	24.0	11.6	1.6	57.3	100.0	23.2	1.3	14.7	24.0	11.6	1.6

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 6, 150.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O L I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.3518E-01	100.0	18.4	0.0	14.7	85.9	15.4	0.0	17.8	24.5	4.4	0.0	3.6	20.9	3.8	0.0	4.2
201	206	3	5	1	1.7853E+00	83.0	17.7	0.0	23.3	100.0	24.1	0.0	17.1	24.2	4.4	0.0	6.0	30.5	6.3	0.0	4.2
201	303	3	1	1	1.4967E-04	100.0	17.3	0.4	18.6	98.4	16.2	0.0	19.0	24.2	4.9	1.5	4.9	23.9	3.8	0.3	4.9
201	202	4	3	1	1.0433E-02	0.0	17.3	100.0	19.0	0.0	14.7	89.5	16.3	0.0	17.3	100.0	19.0	0.0	14.7	89.5	16.3
201	206	4	3	1	1.6216E-01	0.0	27.7	100.0	12.6	0.0	18.6	74.3	7.9	0.0	27.7	100.0	12.6	0.0	18.6	74.3	7.9
202	101	1	7	1	5.7749E-04	0.0	1.9	28.1	5.0	0.7	10.1	100.0	10.3	0.0	0.0	0.4	0.2	0.1	0.7	4.1	0.7
202	102	1	3	1	5.8069E-04	0.0	5.8	100.0	14.0	0.2	3.1	28.0	1.8	0.0	0.4	4.1	1.0	0.0	0.1	0.4	0.1
202	201	4	7	1	2.4744E-04	0.0	10.6	62.7	9.5	0.0	20.3	100.0	18.5	0.0	10.6	62.7	9.5	0.0	20.3	100.0	18.5
202	203	4	3	1	2.6434E-04	0.0	17.5	100.0	18.8	0.0	14.9	89.4	16.0	0.0	17.5	100.0	18.8	0.0	14.9	89.4	16.0
203	202	1	1	1	1.0382E+00	100.0	20.4	0.0	19.0	91.3	17.6	0.0	22.0	28.2	5.0	0.0	4.7	25.3	4.3	0.0	5.5
203	301	1	2	1	3.0899E-05	93.9	100.0	4.8	5.2	27.7	17.3	0.2	4.1	21.6	79.4	18.0	2.9	6.8	21.2	3.3	1.1
203	204	2	5	1	5.7974E-01	81.0	15.8	0.0	18.7	100.0	20.9	0.0	14.1	20.8	3.9	0.0	4.4	26.4	5.1	0.0	3.4
203	202	4	7	1	8.8534E-02	0.0	13.6	87.7	16.7	0.0	16.5	100.0	20.1	0.0	13.6	87.7	16.7	0.0	16.5	100.0	20.1
203	204	4	7	1	4.7073E-02	0.0	17.9	84.5	11.5	0.0	22.5	100.0	14.8	0.0	17.9	84.5	11.5	0.0	22.5	100.0	14.8
204	102	2	7	1	6.0748E-04	0.0	2.3	34.8	3.5	0.2	13.2	100.0	6.1	0.0	0.1	0.5	0.1	0.0	0.9	3.6	0.4
204	103	2	3	1	6.6474E-04	0.0	10.3	100.0	9.7	0.4	5.1	30.3	1.9	0.0	0.8	4.4	0.7	0.1	0.2	0.5	0.0
204	203	4	7	1	9.8091E-05	0.0	21.6	86.9	11.4	0.0	26.6	100.0	12.8	0.0	21.6	86.9	11.4	0.0	26.6	100.0	12.8
204	205	4	7	1	9.5910E-05	0.0	22.1	89.8	10.7	0.0	25.4	100.0	12.7	0.0	22.1	89.8	10.7	0.0	25.4	100.0	12.7
205	204	2	5	1	1.3787E-01	93.8	16.2	0.0	18.3	100.0	17.8	0.0	16.8	22.8	3.9	0.0	4.5	24.5	4.3	0.0	4.1
205	302	2	1	1	2.7392E-05	100.0	24.8	6.2	34.4	55.4	8.1	0.2	23.8	23.5	10.6	24.5	35.1	13.5	4.1	4.3	12.6
205	206	3	1	1	1.9711E+00	100.0	23.7	0.0	16.4	77.0	16.4	0.0	23.8	30.8	6.0	0.0	4.2	22.6	4.2	0.0	6.0
205	204	4	3	1	1.0445E-02	0.0	24.6	100.0	12.9	0.0	22.0	92.6	11.6	0.0	24.6	100.0	12.9	0.0	22.0	92.6	11.6
205	206	4	3	1	2.0628E-01	0.0	26.5	100.0	13.1	0.0	19.4	79.4	9.1	0.0	26.5	100.0	13.1	0.0	19.4	79.4	9.1
206	103	3	7	1	1.8458E-04	0.7	1.9	32.4	3.0	0.6	10.2	100.0	7.2	0.0	0.1	0.5	0.1	0.0	0.7	4.1	0.5
206	101	3	3	1	1.7349E-04	1.2	7.4	100.0	10.4	1.8	3.2	33.1	1.9	0.1	0.5	3.5	0.7	0.1	0.1	0.5	0.1
206	205	4	7	1	3.1607E-03	0.0	20.5	83.6	9.6	0.0	25.9	100.0	12.6	0.0	20.5	83.6	9.6	0.0	25.9	100.0	12.6
206	201	4	7	1	3.2132E-03	0.0	19.8	80.6	9.1	0.0	26.3	100.0	12.6	0.0	19.8	80.6	9.1	0.0	26.3	100.0	12.6
301	203	1	4	1	2.0073E-06	50.5	22.4	55.8	100.0	27.4	3.8	2.2	18.3	10.6	14.0	86.1	73.6	5.7	3.5	14.0	14.5
301	302	1	1	1	5.1883E-04	100.0	15.2	0.0	18.1	83.4	12.9	0.1	22.7	23.9	3.6	0.0	4.6	20.5	3.1	0.0	5.7
301	303	3	1	1	4.6893E-05	100.0	36.7	0.1	8.9	63.3	20.0	0.0	10.7	23.3	9.6	0.1	2.1	15.7	5.6	0.0	2.4
301	302	4	3	1	2.7560E-07	3.3	39.6	100.0	13.5	1.2	26.8	84.3	10.9	3.3	39.6	100.0	13.5	1.2	26.8	84.3	10.9
301	303	4	6	1	2.7218E-08	2.2	46.5	53.5	5.6	9.0	100.0	79.3	5.5	2.2	46.5	53.5	5.6	9.0	100.0	79.3	5.5
302	301	1	1	1	6.5453E-05	100.0	65.9	0.5	2.1	49.0	36.8	0.2	3.9	23.1	18.3	0.2	0.5	12.5	11.1	0.1	0.7
302	205	2	2	1	9.9579E-06	45.7	100.0	16.1	1.4	3.5	7.5	0.5	0.6	8.2	61.9	26.9	1.1	1.0	12.0	4.3	0.3
302	303	2	1	1	5.2159E-05	100.0	7.5	0.1	16.5	36.6	4.3	0.6	52.4	22.4	1.6	0.1	5.0	9.4	1.0	0.3	13.9

302	301	4	6	1	8.5626E-08	3.6	54.5	20.5	0.5	10.0	100.0	40.0	0.6	3.6	54.5	20.5	0.5	10.0	100.0	40.0	0.6
302	303	4	2	1	5.6675E-08	22.7	100.0	39.1	1.6	3.1	26.6	16.1	0.9	22.7	100.0	39.1	1.6	3.1	26.6	16.1	0.9
303	302	2	1	1	5.2156E-04	100.0	24.7	0.1	11.7	79.0	17.6	0.0	14.2	23.8	6.2	0.0	2.8	19.4	4.6	0.0	3.3
303	201	3	5	1	1.0800E-05	98.5	26.3	3.3	14.1	100.0	22.6	0.1	13.4	23.9	9.5	5.2	3.3	24.2	6.7	0.9	2.8
303	301	3	1	1	2.2318E-05	100.0	7.5	0.1	20.2	44.2	4.2	0.2	45.1	22.8	1.6	0.0	6.0	11.3	1.0	0.1	12.0
303	302	4	7	1	2.7144E-07	1.2	34.1	80.9	6.3	7.3	59.5	100.0	8.3	1.2	34.1	80.9	6.3	7.3	59.5	100.0	8.3
303	301	4	2	1	1.8423E-08	11.5	100.0	55.8	1.8	2.9	40.9	26.2	1.4	11.5	100.0	55.8	1.8	2.9	40.9	26.2	1.4

BUFFETING DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S D		<==RELATIVE DAMAGES AROUND THE WELD ====>														
					<-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->						
				DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	4.3682E+00	100.0	21.4	0.0	16.6	85.2	17.3	0.0	20.8	28.1	5.2	0.0	4.1	23.3	4.3	0.0	5.1
201	206	3	5	1	4.2437E+00	87.2	17.4	0.0	21.5	100.0	21.8	0.0	17.3	24.0	4.3	0.0	5.4	28.4	5.5	0.0	4.2
201	303	3	1	1	3.5094E-04	100.0	31.3	2.0	21.6	82.5	15.5	0.1	17.6	24.0	16.2	7.3	10.6	20.0	6.6	1.3	6.0
201	202	4	3	1	3.9633E-01	0.0	17.6	100.0	19.0	0.0	14.4	87.5	15.8	0.0	17.6	100.0	19.0	0.0	14.4	87.5	15.8
201	206	4	3	1	3.4706E-01	0.0	26.7	100.0	12.7	0.0	19.9	80.9	9.3	0.0	26.7	100.0	12.7	0.0	19.9	80.9	9.3
202	101	1	7	1	2.3187E-03	0.1	1.7	27.7	3.9	0.5	11.8	100.0	7.9	0.0	0.1	0.4	0.1	0.1	0.8	4.1	0.6
202	102	1	3	1	2.3306E-03	0.1	7.8	100.0	11.5	0.4	3.2	27.0	1.8	0.0	0.6	4.1	0.8	0.0	0.1	0.4	0.1
202	201	4	7	1	4.8372E-03	0.0	14.3	83.4	14.2	0.0	18.5	100.0	18.3	0.0	14.3	83.4	14.2	0.0	18.5	100.0	18.3
202	203	4	7	1	4.8571E-03	0.0	14.0	81.4	13.7	0.0	18.7	100.0	18.2	0.0	14.0	81.4	13.7	0.0	18.7	100.0	18.2
203	202	1	5	1	4.3299E+00	93.1	18.5	0.0	21.0	100.0	20.7	0.0	19.0	25.6	4.5	0.0	5.2	27.8	5.1	0.0	4.7
203	301	1	1	1	4.6159E-04	100.0	31.9	1.5	17.3	82.8	17.2	0.1	15.6	24.0	16.6	6.0	7.1	20.1	7.4	1.2	4.5
203	204	2	1	1	2.9001E+00	100.0	20.0	0.0	15.8	85.3	16.5	0.0	19.5	26.4	4.8	0.0	3.9	22.2	4.1	0.0	4.7
203	202	4	3	1	3.6182E-01	0.0	17.9	100.0	18.5	0.0	15.3	91.0	16.5	0.0	17.9	100.0	18.5	0.0	15.3	91.0	16.5
203	204	4	3	1	2.3543E-01	0.0	24.9	100.0	13.1	0.0	20.8	88.6	11.2	0.0	24.9	100.0	13.1	0.0	20.8	88.6	11.2
204	102	2	7	1	2.9186E-03	0.1	2.0	30.4	3.4	0.4	11.0	100.0	8.2	0.0	0.1	0.4	0.1	0.0	0.7	3.8	0.6
204	103	2	3	1	3.2073E-03	0.1	7.4	100.0	12.5	0.3	3.7	26.6	1.4	0.0	0.6	4.5	0.9	0.0	0.1	0.4	0.0
204	203	4	7	1	3.8063E-03	0.0	19.3	79.0	8.9	0.0	26.4	100.0	12.7	0.0	19.3	79.0	8.9	0.0	26.4	100.0	12.7
204	205	4	7	1	3.7365E-03	0.0	21.5	87.4	10.3	0.0	25.7	100.0	12.6	0.0	21.5	87.4	10.3	0.0	25.7	100.0	12.6
205	204	2	5	1	4.2018E+00	94.3	18.7	0.0	21.1	100.0	20.6	0.0	19.3	26.0	4.6	0.0	5.2	27.8	5.1	0.0	4.8
205	302	2	1	1	3.3168E-04	100.0	40.7	3.0	20.1	76.0	16.1	0.1	16.0	23.8	26.5	12.7	11.1	18.4	9.5	2.8	5.9
205	206	3	1	1	4.7154E+00	100.0	22.0	0.0	16.5	82.8	17.0	0.0	21.6	28.7	5.5	0.0	4.1	23.0	4.3	0.0	5.3
205	204	4	3	1	3.7282E-01	0.0	24.7	100.0	13.0	0.0	22.0	92.4	11.7	0.0	24.7	100.0	13.0	0.0	22.0	92.4	11.7
205	206	4	3	1	4.5345E-01	0.0	25.5	100.0	13.2	0.0	20.2	84.8	10.4	0.0	25.5	100.0	13.2	0.0	20.2	84.8	10.4
206	103	3	7	1	2.9602E-03	0.1	1.4	27.0	3.4	0.2	12.5	100.0	7.1	0.0	0.0	0.4	0.1	0.0	0.9	4.5	0.6
206	101	3	3	1	2.7148E-03	0.2	8.2	100.0	10.7	0.4	3.4	29.8	1.8	0.0	0.6	3.8	0.7	0.0	0.1	0.4	0.0
206	205	4	7	1	6.0119E-03	0.0	20.6	84.0	9.7	0.0	25.9	100.0	12.6	0.0	20.6	84.0	9.7	0.0	25.9	100.0	12.6
206	201	4	7	1	6.1149E-03	0.0	19.8	80.5	9.1	0.0	26.3	100.0	12.7	0.0	19.8	80.5	9.1	0.0	26.3	100.0	12.7
301	203	1	1	1	4.1870E-05	100.0	57.9	13.2	26.9	79.3	18.7	0.7	14.0	22.7	29.4	21.5	12.7	19.0	9.5	4.2	5.1

301	302	1	1	1	1.0010E-03	100.0	14.3	0.0	18.4	79.4	12.1	0.1	26.0	23.8	3.4	0.0	4.8	19.5	2.9	0.1	6.6
301	303	3	1	1	9.6257E-04	100.0	32.2	0.2	10.2	72.3	19.8	0.0	12.5	23.6	8.3	0.1	2.4	17.8	5.4	0.0	2.9
301	302	4	3	1	5.3046E-07	7.2	58.4	100.0	12.7	1.8	31.3	80.5	10.2	7.2	58.4	100.0	12.7	1.8	31.3	80.5	10.2
301	303	4	6	1	4.7681E-07	3.6	49.9	72.4	5.6	15.4	100.0	96.0	7.1	3.6	49.9	72.4	5.6	15.4	100.0	96.0	7.1
302	301	1	1	1	7.1088E-04	100.0	33.9	0.2	10.4	73.0	21.1	0.1	12.4	23.6	8.9	0.1	2.5	18.0	5.8	0.0	2.9
302	205	2	1	1	3.4313E-05	100.0	82.1	24.1	31.6	67.6	21.1	1.3	12.0	22.1	47.5	42.4	19.4	16.2	14.4	8.8	5.9
302	303	2	1	1	9.1756E-04	100.0	13.6	0.1	19.1	75.3	11.2	0.2	29.1	23.7	3.2	0.0	5.1	18.6	2.7	0.1	7.5
302	301	4	7	1	3.7547E-07	2.8	47.8	74.4	9.1	11.5	97.1	100.0	10.8	2.8	47.8	74.4	9.1	11.5	97.1	100.0	10.8
302	303	4	3	1	4.4485E-07	15.3	88.2	100.0	8.4	4.4	46.9	78.0	6.4	15.3	88.2	100.0	8.4	4.4	46.9	78.0	6.4
303	302	2	1	1	1.1214E-03	100.0	31.5	0.2	9.9	72.6	20.3	0.0	12.4	23.6	8.2	0.1	2.4	17.9	5.5	0.0	2.9
303	201	3	1	1	3.5316E-05	100.0	92.2	16.7	16.5	53.6	19.9	0.8	8.5	21.4	48.2	25.3	8.2	13.1	13.3	4.4	2.9
303	301	3	1	1	6.1571E-04	100.0	12.6	0.1	18.8	69.2	9.9	0.3	32.3	23.5	2.9	0.0	5.1	17.1	2.4	0.1	8.4
303	302	4	7	1	5.6470E-07	3.4	52.5	75.3	5.4	13.0	97.3	100.0	7.2	3.4	52.5	75.3	5.4	13.0	97.3	100.0	7.2
303	301	4	2	1	3.3197E-07	18.5	100.0	93.3	7.0	4.7	46.3	67.6	5.1	18.5	100.0	93.3	7.0	4.7	46.3	67.6	5.1

20 WORST BUFFETING DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
205	206	3	1	1	4.7154E+00	100.0	22.0	0.0	16.5	82.8	17.0	0.0	21.6	28.7	5.5	0.0	4.1	23.0	4.3	0.0	5.3
201	202	1	1	1	4.3682E+00	100.0	21.4	0.0	16.6	85.2	17.3	0.0	20.8	28.1	5.2	0.0	4.1	23.3	4.3	0.0	5.1
203	202	1	5	1	4.3299E+00	93.1	18.5	0.0	21.0	100.0	20.7	0.0	19.0	25.6	4.5	0.0	5.2	27.8	5.1	0.0	4.7
201	206	3	5	1	4.2437E+00	87.2	17.4	0.0	21.5	100.0	21.8	0.0	17.3	24.0	4.3	0.0	5.4	28.4	5.5	0.0	4.2
205	204	2	5	1	4.2018E+00	94.3	18.7	0.0	21.1	100.0	20.6	0.0	19.3	26.0	4.6	0.0	5.2	27.8	5.1	0.0	4.8
203	204	2	1	1	2.9001E+00	100.0	20.0	0.0	15.8	85.3	16.5	0.0	19.5	26.4	4.8	0.0	3.9	22.2	4.1	0.0	4.7
205	206	4	3	1	4.5345E-01	0.0	25.5	100.0	13.2	0.0	20.2	84.8	10.4	0.0	25.5	100.0	13.2	0.0	20.2	84.8	10.4
201	202	4	3	1	3.9633E-01	0.0	17.6	100.0	19.0	0.0	14.4	87.5	15.8	0.0	17.6	100.0	19.0	0.0	14.4	87.5	15.8
205	204	4	3	1	3.7282E-01	0.0	24.7	100.0	13.0	0.0	22.0	92.4	11.7	0.0	24.7	100.0	13.0	0.0	22.0	92.4	11.7
203	202	4	3	1	3.6182E-01	0.0	17.9	100.0	18.5	0.0	15.3	91.0	16.5	0.0	17.9	100.0	18.5	0.0	15.3	91.0	16.5
201	206	4	3	1	3.4706E-01	0.0	26.7	100.0	12.7	0.0	19.9	80.9	9.3	0.0	26.7	100.0	12.7	0.0	19.9	80.9	9.3
203	204	4	3	1	2.3543E-01	0.0	24.9	100.0	13.1	0.0	20.8	88.6	11.2	0.0	24.9	100.0	13.1	0.0	20.8	88.6	11.2
206	201	4	7	1	6.1149E-03	0.0	19.8	80.5	9.1	0.0	26.3	100.0	12.7	0.0	19.8	80.5	9.1	0.0	26.3	100.0	12.7
206	205	4	7	1	6.0119E-03	0.0	20.6	84.0	9.7	0.0	25.9	100.0	12.6	0.0	20.6	84.0	9.7	0.0	25.9	100.0	12.6
202	203	4	7	1	4.8571E-03	0.0	14.0	81.4	13.7	0.0	18.7	100.0	18.2	0.0	14.0	81.4	13.7	0.0	18.7	100.0	18.2
202	201	4	7	1	4.8372E-03	0.0	14.3	83.4	14.2	0.0	18.5	100.0	18.3	0.0	14.3	83.4	14.2	0.0	18.5	100.0	18.3
204	203	4	7	1	3.8063E-03	0.0	19.3	79.0	8.9	0.0	26.4	100.0	12.7	0.0	19.3	79.0	8.9	0.0	26.4	100.0	12.7
204	205	4	7	1	3.7365E-03	0.0	21.5	87.4	10.3	0.0	25.7	100.0	12.6	0.0	21.5	87.4	10.3	0.0	25.7	100.0	12.6
204	103	2	3	1	3.2073E-03	0.1	7.4	100.0	12.5	0.3	3.7	26.6	1.4	0.0	0.6	4.5	0.9	0.0	0.1	0.4	0.0
206	103	3	7	1	2.9602E-03	0.1	1.4	27.0	3.4	0.2	12.5	100.0	7.1	0.0	0.0	0.4	0.1	0.0	0.9	4.5	0.6

```
BUFFETING DAMAGE EVALUATED FOR 42 JOINT CONNECTIONS OVER ALL ANALYSIS PLANES
--------------------------------------------------------------------------------


 ************************************************************************

 PRINT OF                : WIND FATIGUE RESULTS

 RUN NAME                : X505B
 RUN DESCRIPTION         : None
 RESULTS INTERFACE FILE  : X505BR1.SIN
 PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  15:44:59

 ************************************************************************

 RUN SCENARIO:
 =============
 ANALYSIS CASE              : MULTI BRACE FATIGUE CHECK
 FIRST WIND DIRECTION       : 1
 LAST  WIND DIRECTION       : 6
 FIRST NODE CHECKED         : 101
 LAST  NODE CHECKED         : 303
 FIRST ANALYSIS PLANE       : 1
 LAST  ANALYSIS PLANE       : 4
 NUMBER OF EIGENMODES       : 2
 SHOW PROGRESS OF EXECUTION : OFF

 WIND LOAD MODELLING:
 ====================
 WIND LOAD TYPE             : WIND BUFFETING
 WIDE BAND CORRECTION       : NONE
 WIND PROFILE               : API (WIND PROFILE TYPE READ FROM SIN FILE)
 GUST COMPONENTS CONSIDERED : ALL (ALONG + ACROSS WIND COMPONENTS)
 GUST DIRECTION MOMENT      : DAMAGE BY ADD OF GUST SPECTRUM MOMENTS
 WIND SPECTRA :
     LONGITUDINAL DIRECTION : DAVENPORT
     LATERAL      DIRECTION : PANOFSKY LATERAL
     VERTICAL     DIRECTION : PANOFSKY VERTICAL
 COHERENCE FUNCTIONS :
     LONGITUDINAL DIRECTION : GUST02
     LATERAL      DIRECTION : GUST02
     VERTICAL     DIRECTION : GUST02

 INPUT DATA:
```

```
===========

PARAMETERS READ FROM SIN FILE :
(l = current length unit)
------------------------------

WATER DEPTH - WD  (l)                          : 10.0
Z-COORDINATE OF MUDLINE - ZMUD  (l)            : -10.0
Z-COORDINATE OF STILL WATER LEVEL/GROUND  (l)   : 0.0
                      (Z0 = ZMUD + WD)
WIND DIRECTIONS (RELATIVE TO GLOBAL X-AXIS)    : DIR  ANGLE (deg)
                                                 1    0.0
                                                 2    30.0
                                                 3    60.0
                                                 4    90.0
                                                 5    120.0
                                                 6    150.0
MEAN WIND VELOCITY  (l/sec)                    : 30.0
MEAN WIND VELOCITY LEVEL  (l)                  : 10.0
HEIGHT EXPONENT, API WIND PROFILE              : .125
GUST FACTOR, API WIND PROFILE                  : 1.0
ACCELERATION OF GRAVITY (g)  (l/sec^2)         : 9.81
UNIT LENGTH ADJUSTMENT FACTOR (9.81/g)         : 1.0

DIRECT INPUT PARAMETERS :
(l = current length unit)
-------------------------

DAMAGE CALCULATION OF BENT CAN JOINTS          : ON
COHERENCE FUNCTION CONSTANT (GUSTO, DAVENPORT) : 8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz ALONG DIR.  : 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz LATERAL DIR.: 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz VERTICAL DIR: 16.0   16.0   8.0
GROUND ROUGNESS COEFFICIENT                    : 1.5E-02
TURBULENCE LENGTH SCALE DAVENPORT SPECTRUM  (l) : 1200.0
TURBULENCE LENGTH SCALE HARRIS SPECTRUM  (l)   : 1800.0
DEFAULT SN CURVE                               : DOE-T
MINIMUM PARAMETRIC SCFS                        : 1.6    1.6    1.6
DEFAULT GLOBAL SCFS                            : 1.6    1.6    1.6
DEFAULT SCF SCHEME, Alt.: EFTHYMIOU, LLOYDS    : EFTHYMIOU
(New default overrules previously assigned SCFs)
DAMPING RATIO                                  : 1.0E-02
CHORD LENGTH/DIAMETER RATIO (L/D)              : 30.0
ANGULAR TOLERANCE ANALYSIS PLANES (DEG)        : 1.0
```

```
LIMIT FOR PRINTING DAMAGE VALUES                  : 1.0E-12
MIN. WIND FORCE USED RELATIVE TO MAX.             : 1.000E-05
LIMIT VALUE ON COHERENCE EFFECT                   : 1.000E-03
(NO COHERENCE = 1.0, FULL COHERENCE = 0 in limit)
NUMBER OF WIND SPEEDS                             : 5

WIND PROBABILITIES AND DRAG CORRECTION COEFFICIENT
-----------------------------------------------------------
   DIR    WIND          WIND          WIND    DRAG COEFF
    NO   SPEED         SPEED   PROBABILITY    CORRECTION
           NO                                    FACTORS
     1      1        10.0000        0.3000        1.0000
     1      2        15.0000        0.2500        0.9000
     1      3        20.0000        0.2000        0.8000
     1      4        25.0000        0.1500        0.7500
     1      5        30.0000        0.1000        0.7000
     2      1        10.0000        0.3500        1.0100
     2      2        15.0000        0.2000        0.9100
     2      3        20.0000        0.2000        0.8100
     2      4        25.0000        0.1500        0.7600
     2      5        30.0000        0.1000        0.7100
     3      1        10.0000        0.4000        1.0200
     3      2        15.0000        0.2000        0.9200
     3      3        20.0000        0.1500        0.8200
     3      4        25.0000        0.1500        0.7700
     3      5        30.0000        0.1000        0.7200
     4      1        10.0000        0.2000        1.0300
     4      2        15.0000        0.2000        0.9300
     4      3        20.0000        0.2000        0.8300
     4      4        25.0000        0.2000        0.7800
     4      5        30.0000        0.2000        0.7300
     5      1        10.0000        0.3000        1.0400
     5      2        15.0000        0.2500        0.9400
     5      3        20.0000        0.2000        0.8400
     5      4        25.0000        0.1500        0.7900
     5      5        30.0000        0.1000        0.7400
     6      1        10.0000        0.3600        1.0500
     6      2        15.0000        0.2200        0.9500
     6      3        20.0000        0.2100        0.8500
     6      4        25.0000        0.1100        0.8000
     6      5        30.0000        0.1000        0.7500

NODES DEFINING THE ANALYSIS PLANES:
 1    101    203    301
```

```
  2    102    205    302
  3    103    201    303
  4    201    203    205


 NUMBER OF COHERENCE MATRICES FOR THE U, V AND W  WIND GUST DIRECTIONS :   1
 Note! 1,2 or 3 coherence matrices are formed depending on the choice of
       wind spectrum and coherence models. Theexecution time increases
       with the number of coherence matrices applied in the run.

 ************************************************************************

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-12)
================================================================================
      N       N P P S                                                <==RELATIVE DAMAGES AROUND THE WELD ====>
      O       O L O I                  | <--     Side 1: Chord side points       -->  | <--     Side 2: Brace side points       --> |
      D       D A S D                                                                                                                 |
      E       E N N E                                                                                                                 |
      1       2 E              DAMAGE     1     2     3     4     5     6     7     8     1     2     3     4     5     6     7     8

    201     202 1 1 1       5.0537E-02 100.0  18.3   0.0  16.0  93.6  17.1   0.0  17.5  24.3   4.4   0.0   3.9  22.7   4.2   0.0   4.2
    201     206 3 5 1       2.3718E-01  93.4  16.4   0.0  18.5 100.0  18.2   0.0  16.8  23.0   4.0   0.0   4.5  24.8   4.4   0.0   4.1
    201     303 3 1 1       9.6645E-05 100.0  41.5   0.2   3.3  46.8  16.2   0.0   9.1  23.8  18.7   0.9   1.0  11.6   8.6   0.2   1.0
    201     202 4 3 1       3.9054E-03   0.0  16.9 100.0  19.1   0.0  15.5  95.3  18.2   0.0  16.9 100.0  19.1   0.0  15.5  95.3  18.2
    201     206 4 3 1       1.6104E-02   0.0  24.9 100.0  12.8   0.0  22.0  91.4  11.3   0.0  24.9 100.0  12.8   0.0  22.0  91.4  11.3
    202     101 1 7 1       9.5878E-04   0.0   1.1  21.9   1.9   0.0  10.5 100.0   7.5   0.0   0.0   0.2   0.0   0.0   0.8   4.3   0.6
    202     102 1 3 1       9.5702E-04   0.0   7.6 100.0  10.4   0.0   1.9  21.9   1.1   0.0   0.6   4.3   0.8   0.0   0.0   0.2   0.0
    202     201 4 7 1       4.2776E-05   0.0  14.2  82.9  14.1   0.0  18.5 100.0  18.3   0.0  14.2  82.9  14.1   0.0  18.5 100.0  18.3
    202     203 4 7 1       4.2881E-05   0.1  14.2  82.6  14.0   0.0  18.7 100.0  18.2   0.1  14.2  82.6  14.0   0.0  18.7 100.0  18.2
    203     202 1 5 1       5.4343E-02  98.6  17.1   0.0  18.1 100.0  17.6   0.0  17.9  23.9   4.1   0.0   4.4  24.3   4.3   0.0   4.4
    203     301 1 3 2       1.1936E-05  66.3  46.0  25.3  18.1  62.7  17.4   1.1  16.0  16.0  63.1 100.0  19.6  15.2  17.1  21.4  10.7
    203     204 2 1 1       2.1552E-01 100.0  18.6   0.0  14.7  85.4  15.4   0.0  18.0  24.7   4.5   0.0   3.6  20.9   3.8   0.0   4.3
    203     202 4 3 1       3.8476E-03   0.0  17.2 100.0  18.6   0.0  16.4  98.3  18.8   0.0  17.2 100.0  18.6   0.0  16.4  98.3  18.8
    203     204 4 3 1       1.6266E-02   0.0  24.5 100.0  13.2   0.0  20.9  89.0  11.1   0.0  24.5 100.0  13.2   0.0  20.9  89.0  11.1
    204     102 2 7 1       5.7101E-05   0.3   2.8  33.1   5.1   0.6  16.0 100.0   7.0   0.0   0.1   0.5   0.2   0.1   1.0   3.7   0.5
    204     103 2 3 1       6.6348E-05   0.4  14.3 100.0   9.6   0.5   3.5  23.9   2.9   0.1   1.1   4.5   0.7   0.1   0.1   0.3   0.1
    204     203 4 7 1       1.6942E-04   0.0  21.4  86.9  10.2   0.0  25.7 100.0  12.6   0.0  21.4  86.9  10.2   0.0  25.7 100.0  12.6
    204     205 4 7 1       1.6992E-04   0.0  18.9  76.7   8.5   0.0  26.7 100.0  12.7   0.0  18.9  76.7   8.5   0.0  26.7 100.0  12.7
    205     204 2 5 1       1.0432E-01  79.8  13.7   0.0  18.3 100.0  19.0   0.0  13.3  19.2   3.3   0.0   4.5  24.5   4.7   0.0   3.2
    205     302 2 5 1       5.0356E-05  46.8   8.2   0.6  53.1 100.0   7.8   0.0  18.4  11.6   5.8   2.9  30.0  23.4   2.1   0.7  13.1
    205     206 3 1 1       1.0360E-01 100.0  18.3   0.0  11.9  69.3  11.8   0.0  18.6  24.5   4.3   0.0   2.9  16.7   2.9   0.0   4.4
    205     204 4 3 1       7.9401E-03   0.0  27.6 100.0  12.4   0.0  19.1  76.5   8.5   0.0  27.6 100.0  12.4   0.0  19.1  76.5   8.5
    205     206 4 3 1       7.8717E-03   0.0  26.7 100.0  12.8   0.0  18.6  76.8   8.7   0.0  26.7 100.0  12.8   0.0  18.6  76.8   8.7
    206     103 3 7 1       6.2782E-05   0.4   3.0  25.9   4.0   0.6   9.9 100.0  14.4   0.1   0.1   0.4   0.2   0.1   0.7   4.5   1.1
```

206	101	3	3	1	5.7280E-05	0.3	7.0	100.0	15.8	0.6	4.6	29.3	2.3	0.0	0.5	3.8	1.0	0.1	0.1	0.4	0.1
206	205	4	7	1	1.6841E-04	0.0	19.1	78.0	8.7	0.0	26.5	100.0	12.7	0.0	19.1	78.0	8.7	0.0	26.5	100.0	12.7
206	201	4	7	1	1.6863E-04	0.0	21.8	88.0	10.3	0.0	25.8	100.0	12.5	0.0	21.8	88.0	10.3	0.0	25.8	100.0	12.5
301	203	1	3	2	4.2609E-06	11.1	57.9	60.7	11.2	7.2	4.8	3.5	4.4	2.3	51.6	100.0	14.5	1.8	8.3	20.3	4.4
301	302	1	1	1	5.2058E-05	100.0	7.5	0.3	26.4	47.6	5.7	1.3	64.7	22.8	1.7	0.2	8.2	12.0	1.4	0.5	17.9
301	303	3	1	1	7.1598E-06	100.0	38.9	0.4	9.6	86.5	33.7	0.2	11.2	24.0	10.6	0.2	2.2	21.2	9.3	0.1	2.6
301	302	4	2	1	8.0667E-08	22.8	100.0	33.6	2.1	5.3	36.7	16.7	1.6	22.8	100.0	33.6	2.1	5.3	36.7	16.7	1.6
301	303	4	6	1	4.7770E-09	11.1	82.0	60.9	4.2	22.6	100.0	70.0	4.7	11.1	82.0	60.9	4.2	22.6	100.0	70.0	4.7
302	301	1	1	1	8.3114E-05	100.0	65.5	0.9	3.7	41.9	27.8	0.2	5.6	22.7	18.0	0.4	0.9	10.7	8.6	0.1	1.2
302	205	2	1	1	1.5161E-05	100.0	77.3	1.9	1.8	28.2	21.9	0.1	3.8	21.3	36.3	3.7	1.3	8.0	15.1	0.9	0.4
302	303	2	1	1	5.5888E-06	100.0	14.4	0.1	17.3	77.3	11.9	0.6	28.5	23.6	3.4	0.1	4.5	19.0	2.9	0.3	7.3
302	301	4	6	1	1.2056E-07	4.0	39.6	15.8	1.1	16.5	100.0	35.8	1.4	4.0	39.6	15.8	1.1	16.5	100.0	35.8	1.4
302	303	4	3	1	2.7332E-09	43.8	97.6	100.0	8.9	9.5	39.8	80.1	7.5	43.8	97.6	100.0	8.9	9.5	39.8	80.1	7.5
303	302	2	1	1	2.5945E-05	100.0	29.9	0.2	11.0	76.6	19.7	0.0	13.2	23.7	7.7	0.1	2.6	18.9	5.3	0.0	3.1
303	201	3	5	1	3.6364E-06	28.5	13.9	3.5	72.1	100.0	6.1	0.3	13.6	7.4	7.8	6.0	30.1	20.5	2.3	1.6	9.1
303	301	3	1	1	2.4437E-05	100.0	14.0	0.1	22.6	82.6	11.7	0.1	27.7	23.9	3.3	0.1	6.1	20.3	2.8	0.1	7.2
303	302	4	7	1	1.3215E-08	3.2	47.3	79.2	6.5	17.8	91.3	100.0	8.0	3.2	47.3	79.2	6.5	17.8	91.3	100.0	8.0
303	301	4	3	1	1.2635E-08	10.9	77.1	100.0	8.3	7.6	60.3	83.7	6.5	10.9	77.1	100.0	8.3	7.6	60.3	83.7	6.5

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 2, 30.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points --> | <-- Side 2: Brace side points --> |															
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	2.5133E-01	100.0	18.7	0.0	14.2	82.3	14.8	0.0	18.3	24.9	4.5	0.0	3.5	20.2	3.6	0.0	4.4
201	206	3	5	1	2.9107E-01	91.1	16.1	0.0	18.6	100.0	18.6	0.0	16.4	22.5	3.9	0.0	4.6	25.0	4.5	0.0	4.0
201	303	3	1	1	3.0649E-05	100.0	96.4	4.0	4.8	29.2	17.2	0.1	5.3	23.3	71.4	13.8	2.4	7.2	18.9	2.4	1.2
201	202	4	3	1	1.9521E-02	0.0	17.7	100.0	18.9	0.0	14.2	86.5	15.6	0.0	17.7	100.0	18.9	0.0	14.2	86.5	15.6
201	206	4	3	1	2.0011E-02	0.0	25.5	100.0	12.7	0.0	21.4	88.3	10.8	0.0	25.5	100.0	12.7	0.0	21.4	88.3	10.8
202	101	1	7	1	5.3552E-04	0.0	0.8	24.2	3.4	0.2	14.6	100.0	5.0	0.0	0.0	0.3	0.1	0.0	1.0	4.1	0.4
202	102	1	3	1	5.3312E-04	0.1	10.6	100.0	7.3	0.1	1.5	24.0	2.1	0.0	0.8	4.1	0.5	0.0	0.0	0.3	0.0
202	201	4	7	1	2.6757E-04	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3
202	203	4	7	1	2.6817E-04	0.0	14.1	82.3	13.9	0.0	18.6	100.0	18.3	0.0	14.1	82.3	13.9	0.0	18.6	100.0	18.3
203	202	1	5	1	2.6861E-01	90.2	15.8	0.0	18.6	100.0	18.5	0.0	16.1	22.2	3.8	0.0	4.5	24.9	4.5	0.0	3.9
203	301	1	1	1	1.4801E-05	100.0	28.8	9.0	46.3	59.2	9.5	0.3	23.6	23.6	13.9	32.6	47.5	14.3	5.5	5.5	14.5
203	204	2	1	1	2.6421E-01	100.0	18.7	0.0	14.2	82.1	14.7	0.0	18.3	24.9	4.5	0.0	3.5	20.1	3.6	0.0	4.4
203	202	4	3	1	1.9664E-02	0.0	18.1	100.0	18.4	0.0	14.8	87.7	15.5	0.0	18.1	100.0	18.4	0.0	14.8	87.7	15.5
203	204	4	3	1	1.9928E-02	0.0	25.0	100.0	13.1	0.0	20.3	86.2	10.6	0.0	25.0	100.0	13.1	0.0	20.3	86.2	10.6
204	102	2	7	1	1.4152E-04	0.2	2.6	39.6	4.4	0.4	10.6	100.0	7.4	0.0	0.1	0.6	0.2	0.0	0.7	3.4	0.5
204	103	2	3	1	1.5940E-04	0.1	7.0	100.0	10.8	0.3	3.6	31.8	1.7	0.0	0.5	4.1	0.8	0.0	0.1	0.5	0.1
204	203	4	7	1	2.7264E-04	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7

204	205	4	7	1	2.7024E-04	0.0	20.2	82.1	9.4	0.0	26.2	100.0	12.6	0.0	20.2	82.1	9.4	0.0	26.2	100.0	12.6
205	204	2	5	1	2.5807E-01	89.8	15.7	0.0	18.6	100.0	18.5	0.0	16.0	22.1	3.8	0.0	4.5	24.9	4.5	0.0	3.9
205	302	2	1	1	1.3692E-04	100.0	17.0	0.5	18.9	99.1	16.2	0.0	19.2	24.2	4.9	2.0	5.1	24.0	3.8	0.4	5.1
205	206	3	1	1	2.5707E-01	100.0	18.7	0.0	14.2	82.0	14.7	0.0	18.3	24.9	4.5	0.0	3.5	20.1	3.6	0.0	4.4
205	204	4	3	1	1.9916E-02	0.0	25.5	100.0	12.8	0.0	21.1	87.8	10.8	0.0	25.5	100.0	12.8	0.0	21.1	87.8	10.8
205	206	4	3	1	2.0444E-02	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.7	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.7
206	103	3	7	1	5.7236E-04	0.1	1.9	22.2	1.4	0.1	7.1	100.0	10.9	0.0	0.0	0.3	0.0	0.0	0.6	4.5	0.8
206	101	3	3	1	5.2211E-04	0.0	5.4	100.0	13.8	0.2	3.4	26.1	1.0	0.0	0.4	3.7	0.9	0.0	0.1	0.3	0.0
206	205	4	7	1	2.7457E-04	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7
206	201	4	7	1	2.7834E-04	0.0	20.4	82.6	9.4	0.0	26.2	100.0	12.6	0.0	20.4	82.6	9.4	0.0	26.2	100.0	12.6
301	203	1	2	1	8.2556E-06	49.6	100.0	14.3	1.1	3.0	7.2	0.5	0.5	8.8	57.5	22.0	0.8	0.9	10.6	3.4	0.2
301	302	1	1	1	5.6970E-05	100.0	8.7	0.1	18.0	48.1	6.5	0.6	49.5	22.7	2.0	0.1	5.3	12.1	1.6	0.3	13.2
301	303	3	1	1	8.4379E-05	100.0	51.3	0.3	4.9	57.9	30.2	0.1	7.0	23.3	14.0	0.1	1.1	14.6	8.8	0.1	1.5
301	302	4	2	1	5.7343E-08	17.5	100.0	51.6	3.6	2.2	28.0	25.9	2.9	17.5	100.0	51.6	3.6	2.2	28.0	25.9	2.9
301	303	4	6	1	8.0353E-08	4.8	55.7	27.4	1.3	12.5	100.0	45.2	1.6	4.8	55.7	27.4	1.3	12.5	100.0	45.2	1.6
302	301	1	1	1	7.4930E-05	100.0	48.0	0.6	7.3	55.8	20.3	0.1	9.2	23.0	12.8	0.3	1.7	13.9	5.9	0.1	2.1
302	205	2	5	1	1.3970E-05	99.5	25.0	2.8	14.1	100.0	22.5	0.1	13.7	24.1	8.9	5.0	3.4	24.2	6.7	0.9	2.8
302	303	2	1	1	4.3755E-05	100.0	12.1	0.0	18.0	66.3	9.1	0.1	30.3	23.5	2.8	0.0	4.8	16.5	2.2	0.0	7.8
302	301	4	6	1	7.1976E-08	2.6	32.3	31.4	3.3	17.8	100.0	54.3	4.0	2.6	32.3	31.4	3.3	17.8	100.0	54.3	4.0
302	303	4	3	1	2.0768E-08	7.3	88.6	100.0	6.9	1.7	43.8	69.3	5.2	7.3	88.6	100.0	6.9	1.7	43.8	69.3	5.2
303	302	2	1	1	4.7494E-05	100.0	34.6	0.1	7.7	61.9	19.5	0.0	10.6	23.4	9.0	0.0	1.8	15.5	5.4	0.0	2.4
303	201	3	4	1	1.4231E-06	47.3	23.7	61.3	100.0	25.0	3.6	2.3	17.5	9.8	15.2	88.0	70.8	5.0	3.5	13.4	13.1
303	301	3	1	1	5.5832E-05	100.0	10.6	0.3	27.0	64.8	8.2	0.6	46.2	23.4	2.4	0.1	7.9	16.1	2.0	0.3	12.7
303	302	4	6	1	2.5821E-08	2.2	48.4	58.6	3.9	8.6	100.0	90.1	5.1	2.2	48.4	58.6	3.9	8.6	100.0	90.1	5.1
303	301	4	2	1	5.4148E-08	24.1	100.0	49.5	3.3	9.8	53.4	33.9	2.4	24.1	100.0	49.5	3.3	9.8	53.4	33.9	2.4

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 3, 60.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I D		<==RELATIVE DAMAGES AROUND THE WELD ====>														
					<-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->						
				DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	2.3001E-01	100.0	18.7	0.0	14.7	85.0	15.3	0.0	18.0	24.8	4.5	0.0	3.6	20.8	3.8	0.0	4.3
201	206	3	5	1	6.8729E-02	98.3	17.0	0.0	18.1	100.0	17.6	0.0	17.9	23.9	4.1	0.0	4.4	24.3	4.3	0.0	4.3
201	303	3	3	2	1.0898E-05	78.7	53.7	27.4	20.1	72.8	18.6	1.1	19.4	18.9	68.9	100.0	18.7	17.7	16.8	19.2	11.4
201	202	4	3	1	1.7928E-02	0.0	17.4	100.0	19.0	0.0	14.5	88.6	16.1	0.0	17.4	100.0	19.0	0.0	14.5	88.6	16.1
201	206	4	3	1	4.5612E-03	0.0	24.5	100.0	12.9	0.0	23.3	98.0	13.0	0.0	24.5	100.0	12.9	0.0	23.3	98.0	13.0
202	101	1	7	1	6.4750E-05	0.2	2.4	29.5	5.0	0.7	17.8	100.0	6.7	0.0	0.1	0.4	0.1	0.1	1.2	4.0	0.5
202	102	1	3	1	6.6814E-05	0.4	13.1	100.0	9.9	0.7	3.7	25.7	3.0	0.0	0.9	4.2	0.7	0.1	0.1	0.3	0.1
202	201	4	7	1	1.8785E-04	0.0	14.9	86.6	14.9	0.0	18.3	100.0	18.2	0.0	14.9	86.6	14.9	0.0	18.3	100.0	18.2
202	203	4	7	1	1.9043E-04	0.0	13.2	77.1	12.7	0.0	19.0	100.0	18.4	0.0	13.2	77.1	12.7	0.0	19.0	100.0	18.4
203	202	1	5	1	1.2277E-01	80.9	13.9	0.0	18.4	100.0	18.9	0.0	13.6	19.5	3.3	0.0	4.5	24.6	4.6	0.0	3.3

203	301	1	5	1	4.9983E-05	50.2	9.5	0.5	48.7	100.0	8.7	0.0	17.5	12.4	6.0	2.4	25.2	23.6	2.2	0.6	10.9
203	204	2	1	1	1.2254E-01	100.0	18.4	0.0	12.0	70.2	12.0	0.0	18.5	24.6	4.4	0.0	3.0	16.9	3.0	0.0	4.4
203	202	4	3	1	8.9201E-03	0.0	19.4	100.0	18.1	0.0	13.2	76.9	12.7	0.0	19.4	100.0	18.1	0.0	13.2	76.9	12.7
203	204	4	3	1	8.8628E-03	0.0	26.3	100.0	13.0	0.0	18.5	77.2	8.9	0.0	26.3	100.0	13.0	0.0	18.5	77.2	8.9
204	102	2	7	1	6.4364E-05	0.3	2.7	30.0	4.5	0.8	9.8	100.0	12.1	0.0	0.1	0.4	0.2	0.1	0.6	3.8	0.8
204	103	2	3	1	7.0814E-05	0.2	7.0	100.0	18.5	0.8	5.3	25.8	1.9	0.0	0.6	4.5	1.3	0.1	0.2	0.4	0.1
204	203	4	7	1	1.9021E-04	0.0	19.1	78.3	8.8	0.0	26.3	100.0	12.8	0.0	19.1	78.3	8.8	0.0	26.3	100.0	12.8
204	205	4	7	1	1.8631E-04	0.0	21.6	87.6	10.3	0.0	25.7	100.0	12.6	0.0	21.6	87.6	10.3	0.0	25.7	100.0	12.6
205	204	2	5	1	2.3582E-01	92.8	16.2	0.0	18.6	100.0	18.2	0.0	16.7	22.8	3.9	0.0	4.5	24.8	4.4	0.0	4.0
205	302	2	1	1	1.0250E-04	100.0	41.8	0.3	3.4	44.8	15.4	0.0	9.2	23.5	19.7	1.3	1.3	11.2	8.9	0.4	1.0
205	206	3	1	1	6.0415E-02	100.0	18.4	0.0	15.8	93.0	17.1	0.0	17.5	24.3	4.4	0.0	3.8	22.5	4.2	0.0	4.2
205	204	4	3	1	1.8104E-02	0.0	24.8	100.0	12.9	0.0	21.8	91.3	11.4	0.0	24.8	100.0	12.9	0.0	21.8	91.3	11.4
205	206	4	3	1	4.7898E-03	0.0	23.9	100.0	13.4	0.0	21.8	95.0	12.8	0.0	23.9	100.0	13.4	0.0	21.8	95.0	12.8
206	103	3	7	1	1.1638E-03	0.0	1.0	20.3	1.7	0.0	10.7	100.0	7.5	0.0	0.0	0.2	0.0	0.0	0.8	4.7	0.6
206	101	3	3	1	1.0501E-03	0.0	7.8	100.0	10.4	0.0	2.0	23.9	1.3	0.0	0.5	3.9	0.7	0.0	0.0	0.2	0.0
206	205	4	7	1	5.2012E-05	0.0	20.3	83.1	9.6	0.0	26.1	100.0	12.6	0.0	20.3	83.1	9.6	0.0	26.1	100.0	12.6
206	201	4	7	1	5.2740E-05	0.1	20.4	82.8	9.5	0.0	26.2	100.0	12.6	0.1	20.4	82.8	9.5	0.0	26.2	100.0	12.6
301	203	1	1	1	1.4692E-05	100.0	68.7	1.5	1.9	27.6	18.7	0.1	4.5	21.2	29.7	2.8	1.2	7.8	11.8	0.7	0.4
301	302	1	1	1	6.4765E-06	100.0	14.2	0.1	17.0	77.0	12.0	0.7	29.7	23.6	3.3	0.1	4.5	18.9	2.9	0.3	7.6
301	303	3	1	1	9.6717E-05	100.0	64.1	0.8	3.6	41.5	27.2	0.2	5.6	22.8	17.6	0.3	0.9	10.6	8.4	0.1	1.2
301	302	4	3	1	3.4167E-09	35.8	96.6	100.0	12.7	6.7	31.7	78.4	10.4	35.8	96.6	100.0	12.7	6.7	31.7	78.4	10.4
301	303	4	6	1	1.3490E-07	5.7	39.8	13.3	0.6	21.6	100.0	29.3	0.9	5.7	39.8	13.3	0.6	21.6	100.0	29.3	0.9
302	301	1	1	1	3.0476E-05	100.0	29.7	0.2	11.6	77.8	19.7	0.0	13.5	23.7	7.7	0.1	2.8	19.1	5.2	0.0	3.2
302	205	2	5	1	5.8234E-06	29.4	11.6	3.1	68.7	100.0	6.4	0.3	14.3	7.8	7.2	6.2	29.6	20.8	2.2	1.7	9.7
302	303	2	1	1	3.2459E-05	100.0	14.1	0.1	22.9	83.6	11.9	0.1	27.4	23.9	3.3	0.0	6.1	20.5	2.9	0.0	7.1
302	301	4	7	1	1.6123E-08	2.0	38.1	79.0	10.1	11.2	77.9	100.0	12.0	2.0	38.1	79.0	10.1	11.2	77.9	100.0	12.0
302	303	4	3	1	1.5903E-08	8.7	74.8	100.0	8.6	6.2	60.4	84.6	6.8	8.7	74.8	100.0	8.6	6.2	60.4	84.6	6.8
303	302	2	1	1	9.1620E-06	100.0	39.2	0.4	8.8	86.4	34.2	0.2	10.5	24.0	10.7	0.2	2.0	21.2	9.5	0.1	2.4
303	201	3	3	2	3.8366E-06	12.8	70.6	65.3	10.1	6.7	4.8	3.3	4.1	2.5	57.7	100.0	12.8	1.6	8.2	18.4	3.7
303	301	3	1	1	5.7975E-05	100.0	6.9	0.3	26.6	45.3	5.1	1.2	65.7	22.8	1.5	0.2	8.3	11.5	1.2	0.5	18.3
303	302	4	6	1	6.2377E-09	9.8	83.0	62.4	3.8	21.2	100.0	71.9	4.3	9.8	83.0	62.4	3.8	21.2	100.0	71.9	4.3
303	301	4	2	1	9.2537E-08	29.0	100.0	27.5	1.2	7.4	37.2	13.9	0.9	29.0	100.0	27.5	1.2	7.4	37.2	13.9	0.9

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 4, 90.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points --> 1	2	3	4	5	6	7	8	<-- Side 2: Brace side points --> 1	2	3	4	5	6	7	8
201	202	1	1	1	5.4241E-01	100.0	18.9	0.0	14.3	82.0	14.8	0.0	18.4	25.1	4.5	0.0	3.5	20.2	3.6	0.0	4.4
201	206	3	5	1	6.1912E-01	91.1	16.2	0.0	18.8	100.0	18.7	0.0	16.5	22.7	3.9	0.0	4.6	25.3	4.6	0.0	4.0
201	303	3	1	1	2.8858E-05	100.0	28.0	9.1	40.5	56.4	9.8	0.2	22.1	23.8	12.5	30.8	41.3	13.7	5.1	4.6	11.9

201	202	4	3	1	4.2520E-02	0.0	17.7	100.0	18.9	0.0	14.1	86.1	15.5	0.0	17.7	100.0	18.9	0.0	14.1	86.1	15.5
201	206	4	3	1	4.3034E-02	0.0	25.5	100.0	12.7	0.0	21.3	88.1	10.7	0.0	25.5	100.0	12.7	0.0	21.3	88.1	10.7
202	101	1	7	1	2.9510E-04	0.1	2.1	36.8	4.3	0.4	11.2	100.0	6.9	0.0	0.1	0.6	0.2	0.0	0.7	3.7	0.5
202	102	1	3	1	3.0340E-04	0.1	6.9	100.0	11.3	0.4	4.0	33.2	1.8	0.0	0.5	3.8	0.7	0.0	0.1	0.5	0.1
202	201	4	7	1	5.7975E-04	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3
202	203	4	7	1	5.8109E-04	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2
203	202	1	5	1	5.7020E-01	90.1	15.9	0.0	18.8	100.0	18.7	0.0	16.2	22.4	3.8	0.0	4.6	25.2	4.6	0.0	3.9
203	301	1	1	1	2.8491E-04	100.0	18.7	0.4	17.0	98.2	17.6	0.0	17.4	24.2	5.5	1.6	4.2	23.8	4.5	0.3	4.1
203	204	2	1	1	5.6719E-01	100.0	18.9	0.0	14.4	82.3	14.9	0.0	18.5	25.2	4.5	0.0	3.5	20.3	3.7	0.0	4.4
203	202	4	3	1	4.2189E-02	0.0	18.2	100.0	18.4	0.0	14.8	87.3	15.5	0.0	18.2	100.0	18.4	0.0	14.8	87.3	15.5
203	204	4	3	1	4.3228E-02	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.6	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.6
204	102	2	7	1	1.0929E-03	0.1	2.0	25.2	1.8	0.1	8.0	100.0	10.0	0.0	0.0	0.3	0.1	0.0	0.5	3.8	0.7
204	103	2	3	1	1.1923E-03	0.0	4.6	100.0	15.7	0.2	3.5	23.1	0.7	0.0	0.4	4.4	1.2	0.0	0.1	0.3	0.0
204	203	4	7	1	5.9326E-04	0.0	20.2	82.7	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.7	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	5.8770E-04	0.0	20.3	82.3	9.4	0.0	26.2	100.0	12.6	0.0	20.3	82.3	9.4	0.0	26.2	100.0	12.6
205	204	2	5	1	5.5766E-01	90.5	16.0	0.0	18.8	100.0	18.7	0.0	16.3	22.5	3.9	0.0	4.6	25.1	4.6	0.0	4.0
205	302	2	2	1	6.6381E-05	97.4	100.0	4.9	5.9	31.3	18.1	0.2	4.7	22.2	82.2	20.1	3.5	7.7	23.0	4.1	1.4
205	206	3	1	1	5.4289E-01	100.0	18.9	0.0	14.4	82.5	15.0	0.0	18.5	25.1	4.5	0.0	3.5	20.4	3.7	0.0	4.4
205	204	4	3	1	4.3470E-02	0.0	25.5	100.0	12.8	0.0	21.3	88.4	10.9	0.0	25.5	100.0	12.8	0.0	21.3	88.4	10.9
205	206	4	3	1	4.3588E-02	0.0	25.0	100.0	13.1	0.0	20.4	86.6	10.8	0.0	25.0	100.0	13.1	0.0	20.4	86.6	10.8
206	103	3	7	1	1.2054E-03	0.0	0.7	23.3	3.6	0.2	15.9	100.0	4.5	0.0	0.0	0.3	0.1	0.0	1.2	4.4	0.4
206	101	3	3	1	1.1101E-03	0.1	10.1	100.0	7.9	0.1	1.8	25.1	2.0	0.0	0.7	3.8	0.5	0.0	0.1	0.3	0.0
206	205	4	7	1	5.8671E-04	0.0	20.3	82.5	9.5	0.0	26.1	100.0	12.6	0.0	20.3	82.5	9.5	0.0	26.1	100.0	12.6
206	201	4	7	1	5.9470E-04	0.0	20.3	82.7	9.5	0.0	26.1	100.0	12.7	0.0	20.3	82.7	9.5	0.0	26.1	100.0	12.7
301	203	1	5	1	2.6076E-05	98.1	21.2	2.7	16.9	100.0	18.9	0.1	16.2	23.8	7.1	4.4	4.3	24.2	5.1	0.8	3.8
301	302	1	1	1	8.7307E-05	100.0	12.1	0.0	18.6	67.5	9.4	0.1	31.1	23.5	2.8	0.0	5.0	16.7	2.2	0.0	8.0
301	303	3	1	1	1.6940E-04	100.0	48.0	0.6	7.2	54.6	20.0	0.1	9.1	23.0	12.8	0.2	1.7	13.6	5.8	0.1	2.1
301	302	4	3	1	4.6010E-08	5.2	76.4	100.0	9.9	1.2	36.3	69.1	7.7	5.2	76.4	100.0	9.9	1.2	36.3	69.1	7.7
301	303	4	6	1	1.6398E-07	3.9	33.3	27.4	2.0	23.3	100.0	45.5	2.5	3.9	33.3	27.4	2.0	23.3	100.0	45.5	2.5
302	301	1	1	1	1.0486E-04	100.0	34.6	0.1	8.1	63.2	19.7	0.0	10.8	23.4	9.0	0.0	1.9	15.8	5.4	0.0	2.4
302	205	2	4	1	5.0839E-06	40.1	19.2	48.9	100.0	28.5	3.3	2.1	16.7	8.5	13.0	81.8	75.7	5.8	3.5	14.5	15.9
302	303	2	1	1	1.4180E-04	100.0	10.7	0.2	26.5	65.4	8.3	0.5	44.8	23.5	2.5	0.1	7.7	16.3	2.0	0.2	12.2
302	301	4	7	1	5.5161E-08	1.3	42.7	65.0	6.7	5.8	91.2	100.0	8.4	1.3	42.7	65.0	6.7	5.8	91.2	100.0	8.4
302	303	4	2	1	1.2388E-07	21.6	100.0	52.1	3.5	8.7	54.0	35.9	2.6	21.6	100.0	52.1	3.5	8.7	54.0	35.9	2.6
303	302	2	1	1	1.8370E-04	100.0	50.7	0.3	4.6	57.1	29.8	0.1	6.8	23.3	13.8	0.1	1.0	14.4	8.7	0.1	1.4
303	201	3	2	1	1.7237E-05	48.7	100.0	14.5	0.8	2.1	6.6	0.4	0.5	8.6	56.2	21.2	0.6	0.7	9.9	3.0	0.2
303	301	3	1	1	1.2121E-04	100.0	8.3	0.1	17.5	45.2	5.8	0.5	48.8	22.6	1.8	0.0	5.2	11.4	1.4	0.2	12.9
303	302	4	6	1	1.7757E-07	4.3	55.6	28.0	1.2	11.6	100.0	47.1	1.5	4.3	55.6	28.0	1.2	11.6	100.0	47.1	1.5
303	301	4	2	1	1.2269E-07	20.4	100.0	45.3	2.1	2.9	29.1	22.9	1.6	20.4	100.0	45.3	2.1	2.9	29.1	22.9	1.6

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 5, 120.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N	N P P S	
O	O L O I	<==RELATIVE DAMAGES AROUND THE WELD ====>

DE1	DE2	AE	SN	DE	DAMAGE	Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
201	202	1	1	1	1.3972E-01	100.0	18.5	0.0	11.9	70.0	12.0	0.0	18.5	24.6	4.4	0.0	3.0	16.9	3.0	0.0	4.4
201	206	3	5	1	1.4800E-01	81.9	14.1	0.0	18.3	100.0	18.9	0.0	13.8	19.8	3.4	0.0	4.5	24.6	4.7	0.0	3.3
201	303	3	5	1	6.1219E-05	50.5	9.0	0.5	52.4	100.0	8.0	0.0	19.4	12.4	5.6	2.2	28.1	23.7	2.1	0.5	12.4
201	202	4	3	1	1.0463E-02	0.0	18.7	100.0	18.7	0.0	12.8	77.1	13.1	0.0	18.7	100.0	18.7	0.0	12.8	77.1	13.1
201	206	4	3	1	1.0082E-02	0.0	27.2	100.0	12.5	0.0	19.0	77.1	8.6	0.0	27.2	100.0	12.5	0.0	19.0	77.1	8.6
202	101	1	7	1	7.4730E-05	0.4	3.1	28.1	4.2	0.7	10.0	100.0	13.1	0.0	0.1	0.4	0.2	0.1	0.7	4.1	0.9
202	102	1	3	1	7.6609E-05	0.2	6.6	100.0	17.4	0.7	4.6	26.2	1.9	0.0	0.5	4.1	1.2	0.1	0.1	0.4	0.1
202	201	4	7	1	2.2206E-04	0.0	13.3	78.3	13.0	0.0	18.8	100.0	18.4	0.0	13.3	78.3	13.0	0.0	18.8	100.0	18.4
202	203	4	7	1	2.2015E-04	0.0	15.1	87.1	14.9	0.0	18.3	100.0	18.1	0.0	15.1	87.1	14.9	0.0	18.3	100.0	18.1
203	202	1	5	1	2.8307E-01	92.4	16.3	0.0	18.7	100.0	18.4	0.0	16.6	22.8	3.9	0.0	4.6	25.0	4.5	0.0	4.0
203	301	1	1	1	1.3450E-04	100.0	44.4	0.2	3.0	46.0	17.3	0.0	8.4	23.6	21.5	1.1	1.0	11.5	10.1	0.3	0.8
203	204	2	1	1	6.9106E-02	100.0	18.3	0.0	15.8	92.4	16.8	0.0	17.5	24.3	4.4	0.0	3.8	22.4	4.1	0.0	4.2
203	202	4	3	1	2.0713E-02	0.0	17.7	100.0	18.5	0.0	15.2	90.3	16.1	0.0	17.7	100.0	18.5	0.0	15.2	90.3	16.1
203	204	4	3	1	5.1810E-03	0.0	24.1	100.0	13.2	0.0	21.9	94.5	12.5	0.0	24.1	100.0	13.2	0.0	21.9	94.5	12.5
204	102	2	7	1	1.2287E-03	0.0	1.3	24.5	2.1	0.1	10.6	100.0	7.7	0.0	0.0	0.3	0.1	0.0	0.7	3.9	0.5
204	103	2	3	1	1.3593E-03	0.0	7.6	100.0	10.6	0.0	1.8	20.8	1.0	0.0	0.6	4.7	0.8	0.0	0.0	0.2	0.0
204	203	4	7	1	5.9739E-05	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7
204	205	4	7	1	5.9129E-05	0.1	20.5	83.2	9.6	0.0	26.2	100.0	12.6	0.1	20.5	83.2	9.6	0.0	26.2	100.0	12.6
205	204	2	5	1	7.3143E-02	99.0	17.1	0.0	18.2	100.0	17.5	0.0	18.2	24.0	4.1	0.0	4.4	24.3	4.2	0.0	4.4
205	302	2	3	2	2.0411E-05	56.0	38.6	22.8	17.3	53.6	14.7	1.1	14.4	13.5	57.6	100.0	21.5	13.0	16.1	23.4	11.3
205	206	3	1	1	2.6203E-01	100.0	18.8	0.0	14.8	85.7	15.6	0.0	18.1	24.9	4.5	0.0	3.6	21.1	3.8	0.0	4.3
205	204	4	3	1	5.4962E-03	0.0	24.1	100.0	13.1	0.0	23.1	99.1	13.5	0.0	24.1	100.0	13.1	0.0	23.1	99.1	13.5
205	206	4	3	1	2.1051E-02	0.0	24.4	100.0	13.2	0.0	20.8	89.2	11.3	0.0	24.4	100.0	13.2	0.0	20.8	89.2	11.3
206	103	3	7	1	8.0923E-05	0.2	2.3	28.9	5.9	0.9	19.2	100.0	7.0	0.0	0.1	0.4	0.2	0.1	1.3	4.3	0.5
206	101	3	3	1	7.8207E-05	0.3	12.2	100.0	9.5	0.8	3.9	27.1	2.6	0.0	0.8	3.8	0.6	0.1	0.2	0.4	0.1
206	205	4	7	1	2.1369E-04	0.0	21.3	86.9	10.2	0.0	25.7	100.0	12.6	0.0	21.3	86.9	10.2	0.0	25.7	100.0	12.6
206	201	4	7	1	2.1911E-04	0.0	18.9	77.2	8.6	0.0	26.5	100.0	12.8	0.0	18.9	77.2	8.6	0.0	26.5	100.0	12.8
301	203	1	5	1	6.7128E-06	27.1	10.7	3.3	78.9	100.0	5.1	0.3	16.7	7.3	6.5	6.0	35.2	20.7	2.0	1.6	11.8
301	302	1	1	1	3.2167E-05	100.0	14.3	0.1	22.5	84.7	12.4	0.1	27.1	23.9	3.4	0.0	6.0	20.8	3.0	0.1	7.1
301	303	3	1	1	3.7826E-05	100.0	29.4	0.2	11.4	77.0	19.2	0.0	13.4	23.7	7.6	0.1	2.7	18.9	5.1	0.0	3.1
301	302	4	3	1	1.7090E-08	6.9	63.0	100.0	12.7	4.3	48.6	85.6	10.5	6.9	63.0	100.0	12.7	4.3	48.6	85.6	10.5
301	303	4	7	1	1.8272E-08	2.7	44.9	79.9	6.8	16.0	89.4	100.0	8.3	2.7	44.9	79.9	6.8	16.0	89.4	100.0	8.3
302	301	1	1	1	9.8176E-06	100.0	41.0	0.5	9.6	87.5	36.1	0.2	11.2	24.0	11.3	0.2	2.3	21.4	10.1	0.1	2.6
302	205	2	3	2	7.4831E-06	9.5	48.6	55.7	10.9	6.9	4.9	3.4	3.9	2.0	47.6	100.0	15.2	1.7	8.7	21.9	4.4
302	303	2	1	1	7.6575E-05	100.0	7.3	0.3	25.8	46.4	5.4	1.1	63.4	22.8	1.6	0.2	8.0	11.8	1.3	0.5	17.4
302	301	4	6	1	6.9575E-09	8.9	83.3	66.2	6.0	18.0	100.0	75.1	7.1	8.9	83.3	66.2	6.0	18.0	100.0	75.1	7.1
302	303	4	2	1	1.1177E-07	28.9	100.0	28.7	1.4	7.3	37.2	14.9	1.0	28.9	100.0	28.7	1.4	7.3	37.2	14.9	1.0
303	302	2	1	1	1.0925E-04	100.0	65.1	0.8	3.3	40.1	27.2	0.2	5.3	22.7	18.0	0.3	0.8	10.3	8.5	0.1	1.1
303	201	3	1	1	1.7004E-05	100.0	77.1	1.8	1.5	26.3	21.2	0.1	3.7	21.2	34.4	3.0	1.0	7.5	13.9	0.8	0.3
303	301	3	1	1	7.0885E-06	100.0	13.6	0.2	17.0	73.3	11.1	0.7	30.9	23.4	3.2	0.1	4.5	18.0	2.7	0.3	8.0

303	302	4	6	1	1.6183E-07	5.5	39.5	12.6	0.6	21.3	100.0	29.0	0.8	5.5	39.5	12.6	0.6	21.3	100.0	29.0	0.8
303	301	4	2	1	4.0342E-09	42.3	100.0	89.5	7.4	10.2	37.0	68.8	6.0	42.3	100.0	89.5	7.4	10.2	37.0	68.8	6.0

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 6, 150.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	I D		<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
					DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	3.1438E-01	100.0	19.0	0.0	14.4	82.4	15.0	0.0	18.5	25.2	4.6	0.0	3.5	20.4	3.7	0.0	4.4
201	206	3	5	1	3.5031E-01	91.0	16.3	0.0	19.0	100.0	18.9	0.0	16.5	22.8	3.9	0.0	4.6	25.4	4.6	0.0	4.0
201	303	3	1	1	1.6653E-04	100.0	17.3	0.4	18.5	98.2	16.2	0.0	19.0	24.2	4.8	1.4	4.9	23.8	3.8	0.2	4.9
201	202	4	3	1	2.4799E-02	0.0	17.7	100.0	18.9	0.0	14.2	86.3	15.6	0.0	17.7	100.0	18.9	0.0	14.2	86.3	15.6
201	206	4	3	1	2.4485E-02	0.0	25.5	100.0	12.7	0.0	21.2	88.0	10.7	0.0	25.5	100.0	12.7	0.0	21.2	88.0	10.7
202	101	1	7	1	6.4372E-04	0.1	2.1	24.0	1.6	0.1	7.4	100.0	10.6	0.0	0.0	0.3	0.0	0.0	0.5	4.1	0.8
202	102	1	3	1	6.4728E-04	0.0	5.1	100.0	14.6	0.2	3.4	24.0	0.8	0.0	0.4	4.1	1.0	0.0	0.1	0.3	0.0
202	201	4	7	1	3.3520E-04	0.0	14.1	82.6	14.0	0.0	18.5	100.0	18.3	0.0	14.1	82.6	14.0	0.0	18.5	100.0	18.3
202	203	4	7	1	3.3609E-04	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2
203	202	1	5	1	3.2578E-01	90.5	16.1	0.0	18.9	100.0	18.8	0.0	16.4	22.6	3.9	0.0	4.6	25.3	4.6	0.0	4.0
203	301	1	2	1	3.5634E-05	96.2	100.0	4.8	5.0	27.8	16.9	0.1	4.6	22.1	79.0	17.7	2.7	6.9	20.8	3.1	1.2
203	204	2	1	1	3.2401E-01	100.0	19.0	0.0	14.5	82.6	15.0	0.0	18.6	25.3	4.6	0.0	3.5	20.5	3.7	0.0	4.4
203	202	4	3	1	2.4225E-02	0.0	18.2	100.0	18.4	0.0	14.9	87.8	15.6	0.0	18.2	100.0	18.4	0.0	14.9	87.8	15.6
203	204	4	3	1	2.4824E-02	0.0	25.0	100.0	13.1	0.0	20.4	86.4	10.7	0.0	25.0	100.0	13.1	0.0	20.4	86.4	10.7
204	102	2	7	1	6.5242E-04	0.0	1.0	26.8	3.6	0.2	14.0	100.0	5.4	0.0	0.0	0.3	0.1	0.0	0.9	3.7	0.4
204	103	2	3	1	7.1707E-04	0.1	11.0	100.0	7.1	0.1	1.4	22.6	2.0	0.0	0.8	4.5	0.6	0.0	0.0	0.3	0.0
204	203	4	7	1	3.4401E-04	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	3.4071E-04	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7
205	204	2	5	1	3.2377E-01	90.3	16.0	0.0	18.9	100.0	18.8	0.0	16.3	22.5	3.9	0.0	4.6	25.3	4.6	0.0	4.0
205	302	2	1	1	1.7503E-05	100.0	29.1	11.0	54.4	59.4	9.0	0.3	24.2	23.5	14.8	43.4	60.4	14.3	5.7	7.4	17.1
205	206	3	1	1	3.0806E-01	100.0	19.0	0.0	14.4	82.2	14.9	0.0	18.5	25.2	4.5	0.0	3.5	20.4	3.7	0.0	4.4
205	204	4	3	1	2.5386E-02	0.0	25.5	100.0	12.8	0.0	21.2	88.1	10.8	0.0	25.5	100.0	12.8	0.0	21.2	88.1	10.8
205	206	4	3	1	2.4828E-02	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.7	0.0	25.0	100.0	13.1	0.0	20.3	86.3	10.7
206	103	3	7	1	1.8946E-04	0.1	2.0	34.9	3.9	0.3	10.8	100.0	7.0	0.0	0.1	0.6	0.1	0.0	0.8	4.0	0.5
206	101	3	3	1	1.7809E-04	0.2	7.4	100.0	10.7	0.4	4.0	35.6	2.3	0.0	0.5	3.5	0.7	0.0	0.1	0.5	0.1
206	205	4	7	1	3.3401E-04	0.0	20.2	82.4	9.4	0.0	26.1	100.0	12.6	0.0	20.2	82.4	9.4	0.0	26.1	100.0	12.6
206	201	4	7	1	3.3831E-04	0.0	20.3	82.5	9.4	0.0	26.2	100.0	12.6	0.0	20.3	82.5	9.4	0.0	26.2	100.0	12.6
301	203	1	4	1	2.2841E-06	39.3	18.9	55.9	100.0	24.5	3.1	2.0	15.2	8.2	12.6	85.8	73.6	4.8	3.0	13.4	13.4
301	302	1	1	1	7.0566E-05	100.0	11.1	0.2	25.9	66.9	8.8	0.5	43.9	23.5	2.6	0.1	7.5	16.6	2.1	0.2	12.0
301	303	3	1	1	6.2157E-05	100.0	33.7	0.1	8.0	62.9	19.3	0.0	10.8	23.4	8.7	0.0	1.9	15.7	5.3	0.0	2.4
301	302	4	2	1	6.0120E-08	17.4	100.0	61.8	5.9	6.4	52.2	42.4	4.6	17.4	100.0	61.8	5.9	6.4	52.2	42.4	4.6
301	303	4	6	1	3.0840E-08	2.0	49.1	61.9	4.3	8.0	100.0	93.8	5.5	2.0	49.1	61.9	4.3	8.0	100.0	93.8	5.5
302	301	1	1	1	1.0305E-04	100.0	53.2	0.3	5.0	58.6	31.5	0.1	7.0	23.3	14.6	0.2	1.2	14.7	9.3	0.1	1.5

302	205	2	2	1	1.1410E-05	44.9	100.0	16.0	1.2	3.1	7.3	0.5	0.4	8.0	61.9	26.7	0.9	0.8	11.9	4.2	0.3
302	303	2	1	1	7.1718E-05	100.0	9.1	0.1	17.1	48.7	6.6	0.5	46.7	22.8	2.0	0.0	5.0	12.2	1.6	0.2	12.3
302	301	4	6	1	1.0142E-07	3.5	55.5	32.3	2.1	9.7	100.0	53.4	2.6	3.5	55.5	32.3	2.1	9.7	100.0	53.4	2.6
302	303	4	2	1	6.6574E-08	22.1	100.0	47.4	2.6	3.0	28.7	25.8	2.0	22.1	100.0	47.4	2.6	3.0	28.7	25.8	2.0
303	302	2	1	1	8.7747E-05	100.0	48.5	0.7	7.3	55.8	20.3	0.1	9.2	23.0	13.0	0.3	1.7	13.9	5.9	0.1	2.1
303	201	3	5	1	1.2417E-05	98.5	25.7	2.9	14.0	100.0	22.6	0.1	13.4	23.9	9.1	4.5	3.2	24.2	6.6	0.8	2.8
303	301	3	1	1	4.9185E-05	100.0	11.7	0.0	18.6	65.9	8.8	0.1	31.5	23.4	2.7	0.0	5.1	16.4	2.1	0.0	8.1
303	302	4	6	1	9.0782E-08	4.1	33.2	27.7	2.0	24.9	100.0	45.1	2.5	4.1	33.2	27.7	2.0	24.9	100.0	45.1	2.5
303	301	4	3	1	2.4538E-08	8.7	94.8	100.0	6.6	2.2	46.9	68.9	4.9	8.7	94.8	100.0	6.6	2.2	46.9	68.9	4.9

BUFFETING DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.5284E+00	100.0	18.8	0.0	14.2	81.9	14.7	0.0	18.3	25.0	4.5	0.0	3.5	20.1	3.6	0.0	4.4
201	206	3	5	1	1.7144E+00	90.9	16.1	0.0	18.7	100.0	18.6	0.0	16.3	22.5	3.9	0.0	4.6	25.1	4.5	0.0	3.9
201	303	3	1	1	3.6215E-04	100.0	32.5	2.2	22.5	83.7	15.9	0.1	17.2	24.0	17.2	7.9	11.3	20.3	6.9	1.4	6.0
201	202	4	3	1	1.1914E-01	0.0	17.7	100.0	18.9	0.0	14.2	86.1	15.5	0.0	17.7	100.0	18.9	0.0	14.2	86.1	15.5
201	206	4	3	1	1.1828E-01	0.0	25.6	100.0	12.7	0.0	21.3	88.0	10.7	0.0	25.6	100.0	12.7	0.0	21.3	88.0	10.7
202	101	1	7	1	2.5726E-03	0.1	1.5	25.0	2.5	0.2	10.8	100.0	7.8	0.0	0.0	0.3	0.1	0.0	0.8	4.1	0.6
202	102	1	3	1	2.5842E-03	0.1	7.6	100.0	11.1	0.2	2.5	24.4	1.4	0.0	0.6	4.1	0.8	0.0	0.1	0.3	0.0
202	201	4	7	1	1.6352E-03	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3	0.0	14.1	82.4	13.9	0.0	18.5	100.0	18.3
202	203	4	7	1	1.6388E-03	0.0	14.1	82.2	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.2	13.8	0.0	18.6	100.0	18.2
203	202	1	5	1	1.6248E+00	90.2	15.9	0.0	18.7	100.0	18.6	0.0	16.2	22.3	3.8	0.0	4.6	25.1	4.5	0.0	3.9
203	301	1	1	1	5.0149E-04	100.0	32.6	1.6	17.5	83.3	17.4	0.1	15.3	24.0	17.0	6.0	7.2	20.2	7.5	1.2	4.4
203	204	2	1	1	1.5626E+00	100.0	18.8	0.0	14.3	82.3	14.8	0.0	18.4	25.0	4.5	0.0	3.5	20.2	3.6	0.0	4.4
203	202	4	3	1	1.1956E-01	0.0	18.1	100.0	18.4	0.0	14.8	87.6	15.5	0.0	18.1	100.0	18.4	0.0	14.8	87.6	15.5
203	204	4	3	1	1.1829E-01	0.0	25.0	100.0	13.1	0.0	20.3	86.4	10.7	0.0	25.0	100.0	13.1	0.0	20.3	86.4	10.7
204	102	2	7	1	3.2370E-03	0.1	1.6	26.1	2.5	0.1	10.5	100.0	8.1	0.0	0.0	0.3	0.1	0.0	0.7	3.8	0.6
204	103	2	3	1	3.5652E-03	0.0	7.4	100.0	11.7	0.1	2.5	22.6	1.2	0.0	0.6	4.5	0.9	0.0	0.1	0.3	0.0
204	203	4	7	1	1.6293E-03	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.0	100.0	12.7
204	205	4	7	1	1.6140E-03	0.0	20.3	82.3	9.4	0.0	26.2	100.0	12.6	0.0	20.3	82.3	9.4	0.0	26.2	100.0	12.6
205	204	2	5	1	1.5528E+00	90.3	15.9	0.0	18.7	100.0	18.6	0.0	16.2	22.3	3.8	0.0	4.6	25.0	4.5	0.0	3.9
205	302	2	1	1	3.5657E-04	100.0	42.0	3.1	20.5	76.9	16.4	0.1	15.5	23.8	27.7	13.1	11.4	18.6	9.8	2.8	5.8
205	206	3	1	1	1.5341E+00	100.0	18.8	0.0	14.3	82.4	14.9	0.0	18.4	25.0	4.5	0.0	3.5	20.3	3.7	0.0	4.4
205	204	4	3	1	1.2031E-01	0.0	25.5	100.0	12.8	0.0	21.2	88.4	10.9	0.0	25.5	100.0	12.8	0.0	21.2	88.4	10.9
205	206	4	3	1	1.2257E-01	0.0	25.0	100.0	13.1	0.0	20.3	86.6	10.8	0.0	25.0	100.0	13.1	0.0	20.3	86.6	10.8
206	103	3	7	1	3.2747E-03	0.0	1.2	22.9	2.6	0.2	12.2	100.0	7.1	0.0	0.0	0.3	0.1	0.0	0.9	4.5	0.6
206	101	3	3	1	2.9959E-03	0.1	8.3	100.0	10.2	0.1	2.4	25.6	1.6	0.0	0.6	3.8	0.7	0.0	0.1	0.3	0.0
206	205	4	7	1	1.6294E-03	0.0	20.3	82.6	9.5	0.0	26.1	100.0	12.7	0.0	20.3	82.6	9.5	0.0	26.1	100.0	12.7

206	201	4	7	1	1.6518E-03	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7
301	203	1	1	1	4.7572E-05	100.0	57.8	13.0	27.0	79.8	18.7	0.6	13.8	22.8	29.2	21.0	12.6	19.1	9.4	4.0	5.0
301	302	1	1	1	3.0555E-04	100.0	10.7	0.1	21.9	62.4	8.4	0.5	42.8	23.3	2.5	0.1	6.3	15.5	2.0	0.2	11.5
301	303	3	1	1	4.5763E-04	100.0	48.4	0.5	6.5	55.9	23.4	0.1	8.6	23.1	13.0	0.2	1.5	14.0	6.8	0.1	1.9
301	302	4	2	1	2.4734E-07	17.6	100.0	64.8	5.9	4.4	41.7	41.6	4.6	17.6	100.0	64.8	5.9	4.4	41.7	41.6	4.6
301	303	4	6	1	4.3117E-07	4.5	41.8	28.2	1.8	19.5	100.0	46.6	2.3	4.5	41.8	28.2	1.8	19.5	100.0	46.6	2.3
302	301	1	1	1	4.0625E-04	100.0	47.9	0.4	6.6	58.0	24.9	0.1	8.7	23.2	12.9	0.2	1.6	14.5	7.2	0.1	1.9
302	205	2	1	1	3.8651E-05	100.0	82.6	24.2	31.8	68.3	21.2	1.2	11.7	22.1	47.7	42.2	19.4	16.4	14.3	8.4	5.7
302	303	2	1	1	3.7190E-04	100.0	10.2	0.2	23.1	60.1	7.8	0.6	45.5	23.2	2.3	0.1	6.7	15.0	1.9	0.2	12.3
302	301	4	6	1	3.6379E-07	3.2	44.7	35.1	3.2	13.4	100.0	58.5	3.9	3.2	44.7	35.1	3.2	13.4	100.0	58.5	3.9
302	303	4	2	1	3.3519E-07	23.2	100.0	50.0	3.2	6.7	43.9	32.3	2.4	23.2	100.0	50.0	3.2	6.7	43.9	32.3	2.4
303	302	2	1	1	4.6330E-04	100.0	50.6	0.5	5.5	55.0	25.8	0.1	7.7	23.1	13.8	0.2	1.3	13.8	7.6	0.1	1.7
303	201	3	1	1	3.9826E-05	100.0	93.1	16.7	16.5	54.0	20.1	0.7	8.2	21.5	48.7	25.2	8.2	13.2	13.4	4.3	2.7
303	301	3	1	1	3.1573E-04	100.0	9.5	0.1	21.4	55.5	7.1	0.6	46.7	23.0	2.2	0.1	6.3	13.9	1.7	0.2	12.6
303	302	4	6	1	4.7431E-07	4.6	45.7	26.3	1.5	17.6	100.0	44.8	1.9	4.6	45.7	26.3	1.5	17.6	100.0	44.8	1.9
303	301	4	2	1	3.0642E-07	22.9	100.0	48.5	2.8	5.7	39.1	29.2	2.1	22.9	100.0	48.5	2.8	5.7	39.1	29.2	2.1

20 WORST BUFFETING DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points --> |							<-- Side 2: Brace side points --> |						
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	206	3	5	1	1.7144E+00	90.9	16.1	0.0	18.7	100.0	18.6	0.0	16.3	22.5	3.9	0.0	4.6	25.1	4.5	0.0	3.9
203	202	1	5	1	1.6248E+00	90.2	15.9	0.0	18.7	100.0	18.6	0.0	16.2	22.3	3.8	0.0	4.6	25.1	4.5	0.0	3.9
203	204	2	1	1	1.5626E+00	100.0	18.8	0.0	14.3	82.3	14.8	0.0	18.4	25.0	4.5	0.0	3.5	20.2	3.6	0.0	4.4
205	204	2	5	1	1.5528E+00	90.3	15.9	0.0	18.7	100.0	18.6	0.0	16.2	22.3	3.8	0.0	4.6	25.0	4.5	0.0	3.9
205	206	3	1	1	1.5341E+00	100.0	18.8	0.0	14.3	82.4	14.9	0.0	18.4	25.0	4.5	0.0	3.5	20.3	3.7	0.0	4.4
201	202	1	1	1	1.5284E+00	100.0	18.8	0.0	14.2	81.9	14.7	0.0	18.3	25.0	4.5	0.0	3.5	20.1	3.6	0.0	4.4
205	206	4	3	1	1.2257E-01	0.0	25.0	100.0	13.1	0.0	20.3	86.6	10.8	0.0	25.0	100.0	13.1	0.0	20.3	86.6	10.8
205	204	4	3	1	1.2031E-01	0.0	25.5	100.0	12.8	0.0	21.2	88.4	10.9	0.0	25.5	100.0	12.8	0.0	21.2	88.4	10.9
203	202	4	3	1	1.1956E-01	0.0	18.1	100.0	18.4	0.0	14.8	87.6	15.5	0.0	18.1	100.0	18.4	0.0	14.8	87.6	15.5
201	202	4	3	1	1.1914E-01	0.0	17.7	100.0	18.9	0.0	14.2	86.1	15.5	0.0	17.7	100.0	18.9	0.0	14.2	86.1	15.5
203	204	4	3	1	1.1829E-01	0.0	25.0	100.0	13.1	0.0	20.3	86.4	10.7	0.0	25.0	100.0	13.1	0.0	20.3	86.4	10.7
201	206	4	3	1	1.1828E-01	0.0	25.6	100.0	12.7	0.0	21.3	88.0	10.7	0.0	25.6	100.0	12.7	0.0	21.3	88.0	10.7
204	103	2	3	1	3.5652E-03	0.0	7.4	100.0	11.7	0.1	2.5	22.6	1.2	0.0	0.6	4.5	0.9	0.0	0.1	0.3	0.0
206	103	3	7	1	3.2747E-03	0.0	1.2	22.9	2.6	0.2	12.2	100.0	7.1	0.0	0.0	0.3	0.1	0.0	0.9	4.5	0.6
204	102	2	7	1	3.2370E-03	0.1	1.6	26.1	2.5	0.1	10.5	100.0	8.1	0.0	0.0	0.3	0.1	0.0	0.7	3.8	0.6
206	101	3	3	1	2.9959E-03	0.1	8.3	100.0	10.2	0.1	2.4	25.6	1.6	0.0	0.6	3.8	0.7	0.0	0.1	0.3	0.0
202	102	1	3	1	2.5842E-03	0.1	7.6	100.0	11.1	0.2	2.5	24.4	1.4	0.0	0.6	4.1	0.8	0.0	0.1	0.3	0.0
202	101	1	7	1	2.5726E-03	0.1	1.5	25.0	2.5	0.2	10.8	100.0	7.8	0.0	0.0	0.3	0.1	0.0	0.8	4.1	0.6
206	201	4	7	1	1.6518E-03	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7	0.0	20.3	82.4	9.4	0.0	26.2	100.0	12.7

```
    202     203 4 7 1       1.6388E-03   0.0  14.1  82.2  13.8   0.0  18.6 100.0  18.2   0.0  14.1  82.2  13.8   0.0  18.6 100.0  18.2

BUFFETING DAMAGE EVALUATED FOR 42 JOINT CONNECTIONS OVER ALL ANALYSIS PLANES
--------------------------------------------------------------------------------


 ************************************************************************

 PRINT OF               : WIND FATIGUE RESULTS

 RUN NAME               : X505B
 RUN DESCRIPTION        : None
 RESULTS INTERFACE FILE  : X505BR1.SIN
 PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  15:45:00

 ************************************************************************

 RUN SCENARIO:
 =============
 ANALYSIS CASE              : MULTI BRACE FATIGUE CHECK
 FIRST WIND DIRECTION       : 1
 LAST  WIND DIRECTION       : 6
 FIRST NODE CHECKED         : 101
 LAST  NODE CHECKED         : 303
 FIRST ANALYSIS PLANE       : 1
 LAST  ANALYSIS PLANE       : 4
 NUMBER OF EIGENMODES       : 2
 SHOW PROGRESS OF EXECUTION : OFF

 WIND LOAD MODELLING:
 ====================
 WIND LOAD TYPE             : WIND BUFFETING
 WIDE BAND CORRECTION       : NONE
 WIND PROFILE               : API (WIND PROFILE TYPE READ FROM SIN FILE)
 GUST COMPONENTS CONSIDERED : ALL (ALONG + ACROSS WIND COMPONENTS)
 GUST DIRECTION MOMENT      : DAMAGE BY ADD OF GUST SPECTRUM MOMENTS
 WIND SPECTRA :
     LONGITUDINAL DIRECTION : NPD
     LATERAL      DIRECTION : PANOFSKY LATERAL
     VERTICAL     DIRECTION : PANOFSKY VERTICAL
 COHERENCE FUNCTIONS :
     LONGITUDINAL DIRECTION : NPD
     LATERAL      DIRECTION : GUSTO2
     VERTICAL     DIRECTION : GUSTO2
```

```
INPUT DATA:
===========

PARAMETERS READ FROM SIN FILE :
(l = current length unit)
------------------------------

WATER DEPTH - WD  (l)                          : 10.0
Z-COORDINATE OF MUDLINE - ZMUD  (l)            : -10.0
Z-COORDINATE OF STILL WATER LEVEL/GROUND  (l)   : 0.0
                       (Z0 = ZMUD + WD)
WIND DIRECTIONS (RELATIVE TO GLOBAL X-AXIS)    : DIR  ANGLE (deg)
                                                 1    0.0
                                                 2    30.0
                                                 3    60.0
                                                 4    90.0
                                                 5    120.0
                                                 6    150.0
MEAN WIND VELOCITY  (l/sec)                    : 30.0
MEAN WIND VELOCITY LEVEL  (l)                  : 10.0
HEIGHT EXPONENT, API WIND PROFILE              : .125
GUST FACTOR, API WIND PROFILE                  : 1.0
ACCELERATION OF GRAVITY (g)  (l/sec^2)         : 9.81
UNIT LENGTH ADJUSTMENT FACTOR (9.81/g)         : 1.0

DIRECT INPUT PARAMETERS :
(l = current length unit)
-------------------------

DAMAGE CALCULATION OF BENT CAN JOINTS          : ON
COHERENCE FUNCTION CONSTANT (GUSTO, DAVENPORT) : 8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz ALONG DIR.  : 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz LATERAL DIR.: 16.0   16.0   8.0
GENERAL COHERENCE FUNCTION - Cx,Cy,Cz VERTICAL DIR: 16.0   16.0   8.0
GROUND ROUGNESS COEFFICIENT                    : 1.5E-02
TURBULENCE LENGTH SCALE DAVENPORT SPECTRUM  (l) : 1200.0
TURBULENCE LENGTH SCALE HARRIS SPECTRUM  (l)   : 1800.0
DEFAULT SN CURVE                               : DOE-T
MINIMUM PARAMETRIC SCFS                        : 1.6    1.6    1.6
DEFAULT GLOBAL SCFS                            : 1.6    1.6    1.6
DEFAULT SCF SCHEME, Alt.: EFTHYMIOU, LLOYDS    : EFTHYMIOU
(New default overrules previously assigned SCFs)
DAMPING RATIO                                  : 1.0E-02
```

```
CHORD LENGTH/DIAMETER RATIO (L/D)                : 30.0
ANGULAR TOLERANCE ANALYSIS PLANES (DEG)          : 1.0
LIMIT FOR PRINTING DAMAGE VALUES                 : 1.0E-12
MIN. WIND FORCE USED RELATIVE TO MAX.            : 1.000E-05
LIMIT VALUE ON COHERENCE EFFECT                  : 1.000E-03
(NO COHERENCE = 1.0, FULL COHERENCE = 0 in limit)
NUMBER OF WIND SPEEDS                            : 5

WIND PROBABILITIES AND DRAG CORRECTION COEFFICIENT
-------------------------------------------------------
   DIR    WIND          WIND          WIND    DRAG COEFF
    NO   SPEED         SPEED   PROBABILITY    CORRECTION
           NO                                    FACTORS
     1      1        10.0000        0.3000        1.0000
     1      2        15.0000        0.2500        0.9000
     1      3        20.0000        0.2000        0.8000
     1      4        25.0000        0.1500        0.7500
     1      5        30.0000        0.1000        0.7000
     2      1        10.0000        0.3500        1.0100
     2      2        15.0000        0.2000        0.9100
     2      3        20.0000        0.2000        0.8100
     2      4        25.0000        0.1500        0.7600
     2      5        30.0000        0.1000        0.7100
     3      1        10.0000        0.4000        1.0200
     3      2        15.0000        0.2000        0.9200
     3      3        20.0000        0.1500        0.8200
     3      4        25.0000        0.1500        0.7700
     3      5        30.0000        0.1000        0.7200
     4      1        10.0000        0.2000        1.0300
     4      2        15.0000        0.2000        0.9300
     4      3        20.0000        0.2000        0.8300
     4      4        25.0000        0.2000        0.7800
     4      5        30.0000        0.2000        0.7300
     5      1        10.0000        0.3000        1.0400
     5      2        15.0000        0.2500        0.9400
     5      3        20.0000        0.2000        0.8400
     5      4        25.0000        0.1500        0.7900
     5      5        30.0000        0.1000        0.7400
     6      1        10.0000        0.3600        1.0500
     6      2        15.0000        0.2200        0.9500
     6      3        20.0000        0.2100        0.8500
     6      4        25.0000        0.1100        0.8000
     6      5        30.0000        0.1000        0.7500
```

```
 NODES DEFINING THE ANALYSIS PLANES:
  1    101    203    301
  2    102    205    302
  3    103    201    303
  4    201    203    205


 NUMBER OF COHERENCE MATRICES FOR THE U, V AND W  WIND GUST DIRECTIONS :   2
 Note! 1,2 or 3 coherence matrices are formed depending on the choice of
       wind spectrum and coherence models. Theexecution time increases
       with the number of coherence matrices applied in the run.

 ************************************************************************

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 1, 0.0 DEG. (PRINT OF DAMAGE > 1.000E-12)
================================================================================
```

