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Petroleum and natural gas industries — General requirements for offshore structures

Industries du pétrole et du gaz naturel — Exigences générales relatives aux structures en mer

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 7, *Offshore structures*.

This third edition cancels and replaces the second edition (ISO 19900:2013), which has been technically revised. The main changes compared to the previous edition are as follows:

— Terms and definitions have been updated;

— Design/assessment situations are described, and the process for limit state design/assessment verification has been clarified;

— Contents have been reorganized and many clarifications to provisions have been made;

— Annex A has been reorganized to mirror the numbering of the normative clauses and it has been updated with substantial guidance moved from normative clauses.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The International Standards on offshore structures prepared by TC 67/SC 7 (i.e. ISO 19900, the ISO 19901 series, ISO 19902, ISO 19903, ISO 19904-1, the ISO 19905 series, ISO 19906) constitute a common basis addressing design requirements and assessments of all types of offshore structures used by the petroleum and natural gas industries worldwide.

NOTE These are sometimes referred to as the ISO 19900 series on offshore structures.

Through their application, the intention is to achieve adequate structural integrity and performance based on reliability levels appropriate for manned and unmanned offshore structures, whatever the nature or combination of the materials used.

Structural integrity is an overall concept comprising: models for describing actions, structural analyses, design rules, safety elements, workmanship, quality management, and national requirements, all of which are mutually dependent. The modification of any of these elements in isolation can cause an imbalance or inconsistency, with possible impact on the reliability inherent in the offshore structure. The implications involved in modifying one element, therefore, need to be considered in relation to all the elements and the overall reliability of the offshore structure.

The International Standards on offshore structures prepared by TC 67/SC 7 are intended to provide latitude in the choice of structural configurations, materials and techniques and to allow for innovative solutions. Sound engineering judgement is, therefore, necessary in the use of these documents.

Figure 1 gives a general indication of the relationships between the International Standards on offshore structures prepared by TC 67/SC 7.

This document, i.e. ISO 19900, follows the principles of ISO 2394 and is the unifying document for International Standards on offshore structures prepared by TC 67/SC 7, which encompass both specific requirements for offshore structures (the ISO 19901 series) and "structure type" documents (ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3, and ISO 19906).

The ISO 19901 series addresses particular aspects of the design, construction, and operation of offshore structures for the petroleum and natural gas industries. The provisions can be applicable to structures of different types, materials and operating environments.

In addition to the relationships between the "structure type" documents and the ISO 19901 series, there is also some interdependence among the "structure type" documents, in that one can reference another, e.g. ISO 19906 on arctic offshore structures builds upon the requirements of ISO 19902 on fixed steel offshore structures.

In ISO International Standards, the following verbal forms are used:

— "shall" and "shall not" are used to indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted;

— "should" and "should not" are used to indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited;

— "may" is used to indicate a course of action permissible within the limits of the document;

— "can" and "cannot" are used for statements of possibility and capability, whether material, physical or causal.

Additional information and guidance are given in Annex A, where the clause numbering mirrors the normative clauses to facilitate cross referencing.

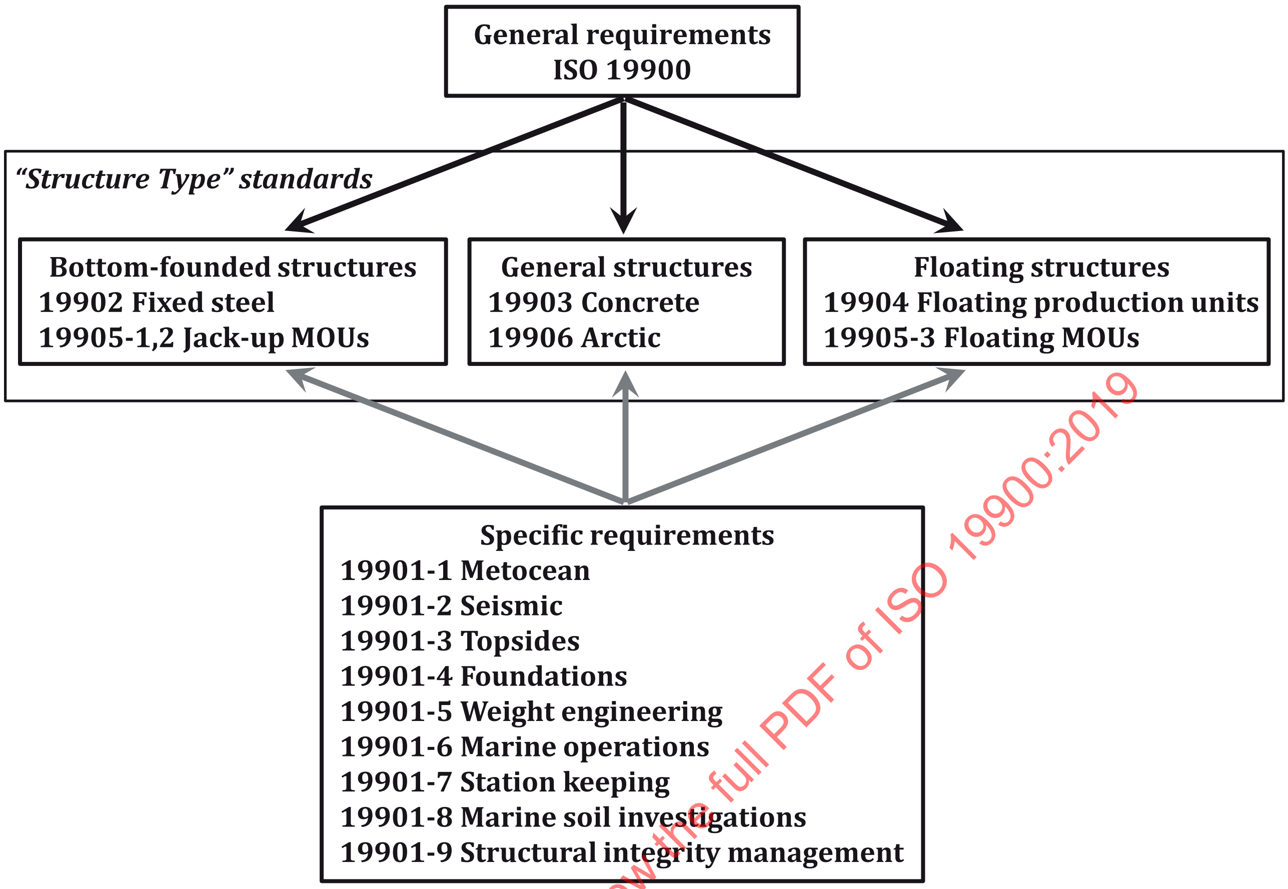


Figure 1 — Relationship of International Standards on offshore structures prepared by TC67/SC7

Petroleum and natural gas industries — General requirements for offshore structures

1 Scope

This document specifies general requirements and recommendations for the design and assessment of bottom-founded (fixed) and buoyant (floating) offshore structures.

This document is applicable for all phases of the life of the structure, including:

— successive stages of construction (i.e. fabrication, transportation, and installation),

— service in-place, both during design life and during any life extensions, and

— decommissioning, and removal.

This document contains general requirements and recommendations for both the design of new build structures and for the structural integrity management and assessment of existing structures.

This document does not apply to subsea and riser systems or pipeline systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 19901-1, *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 19901-3, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 3: Topsides structure*

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

ISO 19901-5, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 5: Weight control during engineering and construction*

ISO 19901-6, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 6: Marine operations*

ISO 19901-7, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units*

ISO 19901-8, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 8: Marine soil investigations*

ISO 19901-9, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 9: Structural integrity management*

ISO 19902, *Petroleum and natural gas industries — Fixed steel offshore structures*

ISO 19903, *Petroleum and natural gas industries — Concrete offshore structures*

ISO 19904-1, *Petroleum and natural gas industries — Floating offshore structures — Part 1: Monohulls, semisubmersibles and spars*

ISO 19905-1, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 1: Jack-ups*

ISO 19905-3, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 3: Floating unit*

ISO 19906, *Petroleum and natural gas industries — Arctic offshore structures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
abnormal environmental event
environmental *hazardous event* (3.27) having probability of occurrence not greater than 10^{-3} per annum (1 in 1 000 years)

3.2
accidental event
non-environmental *hazardous event* (3.27) having probability of occurrence not greater than 10^{-3} per annum (1 in 1 000 years)

Note 1 to entry: Accidental events, as referred to in this document, are associated with a substantial release of energy, such as vessel collisions, fires, and explosions.

Note 2 to entry: Lesser accidents that could be expected during the life of the structure, such as dropped objects and low energy vessel impact, are termed incidents and are addressed under operational design situations.

3.3
action
external load applied to the *structure* (3.53) (direct action) or an imposed deformation or acceleration (indirect action)

EXAMPLE An imposed deformation can be caused by fabrication tolerances, differential settlement, temperature change or moisture variation. An imposed acceleration can be caused by an earthquake.

3.4
action effect
result of *actions* (3.3) on a *structural component* (3.49) (e.g. internal force, moment, stress, strain) or on the *structure* (3.53) (e.g. deflection, rotation)

3.5
air gap
distance between the highest water elevation and the lowest exposed part of the primary deck *structure* (3.53) not designed to withstand associated environmental *action effects* (3.4) for a defined *return period* (3.42)

Note 1 to entry: This definition can be refined for different platform types in their respective standards.

3.6
appurtenance
accessory or attachment to the *structure* (3.53) which typically assists installation, provides access or protection, or carries fluids or gas

Note 1 to entry: Appurtenances do not normally contribute to the stiffness of the structure but can attract significant hydrodynamic loading.

EXAMPLE Riser, caisson, boat landing, fender, and protection frames.

3.7
basic variable
variable representing physical quantities which characterize *actions* (3.3) and environmental influences, geometric quantities, or material properties including soil properties

Note 1 to entry: Basic variables are typically uncertain random variables or random processes used in the calculation or assessment of representative values of actions or resistance.

3.8
calibration
process used to determine and optimize partial factors using *structural reliability analysis* (3.52) and target reliabilities

3.9
characteristic value
value assigned to a *basic variable* (3.7) with a prescribed probability

Note 1 to entry: In some design/assessment situations, a variable can have two characteristic values, an upper value and a lower value.

3.10
conductor
tubular pipe set into the ground to provide the initial stable structural foundation for setting the surface casing and protecting the internal well string from metocean actions

Note 1 to entry: The conductor provides lateral and, in some cases, axial support, enables circulation of drilling fluid, and guides the drill string to facilitate setting of the surface casing.

3.11
decommissioning
process of shutting down a *platform* (3.37) enabling preparations for cleaning, dismantling and/or removal from location at the end of *total service life* (3.18)

3.12
design resistance
resistance limit calculated using factored *representative values* (3.40) of *basic variables* (3.7) or from factored expressions based on unfactored *representative values* (3.40) of *basic variables* (3.7)

EXAMPLE Examples of basic variables relevant to resistance are material properties.

3.13
design service life
planned period for which a *structure* (3.53) is used for its intended purpose with anticipated maintenance, but without substantial repair being necessary

3.14
design value
value derived from the *representative value* (3.40) for use in *limit state verification* (3.32)

Note 1 to entry: Design values can be different in different design/assessment situations due to different partial factors.

3.15
design/assessment criteria
quantitative formulations describing the conditions to be fulfilled for each *design/assessment situation* (3.16)

3.16
design/assessment situation
set of physical conditions for which the *structure* (3.53) or its components are verified

3.17
deterioration
process that adversely affects *structural integrity* (3.50) over time

Note 1 to entry: Deterioration can be caused by naturally occurring chemical, physical, or biological actions including corrosion, by severe environmental actions, by incidents and accidental actions, by repeated actions such as those causing fatigue, by wear due to use, and by improper operation and maintenance of the structure.

