

# ISO 19902:2020-11 (E)

## Petroleum and natural gas industries - Fixed steel offshore structures

---

<b>Contents</b>		<b>Page</b>
Foreword.....		xiv
Introduction.....		xvii
1	Scope .....	1
2	Normative references .....	1
3	Terms and definitions.....	2
4	Symbols .....	10
5	Abbreviated terms .....	14
6	Overall considerations.....	16
6.1	Types of fixed steel offshore structure.....	16
6.1.1	General .....	16
6.1.2	Jackets .....	16
6.1.3	Towers.....	17
6.1.4	Jack-ups.....	17
6.2	Planning.....	18
6.2.1	General.....	18
6.2.2	Hazards .....	18
6.2.3	Designing for hazards .....	19
6.2.4	Design situations and criteria.....	19
6.2.5	Design for inspection and maintenance.....	19
6.2.6	Foundations and active geological processes .....	20
6.2.7	Regulations.....	20
6.3	Service and operational considerations .....	20
6.3.1	General considerations .....	20
6.3.2	Water depth.....	20
6.3.3	Structural configuration .....	20
6.3.4	Access and auxiliary systems .....	21
6.4	Safety considerations.....	21
6.5	Environmental considerations.....	21
6.5.1	General.....	21
6.5.2	Selecting design metocean parameters and action factors.....	22
6.6	Exposure levels .....	22
6.7	Assessment of existing structures.....	23
6.8	Structure reuse .....	23
7	General design requirements.....	23
7.1	General.....	23
7.2	Material properties for steel .....	24
7.3	Incorporating limit states .....	24
7.4	Determining design situations .....	24
7.5	Structural modelling and analysis .....	25
7.6	Design for pre-service and removal situations .....	25
7.7	Design for the in-place situation.....	25
7.8	Determination of component resistances .....	25
7.8.1	General.....	25
7.8.2	Physical testing to derive resistances.....	26
7.8.3	Resistances derived from computer simulations validated by physical testing.....	26

7.8.4	Resistances derived from computer simulations validated against design formulae.....	26
7.8.5	Resistances derived from unvalidated computer simulations .....	26
7.9	Strength and stability checks .....	26
7.9.1	Action and resistance factors .....	26
7.9.2	Strength and stability equations .....	26
7.9.3	Unfactored actions .....	27
7.10	Robustness .....	27
7.10.1	General .....	27
7.10.2	Damage tolerance .....	27
7.11	Reserve strength.....	28
7.11.1	New structures.....	28
7.11.2	Existing structures .....	29
7.12	Indirect actions.....	29
7.13	Structural reliability analysis.....	29
<b>8</b>	<b>Actions for pre-service and removal situations.....</b>	<b>30</b>
8.1	General .....	30
8.1.1	Coverage.....	30
8.1.2	Design situations.....	30
8.1.3	Actions .....	30
8.2	General requirements.....	31
8.2.1	Weight control .....	31
8.2.2	Dynamic effects.....	31
8.2.3	Action effects .....	31
8.3	Onshore lifting.....	33
8.3.1	General .....	33
8.3.2	Dynamic effects.....	33
8.3.3	Effect of tolerances .....	34
8.3.4	Multi-crane lift .....	34
8.3.5	Local factor.....	34
8.3.6	Member and joint strengths.....	35
8.3.7	Lifting attachments .....	35
8.3.8	Slings, shackles and fittings .....	36
8.4	Fabrication.....	36
8.5	Loadout.....	36
8.5.1	Direct lift .....	36
8.5.2	Horizontal movement onto vessel .....	36
8.5.3	Self-floating structures .....	37
8.6	Transportation .....	37
8.6.1	General .....	37
8.6.2	Metocean conditions.....	37
8.6.3	Determination of actions .....	37
8.6.4	Other considerations.....	38
8.7	Installation .....	38
8.7.1	Lifted structures.....	38
8.7.2	Launched structures .....	38
8.7.3	Crane assisted uprighting of structures .....	38
8.7.4	Submergence pressures .....	38
8.7.5	Member flooding.....	39
8.7.6	Actions on the foundation during installation .....	39
<b>9</b>	<b>Actions for in-place situations.....</b>	<b>39</b>
9.1	General .....	39
9.2	Permanent actions ( <i>G</i> ) and variable actions ( <i>Q</i> ) .....	40

