

Petroleum and natural gas industries — Fixed steel offshore structures

ICS 75.180.10

National foreword

This British Standard is the UK implementation of EN ISO 19902:2007+A1:2013. It is identical to ISO 19902:2007, incorporating amendment 1:2013. It supersedes BS EN ISO 19902:2007, which is withdrawn.

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Foreword

This document (EN ISO 19902:2007) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum and natural gas industries" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2008, and conflicting national standards shall be withdrawn at the latest by June 2008.

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Foreword to amendment A1

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Introduction

The series of International Standards applicable to types of offshore structure, ISO 19900 to ISO 19906, constitutes a common basis covering those aspects that address design requirements and assessments of all offshore structures used by the petroleum and natural gas industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for manned and unmanned offshore structures, whatever the type of structure and the nature or combination of the materials used.

It is important to recognize that structural integrity is an overall concept comprising models for describing actions, structural analyses, design rules, safety elements, workmanship, quality control procedures and national requirements, all of which are mutually dependent. The modification of one aspect of design in isolation can disturb the balance of reliability inherent in the overall concept or structural system. The implications involved in modifications, therefore, need to be considered in relation to the overall reliability of all offshore structural systems.

The series of International Standards applicable to the various types of offshore structure is intended to provide wide latitude in the choice of structural configurations, materials and techniques without hindering innovation. Sound engineering judgment is therefore necessary in the use of these International Standards.

Annex A provides background to and guidance on the use of this document and needs to be read in conjunction with the main body of this document. The clause numbering in Annex A is the same as in the normative text to facilitate cross-referencing.

Materials, welding and weld inspection requirements can be based either on a “material category” or on a “design class” approach, as discussed in Clauses 19 and 20. If the material category approach is used, the corresponding provisions of Annexes C and E are normative; if the design class approach is used, the corresponding provisions of Annexes D and F are normative.

Annex G gives requirements on fabrication tolerances.

Regional information on the application of the document to certain specific offshore areas is provided in informative Annex H.

To meet certain needs of industry for linking software to specific elements in this International Standard, a special numbering system has been permitted for figures, tables, equations and bibliographic references.

Petroleum and natural gas industries — Fixed steel offshore structures

1 Scope

This International Standard specifies requirements and provides recommendations applicable to the following types of fixed steel offshore structures for the petroleum and natural gas industries:

- caissons, free-standing and braced;
- jackets;
- monotowers;
- towers.

In addition, it is applicable to compliant bottom founded structures, steel gravity structures, jack-ups, other bottom founded structures and other structures related to offshore structures (such as underwater oil storage tanks, bridges and connecting structures), to the extent to which its requirements are relevant.

This International Standard contains requirements for planning and engineering of the following tasks:

- a) design, fabrication, transportation and installation of new structures as well as their future removal;
- b) in-service inspection and integrity management of both new and existing structures;
- c) assessment of existing structures;
- d) evaluation of structures for reuse at different locations.

NOTE 1 Specific additional requirements for the design of fixed steel offshore structures in arctic environments are to be contained in ISO 19906^[1].

NOTE 2 Requirements for topsides structures are to be contained in ISO 19901-3^[2], for marine operations in ISO 19901-6^[3] and for the site-specific assessment of jack-ups in ISO 19905-1^[4].

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10414-1, *Petroleum and natural gas industries — Field testing of drilling fluids — Part 1: Water-based fluids*

ISO 12135, *Metallic materials — Unified method of test for the determination of quasistatic fracture toughness*

ISO 13702, *Petroleum and natural gas industries — Control and mitigation of fires and explosions on offshore production installations — Requirements and guidelines*

ISO 19900:2002, *Petroleum and natural gas industries — General requirements for offshore structures*

ISO 19901-1:2005, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations*

ISO 19901-2, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 2: Seismic design procedures and criteria*

ISO 19901-4, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 4: Geotechnical and foundation design considerations*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19900, ISO 19901-1, ISO 19901-2 and ISO 19901-4, and the following apply.

3.1

abnormal value

value of a parameter of abnormal severity used in accidental limit state checks in which a structure should not suffer complete loss of integrity

NOTE 1 Abnormal design situations are used to provide robustness against events with a probability of exceedance of typically between 10^{-3} and 10^{-4} per annum by avoiding, for example, gross overloading.

NOTE 2 Abnormal values and events have probabilities of exceedance of the order of 10^{-3} to 10^{-4} per annum. In the limit state checks, some or all of the partial factors are set to 1,0.

NOTE 3 Adapted from ISO 19901-1:2005, definition 3.1.

3.2

accidental design situation

design situation involving exceptional conditions of the structure or its exposure

EXAMPLE Impact, fire, explosion, local failure, loss of intended differential pressure (e.g. buoyancy).

3.3

after damage design situation

design situation for which the condition of the structure reflects damage due to an accidental design situation and for which the environmental conditions are specially defined

3.4

analysis type

method including governing equations for deriving action effects

EXAMPLE Static analysis, transient dynamic analysis, non-linear analysis.

3.5

basic variable

one of a specified set of variables representing physical quantities which characterize actions, environmental influences, geometrical quantities, or material properties including soil properties

[ISO 19900:2002]

3.6

boundary conditions

actions and constraints on a [section of a] structural component [or a group of structural components] by other structural components or by the environment surrounding it

NOTE Boundary conditions can be used to generate reaction forces at locations of restraint.

3.7

braced caisson

monotower where the lower part of the monocolumn is supported laterally by one or more inclined braces between the column and one or more foundation piles

3.8

bucket foundation

foundation consisting of a cylindrical shell open on one end and installed by suction

3.9

characteristic value

value assigned to a basic variable associated with a prescribed probability of not being violated by unfavourable values during some reference period

NOTE The characteristic value is the main representative value. In some design situations a variable can have two characteristic values, an upper and a lower value.

[ISO 19900:2002]

3.10

compliant bottom founded structure

structure which is supported at its base by foundation piles or by another non-superficial foundation system and which is sufficiently flexible that applied lateral dynamic actions are substantially balanced by inertial reactions

NOTE Although this International Standard is applicable to fixed steel offshore structures and is not intended to form a complete standard for compliant bottom founded structures, some of its requirements and guidance can be applied to compliant bottom founded structures. Parts of its requirements can also apply to other bottom founded structures (e.g. some forms of minimal structure), as considered appropriate and as agreed upon by parties concerned on a case by case basis.

3.11

consequence category

classification system for identifying the environmental, economic and indirect personnel safety consequences of failure of a platform

NOTE Categories for environmental and economic consequences are (see 6.6.3)

C1 high environmental and/or economic consequences,

C2 medium environmental and/or economic consequences, and

C3 low environmental and economic consequences.

3.12

critical component

structural component, failure of which would cause failure of the whole structure, or a significant part of it

NOTE A critical component is part of the primary structure.

3.13

deformation capacity

ability of a structure or structural component to deform without significant loss of resistance, or the extent to which it can do so

3.14

design service life

assumed period for which a structure is to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary

[ISO 19900:2002]

3.15

design value

value derived from the representative value for use in the design verification procedure

[ISO 19900:2002]

3.16

dynamic amplification factor

DAF

ratio of a dynamic action effect to the corresponding static action effect

NOTE An appropriately selected dynamic amplification factor can be applied to static actions to simulate the effects of dynamic actions.

3.17

explosion

rapid chemical reaction of gas or dust in air

NOTE An explosion results in increased temperatures and pressure impulses. A gas explosion on an offshore platform is usually a deflagration in which flame speeds remain subsonic.

3.18

exposure level

classification system used to define the requirements for a structure based on consideration of life-safety and of environmental and economic consequences of failure

[ISO 19900:2002]

3.19

extreme value

value of a parameter used in ultimate limit state checks, in which a structure's global behaviour is intended to stay in the elastic range

NOTE Extreme values and events have probabilities of exceedance of the order of 10^{-2} per annum.

[ISO 19901-1:2002]

3.20

fit-for-purpose

meeting the intent of an International Standard although not meeting specific provisions of that International Standard in local areas, such that failure in these areas will not cause unacceptable risk to life-safety or the environment

[ISO 19900:2002]

3.21

fixed structure

structure that is bottom founded and transfers all actions on it to the sea floor

[ISO 19900:2002]

3.22

free-standing caisson

monotower where the structure consists, over its full height, of a single vertical column that continues into the seabed as the foundation pile

3.23

global analysis

determination of a consistent set of internal forces and moments, or stresses, in a structure that are in equilibrium with a defined set of actions on the entire structure

NOTE When a global analysis is of a transient situation (e.g. seismic), the inertial response is part of the equilibrium.

3.24

hazard

potential for human injury, damage to the environment, damage to property, or a combination of these

[ISO 13702:1999]

NOTE Several of the usual hazards to a platform (e.g. extreme storms) are treated as design situations for a structure. In this International Standard, hazards are errors and abnormal and accidental situations.

3.25

jacket

fixed structure with leg piles and axial force transfer from the structure and topsides into the piles at the top of the structure

NOTE See 6.1.2.

3.26

jack-up

mobile offshore unit that can be relocated and is bottom founded in its operating mode

[ISO 19900:2002].

NOTE See 6.1.4.

3.27

life-safety category

classification system for identifying the applicable level of life-safety for a platform

NOTE Categories for life-safety are (see 6.6.2)

S1 manned non-evacuated,

S2 manned evacuated, and

S3 unmanned.