N O D E 1	N O D E 2	P L A N E	P O S N	S I D E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> Side 1: Chord side points 1	2	3	4	5	6	7	8	Side 2: Brace side points 1	2	3	4	5	6	7	8
201	202	1	1	1	1.6958E-02	100.0	18.3	0.0	14.9	87.5	15.7	0.0	17.7	24.3	4.4	0.0	3.6	21.2	3.8	0.0	4.2
201	206	3	5	1	5.7240E-02	91.7	15.8	0.0	18.1	100.0	17.9	0.0	16.1	22.1	3.8	0.0	4.4	24.4	4.4	0.0	3.9
201	303	3	1	1	2.7954E-06	100.0	39.5	5.0	34.2	82.7	20.9	0.5	12.8	23.9	20.7	22.7	28.4	19.9	11.2	7.3	7.6
201	202	4	3	1	1.2992E-03	0.0	17.3	100.0	19.0	0.0	14.9	90.8	16.9	0.0	17.3	100.0	19.0	0.0	14.9	90.8	16.9
201	206	4	3	1	3.8212E-03	0.0	25.2	100.0	12.8	0.0	21.6	89.4	10.9	0.0	25.2	100.0	12.8	0.0	21.6	89.4	10.9
202	101	1	7	1	2.5697E-05	0.1	1.4	26.2	3.1	0.2	10.8	100.0	7.3	0.0	0.1	0.4	0.1	0.0	0.8	4.1	0.5
202	102	1	3	1	2.5681E-05	0.1	7.4	100.0	10.7	0.2	2.9	25.8	1.4	0.0	0.6	4.1	0.8	0.0	0.1	0.4	0.0
202	201	4	7	1	1.6477E-05	0.0	14.0	81.9	13.8	0.0	18.6	100.0	18.3	0.0	14.0	81.9	13.8	0.0	18.6	100.0	18.3
202	203	4	7	1	1.6488E-05	0.0	14.3	83.3	14.1	0.0	18.6	100.0	18.2	0.0	14.3	83.3	14.1	0.0	18.6	100.0	18.2
203	202	1	5	1	2.0449E-02	95.8	16.5	0.0	18.1	100.0	17.7	0.0	17.2	23.2	4.0	0.0	4.4	24.3	4.3	0.0	4.2
203	301	1	5	1	7.1436E-06	99.0	30.1	2.8	27.1	100.0	27.8	1.4	25.1	24.0	22.8	19.5	19.0	24.2	19.7	14.5	17.1
203	204	2	1	1	4.8771E-02	100.0	18.3	0.0	14.5	85.3	15.2	0.0	17.7	24.3	4.4	0.0	3.5	20.6	3.7	0.0	4.2
203	202	4	3	1	1.4507E-03	0.0	17.5	100.0	18.6	0.0	15.9	94.9	17.6	0.0	17.5	100.0	18.6	0.0	15.9	94.9	17.6
203	204	4	3	1	3.6222E-03	0.0	24.5	100.0	13.2	0.0	20.9	89.1	11.2	0.0	24.5	100.0	13.2	0.0	20.9	89.1	11.2
204	102	2	7	1	2.7253E-05	0.2	4.1	33.3	2.0	0.2	7.8	100.0	11.0	0.0	0.2	0.5	0.1	0.0	0.6	3.8	0.7
204	103	2	3	1	3.1553E-05	0.1	5.3	100.0	15.2	0.4	4.4	24.3	0.7	0.0	0.5	4.6	1.1	0.1	0.2	0.4	0.0
204	203	4	7	1	3.9121E-05	0.0	21.1	86.2	10.1	0.0	25.7	100.0	12.6	0.0	21.1	86.2	10.1	0.0	25.7	100.0	12.6
204	205	4	7	1	3.9047E-05	0.0	19.2	78.0	8.7	0.0	26.7	100.0	12.6	0.0	19.2	78.0	8.7	0.0	26.7	100.0	12.6
205	204	2	5	1	2.7012E-02	83.2	14.3	0.0	18.2	100.0	18.7	0.0	14.2	20.0	3.4	0.0	4.4	24.4	4.6	0.0	3.4
205	302	2	1	1	4.8081E-06	100.0	73.0	3.8	15.2	45.7	14.7	0.3	12.1	23.2	59.9	19.6	8.9	11.2	18.8	5.9	5.0
205	206	3	1	1	3.1722E-02	100.0	18.2	0.0	12.5	73.4	12.7	0.0	18.3	24.4	4.3	0.0	3.1	17.7	3.1	0.0	4.3
205	204	4	3	1	2.0451E-03	0.0	26.9	100.0	12.5	0.0	19.8	80.6	9.3	0.0	26.9	100.0	12.5	0.0	19.8	80.6	9.3

205	206	4	3	1	2.4255E-03	0.0	26.1	100.0	12.9	0.0	19.2	80.1	9.4	0.0	26.1	100.0	12.9	0.0	19.2	80.1	9.4
206	103	3	7	1	2.9368E-05	0.1	0.9	29.2	5.4	0.4	15.9	100.0	5.0	0.0	0.0	0.5	0.2	0.1	1.2	4.5	0.4
206	101	3	3	1	2.8597E-05	0.2	10.6	100.0	8.3	0.2	1.7	26.4	3.0	0.0	0.7	4.0	0.6	0.0	0.1	0.4	0.1
206	205	4	7	1	4.4330E-05	0.0	19.6	79.7	9.0	0.0	26.4	100.0	12.7	0.0	19.6	79.7	9.0	0.0	26.4	100.0	12.7
206	201	4	7	1	4.4664E-05	0.0	21.2	86.0	10.0	0.0	25.9	100.0	12.6	0.0	21.2	86.0	10.0	0.0	25.9	100.0	12.6
301	203	1	3	2	4.2027E-07	75.5	56.8	36.0	49.3	72.2	43.6	24.2	44.0	18.2	52.2	100.0	46.6	17.6	42.3	82.1	41.6
301	302	1	1	1	3.1368E-06	100.0	14.2	0.1	19.2	80.9	12.3	0.2	28.0	23.8	3.3	0.0	5.1	19.8	3.0	0.1	7.2
301	303	3	1	1	1.2317E-06	100.0	34.8	1.8	12.1	79.8	20.2	0.5	14.2	23.7	9.4	0.8	2.9	19.6	5.5	0.3	3.3
301	302	4	3	1	1.6620E-09	12.0	72.1	100.0	12.6	2.8	36.0	81.9	10.6	12.0	72.1	100.0	12.6	2.8	36.0	81.9	10.6
301	303	4	6	1	9.4582E-10	20.9	39.4	52.4	6.7	76.2	100.0	63.3	5.7	20.9	39.4	52.4	6.7	76.2	100.0	63.3	5.7
302	301	1	1	1	3.1944E-06	100.0	33.0	0.2	10.3	71.9	20.1	0.1	12.6	23.6	8.7	0.1	2.5	17.8	5.5	0.0	2.9
302	205	2	3	2	2.5379E-07	66.3	54.5	46.7	94.5	54.9	19.1	5.7	8.8	14.3	33.4	100.0	76.9	11.7	14.7	33.7	17.6
302	303	2	1	1	1.3285E-06	100.0	14.0	0.6	21.8	76.2	11.5	1.3	35.6	23.7	3.3	0.3	6.1	18.8	2.8	0.5	9.6
302	301	4	7	1	1.6868E-09	3.1	44.9	73.3	8.4	12.8	95.3	100.0	10.8	3.1	44.9	73.3	8.4	12.8	95.3	100.0	10.8
302	303	4	2	1	9.9295E-10	55.1	100.0	64.7	5.8	23.6	50.2	51.3	4.9	55.1	100.0	64.7	5.8	23.6	50.2	51.3	4.9
303	302	2	1	1	6.7808E-06	100.0	45.9	0.3	5.9	60.8	27.6	0.1	8.2	23.4	12.5	0.1	1.4	15.3	8.0	0.1	1.8
303	201	3	2	1	4.9928E-07	92.9	100.0	17.1	8.9	18.5	12.4	2.3	11.2	18.4	57.1	32.4	6.1	5.0	15.1	11.0	4.6
303	301	3	1	1	3.4313E-06	100.0	11.5	0.1	19.3	64.5	9.0	0.4	36.6	23.3	2.6	0.1	5.4	16.0	2.1	0.2	9.7
303	302	4	6	1	5.7919E-09	5.0	56.0	34.8	1.8	12.8	100.0	54.7	2.3	5.0	56.0	34.8	1.8	12.8	100.0	54.7	2.3
303	301	4	2	1	2.2727E-09	20.6	100.0	74.3	5.1	5.3	42.6	50.9	3.9	20.6	100.0	74.3	5.1	5.3	42.6	50.9	3.9

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 2, 30.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	S I D E	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points --> |							<-- Side 2: Brace side points --> |						
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	9.7262E-02	100.0	18.4	0.0	12.4	73.1	12.7	0.0	18.3	24.5	4.4	0.0	3.1	17.6	3.1	0.0	4.3
201	206	3	5	1	1.0549E-01	84.3	14.5	0.0	18.2	100.0	18.6	0.0	14.4	20.3	3.5	0.0	4.5	24.5	4.6	0.0	3.5
201	303	3	5	1	4.9179E-06	70.9	29.2	2.2	27.3	100.0	29.4	0.7	11.9	17.2	21.2	11.7	14.4	23.8	17.5	6.8	6.2
201	202	4	3	1	7.3014E-03	0.0	18.4	100.0	18.7	0.0	13.2	79.7	13.8	0.0	18.4	100.0	18.7	0.0	13.2	79.7	13.8
201	206	4	3	1	7.1320E-03	0.0	26.7	100.0	12.6	0.0	19.7	80.2	9.2	0.0	26.7	100.0	12.6	0.0	19.7	80.2	9.2
202	101	1	7	1	1.8248E-05	0.4	3.7	40.2	7.5	1.5	15.7	100.0	6.7	0.0	0.2	0.9	0.3	0.1	1.0	4.0	0.5
202	102	1	3	1	1.9080E-05	0.5	9.6	100.0	10.8	0.7	5.1	34.1	3.0	0.0	0.7	4.1	0.8	0.1	0.2	0.7	0.1
202	201	4	7	1	1.3672E-04	0.0	13.5	79.5	13.2	0.0	18.7	100.0	18.3	0.0	13.5	79.5	13.2	0.0	18.7	100.0	18.3
202	203	4	7	1	1.3605E-04	0.0	14.8	85.8	14.7	0.0	18.4	100.0	18.2	0.0	14.8	85.8	14.7	0.0	18.4	100.0	18.2
203	202	1	5	1	1.6674E-01	91.6	15.9	0.0	18.3	100.0	18.1	0.0	16.2	22.3	3.8	0.0	4.5	24.6	4.4	0.0	3.9
203	301	1	1	1	1.3467E-05	100.0	30.0	0.9	9.9	44.3	9.4	0.2	22.3	23.6	14.4	4.8	6.5	11.1	5.9	2.6	9.1
203	204	2	1	1	6.1553E-02	100.0	18.3	0.0	15.1	88.2	15.9	0.0	17.7	24.3	4.4	0.0	3.7	21.3	3.9	0.0	4.2
203	202	4	3	1	1.1999E-02	0.0	17.8	100.0	18.5	0.0	15.1	89.6	16.0	0.0	17.8	100.0	18.5	0.0	15.1	89.6	16.0
203	204	4	3	1	4.5855E-03	0.0	24.4	100.0	13.2	0.0	21.3	91.3	11.7	0.0	24.4	100.0	13.2	0.0	21.3	91.3	11.7
204	102	2	7	1	1.3896E-04	0.0	2.3	37.9	3.7	0.1	10.2	100.0	7.3	0.0	0.1	0.6	0.1	0.0	0.6	3.4	0.5

204	103	2	3	1	1.5670E-04	0.0	7.0	100.0	10.5	0.1	3.0	30.2	1.6	0.0	0.5	4.1	0.8	0.0	0.1	0.4	0.0
204	203	4	7	1	5.6482E-05	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7	0.0	20.2	82.6	9.5	0.0	26.1	100.0	12.7
204	205	4	7	1	5.5915E-05	0.0	20.4	82.9	9.5	0.0	26.2	100.0	12.6	0.0	20.4	82.9	9.5	0.0	26.2	100.0	12.6
205	204	2	5	1	6.3540E-02	95.5	16.4	0.0	18.2	100.0	17.7	0.0	17.2	23.1	4.0	0.0	4.4	24.3	4.3	0.0	4.2
205	302	2	1	1	3.9855E-06	100.0	39.4	16.4	18.1	91.7	15.4	0.3	19.1	24.1	46.0	67.7	9.6	22.3	9.4	12.1	5.3
205	206	3	1	1	1.5500E-01	100.0	18.5	0.0	14.5	84.5	15.1	0.0	17.9	24.5	4.4	0.0	3.5	20.5	3.7	0.0	4.3
205	204	4	3	1	4.7809E-03	0.0	24.6	100.0	13.0	0.0	22.4	94.8	12.4	0.0	24.6	100.0	13.0	0.0	22.4	94.8	12.4
205	206	4	3	1	1.2233E-02	0.0	24.6	100.0	13.2	0.0	20.7	88.5	11.1	0.0	24.6	100.0	13.2	0.0	20.7	88.5	11.1
206	103	3	7	1	1.9877E-05	0.3	2.9	38.4	6.5	0.7	11.2	100.0	9.5	0.0	0.1	0.9	0.4	0.1	0.8	4.3	0.7
206	101	3	3	1	1.8699E-05	0.5	6.7	100.0	15.7	1.8	8.1	38.3	2.8	0.0	0.5	3.8	1.0	0.2	0.3	0.7	0.1
206	205	4	7	1	1.3334E-04	0.0	21.0	85.7	10.0	0.0	25.8	100.0	12.6	0.0	21.0	85.7	10.0	0.0	25.8	100.0	12.6
206	201	4	7	1	1.3619E-04	0.0	19.3	78.7	8.8	0.0	26.5	100.0	12.7	0.0	19.3	78.7	8.8	0.0	26.5	100.0	12.7
301	203	1	5	1	1.6051E-07	42.9	84.8	41.5	58.4	100.0	68.2	16.7	6.6	9.5	69.9	97.4	40.2	20.1	53.9	59.9	12.3
301	302	1	1	1	9.1573E-06	100.0	15.3	0.0	17.6	84.0	13.1	0.1	22.1	23.9	3.6	0.0	4.5	20.6	3.2	0.0	5.5
301	303	3	1	1	9.8436E-06	100.0	23.1	0.1	12.8	83.9	18.4	0.0	14.9	23.9	5.8	0.0	3.1	20.6	4.7	0.0	3.5
301	302	4	3	1	4.8635E-09	3.2	36.7	100.0	13.6	1.6	24.4	84.9	11.1	3.2	36.7	100.0	13.6	1.6	24.4	84.9	11.1
301	303	4	7	1	4.8993E-09	1.9	35.1	85.2	8.0	7.8	50.8	100.0	9.3	1.9	35.1	85.2	8.0	7.8	50.8	100.0	9.3
302	301	1	1	1	8.7872E-06	100.0	34.1	0.1	10.4	93.2	30.8	0.1	10.9	24.1	9.1	0.1	2.4	22.6	8.3	0.0	2.5
302	205	2	3	2	6.9802E-07	28.6	60.6	56.0	9.0	21.9	5.6	2.1	3.4	6.2	52.5	100.0	12.0	5.3	7.2	18.9	1.8
302	303	2	1	1	2.3896E-05	100.0	9.2	0.0	18.8	50.9	5.7	0.2	39.0	23.1	2.0	0.0	5.4	12.9	1.4	0.1	10.2
302	301	4	7	1	4.6796E-09	3.3	70.0	93.6	7.8	6.4	83.6	100.0	8.2	3.3	70.0	93.6	7.8	6.4	83.6	100.0	8.2
302	303	4	2	1	1.5132E-08	10.0	100.0	71.1	3.3	2.4	42.2	38.5	2.2	10.0	100.0	71.1	3.3	2.4	42.2	38.5	2.2
303	302	2	1	1	2.9647E-05	100.0	43.3	0.2	4.4	47.5	20.8	0.0	7.7	23.0	11.5	0.1	1.0	12.1	6.1	0.0	1.6
303	201	3	1	1	6.4871E-07	100.0	44.5	9.5	15.3	22.6	7.8	4.0	35.8	20.8	22.4	21.4	13.2	6.6	7.7	13.5	18.2
303	301	3	1	1	6.5489E-06	100.0	12.8	0.0	13.4	51.5	7.2	0.1	27.6	22.9	2.9	0.0	3.6	12.9	1.7	0.0	6.9
303	302	4	6	1	2.2661E-08	2.5	43.7	30.5	1.3	9.8	100.0	60.7	2.0	2.5	43.7	30.5	1.3	9.8	100.0	60.7	2.0
303	301	4	3	1	3.2941E-09	7.1	76.4	100.0	8.3	2.2	31.1	54.1	3.9	7.1	76.4	100.0	8.3	2.2	31.1	54.1	3.9

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 3, 60.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S D		<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
				DAMAGE	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	5.7834E-02	100.0	18.3	0.0	14.5	84.7	15.1	0.0	17.7	24.3	4.4	0.0	3.5	20.5	3.7	0.0	4.2
201	206	3	5	1	2.2569E-02	96.8	16.7	0.0	18.1	100.0	17.6	0.0	17.4	23.4	4.0	0.0	4.4	24.3	4.3	0.0	4.2
201	303	3	5	1	7.3633E-06	99.0	26.7	2.2	26.7	100.0	25.7	1.2	25.9	24.0	17.7	13.5	16.7	24.2	15.9	10.3	16.0
201	202	4	3	1	4.4251E-03	0.0	17.4	100.0	19.0	0.0	14.6	88.7	16.2	0.0	17.4	100.0	19.0	0.0	14.6	88.7	16.2
201	206	4	3	1	1.4982E-03	0.0	24.6	100.0	12.8	0.0	22.8	96.0	12.4	0.0	24.6	100.0	12.8	0.0	22.8	96.0	12.4
202	101	1	7	1	3.0593E-05	0.2	3.8	31.9	1.8	0.1	7.5	100.0	11.2	0.0	0.1	0.5	0.1	0.0	0.6	4.1	0.8
202	102	1	3	1	3.3136E-05	0.1	5.7	100.0	14.7	0.5	4.3	24.1	0.8	0.0	0.5	4.4	1.0	0.1	0.2	0.3	0.0
202	201	4	7	1	4.7294E-05	0.0	14.8	86.2	14.8	0.0	18.2	100.0	18.3	0.0	14.8	86.2	14.8	0.0	18.2	100.0	18.3

202	203	4	7	1	4.7791E-05	0.0	13.3	77.9	12.8	0.0	19.0	100.0	18.3	0.0	13.3	77.9	12.8	0.0	19.0	100.0	18.3
203	202	1	5	1	3.2985E-02	82.7	14.2	0.0	18.3	100.0	18.6	0.0	14.1	19.9	3.4	0.0	4.5	24.4	4.6	0.0	3.4
203	301	1	1	1	6.0038E-06	100.0	65.6	3.1	12.3	44.4	14.1	0.2	12.3	23.4	48.8	14.7	6.6	10.9	15.1	4.3	4.2
203	204	2	1	1	3.6017E-02	100.0	18.3	0.0	12.4	72.5	12.5	0.0	18.3	24.4	4.3	0.0	3.0	17.4	3.1	0.0	4.3
203	202	4	3	1	2.3790E-03	0.0	19.2	100.0	18.2	0.0	13.6	79.2	13.3	0.0	19.2	100.0	18.2	0.0	13.6	79.2	13.3
203	204	4	3	1	2.6062E-03	0.0	26.0	100.0	13.0	0.0	18.9	79.2	9.3	0.0	26.0	100.0	13.0	0.0	18.9	79.2	9.3
204	102	2	7	1	3.0828E-05	0.1	1.4	35.3	5.7	0.5	13.9	100.0	5.8	0.0	0.0	0.6	0.2	0.1	0.9	3.7	0.4
204	103	2	3	1	3.7458E-05	0.1	11.5	100.0	7.6	0.1	1.3	21.9	2.7	0.0	0.9	4.8	0.7	0.0	0.0	0.3	0.1
204	203	4	7	1	5.1306E-05	0.0	19.4	79.3	8.9	0.0	26.3	100.0	12.7	0.0	19.4	79.3	8.9	0.0	26.3	100.0	12.7
204	205	4	7	1	5.0443E-05	0.0	21.2	86.4	10.1	0.0	25.8	100.0	12.6	0.0	21.2	86.4	10.1	0.0	25.8	100.0	12.6
205	204	2	5	1	6.1336E-02	91.6	15.7	0.0	18.2	100.0	17.9	0.0	16.1	22.1	3.8	0.0	4.4	24.3	4.4	0.0	3.9
205	302	2	1	1	3.0367E-06	100.0	40.4	6.7	44.1	93.7	22.2	0.5	13.4	23.8	24.5	35.4	40.2	22.3	13.3	11.3	10.4
205	206	3	1	1	1.8563E-02	100.0	18.3	0.0	15.2	89.5	16.2	0.0	17.6	24.3	4.4	0.0	3.7	21.7	4.0	0.0	4.2
205	204	4	3	1	4.6225E-03	0.0	25.0	100.0	12.8	0.0	21.6	90.2	11.1	0.0	25.0	100.0	12.8	0.0	21.6	90.2	11.1
205	206	4	3	1	1.4628E-03	0.0	24.2	100.0	13.3	0.0	21.3	92.5	12.1	0.0	24.2	100.0	13.3	0.0	21.3	92.5	12.1
206	103	3	7	1	3.1859E-05	0.0	1.2	24.9	3.0	0.2	10.9	100.0	7.1	0.0	0.1	0.4	0.1	0.0	0.8	4.5	0.6
206	101	3	3	1	2.8639E-05	0.1	7.5	100.0	10.7	0.2	3.3	28.7	1.6	0.0	0.5	3.7	0.7	0.0	0.1	0.4	0.1
206	205	4	7	1	1.7237E-05	0.0	20.2	82.4	9.5	0.0	26.2	100.0	12.6	0.0	20.2	82.4	9.5	0.0	26.2	100.0	12.6
206	201	4	7	1	1.7454E-05	0.0	20.5	83.2	9.6	0.0	26.1	100.0	12.6	0.0	20.5	83.2	9.6	0.0	26.1	100.0	12.6
301	203	1	3	2	2.3322E-07	71.2	55.2	50.5	96.4	64.9	21.2	6.3	8.8	15.4	34.2	100.0	72.4	13.7	15.6	33.1	14.9
301	302	1	1	1	1.2424E-06	100.0	14.3	0.6	21.7	78.9	12.1	1.4	34.7	23.8	3.4	0.3	6.1	19.4	2.9	0.6	9.4
301	303	3	1	1	3.9870E-06	100.0	32.1	0.2	10.1	71.4	19.7	0.1	12.6	23.6	8.4	0.1	2.4	17.7	5.4	0.0	2.9
301	302	4	2	1	9.5109E-10	48.6	100.0	69.2	8.9	20.6	48.8	55.4	7.4	48.6	100.0	69.2	8.9	20.6	48.8	55.4	7.4
301	303	4	6	1	1.9889E-09	4.2	50.1	71.1	5.3	16.0	100.0	95.5	7.1	4.2	50.1	71.1	5.3	16.0	100.0	95.5	7.1
302	301	1	1	1	7.6873E-06	100.0	47.3	0.3	6.4	62.6	28.6	0.1	8.4	23.4	12.9	0.1	1.5	15.6	8.3	0.1	1.9
302	205	2	2	1	6.6555E-07	90.0	100.0	19.5	11.0	22.2	13.1	2.4	11.7	18.1	62.9	42.0	8.3	5.9	17.3	14.1	5.6
302	303	2	1	1	4.4601E-06	100.0	12.6	0.1	18.4	69.0	10.1	0.3	32.4	23.5	2.9	0.0	5.0	17.1	2.4	0.1	8.4
302	301	4	6	1	6.4452E-09	3.9	55.5	40.4	3.2	10.5	100.0	62.8	3.9	3.9	55.5	40.4	3.2	10.5	100.0	62.8	3.9
302	303	4	2	1	2.3117E-09	19.1	100.0	91.7	7.0	4.5	44.2	66.6	5.5	19.1	100.0	91.7	7.0	4.5	44.2	66.6	5.5
303	302	2	1	1	1.1983E-06	100.0	36.8	2.5	11.6	78.9	20.8	0.8	13.9	23.7	10.1	1.1	2.8	19.4	5.8	0.4	3.3
303	201	3	3	2	3.0247E-07	89.1	66.1	38.2	50.6	83.1	53.4	28.5	50.8	21.4	57.2	100.0	45.8	20.3	48.5	87.0	44.7
303	301	3	1	1	3.4246E-06	100.0	13.7	0.1	19.2	78.1	11.5	0.2	28.8	23.7	3.2	0.0	5.1	19.2	2.8	0.1	7.5
303	302	4	6	1	1.0861E-09	25.1	38.8	46.2	6.8	87.9	100.0	56.5	5.0	25.1	38.8	46.2	6.8	87.9	100.0	56.5	5.0
303	301	4	3	1	1.7583E-09	16.6	86.4	100.0	8.2	4.2	45.5	80.6	6.5	16.6	86.4	100.0	8.2	4.2	45.5	80.6	6.5

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 4, 90.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.2831E-01	100.0	18.3	0.0	15.2	88.9	16.0	0.0	17.6	24.3	4.4	0.0	3.7	21.5	3.9	0.0	4.2

201	206	3	5	1	3.9475E-01	92.8	16.2	0.0	18.4	100.0	18.2	0.0	16.6	22.8	3.9	0.0	4.5	24.8	4.4	0.0	4.0
201	303	3	1	1	2.4768E-05	100.0	29.8	0.6	8.2	43.1	9.7	0.2	21.0	23.7	13.3	3.1	4.6	10.7	5.6	1.7	7.5
201	202	4	3	1	9.8643E-03	0.0	17.2	100.0	19.0	0.0	15.0	91.9	17.2	0.0	17.2	100.0	19.0	0.0	15.0	91.9	17.2
201	206	4	3	1	2.6780E-02	0.0	25.1	100.0	12.8	0.0	21.8	90.5	11.1	0.0	25.1	100.0	12.8	0.0	21.8	90.5	11.1
202	101	1	7	1	2.9039E-04	0.0	1.9	35.3	3.7	0.1	10.8	100.0	6.8	0.0	0.1	0.5	0.1	0.0	0.7	3.7	0.5
202	102	1	3	1	2.9871E-04	0.0	6.8	100.0	10.9	0.1	3.3	31.7	1.6	0.0	0.5	3.8	0.7	0.0	0.1	0.5	0.0
202	201	4	7	1	1.1708E-04	0.0	14.1	82.7	14.0	0.0	18.5	100.0	18.3	0.0	14.1	82.7	14.0	0.0	18.5	100.0	18.3
202	203	4	7	1	1.1736E-04	0.0	14.1	82.5	13.9	0.0	18.6	100.0	18.2	0.0	14.1	82.5	13.9	0.0	18.6	100.0	18.2
203	202	1	5	1	1.3702E-01	95.2	16.4	0.0	18.2	100.0	17.8	0.0	17.1	23.1	4.0	0.0	4.4	24.3	4.3	0.0	4.1
203	301	1	1	1	8.9833E-06	100.0	38.8	13.4	16.0	89.8	16.2	0.3	17.5	24.1	38.6	51.4	7.4	21.8	8.3	9.0	4.5
203	204	2	1	1	3.5904E-01	100.0	18.6	0.0	14.6	84.5	15.2	0.0	18.0	24.7	4.5	0.0	3.6	20.6	3.7	0.0	4.3
203	202	4	3	1	9.7445E-03	0.0	17.6	100.0	18.5	0.0	15.8	94.1	17.4	0.0	17.6	100.0	18.5	0.0	15.8	94.1	17.4
203	204	4	3	1	2.7001E-02	0.0	24.6	100.0	13.2	0.0	20.7	88.3	11.0	0.0	24.6	100.0	13.2	0.0	20.7	88.3	11.0
204	102	2	7	1	3.8802E-05	0.7	4.2	48.3	7.2	0.8	10.6	100.0	9.7	0.1	0.2	1.1	0.4	0.1	0.6	3.6	0.6
204	103	2	3	1	4.7416E-05	0.3	7.0	100.0	15.7	1.2	6.9	31.2	2.2	0.0	0.6	4.7	1.1	0.1	0.3	0.6	0.1
204	203	4	7	1	3.0137E-04	0.0	21.1	85.8	10.0	0.0	25.8	100.0	12.6	0.0	21.1	85.8	10.0	0.0	25.8	100.0	12.6
204	205	4	7	1	3.0088E-04	0.0	19.3	78.3	8.7	0.0	26.6	100.0	12.6	0.0	19.3	78.3	8.7	0.0	26.6	100.0	12.6
205	204	2	5	1	2.1040E-01	82.6	14.2	0.0	18.3	100.0	18.8	0.0	14.0	19.9	3.4	0.0	4.5	24.5	4.6	0.0	3.4
205	302	2	5	1	1.4068E-05	60.3	29.4	2.8	27.2	100.0	32.9	0.7	8.9	14.7	26.7	18.3	16.2	23.6	23.1	10.0	6.1
205	206	3	1	1	2.0747E-01	100.0	18.3	0.0	12.4	72.8	12.6	0.0	18.4	24.5	4.3	0.0	3.1	17.6	3.1	0.0	4.4
205	204	4	3	1	1.6007E-02	0.0	26.9	100.0	12.5	0.0	19.6	79.7	9.1	0.0	26.9	100.0	12.5	0.0	19.6	79.7	9.1
205	206	4	3	1	1.5908E-02	0.0	26.2	100.0	12.9	0.0	19.1	79.5	9.3	0.0	26.2	100.0	12.9	0.0	19.1	79.5	9.3
206	103	3	7	1	4.4509E-05	0.3	3.0	34.6	7.2	1.2	16.1	100.0	6.9	0.0	0.2	0.8	0.3	0.1	1.1	4.5	0.6
206	101	3	3	1	3.9432E-05	0.7	9.8	100.0	10.4	0.8	5.7	41.0	3.8	0.1	0.6	3.6	0.7	0.1	0.3	0.8	0.1
206	205	4	7	1	2.9880E-04	0.0	19.5	79.3	8.9	0.0	26.4	100.0	12.7	0.0	19.5	79.3	8.9	0.0	26.4	100.0	12.7
206	201	4	7	1	3.0050E-04	0.0	21.3	86.5	10.1	0.0	25.8	100.0	12.5	0.0	21.3	86.5	10.1	0.0	25.8	100.0	12.5
301	203	1	3	2	1.1553E-06	32.3	69.6	60.1	9.3	25.4	5.9	2.4	4.4	7.1	57.5	100.0	10.5	6.2	7.9	18.6	1.7
301	302	1	1	1	4.8055E-05	100.0	9.0	0.0	19.7	51.7	5.8	0.2	40.3	23.1	2.0	0.0	5.6	13.1	1.4	0.1	10.6
301	303	3	1	1	1.8209E-05	100.0	30.5	0.1	11.2	92.5	27.2	0.0	11.9	24.0	8.0	0.0	2.6	22.5	7.2	0.0	2.7
301	302	4	2	1	3.0316E-08	7.8	100.0	82.9	5.3	1.8	41.8	44.6	3.8	7.8	100.0	82.9	5.3	1.8	41.8	44.6	3.8
301	303	4	7	1	8.7108E-09	3.1	69.7	93.3	6.0	7.2	84.1	100.0	6.6	3.1	69.7	93.3	6.0	7.2	84.1	100.0	6.6
302	301	1	1	1	6.6586E-05	100.0	43.2	0.2	4.7	49.0	21.1	0.0	7.8	23.0	11.4	0.1	1.1	12.4	6.1	0.0	1.7
302	205	2	1	1	2.0069E-06	100.0	45.6	12.2	22.2	29.4	8.4	4.2	38.2	21.3	25.7	31.2	20.3	8.2	8.9	17.9	22.5
302	303	2	1	1	1.3767E-05	100.0	13.3	0.0	13.9	56.4	8.2	0.1	26.3	23.1	3.0	0.0	3.7	14.1	2.0	0.0	6.5
302	301	4	6	1	4.5729E-08	1.5	43.0	38.9	2.5	7.0	100.0	76.1	3.6	1.5	43.0	38.9	2.5	7.0	100.0	76.1	3.6
302	303	4	3	1	6.6151E-09	6.1	69.6	100.0	8.4	2.0	30.9	59.0	4.6	6.1	69.6	100.0	8.4	2.0	30.9	59.0	4.6
303	302	2	1	1	1.9747E-05	100.0	23.6	0.2	12.3	82.3	18.5	0.0	14.6	23.9	6.0	0.1	3.0	20.2	4.8	0.0	3.4
303	201	3	2	1	2.2594E-07	52.2	100.0	39.7	59.4	91.0	59.7	18.5	8.2	10.5	69.9	86.4	39.7	17.7	45.8	57.1	13.9
303	301	3	1	1	1.9668E-05	100.0	14.8	0.1	17.8	81.8	12.4	0.1	22.7	23.9	3.5	0.0	4.6	20.1	3.0	0.0	5.7
303	302	4	7	1	1.0345E-08	2.8	36.1	83.7	7.9	11.0	53.6	100.0	8.9	2.8	36.1	83.7	7.9	11.0	53.6	100.0	8.9
303	301	4	3	1	1.0338E-08	5.5	49.0	100.0	8.8	3.5	34.2	83.1	6.7	5.5	49.0	100.0	8.8	3.5	34.2	83.1	6.7

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 5, 120.0 DEG. (PRINT OF DAMAGE > 1.000E-12)
==========

NODE 1	NODE 2	PLANE	POS	SIDE	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> <-- Side 1: Chord side points -->								<-- Side 2: Brace side points -->							
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	3.5584E-02	100.0	18.3	0.0	12.3	72.6	12.6	0.0	18.3	24.4	4.4	0.0	3.0	17.5	3.1	0.0	4.3
201	206	3	5	1	4.6219E-02	84.1	14.5	0.0	18.2	100.0	18.6	0.0	14.3	20.2	3.5	0.0	4.5	24.4	4.6	0.0	3.4
201	303	3	1	1	6.4955E-06	100.0	69.7	2.9	14.1	46.9	16.0	0.2	11.9	23.6	51.4	12.8	7.3	11.5	16.7	3.8	4.3
201	202	4	3	1	2.6603E-03	0.0	18.5	100.0	18.7	0.0	13.2	79.3	13.7	0.0	18.5	100.0	18.7	0.0	13.2	79.3	13.7
201	206	4	3	1	3.1158E-03	0.0	26.8	100.0	12.6	0.0	19.7	80.0	9.2	0.0	26.8	100.0	12.6	0.0	19.7	80.0	9.2
202	101	1	7	1	3.6240E-05	0.1	0.9	30.0	5.6	0.5	15.4	100.0	5.3	0.0	0.0	0.5	0.2	0.1	1.1	4.2	0.4
202	102	1	3	1	3.7649E-05	0.1	10.8	100.0	7.9	0.1	1.6	25.8	2.9	0.0	0.8	4.3	0.6	0.0	0.0	0.4	0.1
202	201	4	7	1	5.2816E-05	0.0	13.5	78.9	13.1	0.0	18.8	100.0	18.3	0.0	13.5	78.9	13.1	0.0	18.8	100.0	18.3
202	203	4	7	1	5.2511E-05	0.0	14.9	86.6	14.9	0.0	18.3	100.0	18.2	0.0	14.9	86.6	14.9	0.0	18.3	100.0	18.2
203	202	1	5	1	6.8989E-02	92.4	15.9	0.0	18.2	100.0	17.9	0.0	16.3	22.4	3.8	0.0	4.4	24.3	4.3	0.0	3.9
203	301	1	1	1	3.6990E-06	100.0	42.5	5.5	36.4	78.1	20.5	0.5	12.2	23.8	22.9	26.8	34.0	18.8	11.9	8.9	9.2
203	204	2	1	1	2.4383E-02	100.0	18.3	0.0	15.4	90.4	16.3	0.0	17.6	24.3	4.4	0.0	3.7	21.9	4.0	0.0	4.2
203	202	4	3	1	4.9158E-03	0.0	17.7	100.0	18.5	0.0	15.3	90.7	16.3	0.0	17.7	100.0	18.5	0.0	15.3	90.7	16.3
203	204	4	3	1	1.8226E-03	0.0	24.2	100.0	13.2	0.0	21.7	93.0	12.1	0.0	24.2	100.0	13.2	0.0	21.7	93.0	12.1
204	102	2	7	1	3.3653E-05	0.1	1.8	29.7	3.4	0.2	10.7	100.0	7.4	0.0	0.1	0.5	0.1	0.0	0.7	3.7	0.5
204	103	2	3	1	3.7574E-05	0.0	7.2	100.0	10.9	0.2	3.0	24.9	1.2	0.0	0.6	4.5	0.8	0.0	0.1	0.4	0.0
204	203	4	7	1	2.0623E-05	0.0	20.4	83.4	9.6	0.0	26.0	100.0	12.7	0.0	20.4	83.4	9.6	0.0	26.0	100.0	12.7
204	205	4	7	1	2.0462E-05	0.0	20.1	81.8	9.4	0.0	26.3	100.0	12.6	0.0	20.1	81.8	9.4	0.0	26.3	100.0	12.6
205	204	2	5	1	2.2221E-02	95.3	16.4	0.0	18.2	100.0	17.7	0.0	17.2	23.1	3.9	0.0	4.4	24.3	4.3	0.0	4.2
205	302	2	5	1	1.0671E-05	99.3	31.3	3.6	30.0	100.0	27.4	1.7	26.5	24.1	26.7	28.0	24.5	24.2	21.9	20.1	20.8
205	206	3	1	1	6.7983E-02	100.0	18.3	0.0	14.2	83.5	14.8	0.0	17.8	24.3	4.4	0.0	3.5	20.2	3.6	0.0	4.2
205	204	4	3	1	1.6708E-03	0.0	24.7	100.0	12.9	0.0	22.3	94.6	12.4	0.0	24.7	100.0	12.9	0.0	22.3	94.6	12.4
205	206	4	3	1	5.3184E-03	0.0	24.7	100.0	13.2	0.0	20.6	87.8	11.0	0.0	24.7	100.0	13.2	0.0	20.6	87.8	11.0
206	103	3	7	1	3.9939E-05	0.2	3.6	26.8	1.4	0.1	7.1	100.0	12.1	0.0	0.1	0.4	0.0	0.0	0.6	4.6	0.9
206	101	3	3	1	3.7029E-05	0.1	6.2	100.0	13.3	0.5	4.4	28.5	1.2	0.0	0.5	3.9	0.9	0.1	0.2	0.4	0.0
206	205	4	7	1	5.9168E-05	0.0	21.0	85.7	10.0	0.0	25.7	100.0	12.6	0.0	21.0	85.7	10.0	0.0	25.7	100.0	12.6
206	201	4	7	1	6.0383E-05	0.0	19.4	78.8	8.8	0.0	26.5	100.0	12.7	0.0	19.4	78.8	8.8	0.0	26.5	100.0	12.7
301	203	1	2	1	7.0772E-07	81.0	100.0	18.0	10.3	18.6	13.1	2.5	9.3	16.1	61.5	36.6	6.7	4.9	17.4	13.0	4.3
301	302	1	1	1	5.0793E-06	100.0	12.4	0.1	19.4	69.2	10.1	0.4	35.0	23.5	2.9	0.1	5.3	17.1	2.4	0.2	9.2
301	303	3	1	1	8.5297E-06	100.0	44.9	0.2	6.2	62.1	27.3	0.1	8.5	23.4	12.1	0.1	1.5	15.5	7.8	0.0	1.9
301	302	4	2	1	2.9597E-09	18.0	100.0	90.4	9.7	4.5	41.5	64.0	7.8	18.0	100.0	90.4	9.7	4.5	41.5	64.0	7.8
301	303	4	6	1	6.7238E-09	4.9	56.5	36.6	2.0	12.2	100.0	56.3	2.5	4.9	56.5	36.6	2.0	12.2	100.0	56.3	2.5
302	301	1	1	1	1.4896E-06	100.0	35.1	1.9	12.2	80.1	20.3	0.5	14.2	23.7	9.5	0.8	2.9	19.7	5.6	0.3	3.3
302	205	2	3	2	9.0520E-07	58.8	51.7	33.4	39.4	56.6	37.5	20.1	31.5	14.1	51.7	100.0	40.7	13.7	40.3	77.6	33.5
302	303	2	1	1	4.1790E-06	100.0	13.8	0.1	19.4	79.4	12.0	0.2	28.8	23.7	3.2	0.0	5.1	19.5	2.9	0.1	7.4
302	301	4	6	1	1.2312E-09	16.3	36.2	52.1	7.8	64.5	100.0	64.1	8.2	16.3	36.2	52.1	7.8	64.5	100.0	64.1	8.2
302	303	4	3	1	2.0328E-09	17.3	87.7	100.0	8.5	4.4	46.2	82.1	7.3	17.3	87.7	100.0	8.5	4.4	46.2	82.1	7.3
303	302	2	1	1	4.6092E-06	100.0	32.2	0.2	9.9	71.0	19.7	0.1	12.5	23.6	8.4	0.1	2.4	17.6	5.4	0.0	2.9

303	201	3	3	2	2.1544E-07	86.7	70.2	53.2	99.5	56.1	22.5	7.1	9.1	18.5	38.4	100.0	76.1	12.2	16.3	33.8	16.3
303	301	3	1	1	1.4076E-06	100.0	13.9	0.9	22.9	77.0	11.5	1.9	38.0	23.7	3.2	0.4	6.6	19.0	2.8	0.8	10.5
303	302	4	6	1	2.4046E-09	4.0	50.0	71.4	5.2	15.6	100.0	96.4	7.1	4.0	50.0	71.4	5.2	15.6	100.0	96.4	7.1
303	301	4	2	1	1.2829E-09	67.5	100.0	56.0	5.0	29.7	49.6	44.8	4.7	67.5	100.0	56.0	5.0	29.7	49.6	44.8	4.7

BUFFETING DAMAGE TABLE FOR WIND DIRECTION 6, 150.0 DEG. (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S	I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points -->								| <-- Side 2: Brace side points --> |						
						1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	1.9287E-01	100.0	18.6	0.0	14.5	84.2	15.1	0.0	18.0	24.7	4.5	0.0	3.5	20.6	3.7	0.0	4.3
201	206	3	5	1	8.6352E-02	95.3	16.5	0.0	18.2	100.0	17.8	0.0	17.1	23.1	4.0	0.0	4.4	24.4	4.3	0.0	4.1
201	303	3	1	1	5.5233E-06	100.0	37.3	11.5	16.8	88.4	15.0	0.3	18.9	24.1	35.5	41.2	6.6	21.5	7.8	6.9	5.0
201	202	4	3	1	1.4956E-02	0.0	17.4	100.0	19.0	0.0	14.4	88.0	16.0	0.0	17.4	100.0	19.0	0.0	14.4	88.0	16.0
201	206	4	3	1	5.7569E-03	0.0	24.9	100.0	12.8	0.0	22.5	94.1	12.0	0.0	24.9	100.0	12.8	0.0	22.5	94.1	12.0
202	101	1	7	1	2.2769E-05	0.5	3.3	39.3	6.3	0.8	10.9	100.0	9.6	0.0	0.1	0.9	0.3	0.1	0.7	4.0	0.7
202	102	1	3	1	2.3368E-05	0.4	6.7	100.0	15.6	1.5	7.4	35.5	2.7	0.0	0.5	4.1	1.0	0.1	0.3	0.7	0.1
202	201	4	7	1	1.6769E-04	0.0	14.6	85.5	14.6	0.0	18.3	100.0	18.2	0.0	14.6	85.5	14.6	0.0	18.3	100.0	18.2
202	203	4	7	1	1.6932E-04	0.0	13.4	78.6	13.0	0.0	18.9	100.0	18.3	0.0	13.4	78.6	13.0	0.0	18.9	100.0	18.3
203	202	1	5	1	1.2414E-01	83.5	14.4	0.0	18.4	100.0	18.7	0.0	14.3	20.2	3.4	0.0	4.5	24.6	4.6	0.0	3.4
203	301	1	5	1	5.8935E-06	63.9	28.5	2.3	28.3	100.0	29.9	0.7	10.5	15.5	22.5	13.4	15.6	23.7	18.6	7.7	6.4
203	204	2	1	1	1.2285E-01	100.0	18.4	0.0	12.6	73.5	12.7	0.0	18.4	24.6	4.4	0.0	3.1	17.7	3.1	0.0	4.4
203	202	4	3	1	8.9990E-03	0.0	19.0	100.0	18.2	0.0	13.7	79.9	13.5	0.0	19.0	100.0	18.2	0.0	13.7	79.9	13.5
203	204	4	3	1	8.9587E-03	0.0	25.9	100.0	13.0	0.0	19.1	79.8	9.4	0.0	25.9	100.0	13.0	0.0	19.1	79.8	9.4
204	102	2	7	1	2.2929E-05	0.5	3.8	43.5	8.3	1.8	15.7	100.0	6.7	0.0	0.2	1.0	0.4	0.2	1.0	3.6	0.4
204	103	2	3	1	2.6164E-05	0.3	9.4	100.0	11.0	0.6	5.3	33.9	2.7	0.0	0.7	4.4	0.8	0.1	0.3	0.7	0.1
204	203	4	7	1	1.6942E-04	0.0	19.4	79.6	9.0	0.0	26.3	100.0	12.7	0.0	19.4	79.6	9.0	0.0	26.3	100.0	12.7
204	205	4	7	1	1.6655E-04	0.0	21.2	86.1	10.0	0.0	25.8	100.0	12.6	0.0	21.2	86.1	10.0	0.0	25.8	100.0	12.6
205	204	2	5	1	1.9764E-01	92.0	16.0	0.0	18.5	100.0	18.2	0.0	16.5	22.6	3.9	0.0	4.5	24.7	4.4	0.0	4.0
205	302	2	1	1	1.6282E-05	100.0	30.1	0.9	9.9	42.5	8.9	0.2	22.7	23.5	14.9	5.6	7.1	10.7	6.0	3.0	9.7
205	206	3	1	1	7.6052E-02	100.0	18.4	0.0	15.1	88.6	16.1	0.0	17.6	24.3	4.4	0.0	3.7	21.5	3.9	0.0	4.2
205	204	4	3	1	1.5128E-02	0.0	25.0	100.0	12.9	0.0	21.6	90.5	11.2	0.0	25.0	100.0	12.9	0.0	21.6	90.5	11.2
205	206	4	3	1	5.9955E-03	0.0	24.3	100.0	13.3	0.0	21.2	91.8	12.0	0.0	24.3	100.0	13.3	0.0	21.2	91.8	12.0
206	103	3	7	1	1.8614E-04	0.0	1.8	33.2	3.3	0.1	10.4	100.0	7.0	0.0	0.1	0.5	0.1	0.0	0.7	4.1	0.5
206	101	3	3	1	1.7496E-04	0.0	7.4	100.0	10.3	0.1	3.3	33.9	2.0	0.0	0.5	3.5	0.7	0.0	0.1	0.5	0.1
206	205	4	7	1	7.0331E-05	0.0	20.3	82.9	9.5	0.0	26.1	100.0	12.6	0.0	20.3	82.9	9.5	0.0	26.1	100.0	12.6
206	201	4	7	1	7.1313E-05	0.0	20.3	82.7	9.5	0.0	26.2	100.0	12.6	0.0	20.3	82.7	9.5	0.0	26.2	100.0	12.6
301	203	1	1	1	8.7571E-07	100.0	43.6	9.2	15.8	23.9	7.9	3.8	35.8	20.9	22.3	21.8	13.9	6.9	7.9	13.7	18.5
301	302	1	1	1	8.2706E-06	100.0	12.5	0.0	14.0	54.2	7.7	0.1	28.5	23.0	2.8	0.0	3.8	13.6	1.9	0.0	7.1
301	303	3	1	1	3.8994E-05	100.0	42.0	0.1	4.6	48.6	20.5	0.0	7.9	23.0	11.0	0.1	1.1	12.3	5.9	0.0	1.7
301	302	4	3	1	4.3184E-09	5.0	66.9	100.0	10.9	1.4	25.6	56.2	6.4	5.0	66.9	100.0	10.9	1.4	25.6	56.2	6.4

301	303	4	6	1	2.7058E-08	2.3	44.2	32.7	1.5	9.1	100.0	63.6	2.1	2.3	44.2	32.7	1.5	9.1	100.0	63.6	2.1
302	301	1	1	1	1.1629E-05	100.0	23.1	0.1	13.1	84.5	18.5	0.0	15.1	23.9	5.8	0.0	3.1	20.7	4.7	0.0	3.6
302	205	2	5	1	2.4009E-07	39.0	77.7	37.8	58.2	100.0	63.6	14.6	6.9	8.9	67.2	95.0	40.9	20.2	51.4	57.7	13.0
302	303	2	1	1	1.2833E-05	100.0	15.2	0.0	17.5	82.5	12.7	0.1	22.0	23.9	3.6	0.0	4.4	20.3	3.1	0.0	5.5
302	301	4	7	1	6.1786E-09	1.4	27.4	85.4	11.7	6.0	41.5	100.0	13.7	1.4	27.4	85.4	11.7	6.0	41.5	100.0	13.7
302	303	4	3	1	6.4129E-09	3.9	45.4	100.0	9.2	2.1	32.3	83.8	7.1	3.9	45.4	100.0	9.2	2.1	32.3	83.8	7.1
303	302	2	1	1	1.1699E-05	100.0	31.8	0.1	11.0	93.2	28.5	0.1	11.5	24.1	8.4	0.0	2.6	22.7	7.6	0.0	2.7
303	201	3	3	2	5.6240E-07	39.8	90.0	64.0	8.8	24.7	6.8	2.5	4.1	8.2	66.1	100.0	10.1	6.0	8.3	17.7	1.7
303	301	3	1	1	2.6599E-05	100.0	8.7	0.0	19.7	50.1	5.4	0.2	41.1	23.0	1.9	0.0	5.7	12.7	1.3	0.1	10.8
303	302	4	7	1	5.8800E-09	4.0	75.5	94.1	6.5	8.2	90.1	100.0	6.5	4.0	75.5	94.1	6.5	8.2	90.1	100.0	6.5
303	301	4	2	1	1.9199E-08	11.1	100.0	65.3	2.8	2.8	42.5	34.8	1.9	11.1	100.0	65.3	2.8	2.8	42.5	34.8	1.9

BUFFETING DAMAGE TABLE FOR ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P S O I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points --> |								<-- Side 2: Brace side points --> |						
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	202	1	1	1	5.2882E-01	100.0	18.4	0.0	14.2	82.7	14.7	0.0	17.9	24.5	4.4	0.0	3.5	20.1	3.6	0.0	4.3
201	206	3	5	1	7.1263E-01	91.3	15.9	0.0	18.3	100.0	18.2	0.0	16.2	22.2	3.8	0.0	4.5	24.6	4.4	0.0	3.9
201	303	3	1	1	5.0355E-05	100.0	36.7	2.8	16.1	65.9	16.3	0.4	19.6	23.9	22.9	12.1	9.4	16.1	10.4	4.7	8.2
201	202	4	3	1	4.0506E-02	0.0	17.6	100.0	18.9	0.0	14.3	87.1	15.8	0.0	17.6	100.0	18.9	0.0	14.3	87.1	15.8
201	206	4	3	1	4.8104E-02	0.0	25.4	100.0	12.7	0.0	21.4	88.8	10.8	0.0	25.4	100.0	12.7	0.0	21.4	88.8	10.8
202	101	1	7	1	4.2394E-04	0.1	2.1	34.5	4.0	0.3	11.2	100.0	7.1	0.0	0.1	0.6	0.1	0.0	0.8	3.9	0.5
202	102	1	3	1	4.3762E-04	0.1	7.2	100.0	11.1	0.3	3.5	30.6	1.8	0.0	0.5	3.9	0.8	0.0	0.1	0.5	0.1
202	201	4	7	1	5.3807E-04	0.0	14.1	82.7	14.0	0.0	18.5	100.0	18.3	0.0	14.1	82.7	14.0	0.0	18.5	100.0	18.3
202	203	4	7	1	5.3952E-04	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2
203	202	1	5	1	5.5032E-01	90.4	15.6	0.0	18.3	100.0	18.1	0.0	15.9	21.9	3.8	0.0	4.5	24.5	4.4	0.0	3.8
203	301	1	1	1	4.2990E-05	100.0	39.2	4.8	19.7	75.9	18.8	0.5	19.0	23.9	28.2	21.7	12.7	18.4	12.5	7.5	8.9
203	204	2	1	1	6.5261E-01	100.0	18.5	0.0	14.1	82.4	14.7	0.0	18.0	24.6	4.4	0.0	3.5	20.0	3.6	0.0	4.3
203	202	4	3	1	3.9488E-02	0.0	18.1	100.0	18.4	0.0	14.9	88.2	15.7	0.0	18.1	100.0	18.4	0.0	14.9	88.2	15.7
203	204	4	3	1	4.8597E-02	0.0	24.9	100.0	13.1	0.0	20.4	86.8	10.7	0.0	24.9	100.0	13.1	0.0	20.4	86.8	10.7
204	102	2	7	1	2.9242E-04	0.2	2.7	38.1	4.5	0.4	10.9	100.0	7.8	0.0	0.1	0.7	0.2	0.0	0.7	3.6	0.5
204	103	2	3	1	3.3686E-04	0.1	7.6	100.0	11.4	0.3	3.7	28.5	1.8	0.0	0.6	4.4	0.9	0.0	0.1	0.5	0.1
204	203	4	7	1	6.3832E-04	0.0	20.4	83.3	9.6	0.0	26.0	100.0	12.7	0.0	20.4	83.3	9.6	0.0	26.0	100.0	12.7
204	205	4	7	1	6.3330E-04	0.0	20.0	81.5	9.3	0.0	26.3	100.0	12.6	0.0	20.0	81.5	9.3	0.0	26.3	100.0	12.6
205	204	2	5	1	5.8215E-01	88.7	15.3	0.0	18.3	100.0	18.3	0.0	15.6	21.5	3.7	0.0	4.5	24.5	4.5	0.0	3.8
205	302	2	1	1	4.7187E-05	100.0	39.6	4.2	24.2	85.5	23.3	0.8	20.2	23.9	30.7	23.7	17.1	20.6	17.5	10.9	11.5
205	206	3	1	1	5.5680E-01	100.0	18.4	0.0	13.7	80.1	14.2	0.0	18.0	24.4	4.4	0.0	3.4	19.4	3.5	0.0	4.3
205	204	4	3	1	4.4254E-02	0.0	25.7	100.0	12.7	0.0	20.9	86.7	10.5	0.0	25.7	100.0	12.7	0.0	20.9	86.7	10.5
205	206	4	3	1	4.3344E-02	0.0	25.2	100.0	13.1	0.0	20.1	85.2	10.5	0.0	25.2	100.0	13.1	0.0	20.1	85.2	10.5
206	103	3	7	1	3.5169E-04	0.1	2.1	31.9	3.9	0.3	11.3	100.0	7.5	0.0	0.1	0.6	0.2	0.0	0.8	4.3	0.6

206	101	3	3	1	3.2735E-04	0.2	7.8	100.0	10.8	0.4	3.9	33.3	2.2	0.0	0.5	3.6	0.7	0.0	0.1	0.5	0.1
206	205	4	7	1	6.2321E-04	0.0	20.1	81.8	9.3	0.0	26.2	100.0	12.6	0.0	20.1	81.8	9.3	0.0	26.2	100.0	12.6
206	201	4	7	1	6.3050E-04	0.0	20.6	83.5	9.6	0.0	26.1	100.0	12.6	0.0	20.6	83.5	9.6	0.0	26.1	100.0	12.6
301	203	1	3	2	2.4146E-06	98.3	99.3	51.3	35.0	51.8	23.7	9.2	26.8	21.0	70.7	100.0	29.8	12.6	24.2	39.1	18.3
301	302	1	1	1	7.4942E-05	100.0	10.7	0.1	18.8	58.8	7.6	0.2	35.8	23.2	2.4	0.0	5.2	14.7	1.8	0.1	9.3
301	303	3	1	1	8.0796E-05	100.0	36.8	0.2	7.6	65.8	22.4	0.1	10.1	23.4	9.6	0.1	1.8	16.3	6.2	0.0	2.3
301	302	4	2	1	4.0095E-08	9.8	100.0	98.0	8.3	2.7	43.1	59.5	6.1	9.8	100.0	98.0	8.3	2.7	43.1	59.5	6.1
301	303	4	6	1	4.6535E-08	3.4	53.6	54.8	3.5	11.4	100.0	79.7	4.2	3.4	53.6	54.8	3.5	11.4	100.0	79.7	4.2
302	301	1	1	1	9.9373E-05	100.0	39.9	0.2	6.6	59.3	22.2	0.1	9.2	23.3	10.5	0.1	1.6	14.8	6.3	0.0	2.0
302	205	2	1	1	3.5991E-06	100.0	77.7	35.5	36.6	49.5	23.2	9.6	33.1	21.6	56.0	83.1	33.6	12.3	24.2	42.0	24.5
302	303	2	1	1	6.0464E-05	100.0	12.1	0.0	17.5	62.7	8.7	0.2	31.2	23.3	2.7	0.0	4.8	15.6	2.1	0.1	8.0
302	301	4	6	1	6.1493E-08	2.4	47.9	51.9	4.4	9.0	100.0	84.8	5.6	2.4	47.9	51.9	4.4	9.0	100.0	84.8	5.6
302	303	4	3	1	2.8576E-08	12.3	97.1	100.0	7.1	3.7	45.3	65.9	5.0	12.3	97.1	100.0	7.1	3.7	45.3	65.9	5.0
303	302	2	1	1	7.3681E-05	100.0	35.6	0.2	8.2	67.3	22.0	0.1	10.6	23.5	9.4	0.1	1.9	16.7	6.1	0.0	2.4
303	201	3	1	1	1.9109E-06	100.0	97.9	43.3	36.4	50.0	25.9	10.2	26.3	21.0	63.6	82.5	29.6	12.0	23.9	37.0	18.4
303	301	3	1	1	6.1079E-05	100.0	11.7	0.1	18.4	63.5	8.5	0.2	32.7	23.4	2.6	0.0	5.1	15.8	2.0	0.1	8.5
303	302	4	6	1	4.2785E-08	4.1	53.6	59.2	4.2	13.8	100.0	84.3	4.9	4.1	53.6	59.2	4.2	13.8	100.0	84.3	4.9
303	301	4	2	1	3.1854E-08	14.3	100.0	95.3	6.4	4.8	47.5	63.5	4.6	14.3	100.0	95.3	6.4	4.8	47.5	63.5	4.6

20 WORST BUFFETING DAMAGES - ALL WIND DIRECTIONS (PRINT OF DAMAGE > 1.000E-12)

N O D E 1	N O D E 2	P L A N E	P O S I D	DAMAGE	<==RELATIVE DAMAGES AROUND THE WELD ====> | <-- Side 1: Chord side points --> |							<-- Side 2: Brace side points --> |						
					1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
201	206	3	5	1	7.1263E-01	91.3	15.9	0.0	18.3	100.0	18.2	0.0	16.2	22.2	3.8	0.0	4.5	24.6	4.4	0.0	3.9
203	204	2	1	1	6.5261E-01	100.0	18.5	0.0	14.1	82.4	14.7	0.0	18.0	24.6	4.4	0.0	3.5	20.0	3.6	0.0	4.3
205	204	2	5	1	5.8215E-01	88.7	15.3	0.0	18.3	100.0	18.3	0.0	15.6	21.5	3.7	0.0	4.5	24.5	4.5	0.0	3.8
205	206	3	1	1	5.5680E-01	100.0	18.4	0.0	13.7	80.1	14.2	0.0	18.0	24.4	4.4	0.0	3.4	19.4	3.5	0.0	4.3
203	202	1	5	1	5.5032E-01	90.4	15.6	0.0	18.3	100.0	18.1	0.0	15.9	21.9	3.8	0.0	4.5	24.5	4.4	0.0	3.8
201	202	1	1	1	5.2882E-01	100.0	18.4	0.0	14.2	82.7	14.7	0.0	17.9	24.5	4.4	0.0	3.5	20.1	3.6	0.0	4.3
203	204	4	3	1	4.8597E-02	0.0	24.9	100.0	13.1	0.0	20.4	86.8	10.7	0.0	24.9	100.0	13.1	0.0	20.4	86.8	10.7
201	206	4	3	1	4.8104E-02	0.0	25.4	100.0	12.7	0.0	21.4	88.8	10.8	0.0	25.4	100.0	12.7	0.0	21.4	88.8	10.8
205	204	4	3	1	4.4254E-02	0.0	25.7	100.0	12.7	0.0	20.9	86.7	10.5	0.0	25.7	100.0	12.7	0.0	20.9	86.7	10.5
205	206	4	3	1	4.3344E-02	0.0	25.2	100.0	13.1	0.0	20.1	85.2	10.5	0.0	25.2	100.0	13.1	0.0	20.1	85.2	10.5
201	202	4	3	1	4.0506E-02	0.0	17.6	100.0	18.9	0.0	14.3	87.1	15.8	0.0	17.6	100.0	18.9	0.0	14.3	87.1	15.8
203	202	4	3	1	3.9488E-02	0.0	18.1	100.0	18.4	0.0	14.9	88.2	15.7	0.0	18.1	100.0	18.4	0.0	14.9	88.2	15.7
204	203	4	7	1	6.3832E-04	0.0	20.4	83.3	9.6	0.0	26.0	100.0	12.7	0.0	20.4	83.3	9.6	0.0	26.0	100.0	12.7
204	205	4	7	1	6.3330E-04	0.0	20.0	81.5	9.3	0.0	26.3	100.0	12.6	0.0	20.0	81.5	9.3	0.0	26.3	100.0	12.6
206	201	4	7	1	6.3050E-04	0.0	20.6	83.5	9.6	0.0	26.1	100.0	12.6	0.0	20.6	83.5	9.6	0.0	26.1	100.0	12.6
206	205	4	7	1	6.2321E-04	0.0	20.1	81.8	9.3	0.0	26.2	100.0	12.6	0.0	20.1	81.8	9.3	0.0	26.2	100.0	12.6
202	203	4	7	1	5.3952E-04	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2	0.0	14.1	82.1	13.8	0.0	18.6	100.0	18.2

```
     202      201 4 7 1       5.3807E-04   0.0  14.1  82.7  14.0   0.0  18.5 100.0  18.3   0.0  14.1  82.7  14.0   0.0  18.5 100.0  18.3
     202      102 1 3 1       4.3762E-04   0.1   7.2 100.0  11.1   0.3   3.5  30.6   1.8   0.0   0.5   3.9   0.8   0.0   0.1   0.5   0.1
     202      101 1 7 1       4.2394E-04   0.1   2.1  34.5   4.0   0.3  11.2 100.0   7.1   0.0   0.1   0.6   0.1   0.0   0.8   3.9   0.5

BUFFETING DAMAGE EVALUATED FOR 42 JOINT CONNECTIONS OVER ALL ANALYSIS PLANES
--------------------------------------------------------------------------------
```

A.2.6.2 Diagnostics file – X505BDiagnostics.txt

```
  ******      ******       ******       ******      ** ***  ****
 ********    ********     ********     ********     **************
**      **  **      **   **      **   **      **    **    **    **
**          **      **   **                  **    **    **    **
 *******    **********    *******     *********    **    **    **
  *******   *********      *******    **********    **    **    **
        **  **                    **   **      **    **    **    **
**      **  **      **   **      **   **      **    **    **    **
 ********    ********     ********     *********    **    **    **
  ******      ******       ******       ****** **   **    **    **


            *******************************************
            *                                         *
            *           F R A M E W O R K             *
            *                                         *
            *    Postprocessing of Frame Structures   *
            *                                         *
            *******************************************

                Marketing and Support by DNV GL - Software

 Program id   : D3.14-03                Computer         : 586
 Release date : 17-MAR-2017             Impl. update     :
 Access time  : 24-MAR-2017 14:46:56    Operating system : Win NT 6.1 [7601]
 User id      : lzhan                   CPU id           : 0405880964
                                        Installation     : , HOUL130304

 Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway




**********************************************************************

PRINT OF               : WIND FATIGUE DIAGOSTICS
```

```
 RUN NAME                : X505B
 RUN DESCRIPTION         : None
 RESULTS INTERFACE FILE  : X505BR1.SIN
 PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  14:46:56

 ************************************************************************

 SCF factors: S1  S2  S3  S4  S5  S6  S7  S8
 ----------------------------------------
 S1 = Axial                 Crown  Chord side
 S2 = Axial                 Crown  Brace side
 S3 = In-plane Bending      Crown  Chord side
 S4 = In-plane Bending      Crown  Brace side
 S5 = Axial                 Saddle Chord side
 S6 = Axial                 Saddle Brace side
 S7 = Out-of-plane Bending  Saddle Chord side
 S8 = Out-of-plane Bending  Saddle Brace side


  NO OF MODES                          2
  RANGING FROM PLANE                   1
            TO PLANE                   4
  JOINT NUMBER IS                    101
  OTHER END NODE IS                    0
  RANGE NODE IS                      303
Jnt 201     Pln 1: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 201     202     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.09  4.18  3.31  2.85 11.55  9.05  8.32  6.27
Jnt 201     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 201     206     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.68  5.47  3.31  2.85  6.68  5.47  8.60  6.47
                   BrcEnds 201     303     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.63  2.58  2.16  3.30  3.63  2.58  5.55  4.18
Jnt 201     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 201     202     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 201     206     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 202     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.236E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 202     101     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
                   BrcEnds 202     102     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
Jnt 202     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 202     201     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 202     203     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 203     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 203     202     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.92  5.63  3.31  2.85  6.92  5.63  8.50  6.40
                   BrcEnds 203     301     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.69  2.59  2.13  3.32  3.69  2.59  5.35  4.03
```

```
Jnt 203     Pln 2: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 203     204     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.11  4.18  3.31  2.85 11.56  9.10  8.36  6.29
Jnt 203     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 203     202     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 203     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 204     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 204     102     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
                   BrcEnds 204     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
Jnt 204     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 204     203     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 204     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 205     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 205     204     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  7.12  5.74  3.30  2.85  7.12  5.74  8.38  6.31
                   BrcEnds 205     302     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.71  2.57  2.09  3.34  3.71  2.57  5.12  3.86
Jnt 205     Pln 3: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 205     206     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.08  4.18  3.30  2.85 11.53  8.98  8.26  6.22
Jnt 205     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 205     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 205     206     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 206     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 206     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
                   BrcEnds 206     101     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
Jnt 206     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 206     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 206     201     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 301     Pln 1: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  9.206E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 301     203     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.49  3.14  3.89  2.27  3.77  2.84
                   BrcEnds 301     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 301     Pln 3: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 301     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 301     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 301     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 301     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 302     Pln 1: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 302     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 302     Pln 2: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.248E-02 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 302     205     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.29  2.16  2.46  3.15  3.77  2.20  3.66  2.76
```

```
                  BrcEnds 302     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 302     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                  User defined Bent Can SCFs not found.  Global Scfs are used.
                  BrcEnds 302     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                  BrcEnds 302     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 303     Pln 2: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                  BrcEnds 303     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 3: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                  Overlapping K-joint. Overlap  4.867E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                  BrcEnds 303     201     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.51  3.13  3.98  2.32  3.86  2.91
                  BrcEnds 303     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                  User defined Bent Can SCFs not found.  Global Scfs are used.
                  BrcEnds 303     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                  BrcEnds 303     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
```

```
 ************************************************************************

 PRINT OF                : WIND FATIGUE DIAGOSTICS

 RUN NAME                : X505B
 RUN DESCRIPTION         : None
 RESULTS INTERFACE FILE  : X505BR1.SIN
 PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  14:46:57

 ************************************************************************

 SCF factors: S1  S2  S3  S4  S5  S6  S7  S8
 ----------------------------------------
 S1 = Axial                Crown  Chord side
 S2 = Axial                Crown  Brace side
 S3 = In-plane Bending     Crown  Chord side
 S4 = In-plane Bending     Crown  Brace side
 S5 = Axial                Saddle Chord side
 S6 = Axial                Saddle Brace side
 S7 = Out-of-plane Bending Saddle Chord side
 S8 = Out-of-plane Bending Saddle Brace side


  NO OF MODES                          2
  RANGING FROM PLANE                   1
```

```
           TO PLANE                    4
  JOINT NUMBER IS                    101
  OTHER END NODE IS                    0
  RANGE NODE IS                      303
Jnt 201     Pln 1: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 201     202     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.09  4.18  3.31  2.85 11.55  9.05  8.32  6.27
Jnt 201     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 201     206     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  6.68  5.47  3.31  2.85  6.68  5.47  8.60  6.47
                   BrcEnds 201     303     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.63  2.58  2.16  3.30  3.63  2.58  5.55  4.18
Jnt 201     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 201     202     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 201     206     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 202     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.236E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 202     101     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
                   BrcEnds 202     102     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
Jnt 202     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 202     201     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 202     203     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 203     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 203     202     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  6.92  5.63  3.31  2.85  6.92  5.63  8.50  6.40
                   BrcEnds 203     301     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.69  2.59  2.13  3.32  3.69  2.59  5.35  4.03
Jnt 203     Pln 2: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 203     204     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.11  4.18  3.31  2.85 11.56  9.10  8.36  6.29
Jnt 203     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 203     202     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 203     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 204     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 204     102     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
                   BrcEnds 204     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
Jnt 204     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 204     203     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 204     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 205     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 205     204     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  7.12  5.74  3.30  2.85  7.12  5.74  8.38  6.31
                   BrcEnds 205     302     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.71  2.57  2.09  3.34  3.71  2.57  5.12  3.86
Jnt 205     Pln 3: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 205     206     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.08  4.18  3.30  2.85 11.53  8.98  8.26  6.22
Jnt 205     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 205     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 205     206     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
```

```
Jnt 206     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 206     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
                   BrcEnds 206     101     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
Jnt 206     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 206     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 206     201     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 301     Pln 1: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  9.206E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 301     203     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.49  3.14  3.89  2.27  3.77  2.84
                   BrcEnds 301     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 301     Pln 3: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 301     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 301     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 301     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 301     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 302     Pln 1: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 302     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 302     Pln 2: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.248E-02 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 302     205     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.29  2.16  2.46  3.15  3.77  2.20  3.66  2.76
                   BrcEnds 302     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 302     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 302     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 302     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 303     Pln 2: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 303     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 3: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  4.867E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 303     201     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.51  3.13  3.98  2.32  3.86  2.91
                   BrcEnds 303     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 303     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 303     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60

 ************************************************************************
```

```
 PRINT OF               : WIND FATIGUE DIAGOSTICS

 RUN NAME               : X505B
 RUN DESCRIPTION        : None
 RESULTS INTERFACE FILE  : X505BR1.SIN
 PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  14:46:57

 ************************************************************************

 SCF factors: S1  S2  S3  S4  S5  S6  S7  S8
 ------------------------------------------
 S1 = Axial                 Crown  Chord side
 S2 = Axial                 Crown  Brace side
 S3 = In-plane Bending      Crown  Chord side
 S4 = In-plane Bending      Crown  Brace side
 S5 = Axial                 Saddle Chord side
 S6 = Axial                 Saddle Brace side
 S7 = Out-of-plane Bending  Saddle Chord side
 S8 = Out-of-plane Bending  Saddle Brace side


  NO OF MODES                          2
  RANGING FROM PLANE                   1
            TO PLANE                   4
  JOINT NUMBER IS                    101
  OTHER END NODE IS                    0
  RANGE NODE IS                      303
Jnt 201     Pln 1: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 201     202     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.09  4.18  3.31  2.85 11.55  9.05  8.32  6.27
Jnt 201     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 201     206     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.68  5.47  3.31  2.85  6.68  5.47  8.60  6.47
                   BrcEnds 201     303     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.63  2.58  2.16  3.30  3.63  2.58  5.55  4.18
Jnt 201     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 201     202     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 201     206     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 202     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.236E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 202     101     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
                   BrcEnds 202     102     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
Jnt 202     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 202     201     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 202     203     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 203     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
```

```
                BrcEnds 203     202     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  6.92  5.63  3.31  2.85  6.92  5.63  8.50  6.40
                BrcEnds 203     301     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.69  2.59  2.13  3.32  3.69  2.59  5.35  4.03
Jnt 203     Pln 2: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 203     204     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.11  4.18  3.31  2.85 11.56  9.10  8.36  6.29
Jnt 203     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                BrcEnds 203     202     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                BrcEnds 203     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 204     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 204     102     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
                BrcEnds 204     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
Jnt 204     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 204     203     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 204     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 205     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                BrcEnds 205     204     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  7.12  5.74  3.30  2.85  7.12  5.74  8.38  6.31
                BrcEnds 205     302     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.71  2.57  2.09  3.34  3.71  2.57  5.12  3.86
Jnt 205     Pln 3: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 205     206     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.08  4.18  3.30  2.85 11.53  8.98  8.26  6.22
Jnt 205     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                BrcEnds 205     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                BrcEnds 205     206     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 206     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 206     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
                BrcEnds 206     101     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
Jnt 206     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 206     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 206     201     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 301     Pln 1: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  9.206E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 301     203     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.49  3.14  3.89  2.27  3.77  2.84
                BrcEnds 301     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 301     Pln 3: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 301     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 301     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 301     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 301     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 302     Pln 1: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 302     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 302     Pln 2: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
```

```
                  Overlapping K-joint. Overlap  1.248E-02 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                  BrcEnds 302     205     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.29  2.16  2.46  3.15  3.77  2.20  3.66  2.76
                  BrcEnds 302     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 302     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                  User defined Bent Can SCFs not found.  Global Scfs are used.
                  BrcEnds 302     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                  BrcEnds 302     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 303     Pln 2: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                  BrcEnds 303     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 3: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                  Overlapping K-joint. Overlap  4.867E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                  BrcEnds 303     201     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.51  3.13  3.98  2.32  3.86  2.91
                  BrcEnds 303     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                  User defined Bent Can SCFs not found.  Global Scfs are used.
                  BrcEnds 303     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                  BrcEnds 303     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
```

```
 ************************************************************************

 PRINT OF               : WIND FATIGUE DIAGOSTICS

 RUN NAME               : X505B
 RUN DESCRIPTION        : None
 RESULTS INTERFACE FILE  : X505BR1.SIN
 PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  14:46:57

 ************************************************************************

 SCF factors: S1  S2  S3  S4  S5  S6  S7  S8
 ----------------------------------------
 S1 = Axial                Crown  Chord side
 S2 = Axial                Crown  Brace side
 S3 = In-plane Bending     Crown  Chord side
 S4 = In-plane Bending     Crown  Brace side
 S5 = Axial                Saddle Chord side
 S6 = Axial                Saddle Brace side
 S7 = Out-of-plane Bending  Saddle Chord side
 S8 = Out-of-plane Bending  Saddle Brace side
```

```
  NO OF MODES                          2
  RANGING FROM PLANE                   1
            TO PLANE                   4
  JOINT NUMBER IS                    101
  OTHER END NODE IS                    0
  RANGE NODE IS                      303
Jnt 201     Pln 1: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 201     202     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.09  4.18  3.31  2.85 11.55  9.05  8.32  6.27
Jnt 201     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 201     206     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.68  5.47  3.31  2.85  6.68  5.47  8.60  6.47
                   BrcEnds 201     303     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.63  2.58  2.16  3.30  3.63  2.58  5.55  4.18
Jnt 201     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 201     202     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 201     206     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 202     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.236E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 202     101     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
                   BrcEnds 202     102     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
Jnt 202     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 202     201     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 202     203     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 203     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 203     202     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.92  5.63  3.31  2.85  6.92  5.63  8.50  6.40
                   BrcEnds 203     301     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.69  2.59  2.13  3.32  3.69  2.59  5.35  4.03
Jnt 203     Pln 2: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 203     204     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.11  4.18  3.31  2.85 11.56  9.10  8.36  6.29
Jnt 203     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 203     202     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 203     204     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 204     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 204     102     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
                   BrcEnds 204     103     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
Jnt 204     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 204     203     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 204     205     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 205     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 205     204     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  7.12  5.74  3.30  2.85  7.12  5.74  8.38  6.31
                   BrcEnds 205     302     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.71  2.57  2.09  3.34  3.71  2.57  5.12  3.86
Jnt 205     Pln 3: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 205     206     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.08  4.18  3.30  2.85 11.53  8.98  8.26  6.22
Jnt 205     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
```

```
                BrcEnds 205     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                BrcEnds 205     206     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 206     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 206     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
                BrcEnds 206     101     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
Jnt 206     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 206     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 206     201     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 301     Pln 1: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  9.206E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 301     203     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.49  3.14  3.89  2.27  3.77  2.84
                BrcEnds 301     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 301     Pln 3: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 301     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 301     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 301     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 301     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 302     Pln 1: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 302     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 302     Pln 2: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.248E-02 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 302     205     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.29  2.16  2.46  3.15  3.77  2.20  3.66  2.76
                BrcEnds 302     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 302     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 302     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 302     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 303     Pln 2: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 303     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 3: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  4.867E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 303     201     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.51  3.13  3.98  2.32  3.86  2.91
                BrcEnds 303     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 303     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 303     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
```

```
************************************************************************

PRINT OF               : WIND FATIGUE DIAGOSTICS

RUN NAME               : X505B
RUN DESCRIPTION        : None
RESULTS INTERFACE FILE  : X505BR1.SIN
PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  14:46:57

************************************************************************

SCF factors: S1  S2  S3  S4  S5  S6  S7  S8
-----------------------------------------
S1 = Axial                 Crown  Chord side
S2 = Axial                 Crown  Brace side
S3 = In-plane Bending      Crown  Chord side
S4 = In-plane Bending      Crown  Brace side
S5 = Axial                 Saddle Chord side
S6 = Axial                 Saddle Brace side
S7 = Out-of-plane Bending  Saddle Chord side
S8 = Out-of-plane Bending  Saddle Brace side


  NO OF MODES                          2
  RANGING FROM PLANE                   1
           TO PLANE                    4
  JOINT NUMBER IS                    101
  OTHER END NODE IS                    0
  RANGE NODE IS                      303
Jnt 201     Pln 1: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 201     202     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.09  4.18  3.31  2.85 11.55  9.05  8.32  6.27
Jnt 201     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 201     206     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.68  5.47  3.31  2.85  6.68  5.47  8.60  6.47
                   BrcEnds 201     303     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.63  2.58  2.16  3.30  3.63  2.58  5.55  4.18
Jnt 201     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 201     202     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 201     206     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 202     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.236E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 202     101     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
                   BrcEnds 202     102     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
Jnt 202     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 202     201     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
```

```
                BrcEnds 202     203     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 203     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                BrcEnds 203     202     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  6.92  5.63  3.31  2.85  6.92  5.63  8.50  6.40
                BrcEnds 203     301     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.69  2.59  2.13  3.32  3.69  2.59  5.35  4.03
Jnt 203     Pln 2: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 203     204     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.11  4.18  3.31  2.85 11.56  9.10  8.36  6.29
Jnt 203     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                BrcEnds 203     202     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                BrcEnds 203     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 204     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 204     102     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
                BrcEnds 204     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
Jnt 204     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 204     203     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 204     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 205     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                BrcEnds 205     204     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  7.12  5.74  3.30  2.85  7.12  5.74  8.38  6.31
                BrcEnds 205     302     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.71  2.57  2.09  3.34  3.71  2.57  5.12  3.86
Jnt 205     Pln 3: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 205     206     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.08  4.18  3.30  2.85 11.53  8.98  8.26  6.22
Jnt 205     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                BrcEnds 205     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                BrcEnds 205     206     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 206     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 206     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
                BrcEnds 206     101     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
Jnt 206     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 206     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 206     201     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 301     Pln 1: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  9.206E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 301     203     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.49  3.14  3.89  2.27  3.77  2.84
                BrcEnds 301     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 301     Pln 3: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 301     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 301     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 301     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 301     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 302     Pln 1: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
```

```
                  BrcEnds 302     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 302     Pln 2: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                  Overlapping K-joint. Overlap  1.248E-02 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                  BrcEnds 302     205     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.29  2.16  2.46  3.15  3.77  2.20  3.66  2.76
                  BrcEnds 302     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 302     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                  User defined Bent Can SCFs not found.  Global Scfs are used.
                  BrcEnds 302     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                  BrcEnds 302     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 303     Pln 2: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                  BrcEnds 303     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 3: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                  Overlapping K-joint. Overlap  4.867E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                  BrcEnds 303     201     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.51  3.13  3.98  2.32  3.86  2.91
                  BrcEnds 303     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                  User defined Bent Can SCFs not found.  Global Scfs are used.
                  BrcEnds 303     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                  BrcEnds 303     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
```

```
 ************************************************************************

 PRINT OF               : WIND FATIGUE DIAGOSTICS

 RUN NAME               : X505B
 RUN DESCRIPTION        : None
 RESULTS INTERFACE FILE  : X505BR1.SIN
 PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  14:46:58

 ************************************************************************

 SCF factors: S1  S2  S3  S4  S5  S6  S7  S8
 ----------------------------------------
 S1 = Axial                 Crown  Chord side
 S2 = Axial                 Crown  Brace side
 S3 = In-plane Bending      Crown  Chord side
 S4 = In-plane Bending      Crown  Brace side
 S5 = Axial                 Saddle Chord side
 S6 = Axial                 Saddle Brace side
 S7 = Out-of-plane Bending  Saddle Chord side
 S8 = Out-of-plane Bending  Saddle Brace side
```

```
  NO OF MODES                          2
  RANGING FROM PLANE                   1
           TO PLANE                    4
  JOINT NUMBER IS                    101
  OTHER END NODE IS                    0
  RANGE NODE IS                      303
Jnt 201     Pln 1: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 201     202     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.09  4.18  3.31  2.85 11.55  9.05  8.32  6.27
Jnt 201     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 201     206     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.68  5.47  3.31  2.85  6.68  5.47  8.60  6.47
                   BrcEnds 201     303     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.63  2.58  2.16  3.30  3.63  2.58  5.55  4.18
Jnt 201     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 201     202     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 201     206     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 202     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.236E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 202     101     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
                   BrcEnds 202     102     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
Jnt 202     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 202     201     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 202     203     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 203     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 203     202     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.92  5.63  3.31  2.85  6.92  5.63  8.50  6.40
                   BrcEnds 203     301     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.69  2.59  2.13  3.32  3.69  2.59  5.35  4.03
Jnt 203     Pln 2: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 203     204     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.11  4.18  3.31  2.85 11.56  9.10  8.36  6.29
Jnt 203     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 203     202     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 203     204     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 204     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 204     102     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
                   BrcEnds 204     103     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
Jnt 204     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                   User defined Bent Can SCFs not found.  Global Scfs are used.
                   BrcEnds 204     203     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                   BrcEnds 204     205     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 205     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 205     204     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  7.12  5.74  3.30  2.85  7.12  5.74  8.38  6.31
                   BrcEnds 205     302     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.71  2.57  2.09  3.34  3.71  2.57  5.12  3.86
Jnt 205     Pln 3: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
```

```
                BrcEnds 205     206     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.08  4.18  3.30  2.85 11.53  8.98  8.26  6.22
Jnt 205     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                BrcEnds 205     204     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                BrcEnds 205     206     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 206     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 206     103     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
                BrcEnds 206     101     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
Jnt 206     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 206     205     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 206     201     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 301     Pln 1: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  9.206E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 301     203     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.28  2.16  2.49  3.14  3.89  2.27  3.77  2.84
                BrcEnds 301     302     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 301     Pln 3: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 301     303     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 301     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 301     302     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 301     303     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 302     Pln 1: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 302     301     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 302     Pln 2: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.248E-02 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 302     205     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.29  2.16  2.46  3.15  3.77  2.20  3.66  2.76
                BrcEnds 302     303     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 302     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 302     301     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 302     303     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 303     Pln 2: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 303     302     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 3: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  4.867E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 303     201     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.28  2.16  2.51  3.13  3.98  2.32  3.86  2.91
                BrcEnds 303     301     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 303     302     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 303     301     SNcrv DOE-T            BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
```

```
************************************************************************

PRINT OF                : WIND FATIGUE DIAGOSTICS

RUN NAME                : X505B
RUN DESCRIPTION         : None
RESULTS INTERFACE FILE  : X505BR1.SIN
PROGRAM/ID/RELEASE DATE : FRAMEWORK   D3.14-03    17-MAR-2017  14:46:58

************************************************************************

SCF factors: S1  S2  S3  S4  S5  S6  S7  S8
-----------------------------------------
S1 = Axial                 Crown  Chord side
S2 = Axial                 Crown  Brace side
S3 = In-plane Bending      Crown  Chord side
S4 = In-plane Bending      Crown  Brace side
S5 = Axial                 Saddle Chord side
S6 = Axial                 Saddle Brace side
S7 = Out-of-plane Bending  Saddle Chord side
S8 = Out-of-plane Bending  Saddle Brace side


 NO OF MODES                          2
 RANGING FROM PLANE                   1
          TO PLANE                    4
 JOINT NUMBER IS                    101
 OTHER END NODE IS                    0
 RANGE NODE IS                      303
Jnt 201     Pln 1: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                   BrcEnds 201     202     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU  8.09  4.18  3.31  2.85 11.55  9.05  8.32  6.27
Jnt 201     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   BrcEnds 201     206     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  6.68  5.47  3.31  2.85  6.68  5.47  8.60  6.47
                   BrcEnds 201     303     SNcrv DOE-T            K -jnt   Scf EFTHYMIOU  3.63  2.58  2.16  3.30  3.63  2.58  5.55  4.18
Jnt 201     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                   BrcEnds 201     202     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                   BrcEnds 201     206     SNcrv DOE-T            BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 202     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                   Overlapping K-joint. Overlap  1.236E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                   BrcEnds 202     101     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
                   BrcEnds 202     102     SNcrv DOE-T            T -jnt   Scf EFTHYMIOU 14.82  7.00  2.64  2.38  2.92  2.58  4.53  2.45
Jnt 202     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
```

```
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 202     201     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 202     203     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 203     Pln 1: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                BrcEnds 203     202     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  6.92  5.63  3.31  2.85  6.92  5.63  8.50  6.40
                BrcEnds 203     301     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.69  2.59  2.13  3.32  3.69  2.59  5.35  4.03
Jnt 203     Pln 2: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 203     204     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.11  4.18  3.31  2.85 11.56  9.10  8.36  6.29
Jnt 203     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                BrcEnds 203     202     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                BrcEnds 203     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 204     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 204     102     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
                BrcEnds 204     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
Jnt 204     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 204     203     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 204     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 205     Pln 2: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                BrcEnds 205     204     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  7.12  5.74  3.30  2.85  7.12  5.74  8.38  6.31
                BrcEnds 205     302     SNcrv DOE-T           K -jnt   Scf EFTHYMIOU  3.71  2.57  2.09  3.34  3.71  2.57  5.12  3.86
Jnt 205     Pln 3: 2 chord elements and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 205     206     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  8.08  4.18  3.30  2.85 11.53  8.98  8.26  6.22
Jnt 205     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                BrcEnds 205     204     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
                BrcEnds 205     206     SNcrv DOE-T           BentCan  Scf BENTCAN    5.00  5.00  5.00  5.00  5.00  5.00  5.00  5.00
Jnt 206     Pln 3: 2 chord elements and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.239E-01 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 206     103     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.66  7.00  2.61  2.39  2.84  2.53  4.41  2.38
                BrcEnds 206     101     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU 14.99  7.00  2.67  2.36  3.00  2.63  4.65  2.51
Jnt 206     Pln 4: 2 elements meet at the joint within the analysis plane. Connection classified as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 206     205     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 206     201     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 301     Pln 1: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  9.206E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 301     203     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.49  3.14  3.89  2.27  3.77  2.84
                BrcEnds 301     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 301     Pln 3: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 301     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 301     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 301     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
```

```
                BrcEnds 301     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 302     Pln 1: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 302     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.68  4.98  7.22  5.44
Jnt 302     Pln 2: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  1.248E-02 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 302     205     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.29  2.16  2.46  3.15  3.77  2.20  3.66  2.76
                BrcEnds 302     303     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.31  2.85  7.72  5.01  7.25  5.46
Jnt 302     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 302     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 302     303     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
Jnt 303     Pln 2: 1 chord element  and  1 braces meet at the joint within the analysis plane (evaluated as T joint).
                BrcEnds 303     302     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 3: 1 chord element  and  2 braces meet at the joint within the analysis plane (K joint tried).
                Overlapping K-joint. Overlap  4.867E-03 (>0.0). T -jnt   Scf used. Alt. try 'Read' Scfs option.
                BrcEnds 303     201     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.28  2.16  2.51  3.13  3.98  2.32  3.86  2.91
                BrcEnds 303     301     SNcrv DOE-T           T -jnt   Scf EFTHYMIOU  3.07  2.16  3.30  2.85  7.63  4.93  7.17  5.40
Jnt 303     Pln 4: 2 elements meet at the joint within the analysis plane. No chord. Connection treated as Bent Can.
                User defined Bent Can SCFs not found.  Global Scfs are used.
                BrcEnds 303     302     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
                BrcEnds 303     301     SNcrv DOE-T           BentCan  Scf BENTCAN    1.60  1.60  1.60  1.60  1.60  1.60  1.60  1.60
```

A.3 Example 3 – Direct Deterministic Fatigue (X31314K)

For a Direct Deterministic fatigue, a simple 2-dim frame structure is shown. There are 5 basic load cases: 4 from wave analysis, and 1 from the line load and point load acting on the structure.