9.2.1	Permanent action 1, $G_1$ .....	40
9.2.2	Permanent action 2, $G_2$ .....	40
9.2.3	Variable action 1, $Q_1$ .....	40
9.2.4	Variable action 2, $Q_2$ .....	41
9.2.5	Unintentional flooding .....	41
9.2.6	Position and range of permanent and variable actions .....	41
9.2.7	Carry down factors.....	41
9.2.8	Representation of actions from topsides.....	41
9.2.9	Weight control.....	41
9.3	Extreme metocean actions.....	42
9.3.1	General.....	42
9.3.2	Notation .....	42
9.4	Extreme quasi-static action due to wind, waves and current ( $E_e$ ).....	42
9.4.1	Procedure for determining $E_e$ .....	42
9.4.2	Direction of extreme wind, waves and current.....	43
9.4.3	Extreme global actions .....	44
9.4.4	Extreme local actions and action effects.....	44
9.4.5	Vortex induced vibrations (VIV).....	45
9.5	Extreme quasi-static action caused by waves only ( $E_{we}$ ) or by waves and currents ( $E_{wce}$ ).....	45
9.5.1	Procedure for determining $E_{we}$ and $E_{wce}$ .....	45
9.5.2	Models for hydrodynamic actions.....	46
9.5.3	Hydrodynamic models for appurtenances .....	50
9.6	Actions caused by current.....	50
9.7	Actions caused by wind .....	51
9.7.1	General .....	51
9.7.2	Determining actions caused by wind .....	51
9.7.3	Wind actions determined from models .....	52
9.8	Equivalent quasi-static action representing dynamic response caused by extreme wave conditions .....	52
9.8.1	General .....	52
9.8.2	Equivalent quasi-static action ( $D_e$ ) representing the dynamic response.....	53
9.8.3	Global dynamic analysis in waves .....	53
9.9	Factored actions .....	55
9.9.1	General .....	55
9.9.2	Factored permanent and variable actions .....	55
9.9.3	Factored extreme metocean action .....	55
9.10	Design situations .....	56
9.10.1	General considerations on the ultimate limit state .....	56
9.10.2	Demonstrating sufficient RSR under metocean actions.....	56
9.10.3	Partial factor design format .....	57
9.11	Local hydrodynamic actions .....	58
10	Accidental and abnormal situations.....	59
10.1	General.....	59
10.1.1	Treatment of ALS events.....	59
10.1.2	Accidental events .....	60
10.1.3	Abnormal environmental events.....	60
10.2	Vessel collisions.....	60
10.2.1	General .....	60
10.2.2	Collision events .....	61
10.2.3	Collision process.....	61

10.3	Dropped objects .....	61
10.4	Fires and explosions .....	62
10.5	Abnormal environmental actions .....	62
10.6	Assessment of structures following damage .....	63
11	Seismic design considerations .....	63
11.1	General .....	63
11.2	Seismic design procedure .....	63
11.3	Seismic reserve capacity factor .....	64
11.4	Recommendations for ductile design .....	64
11.5	ELE requirements .....	66
11.5.1	Partial action factors .....	66
11.5.2	ELE structural and foundation modelling .....	66
11.6	ALE requirements .....	67
11.6.1	General .....	67
11.6.2	ALE structural and foundation modelling .....	68
11.6.3	Non-linear static pushover analysis .....	68
11.6.4	Time-history analysis .....	70
12	Structural modelling and analysis .....	70
12.1	Purpose of analysis .....	70
12.2	Analysis principles .....	71
12.2.1	Extent of analysis .....	71
12.2.2	Calculation methods .....	71
12.3	Modelling .....	71
12.3.1	General .....	71
12.3.2	Level of accuracy .....	71
12.3.3	Geometrical definition for framed structures .....	72
12.3.4	Modelling of material properties .....	75
12.3.5	Topsides structure modelling .....	75
12.3.6	Appurtenances .....	75
12.3.7	Soil-structure interaction .....	76
12.3.8	Other support conditions .....	77
12.3.9	Local analysis structural models .....	77
12.3.10	Actions .....	78
12.3.11	Mass simulation .....	78
12.3.12	Damping .....	79
12.4	Analysis requirements .....	79
12.4.1	General .....	79
12.4.2	Fabrication .....	81
12.4.3	Other pre-service and removal situations .....	81
12.4.4	In-place situations .....	84
12.5	Types of analysis .....	86
12.5.1	Natural frequency analysis .....	86
12.5.2	Dynamically responding structures .....	86
12.5.3	Static and quasi-static linear analysis .....	86
12.5.4	Static ultimate strength analysis .....	87
12.5.5	Dynamic linear analysis .....	87
12.5.6	Dynamic ultimate strength analysis .....	87
12.6	Non-linear analysis .....	88
12.6.1	General .....	88
12.6.2	Geometry modelling .....	88
12.6.3	Component strength .....	89
12.6.4	Models for member strength .....	89
12.6.5	Models for joint strength .....	89