3.28

load arrangement

identification of the position, magnitude and direction of a free action

3.29

load case

compatible load arrangements, sets of deformations and imperfections considered simultaneously with permanent actions and fixed variable actions for a particular design or verification

3.30

local analysis

determination of a consistent set of internal forces and moments, or stresses, in a cross-section of a structural component, or in a subset of structural components forming part of the structural system, that are in equilibrium with the boundary conditions

3.31

maintenance

set of activities performed during the working life of the structure in order to enable it to fulfil the requirements for reliability

NOTE Activities to restore the structure after an abnormal, accidental or seismic event are outside the scope of maintenance.

3.32

monotower

fixed structure in which the whole structure, or at least the upper part of the structure, consists of a single vertical column (tubular or framed) that carries the topsides

NOTE Where only the upper part of the structure is a single vertical column, the lower part of the structure consists of tubular members or frames that connect the vertical column to the foundation piles or to another non-superficial foundation system that supports the monotower at its base, such as bucket foundations.

3.33

nominal geometrical properties

properties of a structural component derived from its representative geometrical dimensions, remote from the location under consideration and with any corrosion allowance removed

NOTE 1 The nominal cross-section of a member at a joint is the cross-section beyond any joint can or brace stub forming part of the joint.

NOTE 2 Nominal geometrical properties are used in a global analysis to calculate the global behaviour of the structure.

NOTE 3 The nominal thickness of a component excludes any thickening of the component due to weldments.

3.34

nominal stress

stress calculated in a sectional area, including the stress raising effects of the macro-geometrical shape of the component of which the section forms a part, but disregarding the local stress raising effects from the section shape and any weldment or other fixing detail

NOTE Overall elastic behaviour is assumed when calculating nominal stresses.

3.35

nominal value

value assigned to a basic variable determined on a non-statistical basis, typically from acquired experience or physical conditions

[ISO 19900:2002]

3.36

owner

representative of the companies which own a development

NOTE The owner will normally be the operator on behalf of co-licensees.

3.37

primary structure

all main structural components that provide the structure's main strength and stiffness

3.38

quasi-static analysis

static analysis of a structure subjected to actions that vary slowly in relation to the structure's fundamental natural period such that the influence of structural accelerations can be either safely neglected or is approximated by using an equivalent quasi-static action

3.39

redundancy

ability of a structure to find alternative load paths following failure of one or more non-critical components, thus limiting the consequences of such failures

NOTE All structures having redundancy are statically indeterminate.

3.40

regulator

authority established by a national governmental administration to oversee the activities of the offshore oil and natural gas industries within its jurisdiction, with respect to the overall safety to life and protection of the environment

NOTE 1 The term *regulator* can encompass more than one agency in any particular territorial waters.

NOTE 2 The regulator can appoint other agencies, such as marine classification societies, to act on its behalf, and in such cases, *regulator* as it is used in this International Standard includes such agencies.

NOTE 3 In this International Standard, the term *regulator* does not include any agency responsible for approvals to extract hydrocarbons, unless such agency also has responsibility for safety and environmental protection.

3.41

repair

activities performed to preserve or to restore the function of a structure that fall outside the definition of maintenance

3.42

representative value

value assigned to a basic variable for verification of a limit state

[ISO 19900:2002]

3.43

representative yield strength

stress at which a material exhibits a specified deviation from proportionality of stress and strain

NOTE An offset of 0,2 % is used for many metals, including the steels covered by this International Standard.

3.44

reserve strength ratio

measure of the capacity of a structural system to withstand overload

NOTE For fixed steel offshore structures, the concept of a reserve strength ratio is usually applied to environmental actions (see 7.10), but is not limited to these actions.

3.45

risk reducing measures

measures undertaken to reduce either the probability or the consequences of an accident, including the preparation of contingency plans

3.46

robustness

ability of a structure to withstand events with a reasonable likelihood of occurring without being damaged to an extent disproportionate to the cause

3.47

secondary structure

structural components that, when removed, do not significantly alter the overall strength and stiffness of the structure

3.48

steel gravity structure

fixed structure that is held in place against environmental actions solely by the weight of the structure and any contained ballast, together with foundation resistance resulting from its weight and lateral resistance from any skirts

NOTE Although this International Standard is not intended to form a complete standard for gravity structures, some of the requirements and guidance could be applied to gravity structures.

3.49

strength

mechanical property of a material indicating its ability to resist actions, usually given in units of stress

3.50

stress concentration factor

SCF

factor relating a nominal stress to the local stress at a detail

NOTE SCFs are very important for and especially used in determining fatigue damage (see 16.10.2).

3.51

structural analysis

process or algorithm for determining action effects from a given set of actions

NOTE Structural analyses are performed at three levels (global analysis of an entire structure, local analysis of a structural component, local analysis of a section of a structural component) using different structural models.

3.52

structural component

physically distinguishable part of a structure

[ISO 19900:2002]

NOTE The main structural components of a fixed steel structure are tubular members (see Clause 13), tubular joints (see Clause 14), mechanical connectors and clamps (see Clause 15), foundation piles and bucket foundations (see Clause 17).

3.53

structural system

load-bearing components of a structure and the way in which these components function together

[ISO 19900:2002]

3.54

topsides

structures and equipment placed on a supporting structure (fixed or floating) to provide some or all of a platform's functions

[ISO 19900:2002]

NOTE 1 For a ship-shaped floating structure, neither the deck nor a superstructure integral with the hull is part of the topsides.

NOTE 2 For a jack-up, the hull is not part of the topsides.

NOTE 3 A separate fabricated deck or module support frame is part of the topsides.

3.55

tower

fixed structure that is supported by foundation arrangements at the base of the structure

NOTE See 6.1.3.

3.56

utilization member utilization joint utilization

maximum value of the ratio of the generalized representation of the design stress (force) in a structural component to the generalized representation of the design resistance in stress (force) units of the component

NOTE 1 The utilization is the maximum absolute value of the ratio for all conditions being considered.

NOTE 2 Only utilizations smaller than or equal to 1,0 satisfy the design criteria for a particular limit state.

NOTE 3 The design stress (force) is the stress (force) due to factored actions: $F_d = F_r \gamma_f$. The design resistance is the representative resistance divided by the partial resistance factor: $R_d = R_r / \gamma_R$.

NOTE 4 For members and joints subjected to a single force, the utilization, U , is equal to: $F_d / R_d = F_r \gamma_f \gamma_R / R_r$.

NOTE 5 For members and joints subjected to combined forces, the internal stress (force) pattern and the design resistance combine into an interaction equation. If the interaction equation governing the design check is, or can be, reduced to an inequality of the form $I \leq 1,0$, then the utilization is equal to I .

4 Symbols

The following is a summary of the main symbols that are used throughout this International Standard. Many other symbols are locally defined where they are used. Local use includes main symbols with one or more subscripts when a more specific use and associated definition of the symbol is intended.

A	accidental action (from ISO 19900)
A	area
C	coefficient in general
C_d	hydrodynamic drag coefficient
C_m	hydrodynamic inertia coefficient
C_m	moment reduction factor
C_r	seismic reserve capacity factor
C_s	shape coefficient
C_s	slamming coefficient
c_u	undrained shear strength of the soil, in stress units
D	diameter of a circular cylindrical element
D	diameter of a tubular joint chord
D	Palmgren-Miner fatigue damage ratio
D	equivalent quasi-static action representing dynamic effects
D_r	relative density of sand
d	water depth
d	diameter of tubular joint brace
E	Young's modulus of elasticity, which may be taken as 205 000 MPa for structural steel, in lieu of more detailed information
E	quasi-static environmental action
E_e	extreme quasi-static environmental action due to wind, waves and current
E_o	environmental action due to owner defined operating wind, wave and current parameters

F	action
F_d	design value of action (from ISO 19900)
F_r	representative value of action (from ISO 19900)
f	unit skin friction of a pile, in stress units
f	representative strength in general, in stress units
f_b	representative bending strength, in stress units
f_c	representative axial compressive strength, in stress units
f_{cu}	unconfined cube strength of grout
f_e	Euler buckling strength, in stress units
f_h	representative hoop buckling strength, in stress units
f_t	representative axial tensile strength, in stress units
f_v	representative shear strength, in stress units
f_y	representative yield strength, in stress units
G	permanent action (from ISO 19900)
g	acceleration due to gravity
g	gap
H	height of an individual wave
H_s	significant wave height
I	moment of inertia
K	factor (locally defined with subscript for specific meaning)
K	effective length factor
K	dimensionless coefficient of lateral earth pressure
K	Keulegan-Carpenter number
k	factor (locally defined with subscript for specific meaning)
k	wave number
k_{DAF}	dynamic amplification factor
L	length
M	moment (bending or torsion) due to factored actions
M_d	design value of joint bending moment strength, in moment units
M_{uj}	representative value of joint bending moment strength, in moment units
m	inverse slope of the S - N curve
m	mass
N	number of cycles to failure in fatigue of a specified constant amplitude stress range, S
n	number of occurrences of a specified stress range, S , during a specified time
P	percentage
P	member axial force due to factored actions
P_d	design value of joint axial strength, in force units
P_{uj}	representative value of joint axial strength, in force units