3.18
total service life
design service life (3.13) plus any subsequent operational life extension period(s)

3.19
durability
ability of a *structure* (3.53) or *structural component* (3.49) to maintain its function throughout its *total service life* (3.18)

3.20
exposure level
classification system used to establish relevant criteria for a *structure* (3.53) based on consequences of failure

3.21
extreme environmental event
environmental *hazardous event* (3.27) typically having probability of occurrence of 10^{-2} per annum (1 in 100 years)

3.22
fit-for-service
fulfilling defined *structural integrity* (3.50) and *performance* (3.36) requirements

Note 1 to entry: A structure not meeting all the specific provisions can be fit-for-service, provided it does not cause unacceptable risk to life-safety or the environment.

3.23
fitness-for-service assessment
engineering evaluations to demonstrate that a *structure* (3.53) or a *structural component* (3.49) which deviates from its design basis, is *fit-for-service* (3.22)

Note 1 to entry: Deviations can include deterioration or damage, life extension, and other changes and modifications to the structure or to the design basis.

3.24
fixed structure
structure (3.53) that is bottom founded and transfers most of the *actions* (3.3) on it to the *seabed* (3.47)

3.25
floating structure
structure (3.53) where the full weight is supported by buoyancy

3.26
hazard
potential source of harm

Note 1 to entry: Harm is typically differentiated between harm to people, harm to the environment, or harm in terms of costs to organization(s) or society in general.

3.27
hazardous event
event which occurs when a *hazard* (3.26) interacts with a *structure* (3.53)

EXAMPLE Wave impacting the structure, iceberg impacting the structure, excessive topside weight added to the structure, vessel collision, fire, explosion, and landslip in the vicinity of structural anchors (piles).

3.28
ice gouge
ice scour
incision in the *seabed* (3.47) or removal of seabed material by an ice feature

3.29
incident
non-environmental *hazardous event* (3.27) considered in an operational *design/assessment situation* (3.16)

Note 1 to entry: Incident, as referred to in this document, is a lesser accidental event, associated with possible local damage or damage to structural components, occurring with low probability, most typically associated with probabilities not less than 10^{-2} per annum (1 in 100 years).

3.30
jack-up
mobile offshore unit with a buoyant hull and one or more legs that can be moved up and down relative to the hull

Note 1 to entry: A jack-up reaches its operational mode by lowering the leg(s) to the seabed 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 in the seabed by spudcans.

3.31
limit state
state beyond which the *structure* (3.53) or *structural component* (3.49) no longer satisfies the *design/assessment criteria* (3.15)

3.32
limit state verification
demonstration that the total design *action effect* (3.4) in each *design/assessment situation* (3.16) does not exceed the *limit state* (3.31) *design resistance* (3.12)

3.33
nominal value
value assigned to a variable specified or determined on a non-statistical basis, typically from acquired experience or physical conditions, or as published in a recognized code or standard

Note 1 to entry: In some design/assessment situations, a variable can have two nominal values, an upper value and a lower value.

3.34
offshore
situated in water some distance from the shore

Note 1 to entry: Alternatively, near shore can be used to specify locations next to the coast or in mouths of rivers.

3.35
operator
representative of the company or companies leasing the site

Note 1 to entry: The operator is normally the oil company acting on behalf of co-licensees.

Note 2 to entry: The operator can be termed the owner or the duty holder.

3.36
performance
ability of a *structure* (3.53) or a *structural component* (3.49) to fulfil specified requirements

Note 1 to entry: Specified requirements include requirements for structural integrity and functionality.

3.37
platform
complete assembly of structural and non-structural systems for the purpose of development and production of petroleum and natural gas fields

Note 1 to entry: The platform includes the structure and non-structural systems such as topsides equipment, piping and accommodation.

Note 2 to entry: The platform includes the structural conductors and risers but does not include the non-structural components of the hydrocarbon wells.

Note 3 to entry: The platform does not include the geological strata supporting the foundation. However, site-specific geotechnical parameters provide the boundary conditions necessary to model the platform's foundation or anchoring.

3.38
reference period
period of time used as a basis for determining the *representative value* (3.40) of operational, environmental, accidental and/or repetitive actions

3.39
reliability
performance (3.36) over a specified period of time

Note 1 to entry: When reliability is used in the context of limit states, it can be expressed as the probability that the limit is not exceeded.

Note 2 to entry: The specified period of time is typically one year.

3.40
representative value
value assigned to a *basic variable* (3.7) for verification of a *limit state* (3.31) in a *design/assessment situation* (3.16)

Note 1 to entry: Two types of representative value used in design verification are characteristic value and nominal value.

3.41
resistance
ability of a *structure* (3.53), or a *structural component* (3.49), to withstand *action effects* (3.4)

3.42
return period
average time between occurrences of an event

Note 1 to entry: The offshore industry commonly uses a return period measured in years for environmental events. The return period in years is equal to the reciprocal of the annual probability of occurrence of the event.

Note 2 to entry: For the purpose of this definition, events include both discrete hazardous events as well as exceedances of a threshold value of a relevant variable.

3.43
riser
part of an offshore pipeline, including any subsea spool pieces, which extends from the *sea floor* (3.46) to the pipeline termination point on a *platform* (3.37)

Note 1 to entry: For fixed structures, the termination point is usually the topsides.

Note 2 to entry: For floating structures, the riser can terminate at other locations on the platform.

3.44
robustness
ability of a *structure* (3.53) to withstand *hazardous events* (3.27) without being damaged to an extent disproportionate to the cause

3.45
scour
removal of *seabed* (3.47) material caused by currents and/or waves

3.46
sea floor
interface between sea and *seabed* (3.47)

3.47
seabed
materials below the *sea floor* (3.46)

3.48
splash zone
part of a *structure* (3.53) that is intermittently exposed to air and immersed in the sea

3.49
structural component
discrete part of a *structure* (3.53)

Note 1 to entry: For this document, a component can include an assembly of components, e.g. a subsystem.

EXAMPLE Examples of components include columns, beams, stiffened plates, tubular members and joints, mooring lines and tendons, gravel fill, foundation anchors and piles, but not the geological strata.

3.50
structural integrity
ability of a *structure* (3.53) or a *structural component* (3.49) to maintain *performance* (3.36) throughout the *total service life* (3.18), with respect to structural safety, *robustness* (3.44), serviceability, and *durability* (3.19)

3.51
structural integrity management
SIM
systematic multi-step cyclic process intended to assure *structural integrity* (3.50) and functionality of a *structure* (3.53) throughout its *total service life* (3.18)

Note 1 to entry: Typical steps include data collection, data evaluation, development of an inspection strategy, development and execution of an inspection programme, and consequent remedial works.

3.52
structural reliability analysis
probabilistic methodology for determining *limit state* (3.31) failure probabilities

3.53
structure
combination of physically connected *structural components* (3.49)

3.54
topsides
structure (3.53) and equipment placed on a supporting structure [fixed or floating] to provide some or all of a *platform's* (3.37) functions

Note 1 to entry: For a ship-shaped floating structure, the deck is not part of the topsides.

Note 2 to entry: For a jack-up, the hull is not part of the topsides.

Note 3 to entry: A separate fabricated deck or module support frame is part of the topsides.

3.55
ductility
<material> ability of a material to deform and absorb energy beyond its elastic limit

3.56
ductility
<structural component> ability of a *structural component* (3.49) to sustain *action effects* (3.4) beyond yield

3.57
ductility
<structural system> ability of a structural system to deform and dissipate energy, and to redistribute *action effects* (3.4)

4 Symbols and abbreviated terms

4.1 Symbols

A	accidental action
a_d	design value of geometric variable
a_k	characteristic value of geometric variable
a_r	representative value of geometric variable
E	environmental action
F_d	design action
F_r	representative value of an action
f_d	design value of material property (for example strength)
f_r	representative value of material property (for example yield strength)
G	permanent action
L1, L2, L3	exposure levels of structures
P	annual probability of occurrence or probability of exceedance
p_f	probability of failure
Q	operational action

Q_1 operational action of long duration

Q_2 operational action of short duration

R reliability of a structural system

R_d design value of resistance

R_k characteristic value of resistance, or value based on characteristic values of material properties

R_r representative value of resistance

S_d total design action effect

T annual return period of an event or an action

γ_f partial action factor the value of which reflects the uncertainty or randomness of the action

γ_m partial material factor the value of which reflects the uncertainty or variability of the material property

γ_R partial resistance factor the value of which reflects the uncertainty or variability of the component resistance including those of material properties

Δa additive partial geometric quantity the value of which reflects the uncertainties of the geometric variable

4.2 Abbreviated terms

ALS abnormal/accidental limit state

FLS fatigue limit state

IMO International Maritime Organization

QA quality assurance

QC quality control

SLS serviceability limit state

ULS ultimate limit state

5 Fundamental requirements

5.1 General

Offshore structures shall be planned, designed, constructed, operated, and assessed in such a way that they perform with adequate structural integrity (see 5.2), and meet all functional requirements (see 5.3), for all phases of their life (see 5.4).

Requirements set by regional, national, and local regulations and standards can be different from those given in this document. While such requirements take precedence, conformance to this document can be claimed only if the requirements of this document are also met.

NOTE Requirements for personnel safety set by flag states and coastal state authorities can have a substantial effect on the design of a floating structure.

5.2 Structural integrity requirements

Structural integrity is achieved by the following:

— conformance to this document;

— verification of structural reliability using the limit state approach, see 8.1;

— quality management during constructional phases of an offshore project;

— structural integrity management in service;

— operational procedures aligned with the design and assessment assumptions.

To protect safety of life, prevent damage to the environment, and protect against financial or societal loss, a structure and its structural components shall have adequate structural integrity to

a) withstand actions arising from hazardous events and other sources of actions during their construction and service in-place,

b) perform adequately under all design/assessment situations, including serviceability, expected during the total service life,

c) not fail under repeated actions (fatigue) or deterioration mechanisms (e.g. corrosion, wear), and

d) provide an appropriate level of robustness (see 5.5.2) against damage and failure, taking due account of

  — the cause and mode of damage or failure, and

  — the possible consequences of damage or failure in terms of risk to life, environment and property.

The integrity of a structure and its components is described in terms of adequate reliability associated with a specified set of limit states. Adequate reliability is realized by conforming to the limit state verification requirements in Clause 8, and to the appropriate structure type standard (ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3, and ISO 19906).

5.3 Functional requirements

The functions of an offshore platform can include drilling, producing, processing, storage, offloading, personnel accommodation, or another function or combination of functions in support of the petroleum and natural gas industries.

The platform's (including the structure's) functional requirements and design service life shall be specified by the operator.

Functional requirements for control and mitigation of fires and explosions should be specified according to ISO 13702[3]. The selection of a suitable approach and mitigating measures including safety systems can depend upon the function of the platform.

All functional and operational requirements including site-specific marine biological, physical environmental, and geotechnical conditions affecting the layout and design of the structure shall be established and documented.

All functional and operational requirements in temporary and in-service phases, as well as robustness against accidental events that can influence the layout and the structural design, shall be established and documented.

NOTE Functional requirements for floating structures also include maritime functions.

5.4 Requirements for specific phases of the life of the structure

5.4.1 Planning

For new build structures, planning shall be completed before design is started to obtain a safe, workable, and economical offshore structure. Planning can be associated with conceptual field development, or in a broad concept development phase.

For existing structures, planning shall be completed to obtain data and models which represent the structure's current conditions before the structure is assessed to be fit-for-service for its remaining service life including any life extension.

Relevant and related sustainability aspects impacting the environment, the economy and society, along with their interdependence and interrelationships, should be considered.

Structure related requirements should be established in association with functional requirements associated with non-structure related disciplines. In some cases, significant modifications are required to the planned structural configuration to meet functional requirements and to mitigate risks in non-structural disciplines.

5.4.2 Construction and deployment

Consideration shall be given to all activities and operations required for construction including, where appropriate, fabrication, load-out, transportation, installation and securing in place of the structure, and hook-up of subsea equipment and facilities.

Design requirements shall be established accounting for the following:

a) the type of structure and its location;

b) the environmental conditions including seasonality;

c) the construction equipment;

d) the nature and duration of the construction operations.