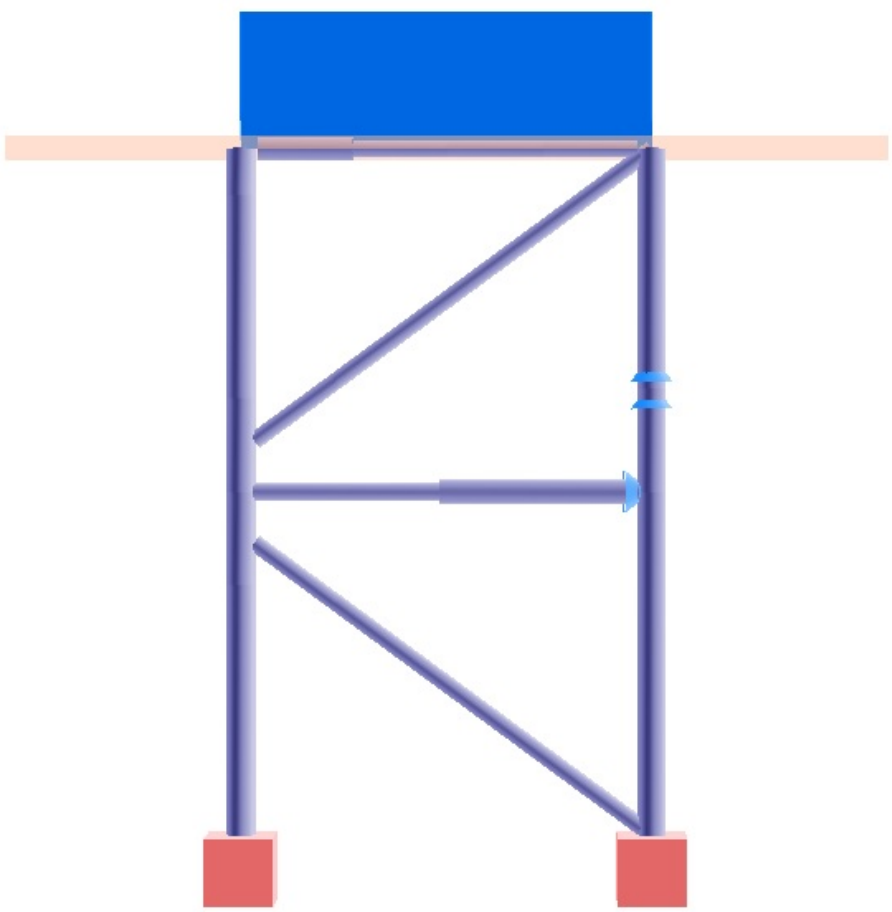


Figure A.1: 2-dim frame structure

The finite element model is

```
% Finite element model of the frame
% For direct deterministic fatigue analysis
IDENT     1.00000000E+00  1.00000000E+00  3.00000000E+00  0.00000000E+00
DATE      1.00000000E+00  0.00000000E+00  4.00000000E+00  7.20000000E+01
        DATE:     10-Sep-2016         TIME:          14:05:46
        PROGRAM:  SESAM GeniE         VERSION:       V7.3-15 07-Mar-2016
        COMPUTER: X86 Windows         INSTALLATION:
        USER:     lzhan               ACCOUNT:
TDMATER   4.00000000E+00  1.00000000E+00  1.04000000E+02  0.00000000E+00
        Mat1
TDMATER   4.00000000E+00  2.00000000E+00  1.04000000E+02  0.00000000E+00
        Mat2
MISOSEL   1.00000000E+00  1.99899988E+11  3.00000012E-01  9.99999866E-02
          0.00000000E+00  1.20000004E-05  1.00000000E+00  2.48199984E+08
MISOSEL   2.00000000E+00  1.99899988E+11  3.00000012E-01  7.84899951E+03
```

```
          0.00000000E+00  1.20000004E-05  1.00000000E+00  2.48199984E+08
TDSECT    4.00000000E+00  1.00000000E+00  1.04000000E+02  0.00000000E+00
        COL1
TDSECT    4.00000000E+00  2.00000000E+00  1.05000000E+02  0.00000000E+00
        BR1_3
TDSECT    4.00000000E+00  3.00000000E+00  1.05000000E+02  0.00000000E+00
        BR1_2
TDSECT    4.00000000E+00  4.00000000E+00  1.05000000E+02  0.00000000E+00
        BR1_1
GBEAMG    1.00000000E+00  0.00000000E+00  1.61988363E-02  6.89716137E-04
          3.44858068E-04  3.44858068E-04  0.00000000E+00  3.24572297E-03
          1.62286148E-03  1.62286148E-03  8.10437556E-03  8.10437556E-03
          0.00000000E+00  0.00000000E+00  1.06380205E-03  1.06380205E-03
GBEAMG    2.00000000E+00  0.00000000E+00  3.84845142E-03  5.77748760E-05
          2.88874380E-05  2.88874380E-05  0.00000000E+00  4.62199008E-04
          2.31099504E-04  2.31099504E-04  1.92475994E-03  1.92475994E-03
          0.00000000E+00  0.00000000E+00  1.50083346E-04  1.50083346E-04
GBEAMG    3.00000000E+00  0.00000000E+00  5.41924872E-03  1.61290445E-04
          8.06452226E-05  8.06452226E-05  0.00000000E+00  9.21659579E-04
          4.60829790E-04  4.60829790E-04  2.71000387E-03  2.71000387E-03
          0.00000000E+00  0.00000000E+00  2.97583465E-04  2.97583465E-04
GBEAMG    4.00000000E+00  0.00000000E+00  3.84845142E-03  5.77748797E-05
          2.88874398E-05  2.88874398E-05  0.00000000E+00  4.62199008E-04
          2.31099504E-04  2.31099504E-04  1.92475994E-03  1.92475994E-03
          0.00000000E+00  0.00000000E+00  1.50083346E-04  1.50083346E-04
GBEAMG    5.00000000E+00  0.00000000E+00  3.84845142E-03  5.77748760E-05
          2.88874380E-05  2.88874380E-05  0.00000000E+00  4.62199008E-04
          2.31099504E-04  2.31099504E-04  1.92475994E-03  1.92475994E-03
          0.00000000E+00  0.00000000E+00  1.50083346E-04  1.50083346E-04
GPIPE     1.00000000E+00  4.00000006E-01  4.25000012E-01  1.25000002E-02
          1.00000000E+00  1.00000000E+00
GPIPE     2.00000000E+00  2.39999995E-01  2.50000000E-01  5.00000082E-03
          1.00000000E+00  1.00000000E+00
GPIPE     3.00000000E+00  3.40000063E-01  3.50000054E-01  5.00000082E-03
          1.00000000E+00  1.00000000E+00
GPIPE     4.00000000E+00  2.39999995E-01  2.50000000E-01  5.00000082E-03
          1.00000000E+00  1.00000000E+00
GPIPE     5.00000000E+00  2.39999995E-01  2.50000000E-01  5.00000082E-03
          1.00000000E+00  1.00000000E+00
TDSCONC   4.00000000E+00  1.00000000E+00  1.03000000E+02  0.00000000E+00
        Bm1
TDSCONC   4.00000000E+00  2.00000000E+00  1.11000000E+02  0.00000000E+00
        Bm12_Test01
TDSCONC   4.00000000E+00  3.00000000E+00  1.14000000E+02  0.00000000E+00
        Bm20_test_0001
TDSCONC   4.00000000E+00  4.00000000E+00  1.14000000E+02  0.00000000E+00
        Bm21_test_0001
TDSCONC   4.00000000E+00  5.00000000E+00  1.03000000E+02  0.00000000E+00
        Bm3
TDSCONC   4.00000000E+00  6.00000000E+00  1.03000000E+02  0.00000000E+00
        Bm4
TDSCONC   4.00000000E+00  7.00000000E+00  1.03000000E+02  0.00000000E+00
        Bm5
TDSCONC   4.00000000E+00  8.00000000E+00  1.03000000E+02  0.00000000E+00
        Bm6
SCONCEPT  1.10000000E+01  1.00000000E+00  7.00000000E+00  0.00000000E+00
          0.00000000E+00  4.00000000E+00  0.00000000E+00  9.00000000E+00
          1.00000000E+01  1.10000000E+01  1.20000000E+01
SCONCEPT  9.00000000E+00  2.00000000E+00  7.00000000E+00  0.00000000E+00
```

```
          0.00000000E+00  2.00000000E+00  0.00000000E+00  1.30000000E+01
          1.40000000E+01
SCONCEPT  9.00000000E+00  3.00000000E+00  7.00000000E+00  0.00000000E+00
          0.00000000E+00  2.00000000E+00  0.00000000E+00  1.50000000E+01
          1.60000000E+01
SCONCEPT  8.00000000E+00  4.00000000E+00  7.00000000E+00  0.00000000E+00
          0.00000000E+00  1.00000000E+00  0.00000000E+00  1.70000000E+01
SCONCEPT  9.00000000E+00  5.00000000E+00  7.00000000E+00  0.00000000E+00
          0.00000000E+00  2.00000000E+00  0.00000000E+00  1.80000000E+01
          1.90000000E+01
SCONCEPT  9.00000000E+00  6.00000000E+00  7.00000000E+00  0.00000000E+00
          0.00000000E+00  2.00000000E+00  0.00000000E+00  2.00000000E+01
          2.10000000E+01
SCONCEPT  9.00000000E+00  7.00000000E+00  7.00000000E+00  0.00000000E+00
          0.00000000E+00  2.00000000E+00  0.00000000E+00  2.20000000E+01
          2.30000000E+01
SCONCEPT  1.00000000E+01  8.00000000E+00  7.00000000E+00  0.00000000E+00
          0.00000000E+00  3.00000000E+00  0.00000000E+00  2.40000000E+01
          2.50000000E+01  2.60000000E+01
SCONCEPT  5.00000000E+00  9.00000000E+00  2.00000000E+00  4.00000000E+00
          1.00000000E+00
SCONCEPT  5.00000000E+00  1.00000000E+01  2.00000000E+00  3.00000000E+00
          1.00000000E+00
SCONCEPT  5.00000000E+00  1.10000000E+01  2.00000000E+00  4.00000000E+00
          1.00000000E+00
SCONCEPT  5.00000000E+00  1.20000000E+01  2.00000000E+00  4.00000000E+00
          1.00000000E+00
SCONCEPT  5.00000000E+00  1.30000000E+01  2.00000000E+00  4.00000000E+00
          2.00000000E+00
SCONCEPT  5.00000000E+00  1.40000000E+01  2.00000000E+00  4.00000000E+00
          2.00000000E+00
SCONCEPT  5.00000000E+00  1.50000000E+01  2.00000000E+00  4.00000000E+00
          3.00000000E+00
SCONCEPT  5.00000000E+00  1.60000000E+01  2.00000000E+00  4.00000000E+00
          3.00000000E+00
SCONCEPT  5.00000000E+00  1.70000000E+01  2.00000000E+00  4.00000000E+00
          4.00000000E+00
SCONCEPT  5.00000000E+00  1.80000000E+01  2.00000000E+00  1.00000000E+00
          5.00000000E+00
SCONCEPT  5.00000000E+00  1.90000000E+01  2.00000000E+00  4.00000000E+00
          5.00000000E+00
SCONCEPT  5.00000000E+00  2.00000000E+01  2.00000000E+00  1.00000000E+00
          6.00000000E+00
SCONCEPT  5.00000000E+00  2.10000000E+01  2.00000000E+00  4.00000000E+00
          6.00000000E+00
SCONCEPT  5.00000000E+00  2.20000000E+01  2.00000000E+00  4.00000000E+00
          7.00000000E+00
SCONCEPT  5.00000000E+00  2.30000000E+01  2.00000000E+00  2.00000000E+00
          7.00000000E+00
SCONCEPT  5.00000000E+00  2.40000000E+01  2.00000000E+00  2.00000000E+00
          8.00000000E+00
SCONCEPT  5.00000000E+00  2.50000000E+01  2.00000000E+00  4.00000000E+00
          8.00000000E+00
SCONCEPT  5.00000000E+00  2.60000000E+01  2.00000000E+00  4.00000000E+00
          8.00000000E+00
SCONMESH  6.00000000E+00  9.00000000E+00  1.00000000E+00  2.00000000E+00
          1.00000000E+00  4.00000000E+00
SCONMESH  6.00000000E+00  1.00000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  3.00000000E+00
```

```
SCONMESH  6.00000000E+00  1.10000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  2.00000000E+00
SCONMESH  6.00000000E+00  1.20000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.00000000E+00
SCONMESH  6.00000000E+00  1.30000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  6.00000000E+00
SCONMESH  6.00000000E+00  1.40000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  5.00000000E+00
SCONMESH  6.00000000E+00  1.50000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  7.00000000E+00
SCONMESH  6.00000000E+00  1.60000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  8.00000000E+00
SCONMESH  6.00000000E+00  1.70000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  9.00000000E+00
SCONMESH  6.00000000E+00  1.80000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.00000000E+01
SCONMESH  6.00000000E+00  1.90000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.10000000E+01
SCONMESH  6.00000000E+00  2.00000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.20000000E+01
SCONMESH  6.00000000E+00  2.10000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.30000000E+01
SCONMESH  6.00000000E+00  2.20000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.40000000E+01
SCONMESH  6.00000000E+00  2.30000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.50000000E+01
SCONMESH  6.00000000E+00  2.40000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.60000000E+01
SCONMESH  6.00000000E+00  2.50000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.70000000E+01
SCONMESH  6.00000000E+00  2.60000000E+01  1.00000000E+00  2.00000000E+00
          1.00000000E+00  1.80000000E+01
SCONPLIS  5.00000000E+00  1.50000000E+01  1.00000000E+00  1.00000000E+00
          1.00000000E+00
SCONPLIS  5.00000000E+00  1.60000000E+01  1.00000000E+00  1.00000000E+00
          1.00000000E+00
SCONPLIS  5.00000000E+00  1.70000000E+01  1.00000000E+00  1.00000000E+00
          1.00000000E+00
SCONPLIS  5.00000000E+00  2.20000000E+01  1.00000000E+00  1.00000000E+00
          1.00000000E+00
SCONPLIS  5.00000000E+00  2.30000000E+01  1.00000000E+00  1.00000000E+00
          1.00000000E+00
SCONPLIS  5.00000000E+00  2.40000000E+01  1.00000000E+00  1.00000000E+00
          1.00000000E+00
SCONPLIS  5.00000000E+00  2.50000000E+01  1.00000000E+00  1.00000000E+00
          1.00000000E+00
SCONPLIS  5.00000000E+00  2.60000000E+01  1.00000000E+00  1.00000000E+00
          1.00000000E+00
SPROSELE  5.00000000E+00  1.00000000E+00  1.00000000E+00  5.00000000E+00
          1.00000000E+00
SPROHYDR  1.50000000E+01  1.00000000E+00  6.00000000E+00  5.01000000E+02
          0.00000000E+00  5.02000000E+02  6.99999988E-01  5.03000000E+02
          6.99999988E-01  5.04000000E+02  0.00000000E+00  5.05000000E+02
          2.00000000E+00  5.06000000E+02  2.00000000E+00
GUNIVEC   1.00000000E+00  0.00000000E+00  1.00000000E+00  0.00000000E+00
GUNIVEC   2.00000000E+00  6.40184343E-01  0.00000000E+00  7.68221319E-01
GUNIVEC   3.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
GUNIVEC   4.00000000E+00 -6.40184343E-01  0.00000000E+00  7.68221319E-01
GECCEN    1.00000000E+00  2.00000018E-01  0.00000000E+00 -7.43189692E-01
```

```
GECCEN    2.00000000E+00  1.59134433E-01  0.00000000E+00 -5.91335297E-01
GECCEN    3.00000000E+00  1.59134433E-01  0.00000000E+00 -5.91335297E-01
GECCEN    4.00000000E+00 -2.00000003E-01  0.00000000E+00  0.00000000E+00
GECCEN    5.00000000E+00 -1.00000001E-01  0.00000000E+00  0.00000000E+00
GECCEN    6.00000000E+00 -1.00000001E-01  0.00000000E+00  0.00000000E+00
GECCEN    7.00000000E+00  2.00000018E-01  0.00000000E+00  7.43189692E-01
GECCEN    8.00000000E+00  1.59134433E-01  0.00000000E+00  5.91335297E-01
GECCEN    9.00000000E+00  1.59134433E-01  0.00000000E+00  5.91335297E-01
GECCEN    1.00000000E+01 -2.00000003E-01  0.00000000E+00  0.00000000E+00
GECCEN    1.10000000E+01 -8.74999836E-02  0.00000000E+00  0.00000000E+00
GECCEN    1.20000000E+01 -8.74999836E-02  0.00000000E+00  0.00000000E+00
GECCEN    1.30000000E+01  2.50000097E-02  0.00000000E+00  0.00000000E+00
GECCEN    1.40000000E+01  2.50000097E-02  0.00000000E+00  0.00000000E+00
GECCEN    1.50000000E+01  1.37500003E-01  0.00000000E+00  0.00000000E+00
GECCEN    1.60000000E+01  1.37500003E-01  0.00000000E+00  0.00000000E+00
GECCEN    1.70000000E+01  2.50000000E-01  0.00000000E+00  0.00000000E+00
TDNODE    4.00000000E+00  7.00000000E+00  1.03000000E+02  0.00000000E+00
        Jt1
TDNODE    4.00000000E+00  8.00000000E+00  1.03000000E+02  0.00000000E+00
        Jt2
GNODE     1.00000000E+00  1.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     2.00000000E+00  2.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     3.00000000E+00  3.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     4.00000000E+00  4.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     5.00000000E+00  5.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     6.00000000E+00  6.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     7.00000000E+00  7.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     8.00000000E+00  8.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     9.00000000E+00  9.00000000E+00  6.00000000E+00  1.23456000E+05
GNODE     1.00000000E+01  1.00000000E+01  6.00000000E+00  1.23456000E+05
GNODE     1.10000000E+01  1.10000000E+01  6.00000000E+00  1.23456000E+05
GNODE     1.20000000E+01  1.20000000E+01  6.00000000E+00  1.23456000E+05
GNODE     1.30000000E+01  1.30000000E+01  6.00000000E+00  1.23456000E+05
GNODE     1.40000000E+01  1.40000000E+01  6.00000000E+00  1.23456000E+05
GNODE     1.50000000E+01  1.50000000E+01  6.00000000E+00  1.23456000E+05
GNODE     1.60000000E+01  1.60000000E+01  6.00000000E+00  1.23456000E+05
GCOORD    1.00000000E+00  1.49999976E+00  0.00000000E+00  0.00000000E+00
GCOORD    2.00000000E+00 -2.38418579E-07  0.00000000E+00  0.00000000E+00
GCOORD    3.00000000E+00  2.99999976E+00  0.00000000E+00  0.00000000E+00
GCOORD    4.00000000E+00  4.50000000E+00  0.00000000E+00  0.00000000E+00
GCOORD    5.00000000E+00  6.00000000E+00  0.00000000E+00  0.00000000E+00
GCOORD    6.00000000E+00  3.00000000E+00  0.00000000E+00 -5.00000000E+00
GCOORD    7.00000000E+00 -2.38418579E-07  0.00000000E+00 -5.00000000E+00
GCOORD    8.00000000E+00  6.00000000E+00  0.00000000E+00 -5.00000000E+00
GCOORD    9.00000000E+00  6.00000000E+00  0.00000000E+00 -3.50000000E+00
GCOORD    1.00000000E+01  6.00000000E+00  0.00000000E+00 -1.00000000E+01
GCOORD    1.10000000E+01  1.22596753E+00  0.00000000E+00 -3.97836018E+00
GCOORD    1.20000000E+01  1.22596753E+00  0.00000000E+00 -6.02163982E+00
GCOORD    1.30000000E+01 -2.38418579E-07  0.00000000E+00 -1.00000000E+01
GCOORD    1.40000000E+01 -2.38418579E-07  0.00000000E+00 -6.36152649E+00
GCOORD    1.50000000E+01 -2.38418579E-07  0.00000000E+00 -3.63847351E+00
GCOORD    1.60000000E+01 -2.38418579E-07  0.00000000E+00 -6.75000072E-01
BNBCD     1.00000000E+01  6.00000000E+00  1.00000000E+00  1.00000000E+00
          1.00000000E+00  1.00000000E+00  1.00000000E+00  1.00000000E+00
BNBCD     1.30000000E+01  6.00000000E+00  1.00000000E+00  1.00000000E+00
          1.00000000E+00  1.00000000E+00  1.00000000E+00  1.00000000E+00
GELMNT1   1.00000000E+00  1.00000000E+00  1.50000000E+01  0.00000000E+00
          1.00000000E+00  2.00000000E+00
GELMNT1   2.00000000E+00  2.00000000E+00  1.50000000E+01  0.00000000E+00
```

```
          3.00000000E+00  1.00000000E+00
GELMNT1   3.00000000E+00  3.00000000E+00  1.50000000E+01  0.00000000E+00
          4.00000000E+00  3.00000000E+00
GELMNT1   4.00000000E+00  4.00000000E+00  1.50000000E+01  0.00000000E+00
          5.00000000E+00  4.00000000E+00
GELMNT1   5.00000000E+00  5.00000000E+00  1.50000000E+01  0.00000000E+00
          6.00000000E+00  7.00000000E+00
GELMNT1   6.00000000E+00  6.00000000E+00  1.50000000E+01  0.00000000E+00
          8.00000000E+00  6.00000000E+00
GELMNT1   7.00000000E+00  7.00000000E+00  1.50000000E+01  0.00000000E+00
          8.00000000E+00  9.00000000E+00
GELMNT1   8.00000000E+00  8.00000000E+00  1.50000000E+01  0.00000000E+00
          9.00000000E+00  5.00000000E+00
GELMNT1   9.00000000E+00  9.00000000E+00  1.50000000E+01  0.00000000E+00
          1.00000000E+01  8.00000000E+00
GELMNT1   1.00000000E+01  1.00000000E+01  1.50000000E+01  0.00000000E+00
          7.00000000E+00  1.10000000E+01
GELMNT1   1.10000000E+01  1.10000000E+01  1.50000000E+01  0.00000000E+00
          1.10000000E+01  5.00000000E+00
GELMNT1   1.20000000E+01  1.20000000E+01  1.50000000E+01  0.00000000E+00
          7.00000000E+00  1.20000000E+01
GELMNT1   1.30000000E+01  1.30000000E+01  1.50000000E+01  0.00000000E+00
          1.20000000E+01  1.00000000E+01
GELMNT1   1.40000000E+01  1.40000000E+01  1.50000000E+01  0.00000000E+00
          1.30000000E+01  1.40000000E+01
GELMNT1   1.50000000E+01  1.50000000E+01  1.50000000E+01  0.00000000E+00
          1.40000000E+01  7.00000000E+00
GELMNT1   1.60000000E+01  1.60000000E+01  1.50000000E+01  0.00000000E+00
          7.00000000E+00  1.50000000E+01
GELMNT1   1.70000000E+01  1.70000000E+01  1.50000000E+01  0.00000000E+00
          1.50000000E+01  1.60000000E+01
GELMNT1   1.80000000E+01  1.80000000E+01  1.50000000E+01  0.00000000E+00
          1.60000000E+01  2.00000000E+00
GELREF1   1.00000000E+00  2.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          3.00000000E+00  0.00000000E+00 -1.00000000E+00  3.00000000E+00
          1.60000000E+01  1.70000000E+01
GELREF1   2.00000000E+00  2.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          2.00000000E+00  0.00000000E+00 -1.00000000E+00  3.00000000E+00
          1.40000000E+01  1.50000000E+01
GELREF1   3.00000000E+00  2.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          5.00000000E+00  0.00000000E+00 -1.00000000E+00  3.00000000E+00
          1.20000000E+01  1.30000000E+01
GELREF1   4.00000000E+00  2.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          4.00000000E+00  0.00000000E+00 -1.00000000E+00  3.00000000E+00
          1.00000000E+01  1.10000000E+01
GELREF1   5.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          4.00000000E+00  0.00000000E+00 -1.00000000E+00  3.00000000E+00
          6.00000000E+00  0.00000000E+00
GELREF1   6.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          3.00000000E+00  0.00000000E+00 -1.00000000E+00  3.00000000E+00
          4.00000000E+00  5.00000000E+00
GELREF1   7.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
```

```
          1.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   8.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   9.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   1.00000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          2.00000000E+00  0.00000000E+00 -1.00000000E+00  4.00000000E+00
          7.00000000E+00  8.00000000E+00
GELREF1   1.10000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          2.00000000E+00  0.00000000E+00 -1.00000000E+00  4.00000000E+00
          9.00000000E+00  0.00000000E+00
GELREF1   1.20000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          2.00000000E+00  0.00000000E+00 -1.00000000E+00  2.00000000E+00
          1.00000000E+00  2.00000000E+00
GELREF1   1.30000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          2.00000000E+00  0.00000000E+00 -1.00000000E+00  2.00000000E+00
          3.00000000E+00  0.00000000E+00
GELREF1   1.40000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   1.50000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   1.60000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   1.70000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
GELREF1   1.80000000E+01  1.00000000E+00  0.00000000E+00  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  0.00000000E+00
          1.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+00
TDSETNAM  4.00000000E+00  1.00000000E+00  1.04000000E+02  0.00000000E+00
        Bm_1
TDSETNAM  4.00000000E+00  2.00000000E+00  1.06000000E+02  0.00000000E+00
        Braces
GSETMEMB  9.00000000E+00  1.00000000E+00  1.00000000E+00  2.00000000E+00
          0.00000000E+00  1.00000000E+00  2.00000000E+00  3.00000000E+00
          4.00000000E+00
GSETMEMB  9.00000000E+00  2.00000000E+00  1.00000000E+00  2.00000000E+00
          0.00000000E+00  1.00000000E+00  2.00000000E+00  3.00000000E+00
          4.00000000E+00
TDLOAD    4.00000000E+00  1.00000000E+00  1.06000000E+02  0.00000000E+00
        LCMisc
TDLOAD    4.00000000E+00  2.00000000E+00  1.04000000E+02  0.00000000E+00
        WLC1
TDLOAD    4.00000000E+00  3.00000000E+00  1.04000000E+02  0.00000000E+00
        WLC2
TDLOAD    4.00000000E+00  4.00000000E+00  1.04000000E+02  0.00000000E+00
        WLC3
TDLOAD    4.00000000E+00  5.00000000E+00  1.04000000E+02  0.00000000E+00
        WLC4
BNLOAD    1.00000000E+00  1.00000000E+00  0.00000000E+00  0.00000000E+00
```

```
          8.00000000E+00  6.00000000E+00  1.00000000E+04  0.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00  1.00000000E+06
BELOAD1   1.00000000E+00  1.00000000E+00  0.00000000E+00  1.00000000E+00
          1.00000000E+00 -1.37500003E-01  0.00000000E+00  6.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00 -5.00000000E+03
          0.00000000E+00  0.00000000E+00 -5.00000000E+03
BELOAD1   1.00000000E+00  1.00000000E+00  0.00000000E+00  1.00000000E+00
          2.00000000E+00 -2.50000097E-02  1.37500003E-01  6.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00 -5.00000000E+03
          0.00000000E+00  0.00000000E+00 -5.00000000E+03
BELOAD1   1.00000000E+00  1.00000000E+00  0.00000000E+00  1.00000000E+00
          3.00000000E+00  8.74999836E-02  2.50000097E-02  6.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00 -5.00000000E+03
          0.00000000E+00  0.00000000E+00 -5.00000000E+03
BELOAD1   1.00000000E+00  1.00000000E+00  0.00000000E+00  1.00000000E+00
          4.00000000E+00  0.00000000E+00 -8.74999836E-02  6.00000000E+00
          0.00000000E+00  0.00000000E+00  0.00000000E+00 -5.00000000E+03
          0.00000000E+00  0.00000000E+00 -5.00000000E+03
IEND                0.00            0.00            0.00            0.00
```

A.3.1 Wajac input file – DirectFatWajac.INP

```
WAJAC
TITL      Wajac run name : Analysis1.step(2)
C
C                                        PREFIX
FMOD      DirectFat_
C
C                                        PREFIX        FORM
FWAVE     DirectFat_                     FORMATTED
C
C              UNITS   GRAVITY       RHO      VISC    RHOAIR   VISCAIR
CONS              1.   9.80665     1028.  1.899e-6     1.226  1.462e-5
C
C               OPT1      OPT2      OPT3      OPT4      OPT5      OPT6      OPT7
OPTI              0.        0.        0.        0.        0.        0.        0.
                  0.        0.        0.        0.        0.
C
C                      ILFSAV    ISETOP
MODE                      1.        1.
C
C                LN
LONO             2.
C         ************************** GEOM Section ****************************
GEOM
C
C                 Z
MUDP           -30.
C         ************************** HYDR Section ****************************
HYDR
C
C              TYPE
CPRI      FEM
CPRI      SPEC
CPRI      CDIR
C
C              ADMAS      DAMP
MASS              0.        0.
C
C         HydroDynamicDiameter1 (  Hydrodynamic Diameter property )
```

```
C
C                M1        M2       INC STYP  IDX      DIAM                     IGWD
SPEX             7.         9.        1.   1.   1.       1.2  -1.  -1.  -1.  -1.
SPEX            14.        18.        1.   1.   1.       1.2  -1.  -1.  -1.  -1.
C         ************************** LOAD Section ****************************
LOAD
C
C         ElementRefinement2 (  Element refinement property )
C
C                Z1        Z2       SEG     SLMIN     SLMAX IMEM
SEGM             0.   35.8725        1.        0.        0.   1.
C
C                M1        M2       INC STYP  IDX IMEM
MEMSEG           7.         9.        1.   1.   1.   1.
MEMSEG          16.        18.        1.   1.   1.   1.
C
C         ElementRefinement3 (  Element refinement property )
C
C                Z1        Z2       SEG     SLMIN     SLMAX IMEM
SEGM             0.   35.8725        1.        0.        0.   2.
C
C                M1        M2       INC STYP  IDX IMEM
MEMSEG          14.        15.        1.   1.   1.   2.
C
C          ISEA THEO    HEIGHT    PERIOD      PHIO        TO      STEP     NSTEP
SEA          1.  1.1      4.85       8.        0.        0.       20.      -18.
SEA          2.  1.1      7.83      10.        0.        0.       20.      -18.
C
C          ISEA BETA WKFA CTNO CBFA CSTR LOAD DLOA  WID WIME IDPT
SEAOPT       1.  45.   1.   0.   1.  -1.   0.   1.   0.   0.   0.
SEAOPT       2.  90.   1.   0.   1.  -1.   0.   1.   0.   0.   0.
C
C             DEPTH IDPT
DPTH            30.   0.
C
C                 X         Y         Z
MOMT             0.        0.        0.
END
```

A.3.2 Sestra data file – DirectFat_Sestra.Inp

Results file name is DirectFat_R1.SIN. This example is a static analysis. It is identical to regression testing case X31314K.

```
COMM    Sestra input file for a static analysis
HEAD
COMM
COMM    Created by: GeniE  V7.3-15  07-Mar-2016
COMM
COMM    Date : 10-Sep-2016   Time : 14:05:56   User : lzhan
COMM
COMM  CHCK ANTP MSUM MOLO STIF RTOP LBCK      PILE CSING     SIGM
CMAS    0.   1.   1.   0.   0.   0.   0.        0.        0.        0.
COMM
COMM            ORDR                          CACH MFRWORK
SOLM              0.                            0.        0.
COMM
COMM                WCOR
ELOP                  1.
COMM
```

```
COMM  ITYP
ITOP    1.
COMM
COMM  PREFIX
INAM  DirectFat_
COMM
COMM  PREFIX FORMAT
LNAM  DirectFat_ UNFORMATTED
COMM
COMM  PREFIX FORMAT
RNAM  DirectFat_ NORSAM
COMM
COMM  SEL1 SEL2 SEL3 SEL4 SEL5 SEL6 SEL7 SEL8
RSEL    1.   0.   0.   0.   0.   0.   1.   0.
COMM
COMM  RTRA
RETR    3.
Z
```

A.3.3 Framework journal file for Direct Deterministic fatigue – DirectFat_FRAMEWORK_IN.JNL

```
% FRAMEWORK : DIRECT DETERMINISTIC FATIGUE

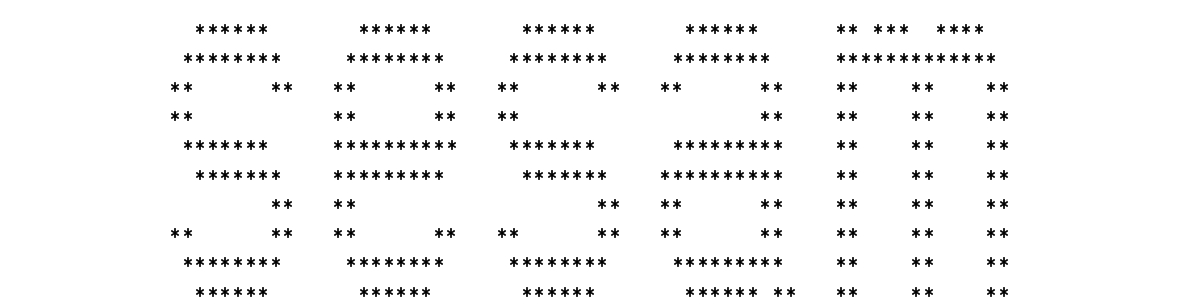
%
% Define default options before open the result SIN file
%

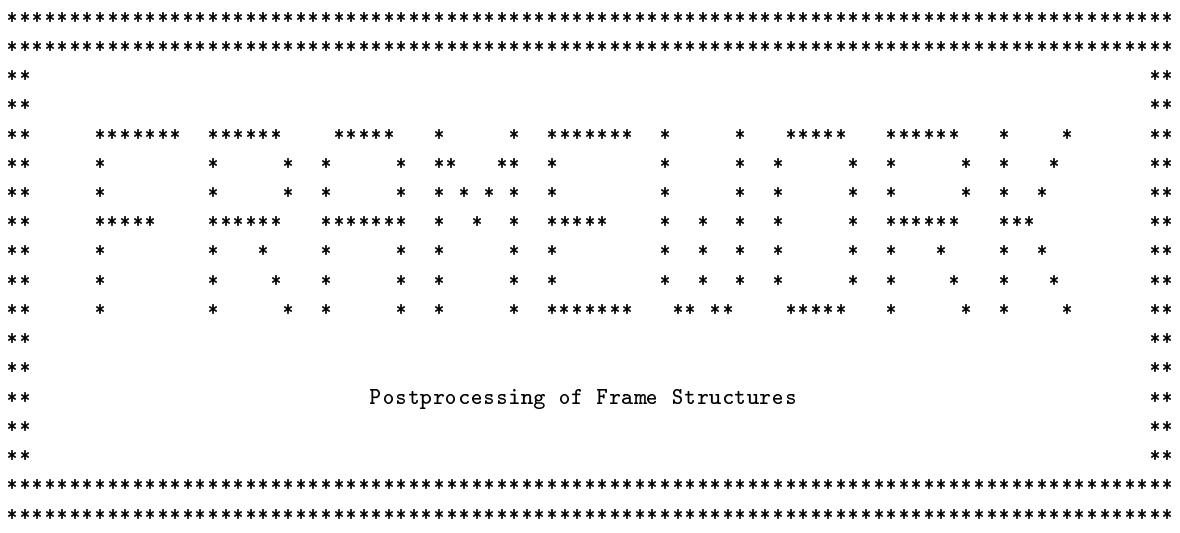
DEFINE FATIGUE-CONSTANTS DEFAULT-SN-CURVE API-XP
DEFINE FATIGUE-CONSTANTS MARSHALL-REDUCTION 0.8
DEFINE FATIGUE-CONSTANTS SHORT-CHORD-FIXITY-PARAMETER 1.0
DEFINE FATIGUE-CONSTANTS SHORT-CHORD-FIXITY-OPTION GLOBAL
DEFINE FATIGUE-CONSTANTS TARGET-FATIGUE-LIFE 20.0
DEFINE FATIGUE-CONSTANTS FATIGUE-EXPOSURE-TIME -1.0
DEFINE FATIGUE-CONSTANTS DEFAULT-FATIGUE-SAFETY-FACTOR 1.0
DEFINE FATIGUE-CONSTANTS GLOBAL-FATIGUE-PART-DAMAGE 0.0
DEFINE FATIGUE-CONSTANTS FABRICATION-TOLERANCE-OPTION 0.15TS
DEFINE FATIGUE-CONSTANTS DEFAULT-FABRICATION-TOLERANCE 0.0
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-SCF-FORMULA DNVGL-RPC203-2014
DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-UPPER-LIMIT-ELEVATION  5.0
DEFINE FATIGUE-CONSTANTS SPLASH-ZONE-LOWER-LIMIT-ELEVATION -2.0
DEFINE FATIGUE-CONSTANTS ACCUMULATE-FATIGUE-RUN NONE
DEFINE FATIGUE-CONSTANTS AXIAL-MINIMUM-SCF 2.5
DEFINE FATIGUE-CONSTANTS IN-PLANE-MINIMUM-SCF 2.5
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-MINIMUM 2.5
DEFINE FATIGUE-CONSTANTS BUTTWELD-CONE-MIN-SCF 1.0
DEFINE FATIGUE-CONSTANTS AXIAL-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-GLOBAL-SCF 1.0
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-GLOBAL 1.0
DEFINE FATIGUE-CONSTANTS IN-PLANE-FACTOR 0.7071
DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-FACTOR 0.7071
%
FILE OPEN SIN-DIRECT-ACCESS 'DirectFat_' R1
FILE TRANSFER 1 JACKET LOADS None
SET PRINT DESTINATION FILE
SET PRINT PAGE-HEIGHT 200
SET PRINT SCREEN-HEIGHT 24
SET PRINT FILE DirectFat_ Framework
SET PRINT PAGE-ORIENTATION LANDSCAPE
%
SELECT FATIGUE-CHECK-TYPE DIRECT-DETERMINISTIC
%
% Specify SCF
SELECT JOINTS INCLUDE ALL
ASSIGN JOINT-TYPE ALL ( ) LOADPATH
ASSIGN JOINT-GAP ALL ( ) AUTOMATIC
ASSIGN SCF JOINT ALL ( ) None PARAMETRIC EFTHYMIOU
%
%
CREATE LOAD-COMBINATION LCOMB None STATIC ( ONLY
    2     1.333
    4     1.333 )
%
CREATE FATIGUE-LOAD-SERIES SR1 None 1.0E4 1.0 BY-LOADCASE MAXMIN ( ONLY
    LCOMB      1.0
    LCOMB     -1.0 )
CREATE FATIGUE-LOAD-SERIES SR2 None 1.0E3 1.0 BY-LOADCASE SRSS ( ONLY
    2     1.0
    3     1.0
    4     1.0
```

```
    5     1.0 )
%
%  Confirm the fatigue load series
PRINT FATIGUE-CHECK-TYPE
SELECT MEMBERS INCLUDE ALL
%
%  Print a dump file for intermediate results
DEFINE FATIGUE-DUMP FILE-NAME FRAMEWORK
DEFINE FATIGUE-DUMP HOTSPOT-STRESS-RANGE ON
%
RUN FATIGUE-CHECK DDF None ALL ( )
PRINT FATIGUE-CHECK-RESULTS DDF SELECTED-MEMBERS ( ) FULL ABOVE 0.0
```

A.3.4 Results from Direct Deterministic Fatigue analysis–DirectFat_Framework.LIS

1





Marketing and Support by DNV GL - Software

```
              Program id   : D3.13-03                          Computer         : 586
              Release date : 30-AUG-2016                      Impl. update     :
              Access time  : 19-SEP-2016 11:26:14             Operating system : Win NT 6.1 [7601]
              User id      : lzhan                            CPU id           : 0405880964
                                                              Installation     : , HOUL130304


              Copyright DNV GL AS, P.O.Box 300, N-1322 Hovik, Norway


DATE: 19-SEP-2016 TIME: 11:26:14   PROGRAM: SESAM    FRAMEWORK D3.13-0 30-AUG-2016                    PAGE:     1

                                   Current Fatigue Check                                          SUB PAGE:     1


Current Fatigue Check Type is ...... : DIRECTDETFAT

Axial Global SCF ................... : 1.000
In Plane (Bending) Global SCF ...... : 1.000
Out of Plane (Bending) Global SCF .. : 1.000

Axial Minimum SCF .................. : 2.500
In Plane (Bending) Minimum SCF ..... : 2.500
Out of Plane (Bending) Minimum SCF . : 2.500

In Plane (Bending SCF) factor ...... : 0.707
Out of Plane (Bending SCF) factor .. : 0.707
Marshall reduction factor .......... : 0.800

Global Fatigue Part Damage ......... : 0.00000
Accumulate Fatigue Damage from ..... : NONE

Target Fatigue Life ................ : 20.00

Efthymiou influence function method not active.

Butt-weld and cone transition SCF global option  : DNVGL2014
Minimum SCF of Butt-weld and cone transition ... : 1.000

Splash Zone elevation upper limit ...... :  5.00
```

```
Splash Zone elevation lower limit ..... :  -2.00

  ........ Direct Deterministic Fatigue .........

 Fatigue Load Series ............. NAME       CYCLES         WEIGHT
                                  SR1      0.1000000E+05     1.000
    LC   NO.   NAME     Factor
         1    LCOMB    1.000
         2    LCOMB    -1.000
    Stress Range calculation option: MaxMin

 Fatigue Load Series ............. NAME       CYCLES         WEIGHT
                                  SR2      0.1000000E+04     1.000
    LC   NO.   NAME     Factor
         1    2        1.000
         2    3        1.000
         3    4        1.000
         4    5        1.000
    Stress Range calculation option: SRSS

DATE: 19-SEP-2016 TIME: 11:26:14   PROGRAM: SESAM    FRAMEWORK D3.13-0 30-AUG-2016                    PAGE:     2


                                  DIRECTDETFAT     fatigue check results
                                  Run:      Superelement:     Loadset:
                                  DDF       JACKET            LOADS
                                  Priority....: Selected Members
                                  Usage factor: Above   0.00                              SUB PAGE:     1



NOMENCLATURE:

Member      Name of member
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Damage      Accumulated damage
Life        Fatigue life
WeldSide    Side of weld
Hot         Hotspot (stress point) with maximum damage
SCFrule     Method used for SCF calculation
SCFax       SCF for axial force
SCFipb      SCF for in plane bending
```

```
SCFopb      SCF for out of plane bending
SNcurve     SN curve name
SctNam      Section name
Alpha       Moment transformation angle from local to in/out-of-plane co. system
Symmet      Symmetry in SCF specifiation
DiaBra      Brace diameter
ThiBra      Brace thickness
Gap         Gap between braces
ThiFac      Thickness correction factor on SN-curve
QR          Marchall reduction factor applied on SCFs
Cycles      Total number of stress cycles
Theta       Angle between brace and chord in degrees
Jtype       Joint type
DiaCho      Chord diameter
ThiCho      Chord thickness
LenCho      Chord length
FixCho      Chord end fixity parameter
SCFaxC      SCF for axial force at Crown  (Hotspot 7)
SCFaxS      SCF for axial force at Saddle (Hotspot 1)

DATE: 19-SEP-2016 TIME: 11:26:14   PROGRAM: SESAM    FRAMEWORK D3.13-0 30-AUG-2016                                  PAGE:     3


                                DIRECTDETFAT     fatigue check results
                                Run:      Superelement:     Loadset:
                                DDF       JACKET            LOADS
                                Priority....: Selected Members
                                Usage factor: Above   0.00                                                  SUB PAGE:     2

Member       Type     Joint/Po Outcome   Damage     Life    WeldSide        Hot SCFrule    SCFax    SCFipb SCFopb SNcurve
             SctNam                                Alpha    Symmet     DiaBra    ThiBra      Gap    ThiFac   QR       Cycles
                                                   Theta    Jtype      DiaCho    ThiCho    LenCho   FixCho SCFaxC      SCFaxS
-------------------------------------------------------------------------------------------------------------------------------
M6           PIPE     JT2                1.66E-02  1.21E+03 CHORD-SID        22 EFTHYMIOU   6.955    2.500  6.236 API-XP
             BR1_2                                  180.000  CROWN-SAD  3.50E-01   0.005    0.00E+00  1.000  1.000     1.10E+04
                                                     90.000  YT         4.25E-01   0.013    1.00E+01  1.000  8.737       5.172
                      JT2                1.19E-02  1.68E+03 BRACE-SID        22 EFTHYMIOU   5.527    2.500  5.679 API-XP
                                                   180.000  CROWN-SAD  3.50E-01   0.005    0.00E+00  1.000  1.000     1.10E+04
                                                    90.000  YT         4.25E-01   0.013    1.00E+01  1.000  4.714       6.339
                      0.50               6.58E-05  3.04E+05 BR1_2             22 *ILLEGAL*   1.000    1.000  1.000 API-XP
                                                     0.000  0.15TS     3.50E-01   0.005    0.00E+00  1.000  1.000     1.10E+04
                                                     0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
             PIPE     0.50               4.91E-04  4.07E+04 BR1_1             22 *ILLEGAL*   1.000    1.000  1.000 API-XP
             BR1_1                                   0.000  0.15TS     2.50E-01   0.005    0.00E+00  1.000  1.000     1.10E+04
```

```
                                                0.000                0.00E+00    0.000    0.00E+00  1.000  1.000       1.000
                    JT1              9.95E-02  2.01E+02 BRACE-SID         7 EFTHYMIOU   3.832    2.611  6.163 API-XP
                                                0.000  CROWN-SAD  2.50E-01    0.005    4.72E-01  1.000  1.000     1.10E+04
                                               90.000  KTT/LPD    4.25E-01    0.013    1.00E+01  1.000  3.832       3.832
                    JT1              8.54E-02  2.34E+02 CHORD-SID         7 EFTHYMIOU   4.187    2.500  5.988 API-XP
                                                0.000  CROWN-SAD  2.50E-01    0.005    4.72E-01  1.000  1.000     1.10E+04
                                               90.000  KTT/LPD    4.25E-01    0.013    1.00E+01  1.000  4.187       4.187

M7          PIPE    JT2              9.27E-02  2.16E+02 BOTH-SIDE         7 GLOBAL      1.000    1.000  1.000 API-XP
            COL1                                0.000  UNIFORM    4.25E-01    0.013    0.00E+00  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    0.00E+00  1.000  1.000       1.000
                    0.30             1.40E-02  1.42E+03 COL1              7 BUTT-DNVG   1.128    1.128  1.128 API-XP
                                                0.000  0.15TS     4.25E-01    0.013    6.25E-04  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    1.25E-02  1.000  1.128       1.128
                    5                1.03E-05  1.95E+06 BOTH-SIDE         1 GLOBAL      1.000    1.000  1.000 API-XP
                                                0.000  UNIFORM    4.25E-01    0.013    0.00E+00  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    5.00E+00  1.000  1.000       1.000

M9          PIPE    10      **Fail** 9.99E+00  2.00E+00 BOTH-SIDE         7 GLOBAL      1.000    1.000  1.000 API-XP
            COL1                                0.000  UNIFORM    4.25E-01    0.013    0.00E+00  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    5.00E+00  1.000  1.000       1.000
                    JT2              9.00E-02  2.22E+02 BOTH-SIDE         7 GLOBAL      1.000    1.000  1.000 API-XP
                                                0.000  UNIFORM    4.25E-01    0.013    0.00E+00  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    0.00E+00  1.000  1.000       1.000

BM1         PIPE    5                5.17E-02  3.87E+02 CHORD-SID        10 EFTHYMIOU   2.500    2.571  7.799 API-XP
            BR1_1                               0.000  CROWN-SAD  2.50E-01    0.005   -1.24E-01  1.000  1.000     1.10E+04
                                               90.000  K/LPD      4.25E-01    0.013    5.00E+00  1.000  2.500       2.500
                    5                7.58E-02  2.64E+02 BRACE-SID        10 EFTHYMIOU   2.849    2.965  8.028 API-XP
                                                0.000  CROWN-SAD  2.50E-01    0.005   -1.24E-01  1.000  1.000     1.10E+04
                                               90.000  K/LPD      4.25E-01    0.013    5.00E+00  1.000  2.849       2.849
                    0.25             5.40E-05  3.70E+05 BR1_1             1 *ILLEGAL*   1.000    1.000  1.000 API-XP
                                                0.000  MAXIMUM    2.50E-01    0.005    0.00E+00  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    0.00E+00  1.000  1.000       1.000
            PIPE    0.25             5.45E-05  3.67E+05 C1_10             1 *ILLEGAL*   1.000    1.000  1.000 API-XP
            C1_10                               0.000  MAXIMUM    2.50E-01    0.005    0.00E+00  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    0.00E+00  1.000  1.000       1.000
            PIPE    0.50             4.94E-04  4.05E+04 C2_10            22 *ILLEGAL*   1.000    1.000  1.000 API-XP
            C2_10                               0.000  MAXIMUM    2.50E-01    0.005    0.00E+00  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    0.00E+00  1.000  1.000       1.000
            PIPE    0.50             4.96E-04  4.03E+04 BR1_3            22 *ILLEGAL*   1.000    1.000  1.000 API-XP
            BR1_3                               0.000  MAXIMUM    2.50E-01    0.005    0.00E+00  1.000  1.000     1.10E+04
                                                0.000                0.00E+00    0.000    0.00E+00  1.000  1.000       1.000
                    0.75             5.84E-05  3.43E+05 BR1_3            22 *ILLEGAL*   1.000    1.000  1.000 API-XP
```

					0.000	0.15TS	2.50E-01	0.005	0.00E+00	1.000	1.000	1.10E+04	
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000	
	PIPE	0.75		7.90E-06	2.53E+06	BR1_2	22	*ILLEGAL*	1.000	1.000	1.000	API-XP	
	BR1_2				0.000	0.15TS	3.50E-01	0.005	0.00E+00	1.000	1.000	1.10E+04	
					0.000		0.00E+00	0.000	0.00E+00	1.000	1.000	1.000	
		2		1.13E-02	1.76E+03	BRACE-SID	10	EFTHYMIOU	4.583	2.500	5.679	API-XP	
					0.000	CROWN-SAD	3.50E-01	0.005	0.00E+00	1.000	1.000	1.10E+04	
					90.000	YT	4.25E-01	0.013	5.00E+00	1.000	3.164	6.002	
		2		1.36E-02	1.48E+03	CHORD-SID	10	EFTHYMIOU	5.017	2.500	6.236	API-XP	
					0.000	CROWN-SAD	3.50E-01	0.005	0.00E+00	1.000	1.000	1.10E+04	
					90.000	YT	4.25E-01	0.013	5.00E+00	1.000	4.861	5.172	
BM3	PIPE	JT1	**Fail**	1.55E+00	1.29E+01	CHORD-SID	4	EFTHYMIOU	3.199	2.500	4.455	API-XP	
	BR1_3				180.000	CROWN-SAD	2.50E-01	0.005	4.72E-01	1.000	1.000	1.10E+04	
					53.724	KTK/LPD	4.25E-01	0.013	1.00E+01	1.000	3.199	3.199	
		JT1	**Fail**	1.73E+00	1.15E+01	BRACE-SID	4	EFTHYMIOU	2.861	2.661	4.586	API-XP	
					180.000	CROWN-SAD	2.50E-01	0.005	4.72E-01	1.000	1.000	1.10E+04	
					53.724	KTK/LPD	4.25E-01	0.013	1.00E+01	1.000	2.861	2.861	
		0.20		4.58E-04	4.37E+04	BR1_3	13	BUTT-DNVG	1.132	1.132	1.132	API-XP	
					0.000	0.15TS	2.50E-01	0.005	2.50E-04	1.000	1.000	1.10E+04	
					0.000		0.00E+00	0.000	5.00E-03	1.000	1.132	1.132	
		5		6.45E-02	3.10E+02	BRACE-SID	16	EFTHYMIOU	2.595	3.021	7.377	API-XP	
					0.000	CROWN-SAD	2.50E-01	0.005	-1.24E-01	1.000	1.000	1.10E+04	
					53.724	K/LPD	4.25E-01	0.013	5.00E+00	1.000	2.595	2.595	
		5		4.69E-02	4.26E+02	CHORD-SID	16	EFTHYMIOU	2.500	2.500	7.167	API-XP	
					0.000	CROWN-SAD	2.50E-01	0.005	-1.24E-01	1.000	1.000	1.10E+04	
					53.724	K/LPD	4.25E-01	0.013	5.00E+00	1.000	2.500	2.500	
BM4	PIPE	JT1	**Fail**	6.16E+00	3.24E+00	CHORD-SID	1	EFTHYMIOU	3.199	2.500	4.455	API-XP	
	BR1_3				0.000	CROWN-SAD	2.50E-01	0.005	4.72E-01	1.000	1.000	1.10E+04	
					53.724	KTK/LPD	4.25E-01	0.013	1.00E+01	1.000	3.199	3.199	
		JT1	**Fail**	4.17E+00	4.80E+00	BRACE-SID	4	EFTHYMIOU	2.861	2.661	4.586	API-XP	
					0.000	CROWN-SAD	2.50E-01	0.005	4.72E-01	1.000	1.000	1.10E+04	
					53.724	KTK/LPD	4.25E-01	0.013	1.00E+01	1.000	2.861	2.861	
		0.20		1.59E-02	1.26E+03	BR1_3	1	BUTT-DNVG	1.132	1.132	1.132	API-XP	
					0.000	0.15TS	2.50E-01	0.005	2.50E-04	1.000	1.000	1.10E+04	
					0.000		0.00E+00	0.000	5.00E-03	1.000	1.132	1.132	
		10	**Fail**	2.62E+01	7.65E-01	BRACE-SID	13	EFTHYMIOU	5.099	2.661	4.335	API-XP	
					180.000	CROWN-SAD	2.50E-01	0.005	0.00E+00	1.000	1.000	1.10E+04	
					53.724	YT	4.25E-01	0.013	5.00E+00	1.000	2.933	5.099	
		10	**Fail**	2.82E+01	7.09E-01	CHORD-SID	13	EFTHYMIOU	6.124	2.500	4.212	API-XP	
					180.000	CROWN-SAD	2.50E-01	0.005	0.00E+00	1.000	1.000	1.10E+04	
					53.724	YT	4.25E-01	0.013	5.00E+00	1.000	3.544	6.124	

```
BM5          PIPE      13        **Fail**  1.05E+01  1.91E+00 BOTH-SIDE        19 GLOBAL      1.000    1.000  1.000 API-XP
             COL1                                    0.000  UNIFORM    4.25E-01   0.013    0.00E+00  1.000  1.000     1.10E+04
                                                     0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                       0.73               7.55E-01  2.65E+01 COL1              19 BUTT-DNVG   1.128    1.128  1.128 API-XP
                                                     0.000  0.15TS     4.25E-01   0.013    6.25E-04  1.000  1.000     1.10E+04
                                                     0.000             0.00E+00   0.000    1.25E-02  1.000  1.128       1.128
                       JT1                8.30E-02  2.41E+02 BOTH-SIDE        19 GLOBAL      1.000    1.000  1.000 API-XP
                                                     0.000  UNIFORM    4.25E-01   0.013    0.00E+00  1.000  1.000     1.10E+04
                                                     0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000

BM6          PIPE      JT1                7.94E-02  2.52E+02 BOTH-SIDE         7 GLOBAL      1.000    1.000  1.000 API-XP
             COL1                                    0.000  UNIFORM    4.25E-01   0.013    0.00E+00  1.000  1.000     1.10E+04
                                                     0.000             0.00E+00   0.000    0.00E+00  1.000  1.000       1.000
                       0.27               1.55E-02  1.29E+03 COL1              7 BUTT-DNVG   1.128    1.128  1.128 API-XP
                                                     0.000  0.15TS     4.25E-01   0.013    6.25E-04  1.000  1.000     1.10E+04
                                                     0.000             0.00E+00   0.000    1.25E-02  1.000  1.128       1.128
                       0.86               1.50E-05  1.34E+06 COL1             10 BUTT-DNVG   1.128    1.128  1.128 API-XP
                                                     0.000  0.15TS     4.25E-01   0.013    6.25E-04  1.000  1.000     1.10E+04
                                                     0.000             0.00E+00   0.000    1.25E-02  1.000  1.128       1.128
                       2                  2.45E-06  8.17E+06 BOTH-SIDE        13 GLOBAL      1.000    1.000  1.000 API-XP
                                                     0.000  UNIFORM    4.25E-01   0.013    0.00E+00  1.000  1.000     1.10E+04
                                                     0.000             0.00E+00   0.000    5.00E+00  1.000  1.000       1.000
```

B Theoretical information

This Appendix includes additional information regarding:

- Use of the NORSOK code of practice. (Appendix B.1)
- Use of the EUROCODE / NS3472 code of practice. (Appendix B.2)
- Automatic buckling factor calculations. (Appendix B.3)
- Codified S-N Curves. (Appendix B.4)
- Wide Band Correction Factor for Spectral Fatigue Analysis. (Appendix B.5)
- Power spectra and coherence models. (Appendix B.6)
- SCF formulae and generalised influence functions (Appendix B.7)

B.1 Use of the NORSOK code of practice

The NORSOK code check is based on:

NORSOK STANDARD, Design of Steel Structures, N-004, Rev. 2, October 2004, [57] and Rev. 3, February 2013, inclusive Corrigendum issued May 2013, [58].

B.1.1 NORSOK N-004 Rev. 2

Ultimate Limit States:

- Tubular Members (section 6.3)
- Tubular Joints (section 6.4)
- Strength of Conical Transitions (section 6.5)

The code check covers check of tubular (pipe-sections) members and joints according to the following:

It should be noticed that the member code check is a combined check for members in tension and compression. (The check is not split in Yield check and Stability check.) Hence, if a simple yield check is wanted, the NPD-NS3472 code of practice should be used. This code of practice must currently also be selected for code check of non-tubular profiles.

For the member check and the conical transition check, local element forces and moments are used. For the punching shear check, the in-plane and out-of-plane reference system is used.

Hydrostatic pressure effects are included in the member check and the conical transition check if a water plane is defined prior to the run.

Select the NORSOK code of practice by the command:

```
SELECT CODE-OF-PRACTICE NORSOK
```

Tubular Members Code Check (section 6.3)

Tubular (pipe cross section) members are checked according to the NORSOK standard section 6.3.8 “Tubular members subjected to combined loads without hydrostatic pressure” or section 6.3.9 “Tubular members subjected to combined loads with hydrostatic pressure”. Hydrostatic pressure effects are included in the member check if a water plane is defined prior to the run.

A tubular member code check is performed by the command:

```
RUN MEMBER-CHECK run-name run-text sel-mem sel-lcs
```

where

```
run-name = name given to the run
run-text = description associated to the run
sel-mem = members to be checked
sel-lcs = load cases to be checked
```

Code check parameters:

Two new code check parameters have been introduced in connection with NORSOK:

```
DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR value
DEFINE MEMBER-CHECK-PARAMETERS CALCULATION-METHOD method
```

Unit length factor:

The unit length factor is used in connection with geometric requirements, i.e. to verify that the tubular to be checked has a wall thickness greater or equal to 6 mm. The code check is based on the SI unit Meter. The value to be used is the factor which multiplied with the unit length used in the analysis gives 1.0 meter. (E.g. if the unit length used is millimetres => value = 1000.0).

Calculation method:

For members exposed to external hydrostatic pressure, the design provisions is divided into two categories, i.e. method A and method B. In method A it is assumed that the capped-end compressive forces due to the external hydrostatic pressure are not included in the structural analysis. Alternatively, the design provisions in method B assume that such forces are included in the analysis as external nodal forces. Note that if Wajac has been used to calculate the seastate loads, method B should be used. The default method selected by Framework is method B.

In connection with section 6.3.6.1, Hoop buckling, the length between stiffening rings (L used in geometric parameter μ) is given by the stability parameter ‘Stiffeners spacing’ defined by the command:

```
ASSIGN STABILITY sel-mem STIFFENER-SPACING length
```

where

```
sel-mem = members to be checked
length = length to be used
```

There are four available alternatives regarding calculation of the bending moments reduction factor according to Table 6-2, Notes: 1, i.e. alternative:

- (a): Cm = 0.85
- (b): for members with no transverse loading, Cm = 0.6 - 0.4 M1,Sd / M2,Sd
- (c): for members with transverse loading, Cm = 1.0 - 0.4 Nc,Sd / NE (but not > 0.85)
- (b) or (c): as above dependant of transverse load or not

To activate the calculation of moment reduction factor Cm, use the command:

```
ASSIGN STABILITY sel-mem MOMENT-REDUCTION-FACTOR method
```

where

```
sel-mem = members to be checked
method = NORSOK-A, NORSOK-B, NORSOK-C or NORSOK-B-C
```

If a non-supported method is selected (e.g. API-A), the Cm value is set to 1.0.

Material factor:

The default material factor γm used by Framework is 1.15. According to section 6.3.7 in the NORSOK standard, the material factor is dependent of the stress level (and geometric conditions). For some design conditions, e.g. accidental limit state or lifting analysis, it must be possible to specify the material factor to be used. By changing the (default) material factor (DEFINE CONSTANTS MATERIAL-FACTOR mat-factor), the specified material factor will be used, and section 6.3.7 will be neglected.

For the following design resistances a material factor of 1.15 is used (unless the material factor is specified by the user):

$N_{t,Rd}$ = Axial tension (section 6.3.2)

V_{rd} = Beam shear force (section 6.3.5)

$M_{T,Rd}$ = Torsional moment (section 6.3.5)

However, the material factor presented in the print is the material factor calculated according to section 6.3.7 (unless the material factor is specified by the user).

The check performed to evaluate if the user has given a material factor different from the default value is to check if the material factor differs from 1.15 by more than 0.0001. Hence, for a case where a user given material factor of 1.15 shall be used (i.e. no automatic calculation) the user must specify a material factor equal to e.g. 1.1502.

Members with two or more cross sections:

For members with two or more cross sections, the design compressive resistance Ncr.Rd is calculated according to equations 12.1 or 12.2. However, the elastic buckling load NE is calculated based on the cross section at the middle of the member.

See also command:

```
ASSIGN STABILITY ( ) NORSOK-AXIAL-COMPRESSION ...
```

Geometric requirements (calculated usage factors):

The following two geometric requirements are checked:

- $t \geq 6$ mm
- $D/t < 120$

The code check will be performed with the given geometric properties (even if they are outside the limits), but the print of results will give the following utilisation factors:

- $t < 6$ mm => Usfact = 999.0
- $D/t \geq 120$ => Usfact = 998.0

However, the usage factor for axial load contribution and bending moment contribution will be as calculated according to governing check, hence the sum of UsfaN + UsfaM will give the ‘correct’ utilisation without taking into consideration the geometric requirements.

See also command:

```
DEFINE GEOMETRY-VALIDITY-RANGE ON/OFF
```

Print of results (outcome):

When printing results, the governing case (equation number used in the NORSOK standard) is referred to in Outcome column on the print. The following texts are being used in addition to the equation number (positioned in front of the equation number):

- Tns: member is in tension
- Cmp: member is in compression
- T+H: member is in tension + external hydrostatic pressure
- C+H: member is in compression + external hydrostatic pressure
- Hyd: hydrostatic pressure check is governing (eq. 6.15)
- THA: hydrostatic pressure check is governing (eq. 6.41), method A, member in tension
- CHA: hydrostatic pressure check is governing (eq. 6.41), method A, member in compression
- CHB: hydrostatic pressure check is governing (eq. 6.41), method B, member in compression
- S+B: interaction shear + bending moment governing
- SBT: interaction shear, bending moment + torsion moment governing

When the usage factor is above unity, the following texts will appear instead of the above texts:

- *Fai: Unity check above 1.0 (but less than 998.0)
- *Thk: t < 6 mm (Usfact = 999.0)
- *D/t: D/t ≥ 120 (Usfact = 998.0)
- *Euler!*: Euler stress exceeded (Usfact = 997.0), see below

For members in compression which exceeds the Euler buckling strength, the total usage factor is set to 997.0 and the usage factors for the axial part and bending moment part are set to 0.0.

For members in tension, the Cm factors are set to 1.0 in the print, and the Euler capacity is reported as if the member is in compression (Cm and Euler capacity not used in the calculations).

See also command:

```
DEFINE GEOMETRY-VALIDITY-RANGE ON/OFF
```

Notes / comments:

Section 6.3.6.2 “Ring stiffener design” is not covered in the code check.

In the code checking, a user given buckling length will be limited to minimum 0.01 meters (or equivalent when converted to current length unit (ref. DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR value)).

In the heading for print of the check results, the following symbols represent forces and moments when the member is not exposed to external water pressure, and axial and bending stresses when water pressure is present:

- Nsd: Design axial force (stress when hydrostatic pressure)
- Ney: Euler buckling strength y direction (stress when hydrostatic pressure)
- Nez: Euler buckling strength z direction (stress when hydrostatic pressure)
- Nrd: Design axial resistance (stress when hydrostatic pressure)
- MySd: Design bending moment about y-axis (stress when hydrostatic pressure)
- MzSd: Design bending moment about z-axis (stress when hydrostatic pressure)
- Mrd: Design bending resistance (stress when hydrostatic pressure)
- Nsd is reported with negative sign when the member is in compression.

In the check performed according to section 6.3.8.3 “Interaction shear and bending moment” the vector sums of shear forces and bending moments are used in the formulas.

In section 6.3.8.1 “Axial tension and bending” the axial part of the utilisation is $(NSd / Nt,Rd)^{1.75}$. To avoid too small utilisations for members with small bending moments, an additional check is performed according to section 6.3.2 “Axial tension”.

In stability checks, i.e. equations containing the moment reduction factors Cmy and Cmz (equations 6.27, 6.43 and 6.50), the maximum bending moments about Y- and Z-axes are used at all cross sections (positions) checked along the member length.

Nomenclature in heading of result print is as follows:

```
Member      Name of member
LoadCase    Name of loadcase
CND         Operational, storm or earthquake condition
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Usfac       Total usage factor
fy          Material yield strength
Gamma-m     Material factor
Kly         Effective length factor * buckling length in y direction
Klz         Effective length factor * buckling length in z direction
fcle        Characteristic elastic local buckling strength
fhe         Elastic hoop buckling strength
spSd        Design hoop stress due to hydrostatic pressure
Phase       Phase angle in degrees
SctNam      Section name
UsfaN       Usage factor due to axial force
Nsd         Design axial force (stress when hydrostatic pressure)
fc          Characteristic axial compressive strength
fcl         Characteristic local buckling strength
Ney         Euler buckl. strength y direction (stress when hydr. pressure)
Nez         Euler buckl. strength z direction (stress when hydr. pressure)
Nrd         Design axial resitance (stress when hydrostatic pressure)
fh          Characteristic hoop buckling stress
UsfaM       Usage factor due to bending moment
MySd        Design bending moment about y-axis (stress when hydr. pressure)
MzSd        Design bending moment about z-axis (stress when hydr. pressure)
Cmy         Moment reduction factor about y-axis
Cmz         Moment reduction factor about z-axis
fm          Characteristic bending strength
Mrd         Design bending resitance (stress when hydrostatic pressure)
sqSd        Capped-end design axial compression stress
```

Tubular Joints Capacity Check (section 6.4)

A tubular joint code check is performed by the command:

```
RUN PUNCH-CHECK run-name run-text sel-jnt sel-lcs
```

where

```
  run-name = name given to the run
  run-text = description associated to the run
  sel-jnt = joints to be checked
  sel-lcs = load cases to be checked
```

Geometric requirements (calculated usage factors):

The following geometric requirements are checked:

- 0.2 ≤ beta ≤ 1.0 (beta = d / D)
- 10 ≤ gamma ≤ 50 (gamma = D / 2T)
- 30 deg. ≤ theta (≤ 90 deg.)
- g/D ≥ -0.6 (for K joints)

The code check will be performed with the given geometric properties (even if they are outside the limits), but the print of results will give the following utilisation factors:

- beta < 0.2 => Usfact = 999.0
- beta >1.0 => Usfact = 998.0
- gamma < 10 => Usfact = 997.0
- gamma > 50 => Usfact = 996.0

- theta < 30 deg. => Usfact = 995.0
- g/D < -0.6 => Usfact = 994.0

However, the usage factor for axial load contribution and bending moment contribution will be as calculated according to governing check, hence the sum of UsfaN + UsfaM will give the 'correct' utilisation without taking into consideration the geometric requirements.

See also command:

```
DEFINE GEOMETRY-VALIDITY-RANGE ON/OFF
```

Print of results (outcome):

When the usage factor is above unity, the following texts will appear:

- **Fail**: Unity check above 1.0 (but less than 994.0)
- **Bta<.2 or **Beta>1: (Usfact = 999.0 or 998.0)
- **Gam<10 or **Gam>50: (Usfact = 997.0 or 996.0)
- **The<30: (Usfact = 995.0)
- **g/D**: (Usfact = 994.0)

Notes / comments:

When a joint is assigned joint type interpolate or loadpath, the following parameters will be calculated according to the joint type percentages:

- Qu-factor for axial load (ref. Table 6-3)
- C1 and C2 used in A which again used in the Qf-factor (ref. section 6.4.3.4)

The total axial capacity N_{Rd} will be calculated according to the joint type percentages.

In addition to formulae given in the standard, the axial design resistance reduction used in section 6.4.3.5 "Design axial resistance for X and Y joints with joint cans" is also adjusted with respect to the yield stress in can section and chord member, hence equation (6.56) will be:

$$N_{Rd} = (r + (1-r)(Tn/Tc)^2(fyn/fy,can)) * N_{can,Rd}$$

where

fyn = yield strength in chord member

fy,can = yield strength in can section

Nomenclature in heading of result print is as follows:

Joint	Name of joint
Brace	Member name of the brace
LoadCase	Name of loadcase
CND	Operational, storm or earthquake condition
Jnt/Per	Joint type
Outcome	Outcome message from the code check
Usfac	Total usage factor
NSd	Design axial force in brace
My,Sd	Design in-plane bending moment
Mz,Sd	Design out-of-plane bending moment
A**2	Parameter used in calculation of Qf
Qux	Ultimate strength factor due to axial force
Qfx	Factor accounting chord stress due to axial force
L	Least distance between crown and edge of chord can
Chord	Member name of the corresponding chord
Phase	Phase angle in degrees
UsfaN	Usage factor due to axial force
NRd	Joint design axial resistance
My,Rd	Design in-plane bending resistance
Mz,Rd	Design out-of-plane bending resistance
Theta	Angle between brace and chord in degrees
Quipb	Ultimate strength factor due to in-plane moment
Qfipb	Factor accounting chord stress due to in-plane moment
NRd/Ncan	Reduction factor used in eq. (6.56)

```
 UsfaM       Usage factor due to bending moments
 Method      Method used for joint type assignment
 fy          Chord material yield strength
 Gamma-m     Material factor
 Gap         Gap value used for K/KTT/KTK joint (negative if overlap)
 Quopb       Ultimate strength factor due to out-of-plane moment
 Qfopb       Factor accounting chord stress due to out-of-plane moment
 Beta        Diameter brace / Diameter chord
```

NORSOK Rev. 2, October 2004 chapter 6.4.4 "Overlap joints" give some instructions regarding additional checks to be performed. The "Outcome" column in the result print has different content dependant of governing check as follows:

```
Ove Shea = Shear parallell to chord is governing
Othrough = The through brace, according to eq. (6.57)
Othr com = The through brace, according to eq. (6.57) but based on
           modified forces due to portion of load in overlapping brace
Othr amo = The through brace, according to eq. (6.57) but based on
           forces in the overlapping brace
Ooverlap = The overlapping brace, according to eq. (6.57)
Oove Yot = The overlapping brace, calculated as Y using the through
           brace as chord
```

Strength of Conical Transitions (section 6.5)

A conical transition code check is performed by the command:

```
RUN CONE-CHECK run-name run-text sel-mem sel-lcs
```

where

```
  run-name = name given to the run
  run-text = description associated to the run
  sel-mem = members to be checked
  sel-lcs = load cases to be checked
```

Geometric requirements (calculated usage factors):

The following geometric requirement is checked:

alpha < 30 deg. (slope angle of cone)

The code check will be performed with the given geometric properties (even if they are outside the limits), but the print of results will give the following utilisation factor:

alpha ≥ 30 deg. => Usfact = 999.0

However, the usage factor for tubular side and the cone side of the junction will be as calculated according to governing check.

Print of results (outcome):

When printing results, the governing case (equation number used in the NORSOK standard) is referred to in Outcome column on the print. The following texts are being used in addition to the equation number (positioned in front of the equation number):

- LBU: local buckling under axial compression
- Hyd: hydrostatic pressure check is governing (eq. 6.15)
- YLD: junction yielding, hoop stress is tensile
- JBU: junction buckling, hoop stress is compressive

When the usage factor is above unity, the following texts will appear instead of the above texts:

- *Fai: Unity check is above 1.0 (but less than 999.0)
- *Ang: Unity check = 999.0

Notes / comments:

Section 6.5.5 “Ring design” is not covered in the code check.

In connection with section 6.5.4.1 “Hoop buckling”, the cone length used is the less of the slant height of the cone and the stability parameter ‘Stiffeners spacing’ defined by the command:

```
ASSIGN STABILITY sel-mem STIFFENER-SPACING length
```

where

```
sel-mem = members to be checked
length = length of cone to be used
```

Nomenclature in heading of result print is as follows:

```
Member      Name of member
LoadCase    Name of loadcase
CND         Operational, storm or earthquake condition
Type        Section type
Joint/Po    Joint name or position within the member
Outcome     Outcome message from the code check
Usfact      Max usage factor of cone and cylinder side
fy          Material yield strength
Gamma-m     Material factor
sequSd      Equivalent design axial stress within the conical transition
sacSd       Design axial stress at the section within the cone
smcSd       Design bending stress at the section within the cone
fclc        Local buckling strength of conical transition
shSd        Design hoop stress due to external hydrostatic pressure
Phase       Phase angle in degrees
SctNam      Section name
Usfcon      Usage factor cone side
Dj          Cylinder diameter at junction
t           Tubular wall thickness
satSd       Design axial stress in tubular section at junction
smlcSd      Local design bending stress at the tubular side of junction
shcSd       Design hoop stress due to unbalanced radial line force
fcj         Characteristic axial (local) compressive strength
shjSd       Net design hoop stress
Usfcyl      Usage factor cylinder side
alpha       Angle (deg.) between cylinder and cone
tc          Cone wall thickness
smtSd       Design bending stress in tubular section at junction
smltSd      Local design bending stress at the cone side of junction
stotSd      Resulting total design stress in axial direction
fh          Characteristic hoop buckling strength
```

Fatigue Limit States, SN curves:

The SN curves defined in NORSOK N-004 ANNEX C (ref. the 1998 release, moved to DNV-RP-C203 section 2.4) for use in sea water with cathodic protection (Table C.2-2) have been added to the SN curve library. The new SN curves are entitled ‘NO-name-S’ where name is the SN curve name, e.g. B1, C2 etc.

Default thickness correction factors have been predefined for these SN curves. The correction reference thickness and cut-off thickness are applied in SI unit meters. The thickness corrections are converted to current length unit by use of the command:

```
DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR value
```

The value to be used is the factor which multiplied with the unit length used in the analysis gives 1.0 meter. (E.g. if the unit length used is millimetres => value = 1000.0).

Note that the thickness corrections are converted to current units only for library SN curves from NORSOK. (Thickness corrections applied to non-NORSOK, or user defined SN curves, must be given in current consistent unit.)

For the NORSOK T curve, the thickness exponent is automatically increased from 0.25 to 0.3 for SCFs > 10.0.

Note that for thickness corrections with thickness exponent = 0.25 (except for the T-curve), the cut-off thickness is set to 1/10 of a millimetre less than the reference thickness to avoid that the thickness correction is reported as a ‘Standard T curve’ thickness correction.

B.1.2 NORSOK N-004 Rev. 3

Commands and issues described for NORSOK N-004, revision 2 in Appendix B 1.1 are also relevant for revision 3. In addtion some specific issues related to printing of results for revision 3 are outlined in the present section.

Printing Results:

When printing the results from the analysis the Outcome column gives information as explained below.

Member check:

Normally the governing equation according to the standard is printed.

Two geometric limitations are checked, the D/t ratio and wall thickness.

- If D/t > 120 the text *D/t is reported. If DEFINE GEOMETRY-VALIDITY-RANGE is switched ON a usage factor of 999 is reported.
- If wall thickness t < 6mm the text *thk is reported. If DEFINE GEOMETRY-VALIDITY-RANGE is switched ON a usage factor of 998 is reported.

If the usage factor is > 1.0, the text *F (for Failed) is added in front of the equation number or geometric limitation info text.

Joint check:

Normally no info is given, i.e. brace with positive gap and usage factor less than 1.0. For other conditions the following alternatives are used:

- **Fail** : Usage factor > 1.0
- OvThr : The through brace in an overlapping joint
- OvOve : The overlapping brace in an overlapping joint
- OvShe : The shear capacity check in an overlapping joint
- **FailOT : The through brace in an overlapping joint, uf > 1
- **FailOO : The overlapping brace in an overlapping joint, uf > 1
- **FailOS : The shear capacity check in an overlapping joint, uf > 1

Seven geometric limitations are checked. The value given in parentesis below are the usage factors reported when the geometric limitation is exceeded and DEFINE GEOMETRY-VALIDITY-RANGE is switched ON.

- **Bta<.2 : beta ratio < 0.2 (999)
- **Beta>1 : beta ratio > 1 (998)
- **Gam<10 : gamma ratio < 10 (997)
- **Gam>50 : gamma ratio > 50 (996)
- **The<30 : theta ratio < 30 (995)
- **g/D** : the gap / chord Diameter ratio < -0.6 (994)
- **Tau** : tau ratio > 1 (993)

Cone check:

Normally the governing equation according to the standard is printed. If the usage factor is > 1.0, the text *Fai (for Failed) is added in front of the equation number.

Two geometric limitations are checked, the cone angle and the tc/t ratio at the smaller diameter cone end.

- If alpha > 30 deg. the text >30 is also reported. If DEFINE GEOMETRY-VALIDITY-RANGE is switched ON a usage factor of 999 is reported. If the usage factor is > 1.0 the additional info text is *F >.
- If wall thickness of the cone 'tc' is less than the wall thickness of the tubular 't' at the smaller diameter end of the cone, the text tc<t is reported. If DEFINE GEOMETRY-VALIDITY-RANGE is switched ON a usage factor of 998 is reported. If the usage factor is > 1.0 the additional info text is *Ftc.

B.2 Use of EUROCODE / NS3472 code of practice

The Framework member code check according to Eurocode / NS3472 is based on:

- Eurocode 3 ENV 1993-1-1, further herein referred to as EC3
- NS3472 release 3 2001, further herein referred to as NS

The code check covers **Ultimate Limit State** check of:

- resistance of cross section incl. von Mises stress check, ref. EC3 sect. 5.4 / NS sect. 12.2
- buckling resistance of members, ref. EC3 sect. 5.5 / NS sect. 12.3

for beams of type:

- H (I) profiles (double and single symmetric)
- rectangular hollow section (BOX)
- massive bar section
- channel profiles
- pipe (tubular) profiles
- general profiles

Select this code of practice by the command:

```
SELECT CODE-OF-PRACTICE EUROCODE-NS3472
```

It should be noticed that this member code check is a combined check for members in tension and compression. A member code check is performed by the command:

```
RUN MEMBER-CHECK run-name run-text sel-mem sel-lcs
```

where

```
  run-name = name given to the run
  run-text = description associated to the run
  sel-mem  = members to be checked
  sel-lcs  = load cases to be checked
```

Code check parameters:

Five code check parameters to be aware of in connection with this code check:

```
DEFINE MEMBER-CHECK-PARAMETERS UNIT-LENGTH-FACTOR value
DEFINE CONTANTS MATERIAL-FACTOR value
DEFINE MEMBER-CHECK-PARAMETERS VON-MISES-CHECK option
DEFINE MEMBER-CHECK-PARAMETERS SECTION-CAPACITY-CHECK option
DEFINE MEMBER-CHECK-PARAMETERS STABILITY-CAPACITY-CHECK option
```

Unit length factor:

The unit length factor is used in connection with geometric properties for automatic determination of buckling curves. The code check is based on the SI unit Meter. The value to be used is the factor which multiplied with the unit length used in the analysis gives 1.0 meter. (E.g. if the unit length used is millimetres => value = 1000.0).

Material factor:

Defines the material factor (partial safety factor) γ_{M1} (= γ_{M0}) defined in the standards. Note that the default value is 1.15 (due to other available code checks in Framework) and hence the following command should normally be used:

```
DEFINE CONSTANTS MATERIAL-FACTOR 1.10
```

von Mises check (ref. NS sect. 12.2.2):

This command is used to select how the von Mises stress check criteria is handled. The options are:

ON: include a von Mises stress check at each check position (default)

OFF: skip the von Mises check

ONLY: do the check based on von Mises check only (skip other checks)

The von Mises stress check is based on a linear elastic analysis and use of elastic section modulus.

Section capacity check:

This command is used to select how to handle the resistance of cross section checks. The options are:

ON: perform shear check and the axial + bending moment check (default)

OFF: skip the section capacity checks

SHEAR: ON, but only perform shear check

COMBINED: ON, but only perform the axial + bending moment check

Stability capacity check:

This command is used to select how to handle the buckling resistance check. The options are:

ON: perform the stability checks (default)

OFF: skip the stability checks

Classification of cross sections (ref. EC3 sect. 5.3 table 5.3.1 / NS sect. 12.1 table 7):

The cross sections are classified for web and flange at each check position and for each loadcase investigated. When calculating the yield stress ratio e (defined by sqrt(235./fy)) the yield stress fy is converted from current unit into N/mm^2 by a factor $2.1*10^5$ / E, where E is the Young's modulus in current units.

Classification of cross section for use in the stability check is based on maximum bending moments along the member length. However, in cases where the bending moment at midspan has opposite sign compared to the maximum bending moment and is larger than 50% of the maximum bending moment, the classification based on bending moments at midspan is used.

For cross sections classified in class 1 and 2 the plastic section modulus is used even if the linear elastic analysis shows that the extreme fibre in the cross section has not reached yielding.

It is also possibility to lock to elastic section capacity. Hence, the sections will always be classified in class 3 or 4. This feature is controlled by use of the command:

```
DEFINE MEMBER-CHECK-PARAMETERS ELASTIC-CAPACITY-ONLY ON (or OFF)
```

Please note the following:

- Pipe (tubular) profiles are calculated according to class 3 even if class 4 is indicated in the print
- Channel profiles are only classified as class 3 sections
- General profiles and massive bar profiles are only classified as class 3 sections

Buckling curves (ref. EC3 table 5.5.3 / NS table 11):

The buckling curves to be used for I (H) sections and welded box sections may automatically be selected by use of the commands:

```
ASSIGN STABILITY ( ) BUCKLING-CURVE-Y AUTO
ASSIGN STABILITY ( ) BUCKLING-CURVE-Z AUTO
```

Note that the ( ) reefers to the current/active selection of members.

For pipe profiles and rolled box sections curve A is used as default for both axes.

For other profile types than mentioned above curve C is used as default for both axes.

Resistance of cross section (ref. EC3 sect. 5.4 / NS sect. 12.2):

The check includes effective cross section properties for class 4 cross-sections.

For I (H) sections and for box sections it is also investigated if the shear capacity is limited due to shear buckling when web(s) is classified in class 4. When calculating the buckling coefficient χv, the contribution from the flanges is neglected, hence $\chi v = \chi w$, where χw is calculated for the situation with rigid transverse stiffeners at the supports. The distance between intermediate transverse stiffeners is given by the command:

```
ASSIGN STABILITY ( ) STIFFENER-SPACING value
```

where

```
  value = distance between intermediate transverse stiffeners
```

Please note the following:

- Channel profiles are only calculated as class 3 sections.
- General profiles are only calculated as class 3 sections.

- For box profiles a reduced yield stress is used in the check to account for torsion stress, i.e. $fy' = (fy^2 - 3\tau^2)^{0.5}$, where τ is the shear stress caused by torsion moment (based on average shear flow in section).

- Pipe (tubular) profiles are calculated according to class 3 even if class 4 is indicated in the print. (I.e. Aeff and Weff similar to class 3 section properties (A and We).) For sections in class 1 and 2 the linear interaction check is used, i.e. usage factor = n + my + mz where n and m are the normalised force components. A reduced yield stress is used in the check to account for torsion stress, i.e. $fy' = (fy^2 - 3\tau^2)^{0.5}$, where τ is the shear stress caused by torsion moment.

- For I (H) sections and channel sections a warning will be given if the maximum shear stress caused by torsional moment exceeds 50% of the material strength ($fy/\gamma m$).

Buckling resistance of members (ref. EC3 sect. 5.5 / NS sect. 12.3):

When classifying cross section class for use in the buckling resistance check the maximum bending moments along the member about weak and strong axes are used. However, in cases where the bending moment at midspan has opposite sign compared to the maximum bending moment and is larger than 50% of the maximum bending moment, the classification based on bending moments at midspan is used. The buckling resistance check is only calculated based on the geometry at midspan of the member.

Compared with other member / stability code checks available in Framework it is the equivalent uniform moment factors ß (i.e. not the moment amplification factor k) which are given through the command:

```
ASSIGN STABILITY ( ) MOMENT-REDUCTION-FACTOR ...
```

The ß factors may be manually given or automatically calculated by the program. Automatic calculation based on moment distribution along member (see EC3 figure 5.5.3 / NS table 12) is activated by using the command:

```
ASSIGN STABILITY ( ) MOMENT-REDUCTION-FACTOR EUROCODE
```

or

```
ASSIGN STABILITY ( ) MOMENT-REDUCTION-FACTOR NS3472
```

Note that for some profiles (e.g. I (H) sections with small height/width ratio) a buckling check without taking into account a lateral-torsional failure mode will be governing even if lateral-torsion buckling is a potential failure mode.

For lateral buckling the user may specify a value for the length of member between points with lateral restraint inclusive the end rotation, the 'lateral buckling length' kL (see EC3 Annex F.1.2 / NS sect. B.12.3.4). Use the command:

```
ASSIGN STABILITY ( ) UNSUPPORTED-FLANGE-LENGTH LENGTH-BETWEEN-JOINTS
```

or

```
ASSIGN STABILITY ( ) UNSUPPORTED-FLANGE-LENGTH value
```

where

```
  value = length of member between points with lateral restraint
          (adjusted for end rotation)
```

The correction factor C_1 (factor depending on the loading) is given by:

```
ASSIGN STABILITY ( ) LATERAL-BUCKLING-FACTOR AUTO
```

or

```
ASSIGN STABILITY ( ) LATERAL-BUCKLING-FACTOR value
```

where

```
  value = C1 to be used
```

The C_1 factor calculated when using the AUTO option is $C_1 = 1.88 - 1.40\psi + 0.52\psi^2$ which assumes a linear moment distribution along the member.