P_f	probability of failure
$P-\Delta$	second order bending effect due to axial compressive force, P , and lateral deflection, Δ
$P(x)$	cumulative probability of variable x
p	factored hydrostatic pressure
p_a	atmospheric pressure
p_0'	effective overburden stress of the soil
$p(x)$	probability density function of variable x
$p-y$	lateral soil resistance versus local pile displacement
Q	variable action (from ISO 19900)
Q_d	design axial pile capacity
Q_f	representative value of the total skin friction resistance of a pile, in force units
Q_f	chord force factor
Q_g	gap factor for a joint
Q_p	representative value of the end bearing capacity of a pile, in force units
Q_r	representative value of the axial pile capacity
Q_u	chord strength factor
$Q-z$	pile end bearing resistance versus pile tip displacement
Q_β	geometrical factor for a joint
q	unit end bearing of a pile, in stress units
R	radius of a circular cross-section
R_d	design value of a component resistance (from ISO 19900)
Re	Reynolds number
R_{RS}	reserve strength ratio (RSR)
r	radius of gyration
S	internal force (action effect)
S	constant amplitude stress range for fatigue assessments
Str	Strouhal number
S_r	Stress range
T	quasi-static transient action
T	wall thickness of the chord member
T	period in general
T_i	intrinsic wave period
T_z	average zero-crossing wave period
t	time
t	wall thickness in general
t	wall thickness of the brace member
$t-z$	soil pile shear transfer versus local pile displacement
U	utilization

V	beam shear due to factored actions
V	displaced volume
V	coefficient of variation
Z_e	elastic section modulus
Z_p	plastic section modulus
α	slope angle of a cone section
β	ratio of brace outside diameter to chord outside diameter
γ	ratio of chord outside radius to chord wall thickness
γ'	submerged unit weight of soil
γ_f	partial action factor of which the value reflects the uncertainty or randomness of the action (from ISO 19900)
γ_R	partial resistance factor of which the value reflects the uncertainty or variability of the component resistance including those of material properties (from ISO 19900)
λ	wave length
λ	column slenderness parameter
ν	Poisson's ratio, which may be taken as 0,3 for structural steel, in lieu of more detailed information
ν	kinematic viscosity of water
θ	angle in general
θ_m	mean wave direction
ρ_a	mass density of air, which may be taken as 1,22 kg/m ³ in lieu of more detailed information
ρ_s	mass density of steel, which may be taken as 7 850 kg/m ³ for structural steel, in lieu of more detailed information
ρ_w	mass density of sea water, which may be taken as 1 025 kg/m ³ , in lieu of more detailed information
σ	stress in general
τ	shear stress in general
τ	ratio of brace wall thickness to chord wall thickness
ϕ'	angle of internal friction in sand
Ω	ratio of frequency of excitation to natural frequency
ω	circular frequency
ω_e	frequency of excitation
ω_n	natural frequency in general
ω_1	first natural frequency
ξ	factor (locally defined with subscript for specific meaning)
ξ	fraction of critical damping
$\varnothing$	diameter

5 Abbreviated terms

ADS	atmospheric diving suit
ALE	abnormal level earthquake
ALS	accidental limit states
API	American Petroleum Institute
ASD	allowable stress design
AW	as-welded (in Annex D)
CHS	circular hollow section
COV	coefficient of variation
CTOD	crack tip opening displacement
CVN	Charpy V-notch
DAF	dynamic amplification factor
DC	design class
ELE	extreme level earthquake
ERW	electric resistance welded
FEA	finite element analysis
FLS	fatigue limit states
FMD	flooded member detection
GS	geometrical stress
GSR	geometrical stress range
HAT	highest astronomical tide
HAZ	heat affected zone
HISC	hydrogen induced stress cracking
IACS	International Association of Classification Societies
IC	impressed current
ipb	in-plane bending
JIP	joint industry project
LAST	lowest anticipated service temperature
LAT	lowest astronomical tide
LBZ	local brittle zone
LRFD	load and resistance factor design
MC	material category
MIC	microbiologically influenced corrosion
MPI	magnetic particle inspection
MPM	most probable maximum

NDT	non-destructive testing
opb	out-of-plane bending
 PLS	progressive collapse limit states 
POD	probability of detection
PQR	procedure qualification record
PWHT	post weld heat treatment
QA	quality assurance
QC	quality control
QMS	quality management system
Q&T	quenched and tempered
RAO	response amplitude operator
RHS	rectangular hollow section
rms	root-mean-square
RSR	reserve strength ratio
RT	radiographic testing
SAW	submerged arc welding
SCF	stress concentration factor
SDOF	single degree of freedom
SIM	structural integrity management (system)
SLS	serviceability limit states
SMYS	specified minimum yield strength
SRA	structural reliability analysis
SRC	seismic risk category
SRD	soil resistance to driving
SSSV	subsurface safety valve
TMCP	thermo-mechanically controlled process
TRF	transfer function
ULS	ultimate limit states
UT	ultrasonic testing
UU	unconsolidated and undrained
VIV	vortex induced vibrations
WPS	welding procedure specification
WSD	working stress design
WPQ	welding procedure qualification

6 Overall considerations

6.1 Types of fixed steel offshore structure

6.1.1 General

A fixed steel offshore structure can take many forms including:

- braced caisson (3.7);
- free-standing caisson (3.22);
- jacket (3.25, see 6.1.2);
- monotower (3.32).
- tower (3.55, see 6.1.3);
- steel gravity structure (3.48);
- jack-up (3.26, see 6.1.4).

This International Standard specifies requirements for braced caissons, free-standing caissons, jackets, monotowers and towers. Some of the requirements may also be used, as appropriate, for other forms of steel bottom founded offshore structures. The design of other forms of fixed steel bottom founded offshore structures shall achieve a level of reliability consistent with that intended by this International Standard.

A1 NOTE 1 There have been historical differences in the usage and understanding of the terms “jacket” and “tower”, particularly between the USA and Europe. The difference in such understanding of the terms has no significant impact on the application of this International Standard as long as the differences in structural behaviour are considered in the analyses of the different structures.

NOTE 2 There have been historical differences, which continue to exist, in the use and understanding of the term “caisson”. In the offshore oil and gas industry this term, together with its variants “braced caisson” or “free-standing caisson” (see, respectively, 3.7 and 3.22), has traditionally been used to refer to a particular type of minimum fixed structure, where the main component is a relatively large diameter tubular member, with or without additional lateral support, intended to satisfy various functional requirements such as supporting one or more wells, or supporting small decks and associated facilities. Conversely, in the geotechnical arena the term “caisson” has traditionally been used to refer to “foundation caisson”, i.e. foundation component /system consisting of shorter and more rigid chamber of larger diameter or larger lateral dimensions than the caisson structures described above.

Clause 17 covers the geotechnical design of long slender piles (i.e. satisfying the condition $L/D \geq 10$, where L is the length embedded in the soil, and D is the outside diameter) for fixed steel structures. The provisions of that clause apply also to braced or free-standing caisson structures with $L/D \geq 10$. However, the content of Clause 17 does not apply to the design of short and rigid, large diameter foundations with $L/D < 10$. Guidance on the geotechnical design of this type of foundations is within the scope of ISO 19901-4. **A1**

6.1.2 Jackets

Jackets and towers are superficially similar structures, the essential differences between them being the arrangement of the foundation piles and, associated with this, the location of axial force transfer from the structure and topsides into the piles. The location and method of transferring the axial forces results in significant differences in the behaviour of jackets and towers.

A jacket is a welded tubular space frame with three or more vertical (or near vertical) tubular chords (the legs) and a bracing system between the legs. The jacket provides support for the foundation piles, conductors, risers, and other appurtenances.

A jacket foundation includes leg piles which are inserted through the legs and are connected to the legs either at the top, by welding or mechanical means, or along the length of the legs, by grouting. Additional piles, called skirt piles, can be inserted through and connected to sleeves at the base of the structure. Leg and skirt piles jointly anchor the structure and transfer both vertical and horizontal actions to the seabed.

Where the foundation piles are connected to the legs only at the top of the jacket, the axial forces (including moments caused by shear forces) are transferred to the piles at the connection and the jacket “hangs” from the piles.

Where the foundation piles are connected to the legs by grouting along the full length of the leg, the jacket behaviour is similar to that of a tower, with the legs and piles acting together as composite components.

6.1.3 Towers

A tower type structure is supported by foundation arrangements at the base of the structure.

The tower is again made of a welded tubular space frame with three or more vertical (or near vertical) tubular chords, called legs, with a bracing system between the legs. The tower provides support for the topsides, conductors, risers and other appurtenances.

A tower foundation usually includes cluster piles which are inserted through and connected to sleeves around the (corner) legs at the base of the structure. Additional piles, called skirt piles, can be inserted through and connected to sleeves at the base and along the perimeter of the structure. As an alternative to piles, a tower can be supported by another non-superficial foundation system that supports it at its base, such as bucket foundations. Cluster and skirt piles, or another non-superficial foundation system, anchor the structure and transfer both vertical and horizontal actions to the seabed.

The global behaviour of a tower is that of a vertical cantilever, with all actions being transferred to the foundation system at the base of the tower.

6.1.4 Jack-ups

A jack-up comprises a floating hull and one or more legs, which can move up and down relative to the hull. A jack-up reaches its operational mode by lowering the leg(s) to the sea floor and then raising the hull to the required elevation. The majority of jack-ups have three or more legs, each of which can be moved independently and which are supported on the sea floor by spudcans.

The majority of jack-ups are built for short-term operations at different locations around the world. As metocean and foundation conditions vary between locations, such jack-ups are assessed for each particular location, see ISO 19905-1^[4]. A few jack-ups are purpose built for production operations at a single location, albeit that there can be an intent for eventual reuse at further locations.