Planning, engineering and safe execution of marine operations for all types of offshore structures within the scope of this document shall be in accordance with ISO 19901-6.

NOTE Marine operations for marine site investigations, mobile jack-ups, pipe-laying barges, and diving support vessels are outside the scope of ISO 19901-6.

5.4.3 Structural integrity management

A system for structural integrity management shall be developed during the design phase and maintained throughout the total service life of the structure in accordance with Clause 13 and with the appropriate document for the actual structure type (i.e. ISO 19901-9, ISO 19902, ISO 19903, ISO 19904-1 or ISO 19905-1).

5.4.4 Decommissioning and removal

Consideration shall be given at the design stage to decommissioning and possible removal of the structure or parts of the structure at the end of its design service life.

Decommissioning shall be conducted in accordance with the operator's specifications and can be subject to local and international legislation and IMO rules.

5.5 Requirements for durability and robustness

5.5.1 Durability, maintenance and inspection

The durability of the structure shall be achieved by adequate design and assessment, inspection, monitoring, maintenance and repair. Effects of corrosion, loss of material by abrasion, and other forms of deterioration that can affect the resistance of the structure or structural components shall be taken into account.

NOTE 1 Deterioration can also be caused by operational incidents such as dropped objects and spillage of corrosive or refrigerated fluids.

Durability of the structure and structural components shall be achieved by

a) an inspection and maintenance programme,

b) designing the structure so as to allow for deterioration in those areas that cannot be, or are not expected to be, maintained during the design service life of the structure, or

c) a combination of a) and b).

NOTE 2 Structural integrity, serviceability, and durability throughout the design service life are not simply the outcome of the design calculations, but are also dependent on the quality of materials, the quality management exercised in construction, the supervision on site and the manner in which the structure is installed, used and maintained.

NOTE 3 The rate of deterioration can be estimated on the basis of calculations, experimental investigations, experience from other structures, or a combination of these. Deterioration can be reduced or prevented by providing suitable protection systems.

An inspection and maintenance programme shall be consistent with the design and use of the structure, the environmental conditions to which it is exposed, and the consequent rate of deterioration.

The structure or structural components shall be designed and constructed so that deterioration remains below defined thresholds within the time intervals between inspections. The design shall allow easy access to relevant parts of the structure for inspection without unnecessary or unreasonably complicated dismantling.

The planning and the execution of inspection should include scheduled baseline inspection, periodic inspections, special inspections, and unscheduled inspections (e.g. after a hazardous event such as an earthquake or other severe environmental or accidental event).

In the event of deterioration or damage to protection systems or to structural components, maintenance shall include upgrading of the affected protection systems or repair of the affected structural components.

5.5.2 Robustness

A structure shall incorporate robustness so that damage arising from a hazardous event is not disproportionate to the cause.

Robustness shall be realized by

a) ensuring (by design or by protective measures) that no critical part of the structure exposed to a hazardous event can suffer complete loss of integrity,

b) providing alternate load-carrying paths (structural redundancy) in such a way that any single structural component exposed to a hazardous event can fail without complete loss of integrity of the structure or a critical part of the structure,

c) providing sufficient residual resistance after relevant damage conditions associated with certain abnormal and accidental design/assessment situations, see 7.4.4 and 7.4.5, or

d) a combination of a), b) and c).

Structures in a floating state shall be designed/assessed to have adequate stability in all associated design/assessment situations in both the intact and damaged conditions, during construction, transportation, installation, service in place, decommissioning and removal phases.

Structures in a floating state for which buoyancy is important should be subdivided into compartments to limit the consequences of unintended flooding. The configuration of compartments should be determined after considering protection measures (including operation of those measures) that can be used to prevent flooding.

Stationary floating structures (temporarily located mobile offshore units or permanently located floating structures) shall incorporate sufficient damaged stability and reserve of buoyancy so that design/assessment situations involving unintended flooding do not result in complete loss of the structure.

Robustness requirements for permanently located floating structures shall be in accordance with those of ISO 19904-1. Site-specific robustness requirements for temporarily moored mobile offshore units shall be in accordance with those of 19905-3.

NOTE General robustness requirements for temporarily moored mobile offshore units are based on IMO rules.

The stationkeeping systems of floating structures shall incorporate sufficient robustness so that the structure can withstand the loss of at least one stationkeeping component (such as a mooring line, a thruster, or a fairlead) in accordance with the provisions of ISO 19901-7.

6 Basis for design/assessment

6.1 General

The basis for design/assessment for the structure shall include all relevant hazardous events (see 7.2) and functional requirements (see 5.3), described in terms of their associated design/assessment situations (see 7.4) for all the phases of the life of the structure (see 5.4), including design/assessment situations arising during construction, fabrication, transportation, installation, and decommissioning of the structure.

Equipment and material layouts shall be specified and associated weights and centres of gravity shall be determined. Exposure of such equipment and material to hazardous events, such as those due to the environment or accidents, shall be taken into account.

The conditions and requirements identified in 6.2 to 6.5 shall also be included in the basis for design/assessment.

Structures and structural components shall be configured and designed/assessed so that accelerations, velocities and displacements do not impair the safety and health of personnel, and the serviceability of processes and equipment.

6.2 Platform location and orientation

The site location, structure position and orientation with respect to true north, and the tolerances on position and orientation shall be specified.

The position and orientation of the structure and its ancillary systems (such as piles, mooring lines, anchors, conductor pipes, risers, offloading systems, tendons, berms, movable protection barriers, temporary refuges, and evacuation systems) should take account of the following:

— the reservoir geometry;

— construction requirements (including access for drilling and/or construction vessels, their stationkeeping systems and their support spread);

— the physical environment (including prevailing wind, wave and ice drift directions);

— other platforms and infrastructure in the vicinity (such as subsea wells, manifolds, flowlines, and pipelines);

— accessibility by ships and helicopters.

6.3 Physical environmental conditions

The physical environmental conditions applicable at the region or location shall be specified.

Metocean conditions shall be established in accordance with ISO 19901-1. Tidal, wind driven, pressure driven, global circulation, loop and eddy currents, and the occurrence of fluid motion caused by internal waves should be considered, if relevant. Waves and currents of seismic origin (tsunamis) shall also be included in accordance with ISO 19901-1, in association with ISO 19901-2. For floating structures, the effects of pressure waves generated by seismic events should be considered.

Ice conditions involving sea ice and icebergs shall be established in accordance with ISO 19906.

Metocean and ice variables should utilize data from site measurements or from applicable hindcast models.

The water depth shall be determined along with an estimate of possible changes in water depth throughout the design service life, including potential seabed subsidence.

Due to climate change or for other reasons, changes in the frequency and magnitude of environmental events such as waves, ice, ocean circulation, and water level changes can occur during the design service life of the structure. The potential progression of these changes during the design service life of the structure should be considered.

Site-specific information on seismotectonic and site characterizations, including fault locations, ground motions, and the history of previous seismic events, shall be established in accordance with ISO 19901-2. Hazardous events associated with seabed material displaced by the platform and other structures in the vicinity should also be assessed.

Environmental conditions derived in accordance with the above, shall be expressed by physical characteristics and, where available, by statistics of basic variables. Any periodicity shall be defined. The joint occurrence of different basic variables may also be defined if suitable data are available.

Environmental actions acting on a structure shall be established for both global and local design/assessment.

The characteristics of marine growth and the associated basic variables shall be established in accordance with the requirements of ISO 19901-1 and the relevant structure type standards (ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3 and ISO 19906). When the design/assessment relies on periodic marine growth cleaning or anti-fouling systems such reliance shall be documented, and the cleaning programme established over the life of the structure, including potential life extension.

NOTE Although biological growth can retard corrosion, corrosive metabolites from bacteria can cause an alternative corrosion mechanism, especially for components in the seabed.

6.4 Geotechnical and geophysical conditions

6.4.1 Marine site investigations

Marine site investigations shall be performed at the structure's proposed location in accordance with ISO 19901-8 and ISO 19901-4.

The investigations shall be to adequate depth and areal extent in order to

— establish the various soil strata,

— identify potential hazards to the structure and its operation, such as the presence of shallow gas, UXO (unexploded ordnance), etc., and

— characterize and quantify the physical and engineering properties throughout the zone of influence of the structure's foundation.

Marine geophysical investigation should be performed in advance of marine soil investigation programmes and be used to help establish such programmes (borehole logging, *in situ* testing and soil sampling for laboratory testing). The number of geotechnical boreholes and their depth can depend on the lateral soil variability of the site, the structure configuration and the expected actions. The data obtained should be considered in combination with an evaluation of the shallow geology of the region.

Previous soil investigations and experience at the site can be used to adapt the number and extent of investigations or studies required.

NOTE The assessment of the shallow gas hazard can sometimes be done on the basis of 3D seismic data, especially at deep water sites.

6.4.2 Seabed instability

The nature, magnitude and the probabilities of occurrence (return periods) of potential seabed movements shall be evaluated by one of the following:

a) site investigations and analyses in accordance with ISO 19901-2, ISO 19901-4 and ISO 19901-8;

b) model testing;

c) a combination of a) and b).

The scope of marine site investigations in areas of potential seabed instability shall focus on:

— identification of metastable geological features at and around the site;

— characterization and quantification of the soil properties required for modelling and estimating seabed movement.

Seabed behaviour and its influence on the overall integrity of the structure and foundation shall be documented. Information should include such items as relict permafrost in cold regions, the potential for subsidence and slides, and active processes such as mud volcanoes and gas escape features.

NOTE In most offshore areas, geological processes associated with movement of the near surface sediments can occur within the design service life.

6.4.3 Seabed disturbance

The possibility of disturbance to the seabed arising from scour and, in arctic and cold regions, ice gouge, shall be accounted for in the design.

The extent of scour should be determined in accordance with ISO 19901-4 from one or more of the following:

— previous records from sites with similar seabed features;

— model tests;

— calculations calibrated by prototype or model tests.

The extent of ice gouges shall be determined in accordance with ISO 19906.

6.5 Specific design/assessment requirements

6.5.1 Topsides structures

Topsides structures shall be designed/assessed in accordance with ISO 19901-3.

Winterization of topsides shall be in accordance with ISO 19906.

While layout and arrangement of the topsides is outside the scope of this document, measures should be considered that reduce risks that can affect the structure or structural components.

Specific recommendations include the following:

a) personnel accommodation should not be located directly above or below produced oil, gas storage tanks, or process vessels;

b) personnel accommodation should not be located above or below surface trees and wellheads, and above or below the risers;

c) personnel accommodation should be positioned as far as possible from the process facilities and from the flare;

d) process vessels, hydrocarbon storage tanks, or other items which could become a source of fuel in the event of a fire should be located as far as possible, or otherwise protected, from wellheads and potential ignition sources;

e) arrangements and layout of the facilities should account for prevailing waves and winds;

f) arrangements and layout of the facilities, accommodations, control rooms, and lifesaving appliances should be such that a fire in a process area, hydrocarbon storage area, wellhead area, or other classified areas does not prevent or impede the safe exit of personnel from the accommodation and temporary refuges along designated escape routes to boat landings or life boat locations.

6.5.2 Deck elevation

Topsides structures shall have clearance margins above wave and/or ice conditions. Where it is impractical to provide clearance margins, topsides structural component, piping or other elements may be designed/assessed for actions caused by immersion/impact.

EXAMPLE Vertical water jets due to wave impacts.

Particular attention shall be paid to accommodation, temporary refuges, escape routes, evacuation equipment, and equipment containing hydrocarbons.