12.6.6	Ductility limits.....	89
12.6.7	Yield strength of structural steel.....	90
12.6.8	Models for foundation strength .....	90
12.6.9	Investigating non-linear behaviour.....	90
<b>13</b>	<b>Strength of tubular members.....</b>	<b>91</b>
13.1	General.....	91
13.2	<b>Tubular members subjected to tension, compression, bending, shear, torsion or hydrostatic pressure .....</b>	<b>93</b>
13.2.1	General.....	93
13.2.2	Axial tension.....	93
13.2.3	Axial compression.....	94
13.2.4	Bending.....	95
13.2.5	Shear .....	97
13.2.6	Hydrostatic pressure .....	98
13.3	<b>Tubular members subjected to combined forces without hydrostatic pressure ....</b>	<b>101</b>
13.3.1	General.....	101
13.3.2	Axial tension and bending.....	101
13.3.3	Axial compression and bending.....	102
13.3.4	Axial tension or compression, bending, shear and torsion.....	103
13.3.5	Piles .....	105
13.4	<b>Tubular members subjected to combined forces with hydrostatic pressure .....</b>	<b>105</b>
13.4.1	General.....	105
13.4.2	Axial tension, bending and hydrostatic pressure.....	106
13.4.3	Axial compression, bending and hydrostatic pressure .....	107
13.4.4	Axial tension or compression, bending, hydrostatic pressure, shear and torsion.....	108
13.5	Effective lengths and moment reduction factors.....	108
13.6	Conical transitions.....	110
13.6.1	General.....	110
13.6.2	Design stresses.....	110
13.6.3	Strength requirements without external hydrostatic pressure.....	113
13.6.4	Strength requirements with external hydrostatic pressure .....	118
13.6.5	Ring design .....	118
13.7	Dented tubular members .....	121
13.7.1	General.....	121
13.7.2	Dented tubular members subjected to tension, compression, bending or shear .....	121
13.7.3	Dented tubular members subjected to combined forces.....	126
13.8	Corroded tubular members.....	129
13.9	Grouted tubular members .....	129
13.9.1	General.....	129
13.9.2	Grouted tubular members subjected to tension, compression or bending .....	129
13.9.3	Grouted tubular members subjected to combined forces.....	133
<b>14</b>	<b>Strength of tubular joints.....</b>	<b>134</b>
14.1	General.....	134
14.2	Design considerations .....	135
14.2.1	Materials.....	135
14.2.2	Design forces and joint flexibility.....	136
14.2.3	Minimum joint strength .....	136
14.2.4	Weld strength .....	136
14.2.5	Joint classification.....	136
14.2.6	Detailing practice .....	139