The following limitations occur in the current implementation regarding elastic critical moment for lateral torsional buckling:

- It is k*L that is given through ASSIGN STABILITY ( ) UNSUPPORTED-FLANGE-LENGTH, hence no fixity ('fork support') is assumed at both ends, and no special provision is made for end warping fixity, hence $k = k_w = 1.0$.

- Also $z_g = z_j = 0.0$ is assumed, i.e. C2 and C3 not used.

Please note the following:

- Channel profiles are only calculated as class 3 sections.

- General profiles are only calculated as class 3 sections.
- For box profiles a reduced yield stress is used in the check to account for torsion stress, i.e. fy' = $(fy^2 - 3\tau^2)^{0.5}$, where τ is the shear stress caused by torsion moment (based on average shear flow in section).
- Pipe (tubular) profiles are calculated according to class 3 even if class 4 is indicated in the print. (I.e. Aeff and Weff similar to class 3 section properties (A and We).) A reduced yield stress is used in the check to account for torsion stress, i.e. fy' = $(fy^2 - 3\tau^2)^{0.5}$, where τ is the shear stress caused by torsion moment.

Print of results:

The nomenclature used in the print is as follows:

Member	Name of member
LoadCase	Name of loadcase
CND	Condition (not in use for this code of practice)
Type	Section type
Joint/Po	Joint name or position within the member
Outcome	Outcome message from the code check
UsfTot	Total usage factor: UsfTot = UsfAx + UsfMy + UsfMz
UsfAx	Usage factor due to axial stress
N	Acting axial force
Ndy(Nkdy)	Axial (buckling) force capacity about y-axis
My*ky	Design bending moment used for bending about y-axis
Mdy	Moment capacity for bending about y-axis
Ky	Effective length factor for bending about y-axis
Ly	Buckling length for bending about y-axis
Phase	Phase angle in degrees
SctNam	Section name
EleNum	Element number
UsfMy	Usage factor due to bending about y-axis
Fy	Yield strength
Ndz(Nkdz)	Axial (buckling) force capacity about z-axis
Mz*kz	Design bending moment used for bending about z-axis
Mdz	Moment capacity for bending about z-axis
Kz	Effective length factor for bending about z-axis
Lz	Buckling length for bending about z-axis
UsfMz	Usage factor due to bending about z-axis
Gamma-m	Material factor, gamma-M1
vMises	Equivalent stress used in von Mises stress check
Lbuck	Length between lateral support of compression flange
C1	Lateral buckling factor
BCrv y,z	Buckling curve for bending about y,z-axes
Class w,f	Cross section class for web, flange

Some of the positions in the print are used to show different content dependant of which of the part checks that is the governing check:

<u>von Mises stress check is governing:</u>

Ndy = axial capacity in tension

Ndz = axial capacity in compression

<u>Euler axial load is exceeded:</u>

Ndy = Euler capacity about y-axis

Ndz = Euler capacity about z-axis

<u>Lateral buckling is governing:</u>

My*ky = Maximum moment * kLT

Mdy = Moment capacity * χLT

The outcome column in the code check results print indicates which check that is governing. The +A indicates tension, and a -A will be used when in compression:

vMis	von Mises check
M+Ax	Resistance of cross-section (Bending Moment + Axial force)
AxLd	Resistance of cross-section (Bending Moment + Axial force). Class 1 and 2 only, case where n is greater than the utilisation given from expression $m_y^{\alpha} + m_z^{ß}$
My+A	Resistance of cross-section (Bending Moment + Axial force). Class 1 and 2 only, case where $m_y + n^2$ is greater than the utilisation given from expression $m_y^{\alpha} + m_z^{ß}$
Mz+A	Resistance of cross-section (Bending Moment + Axial force). Class 1 and 2 only, case where $m_z + n^2$ is greater than the utilisation given from expression $m_y^{\alpha} + m_z^{ß}$
RM+A	Resistance of cross-section (Reduced bending Moment capacity due to shear + Axial force). Class 3 and 4 only
MS+A	Resistance of cross-section (Bending Moment, Shear + Axial force). Class 1 and 2 only
Shea	Resistance of cross-section (Shear force)
Stab	Stability check (not a lateral buckling case or lateral buckling not governing)
StaL	Stability check inclusive lateral buckling
Lbck	Lateral buckling, axial tension (Compressive stress from bending moment is larger than tension stress from 0.8*axial force)

‘Outcome’ message field:

For some conditions the UsfTot is given a large value to indicate that a special situation has occurred. Note that in such cases the UsfAx, UsfMy and UsfMz show ‘normal’ values.

When Euler axial load is exceeded UsfTot = 997 and the outcome column shows: *Euler! *

For slender members the usage factor is calculated and reported neglecting the slenderness requirement. The outcome column, however, will indicate a slender member. To activate the program to report a usage factor equal to 995 for such conditions the following command must be executed prior to the run command:

```
DEFINE GEOMETRY-VALIDITY-RANGE ON
```

UsfTot = 995: The profile is slender, i.e. slenderness is greater than 250. The three first characters in the outcome column shows: *Sl

In general, for utilizations above 1.0, the three first characters in the outcome column shows: *Fa

Dump of intermediate code check data:

For each code check run important parameters and buckling factors may be written to a separate file. The files will be named run-name-MCC.TMP. Activate this option by the command:

```
DEFINE MEMBER-CODE-CHECK-DUMP ON
```

Example print and explanation to the dump values are given below:

```
 Member:        1 Scttyp: GIORHR   Loadcase:        2 Position:  2
 ------------------------------------------------------------------
 Fx       = -0.5000E+06 Fy       =  -300.0     Fz       =   2000.
 Mx       =      0.0000 My       =  0.2000E+08 Mz       =  0.3000E+07
 Area     =   5120.     Wymin    =  0.5018E+06 Wzmin    =  0.1452E+06
 E-mod    =  0.2100E+06 Fy       =   235.0     Gamma_m  =   1.100
 Ndtens   =  0.1094E+07 Ndcomp   =  0.1094E+07 Mycap    =  0.1072E+09
 Mzcap    =  0.3102E+08 Vcapa    =  0.1603E+06 a-ratio  =   1300.
 betaA    =   1.000     betaWpy  =  0.9217     Wpy      =  0.5445E+06
 betaWpz  =  0.6624     Wpz      =  0.2193E+06 Mpf      =  0.1019E+09
 n        =  0.4571     my       =  0.1865     mz       =  0.9670E-01
 Mcr      =  0.6431E+09 lamdab_LT=  0.4282     phi_LT   =  0.6157
 chi_LT   =  0.9452     mu_LT    =  0.5731E-01 kLT      =  0.9580
 lamdab_y =  0.4810     phi_y    =  0.6634     chi_y    =  0.8925
 lamdab_z =  0.9532     phi_z    =   1.139     chi_z    =  0.5676
 beta_My  =   1.450     mu_y     = -0.5291     ky       =   1.246
 beta_Mz  =   1.450     mu_z     =  -1.048     kz       =   1.500
```

where:

Member	=	Member name
Scttyp	=	Cross Section type names according to SESAM Input Interface Format
Loadcase	=	Loadcase name
Position	=	Code check position number along beam (ascending from 1 to n positions)
Fx	=	Axial force (compression negative)
Fy	=	Shear force in cross section Y direction
Fz	=	Shear force in cross section Z direction
Mx	=	Torsion moment
My	=	Bending moment about cross section Y-axis
Mz	=	Bending moment about cross section Z-axis
Area	=	Cross section area
Wymin	=	Mininmum section modulus about Y-axis
Wzmin	=	Mininmum section modulus about Z-axis
E-mod	=	Modulus of elasticity
Fy	=	Yield stress
Gamma_m	=	Material factor (safety factor)
Ndtens	=	Design tension resistance of the cross section
Ndcomp	=	Design compression resistance of the cross section
Mycap	=	Design moment resistance of the cross section about Y-axis
Mzcap	=	Design moment resistance of the cross section about Z-axis
Vcapa	=	Design plastic shear resistance (Z direction) (Shear capacity in Z direction when general cross section, GBEAMG)
a-ratio	=	Ratio shear area between flanges / total area when class 1 or 2. Shear area in Z direction when class 3 or 4. (Shear capacity in Y direction when general cross section, GBEAMG)
betaA	=	Cross section area scaling factor = 1 for class 1,2 and 3 = Aeff/A for class 4
betaWpy	=	Plastic section modulus scaling factor about Y-axis; = 1 for class 1 and 2; = We/Wp for class 3; = Weff/Wp for class 4
Wpy	=	Plastic section modulus about Y-axis
betaWpz	=	Plastic section modulus scaling factor about Z-axis; = 1 for class 1 and 2; = We/Wp for class 3; = Weff/Wp for class 4
Wpz	=	Plastic section modulus about Z-axis
n	=	Normalised axial force
my	=	Normalised bending moment about Y-axis
mz	=	Normalised bending moment about Z-axis
Mcr	=	Elastic critical moment for lateral torsional buckling
lamdab_LT	=	non-dimentional slenderness for lateral torsional buckling
phi_LT	=	Φ_{LT} for lateral torsional buckling
chi_LT	=	χ_{LT} reduction factor for lateral torsional buckling
mu_LT	=	μ_{LT} for lateral torsional buckling
kLT	=	k_{LT} for lateral torsional buckling
lamdab_y	=	non-dimentional slenderness about Y-axis
phi_y	=	Φ_y for buckling about Y-axis
chi_y	=	χ_y reduction factor for buckling about Y-axis
lamdab_z	=	non-dimentional slenderness about Z-axis
phi_z	=	Φ_z for buckling about Z-axis
chi_z	=	χ_z reduction factor for buckling about Z-axis

beta_My	=	Equivalent uniform moment factor about Y-axis
mu_y	=	μ_y for buckling about Y-axis
ky	=	Bending moment correction factor for buckling about Y-axis
beta_Mz	=	Equivalent uniform moment factor about Y-axis
mu_z	=	μ_z for buckling about Z-axis
kz	=	Bending moment correction factor for buckling about Z-axis

B.3 Automatic buckling factor calculations

B.3.1 How to use the automatic buckling length (effective length factor) facility

The automatic buckling length calculation feature is activated in a similar way as other stability parameters. The command is:

```
ASSIGN STABILITY ( ) BUCKLING-LENGTH AUTOMATIC
```

The ( ) means the set of current active members. The member effective length factors are then automatically calculated based on member support spring stiffnesses and axial loading condition.

The effective length factors (by default set to 1.0 for both y and z axes) are not in use for members with the automatic calculation activated. One exception is when / if the automatic buckling calculation fails. The buckling length will then be equal to the member length multiplied with the manually given effective length factors, and one of the following messages will be printed.

For a complex load case:
“Automatic buckling length calculation has failed for member ‘mem.name’, loadcase ‘lcs-name’, phase no. ‘xx’. Member length used."

For a non-complex load case:
“Automatic buckling length calculation has failed for member ‘mem.name’, loadcase ‘lcs-name’. Member length used."

The in-plane buckling effective length factor (in Framework denoted ky) is associated with bending moment about local y-axis, i.e. buckling in the x-z plane.

The out-of-plane buckling effective length factor (in Framework denoted kz) is associated with bending moment about local z-axis, i.e. buckling in the x-y plane.

Note that all members in Framework (members automatically defined from each beam element when the Framework model is established, and members spanning more than one beam element, either defined in Preframe or in Framework (CREATE MEMBER COMBINE-AUTOMATIC or CREATE MEMBER ‘mem.name’ ‘description’ ‘start-jnt’ ‘end-jnt’) will be treated as one composed member. The local x-z plane defines the in-plane for the considered member. The in-plane reference direction is given by the command:

```
ASSIGN LOCAL-COORDINATE-SYSTEM ‘mem.name’ Z-AXIS JOINT ‘jnt-no’
```

The other options for assigning local coordinates may as well be used. Elements which have been given local coordinates in Preframe (either by program default or user defined) does not need to be assigned local coordinates in Framework.

The automatic buckling factor option calculates buckling factors for each element which is part of the member. In the code check, the critical axial capacity is calculated at each code check position based on where the position is located, i.e. at which element the check position is located.

For each code check run, the calculated spring stiffnesses and buckling factors may be written to a separate file. The files will be named to identify the different runs according to the following naming convention: ‘run-name’BUCK.TMP. Activate this option by the command:

```
DEFINE BUCKLING-LENGTH-DUMP ON
```

An alternative to the ASSIGN STABILITY ( ) BUCKLING-LENGTH AUTOMATIC is also available. The alternative command is:

```
ASSIGN STABILITY ( ) BUCKLING-LENGTH LATERAL-SUPPORT-AUTO
```

When this command is used, the rotational and lateral spring stiffnesses are not calculated by the program. The lateral springs are under this condition set to 1.0 (i.e. pinned supported), and the rotational stiffnesses are set to 0.0 (i.e. free) for start and end node of the member, and the eigenvalue analysis and effective length factors are calculated based on these end supports only. Hence, this option may be used to neglect the stiffness of incoming members on intermediate nodes, or in cases where the rotational stiffness of the

member start and end shall be neglected. The latter case is relevant for a jacket leg between horizontal levels.

B.3.2 Calculation of buckling length (effective length factor)

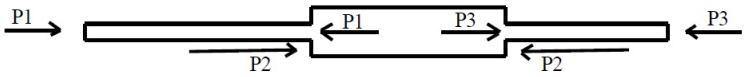
The buckling parameter is calculated using an eigenvalue analysis

$$(K_e - \lambda K_g)r = 0,$$

where

K_e	Elastic stiffness matrix of composite member.
K_g	Geometric stiffness matrix of composite member.
λ	Eigenvalue (critical axial compressive force).
r	Eigenvectors.

The critical axial compressive force will be equal in every beam element which is a part of the member. This is due to the fact that the member is regarded as one system, hence if one single member (beam element) in the member reaches the critical axial force, the member itself has reached the critical axial force also.



We have

$$\lambda = P_{cr_1} = P_{cr_2} = P_{cr_3}.$$

The buckling factors are found by using the Euler buckling capacity formulae

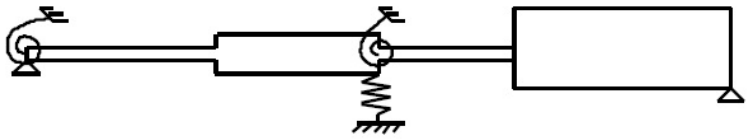
$$P_{cr} = \frac{\pi^2 EI}{(kl)^2},$$

which implies that

$$\lambda = P_{cr} = \frac{\pi^2 EI_1}{(k_1 l_1)^2} = \frac{\pi^2 EI_2}{(k_2 l_2)^2} = \frac{\pi^2 EI_3}{(k_3 l_3)^2}.$$

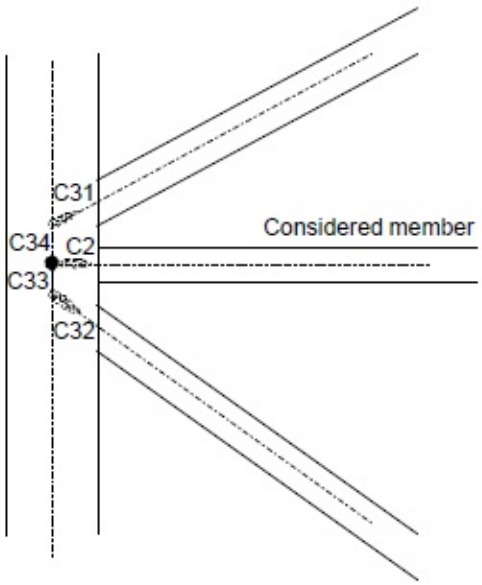
From these relations the different effective length factors may be found. Note that the effective length factors for the different beam elements are dependant of the axial load in the beam.

Framework calculates the “supporting" spring stiffnesses automatically. The planes in which the springs acts are given by the in-plane and out-of-plane definition for the member.



B.3.3 Calculation of rotational spring stiffness

The rotational spring stiffnesses (end restraints) are calculated according to NPD 1997 section 3.2.4.
Ex.:



$$\frac{1}{C} = \frac{1}{C_1} = \frac{1}{C_2},$$

where

C	Rotational spring stiffness for considered member. To be used for calculation of buckling length.
C_1	Total effective rotational stiffness of restraining members. (NPD 3.2.4.1).
C_2	Local rotational stiffness of considered member (according to NPD 3.2.4.2).

C_1 is calculated from

$$C_1 = \sum_{i=1}^{4} \left(\frac{l_i}{NEI\alpha_i} + \frac{1}{C_{3i}} \right)^{-1},$$

where

α_i	is a reduction factor $= (f_k - \sigma_c)/f_k$
f_k	is a characteristic stress for stability control
σ_c	is compressive stress
C_{3i}	local rotational stiffness at the connection between member and the chord. In the example $C_{33} = C_{34} = \infty$. C_{31} and C_{32} are calculated according to NPD 3.2.4.2.

The example shown is valid for buckling in the chord-brace plane. The global rotational stiffness when buckling in the chord-brace plane is written as:

$$C_{g(inp)} = \frac{NEIa_i}{l_i}, \qquad N = 3.5 \qquad \text{(see NPD rules).}$$

Out of the chord-brace plane the rotational stiffness is written as:

$$C_{g(out)} = \frac{GI_t a_i}{l_i},$$

where

G	Shear modulus.
I_t	Torsional moment of inertia.

Only those members which are in the same plane as the considered member and the chord will be taken into account when calculating the global rotational stiffness. This simplification will have only minor effect on the total rotational stiffness. The reason for this is that it is the local rotational stiffnesses in the joint that are dominating.

The rotational stiffness is calculated in (local x-z plane) and out (local x-y plane) of the plane. The in-plane may form an angle φ with the plane defined by the considered member and the chord.

For determining the rotational stiffnesses in and out of the defined plane the global rotational stiffness may be written as:

In the defined plane

$$C_{g(inp)} = \frac{NEI_i a_i}{l_i}\cos^2(\varphi) + \frac{GI_{ti} a_i}{l_i}\sin^2(\varphi).$$

Out of the defined plane

$$C_{g(out)} = \frac{NEI_i a_i}{l_i}\sin^2(\varphi) + \frac{GI_{ti} a_i}{l_i}\cos^2(\varphi).$$

Including the local rotational stiffnesses we will get:

Total rotational stiffness for restraining members in plane

$$C_{1(inp)} = \sum_{i=1}^{n}\left[\left(\frac{NEI_i a_i}{l_i}\cos^2(\varphi) + \frac{GI_{ti} a_i}{l_i}\sin^2(\varphi)\right)^{-1} + \left(C_{3i(inp)}\cos^2(\varphi) + C_{3i(out)}\sin^2(\varphi)\right)^{-1}\right]^{-1}$$

Total rotational stiffness for restraining members out of plane

$$C_{1(out)} = \sum_{i=1}^{n}\left[\left(\frac{NEI_i a_i}{l_i}\sin^2(\varphi) + \frac{GI_{ti} a_i}{l_i}\cos^2(\varphi)\right)^{-1} + \left(C_{3i(inp)}\sin^2(\varphi) + C_{3i(out)}\cos^2(\varphi)\right)^{-1}\right]^{-1}$$

Local stiffness of considered member:

In plane

$$C_{2(loc.inp)} = C_{2(inp)}\cos^2(\varphi) + C_{2(out)}\sin^2(\varphi)$$

Out of plane

$$C_{2(loc.out)} = C_{2(inp)}\sin^2(\varphi) + C_{2(out)}\cos^2(\varphi)$$

The total rotational stiffness may now be derived from:

In plane

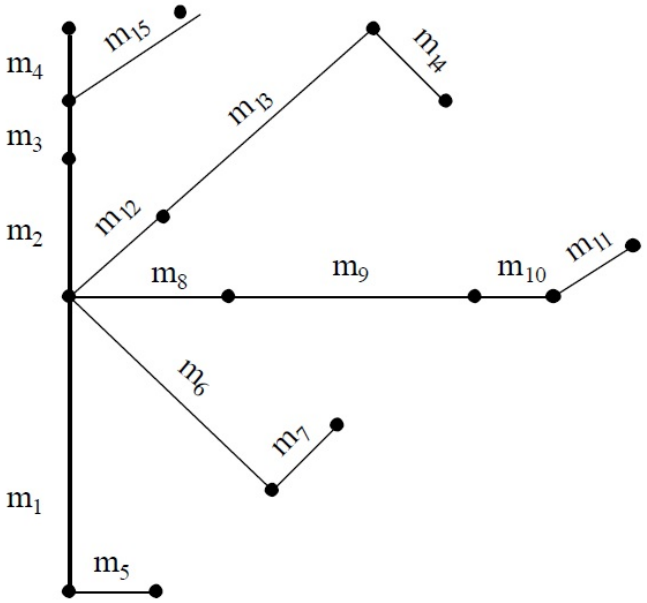
$$\frac{1}{C_{(inp)}} = \frac{1}{C_{1(inp)}} + \frac{1}{C_{2(loc.inp)}}$$

Out of plane

$$\frac{1}{C_{(out)}} = \frac{1}{C_{1(out)}} + \frac{1}{C_{2(loc.out)}}$$

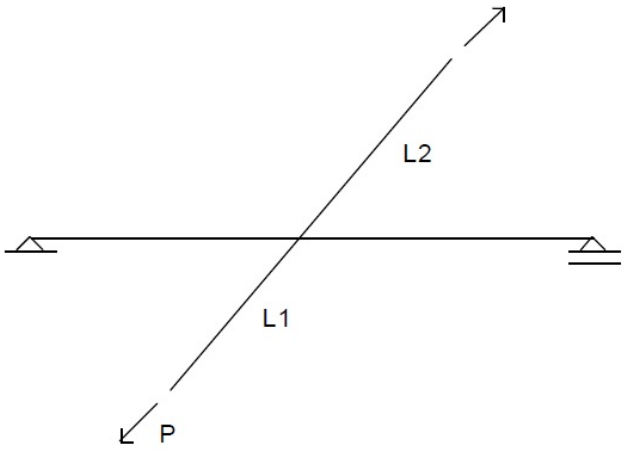
These rotational stiffnesses are then added to the corresponding degree of freedom in the stiffness matrix before running the eigenvalue analysis.

The theory for calculation of rotational spring stiffness is given above. However the interpretation and assumptions made for calculation of the rotational spring stiffness are not given by the theory alone. The program needs to make some assumptions and also simplifications with respect to the model.



From the figure above the task will be to get the rotational spring stiffness for the member m_{12}. The global rotational stiffness is found by considering the restraining members for m_{12}. The restraining members for m_{12} will be m_1 , m_6 , m_8, and m_2.

B.3.4 Calculation of lateral spring stiffness



The lateral spring stiffness is calculated using the formulae:

$$k_{out} = \frac{48EI}{(l_1 + l_2)^3} \cdot \frac{P_e + P}{P_e}, \qquad P > 0 \qquad \text{(tension)},$$
$$k_{out} = \frac{48EI}{(l_1 + l_2)^3} \cdot \frac{P_c + P}{P_e}, \qquad P < 0 \qquad \text{(compression)},$$

where

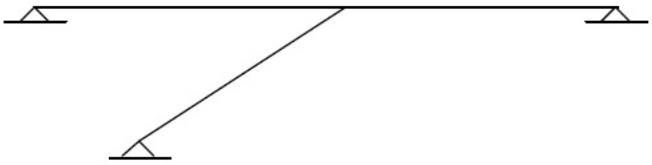
l_1	Length of first restraining member.
l_2	Length of second restraining member (must be parallel and attached to first member).
P	Average axial force in restraining members.
I	Average moment of inertia of restraining members.
P_e	Elastic buckling capacity (Euler).
P_c	Characteristic buckling capacity.

Reference is made to "Arne Selberg, Stålkonstruksjoner, page 398", see ref. [1].

In the example as shown above the lateral spring stiffness in plane will reach infinity. This is provided in the eigenvalue analysis by deleting the row and column in the elastic and geometric stiffness matrix that corresponds to this degree of freedom.

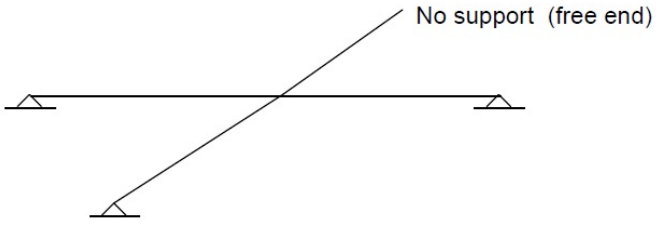
The formulae given will only give contribution to the lateral stiffness provided that there exist a member parallel and attached to the restraining member.

Ex.:



The restraining members must also have lateral supports if they shall give any contribution to the lateral stiffness.

Ex.:



In the two examples shown the lateral spring stiffness in the intersection of the members will be equal zero.

B.3.5 Dump data of spring stiffnesses and buckling factors

For each member code check run, spring stiffnesses and buckling factors (for each loadcase and phase angle if complex loadcase) may be written to file. Buckling factors are reported for each beam element within the member. The files will be named to identify the different runs according to the following naming convention: `'run-name'BUCK.TMP`.

The example print below is given for a member named M1 and loadcase no. 1. The member consist of three beam elements, no. 5, 6 and 7 (the elements have equal length, cross section and axial compressive force, hence equal buckling factors for all three parts).

```
Member       M1              Loadcase        1
-----------------------------------------------------------------
LAT INP
       1.000000    0.000000E+00    0.000000E+00        1.000000
LAT OUT
       1.000000    0.000000E+00    0.000000E+00        1.000000
ROT INP
   5.305613E+08    0.000000E+00    0.000000E+00    5.305623E+08
ROT OUT
   1.198211E+08    0.000000E+00    0.000000E+00    1.198213E+08

BUCKI (ky)         BUCKI (kz)
ELEMENT 5
       2.469703        2.836213
ELEMENT 6
       2.469703        2.836213
ELEMENT 7
       2.469702        2.836212
```

References:

[1] Arne Selberg, Stålkonstruksjoner, TAPIR, Trondheim, Norway, 1971.

B.4 Codified S-N Curves

B.4.1 SN Curve Equations

For practical fatigue design, welded joints are divided into several classes, each with a corresponding design S-N curve.

The joint classification of DNV (1977) and NPD (1984) divides all joints, including tube to plate joints, into eight classes B, C, D, E, F, F2, G or W according to:

1 The geometrical arrangement of the detail

2 The direction of the fluctuating stress relative to the detail

3 The method of fabrication and inspection of the detail

The class T curve, suggested by Department of Energy for tubular joints (1982), is also relevant.

Each construction detail at which fatigue cracks may develop must, whenever possible, be placed in its relevant class in accordance with the criterion given by DNV (1977). Details which cannot be classified according to the classification of DNV should be treated as class G, or class W for load carrying welded metal, unless a higher classification can be justified. It should be noted that in every welded joint there are several locations at which fatigue cracks may develop and each location should be classified separately.

The design S-N curves are based on a statistical analysis of experimental data. They are made of linear or piece wise linear relations between $\log_{10}S$ and $\log_{10}N$ (or $\log_{10}K$). A design curve is defined as the mean curve, obtained from the data fitting, with a parallel shift of the curve (down) of two standard deviations of $\log_{10}N$ (or $\log_{10}K$). As the curves are shifted down (not left, i.e. N_0 is fixed), K will be treated as the random variable in the following. The standard deviation is computed based on the assumption of a fixed and known slope. The design S-N curves are thus of the form

$$\log_{10}N = \log_{10}K - 2\sigma_{\log_{10}K} - m\log_{10}S \tag{B.1}$$

$$\log_{10}N = \log_{10}A - m\log_{10}S \tag{B.2}$$

where

N	number of cycles to failure under stress range S
A	a constant relating to the design S-N curve
$\sigma_{\log_{10}K}$	the standard deviation of $\log_{10}K$
m	the inverse slope of the S-N curve
s_o	endurance limit or stress value for slope change
$\log_{10}A$	$\log_{10}K - 2\sigma_{\log_{10}K}$

The S-N curves used for deterministic design calculations represent the relation between S and N resulting in a small probability of fatigue failure ($\Phi(-2) \sim 0.025$).

$$\log_{10}N = \log_{10}K - m\log_{10}S \tag{B.3}$$

or

$$N = K \cdot S^{-m}, \qquad S > s_o \tag{B.4}$$

The uncertainty in fatigue lifetime applying to the S-N curve is assumed to apply to the first linear segment of the curve. When the curve consists of 2 or 3 segments, or has a horizontal segment corresponding to an endurance limit, the entire curve is shifted vertically as described above, basing the shift on the values calculated for the first slope only.

The fatigue strength of welded joints is dependent on the plate thickness, t, with the strength decreasing with increasing thickness. For the thickness t different from the reference thickness t_{ref}, the stress range S of the S-N curve must be corrected for the thickness effect. In general, the corrected stress range may be written Equation (B.4) may written:

$$S = S_0 \cdot t_c^{exp} \tag{B.5}$$

where S_0 is the stress range without correction of thickness effect and the thickness factor t_c is given by

$$t_c = t/t_{ref}, \qquad t > t_{cut} \tag{B.6}$$

$$t_c = t_{cut}/t_{ref}, \qquad t \le t_{cut} \tag{B.7}$$

where t_{cut} is the cutoff thickness. The log representation of the S-N curve including correction for thickness effect may thus be written

$$\log_{10}N = \log_{10}K - m \cdot \exp \cdot \log_{10}(t_c) - m\log_{10}S_0, \qquad S_0 > s_o \tag{B.8}$$

Equation (B.8) is the general S-N curve including an arbitrary thickness correction of exponential form. The standard design T-curve has an exponent value equal to 1/4 and the reference thickness is equal to the cut-off thickness. With a reference thickness of 32 mm, a modification is carried out when the actual thickness is larger than 32 mm and the T-curve becomes

$$\log_{10}N = \log_{10}K - \frac{m}{4}\log_{10}\left(\frac{t}{32}\right) - m\log_{10}S_0, \qquad S_0 > s_o \tag{B.9}$$

where t is the thickness in mm through which the potential fatigue crack will grow. It is possible in the program to specify a cutoff thickness which is different from the reference thickness and an arbitrary value of the exponent, see the command ASSIGN THICKNESS-CORRECTION. When the actual thickness is smaller than the cutoff thickness, the S-N curve for the cutoff thickness is used, see Figure B.1.

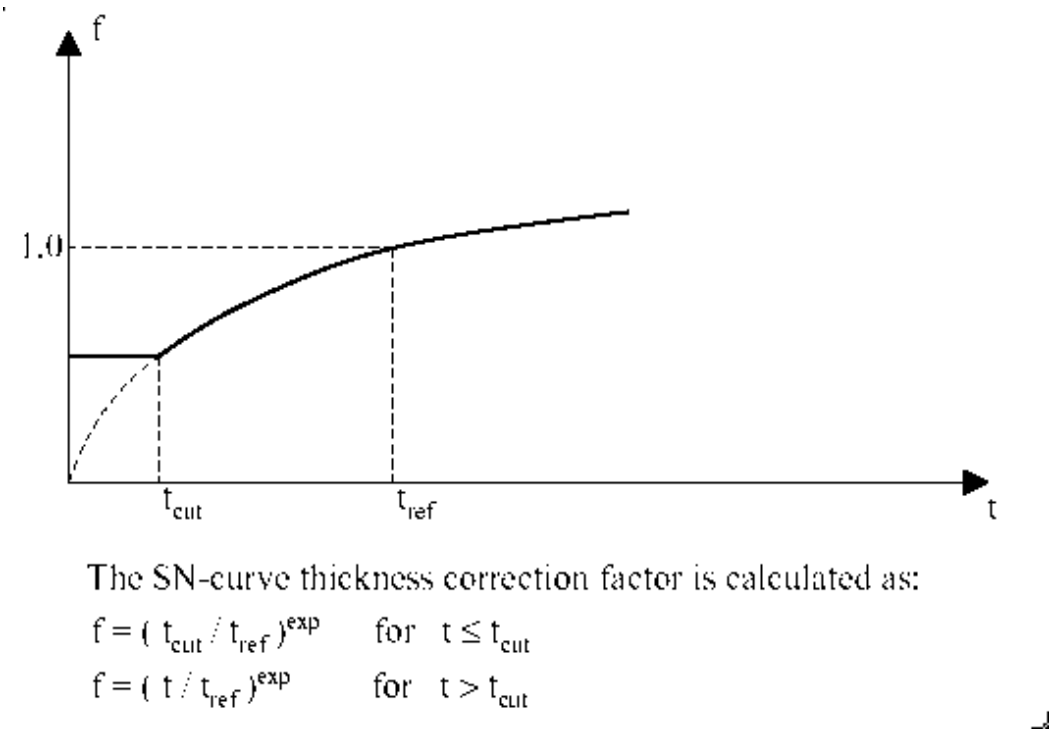


Figure B.1 Thickness correction factor

B.4.2 SN Curve Parameters

Library SN curves:

The SN-curves calculated by the program are converted from SI base units to the current set of consistent units based on the assumption that the Young's modulus of the material corresponds to steel (with $E = 2.1 \cdot 10^{11} N/m^2$). The stress level S of the SN curve is multiplied with a factor scaling the Young's modulus of the material Em, relative to the basic Young's modulus E, i.e:

$$S = S \bullet f_E \tag{B.10}$$

$$f_E = Em / E = Em / 2.1 \cdot 10^{11} \tag{B.11}$$

Note that when Em differs from E, the stress level of SN curve is scaled. Thus, using $Em = 2.05 \cdot 10^{11} N/m$, the stress level is scaled with a factor of f_E = 2.05/2.1 = 0.976 when library SN curves are applied.

User defined SN curves:

When creating codified SN curves, the user must ensure that the input SN curve data are consistent with units applied elsewhere in the analysis. The user may choose between three options when creating an SN curve (see command CREATE SN-CURVE);

- USER: Stress level S0 at end of first segment is given.
- LOGA: Intercept value logA0 of logN-axis by first line segment of SN curve is given
- STOCHASTIC: Intercept logK0 of logN-axis by first line segment of mean SN curve is given together with standard deviation of logN

Input and calculated SN curve parameters for the three input options are as follows:

Input option	SN curve parameters											
	m0	m1	m2	N0	N1	S0	S1	logA0	logA1	logA2	logK0	σ_{logK}
USER	I	I	I	I	I	I	C	C	C	C	-	0.0
LOGA	I	I	I	I	I	C	C	I	C	C	-	0.0
STOCHASTIC	I	I	I	I	I	C	C	C	C	C	I	I

Table B.1 Input (I) and calculated (C) SN curve parameters

SN curve equations:

The SN curve parameters are illustrated in Figure B.2. The SN curve Equation (B.2) applies for the different line segments of the SN curve as follows:

$$\log_{10} N = \log_{10} A_0 - m_0 \log_{10} S \quad \text{for } S > S_0 \tag{B.12}$$

$$\log_{10} N = \log_{10} A_1 - m_1 \log_{10} S \quad \text{for } S1 < S < S_0 \tag{B.13}$$

$$\log_{10} N = \log_{10} A_2 - m_2 \log_{10} S \quad \text{for } S < S_1 \tag{B.14}$$

At the intersection points 0 and 1 of the SN curve line segments, see Figure B.2, we have

$$\log_{10} N_0 = \log_{10} A_0 - m_0 \log_{10} S_0 \quad \text{Intersection 0} \tag{B.15}$$

$$\log_{10} N_1 = \log_{10} A_1 - m_1 \log_{10} S_1 \quad \text{Intersection 1} \tag{B.16}$$

For stochastic SN curve input, the logA of the deterministic SN curve is calculated as given in Figure B.3. The deterministic SN curve is applied in the fatigue analysis.

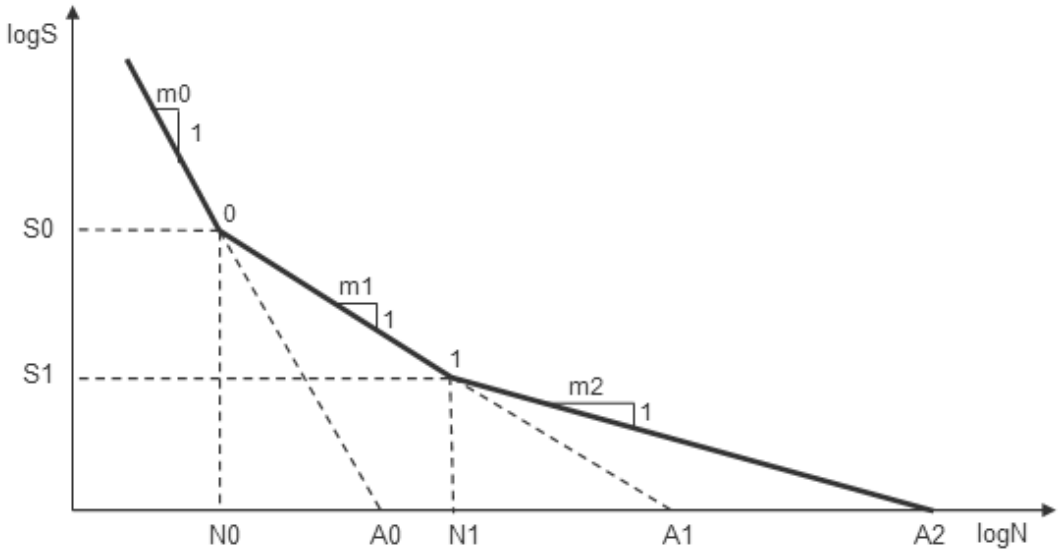


Figure B.2 SN curve parameters for a general three branch SN curve

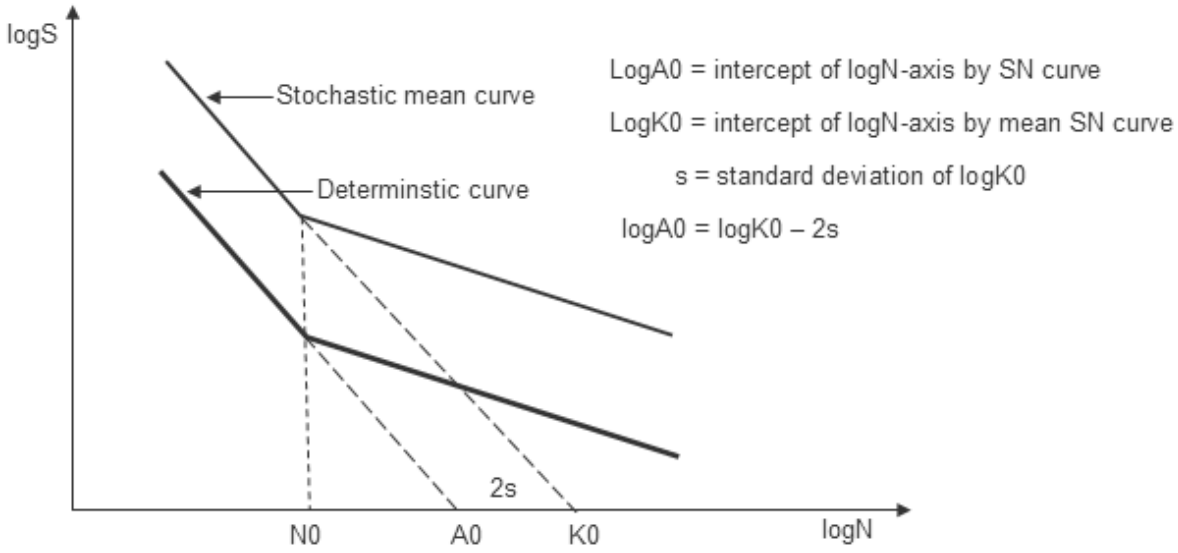


Figure B.3 Stochastic SN-curve parameters

SN curve parameters:

The SN curve parameters calculated by the program for SN curves with of three line segments as shown in Figure B.2 and Figure B.3:

USER input option:

Input parameters: m0, m1, m2, N0, N1, S0

Calculated parameters:

$$\log_{10}A_0 = \log_{10}N_0 + m_0\log_{10}S_0 \quad \text{(B.17)}$$

$$\log_{10}A_1 = \log_{10}N_0 + m_1\log_{10}S_0 \quad \text{(B.18)}$$

$$\log_{10}S_1 = (\log_{10}A_1 - \log_{10}N_1)/m_1 \quad \text{(B.19)}$$

$$\log_{10}A_2 = \log_{10}N_1 + m_2\log_{10}S_1 \quad \text{(B.20)}$$

LOGA input option:

Input parameters: m0, m1, m2, N0, N1, logA0

Calculated parameters:

$$\log_{10}S_0 = (\log_{10}A_0 - \log_{10}N_0)/m_0 \quad \text{(B.21)}$$

$$\log_{10}A_1 = \log_{10}N_0 + m_1\log_{10}S_0 \quad \text{(B.22)}$$

$$\log_{10}S_1 = (\log_{10}A_1 - \log_{10}N_1)/m_1 \quad \text{(B.23)}$$

$$\log_{10}A_2 = \log_{10}N_1 + m_2\log_{10}S_1 \quad \text{(B.24)}$$

STOCHASTIC input option:

Input parameters: m0, m1, m2, N0, N1, logK0, σ_{logK}

Calculated parameters:

$$\log_{10}A_0 = \log_{10}K_0 - 2\sigma_{\log_{10}K} \quad \text{(B.25)}$$

$$\log_{10}S_0 = (\log_{10}A_0 - \log_{10}N_0)/m_0 \quad \text{(B.26)}$$

$$\log_{10}A_1 = \log_{10}N_0 + m_1\log_{10}S_0 \quad \text{(B.27)}$$

$$\log_{10}S_1 = (\log_{10}A_1 - \log_{10}N_1)/m_1 \quad \text{(B.28)}$$

$$\log_{10}A_2 = \log_{10}N_1 + m_2\log_{10}S_1 \quad \text{(B.29)}$$

Units conversion of SN curve parameters:

Use of consistent units in the fatigue analysis is required for valid analysis results. Conversion of SN curve data from one unit to another may be required. Units of parameters calculated by the program are in accordance with units of the input parameters.

When S0 is given as input (USER input option), the values of the calculated parameters (e.g. logA0, logA1) are in accordance with unit and value of S0. When logA0 is given as input (LOGA input option) the value must be in accordance with the unit of the stresses applied in the analysis.

logA0, m1 and m2 are commonly used parameters in SN curve data specifications. The value of logA0 reflects the stress unit of the SN curve. The unit of the SN curve data do not always coincide with the unit applied in the analysis and a conversion of the SN curve data may be required.

A conversion rule may easily established by expressing Equation (B.2) in two different stress values. A general stress value may S may be written as an exponent of 10, e.g.:

$$S = x \bullet 10^{\bar{n}} = 10^{n} \quad \text{(B.30)}$$

which gives

$$\log_{10}S = \log_{10}x + \bar{n} = n \quad \text{(B.31)}$$

Illustrated by an example we have; $S = 7{,}44 \cdot 10^{7} = 10^{7,872}$ which gives $\log_{10}S = 0{,}782 + 7 = 7,872$.

Two stress values $\bar{S}_1$ and $\bar{S}_2$ may be written as:

$$\bar{S}_1 = 10^{n1} \quad \text{(B.32)}$$

$$\bar{S}_2 = 10^{n2} = 10^{c+n1} \quad \text{(B.33)}$$

where the relation between the exponent values is

$$n2 = c + n1 \quad \text{(B.34)}$$

Further we have

$$\log_{10}\bar{S}_1 = \log_{10}(10^{n1}) = n1 \tag{B.35}$$

$$\log_{10}\bar{S}_2 = \log_{10}(10^{n2}) = n2 = c + n1 \tag{B.36}$$

Applying Equation (B.2) for $\bar{S}_1$ and $\bar{S}_2$ in combination with Equation (B.35) and Equation (B.36) we have:

$$\log_{10}\bar{A}_1 = \log_{10}N + m\log_{10}\bar{S}_1 = \log_{10}N + mn1 \tag{B.37}$$

$$\log_{10}\bar{A}_2 = \log_{10}N + m\log_{10}\bar{S}_2 = \log_{10}N + mn2 = \log_{10}N + m(c + n1) \tag{B.38}$$

Subtracting Equation (B.38) from Equation (B.37) gives:

$$\log_{10}\bar{A}_2 = \log_{10}\overline{A_1} + mc \tag{B.39}$$

This equation gives the logA relation for two stress values where c represents the difference of the stress values expressed by their exponent values as outlined above. LogK transforms in a same way as logA. Equation (B.34) may be applied to the various branches of the SN curve by using m and c related to each of the branches.

Equation (B.39) may be used to transform the logA between stress values expresses in different unit. Examples are given in Table B.2

Parameter	S1, n1, logA1=logN+mn	S2, n2=n1+c, logA2=logA1+mc			
	N/mm^2(Mpa)	N/m^2 (Pa)	kN/m^2	psi 1MPa=145.04psi	ksi 1MPa=0-14504psi
S	7.44E+1	7.44E+7	7.44E+4	1.0791E+4	1.0791E+1
n	1.8716	7.8716	4.8716	4.0331	1.0331
c	0	6	3	2.1615	-0.8385
m	3	3	3	3	3
logN	7	7	7	7	7
logA	12.615	30.615	21.615	19.100	10.100

Table B.2 Relations between stress values and logA values

B.5 Wide Band Correction Factor for Spectral Fatigue Analysis

B.5.1 General

Fatigue stresses in offshore structures can be considered as random continuous functions. The determination of fatigue damage from the response spectra is simple in the case where the response is taken as a stationary and narrow banded Gaussian process. With this assumptions it follows that the stress amplitudes are Rayleigh distributed. Penzien and Tseng (1978), Maddox et al. (1975), Madison et al. (1986a) and several others have used this distribution in fatigue damage calculations. It is believed that the assumption of a narrow banded process may not always be valid. The possible error in assuming a narrow banded response has been studied in, e.g. Wirsching and Light (1980), by introducing a correction factor r which describes the spectral width.

$$D_{wideband} = r \times D_{narrowband}. \tag{B.1}$$

The effects of nonlinearity in the drag, nonlinearity of wave kinematics and free surface elevation, make the response of the platform non-Gaussian, especially for higher sea states and small diameter members, Tickells and Holmes (1976). This creates a problem during the frequency domain analysis in choosing the sea state in which stochastic linearisation is performed. The nonlinearity also introduces a systematic error in the fatigue damage calculation due to the non-Gaussian response process, Brouwers and Verbeek (1983), Madsen and Løseth (1986) and Kanegaonkar and Haldar (1987). A method accounting for this type of non-Gaussian response is presented in Skjong and Madsen (1987). Full scale measurements on two instrumented jackets in the North Sea (Valhall QP and Frigg DP2), Haver et al. (1985), show that the response is wide-banded and non-Gaussian. However, the measurements concluded that the fatigue damage estimation based on a narrow-banded Gaussian distribution is not significantly affected by the non-Gaussian response.

Experimental data suggest that the Miner-Palmgren rule predicts fatigue failure reasonable well. Sequence effects seem negligible for random loaded components. On welded joints it appears that the Miner-Palmgren rule is slightly non-conservative. Biases down to 0.7 to 0.8 are being observed, where bias is defined as the ratio of the predicted damage divided by the measured damage. The response in the fatigue damage calculation is assumed to be a narrow banded Gaussian process. However, fatigue stresses are typically somewhat wide banded and a correction factor for wide banded processes is observed.

B.5.2 Wirsching-Light correction factor

Wirsching and Light (1980), introduced a correction factor which describes the spectral width by the spectral width parameter ε defined by:

$$\varepsilon = \sqrt{1 - \gamma^2}. \tag{B.2}$$

where γ is the irregularity factor:

$$\gamma = \frac{\upsilon_0}{\upsilon_p} = \frac{\sqrt{\lambda_2/\lambda_0}}{\sqrt{\lambda_4/\lambda_2}} = \frac{\lambda_2}{\sqrt{\lambda_4\lambda_0}} \tag{B.3}$$

where υ_0 is the ratio of expected number of zero up-crossing periods and υ_p is the ratio of expected number of positive peaks, and λ_i is the spectral moment of order i. The approximated narrow band damage solution is corrected for the wide band loading process by the correction factor r_w:

$$D_{wideband} = r_w \times D_{narrowband}$$

, where

$$r_w = a(m) + (1 - a(m))(1 - \varepsilon)^{b(m)} \tag{B.4}$$
$$a(m) = 0.926 - 0.033m,$$
$$b(m) = 1.587m - 2.323,$$

ε = spectral width parameter. Narrow band: $\varepsilon \to 0$, broad band $\varepsilon \to 1$.

A comparison with rain flow counting on simulated stress histories of a Gaussian stress process for typical ocean structure problems, $\varepsilon = 0.5$, gives $r_w = 0.79$ for $m = 4.38$ and $r_w = 0.86$ for $m = 3$. This means that an assumption of a narrow banded process causes a small overestimation of the fatigue damage.

B.5.3 Gusto empirical correction method for wind fatigue

In this method one third of the zero spectral moment λ_0 is used in the damage equations of the narrow band solution whereupon the obtained damage is multiplied with 10, i.e.

$$D_{wideband} = r_G \times D_{narrowband}. \tag{B.5}$$

where $r_G = 10$ is a constant.

The empirical method is the original wide band correction method of the Framework wind fatigue analysis module taken from the GUSTO source code of the program. No evidence of the method is documented. However, tests shows that for small and medium high stress levels the methods gives damages of about same size as the Wirsching and Ligth method.

B.6 Power spectra and coherence models

B.6.1 Power spectra

The cross-power spectrum is:

$$S(r,s,f) = S(f) \cdot coh(r,s,f) \tag{B.6}$$

Five wind spectra are available in Framework:

1. the HARRIS spectrum representing gust components in the mean wind direction ([7])

$$S(f) = \frac{4 \cdot k \cdot U_{10}^2 \cdot \left(\frac{L_u \cdot f}{U_{10}}\right)}{\left[2 + \left(\frac{L_u \cdot f}{U_{10}}\right)^2\right]^{\frac{5}{6}} \cdot f} \tag{B.7}$$

   The frequency at which the spectra causes the most damage – f_{pk} – as obtained analytically is

$$f_{pk} = \sqrt{3} \cdot \frac{U_{10}}{L_u}. \tag{B.8}$$

2. the DAVENPORT spectrum representing gust components in the mean wind direction ([48])

$$S(f) = \frac{4 \cdot k \cdot U_{10}^2 \left(\frac{L_u \cdot f}{U_{10}}\right)^2}{\left[1 + \left(\frac{L_u \cdot f}{U_{10}}\right)^2\right]^{\frac{4}{3}} \cdot f} \tag{B.9}$$

   The frequency at which the spectra causes the most damage – f_{pk} – as obtained analytically is

$$f_{pk} = \sqrt{3} \cdot \frac{U_{10}}{L_u}. \tag{B.10}$$

3. the NPD spectrum representing gust components in the mean wind direction (Frøya in [22] and [40])

$$\begin{aligned} S(f) &= \frac{320 \cdot \left(\frac{U_{10}}{10}\right)^2 \left(\frac{z}{10}\right)^{0.45}}{\left(1 + f^{*^n}\right)^{\frac{5}{3n}}} \\ f^* &= 172 \cdot f \cdot \left(\frac{z}{10}\right)^{\frac{2}{3}} \cdot \left(\frac{U_{10}}{10}\right)^{-0.75} \\ n &= 0.468 \end{aligned} \tag{B.11}$$

4. the PANOFSKY LATERAL spectrum representing gust components lateral across to the mean wind ([48])

$$S(f) = \frac{15 \cdot k \cdot U_{10}^2 \left(\frac{z \cdot f}{U(z)}\right)}{\left[1 + 9.5 \left(\frac{z \cdot f}{U(z)}\right)\right]^{\frac{5}{3}} \cdot f} \tag{B.12}$$

5. the PANOFSKY VERTICAL spectrum representing gust components vertical across to the mean wind ([48])

$$S(f) = \frac{3.36 \cdot k \cdot U_{10}^2 \left(\frac{z \cdot f}{U(z)}\right)}{\left[1 + 10 \left(\frac{z \cdot f}{U(z)}\right)^{\frac{5}{3}}\right] \cdot f} \tag{B.13}$$

   where

f	is the frequency in Hz
k	is the surface drag coefficient
L_u	is the turbulence length scale
z	is the height in meter above ground or sea level
$U(z)$	is the wind speed at vertical coordinate z
U_{10}	is the surface wind speed at 10 m above ground or mean sea level

B.6.2 Coherence Models

The following coherence models are available in Framework:

1. the GUSTO 1 coherence model associated with the Harris wind spectrum

$$coh(r,s,f) = \exp\left[\frac{-c\cdot|z(r)-z(s)|\cdot f}{U_{10}}\right] \tag{B.14}$$

2. the GUSTO 2 coherence model associated to the Davenport and Panofsky wind spectra

$$coh(r,s,f) = \exp\left[\frac{-c\cdot\left(2-\frac{|z(r)-z(s)|}{R}\right)\cdot R\cdot f}{0.5\cdot(U(r)+U(s))}\right] \tag{B.15}$$

$$R = \sqrt{(x(r)-x(s))^2+(y(r)-y(s))^2+(z(r)-z(s))^2}$$

3. the GENERAL coherence model associated with the Harris, Davenport and Panofsky wind spectra

$$coh(r,s,f) = \exp\left[\frac{-f\cdot\sqrt{C_x^2\cdot(x(r)-x(s))^2+C_y^2\cdot(y(r)-y(s))^2+C_z^2\cdot(z(r)-z(s))^2}}{0.5\cdot(U(r)+U(s))}\right] \tag{B.16}$$

The coherence in mean wind directions, lateral to mean wind direction and vertical to mean wind direction may differ. Accordingly, the coefficients C_x, C_y, C_z (see table below) may differ in each direction which gives at total of 9 coefficients to be specified for the model.

4. the DAVENPORT coherence model associated with the Harris, Davenport and Panofsky wind spectra

$$coh(r,s,f) = \exp\left[\frac{-f\cdot c\cdot\sqrt{b^2\cdot(x(r)-x(s))^2+b^2\cdot(y(r)-y(s))^2+(z(r)-z(s))^2}}{0.5\cdot(U(r)+U(s))}\right] \tag{B.17}$$

5. the NPD (Frøya in [22]) coherence model

$$coh(r,s,f) = \exp\left[-\frac{1}{U_{10}}\sqrt{\sum_{i=1}^{3}A_i^2}\right]$$

$$A_i = \alpha_i\cdot f^{r_i}\cdot\delta_i^{q_i}\cdot z_g^{-P_i} \tag{B.18}$$

$$z_g = \frac{\sqrt{z_1\cdot z_2}}{10}$$

The coefficients a, p, q, r and the separation D for the 3-D coherence model ($i = 1,2,3$) are given in Table B.1. Note that separations are given by absolute values.

The following quantities are used in the coherence models:

b	$\frac{16}{c}$
c	is a coherence constant controlling the compactness of gust
f	is the frequency in Hz
$x(r)$	is the x co-ordinate of point r
$y(r)$	is the y co-ordinate of point r
$z(r)$	is the z co-ordinate of point r
$x(s)$	is the x co-ordinate of point s
$y(s)$	is the y co-ordinate of point s
$z(s)$	is the z co-ordinate of point s
C_x	is a coefficient for the x separation relative to mean wind direction
C_y	is a coefficient for the y separation relative to mean wind direction
C_z	is a coefficient for the z separation relative to mean wind direction
$U(r)$	is the velocity at point r
$U(s)$	is the velocity at point s
U_{10}	is the surface wind speed at 10 m above ground or mean sea level

Table B.1: Coefficients of NPD coherence model

Component i	**Separation**	**Coherence options**			
	D_i	q_i	p_i	r_i	a_i
1	$[x_2 - x_1]$	1.0	0.4	0.92	2.9
2	$[y_2 - y_1]$	1.0	0.4	0.92	45.0
3	$[z_2 - z_1]$	1.25	0.5	0.85	13.0

B.7 SCF formulae and generalised influence functions

SCF formula and generalised influence functions for use in fatigue analysis has been implemented in Framework as [17].

The SCF's are calculated according to Efthymiou [72]. The SCF's are dependent on the load path as well as the geometrical configuration of the joints. These dependencies can be maintained in the calculation of the SCF's by using influence function formulations along with inclusion of multiplanar effects.

In the program the user may choose whether these dependencies shall be accounted for or not.

If the user chooses to neglect the influence of the load path, the SCF's are calculated using Efthymiou model C, see [72] page 9. This approach leads to a fixed set of SCF's which are independent of the loads.

If influence functions are used the SCF's will be a function of the load. This means that in calculation of the stress range the SCF's need not be equal for each load constituting the stress range. In other words in one particular chord-brace connection the SCF's need to be calculated for each and every load.

B.7.1 Dump of intermediate results

Dump of intermediate results is printed to the file `InfluenceFunctionSCF_<runname>.dmp` when the command `DEFINE FATIGUE-DUMP INFLUENCE-FUNCTION-SCFS ON` is used prior to run execution. SCFs are printed for brace end positions for all load cases. All contributions to the total SCFs for the influence function SCF method A or B are printed including SCFs of the reference brace, inplanar and multiplanar influence braces. Dump print may be generated for deterministc fatigue, stochastic fatigue, spectral fatigue and time history fatigue. The type of analysis and the influence function method applied are printed in the header of the file together with explanation of parameters printed, see below.

```
                        ******************************************
                        ***   SCFs Influence Function Method A   ***
                        ***   ------------------------------     ***
                        ***   Run    : FAT1                      ***
                        ***   Type   : Deterministic fatigue     ***
                        ***   Program: Framework    3.11-00      ***
                        ***   Date   : 24-MAR-2015 12:07:44      ***
                        ******************************************
            ************************************************************************
Nomenclature:
-------------
         1        2        3        4        5        6        7        8
SCFs: CsaA     CcrA     BsaA     BcrA     CcrI     CsaO     BcrI     BsaO
C=Chord side, B=Brace side, sa=saddle, cr=crown, A=Axial, I=ipb, O=opb

SCFtot = SCFa + SCFinf
----------------------
SCFa   = SCFs of reference brace
SCFinf = SCFip + SCFim of all influence braces
SCFip  = SCFs of influence planar brace
SCFim  = SCFs of influence multiplanar brace

Forces and moments:
Fxa = Axial force of reference brace
Mia = Inplane bending (IPB) moment of reference brace
Moa = Out-of-plane bending (OPB) moment of reference brace
Fxb = Axial force of influence brace
Mib = IPB moment of influence brace
Mob = OPB moment of influence brace
Fxb/Fxa = Force ratio influence brace/reference brace
Mob/Moa = OPB moment ratio influence brace/reference brace
Limit range of force and moment ratios:
Fxb/Fxa = Actual value   (printed when no limit is set)
Mob/Moa = Actual value   (printed when no limit is set)
-10.0 <= Fxb/Fxa <= 10.0 (printed when limit is set)
-10.0 <= Mob/Moa <= 10.0 (printed when limit is set)

New load step:
Member  = Current reference brace
Pos     = Position along member
Joint   = Member end joint
Type    = Joint type
Loadcase= Load case index
Dir     = Wave direction
Hght    = Wave height              (deterministic fatigue)
```

```
Step    = Step in current wave     (deterministic fatigue, spectral fatigue)
Prd     = Wave period              (spectral fatigue)
Frq     = Wave frequency           (stochastic fatigue)
TimeStep= Time step in time series (time history fatigue)
**********************************************************************
```

Identification of member, member position, joint type, wave direction, load case and load step number are printed in the heading of the detail print for each load case. The heading is adapted to the type of fatigue analysis performed, see below.

Deterministic fatigue:

```
---New load step--- Member: 56115, Pos: 2, Dir: 3, Hght: 5, Step: 8
   Loadcase: 40     Joint : 5110, Type: KT
-----------------------------------------------------------------
```

Stochastic fatigue:

```
---New load step--- Member: BM31, Pos: 1, Dir: 1, Frq: 9
   Loadcase: 9      Joint : JT13, Type: K
-------------------------------------------------------
```

Spectral fatigue:

```
---New load step--- Member: BM5, Pos: 1, Dir: 1, Prd: 5, Step: 12
   Loadcase: 60     Joint : JT2, Type: K
-------------------------------------------------------------
```

Time history fatigue:

```
---New load step--- Member: BM14, Pos: 3, Dir: 1, TimeStep: 196
   Loadcase: 196    Joint : JT58, Type: X
-------------------------------------------------------------
```

The format of the force and SCFs print is shown below. Comments are given to the numbered lines:

```
 1: ---New load step--- Member: H10_06_4, Pos: 1, Dir: 1, Hght: 1, Step: 1
       Loadcase: 1      Joint : JTLD2_04, Type: KT
    ------------------------------------------------------------------
 2: Forces: 384943. 41300.8 98253.9 (Fxa Mia Moa  Reference brace H10_06_4)
 3: Influence planar:
 4: Brace : RW2_35_2
 5: Forces: -981888. 16306.8 30384.5 -2.551 0.30925 (Fxb Mib Mob Fxb/Fxa Mob/Moa)
 6: SCFip : -0.829527 -3.63432 -3.08273 -2.25389 0.0 0.124221 0.0 0.152857
 4: Brace : RW2_40_1
 5: Forces: 167638. 19919.7 24907.3 0.435488 0.2535 (Fxb Mib Mob Fxb/Fxa Mob/Moa)
 6: SCFip : 0.139591 0.628954 0.534147 0.389537 0.0 0.129729 0.0 0.159635
 7: Influence multiplanar:
 8: Brace : RWD_31_2
 9: Forces: -170697. -0.443434 (Fxb Fxb/Fxa)
10: SCFim : 0.617025 5.489987E-08 0.186706 2.195995E-08 0.0 0.0 0.0 0.0
 8: Brace : RWD_41_1
 9: Forces: 6585.0 1.710641E-02 (Fxb Fxb/Fxa)
10: SCFim : -2.036701E-02 -1.812157E-09 -6.162857E-03 -7.248627E-10 0.0 0.0 0.0 0.0
 8: Brace : H10_10_4
 9: Forces: 92794.3 0.24106 (Fxb Fxb/Fxa)
10: SCFim : -0.395421 -3.518264E-08 -0.119651 -1.407305E-08 0.0 0.0 0.0 0.0

11: SCFa  : 2.5682 4.12475 4.23143 3.77146 1.12555 1.91502 1.9188 2.35648
12: SCFinf: -0.488699 -3.00537 -2.48769 -1.86435 0.0 0.25395 0.0 0.312492
13: SCFtot: 2.0795 1.11939 1.74375 1.90711 1.12555 2.16897 1.9188 2.66898
```

1	Start calculating SCFs of current reference brace for a new load case based on given loads
2	Forces in reference brace under consideration: Fxa (Axial), Mia (IPB moment), Moa (OPB moment)
3	List influences for inplanar braces
4	Name of influence inplanar brace
5	Forces in influence brace: Fxb, Mib, Mob. Force and moment ratios: Fxb/Fxa, Mob/Moa
6	SCFip: Adjustments to SCFs from inplanar influence brace
7	List influences for multiplanar braces
8	Name of influence multiplanar brace

9	Axial force in influence multiplanar brace: Fxb. Force ratio: Fxb/Fxa
10	SCFim: Adjustments to SCFs from multiplanar brace
11	SCFa: SCFs for reference brace loaded only (no correction for minimum SCF): SCFs are: CsaA, CcrA, BsaA, BcrA, CcrI, CsaO, BcrI, BsaO where C=Chord side, B=Brace side, sa=saddle, cr=crown,A=axial, I=ipb, O=opb
12	SCFinf: Sum SCFs adjustments of all inplanar and multiplanar influence braces: SCFinf = SCFip+SCFim (no correction for minimum SCF)
13	SCFtot: Total resulting SCFs. SCFtot = SCFa + SCFinf (no correction for minimum SCF)

B.8 SCF of Butt-weld and Cone Transition

B.8.1 SCF of buttweld connections RP-C203:2020 and 2021

Stress concentrations at tubular butt-weld connections are due to eccentricities resulting from many different sources. These may be classified as concentricity (difference in tubular diameters), differences in thickness of joined pipes, out of roundness and centre eccentricity due to fabrication imperfections. Refer to Sections 3.3.7.2 and 3.3.7.3 in DNVGL-RP-C203:2020 [45] and DNV RP-C203:2021 [100]. The RP-C203 standards recommend different SCF at weld toes and weld roots of the buttweld connection. The side where the buttweld is made also matters.

When the buttweld SCF option is `DNVGL-RPC203-2020`, Framework assumes the buttweld is welded from **the outside only** and differentiates the weld root fatigue positions from the weld toes. The SCF of buttweld according to Eqn(3.3.5) and Eqn(3.3.6) required in [45], [100] is applied as follows with the relevant parameters for outside toes and inside roots.

- Outside weld toe with thickness transition at *outside*

$$\mathrm{SCF} = 1 + \frac{6(\delta_t + \delta_m - \delta_0)}{t} \times C \tag{B.19}$$

- Inside weld root with thickness transition at *outside* (with $\delta_0 = 0$)

$$\mathrm{SCF} = 1 - \frac{6(\delta_t - \delta_m)}{t} \times C \tag{B.20}$$

- Outside weld toe with thickness transition at *inside*

$$\mathrm{SCF} = 1 - \frac{6(\delta_t - \delta_m + \delta_0)}{t} \times C \tag{B.21}$$

- Inside weld root with thickness transition at *inside* (with $\delta_0 = 0$)

$$\mathrm{SCF} = 1 + \frac{6(\delta_t + \delta_m)}{t} \times C \tag{B.22}$$

where

$$C = \frac{1}{1 + (\frac{T}{t})^{\beta}} \mathrm{e}^{-\alpha},$$

$$\alpha = \frac{1.82L}{\sqrt{Dt}} \frac{1}{1 + (\frac{T}{t})^{\beta}},$$

$$\beta = 1.5 - \frac{1.0}{\log(D/t)} + \frac{3.0}{[\log(D/t)]^2},$$

and L is the length of thickness transition determined by the transition slope and the difference of thicknesses.

$$L = \text{Slope} \times (T - t)$$

with default Slope $= 4$ and Slope can be specified at ASSIGN SCF MEMBER.

- Euqal thickness at connection

$$\mathrm{SCF} = 1 + \frac{3(\delta_m - \delta_0)}{t} \mathrm{e}^{-\alpha} \tag{B.23}$$

where

$$\alpha = \frac{0.91W}{\sqrt{Dt}},$$

and W is the Width of weld at surface which usually is not less than the plate thickness t and can be specified at ASSIGN SCF MEMBER.

The other symbols are

$\log(*)$	the logarithms function to 10,
$\delta_0 = 0.05t$	the misalignment inherent in the S-N data and analysis procedure,
δ_t	the eccentricity due to difference in thickness, $\delta_t = 0.5(T-t)$
δ_m	the out of roundness and centre eccentricity with certain fabrication tolerance,
D	the larger outside diameter of the tubular pipes,
T	the greater thickness at the transition,
t	the smaller thickness at the transition.

When the buttweld SCF option is `DNV-RPC203-BSWD` based on **DNV RP-C203:2021** [100], Framework assumes the buttweld is made from **the both sides**. In this case, the weld roots are ignored. The program does not generate weld roots positions. Thus, the fatigue check positions should include the weld toes only. The larger SCF of formula B.19 and B.21 is retained for the fatigue check at the both-sides welded position.

The parameter δ_m represents the eccencticity or out-of-roundness due to fabrication imperfections. According to DNV OS C401 [21], the maximum fabrication tolerances depend on the category areas. In DEFINE FATIGUE CONSTANTS FABRICATION-TOLERANCE-OPTION command, $0.10ts$, $0.15ts$, or $0.30ts$ correspond to *special*, *primary*, and *secondary*, respectively. If any of them is selected, the global fabtol is as follows but limited up to 4mm:

$$fabtol_G = \begin{cases} 0.10 \times ts & \text{for special category areas} \\ 0.15 \times ts & \text{for primary category areas} \\ 0.30 \times ts & \text{for secondary category areas} \\ fabtolFactor_G \times ts & \text{Manual} \end{cases}$$

where $fabtolFactor_G$ is defined at command `DEFINE FATIGUE CONSTANTS DEFAULT-FABRICATION-TOLERANCE`. Then,

$$\delta_m = fabtol_G.$$

If there is a local fabtolFactor defined at command `ASSIGN SCF MEMBER`,

$$\delta_m = fabtolFactor_L \times ts$$

as a result of the local override.

Similarly, the inherent misalignment in SN curve data δ_0 can be flexible in the program. The command `DEFINE FATIGUE-CONSTANTS INHERENT-SN-MISALIGNMENT-FACTOR` specifies the global $SNmisFactor_G$. Then,

$$\delta_0 = SNmisFactor_G \times ts.$$

If there is a local SN misalignment factor defined at command `ASSIGN SCF MEMBER`,

$$\delta_0 = SNmisFactor_L \times ts$$

as a result of the local override.

The SCF formula assumes either the outside diameter or the inside diameter is equal at the transition, as determines the thickness transition is made from outside or insdie. If both the outer diameter and inner diameter do not match at the connection, an error message will be reported and the global axial SCF will be applied. A message * *ERROR: Diameters mismatch at transition* will be shown.

B.8.2 SCF of butt-weld connections DNVGL-RP-C203:2014

In the program, the SCF option DNVGL-RP-C203:2014 does not differentiate weld root and weld toe at a butt-weld connection. Instead, Framework applies the Eqn(3.3.5) in DNVGL-RP-0005:2014-06-RP-C203 [42] that yields a conservative SCF value.

- Euqal thickness at connection

$$\mathrm{SCF} = 1 + \frac{3(\delta_m - \delta_0)}{t} \mathrm{e}^{-\alpha} \tag{B.24}$$

where

$$\alpha = \frac{0.91L}{\sqrt{Dt}},$$

and L is the Width of weld at surface which usually is not less than the plate thickness t.

- Connection with thickness transition

  SCF of butt-weld at thickness transition, Eqn(3.3.5) in **DNVGL-RP-C203:2014** [42] is

$$\mathrm{SCF} = 1 + \frac{6(\delta_m + \delta_t - \delta_0)}{t} \frac{1}{1 + (\frac{T}{t})^{\beta}} \mathrm{e}^{-\alpha} \tag{B.25}$$

  where

$$\alpha = \frac{1.82L}{\sqrt{Dt}} \frac{1}{1 + (\frac{T}{t})^{\beta}},$$

$$\beta = 1.5 - \frac{1.0}{\log(D/t)} + \frac{3.0}{[\log(D/t)]^2},$$

  and L is the length of thickness transition determined by the transition slope and the difference of thicknesses.

$$L = \text{Slope} \times (T - t)$$

  with default Slope $= 4$. Only the preferred transition in thickness, that is on outside of tubular butt weld, is supported in this SCF calculation. Refer to Figure 3-11a and 3-12 of DNVGL-RP-C203:2014.

  The other symbols are

$\log(*)$	the logarithms function to 10,
$\delta_0 = 0.1t$	the misalignment inherent in the S-N data and analysis procedure,
δ_t	the eccentricity due to difference in thickness, $\delta_t = 0.5(T - t)$
δ_m	the out of roundness and centre eccentricity with certain fabrication tolerance,
D	the larger outside diameter of the tubular pipes,
T	the greater thickness at the transition,
t	the smaller thickness at the transition.

The parameter δ_m represents the eccencticity due to fabrication imperfections. According to DNV OS C401 [21], the maximum fabrication tolerances depend on the category areas. In the SCF formula B.25,

$$\delta_m = \begin{cases} 0.10 \times ts & \text{for special category areas} \\ 0.15 \times ts & \text{for primary category areas} \\ 0.30 \times ts & \text{for secondary category areas} \\ \textit{fabtol} & \text{if user specified value needed.} \end{cases}$$

In **DEFINE FATIGUE CONSTANTS** FABRICATION-TOLERANCE-OPTION command, $0.10ts$, $0.15ts$, or $0.30ts$ correspond to *special*, *primary*, and *secondary*, respectively. If any of them is selected, δ_m is limited up to 4 mm. δ_m will equal to the user specified value *fabtol* of **DEFINE FATIGUE CONSTANTS** if *Manual* is selected. In this case, the user specified value must be positive and can go beyond 4 mm. Besides the global setting in DEFINE FATIGUE CONSTANTS, this fabrication tolerance option can be overridden for every fatigue check position at section transition. See command description of `ASSIGN SCF MEMNBER`.

The parameter δ_0 is introduced into the equation to account for statistical scatter of tolerances in combination with the statistical scatter in test data for derivation of S-N curve. Thus if the tolerance is fixed, i.e. δ_m is given with *Manual* option, the actual value should be used for calculation of SCF with $\delta_0 = 0$.

The SCF formula assumes either the outside diameter or the inside diameter is equal at the transition. If there is diameter mismatch, an error message will be reported and the global axial SCF will be returned. A message * *ERROR: Diameters mismatch at transition* will be shown. The SCF rule in the listing file will show **ILLEGAL*. If $T/t > 2.0$, a warning message *Warning: SCF formula applied invalid with T/Ts > 2* will be printed but the result from Equation (3.3.5) are calculated using the thicknesses and reported.

The SCF formula butt-welds at thickness transitions of Eqn(C.2.10) in **Norsok N-004:1998** [56] is

$$\mathrm{SCF} = 1 + \frac{6\delta}{t}\frac{1}{1+(\frac{T}{t})^{2.5}}\mathrm{e}^{-\alpha} \tag{B.26}$$

where

$$\alpha = \frac{1.82L}{\sqrt{Dt}}\frac{1}{1+(\frac{T}{t})^{2.5}}.$$

δ in the Norsok code is the total eccentricity resulting from all sources.

$$\delta = \delta_m + \delta_t$$

where δ_m is the Default Fabrication Tolerance, *fabtol*, in **DEFINE FATIGUE CONSTANTS**. The parameter L can be determined either by $L =$ Slope $\times (T - t)$ or by a specified value.

B.8.3 SCF formula for cone transition

In **DNVGL-RP-C203:2014**, the stress concentration at each side of unstiffened tubular-cone junction can be estimated by the following equations Eqn(3.3.12-13)

$$\mathrm{SCF} = 1 + \frac{0.6t\sqrt{D_j(t+t_c)}}{t^2}\tan\alpha, \quad \text{for the tubular side} \tag{B.27}$$

$$\mathrm{SCF} = 1 + \frac{0.6t\sqrt{D_j(t+t_c)}}{t_c^2}\tan\alpha, \quad \text{for the cone side} \tag{B.28}$$

where

- α the slope anlge of the cone,
- D_j tubular member outside diameter at the two sides of the junction (D_s, D_L),
- t tubular member wall thickness (t_s, t_L),
- t_c cone thickness at the junction.

The SCF shall be used together with the stress in the tubular at the junction for both the tubular and the cone side of the weld.

The stress concentration at a junction with ring stiffener can be calculated as

$$\mathrm{SCF} = 1 + (0.54 + \frac{0.91D_jt}{A_r}\tan\alpha)\frac{1}{\beta}, \quad \text{for outside of smaller end} \tag{B.29}$$

$$\mathrm{SCF} = 1 - (0.54 + \frac{0.91D_jt}{A_r}\tan\alpha)\frac{1}{\beta}, \quad \text{for inside of smaller end} \tag{B.30}$$

$$\mathrm{SCF} = 1 + (0.54 - \frac{0.91D_jt}{A_r}\tan\alpha)\frac{1}{\beta}, \quad \text{for outside of larger end} \tag{B.31}$$

$$\mathrm{SCF} = 1 - (0.54 - \frac{0.91D_jt}{A_r}\tan\alpha)\frac{1}{\beta}, \quad \text{for inside of larger end} \tag{B.32}$$

$$\beta = 1.0 + \frac{1.10t\sqrt{D_j t}}{A_r}$$

where A_r is the area of ring stiffener without effective shell.

If a ring stiffener is placed a distance δ_e away from the intersection lines, an additional stress concentration should be included to account for this eccentricity:

$$\text{SCF} = 1 + \frac{3\delta_e}{t}\tan\alpha \frac{1}{1 + \frac{68I}{\sqrt{D_j^3(t+t_c)^5}}} \tag{B.33}$$

where I is the moment of inertia calculated as

$$I = \frac{bt^3}{12} + 0.5b(h + \frac{t}{2} - \bar{y})^2(t + t_c) + t_r h(\frac{h^2}{12} + (\frac{h}{2} - \bar{y})^2)$$

$$\bar{y} = \frac{h^2 t_r + (h + t/2)b(t + t_c)}{2t_r h + b(t + t_c)}$$

where h = height of ring stiffener, t_r = thickness of ringstiffener, b = effective flange width calculated as $b = 0.78\sqrt{D_j(t + t_c)} + \delta_e$.

For the **Norsok Standard, N-004:1998** code [56], the unstiffened cone SCF Eqn(C.2.12), (C.2.13), identical to EqnB.27 and B.28, are not being applied. Instead, the SCF Eqn(C.2.14) of the cone with ring stiffeners are used both unstiffened and ring stiffened junctions. Eqn(C.2.14) are identical to EqnB.29 - EqnB.32.

For un-stiffened cone junctions, Eqn(C.2.14) gives the maximum SCFs that is very close to Eqn(C.2.12) and (C.2.13) when the stiffener area $A_r = 0$ and thickness $t = tc$. A_r is set to a very small number inside the program to avoid numerical problems. At the tubular-cone junctions the maximum SCF will be at the outside at the smaller diameter junction, and at the inside at the larger diameter junction. Equations (C.2.12) and (C.2.13) do only give the maximum SCFs, and hence using the SCFs defined in Eqn(C.2.14) will provide the flexibility to select combination of inside / outside SCF calculation together with SN curve. Equation (C.2.14) presumes equal wall thickness for tubular and cone. However, at cone side of junction, tc is used and if tc > t, t is used; at tubular side of junction, tubular thickness t is always used.

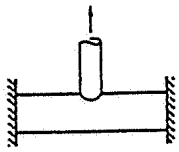
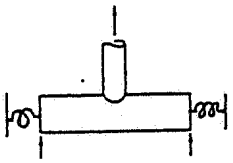
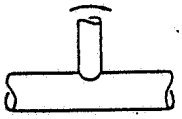
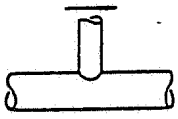
For stiffened cone junctions, the additional SCF due to stiffener offset is different from formula B.33.

$$\text{SCF} = 1 + \frac{3\delta_e}{t}\tan\alpha \tag{B.34}$$

B.9 Efthymiou SCF of tubular joints

This section shows the original Efthymiou's SCF formula of [73].

Table I - Parametric equations for SCFs in T/Y-joints

Load type and fixity conditions	SCF equation	Eqn. No.	short chord correction
Axial load - chord ends fixed 	**chord saddle:** $\gamma\tau^{1.1}\,[1.11-3(\beta-0.52)^2]\,\sin^{1.6}\theta$	T1	F1
	chord crown: $\gamma^{0.2}\tau[2.65+5(\beta-0.65)^2]+\tau\beta(0.25\alpha-3)\,\sin\theta$	T2	None
	brace saddle: $1.3+\gamma\tau^{0.52}\alpha^{0.1}[0.187-1.25\beta^{1.1}(\beta-0.96)]\,\sin^{(2.7-0.01\alpha)}\theta$	T3	F1
	brace crown: $3+\gamma^{1.2}[0.12\,\exp(-4\beta)+0.011\beta^2-0.045]+\beta\tau(0.1\alpha-1.2)$	T4	None
Axial load - General fixity conditions 	**chord saddle:** $[T1]+C_1(0.8\alpha-6)\tau\beta^2(1-\beta^2)^{0.5}\sin^2 2\theta$	T5	F2
	chord crown: $\gamma^{0.2}\tau[2.65+5(\beta-0.65)^2]+\tau\beta(C_2\cdot\alpha-3)\,\sin\theta$	T6	None
	brace saddle: eqn. T3		F2
	brace crown: $3+\gamma^{1.2}[0.12\,\exp(-4\beta)+0.011\beta^2-0.045]+\beta\tau(C_3\cdot\alpha-1.2)$	T7	None
In-plane bending 	**chord crown:** $1.45\,\beta\tau^{0.85}\gamma^{(1-0.68\beta)}\sin^{0.7}\theta$	T8	None
	brace crown: $1+0.65\,\beta\tau^{0.4}\gamma^{(1.09-0.77\beta)}\sin^{(0.06\gamma-1.16)}\theta$	T9	None
Out-of-plane bending 	**chord saddle:** $\gamma\tau\beta(1.7-1.05\beta^3)\,\sin^{1.6}\theta$	T10	F3
	brace saddle: $\tau^{-0.54}\gamma^{-0.05}(0.99-0.47\beta+0.08\beta^4)$ * [T10]	T11	F3

Short chord correction factors ($\alpha < 12$)

$F1 = 1-(0.83\beta-0.56\beta^2-0.02)\gamma^{0.23}\exp[-0.21\,\gamma^{-1.16}\alpha^{2.5}]$

$F2 = 1-(1.43\beta-0.97\beta^2-0.03)\gamma^{0.04}\exp[-0.71\,\gamma^{-1.38}\alpha^{2.5}]$

$F3 = 1-0.55\beta^{1.8}\gamma^{0.16}\exp[-0.49\,\gamma^{-0.89}\alpha^{1.8}]$

Where $\exp[x] = e^x$

Chord-end fixity parameter

$C_1 = 2\,(C-0.5)$

$C_2 = C/2$

$C_3 = C/5$

C = chord-end fixity parameter

$0.5 \leq C \leq 1.0$, Typically C = 0.7

Table 2 - Equations for SCFs in X-joints

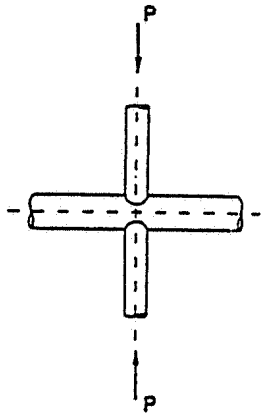
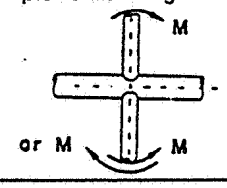
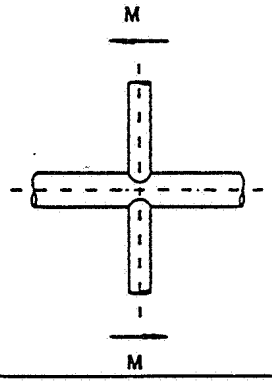
Load type	SCF equation	Eqn. No.
Axial load (balanced)  	**Chord saddle:** $3.87\ \gamma\tau\beta\ (1.10-\beta^{1.8})\ (\sin\theta)^{1.7}$	X1
	Chord crown: $\gamma^{0.2}\tau\ [2.65 + 5\ (\beta-0.65)^2] - 3\tau\beta\ \sin\theta$	X2
	Brace saddle: $1 + 1.9\gamma\tau^{0.5}\ \beta^{0.9}\ (1.09-\beta^{1.7})\ \sin^{2.5}\theta$	X3
	Brace crown: $3 + \gamma^{1.2}\ [0.12\ \exp(-4\beta) + 0.011\beta^2-0.045]$	X4
	In joints with short chords ($\alpha < 12$) the saddle SCFs can be reduced by the factor F1 (fixed chord ends) or F2 (pinned chord ends) where $F1 = 1 - (0.83\beta-0.56\beta^2-0.02)\gamma^{0.23}\exp[-0.21\ \gamma^{-1.16}\alpha^{2.5}]$ $F2 = 1 - (1.43\beta-0.97\beta^2-0.03)\gamma^{0.04}\exp[-0.71\ \gamma^{-1.38}\alpha^{2.5}]$	
In-plane bending  	**Chord crown:** eqn. T8 **Brace crown:** eqn. T9	
Out-of-plane bending (balanced)  	**Chord saddle:** $\gamma\tau\beta(1.56-1.34\beta^4)\ (\sin\theta)^{1.6}$	X5
	Brace saddle: $\tau^{-0.54}\gamma^{-0.05}(0.99-0.47\beta+0.08\beta^4) \cdot [X5]$	X6
	In joints with short chords ($\alpha < 12$) eqns. X5 and X6 can be reduced by the factor F3 where $F3 = 1 - 0.55\beta^{1.8}\gamma^{0.16}\exp[-0.49\ \gamma^{-0.89}\alpha^{1.8}]$	

Table 2 - Equations for SCFs in X-joints (cont'd)

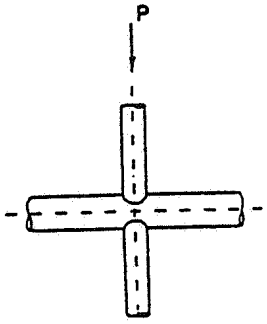
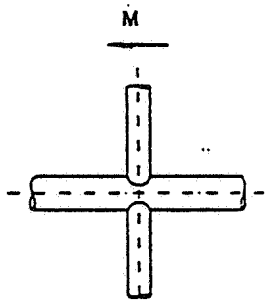
Load type	SCF equation	Eqn. No.
Axial load on one brace only 	**Chord saddle:** [T5] * [1−0.26β^3]	X7
	Chord crown: [T6]	
	Brace saddle: [T3] * [1−0.26β^3]	X8
	Brace crown: [T7]	
	In joints with short chords ($\alpha < 12$) the saddle SCFs can be reduced by the factor F1 (fixed chord ends) or F2 (pinned chord ends) where	
	$F1 = 1 - (0.83\beta - 0.56\beta^2 - 0.02)\gamma^{0.23}\exp[-0.21\ \gamma^{-1.16}\alpha^{2.5}]$	
	$F2 = 1 - (1.43\beta - 0.97\beta^2 - 0.03)\gamma^{0.04}\exp[-0.71\ \gamma^{-1.38}\alpha^{2.5}]$	
Out-of-plane bending on one brace only 	**Chord saddle:** [T10]	
	Brace saddle: [T11]	
	In joints with short chords ($\alpha < 12$) eqns. T10 and T11 can be reduced by the factor F3 where	
	$F3 = 1 - 0.55\beta^{1.8}\gamma^{0.16}\exp[-0.49\ \gamma^{-0.89}\alpha^{1.8}]$	

Table 3 - Equations for SCFs in gap/overlap K-joints

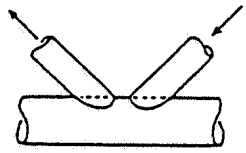
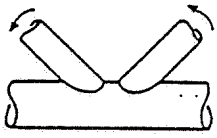
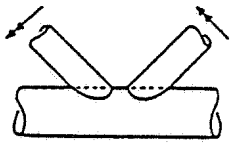
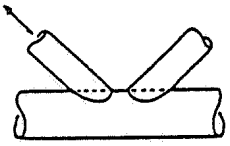
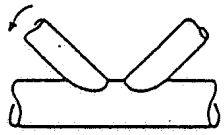
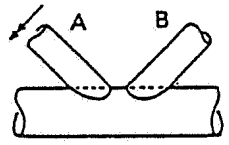
Load type	SCF equation	Eqn. No.	short chord correction
Balanced axial load 	**Chord SCF:** $\tau^{0.9}\gamma^{0.5}(0.67-\beta^2+1.16\beta)\sin\theta\left[\frac{\sin\theta_{max}}{\sin\theta_{min}}\right]^{0.30}\left[\frac{\beta_{max}}{\beta_{min}}\right]^{0.30}$ *		
	$[1.64 + 0.29\,\beta^{-0.38}\,\mathrm{ATAN}\,(8\zeta)]$	K1	None
	Brace SCF: $1 + [K1]\,(1.97 - 1.57\,\beta^{0.25})\,\tau^{-0.14}\sin^{0.7}\theta +$		
	$C.\beta^{1.5}\gamma^{0.5}\tau^{-1.22}\sin^{1.8}(\theta_{max}+\theta_{min})$ * $[0.131 - 0.084\,\mathrm{ATAN}\,(14\zeta + 4.2\beta)]$	K2	None
	where C = 0 for gap joints C = 1 for the through brace C = 0.5 for the overlapping brace Note that τ, β, θ and the nominal stress relate to the brace under consideration. ATAN is arctangent evaluated in radians		
Unbalanced IPB 	**Chord crown SCF:** eqn. T8 (For overlaps exceeding 30% of contact length use 1.2 * T8)		
	Gap joint-brace crown SCF: eqn. T9		
	Overlap joint-brace crown SCF: [T9] * (0.9 + 0.4 β)	K3	
Unbalanced OPB 	**Chord saddle SCF adjacent to brace A:** $[T10]_A\,[1 - 0.08\,(\beta_B\gamma)^{0.5}\exp(-0.8x)] +$ $[T10]_B\,[1 - 0.08\,(\beta_A\gamma)^{0.5}\exp(-0.8x)]\,[2.05\beta_{max}^{0.5}\exp(-1.3x)]$ where $x = 1 + \frac{\zeta\sin\theta_A}{\beta_A}$	K4	F4
	Brace A saddle SCF: $\tau^{-0.54}\gamma^{-0.05}\,(0.99 - 0.47\beta + 0.08\,\beta^4)\cdot[K4]$	K5	F4
$F4 = 1 - 1.07\,\beta^{1.88}\exp[-0.16\,\gamma^{-1.06}\,\alpha^{2.4}]$			
$[T10]_A$ is the chord SCF adjacent to brace A as estimated from eq. T10 Note that the designation of braces A and B is not geometry dependent. It is nominated by the user			

Table 3 - Equations for SCFs in gap/overlap K-joints (cont'd)

Load type	SCF equation	Eqn. No.	short chord correction
Axial load on one brace only 	**chord saddle:** [T5]		F1
	Chord crown: [T6]		—
	Brace saddle: [T3]		F1
	Brace crown: [T7]		—
	Note that all geometric parameters and the resulting SCF's relate to the loaded brace		
IPB on one brace only 	**Chord crown:** eqn. T8		—
	Brace crown: eqn. T9		—
	Note that all geometric parameters and the resulting SCF's relate to the loaded brace		
OPB on one brace only 	**Chord saddle:**		
	$[T10]_A\,[1 - 0.08\,(\beta_B\gamma)^{0.5}\exp(-0.8x)]$	K6	F3
	where $x = 1 + \frac{\zeta \sin\theta_A}{\beta_A}$		
	Brace saddle:		
	$\tau^{-0.54}\gamma^{-0.05}(0.99 - 0.47\beta + 0.08\,\beta^4) \cdot [K6]$	K7	F3

Short chord correction factors

$F1 = 1 - (0.83\beta - 0.56\beta^2 - 0.02)\gamma^{0.23}\exp[-0.21\,\gamma^{-1.16}\alpha^{2.5}]$

$F2 = 1 - (1.43\beta - 0.97\beta^2 - 0.03)\gamma^{0.04}\exp[-0.71\,\gamma^{-1.38}\alpha^{2.5}]$

$F3 = 1 - 0.55\beta^{1.8}\gamma^{0.16}\exp[-0.49\,\gamma^{-0.89}\alpha^{1.8}]$

Table 4 — Equations for SCFs in KT-joints

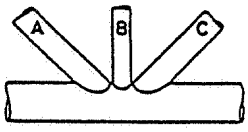
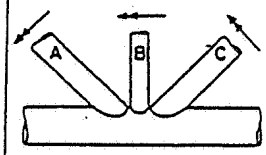
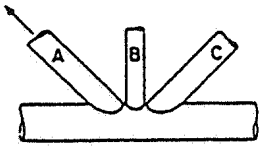
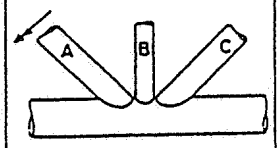
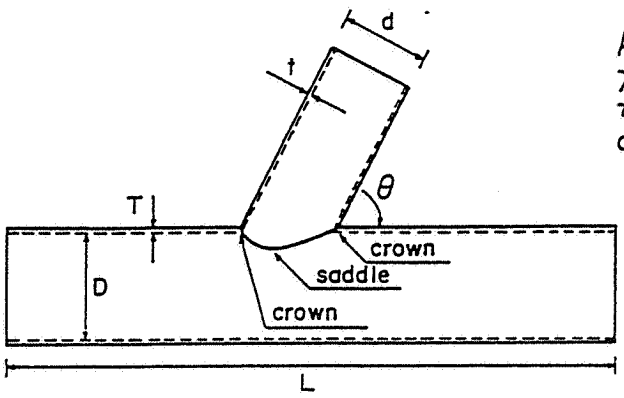
Load type	SCF equation	Eqn. No.
Balanced Axial load 	**Chord SCF:** Eqn. K1 **Brace SCF:** Eqn. K2 For the diagonal braces, A & C use $\zeta = \zeta_{AB} + \zeta_{BC} + \beta_B$ For the central brace, B use ζ = maximum of ζ_{AB}, ζ_{BC}	
In-plane bending	**Chord crown SCF:** Eqn. T8 **Brace Crown SCF:** Eqn. T9	
Unbalanced Out-of-plane bending 	**Chord saddle SCF adjacent to diagonal brace A:** $[T10]_A [1 - 0.08 (\beta_B\gamma)^{0.5}\exp(-0.8x_{AB})] \cdot [1 - 0.08(\beta_C\gamma)^{0.5}\exp(-0.8x_{AC})]$ $+ \quad [T10]_B [1 - 0.08 (\beta_A\gamma)^{0.5}\exp(-0.8x_{AB})] \cdot [2.05\beta_{max}^{0.5}\exp(-1.3x_{AB})]$ $+ \quad [T10]_C [1 - 0.08 (\beta_A\gamma)^{0.5}\exp(-0.8x_{AC})] \cdot [2.05\beta_{max}^{0.5}\exp(-1.3x_{AC})]$ where $x_{AB} = 1 + \frac{\zeta_{AB} \sin\theta_A}{\beta_A}$ $x_{AC} = 1 + \frac{(\zeta_{AB} + \zeta_{BC} + \beta_B) \sin\theta_A}{\beta_A}$ **Chord saddle SCF adjacent to central brace B:** $[T10]_B [1 - 0.08 (\beta_A\gamma)^{0.5}\exp(-0.8x_{AB})]^{(\beta_A/\beta_B)^2} \cdot [1 - 0.08 (\beta_C\gamma)^{0.5}\exp(-0.8x_{BC})]^{(\beta_C/\beta_B)^2}$ $+ \quad [T10]_A [1 - 0.08 (\beta_B\gamma)^{0.5}\exp(-0.8x_{AB})] \cdot [2.05\beta_{max}^{0.5}\exp(-1.3x_{AB})]$ $+ \quad [T10]_C [1 - 0.08 (\beta_B\gamma)^{0.5}\exp(-0.8x_{BC})] \cdot [2.05\beta_{max}^{0.5}\exp(-1.3x_{BC})]$ where $x_{AB} = 1 + \frac{\zeta_{AB} \sin\theta_B}{\beta_B}$ $x_{BC} = 1 + \frac{\zeta_{BC} \sin\theta_B}{\beta_B}$	KT1 KT2
OPB brace SCFs	OPB brace SCFs are obtained directly from the adjacent chord SCFs using $\tau^{-0.54}\gamma^{-0.05}(0.99 - 0.47\beta + 0.08\beta^4) \cdot SCF_{chord}$ where SCF_{chord} = KT1 or KT2	

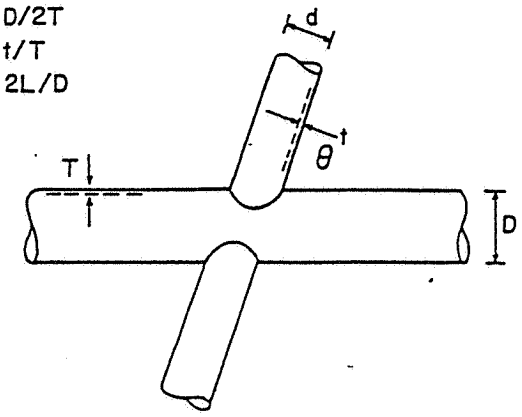
Table 4 — Equations for SCFs in KT-joints (cont'd)

Load type	SCF equation	Eqn. No.
Axial load on one brace only 	**Chord saddle:** [T5] **Chord crown:** [T6] **Brace saddle:** [T3] **Brace crown:** [T7]	
Out-of-plane bending on one brace only 	**Chord SCF adjacent to diagonal brace A:** $[T10]_A\,[1 - 0.08\,(\beta_B\gamma)^{0.5}\exp(-0.8x_{AB})] \cdot [1 - 0.08(\beta_C\gamma)^{0.5}\exp(-0.8x_{AC})]$ where $x_{AB} = 1 + \frac{\zeta_{AB}\sin\theta_A}{\beta_A}$ $x_{AC} = 1 + \frac{(\zeta_{AB} + \zeta_{BC} + \beta_B)\sin\theta_A}{\beta_A}$ **Chord SCF adjacent to central brace B:** $[T10]_B\,[1 - 0.08\,(\beta_A\gamma)^{0.5}\exp(-0.8x_{AB})]^{(\beta_A/\beta_B)^2}$ $[1 - 0.08\,(\beta_C\gamma)^{0.5}\exp(-0.8x_{BC})]^{(\beta_C/\beta_B)^2}$ where $x_{AB} = 1 + \frac{\zeta_{AB}\sin\theta_B}{\beta_B}$ $x_{BC} = 1 + \frac{\zeta_{BC}\sin\theta_B}{\beta_B}$	KT 3 KT4
OPB brace SCFs	OPB brace SCFs are obtained directly from the adjacent chord SCFs using $\tau^{-0.54}\gamma^{-0.05}(0.99 - 0.47\beta + 0.08\beta^4) \cdot SCF_{chord}$	



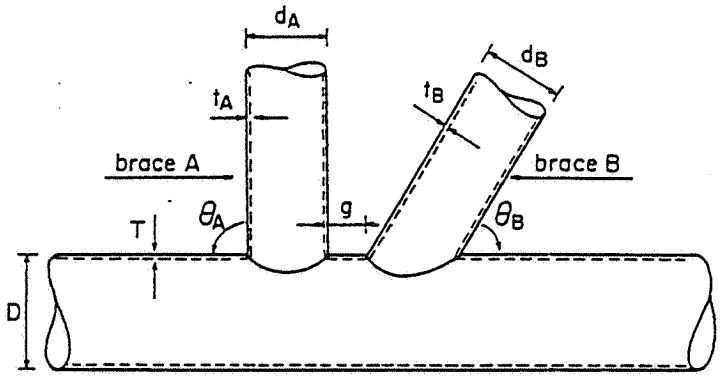
$\beta = d/D$
$\gamma = D/2T$
$\tau = t/T$
$\alpha = 2L/D$

T OR Y – JOINT



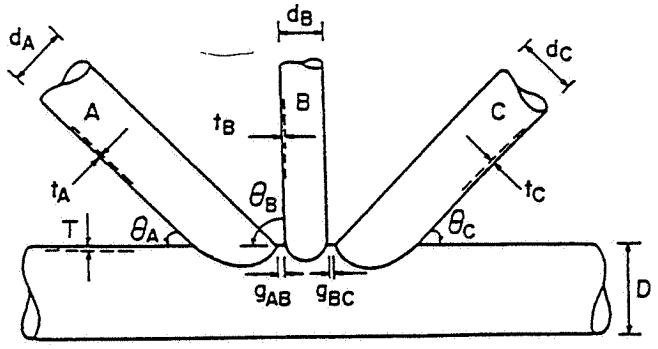
X – JOINT

$\beta_A = d_A/D, \tau_A = t_A/T, \gamma = D/2T$
$\beta_B = d_B/D, \tau_B = t_B/T, \zeta = g/D$



K – JOINT

$\beta_A = d_A/D \quad \tau_A = t_A/T \quad \zeta_{AB} = g_{AB}/D$
$\beta_B = d_B/D \quad \tau_B = t_B/T \quad \zeta_{BC} = g_{BC}/D$
$\beta_C = d_C/D \quad \tau_C = t_C/T \quad \gamma = D/2T$



KT – JOINT

VALIDITY RANGE

$0.2 \geq \beta \geq 1.0$
$0.2 \geq \tau \geq 1.0$
$8 \geq \gamma \geq 32$
$4 \geq \alpha \geq 40$
$20° \geq \theta \geq 90°$
$-\frac{0.6\beta}{\sin\theta} \geq \zeta \geq 1.0$

DRAW. No.: H71706/2	DEFINITION OF GEOMETRICAL PARAMETERS	FIGURE No. 2

B.10 Lotsberg's update to Efthymiou SCF

The latest design standards, e.g. ISO 19902:2007 [33] and API 22nd WSD [55] recommend to consider the nominal stress on chord in the joint can when calculating the stress concentration factors of Efthymiou's SCF formula [73] at crown hot spots. DNVGL RP C203 [42] and [43] provide the explicit SCF expression considering the chord bending stresses of simple tubular T/Y joints. The formula can be found in Table B-1 of RP C203 standards. They are SCFs at chord crown and brace crown subject to axial load with general end fixities.