The deck elevation and air gap shall be determined for a range of hazardous events (typically including operational, extreme and abnormal occurrences), taking into account the values and uncertainties of the site-specific basic variables, as applicable, including the following:

a) water depth;

b) tides and surges;

c) crest elevation of waves;

NOTE Wave crest elevations are usually determined on the basis of point estimates of wave heights. For a typical topsides structure, wave height statistical variability can result in wave heights up to 15 % higher (see ISO 19901-1:2015 A.8.7). However, from a structural design perspective, these wave heights generate only local (as distinct from global) loading.

d) wave-structure interaction;

e) sail height and shape of ice features, such as icebergs;

f) iceberg contact, ice build-up, ride-up, or run-up;

g) motion of floating structures at operational and survival draught (e.g. the setdown associated with floating structures);

h) initial and long-term settlements and inclination;

i) subsidence.

6.5.3 Splash zone

The extent of the splash zone and the drainage of splashed water shall be established accounting for: deck elevation, motions of floating structures, tidal ranges, platform subsidence, wave crests, and wave troughs.

For floating structures with draught adjustment, the splash zone shall be defined relative to the maximum and minimum draught expected.

NOTE The splash zone is important in relation to inspection and maintenance considerations and can have an impact on design for corrosion and fatigue, and the extent of marine growth.

6.5.4 Stationkeeping systems

Floating structures shall have a stationkeeping system in accordance with ISO 19901-7.

The stationkeeping system shall be designed/assessed to maintain position and directional control within specified tolerances. The tolerances are typically based on operational limits, including the motion limits for the risers, the strength and fatigue limits of the moorings and risers, and limits for safe operation of the floating structure and equipment thereon.

A mooring system for floating structures may be designed/assessed to be disconnectable to avoid or mitigate the potential effects of severe storms or other hazardous events. If designed to be disconnectable, all other connected systems such as risers and umbilicals shall also be designed/assessed for safe disconnection and reconnection. Disconnection and reconnection shall be designed/assessed to be accomplished in a controlled manner, without the following:

a) impairing the safety of personnel on board the platform or a neighbouring infrastructure;

b) causing drift off with possible impact to neighbouring infrastructure;

c) creating undue harm to the environment.

6.5.5 Conductor and riser systems

The number, location, size, spacing, and operating conditions of all conductors and risers shall be established prior to structural design. Where applicable, accessibility for jack-up operations should be considered. This can influence overall field layout, winching arrangements for lead lines for interfacing, and overall structural clearances.

Priorities for layout and configuration should be to protect the conductors and risers from damage due to accidental and hazardous events. An alternative approach may be to mitigate the adverse consequences of such potential damage.

6.5.6 Foundations and anchoring

Foundation requirements for steel jacket structures shall be in accordance with ISO 19901-4 and ISO 19902.

Foundation requirements for bottom founded concrete structures shall be in accordance with ISO 19901-4 and ISO 19903.

Foundation requirements for jack-up structures shall be in accordance with ISO 19901-4 and ISO 19905-1.

Foundation and anchoring for floating structures shall be in accordance with ISO 19901-4 and ISO 19901-7. Supplementary foundation requirements are provided in ISO 19904-1 for permanently located floating structures and in ISO 19905-3 for temporarily located mobile offshore units.

Supplementary foundation requirements for offshore structures in arctic and cold regions are provided in ISO 19906.

6.5.7 Additional operational requirements

Further to 5.3, and in addition to the operation of the platform with its facilities and equipment, requirements shall be established for the following:

a) types, sizes and weights of helicopters;

b) types, sizes and displacements of supply and other service vessels and mobile units;

c) number, types, sizes and locations of the deck cranes, laydown areas and other materials handling systems;

d) planned personnel escape, evacuation, and rescue, in accordance with emergency response plans, see ISO 15544[14].

7 Development of design/assessment situations

7.1 Hazards

All hazards relevant to structural reliability that are reasonably foreseeable during all phases of the life of the structure, including decommissioning, shall be identified and evaluated (see A.7.1 for further guidance).

7.2 Hazardous events

All hazardous events which can arise from the identified hazards shall be characterized and evaluated. This is essential for determining design/assessment situations which form the basis of the design/assessment verification procedure (see 8.4).

Characterization of hazardous events can be performed as part of a formal risk assessment, which is a procedure for identifying hazards, quantifying the associated risks and determining approaches for the mitigation of their consequences.

Hazardous events can be divided into the following groups based on the nature of the event and an associated probability of occurrence or return period:

a) low probability operational events, including unexpected or unintended incidents likely to occur during the service life;

b) extreme environmental events, most typically with a probability of occurring or being exceeded of the order of 10^{-2} per annum (return periods of the order of 100 years);

c) abnormal environmental events, typically with a probability of occurring or being exceeded of the order of 10^{-3} to 10^{-4} per annum (return periods of the order of 1 000 to 10 000 years);

d) accidental events, typically with a probability of occurring or being exceeded of the order of 10^{-3} to 10^{-4} per annum (return periods of the order of 1 000 to 10 000 years).

If data for low probabilities of occurrence are not adequate for a precise determination, the above probabilities (return periods) should be considered when making judgements for what magnitudes of hazardous events to include when establishing design/assessment situations (see 7.4) for limit state verification.

Very unlikely hazardous events, with a probability of occurrence less than 10^{-4} per annum (return periods in excess of 10 000 years) do not require a design/assessment situation to be established. Identifying such events can however enable operational measures to be used to further mitigate life safety and other risks in accordance with the operator's risk management policy.

When deciding on which events require verification of the structural design/assessment, and which can be managed by operational measures alone, the uncertainties associated with low probability events shall be taken into account.

If hazardous events arising from a particular hazard have a range of magnitudes and probabilities, or fall in more than one of the above groups, a hazard curve can be developed to describe the variation (see A.7.2).

Strategies and specific measures should be considered both to prevent the occurrence of hazardous events and to counter or mitigate the possible consequences of hazardous events, such as the following:

a) planning for hazards relevant to each phase of development and operation;

b) mitigating the structural effects of the hazardous events by measures such as:

   — eliminating the hazard,

   — preventing the hazardous event, e.g. by avoidance,

   — provision of passive protection such as a physical barrier between hazard and structure, or

   — by active management of the hazard.

c) providing robustness (see 5.5.2);

d) containing the consequences;

e) designing the structure to withstand actions in the corresponding design/assessment situation.

7.3 Exposure levels

7.3.1 General

Exposure levels shall be specified prior to design/assessment. They may be revised during the life of a structure to account for changes in its function, location, or consequence mitigation measures.

Structures shall be classified by exposure level L1 (7.3.2), L2 (7.3.3) or L3 (7.3.4) for in-place conditions, based on

a) life-safety of personnel on, or near to, the platform, and

b) damage to the environment.

Structures may be classified to a more onerous exposure level based on cost-benefit assessment of economic losses to the operator, and other stakeholders, including society in general.

Structures may be classified using different exposure levels for different design/assessment situations.

EXAMPLE A structure can be classified to the most onerous exposure level, L1 (7.3.2), on the expectation of being manned during collision, seismic, winter storm, sudden hurricane and sea ice events, but the second exposure level, L2 (7.3.3), during iceberg impact and seasonal hurricane events, provided personnel can be evacuated or a floating structure removed from such hazardous events.

Different exposure levels may be assigned to different parts of the structure as permitted in structure type documents.

The exposure level for a structure that is, or will be, located adjacent to existing or planned facilities, shall account for their possible harmful interaction during a hazardous event.

NOTE Adjacent facilities include workover platforms, local platforms, transport lines, and subsea structures. Harmful interaction includes structure collapse or drift from location.

7.3.2 Exposure level L1

A structure shall be classified to the most onerous exposure level, L1, for all design/assessment situations, unless it is demonstrated that the requirements for a less stringent exposure level are met.

EXAMPLE Manned, non-evacuated structures and high environmental consequence platforms.

A structure may be classified as exposure level L2 (7.3.3) or L3 (7.3.4) in a design/assessment situation if

a) potential life-safety consequences have been mitigated, and

b) potential environmental pollution consequences have been mitigated.

7.3.3 Exposure level L2

A structure may be classified as exposure level L2 in a hazardous event if all of the following apply:

a) plans are documented to validate that the platform can be safely evacuated prior to the specified hazardous event, including consideration of reliability of forecast data, and time and ability to safely evacuate the platform as the hazard approaches;

b) risks to life-safety for the planned (design) or remaining (in-service assessment) life of the structure are documented to be lowered by evacuation based on the plan specified in a);

c) the platform does not have high hydrocarbon flow rates or large processing capability;

d) the platform does not have large process or storage inventory, unless there are documented plans for the management or reduction of inventory prior to the occurrence of the hazardous event;

e) all potentially free flowing wells are equipped with fully functional subsurface safety valves, manufactured and tested in accordance with applicable specifications. The possibility of flow should be considered as a result of failure in any part of the system including the riser/conductor;

f) plans are documented providing evidence for immediate shut-in of oil or gas production at the occurrence of the hazardous event;

g) pipelines that can be affected by the hazardous event, including by the consequences of the hazardous event, are limited in their ability to release hydrocarbons, either by virtue of inventory and pressure regime, or by subsea isolation valves located at sufficient distance to be unaffected by the failure, and manufactured and tested in accordance with applicable specifications.

Quantification of qualitative descriptors such as “high”, “large”, and “uncontrolled” shall be as determined by the operator and agreed by stakeholders, for the circumstances specific to the platform or the design/assessment situation. The operator may align these descriptors to their in-house classification of risk severity to confirm alignment between life safety, environmental and economic consequences for the three exposure levels.

7.3.4 Exposure level L3

A structure that meets all the requirements of an L2 platform in 7.3.3 may be classified as exposure level L3 in a hazardous event if all of the following apply:

a) the platform is unmanned except for occasional inspection, maintenance and modification visits;

b) visits are not planned to last more than 24 h during seasons in which pre-determined hazardous events, for example environmental events, can occur;

c) visits are not planned to last more than 24 h on bottom founded platforms in regions with seismic zone 4 as defined in ISO 19901-2;

d) the platform has low or no oil flow rates, and/or low or no processing capability, with documented plans providing evidence for shut-in of oil or gas production prior to the occurrence of the hazardous event;

e) the platform limits oil storage to a minimum of process inventory and small “surge” tanks for pipeline transfer.

NOTE A not normally manned minimal structure.

7.4 Design/assessment situations

7.4.1 General

A design/assessment situation shall be established for each hazardous event or other source or cause of a principal action, see 10.2.1. A design/assessment situation is established based on actions, action combinations, structural configuration, limit states, and other parameters. Further guidance is given in A.7.4.

Design/assessment situations can be categorized into the following:

a) operational design/assessment situations (see 7.4.2);

b) extreme design/assessment situations (see 7.4.3);

c) abnormal design/assessment situations (see 7.4.4);

d) accidental design/assessment situations (see 7.4.5);

e) short duration design/assessment situations (see 7.4.6);

f) serviceability design/assessment situations (see 7.4.7).

Sources or causes of principal actions can include permanent and variable weight (see 9.2 and 9.3), and hazardous events (see 7.2). A principal action is combined with companion actions, see 10.2.1, to determine the total action for that action type. The relevant structure type standards (see Figure 1) establish certain design/assessment situations predominant for that structure type.

Design/assessment situations shall be established for maximum and, if relevant, minimum or reversal of actions. Design/assessment situations shall also be established for combinations of lesser-magnitude actions which could result in greater action effects due to dynamic response, e.g. to metocean actions.

Hazardous events which impact a structure in different ways, e.g. directionality and shapes of waves and ice features, may be considered separate design/assessment situations.

For each design/assessment situation, the configuration of the structure shall be specified with respect to the phase of its life and its actual or anticipated condition (e.g. as-built, with deterioration, post-damage).

7.4.2 Operational design/assessment situations

Operational design/assessment situations shall be established for principal actions caused by normal operations and low probability operational events [see 7.2 a)], including incidents.

The principal action types are permanent and operational action types, see 10.2.2. Usually the permanent actions are the same for all design/assessment situations, and therefore each operational design/assessment situation is differentiated by the principal operational action.

If resulting in worse action effects, operational design/assessment situations shall be established for each minimum or reversal of permanent or operational action and shall be with or without accompanying environmental actions.