Two options are available for a jack-up within the framework of the ISO 19900 series, these are

- a) design, assessment and operation to the requirements of this International Standard, and
- b) site-specific assessment to the requirements of ISO 19905-1^[4], in which case either the periodic inspection requirements of the IACS member or the alternative requirements for long-term deployment in ISO 19905-1^[4] shall be satisfied.

NOTE ISO 19905-1^[4] applies only to structures holding valid certification as self-elevating units from an IACS member, or equivalent.

Option a) above shall be used for a jack-up purpose built for production at a particular location and where option b) does not apply. Option b) should be used for a jack-up built to operate in a variety of locations. In other cases, when an existing jack-up is to be used for an extended period at a single location for production (rather than for exploration, appraisal or other short term application) the owners and regulators shall apply either the reuse requirements (see Clause 25) of this International Standard or the requirements of ISO 19905-1^[4].

When option a) is selected, some aspects of the requirements of this International Standard do not apply, including the determination of environmental actions and action effects due to dynamic response, structural behaviour and foundation behaviour. The alternative procedures given in ISO 19905-1^[4] may be used in such cases; however, the procedures shall be modified as necessary to give an equivalent level of structural integrity to that intended by this International Standard. The foundation strength, the foundation preload, overturning, leg chord strength and the strength of the holding system shall be checked in accordance with the requirements of ISO 19905-1^[4].

A limitation on the use of this International Standard for jack-ups is the strength and ductility of high strength jack-up steels (with yield strengths of 700 N/mm² or more) for major structural components — as compared with yield strengths of less than 500 N/mm² for other conventional fixed steel offshore structures. The designer or assessor of such jack-up units shall take note of the limitations of this International Standard for steels with yield strengths higher than 500 N/mm² and shall obtain sufficient data to justify the design for such cases.

6.2 Planning

6.2.1 General

Adequate planning shall be completed before actual design is started in order to obtain a safe, workable, and economical offshore structure. The initial planning shall include the determination of all limit states, design situations and design criteria upon which the design of the structure is to be based, following the general requirements and conditions specified in ISO 19900.

6.2.2 Foundations and active geological processes

The capacity and suitability of the foundations and the susceptibility to active geological processes shall be considered in selecting the type of structure and the location. Requirements and guidance are given in Clause 17 and in ISO 19901-4.

6.2.3 Design for inspection and maintenance

ISO 19900 notes that “Structural integrity, serviceability throughout the intended service life, and durability are not simply functions of the design calculations but are also dependent on the quality control exercised in construction, the supervision on site, and the manner in which the structure is used and maintained.” Therefore, during the planning stage a philosophy for inspection and maintenance should be developed. The design of the structure as a whole, as well as the structural details, should be consistent with this philosophy. In preparing the philosophy, a realistic assessment should be made of the ability to actually achieve the intended quality of the results of inspection and maintenance efforts. This assessment should be taken into account when progressing the design and fine-tuning design situations and criteria. Relevant requirements related to inspection and maintenance requirements are given in Clauses 21 and 23.

6.2.4 Design situations and criteria

Design situations as used herein include all the service and operational requirements resulting from the intended use of the structure and the environmental conditions that can affect the design of the structure in accordance with ISO 19900. In the absence of site-specific information on the environmental conditions, ISO 19901-1 contains indicative values for the extreme conditions in certain areas. These values may be used for conceptual design studies. The owner shall review the validity of these values and, if necessary, use site-specific data for the final design of a structure, see also 6.5.2 and 7.3. Criteria that are to be met by the design are directly related to the specific formulation of the design situations. Therefore, design situations and design criteria shall not be separated from one another. They are jointly specified in Clauses 8 to 17.

6.2.5 Regulations

The requirements of national regulations and standards where a structure will be used can be different from those given in this International Standard. It shall be ensured that the requirements of safety, reliability and durability implicit in the requirements of this International Standard are met. This applies to all phases of planning, design, fabrication, transportation, installation, service and removal.

6.3 Service and operational considerations

6.3.1 General considerations

The principal service and operational requirements to be considered to establish the design basis for fixed steel offshore structures are summarized in ISO 19900. Operational requirements include

- a) service requirements, i.e. function of the platform,
- b) manning,

- c) conductors and risers,
- d) equipment and material layouts, including rig access to conductor slots,
- e) personnel and material transfer,
- f) motions and vibrations,
- g) any special requirements, and
- h) location and orientation.

In addition, requirements for decommissioning and removal shall be considered.

6.3.2 Water depth

The water depth, surge height and tide shall be determined as accurately as possible, so that elevations can be established for boat landings, fenders, decks, and corrosion protection; see ISO 19901-1 for information on these parameters. The potential subsidence of the sea floor and settlement of the structure shall be considered when determining the design water depth.

6.3.3 Structural configuration

6.3.3.1 General

Requirements for the structural configuration are given in ISO 19900; some further requirements are given in 6.3.3.2 and 6.3.3.3.

6.3.3.2 Deck elevation

In general, the elevation of the lowest deck, and any facilities or equipment hanging below the lowest deck, shall provide sufficient clearance to allow the passage of wave crests of abnormal values. See A.6.3.3.2.

Whenever this requirement is not satisfied, the structure shall be designed to resist any wave and current actions on the deck(s), including the actions on facilities or equipment supported by the deck(s).

6.3.3.3 Equipment and material layouts

Layouts and centres of gravity associated with permanent and variable actions, as defined in 9.2, are required in the development of the design. Heavy concentrated actions on the structure shall be located such that proper framing to support these actions can be planned. Consideration shall be given to maintenance requirements and future operations.

If portable equipment or materials are to be placed on a lower deck, then adequately sized hatches shall be provided and conveniently located in the upper decks.

6.3.4 Access and auxiliary systems

The number and location of stairways and access boat landings on the structure shall, as a minimum, be governed by safety considerations. Consideration shall be given to providing access to the water level for sea escape and to facilitate self-rescue in man-overboard situations. Furthermore, operating requirements as well as installation, maintenance and inspection requirements shall be considered in determining the number and location of access platforms, walkways and stairways.

6.4 Safety considerations

6.4.1 General

The safety of life, environment, and property depends upon the ability of the structure to withstand the actions for which it was designed and to survive the environmental conditions which can occur. Good practice dictates the use of certain structural additions, equipment, and operating procedures such that injuries to personnel and the risks of accidental events are minimized.

6.4.2 Accidental events

Personnel safety and possible damage to or loss of the structure require that attention be given to accidental events as summarized in ISO 19900. With regard to methods of protecting against fires and explosions, the selection of the system depends upon the function of the platform. Procedures should conform to any applicable national or regional requirements, as well as being in accordance with ISO 13702.

6.5 Environmental considerations

6.5.1 General

Information on the consideration of environmental conditions and their use is provided in ISO 19900. Further requirements and information are contained in ISO 19901-1, as well as in this International Standard.

6.5.2 Selecting design metocean parameters and action factors

The reliability of a structure depends on the combination of design actions and design resistances. The design actions are the product of selected representative actions and associated partial action factors. Representative environmental actions are governed by the selection of appropriate metocean (meteorological and oceanographic) parameters for design. As a guide, the recurrence interval for metocean design parameters should be several times the design service life of the structure.

Design in accordance with this International Standard shall be based on a return period of 100 years. Where the data are available and sufficient, the 100 year return period may apply to responses (action effects) of the structure instead of to metocean design parameters. Further requirements and guidance are provided in Clause 9 and in ISO 19901-1.

In some cases, lower return periods may be considered, provided that the partial action factors used and the deck elevation selected give equivalent structural reliability for the exposure level of the platform.

Aspects to be considered in selecting partial action factors are

- a) the intended use of the structure,
- b) the structure design service life,
- c) the time and duration of construction, installation, and actions due to environmental conditions during operations,
- d) the exposure level,
- e) the requirements of regulators,
- f) the uncertainty in actions associated with specific metocean parameters and with operating conditions, and the ability to predict the structure's resistance to the actions,
- g) the probability of occurrence and magnitude of extreme and abnormal metocean actions, taking into account the joint frequency of occurrence of extreme winds, waves and currents (both in magnitude and direction),
- h) the probability of occurrence and magnitude of actions due to extreme and abnormal earthquakes, see ISO 19901-2, and
- i) the probability of occurrence and magnitude of extreme and abnormal actions due to sea ice, see ISO 19906 [1].

In addition to specifying extreme and abnormal metocean parameters, the owner shall specify the limiting environmental conditions for performing any particular operation inducing specific actions, or for any particular situation of the platform.

6.6 Exposure levels

6.6.1 General

Structures can be categorized by various levels of exposure to determine criteria that are appropriate for the intended service of the structure. This applies to the design of new structures and to the assessment of existing structures. The levels are determined by consideration of life-safety and of environmental and economic consequences.

The life-safety category addresses personnel on the platform and the likelihood of successful evacuation before a design environmental event occurs.

The consequence category considers the potential risk to life of personnel brought in to react to any incident, the potential risk of environmental damage and the potential risk of economic losses.

6.6.2 Life-safety categories

The category for life-safety shall be selected from the following options with specific requirements.

a) S1 Manned non-evacuated

The manned non-evacuated category refers to a platform that is continuously (or nearly continuously) occupied by persons accommodated and living thereon, and from which personnel evacuation prior to the design environmental event is either not intended or impractical.