Chord crown:

$$\mathrm{SCF_{CC}} = \gamma^{0.2}\tau(2.65 + 5(\beta - 0.65)^2) - 3\beta\tau\sin\theta + \frac{\sigma_{BendingChord}}{\sigma_{AxialBrace}}\mathrm{SCF_{att}} \tag{B.35}$$

Brace crown:

$$\mathrm{SCF_{BC}} = 3 + \gamma^{1.2}(0.12\exp(-4\beta) + 0.011\beta^2 - 0.045) - 1.2\beta\tau + \frac{0.4\sigma_{BendingChord}}{\sigma_{AxialBrace}}\mathrm{SCF_{att}} \tag{B.36}$$

The formula B.35 and B.36 correspond to Eqn (6b) and (7b) in [43],[42] , respectively. These two formula can be used as alternatives to the original Efthymiou's SCF formula (T6) and (T7) of [73], see Appendix B.9. The new chord stress dependent SCFs will be included in the "Lotsberg" SCF option of Framework. With "Lotsberg" SCF option, the other SCF formula except B.35 and B.36 are identical to thoes of "Efthymiou" SCF option.

The latest revision of Eqn.B.35, B.36, Eqn(6b,7b) in the DNVGL RP-C203 are provided by Inge Lotsberg and have been included in the newer edition of RP-C203 [44]

Chord crown:

$$\mathrm{SCF_{CC}} = \gamma^{0.2}\tau(2.65 + 5(\beta - 0.65)^2) - 3\beta\tau\sin\theta + \frac{\sigma_{BendingChord}}{\sigma_{AxialBrace}}\sin\theta\mathrm{SCF_{att}} \tag{B.37}$$

Brace crown:

$$\mathrm{SCF_{BC}} = 3 + \gamma^{1.2}(0.12\exp(-4\beta) + 0.011\beta^2 - 0.045) - 1.2\beta\tau + \frac{0.4\sigma_{BendingChord}}{\sigma_{AxialBrace}}\frac{1}{\sin\theta}, \tag{B.38}$$

in which $\mathrm{SCF_{att}}$ is the attachment SCF and suggested to be 1.20 as default, instead of 1.27. The updated Eqn.B.37 and Eqn.B.38have been included in Framework. If the nominal stress on brace $\sigma_{AxialBrace}$ is zero or close to zero (with magnitude less than 0.01), $\mathrm{SCF_{CC}} = 1.0$ and $\mathrm{SCF_{BC}} = 1.6$ as suggested by Inge Lotsberg.

C Earthquake analysis

C.1 General introduction

Most analysis of structural response to earthquake ground motion have been performed with two-dimensional models with unidirectional, in-plane loading.

However, increasingly complex engineering structures, for which the consequences of failure are severe, necessitates careful modelling of dynamic behaviour. Two-dimensional models with in-plane loading neglects torsion and the effect of eccentric masses on the coupling between response in perpendicular horizontal directions. This may introduce substantial errors in calculated response.

Acknowledging the limitations of two-dimensional analysis, engineers have been expanding successful methods to the time-dimensional domain. This must be done with care, as conditions fulfilled for most two-dimensional structures may not be fulfilled for three-dimensional structures. 'his is the case for modal combination rules, where the commonly used "Square-Root-Sum-of-Squares" (SRSS) method can become quite inadequate [91].

The earthquake analysis capabilities of Framework are designed to perform post-processing for earthquake response analysis of three-dimensional structures.

C.2 Stochastic Analysis of Response of Linear Systems

C.2.1 Introduction

This chapter is a short introduction to stochastic analysis, to lay out the assumptions and techniques that the earthquake analysis in Framework is based upon. The theoretical basis and the mathematical expressions involved may be unfamiliar to many engineers, but the computational effort involved is not significantly more than that involved in deterministic analysis.

C.2.2 Definition of a Stochastic Process

"A stochastic process is a family or ensemble of possible time-histories that may occur as the outcome of the same experiment" [64]. Any single member of the ensemble is called a sample function or a realization of the process. The processes considered here are continuous, as each sample function of the process is a continuous function of time.

C.2.2.1 Stationarity

A stochastic process is called homogeneous if its complete probability structure is independent of a shift in the parametric origin, and it is called stationary if this parameter is time [81].

C.2.2.2 Ergodicity

A stochastic process can be characterized by estimating its ensemble averages. In order to obtain good estimates of these averages one needs a sufficiently large number of sample functions. For a stationary process one may look upon a long sample function as a series of shorter samples, and thereby increase the number of samples. In principle, this means that one can use time averages instead of samle averages. Whenever this is possible the process is called ergodic [80]. The order of ergodicity depends upon the order of the moment of the probability distribution of the process for which the above procedure is accurate.

C.2.2.3 Ensemble Averages in Time and Frequency Domain

The most important averages of a stationary process are the mean and covariance for different instants in time. In general, one is interested in zero-mean processes, since any other process can be looked upon as the superposition of a deterministic mean function and a zero-mean process describing the oscillations about the mean. For convenience, only zero-mean processes will be considered here.

For real-valued zero-mean stationary processes $X(t)$ and $Y(t)$ the auto- and cross-correlation functions $R_{XX}(\tau)$ and $R_{XY}(\tau)$ are defined as

$$R_{XX}(\tau) = E[X(t)X(t+\tau)],$$
$$R_{XY}(\tau) = E[X(t)Y(t+\tau)],$$

where $E[\cdot]$ denotes the expected value over the ensemble of the expression inside the square brackets. These functions are symmetric, that is

$$R_{XX}(\tau) = R_{XX}(-\tau),$$
$$R_{XY}(\tau) = R_{XY}(-\tau).$$

The auto- and cross-power spectral densities can be found by Fourier transformations of $R_{XX}(\tau)$ and $R_{XY}(\tau)$.

$$\Phi_{XX}(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} R_{XX}(\tau) \mathrm{e}^{-i\omega\tau} \mathrm{d}\tau,$$
$$\Phi_{XY}(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} R_{XY}(\tau) \mathrm{e}^{-i\omega\tau} \mathrm{d}\tau.$$

It is noted that for real-valued processes, $\Phi_{XX}(\omega)$ is always real since $R_{XX}(-\tau)$ is an even function, whereas $\Phi_{XY}(\omega)$ can be complex since $R_{XY}(\tau)$ need not be an even function.

The inverse transformations yield

$$R_{XX}(\tau) = \int_{-\infty}^{\infty} \Phi_{XX}(\omega) \mathrm{e}^{i\omega\tau} \mathrm{d}\omega,$$
$$R_{XY}(\tau) = \int_{-\infty}^{\infty} \Phi_{XY}(\omega) \mathrm{e}^{i\omega\tau} \mathrm{d}\omega.$$

For the auto-spectrum one may also use the one-sided spectrum, which only exists for positive ω and has twice the amplitude of the two-sided spectrum. The real part of $\Phi_{XX}(\omega)$ is also symmetric, and since the imaginary part cancels out as shown in the following, $G_{XX}(\omega) = 2\Phi_{XX}(\omega)$ and $G_{XY}(\omega) = 2\mathrm{Re}[\Phi_{XY}(\omega)]$ will be used to denote the one-sided spectra.

The instantaneous variance, σ_X^2, and covariance, σ_{XY}, of the processes are of major interest and can be found from either $R_{XX}(\tau)$ and $R_{XY}(\tau)$ or $G_{XX}(\omega)$ and $G_{XY}(\omega)$, respectively:

$$\sigma_X^2 = R_{XX}(0) = \int_0^{\infty} G_{XX}(\omega) \mathrm{d}\omega, \tag{C.1a}$$
$$\sigma_{XY} = R_{XY}(0) = \int_0^{\infty} G_{XY}(\omega) \mathrm{d}\omega.$$

These quantities are crucial parameters in determining the peak stationary response of a structure.

For multi-directional excitation, the instantaneous correlation coefficient, ρ_{XY}, is defined by

$$\rho_{XY} = \frac{R_{XY}(0)}{[R_{XX}(0) \cdot R_{YY}(0)]^{1/2}} = \frac{R_{XY}(0)}{\sqrt{R_{XX}(0) \cdot R_{YY}(0)}}.$$

C.2.2.4 Spectral Moments

Vanmarcke [94] has shown the analogy between the one-sided power spectral density of a process and the probability density function of a random variable. Both functions are nonnegative and can be normalized to have unit area. Just as moments of a probability density function characterize a random variable, the moments of a power spectral density about the frequency origin characterize a stationary random process.

For certain processes, such as the Gaussian process, the first three spectral moments are capable of describing most characteristics of the process that are of engineering interest. These are defined as

$$\lambda_m = \int_0^\infty \omega^m G_{XX}(\omega) \mathrm{d}\omega \quad \text{for} \quad m = 0, 1, 2. \tag{C.2}$$

From eq. C.1a and eq. C.2 it can be seen that $\lambda_0 = \sigma_X^2$. Also $\lambda_2 = \sigma_{\dot{X}}^2$, the variance of the derivative of the process, whereas λ_1 is related to the envelope of the process [94]. In the present work the spectral moments will be used extensively to determine peak response parameters.

White noise and filtered white noise models of power spectral densities are common in many areas of engineering, and need to be defined for the forthcoming sections. White noise is defined by a constant power spectral density over the complete frequency range $-\infty < \omega < \infty$. Filtered white noise processes are obtained by passing a white noise process through a filter, which is usually linear and of second order. The well known Kanai-Tajimi [76, 93] model for filtered white noise in earthquake engineering is given by:

$$G_{XX}(\omega) = \frac{\omega_g^4 + 4\zeta_g^2\omega_g^2\omega^2}{(\omega_g^2 - \omega^2)^2 + 4\zeta_g^2\omega_g^2\omega^2} \cdot G_0 \tag{C.3}$$

where ω_g denotes the idealized ground frequency and ζ_g the idealized ground damping. G_0 is a scale factor, defining the white noise intensity level. Often the power spectral density is filtered a second time in order to remove singularities at $\omega = 0$.

C.2.2.5 Gaussian Processes

A process is called Gaussian if the values of the process at any selected instants of time are jointly normally distributed. A stationary Gaussian process is completely determined by its mean value and auto-correlation function. Also, it is shown to be invariant under linear transformations [81], i.e. during derivation, integration, or filtering through a linear filter such as a linear oscillator, that the process retains its Gaussian nature. This, of course, is of great interest in structural response analysis, since one only needs to determine the first and second moments of the response in order to completely describe the process.

C.2.3 Modeling Earthquake Ground Motions as Stochastic Processes

It is natural to model the components of ground motion as stochastic processes. Factors influencing the ground motion at a site resulting from an earthquake are numerous. These range from parameters related to slippage along the causative fault to factors describing local geology and topology. Clearly, a potential future earthquake cannot be completely described. However, from knowledge of regional seismicity, the location of the site of the structure relative to existing faults, and the local soil conditions, gross estimates such as the expected intensity and frequency content can be made [69]. Since the variations in ground motion intensity and frequency content are considerable, the effect of a future earthquake on a structure may differ substantially from those of previous earthquakes at the same site. Thus, using a previously recorded time history in design, as often is done in practice, is inadequate and may have serious implications relative to the safety of the structure. Instead, structural design for earthquakes must be performed on probabilistic basis considering the stochastic nature of ground motion.

Components of ground motion resulting from an earthquake usually consist of an initial build-up phase, an approximately stationary strong-motion phase, and a decay phase towards the end, see Figure C.1. In order to model a ground motion component realistically, one clearly needs to consider a non-stationary model

[67]. However, this introduces unwanted complexity in analysis, which considering the magnitude of uncertainties that are generally involved in most design situations, is not justified for practical applications. Based on comparisons with time-history results, it has been shown [67] that for moderate- or long-duration earthquakes, whose strong motion phase is several times longer than the fundamental period of the structure, a time-limited stationary process introduces small errors that are tolerable in practice. Thus, in this study, the components of ground motion will be assumed to be time limited, zero-mean, stationary processes. An additional assumption is that the processes are Gaussian, which is justifiable on the basis of the central limit theorem, since ground motions result from accumulation of many randomly arriving pulses [63]. Under these conditions, the response of a linear, not-too-lightly damped oscillator will also be zero-mean and Gaussian and will quickly approach stationarity [81]. For practical purposes, the response processes are assumed to be time-limited stationary processes with duration equal to the duration of the strong-motion phase of the ground motion.

C.2.4 Probability Distribution of the Peak

For a time limited, zero-mean, stationary Gaussian process, the distribution as well as the mean and variance of the peak can be expressed in terms of the first three spectral moments. Specifically, for the maximum absolute value over the duration τ, denoted by $X_\tau = \max_\tau |X(t)|$, the cumulative distribution as derived by Vanmarcke [95] is

$$F_{X_\tau}(x) = \left(1 - \mathrm{e}^{-\frac{a^2}{2}}\right) \cdot \mathrm{e}^{-\nu\tau \cdot \frac{1 - \mathrm{e}^{-\sqrt{\frac{\pi}{2}} \cdot \delta_e a}}{\mathrm{e}^{-\frac{a^2}{2}} - 1}} \qquad \text{for} \qquad r > 0, \tag{C.4}$$

where

$$a = \frac{x}{\sigma_X} = \frac{x}{\sqrt{\lambda_0}},$$
$$\delta_e = \delta^{1.2}, \quad \delta = \sqrt{1 - \frac{\lambda_1^2}{\lambda_0 \lambda_2}},$$
$$\nu = \frac{1}{\pi} \cdot \sqrt{\frac{\lambda_2}{\lambda_0}}.$$

In these relations, a is the normalized threshold level, ν is the mean zero crossing rate of the process, and δ has a value between zero and one and is a measure of dispersion in the shape of the power spectral density about its centroid [94]. A value for δ close to zero denotes a narrow-band process, and a value close to unity denotes a wide-band process. The mean and standard deviation associated with the above distribution can be obtained as

$$\bar{X}_\tau = p \cdot \sigma_X, \tag{C.5a}$$
$$\sigma_{X_\tau} = q \cdot \sigma_X, \tag{C.5b}$$

where p and q are peak factors. For $10 \leq \nu\tau \leq 1000$, (the earthquake engineering interest range), approximate expressions for p and q based on results in references [68, 70] are

$$p = \sqrt{2 \ln \nu_e \cdot \tau} + \frac{0.5772}{\sqrt{2 \ln \nu_e \cdot \tau}}, \tag{C.6a}$$
$$q = \frac{1.2}{\sqrt{2 \ln \nu_e \cdot \tau}} - \frac{5.4}{13 + (2 \ln \nu_e \cdot \tau)^{3.2}},$$

in which ν_e is a reduced mean zero-crossing rate given by

$$\nu_e\tau = \begin{cases} \max(2.1, 2\delta \cdot \nu\tau) & \text{if} \quad 0 < \delta \leq 0.1 \\ (1.63\delta^{0.45} - 0.38) \cdot \nu\tau & \text{if} \quad 0.1 < \delta < 0.69 \\ \nu\tau & \text{if} \quad 0.69 \leq \delta < 1 \end{cases}. \tag{C.6b}$$

Asymptotic expressions for the mean and standard deviation of the peak response were first developed by Davenport [65], relying in part on previous work by Cartwright and Longuet-Higgins [62], based upon a Poisson model of barrier crossings. However, for narrow-band processes, such as the response of a lightly damped oscillator, the expressions by Davenport are in considerable error due to the significant dependence between barrier crossings [90, 68]. The introduction of ν_e instead of ν in eqs. C.6a-C.6b accounts for this dependence.

C.2.5 Response of Linear SDF Oscillator to Stationary Base Excitation

For a linear single-degree-of-freedom (SDF) oscillator with natural frequency ω_0 and damping factor ξ_0, subjected to base acceleration $\ddot{X}(t)$, the equation of motion can be written as

$$\ddot{U}(t) + 2\zeta_0\omega_0\dot{U}(t) + \omega_0^2 U(t) = -\ddot{X}(t),$$

where $U(t)$ is the displacement relative to the base and a superposed dot denotes differentation with respect to time. Assuming stationary input and output, the Fourier transform yields the complex frequency response function $H(\omega)$

$$\begin{aligned} U(\omega) &= H(\omega)\ddot{X}(\omega), \\ H(\omega) &= \frac{1}{\omega_0^2 - \omega^2 + 2\mathrm{i}\zeta_0\omega_0\omega}. \end{aligned}$$

The one-sided power spectral density of the stationary response, $U(t)$, is given by

$$G_{UU}(\omega) = |H(\omega)|^2 G_{\ddot{X}\ddot{X}}(\omega),$$

where $|H(\omega)|^2 = H(\omega)H^*(\omega)$. The asterisk denotes the complex conjugate.

Based upon the definition in eq. C.2, the spectral moments of the response are

$$\lambda_m = \int_0^\infty \omega^m G_{UU}(\omega)\mathrm{d}\omega = \int_0^\infty \omega^m |H(\omega)|^2 G_{\ddot{X}\ddot{X}}(\omega)\mathrm{d}\omega.$$

C.2.6 Response of Linear MDF System to Uni-Directional Stationary Base Excitation

The equation of motion for a linear multi-degree-of-freedom (MDF) system subjected to a uni-directional ground motion, $\ddot{X}(t)$, is

$$M\ddot{U} + C\dot{U} + KU = -MI_1\ddot{X} \tag{C.7}$$

where M, C, K are mass, damping, and stiffness matrices, respectively. U is the vector of nodal displacements relative to the ground, and I_1 is the influence vector for effective earthquake loading on the structure. The latter defines the load vector on the structure degrees-of-freedom from the excitation of the base of the structure [63].

The equations of motion, eq. C.7, can be uncoupled through the transformation

$$U = \Phi Y,$$

where $Y^T = [Y_1, Y_2, \ldots, Y_n]$ is the vector containing normal co-ordinates, and $\Phi = [\Phi_1 \Phi_2 \cdots \Phi_n]$ is the matrix containing the eigenvectors Φ_i of the n-degree-of-freedom system. The uncoupled modal equations are

$$\ddot{Y}_i + 2\omega_i \zeta_i \dot{Y}_i + \omega_i^2 Y_i = -\Gamma_i \ddot{X} \qquad \text{for} \quad i = 1, \ldots, n \tag{C.8}$$

where ζ_i and ω_i are modal frequencies and damping factors, respectively, and Γ_i is the modal participation factor given by

$$\Gamma_i = \frac{\Phi_i^T M I_1}{\Phi_i^T M \Phi_i}.$$

In arriving at eq. C.8, it is assumed that the system has modal damping, i.e. that the damping matrix is orthogonal to the eigenvectors Φ_i obtained for the undamped system.

The autocorrelation function for the response associated with the r-th degree of freedom, U_r, can be written as

$$\begin{aligned} R_{U_r \cdot U_r}(\tau) &= E[U_r(t) \cdot U_r(t+\tau)] \\ &= E[\sum_i \phi_{i,r} \cdot Y_i(t) \sum_j \phi_{j,r} \cdot Y_j(t+\tau)] \\ &= \sum_i \sum_j \phi_{i,r} \cdot \phi_{j,r} E[Y_i(t) \cdot Y_j(t+\tau)], \end{aligned}$$

where phi_i, r is the r-th element of the i-th eigenvector. Fourier-transformation yields the power spectral density for the response

$$G_{U_r \cdot U_r}(\omega) = \sum_i \sum_j \Psi_{i,r} \cdot \Psi_{j,r} \cdot H_i(\omega) H_j^*(\omega) \cdot G_{\ddot{X} \cdot \ddot{X}}(\omega), \tag{C.9}$$

where $\Psi_{i,r} = \Gamma_i \cdot \phi_{i,r}$ are known as effective modal participation factors. Other displacement related response quantities, e.g. force or stress at a point, can be obtained in a similar manner by simply replacing $\phi_{i,r}$ by the value of the corresponding response quantity when the structure is statistically deformed in its i-th mode shape.

C.2.7 Correlation between Modal Responses

The spectral moments for response of the r-th degree of freedom are obtained, using eq. C.9, as

$$\lambda_{m,r} = \sum_i \sum_j \Psi_{i,r} \cdot \Psi_{j,r} \int_0^\infty \omega^m H_i(\omega) \cdot H_j^*(\omega) \cdot G_{\ddot{X}\ddot{X}}(\omega) \mathrm{d}\omega \qquad \text{for} \qquad m = 0, 1, 2, \ldots \quad .$$

Defining cross-spectral moments $\lambda_{m,ij} = \int_0^\infty \omega^m H_i(\omega) H_j^*(\omega) G_{\ddot{X}\ddot{X}} \mathrm{d}\omega$, and introducing the coefficients

$$\rho_{m,ij} = \frac{\lambda_{m,ij}}{\sqrt{\lambda_{m,ii} \lambda_{m,jj}}} \tag{C.10}$$

the spectral moments of the response can be written as

$$\lambda_{m,r} = \sum_i \sum_j \Psi_{i,r}\Psi_{j,r}\rho_m, ij\sqrt{\lambda_{m,ii}\lambda_{m,jj}} \qquad \text{for} \qquad m = 0, 1, 2, \ldots \quad , \tag{C.11}$$

where $\lambda_{m,ii}$ are the spectral moments of the response in the i-th mode, as normalized by the corresponding effective participation factor and are given by

$$\lambda_{m,ii} = \int_0^\infty \omega^m |H_i(\omega)|^2 G_{\ddot{X}\ddot{X}}(\omega)\mathrm{d}\omega \qquad \text{for} \qquad m = 0, 1, 2, \ldots \quad .$$

It is easy to show that the coefficients, $\rho_{m,ij}$, in the above expressions represent modal correlation coefficients. Specifically, $\rho_{0,ij}$ represents the correlation coefficients between relative displacement responses in modes i and j, whereas $\rho_{2,ij}$ represents the correlation coefficient between relative velocity responses in modes i and j. $\rho_{1,ij}$ is related to the envelope process and has no simple physical meaning. However, it also behaves like a correlation coefficient [68].

Der Kiureghian [68] has developed exact expressions for $\rho_{m,ij}$ where $m = 0, 1, 2$, for responses to white-noise and filtered white-noise excitations. Based on results for response to white noise, he has developed a set of simpler expressions for $\rho_{m,ij}$, which can be used for response analysis to wide-band inputs. This approximation is shown to be reasonable, since $\rho_{m,ij}$ are not sensitive to the shape of the input power spectral density as long as it is wide-banded. These expressions depend only on the natural frequencies and damping factors of the modes, and are given by

$$\rho_{0,ij} = \frac{2\sqrt{\zeta_i\zeta_j}[(\omega_i+\omega_j)^2(\zeta_i+\zeta_j) + (\omega_i^2-\omega_j^2)(\zeta_i-\zeta_j)]}{4(\omega_i-\omega_j)^2 + (\zeta_i+\zeta_j)(\omega_i+\omega_j)^2} \tag{C.12a}$$

$$\rho_{1,ij} = \frac{2\sqrt{\zeta_i\zeta_j}\left[(\omega_i+\omega_j)^2(\zeta_i+\zeta_j) - \frac{4}{\pi}(\omega_i-\omega_j)^2\right]}{4(\omega_i-\omega_j)^2 + (\zeta_i+\zeta_j)(\omega_i+\omega_j)^2} \tag{C.12b}$$

$$\rho_{2,ij} = \frac{2\sqrt{\zeta_i\zeta_j}[(\omega_i+\omega_j)^2(\zeta_i+\zeta_j) - (\omega_i^2-\omega_j^2)(\zeta_i-\zeta_j)]}{4(\omega_i-\omega_j)^2 + (\zeta_i+\zeta_j)(\omega_i+\omega_j)^2} \tag{C.12c}$$

For narrow-band excitations, these expressions become less accurate, as the correlation coefficients become more sensitive to the shape of the input spectrum. In that case one can determine $\rho_{m,ij}$ from eq. C.10 by evaluating the integral for $\lambda_{m,ij}$ for any given power spectral density function. A numerical integration procedure for this purpose may also be used, such as that in Ref [61]. In either case, computations can be far more cumbersome than that required by the expressions in eqs. C.12a-C.12c.

As was indicated before, the filtered white noise given in eq. C.3.5, is often used to describe the ground acceleration process. For this model the parameter ζ_g determines the narrowbandedness of the power spectral density. For earthquakes, ζ_g between 0.2 and 0.6 has been used in the literature. The corresponding power spectral density shapes are shown in Figure C.2. It is assumed that the given expressions for $\rho_{m,ij}$ can be used for response to ground motions for all practical applications.

Knowing the correlation coefficients, $\rho_{m,ij}$, the only quanities one needs to determine are the modal spectral moments, $\lambda_{m,ii}$. As was indicated, closed form expressions for these quantities for response to white noise and filtered white noise inputs are available [68]. Alternatively, for response to wideband inputs, Der Kiureghan [67] has developed a method whereby the modal spectral moments can be obtained approximately in terms of response spectrum ordinates corresponding to the modal frequencies and damping factors. This method is described in the following section.

C.2.8 Use of Response Spectra in Stochastic Analysis

Most engineers involved in design for earthquake loading on structures are better acquainted with the response spectrum than with the power spectral density, which in itself makes the response spectrum an

attractive alternative. Also, for earthquake-type excitations, the response spectrum may be a more appropriate description of the input, since it accounts for the nonstationarity in the excitation in an approximate manner [89, 67]. Furthermore, a general power spectral density function must be integrated in order to find the spectral moments, while the approximation given in Ref [67] makes it possible to determine $\lambda_{m,ii}$ by simple algebra.

The mean response spectrum, $\bar{S}_\tau(\omega,\zeta)$, is defined as the mean value of the maximum absolute response of an oscillator with frequency ω and damping ζ to a stationary input with duration τ. From this definition, it is obvious that $\bar{S}_i = \bar{S}_\tau(\omega_i,\zeta_i)$, is the mean of the absolute maximum of the response of the i-th normal coordinate. Then, using this, the relations $\bar{S}_i = p_i\sqrt{\lambda_{0,ii}}$, $\nu_i = \sqrt{\lambda_{2,ii}/\lambda_{0,ii}}/\pi$ and $\delta_i = \sqrt{1-(\lambda_{1,ii}^2/\lambda_{0,ii}\lambda_{2,ii})}$ and the approximations for ν_i and δ_i for wide-band inputs [67]

$$\begin{aligned}\nu_i &= \frac{\omega_i}{\pi},\\ \delta_i &= 2\sqrt{\frac{\zeta_i}{\pi}},\end{aligned} \tag{C.13}$$

one can find the following approximations for the spectral moments $\lambda_{m,ii}$

$$\lambda_{m,ii} = \epsilon_{m,i}^2\bar{S}_i^2 \qquad \text{for} \qquad m = 0,1,2$$

where the factors $\epsilon_{m,i}$ are given by

$$\begin{aligned}\epsilon_0, i &= \frac{1}{p_i},\\ \epsilon_1, i &= \frac{1}{p_i}\sqrt{\omega_i\sqrt{1-4\cdot\frac{\zeta_i}{\pi}}},\\ \epsilon_2, i &= \frac{\omega_i}{p_i}.\end{aligned} \tag{C.14a}$$

In the above expressions, p_i is the peak factor for mode i as given in eq. C.6a, where ν and δ are substituted by ν_i and δ_i. The approximations for ν_i and δ_i in eq. C.13 are based on response to white noise input and are valid for wide-band inputs such as earthquakes.

Using eq. C.14a and eq. C.11, the spectral moments of the response can now be written in terms of the mean response spectrum ordinates, $\bar{S}_i$, as

$$\lambda_{m,r} = \sum_i\sum_j \Psi_{i,r}\Psi_{j,r}\rho_{m,ij}\epsilon_{m,i}\epsilon_{m,j}\bar{S}_i\bar{S}_j$$

In particular, the mean of the peak response can be written, using eq. C.5a, as

$$\bar{U}_{r,\tau} = p\sqrt{\lambda_{0,r}} = \sqrt{\sum_i\sum_j \Phi_{i,r}\Phi_{j,r}\rho_{m,ij}\frac{p^2}{p_ip_j}\bar{S}_i\bar{S}_j}$$

It is shown in [68] that the ratios $\frac{p}{p_i}$ are near unity and the above expressions may be simplified to the form

$$\bar{U}_{r,\tau} = \sqrt{\sum_i\sum_j \Phi_{i,r}\Phi_{j,r}\rho_{m,ij}\bar{S}_i\bar{S}_j}$$

which is called the CQC method for unidirectional excitations.

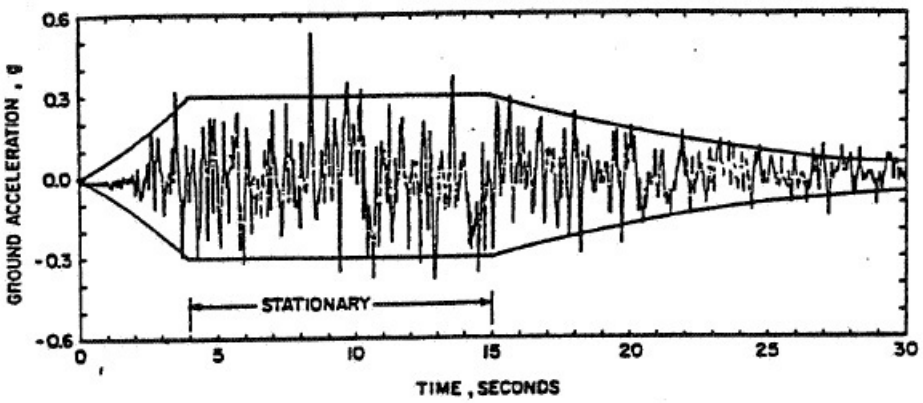


Figure C.1: Typical example of ground motion component with intensity envelope

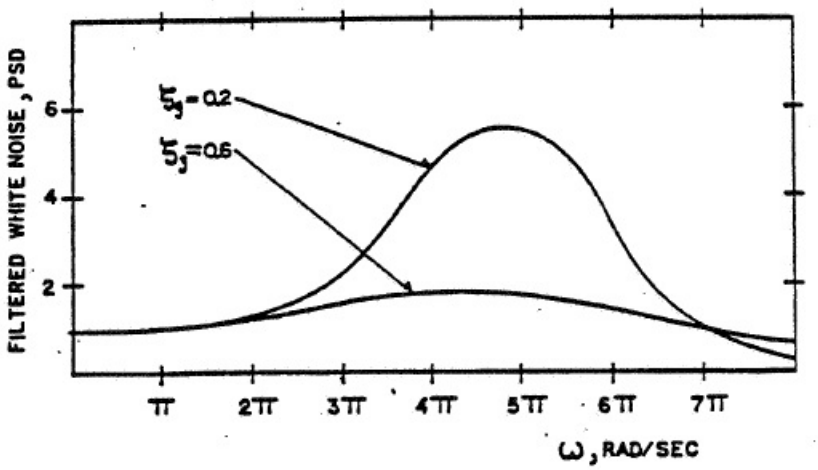


Figure C.2: Power spectral density of filtered white noise for typical ground frequency $\omega_g = 5\pi$, shown for $\xi_g = 0.2$ and $\xi_g = 0.6$. Both curves are for white noise power spectral density, $S_0 = 1.0$

C.3 Modeling Multi-Directional Components of Ground Motion

C.3.1 Introduction

The vector process describing the ground motion at a site during an earthquake is normally resolved into components convenient for design purposes. The rotational components are usually neglected as they have never been recorded properly and their effects are believed to be minor for most engineering structures [85]. The traditional components are usually given in one vertical and two horizontal directions. In general, the translational components of ground motion are correlated processes, which can be handeled if the cross-correlation functions are known. However, in current practice these correlations are usually neglected and the components are treated as statistically uncorrelated processes.

Most recordings of earthquake ground motions have been carried out in three orthologonal directions, which ensures a complete description of the translational vector process. At any instant in time, it is generally possible to find a set of directions along which the ground motion components are uncorrelated. For engineering purposes, however, this property would be of interest only if the uncorrelated directions remain constant during the earthquake. In such a case, the complete translational vector process can be described by uncorrelated component processes along three fixed directions, the so-called principal axes, which would greatly simplify the modelling of multi-component earthquake motions in design situations.

C.3.2 Penzien's Model of Ground Motion Components

Penzien et. al. [78, 79, 87] have shown that there indeed exists a set of orthogonal principal directions of ground motions, along which the component processes can be considered to be approximately uncorrelated. This was found by computing the covariances of the recorded accelerations along the three accelerograph axes over successive time intervals, and thereby determining the change in the direction of principal axes with time. These directions were found to remain approximately constant during the stationary strong motion phase of the earthquake, whereas they varied during the initial build-up phase or the decay phase towards the end of the earthquake [79]. It was also found that during the strong motion phase, the major principal axis remained horizontal and directed from the site towards the epicenter, whereas the intermediate principal axis was horizontal and perpendicular to the major principal axis. The minor principal axis is nearly vertical. As mentioned in Section 2.2.3, it is the stationary strong motion phase of ground motion that is of primary interest. Thus, by using the above model of principal directions, one may describe the multi-component ground motion input as a set of uncorrelated stationary processes along the principal axes. This provides a basis for examining the effect of correlation between components in arbitrary directions on the structural response.

Hadijan [75] has also shown that there exists a set of perpendicular horizontal directions along which the horizontal components of ground motion are uncorrelated. For these directions of the horizontal components, however, he did not find that the vertical component was uncorrelated to both the horizontal ones. However, since the vertical component usually is less significant than the horizontal ones, the contribution of its correlation with the components along the horizontal principal directions can be considered to be small enough to be neglected.

C.3.3 Transformation to Principal Directions

Assuming Penzien's model for uncorrelated principal directions, the transformation between the components along the principal directions, $Z(t) = [Z_1(t), Z_2(t), Z_3(t)]^T$, and those along the structure axes, $X(t) = [X_1(t), X_2(t), X_3(t)]^T$, can be written as

$$X(t) = AZ(t) \tag{C.15}$$

where A is the transformation matrix between the two sets of axes. The correlation matrix for the components of ground motion along the structure axes can be written as

$$R_{XX}(\tau) = E[X(t)X^T(t+\tau)] = E[AZ(t)Z^T(t)A^T] = AR_{ZZ}(\tau)A^T, \tag{C.16}$$

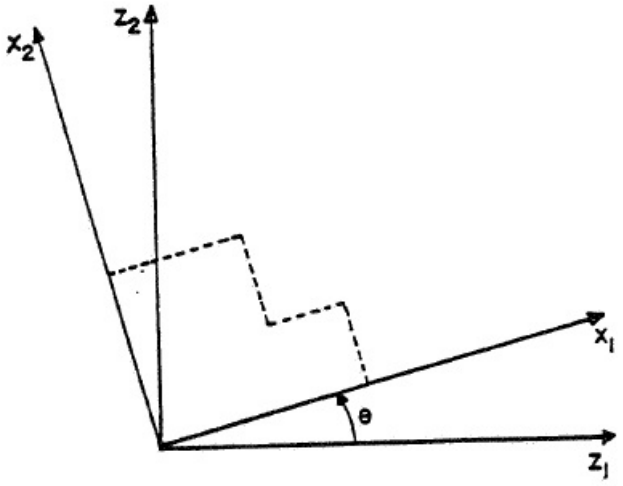


Figure C.3: Rotation about X_3 (Z_3) axis defining the transformation between the principal and the structural axis-systems

where $R_{ZZ}(\tau)$ is the diagonal correlation matrix of components along the principal axes. In most design situations, one of the axes of the structure is vertical which coincides with the minor principal axis. Then, the transformation is a simple rotation about the vertical axis, as shown in Figure C.3, and the matrix A becomes

$$A = \begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{C.17}$$

where θ is the angle of rotation between the two coordinate systems, see Figure C.3. Using eq. C.17 in eq. C.16 and writing in terms of components one obtains

$$R_{X_1X_1}(\tau) = \frac{1}{2}[R_{Z_1Z_1}(\tau) + R_{Z_2Z_2}(\tau)] + \frac{1}{2}[R_{Z_1Z_1}(\tau) - R_{Z_2Z_2}(\tau)]\cos 2\theta, \tag{C.18a}$$

$$R_{X_2X_2}(\tau) = \frac{1}{2}[R_{Z_1Z_1}(\tau) + R_{Z_2Z_2}(\tau)] - \frac{1}{2}[R_{Z_1Z_1}(\tau) - R_{Z_2Z_2}(\tau)]\cos 2\theta, \tag{C.18b}$$

$$R_{X_3X_3}(\tau) = R_{Z_3Z_3}(\tau), \tag{C.18c}$$

$$R_{X_1X_2}(\tau) = R_{X_2X_1}(\tau) = -\frac{1}{2}[R_{Z_1Z_1}(\tau) - R_{Z_2Z_2}(\tau)]\sin 2\theta, \tag{C.18d}$$

$$R_{X_1X_3}(\tau) = R_{X_3X_1}(\tau) = R_{X_2X_3}(\tau) = R_{X_3X_2}(\tau) = 0. \tag{C.18e}$$

Using Fourier transforms on eqs. C.18a-C.18e, similar relationships can be found for the power spectral densities of the two sets of component processes. Also, by taking the derivatives relative to τ of both sides of eqs. C.18a-C.18e, similar relationships can be found for correlation functions of ground velocity and acceleration components. It is mentioned in passing that these relations are analogous to well known tensor transformations, such as those for transformation of the stress tensor [83].

C.3.4 Correlation Coefficient between Ground Motion Components

The instantaneous correlation coefficient, ρ_{12}, between the two horizontal components of ground acceleration is defined as

$$\rho_{12} = \frac{R_{\ddot{X}_1\ddot{X}_2}(0)}{\sqrt{R_{\ddot{X}_1\ddot{X}_1}(0)R_{\ddot{X}_2\ddot{X}_2}(0)}} \tag{C.19}$$

By substituting eqs. C.18a-C.18e in eq. C.19, this coefficient can be determined in terms of the variances of the components along the principal directions. Introducing the ratio

$$\alpha = \frac{\sigma^2_{\ddot{X}_2}}{\sigma^2_{\ddot{X}_1}} = \frac{R_{\ddot{X}_2\ddot{X}_2}(0)}{R_{\ddot{X}_1\ddot{X}_1}(0)},$$

eq. C.19 becomes

$$\rho_{12} = \frac{-(1-\alpha)\sin 2\theta}{\sqrt{(1+\alpha)^2 - (1-\alpha)^2\cos^2 2\theta}} \tag{C.20}$$

The maximum magnitude of ρ_{12} occurs at $\theta = \frac{\pi}{4}$ and $3\frac{\pi}{4}$, and is

$$|\rho_{12}|_{max} = \frac{1-\alpha}{1+\alpha}.$$

Figure C.4 shows ρ_{12} as a function θ for various values of α, and Figure C.5 shows $|\rho_{12}|_{max}$ as a function of α. Note that assuming the component along the major principal axis has the larger variance, which means $0 < \alpha < 1$, results in a correlation coefficient which is negative for $0 < \theta < \frac{\pi}{2}$ and positive for $\frac{\pi}{2} < \theta < \pi$. This can be verified from Figure 2.3, where it is observed that for θ between 0 and $\frac{\pi}{2}$, a large value for Z_1 implies a large value for X_1 and a small value for X_2 and hence the negative correlation between X_1 and X_2. The positive correlation for θ between $\frac{\pi}{2} and \pi$ can be showed similarly. Figure C.4 shows that the correlation between the horizontal ground motion components is small when the ratio between the respective variances, α, is close to unity. At $\alpha = 1$, i. e. when the two horizontal components have equal variance, the correlation coefficient is zero for all values of θ.

C.3.5 Power Spectral Density Shapes for Ground Motion Components

From available geotechnical information it is reasonable to assume approximately similar shapes for the power spectral densities of the two horizontal components of ground motion, whereas the vertical component is usually considered to be more wide-banded. It is common to model the components of ground motion as filtered white-noise processes, with a filter as suggested by Kanai and Tajimi [76, 93]. The power spectral density for such a process is given by eq. . Use of several values for $\zeta_g and \omega_g$ have been reported in the literature. In the original works by Kanai [76] and Tajimi [93], values of ζ_g varying from 0.2 for soft soil to 0.6 for hard rock were suggested.

$\zeta_g = 0.6$ corresponds to a wide-band input, suitable for the approximations based on white noise when calculating correlation coefficients according to eq. C.12a-C.12c, see Ref [95]. $\zeta_g = 0.2$ corresponds to a relatively narrow-band process, but the expressions for correlation coefficients in eq. C.12a-C.12c are still good approximations for most practical purposes. The analysis may also be performed exactly through defining the filtered white-noise power spectral densities of the input components along the principal directions, and using closed form solutions for the cross-spectral moments as given in Ref [68]. Most researchers tend to use $\zeta_g = 0.6$, while Penzien and Kubo [79] use $\zeta_g = 0.2 and \zeta_g = 0.3$ for the components along the horizontal axes and $\zeta_g = 0.6$ for the vertical component.

Using a wide-band power spectral density tends to overestimate the contribution of higher frequencies, which for most cases is not a serious error. More important is to know the value of ω_g, which determines the dominant range of input frequencies. Closeness of the lowest natural frequencies of the structure to the region of frequencies that carry most of the energy through the soil at the site may greatly affect the structural response. A typical value for rock sites is $\omega_g = 5\pi$ [88].

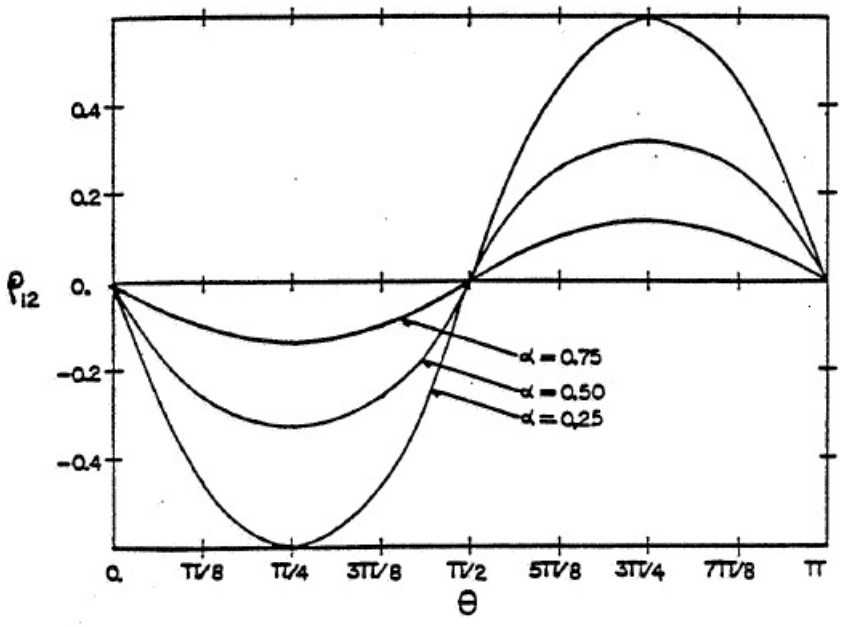


Figure C.4: The correlation coefficient ρ_{12} as function of angle of rotation, θ, for various values of the ratio α between the variances of the ground motion components along the two horizontal principal directions

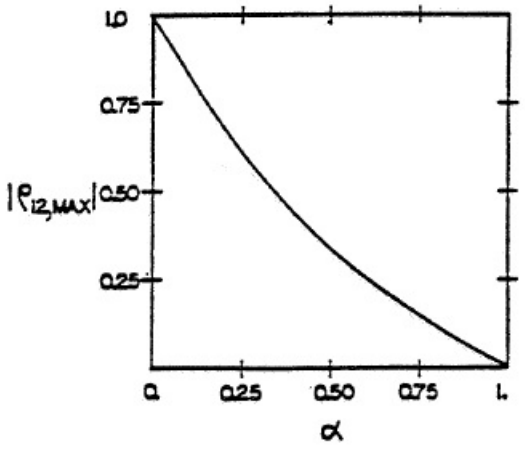


Figure C.5: The maximum value of ρ_{12} as function of α

C.3.6 Relative Intensities for Ground Motion Components

Eq. C.20 in section C.3.3 is based upon the relationship between the variances of the ground motion components. It would be more interesting to develop the same equation based upon data from the response spectrum ordimates of the various components, using the expressions for $\lambda_{m,ii}$ as given in terms of response spectra. From eq. C.14a, it can easily be seen that if the response spectra for the two horizontal principal directions are of the same shape, the ratio $\gamma = \frac{S_i^2}{S_i^1}$ between the response spectrum ordinates of the intermediate principal direction, Z_2, and of the major principal direction, Z_1, is a constant and is given by

$$\gamma = \sqrt{\alpha}$$

where α is previously defined as the ratio between the variances of the components along the horizontal principal directions. The only study known that gives data for the ratios between variances of the components along the principal directions is Penzien and Watabe's [87], which gives the following values

$$\sigma^2_{\ddot{Z}_2} = \frac{3}{4}\sigma^2_{\ddot{Z}_1},$$
$$\sigma^2_{\ddot{Z}_3} = \frac{1}{2}\sigma^2_{\ddot{Z}_1}.$$

For the two horizontal components, this results in

$$\alpha = 0.75,$$
$$\gamma = \sqrt{\alpha} = 0.87,$$
$$|\rho_{12}|_{max} = 0.14.$$

There are limited data in existing codes for values of relative intensities of ground motion components along orthogonal directions. The API code [25] recommends the acceleration spectrum in the second horizontal direction to be of same magnitude as the intensity along the major principal direction, while the vertical component is recommended to be $\frac{1}{2}$. The attentive ATC codes [37] does not specify the magnitude of the second component, but recommends adding 30% of the peak response due to excitation in this direction to the peak response due to loading in the primary direction.

C.4 Structural Response to Multi-Directional Seismic Excitation

C.4.1 Spectral Moments of Response

The equations of motion for a linear, multi-degree-of-freedom structure subjected to three-directional base excitation can be written as

$$M\ddot{U} + C\dot{U} + KU = -MI\ddot{X}, \tag{C.21}$$

where $X = [X_1 \quad X_2 \quad X_3]^T$ is the vector of ground motion translational components with horizontal components along the structural axes X_1 and X_2 and vertical component X_3, see Figure C.6. $I = [I_1 \quad I_2 \quad I_3]^T$ is the influence matrix such that I_k couples the degrees of freedom of the structure to the k-th component of ground motion, X_k.

Transforming into normal coordinates, $U = \Phi Y$, the i-th uncoupled equation of motion can be written as

$$\ddot{Y}_i + 2\xi_i\omega_i\dot{Y}_i + \omega_i^2 Y = -\Gamma_i^T\ddot{X},$$

which is similar to eq. C.8, except that here Γ_i and $\ddot{X}$ are vectors. The vector of participation factors of mode i, Γ_i, has the elements

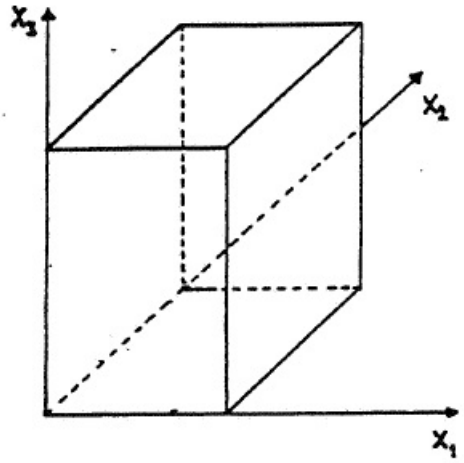


Figure C.6: Structure with axis-system, X

$$\Gamma_{ik} = \frac{\Phi_i^T M I_k}{\Phi_i^T M \Phi_i}, \qquad k = 1, 2, 3,$$

which are associated with the components of ground motion.

Consider the case where $\ddot{X}$ is a zero-mean stationary vector process with power spectral density matrix $G_{\ddot{X}\ddot{X}}(\omega)$. The element $G_{\ddot{X}_k\ddot{X}_l}(\omega)$ of this matrix represents the auto- or the cross-spectral density function of components $\ddot{X}_k(t) and \ddot{X}_l(t)$, depending on whether $k = l$ or $k \neq l$, respectively. In terms of this matrix, the power spectral density matrix of the displacement vector, U, can be shown to be

$$G_{UU}(\omega) = \Phi H(\omega) \Gamma^T G_{\ddot{X}\ddot{X}}(\omega) \Gamma H^*(\omega) \Phi^T \tag{C.22}$$

where $\Gamma = [\Gamma_1 \quad \Gamma_2 \cdots \Gamma_n]$, and where $H(\omega)$ is the diagonal matrix containing the complex frequency transfer functions

$$H_i(\omega) = \frac{1}{\omega_i^2 - \omega^2 + 2i\zeta_i\omega_i\omega}.$$

As before, the superscript asterisk denotes the complex conjugate. Eq. C.22 is the matrix version of eq. C.9 for multi-directional input and for all degrees of freedom of the structure. Note that it contains not only the auto power spectral densities, but also the cross power spectral densities for responses at various degrees of freedom. The formulation of eq. C.22 is most convenient for computational purposes, whereas in the present text the expressions for the diagonal terms of $G_{UU}(\omega)$ will be used in expanded form. This is done to determine the effect of various contributions to the response. Using eq. C.22, the power spectral density of the response in a selected degree of freedom, say r, can be written in the expanded form

$$G_{U_rU_r}(\omega) = \sum_i \sum_j \sum_k \sum_l \Psi_{i,r}^k \Psi_{j,r}^l H_i(\omega) H_j^*(\omega) G_{\ddot{X}_k\ddot{X}_l}(\omega), \tag{C.23}$$

where

$$\Psi_{i,r}^k = \Gamma_{ik} \phi_{i,r},$$

is the effective participation factor associated with mode i, degree of freedom r, and input direction k. Note that the summations on i and j in eq. C.23 are over the modes of the structure and those on k and l are over the components of ground motion. Again, for any displacement related response quantity such as stress or internal force at a point, the effective participation factor will have to be replaced by the value of the corresponding response quantity when the structure is statistically deformed in each of its mode shapes.

It is observed in eq. C.23 that in general for correlated ground motion components along structure axes, both the auto- and cross-power spectral densities of the input components are required to evaluate the response power spectral density. Assuming the model of Penzien and Watabe [87] as described in Section sec:Modeling Multi-Directional Components of Ground Motion, i.e. the existence of a set of orthogonal principal axes of ground motion along which components are uncorrelated, the auto- and cross-spectral densities of the components along the structure axes can be expressed in terms of the auto-power spectral densities of the ground motion components along the principal axes. Let the two sets of axes be related through the transformation matrix A as given in eq. C.15. Using this relation, the covariance matrices of the two sets of components of ground motion are related as given in eq. C.16. Applying Fourier Transforms to the expressions in eq. C.16, the power spectral density matrices for acceleration processes are related through

$$G_{\ddot{X}\ddot{X}}(\omega) = AG_{\ddot{Z}\ddot{Z}}(\omega)A^T \tag{C.24}$$

where $G_{\ddot{Z}\ddot{Z}}$ is diagonal. For computational purposes, it may be of interest to rewrite eq. C.22 as

$$G_{UU}(\omega) = \Phi H(\omega)\Gamma^T AG_{\ddot{Z}\ddot{Z}}(\omega)A^T\Gamma H^*(\omega)\Phi^T.$$

Using the transformation matrix of eq. C.17 in eq. C.24 the elements of $G_{\ddot{X}\ddot{X}}(\omega)$ are obtained as

$$G_{\ddot{X}_1\ddot{X}_1}(\omega) = \frac{1}{2}[G_{\ddot{Z}_1\ddot{Z}_1}(\omega) + G_{\ddot{Z}_2\ddot{Z}_2}(\omega)] + \frac{1}{2}[G_{\ddot{Z}_1\ddot{Z}_1}(\omega) - G_{\ddot{Z}_2\ddot{Z}_2}(\omega)]\cos 2\theta, \tag{C.25a}$$

$$G_{\ddot{X}_2\ddot{X}_2}(\omega) = \frac{1}{2}[G_{\ddot{Z}_1\ddot{Z}_1}(\omega) + G_{\ddot{Z}_2\ddot{Z}_2}(\omega)] - \frac{1}{2}[G_{\ddot{Z}_1\ddot{Z}_1}(\omega) - G_{\ddot{Z}_2\ddot{Z}_2}(\omega)]\cos 2\theta, \tag{C.25b}$$

$$G_{\ddot{X}_3\ddot{X}_3}(\omega) = G_{\ddot{Z}_3\ddot{Z}_3}(\omega,) \tag{C.25c}$$

$$G_{\ddot{X}_1\ddot{X}_2}(\omega) = G_{\ddot{X}_2\ddot{X}_1}(\omega) = -\frac{1}{2}[G_{\ddot{Z}_1\ddot{Z}_1}(\omega) - G_{\ddot{Z}_2\ddot{Z}_2}(\omega)]\sin 2\theta, \tag{C.25d}$$

$$G_{\ddot{X}_1\ddot{X}_3}(\omega) = G_{\ddot{X}_3\ddot{X}_1}(\omega) = G_{\ddot{X}_2\ddot{X}_3}(\omega) = G_{\ddot{X}_3\ddot{X}_2}(\omega) = 0. \tag{C.25e}$$

Substituting these relations in eq. C.23 gives the power spectral density of the response in the r-th degree of freedom in terms of the power spectral densities of the ground motion components along the principal axes

$$\begin{aligned} G_{U_rU_r}(\omega) = &\sum_i\sum_j\sum_k \Psi^k_{i,r}\Psi^k_{j,r}H_i(\omega)H^*_j(\omega)G_{\ddot{Z}_k\ddot{Z}_k}(\omega) \\ &- \sum_i\sum_j[\Psi^1_{i,r}\Psi^1_{j,r} - \Psi^2_{i,r}\Psi^2_{j,r}]H_i(\omega)H^*_j(\omega)[G_{\ddot{Z}_1\ddot{Z}_1}(\omega) - G_{\ddot{Z}_2\ddot{Z}_2}(\omega)]\sin^2\theta \\ &- \sum_i\sum_j[\Psi^1_{i,r}\Psi^2_{j,r} + \Psi^2_{i,r}\Psi^1_{j,r}]H_i(\omega)H^*_j(\omega)[G_{\ddot{Z}_1\ddot{Z}_1}(\omega) - G_{\ddot{Z}_2\ddot{Z}_2}(\omega)]\sin\theta\cos\theta \end{aligned} \tag{C.26}$$

In the preceding equation, the first two terms on the right-hand side come from the replacement of the auto-power spectral densities, $G_{\ddot{X}_k\ddot{X}_k}(\omega)$, whereas the last term arises from the cross power spectral densities, $G_{\ddot{X}_1\ddot{X}_2}(\omega)$ and $G_{\ddot{X}_2\ddot{X}_1}(\omega)$. Therefore, the latter term represents the effect of correlation between the input components. It is also possible to obtain the response power spectral density in terms of only the auto-power

spectral densities of the components along the structure axes. For this purpose, solving for $G_{\ddot{Z}_k\ddot{Z}_k}(\omega)$, from eqs. C.25a-C.25c in terms of $G_{\ddot{X}_k\ddot{X}_k}(\omega)$, and substituting in eq. C.26 one obtains

$$G_{U_rU_r}(\omega) = \sum_i \sum_j \sum_k \Psi^k_{i,r}\Psi^k_{j,r} H_i(\omega)H^*_j(\omega)G_{\ddot{X}_k\ddot{X}_k}(\omega) - \sum_i \sum_j [\Psi^1_{i,r}\Psi^2_{j,r} + \Psi^2_{i,r}\Psi^1_{j,r}]H_i(\omega)H^*_j(\omega)[G_{\ddot{X}_1\ddot{X}_1}(\omega) - G_{\ddot{X}_2\ddot{X}_2}(\omega)]\tan 2\theta$$

This formulation, however, is not appropriate for values of θ approaching 45 degrees, since it assumes an indefinite form as $\tan 2\theta \to \infty$ and $[G_{\ddot{X}_1\ddot{X}_1}(\omega) - G_{\ddot{X}_2\ddot{X}_2}(\omega)] \to 0$. For this reason, eq. C.26 is used.

Taking the spectral moments according to eq. C.2 one obtains

$$\lambda_{m,r} = \int_0^\infty \omega^m G_{U_rU_r}(\omega)d\omega \qquad \text{for} \qquad m = 0, 1, 2$$

Here $\lambda_{m,r}$ denotes the m-th spectral moment for the response in degree of freedom r. Using eq. C.21, the spectral moments of the response can be written as

$$\begin{aligned}\lambda_{m,r} = &\sum_i \sum_j \sum_k \Psi^k_{i,r}\Psi^k_{j,r}\lambda^k_{m,ij} \\ &- \sum_i \sum_j [\Psi^1_{i,r}\Psi^1_{j,r} - \Psi^2_{i,r}\Psi^2_{j,r}][\lambda^1_{m,ij} - \lambda^2_{m,ij}]\sin^2\theta \\ &- \sum_i \sum_j [\Psi^1_{i,r}\Psi^2_{j,r} + \Psi^2_{i,r}\Psi^1_{j,r}][\lambda^1_{m,ij} - \lambda^2_{m,ij}]\sin\theta\cos\theta \qquad \text{for} \qquad m = 0, 1, 2,\end{aligned} \tag{C.27}$$

where

$$\lambda^k_{m,ij} = Re[\int_0^\infty \omega^m H_i(\omega)H^*_j(\omega)G_{\ddot{Z}_k\ddot{Z}_k}(\omega)d\omega] \qquad \text{for} \qquad m = 0, 1, 2 \qquad \text{and} \qquad k = 1, 2, 3,$$

is the m-th cross-spectral moment of the normal coordinates for modes i and j for response to the component of ground motion along the k-th principal axis. As in Section C.2.7, it is useful to include modal correlation coefficients, $\rho^k_{m,ij}$,

$$\rho^k_{m,ij} = \frac{\lambda^k_{m,ij}}{\sqrt{\lambda^k_{m,ii}\lambda_m, jj^k}} \qquad \text{for} \qquad m = 0, 1, 2 \qquad \text{and} \qquad k = 1, 2, 3,$$

where $\lambda^k_{m,ii}$ is the m-th spectral moment of the normal co-ordinate for mode i due to the excitation component along the k-th principal axis. It is noted that $\rho^k_{0,ij}$ and $\rho^k_{2,ij}$ are correlation coefficients between the normal coordinates for modes i and j and between their time derivatives, respectively, for response to the k-th ground motion component. As reported in Section C.2.7, the correlation coefficients for response to wide-band inputs are approximately independant of the shape of the input power spectral density. On this basis, the expressions given in eqs. C.12a-C.12c can be used, and the superscript k on correlation coefficients can be dropped. Introducing these relations in eq. C.27, spectral moments of response can be obtained in terms of the spectral moments of individual normal coordinates excited by the ground motion component in each principal direction separately

$$\lambda_{m,r} = \sum_i \sum_j \sum_k \Psi^k_{i,r}\Psi^k_{j,r}\rho_{m,ij}\sqrt{\lambda^k_{m,ii}\lambda^k_{m,jj}}$$
$$- \sum_i \sum_j \rho_{m,ij}\left[\Psi^1_{i,r}\Psi^1_{j,r} - \Psi^2_{i,r}\Psi^2_{j,r}\right]\left[\sqrt{\lambda^1_{m,ii}\lambda^1_{m,jj}} - \sqrt{\lambda^2_{m,ii}\lambda^2_{m,jj}}\right]\sin^2\theta$$
$$- \sum_i \sum_j \rho_{m,ij}\left[\Psi^1_{i,r}\Psi^2_{j,r} + \Psi^2_{i,r}\Psi^1_{j,r}\right]\left[\sqrt{\lambda^1_{m,ii}\lambda^2_{m,jj}} - \sqrt{\lambda^2_{m,ii}\lambda^2_{m,jj}}\right]\sin\theta\cos\theta \quad \text{for} \quad m = 0, 1, 2. \tag{C.28}$$

The above result can be used for input given in terms of power spectral densities, as long as one can integrate, algebraically or numerically, the expressions for $\lambda_{m,ii}$, and as the input is a wide-band process.

Noting that $\sqrt{\lambda^k_{0,ii}}$ is the root-mean-square of the i-th normal coordinate when excited by the ground motion in principal direction k, one can use eq. C.14 to express the spectral moments of the response of each mode in terms of the corresponding mean response spectrum ordinate denoted by $\bar{S}^k_i$. Thus, the m-th spectral moment of the response given by eq. C.28 can be expressed in terms of the response spectrum ordinates for the three principal directions as

$$\lambda_{m,r} = \sum_i \sum_j \sum_k \epsilon_{m,i}\epsilon_{m,j}\rho_{m,ij}\Psi^k_{i,r}\Psi^k_{j,r}\bar{S}^k_i\bar{S}^k_j$$
$$- \sum_i \sum_j \epsilon_{m,i}\epsilon_{m,j}\rho_{m,ij}[\Psi^1_{i,r}\Psi^1_{j,r} - \Psi^2_{i,r}\Psi^2_{j,r}][\bar{S}^1_i\bar{S}^1_j - \bar{S}^2_i\bar{S}^2_j]\sin^2\theta$$
$$- \sum_i \sum_j \epsilon_{m,i}\epsilon_{m,j}\rho_{m,ij}[\Psi^1_{i,r}\Psi^2_{j,r} + \Psi^2_{i,r}\Psi^1_{j,r}][\bar{S}^1_i\bar{S}^1_j - \bar{S}^2_i\bar{S}^2_j]\sin\theta\cos\theta \quad \text{for} \quad m = 0, 1, 2. \tag{C.29}$$

The aforementioned expression in conjunction with eqs. C.4-C.6 provide the necessary equations needed to find the probability distribution, mean, and variance of the absolute peak response of a structure subjected to three-directional ground motion excitation described through response spectra in the three principal directions.

Eq. C.29 makes it possible to perform analysis for arbitrarily prescribed response spectra in the three principal directions. In many instances, it is possible to assume that the shape of the power spectral densities, and hence the response spectra, along the two horizontal principal directions are approximately the same (see Section C.3.5). Then they only differ in amplitude, and it is useful to introduce the intensity ratio

$$\gamma = \frac{\bar{S}^2_i}{\bar{S}^1_i}.$$

Using the preceding ratio γ in eq. C.29, one obtains

$$\lambda_{m,r} = \sum_i \sum_j \sum_k \epsilon_{m,i}\epsilon_{m,j}\rho_{m,ij}\Psi^k_{i,r}\Psi^k_{j,r}\bar{S}^k_i\bar{S}^k_j$$
$$- \sum_i \sum_j \epsilon_{m,i}\epsilon_{m,j}\rho_{m,ij}[\Psi^1_{i,r}\Psi^1_{j,r} - \Psi^2_{i,r}\Psi^2_{j,r}](1-\gamma^2)\bar{S}^1_i\bar{S}^1_j\sin^2\theta$$
$$- \sum_i \sum_j \epsilon_{m,i}\epsilon_{m,j}\rho_{m,ij}[\Psi^1_{i,r}\Psi^2_{j,r} + \Psi^2_{i,r}\Psi^1_{j,r}](1-\gamma^2)\bar{S}^1_i\bar{S}^1_j\sin\theta\cos\theta \quad \text{for} \quad m = 0, 1, 2. \tag{C.30}$$

It can be seen from eq. C.30 that the magnitude of γ greatly influences both terms that include θ. For $\theta = 1$ these terms vanish, signifying the fact that for isotropic loading, i.e. equal intensity and frequency content in both horizontal principal directions, neither rotation of axes, represented by the second term in

eq. C.30, nor correlation between ground motion components, represented by the third term of eq. C.30, need be considered. The magnitudes of the last two terms in eq. C.30, which contain θ, attain their maxima for $\gamma = 0$. For this case, the components along the horizontal structure axes are vector components of a single process, i.e. the horizontal component along the major principal axis, and are therefore perfectly correlated.

With the spectral moments determined, response quantities of interest, such as the distribution and the mean and the variance of the peak response, can be obtained in the manner discussed in the Section C.2.4. In particular, the mean of the peak response is of special interest in design. This can be obtained from the relation $\bar{U}_{r,\tau} = p\sqrt{\lambda_0}$, where p is the peak factor for the mean and is obtained from eqs. C.6a-C.6b in terms of the spectral moments. When λ_0 from eq. C.30 with $\epsilon_0, i = 1/p_i$ is substituted in this relation, factors $p/\sqrt{p_i p_j}$ appear in the expression. It has been shown that these factors have values near unity and for the sake of simplicity can be replaced by 1 [67]. With this simplification, the expression for the mean peak response becomes

$$\begin{aligned}\bar{U}_{r,\tau} = \Big(&\sum_i \sum_j \sum_k \rho_{0,ij} \Psi^k_{i,r} \Psi^k_{j,r} \bar{S}^k_i \bar{S}^k_j \\ &- \sum_i \sum_j \rho_{0,ij} \left[\Psi^1_{i,r}\Psi^1_{j,r} - \Psi^2_{i,r}\Psi^2_{j,r}\right] \left(1-\gamma^2\right) \bar{S}^1_i \bar{S}^1_j \sin^2\theta \\ &- \sum_i \sum_j \rho_{0,ij} \left[\Psi^1_{i,r}\Psi^2_{j,r} + \Psi^2_{i,r}\Psi^1_{j,r}\right] \left(1-\gamma^2\right) \bar{S}^1_i \bar{S}^1_j \sin\theta\cos\theta\Big)^{\frac{1}{2}}. \end{aligned} \tag{C.31}$$

It is noted that this expression is now independent of duration, τ, except for the duration that is implied through the specified input response spectra.

It can be seen from eq. C.31 that the expression for $\bar{U}_{r,\tau}$ reduces to the well known SRSS form

$$\bar{U}_{r,\tau} = \Big(\sum_i \sum_k (\Psi^k_{i,r} \bar{S}^k_i)^2\Big)^{\frac{1}{2}}, \tag{C.32}$$

if the modal responses are assumed to be uncorrelated, i.e. $\rho_{0,ij} = 0$ for $i \neq j$ is assumed, and $\rho_{0,ij} = 1$ for $i = j$, and either $\theta = 0$, which means structure axes coincide with the principal axes of ground motion, or $\gamma = 1$, which means that the two horizontal components have identical response spectra. It is pointed out that the modal responses for wide-band inputs are generally uncorrelated when frequencies are well spaced and damping coefficients are small.

C.5 Computation of Earthquake Response in Framework

All computations in Framework are based on the response spectrum method, and are various approximations to eq. C.31.

S_{v_i} is the pseudovelocity response of the ground motion for mode i. Accordingly, the spectral displacement in mode i can be written as

$$S_{d_i} = \frac{1}{\omega_i S_{v_i}}, \tag{C.33}$$

and the spectral acceleration in mode i

$$S_{a_i} = \omega_i S_{v_i} = \omega_i^2 S_{d_i}. \tag{C.34}$$

However, eqs. C.33-C.34 cannot be used directly as we have to sum up modal contributions taking into account that their maximum do not occur at the same time. This is taken care of by eq. C.31, and other approximations to this formulation.

The following modal combination methods – adopted by the industry – are included in Framework:

1. The Complete Quadratic Combination Method (CQC). This is eq. C.31.
2. The Square Root Sum of Squares Method (SRSS). This is eq. C.32.
3. The Naval Research Laboratory (NRL) Method. This method adds the absolute value of the largest response mode to the SRSS response of the other modes.

$$\bar{U}_{r,\tau} = |\bar{U}_{i,r}|_{max} + \text{SRSS}_{others}$$

4. The Absolute Sum of each modal response $\bar{U}_{r,\tau} = \sum_{i=1}^{n} |\bar{U}_{i,r}|$

Only method 1 and 2 are considered relevant, for practical applications, except that some codes require the NRL-method for conservatism. Framework computes maximum forces and stresses, maximum relative displacements and velocities and maximum absolute accelerations.

C.6 Code checking of earthquake response

The design against an abnormal earthquake event should ensure that the structural elements have adequate capacity to prevent collapse.

The code checking of earthquake response is based on ultimate strength and plastic theories. Members that are code checked and found to be under the unity criteria satisfy the code requirements. Members that exceed the unity criteria should be further assessed. Thus, the code checking capability in Framework should be used as a scanning facility, to isolate possible problem areas in the structure. Note that the regular code check made after an earthquake analysis usually is NOT able to fulfil the ductility requirements of anti-collapse. If the integrity of the entire structure is of importance, a full non-linear push-over analysis under appropriate sesimic loading is recommeneded.

C.6.1 Load-combinations with Static and Earthquake Response Forces

The design standards API RP2A [15] and [16] require that, for strength level earthquake design, the total design force for each member is obtained by combining the earthquake-induced forces together with static forces due to gravity, buoyancy and hydrostatic loading. The earthquake response produces forces and moments that have lost their phase and sign because the response spectrum method is used. Then, the earthquake components are non-negative by definition while the static components have conventional sign. API RP2A recommends the relative signs of the earthquake related force components acting on a member should be selected such that the most concervative condition will result when adding to the static components.

In Framework, static force-moment load cases can be added to the earthquake response forces before code checking. All the static force loadcases should be added together first, before the earthquake loadcase is added. In Framework, one or more static load cases and one earthquake load case can be included in the list of a load combination. If several static basic load cases are included, Framework adds the components of static load cases together first, and then combine the resulting static component with the associated component of the earthquake load case.

There are two options to create a load combination in Framework.

1. Create a load combination as **Static** type.

   The static plus earthquake load combination is created conservatively by Frameworkduring code check. The earthquake force component is combined with the same sign as the static force component for both the YIELD check and PUNCH shear check. That is, for the yield and punching shear check, the forces and moments are added in the following manner:

$$F_x = \pm F_{x_S} \pm F_{x_E} \tag{C.35}$$
$$F_y = \pm F_{y_S} \pm F_{y_E} \tag{C.36}$$
$$F_z = \pm F_{z_S} \pm F_{z_E} \tag{C.37}$$
$$M_x = \pm M_{x_S} \pm M_{x_E} \tag{C.38}$$
$$M_y = \pm M_{y_S} \pm M_{y_E} \tag{C.39}$$
$$M_z = \pm M_{z_S} \pm M_{z_E} \tag{C.40}$$

where the subscript

S - static analysis forces and moments

E - earthquake response forces and moments

and where F_x , F_y , F_z , M_x , M_y ,and M_z are the resultant load-combination force components.

The STABILITY check will use eqs. C.36-C.40, and the following:

$$F_x = \pm F_{x_S} - F_{x_E}. \tag{C.41}$$

As eq. C.41 indicates, the earthquake axial force component will always be added so that the resultant load combination's axial component will be more compressive.

For a member (combined YIELD and STABILITY) code check, the axial normal force component (for each member) produced for the earthquake load case, is checked for two cases, i.e. investigating for maximum tension force and maximum compression force. The other moment and shear components are combined using the same procedure as for the YIELD check. The two checking rounds are automatically performed for one load combination.

2. Create a load combination as **Earthquake** type.

   Command `CREATE LOAD-COMBINATION` has a new type: "Earthquake" in addition to existing types: Static, Quasi-static, and Scan. For the **axial component** of member forces, an Earthquake type load combination has three ways to sum up the forces from basic static loadcases and the earthquake response. They are: Maximum, Tension, Compression. The three options are described in Table 3.8, which effectively shows below:

$$F_x = \pm F_{x_S} \pm F_{x_E} \quad \text{for Maximum} \tag{C.42}$$
$$F_x = \pm F_{x_S} + F_{x_E} \quad \text{for Tension} \tag{C.43}$$
$$F_x = \pm F_{x_S} - F_{x_E} \quad \text{for Compression} \tag{C.44}$$

   The components of shear forces, bending moments and torque, are calculated the same as the "Static" type.

$$F_y = \pm F_{y_S} \pm F_{y_E}$$
$$F_z = \pm F_{z_S} \pm F_{z_E}$$
$$M_x = \pm M_{x_S} \pm M_{x_E}$$
$$M_y = \pm M_{y_S} \pm M_{y_E}$$
$$M_z = \pm M_{z_S} \pm M_{z_E}$$

   The earthquake induced component is combined with the same sign as the static component. The sign of static component is always retained in combination.

   During code checking on an "Earthquake" type load combination, the member forces applied are calculated according to the selected axial option. The program does not recalculate code checking

forces. The member forces depend on the “Earthquake” type and the selected option only, and do not change with different code check types. Conseqently, user must include all necessary load cases and load combinations in the required code check. The member forces applied in code checking can be viewed by `PRINT FORCE` feature.

C.6.2 Limitations in the Code Checking of Earthquake Response

The code checking of earthquake response for the yield check can be performed on any section type. However, for the stability check, the following limitations should be noted:

- Only column buckling should be assessed for single symmetric sections. Thus, the user should assign 99.0 to single symmetric members using the `ASSIGN STABILITY .. LATERAL-BUCKLING-FACTOR` command. Or, the user may ignore lateral torsional buckling in the printout, and scan the results to detect any criticality with respect to this failure mode.
  For single symmetric sections where the compression flange is not laterally supported, manual calculations should be performed to check the effects of lateral buckling.
- Since the dynamic moment contribution is lost in the response spectrum method, a moment amplification reduction factor of 1.0 should be assigned to both the in-plane and the out-of-plane.

D Calculation of stresses and stress resultant

D.1 Geometric Properties of Plane Areas

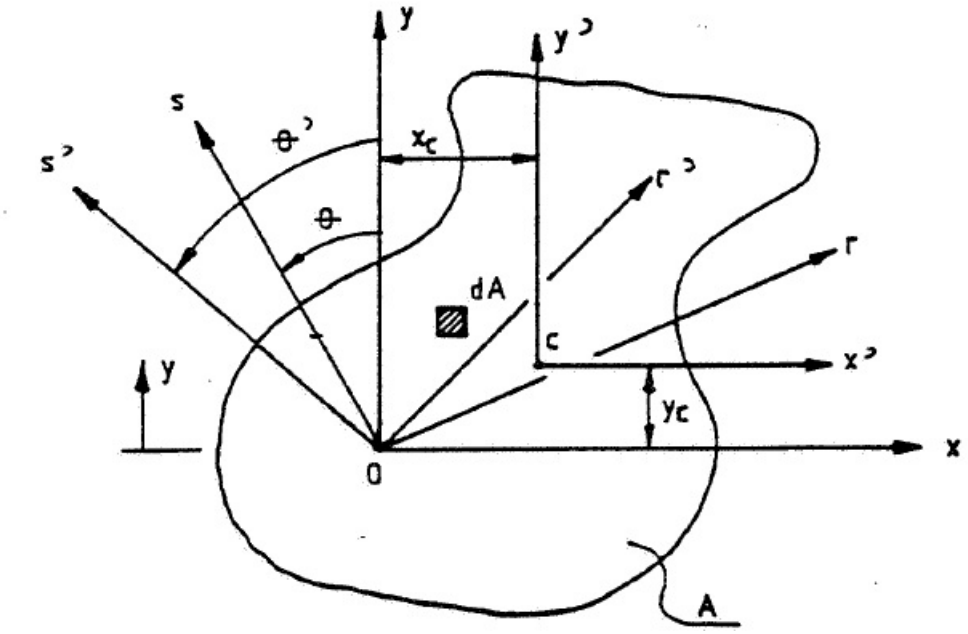


Figure D.1: Geometric Properties of Plane Areas

Framework calculates stresses for plane cross sectional areas. This section will identify the equations that are used for the geometric properties of plane areas.

A	Total area enclosed by the boundary, the area is lying in the $y-z$ plane
dA	Small element of the area, the axes r and s, and r' and s' are rotated counter clockwise with respect to y and z axes by the angles θ and θ', respectively
$r'-s'$	Principal axes, that is, axes about which the product of inertia is zero
c	Centroid of the area and also the origin of $y'-z'$ axis, which are translated with respect to the $y-z$ axis

The neutral axis is the axis along which the bending stress is zero. This axis must pass through the centroid of the cross-section of a homogeneous structure if the axial load on the structure is zero, so that the structure supports only a bending load.

Geometric Properties of Plane Areas:

Location of the centroid with respect to the $y-z$ axis is given by:

$$y_c = \frac{\int_A y \cdot dA}{A}$$

$$z_c = \frac{\int_A z \cdot dA}{A}$$

The area moments of inertia are:

$$I_y = \int_A z^2 \cdot dA$$
$$I_z = \int_A y^2 \cdot dA$$

The area product of inertia is:

$$I_{yz} = \int_A yz \cdot dA$$

The polar area moment of inertia is:

$$I_x = \int_A (y^2 + z^2) \cdot dA$$

The radii of gyration of the area are defined by:

$$r_y = \left[\frac{I_y}{A}\right]^{\frac{1}{2}}$$
$$r_z = \left[\frac{I_z}{A}\right]^{\frac{1}{2}}$$

If the moment of inertia about an axis which passes through the centroid is known, then the moments of inertia about a parallel axis which is translated can easily be computed as follows:

$$I_y = I_{y_c} + z_c^2 \cdot A$$
$$I_z = I_{z_c} + y_c^2 \cdot A$$
$$I_{yz} = I_{y_c z_c} + y_c \cdot z_c \cdot A$$
$$I_x = I_{x_c} + y_c^2 \cdot A + z_c^2 \cdot A$$

These relationships are known as the two-dimensional parallel axes theorem.

If the moments of inertia about one axis is known, then the moment of inertia about a rotated axis can be computed as follows:

$$I_r = I_y \cdot \cos^2\theta + I_z \cdot \sin^2\theta - I_{yz} \cdot \sin 2\theta$$
$$I_s = I_z \cdot \cos^2\theta + I_y \cdot \sin^2\theta + I_{yz} \cdot \sin 2\theta$$
$$I_{rs} = I_{yz} \cdot \cos 2\theta - \frac{1}{2}(I_z - I_y) \cdot \sin 2\theta$$
$$I_x = I_x$$

The above formulae show that

$$I_r + I_s = I_y + I_z$$

or, that the sum of area moments of inertia about two perpendicular axes are independent of the rotation of the two axes.

There exist two mutually perpendicular axes through any given origin in a plane area about which the product of inertia is zero. These axes are called the principal axes. The principal axis $r' - s'$ through the origin 0 are rotated an angle θ' with respect to the $x - y$ axis:

$$\theta' = \frac{\arctan\left(\frac{2I_{yz}}{I_z - I_y}\right)}{2}$$

The area moments of inertia about the principal axes are:

$$I_{r'} = I_y + I_z \pm \frac{1}{2}\left[(I_y - I_z)^2 + 4I_{yz}^2\right]^{\frac{1}{2}}$$

$$I_{s'} = I_y + I_z \mp \frac{1}{2}\left[(I_y - I_z)^2 + 4I_{yz}^2\right]^{\frac{1}{2}}$$

$$I_{r's'} = 0$$

The principal moments of inertia are the maximum and minimum moments of inertia which can be measured about any axis which passes through a given point.

An axis of symmetry is always a principal axis.

The product of inertia is zero for any two axes, one of which is a principal axis.