The global behaviour of the structure is essentially elastic, and a linear structural analysis is usually adopted. However, the analysis should also account for non-linear behaviour and limited plasticity, subject to the characteristics of the structure or structural component, so that

— local stress concentrations can be modelled,

— local yielding and plasticity can be accounted for as the limit state is approached, and

— non-linear behaviour (e.g. pile-soil interaction, moorings) can be modelled.

In operational incidents, inelastic behaviour of some structural components may be considered if their capacity to resist action effects is not reduced, e.g. plates in membrane action, if there is sufficient ductility.

For operational design/assessment situations, limit states ULS_1 and ULS_2 as specified in 8.3.2 shall be included.

Appropriate partial factors (10.4) shall be applied to both actions and resistances for design/assessment verification.

7.4.3 Extreme design/assessment situations

An extreme design/assessment situation shall be established for each extreme environmental event. This event causes the principal action. The principal action type is the environmental action type, see 10.2.2.

The global behaviour of the structure, and provisions for structural analysis, are as described in 7.4.2.

For extreme design/assessment situations, limit states ULS_1 and ULS_2 as specified in 8.3.2 shall be included.

Appropriate partial factors (10.4) shall be applied to both actions and resistances for limit state verification.

Alternatively, for some types of structure possessing reserve strength, such as fixed steel jacket and tower structures, extreme design/assessment situations may be analysed using the ALS directly.

EXAMPLE For some fixed steel structures, a non-linear push-over analysis can be used in which unfactored extreme actions are magnified until the ALS is reached. A reserve strength ratio, given as the ratio of the value of the actions at the ALS to unfactored extreme actions, is then verified with respect to a recommended minimum ratio to ensure adequate reliability. ISO 19902 describes reserve strength ratio determination in detail.

Methodology for extreme design/assessment situations for earthquakes shall be established in accordance with ISO 19901-2 as specified in the relevant structure type document.

7.4.4 Abnormal design/assessment situations

For exposure level L1 and L2, see 7.3, an abnormal design/assessment situation shall be established for each abnormal environmental event. This event causes the principal action. The principal action type is the environmental action type, see 10.2.2.

If possible, the structure shall be designed to avoid or mitigate the effects of abnormal design/assessment situations.

EXAMPLE The base of the deck can be raised so that interaction with the abnormal wave crest elevation is avoided.

System and component ductility and ultimate non-linear capacity may be taken into consideration in determining the ultimate resistance of the structure. Non-linear structural analysis progressing to complete loss of structural integrity, ultimate non-linear resistance, or collapse, may be used. Inelastic behaviour of structural components may be considered (such that design resistance of individual structural components can be exceeded and/or action effects can be redistributed to other components) if there is sufficient ductility and if the overall structural design is adequately robust, see 5.5.2.

For abnormal environmental events when there are life safety implications, sufficient structural integrity shall be confirmed to enable emergency response following an event which, despite satisfying the design/assessment criteria for the ALS, causes component or local damage, see A.8.3. After any such damage, or in anticipation of pre-defined environmental events causing such damage, further design/assessment situations should be established and verified. These further situations could be in any of the categories described in 7.4.1, as determined by the operator or designer.

For abnormal design/assessment situations, limit states ULS_2 and ALS as specified in 8.3.2 and 8.3.3 shall be included; ULS_1 may also be used.

Partial factors of unity and principal actions having a specified probability of exceedance, shall be used for design/assessment verification.

Methodology for abnormal design/assessment situations for earthquakes shall be established in accordance with ISO 19901-2, as specified in the relevant structure type document.

7.4.5 Accidental design/assessment situations

An accidental design/assessment situation shall be established for each accidental event. This event causes the principal action. The principal action type is the accidental action type, see 10.2.2.

System and component ductility and ultimate non-linear capacity may be taken into consideration in determining the ultimate resistance of the structure. Structural analysis and structural behaviour should be as for abnormal design/assessment situations, see 7.4.4.

For accidental events when there are life safety implications, sufficient structural integrity shall be confirmed to enable emergency response following an event which, despite satisfying the design/assessment criteria for the ALS, causes component or local damage, see A.8.3. After any such damage, or in anticipation of pre-defined accidental events causing damage, further design/assessment situations should be established and verified. These further situations could be in any of the categories described in 7.4.1, as determined by the operator or designer.

For accidental design/assessment situations, limit states ULS_2 and ALS as specified in 8.3.2 and 8.3.3 shall be included; ULS_1 may also be used.

Partial factors of unity and principal actions having a specified probability of exceedance, shall be used for design/assessment verification.

7.4.6 Short duration design/assessment situations

Short duration design/assessment situations shall be established for activities or structural configurations with duration usually less than one year, and possibly for only a few days.

Operational, environmental, and accidental design actions may be based on data applicable for the short duration. Environmental design actions may be based on seasonal data and probabilities applicable during the short duration, and based on a reduced return period, if justified. Abnormal and accidental events are usually not relevant for short duration design/assessment situations, but otherwise may also be established.

Short duration design/assessment situations cover a range of different situations, including the following:

a) transient design/assessment situations, such as situations during fabrication including concrete construction, repairs in place, and decommissioning;

b) temporary design/assessment situations, such as situations during the transportation and installation stages;

c) post-damage design/assessment situations, such as when the structure is waiting for repairs.

The post-damage configuration or condition can include reduction in resistance due to missing structural components, excessive deformation, change in geometric properties e.g. due to corrosion or fatigue, and change in material properties, e.g. due to fire.

The principal action types for these design/assessment situations are usually permanent and operational, or environmental.

If it is desired that every component as well as the structure as a whole (or constructed parts) remain within their limit states, for example during transportation, then short duration design/assessment situations should be established and verified as for operational and extreme design/assessment situations, with environmental conditions determined appropriately for the short duration.

If it is desired to address overall collapse and survivability of a damaged structure after the hazard has passed but before action is taken, short duration design/assessment situations should be established and verified as for abnormal and accidental design/assessment situations, with modified structural configuration, and with environmental conditions determined appropriately for the short duration.

NOTE Assessment of a damaged structure during the continuation of the hazardous event causing damage, for example further waves in the same storm, is not intended to be considered as a short duration design/assessment situation. The criteria are as for the hazardous event causing damage.

The structure can be in a damaged condition if structural integrity of critical parts is confirmed for a sufficient period of time under specified environmental conditions to enable evacuation and to allow for repair or removal.

Limit states for short duration design/assessment situations shall include, as a minimum, the limit states ULS_2 and ALS, specified in 8.3.2 and 8.3.3, to address survivability. This can be sufficient for post-damage assessment. Design/assessment situations for which it is intended to avoid all damage, such as those associated with construction stages, shall also include the limit states ULS_1, specified in 8.3.2.

7.4.7 Serviceability design/assessment situations

Serviceability design/assessment situations are usually established for in-place service conditions for verifying that structure and structural components satisfy serviceability requirements for functions such as providing personnel comfort and keeping equipment within relevant operating limits.

Limit states for serviceability design/assessment situations are described in 8.3.4. In limit state verification, partial factors for principal actions are given in 10.6. Principal actions are usually operational actions with accompanying day-to-day environmental actions or, if defined by the operator with respect to particular activities or operations, environmental actions more probable than extreme actions.

8 Limit state verification

8.1 General

The limit state approach shall be used for design and assessment.

The objective of the limit state verification approach is to validate that, in combination with the provisions for construction and operation, the structure and its components have adequate integrity with respect to defined limit states (see 8.3), in all applicable design/assessment situations (see 7.4), dependent on the exposure level (see 7.3).

Design/assessment verification shall be based on the limit state verification procedure specified in 8.4 and in the appropriate structure type standards ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3, ISO 19906.

Alternative design and assessment approaches, such as probabilistic methods and structural reliability analysis, may be used if justified and documented to provide reliability consistent with that implicit in the structure type standards (ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3, and ISO 19906). Probabilistic analysis models should incorporate all appropriate variables and account for all relevant uncertainties, see Clause 11.

Structural reliability analysis and optimization can also be used to determine partial action and resistance factors; the process is known as calibration (see 10.8).

8.2 Basic variables and representative values

Basic variables shall be used to represent physical quantities such as geometric variables (dimensional quantities), mechanical variables, material properties, soil properties, and to represent other variables used in action and resistance models.

EXAMPLE 1 Thickness and diameter of a tubular member, steel yield strength, wave height and associated period.

As part of the limit state verification procedure (see 8.4), values shall be assigned to basic variables or to variables calculated using basic variables, such as actions and resistances resulting from action and resistance models. These values are referred to as the representative values of the variables.

Representative values can be either characteristic values or nominal values, as follows:

— characteristic values are derived on a statistical basis and are the preferred option to determine representative values where adequate data are available. Characteristic values can include mean values, as well as values associated with a prescribed probability of occurrence or exceedance (such as 5 %, 10 %, 90 %, or 95 %), with, in time dependent cases, a specified reference period (usually one year, or more depending on the variable);

— nominal values can include values within a range of tolerance (e.g. structural dimensions), lower bound values to a set of data, codified values (e.g. specified minimum yield strength) or values otherwise specified, derived or, in some cases, unspecified.

For basic variables related to resistance, the characteristic value generally corresponds to a specified fractile of the statistical distribution. If lower values result in the most onerous design condition, the characteristic value shall be defined as the value below which a small specified percentage (e.g. 5 %) of the values are expected to fall. If higher values govern the design, the characteristic value shall be defined as the value below which a high specified percentage (e.g. 95 %) of the values are expected to fall.

The characteristic value for fatigue endurance shall be defined as the value below which a specified small percentage of the values are expected to fall (2,3 % in the Gaussian assumption of mean minus two standard deviations).

Representative values assigned to specific variables can either be different for different design/assessment situations (see 7.4) or consistent for all design/assessment situations.

EXAMPLE 2 For the basic variable wave height, a characteristic value can be selected having a 1, 10, 100, 1 000, or 10 000 year return period. Representative values for structural component strength and thickness can be identical for all design/assessment situations.

Changes in basic variables over the total service life or the period of analysis have the potential to influence structural integrity. In such cases, the representative values of the variables shall take such potential changes into account.

EXAMPLE 3 The potential variability of changes during the lifetime of the structure at its anticipated locations can include:

a) climate change or other long-term effects causing changes in the frequency and magnitude of environmental actions resulting from wave heights, ice conditions, ocean circulation, and water levels during the total service life of the structure; and

b) environmental processes such as corrosion, wear, operating conditions, or accidental events such as fire and explosion which can cause variability in certain material properties or dimensions.

If the deviation of any geometric variable from its specified or described value can exceed tolerance, the formulation of structural resistance and structural response shall take into account such deviations. If the deviations are not corrected (see 10.3.3), modified tolerance limits for the geometric variables shall be specified.

Material properties and soil properties shall be based on either specific qualification tests, acceptance tests, or *in situ* observations in conjunction with other sources of information.

For metals, the variability of yield strength across the structure should be estimated by extracting the certificated tensile test results for each structural component. For the range of temperatures normally encountered offshore, yield strength is not affected, however, it may be affected by the temperatures encountered in fires. Metal toughness, as measured by e.g. a Charpy impact test, is highly temperature dependent.

Variability and uncertainty in the properties of other materials in the structure or of the soil should be obtained from the uncertainties of the standard test results and of the conversion factor or functions that account for any scale effects and any dependence on time and temperature. Guidance on the properties of concrete, grout and related materials is provided in ISO 19903. Guidance on geotechnics and foundations is provided in ISO 19901-4 and ISO 2394[1].

Representative actions for fatigue analysis shall account for the variation in representative values over time by determining the number of repeated actions of each magnitude, rather than by determining a single representative value. Fatigue limit state verification is based on fatigue endurance curves (e.g. S-N-curves or T-N-curves). Fracture mechanics approaches may also be applied in fatigue verification. In such cases, the characteristic values of the crack propagation variables and the value of the initial and failure crack size should be chosen to be consistent with the fatigue endurance curve approach.