A platform shall be categorized as S1 manned-non-evacuated unless the particular requirements for S2 or S3 apply throughout the design service life of the platform.

b) S2 Manned evacuated

The manned evacuated category refers to a platform that is normally manned except during a forecast design environmental event. For categorization purposes, a platform shall not be categorized as a manned evacuated platform unless

- 1) reliable forecast of a design environmental event is technically and operationally feasible, and the weather between any such forecast and the occurrence of the design environmental event is not likely to inhibit an evacuation,
- 2) prior to a design environmental event, evacuation is planned,
- 3) sufficient time and resources exist to safely evacuate all personnel from the platform and all other platforms likely to require evacuation for the same storm.

c) S3 Unmanned

The unmanned category refers to a platform that is only manned for occasional inspection, maintenance and modification visits. For categorization purposes, a platform shall not be categorized as unmanned unless

- 1) visits to the platform are undertaken for specific planned inspection, maintenance or modification operations on the platform itself,
- 2) visits are not expected to last more than 24 h during seasons when severe weather can be expected to occur,
- 3) the evacuation criteria 1) to 3) for S2 manned evacuated platforms are also met.

A platform in this category may also be described as “not normally manned”.

It is recognized that life-safety category definitions include a degree of judgment. The owner of the structure shall determine the applicable category prior to the design of a new structure or the assessment of an existing structure and shall obtain the agreement of the regulator where applicable.

6.6.3 Consequence categories

Factors that should be considered in determining the consequence category include

- life-safety of personnel on or near to the platform brought in to react to any consequence of failure, but not personnel that are part of the normal complement of the platform,
- damage to the environment, and
- anticipated losses to the owner, to other installation owners, to industry and/or to other third parties as well as to society in general.

The consequence category shall be selected from the following options with specific requirements.

a) C1 High consequence category

The high consequence category refers to platforms with high production rates or large processing capability and/or those platforms that have the potential for well flow of either oil or sour gas in the event of platform failure. In addition, it includes platforms where the shut-in of the oil or sour gas production is not planned, or not practical, prior to the occurrence of the design event (such as areas with high seismic activity). Platforms that support trunk oil transport lines and/or storage facilities for intermittent oil shipment are also considered to be in the high consequence category.

A platform shall be categorized as C1, high consequence, unless the particular requirements for C2 or C3 apply throughout the design service life of the platform.

b) C2 Medium consequence category

The medium consequence category refers to platforms where production can be shut-in during the design event. For categorization purposes, a platform shall not be categorized as medium consequence unless

- 1) all wells that can flow on their own in the event of platform failure contain fully-functional subsurface safety valves, manufactured and tested in accordance with applicable specifications,
- 2) oil storage is limited to process inventory and “surge” tanks for pipeline transfer,
- 3) pipelines are limited in their ability to release hydrocarbons, either by virtue of inventory and pressure regime, or by check valves or seabed safety valves.

c) C3 Low consequence category

The low consequence category refers to minimal platforms where production can be shut-in during the design event. These platforms may support production departing from the platform and low volume in-field pipelines. For categorization purposes, a platform shall not be categorized as low consequence unless

- 1) all wells that can flow on their own in the event of platform failure contain fully-functional subsurface safety valves, manufactured and tested in accordance with applicable specifications,
- 2) oil storage is limited to process inventory,
- 3) pipelines are limited in their ability to release hydrocarbons, either by virtue of inventory and pressure regime, or by check valves or seabed safety valves.

It is recognized that consequence category definitions include a degree of judgment. The owner of the structure shall determine the applicable category prior to the design of a new structure or the assessment of an existing structure and shall obtain the agreement of the regulator where applicable.

6.6.4 Determination of exposure level

The three categories for both life-safety and consequence can, in principle, be combined into nine exposure levels. However, the level to be used for structure categorization is the more restrictive level for either life-safety or consequence.

This results in three exposure levels as illustrated in Table 6.6-1:

Table 6.6-1 — Determination of exposure level

Life-safety category	Consequence category		
	C1 High consequence	C2 Medium consequence	C3 Low consequence
S1 Manned non-evacuated	L1	L1	L1
S2 Manned evacuated	L1	L2	L2
S3 Unmanned	L1	L2	L3

The exposure level applicable to a structure shall be determined by the owner prior to the design of a new structure or the assessment of an existing structure, and be agreed upon by the regulator where applicable.

Platform categorization may be revised over the design service life of the structure as a result of changes in factors affecting life-safety or consequence category.

6.7 Assessment of existing structures

Any assessment of existing structures to confirm that they comply with this International Standard or are fit-for-purpose shall be performed in accordance with the assessment requirements of ISO 19900 and with Clause 24.

6.8 Structure reuse

Structures may be removed and relocated for use at a new location. When this is considered, the structure shall be assessed in accordance with the assessment requirements of ISO 19900 and Clause 25, for the use (including exposure level) and conditions that are applicable at the new location. Any repairs or modifications that are necessary shall be in accordance with this International Standard.

7 General design requirements

7.1 General

[A1] The general principles on which structural design requirements are based are documented in ISO 19900. ISO 19900 requires that structural design be performed with reference to a specified set of limit states. For each limit state, design situations shall be determined and an appropriate calculation model shall be established. **[A1]**

- the variables that occur in a calculation model, comprising geometrical parameters, actions and properties of materials and soils,
- the analyses to be performed, and
- the design format using partial action and partial resistance factors.

This clause outlines the overall requirements for

- a) incorporating limit states (see 7.2),
- b) determining design situations (see 7.3),
- c) structural modelling and analysis (see 7.4), and
- d) design of the structure (see 7.5 to 7.11).

These requirements are a minimum.

7.2 Incorporating limit states

ISO 19900 divides the limit states into four categories, as below.

a) Ultimate limit states (ULS)

The design actions to be used in the various ULS are specified in Clauses 8, 9 and 11. The design resistances and the application of the ULS are specified in Clauses 13, 14, 15 and 17.

b) Serviceability limit state (SLS)

The design shall comply with the serviceability requirements of caissons, conductors, risers and topsides interfaces, as defined by the owner.

c) Fatigue limit states (FLS)

The various FLS are addressed in Clause 16, covering methods, actions and resistances. Additionally, FLS requirements for grouted connections, mechanical connections and clamps are given in Clause 15.

d) Accidental limit states (ALS)

ALS are addressed in Clause 10, in respect of actions and modifications to both partial action factors and partial resistance factors.

7.3 Determining design situations

Determination of situations for which structures are to be designed is the responsibility of the owner in accordance with the requirements of a regulator, where one exists. Aspects to be considered in determining design situations include

- a) service requirements for the intended function of the structure,

- b) expected service life for each function,
- c) method and duration of construction activities,
- d) expected method of removal of the structure and, where applicable, any intended relocation,
- e) hazards (accidental and abnormal events) to which the structure can be exposed during its service life,
- f) potential consequences of partial or complete structural failure, and
- g) the nature and severity of environmental conditions (meteorological, oceanographic and active geological processes) to be expected during its construction and service life.

Usually, three sets of environmental conditions should be considered: one associated with operating situations (normal conditions), one associated with extreme conditions and one associated with abnormal conditions.

7.4 Structural modelling and analysis

Internal forces in components shall be determined by an analysis method that is suitable for statically indeterminate structures and that accounts for bending as well as for axial action effects. In general, a linear elastic model of the structure is sufficient; however, the non-linear behaviour of structure-foundation interaction shall be addressed. For piled foundations the non-linear behaviour of the axial and lateral pile-soil support shall be explicitly modelled to ensure load-deflection compatibility between the structure and pile-soil system. For a pile analysis, the effects of geometrical and material non-linearities shall also be considered within the structure-pile-soil system. In no case shall additional or adjusted partial action factors be used as a substitute for a rational analysis to determine internal forces. Other aspects of structural modelling and analysis are discussed in Clauses 8 to 17 and 24.

7.5 Design for pre-service and removal situations

The structure shall be designed to resist actions occurring during fabrication, loadout, transportation, installation and removal, as specified in Clause 8. For structures that are intended to be relocated to new sites, actions resulting from removal, on-loading, transportation, upgrading, and re-installation shall also be considered in the design, in addition to the above construction actions.

Methods for fabrication, assembly, loadout, transportation, installation and removal of the structure shall be considered during design in order to identify potential difficulties and limitations for available equipment. Design situations for partially fabricated components of the structure and for the assembled structure as a whole shall be established. Fabrication and assembly tolerances assumed in design shall be compatible with those specified in the construction specifications and achievable during construction.

7.6 Design for the in-place situation

The structure shall be designed to resist permanent actions, variable actions, environmental actions, repetitive actions and accidental actions occurring during its service life, as well as rational combinations thereof, to obtain the most onerous conditions for all structural components. The representative values of these actions are given in Clauses 9 to 11. Clarification on the selection of representative values and return periods is provided in A.7.6.

7.7 Determination of resistances

7.7.1 General

The resistances of components in a fixed steel offshore structure shall, wherever possible, be derived from the formulae given in Clauses 13 to 15. These formulae provide representative resistances to which the partial resistance factors are applied.

Where the resistance of a component is not adequately described in Clauses 13 to 15, the resistances shall be determined from a rational study of the behaviour of the component. Both physical testing and computer

simulation may be used to derive representative resistances, but in both cases the results shall be compared to any other available test data.

7.7.2 Physical testing to derive resistances

Physical tests may be used to derive resistances for specific components. Care shall be taken to account for the differences between the test arrangements and the arrangement of the component within the structure. Guidance on these differences is given in A.7.7.2.

Comparisons shall be made with other available test data to give an indication of the variability of the component behaviour.