D.2 Limitations in the stress calculations

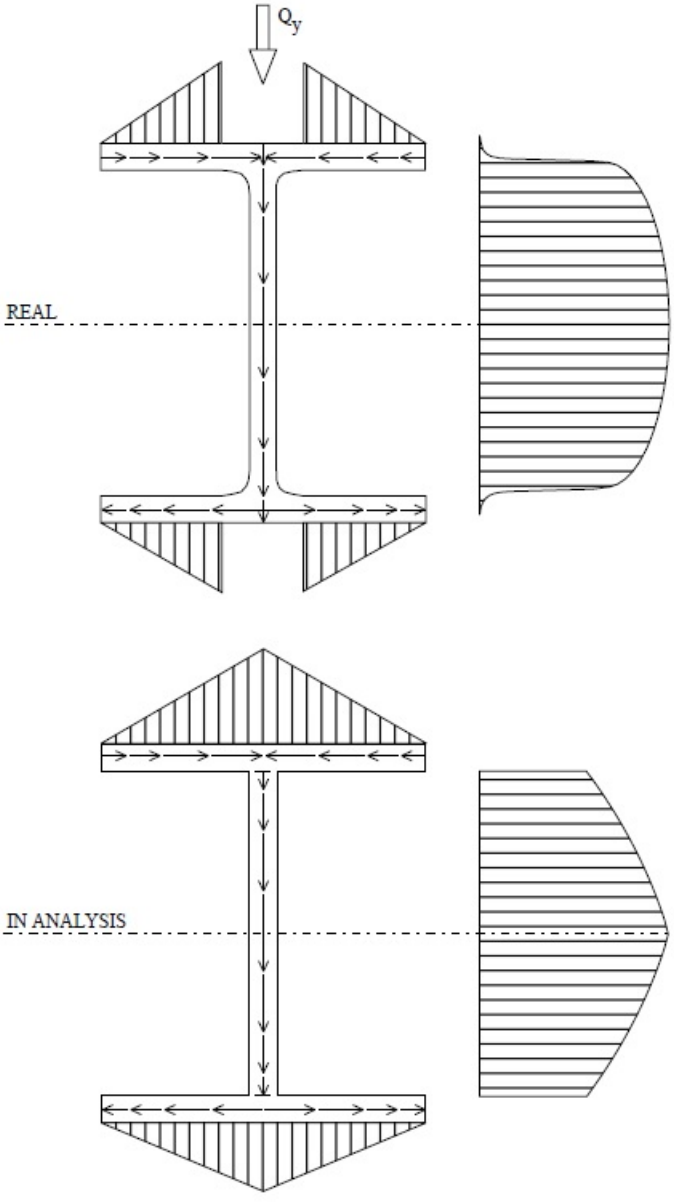


Figure D.2: Shear distribution for an I-beam

The simple flexure formulas used for stress calculation in case of pure bending about a principal axis have the following limitations:

- A linear stress distribution. Thus, for symmetrical open sections, a modified stress distribution is used (See Figure D.2).
- All loads are parallel to a principal plane and the sections rotate about a neutral principal axis perpendicular to the plane of loading. For sections where the principal axes do not coincide with the local coordinate system (non-symmetrical sections) the simple formulas have to be extended or, most correctly, the sectional parameters and the stress resultants have to be related to the principal axes. (See Section D.2.1)
- The sections do not twist. (See Section D.2.2)
- The stress is taken at a section away from the point of application of a concentrated load, at a distance equal to or greater than the depth of the beam. (See Section D.2.3)
- The beam cross section is constant along the span. (See Section D.2.4)
- The material is elastic, with stress directly proportional to strain and with equal moduli in tension and compression.
- The stresses do not exceed the elastic limit.
- The deflections are small compared to the beam depth.
- The beam is initially straight or very near so.
- The span is at least four or five times as great as the depth of the beam.
- The formulas are not valid for multicelled sections.
- Isotropic material properties are assumed.

D.2.1 Axis of symmetry

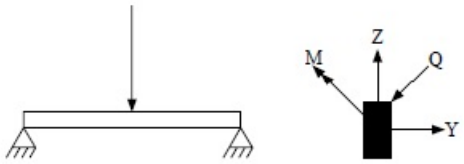


Figure D.3: Stress calculation for single and double symmetric sections

For cross-sections having no axis of symmetry, the stress calculation may be performed by finding the principal axes and then calculating the sectional properties with respect to these axes. Prior to the stress calculation the sectional moment and shear force have to be decomposed into two planes parallel to the principal axes.

In practice, this procedure may be tedious. Expressions for bending and shear stresses in such sections may be written with reference to any arbitrary set of centroidal axes y and z. Provided that a consistent sign convention is followed, the following formulae simplify the numerical calculation of stresses:

$$\sigma_x = \frac{M_z \cdot I_y - M_y \cdot I_{yz}}{I_y \cdot I_z - I_{yz}^2} \cdot y + \frac{M_y \cdot I_z - M_z \cdot I_{yz}}{I_y \cdot I_z - I_{yz}^2} \cdot z \tag{D.1}$$

$$\tau = \frac{Q_y \cdot I_y - Q_z \cdot I_{yz}}{I_y \cdot I_z - I_{yz}^2} \cdot \frac{S_z}{t} + \frac{Q_z \cdot I_z - Q_y \cdot I_{yz}}{I_y \cdot I_z - I_{yz}^2} \cdot \frac{S_y}{t} \tag{D.2}$$

For cross-sections where one or both of the principal axes corresponds to the axes of symmetry, and the sectional moment and shear force are acting in an arbitrary plane, the moment and shear force have to be decomposed into two planes parallel to the principal axes prior to calculating the corresponding stresses. Then the following formulae can be used:

$$\sigma_x = \frac{M_y}{I_y} \cdot z + \frac{M_z}{I_z} \cdot y \tag{D.3}$$

$$\tau = \frac{Q_z \cdot S_y}{I_y \cdot t} + \frac{Q_y \cdot S_z}{I_z \cdot t} \tag{D.4}$$

Framework calculates stresses using the following equations for the following beam section types:

Section	Formulae	Limitation
General	(D.1), (D.2)	
Pipe	(D.3), (D.4)	
I or H	(D.3), (D.4)	Min. one axis of symmetry
Channel	(D.3), (D.4)	
L-section	(D.1), (D.2)	Min. one axis of symmetry
Box	(D.3), (D.4)	Min. one axis of symmetry

All section types that use formulae (D.3) and (D.4) assume that $I_{yz} = 0$. Thus, these section types are valid when there is at least one plane of symmetry.

All section types (GENERAL-section and L-section) that use eqs. (D.1) and (D.2) are valid for sections that have no axis of symmetry (since $I_{yz} \neq 0$). Note that the preprocessor section types I or H or CHANNEL must have at least one axis of symmetry if the stress resultants are to be correctly calculated by Framework. If the preprocessor section type has no axis of symmetry, it should be defined as a GENERAL-section in order for Framework to incorporate the area product of inertia, I_{xy}.

D.2.1.1 The product of inertia for an L-section

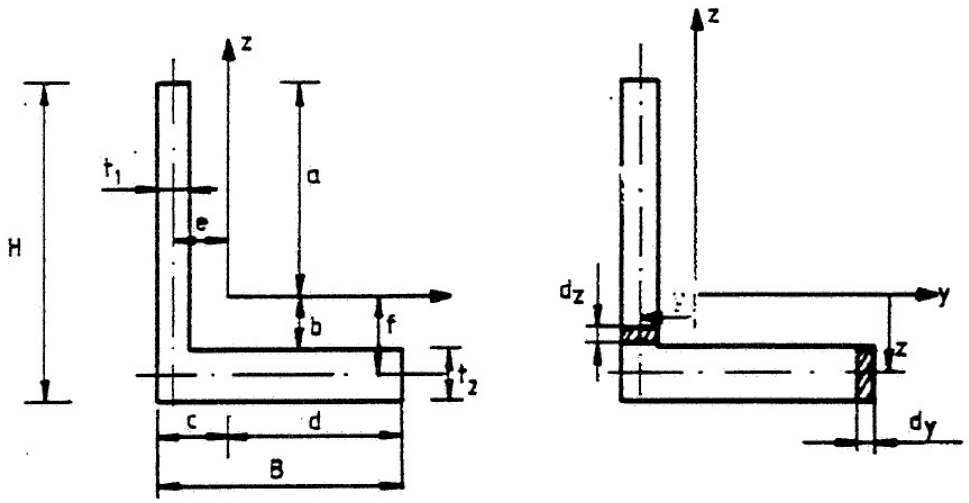


Figure D.4: The product of inertia for an L-section

The following formulae are used to calculate the product of inertia for an L-section:

$$
\begin{aligned}
I_{yz} &= \int_A y \cdot z dA \\
&= -\int_{y=+d}^{y=-c} y \cdot (-f) \cdot t_2 dy + \int_{y=-b}^{y=a} z \cdot (-e) \cdot t_1 dz \\
&= -\left[\frac{-f \cdot t_2}{2} \cdot y^2\right]_{+d}^{-c} + \left[\frac{-e \cdot t_1}{2} \cdot z^2\right]_{-b}^{a} \\
&= -\frac{-f \cdot t_2}{2} \cdot \left(c^2 - d^2\right) + \frac{-e \cdot t_1}{2} \cdot \left(a^2 - b^2\right) \\
I_{yz} &= \frac{f \cdot t_2}{2} \cdot \left(c^2 - d^2\right) - \frac{e \cdot t_1}{2} \cdot \left(a^2 - b^2\right)
\end{aligned}
$$

D.2.2 Twist and shear centre

Framework uses basic flexture theory, that is that plane sections through a beam taken normal to its axis remain plane after the beam is subjected to bending (no twist of plane sections is allowed). The theoretical basis for the shear centre in Framework is based on basic flexture theory.

Equation D.4 in Section D.2.1 for the shear stresses is only valid if the beam does not twist.

This condition is only satisfied if the resulting shear force passes through a definite point, called the centre of twist or the shear centre. The section will rotate for any other position of the resulting shear force.

According to Maxwell's theorem, a pure torsional moment will not produce any translation of the shear centre. Hence, the section will rotate about the shear centre when a torsional moment is applied to the beam. That is why the shear centre is also called the centre of twist.

When the resulting shear force is not acting through the shear centre, the stresses and the deformations have to be calculated by superposition of these two cases:

a) pure bending

b) pure torsion

Open thin-walled sections are often very sensitive to torsional loading. Hence, for these sections it is necessary to include all torsional moments. This can only be done if the position of the shearcenter is known.

Among the sections to be included in Framework, the GENERAL-section and the CHANNEL-section have to be specially considered.

The GENERAL-section shear centre may be specified explicitly in Preframe when it does not coincide with the centre of gravity of the cross section. The theoretical basis for specifying the shear centre of open GENERAL-sections is provided in Section D.2.2.1.

For beams with CHANNEL cross-section, torsional stresses will always appear due to the position of the shear centre. (If the beam is not stiffened). For CHANNEL-sections, the theoretical basis of calculating the shear centre is specified in Section D.2.2.2.

D.2.2.1 Shear centre for an open general section

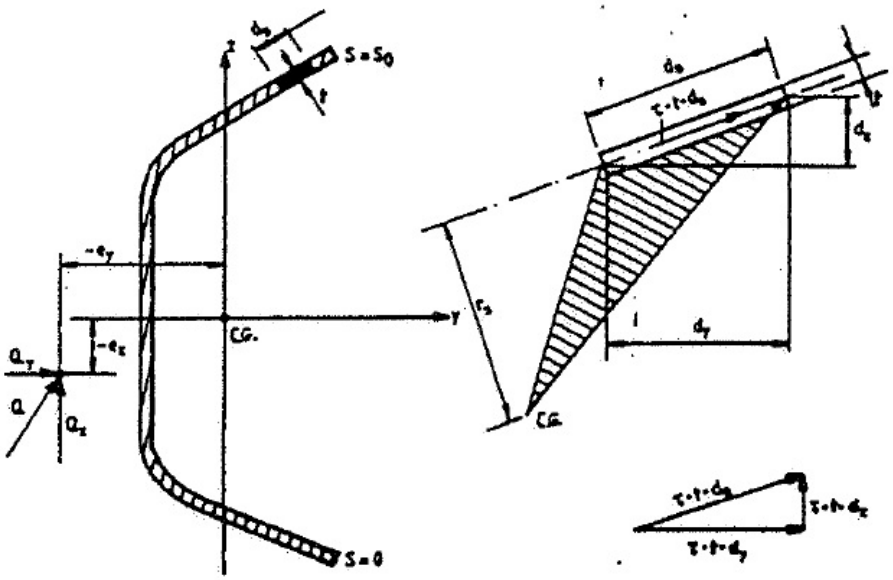


Figure D.5: Shear centre for an open general section

The local x axis of the element goes through the centroid of the cross section. The nodal displacements and consequently the cross sectional constants refer to this axis. The torsional moment of inertia, however, refers to the shear centre. In most beam element theories, the torsional degree of freedom is not coupled to the transversal degrees of freedom. Therefore, when torsion is of importance, the shear centre should either be evaluated and input to Preframe, or the shear centre should coincide with the centroid of the GENERAL-section (this is normally true for closed solid sections).

The open cross-section in Figure D.5 is loaded with a shear force acting through the shear centre. We have yet no information on the direction of the shear force, Q. We assume that the direction is such that the neutral axis coincides with the y axis. Then:

$$\sigma_x = \frac{M_y}{I_y} \cdot z$$

$$\tau = \frac{Q_z \cdot S_y}{I_y \cdot t}$$

To obtain equilibrium between external and internal forces the following conditions have to be satisfied:

$$\int_0^{s_0} \tau \cdot t dy = Q_y$$

$$\int_0^{s_0} \tau \cdot t dz = Q_z$$

$$\int_0^{s_0} \tau \cdot t ds \cdot r_s = -Q_y \cdot (-e_z) + Q_z \cdot (-e_y)$$

Which gives:

$$\int_0^{s_0} \frac{Q_z \cdot S_y}{I_y} \cdot r_s ds = -e_y \cdot \int_0^{s_0} \frac{Q_z \cdot S_y}{I_y} dz + e_z \cdot \int_0^{s_0} \frac{Q_z \cdot S_y}{I_y} dy$$

$$\int_0^{s_0} S_y \cdot r_s ds = -e_y \cdot \int_0^{s_0} S_y dz + e_z \cdot \int_0^{s_0} S_y dy$$

Similarly, if we assume a shear force giving pure bending about the z axis:

$$\int_0^{s_0} S_z \cdot r_s ds = -e_y \int_0^{s_0} S_z dz + e_z \int_0^{s_0} S_z dy$$

S_y and S_z are given by the following expressions:

$$S_y = \int_0^{s_0} z \cdot t ds$$

$$S_z = \int_0^{s_0} y \cdot t ds$$

It can be shown that:

$$r_s \cdot ds = z \cdot dy + dz \cdot dy - (y + dy) \cdot dz = z \cdot dy - y \cdot dz$$

Hence:

$$-e_y \int_0^{s_0} S_y dz + e_z \int_0^{s_0} S_y dy = \int_0^{s_0} S_y \cdot z dy - \int_0^{s_0} S_y \cdot y dz$$

$$-e_y \int_0^{s_0} S_z dz + e_z \int_0^{s_0} S_z dy = \int_0^{s_0} S_z \cdot z dy - \int_0^{s_0} S_z \cdot y dz$$

If y and z are principal axes:

$$\int_0^{s_0} S_y dy = \int_0^{s_0} S_z dz = 0$$

Hence:

$$e_y = \frac{-1}{\int_0^{s_0} S_y \cdot dz} \left[\int_0^{s_0} S_y \cdot z \cdot dy - \int_0^{s_0} S_y \cdot y \cdot dz \right] \tag{D.5}$$

$$e_z = \frac{+1}{\int_0^{s_0} S_z \cdot dy} \left[\int_0^{s_0} S_z \cdot z \cdot dy - \int_0^{s_0} S_z \cdot y \cdot dz \right] \tag{D.6}$$

For GENERAL-sections that are open and are not bisymmetric, formulae D.5 and D.6 should be evaluated and input as the deviation of the shear centre from the centroid in Preframe. This should be performed for open and thin non-bisymmetric sections that are sensitive to torsional loading. In addition, the user should input

the shear area in Preframe if the shear centre does not coincide with the centroid. For GENERAL-sections that are solid, the centroid of the section can be used as the shear centre, thus formulae D.5 and D.6 need not be evaluated for input into Preframe.

For cases where twist is a concern (very thin open sections), the user should model the member using shell elements, and assess the shear components in the finite-element post-processing.

D.2.2.2 Shear centre for a channel section with one axis of symmetry

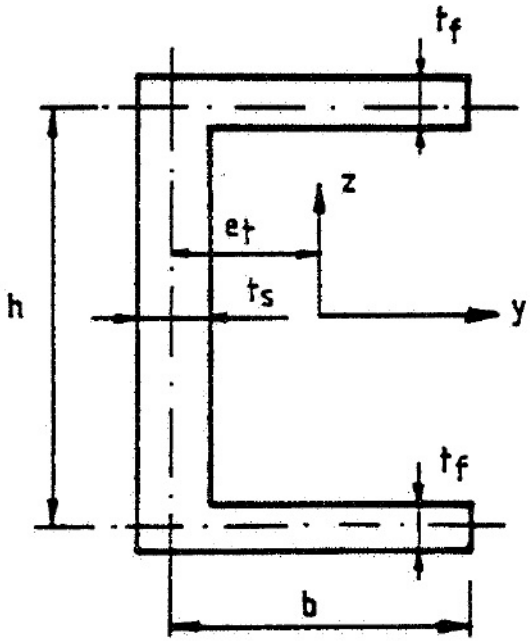


Figure D.6: Shear centre for a channel section with one axis of symmetry

Framework will use the following method to automatically calculate the shear centre for CHANNEL-sections with one axis of symmetry. If the CHANNEL-section has no axis of symmetry, it should be modelled as a GENERAL-section in Preframe, and the user should calculate the shear centre according to Section D.2.2.1.

The shear centre calculation method is based on equations D.5 and D.6 from Section D.2.2.1 which read

$$e_y = \frac{-1}{\int_0^{s_0} S_y \cdot dz} \left[\int_0^{s_0} S_y \cdot z \cdot dy - \int_0^{s_0} S_y \cdot y \cdot dz \right] \tag{D.5}$$

$$e_z = \frac{+1}{\int_0^{s_0} S_z \cdot dy} \left[\int_0^{s_0} S_z \cdot z \cdot dy - \int_0^{s_0} S_z \cdot y \cdot dz \right] \tag{D.6}$$

If there is symmetry about the y-axis, then $e_z = 0$ (see equation D.6), see also Figure D.6.

Rule (only the first one is used for CHANNEL-sections):

- The shear centre will always lie in the symmetry line for cross-sections with one axis of symmetry.
- The shear centre will coincide with the centre of gravity when analyzing double symmetrical cross-sections.

Static moments:

S_y

1. Web:

$$S_y = t_f \cdot b \cdot \frac{h}{2} + \left(\frac{h^2}{4} - z^2\right) \cdot \frac{t_s}{2}.$$

2. Flange:

$$S_y = t_f \cdot (b - e_t - y) \cdot \frac{h}{2}.$$

S_z

1. Web:

$$S_z = t_f \cdot b \cdot \left(\frac{b}{2} - e_t\right) + \left(\frac{h}{2} - z\right) \cdot (-e_t) \cdot t_s.$$

2. Flange:

$$S_z = t_f \cdot (b - e_t - y) \cdot \left(\frac{b - e_t - y}{2} + y\right) = \frac{t_f}{2} \cdot \left((b - e_t)^2 - y^2\right).$$

The distribution of shear stresses calculated by the above formulae (sett inn referanse) is shown in Figure D.7.

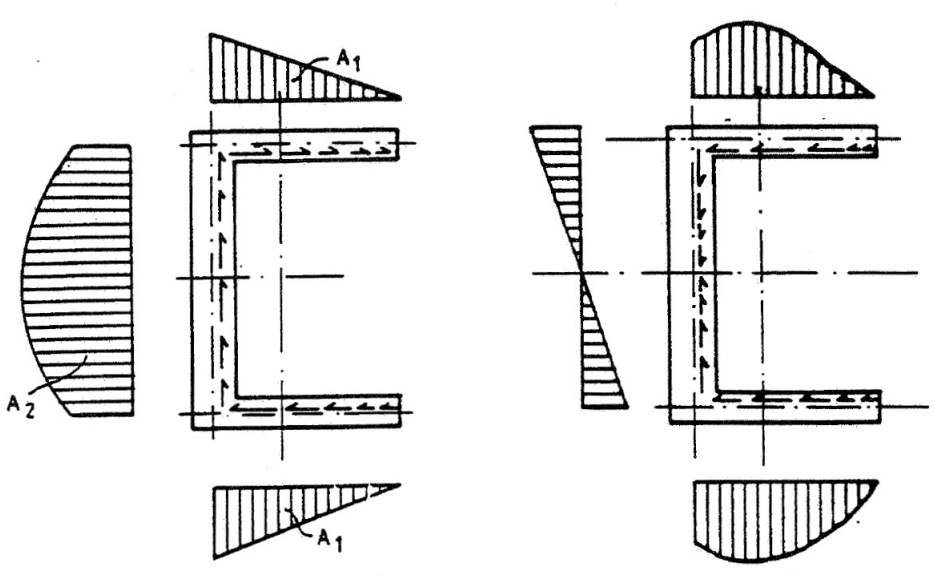


Figure D.7: Shear distribution for a channel section with one axis of symmetry

Next, the formulae for the shear centre of a channel section with one axis of symmetry is derived. The $y = e_y$ co-ordinate of the shear centre is given by D.5 which reads

$$y = e_y = \frac{-1}{\int_0^{s_0} S_y \cdot dz} \left[\int_0^{s_0} S_y \cdot z \cdot dy - \int_0^{s_0} S_y \cdot y \cdot dz\right] \tag{D.5}$$

In turn, we evaluate the integrals of D.5 and end at a closed form for the $y = e_y$ co-ordinate.

1. The integral $\int_0^{s_0} S_y \cdot z \cdot dy$ for $z = \frac{h}{2}$

$$\begin{aligned}\int_0^{s_0} S_y \cdot z \cdot dy &= -2 \cdot \int_{b-e_t}^{e_t} S_y \cdot z \cdot dy = -h \cdot \int_{b-e_t}^{e_t} S_y \cdot dy \\ &= -\frac{t_f \cdot h^2}{2} \cdot \int_{b-e_t}^{e_t} (b - e_t - y) \cdot dy = -\frac{t_f \cdot h^2}{2} \cdot \left[(b-e_t) \cdot y - \frac{1}{2} \cdot y^2\right]_{b-e_t}^{e_t} \\ &= -\frac{t_f \cdot h^2}{2} \cdot \left[(-1) \cdot (b-e_t) \cdot e_t - \frac{1}{2} \cdot e_t^2 - \frac{1}{2}\left(b^2 - 2 \cdot b \cdot e_t + e_t^2\right)\right] \\ &= \frac{t_f \cdot h^2}{2} \cdot \frac{b^2}{2} = \frac{t_f \cdot b^2 \cdot h}{4} \cdot h = A_1 \cdot h.\end{aligned}$$

I.e.

$$A_1 = \frac{t_f \cdot b^2 \cdot h}{4}. \tag{D.7}$$

2. The integral $\int_0^{s_0} S_y \cdot dz$

$$\begin{aligned}A_2 &= \int_0^{s_0} S_y \cdot dz = \int_{-\frac{h}{2}}^{-\frac{h}{2}} \left(t_f \cdot b \cdot \frac{h}{2} + \left(\frac{h^2}{4} - z^2\right) \cdot \frac{t_s}{2}\right) \cdot dz \\ &= \int_{-\frac{h}{2}}^{-\frac{h}{2}} \left(t_f \cdot b \cdot \frac{h}{2} + \frac{h^2}{4} \cdot \frac{t_s}{2} - \frac{z^2 \cdot t_s}{2}\right) \cdot dz = \left[t_f \cdot b \cdot \frac{h}{2} \cdot z + \frac{h^2}{4} \cdot \frac{t_s}{2} \cdot z - \frac{z^3 \cdot t_s}{6}\right]_{-\frac{h}{2}}^{+\frac{h}{2}} \\ &= \left[t_f \cdot b \cdot \frac{h}{2} \cdot \frac{h}{2} + \frac{h^2}{4} \cdot \frac{t_s}{2} \cdot \frac{h}{2} - \frac{h^3 \cdot t_s}{48}\right] - \left[-t_f \cdot b \cdot \frac{h}{2} \cdot \frac{h}{2} - \frac{h^2}{4} \cdot \frac{t_s}{2} \cdot \frac{h}{2} + \frac{h^3 \cdot t_s}{48}\right] \\ &= \frac{t_f \cdot b \cdot h^2}{2} + \frac{t_s \cdot h^3}{8} - \frac{t_s \cdot h^3}{24} = \frac{t_f \cdot b \cdot h^2}{2} + \frac{t_s \cdot h^3}{12} = \frac{t_f \cdot b \cdot h^2}{2}\left(1 + \frac{1}{6} \cdot \frac{t_s}{t_f} \cdot \frac{h}{b}\right).\end{aligned}$$

I.e.

$$A_2 = \frac{t_f \cdot b \cdot h^2}{2}\left(1 + \frac{1}{6} \cdot \frac{t_s}{t_f} \cdot \frac{h}{b}\right). \tag{D.8}$$

3. The integral $\int_0^{s_0} S_y \cdot y \cdot dz$ for $y = -e_t$

$$\int_0^{s_0} S_y \cdot y \cdot dz = -e_t \cdot \int_0^{s_0} S_y \cdot dz = -e_t \cdot A_2.$$

Thus we end at

$$e_y = -\frac{1}{A_2}\left(A_1 \cdot h + A_2 \cdot e_t\right) = -e_t - \frac{A_1}{A_2} \cdot h,$$

where

$$A_1 = \frac{t_f \cdot b^2 \cdot h}{4} \tag{D.7}$$

$$A_2 = \frac{t_f \cdot b \cdot h^2}{2}\left(1 + \frac{1}{6} \cdot \frac{t_s}{t_f} \cdot \frac{h}{b}\right) \tag{D.8}$$

The formula for e_y then becomes

$$e_y = -e_t - e = -e_t - \frac{A_1}{A_2} \cdot h = -e_t - \frac{b}{2\left(1 + \frac{1}{6} \cdot \frac{t_s}{t_f} \cdot \frac{h}{b}\right)} = -e_t - \frac{3 \cdot b^2}{6 \cdot b + \frac{t_s}{t_f} \cdot h}. \tag{D.9}$$

If $t_s = t_f$, then the e-term of formula D.9 reads

$$e = \frac{3 \cdot b^2}{6 \cdot b + \frac{t_s}{t_f} \cdot h} = \frac{3 \cdot b^2}{6 \cdot b + h},$$

which coincide with the formula for e in Table 10.2 of Roark's Formulas for Stress and Strain [99]. See also Figure D.8.

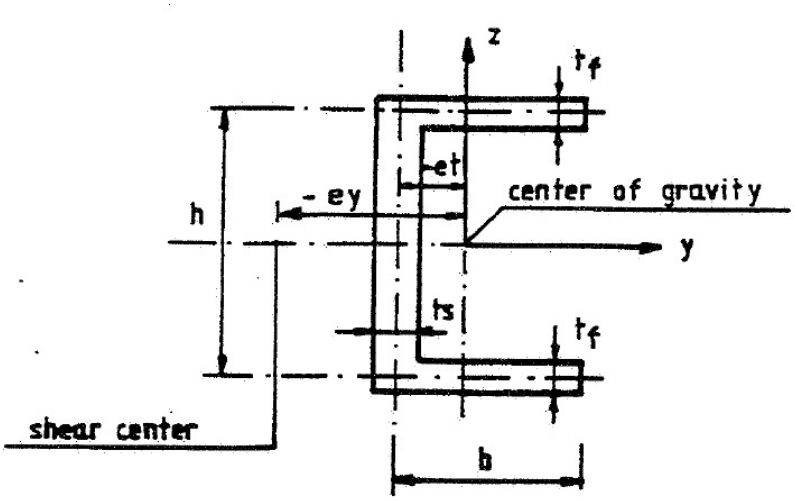


Figure D.8: Shear centre for a channel section with one axis of symmetry

D.2.3 Concentrated loads

Theoretically, under the point of application of a concentrated load, the fiber stress is infinite. However, in actual structures there are no concentrated loads, but the loads are distributed over a very small length along the span. High local bearing stresses will be introduced, and the distribution of the local bending and shear stresses differs considerably from the conventional $\frac{M}{I} \cdot \eta$ and $\frac{Q \cdot S}{t \cdot I}$ stresses. However, the stresses at a distance approximately equal to the depth of the beam agree very well with the conventional theory. The stress concentration due to local loads in I-shaped beams can be decreased by using load-bearing stiffeners which transmit the concentrated load to the web by shears distributed along the web depth.

Assumptions in Framework:

1. The stresses are assumed to be in accordance with conventional theory for all sections over the beam length.
2. Local bearing stresses are not accounted for.

To account for the uncertainty related to stress calculation at a section adjacent to the point of load application, a factor of safety against local yielding of a plate element subjected to normal and shear stresses may be defined with reasonable accuracy by the Hencky-von Mises criterion:

$$\sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau^2} = \frac{\sigma_y}{n},$$

where

σ_y	tensile yield strength of the plate

D.2.4 Tapered beams

The application of simple formulas established for stresses in beams of constant cross section to tapered beams may indicate values appreciably different from actual stresses. It is not possible to establish simple stress-distribution formulas for the general case of tapered beams, thus these beams cannot be evaluated in Framework.

An approximate method for determining stresses in a tapered beam is based on a modification of the conventional formulas. This method gives results that are satisfactory provided the angle $2 \cdot \alpha$ is less than 45 degrees. For such sections, a simple method of hand calculating the axial and shear stresses is provided.

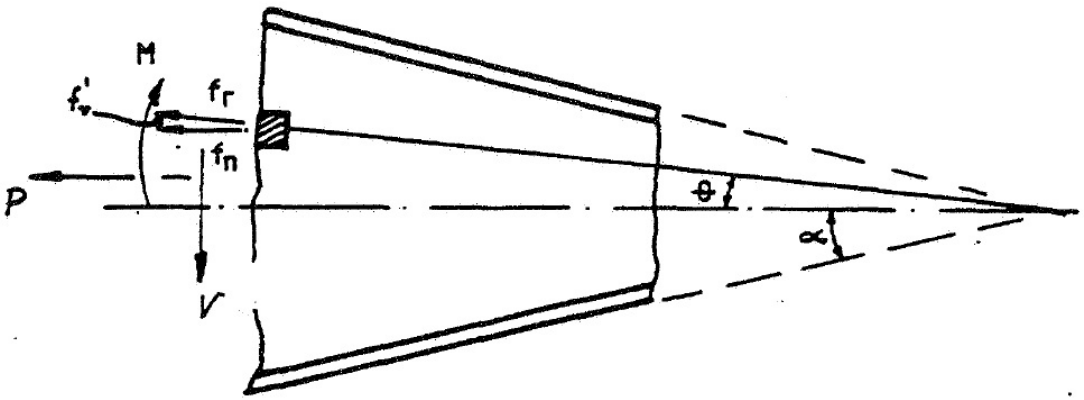


Figure D.9: Tapered section

$$f'_v = f_n \cdot \tan\theta$$

$$f_r = \frac{f_n}{\cos\theta}$$

$$f_n = \frac{P}{A} \pm \frac{M \cdot y}{I}$$

$$V' = \int f'_v dA \quad \text{(does not necessarily balance } V\text{)}$$

$$V" = V' - V \quad \text{(must be resisted by tangential shear stresses)}$$

$$f_v" = \frac{V" \cdot Q}{I \cdot t}$$

D.3 Sign convention of internal stress resultants

The element forces and moments are calculated and may be printed at the midpoint and at the ends of the element. Definitions of signs of forces and moments are given in Figures D.10 through D.17. Note that the shear forces and the torsional moment refer to the axis through the shear centre, and the axial forces and the bending moments refer to the axis through the centre of gravity.

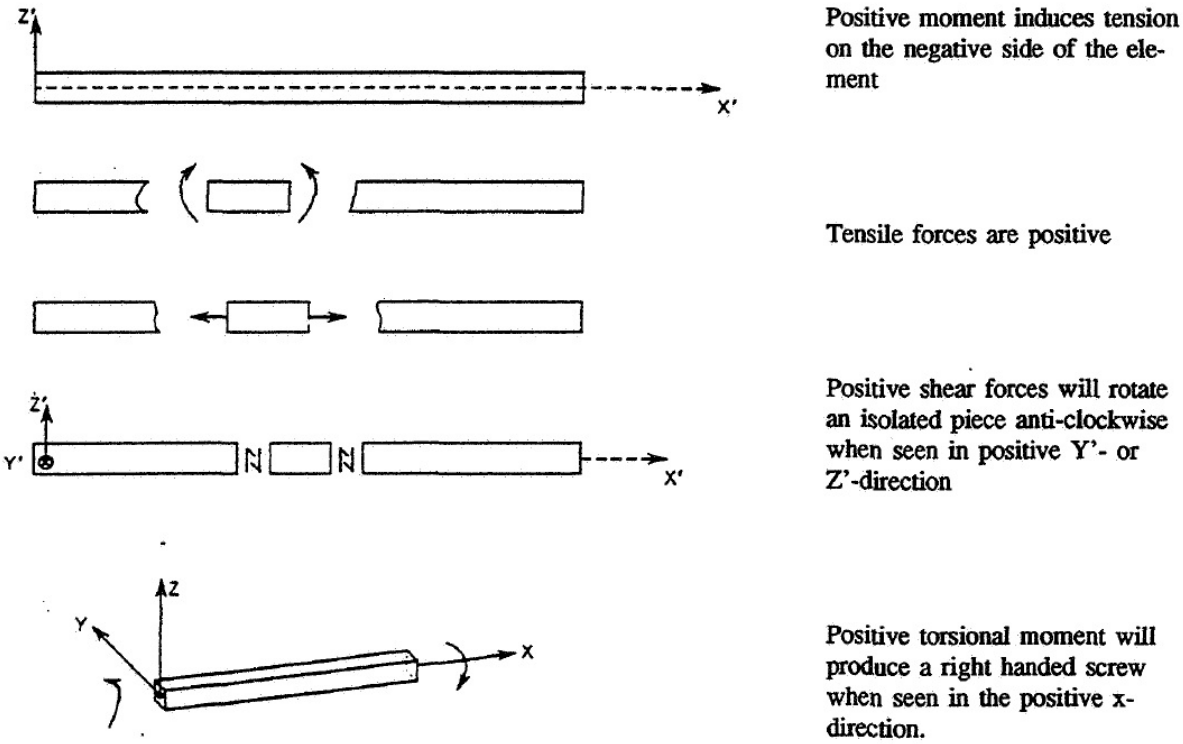


Figure D.10: Definition of sign of moments and forces of a beam element

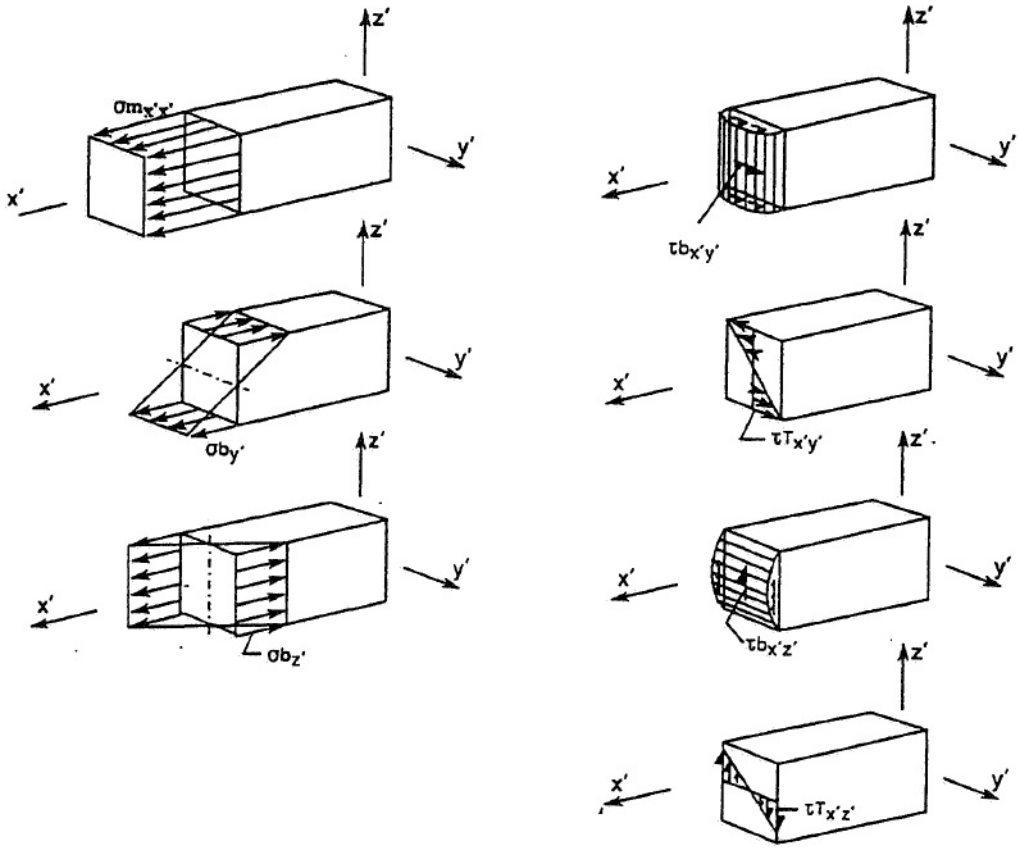


Figure D.11: Stresses in a segment of a beam element in the local axis system

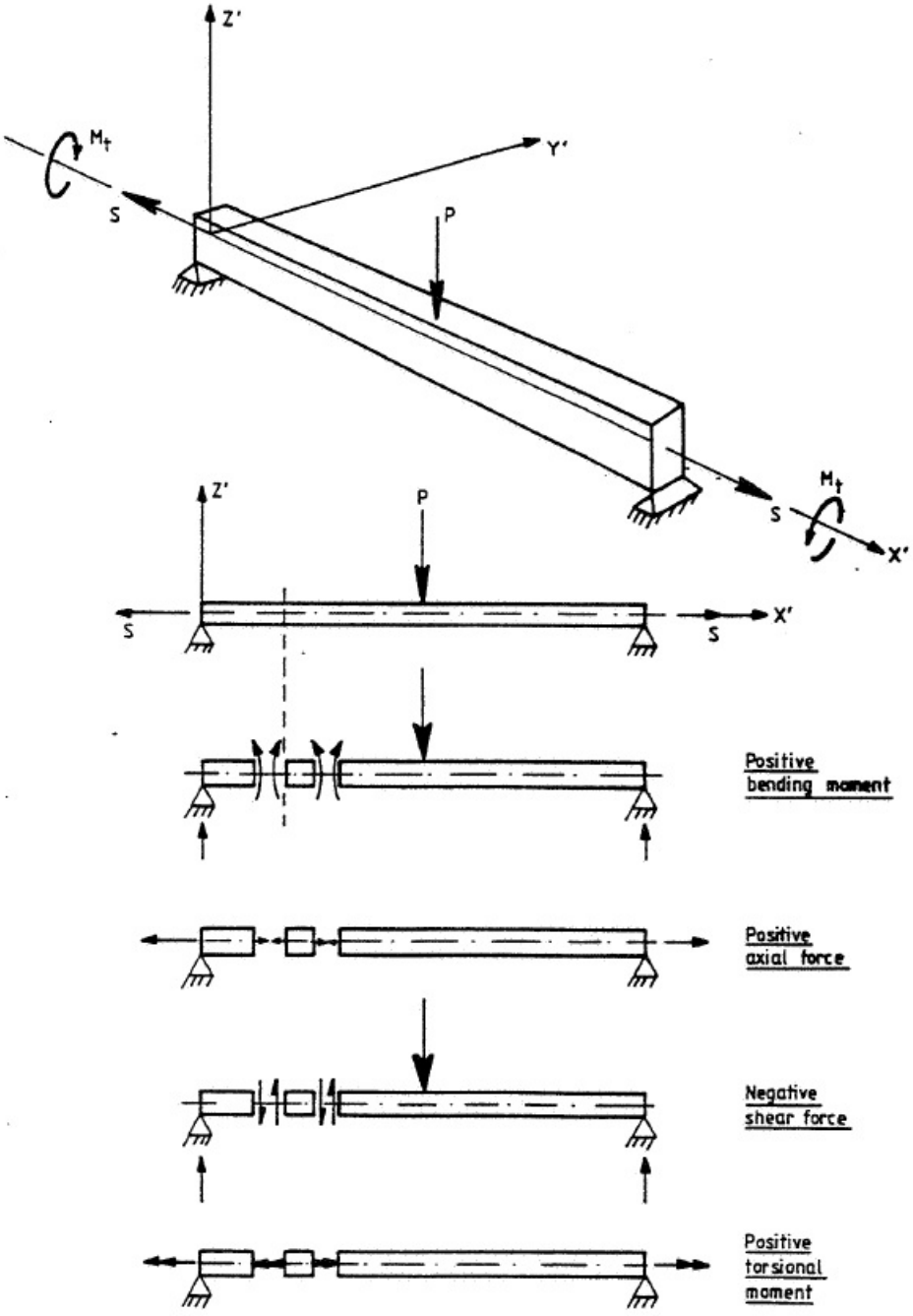


Figure D.12: Sign convention for typical stress resultants

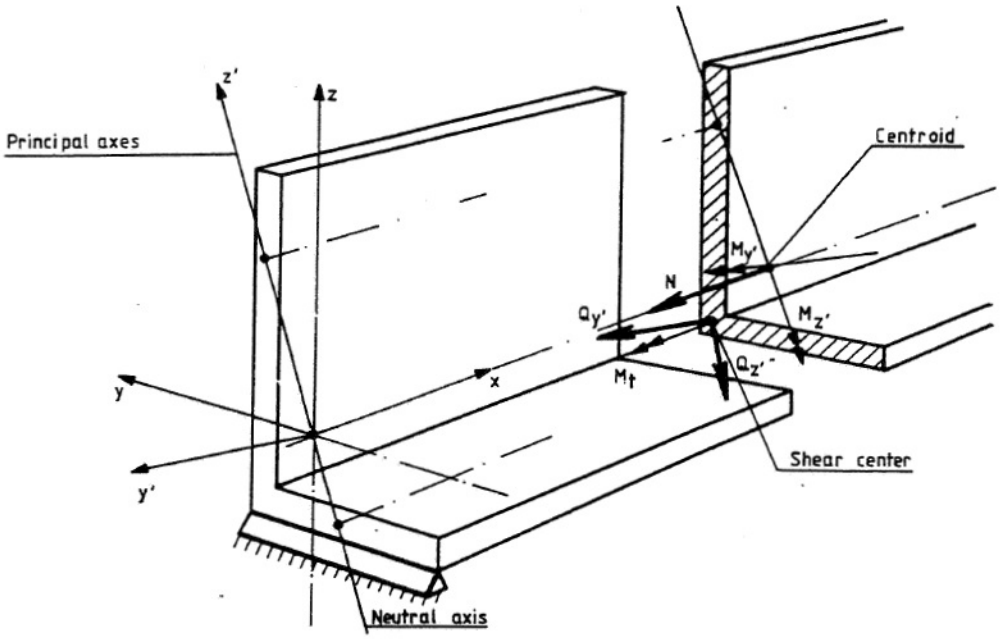


Figure D.13: Sign convention for stress resultants

The stress resultants N, Q_y, Q_z, M_t, M_y, and M_z are defined positive when acting as shown. (See also the Sestra User's manual [32].)

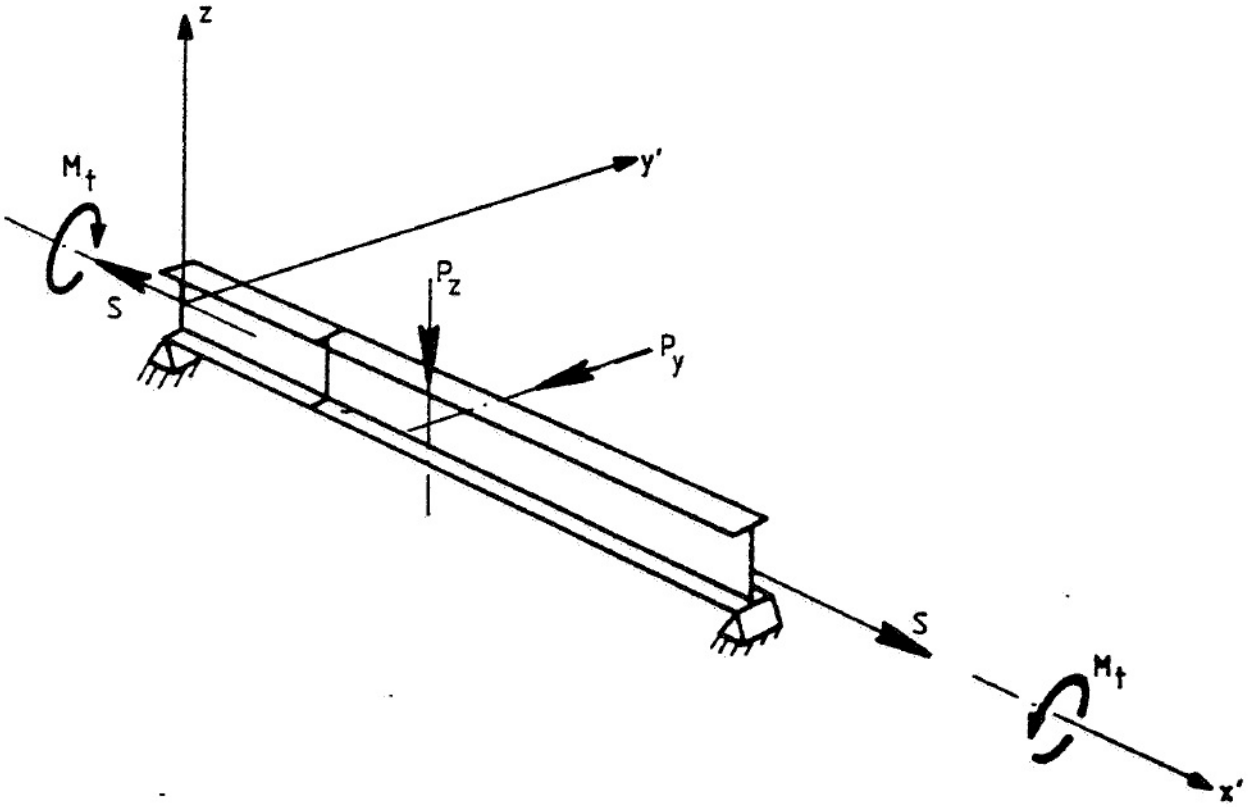


Figure D.14: Co-ordinate system for an element

Positive stresses are tensile stresses.
Negative stresses are compressive stresses.

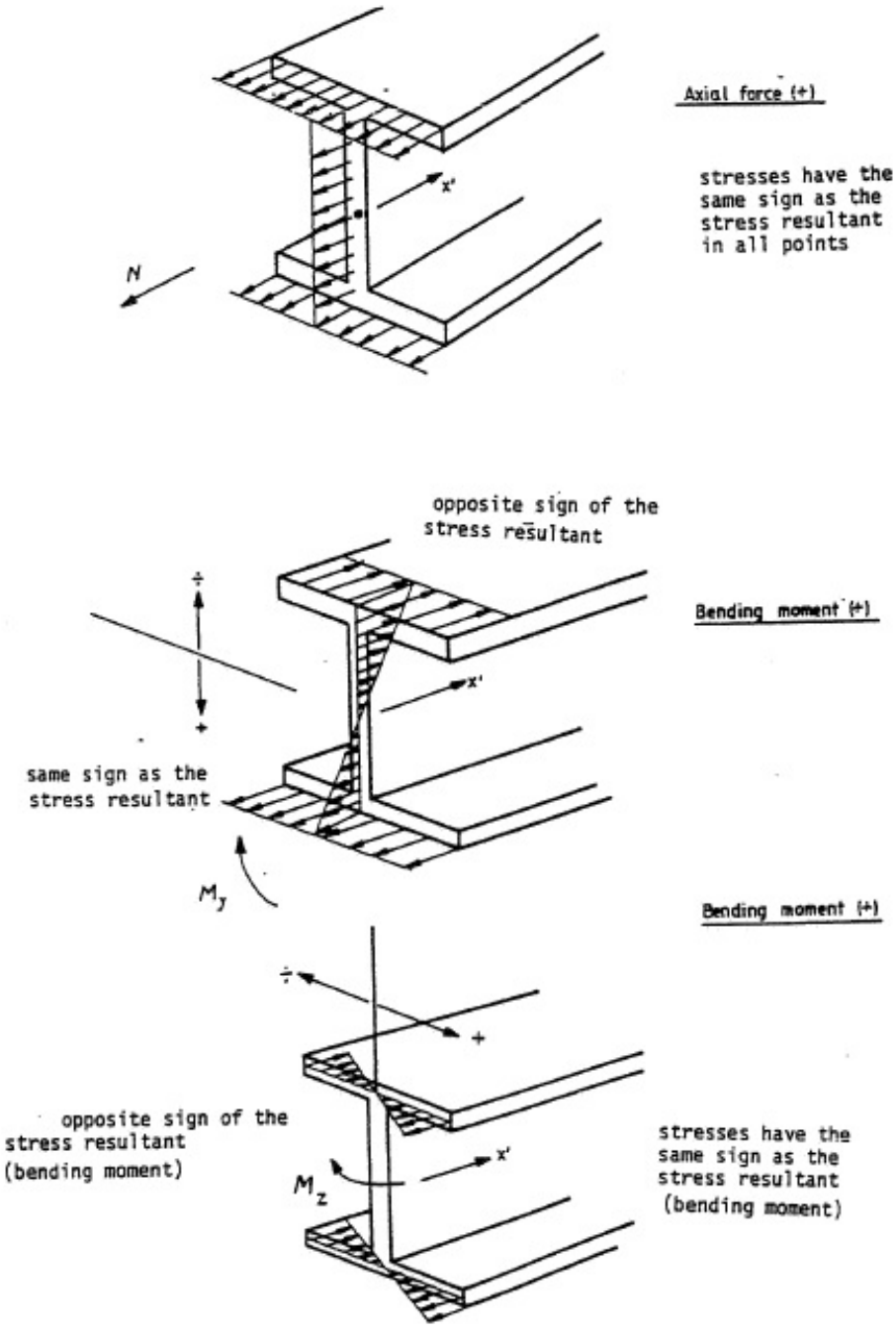


Figure D.15: Sign convention for axial- and bending stresses

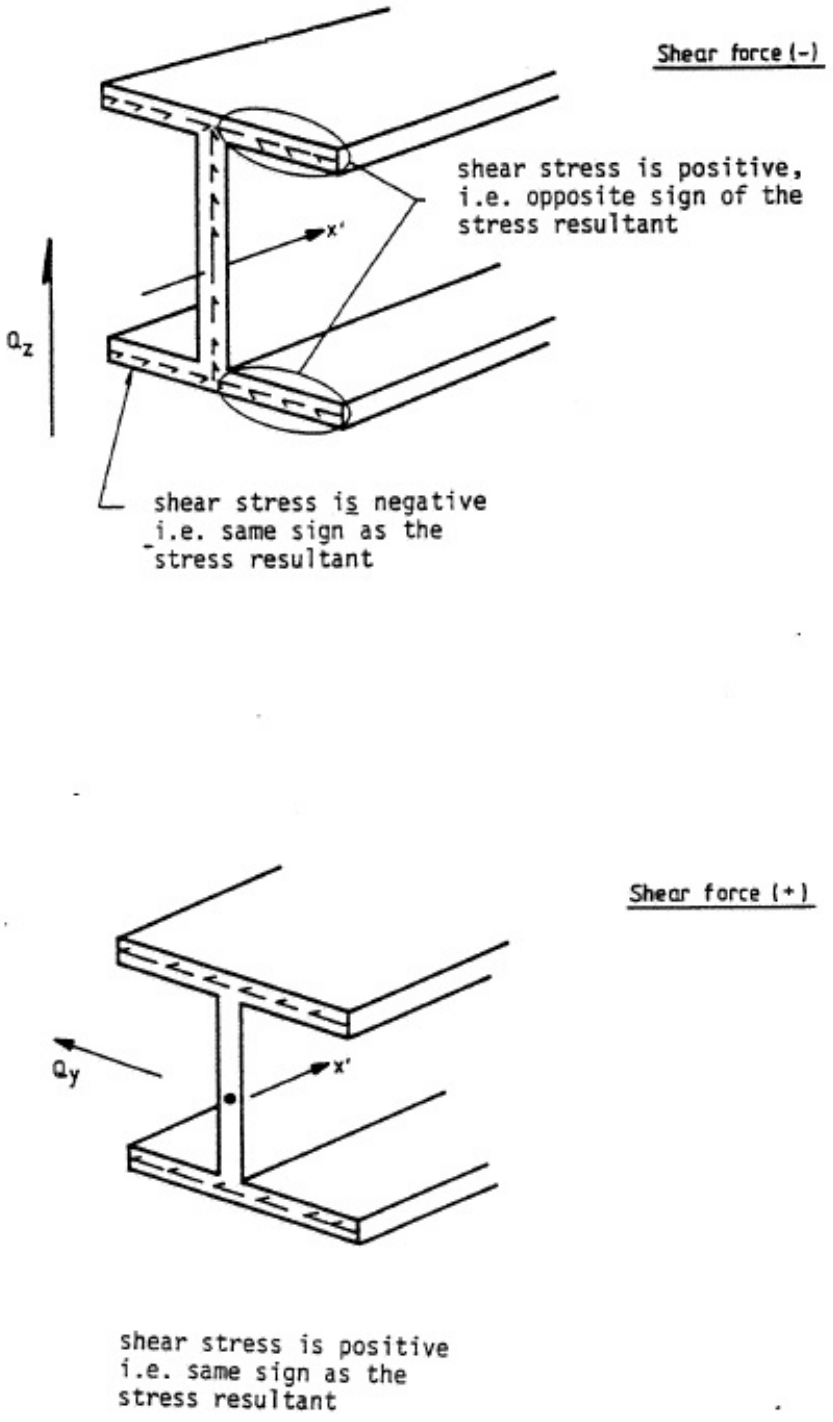


Figure D.16: Sign convention for shear stresses

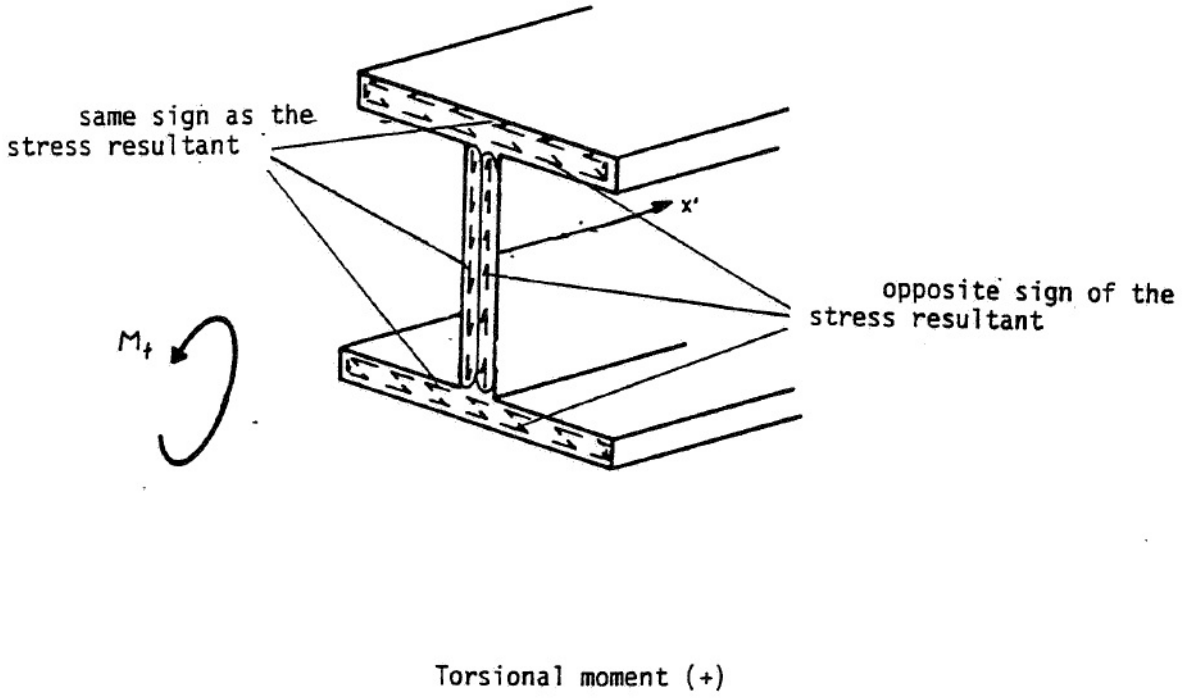


Figure D.17: Sign convention for torsional shear stresses

D.4 Calculation of maximum stress components

For all cross-section types maximum stress components are calculated according to the following formulae:

$$\text{SIG(PX)} = \frac{\text{PX}}{\text{AREA}}$$
$$\text{TAU(PY)} = \frac{\text{PY}}{\text{SHARY}}$$
$$\text{TAU(PZ)} = \frac{\text{PZ}}{\text{SHARZ}}$$
$$\text{TAU(MX)} = \frac{\text{MX}}{\text{WXMIN}}$$
$$\text{SIG(MY)} = \frac{\text{MY}}{\text{WYMIN}}$$
$$\text{SIG(MZ)} = \frac{\text{MZ}}{\text{WZMIN}}$$

where

PX	Axial force
PY	Shear force in y-direction
PZ	Shear force in z-direction
MX	Torsional moment
MY	Bending moment about the y-axis
MZ	Bending moment about the z-axis
AREA	Cross-sectional area
SHARY	Effective shear area in y-direction
SHARZ	Effective shear area in z-direction
WXMIN	Minimum torsional modulus

WYMIN	Minimum section modulus about the y-axis
WZMIN	Minimum section modulus about the z-axis

The y-axis and z-axis referred to above are the local axes.

The shear force resultants, PY, PZ, and MX are with respect to the shear center. The other force resultants, PX, MY, and MZ are about the principal axis of the cross section.

D.4.1 General explanation of stress output

The stress printout is as follows:

1. Static load case:
   - Maximum equivalent stress and its hot spot identification
   - Maximum normal stress and its hot spot identification
   - Maximum normal stress and the maximum equivalent stress will be printed. The maximum normal stress is defined as $\sigma_{PX} + \sigma_{MY} + \sigma_{MZ}$ for each hot spot. Only the hot spot with the highest normal stress is printed.
   - Individual stress components will not add up to the maximum equivalent stress. Rather, stress components are maximum (that is, different stress components will most likely occur at different hot spots)
2. Quasi-static or dynamic load case:
   - Maximum equivalent stress with the corresponding phase angle (in degrees) and its hot spot identification.
   - Maximum normal stress with the corresponding phase angle (in degrees) and its hot spot identification.
   - The individual stress components correspond to the maximum equivalent (or normal) stress.
   - The user may identify a set of phase angles (in degrees) for which individual stress components and the corresponding equivalent and normal stresses with hot spot identification will be printed.
   - General beam normal (but not equivalent) stresses can be printed.
3. Dynamic (or quasi static) + static load combination:
   - Maximum equivalent stress for the load combination with the corresponding phase angle (in degrees) and its hot spot identification.
   - Maximum normal stress for the load combination with the corresponding phase angle (in degrees) and its hot spot identification.
   - The individual stress components correspond to the maximum equivalent (or normal) stress.
   - The user may identify a set of phase angles for which individual stress components and the corresponding equivalent and normal stresses with hot spot identification will be printed.
   - General beam normal (but not equivalent) stresses can be printed.

D.4.2 Notation and basic formulae

The normal and shear stresses are as follows:

σ_s	= static normal stress
τ_s	= static shear stress
σ_{dr}	= dynamic normal stress, real part
σ_{di}	= dynamic normal stress, imaginary part
τ_{dr}	= dynamic shear stress, real part

τ_{di} = dynamic shear stress, imaginary part
θ = phase angle

Normal stress components are calculated as follows:

$$\sigma_s = \sigma_{x_s} + \sigma_{M_{y_s}} + \sigma_{M_{z_s}}$$
$$\sigma_{d_r} = \sigma_{x_r} + \sigma_{M_{y_r}} + \sigma_{M_{z_r}}$$
$$\sigma_{d_i} = \sigma_{x_i} + \sigma_{M_{y_i}} + \sigma_{M_{z_i}}$$

Shear stress components are calculated as follows:

Pipes:

$$\tau_s = \tau_{M_{x_s}} + \tau_{y_s} + \tau_{z_s}$$
$$\tau_{d_r} = \tau_{M_{x_r}} + \tau_{y_r} + \tau_{z_r}$$
$$\tau_{d_i} = \tau_{M_{x_i}} + \tau_{y_i} + \tau_{z_i}$$

Boxes:

$$\tau_s = \pm\tau_{M_{x_s}} + \tau_{y_s} + \tau_{z_s}$$
$$\tau_{d_r} = \pm\tau_{M_{x_r}} + \tau_{y_r} + \tau_{z_r}$$
$$\tau_{d_i} = \pm\tau_{M_{x_i}} + \tau_{y_i} + \tau_{z_i}$$

Remaining sections (except GENERAL):

$$\tau_s = \mid \tau_{M_{x_s}} \mid + \mid \tau_{y_s} + \tau_{z_s} \mid$$
$$\tau_{d_r} = \pm \left[\mid \tau_{M_{x_r}} \mid + \mid \tau_{y_r} + \tau_{z_r} \mid \right]$$
$$\tau_{d_i} = \pm \left[\mid \tau_{M_{x_i}} \mid + \mid \tau_{y_i} + \tau_{z_i} \mid \right]$$

τ_{d_r} and τ_{d_i} will depend on the sign of $\tau_y + \tau_z$.

GENERAL sections:

The stress output is identical to that stated in Section D.4.1. However, shear stresses can be evaluated with more flexibility, as indicated in Section D.5.

D.4.3 Formulae used for static load cases

Equivalent stress for pipes:

$$\sigma_e = \sqrt{\sigma_s^2 + \sigma_h^2 - \sigma_s \cdot \sigma_h + 3 \cdot \tau_s^2},$$

where σ_h is the hoop stress due to hydrostatic pressure. σ_h is positive as tension.

Equivalent stress for non-pipes:

$$\sigma_e = \sqrt{\sigma_s^2 + 3 \cdot \tau_s^2}.$$

Normal stress:

$$\sigma_n = \sigma_s.$$

D.4.4 Formulae used for dynamic load cases

Equivalent stress:

$$\sigma_e = \sqrt{\left(\sigma_{d_r} \cdot \cos\theta + \sigma_{d_i} \cdot \sin\theta\right)^2 + 3 \cdot \left(\tau_{d_r} \cdot \cos\theta + \tau_{d_i} \cdot \sin\theta\right)^2},$$

where

θ - stepped by 10 degrees from $0°$ to $360°$.

Normal stress:

$$\sigma_n = \sqrt{\sigma_{d_r}^2 + \sigma_{d_i}^2},$$
$$\theta = \arctan\left(\frac{\sigma_{d_i}}{\sigma_{d_r}}\right).$$

D.4.5 Formulae used for combined load cases

Equivalent stress for pipes:

$$\sigma_e = \sqrt{\left(\sigma_s + \sigma_{d_r} \cdot \cos\theta + \sigma_{d_i} \cdot \sin\theta\right)^2 + \sigma_h^2 - \sigma_h\left(\sigma_s + \sigma_{d_r} \cdot \cos\theta + \sigma_{d_i} \cdot \sin\theta\right) + 3 \cdot \left(\tau_s + \tau_{d_r}\cos\theta + \tau_{d_i} \cdot \sin\theta\right)^2},$$

where

θ - stepped by 10 degrees from $0°$ to $360°$.

Equivalent stress for non-pipes:

$$\sigma_e = \sqrt{\left(\sigma_s + \sigma_{d_r} \cdot \cos\theta + \sigma_{d_i} \cdot \sin\theta\right)^2 + 3 \cdot \left(\tau_s + \tau_{d_r} \cdot \cos\theta + \tau_{d_i} \cdot \sin\theta\right)^2}$$

Normal stress:

$$\sigma_n = \sigma_s \pm \sqrt{\sigma_{d_r}^2 + \sigma_{d_i}^2},$$

$+$ or $-$ depending on the value of σ_s. The maximum of the absolute value is calculated.

$$\theta = \arctan\left(\frac{\sigma_{d_i}}{\sigma_{d_r}}\right).$$

D.5 General section stresses

GENERAL sections can either be defined in Preframe or in Framework.

For a Preframe specified GENERAL section, by default – four extreme points ($\pm\frac{I_y}{W_y}$, $\pm\frac{I_z}{W_z}$) are used as the four hot spots in Framework. The user may assign other hot spots than the default values, thus overriding the default condition. For example, the unsymmetrical I-beam in Figure D.18 could be defined in Preframe as a general section. In evaluating stresses in Framework, the default hot spots (1, 2, 3, 4) will be used. The user may activate/deactivate individual hot spots.

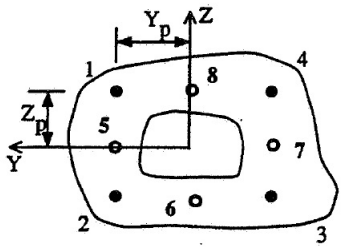


Figure D.18: Cross section axis and “hot-spots" for a hypotetical general section

The shear stresses are combined as follows:

$$\text{TAU} = \text{TAUPY} + \text{TAUPZ} + \text{TAUMX}.$$

In the aforementioned shear combination, the program uses the following:

$$\text{TAUPY} = \text{UFACY} \cdot \frac{F_y}{A_{\text{shear},y}}$$
$$\text{TAUPZ} = \text{UFACZ} \cdot \frac{F_z}{A_{\text{shear},z}}$$

where

UFACY - shear multiplication factor in y-direction

UFACZ - shear multiplication factor in z-direction

D.6 Calculation of equivalent stresses

Equivalent stresses are calculated in a number of predefined points for the following cross section types:

- Pipe elements (PIPE)
- Wide flange elements (IORH)
- Channel elements (CHAN)
- Box elements (BOX)
- General elements (GENE)

Equivalent stresses are calculated according to (von Mises):

$$\sigma_e = \sqrt{\sigma_x^2 + 3 \cdot \tau^2}.$$

With $\sigma_x = \sigma_a + \sigma_b$, σ_a and σ_b being normal stresses caused by axial and bending forces respectively. Hoop stresses due to hydrostatic pressure is included in the von Mises stress check for pipe members.

D.6.1 Equivalent stresses in a pipe element

The equivalent stresses are calculated in 24 points around the pipe section as shown in Figure D.19.

For calculation of stresses the following formula is used:

$$\sigma_e = \sqrt{\sigma^2 + \sigma_h^2 - \sigma \cdot \ \sigma_h + 3 \cdot \tau^2},$$

where

$$\begin{aligned} \sigma &= \sigma(P_x) - \sigma(M_y) \cdot \sin\alpha - \sigma(M_z) \cdot \cos\alpha, \\ \tau &= \tau(M_x) + \tau(P_y) \cdot \sin\alpha + \tau(P_z) \cdot \cos\alpha, \end{aligned}$$

and σ_h is the hoop stress due to external hydrostatic pressure. σ_h is positive as tension. The phase angle α may be user defined. The default phase angles are $\alpha = 0°, 15°, 30°, 45°, \ldots, 345°$ corresponding to 24 hot spots.

See Figure D.10 for sign convention of internal stress resultants.

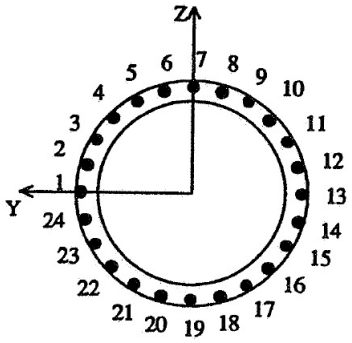


Figure D.19: Predefined points for stress calculations of pipe sections

D.6.2 Equivalent stresses in I- or H-beams

The stresses are calculated in the 13 predefined points as shown on Figure D.20.

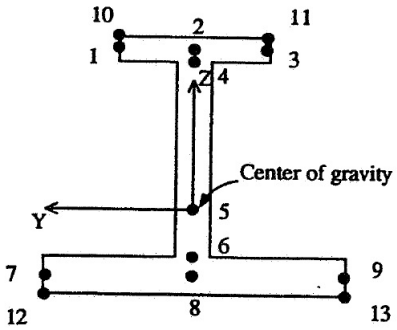


Figure D.20: Predefined points for stress calculations of I- or H sections

The wide flange section is assumed to be symmetrical about the z-axis. The axes y and z are principal axes and the following simple stress formulas are used:

$$\sigma_b = -\frac{M_z}{I_z} \cdot y - \frac{M_y}{I_y} \cdot z,$$
$$\tau = \frac{Q_z \cdot S_y}{I_y \cdot t} + \frac{Q_y \cdot S_z}{I_z \cdot t}.$$

Von Mises equivalent stress in position 2 is calculated by approaching along the flange in the first quadrant, along the flange in the second quadrant, and along the web. The maximum value is selected and printed. The same procedure is followed when calculating von Mises equivalent stress in position 8.

The stress calculations are related to the center lines.

D.6.3 Equivalent stresses in channel elements

Equivalent stresses are calculated in the 11 predefined point as shown in Figure D.21.

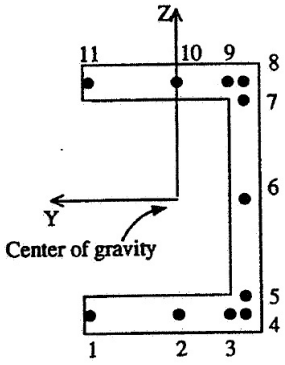


Figure D.21: Predefined points for stress calculations of channel sections

For this section it is assumed that the thickness of the upper flange is equal to the thickness of the lower flange. Hence, the section is symmetrical about the y-axis. The axes y and z are principal axes and the following simple stress formulas are used:

$$\sigma_b = -\frac{M_z}{I_z} \cdot y - \frac{M_y}{I_y} \cdot z,$$
$$\tau = \frac{Q_z \cdot S_y}{I_y \cdot t} + \frac{Q_y \cdot S_z}{I_z \cdot t}.$$

The effect of corners on torsional shear stresses is neglected.

The stress calculations are related to the center lines.

D.6.4 Equivalent stresses in box elements

Equivalent stresses are calculated in the 16 points as shown in Figure D.22.

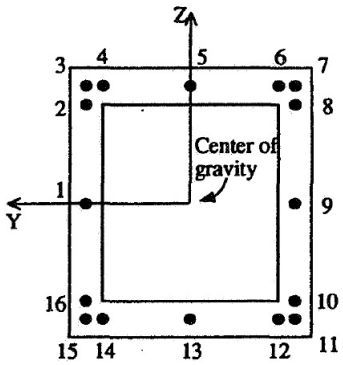


Figure D.22: Predefined points for stress calculations of box sections

This section is assumed to be symmetrical about the z-axis. The axes y and z are principal axes and the following simple stress formulas are used:

$$\sigma_b = -\frac{M_z}{I_z} \cdot y - \frac{M_y}{I_y} \cdot z,$$
$$\tau = \frac{Q_z \cdot S_y}{I_y \cdot t} + \frac{Q_y \cdot S_z}{I_z \cdot t}.$$

Von Mises equivalent stress in the corner is calculated by approaching along the flange and along the web. The maximum value is selected and printed.

The stress calculations are related to the center lines.

D.6.5 Equivalent stresses in general beam elements

Equivalent stress can be calculated in 4 specified points as shown on Figure D.23.

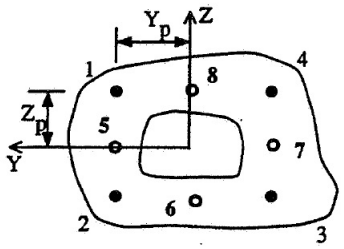


Figure D.23: General section equivalent stresses

For calculation of stresses, the following formulas are used:

$$\sigma_e = \sqrt{\sigma_x^2 + 3 \cdot \tau^2},$$
$$\sigma_x = \frac{F_x}{A} + \frac{M_y}{I_y} \cdot Y_p + \frac{M_z}{I_z} \cdot Z_p.$$

Depending on the type of section, τ is chosen as one of the following alternatives:

1. $\tau = \tau_y + \tau_z + \tau_T$
2. $\tau = \sqrt{(\tau_y + \tau_T)^2 + \tau_z^2}$
3. $\tau = \sqrt{(\tau_z + \tau_T)^2 + \tau_y^2}$
4. $\tau = \mid \tau_y + \tau_z \mid + \mid \tau_T \mid$

The shear stress will be based on the alternative (four available) chosen by the user (see Section D.5).

D.7 Transformation to In-plane/Out-of-plane Co-ordinate System

For some code checks the moments have to be transferred to an in-plane/out-of-plane co-ordinate system. This is described in the following.

D.7.1 Transformation angle

The transformation angle to be used when element moments are transferred from a local to an in-plane/out-of-plane co-ordinate system, is defined as follows:

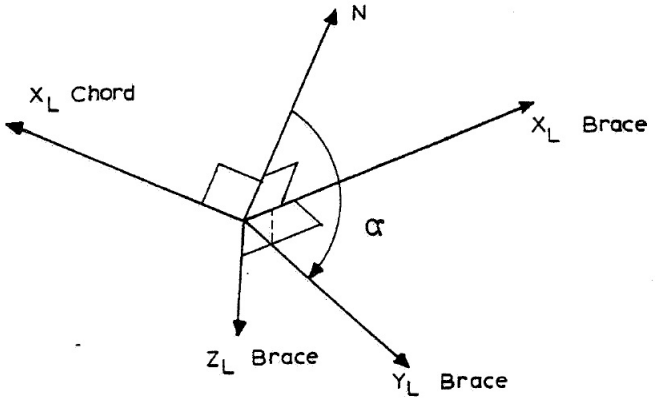


Figure D.24: Definition of transformation angle

As shown in Figure D.24, N is the normal to the plane defined by the vector product of $X_{LBrace} \cdot X_{LChord} \cdot$ X_{LBrace} is a unity vector along the positive local x-axis (from end 1 to end 2) of the brace. X_{LChord} is a unity vector along local x-axis of the chord. X_{LChord} is always positive pointing from the node connecting brace and chord. The transformation angle α is the angle between the normal N and the local y-axis of the brace element taken clockwise when seen in the direction of X_{LBrace} from end 1 to end 2.

Local end 1 is the end with the first node input for a particular element. The user may use a Preframe print of all node and element numbers when working with Framework.

D.7.2 Transformation of element bending moments to in-plane/out-of-plane moments

The same sign-convention for moments is followed in the transformed system as for moments in local element system with in-plane/out-of-plane associated with M_y and M_z respectively (see Section D.3).

The transformation is made according to:

$$\begin{bmatrix} M_{\text{in-plane}} \\ M_{\text{out-of-plane}} \end{bmatrix} = \begin{bmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{bmatrix} \cdot \begin{bmatrix} M_y \\ M_z \end{bmatrix}.$$

For joints (relevant for the punching shear check), the in-plane is described by the plane that contains the local x-axis of the elements. That is, the in-plane contains all four of the nodes at the ends of the two elements (one node is common for the two elements). The out-of-plane is described as the orthogonal to the in-plane.

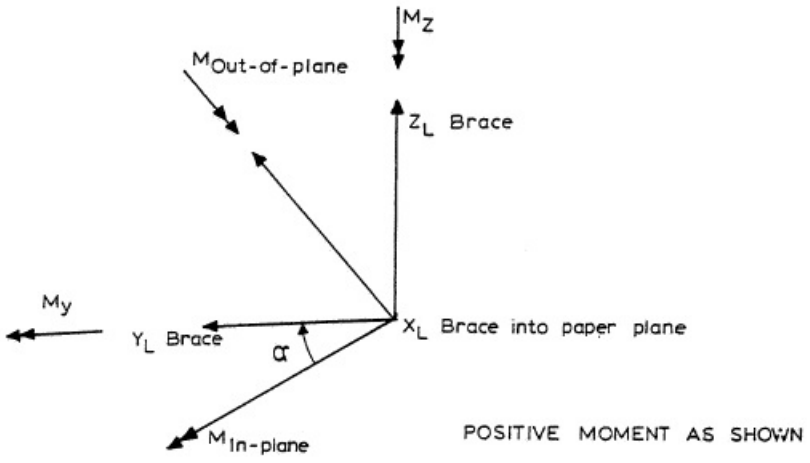


Figure D.25: Transformation of moments

E Code check according to API and AISC – working strength design

This section is on transfer from the original Theory manual to an appendix in the new manual.

It is noted that the latest version of the API RP 2A-WSD "*Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms-Working Stress Design*" is edition 21 reaffirmed October 2010 and issued as API RP 2A-WSD [55] and the latest version of the AISC "*Specification for Structural Steel Buildings*" was issued June 22, 2010 as ANSI/AISC 360-10 [41]. The currect section of this manual – and the implementations in Framework – are yet to be updated according to these standards.

E.1 General description

The API-AISC-WSD code check is based on API RP2A 19th edition, see ref. [25] and AISC ninth edition, see ref. [12]. Where applicable, the API has been used (in areas of overlap, API supercedes the AISC).

The code check is divided into the following parts:

- Yield check
- Stability check
- Hydrostatic check (only for pipe members)
- Punching shear check (only for pipe members)

Local element forces and moments are used for the yield and stability checks while for the punching shear check, forces and moments are referred to the in-plane and out-of-plane system (see Section D.7). For the punching shear check, nominal forces and moments are used.

The checks can be performed for both operating and storm conditions by specifying the relevant condition. For storm condition the allowable stresses will be increased by one third by the program.

All equations in this Chapter are valid for SI units. The AISC formulas in this theoretical description incorporate a variable for the E-modulus. The average E-modulus assumed is $30458 ksi$, corresponding to $2.1 \cdot 10^5 N/mm^2$. This value is used in order to convert the AISC formulas to SI units. In addition, the conversion rate used from ksi to N/mm^2 is $1\ ksi$ to $6.8948\ N/mm^2$.

E.2 Yield check

The yield check is available for the following cross-section types:

- Pipe elements (`PIPE`)
- Wide flange elements (`IORH`)
- Channel elements (`CHAN`)
- Box elements (`BOX`)
- General elements (`GENE`)

The yield check is performed at three different locations along the beam element (both ends and midpoint).

The yield check also includes a check against compactness criteria for reduction of allowable yield and printing of warnings except for general (`GENE`) beam elements.

E.2.1 Yield check pipe elements

The yield criteria is satisfied when [API formula 3.3.1-2, [25]]:

$$\frac{|f_a|}{F_a} + \frac{\sqrt{f_{by}^2 + f_{bz}^2}}{F_b} \leq 1.0, \qquad \text{and} \qquad \frac{f_v}{F_v} \leq 1.0, \tag{E.1}$$

where

$$f_a = \frac{P_x}{A}, \quad f_{by} = \frac{M_y}{W}, \quad f_{bz} = \frac{M_z}{W}, \quad \tau_y = \frac{2 \cdot P_y}{A}, \quad \tau_z = \frac{2 \cdot P_z}{A}.$$

and where

$$f_v = |\tau_t| + \sqrt{\tau_y^2 + \tau_z^2}, \qquad \text{and} \qquad \tau_t = \frac{M_x \cdot r}{I_x}. \tag{E.2}$$

The nomenclature is:

f_a	Acting axial stress
f_{by}	Acting bending stress
f_{bz}	Acting bending stress
f_v	Acting shear stress
τ_y	Acting shear stress
τ_z	Acting shear stress
τ_t	Acting torsional shear stress
F_a	Allowable axial stress
F_b	Allowable bending stress
F_v	Allowable shear stress
P_x, P_y, P_z	Internal beam forces
M_x, M_y, M_z	Internal beam forces
A	Section area
W	Section modulus
r	Outer radius
I_x	Torsional moment of inertia $I_x = I_y + I_z$
F_y	Minimum yield stress

It should be noted that in E.2, the value for τ_t is valid for thin walled sections.

The allowable stresses are for operating condition calculated as shown in Table E.1.

Table E.1: Allowable stresses.

F_a	F_b	F_v	Condition
$0.60 \cdot F_y$	API eq. 3.2.3-1	$0.40 \cdot F_y$	Operating

The allowable stresses are multiplied with a factor $4/3$ for storm condition.

Note that for $D/t > 300$, the stability check is not valid. The user should check that D/t does not exceed 300. It should also be noted that API states that careful consideration should be given for members with D/t greater than 120. The program does not check that the pipe thickness is greater than 0.25 inches.

A sketch of API section 3 – Structural Design of Pipe Member – is shown in Figure E.1. The figure gives an overview of the complete design procedure for a pipe member. However, the yield check reduces to E.1.

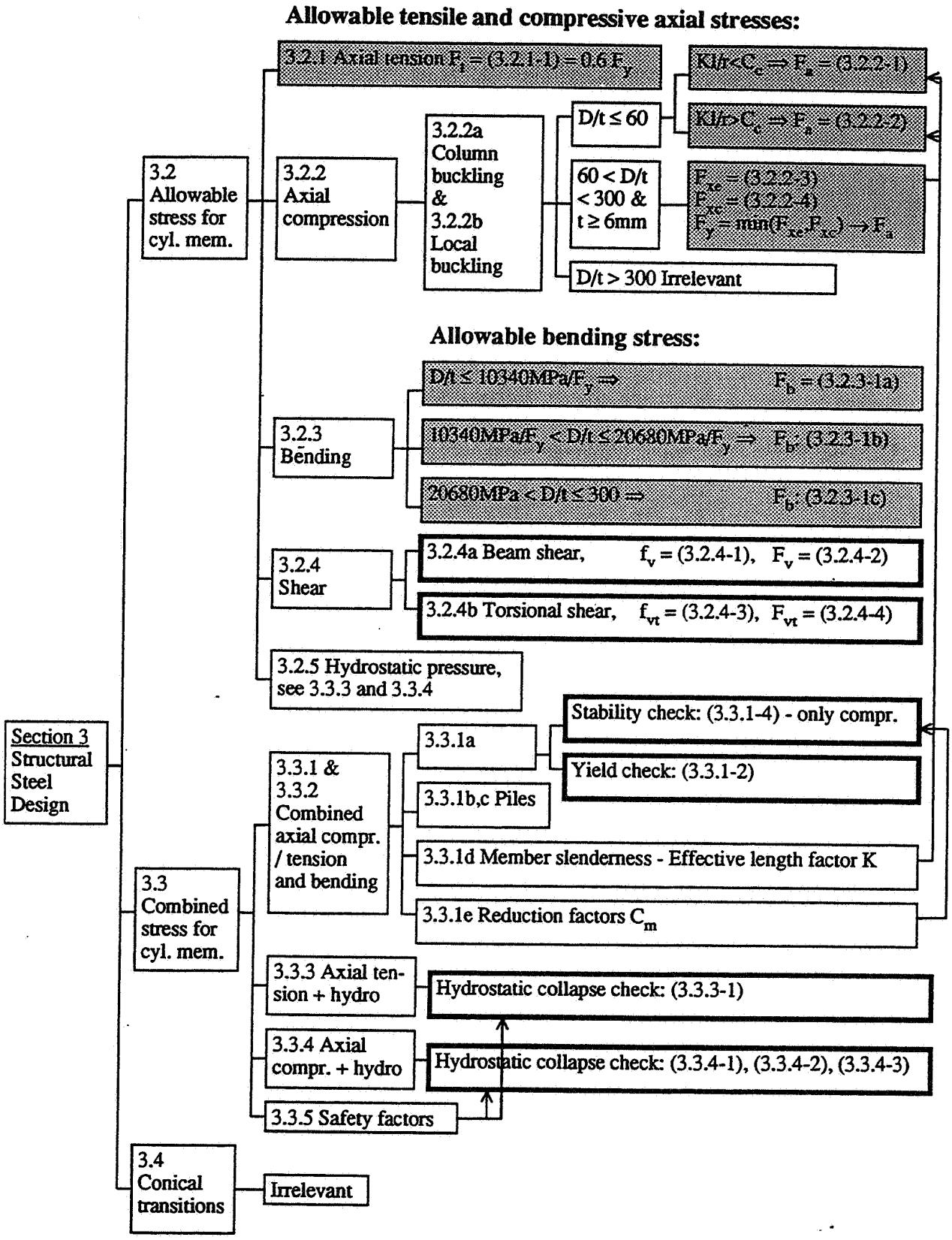


Figure E.1: Sketch of API section 3 – Structural Design of Pipe Member

E.2.2 Yield check I- or H-beams

E.2.2.1 Check for normal stresses [AISC formula H1-2]

Double Symmetric Sections

The yield criteria for double symmetric sections is:

$$\frac{|f_a|}{F_a} + \frac{f_{by}}{F_{by}} + \frac{f_{bz}}{F_{bz}} \leq 1.0 \tag{4.4}$$

where

$$f_a = \frac{P_x}{A} \quad , \quad f_{by} = \frac{|M_y|}{W_y} \quad \text{and} \quad f_{bz} = \frac{|M_z|}{W_z} \tag{4.5}$$

Other Sections

The yield criteria for other sections is:

$$\left|\frac{f_a}{F_a} + \frac{f_{by}}{F_{by}} + \frac{f_{bz}}{F_{bz}}\right| \leq 1.0 \tag{4.6}$$

The stress check is carried out at the four flange edge points with

$$f_a = \frac{P_x}{A} \quad , \quad f_{by} = -\frac{M_y \cdot z}{I_y} \quad \text{and} \quad f_{bz} = -\frac{M_z \cdot y}{I_z} \tag{4.7}$$

where y and z are distances from the centroid to the actual flange tip.

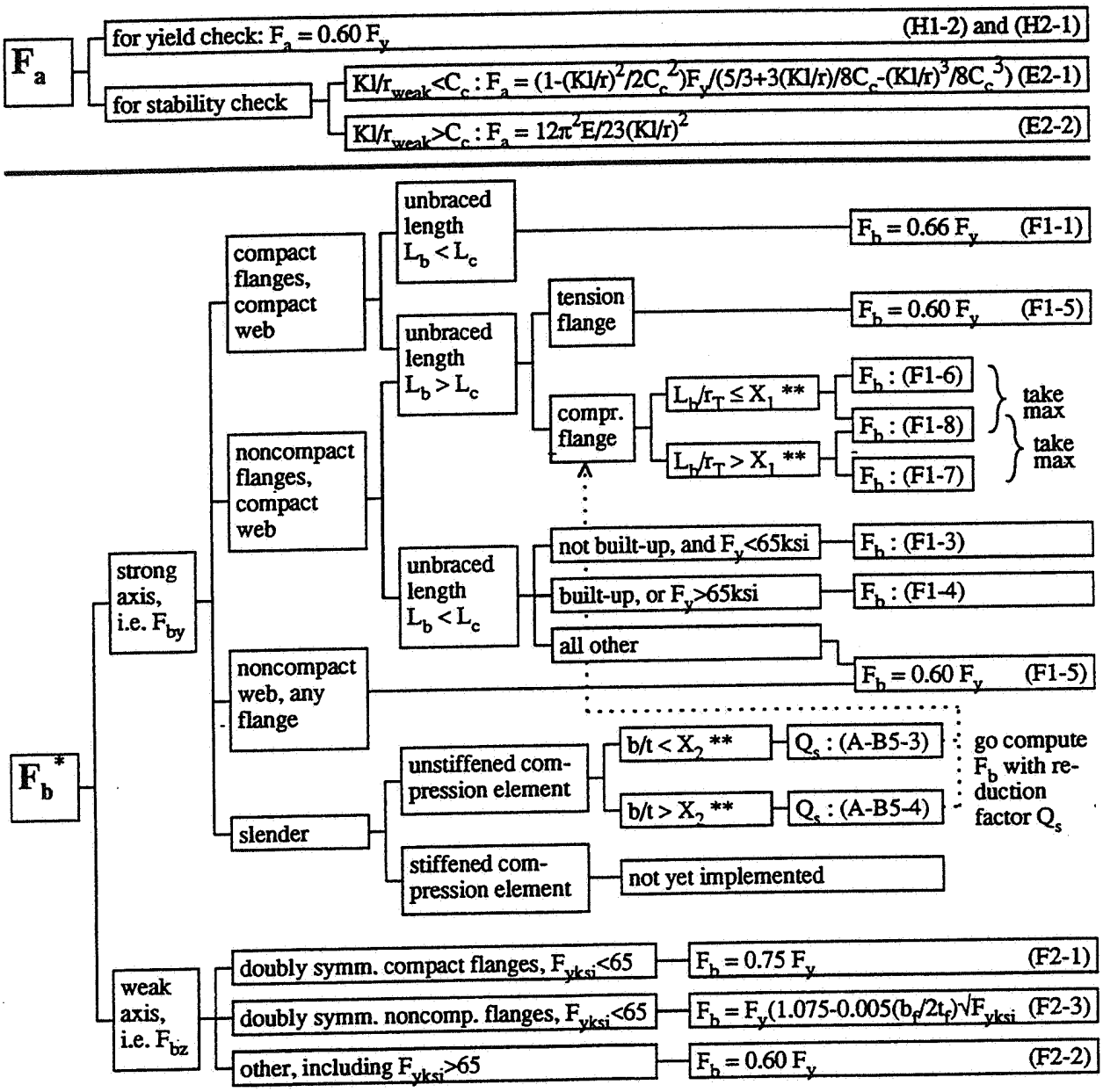
Calculation of allowable stresses

The allowable stresses are for operating condition calculated as:

Table 4.2 Allowable stresses.

F_a	F_{by}	F_{bz}	Condition
0.60 F_y	AISC chapter F	AISC chapter F	Operating

The allowable stresses are multiplied with a factor 4/3 for storm condition.



* There is no difference between yield and stability for F_b.

** $X_1 = (510{,}000\ C_b / F_{yksi})^{½}$, note that there is also a lower limit for L_b/r_T, see AISC.

$X_2 = 195 / (F_{yksi} / K_c)^{½}$, note that there is also a lower limit for b/t, see AISC.

Figure E.2: Sketch of AISC part 5 – Calculation of allowable stresses for I sections

The calculation of F_a, F_{by} and F_{bz} is illustrated in figure 4.2 with references to AISC-WSD. As shown in the figure F_a is taken as $0.6 \cdot F_y$. F_{by} is calculated as for the stability check. This is in order to ensure check of lateral buckling in cases when there not is axial compression in the member (e.g. zero axial force or small tension force together with bending moment). F_{by} (bending about strong axis) depends on the compactness of the cross section and the unsupported flange length of the compression flange. Furthermore will fabrication method and loading conditions influence on F_{by}.

First of all is the cross section classified according to table B5.1 in AISC. Flanges and web are classified independent of each other.

Second is the limiting laterally unsupported flange length L_c calculated according to AISC (F1-2). F_{by} is then calculated according to chapter F as shown in figure 4.2.

A reduction factor for slender sections is calculated according to AISC appendix B in order to take local buckling into account.