8.3 Limit states

8.3.1 Categories of limit states

A limit state is a state of the structure or structural component beyond which it no longer satisfies the design/assessment criteria used in the limit state verification procedure. The limit states are divided into the following four categories:

a) ultimate limit states (ULS);

b) abnormal/accidental limit states (ALS);

c) serviceability limit states (SLS);

d) fatigue limit states (FLS).

8.3.2 Ultimate limit states

ULS for offshore structures address strength and stability of the structure and structural components, avoiding collapse in whole or in part.

Limits for ULS design criteria include the following two groups of limit states:

— ULS_1: action effects in individual structural components exceeding the resistance (in some cases reduced by deterioration), including loss of structural stability (e.g. buckling);

NOTE Resistance can include the ultimate strength or the ultimate deformation of the component.

— ULS_2: loss of static equilibrium of the structure, or of a critical part of the structure, considered as a rigid body (e.g. overturning, sinking, or capsizing).

ULS are applicable to operational design/assessment situations (see 7.4.2), to extreme design/assessment situations (see 7.4.3), and to short duration design/assessment situations (see 7.4.6). ULS are also applicable to abnormal design/assessment situations (see 7.4.4) and to accidental design/assessment situations (see 7.4.5).

8.3.3 Abnormal/accidental limit states

ALS for offshore structures address complete loss of integrity of the structure, or of a critical part of the structure, when there is no further system ductility or reserve strength. ALS include transformation of the structure into a mechanism (collapse or excessive deformation), and loss of stationkeeping (free drifting).

ALS are applicable to abnormal design/assessment situations (see 7.4.4) and to accidental design/assessment situations (see 7.4.5). As part of the design process the ALS can also be applicable to post-damage situations, which are included under short duration design/assessment situations (see 7.4.6).

NOTE The additional system resistance between that when the first component no longer satisfies its individual design/assessment criteria and that when there is complete loss of integrity (overall collapse) is influenced by robustness (see 5.5.2).

8.3.4 Serviceability limit states

SLS for offshore structures correspond to criteria governing functional use.

Examples of serviceability limit states are

— deformations or movements that affect the efficient use of structural or non-structural components,

— motions that cause discomfort to personnel or exceed the limitations of equipment,

— excessive vibrations that cause discomfort or affecting non-structural components or equipment (especially if resonance occurs),

— local damage (including cracking) that affects the intended functions of structural or non-structural components, or

— corrosion that reduces the durability of the structure and affects the properties and geometric variables of structural and non-structural components.

Some SLS limits can be recommended in voluntary documents such as industry guidance or can be prescribed by regulation. Other SLS limits are determined by the operator based on functional requirements such as for durability, equipment operation, and personnel comfort.

To control SLS limits by design, it is often necessary to use one or more constraints (limitations) that describe acceptable limits e.g. for deformations, accelerations, vibrations, and crack widths.

SLS are applicable to serviceability design/assessment situations, see 7.4.7.

8.3.5 Fatigue limit states

FLS for offshore structures address cumulative damage typically due to repetitive environmental actions. These actions cause deterioration such that cumulative damage can reach a limit defined as “failure”, usually of a structural component.

EXAMPLE For tubular steel members, the typical fatigue limit state is first through thickness crack.

If a structural component is deemed to have failed the FLS, it can then be assessed, in its damaged condition, for operational and short duration design situations, pending assessment of the need for repair.

8.4 Limit state verification procedure

The limit state verification procedure shall be as specified in this subclause and in the relevant structure type standard (see Figure 1).

Design/assessment criteria used in the verification including specified partial factors are presented in the International Standards on offshore structures prepared by TC 67/SC 7 for the primary design/assessment situations. The partial factors enable the influence of uncertainties and variabilities originating from different action types and resistance or material variables to be treated separately.

The design or assessment shall be verified by determining that the total design action effect, S_d, in each design/assessment situation (see 7.4) does not exceed the limit state design resistance, R_d, as given in Formula (1):

$$S_d \leq R_d \tag{1}$$

The total design action effect shall be derived from an analysis of appropriate combinations of the different types of design actions, F_d (see 10.1 and 10.2).

NOTE For linear systems, for which the structural response to actions is linear up to at least the total design action, the total design action effect can be determined either by summing the effects of individual design actions applied separately to the structure or by analysis of the structure for the combined design actions. For non-linear systems, the total design action effect can only be determined by analysis of the structure for the combined actions, considering also that the most severe action effects can be caused by smaller actions amplified by dynamic responses.

Each design action, F_d, shall be determined from its representative value, F_r, and the appropriate partial factor, γ_f, using Formula (2) as explained in Clause 10:

$$F_d = \gamma_f F_r \tag{2}$$

Limit state design resistances, R_d, can be expressed in formulations in which strengths of materials, and other relevant quantities and properties including basic variables, shall be expressed by their design values determined as explained in 10.3. Alternatively, the design resistance of a component or of the structure as a whole shall be determined directly from its representative value, R_r, and the appropriate partial factor, γ_R, using Formula (3):

$$R_d = \frac{R_r}{\gamma_R} \tag{3}$$

The design procedure shall not be refined to a point that is incompatible with the standard of workmanship likely to be achieved and the knowledge of the important design parameters.

9 Actions

9.1 Classifications of actions

Actions can be classified into different types by their source, by their variation with time, by their point of application, and by a structure's response to them.

For the purposes of limit state verification for ULS, ALS, and SLS, actions shall be classified into four action types, as follows:

a) permanent (see 9.2);

b) operational (see 9.3);

c) environmental (see 9.4);

d) accidental (see 9.5).

The action type relevant for FLS is repetitive actions (see 9.6).

Actions can be further classified as either static (including quasi-static) or dynamic according to the way in which the structure responds to the action (see also A.9.1).

9.2 Permanent actions and their representative values

Permanent actions (*G*) have no significant variation in magnitude, position or direction throughout a given design/assessment situation.

Permanent actions include actions for which variations over long periods of time are either small in relation to the mean value or attain some limiting value.

Permanent actions generally include the following:

a) self weight of structure;

b) weight of solid ballast and water permanently enclosed (e.g. flooded members);

c) weight of topsides, fixtures, and functional equipment including weight and pre-tension imposed by drilling, production, and export equipment such as risers, which is either permanent or is constant over long periods of time (e.g. drilling equipment that can be removed);

d) actions resulting from soil pressure;

e) actions resulting from external hydrostatic pressure;

f) actions or imposed deformations resulting from support and/or subsidence;

g) indirect actions, such as

— pre-tension in mooring lines,

— deformations imposed and locked in during construction,

— imposed deformations resulting from shrinkage of concrete or distortions due to welding, and

— imposed deformations resulting from prestressing and lack-of-fit.

A permanent action *G* has a representative value, which applies for all design/assessment situations. If the action consists of the self weight of the structure, the representative value should be obtained as a nominal value based on the design values of the geometric variables (see 10.3.3) and the mean density of the material.

Weights shall be evaluated based on weight and centre-of-gravity reports (see 12.4.3). Allowances shall be made for uncertainties, for possible increases in weight, for potential changes in the centre of gravity position, and for planned future operations.

9.3 Operational actions and their representative values

Operational actions (*Q*) are variable actions related to operations and functional use of the platform, but do not include environmental actions. They can vary in magnitude, position and direction during the period under consideration.

Operational actions generally include the following:

a) actions due to expected use and occupancy, including variable functional loads on deck areas and lay-down areas, actions caused by crane loads, drilling hook loads, variable ballast, helicopters, fluids (in pipes, tanks, and other vessels), and consumables;

b) self weight of temporary structures and equipment;

c) actions caused during erection, commissioning, and testing;

d) all moving actions such as for movable drilling derricks;

e) actions caused by incidents, see 7.2 a), which can cause local damage, such as lesser impacts from supply and service vessels, smaller dropped objects, overpressure of non-hydrocarbon tanks, and helicopter emergency landings;

f) imposed deformations resulting from thermal effects such as functional temperature changes (e.g. process related) and spillage of refrigerated fluids;

g) where appropriate, actions due to the weight of marine growth.

Operational actions can be divided into long duration actions, Q_1, and short duration actions, Q_2 (see also ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3, and ISO 19906). A further subdivision of physically limited actions, such as a vessel being full of fluid, can also be defined.

The representative value of an operational action Q can be a characteristic or a nominal value calculated from geometric and material variables and, if relevant, equipment capacity.

Operational actions can have

— a maximum (or minimum) value, or a low probability value in a hazardous event, which is the representative value of a principal action,

— an expected day-to-day operating value which can apply for some serviceability design/assessment situations or can apply as a companion action for a principal action in an operational design/assessment situation,

— a companion value (see 10.2.1) which is derived by considering the joint probability of occurrence with a principal operational action, and

— a value for combination with other action types (see 10.2.2).

Design/assessment situations in which the effect of a smaller action or a reversal of action is more onerous for the structure, or design/assessment situations marked by significant uncertainties, shall be quantified using both upper and lower representative values.

Loading patterns for operational actions shall include consideration of the spatial variability of actions, which can affect e.g. deck beams, topsides supports, and floating stability.

9.4 Environmental actions and their representative values

Environmental actions (E) are variable actions related to physical environmental conditions including seismic. They can be treated as individual (relevant for ULS, ALS, and SLS) or repetitive, see 9.6 (relevant for FLS).

Environmental actions generally include the following:

a) actions caused by wind;

b) actions caused by waves;

c) actions caused by current;

d) the increase in environmental actions resulting from marine growth and/or accumulated snow and ice;

e) actions due to the weight of accumulated snow and ice;

f) actions caused by ice features such as sea ice and icebergs;

g) environmental temperature changes as they can induce actions or affect material properties;

h) actions caused by earthquakes and other geological processes, see 6.4.

The representative value of an environmental action should be its characteristic value, see 8.2.

Depending on the specific design/assessment situation, commonly used environmental action values for limit state verification for ULS and ALS are as follows:

— extreme value, based on an extreme environmental event (see 7.2 b), which is used as the representative value of a principal action;

— abnormal value, based on an abnormal environmental event (see 7.2 c), which is used as the representative value of a principal action;

— companion value (see 10.2.1) which is derived by considering the joint probability of occurrence with a principal extreme or abnormal environmental action.

If operational measures are planned with respect to hazardous events which reduce the frequency of the event or mitigate the actions, then the resulting representative value of the action may be modified.

Environmental actions for limit state verification for SLS should be determined by the operator with reference to the relevant structure type standard.

Design/assessment situations in which the effect of a smaller action or a reversal of action is more onerous for the structure, or design/assessment situations marked by significant uncertainties, shall be quantified using both upper and lower representative values.

9.5 Accidental actions and their representative values

Accidental actions (A) derive from accidental events [see 7.2 d)] and are used as principal actions. Accidental actions generally result from the following:

a) collisions;

b) dropped objects, swinging objects, projectiles;

c) fire;

d) explosions;

e) helicopter crash impacts;

f) unexpected flooding;

g) unexpected changes in pressure differences;

h) unexpected subsidence of the foundation or seabed, or shallow geohazards;

i) unexpected erosion, scour, or ice gouge;

j) unexpected freezing of water in closed compartments.

The representative value of an accidental action should be its characteristic value, see 8.2.

9.6 Repetitive actions

Repetitive actions can cause fatigue effects. Each repetitive action has associated magnitudes, frequencies, and durations. Repetitive actions can include the following:

— high cycle actions, such as due to regular waves;

— low cycle actions, such as due to offloading cycles for structures with storage capacity.

Procedures for the determination of repetitive actions shall be based on the appropriate International Standard for the structural component or structure type, i.e. ISO 19901-7 and ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3, and ISO 19906.

10 Design values and partial factors

10.1 Design values of actions

The design values of actions shall be used in determining the total design action effect used in limit state verification as shown in 8.4. Design values of actions shall be obtained from representative values (see 8.2 and 9.1 to 9.5) by multiplication by partial action factors (γ_f), see Formula (2).