14.3	Simple tubular joints.....	142
14.3.1	General .....	142
14.3.2	Basic joint strength .....	143
14.3.3	Strength factor, $Q_u$ .....	144
14.3.4	Chord force factor, $Q_f$ .....	145
14.3.5	Effect of chord can length on joint strength .....	146
14.3.6	Strength check .....	147
14.4	Overlapping joints.....	148
14.5	Grouted joints .....	148
14.6	Ring stiffened joints.....	149
14.7	Other joint types .....	149
14.8	Damaged joints.....	149
14.9	Non-circular joints .....	150
14.10	Cast joints .....	150
15	Strength and fatigue resistance of other structural components.....	150
15.1	Grouted connections .....	150
15.1.1	General .....	150
15.1.2	Detailing requirements .....	152
15.1.3	Axial force.....	152
15.1.4	Reaction force from horizontal shear force and bending moment in piles.....	152
15.1.5	Interface transfer stress.....	153
15.1.6	Interface transfer strength.....	154
15.1.7	Strength check .....	157
15.1.8	Fatigue assessment .....	157
15.2	Mechanical connections .....	158
15.2.1	Types of mechanical connectors .....	158
15.2.2	Design requirements.....	158
15.2.3	Actions and forces on the connector.....	159
15.2.4	Resistance of the connector .....	159
15.2.5	Strength criteria .....	159
15.2.6	Fatigue criteria .....	160
15.2.7	Stress analysis validation .....	160
15.2.8	Threaded fasteners .....	161
15.2.9	Swaged connections.....	162
15.3	Clamps for strengthening and repair .....	163
15.3.1	General .....	163
15.3.2	Split sleeve clamps .....	163
15.3.3	Prestressed clamps .....	163
15.3.4	Forces on clamps.....	164
15.3.5	Clamp design .....	164
15.3.6	General requirements for bolted clamps.....	166
15.3.7	Bolting considerations.....	167
16	Fatigue.....	167
16.1	General .....	167
16.1.1	Applicability.....	167
16.1.2	The fatigue process .....	167
16.1.3	Fatigue assessment by analysis using $S-N$ data .....	167
16.1.4	Fatigue assessment by analysis using fracture mechanics methods .....	168
16.1.5	Fatigue assessment by other methods.....	168
16.2	General requirements.....	168
16.2.1	Applicability.....	168
16.2.2	Fatigue crack initiation and crack propagation .....	169

16.2.3	Sources of variable stresses causing fatigue .....	169
16.2.4	Service life and fatigue life.....	169
16.2.5	The nature of fatigue damage .....	170
16.2.6	Characterization of the stress range data governing fatigue .....	170
16.2.7	The long-term stress range history .....	170
16.2.8	Partial action and resistance factors.....	171
16.2.9	Fatigue resistance .....	171
16.2.10	Fatigue damage calculation .....	171
16.2.11	Weld improvement techniques.....	171
16.3	Description of the long-term wave environment .....	172
16.3.1	General.....	172
16.3.2	Wave scatter diagram.....	172
16.3.3	Mean wave directions.....	172
16.3.4	Wave frequency spectra .....	173
16.3.5	Wave directional spreading function.....	173
16.3.6	Periodic waves .....	173
16.3.7	Long-term distribution of individual wave heights.....	173
16.3.8	Current.....	173
16.3.9	Wind.....	173
16.3.10	Water depth.....	174
16.3.11	Marine growth.....	174
16.4	Performing the global stress analyses.....	174
16.4.1	General.....	174
16.4.2	Actions caused by waves.....	175
16.4.3	Quasi-static analyses.....	176
16.4.4	Dynamic analyses.....	176
16.5	Characterization of the stress range data governing fatigue .....	177
16.6	The long-term local stress range history.....	178
16.6.1	General.....	178
16.6.2	Probabilistic determination using spectral analysis methods.....	179
16.6.3	Deterministic determination using individual periodic waves .....	179
16.6.4	Approximate determination using simplified methods.....	180
16.7	Determining the long-term stress range distribution by spectral analysis.....	180
16.7.1	General.....	180
16.7.2	Stress transfer functions.....	181
16.7.3	Short-term stress range statistics .....	182
16.7.4	Long-term stress range statistics .....	182
16.8	Determining the long-term stress range distribution by deterministic analysis....	184
16.8.1	General.....	184
16.8.2	Wave height selection.....	184
16.8.3	Wave period selection .....	184
16.8.4	Long-term stress range distribution .....	184
16.9	Determining the long-term stress range distribution by approximate methods...	184
16.10	Geometric stress ranges .....	185
16.10.1	General.....	185
16.10.2	Stress concentration factors for tubular joints .....	185
16.10.3	Geometric stress ranges for other fatigue sensitive locations.....	186
16.11	Fatigue resistance of the material.....	187
16.11.1	Basic S-N curves.....	187
16.11.2	High strength steel.....	188
16.11.3	Cast joints .....	188
16.11.4	Thickness effect .....	188
16.12	Fatigue assessment.....	189
16.12.1	Cumulative damage and fatigue life .....	189