Classification of Cross Section

Classification of the cross section is carried out for points with compression according to the following formulas [AISC table B5.1]:

Web:
For each one of the three sections along the beam (end one, mid-point and end two) the web is checked according to the following:

$$\begin{cases} \dfrac{d}{t_w} \le 3.666 \cdot \sqrt{E/F_y} & \text{if } \dfrac{f_a}{F_y} \ge 0.0 \\ \dfrac{d}{t_w} \le 3.666 \cdot \sqrt{E/F_y} \cdot \left[1.0 - 3.74 \cdot \dfrac{\lvert f_a \rvert}{F_y} \right] & \text{if } -0.16 \le \dfrac{f_a}{F_y} \le 0.0 \\ \dfrac{d}{t_w} \le 1.473 \cdot \sqrt{E/F_y} & \text{if } \dfrac{f_a}{F_y} < -0.16 \end{cases} \qquad (4.8)$$

where

d - full section height
t_w - web thickness

If (4.8) is satisfied the web is classified as compact, otherwise it is classified as non-compact.

Flange:
The local flange check is performed at the four hot spots in the flanges. The width-thickness ratio is compared against three different limits before the allowable stress level is derived.

Compact flange:

$$\frac{b_f}{t_f} \le 0.372 \cdot \left[\frac{E}{F_y} \right]^{1/2} \qquad (4.9)$$

Non-compact flange:

$$0.372 \cdot \left[\frac{E}{F_y}\right]^{1/2} < \frac{b_f}{t_f} \leq 0.544 \cdot \left[\frac{E}{F_y}\right]^{1/2} \tag{4.10}$$

Slender flange:

$$\frac{b_f}{t_f} > 0.544 \cdot \left[\frac{E}{F_y}\right]^{1/2} \tag{4.11}$$

where

b_f - half the flange width

t_f - flange thickness

Calculation of Reduction Factor for Slender Sections

A reduction factor is calculated for slender sections according to AISC Appendix B (A-B5-3) and (A-B5-4). The reduction factor is applied to unstiffened elements that are not fully effective and comprise the compression flange of a flexural member. The allowable yield stress is then modified with a reduction factor Q_s, according to Table 4.3.

Table 4.3 Allowable stresses.

F_a	F_{by}	F_{bz}	Condition
$0.60\,Q_s F_y$	$0.60\,Q_s F_y$	$0.60\,Q_s F_y$	operating
$0.80\,Q_s F_y$	$0.80\,Q_s F_y$	$0.80\,Q_s F_y$	storm

where for $b_f/t_f < 1.11735\sqrt{E/(F_y \cdot k_c)}$:

$$Q_s = 1.293 - 0.53927\frac{b_f}{t_f}\left[\frac{F_y}{(E \cdot k_c)}\right]^{1/2} \tag{4.12}$$

and for $b_f/t_f \geq 1.11735\sqrt{E/(F_y \cdot k_c)}$:

$$Q_s = \frac{0.8602 \cdot k_c}{\frac{F_y}{E}\cdot\left[\frac{b_f}{t_f}\right]^2} \tag{4.13}$$

See AISC Appendix B for definitions of b, t and k_c.

Program Logic and Output

The yield check is performed at three poisitions along the element (END1, L/2, END2). The check is performed at each of the six extreme points in the two flanges, see figure 3.24. Both local flange and local web compactness are checked at each of these three positions.

The compactness check of the flange is performed at four hot spots in the flanges - the extreme flange corners. If the allowable stress and geometry for one of these hot spots results in a slender flange the allowable yield stress will be reduced.

The web compactness is checked at three locations: at the top of the web, the centroid and the bottom of the web. If the compactness test fails at any of these three locations the allowable yield stress will be reduced for that location along the element (END1, L/2 and END2). If the web is non-compact at any one of the three hot spots, then a maximum allowable yield stress of 0.60 F_y will be used as the allowable strong axis stress for all of the four extreme points at which the yield check is performed.

The allowable yield stress reduction is performed for each hot spot separately. This means that even if a reduction in allowable yield is performed for one hot spot, the others can still have an allowable yield of $0.66F_y$. The hot spot giving the largest utilization ratio is stored and printed for each of the three positions along the element (END1, L/2, END2).

FRAMEWORK stores only the hot spot with the largest interaction ratio for each of the three locations along the length of the element. Thus, for an element with local flange failure, 0.66 F_y may still be printed as the allowable yield stress (if the hot spot giving the largest interaction ratio was not the one with the non-compactness failure).

E.2.2.2 Check for shear stresses

The shear check is not valid for non-symmetric sections.

The following checks are made:

Web:

$$|\tau_z| + |\tau_t| \leq F_v \tag{4.14}$$

Flanges:

$$|\tau_y| + |\tau_z| + |\tau_t| \leq F_v \tag{4.15}$$

Where

F_v - is the allowable shear stress calculated according to AISC formula F4-1 or F4-2.

τ_y - shear stress in y-direction $\tau_y = \dfrac{Q_y \Delta S_z}{t_{flange} I_z}$

τ_z - shear stress in z-direction $\tau_z = \dfrac{Q_z \Delta S_y}{t_{web} I_y}$

τ_t - torsional shear stress $\tau_t = \dfrac{M_x t_{actual}}{I_x}$

I_x - torsional moment of inertia $I_x = \dfrac{1}{3}\sum bt^3$

ΔS_y - Static area moment $\Delta S_y = \int_{\Delta A} z \; dA$

ΔS_z - Static area moment $\Delta S_z = \int_{\Delta A} y \; dA$

E.2.3 Yield check channel section

E.2.3.1 Check for normal stresses [AISC formula H1-2]

$$\frac{|f_a|}{N \cdot F_y} + \frac{f_{by}}{F_{by}} + \frac{f_{bz}}{F_{bz}} \leq 1.0 \qquad (4.16)$$

The stress check is carried out at the two extreme flange points and at the two flange/web intersections where

$$f_a = \frac{P_x}{A} \quad , \quad f_{by} = \frac{|M_y|}{W_y} \quad \text{and} \quad f_{bz} = \frac{|M_z|}{W_{zmin}} \qquad (4.17)$$

The maximum interaction ratio is calculated with (for sections that are not fully effective see also Classification of Cross Section and API/AISC Stability Check):

Table 4.4 Allowable stresses.

N	F_{by}	F_{bz}	Condition
0.60	$0.60F_y$	$0.60F_y$	operating
0.80	$0.80F_y$	$0.80F_y$	storm

Classification of Cross Section

A local compactness check is carried out for points with compression according to the following formulas [AISC table B5.1]:

Web:
For each one of the three sections along the beam (end one, mid-point and end two) the web is checked according to eq. (4.8).

Flange: The local flange check is performed at the four hot spots as mentioned above. The width-thickness ratio is compared against three different limits and from that the allowable stress level is derived (see eqs. (4.9), (4.10) and (4.11) where b_f is the flange width and t_f is the flange thickness).

The logic of the aforementioned is as follows:

A) The cross section complies with the requirements in eq. (4.8):
   1) If eq. (4.9) or (4.10) applies to the cross section, Table 4.4 should be used.
   2) If eq. (4.11) applies to the cross section, then an additional reduction in allowable yield should be performed (see Calculation of Reduction Factor for Slender Sections below).

B) The cross section does not comply with the requirements in eq. (4.8), then an additional reduction in allowable yield should be performed (see Calculation of Reduction Factor for Slender Sections below).

Calculation of Reduction Factor for Slender Sections

AISC Appendix B is applied to unstiffened elements that are not fully effective and comprise the compression flange of a flexural member. The allowable yield stress shall be modified with a reduction factor Q_s according to Table 4.3.

Program Logic and Output

The yield check is performed at three poisitions along the element (END1, L/2, END2). The check is performed at each of the four hot spots in the flanges - the extreme flange corners and the intersections of flange and web. Both local flange and local web compactness are checked at each of these three positions.

The compactness check of the flange is performed at four hot spots in the flanges - the extreme flange corners and the intersections of flange and web. If the allowable stress and geometry for one of these hot spots results in a slender flange the allowable yield stress will be reduced.

The web compactness is checked at three locations: at the top of the web, the centroid and the bottom of the web. If the compactness test fails at any of these three locations the allowable yield stress will be reduced for that location along the element (END1, L/2 and END2). If the web is non-compact at any one of the three hot spots, then a maximum allowable yield stress of $0.60F_y$ will be used as the allowable strong axis stress for all of the four extreme points at whick the yield check is performed.

The allowable yield stress reduction is performed for each hot spot separately. This means that even if a reduction in allowable yield is performed for one hot spot, the others can still have an allowable yield of $0.66F_y$. The hot spot giving the largest utilization ratio is stored and printed for each of the three positions along the element (END1, L/2, END2).

FRAMEWORK stores only the hot spot with the largest interaction ratio for each of the three locations along the length of the element. Thus, for an element with local flange failure, 0.66 F_y may still be printed as the allowable yield stress (if the hot spot giving the largest interaction ratio was not the one with the non-compacness failure).

E.2.3.2 Check for shear stresses

The following checks are made

Web:

$$\frac{|P_z|}{H_{TOT} \cdot t_w} \leq F_v \tag{4.18}$$

Flanges:

$$\frac{|P_y|}{2 \cdot b_f \cdot t_f} \leq F_v \tag{4.19}$$

Where

F_v = 0.40 F_y for operating condition 0.53 F_y for storm condition

b_f - flange width

t_f - flange thickness

E.2.4 Yield check box section

E.2.4.1 Check for normal stresses [AISC formula H1-2]

$$\left| \frac{f_a}{N \cdot F_y} + \frac{f_{by}}{F_{by}} + \frac{f_{bz}}{F_{bz}} \right| \leq 1.0 \qquad (4.20)$$

with

$$f_a = \frac{P_x}{A} \quad , \quad f_{by} = -\frac{M_y}{I_y} \cdot z \quad \text{and} \quad f_{bz} = \frac{M_z}{W_z} \qquad (4.21)$$

where z is taken as the distance from centroid to extreme fiber of top and bottom flanges.

The maximum interaction ratio is calculated with (for non-compact sections and sections that are not fully effective see also Classification of Cross Section and API/AISC Stability Check):

A)The element meets the requirements in AISC table B5.1:

Table 4.5 Allowable stresses.			
N	F_{by}	F_{bz}	Condition
0.60	$0.66\,F_y$	$0.66\,F_y$	operating
0.80	$0.88\,F_y$	$0.88\,F_y$	storm

B)The element does not meet the requirements in AISC table B5.1 but the width-thickness ratio is less than $1.36 \cdot \sqrt{E/F_y}$:

Table 4.6 Allowable stresses.			
N	F_{by}	F_{bz}	Condition
0.60	$0.60\,F_y$	$0.60\,F_y$	operating
0.80	$0.80\,F_y$	$0.80\,F_y$	storm

Classification of Cross Section

A local compactness check is carried out for points under compression according to the following formulas (AISC table B5.1):

Web and Flange:

$$\frac{b_{ft}}{t_{ft}} \quad , \quad \frac{b_{fb}}{t_{fb}} \quad \text{and} \quad \frac{h_w}{t_w} \leq 1.09 \cdot \left[\frac{E}{F_y} \right]^{1/2} \qquad (4.22)$$

$$\frac{b_{ft}}{t_{ft}} \quad , \quad \frac{b_{fb}}{t_{fb}} \quad \text{and} \quad \frac{h_w}{t_w} \leq 1.36 \cdot \left[\frac{E}{F_y} \right]^{1/2} \qquad (4.23)$$

where

b_{ft} - width of top flange
b_{fb} - width of bottom flange
h_w - heigth of web
t_{ft} - thickness of top flange
t_{fb} - thickness of bottom flange
t_w - thickness of web
E - Young's modulus
F_y - yield stress

The logic of the aforementioned is as follows:

A)If the cross section complies with the requirements in eq. (4.22) Table 4.5 should be used.

B)If the cross section complies with the requirements in eq. (4.23) Table 4.6 should be used.

C)If the cross section does not comply with eqs. (4.22) and (4.23), then an additional reduction in allowable yield should be performed (see Calculation of Reduction Factor for Slender Sections below).

Calculation of Reduction Factor for Slender Sections

AISC Appendix B is applied to elements that are not fully effective and comprise the compression flange of a flexural member. The allowable yield stress shall be modified with a reduction factor Q_a according to Table 4.7.

Table 4.7 Allowable stresses.

N	F_{by}	F_{bz}	Condition
$0.60Q_a$	$0.60Q_aF_y$	$0.60Q_aF_y$	operating
$0.80Q_a$	$0.80Q_aF_y$	$0.80Q_aF_y$	storm

where

$$Q_a=\frac{\text{effective area}}{\text{actual area}} \tag{4.24}$$

where the effective area is equal to the actual area less $\sum(b-b_e)\cdot t$ and

$$b_e=1.4497\cdot t\left[\frac{E}{f}\right]^{1/2}\cdot\left[1.0-\frac{0.288\sqrt{E}}{(b/t\cdot\sqrt{f}}\right] \leq b \tag{4.25}$$

b - actual width of the stiffened compression element. The width of such element is the distance between nearest lines of fasteners or welds, or between the roots of the flanges in the case of rolled sections.

t - its thickness

f - computed compressive stress in the stiffened element.

Program Logic and Output

The yield check is performed at three poisitions along the element (END1, L/2, END2). The check is performed at the four cross sectional corners. Both local flange and local web compactness are checked

at each of these three positions.

The compactness check of the flange/web is performed at the four hot spots at the cross section corners. If the allowable stress and geometry for one of these hot spots results in a non-compact flange/web the allowable yield stress will be reduced.

The allowable yield stress reduction is performed for each hot spot separately. This means that even if a reduction in allowable yield is performed for one hot spot, the others can still have an allowable yield of $0.66F_y$. The hot spot giving the largest utilization ratio is stored and printed for each of the three positions along the element (END1, L/2, END2).

FRAMEWORK stores only the hot spot with the largest interaction ratio for each of the three locations along the length of the element. Thus, for an element with local flange failure, $0.66\ F_y$ may still be printed as the allowable yield stress (if the hot spot giving the largest interaction ratio was not the one with the non-compacness failure).

E.2.4.2 Check for shear stresses

The following checks are made

$$\frac{|P_z|}{2\ H_{TOT}\cdot t_w} \leq F_v \tag{4.26}$$

$$\frac{|P_y(z-\frac{t_{fb}}{2}+SHCENZ)|}{b_{ft}\cdot t_{ft}\cdot H_m} \leq F_v \tag{4.27}$$

Torsional shear stresses are neglected.

$$\frac{|P_y(H_m-(z-\frac{t_{fb}}{2}+SHCENZ))|}{b_{fb}\cdot t_{fb}\cdot H_m} \leq F_v \tag{4.28}$$

Where z is distance from centroid to extreme fibre of lower flange.

$$H_m = H_{tot} - \frac{t_{ft}}{2} - \frac{t_{fb}}{2} \tag{4.29}$$

$F_v = 0.40\ F_y$ in operating load condition
$F_v = 0.53\ F_y$ in storm load condition

E.2.5 Yield check general beam section

For a general beam section the yield check does not include a check of local stability criterias.

E.2.5.1 Check for normal stresses

$$\left| \frac{f_a}{N \cdot F_y} + \frac{f_{by}}{F_{by}} + \frac{f_{bz}}{F_{bz}} \right| \leq 1.0 \tag{4.30}$$

Table 4.8 Allowable stresses.

N	F_{by}	F_{bz}	condition
0.60	$0.66\,F_y$	$0.66\,F_y$	operating
0.80	$0.88\,F_y$	$0.88\,F_y$	storm

This check is made at the user defined four hot spots. If the user choses not to define four hot spots, the check will be performed at the four default hot spots: ($\pm I_y/W_y$, $\pm I_z/W_z$).

E.2.5.2 Check for shear stresses

The following checks are made

$$y\text{–}dir: \frac{|P_y|}{SHARY} \leq P_q \tag{4.31}$$

$$z\text{–}dir: \frac{|P_z|}{SHARZ} \leq P_q \tag{4.32}$$

where

P_z - shear force in z-direction
P_y - shear force in y-direction
M_T - torsional moment
SHARZ - shear area in z-direction
SHARY - shear area in y-direction
W_T - torsional modulus
P_q - allowable shear stress, $P_q = 0.40\,F_y$ operating condition, $P_q = 0.53\,F_y$ storm condition

E.2.5.3 Combined stress check

$$\sigma_j = \left[\left(\frac{f_a}{0.6} + \frac{f_{by} + f_{bz}}{0.66} \right)^2 + 3 \left(\frac{\tau}{0.4} \right)^2 \right]^{1/2} \leq n \cdot F_y \tag{4.33}$$

where

τ - as defined in section 3
n = 1 for operating condition and 4/3 for storm condition

Four possibilities are available for adding the shear force at each hot spot. These are:

Formula 1:

Both directions:

$$\left| \frac{UFACY \cdot P_y}{SHARY} + \frac{UFACZ \cdot P_z}{SHARZ} + \frac{UFACYZ \cdot M_T}{W_T} \right| \leq P_q \tag{4.34}$$

Formula 2:

y-direction:

$$\left| \frac{UFACY \cdot P_y}{SHARY} + \frac{UFACYZ \cdot M_T}{W_T} \right| \leq P_q \tag{4.35}$$

z-direction:

$$\left| \frac{UFACZ \cdot P_z}{SHARZ} \right| \leq P_q \tag{4.36}$$

Formula 3:

y-direction:

$$\left| \frac{UFACY \cdot P_y}{SHARY} \right| \leq P_q \tag{4.37}$$

z-direction:

$$\left| \frac{UFACZ \cdot P_z}{SHARZ} + \frac{UFACYZ \cdot M_T}{W_T} \right| \leq P_q \tag{4.38}$$

Formula 4:

Both directions:

$$\left| \frac{UFACY \cdot P_y}{SHARY} + \frac{UFACZ \cdot P_z}{SHARZ} \right| + \left| \frac{UFACYZ \cdot M_T}{W_T} \right| \leq P_q \tag{4.39}$$

y-direction:

$$\left| \frac{UFACY \cdot P_y}{SHARY} \right| + \left| \frac{UFACYZ \cdot M_T}{W_T} \right| \leq P_q \tag{4.40}$$

z-direction:

$$\left| \frac{UFACZ \cdot P_z}{SHARZ} \right| + \left| \frac{UFACYZ \cdot M_T}{W_T} \right| \leq P_q \tag{4.41}$$

where

UFACY - user defined y-direction shear multiplification factor (default is 1.0)

UFACZ - same as UFACY but for z-direction

Program Logic and Output

The GENERAL-beam section should be used for sections where the proper assessment of shear stresses is important. Closed hollow sections can use Formula 1; open sections can use Formula 4; and, solid sections can use Formulas 2 or 3, depending upon the location of the user defined hot spots. The GENERAL-section is especially useable for elements in which the torsional stress may be a factor (for example thin hollow sections).

By default the program will use $\pm I_y/W_y$ and $\pm I_z/W_z$ as the four hot spots for the GENERAL-beam section. The default values are valid for double symmetric sections. The user may define other hot spots than the default values for sections that are not double symmetric. The program will calculate normal, shear and combined stresses for all hot spots, and print the maximum value of each.

The program will not check the geometric dimensions of the section. Thus no reduction in allowable yield is performed.

The GENERAL-beam section should also be used when additional output information is required with regard to normal, shear and/or combined stresses.

The output for the GENERAL-beam section will contain additional stress information (compared to other section types). The output will include information such as the maximum compressive stress, the allowable compressive stress, and the hot spot at which the compressive stress is at maximum. Also, the hot spot with the maximum shear stress (and the formula used for adding the shear stresses) will be indicated. In addition, the yield check print will include the combined stress and the hot spot at which the combined stress is at maximum.

E.3 Stability check

The The stability check is carried out based on the assumption that the ends of the element to be checked are joints in a frame braced against joint translation.

The stability check includes column buckling as well as lateral torsional beam buckling. For thin walled sections a local buckling check is carried out. This check is performed for PIPES, IORH, BOX or CHANNEL sections. Furthermore, a hydrostatic collapse check can be performed for PIPE elements.

For the stability check, local moments are referred to the local coordinate system.

The stability check is available for the following cross section types:

- Pipe elements (`PIPE`)
- Wide flange elements (`IORH`)
- Channel elements (`CHAN`)
- Box elements (`BOX`)
- General elements (`GENE`)

Program Logic and Output
The user should be aware of that lateral buckling is not performed for elements with a section of type `GENE`, `BOX` or `PIPE`.

Warning messages

- Member under axial tensile stress. This means that column buckling was not checked, and lateral buckling was not checked because the unsupported compression flange did not exceed allowable criteria. No stability check was performed. This is printed for each element and loadcase.
- Euler Buckling Stress Exceeded. This means that no stability check was performed, neither column buckling, nor lateral buckling. This will be printed for each element and loadcase.
- $D/t > 300$ (only for pipe sections).

E.3.1 Stability check pipe elements

A schematic description of the stability check is given in Figure E.1.

The following formula is checked for combined axial compression and bending [API formula 3.3.1-4, [25]]:

$$\frac{|f_{ac}|}{F_{ac}} + \left[\left(\frac{C_{my} \cdot f_{by}}{\left(1 - \frac{|f_{ac}|}{F'_{ey}}\right) \cdot F_b} \right)^2 + \left(\frac{C_{mz} \cdot f_{bz}}{\left(1 - \frac{|f_{ac}|}{F'_{ez}}\right) \cdot F_b} \right)^2 \right]^{\frac{1}{2}} = \frac{|f_{ac}|}{F_{ac}} + \frac{\sqrt{\left(\frac{C_{my} \cdot f_{by}}{\left(1 - \frac{|f_{ac}|}{F'_{ey}}\right)} \right)^2 + \left(\frac{C_{mz} \cdot f_{bz}}{\left(1 - \frac{|f_{ac}|}{F'_{ez}}\right)} \right)^2}}{F_b} \leq 1.0 \tag{E.3}$$

The current latest version of the API-RP2A-WSD code check is the 21th edition, [55] – this edition specifies the following formula [API formula 3.3.1-4, [55] page 42]:

$$\frac{f_{ac}}{F_{ac}} + \frac{\sqrt{\left(\frac{C_{my} \cdot f_{by}}{\left(1 - \frac{f_{ac}}{F'_{ey}}\right)} \right)^2 + \left(\frac{C_{mz} \cdot f_{bz}}{\left(1 - \frac{f_{ac}}{F'_{ez}}\right)} \right)^2}}{F_b} \leq 1.0 \tag{E.4}$$

We observe that the only difference is the absolute value on $|f_{ac}|$ in the formula E.3 of edition 19 – as implemented in Framework, compared to formula E.4 of edition 21.

Notations z and y are used for in-plane and out-of-plane axes respectively. The axial compressive stress is

$$f_{ac}=\frac{P_x}{A} \tag{4.43}$$

and the stresses caused by the bending moments are

$$f_{by}=\frac{M_y}{W} \quad \text{and} \quad f_{bz}=\frac{M_z}{W} \tag{4.44}$$

where

M_y and M_z - bending moments
W - section modulus

The axial compressive stress that would be permitted if axial force alone existed is [according to API section 3.2.2a]

$$F_{ac}=\frac{\left[1-\frac{(kl/r)^2}{2\,C_c^2}\right]F_y}{\frac{5}{3}+\frac{3(kl/r)}{8C_c}-\frac{(kl/r)^3}{8C_c^3}} \tag{4.45}$$

where

$$C_c=\left[\frac{2\pi^2E}{F_y}\right]^{1/2} \tag{4.46}$$

When kl/r exceeds C_c, the allowable axial stress is

$$F_{ac}=\frac{12\pi^2E}{23(kl/r)^2} \tag{4.47}$$

In the foregoing, kl is set to the maximum effective length of $k_y \cdot l_y$ and $k_z \cdot l_z$.

C_{my} and C_{mz} are calculated according to API section 3.3.1e.

The Euler stress is calculated as

$$F'_{ey}=\frac{12\pi^2E}{23(k_y l_y/r_y)^2} \quad \text{and} \quad F'_{ez}=\frac{12\pi^2E}{23(k_z l_z/r_z)^2} \tag{4.48}$$

The allowable stresses are adjusted depending on loading condition.

Furthermore, in storm condition F_{ac}, F_b, F'_{ey} and F'_{ez} should be increased by a factor of 4/3.

Reduction for Local Buckling

If

$$60<\frac{D}{t}<300 \tag{4.49}$$

then the yield stress is substituted by a reduced yield stress according to [API eq. (3.2.2-4)]

$$\begin{aligned} F_{xc}&=F_y[1.64-0.23(D/t)^{0.25}]\le F_{xe} \\ F_{xe}&=2\cdot(0.3)\cdot E\cdot t/D \end{aligned} \tag{4.50}$$

where F_{xc} is the inelastic local buckling stress, and F_{xe} is the elastic local buckling stress.

E.3.1.1 Hydrostatic collapse

In tubular members exposed to external hydrostatic pressure, the acting membrane hoop stress, f_h, should not exceed the critical hoop buckling stress, F_{hc}. This can be expressed as

$$\frac{f_h}{F_{hc}/SF_h} \leq 1.0 \tag{4.51}$$

where

f_h - hoop compression stress = pD/2t

p - external hydrostatic pressure

SF_h - safety factor against hydrostatic collapse. (SF_h = 2.0 in operating condition and 1.5 in extreme condition.)

The elastic hoop buckling stress is determined from API (3.2.5-4)

$$F_{he}=2C_hEt/D \tag{4.52}$$

where

$$\begin{aligned}
&C_h=0.44t/D && M\geq 1.6\ D/t\\
&C_h=0.44(t/D)+\frac{0.21(D/t)^3}{M^4} && 0.825\ D/t\leq M<1.6\ D/t\\
&C_h=0.736/(M-0.636) && 3.5\leq M<0.825\ D/t\\
&C_h=0.755/(M-0.559) && 1.5\leq M<3.5\\
&C_h=0.8 && M<1.5
\end{aligned} \tag{4.53}$$

The geometric parameter M is defined as

$$M=\frac{L}{D}(2D/t)^{1/2} \tag{4.54}$$

where

L - length of cylinder between stiffening rings. The program uses the total length of the element (or the assigned local length if specified).

The critical hoop buckling stress, F_{hc}, is determined from

$$\begin{aligned}
&F_{hc}=F_{he} && F_{he}\leq 0.55F_y\\
&F_{hc}=0.45\ F_y+0.18\ F_{he} && 0.55\ F_y<F_{he}\leq 1.6\ F_y\\
&F_{hc}=\frac{1.31\ F_y}{1.15+(F_y/F_{he})} && 1.6\ F_y<F_{he}\leq 6.2\ F_y\\
&F_{hc}=F_y && F_{he}>6.2\ F_y
\end{aligned} \tag{4.55}$$

and the external hydrostatic pressure is determined from:

$$p=\gamma H_z \tag{4.56}$$

$$H_z=z+\frac{H_w\cosh[k(d-z)]}{2\cosh[kd]} \tag{4.57}$$

where

z	- depth below still water surface. z is positive measured downward from the still water surface level.
Hw	- maximum wave height
k	$= 2\pi/l$
d	- still water depth.
γ	- seawater density.
l	- wave length.

E.3.1.2 Axial tension and hydrostatic collapse interaction

When a member is exposed to external hydrostatic pressure and axial tension, the following equation should be satisfied

$$A^2+B^2+2\nu|A|B\leq 1.0 \tag{4.58}$$

where

$$A=\left[\frac{f_a+f_b-(0.5\,f_h)}{F_y}\right]SF_x \tag{4.59}$$

$$B=\left[\frac{f_h}{F_{hc}}\right]SF_h \tag{4.60}$$

ν	- Poisson's ratio = 0.3.
f_a	- absolute value of acting axial stress.
f_b	$=\sqrt{f_{bIP}^2+f_{bOP}^2}=$ absolute value of acting resultant bending.
f_h	- absolute value of hoop compression stress.
F_y	- yield strength
SF_x	- safety factor for axial tension = 1.67 (in extreme condition SF_x = 1.25).

E.3.1.3 Axial compression and hydrostatic pressure

When a member is exposed to axial compression and external hydrostatic pressure the following two equations should be satisfied

$$\frac{f_a+0.5\,f_h}{F_{xc}}(SF_x)+\frac{f_b}{F_y}(SF_b)<1.0 \tag{4.61}$$

$$\frac{f_h}{F_{hc}}(SF_h)<1.0 \tag{4.62}$$

Furthermore, if $f_x>0.5F_{ha}$ the following equation should also be satisfied

$$\frac{f_x-0.5\,F_{ha}}{F_{aa}-0.5\,F_{ha}}+\left[\frac{f_h}{F_{ha}}\right]^2<1.0 \tag{4.63}$$

In the above formulas

$$F_{aa}=\frac{F_{xe}}{SF_x} \quad \text{and} \quad F_{ha}=\frac{F_{he}}{SF_h} \tag{4.64}$$

$$f_x=f_a+f_b+(0.5\ f_h) \tag{4.65}$$

$$F_{xe}=2\cdot 0.3Et/D \tag{4.66}$$

where

t - thickness at the middle of the element

D - diameter at the middle of the element.

The safety factor SF_x is calculated according to

$$SF_x=\frac{5}{3}+\frac{3kl/r}{8C_c}-\frac{(kl/r)^3}{8C_c^3} \tag{4.67}$$

When $kl/r \geq C_c$ the safety factor SF_x should be calculated according to

$$SF_x=\frac{23}{12} \tag{4.68}$$

In the above equations C_c is according to eq. (4.46).

E.3.2 Stability check I- or H- elements

The stability check is carried out for all elements under compression. A schematic description of the stability check for a double symmetric I-section is given in Figure 4.1.

E.3.2.1 General

Compression

The general stability requirement is according to eq. (4.69) [AISC formula H1-1] and is valid for most cases. In some instances though, a modified formulation should be used, eq. (4.70). This modified formulation is applied when the area of the compression flange is greater than the area of the tension flange and the stresses caused by bending around the local y-axis (strong axis) is greater than the stresses caused by bending around local z-axis (weak axis). The two equations are:

$$\frac{|f_{ac}|}{F_{ac}}+\frac{C_{my}f_{by}}{\left[1-\frac{|f_{ac}|}{F'_{ey}}\right]F_{by}}+\frac{C_{mz}f_{bz}}{\left[1-\frac{|f_{ac}|}{F'_{ez}}\right]F_{bz}} \leq 1.0 \tag{4.69}$$

and

$$\frac{|f_{ac}|}{F_{ac}}-\frac{|f_{ac}|}{F_a}+\frac{C_{my}\cdot f_{by}}{\left[1-\frac{|f_{ac}|}{F'_{ey}}\right]F_{by}}+\frac{C_{mz}\cdot f_{bz}}{\left[1-\frac{|f_{ac}|}{F'_{ez}}\right]F_{bz}} \leq 1.0 \tag{4.70}$$

The stress caused by the axial compression, f_{ac}, is calculated according to eq. (4.43). For the stresses imposed by the two bending moments the calculation method will vary depending on which flange the calculation is for.

The following formulas are applied to the compression and tension flanges respectively

$$f_{byc}=\frac{|M_y|}{I_y}\cdot z_c \quad \text{and} \quad f_{byt}=\frac{|M_y|}{I_y}\cdot z_t \tag{4.71}$$

and

$$f_{bzc}=\frac{|M_z|}{I_z}\cdot\frac{b_c}{2} \quad \text{and} \quad f_{bzt}=\frac{|M_z|}{I_z}\cdot\frac{b_t}{2} \tag{4.72}$$

where

z_c - distance from centroid to extreme fibre of compression flange.

z_t - distance from centroid to extreme fibre of tension flange.

b_c - width of compression flange.

b_t - width of tension flange.

The moment amplification reduction factors, C_{my} and C_{mz}, are calculated according to AISC section H1. The allowable axial compressive stress, F_{ac}, is calculated according to eqs. (4.45), (4.46) and (4.47) using the maximum value of

$$\lambda_y=\frac{k_y l_y}{r_y} \quad \text{and} \quad \lambda_z=\frac{k_z l_z}{r_z} \tag{4.73}$$

where

k_y and k_z - the effective buckling length factors for local y- and z-axis (out-of-plane and in-plane).

l_y and l_z - element buckling length for local y- and z-axis.

r_y and r_z - radius of gyration for local y- and z-axis.

The allowable axial stress, F_a, is set to $0.60\cdot F_y$ for operating condition and $0.80\cdot F_y$ for storm condition.

The allowable Euler buckling stresses are caluclated according to

$$F'_{ey}=\frac{12\pi^2 E}{23\left[\frac{k_y l_y}{r_y}\right]^2} \quad \text{and} \quad F'_{ez}=\frac{12\pi^2 E}{23\left[\frac{k_z l_z}{r_z}\right]^2} \tag{4.74}$$

The allowable bending stresses, F_{by} and F_{bz}, are according to section 4.3.2.3.

Tension

The lateral buckling check for members with zero or positive axial force is in FRAMEWORK performed under the yield check.

E.3.2.2 Element and section criteria

The section properties of the elements mid-point are checked to see if they comply with the requirements in AISC table B5.1. For an element to fall into this group, its section must be symmetrical about, and loaded in, the plane of its minor axis (local z-axis). Futhermore, the set of compactness criterias should be satisfied. The classification criterias are given in (4.8) - (4.11).

Furthermore, the laterally unsupported length (user specified or the default element length) of the compression flange should not exceed the following criteria (AISC F1-2).

$$\frac{b_f}{2.291}\cdot\left[\frac{E}{F_y}\right]^{1/2} \quad \text{nor} \quad \frac{0.657\,A_{fc}}{h_w}\cdot\frac{E}{F_y} \tag{4.75}$$

where

A_{fc} - area of the compression flange

E.3.2.3 Allowable stresses

The allowable stresses are based on what set of equations in the previous section that are applicable to the element and its section. Furthermore, there is differentiation if the cross section is non-symmetric, single symmetric or double symmetric. A schematic overview of calculation of allowable stresses for symmetric I-sections is given in fig. 4-2.

E.3.3 Stability check channel elements

The stability check is carried out for all elements under compression.

E.3.3.1 General

Compression

The general stability requirement is [AISC formula H1-1]

$$\frac{|f_{ac}|}{F_{ac}} + \frac{C_{my}f_{by}}{\left[1-\frac{|f_{ac}|}{F'_{ey}}\right]F_{by}} + \frac{C_{mz}f_{bz}}{\left[1-\frac{|f_{ac}|}{F'_{ez}}\right]F_{bz}} \le 1.0 \tag{4.76}$$

The stress caused by the axial compression, f_{ac}, is calculated according to eq. (4.43). The stresses imposed by the two bending moments are calculation as

$$f_{by}=\frac{|M_y|}{W_y} \quad \text{and} \quad f_{bz}=\frac{|M_z|}{W_{z,min}} \tag{4.77}$$

The moment amplification reduction factors, C_{my} and C_{mz}, are calculated according to AISC section H1. The allowable axial compressive stress, F_{ac}, is calculated according to eqs. (4.45), (4.46) and (4.47) using the maximum value of

$$\lambda_y=\frac{k_y l_y}{r_y} \quad \text{and} \quad \lambda_z=\frac{k_z l_z}{r_z} \tag{4.78}$$

where

k_y and k_z - the effective buckling length factors for local y- and z-axis (out-of-plane and in-plane).

l_y and l_z - element buckling lengths for local y- and z-axis.

r_y and r_z - radius of gyration for local y- and z-axis.

The allowable Euler buckling stresses are caluclated according to

$$F'_{ey}=\frac{12\pi^2 E}{23\left[\frac{k_y l_y}{r_y}\right]^2} \quad \text{and} \quad F'_{ez}=\frac{12\pi^2 E}{23\left[\frac{k_z l_z}{r_z}\right]^2} \tag{4.79}$$

The allowable bending stresses, F_{by} and F_{bz}, are according to section 4.3.3.3.

Tension

The lateral buckling check for members with zero or positive axial force is in Framework performed under the yield check.

E.3.3.2 Element and section criteria

A classification of the element is performed to establish the allowable yield stresses and to verify that the length of the element is according to guide lines set forth in AISC. These checks shows among other things if the element is compact and fully effective.

The classification of the cross section is described in detail in p. 4-7.

E.3.3.3 Allowable stresses

The allowable stresses are calculated according to AISC section F1.

E.3.4 Stability check box elements

The stability check is carried out for all elements under compression.

E.3.4.1 General

Compression

The general stability requirement is according to eq. (4.80) [AISC formula H1-1] and is valid for most cases. In some instances though, a modified formulation should be used, eq. (4.81). This modified formulation is applied when the area of the compression flange is greater than the area of the tension flange and the stresses caused by bending around the local y-axis (strong axis) is greater than the stresses caused by bending around local z-axis (weak axis). The two equations are:

$$\frac{|f_{ac}|}{F_{ac}} + \frac{C_{my} f_{by}}{\left(1 - \frac{|f_{ac}|}{F'_{ey}}\right) F_{by}} + \frac{C_{mz} f_{bz}}{\left(1 - \frac{|f_{ac}|}{F'_{ez}}\right) F_{bz}} \leq 1.0 \qquad (4.80)$$

and

$$\frac{|f_{ac}|}{F_{ac}} - \frac{|f_{ac}|}{F_a} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{|f_{ac}|}{F'_{ey}}\right) F_{by}} + \frac{C_{mz} \cdot f_{bz}}{\left(1 - \frac{|f_{ac}|}{F'_{ez}}\right) F_{bz}} \leq 1.0 \qquad (4.81)$$

The stress caused by the axial compression, f_{ac}, is calculated according to eq. (4.43). The stresses imposed by the two bending moments are calculation as

$$f_{by} = \frac{|M_y|}{I_y} \cdot z_c \quad \text{and} \quad f_{bz} = \frac{|M_z|}{W_z} \qquad (4.82)$$

where

z_c - distance from centroid to extreme fibre.

The moment amplification reduction factors, C_{my} and C_{mz}, are calculated according to AISC section H1. The allowable axial compressive stress, F_{ac}, is calculated according to eqs. (4.45), (4.46) and (4.47) using the maximum value of

$$\lambda_y = \frac{k_y l_y}{r_y} \quad \text{and} \quad \lambda_z = \frac{k_z l_z}{r_z} \qquad (4.83)$$

where

k_y and k_z - the effective buckling length factors for local y- and z-axis (out-of-plane and in-plane).

l_y and l_z - element buckling length for local y- and z-axis.

r_y and r_z - radius of gyration for local y- and z-axis.

The allowable axial stress, F_a, is set to $0.60 \cdot F_y$ for operating condition and $0.80 \cdot F_y$ for storm condition.

The allowable Euler buckling stresses are caluclated according to

$$F'_{ey} = \frac{12\pi^2 E}{23\left(\frac{k_y l_y}{r_y}\right)^2} \quad \text{and} \quad F'_{ez} = \frac{12\pi^2 E}{23\left(\frac{k_z l_z}{r_z}\right)^2} \qquad (4.84)$$

The allowable bending stresses, F_{by} and F_{bz}, are according to Section E.3.4.3.

E.3.4.2 Element and section criteria

A classification of the element is performed to establish the allowable yield stresses and to verify that the length of the element is according to guide lines set forth in AISC. These checks shows among other things if the element is compact and fully effective.

The section properties of the elements mid-point are checked to see if they comply with the requirements in AISC table B5.1. For an element to fall into this group, its section must be symmetrical about, and loaded in, the plane of its minor axis (local z-axis). Furthermore, a set of compactness criteria should be satisfied.

Since there is no way to distinguish between web and flange for a box section, all "flanges" are checked according to the following set of equations

$$\frac{b_{ff}}{t_{ff}} \le 1.09 \cdot \left[\frac{E}{F_y}\right]^{1/2} \tag{4.85}$$

$$1.09 \cdot \left[\frac{E}{F_y}\right]^{1/2} < \frac{b_{ff}}{t_{ff}} \le 1.36 \cdot \left[\frac{E}{F_y}\right]^{1/2} \tag{4.86}$$

$$\frac{b_{ff}}{t_{ff}} > 1.36 \cdot \left[\frac{E}{F_y}\right]^{1/2} \tag{4.87}$$

where

b_{ff} - distance between the roots of the flanges

t_f - flange thickness

Furthermore, the laterally unsupported length of the compression flange is checked against the following criteria

$$\left[0.064 + 0.039\frac{M_1}{M_2}\right] b_{ff} \frac{E}{F_y} \tag{4.88}$$

except that it need not be less than

$$0.039 b_{ff} \frac{E}{F_y} \tag{4.89}$$

where

M_1 and M_2- are according to AISC section F3.1

E.3.4.3 Allowable stresses

The allowable stresses are based on what set of equations in the previous section that are applicable to the element and its section. In the following the allowable stresses will be specified for the different sections depending on the different categories that they fall in.

The allowable stress levels should be taken according to AISC section F3.1.

E.3.5 Stability check of general beam elements

The stability check is carried out for all elements in compression with one axis of symmetry. There is not carried out a lateral buckling check or a local stability check for general beam elements. That is, only a global stability check is carried out for a general beam element. One consequence is that the results are independent of the chosen hot spot locations in the general beam element cross-section. The stability criteria is [according to AISC formula H1-1]:

$$\frac{|f_{ac}|}{F_{ac}} + \frac{C_{my} \cdot f_{by}}{\left(1 - \frac{|f_{ac}|}{F'_{ey}}\right) \cdot F_{by}} + \frac{C_{mz} \cdot f_{bz}}{\left(1 - \frac{|f_{ac}|}{F'_{ez}}\right) \cdot F_{bz}} \leq 1.0,$$

where

$f_{ac} = \frac{P_x}{A}$ and where P_x is the axial force and A is the area

F_{ac} is calculated as for pipe elements using maximum of the slenderness ratios $\lambda_y = \frac{k_y \cdot l_y}{r_y}$ and $\lambda_z = \frac{k_z \cdot l_z}{r_z}$.

C_{my} and C_{mz} are calculated according to AISC H1.

F'_{ey} and F'_{ez} are calculated according to:

$$F'_{ey} = \frac{12\pi^2 \cdot E}{23 \cdot \lambda_y^2} = \frac{12\pi^2 \cdot E}{23 \cdot \left(\frac{k_y \cdot l_y}{r_y}\right)^2},$$
$$F'_{ez} = \frac{12\pi^2 \cdot E}{23 \cdot \lambda_z^2} = \frac{12\pi^2 \cdot E}{23 \cdot \left(\frac{k_z \cdot l_z}{r_z}\right)^2}.$$

f_{by} and f_{bz} are calculated according to:

$$f_{by} = \frac{|M_y|}{\text{WYMIN}},$$
$$f_{bz} = \frac{|M_z|}{\text{WZMIN}}.$$

$F_{by} = F_{bz} = 0.60 \cdot F_y$ in operating condition.

In storm condition $F_{by}, F_{bz}, F'_{ey},$ and F'_{ez} are increased by a factor of 4/3.

E.4 Punching shear check

The design is based on nominal loads in the brace.

Acting moments are transferred to in-plane and out-of-plane reference system, see Section D.7 for definitions.

E.4.1 Simple joints

The punching shear unity criterions are defined as:

$$\left|\frac{P}{P_a}\right|+\frac{2}{\pi}\arcsin\left[\left[\frac{M_I}{M_a}\right]_{IPB}^{2}+\left[\frac{M_O}{M_a}\right]_{OPB}^{2}\right]^{1/2}\leq 1.0 \tag{4.93}$$

$$\left[\frac{M_I}{M_a}\right]_{IPB}^{2}+\left[\frac{M_O}{M_a}\right]_{OPB}^{2}\leq 1.0 \tag{4.94}$$

where:

P	- acting axial force in brace.
M_I	- acting in-plane bending moment.
M_O	- acting out-of-plane bending moment.
P_a	- allowable capacity for brace axial load.
M_a	- allowable capacity for brace bending moment.

$$P_a=Q_u Q_f \frac{F_y T^2}{1.7\sin\theta} \tag{4.95}$$

$$M_a=Q_u Q_f \frac{F_y T^2}{1.7\sin\theta}(0.8d) \tag{4.96}$$

In storm condition P_a and M_a are increased with 1/3.

In eqs. (4.95) and (4.96),

$$Q_f=1.0-\lambda\gamma A^2 \tag{4.97}$$

where

$\lambda = 0.030$ for brace axial load.
$\lambda = 0.045$ for brace in–plane bending.
$\lambda = 0.021$ for brace out–of–plane bending.
$\gamma = D/2T$ see Figure 4.3. (4.98)

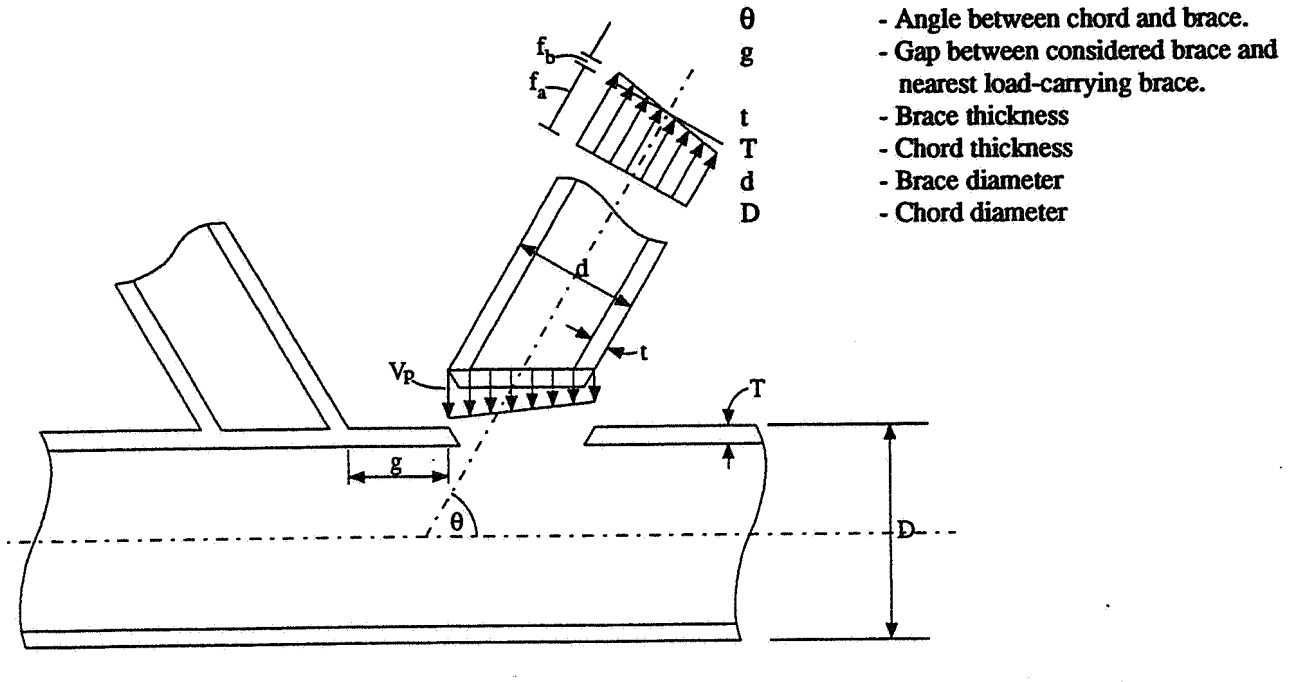


Figure 4.3 Geometry Definition

In eq. (4.97),

$$A = \frac{\sqrt{f_{ax}^2 + f_{IP}^2 + f_{OP}^2}}{0.6\, F_y} \tag{4.99}$$

In the value, A , in eq. (4.99), the denominator is increased by 1/3 for the storm condition.

If all extreme fibre stresses in the chord are tensile stresses, i.e.

$$f_{ax} - \sqrt{f_{IPB}^2 + f_{OPB}^2} > 0 \text{ and } f_{ax} - f_{IPB} > 0 \text{ and } f_{ax} - f_{OPB} > 0 \tag{4.100}$$

then Q_f = 1.0 in eqs. (4.95) and (4.96).

The values in eq. (4.100) are

$$f_{ax} = \frac{P_{AC}}{A_C} = \text{nominal axial stress in chord} \tag{4.101}$$

$$f_{IP} = \frac{M_{IPC}}{W_C} = \text{nominal in–plane bending stress in chord} \tag{4.102}$$

$$f_{OP} = \frac{M_{OPC}}{W_C} = \text{nominal out–of–plane bending stress in chord} \tag{4.103}$$

The value of Q_u in eqs. (4.95) and (4.96) is defined in Table 4.9.

Table 4.9

	T & Y	X	K
AXIAL TENSION	$3.4 + 19\beta$	$3.4 + 19\beta$	$(3.4 + 19\beta)\, Q_g$
AXIAL COMPRESSION	$3.4 + 19\beta$	$(3.4 + 13\beta)\, Q_\beta$	$(3.4 + 19\beta)\, Q_g$
IN-PLANE BENDING	$3.4 + 19\beta$	$3.4 + 19\beta$	$3.4 + 19\beta$
OUT-OF-PLANE BENDING	$(3.4 + 7\beta)\, Q_\beta$	$(3.4 + 7\beta)\, Q_\beta$	$(3.4 + 7\beta)\, Q_\beta$

The variables in Table 4.9 have the following values:

$$\beta = \frac{d}{D} \quad \text{see Figure 4.3} \tag{4.104}$$

$$Q_\beta = \frac{0.3}{\beta(1-0.833\beta)} \quad \text{for } \beta > 0.6 \tag{4.105}$$

$$Q_\beta = 1.0 \quad \text{for } \beta \le 0.6 \tag{4.106}$$

$$Q_g = 1.8 - 0.1\frac{g}{T} \quad \text{for } \gamma \le 20. \tag{4.107}$$

$$Q_g = 1.8 - 4\frac{g}{D} \quad \text{for } \gamma > 20. \tag{4.108}$$

$$Q_g \ge 1.0 \quad \text{for all } \gamma \tag{4.109}$$

The gap defined in eqs. (4.107) and (4.108) is the distance between the weld toe of the two brace elements. This value, g , is shown in Figure 4.3.

E.4.2 Overlapping joints

The punching shear unity criteria is defined as

$$\frac{P_p}{P_{ap}} \leq 1.0 \tag{4.110}$$

where:

P_p - applied axial load component perpendicular to the chord

P_{ap} - allowable axial load component perpendicular to the chord according to eq. (4.111)

The allowable axial load component perpendicular to the chord is for overlapping joints

$$P_p = P_a \cdot \frac{l_1}{l} \cdot \sin\theta + 2.0 \cdot 0.4 \cdot F_y \cdot t_w \cdot l_2 \tag{4.111}$$

where:

P_a - allowable axial load according to eq. (4.95) except that Q_u should be calculated according to eq. (4.112).

l_1 - circumference for that portion of the brace which contacts the chord (actual length)

l - circumference of brace contact with chord, neglecting presence of overlap.

l_2 - the projected chord length (one side) of the overlapping weld, measured perpendicular to the chord.

t_w - the lesser of the weld throat thickness or the thickness t of the inner brace.

$$Q_u = 1.8 \cdot (3.4 + 19\ \beta) \tag{4.112}$$

E.5 Nomenclature

Nomenclature AISC and API Code

f_a	- Acting axial stress
f_{by}	- Acting bending stress caused by M_y
f_{bz}	- Acting bending stress caused by M_z
f_p	- Acting punching shear stress
N	- Allowable stress factor
F_a	- Allowable axial stress
F_b	- Allowable bending stress
F_v	- Allowable shear stress
τ_{by}	- Acting shear stress from F_y
τ_{bz}	- Acting shear stress from F_z
F_x, F_y, F_z	- Applied forces
M_x, M_y, M_z	- Applied moments
E	- Young's modulus
D	- Diameter
t	- Thickness
A	- Section area
W	- Section modulus
A_{fc}	- Area compression flange
H	- Height of cross section
F_y	- Minimum yield stress
C_b	- Lateral buckling factor
C_m	- Amplification reduction factor

F Code check according to API and AISC – load and resistance factor design

This section is from the original manual.

F.1 General description

The API-AISC-LRFD code check is based on API RP2A-LRFD 1st edition (draft), see [27] and AISC-LRFD 1st edition, see [59]. Where applicable, the API has been used (in areas of overlap, API has superseded the AISC).

The code check is divided into the following parts:

- Yield check
- Stability check
- Hydrostatic check (only for pipe members)
- Punching shear check (only for pipe members)

Local element forces and moments are used for the yield and stability checks while for the punching shear check, forces and moments are referred to the in-plane and out-of-plane system (see Section 3.7).

All equations in this Chapter are valid for SI units. The AISC formulas in this theoretical description incorporate a variable for the E-modulus. The average E-modulus assumed is 30458 ksi corresponding to $2.1 \cdot 10^5 N/mm^2$. This value is used in order to convert the AISC formulas to SI units. In addition, the conversion rate used from ksi to N/mm^2 is 1 ksi to 6.8948 N/mm^2.

F.2 Yield check

The yield check is available for the following cross-section types:

- Pipe elements (PIPE)
- Wide flange elements (IORH)

The yield check is as default performed at three different locations along the beam element (both ends and mid-point).

F.2.1 Yield check pipe elements

The resistance factors for yield check of pipe members are given as:

$\phi_t = 0.95$ tension
$\phi_c = 0.85$ compression
$\phi_b = 0.95$ bending
$\phi_v = 0.95$ shear
$\phi_h = 0.80$ hydrostatic pressure

The yield criteria is satisfied when [API formula D.3.1-1]:

$$1 - \cos\left[\frac{\pi}{2}\frac{|f_a|}{\phi_t F_y}\right] + \frac{\sqrt{f_{by}^2+f_{bz}^2}}{\phi_b F_{bn}} \le 1.0 \qquad (5.1)$$

and

$$\frac{f_v}{\phi_v F_{vn}} \le 1.0 \qquad (5.2)$$

The stresses are calculated as:

$$f_a = \frac{P_x}{A}\ ,\ f_{by} = \frac{M_y}{W}\ ,\ f_{bz} = \frac{M_z}{W}\ ,$$
$$\tau_y = \frac{2{\cdot}P_y}{A}\ ,\ \tau_z = \frac{2{\cdot}P_z}{A}\ \text{and}\ \tau_t = \frac{M_x{\cdot}r}{I_x} \qquad (5.3)$$
$$f_v = |\tau_t| + \sqrt{\tau_y^2 + \tau_z^2}$$

where

f_a	- Axial stress due to factored load
f_{by}	- Bending stress due to factored load
f_{bz}	- Bending stress due to factored load
τ_y	- Shear stress due to factored load
τ_z	- Shear stress due to factored load
τ_t	- Torsional shear stress due to factored load
F_{bn}	- Nominal bending strength
F_{vn}	- Nominal shear strength
P_x, P_y, P_z	- Internal beam forces
M_x, M_y, M_z	- Internal beam forces
A	- Section area
W	- Section modulus
r	- Outer radius
I_x	- Torsional moment of inertia $I_x = I_y + I_z$
F_y	- Minimum yield strength

It should be noted that in eq. (5.3), the value for τ_t is valid for thin walled sections.

The nominal strengths are calculated as:

Table 5.1 Nominal strength.

F_{bn}	F_{vn}
API eq. D.2.3-2	$F_y/\sqrt{3}$

Note that for $D/t > 300$, the stability check is not valid. The user should check that D/t does not exceed 300. It should also be noted that API states that careful consideration should be given for members with D/t greater than 120. The program does not check that the pipe thickness is greater than 0.25 inches.

F.2.2 Yield check I- or H-beams

The resistance factors for yield check of I-beams are given as:

$\phi_t = 0.90$ tension

$\phi_c = 0.85$ compression

$\phi_b = 0.90$ bending

$\phi_v = 0.90$ shear

F.2.2.1 Check for Normal Stresses [AISC formula H1-1]

The yield criteria is as follows:

$$\frac{|f_a|}{\phi_t F_a} + \frac{8}{9}\left[\frac{f_{by}}{\phi_b F_{by}} + \frac{f_{bz}}{\phi_b F_{bz}}\right] \leq 1.0 \qquad \text{for} \quad \frac{|f_a|}{\phi_t F_a} > 0.2 \tag{5.4}$$

and

$$\frac{|f_a|}{2\phi_t F_a} + \left[\frac{f_{by}}{\phi_b F_{by}} + \frac{f_{bz}}{\phi_b F_{bz}}\right] \leq 1.0 \qquad \text{for} \quad \frac{|f_a|}{\phi_t F_a} \leq 0.2 \tag{5.5}$$

where

$$f_a = \frac{P_x}{A}, \quad f_{by} = \frac{|M_y|}{W_y} \quad \text{and} \quad f_{bz} = \frac{|M_z|}{W_z} \tag{5.6}$$

Calculation of nominal strengths

The nominal strengths are calculated as:

Table 5.2 Nominal strengths.		
F_a	F_{by}	F_{bz}
F_y	AISC chapter F	F_y

Note that the upper limit for F_{by} is M_p/W_y, i.e. the nominal bending strength may exceed the yield strength.

F_{by} is calculated as for the stability check. This is in order to ensure check of lateral buckling in cases when there not is axial compression in the member (e.g. zero axial force or small tension force together with bending moment). F_{by} (bending about strong axis) depends on the compactness of the cross section and the unsupported flange length of the compression flange. Furthermore will fabrication method and loading conditions influence on F_{by}.

First of all is the cross section classified according to table B5.1 in AISC-LRFD. Flanges and web are classified independent of each other.

Second is the limiting laterally unsupported flange length L_r calculated according to AISC (F1-6). F_{by} is then calculated according to chapter F as shown in figure 5.2.

A reduction factor for slender sections is calculated according to AISC-LRFD appendix B in order to take local buckling into account.

Classification of Cross Section

Classification of the cross section is carried out for points with compression according to the following formulas [AISC-LRFD table B5.1]:

Web:
For each one of the three sections along the beam (end one, mid-point and end two) the web is checked according to the following:

$$\lambda_p = 3.666 \cdot \sqrt{E/F_y} \quad \text{for} \quad \frac{f_a}{\phi_b F_y} > 0.0$$

$$\lambda_p = 3.666 \cdot \sqrt{E/F_y} \cdot \left[1.0 - 2.75 \cdot \frac{|f_a|}{\phi_b F_y} \right] \quad \text{for} \quad -0.125 \le \frac{f_a}{\phi_b F_y} \le 0.0 \quad (5.7)$$

$$\lambda_p = \max\left(1.4497 \cdot \sqrt{E/F_y} \; ; \; 1.0944 \cdot \sqrt{E/F_y} \left[2.33 - \frac{|f_a|}{\phi_b F_y} \right] \right) \quad \text{for} \quad \frac{f_a}{\phi_b F_y} < -0.125$$

$$\lambda_r = 5.558 \cdot \sqrt{E/F_y} \quad (5.8)$$

The web is classified according to the limits calculated above.

Compact web

$$\frac{h_c}{t_w} \le \lambda_p \quad (5.9)$$

Non-compact web

$$\lambda_p < \frac{h_c}{t_w} \le \lambda_r \quad (5.10)$$

Slender web

$$\lambda_r < \frac{h_c}{t_w} \quad (5.11)$$

where

h_c - twice the distance from the neutral axis to the inside face of the compression flange.

t_w - web thickness

Flange:
The local flange check is performed at the four hot spots in the flanges.

$$\lambda_p = 0.372 \cdot \left[\frac{E}{F_y}\right]^{1/2} \tag{5.12}$$

For rolled sections λ_r is calculated as:

$$\lambda_r = \frac{141.}{\sqrt{\frac{30458 \cdot F_y}{E} - 10}} \tag{5.13}$$

For welded sections λ_r is calculated as:

$$\lambda_r = \frac{106.}{\sqrt{\frac{30458 \cdot F_y}{E} - 16.5}} \tag{5.14}$$

The width-thickness ratio is compared against the limits before the nominal strength level is derived.

Compact flange

$$\frac{b_f}{t_f} \leq \lambda_p \tag{5.15}$$

Non-compact flange

$$\lambda_p < \frac{b_f}{t_f} \leq \lambda_r \tag{5.16}$$

Slender flange

$$\lambda_r < \frac{b_f}{t_f} \tag{5.17}$$

where

b_f - half the flange width

t_f - flange thickness

Calculation of Reduction Factor for Slender Sections

A reduction factor is calculated for slender sections according to AISC-LRFD Appendix B (A-B5-3) and (A-B5-4). The reduction factor is applied to unstiffened elements that are not fully effective and comprise the compression flange of a flexural member. The nominal axial strength and the nominal bending strength is then modified with a reduction factor Q_s.

See AISC-LRFD Appendix B for calculation of Q_s.

Program Logic and Output

The yield check is performed at three positions along the element (END1, L/2, END2). The check is performed at each of the six extreme points in the two flanges, see Figure (3.25->3.24?) D.20. Both local flange and local web compactness are checked at each of these three positions.

F.2.2.2 Check for Shear Stresses

The shear check is not valid for non-symmetric sections.

The following checks are made:

Web:

$$\frac{|\tau_z|}{\phi_v F_{vn}} + \frac{|\tau_t|}{\phi_v F_{tn}} \leq 1.0 \qquad (5.18)$$

Flanges:

$$\frac{|\tau_y| + |\tau_z|}{\phi_v F_{vn}} + \frac{|\tau_t|}{\phi_v F_{tn}} \leq 1.0 \qquad (5.19)$$

Where

F_{vn} - nominal shear strength calculated according to AISC section F2.

F_{tn} - nominal torsional shear strength calculated according to AISC formulae (H2-2).

τ_y - shear stress in y-direction $\tau_y = \dfrac{Q_y \Delta S_z}{t_{flange} I_z}$

τ_z - shear stress in z-direction $\tau_z = \dfrac{Q_z \Delta S_y}{t_{web} I_y}$

τ_t - torsional shear stress $\tau_t = \dfrac{M_x t_{actual}}{I_x}$

I_x - torsional moment of inertia $I_x = \dfrac{1}{3}\sum bt^3$

ΔS_y - Static area moment $\Delta S_y = \int_{\Delta A} z \; dA$

ΔS_z - Static area moment $\Delta S_z = \int_{\Delta A} y \; dA$

F.3 Stability Check

The stability check is carried out based on the assumption that the ends of the element to be checked are joints in a frame braced against joint translation.

The stability check includes column buckling as well as lateral buckling. For thin walled sections a local buckling check is carried out. This check is performed for PIPES and IORH sections. Furthermore, a hydrostatic collapse check can be performed for PIPE elements.

For the stability check, local moments are referred to the local coordinate system.

The stability check is available for the following cross section types:

- Pipe elements (PIPE)
- Wide flange elements (IORH)

F.3.1 Program logic and output

Warning messages:

- Member under axial tensile stress. This means that column buckling was not checked, and lateral buckling was not checked because the unsupported compression flange did not exceed allowable criteria. No stability check was performed. This is printed for each element and loadcase.
- Euler Buckling Stress Exceeded. This means that no stability check was performed, neither column buckling, nor lateral buckling. This will be printed for each element and loadcase.
- D/t > 300 (only for pipe sections).

F.3.2 Stability check pipe elements

The stability criterias are as follows: [API-LRFD formula D.3.2-1]:

$$\frac{|f_c|}{\phi_c F_{cn}} + \left[\left(\frac{C_{my} f_{by}}{\left(1 - \frac{|f_c|}{\phi_c F_{ey}}\right) \phi_b F_{bn}} \right)^2 + \left(\frac{C_{mz} f_{bz}}{\left(1 - \frac{|f_c|}{\phi_c F_{ez}}\right) \phi_b F_{bn}} \right)^2 \right]^{1/2} \leq 1.0 \qquad (5.20)$$

$$1 - \cos\left(\frac{\pi}{2} \frac{|f_c|}{\phi_c F_{xc}} \right) + \frac{\sqrt{f_{by}^2 + f_{bz}^2}}{\phi_b F_{bn}} \leq 1.0 \qquad (5.21)$$

The axial compressive stress is

$$f_c = \frac{P_x}{A} \tag{5.22}$$

and the stresses caused by the bending moments are

$$f_{by} = \frac{M_y}{W} \quad \text{and} \quad f_{bz} = \frac{M_z}{W} \tag{5.23}$$

where

M_y and M_z - bending moments
W - section modulus

The nominal axial compressive strength F_{cn} and the inelastic local buckling strenght F_{xc} are calculated according to API section D.2.2.

C_{my} and C_{mz} are calculated according to API-LRFD table D.3-1.

The Euler stress is calculated as

$$F_{ey} = \frac{\pi^2 E}{(k_y l_y / r_y)^2} \quad \text{and} \quad F_{ez} = \frac{\pi^2 E}{(k_z l_z / r_z)^2} \tag{5.24}$$

The nominal bending strength is calculated according to API-LRFD section D.2.3.

Reduction for Local Buckling

If

$$60 < \frac{D}{t} < 300 \tag{5.25}$$

then the yield stress is substituted by a reduced yield stress according to API-LRFD section D.2.2.

$$\begin{aligned} F_{xc} &= F_y[1.64 - 0.23(D/t)^{0.25}] \le F_{xe} \\ F_{xe} &= 2 \cdot (0.3) \cdot E \cdot t / D \end{aligned} \tag{5.26}$$

where F_{xc} is the inelastic local buckling stress, and F_{xe} is the elastic local buckling stress.

Interpretation of FRAMEWORK result table

The usage factors calculated by FRAMEWORK are as follows:

USF_{tot1} = according to: (5.20)

where

$$USF_{ax} = \frac{|f_c|}{\phi_c F_{cn}}$$

$$USF_{my} = \frac{C_{my}\, f_{by}}{\left[1 - \frac{|f_c|}{\phi_c F_{ey}}\right] \phi_b F_{bn}}$$

$$USF_{mz} = \frac{C_{mz}\, f_{bz}}{\left[1 - \frac{|f_c|}{\phi_c F_{ez}}\right] \phi_b F_{bn}}$$

and

$$USF_{tot2} = \text{according to: (5.21)}$$

where

$$USF_{ax} = \frac{|f_c|}{\phi_c F_{xc}}$$

$$USF_{my} = \frac{|f_{by}|}{\phi_b F_{bn}}$$

$$USF_{mz} = \frac{|f_{bz}|}{\phi_b F_{bn}}$$

The reported usage factor is:

$$USF_{tot} = \max(USF_{tot1}, USF_{tot2})$$

F.3.2.1 Hydrostatic collapse

In tubular members exposed to external hydrostatic pressure, the acting membrane hoop stress, f_h, should not exceed the critical hoop buckling stress, F_{hc}. This can be expressed as

$$\frac{f_h}{\phi_h F_{hc}} \le 1.0 \qquad (5.27)$$

where

f_h - hoop compression stress = pD/2t

p - external hydrostatic pressure

The elastic hoop buckling stress is determined from API (D.2.5-5)

$$F_{he} = 2C_h Et/D \qquad (5.28)$$

where

$$\begin{aligned} C_h &= 0.44t/D && M \ge 1.6\ D/t \\ C_h &= 0.44(t/D) + \frac{0.21(D/t)^3}{M^4} && 0.825\ D/t \le M < 1.6\ D/t \\ C_h &= 0.737/(M - 0.579) && 1.5 \le M < 0.825\ D/t \\ C_h &= 0.80 && M < 1.5 \end{aligned} \qquad (5.29)$$

The geometric parameter M is defined as

$$M = \frac{L}{D}(2D/t)^{1/2} \tag{5.30}$$

where

L - length of cylinder between stiffening rings. The program uses the total length of the element (or the assigned local length if specified).

The critical hoop buckling stress, F_{hc}, is determined from

$$\begin{aligned} F_{hc} &= F_{he} && F_{he} \le 0.55F_y \\ F_{hc} &= 0.7F_y\left[\frac{F_{he}}{F_y}\right]^{0.4} \le F_y && F_{he} > 0.55F_y \end{aligned} \tag{5.31}$$

and the external hydrostatic pressure is determined from:

$$p = \gamma_D \gamma H_z \tag{5.32}$$

$$H_z = z + \frac{H_w \cosh[k(d-z)]}{2\cosh[kd]} \tag{5.33}$$

where

z - Depth below still water surface. z is positive measured downward from the still water surface level.

H_w - Maximum wave height

k $= 2\pi/l$

d - Still water depth.

γ - Seawater density.

l - Wave length.

γ_D - Hydrostatic pressure load factor, equal to 1.3 for operating and 1.1 for extreme conditions.

F.3.2.2 Axial tension and hydrostatic collapse interaction

When a member is exposed to external hydrostatic pressure and axial tension, the following equation should be satisfied

$$A^2 + B^2 + 2\nu|A|B \le 1.0 \tag{5.34}$$

where

$$A = \frac{f_t + f_b - (0.5\, f_h)}{\phi_t F_y} \tag{5.35}$$

$$B = \frac{f_h}{\phi_h F_{hc}} \tag{5.36}$$

ν - Poisson's ratio = 0.3.

f_t - Absolute value of acting axial stress.

f_b $=\sqrt{f_{bIP}^2+f_{bOP}^2}=$ Absolute value of acting resultant bending.

f_h - Absolute value of hoop compression stress.

F_y - Yield strength

F.3.2.3 Axial compression and hydrostatic pressure

When a member is exposed to axial compression and external hydrostatic pressure equation (5.20) and (5.27) should be satisfied.

Furthermore, if $f_x > 0.5\phi_h F_{hc}$ the following equation should also be satisfied

$$\frac{f_x - 0.5\ \phi_h F_{hc}}{\phi_c F_{xe} - 0.5\ \phi_h F_{hc}} + \left[\frac{f_h}{\phi_h F_{hc}}\right]^2 < 1.0 \qquad (5.37)$$

where

$$f_x = f_a + f_b + (0.5\ f_h) \qquad (5.38)$$

Interpretation of FRAMEWORK result table

The usage factors calculated by FRAMEWORK are as follows:

$$USF_1 = \text{according to: (5.27)}$$

Tension:

$$USF_2 = \text{according to: (5.34)}$$

$$USF_3 = 0.0$$

Compression:

$$USF_2 = 0.0$$

$$USF_3 = USF_1 \quad \text{for} \quad f_x \le 0.5\phi_h F_{hc}$$

$$USF_3 = \text{according to: (5.37) for} \quad f_x > 0.5\phi_h F_{hc}$$

F.3.3 Stability check I- or H-elements

The stability check is carried out for all elements under compression.

F.3.3.1 General

Second order effects shall be considered in the design of frames as stated in AISC-LRFD, part 6, chapter C. However, no second order effects are accounted for in Framework. The user is for this reason responsible for that the member forces from the finite element analysis includes all significant second order effects.

Compression

The general stability requirement is according to AISC-LRFD formula H1-1.

$$\frac{|f_c|}{\phi_c F_{cn}} + \frac{8}{9}\left[\frac{C_{my} f_{by}}{\left(1-\frac{|f_c|}{F_{ey}}\right)\phi_b F_{by}} + \frac{C_{mz} f_{bz}}{\left(1-\frac{|f_c|}{F_{ez}}\right)\phi_b F_{bz}}\right] \le 1.0 \quad \text{for} \quad \frac{f_c}{\phi_c F_{cn}} \ge 0.2 \qquad (5.39)$$

and

$$\frac{|f_c|}{2\phi_c F_{cn}} + \frac{C_{my} f_{by}}{\left(1-\frac{|f_c|}{F_{ey}}\right)\phi_b F_{by}} + \frac{C_{mz} f_{bz}}{\left(1-\frac{|f_c|}{F_{ez}}\right)\phi_b F_{bz}} \le 1.0 \quad \text{for} \quad \frac{f_c}{\phi_c F_{cn}} < 0.2 \qquad (5.40)$$

The moment amplification reduction factors, C_{my} and C_{mz}, are calculated according to AISC-LRFD section H1.2.a.

The nominal axial compressive strength, F_{cn}, is calculated according to section E2 and Appendix B5 using the maximum value of

$$\lambda_y = \frac{k_y l_y}{r_y} \quad \text{and} \quad \lambda_z = \frac{k_z l_z}{r_z} \qquad (5.41)$$

where

k_y and k_z - the effective buckling length factors for local y- and z-axis

l_y and l_z - element buckling length for local y- and z-axis.

r_y and r_z - radius of gyration for local y- and z-axis.

The allowable Euler buckling stresses are caluclated according to

$$F_{ey} = \frac{\pi^2 E}{\left(\frac{k_y l_y}{r_y}\right)^2} \quad \text{and} \quad F_{ez} = \frac{\pi^2 E}{\left(\frac{k_z l_z}{r_z}\right)^2} \qquad (5.42)$$

The nominal bending strength, F_{by}, is calculated according to section 5.2.2.1. F_{bz} is taken as F_{by}.

Tension

The lateral buckling check for members with zero or positive axial force is in FRAMEWORK performed under the yield check.

F.3.3.2 Element and section criteria

The section properties of the elements mid-point are checked to see if they comply with the requirements in AISC-LRFD table B5.1. The section is classified as compact, non-compact or slender according to the slenderness criterias given in the table.

Further, the limiting laterally unbraced length L_r is calculated as described in AISC-LRFD chapter F.

F.3.3.3 Nominal strength

The nominal strength is besed on the section classification.

F.3.3.4 Interpretation of Framework result table

The usage factors calculated by FRAMEWORK are as follows:

$$USF_{ax} = \frac{|f_c|}{\phi_c F_{cn}}$$

$$USF_{my} = \frac{C_{my} f_{by}}{\left[1 - \frac{|f_c|}{F_{ey}}\right] \phi_b F_{by}}$$

$$USF_{mz} = \frac{C_{mz} f_{bz}}{\left[1 - \frac{|f_c|}{F_{ez}}\right] \phi_b F_{bz}}$$

The total usage factor USF_{tot} is calculated according to (5.39) or (5.40) as applicable.

F.4 Punching shear check

The design is based on nominal loads in the brace.

Acting moments are transferred to in-plane and out-of-plane reference systems, see Section D.7 for definitions.

Tubular joint design according to API-LRFD.

F.4.1 Simple joints

The following geometric condition for simple joints is checked:

$$\frac{F_{yb}}{F_y} \cdot \frac{\gamma\tau\sin\theta}{11 + 1.5/\beta} \leq 1.0 \qquad (5.43)$$

See API-LRFD for definitions.

The punching shear strength check criterias are defined as:

$$\frac{P_D}{\phi_j P_{uj}} \leq 1.0 \tag{5.44}$$

$$\frac{M_D}{\phi_j M_{uj}} \leq 1.0 \tag{5.45}$$

and

$$1 - \cos\left[\frac{\pi}{2}\frac{P_D}{\phi_j P_{uj}}\right] + \left[\left[\frac{M_D}{\phi_j M_{uj}}\right]_{IPB}^2 + \left[\frac{M_D}{\phi_j M_{uj}}\right]_{OPB}^2\right]^{1/2} \leq 1.0 \tag{5.46}$$

where:

P_D - acting axial force in brace.

$M_{D,IPB}$ - acting in-plane bending moment.

$M_{D,OPB}$ - acting out-of-plane bending moment.

P_{uj} - nominal capacity for brace axial load.

M_{uj} - nominal capacity for brace bending moment.

ϕ_j - resistance factor in the range 0.90 - 0.95 depending on joint classification. See API-LRFD for details.

$$P_{uj} = Q_u Q_f \frac{F_y T^2}{\sin\theta} \tag{5.47}$$

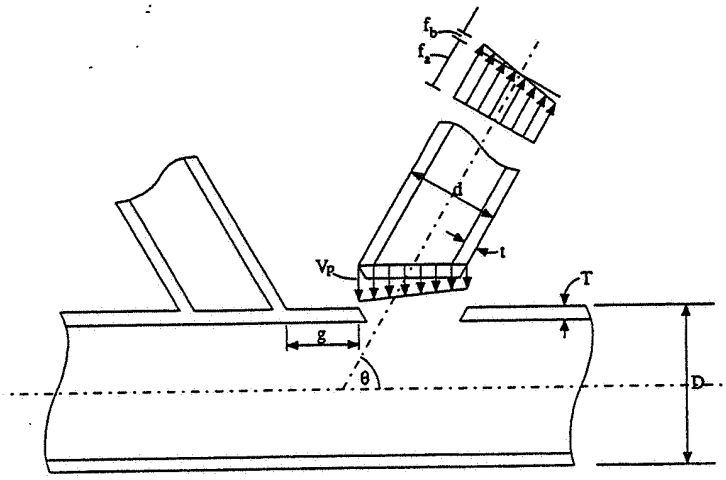
$$M_{uj} = Q_u Q_f \frac{F_y T^2}{\sin\theta}(0.8d) \tag{5.48}$$

In eqs. (5.47) and (5.48),

$$Q_f = 1.0 - \lambda\gamma A^2 \tag{5.49}$$

where

$\lambda = 0.030$ for brace axial load.
$\lambda = 0.045$ for brace in–plane bending.
$\lambda = 0.021$ for brace out–of–plane bending.
$\gamma = D/2T$ see Figure 5.5. (5.50)



θ - Angle between chord and brace.
g - Gap between considered brace and nearest load-carrying brace.
t - Brace thickness
T - Chord thickness
d - Brace diameter
D - Chord diameter

Figure 5.5 Geometry Definition

In eq. (5.49),

$$A = \frac{\sqrt{f_{ax}^2 + f_{IP}^2 + f_{OP}^2}}{\phi_q \, F_y} \tag{5.51}$$

where $\phi_q = 0.95$.

If all extreme fibre stresses in the chord are tensile stresses, i.e.

$$f_{ax} - \sqrt{f_{IPB}^2 + f_{OPB}^2} > 0 \text{ and } f_{ax} - f_{IPB} > 0 \text{ and } f_{ax} - f_{OPB} > 0 \tag{5.52}$$

then $Q_f = 1.0$ in eqs. (5.47) and (5.48).

The values in eq. (5.52) are

$$f_{ax} = \frac{P_{AC}}{A_C} = \text{nominal axial stress in chord} \tag{5.53}$$

$$f_{IP} = \frac{M_{IPC}}{W_C} = \text{nominal in–plane bending stress in chord} \tag{5.54}$$

$$f_{OP} = \frac{M_{OPC}}{W_C} = \text{nominal out–of–plane bending stress in chord} \tag{5.55}$$

The value of Q_u in eqs. (5.47) and (5.48) is defined in Table 5.9.

Table 5.9

	T & Y	X	K
AXIAL TENSION	3.4 + 19β	3.4 + 19β	(3.4 + 19β) Q_g
AXIAL COMPRESSION	3.4 + 19β	(3.4 + 13β) Q_β	(3.4 + 19β) Q_g
IN-PLANE BENDING	3.4 + 19β	3.4 + 19β	3.4 + 19β
OUT-OF-PLANE BENDING	(3.4 + 7β) Q_β	(3.4 + 7β) Q_β	(3.4 + 7β) Q_β

The variables in Table 5.9 have the following values:

$$\beta=\frac{d}{D} \quad \text{see Figure 5.5} \tag{5.56}$$

$$Q_\beta=\frac{0.3}{\beta(1-0.833\beta)} \quad \text{for } \beta > 0.6 \tag{5.57}$$

$$Q_\beta=1.0 \quad \text{for } \beta \le 0.6 \tag{5.58}$$

$$Q_g=1.8-0.1\frac{g}{T} \quad \text{for } \gamma \le 20. \tag{5.59}$$

$$Q_g=1.8-4\frac{g}{D} \quad \text{for } \gamma > 20. \tag{5.60}$$

$$Q_g \ge 1.0 \quad \text{for all } \gamma \tag{5.61}$$

The gap defined in eqs. (5.59) and (5.60) is the distance between the weld toe of the two brace elements. This value, g , is shown in Figure 5.5.

F.4.2 Overlapping joints

The punching shear unity criteria is defined as

$$\frac{P_D}{P_{ns}} \le 1.0 \tag{5.62}$$

where:

P_D - applied axial load component perpendicular to the chord

P_{ns} - nominal axial strength perpendicular to the chord according to eq. (5.63)

The allowable axial load component perpendicular to the chord is for overlapping joints

$$P_{ns} = P_{uj}\cdot\frac{l_1}{l}\cdot\sin\theta + 2\cdot\phi_{sh}\cdot F_y\cdot t_w\cdot l_2 \tag{5.63}$$

where:

P_{uj} - nominal axial strength according to eq. (5.47).

l_1 - circumference for that portion of the brace which contacts the chord (actual length)

l - circumference of brace contact with chord, neglecting presence of overlap.

l_2 - the projected chord length (one side) of the overlapping weld, measured perpendicular to the chord.

t_w - the lesser of the weld throat thickness or the thickness t of the inner brace.

ϕ_{sh} - resistance factor for the weld $\phi_{sh} = 0.9 \cdot 0.6 = 0.54$ according to AISC-LRFD table J2.3.

G Code check according to NPD/NS3472

G.1 General description

The code check consists of the following:

- Yield check according to NPD [28] and NS3472 [39]
- Stability check according to NPD [28] and NS3472 [39]
- Punching shear check according to NPD [28]

For the yield check and the stability check, local element forces and moments are used. For the punching shear check, the in-plane and out-of-plane reference system is used.

The code checking of earthquake calculations can be performed. For a description of how stresses are added for earthquake calculation, see Section C.6.

Hydrostatic pressure effects is included in the yield and the stability check for pipe elements if a water plane is defined prior to the run.

G.2 Yield check

The yield check is available for the following cross-section types:

- Pipe elements (PIPE)
- General beam elements (GENE)
- Wide flange elements (IORH)
- Channel elements (CHAN)
- Box elements (BOX)

The yield check is performed at three different locations along the beam (at both ends and the mid-point). For each point the relevant section forces together with the cross-sectional data are used in the calculation. The yield criteria is satisfied when:

$$\sigma_{eq} < \frac{f_y}{\gamma_m} \tag{6.1}$$

where:

σ_{eq} - maximum equivalent stress
f_y - yield stress
γ_m - material coefficient = 1.15

The general expression for the equivalent stress is:

$$\sigma_{eq} = \left[(\sigma_a + \sigma_{by} + \sigma_{bz})^2 + \sigma_h^2 - \sigma_h(\sigma_a + \sigma_{by} + \sigma_{bz}) + 3(\tau_{xy} + \tau_{xz} + \tau_t)^2 \right]^{1/2} \tag{6.2}$$

The equivalent stress is calculated according to the formulae given above in a number of predefined points in the cross section. The hot spot with the largest equivalent stress is then used in the yield check.

The hot spot with the largest usage factor is reported together with the corresponding stresses. The corresponding stresses are not necessarily the maximum stresses.

Hoop stresses due to hydrostatic pressure is only taken into account for pipe sections.

G.3 Stability checks according to the NPD/NS3472 codes

The check is valid for section types:

- Pipe elements (PIPE)
- General beam elements (GENE)
- Wide flange elements (IORH)
- Channel elements (CHAN)
- Box elements (BOX)

The stability check is based on the assumption that each end of the element are structural joints of a fully braced frame.

In general, for elements in sway frames or members with nodes between the structural joints, the program will not use valid buckling lengths, moment values or moment amplification factors. The reliability of the results for such elements have to be checked in each case, unless special precautions are taken to ensure conservative results.

The nomenclature for all equations in the NPD/NS3472 stability check is described in Section G.5.

G.3.1 Stability check of pipe Elements

The general stability criteria is:

$$\sigma_c \gamma_{mk} + B\sigma_b^* + \sqrt{(B_y \sigma_{by})^2 + (B_z \sigma_{bz})^2} < \frac{f_y}{\gamma_m}, \tag{G.1}$$

where y and z refer to the element local co-ordinate system. See NPD section 3.2.2 for definitions.

For elements with large diameter to thickness ratios, local buckling interaction effects are taken into account with the method of modified yield, as described in Section G.3.1.1 For calculation of design moments, see Section G.3.2.5

However, there is a possibility that a yield check at the compression zone will give a higher usage factor in some cases. Framework does for this reason perform a yield check with the reduced yield strength at the compression zone.

G.3.1.1 Interaction Effects from Local Buckling for Pipe Elements

The interaction effects from local buckling are taken into account by the method of modified yield. The general stability criteria is used but the yield stress is reduced according to formulas given in NPD section 3.4.4 and 3.4.6.

G.3.1.2 Default value for column buckling factors

The default values for the column buckling factors k_y and k_z are taken as 1.0. Framework will calculate k_y according to NPD section 3.2.4.4 if k_y is given a value less than 0.001. The same procedure applies for k_z.

G.3.1.3 Interpretation of Framework result table

The output from Framework is interpreted as described below.

General stability criteria:

$$USF_{ax} = \sigma_c \gamma_{mk} \frac{\gamma_m}{f_y} \qquad USF_{my} = B \sigma_b^* \frac{\gamma_m}{f_y} \qquad USF_{mz} = \left[(B_y \sigma_{by})^2 + (B_z \sigma_{bz})^2 \right]^{1/2} \frac{\gamma_m}{f_y}$$

$$USF_{tot} = USF_{ax} + USF_{my} + USF_{mz} \tag{6.4}$$

I. e. the heading of the result table may be misleading wrt. interpretation of USF_{my} and USF_{mz}.

Von Mises yield check at compression zone with reduced yield strength:

$$USF_{ax} = 0 \qquad USF_{my} = 0 \qquad USF_{mz} = 0$$

$$USF_{tot} = \frac{\sigma_{eq}}{f_y} \gamma_m \tag{6.5}$$

This gives the user a possibility to distinguish between failure due to the general stability criteria and failure due to yield check at the compression zone.

G.3.2 Stability check of non-pipe elements

The general stability criteria for strong axis column buckling is, as defined in NS3472 table 5.4.1:

$$\frac{N}{N_{kyd}} + \left(\frac{\bar{M}_y}{M_{yd}} + K_E \frac{\bar{M}_z}{M_{zd}} \right) \cdot \frac{1}{1 - \frac{N}{N_{Eyd}} \cdot \frac{N_{kyd}}{N_d}} < 1.0 \tag{6.6}$$

For weak axis buckling:

$$\frac{N}{N_{kzd}} + \left(\frac{\bar{M}_y}{M_{yd}} \cdot \frac{1}{K_E} + \frac{\bar{M}_z}{M_{zd}} \right) \cdot \frac{1}{1 - \frac{N}{N_{Ezd}} \cdot \frac{N_{kzd}}{N_d}} < 1.0 \tag{6.7}$$

For lateral buckling only, the criteria is according to NS3472 section 5.5.2:

$$\frac{M_{\max}}{M_{vd}} < 1.0 \tag{6.8}$$

The following symbols are used in the above expressions:

$$N_d = \frac{f_y A}{\gamma_m} \qquad N_{kyd} = \frac{f_{ky} A}{\gamma_m} \qquad N_{kzd} = \frac{f_{kz} A}{\gamma_m} \tag{6.9}$$

$$N_{Eyd} = \frac{\pi^2 EA}{\gamma_m \lambda_y^2} \qquad N_{Ezd} = \frac{\pi^2 EA}{\gamma_m \lambda_z^2} \tag{6.10}$$

$$K_E = \frac{1 - \frac{N}{N_{Eyd}}}{1 - \frac{N}{N_{Ezd}}} \tag{6.11}$$

$\overline{M}_y$ and $\overline{M}_z$ are the design moments.

$$M_{vd} = \frac{f_v}{\gamma_m} W_{weak\ axis} \tag{6.12}$$

M_{max} is the maximum moment about the strong axis.

Flexural-torsional buckling is taken into account by substituting the elastic buckling stress for weak axis buckling with the elastic flexural-torsional buckling stress, see section 6.3.2.3.

G.3.2.1 Calculation of axial compression buckling strength

The characteristic buckling strength f_k is given as a function of the relative slenderness in NS3472 section 5.4.

$$f_{ky} = f_y \cdot \kappa_y \qquad f_{kz} = f_y \cdot \kappa_z \tag{6.13}$$

Radii of gyration

$$i_y = \left[\frac{I_y}{A}\right]^{1/2} \tag{6.14}$$

$$i_z = \left[\frac{I_z}{A}\right]^{1/2} \tag{6.15}$$

Member slenderness ratios:

$$\lambda_y = \frac{k_y \cdot l_y}{i_y} \tag{6.16}$$

$$\lambda_z = \frac{k_z \cdot l_z}{i_z} \tag{6.17}$$

Relative slenderness ratios:

$$\bar{\lambda}_y = \frac{\lambda_y}{\pi}\left[\frac{f_y}{E}\right]^{1/2} \tag{6.18}$$

$$\bar{\lambda}_z = \frac{\lambda_z}{\pi}\left[\frac{f_y}{E}\right]^{1/2} \tag{6.19}$$

If $\bar{\lambda}_y < 0.2$ then $\kappa_y = 1.0$

Else:

$$\kappa_y = \gamma_y - \left[\gamma_y^2 - \frac{1.0}{\bar{\lambda}_y^2}\right]^{1/2} \tag{6.20}$$

where

Curve A: $\alpha_y = 0.21$
Curve B: $\alpha_y = 0.34$
Curve C: $\alpha_y = 0.49$

and

$$\gamma_y = \frac{1 + \alpha_y(\bar{\lambda}_y - 0.2) + \bar{\lambda}_y^2}{2 \cdot \bar{\lambda}_y^2} \tag{6.21}$$

Curve A applies as default for pipe sections and curve C applies as default for other sections.

The above formulas applies for calculation of κ_z as well.

G.3.2.2 Calculation of lateral buckling strength

The lateral buckling strength is calculated according to NS3472 section 5.5 and appendix A5.5.

The lateral buckling strength is as follows.

$$f_v = f_y \cdot \left[1 + \left[\frac{f_y}{f_{vi}}\right]^n\right]^{-\frac{1}{n}} \tag{6.22}$$

The factor n is depending on the fabrication method. For welded sections $n = 1.5$ and for rolled sections $n = 2.0$. In the above expression is the ideal or elastic lateral buckling stress defined as:

$$f_{vi} = \frac{\psi \cdot \pi}{W_{ymin} \cdot l_{lat.buck.}} \sqrt{EI_z \cdot G \cdot I_x} \cdot \left[\left[1 + \frac{EI_w}{GI_x} \cdot \left[\frac{\pi}{l_{lat.buck.}}\right]^2 \left[1 + \frac{h^2(I_c - I_T)^2}{4I_w \cdot I_z}\right] + \frac{\pi h (I_c - I_T)}{2l_{lat.buck.} I_z} \left[\frac{EI_z}{GI_x}\right]^{1/2}\right]^{1/2}\right] \tag{6.23}$$

where

ψ $(or\ C_b)$ - Load dependent lateral buckling factor. The default value is conservatively taken as 1.0. The value can be assigned by the user.

$l_{lat.buck.}$ - Distance between lateral supports. The distance is as default taken as the element length.

Recommended factors for ψ are given in NS3472 figure A.5.5.2a-e. However, three important cases are mentioned table 6.1.