7.7.3 Resistances derived from computer simulations validated by physical testing

Computer simulations can provide an indication of resistance and can be particularly valuable for investigating the effects of changes of various parameters. Computer simulations shall be validated against physical test data wherever possible. If test data are not available, the requirements of 7.7.5 apply.

7.7.4 Resistances derived from computer simulations validated against design formulae

As an alternative to validation against physical test data, computer simulations may be validated against the formulae given in Clauses 13 to 15. It should be noted that Clauses 13 to 15 give representative resistances, and therefore take account of structural behaviour variability.

7.7.5 Resistances derived from unvalidated computer simulations

Unvalidated computer simulations may only be used when no physical test data or design formulae are available. The similarity of available data and the component being simulated is a matter of judgment, and the analyst shall take account of statistical variability of material and component behaviour, and limitations and errors that can be introduced in computer simulations.

7.8 Strength and stability checks

7.8.1 Action and resistance factors

A partial action factor shall be applied to each of the external actions in the combinations given in Clauses 8 to 11. The combination of factored representative actions results in design values of internal forces. These internal forces are designated by the symbol S in Clauses 8 to 11.

A partial resistance factor is applied to the strength of each member, joint and foundation component to determine its design resistance.

7.8.2 Strength and stability equations

Each component shall be proportioned to resist the internal forces, S . The appropriate strength and stability equations are given in Clauses 13, 14, 15 and 17. These equations comprise

- a) the formulae for the representative strength of the component,
- b) the partial resistance factors, and
- c) the internal force, S , from the design actions specified in Clauses 8 to 11.

7.8.3 Unfactored actions

Where actions are time-varying and non-synchronous, the most onerous values of action effects cannot generally be determined by simply adding factored individual actions. In some construction and installation situations, the action effects are best computed from unfactored actions and by investigating the sensitivity of

the action effects with realistic variations of the governing parameters. The design values of the internal forces, S , may then be obtained by factoring the action effects by the partial action factors given in Clause 8.

7.9 Robustness

A structure shall incorporate robustness through consideration of the effects of all hazards and their probabilities of occurrence, to ensure that consequent damage is not disproportionate to the cause. Damage from an event with a reasonable likelihood of occurrence shall not lead to complete loss of integrity of the structure. In such cases, the structural integrity in the damaged state shall be sufficient to allow a process system close down and a safe evacuation, see Clause 10.

Robustness is achieved by either

- a) designing the structure in such a way that any single load bearing component exposed to hazard can become incapable of carrying its normal design actions without causing collapse of the structure or any significant part of it, or
- b) ensuring (by design or by protective measures) that no critical component exposed to hazard can be made ineffective, or
- c) a combination of a) and b), above.

7.10 Reserve strength

7.10.1 New structures

All new structures complying with this International Standard are intended to have a similar margin of system reserve strength for the same exposure level (L-level). The system reserve strength gives the structure a margin to withstand environmental action effects that exceed the design action effects and is evaluated as the reserve strength ratio (RSR), R_{RS} , expressed in Equation (7.10-1).

$$R_{RS} = F_{\text{collapse}}/F_{100} \quad (7.10-1)$$

where

F_{collapse} is the unfactored global environmental action which, when co-existing unfactored permanent and variable actions are added, causes collapse of the structure;

F_{100} is the unfactored 100 year global environmental action calculated in accordance with Clause 9.

This intent may be achieved in either of two ways, as described in 9.10. The partial action factors for environmental actions shall be determined based on the considerations given in Clause 9.

When using this International Standard for structures that provide less inherent system reserve strength (smaller RSR) for the environmental actions than a typical space frame type structure, the partial action factor for environmental actions shall be increased to yield the same RSR as for a typical space frame type structure.

7.10.2 Existing structures

During its service life, the reserve strength of a structure can vary (increase or decrease) due to a variety of causes. Clause 24 provides requirements for the assessment of existing structures, including the use of system strength approaches.

7.11 Indirect actions

Consideration shall be given to internal forces and stresses induced by indirect actions, including imposed or constrained deformations, temperature changes, relaxation, and prestressing.

7.12 Structural reliability analysis

Structural reliability analysis (SRA) methods are used to assess the effects of uncertainties in the actions, resistances and modelling of (parts of) a structure and its performance. Uncertainties exist due to the natural variation, the physical uncertainty or the randomness in the basic variables (aleatoric or Type I uncertainties), and due to those factors that are a function of a lack of complete understanding or knowledge (epistemic or Type II uncertainties).

SRA is not normally undertaken as part of a new design in accordance with this International Standard, but may be used during the initial design process to provide comparative data. SRA may be used in the (re-)calibration of partial action and resistance factors for special or unusual circumstances, in decision analyses to support inspection and monitoring programmes, and in some cases in the structural assessment of existing structures. The design procedures in this International Standard shall be used for new designs.

The objective of SRA is to determine the probability of an event (usually a failure event) occurring during a specified reference period. The failure probability during the structure's design service life (or for some other specified reference period) can be of use in economic risk models; annual failure probabilities are generally evaluated when considering life-safety issues.

Where SRA methods are used, it is generally necessary to compare evaluated failure probabilities with appropriate target values. Target reliabilities should allow for the consequences and nature of failure, and where possible, should be calibrated against well established cases that are known to have adequate safety.

8 Actions for pre-service and removal situations

⚠ IMPORTANT — Users of this document should be aware of the publication of ISO 19901-6, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 6: Marine operations*, which followed publication of the first edition of ISO 19902. Where the provisions in ISO 19901-6 now overlap with ISO 19902, ISO 19901-6 may be used in preference. **⚠**

8.1 General

8.1.1 Coverage

This clause presents requirements for pre-service and removal situations. The requirements apply to both the structure and to any temporary components such as buoyancy aids attached to the structure for pre-service or removal situations. The primary objective is to ensure that a structure begins its service life at an offshore location with its required strength and structural integrity intact. The clause covers the following topics, following the requirements of ISO 19900:

- a) the type of actions to be included;
- b) procedures for determining representative values for the actions;
- c) the partial action factors to be applied;
- d) methods for determining the internal forces due to the effect of factored actions or combinations of factored actions.

8.1.2 Situations

Design situations to be considered during pre-service and removal situations of the structure are transient situations, in accordance with ISO 19900, and are listed below.

- a) Pre-service situations comprise
 - 1) fabrication (including assembly during fabrication),
 - 2) loadout (including float-out),

- 3) transportation, and
 - 4) installation (including launching and uprighting).
- i) Removal situations comprise
- 1) removal prior to relocation to a new location for a new period of service, and
 - 2) removal at the end of service life.

Further requirements concerning pre-service situations are given in Clauses 19 to 21.

Actions on (parts of) the structure and internal forces in components of the structure shall be calculated for each phase of pre-service or removal situations in accordance with the principles given in 7.3 to 7.5.

The requirements of 8.2 and 8.3 apply to all pre-service and removal situations. Specific requirements for each phase of pre-service situations are subsequently given in 8.4 to 8.7. Requirements for removal situations are given in 8.8.

8.2 General requirements

8.2.1 Design situations

Design situations during pre-service and removal situations are generally governed by permanent and variable actions. These actions are predominantly static actions, in particular due to weights of structural components, appurtenances and equipment. When dynamic effects can be important, these shall be considered. When appropriate, environmental and accidental actions shall also be given due attention, following the requirements of Clauses 9 and 10.

8.2.2 Weight control

The weight and centre of gravity of each structure or part of a structure shall be evaluated during design and during all pre-service and removal situations. This applies in particular prior to any lifting being performed. Where applicable, allowances for weight variations based on weight reports, the status of design and/or fabrication, known outstanding items and/or operational modifications to the structures should be applied.

During pre-service and removal situations the behaviour of the structure and the magnitude and distribution of internal forces in the structure can be very sensitive to the position of the centre of gravity. In such cases, due allowances shall be made for uncertainties and potential changes in the position of the centre of gravity.

NOTE Guidance on weight control is given in ISO 19901-5^[5].

8.2.3 Dynamic effects

If operations during pre-service and removal situations involve significant motion of large masses, the dynamic actions involved shall be considered.

The action effects shall be adjusted to arrive at adequate representative internal forces for the design of the components affected. These representative internal forces can be derived from an appropriate analysis to determine the static and dynamic effects due to both the external actions and the motion, or they can be based on relevant previous experience.

For dynamic effects during lifting, see the requirements given in 8.3.2.

8.2.4 Internal forces

8.2.4.1 Internal forces due to factored actions

Each member, joint and other relevant component shall be checked for strength using the internal force (action effect) (S) resulting from the design action (F_d).

The design action, F_d , is due to the following:

- factored permanent actions (G);
- factored variable actions (Q);
- factored quasi-static transient actions (T).

Equation (8.2-1) defines F_d for situations not involving lift (additional factors are applied for lift conditions, see 8.3.6):

$$F_d = \gamma_{f,GT} G_T + \gamma_{f,QT} Q_T + \gamma_{f,T} T \quad (8.2-1)$$

where

G_T is the action imposed either by the weight of the structure in air, or by the submerged weight of the structure in water, during the transient situation being considered, including any permanent equipment or other objects and any piles or conductors installed on the structure, as well as any ballast installed in or carried by the structure;

Q_T is the action imposed by the weight of the temporary equipment or other objects, including any rigging installed or carried by the structure, during the transient situation being considered;

T represents the actions from the transient situation being considered, including:

- a) when appropriate, environmental actions,
- b) when appropriate, a suitable representation of dynamic effects (see A.8.1 and 8.2.4.2),
- c) for lifting, the effects of fabrication tolerances and variances in sling length as detailed in 8.3.3 and for a dual lift as detailed in 8.3.4,
- d) for loadout, allowances for misalignment as detailed in 8.5,
- e) for transportation, any hydrostatic and hydrodynamic actions on the structure, including any inertial actions resulting from accelerations of the structure (see 8.6), and
- f) for installation, the lifting actions and hydrostatic pressure actions on the structure (see 8.7);

$\gamma_{f,GT}$, $\gamma_{f,QT}$ and $\gamma_{f,T}$ are the partial action factors.