The partial action factor for each action type depends on the design/assessment situation, the exposure level, and the limit state considered. Partial action factors can also depend on the source of action within an action type. For example, the partial action factor applicable to operational actions physically limited to a maximum value can be the same as that for permanent actions.

The partial action factors take account of

a) the uncertainty associated with the actions, and

b) the uncertainty in the modelling of actions.

10.2 Actions acting in combination

10.2.1 Principal and companion actions for the same action type

The principal action is the action caused by the hazardous event or other source of action, such as gravity and equipment operating loads, that dominates the design/assessment situation, see 7.4.1. The representative value is quantified in accordance with Clause 9.

The principal action shall be combined with any other actions of the same action type (see Clause 9) that could act simultaneously, in order to calculate the representative value for the action type as a whole. These other actions of the same action type are termed companion actions.

Representative values of companion actions for combination with the representative value of the principal action can be determined by analysis of data and consideration of stochastic dependence, or by judgement based on available information.

Actions that are mutually exclusive should not be combined.

For actions modelled probabilistically, the representative value of the combined action for the relevant action type shall be quantified with respect to the prescribed probability of exceedance (or return period). This can be achieved by a detailed analysis of joint probabilities, if adequate data exist, to determine a characteristic value for the action type as a whole. Otherwise, the representative value of the combined action can be estimated as either

— the representative value of the principal action, combined with companion actions having values expected to be associated with the principal action, e.g. by applying Turkstra's rule [10], or

— the sum of the representative values of each action considered independently and quantified as if each were the principal action, which usually provides a conservative estimate.

If accidental actions are assumed to occur simultaneously, the annual probability level shall apply to the combination of these actions. Unless the accidental actions are caused by the same phenomenon (such as hydrocarbon gas fires and explosions), the occurrence of different accidental actions may be assumed to be statistically independent.

10.2.2 Principal and accompanying actions for specific design/assessment situations

Design values of the different action types which occur in a design/assessment situation shall be combined in the verification of a limit state. For each design/assessment situation, one or more action types shall be designated as principal action types, and other action types designated as accompanying actions.

The action types shall be combined so that they produce the most unfavourable effect on the structure for the limit state considered. Combinations for operational design/assessment situations shall be both with and without an accompanying environmental action *E*.

For ULS and ALS, the usual combinations of the action types for the four main design/assessment situations are summarized in Table 1.

Table 1 — Action types combined in ULS and ALS design/assessment situations

Design/assessment situation	*G*	*Q*	*E*	*A*
Operational (see 7.4.2)	Principal	Principal	Accompanying, or None	None
Extreme (see 7.4.3)	Accompanying	Accompanying	Principal	None
Abnormal (see 7.4.4)	Accompanying	Accompanying	Principal	None
Accidental (see 7.4.5)	Accompanying	Accompanying	Accompanying	Principal

For FLS, the cumulative effect of all repetitive actions during the life of the structure shall be taken into account, if relevant. The combined time series of action effects can include high cycle and low cycle time-variant actions which have different fatigue effects on different types of structure.

10.3 Design values of resistance

10.3.1 General

Limit state design resistances, R_d, shall be expressed in formulations in which design values of strengths of materials (see 10.3.2), design values of geometric variables (see 10.3.3), and appropriate modelling uncertainties (see 10.3.4) are used. Alternatively, the design resistance of a component or of the structure as a whole can be determined directly from its representative value, R_r, and the appropriate partial factor, γ_R, using Formula (3).

10.3.2 Design values of materials including soils

The design value, f_d, of a material property is obtained from the representative value, f_r, using Formula (4):

$$f_d = \frac{f_r}{\gamma_m} \quad (4)$$

The value, γ_m, in Formula (4) takes account of the following:

a) uncertainties associated with the material properties;

b) uncertainties in the modelling of resistance;

c) uncertainties in geometric variables, if they are not taken into account according to 10.3.3;

d) uncertainties in the relationship between the properties of the material in the structure and in the soil foundation, and those measured by tests on control specimens, for example, uncertainties in the conversion factor or function according to Clause 11.

The value of γ_m depends on the material property, the actual limit state and, for some materials, the component resistance formulation.

10.3.3 Design values of geometric variables

Design values of geometric variables, a_d, shall be derived using Formula (5):

$$a_d = a_r + \Delta a \quad (5)$$

where a_r is the representative value and Δa is the deviation as described in 6.5.

In cases where deviations of the geometric variables are within specified tolerances, have insignificant effects, or where the effects are accounted for within the partial resistance factor (γ_R), Δa may be taken as zero.

10.3.4 Uncertainties in analysis models

The uncertainties in a calculation or analysis model are generally accounted for by one or more of the partial factors. Guidance on models and analysis is provided in Clause 11.

10.4 Partial factors for operational and extreme design/assessment situations

Partial action factors for exposure level L1 for the action types in operational and extreme design/assessment situations are specified in the document applicable for the structure type (i.e. ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3, and ISO 19906).

For exposure levels L2 and L3, partial action factors for extreme-level actions may be reduced from the L1 values. Information and some values are provided in some of the relevant documents in the International Standards on offshore structures prepared by TC 67/SC 7. In the absence of information for L2 or L3 exposure levels, these values may be determined by the operator, e.g. by calibration, but any reduction from the values specified for L1 shall be justified.

The value of the partial action factor depends on whether the action type is a principal or an accompanying action (see 10.2.2). The action types may be further subdivided, so that different partial action factors can be calibrated and applied.

Partial resistance factors in operational and extreme design/assessment situations embody a margin to account for the variability in material properties and the uncertainties listed in 10.3. These factors shall be in accordance with ISO 19901-4, ISO 19901-7 and the appropriate document for the structure type (i.e. ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1, ISO 19905-3, and ISO 19906). These factors do not depend on exposure level.

10.5 Partial factors for abnormal and accidental design/assessment situations

Partial action factors for all action types in accidental and abnormal design/assessment situations shall be taken as 1,0. This is due to the very low probability of exceedance level used to determine the representative value for the principal action.

For all exposure levels, information on exceedance probabilities or return periods for abnormal-level and accidental actions is provided in 7.2 and in the relevant documents in the International Standards on offshore structures prepared by TC 67/SC 7. In the absence of information for L2 and L3 exposure levels, values for L2 and L3 with probabilities of exceedance greater than that for L1 may be determined by the operator, provided these are justified by means of a site-specific calibration including verifiable application of operational constraints.

Partial resistance factors in accidental and abnormal design/assessment situations should be taken as 1,0 for all exposure levels, except if a structure type standard provides otherwise.

10.6 Partial factors for serviceability design/assessment situations

Partial action factors in serviceability design/assessment situations shall be taken to be 1,0.

Partial factors for materials and resistances in serviceability design/assessment situations shall be taken to be 1,0.

Different serviceability limits can be achieved by using different values for constraints such as acceptable deformations, accelerations and crack widths.

10.7 Partial factors for fatigue design/assessment verification

Partial action factors in fatigue design/assessment verification shall be taken to be 1,0.

Design fatigue factors used in fatigue limit state verification account for the significant uncertainty in determining fatigue endurance. These factors shall be in accordance with the appropriate document of the structure type (i.e. ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1 and ISO 19905-3), and with ISO 19901-4 for soils.

10.8 Probabilistic modelling and analysis

The partial action factors and the partial resistance factors given in the International Standards on offshore structures prepared by TC 67/SC 7 have been established or calibrated using probabilistic modelling and analysis. They have been calibrated on the basis of relevant test data for structural components and full-scale offshore load monitoring programmes.

Partial factors different than those provided in this clause and within the International Standards on offshore structures prepared by TC 67/SC 7 may be used, if justified, e.g. using site-specific calibration. Attention shall be given to ensuring that adequate reliability of the structure is achieved, see A.10.8 for further guidance.

11 Models and analysis

The structural analytical procedures and calculations described in the International Standards on offshore structures prepared by TC 67/SC 7 may be performed with the assistance of computer-aided engineering tools, physical scale model tests, full-scale prototype model testing, or a combination of these methods.

Basic variables used in models need quantification, validation and quality assurance. Specifically, the bias and uncertainty in results from both analytical calculations and from model tests, should be assessed. These are generally a function of the assumptions specified and agreed upon, of the novelty of the structural configuration, of the complexity of the calculations performed, of the history of verification and validation of the software or physical tools being used, and of the expertise and experience of the operator or the analyst.

Models used in the analysis and the design/assessment verification of the offshore structure shall be maintained and kept up to date throughout all phases of the structure's life cycle. The operator shall be responsible for ensuring this.

Guidance on analyses and models used in design/assessment is provided in A.11.

12 Quality management

12.1 General

All design, fabrication and installation of offshore structures should be performed in accordance with a documented quality management system conforming with an agreed industry quality management system standard such as ISO 9001[2] and ISO 29001[5].

NOTE Quality provisions relating to specific types of offshore structures are defined in the applicable standards (ISO 19902, ISO 19903, ISO 19904-1, ISO 19905-1 or ISO 19906) and in ISO 19901-6 for transportation and installation.

The operator shall validate conformity with the technical requirements in the defined plan and shall perform conformity assessment activities. Inspection and testing shall be performed as necessary to confirm that the product and/or service delivered meet all requirements.

Quality plans and/or inspection and test plans developed as outputs to operational planning and control for the products and/or services shall establish the specific controls to be implemented by the supplier and when applicable, sub-suppliers, to validate conformity with the specified requirements.

Conformity assessment requirements shall be commensurate with the structure's exposure level (L1, L2, or L3), as described in 7.3. If exposure level varies with design situation, the requirements for each part of the structure should be commensurate with the highest exposure level for all design/assessment situations for that part of the structure (where L1 is the highest).

If a structure is one of a series built to a standard design, the extent of quality management can reflect the potential reduced scope afforded by commonality. As a minimum, the quality management process should be used to confirm that the site-specific foundation requirements are accounted for, that the production system weights and actions are correctly identified and are within the design capability of the structure, and that the structure is fabricated to the quality requirements of the standard design.

12.2 Installation inspection

At the conclusion of the transportation, and prior to commencement of installation operations, appropriate inspection shall be conducted to confirm the structure is undamaged. Inspections shall verify that all installation aids and appurtenances have been installed and tested in accordance with the specified requirements, including any manufacturer's recommendations.

Following installation, the structure shall be re-inspected to confirm that key aspects are in conformance with the design specifications.

NOTE Key aspects include deck elevation, air gap, pile penetration, ballast, anchor positions, line lengths, and cathodic protection.

12.3 In-service inspection, maintenance and repair

Requirements for in-service inspection, maintenance, and repair shall be documented in the system for structural integrity management.

As a minimum, an inspection strategy shall be established.

The structure shall be maintained in such a way that it can safely fulfil its intended functional use throughout its total service life according to the provisions of this document and of the appropriate document of the actual structure type in the International Standards on offshore structures prepared by TC 67/SC 7.

Maintenance should be specified, accounting for the importance and function, knowledge of the durability of the components and the redundancy of the structure, environmental conditions and the protection against external actions.

Structural components that are essential to the stability and resistance of a structure should, as far as possible, be accessible for inspection.

12.4 Records and documentation of design and construction

12.4.1 General

During the design and construction phases, and especially during the fabrication, erection, load out and installation stages, data needed for the in-service inspection and maintenance of the platform shall be recorded as the project progresses and compiled in a form suitable for retention as a permanent record.

The documents and data listed in Table 2 shall be prepared insofar as they apply to the particular structure and to its exposure level. All documentation referenced in Table 2 shall be retained and shall be accessible for the total service life of the structure, unless noted otherwise in the project's approved quality assurance manual, and shall be made available to new operators, where appropriate.

Table 2 — Documentation requirements

Documentation description	Exposure level		
	L1	L2	L3
Material tracing records	M	M	R
Engineering drawings	M	M	M
Shop drawings	M	M	R
Design calculations for construction purposes	M	M	R
Dimensional control/survey records	M	M	R
Material certificates	M	M	R
Inspection records	M	M	R
Equipment operability test reports	M	M	R
Other reports	M	M	R
Weight reports	M	M	M
Foundation verification reports	M	M	M
As-built drawings	M	M	R
Key M: Minimum requirement R: Recommended requirement			

12.4.2 Calculations

The structural integrity of components and adequacy of equipment during all stages of construction shall be documented in calculations.