Table 6.1 Lateral buckling factor	
Constant moment distribution	$\psi = 1.0$ (default)
Simply supported beam with constant lateral line load, i.e. parabolic moment distribution	$\psi = 1.13$
Simply supported beam with concentrated force at middle, i.e piecewise linear moment distribution	$\psi = 1.35$

For section types IORH:

$$I_{top} = \frac{1}{12} t_1 b_1^3 \tag{6.24}$$

$$I_{btm} = \frac{1}{12} t_3 b_2^3 \tag{6.25}$$

If $M_y > 0$: $I_c - I_T = I_{top} - I_{btm}$

If $M_y < 0$: $I_c - I_T = I_{btm} - I_{top}$

$$I_w = \frac{h^2 I_c \cdot I_T}{I_z} \tag{6.26}$$

For section types CANA:

For section types CANA:

$$I_c - I_T = 0 \tag{6.27}$$

$$I_w = \frac{h^2 b^3 t_1 \cdot (3 \cdot b \cdot t_1 + 2 \cdot h \cdot t_2)}{12(6 \cdot b \cdot t_1 + h \cdot t_2)} \tag{6.28}$$

G.3.2.3 Flexural-torsional buckling

If section type CANA or if section type IORH with single symmetry, a flexural-torsional buckling resistance is calculated according to NS3472 section A5.4.5.

Section type IORH:

Euler buckling stress

$$f_{ez} = \frac{\pi^2 \cdot E \cdot I_z}{l_{kz}^2 \cdot A} \qquad l_{kz} = k_z \cdot l_z \tag{6.29}$$

Torsional buckling stress

$$f_{Ti} = \frac{G \cdot I_x}{I_p} + \frac{\pi^2 E I_w}{I_p \cdot l_{lat.buck.}^2} \tag{6.30}$$

where

$$I_p = I_y + I_z \tag{6.31}$$

$$I_w = \frac{h^2 \cdot I_c I_T}{I_z} \tag{6.32}$$

Combined elastic flexural-torsional buckling strength

$$f_{EFT} = \frac{1}{2 \cdot c}\left[(f_{ez} + f_{Ti}) - \sqrt{(f_{ez} + f_{Ti})^2 - 4 \cdot c \cdot f_{ez} \cdot f_{Ti}}\right] \tag{6.33}$$

where

$$c = 1 - z_s^2 \cdot A / I_p \tag{6.34}$$

z_s = distance from centroid to shear centre along the z-axis.

Relative slenderness

$$\bar{\lambda}_T = \left[\frac{f_y}{f_{EFT}}\right]^{1/2} \tag{6.35}$$

Section type CANA:

Euler buckling stress

$$f_{ey} = \frac{\pi^2 \cdot E \cdot I_y}{l_{ky}^2 \cdot A} \qquad l_{ky} = k_y \cdot l_y \tag{6.36}$$

Torsional buckling stress

$$f_{Ti} = \frac{G \cdot I_x}{I_p} + \frac{\pi^2 E I_w}{I_p \cdot l^2_{lat.buck.}} \tag{6.37}$$

where

$$I_p = I_y + I_z \tag{6.38}$$

$$I_w = \frac{h^2 b^3 t_1 (3 \cdot b \cdot t_1 + 2 \cdot h \cdot t_2)}{12 \cdot (6 \cdot b \cdot t_1 + h \cdot t_2)} \tag{6.39}$$

Combined elastic flexural-torsional buckling strength

$$f_{EFT} = \frac{1}{2 \cdot c}\left[(f_{ey} + f_{Ti}) - \sqrt{(f_{ey} + f_{Ti})^2 - 4 \cdot c \cdot f_{ey} \cdot f_{Ti}}\right] \tag{6.40}$$

where

$$c = 1 - y_s^2 \cdot A / I_p \tag{6.41}$$

y_s = distance from centroid to shear centre along the y-axis.

Relative slenderness

$$\bar{\lambda}_T = \left[\frac{f_y}{f_{EFT}}\right]^{1/2} \tag{6.42}$$

The buckling stress reduction factor is for both IORH and CANA sections taken as $\kappa_T = 1.0$ if $\bar{\lambda} < 0.2$, otherwise:

$$\gamma_T = \frac{1 + \alpha_T(\bar{\lambda}_T - 0.2) + \bar{\lambda}_T^2}{2 \cdot \bar{\lambda}_T^2} \tag{6.43}$$

where $\alpha_T = \max(\alpha_y, \alpha_z)$

$$\kappa_T = \gamma_T - \left[\gamma_T^2 - \frac{1.0}{\bar{\lambda}_T^2}\right]^{1/2} \tag{6.44}$$

The buckling stress reduction factor κ in (6.37) is then substituted by κ^* in the following manner:

$\kappa_y^* = \min(\kappa_y, \kappa_T)$ for section type CANA

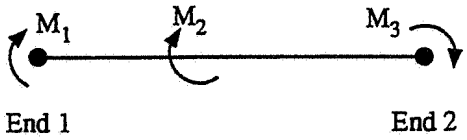
$\kappa_z^* = \min(\kappa_z, \kappa_T)$ for section type single symmetric IORH

G.3.2.4 Local buckling of web and/or flange

Local buckling of web and/or flanges is not taken into account.

G.3.2.5 Calculation of Design Moments

Unless the user defines moment amplification reduction factors, the design moments are calculated according to NS3472 section 5.4.2 as described below.



$$\beta = \frac{M_1}{M_3} \text{ if } |M_3| > |M_1|$$

$$\beta = \frac{M_3}{M_1} \text{ if } |M_1| > |M_3|$$

$$m = 0.6 + 0.4 \cdot \beta \geq 0.4$$

$$M = \max|M_1|, |M_3|$$

$$M_0 = \frac{M + \beta M}{2} - M_2$$

$$M'_{max} = M_1 - \frac{(3M_1 - 4M_2 + M_3)^2}{8(M_1 - 2M_2 + M_3)} \tag{6.45}$$

$$M_{max} = \max(|M_1|, |M'_{max}|, |M_3|)$$

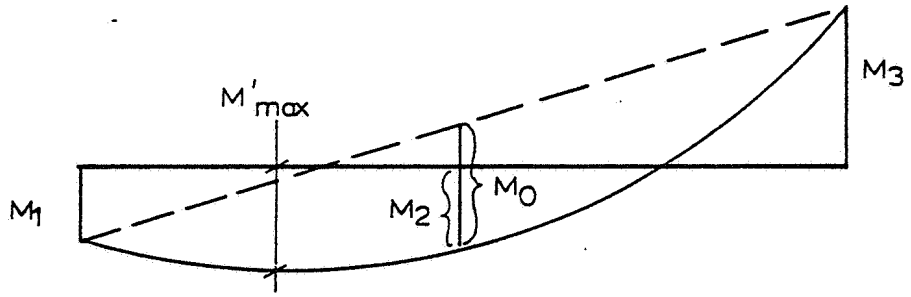


Figure 6.3 Nomenclature for calculation of design moments

a) $M_2 = \frac{M_1 = M_3}{2}$ (6.46a)

$\rightarrow \overline{M} = m \cdot M$ (case 7 and 8)

b) $M_2 \neq \frac{M_1 + M_3}{2}$, $\beta < 0$, $sign\ (M_2) = sign\ (M)$ (6.46b)

$\rightarrow \overline{M} = m \cdot M + M_0$ (case 4)

c) $M_2 \neq \frac{M_1 + M_3}{2}$, $\beta < 0$, $sign\ (M_2) \neq sign\ (M)$ (6.46c)

$\rightarrow \overline{M} = \max(M_0, mM)$ (case 5 and 6)

$d)$ $M_2 \neq \frac{M_1 + M_3}{2}$, $\beta > 0$, $sign\ (M_2) \neq sign\ (M)$ (6.46d)

$\rightarrow \overline{M} = M_0 - mM$ (case 3)

$e)$ $M_2 \neq \frac{M_1 + M_3}{2}$, $\beta > 0$, $M_2 < \frac{M_1 + M_3}{2}$ (6.46e)

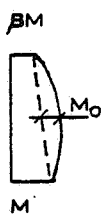
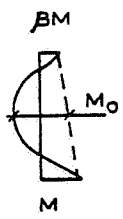
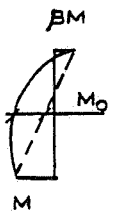
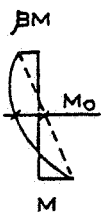
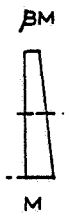
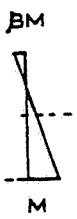
$\rightarrow \overline{M} = mM$ (case 2)

$f)$ $M_2 \neq \frac{M_1 + M_3}{2}$, $\beta > 0$, $M_2 > \frac{M_1 + M_3}{2}$ (6.46f)

$\rightarrow \overline{M} = m \cdot M + M_0$ (case 1)

For all cases: $\overline{M} \leq M_{max}$

Table 6.2 Calculation of design moment

1	2	3	4	5	6	7	8
							
$\overline{M} = mM \cdot M_0$	$\overline{M} = m \cdot M$	$\overline{M} = M_0 \cdot mM$ but $\overline{M} < M_{max}$	$\overline{M} = mM \cdot M_0$	$\overline{M} = M_0 \cdot mM$ but $\overline{M} < M_{max}$	$\overline{M} = mM > M_0$ but $\overline{M} < M_{max}$	$\overline{M} = m \cdot M$	$\overline{M} = m \cdot M$
$I_c - I_T$	$I_c - I_T$		$I_T - I_c$	$I_T - I_c$	$I_c - I_T$	$I_c - I_T$	$I_c - I_T$

In table 6.2, the following is appliciable:

$$m = 0.6 + 0.4 \cdot \beta \geq 0.4$$
$$-1 \leq \beta \leq 1$$
$$M_0 = \frac{M + \beta M}{2} - M_{mid}$$

where M, βM, and M_{mid} are the computed end- and midpoint moments (from SESTRA).

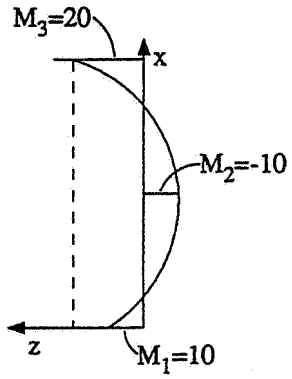
For unsymmetrical IORH-sections, the sign of $\overline{M}$ is of importance when determining which flange is in compression.

The sign of $\overline{M}$ will correspond to the sign of M_{max}, except for case 3. For this moment distribution one has:

$$|M_2| \geq \left|\frac{M + \beta M}{2}\right| \rightarrow \overline{M} = |\overline{M}| \cdot sign(M_2) \quad (6.47)$$

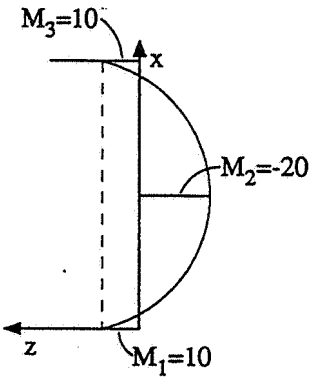
$$|M_2| < \left|\frac{M + \beta M}{2}\right| \rightarrow \overline{M} = |\overline{M}| \cdot sign(M) \quad (6.48)$$

Examples:



$$|M_2| = 10 < \left|\frac{M + \beta M}{2}\right| = 15 \rightarrow \overline{M} > 0$$

Tension flange on positive z-axis
Compression flange on negative z-axis



$$|M_2| = 20 > \left|\frac{M + \beta M}{2}\right| = 10 \rightarrow \overline{M} < 0$$

Tension flange on negative z-axis
Compression flange on positive z-axis

If the user has assigned moment amplification factors, the program calculated design moments $\overline{M}_y$ and $\overline{M}_z$ will be overwritten by:

$$\overline{M}_y = M_{max,y} \cdot C_{my}$$
$$\overline{M}_z = M_{max,z} \cdot C_{mz} \quad (6.49)$$

where:

$M_{max,y}$	Maximum absolute moment about y-axis at element ends or at element midpoint
$M_{max,z}$	Maximum absolute moment about z-axis at element ends or at element midpoint
C_{my}	User assigned amplification factor for moment about local y-axis
C_{mz}	User assigned amplification factor for moment about local z-axis

However, there are some exceptions from this rule as shown in table 6.4.

Table 6.4 Design Moment

Tension (Lateral buckling check)	Compression
$\overline{M}_y = M_{max,y}$	$\overline{M}_z$ according to (6.49)
$\overline{M}_z = M_{max,z}$	If lateral buckling check then $\overline{M}_y = M_{max,y}$
	else $\overline{M}_y$ according to (6.49)

G.3.2.6 Calculation of usage factors for non-pipe members

There are three failure modes for non-pipe members under compression: ordinary column buckling, combined flexural-torsional buckling and lateral buckling.

Furthermore, lateral buckling is checked for elements with zero or positive axial force (if there is net compressive stress in a flange).

Elements in Compression :

Axial Usage Factor

$$USF_{ax,y} = \frac{|N|}{f_{ky}/\gamma_m \cdot A} \qquad USF_{ax,z} = \frac{|N|}{f_{kz}/\gamma_m \cdot A} \tag{6.50}$$

where the axial compression buckling strength, f_k is found as described in 6.3.2.1 and 6.3.2.3 for buckling about both y- and z-axis.

Usage Factor - Bending about y-Axis

Lateral buckling:

If section type IORH, CANA, or GENE with $I_y > I_z$, the usage factor will be:

$$USF_{my,z} = \frac{M_{max,y}}{\frac{f_{kv}}{\gamma_m} \cdot W_{ymin}} \cdot \frac{1}{1 - \frac{N}{N_{Ezd}} \cdot \frac{N_{kzd}}{N_d}} \cdot \frac{1}{K_E} \tag{6.51}$$

The lateral buckling strength f_{kv} is found as described in 6.3.2.2.

Column buckling:

Buckling about y-axis

$$USF_{my,y} = \frac{\bar{M}_y}{\frac{f_y}{\gamma_m} \cdot W_{ymin}} \cdot \frac{1}{1 - \frac{N}{N_{Eyd}} \cdot \frac{N_{kyd}}{N_d}} \tag{6.52}$$

where the design moment $\bar{M}_y$ is found as described in 6.3.2.4.

Buckling about z-axis

$$USF_{my,z} = \frac{\bar{M}_y}{\frac{f_y}{\gamma_m} \cdot W_{ymin}} \cdot \frac{1}{1 - \frac{N}{N_{Ezd}} \cdot \frac{N_{kzd}}{N_d}} \cdot \frac{1}{K_E} \tag{6.53}$$

Usage factor - bending about z-axis

Buckling about y-axis

$$USF_{mz,y} = \frac{\bar{M}_z}{\frac{f_y}{\gamma_m} \cdot W_{zmin}} \cdot \frac{1}{1 - \frac{N}{N_{Eyd}} \cdot \frac{N_{kyd}}{N_d}} \cdot K_E \tag{6.54}$$

Calculation of the design moment $\bar{M}_z$, see 6.3.2.4.

Buckling about z-axis

$$USF_{mz,z} = \frac{\bar{M}_z}{\frac{f_y}{\gamma_m} \cdot W_{zmin}} \cdot \frac{1}{1 - \frac{N}{N_{Ezd}} \cdot \frac{N_{kzd}}{N_d}} \tag{6.55}$$

Total usage factor

Total usage factor is calculated both for buckling about y-axis and z-axis and the largest usage factor is printed.

$$USF_{tot,y} = USF_{ax,y} + USF_{my,y} + USF_{mz,y}$$

$$USF_{tot,z} = USF_{ax,z} + USF_{my,z} + USF_{mz,z}$$

$$USF_{tot} = max(\, USF_{tot,y} \,,\, USF_{tot,z} \,) \tag{6.56}$$

Elements in Tension :

Only lateral buckling is considered.

Axial Usage Factor

$$USF_{ax} = 0.0 \tag{6.57}$$

Usage Factor - Bending about y-Axis

If the section type is IORH, CANA, or GENE with $I_y > I_z$, and if lateral buckling not is restricted by the user, the usage factor is

$$USF_{my} = \frac{\frac{M_{max,y}}{W_{yc}} - \frac{N}{A}}{\frac{f_{kv}}{\gamma_m}} \tag{6.58}$$

For f_{kv} - see 6.3.2.2

W_{yc} is the section modulus on compression side of the section.

If lateral buckling is restricted, strong axis bending is not considered.

Usage Factor - Bending about z-Axis

$$USF_{mz} = \frac{M_{max,z}}{\frac{f_y}{\gamma_m} \cdot W_{zmin}} \tag{6.59}$$

Total Usage Factor

$$USF_{tot} = USF_{my} + USF_{mz} \tag{6.60}$$

I. e. only the compression flange is checked.

G.4 Punching shear check

For the punching shear check the forces and moments are transferred to in-plane and out-of-plane reference system. For transformation details, see Section 3.7.

The design is based on nominal loads.

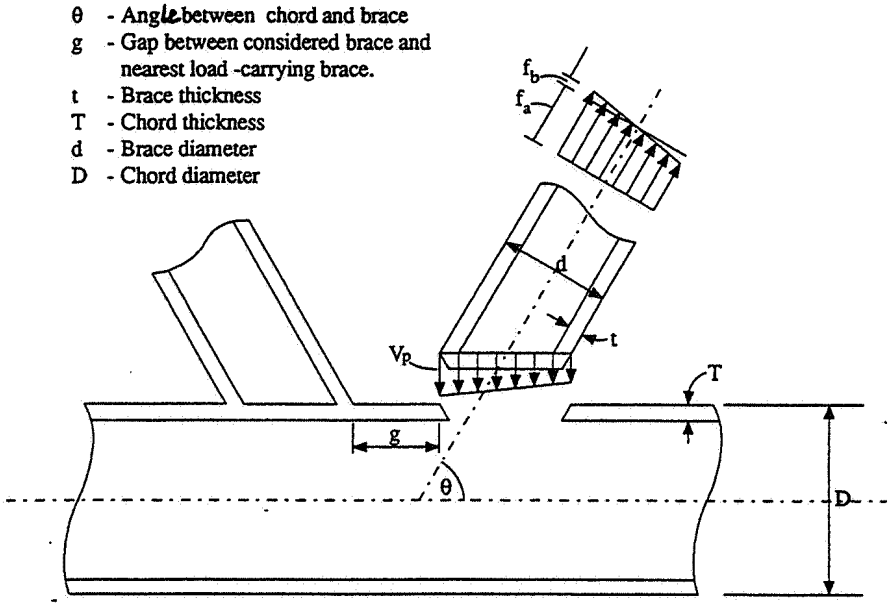


Figure 6.5Punching Shear, Symbols, and Geometry

The design criteria for non-overlapped joints is:

$$\frac{N}{N_k} + \left[\frac{M_{ip}}{M_{ipk}}\right]^2 + \frac{M_{op}}{M_{opk}} < \frac{1}{\gamma_m} \qquad (6.61)$$

where

N	- is the acting axial force
M_{ip}	- is the acting "in-plane" bending moment
M_{op}	- is the acting "out-of-plane" bending moment
N_k	- is the characteristic axial capacity
M_{ipk}	- is the characteristic "in-plane" bending capacity
M_{opk}	- is the characteristic "out-of-plane" bending capacity

The characteristic capacities as calculated according to NPD section 3.5, where the design criteria for overlapped joints is described in detail as well.

G.5 Nomenclature

Nomenclature for NPD/NS3472 code check.

A	- Area of cross-section
C_{my}	- Moment amplification factor
C_{mz}	- Moment amplification factor
D	- Outer diameter of pipe members
E	- Young's modulus
f_e	- Euler buckling stress
f_{Ti}	- Elastic torsional buckling stress
f_{EFT}	- Elastic flexural-torsional buckling stress
f_v	- Lateral buckling strength
f_k	- Characteristic buckling strength
f_{vi}	- Elastic lateral buckling strength
f_y	- Material yield strength
G	- Shear modulus
h	- Height of cross-section
I_c	- Moment of inertia of compressed flange (IORH-sect.)
I_T	- Moment of inertia of tensioned flange (IORH-sect.)
I_w	- Warping stiffness
I_x	- Torsional stiffness
I_y	- Moment of inertia about y-axis
I_z	- Moment of inertia about z-axis
i_y	- Radius of gyration about y-axis
i_z	- Radius of gyration about z-axis
k_y	- Buckling length factor about y-axis
k_z	- Buckling length factor about z-axis
l	- Member length (between nodal points)
l_y	- Buckling length about y-axis
l_z	- Buckling length about z-axis
$l_{lat.buck.}$	- Distance between lateral supports
$\overline{M}_y$	- Design moment
$\overline{M}_z$	- Design moment
M_{vd}	- Lateral buckling moment capacity
N_{Ey}	- Euler buckling load about y-axis
N_{Ez}	- Euler buckling load about z-axis
r	- Mean radius of pipe members
t	- Wall thickness of pipe members
W_{el}	- Elastic section modulus
$W_{y,min}$	- Minimum section modulus about y-axis
$W_{z,min}$	- Minimum section modulus about z-axis
$W_{y,c}$	- Section modulus of compressed flange about y-axis
$W_{y,T}$	- Section modulus of tensioned flange about y-axis
γ_m	- Material factor
λ_y	- Slenderness ratio about y-axis
λ_z	- Slenderness ratio about z-axis
$\overline{\lambda}_k$	- Maximum reduced slenderness ratio
κ	- Reduction factor
ψ (or C_b)	- Load dependent factor for calculating lateral buckling strength
σ_{eq}	- Von Mises equivalent stress
σ_h	- Hoop stress due to external water pressure

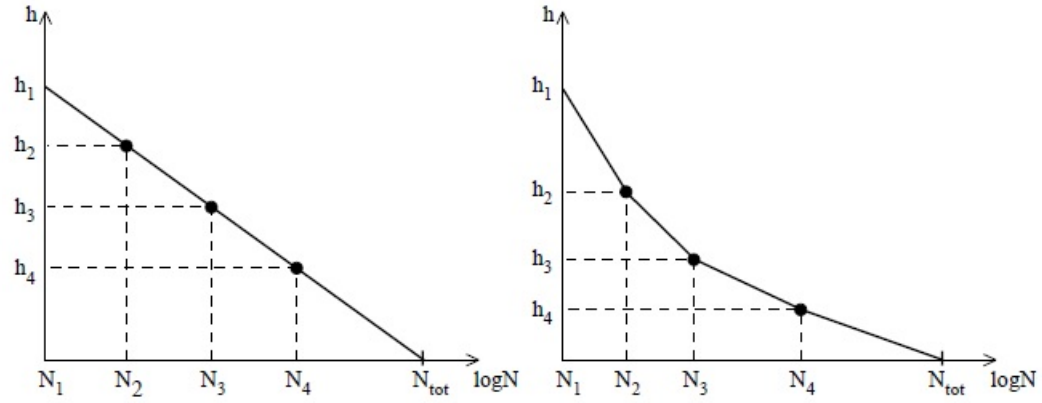


Figure H.1: Long term distribution of wave heights for a wave direction

H Deterministic fatigue analysis (discrete wave approach)

H.1 Summary

The static fatigue check based on stresses computed in a static analysis, is performed according to the AWS code (American Welding Society) [10]. The stress fluctuations are caused by wave loads. A linear or piecewise linear long term distribution of wave heights is assumed. The resulting stresses, or stress ranges, are entered on a S/N-curve. The accumulated damage due to the influence of various wave heights is summed up according to Miner's rule.

H.2 Theoretical description

H.2.1 Wave data

Most of the wave data is given as input to other Sesam programs, Wajac or Wadam. The input in Wajac/Wadam must be consistent with the limitations in Framework.

Consult Appendix L for the limitations in Framework regarding the wave conditions that can be specified in the deterministic fatigue analysis.

H.2.2 Wave loading

The total number of waves from each wave direction is given as input to Framework by the user. A long term distribution of wave heights (Figure H.1) is produced for each wave direction. For each wave height, a certain associated number of waves is derived from the long ten distribution this can be linear or piecewise linear in a semi-logarithmic mapping, as shown in Figure H.1). The linear form corresponds to a long term Weibull distribution.

H.2.3 Member forces

The member forces are computed by stepping the waves through the structure. For each position (time step) of the wave, the member forces are computed by a static analysis and are stored as a load case.

When performing a fatigue check, the forces and moments are transformed to the in-plane and out-of-plane reference system. The transformation is described in Section D.7.

Consult Appendix L for the limitations in Framework regarding the wave conditions that can be specified in the deterministic fatigue analysis.

H.2.4 Stress Calculation for pipe elements

In Figure H.2

- M_O: Out-of-plane moment

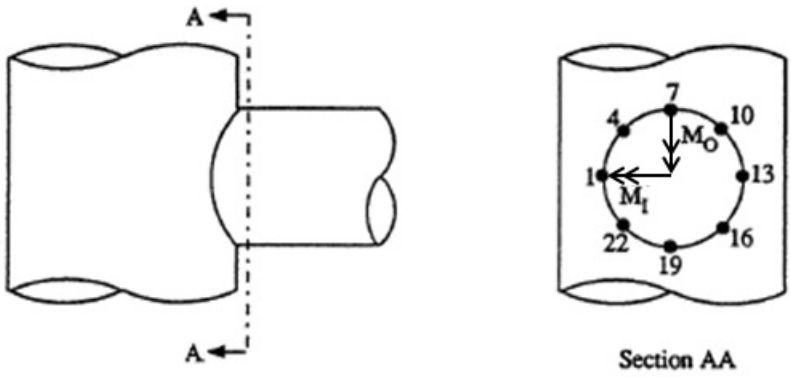


Figure H.2: Hot Spot Numbering for pipe section (Here $\alpha = 0$, see definition of α in Figure D.25)

- M_I: In-plane moment

The fatigue check is as default carried out for 8 selected hot spots around the circumference of the brace-to-chord attachment as shown in Figure H.2. The effects of the shear forces and the torsional moments are ignored. The largest nominal axial stresses in the brace due to the axial force, the in-plane bending moment and the out-of-plane bending moment are given as

$$\sigma_x = \frac{N}{A} \tag{H.1}$$

$$\sigma_{by} = \frac{M_y}{W_y} \tag{H.2}$$

$$\sigma_{bz} = \frac{M_z}{W_z} \tag{H.3}$$

where

N	axial force
M_y	bending moment about local y-axis
M_z	bending moment about local z-axis
A	cross section area
W_y	section modulus about local y-axis
W_z	section modulus about local z-axis (equal to W_y for a PIPE element)

For tubular sections, the hot spot numbering is shown in Figure H.2. Hot spots 7 and 19 are always crown points, whereas hot spots 1 and 13 are always saddle points. The angle α in Figure H.2 is the same as that calculated in Figure D.25 in Section D.7.

For chords and other non-brace members, hot spot 1 lies on the local y-axis and 7 on the local z-axis.

See Figure H.3 for active hot spots for different section types.

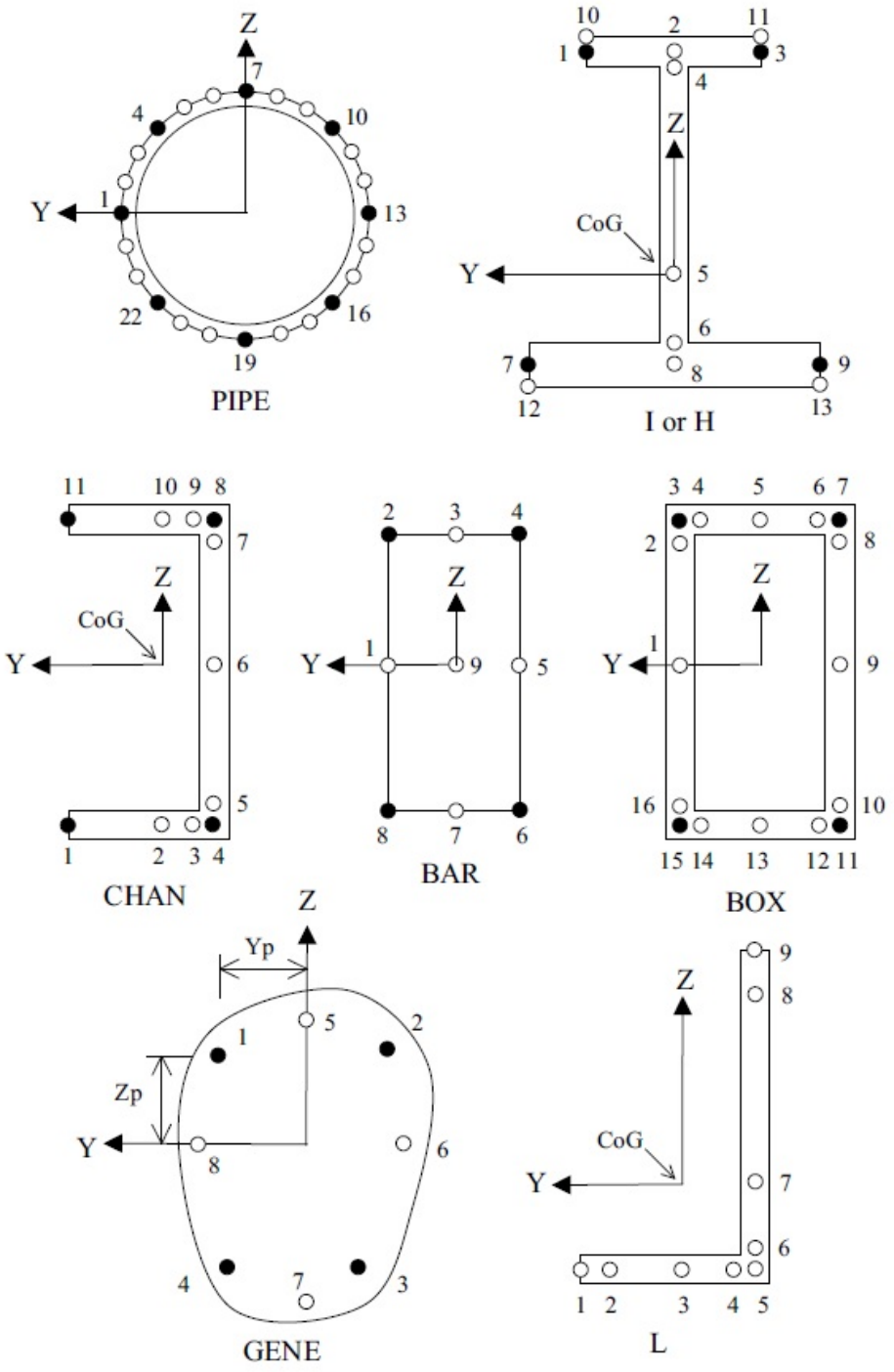


Figure H.3: Hot spot numbering system employed in Framework for various sections. Filled hot spots are checked in a fatigue analysis. For PIPE, see definition of co-ordinate system in Figure H.2

The stress concentration factors are applied as follows:

$$\sigma_{hot} = SCF_{ax} \cdot \frac{N}{A} - SCF_{ipb} \cdot \frac{M_y}{I_y} \cdot z_{local} - SCF_{opb} \cdot \frac{M_z}{I_z} \cdot y_{local} \tag{H.4}$$

where

I_y, I_z	the moment of inertia about a given axis
y_{local}, z_{local}	the co-ordinates of the stress point relative to the section centre of gravity, in the local axis system.

For PIPE sections 24 hot spots are available, but for fatigue only hotspots 1, 4, 7, 10, 13, 16, 19 and 22 are checked as default.

In the printout, for non-tubular members, chords and non-brace members, M_{ipb} denominates M_y (moment about the local y-axis) and M_{opb} denominates M_z (moment about the local z-axis).

For brace end sections the equation for hotspot stress may be written as:

$$\sigma_{hot} = SCF_{ax} \cdot \frac{N}{A} - SCF_{ipb} \cdot \frac{M_{ipb}}{I} \cdot z'_{local} - SCF_{opb} \cdot \frac{M_{opb}}{I} \cdot y'_{local} \tag{H.5}$$

where

I	the moment of inertia for the PIPE section
y'_{local}, z'_{local}	the c-ordinates of the stress point relative to the section centre of gravity, in the in-plane/out-of-plane axis system.
N, M_{ipb}, M_{opb}	brace axial force, in-plane bending and out-of-plane bending moments at the brace end section.

When using the CROWN-SADDLE or parametric SCF's, the commands DEFINE FATIGUE-CONSTANTS IN-PLANE-FACTOR and DEFINE FATIGUE-CONSTANTS OUT-OF-PLANE-FACTOR may be used to modify the SCF's for in-plane and out-of-plane bending hotspots 4, 10, 16 and 22 for PIPE members as described below.

The correction factors are applied as follows:

$$SCF'_{ipb} = SCF_{ipb} \cdot Fac_{ipb} \cdot \sqrt{2} \tag{H.6}$$

$$SCF'_{opb} = SCF_{opb} \cdot Fac_{opb} \cdot \sqrt{2} \tag{H.7}$$

Default is $Fac_{ipb} = 1.0$ and $Fac_{opb} = 1.0$. A factor of 0.707 ($= 1/\sqrt{2}$) gives SCF's that correspond to the generalised hotspot stress formula H.4.

For the use of LOCAL (UNIFORM, SYMMETRIC, BI-SYMMETRIC, NON-SYMMETRIC) or GLOBAL SCF's no correction is applied, hence the SCF's values must be made larger at hotspots 4, 10, 16, 22 if the nominal stress computed at the hotspot does not yield the correct hot spot stress.

The stress concentration factors can be specified by the user, but are otherwise computed by the program itself based on formulas by Kuang [77] *K*-, *KT*-, and *YT*-joints, by Wordsworth and Smedley [98] for *X*-joints, or by Efthymiou for *K*-, *KT*-, *YT*- and *X*-joints.

The stresses at the hot spots (namely Hot Spot Stress-HSS) will be computed as the product of brace-side nominal stress components multiplied with associated SCF, as Eqn H.5, on both the brace and the chord side of the weld since the stress concentration factors on the brace side and on the chord side can be different.

In the program calculated parametric formulas listed below, the following is used:

α	ratio outer diameter chord to chord length
β	ratio outer diameter brace to outer diameter chord

γ	ratio wall thickness chord to outer diameter chord
g	ratio separation (gap) to outer diameter chord (g is the sum of the two gaps for TK-joints.)
τ	ratio brace wall thickness to chord wall thickness
θ	angle between chord and considered brace

In the parametric formulas, the following notation is used:

SCFXB	SCF for axial stress, brace side
SCFXC	SCF for axial stress, chord side
SCFBYB	SCF for in-plane bending stress, brace side
SCFBYC	SCF for in-plane bending stress, chord side
SCFBZB	SCF for out-of-plane bending stress, brace side
SCFBZC	SCF for out-of-plane bending stress, chord side

H.2.4.1 Kuang Formulas

The general validity range for all of the joint types is described below in the Notes paragraph H.2.4.3 of the *T*- and *Y*-joint.

T- and *Y*-joints

SCF Formula			Validity range	Notes
SCFXB	=	$2.784 \cdot \gamma^{-0.55} \cdot e^{-1.35\beta^3} \cdot \tau \cdot \alpha^{-0.12} \cdot \sin^{1.94}\theta$		1
SCFXC	=	$1.177 \cdot \gamma^{-0.808} \cdot e^{-1.2\beta^3} \cdot \tau^{1.333} \cdot \alpha^{-0.057} \cdot \sin^{1.694}\theta$		1
SCFBYB	=	$1.109 \cdot \gamma^{-0.23} \cdot \beta^{-0.38} \cdot \tau^{0.38} \cdot \sin^{0.21}\theta$		2
SCFBYC	=	$0.463 \cdot \gamma^{-0.6} \cdot \beta^{-0.04} \cdot \tau^{0.86} \cdot \sin^{0.57}\theta$		2
SCFBZB	=	$0.843 \cdot \gamma^{-0.852} \cdot \beta^{0.801} \cdot \tau^{0.543} \cdot \sin^{2.033}\theta$	$0.3 \le \beta \le 0.55$	3
SCFBZB	=	$0.441 \cdot \gamma^{-0.852} \cdot \beta^{-0.281} \cdot \tau^{0.543} \cdot \sin^{2.033}\theta$	$0.55 \le \beta \le 0.75$	3
SCFBZC	=	$0.507 \cdot \gamma^{-1.014} \cdot \beta^{0.787} \cdot \tau^{0.889} \cdot \sin^{1.577}\theta$	$0.3 \le \beta \le 0.55$	3
SCFBZC	=	$0.229 \cdot \gamma^{-1.014} \cdot \beta^{-0.619} \cdot \tau^{0.889} \cdot \sin^{1.577}\theta$	$0.55 \le \beta \le 0.75$	3

K-joints

SCF Formula			Validity range	Notes
SCFXB	=	$0.825 \cdot \gamma^{-0.157} \cdot \beta^{-0.441} \cdot \tau^{0.56} \cdot g^{0.058} \cdot \sin^{1.448}\theta$	$30 \le \theta \le 90$ $0.01 \le g \le 1$	2
SCFXC	=	$0.949 \cdot \gamma^{-0.666} \cdot \beta^{-0.059} \cdot \tau^{1.104} \cdot g^{0.067} \cdot \sin^{1.521}\theta$	$30 \le \theta \le 90$ $0.01 \le g \le 1$	2
SCFBYB	=	$2.827 \cdot \beta^{-0.35} \cdot \tau^{0.35} \cdot \sin^{0.5}\theta$	$30 \le \theta \le 90$	2
SCFBYC	=	$1.40 \cdot \gamma^{-0.38} \cdot \beta^{0.06} \cdot \tau^{0.94} \cdot \sin^{0.9}\theta$	$30 \le \theta \le 90$	2
SCFBZB	=	As for T- and Y-joint		1

continued . . .

SCF Formula			Validity range	Notes
SCFBZC	=	As for T- and Y-joint		1

K-part of *TK*-joints

SCF Formula			Validity range	Notes
SCFXB	=	$5.65 \cdot \gamma^{-0.1} \cdot \beta^{-0.36} \cdot \tau^{0.68} \cdot g^{0.126} \cdot \sin^{0.5} \theta$	$0 \leq \theta \leq 45$ $0.01 \leq g \leq 1$	2
SCFXB	=	$12.88 \cdot \gamma^{-0.1} \cdot \beta^{-0.36} \cdot \tau^{0.68} \cdot g^{0.126} \cdot \sin^{2.98} \theta$	$45 \leq \theta \leq 90$ $0.01 \leq g \leq 1$	2
SCFXC	=	$1.26 \cdot \gamma^{-0.54} \cdot \beta^{0.12} \cdot \tau^{1.068} \cdot \sin \theta$	$0 \leq \theta \leq 90$	2
SCFBYB	=	As for K-joints		
SCFBYC	=	As for K-joints		
SCFBZB	=	As for T- and Y-joint		2
SCFBZC	=	As for T- and Y-joint		2

T-part of *TK*-joints

SCF Formula			Validity range	Notes
SCFXB	=	$4.491 \cdot \gamma^{-0.123} \cdot \beta^{-0.396} \cdot \tau^{0.672} \cdot g^{0.159} \cdot \sin^{2.267} \theta$		2
SCFXC	=	As for K-part of TK-joints		
SCFBYB	=	As for K-joints		
SCFBYC	=	As for K-joints		
SCFBZB	=	As for T- and Y-joint		
SCFBZC	=	As for T- and Y-joint		

H.2.4.2 Wordsworth/Smedley Formulas

X-joints

SCF Formula			Validity range	Notes
SCFXC	=	$0.85 \cdot \gamma^{-1} \cdot \tau \cdot \beta \cdot \left(2.42 - 2.28 \cdot \beta^{2.2}\right) \cdot \sin^{(15-14.4 \cdot \beta) \cdot \beta^2} \theta$		2
SCFXB	=	$1 + 0.63 \cdot$ SCFXC		2
SCFBYC	=	$0.49 \cdot \gamma^{-0.6} \cdot \tau^{0.8} \cdot \left(1.6 \cdot \beta^{0.25} - 0.7 \cdot \beta^2\right) \cdot \sin^{(1.5-1.6 \cdot \beta)} \theta$		2
SCFBYB	=	$1 + 0.63 \cdot$ SCFBYC		2
SCFBZC	=	$0.5 \cdot \gamma^{-1} \cdot \tau \cdot \beta \cdot \left(1.56 - 1.46 \cdot \beta^5\right) \cdot \sin^{(15-14.4 \cdot \beta) \cdot \beta^2} \theta$		2
SCFBZB	=	$1 + 0.63 \cdot$ SCFBZC		2

H.2.4.3 Notes

Joints not in conformity to the validity range will be highlighted with a warning.

1	$0.05 \leq \alpha \leq 0.3$	$0.3 \leq \beta \leq 0.8$	$0.015 \leq \gamma \leq 0.060$	$0.2 \leq \tau \leq 0.8$	$0 < \theta < 90$
2		$0.3 \leq \beta \leq 0.8$	$0.015 \leq \gamma \leq 0.060$	$0.2 \leq \tau \leq 0.8$	$0 < \theta < 90$
3			$0.015 \leq \gamma \leq 0.060$	$0.2 \leq \tau \leq 0.8$	$0 < \theta < 90$

H.2.4.4 Efthymiou Formulas

The Efthymiou stress concentration factors are implemented according to "Development of SCF formulae and generalised influence functions for use in fatigue analysis" by M. Efthymiou [73].

The load path assumptions are conservatively taken according to recommendation as follows:

- Axial load in *K*, *KT* and *X* joints assumed to be balanced
- Out-of-plane bending in *K* and *KT* joints is assumed to be unbalanced
- Out-of-plane bending in *X* joints is assumed to be balanced
- In-of-plane bending in *K* joints is assumed to be unbalanced

The chord end fixity parameter is as default taken as 1.0 (valid for pinned elements). The parameter may be modified by resetting the column buckling factors K_y and K_z.

The chord length is as default taken as the sum of the lengths of CHORD and ALIGNED elements at a joint (but length of CHORD element only if no ALIGNED element). The chord length may be modified by resetting the column buckling length L_y and L_z.

The formulas for the Efthymoiu SCF's are included in Appendix B.9.

H.2.4.5 Marshall reduction factor

The brace side SCF's of *T*, *Y*, *K*, *KTK*, and *TTK* joints may be modified by the Marshall reduction factor Q_r [84]. The SCF's are then modified as follows:

$$\begin{aligned} \text{SCFXB}^* &= 1 + Q_r \cdot (\text{SCFXB} - 1)\,, \\ \text{SCFBYB}^* &= 1 + Q_r \cdot (\text{SCFBYB} - 1)\,, \\ \text{SCFBZB}^* &= 1 + Q_r \cdot (\text{SCFBZB} - 1)\,, \end{aligned}$$

and

$$Q_r = e^{-\frac{0.5 \cdot T_c + T_b}{\sqrt{R_b \cdot T_b}}}\,, \tag{H.8}$$

where

T_c	tube thickness chord
T_b	tube thickness brace
R_b	outer radius brace

The Marshall reduction factor will only be applied to parametric SCF's according to Kuang.

H.2.5 Long term distribution of stress ranges

For each wave direction and each hot spot (brace and chord side), the program will calculate a long term distribution of stress (Figure H.4 left). The stress range is calculated by assessing wave heights. For each of the wave heights, the maximal hot spot stresses are obtained from the formulas in Section D. The stress range for each wave height is calculated by determining the largest hot spot stress difference between the loadcases. The hot spot stress ranges are plotted versus the number of waves to give a long term distribution of the stress range (Figure H.4 right). The number of waves on the long term distribution of stresses for each wave height is found from the long term distribution of wave heights (Figure H.1). A long term distribution of stress range is thereby obtained for each wave direction and each hot spot, brace and

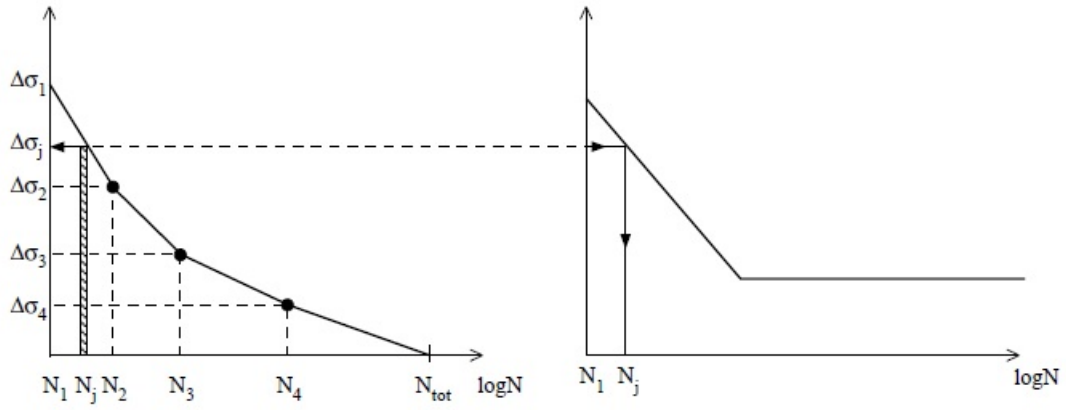


Figure H.4: Long term distribution of stress

chord side. The long term distribution of stresses for each wave direction is then divided into 100 blocks, and the corresponding damage is calculated for each wave height, and then is summed for all the wave heights.

Consult Appendix L for the limitations in Framework regarding the wave conditions that can be specified in the deterministic fatigue analysis.

H.2.6 SN curves

The SN curve is used to define the fatigue characteristics of a material subjected to a repeated cycle of stress of constant magnitude. The SN curve delivers the number of cycles required to produce failure for a given magnitude of stress. The SN curve may be calculated by the program or it may be defined by the user.

The program default SN curve, the DNV-X curve, is similar to the X-curve stipulated by the American Welding Society, AWS D1.1 1972 sec. 10. The SN curve library contains a subset of DNV, API and NS3472 curves.

The program defined SN curves is converted from SI base units to the current set of consistent units based on the assumption that the Youngs modulus of the material corresponds to steel (with $E = 2.1 \cdot 10^{11} N/m^2$).

The user defined SN curves requires the definition of slopes and intersection points. A maximum of three slopes (and two intersection points) may be specified. A consistent set of units must be used.

For tubular members only, it is possible to incorporate thickness effects in the SN curve by factoring the hot spot stresses as described below.

The thickness correction factor, f, to be applied to the hotspot stress is computed according to the following formula for a given section thickness t.

$$f = f(t) = \begin{cases} \left(\frac{t_{cut}}{t_{ref}}\right)^{t_{exp}} & \text{for} \quad t \leq t_{cut}, \\ \left(\frac{t}{t_{ref}}\right)^{t_{exp}} & \text{for} \quad t > t_{cut}, \end{cases} \tag{H.9}$$

For the standard T-curve option, an exponent t_{exp} of 0.25 is used, and $t_{cut} = t_{ref} = 32mm$ (specified in the current consistent set of units). Figure H.5 shows an example of the thickness correction factor f as a function of t, t_{cut} and t_{ref}

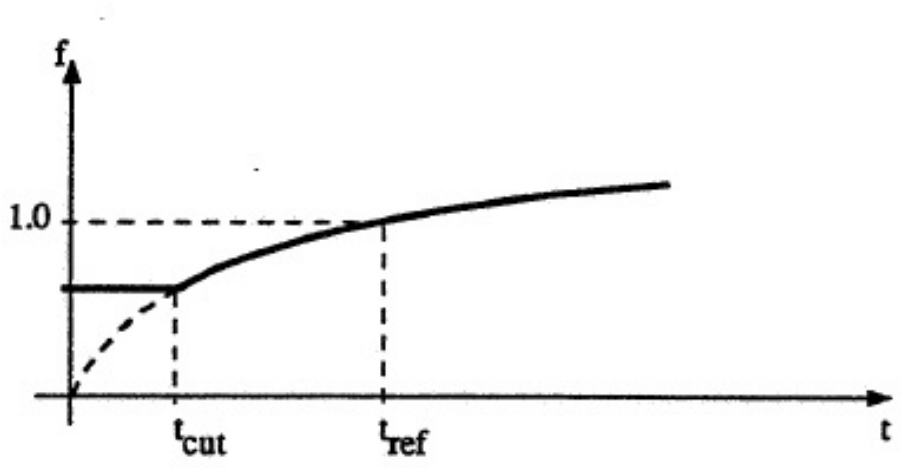


Figure H.5: Thickness correction factor f as a function of t, t_{cut} and t_{ref}

H.2.7 Calculation of accumulated fatigue damage

The accumulated damage is computed using the Palmgren-Miner summation rule. The long term distribution of stress ranges is divided into 100 blocks of equal length along the horizontal axis. Since the independent variable N is plotted with a log-scale, the number of stress ranges within each block will increase rapidly going from left to right. The number of stress ranges (n_j) and the average stress range ($\Delta\sigma_j$) within each block are computed by the program.

For the average stress range within each of the 100 blocks, the number N_j of stress cycles necessary to cause failure is determined from the SN curve as illustrated to the right in Figure H.4.

The damage for each direction, D_i^* is then.

$$D_i^* = \sum_{j=1}^{100} \frac{n_j}{N_j} \tag{H.10}$$

The total damage D taking into account the different wave directions is

$$D = \sum_{i=1}^{n_{dir}} D_i \tag{H.11}$$

This summation is done for each hot spot both for the brace-side and for the chord-side of the weld. The largest damage number is then given together with the location of the corresponding hot spot and an index telling which side of the weld (brace or chord) the largest damage occurred.

I Spectral fatigue analysis (time domain analysis)

I.1 Introduction

The method implemented in Sesam - and in particular as command “SPECTRAL” in Framework, is briefly described as method 1 in "API RECOMMENDED PRACTICE 2A-WSD (RP 2A-WSD)" section C.5.2.2, [15]. The spectral analysis technique uses time domain regular waves to obtain the transfer functions. Some key points are cited as follows.

- The wave statistics is the same as the other stochastic method (frequency domain), i.e. wave spectra in a wave scatter diagram. The long term statistics will be obtained by the summation of the short term statistics of all individual sea states in the wave scatter diagram for all wave directions.
- When defining the wave loads, select a sufficient number of wave frequencies to define all the peaks and valleys inherent in the jacket response transfer functions. The typical set of frequencies should be able to capture the global response of the jacket and eliminate most of the local modes. Developing a global base shear transfer function may be helpful in defining frequencies to be used in the detailed analysis. (Currently, Prepost and Postresp can be utilized to produce plots of global base shear transfer functions.)
- Select a wave height for each frequency. A constant wave steepness can be used. Otherwise, appropriate wave heights shall be chosen.
- A sufficient number of time steps in the wave cycle at which members stresses are computed should be selected to determine the maximum brace hot spot stress range.
- At each frequency, a point on the transfer function is determined by dividing the response stress range by the wave height.
- Compute the stress response spectra in the same way as the stochastic fatigue method.

I.2 Deterministic wave load Calculation

In Wajac, the deterministic wave loads are calculated in the time domain. That is, calculated at given time instants or phase angles of the wave cycle, see Figure I.1. The hydrodynamic forces are calculated according to Morison’s equation with non-linear drag formulation. The drag force linearization as the frequency domain method requires is not needed with Spectral fatigue analysis. By default buoyancy is calculated and added to the hydrodynamic forces for all members. The buoyancy forces can, however, be neglected in the subsequent finite element analysis in Sestra. In addition to surface waves the structure may also be exposed to current.

Four different wave models are available in Wajac for deterministic wave load calculations

- linear harmonic waves (Airy wave theory),
- Stokes’ fifth order wave theory,
- Dean’s stream function wave theory, and
- cnoidal wave theory.

A deterministic wave from Wajac is in Framework characterized by means of $\widetilde{W}(H_w, \omega, N, \theta)$ in which H_w is the wave height, ω is the angular frequency with dimension [rad/s] (the wave period is $P = 2\pi/\omega$), N is the number of time instants (discrete time steps) in a wave cycle, and θ is the wave direction.

In the Sesam implementation of Spectral fatigue analysis, Sestra and Framework accept any deterministic wave theory from Wajac – but keep in mind the following note from [15] if non-regular wave theories are considered:

> *At each frequency, a point on the transfer function is determined by passing an Airy wave of the appropriate height through the structure and dividing the response stress range by the wave height*[3].

[3] Cited from the description of method 1 in appendix C.5.2.2 of "API RECOMMENDED PRACTICE 2A-WSD (RP 2A-WSD)", [15].

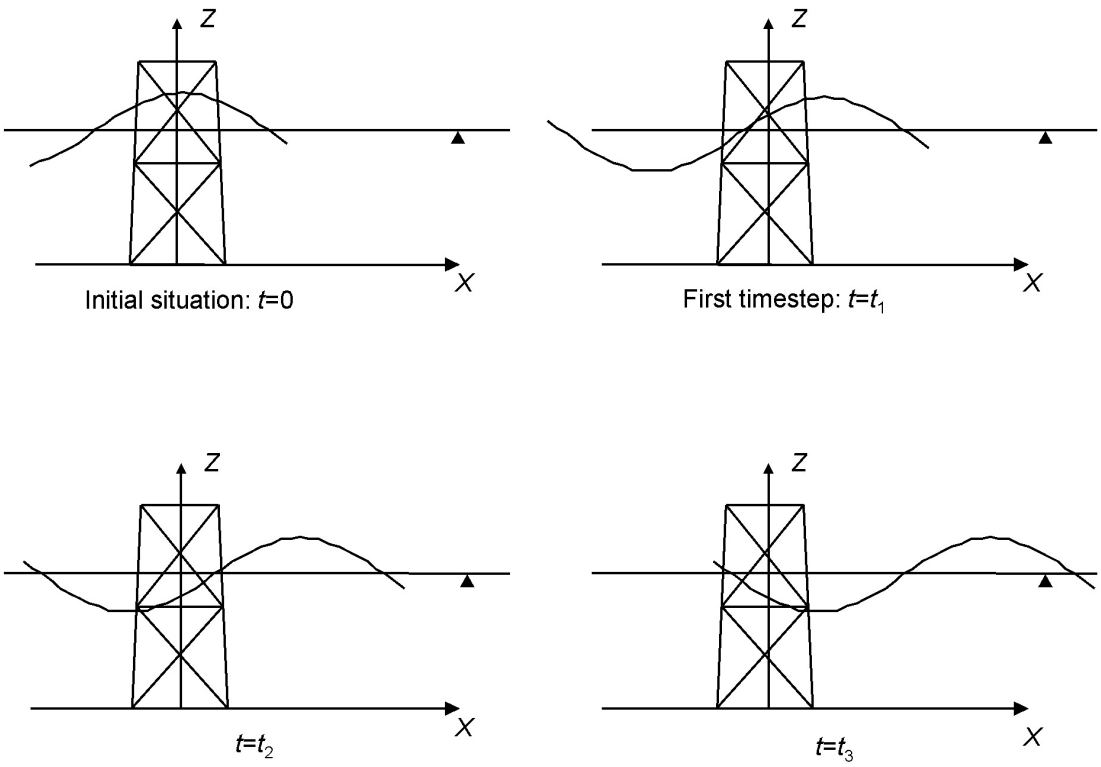


Figure I.1: Time instants

I.3 Transfer function computation

The hot spot stress range (HSSR) $\Delta\sigma$ is computed for each hot spot at a fatigue check position in each member as

$$\Delta\sigma = \sigma_{max} - \sigma_{min} \tag{I.1}$$

where σ_{max} and σ_{min} are the maximal- and minimal stresses, respectively in the hot spot when one wave cycle of wave ($\widetilde{W}$) passes through the structure. A point on the transfer function H_ω is computed

$$\mathbf{H}_\sigma(\omega) = \frac{\Delta\sigma}{H_w} = \frac{\sigma_{max} - \sigma_{min}}{H_w}. \tag{I.2}$$

where H_w is the wave height. The transfer function $\mathbf{H}_\sigma(\omega)$ is a function of the wave $\widetilde{W}$. Thus, the transfer function $\mathbf{H}_\sigma(\omega)$ is computed for each hot spot in each member for each value of the wave $\widetilde{W}$. The transfer function $\mathbf{H}_\sigma(\omega)$ is further input to the damage calculations along with the sea state properties, see Section I.5 below.

I.3.1 Stress Concentration Factors

It should be noted that the hot spot stress σ includes the geometric effect at the fatigue check position. The appropriate stress concentration should be considered. For more details about the stress concentration factors, see Appendix B.

I.4 Wave statistics

I.4.1 Short term and long term wave conditions

The short term wave conditions refer to a stationary situation in which the sea remains the same in a statistical means. A theoretical model in the form of a wave spectrum can be used to characterize the statistical properties of this short term sea state during certain period, typically a few hours. By contrast, the long term wave conditions are usually over a span of years. For an in-place fatigue analysis, the long term wave climate is supplied for a typical service year. By definition, the long term wave conditions consist of a series of short term conditions. Hence, it can be approximated using the accumulation of the statistics of all short term sea states under particular assumptions. The long term statistics of the stress range response directly relates to the fatigue of that position on the structure.

Unlike the deterministic method in H in which the long term statistics of wave heights and stress range is assumed in certain form, the spectral and stochastic fatigue analyses use the statistics of short term sea states and take the weighted summation of all of them to obtain the long term behaviour by assuming the short term stress responses comply with Gaussian processes. The short term statistics of a sea state is respresented by the wave spectrum in a wave scatter diagram. For more details for wave spectrum shape, please see J.2.4 in stochastic fatigue analysis J.

I.4.2 Wave scatter diagram

The wave scatter diagram is in general the most widely used method to represent the long term wave conditions at a certain location. A wave scatter diagram is composed of the joint probability of three major parameters that define the sea state in theoretical model. In this text (Framework) it is a set of triples $\widetilde{S} = \widetilde{S}(H_S, T_Z, o)$, where H_S is the significant wave height, T_Z is the mean wave period and o is number of occurences of the pair (H_S, T_Z) for a sea state – for instance a part of the north sea or atlantic sea. Then every triple of H_S, T_Z, and occurrence ends up with a probability function $\widetilde{P}(H_S, T_Z)$. All of them compose a two-dimensional wave diagram, in which every$\widetilde{P}(H_S, T_Z)$ represents the occurrence probability of the short term sea state with certain significant wave height and mean period (H_S, T_Z) over the period that the scatter diagram represents. The damage for a short term sea state is call partial damage. See J.11.

I.5 Damage calculation

I.5.1 Main wave direction, spreading function and stress transfer function

The wave surface elevation in a real sea is short-crested, i.e. the frequency components are spread over a range of directions around the mean wave direction. The directional influence should be considered in the power spectral density of the stress response. In a spectral fatigue analysis in its most general form, each sea state is represented by a power spectral density function $S_\alpha(\omega)$ for each direction of wave approach α, where ω is circular frequency (see J.2.4). At each hot spot, the stress response spectrum for each sea state is:

$$S_{\sigma,\alpha} = \int_{-\pi/2}^{\pi/2} |\mathbf{H}_\sigma(\omega, \theta)|^2 D(\theta) S_\alpha(\omega) d\theta \tag{I.3}$$

where where θ is measured from the central wave approach direction, $\mathbf{H}_\sigma(\omega, \theta)$ is the stress range transfer function and $D(\theta)$ is the spreading function, which satisfies

$$\int_{-\pi/2}^{\pi/2} D(\theta) d\theta = 1 \tag{I.4}$$

The directional spreading function defines the distribution of wave energy in a sea state. A commonly used spreading function is

$$D(\theta) = C_n cos^n(\theta) \tag{I.5}$$

where n is a positive integer and C_n is a coefficient that make EqI.4 holds. A value of $n = 0$ means the energy is distributed in all directions. For wind dirven seas, an appropriate spreading function is a cosine square function ($n = 2$).

In the program, the squared moduli of elementary wave direction transfer functions $\mathbf{H}_\sigma(\omega_i, \theta_i)$ are multiplied with spreading function weights (δ_i) to generate the modulus of the stress transfer function for each main wave direction ($\mathbf{H}_\sigma(\omega, \bar{\theta})$).

$$|\mathbf{H}_\sigma(\omega, \bar{\theta}|^2 = \sum_{i=1}^{n} D(\theta_i)|\mathbf{H}_\sigma(\omega_i, \theta_i)|^2 \tag{I.6}$$

where

$$\sum_{i=1}^{n} D(\theta_i) = 1 \tag{I.7}$$

For a given power integer n, the program will automatically calcualte the associated spreading function D applied as the directional weight to stress transfer functions.

I.5.2 Stress response spectrum

The wave spectrum ($S_\eta(\omega)$) (J.2.4) corresponding to the H_S, and T_Z, pair defined for a specific sea state is calculated. It is multiplied by the modulus of the hot spot stress transfer function for the main wave direction to provide the hot spot stress response spectrum. Based on EqI.3, the stress response spectrum

$$S_\sigma(\omega) = |\mathbf{H}_\sigma(\omega, \bar{\theta})|^2 S_\eta(\omega) \tag{I.8}$$

The spectral moments of order 0, 1, 2 are computed according to Eq. J.1.

I.5.3 SN curves

See Section H.2.6.

I.5.4 Formula of Damage Calculation

The damage calculation for the Spectral fatigue analysis is organised as the damage calculations in Sections J.2.8 and J.2.9 for the Stochastic fatigue analysis described in Section J. By assuming the HSSR follows Rayleigh distribution, the closed form formula to calculate the partial damage for one sea state is (according to (J.11) of Section J.2.8) computed as

$$\begin{aligned} d_{ij} &= \frac{1}{2\pi}\left(\frac{\lambda_2}{\lambda_0}\right)^{1/2} T\left[(2\sqrt{2}\sigma)^{m_1}\frac{1}{K_1}\gamma\left\{1+\frac{m_1}{2};\left(\frac{S_1}{2\sqrt{2}\sigma}\right)^2\right\}\right. \\ &+ (2\sqrt{2}\sigma)^{m_2}\frac{1}{K_2}\left\{\gamma\left[1+\frac{m_2}{2};\left(\frac{S_1}{2\sqrt{2}\sigma}\right)^2\right]-\gamma\left[1+\frac{m_2}{2};\left(\frac{S_2}{2\sqrt{2}\sigma}\right)^2\right]\right\} \\ &+ \left.(2\sqrt{2}\sigma)^{m_3}\frac{1}{K_3}\gamma\left\{1+\frac{m_3}{2};\left(\frac{S_2}{2\sqrt{2}\sigma}\right)^2\right\}\right] \end{aligned}$$

where

λ_0	spectral shape factor. Description to be improved.
λ_2	spectral shape factor. Description to be improved.
i	sea state number
j	main wave direction number
T	number of years in seconds
(m)	gamma function
$\gamma(m;s)$	$(m)-(m;s)$
$(m;s)$	incomplete gamma function
σ	$\sqrt{\lambda_0}$

The total damage (according to (J.13) of Section J.2.9) is computed as

$$D = \sum_{i=1}^{n} \sum_{j=1}^{n} P_{s,i} P_{d,j} d_{ij}$$

where

$P_{s,i}$	probability of occurrence of sea state number i
$P_{d,j}$	probability of occurrence of main wave direction number j
d_{ij}	partial damage for one sea state

Note that the number of segments of the SN curve is limited up to 3.

J Stochastic fatigue analysis (frequency domain fatigue analysis)

J.1 Introduction

The method based on transfer functions for stresses computed from a frequency domain dynamic analysis is often named probabilistic or stochastic fatigue analysis. To avoid mixing this procedure with the true probabilistic methods based on reliability analysis, the notion of a frequency domain fatigue analysis is, however, used here.

The procedure is based on frequency domain transfer functions from a dynamic structural analysis. The structural analysis is performed in the frequency domain[4] - ref Wajac and Sestra. Spectral analysis is used to evaluate stress statistics for each short term sea state in the wave climate. Long term stress statistics are derived from long term sea state probabilities and short term stress statistics for each sea state. The fatigue stress under constant amplitude loading is expressed through a SN curve and the fatigue damage under variable loading is computed using Miner's law.

For a comprehensive description of the method, see [96].

J.2 Theoretical description

J.2.1 Wave loading

Spectral analysis can relate statistically the cause and effect of randomly occurring phenomena in a linear system. Spectral analysis is applicable only to a linear system or to systems that can be linearised effectively. Under normal wave conditions, the response of most offshore structures can be linearised effectively. In a linear system, stress response is similar to the wave input, see ref [45].

There are two non-linear effects incorporated in the calculation of wave forces that must be addressed. The first involves the wave kinematics. The Airy wave theory (acceptable for low to moderate seas) must be used in Wajac since it uses linear wave kinematics [5]. Secondly, the user must linearise the non-linear drag term in the Morison equation. The user should perform this linearisation with an average amplitude wave height (since most damage in a fatigue analysis is caused by many cycles at small stress ranges). This linearisation is also performed in Wajac. Wajac will calculate transfer functions for each frequency in each wave direction. A transfer function relates the response of the system to an excitation force. It describes the receptibility of the structure relative to the forcing function.

J.2.2 Member forces

From a dynamic analysis-in the structural analysis program, e.g. Sestra, transfer functions for forces at the element ends are obtained. For each frequency and wave direction a complex load case is stored. The fatigue analysis uses the axial forces and the in-plane and out-of-plane bending moments for each end of a beam element (see Section D.7).

J.2.3 Stress Concentration Factors

See Section H.2.4.

J.2.4 Short term description of sea states

The probabilistic structure of a particular sea state is governed entirely by the wave spectrum. In this respect, a sea state is considered the condition of the water surface during a certain interval in which the statistical properties do not change. By this definition, a sea state is a stationary random process [96].

In a unidirectional sea, each short term sea state can be characterized by the significant-wave amplitude, the mean zero-crossing period, and the spectral width. All three parameters are related to the moments of the wave spectrum about the origin:

$$M_n = \int_0^\infty \omega^n s_w(\omega) d\omega \tag{J.1}$$

[4] Ref also Spectral fatigue analysis, where the structural analysis is performed in the time domain
[5] Stokes can be used with Spectral fatigue analysis.

The root-mean-square (rms) wave elevation and the significant-wave amplitude are given in terms of the zero-order moment as

$$\begin{aligned} rms(Z) &= \sqrt{M_0} \\ H_s &= \bar{A}_{w_{1/3}} = \tfrac{1}{2}\bar{h}_{1/3} = C\sqrt{M_0} \end{aligned} \tag{J.2}$$

where C is a constant depending on the spectral width (C = 4 in Framework). The mean-zero-crossing period is expressed in terms of the moments M_0 and M_2 as

$$\bar{T} = 2\pi \left(\frac{M_0}{M_2}\right)^{1/2} \tag{J.3}$$

and the spectral width is defined by the moments M_0, M_2 and M_4 as

$$b_w = \left(\frac{M_0 M_2 - M_2^2}{M_0 M_4}\right)^{1/2} = \left(1 - \frac{M_2^2}{M_0 M_4}\right)^{1/2} \tag{J.4}$$

The spectral width is a measurement of the irregularity of the sea and may assume values between 0 and 1, where $b_w = 0$ corresponds to an infinitely narrow spectrum and $b_w = 1$ to an infinitely broad wave spectrum [96]. The wave spectrum can be of the Pierson-Moskowitz or JONSWAP type.

The method used for the Pierson-Moskowitz spectrum (P-M) corresponds to a Gamma spectrum with parameters $\xi = 5$ and $\zeta = 4$. The Gamma spectrum is given by

$$S_\eta(\omega) = A\omega^{-\xi} e^{-B\omega^{-\zeta}}; \quad \omega > 0 \tag{J.5}$$

The constants A and B are uniquely defined by the significant wave height H_S and the wave period T_Z

$$A = \frac{1}{16} H_S^2 \zeta \left(\frac{2\pi}{T_Z}\right)^{\xi-1} \frac{\Gamma\left(\frac{\xi-1}{\zeta}\right)^{\frac{\xi-3}{2}}}{\Gamma\left(\frac{\xi-3}{\zeta}\right)^{\frac{\xi-1}{2}}} \tag{J.6}$$

$$B = \left(\frac{2\pi}{T_Z}\right)^{\zeta} \frac{\Gamma\left(\frac{\xi-1}{\zeta}\right)^{\frac{\zeta}{2}}}{\Gamma\left(\frac{\xi-3}{\zeta}\right)^{\frac{\zeta}{2}}} \tag{J.7}$$

This method takes advantage of the fact that wave spectra on Gamma form multiplied by a piecewise linear (or quadratic fit) transfer function may be integrated analytically for the range between two neighbouring points of the transfer function.

As this makes interpolation of the transfer function unnecessary, the number of multiplications will be reduced.

The weights that are used for each frequency for a given wave-spectrum are computed once, and then recovered when needed.

The JONSWAP spectrum can be used to take into account the imbalance of energy flow in the wave system (for example, when the sea is not fully developed). This will often be the case with a high wind speed. The P-M spectrum on the other hand, is a special case that is valid for fully developed seas.

The JONSWAP spectrum has a higher peak spectral value than the P-M spectrum but is narrower away from the peak so that energy balance is maintained.

For the JONSWAP spectrum, the transfer function is given for N frequencies in the range $[\omega_1, \omega_N]$, where N is typically between 10 and 30.

The frequency range $[\omega_1, \omega_N]$ is divided into 200 equidistantly spaced frequencies. The transfer function is interpolated linearly between the frequencies for which ordinates are given.

Response spectrum ordinates are computed by multiplying squared transfer function ordinates with wave spectrum ordinates. The moments of the response spectrum is calculated using trapezoidal integration (assumes linear variation between neighbouring response spectrum ordinates).

The short crestedness of the sea is described by a discretised spreading function, giving different weight (δ_i) to elementary waves from different directions.

Measurement of CPU-time used shows that the Pierson-Moskowitz spectrum is about 10 times faster than the JONSWAP spectrum. The implementation has been verified by comparing the results from JONSWAP spectrum with $\gamma = 1.0$, as this degenerates to the P-M spectrum.

Sligthly higher spectral moments are observed for he P-M spectrum. This is due to the increased accuracy, and the fact that the routines assumes that the transfer function value is constant to $\omega \rightarrow \infty$ from the highest frequency computed, (ω_N).

J.2.5 Main wave direction stress transfer function

Similar to I.5.1, the squared moduli of elementary wave direction transfer functions $H_\sigma(\omega_i, \theta_i)$ are multiplied with spreading function weights (δ_i) to generate the modulus of the stress transfer function for each main wave direction ($H_\sigma(\omega, \bar{\theta})$).

$$|H_\sigma(\omega, \bar{\theta}|^2 = \sum_{i=1}^{n} \delta_i |H_\sigma(\omega_i, \theta_i)|^2 \tag{J.8}$$

where

$$\sum_{i=1}^{n} \delta_i = 1 \tag{J.9}$$

J.2.6 Stress response spectrum

The wave spectrum ($S_\eta(\omega)$) corresponding to the H_S, and T_Z, pair defined for a specific sea state is calculated. It is multiplied by the modulus of the hot spot stress transfer function for the main wave direction to provide the hot spot stress response spectrum.

$$S_\sigma(\omega) = |H_\sigma(\omega, \bar{\theta})|^2 S_\eta(\omega) \tag{J.10}$$

The spectral moments of order 0, 1, 2 are computed according to eq. J.1.

J.2.7 SN curves

See Section H.2.6.

J.2.8 Calculation of partial damage for one sea state

Based on the assumption that the stress process is Gaussian and narrow banded, the stress ranges are Rayleigh distributed for each short term sea state.

The SN curve is made of maximum 3 linear segments in a double logarithmic scale.

The partial damages may then be calculated directly from the parameters describing each segment of the SN curve and the moments of the stress spectrum for the sea state.

Partial damage for one sea state is

$$
\begin{aligned}
d_{ij} &= \frac{1}{2\pi}\left(\frac{\lambda_2}{\lambda_0}\right)^{1/2} T\left[(2\sqrt{2}\sigma)^{m_1}\frac{1}{K_1}\gamma\left\{1+\frac{m_1}{2};\left(\frac{S_1}{2\sqrt{2}\sigma}\right)^2\right\}\right. \\
&+ (2\sqrt{2}\sigma)^{m_2}\frac{1}{K_2}\left\{\gamma\left[1+\frac{m_2}{2};\left(\frac{S_1}{2\sqrt{2}\sigma}\right)^2\right]-\gamma\left[1+\frac{m_2}{2};\left(\frac{S_2}{2\sqrt{2}\sigma}\right)^2\right]\right\} \\
&+ \left.(2\sqrt{2}\sigma)^{m_3}\frac{1}{K_3}\gamma\left\{1+\frac{m_3}{2};\left(\frac{S_2}{2\sqrt{2}\sigma}\right)^2\right\}\right]
\end{aligned}
\tag{J.11}
$$

where

λ_0	spectral shape factor. Description to be improved.
λ_2	spectral shape factor. Description to be improved.
i	sea state number
j	main wave direction number
T	number of years in seconds
(m)	gamma function
$\gamma(m;s)$	$(m)-(m;s)$
$(m;s)$	incomplete gamma function
σ	$\sqrt{\lambda_0}$

$$
N = \begin{cases} K_1 S^{-m_1} & S > S_1 \\ K_2 S^{-m_2} & S_2 \le S \le S_1 \\ K_3 S^{-m_3} & 0 < S \le S_2 \end{cases}
\tag{J.12}
$$

J.2.9 Calculation of accumulated damage

Partial damages d_{ij} are weighted over sea states and main wave directions to provide the total damage

$$
D = \sum_{i=1}^{n}\sum_{j=1}^{n} P_{s,i} P_{d,j} d_{ij}
\tag{J.13}
$$

where

$P_{s,i}$	probability of occurrence of sea state number i
$P_{d,j}$	probability of occurrence of main wave direction number j
d_{ij}	partial damage for one sea state

K Notation used in the text

Symbol/Subscript	Description
$\langle(\cdot)\rangle$	time average of $(\cdot)$, discussion here.

L Program limitations

The maximum model size is dependent on the number of:

- Joints
- Members
- Loadcases

Model size	Limitation
Maximum number of load cases	100000
Maximum number of members connected to a joint	80
Maximum number of cross sections	1500
Maximum number of materials	1500

Code checks/print	Limitation
Maximum number of selected phase angles for complex loads	50

Deterministic and spectral fatigue	Limitation
Maximum number of wave directions	36
Maximum number of wave heights per wave direction	100
Minimum number of phase angles per wave height	2
Maximum number of phase angles per wave height	36
Maximum number of time steps per wave height (deterministic and static spectral fatigue)	36
Maximum number of time steps per wave height (dynamic spectral fatigue)	35

Notes:

Different wave periods may be employed for different wave heights.

A minimum of 2 and a maximum of 36 time steps can be considered when member forces are computed.

Stochastic fatigue	Limitation
Maximum number of main wave directions	36
Maximum number of wave frequencies/main wave direction	3600
Maximum number of spreading function/main wave direction pairs	72
Maximum number of seastates in a scatter diagram	625
Maximum number of seastates summed over all wave directions	7500
Maximum number of non-repeated T_Z and spectrum shapes combinations	2000
Maximum number of H_S in a scatter diagram summed over all wave directions	1800

Earthquake analysis	**Limitation**
Maximum number of mode shapes	200

Wind fatigue analysis	**Limitation**
Maximum number of wind directions in a fatigue analysis	6
Maximum number of static wind load cases	30
Maximum number of eigenmodes/eigenvalues	15
Maximum number of wind speed	12
Maximum number of analysis planes	10
Maximum number of wind probabilities and drag correction factors per wind direction	12
Maximum number of fixity steps in vortex shedding fatigue calculation	5

References

[1] Gusto theory manual - version 6.00. *Brown and Root Document Number 308-7222-ST-13-046-B*.

[2] Gusto user manual - version 6.00. *Brown and Root Document Number 308-7222-MA-13-013-D*.

[3] Lloyd's register of shipping recommended parametric stress concentration factors. *LR. (report OD/TN/95001)*.

[4] Recommended sea spectra from issc (international ship and offshore structures congress) and ittc (international towing tank conference). *e.g. explained in Faltinsen, O. M. (1990). Sea Loads on Ships and Offshore Structures.*

[5] Cumulative damage in fatigue. *Miner, Journal of Applied Mechanics. 12(3)*, 1945.

[6] Reduction of stiffness and mass matrices. *Guyan, AIAA Journal Vol. 3 no 2*, 1965.

[7] The modern design of wind-sensitive structures. *CIRIA*, 1970.

[8] Dynamic analysis of offshore structures. *Brebbia and Walker, Butterworths*, 1979.

[9] AISC Seismic Provisions for Structural Steel Buildings. *AISC*, May 2002.

[10] Aws d1.1 structural welding code. 1980.

[11] Wind engineering in the eighties. *CIRIA*, 1980.

[12] Specifications for structural steel buildings – allowable stress design and plastic design. *Manual of Steel Construction, AISC, Ninth Edition*, 1989.

[13] Norwegian standard ns3472 , 3rd edition. 1999 (2001).

[14] American bureau of shipping guide for fatigue assessment of offshore structures. *ABS.*, 2003.

[15] Api rp 2a-wsd (r2010) planning, designing and constructing fixed offshore platforms - working stress design - includes supplement 2, edition - 21st 2007.

[16] Designing and constructing fixed offshore platforms - working steel design. *API RP2A Recommended Practise for Planning. American Petroleum Institute, 22nd Edition*, 2014.

[17] Scf formulae and generalised influence functions. *DNVGL-Software Internal Verification*, 2014.

[18] Offshore installations: Guideance on design and construction. *Department of Energy, HMSO.*, 4th Edition, 1990.

[19] Eurocode 3: Design of steel structures - part 1.1: General rules and rules for buildings. *ENV 1993-1-1.*, April 1992.

[20] Environmental conditions and environmental loads. *DNV, Det Norske Veritas. RECOMMENDED PRACTICE DNV-RP-C205.*, April 2007.

[21] Offshore standard dnv-os-c401: Fabrication and testing of offshore structures. April 2013.

[22] Recommended practice dnv-rp-c205, environmental conditions and environmental loads. *DNV*, April 2014.

[23] Fatigue design of offshore steel structures. *DNV, Det Norske Veritas, RECOMMENDED PRACTICE DNV-RP-C203*, Aug. 2005.

[24] Sesam, framework , wind fatigue design, theory manual. rev 1. Aug 2015.

[25] Api recommended practise for planning, designing and constructing fixed offshore platforms. *American Petroleum Institute RP 2A, 19th Edition.*, August 1991.

[26] Sesam, framework, steel frame design, theoretical manual. August 1993.

[27] Api recommended practice 2a-lrfd (rp 2a-lrfd), first edition, draft. December 15, 1989.

[28] Veiledning om utforming, beregning og dimensionering av stlkonstruktioner i petroleumsvirksomheden (in norwegian). *Norwegian Petroleum Directorate*, December 1989.

[29] Aisc manual of steel construction. load and recistance factor design specification for structural steel buildings. *American Institute of Steel Constructions, Inc.*, December 1999.

[30] Health and safety executive (oth 92 390) background to new fatigue guidance for steel joints and connections in offshore structures. December 1999.

[31] Api recommended practise for planning, designing and constructing fixed offshore platforms. *American Petroleum Institute RP 2A, 21th Edition.*, December 2000.

[32] Sesam, sestra, superelement structural analysis, user manual. Feb, 2013.

[33] Iso 19902 standard "petroleum and natural gas industries - fixed steel offshore structures". First Edition, 2007-12-01.

[34] Health and safety executive, offshore installations: Guidance on design, construction and certification. Fourth Edition, February 1995.

[35] Veiledning om utforming, beregning og dimensjonering av staalkonstruksjoner (january 1990). regelverksamling for petroleumsvirksomheten. *Norwegian Petroleum Directorate, Volume 2.*, January 1994.

[36] Recommended practise for planning, designing and constructing fixed offshore platforms. load and recistance factor design. *(API RP2A-LRFD) American Petroleum Institute, First Edition.*, July 1993.

[37] Tentative provisions for the development of seismic regulations for buildings. *Report No. ATC 3-06, ATC*, June 1978.

[38] Norwegian standard ns3472e, 2nd edition. June 1984.

[39] Ns3472 e, steel structures, design rules. 2. ed. *Norwegian Standards Association*, June 1984.

[40] Npd, regulations and provisions for the petroleum activities. June 1997.

[41] American Institute of Steel Construction (AISC) "specification for structural steel buildings". *AISC 360-10.*, June 2010.

[42] Fatigue design of offshore steel structures. *DNV GL RECOMMENDED PRACTICE DNVGL-RP-0005:2014-06 RP-C203*, June 2014.

[43] Fatigue design of offshore steel structures. *DNV GL RECOMMENDED PRACTICE DNVGL-RP-0005:2016-04 RP-C203*, April 2016.

[44] Fatigue design of offshore steel structures. *Recommended practice DNVGL-RP-C203*, September 2019.

[45] Fatigue design of offshore steel structures. *Recommended practice — DNVGLRPC203 Edition September 2019, amended*, January 2020.

[46] Fatigue design of offshore steel structures. *Recommended Practice DNV-RP-C203*, August 2005.

[47] ENVIRONMENTAL CONDITIONS AND ENVIRONMENTAL LOADS *Recommended Practice DNV-RP-C205*, June 2007.

[48] Wind load and dynamic response of marine structures. *NTNF Research Project Programme for Marine Structures, Report No 4*, May 1984.

[49] Aisc seismic provisions for structural steel buildings. May 21, 2002.

[50] Aisc manual of steel construction. *American Institute of Steel Constructions, Inc.*, Ninth Edition, 1989.

[51] Sesam, prefame, preprocessor for generation of frame structures, user manual. November 1996.

[52] Fatigue design of offshore steel structures. *DNV, Det Norske Veritas, RECOMMENDED PRACTICE DNV-RP-C203.*, Oct 2012.

[53] Sesam, stofat, fatigue damage calculation of welded plates and shells. October 15th, 2003.

[54] Designing and constructing fixed offshore platforms - working steel design. *API RP2A WSD, Recommended Practise for Planning. American Petroleum Institute, 21th Edition, inclusive Errata/Supplement*, October 2007.

[55] Api recommended practice for planning, designing and constructing fixed offshoreplatforms – working stress design. *American Petroleum Institute RP 2A, 21th Edition – DECEMBER 2000, ERRATA AND SUPPLEMENT 1 – DECEMBER 2002, ERRATA AND SUPPLEMENT 2 – SEPTEMBER 2005, ERRATA AND SUPPLEMENT 3 – OCTOBER 2007, REAFFIRMED – OCTOBER 2010*, October 2010.

[56] Design of steel structures. *NORSOK Standard, N-004.*, Rev. 1 dated December 1998.

[57] Design of steel structures. *NORSOK Standard, N-004. (Note that references to ANNEX C (Fatigue) are with respect to the 1998 release, in 2004 moved to DNV-RP-C203 (Ref. [46]))*, Rev. 2, October 2004.

[58] Design of steel structures. *NORSOK Standard, N-004.*, Rev. 3 dated February 2013, inclusive the Corrigendum issued May 2013.

[59] Load and resistance factor design specification for structural steel buildings, manual of steel construction, aisc, first edition. *first revised printing 1/91, second imprinture 9/92*, September 1, 1986.

[60] Sesam, wajac, wave and current loads on fixid rigid frame structures, user manual. September 2000.

[61] Der Kiureghian A. Button, M. and E.L. Wilson. Stocal user information manual. *Report No. UCB/SESM-81/02, Dept. of Civil Engineering, University of California, Berkeley*, June 1981.

[62] D.E. Cartwright and M.S. Longuet-Higgins. The statistical distribution of the maxima of a random function. *Proceedings, the Royal Society of London, Ser. A, vol 237, pp 212-232*, 1956.

[63] R.W. Clough and J. Penzien. Dynamics of structures. *McGraw-Hill, N.Y.*, 1975.

[64] S.H. Crandall and W.D. Mark. Random vibrations in mechanical systems. *Academic Press, New York*, 1973.

[65] A.G. Davenport. Note on the distribution of the largest value of a random function with application to gust loading. *Proceedings, the Institute of Civil Engineers, vol. 28, pp 187-196*, 1964.

[66] Van der Hoven. Power spectrum of horizontal wind speed. *J Met. (14)*, 1957.

[67] A. Der Kiureghian. A response spectrum method for random vibration analysis of mdf systems. *Earthquake Engineering and Structural Dynamics, vol 9, pp 419-435*, 1981.

[68] A. Der Kiureghian. Structural response to stationary excitation. *Journal of the Engineering Mechanics Division, ASCE, vol 106, pp 1195-1213*, December 1980.

[69] A. Der Kiureghian. Seismic risk analysis of structural systems. *Journal of the Engineering Mechanics Division, ASCE, vol 107, No.EM6, pp 1133-1153*, December 1981.

[70] Sackman J.L. Der Kiureghian, A. and B. Nour-Omid. Response of light equipment in structures. *Report No. UCB/EERC-81/05, Dept. ofCivil Engineering, University of California, Berkeley*, 1981.

[71] N. W. M. Dr Bishop and F. Dr F Sherratt. Nafems, finite element based fatigue calculations. *NAFEMS Ltd.*, 2000.

[72] M. Efthymiou. (shell international petroleum mij. b.v.) development of scf formulae and generalised influence functions for use in fatigue analysis. *OTJ'88 Recent Developments in Tubular Joints Technology, Surrey, UK.*, 5 October 1988.

[73] M. Efthymiou. Development of scf formulae and generalised influence functions for use in fatigue analysis. *Recent Developments in Tubular Joint Technology, OTJ'88*, October 1988, London.

[74] Gould and Abu-Sitta. Dynamic response of structures to wind & earthquake loading. *Pentech Press*, 1980.

[75] A.H. Hadjian. On the correlation of the components of strong ground motion. *Proceedings, 2nd International Conference on Microzonation, vol III, San Francisco*, December 1978.

[76] K. Kanai. Semi-empirical formula for seismic characterization of the ground. *Bulletin of the Earthquake Research Institute, vol. 35, University of Tokyo, Japan,*, June 1967.

[77] J.G. Kuang. Stress concentration factors in tubular connection. *SPE Journal 5472*, 1977.

[78] T. Kubo and J. Penzien. Analysis of three-dimensional strong ground motions along principal axes, san fernando earthquake. *Earthquake Engineering and Structural Dynamics, vol. 7, pp 265-278*, 1979.

[79] T. Kubo and J. Penzien. Simulation of three-dimensional strong ground motions along principal axes, san fernando earthquake. *Earthquake Engineering and Structural Dynamics, vol. 7, pp 279-294*, 1979.

[80] I. Langen and R. Sigbjornsson. Dynamisk analyse av konstruksjoner. *Tapir Forlag, University of Trondheim, Norway (In Norwegian)*, 1979.

[81] Y.K. Lin. Probabilistic theory of structural dynamics. *R.E. Krieger Publishing Co., Huntington, New York*, 1976.

[82] I. Lotsberg. On stress concentration factors for tubular y- and t-joints in frame structures. *Marine Structures 24, 60-69.*, 2011.

[83] L.E. Malvern. Introduction to the mechanics of a continuous medium. *Prentice-Hall, Englewood Cliffs, New Jersey*, 1969.

[84] P. W. Marshall. Api provisions for scf, s-n, and size-profile effects. *OTC Paper no 7155. Houston*, May 1993.

[85] N.M. Newmark and E. Rosenbleuth. Fundamentals of earthquake engineering. *Prentice-Hall, Englewood Cliffs, New Jersey*, 1971.

[86] Timoshenko S. P. and Young D. H. Vibration problems in engineering. *D. Van Nostrand and Company. Third edition*, 1955.

[87] J. Penzien and M. Watabe. Characteristics of 3-dimensional earthquake ground motion. *Earthquake Engineering and Structural Dynamics, vol. 3, pp 365-374*, 1975.

[88] P. Ruiz and J. Penzien. Pseqn - artificial generation of earthquake accerograms. *Report No. UCB/EERC, Dept of Civil Engineering, University of California, Berkeley*, March 1969.

[89] M.D. Singh. Seismic response by srss for nonproportional damping. *Journal of the Engineering Mechanics Division, ASCE, vol 106, EM6*, December 1980.

[90] W. Smeby. An investigation of the distribution of number of upcrossings of given levels of a stationary process. *unpublished*.

[91] W. Smeby and A. Der Kiureghian. Stochastic analysis of response of slructures and multiply supported secondary systems to multidirectional ground motion. *Veritas Report No. 82-0510, Det norske Veritas, Norway*, 1982.

[92] P. Smedley and P. Fisher. Stress concentration factors for ring-stiffened tubular joints. *Lloyd's Register of Shipping, London, U.K.*

[93] H. Tajimi. A standard method of determining the maximum response of a structure during an earthquake. *Proceedings, 2nd World Conference on Earthquake Engineering, vol. II, Tokyo, Japan*, July 1960.

[94] E.H. Vanmarcke. Properties of spectral moments with application to random vibration. *Journal of the Engineering Mechanics Division, ASCE, vol. 98, EM2, Proc. Paper 8822, pp 425-446*, April 1979.

[95] E.H. Vanmarcke. On the distribution of the first passage time for normal stationary random processes. *Journal of Applied Mechanics, vol. 42, pp 215-220*, March 1975.

[96] J.H. Vugts and R.K. Kinra. Probabilistic fatigue analysis of fixed offshore structures. *Journal of Petroleum Technology*, April 1978.

[97] Robinson R. W. and Hamilton J. A criterion for assessing wind induced crossflow vortex vibrations in wind sensitive structures. *Health and Safety Executive Offshore Technology. Report OTH 92 379*, 1992.

[98] A.C. Wordsworth and G.P. Smedley. Stress concentration in tubular joints.

[99] Warren C. Young and Richard G. Budynas. *Roark's Formulas for Stress and Strain, Seventh Edition*. McGraw-Hill, 2002.

[100] Fatigue design of offshore steel structures. *Recommended practice DNV-RP-C203 Edition September 2019, amended*, September 2021.



About DNV

We are the independent expert in risk management and quality assurance. Driven by our purpose, to safeguard life, property and the environment, we empower our customers and their stakeholders with facts and reliable insights so that critical decisions can be made with confidence. As a trusted voice for many of the world’s most successful organizations, we use our knowledge to advance safety and performance, set industry benchmarks, and inspire and invent solutions to tackle global transformations.

Digital Solutions

DNV is a world-leading provider of digital solutions and software applications with focus on the energy, maritime and healthcare markets. Our solutions are used worldwide to manage risk and performance for wind turbines, electric grids, pipelines, processing plants, offshore structures, ships, and more. Supported by our domain knowledge and Veracity assurance platform, we enable companies to digitize and manage business critical activities in a sustainable, cost-efficient, safe and secure way.

DNV | digital@dnv.com | dnv.com/digital