16.12.2	Fatigue damage design factors.....	190
16.12.3	Local experience factor.....	190
16.13	Other causes of fatigue damage than wave action.....	190
16.13.1	General .....	190
16.13.2	Vortex induced vibrations.....	191
16.13.3	Wind induced vibrations.....	191
16.13.4	Transportation .....	191
16.13.5	Installation .....	191
16.13.6	Risers.....	191
16.14	Further design considerations.....	192
16.14.1	General .....	192
16.14.2	Conductors, caissons and risers .....	192
16.14.3	Miscellaneous non-load carrying attachments.....	192
16.14.4	Miscellaneous load carrying attachments .....	192
16.14.5	Conical transitions.....	192
16.14.6	Members in the splash zone.....	192
16.14.7	Topsides structure .....	193
16.14.8	Inspection strategy.....	193
16.15	Fracture mechanics methods .....	193
16.15.1	General .....	193
16.15.2	Fracture assessment.....	194
16.15.3	Fatigue crack growth law.....	194
16.15.4	Stress intensity factors .....	195
16.15.5	Fatigue stress ranges.....	195
16.15.6	Castings.....	195
16.16	Fatigue performance improvement of existing components .....	195
Foundation design .....		195
17.1	General .....	195
17.2	Design of pile foundations.....	196
17.3	Pile wall thickness.....	198
17.3.1	General .....	198
17.3.2	Pile stresses .....	198
17.3.3	Pile design checks.....	198
17.3.4	Check for design situation due to weight of hammer during hammer placement.....	198
17.3.5	Stresses during driving.....	199
17.3.6	Minimum wall thickness .....	200
17.3.7	Allowance for underdrive and overdrive.....	200
17.3.8	Driving shoe.....	200
17.3.9	Driving head .....	200
17.4	Length of pile sections .....	200
17.5	Shallow foundations .....	201
17.5.1	General .....	201
17.5.2	Stability of shallow foundations.....	202
Corrosion control.....		202
18.1	General .....	202
18.2	Corrosion zones and environmental parameters affecting corrosivity .....	202
18.3	Forms of corrosion, associated corrosion rates and corrosion damage .....	203
18.4	Design of corrosion control.....	204
18.4.1	General .....	204
18.4.2	Considerations in design of corrosion control.....	204
18.4.3	Coatings, linings and wrappings.....	204
18.4.4	Cathodic protection.....	205

	18.4.5	Corrosion resistant materials.....	208
	18.4.6	Corrosion allowance .....	208
18.5		<b>Fabrication and installation of corrosion control.....</b>	<b>209</b>
	18.5.1	General.....	209
	18.5.2	Coatings and linings .....	209
	18.5.3	Cathodic protection.....	209
	18.5.4	Corrosion resistant materials.....	209
18.6		<b>In-service inspection, monitoring and maintenance of corrosion control .....</b>	<b>209</b>
	18.6.1	General.....	209
	18.6.2	Coatings and linings .....	210
	18.6.3	Cathodic protection.....	210
	18.6.4	Corrosion resistant materials.....	211
19		<b>Materials.....</b>	<b>211</b>
	19.1	General.....	211
	19.2	Lowest anticipated service temperature.....	212
	19.3	Chemical composition .....	212
	19.3.1	General.....	212
	19.3.2	Carbon equivalent.....	212
	19.3.3	Modified carbon equivalent .....	213
19.4		<b>Strength, toughness and other considerations .....</b>	<b>213</b>
	19.4.1	Yield strength .....	213
	19.4.2	Toughness.....	213
	19.4.3	Other considerations .....	214
19.5		<b>Material category approach .....</b>	<b>214</b>
	19.5.1	Steel selection philosophy .....	214
	19.5.2	Material characterization.....	214
	19.5.3	Material selection criteria.....	214
	19.5.4	Selection process.....	215
	19.5.5	Steel strength groups.....	216
	19.5.6	Toughness class .....	216
	19.5.7	Applicable steels.....	217
19.6		<b>Design class approach .....</b>	<b>217</b>
	19.6.1	General.....	217
	19.6.2	DC component classification .....	218
	19.6.3	Materials.....	218
	19.6.4	Applicable steels.....	221
19.7		<b>Cement grout .....</b>	<b>221</b>
	19.7.1	Grout materials.....	221
	19.7.2	Onshore grout trial .....	221
	19.7.3	Offshore grout trial.....	222
	19.7.4	Offshore quality control.....	222
20		<b>Welding, weld inspection and fabrication.....</b>	<b>222</b>
	20.1	General.....	222
	20.2	Welding.....	223
	20.2.1	Selected generic welding and fabrication standards .....	223
	20.2.2	Weld metal and HAZ properties.....	225
	20.2.3	Tubular T-, Y- and K-joints.....	229
20.3		<b>Inspection .....</b>	<b>229</b>
20.4		<b>Fabrication .....</b>	<b>229</b>
	20.4.1	General.....	229
	20.4.2	Weld requirements.....	230
	20.4.3	Forming.....	232
	20.4.4	Fabrication tolerances.....	232