The three design situations in Table 8.2-1 shall all be considered.

Table 8.2-1 — Partial action factors for calculating internal forces

Situation	Partial action factor		
	$\gamma_{f,GT}$	$\gamma_{f,QT}$	$\gamma_{f,T}$
1	1,3	1,3	1,0
2	1,1	1,1	1,35
3	0,9	0,9	1,35
NOTE Situation 1 governs for components in which permanent and variable action effects are dominant. Situation 2 governs for components in which transient action effects are dominant and in which the permanent and variable actions increase the magnitudes of the internal forces. Situation 3 governs for components in which transient action effects are dominant but in which the permanent and variable actions decrease the magnitudes of the internal forces.			

Additional requirements and factors for lifting situations are given in 8.3.

8.2.4.2 Internal forces due to unfactored actions

In some situations it is not possible or appropriate to apply action factors to each of the individual actions, see A.8.1 and 7.8.3. Examples of such situations are transportation, launching or lifting in which substantial dynamic or non-linear effects can occur. In such cases each member, joint and other relevant component shall be checked for strength using the internal force (action effect) (S) determined from the following equations:

$$F_{un} = G_T + Q_T + T$$
$$S = \gamma_{f,Sun} S_{un} \quad (8.2-2)$$

where

F_{un} is the total action due to the unfactored actions G_T , Q_T and T defined in 8.2.4.1;

S_{un} is the internal force resulting from F_{un} ;

$\gamma_{f,Sun}$ is the partial factor to be applied to S_{un} , usually 1,3.

Additional requirements and factors for lifting situations are given in 8.3.

If both this method and the one according to 8.2.4.1 can be applied, that giving the more onerous result shall be used.

8.3 Actions associated with lifting

8.3.1 General

Lifting imposes static and dynamic actions on the structure during various stages of pre-service and removal situations. The magnitude of these actions shall be based on the weight of the (part of the) structure to be lifted and shall be determined considering static and dynamic equilibrium during the lift. The internal forces in the structure and in the lifting slings and rigging equipment (e.g. spreader bars) shall be derived from a rational analysis of the lifting arrangement. General guidance on lifting is given in A.8.3.1.

Dynamic amplification (8.3.2), as well as the effects of fabrication and sling length tolerances (8.3.3), and weight and centre of gravity location inaccuracies (8.2.2), shall be included in such rational analysis.

Additional factors and considerations apply to members adjacent to lifting attachments (8.3.5), and to the lifting attachments themselves (see 8.3.6 and 8.3.7).

Alternative lift criteria can be appropriate, for example when the characteristics of, and interactions between, the transportation barge, structure and crane are fully understood. Alternative criteria may be used, subject to demonstration of an acceptable margin of safety and to the agreement of the owners of the structure, the contractors and any appropriate regulator or warranty surveyor.

8.3.2 Dynamic effects

A dynamic amplification factor (DAF), k_{DAF} , accounting for dynamic effects of the crane taking up the load and for movements of the crane or of the lifted structure, shall be derived from the following.

a) For offshore lifts in air:

1) $k_{DAF} = 1,10$ for heavy lift by semi-submersible crane vessel;

2) $k_{DAF} = 1,30$ in other cases.

- b) For lifts in air, onshore or in sheltered waters:

$$k_{DAF} = 1,10$$

- c) For lifts partially or wholly in water, k_{DAF} shall be specially investigated taking into account factors including

- the lift arrangement,
- the orientation of the lifted structure,
- the ratio of the allowable hook load to the lifted weight (including the effect of any hydrodynamic added mass),
- the drag loads on the lifted structure, and
- the motions of the boom tip in the environmental conditions in which the lift is to be made.

Special investigations may be performed to substantiate a lower DAF value for case a) 2) above; however, k_{DAF} shall not be less than 1,10.

See also ISO 19901-6^[3].

8.3.3 Effect of tolerances

Fabrication misalignments in the structure and sling length variances both affect the distribution of forces in the lifting system. The requirements and partial action factors specified in 8.2.4, 8.3.1 and 8.3.2 apply to situations where fabrication misalignments are consistent with the tolerances specified in Annex G and where the variance on the length of slings does not exceed the greater of 0,25 % of the nominal sling length or 40 mm.

The effect of sling variances in statically indeterminate lift systems (e.g. four slings from four lift points to one hook) shall be taken into account. Sling forces or sling lengths shall be varied in a stiffness analysis of the structure and lifting system so as to determine the redistribution of forces in both slings and structural members. The tolerances in sling length shall be applied to the slings to maximize the sling forces, see A.8.3.3.

The resulting sling force should be increased by a factor of not less than 1,25 (1,15 for floating spreader beams) to determine the required safe working load of the sling in 8.3.8; the local effects on the structure shall be checked using the local factor given in 8.3.5.

8.3.4 Dual lift

For a dual lift from a floating vessel (i.e. a lift operation with two cranes on a single crane vessel), an additional rigging factor should be considered in lieu of assessment of the effects of tilt and yaw on lift forces. Unless special and reliable investigations are performed to substantiate lower values, a minimum value of such a rigging factor of $\gamma_{f,dl} = 1,10$ should be applied. For single crane lifts, $\gamma_{f,dl} = 1,00$.

Where a dual lift is used for uprighting a structure, the most onerous orientations of the structure shall be considered and the design of lifting attachments shall allow for any necessary rotation of the lifting arrangements.

8.3.5 Local factor

Due to the local inaccuracies which often occur in the analysis of internal force distributions around the lifting points, a further local factor ($\gamma_{f,lf}$) shall be applied in order to account for the importance of the structural components involved. This local factor includes the effect of tolerances (see 8.3.3), but shall be applied in addition to the DAF (k_{DAF}) in accordance with 8.3.2 and the rigging factor ($\gamma_{f,dl}$) in accordance with 8.3.4.

The local factor, both for statically determinate and statically indeterminate lifts (where the effect of tolerances on the force distribution is taken into account in the analysis in accordance with 8.3.3), is given below.

- a) For lifting attachments (padeyes, trunnions, padears), spreader beams, and internal members (including both end connections) framing into the joint where the lifting attachment is attached and transmitting lift forces:

$$\gamma_{f,lf} = 1,25 \text{ (for a lift in open waters);}$$

$$\gamma_{f,lf} = 1,15 \text{ (for a lift onshore or in sheltered waters).}$$

- b) For other structural members:

$$\gamma_{f,lf} = 1,00$$

8.3.6 Member and joint strengths

The DAF (k_{DAF}), the rigging factor ($\gamma_{f,dl}$) and the local factor ($\gamma_{f,lf}$) shall be applied to either the factored actions to determine the design action (F_d) as in Equation (8.2-1), giving Equation (8.3-1), or to unfactored actions to give the internal forces (S) as in Equation (8.2-2), giving Equation (8.3-2):

$$F_d = k_{DAF} \gamma_{f,dl} \gamma_{f,lf} (\gamma_{f,GT} G_T + \gamma_{f,QT} Q_T + \gamma_{f,T} T) \quad (8.3-1)$$

$$S = k_{DAF} \gamma_{f,dl} \gamma_{f,lf} \gamma_{f,Sun} S_{un} \quad (8.3-2)$$

where

$\gamma_{f,GT}$, G_T , $\gamma_{f,QT}$, Q_T , $\gamma_{f,T}$, T , $\gamma_{f,Sun}$, S_{un} are as defined in 8.2.4;

k_{DAF} is as specified in 8.3.2;

$\gamma_{f,dl}$ is as specified in 8.3.4;

$\gamma_{f,lf}$ is as specified in 8.3.5.

8.3.7 Lifting attachments

Lifting attachments can be of various forms, including the following.

- a) **Padeyes**, where a shackle pin passes through a hole in a padeye plate attached to or built into the structure, the sling being connected to the shackle. The padeye plate is normally reinforced to increase strength and avoid undue slack between the shackle and the padeye, thereby reducing eccentricity between the padeye plate and the sling.
- b) **Trunnions**, where the sling, or an eye of a sling, passes round a short tubular which transfers the forces into the structure, and which allows rotation of the sling around the axis of the trunnion. Trunnions can be arranged to carry either end of a sling on either side of a central plate.
- c) **Padears**, which are similar to trunnions, but in which rotation of the sling is not intended.

Padeye plates shall be oriented in such a direction that the possibility for out-of-plane loading of the padeye plate and shackle is minimized.

To account for any side loading on lifting attachments, lifting attachments and the connections to the supporting structural members shall be designed for a lateral force of 5 % of the sling force, in addition to the calculated horizontal and vertical components of the sling force (including DAF, rigging factor, local factor and partial action factors) for the equilibrium lifting condition. This lateral force acts simultaneously with the static

sling force and shall be applied perpendicular to the lifting attachment at the centre of the pinhole or tubular. Where a spreader bar is directly connected to the padeyes, a lateral force of 8 % shall be used.