	20.4.5	Grouted connections.....	233
21		Quality control, quality assurance and documentation .....	233
	21.1	General .....	233
	21.2	Quality management system .....	234
	21.3	Quality control plan .....	235
	21.3.1	General .....	235
	21.3.2	Inspector qualifications.....	235
	21.3.3	NDT personnel qualifications.....	235
	21.3.4	Inspection of materials .....	235
	21.3.5	Inspection of fabrication .....	236
	21.3.6	Inspection of welding .....	236
	21.4	Documentation .....	236
	21.4.1	General .....	236
	21.4.2	Calculations.....	237
	21.4.3	Weight and centre of gravity reports .....	237
	21.4.4	Fabrication inspection documentation .....	237
	21.5	Drawings and specifications.....	237
22		Loadout, transportation and installation .....	238
	22.1	General .....	238
	22.1.1	Planning .....	238
	22.1.2	Records and documentation.....	239
	22.1.3	Actions and required resistance .....	239
	22.1.4	Temporary bracing and rigging.....	239
	22.2	Loadout and transportation .....	239
	22.2.1	General .....	239
	22.2.2	Loadout.....	239
	22.2.3	Cargo and launch vessels .....	240
	22.2.4	Towing vessels.....	240
	22.2.5	Actions on the platform components .....	241
	22.2.6	Buoyancy and flooding systems .....	241
	22.3	Transfer of the structure from the transport vessel into the water .....	241
	22.3.1	General .....	241
	22.3.2	Lifting operations .....	241
	22.3.3	Launching .....	242
	22.4	Placement on the sea floor and assembly of the structure.....	242
	22.4.1	General .....	242
	22.4.2	Safety of navigation.....	243
	22.4.3	Stationkeeping.....	243
	22.4.4	Positioning of the structure .....	243
	22.5	Pile installation .....	244
	22.5.1	General .....	244
	22.5.2	Stabbing guides.....	244
	22.5.3	Lifting methods.....	244
	22.5.4	Field welds.....	245
	22.5.5	Driveability studies.....	245
	22.5.6	Drilled and grouted piles .....	245
	22.5.7	Grouting pile-to-sleeve connections and grouted repairs .....	245
	22.5.8	Pile installation records .....	245
	22.6	Installation of conductors.....	245
	22.7	Topsides installation .....	245
	22.7.1	General .....	245
	22.7.2	Alignment and tolerances.....	246
	22.7.3	Securing topsides.....	246

22.8	Grounding of installation welding equipment .....	246
22.8.1	General .....	246
22.8.2	Welding equipment .....	246
22.8.3	Monitoring remote ground efficiency .....	246
Annex A (informative)	Additional information and guidance.....	247
Annex B (normative)	Weld CTOD testing procedures.....	497
Annex C (informative)	Material category approach.....	502
Annex D (informative)	Design class approach.....	508
Annex E (informative)	Welding and weld inspection requirements — Material category approach .....	512
Annex F (informative)	Welding and weld inspection requirements - Design class approach...	516
Annex G (normative)	Fabrication tolerances .....	523
Annex H (informative)	Regional information .....	538
Bibliography	.....	544