Where two slings are connected to one padeye, or where a sling is doubled over a trunnion, the padeye or trunnion should be designed for a 45:55 % split of the lift point force between the two slings.

8.3.8 Slings, shackles and fittings

For normal offshore conditions, slings should have a total resistance factor of 4,0 on the manufacturer's rated minimum breaking strength of the cable compared to the calculated sling force. The calculated sling force is the maximum force on each sling, as calculated in 8.3.1 to 8.3.4, by taking into account all actions, the equilibrium position of the lift, any dynamic amplification, the effect of tolerances and dual lift considerations. This total resistance factor includes all necessary partial resistance factors. The total resistance factor should be increased when unusually severe conditions are anticipated. Conversely, the total resistance factor may be reduced to a minimum of 3,0 for carefully controlled conditions.

Where two slings are connected to one padeye, or where a sling is doubled over a trunnion, the slings should be assumed to carry the lift point force in a 45:55 % split of the lift point force between the two slings.

Shackles and fittings should be such that the manufacturer's rated working load is greater than or equal to the calculated sling force, provided the manufacturer's specifications include a minimum resistance factor of 3,0 on the minimum breaking strength.

8.4 Actions associated with fabrication

In addition to the associated permanent and variable actions, the effects of wind-induced vortex shedding vibrations on long slender members during fabrication should be considered.

8.5 Actions associated with loadout

8.5.1 Direct lift

Actions on a structure that is lifted onto the transportation barge shall be evaluated in accordance with 8.3. If the lifting arrangement is the same as that used to offload the structure from the transportation barge at sea, it will normally suffice to check the latter load case(s) only. See 8.7.1.

8.5.2 Horizontal movement onto barge

Structures skidded onto transportation barges are subject to actions resulting from horizontal and/or vertical movement of the barge due to tidal fluctuations, nearby marine traffic, environmental conditions and/or changes in draught, as well as to actions derived from the location, slope, and/or settlement of supports onshore and the flexibility of the barge, at all stages of the skidding operation.

The effect of actions on the structure during loadout shall be investigated, taking account of the tolerances on the levels of support on land and on the barge. The effect of pulling/pushing, friction forces and twisting of the structure due to differential horizontal jacking or winching during loadout shall be considered.

In cases of loadout with trailers, the effect of distributed actions imposed by hydraulic trailers and the effect of dynamic actions due to the braking of the trailers should be considered. This can require consideration of the methods of controlling the elevation and alignment of trailers.

Since movement is normally slow, impact does not need to be considered.

8.5.3 Self-floating structures

Self-floating structures are generally not transported on a barge but are towed while floating to the offshore location.

Self-floating structures skidded directly into the water at the fabrication yard shall be analysed to determine the actions on the structures as they move down the slipways and into the floating position. Consideration should be given to local environmental conditions and dynamically induced forces.

This subclause does not apply to self-floating structures built in a dry dock and floated by flooding the dock.

8.6 Actions associated with transportation

8.6.1 General

Actions on a structure or structural part during transportation shall be considered in the design of the structure, whether it is transported on barges or is self-floating. Such actions result from the way in which the structure is supported, either by barge or by buoyancy, and from the response of the towing arrangement (structure, tug boats, tow lines and, where applicable, barge and/or additional buoyancy) to environmental conditions encountered en route to the site.

8.6.2 Environmental conditions

For the selection of environmental conditions to be used in determining the motions of the towing arrangement and the resulting actions on the structure, the sea-fastenings and the barge system, the following should be considered:

- a) previous experience along the tow route;
- b) exposure time and reliability of predicted weather windows;
- c) accessibility of safe havens;
- d) seasonal weather systems;
- e) appropriateness of the recurrence interval used in determining design wind, wave and current conditions in relation to the characteristics of the tow.

8.6.3 Determination of actions

The motions of the towing arrangement due to the environmental conditions determined from 8.6.2 shall be analysed using suitable methods. The motions should be based on the results of model basin tests or appropriate analytical methods. Analytical methods shall use spectral analysis techniques to account for the distribution of wave energy over frequency; when appropriate, the distribution of wave energy over wave directions shall also be considered. Sea states with peak periods corresponding to the natural periods of the loaded barge, as well as peak periods corresponding to wave lengths which are critical in relation to the dimensions of the barge, shall be considered, as these can represent governing conditions. In combining responses, the analysis shall correctly account for relative phasing between motion components (heave, pitch, roll, etc.).

Head, beam and quartering winds and seas should be considered to determine maximum responses due to the environmental actions on the overall system. In cases of large barge-transported structures, the stiffnesses of both the structure and the barge shall be included in the structural analysis.

Actions on the structure, sea-fastenings and the barge system shall be derived from appropriate combinations of permanent, environmental and inertial actions resulting from the state of motion, taking due account of the position, orientation and possible differential deformations of parts of the overall system.

Where circumstances and experience make such simplifications reasonable, tows may be analysed for strength, based on a combination of permanent and inertial actions resulting from the tow's rigid body motions and determined using appropriately selected single period(s) and amplitude(s), and combining

- a) roll with heave, and
- b) pitch with heave.

8.6.4 Other considerations

Large structures overhanging the barge are usually subjected to partial submersion during tow. Submerged members should be investigated for actions due to slamming and buoyancy. These actions should be included in the local and, where relevant, overall design of the structure and the sea-fastenings. Large buoyant overhanging members can also affect motions and this effect should also be considered. The effects of vortex induced vibrations (VIV) due to wind on long slender members also should be investigated.

The effects of repetitive actions during tow can become significant to the fatigue life of certain members, joints or other components, especially for long transoceanic tows. These effects should be investigated using methods and acceptance criteria agreed upon by the owner and the design or transportation contractor.

8.7 Actions associated with installation

8.7.1 Lifted structures

Actions on a structure that is lifted off the transportation barge at sea shall be evaluated in accordance with 8.3.

8.7.2 Launched structures

A structure shall not be launched from a barge if the significant wave height exceeds 2,0 m or if it is expected to exceed 2,0 m before sufficient on-bottom stability is achieved (see 8.7.6).

Barge-launched structures shall be analysed to determine the actions on the structure throughout the launch. Consideration shall be given to hydrostatic pressure (8.7.4), wind and current actions, and the development of dynamically induced actions resulting from the launch.

Horizontal actions required to initiate movement of the structure should also be evaluated. Expected actions on both the structure and the barge during launching should be considered.

8.7.3 Crane assisted uprighting of structures

Where lifting equipment is used to assist in the uprighting of a structure as part of the installation, the structure should be analysed for the permanent and variable actions together with the dynamically induced actions during uprighting. The requirements of 8.3 apply to this situation.

8.7.4 Submergence pressures

Submerged non-flooded, or partially-flooded, components shall be designed to resist pressure-induced stresses during launching and uprighting, in addition to other internal forces acting on the components at the same time.

8.7.5 Member flooding

Consideration shall be given to the effects of unexpected flooding of members or failure of members to flood when intended, either by allowing for such occurrences or by making adequate provisions to prevent such occurrences. Any one failure of the flooding control shall be considered, including common-mode failures such as failure of a valve at a manifold.

8.7.6 Actions on the foundation during installation

8.7.6.1 General

The environmental conditions considered for installation shall be consistent with the limiting environmental conditions in the installation procedure. A more severe environmental condition should also be checked, corresponding to the last stage of installation, when the structure is upright and placed on the sea floor but not yet permanently anchored.

For structures that are to be piled, the actions to be expected from contact with the sea floor during installation of the structure should be assessed to give adequate assurance that the structure will remain at the planned elevation, location and attitude until piles can be installed.

The design shall ensure that

- a) the footings or mudmats have adequate capacity against sliding and bearing failure, and that pin-piles, if any, have adequate strength to avoid being damaged,
- b) the footings, mudmats, or other bearing components and structural members supporting these, have adequate strength to avoid being damaged, and
- c) the safety margins against overturning of the structure are adequate, with the recommendation that the structure be checked in a piled condition but without the permanent action of the topsides if placement of the topsides does not follow shortly after structure installation.

8.7.6.2 Determination of actions

Both vertical and horizontal actions shall be determined, taking into account changes in configuration and exposure, construction equipment and additional ballast that can be required for stability during storms.

8.8 Actions associated with removal

Differences between installation of a new structure and its eventual removal (e.g. the weight of piles and grout within the pile sleeves or structure legs) shall be considered during design to ensure that safe removal is viable. The owner may specify particular removal requirements to be considered during design.

9 Actions for in-place situations

9.1 General

This clause presents actions and combinations of actions and their effects that are to be considered for the in-place situation. It covers the following topics, following the requirements of ISO 19900:

- a) the type of actions to be included;
- b) procedures for determining representative values for the actions;
- c) the partial action factors to be applied;
- d) methods for determining the internal forces due to the effect of factored actions or combinations of factored actions.

Design situations to be considered for the structure in-place can be distinguished between persistent situations and accidental situations, in accordance with ISO 19900. In this clause, only the persistent situations are addressed; accidental situations are addressed in Clause 10.

9.2 Permanent actions (G) and variable actions (Q)

9.2.1 Permanent action 1, G_1

G_1 is the action imposed on the structure by the self weight of the structure with associated equipment and other objects. G_1 includes the following:

- a) weight of the structure in air, including, where appropriate, the weight of piles, grout, and solid ballast;
- b) weight of equipment and other objects permanently mounted on the structure that do not change with the mode of operation;