Calculations should

a) address the structure, attachments, temporary works, cranes, equipment, and rigging,

b) address structural strength and stability,

c) address all actions, stresses and deflections, and

d) reference appropriate drawings and specifications.

Calculation documentation should identify the source of calculation methods.

12.4.3 Weight and centre of gravity reports

Requirements on weight management shall be in accordance with ISO 19901-5.

12.4.4 Drawings and specifications

The drawings and specifications prepared through the course of the design and construction phases should comprise the following:

a) conceptual drawings;

b) bid drawings and specifications;

c) design drawings and specifications;

d) fabrication drawings and specifications;

e) shop drawings;

f) installation drawings and specifications;

g) as-built drawings and specifications.

Further to d) above, the contractor shall prepare and provide fabrication procedures and assembly drawings describing and showing the proposed methods and order of assembly of the structure. These procedures and drawings shall include rigging components, rigging configuration, lifting crane capacity and location, temporary aids and attachments to the structure.

Further to e) above, shop drawings shall include all shop details, including material types, cuts, copes, joint details, holes, bolts and piece numbers in accordance with the contract drawings.

Further to g) above, as-built versions of the design drawings and specifications shall be prepared which accurately reflect the structure as built.

13 Assessment of existing structures

13.1 General

A fitness-for-service assessment shall be conducted if an existing offshore structure experiences significant deviations from its basis of design, such as the following:

— damage or deterioration in excess of design allowances;

— extension of intended design service life, resulting in an extended service life;

— changes in manning level;

— modifications including additional topsides equipment, wells or appurtenances;

— changes in component or foundation resistance criteria;

— changes in design environmental criteria;

— scour, ice gouge, or subsidence in excess of what has been planned for in the original design;

— changes in relevant technology.

NOTE The basis of design can be the original basis of design, or the updated basis of design if modifications have been agreed and incorporated.

If aspects of the design no longer comply with the basis of design, the assessment shall determine whether the structure and its components are fit-for-service with respect to retaining adequate structural integrity and performance for their remaining life, in accordance with an updated basis of design.

If operational experience shows that the acceptability of aspects of design or of structural integrity, is uncertain, reliability shall be determined by specific assessment. If necessary, appropriate measures shall be taken to maintain acceptable levels of structural integrity and performance.

If there are changes to the environmental design criteria, it shall be demonstrated that the structure has adequate reliability for applicable limit states. This can involve site-specific calibration of action factors, explicit consideration of the joint distribution of environmental actions or changes to operating procedures that can mitigate the effect of environmental actions. A reduced partial environmental action factor may be acceptable for exposure level L2 and L3 structures, if survivability under all relevant design/assessment situations (see 7.4) can be demonstrated, i.e. no failure would occur that could lead to complete loss of integrity of the structure.

13.2 Condition assessment

13.2.1 General

When a platform requires assessment, it shall not be assumed that the basis of design remains valid. The platform condition (resistance) and actions shall be assessed based on current information.

When conducting an assessment, values of physical variables confirmed by construction (e.g. weight, pile penetration, material properties, and other information from the as-built and in-service documentation) shall be used instead of the values used during the original design.

13.2.2 Service and operating requirements

The actions acting on or resulting from topsides equipment, including additional topsides, wells, or appurtenances not included in the original design shall be reviewed and assessed to determine any significant changes in weights and their centres of gravity.

Any functional or operational changes that affect the structure shall also be accounted for.

13.2.3 Environmental conditions

The physical environmental conditions (see 6.3), including metocean, ice, geological processes, and soil properties which provided the basis for the original design situations, shall be reviewed based on all available data. The extent of any new analysis required will depend on the time elapsed and the additional data available since the original design. The design criteria shall be modified as required and used in the assessment.

Data may be taken from the following:

a) measurements at the site;

b) measurements at nearby sites;

c) hindcast studies.

13.2.4 Testing, inspection, maintenance and repair history

The records of testing, inspection, maintenance and repair during the structure’s total service life shall be reviewed to ascertain whether there are any defects or trends of deterioration that require repair or justification through the assessment process.

If the records are insufficient or incomplete, additional inspection shall be planned in order to establish the condition of the structure.

13.3 Action assessment

If available, records of measured actions and responses of the structure shall be taken into consideration.

If the measured actions and responses have been correlated with the measured physical environment, these records shall also be used in the assessment.

13.4 Resistance assessment

The effect of damage, material deterioration or any other modifications to the resistance of the structure shall be taken into account.

Fatigue damage is one type of damage. Fatigue damage that has previously occurred shall be taken into account in the fatigue evaluations. The adequacy of the fatigue life for the intended remaining life of the structure shall be reviewed, if possible, supported by analysis or inspection, and shall be taken into account when planning any future inspection programme.

13.5 Component and system failure consequences

When considering assessment of existing structures, a limited number of failures of individual structural components, under limit states ULS_1 defined in 8.3.2 may be accepted if the overall reliability, i.e. the reserve against complete loss of integrity of the structure under ALS (see 8.3.3) remains acceptable.

NOTE As an example for space frame structures, a pushover type analysis can be used to demonstrate that the reserve strength of the structural system meets acceptable levels. Such action redistribution can have an effect on the low as well as high cycle fatigue.

13.6 Mitigation

If the assessment process cannot confirm that the structure and its components have adequate reliability in its existing condition, mitigating actions shall be taken to achieve conformance with the intent of this document. Mitigations can include the following:

— reducing the probability of structural failure;

— change of exposure level;

— a combination of both.

The probability of structural failure can be reduced by decreasing action effects, increasing resistance, or both.

Action effect decreasing measures can include removing un-used risers/conductors, implementing procedures for removal of marine growth or in case of wave-in-deck or ice-on-deck actions, by increasing air gap or deck elevation.

Resistance increasing measures can include grouting of tubulars, fatigue improvement or increasing cross section of beams or columns.

Exposure level can be changed by reducing the consequences of a structural failure in order to satisfy the criteria specified in 7.3.3 or 7.3.4.

Annex A
(informative)

Additional information and guidance

NOTE The clauses and subclauses in this annex provide additional information and guidance on the clauses and subclauses in the body of this document. The numbering system and heading titles are consistent, for ease in identifying the clause or subclause in the body of this document to which it relates.

A.1 Scope

No additional guidance is offered.

A.2 Normative references

No additional guidance is offered.

A.3 Terms and definitions

No additional guidance is offered.

A.4 Symbols and abbreviated terms

No additional guidance is offered.

A.5 Fundamental requirements

A.5.1 General

No additional guidance is offered.

A.5.2 Structural integrity requirements

The principles outlined in this document can be used for the following:

— derivation of partial factors;

— demonstration that adequate reliability is achieved using the limit state verification procedure described in this document;

— demonstration that adequate reliability is achieved through operational procedures such as transportation, emergency response procedures, and ice management.

In this document, the term "reliability" is used primarily in the context of "structural reliability", which is one contributor to the overall safety of personnel, risk to the environment and economic/societal risk. This document addresses reliability in the context of design and assessment of the structure for its exposure level, not of operations, such as helicopter operations, which are not related to structural integrity.

Reliability can be expressed as the probability of not having a failure during a reference period, which is generally one year. The relationship between reliability, R, and failure probability, p_f, is given by Formula (A.1):

$$R = 1 - p_f \quad \text{(A.1)}$$

Additional information and guidance on reliability is provided in A.10.8.

It is important to not confuse limit state exceedance in an established design/assessment situation, with hazardous events for which actions are determined for the purpose of verification. Target failure probabilities can be specified for exceeding specific limit states (see Reference [6]), depending on life safety criteria, the type of event and, in some approaches, likelihood of other failure events. For hazardous events, annual occurrence probabilities can be used, e.g. 10^{-2} per annum, 10^{-3} per annum or 10^{-4} per annum.

A fundamental approach to safety includes eliminating or reducing hazardous events at source. This safety approach can be termed inherently safer design or fail safe design and is typically permanent through the total service life and inseparable from the structure or structural component. Any such system can be highly effective in reducing risk provided it is maintained throughout the full life cycle of the structure.

Examples include specification of two bridge linked platforms separating accommodation functions from processing functions, and specification of a naturally buoyant floating structure in the event of loss of some, or all, of the mooring system.

Historically, structural engineering standards have dealt with structures which, if appropriately designed, built and operated, required little or no human intervention to ensure their integrity. However, the petroleum and natural gas industries now have some structures for which regular and frequent human intervention is needed to ensure that they perform as designed. Often the human intervention is in conjunction with computer-assistance that, whilst optimising routine performance, can complicate the human response to unexpected events.

Errors arising from human intervention have led to some significant incidents. Risk of human error can be minimized by a combination of design to eliminate the need for intervention, where possible, together with the introduction of appropriate procedures, alert and alarm systems, training, and supervision.

Typical examples of structural situations where the day-to-day operation and integrity requires human intervention include:

— ballasting operations on floating structures,

— cargo loading and unloading at sea from floating structures,

— positioning and control of tankers loading from a floating structure,

— control of the number of watertight doors open during tank inspections,

— shaft water management of gravity based structures, and

— ice management by support vessels.

Typical examples of infrequent activities where human input is critical include:

— positioning a jack-up mobile offshore unit in close proximity to a fixed platform, and

— response to hazardous events.

A.5.3 Functional requirements

No additional guidance is offered.

A.5.4 Requirements for specific phases of the life of the structure

No additional guidance is offered.

A.5.5 Requirements for durability and robustness

A.5.5.1 Durability, maintenance and inspection

No additional guidance is offered.

A.5.5.2 Robustness

Robustness implies insensitivity to small changes in conditions. The structure should be relatively insensitive to local damage and be damage tolerant, such that local damage does not escalate into complete loss of integrity of the structure or a critical part of the structure. In addition, a robust structure is also insensitive to small changes in actions, boundary conditions, stiffness and other assumptions (e.g. damping).

In post-damage design/assessment situations, robustness can also ensure that structural integrity in a damaged state is sufficient to prevent progressive collapse and as a minimum allow a process system shutdown, isolation of the reservoir and a safe evacuation, where applicable.

Ductility and reserve strength are important corollaries of robustness, which provide additional system resistance. When the first component reaches its ultimate strength (for extreme design/assessment situations, with a significant margin of safety with respect to its ULS criteria), the system as a whole is resisting the action effects. When the system or a critical part of the structure reaches its ultimate strength, the system as a whole is still resisting the action effects. However, some of the components will have suffered a loss of strength (due to yielding, buckling and the formation of plastic mechanisms) and, consequently, some of the actions they resisted will have redistributed to other components.

The extent to which structural robustness is available and can be mobilized depends on the configuration of the structure, the design/assessment situation, and the mode of failure. Multi-legged, lattice framed structures such as steel jackets and towers can be configured to achieve significant levels of robustness as can floaters through the introduction of multiple longitudinal bulkheads and double skin structure. For failure as a rigid body (e.g. sliding of a gravity-base structure, or loss of stability of a floating structure) the effect of robustness is generally minimal.

A.6 Basis for design/assessment

A.6.1 General

No additional guidance is offered.

A.6.2 Platform location and orientation

The site for the structure in latitude and longitude should be identified at the beginning of the design process to facilitate development of site-specific design parameters such as physical environmental conditions, geotechnical and geophysical parameters, and seismic exposure.

Minimum clearances between any combination of surface facilities and subsea infrastructures and components are in some cases addressed by the appropriate document for the actual structure type (i.e. document in the International Standards on offshore structures prepared by TC 67/SC 7). For circumstances not covered by these documents, the minimum clearance requirements should be identified through a suitable risk assessment process.

A.6.3 Physical environmental conditions

The need for appropriate physical environmental conditions can depend on the following:

— type of structure being designed/assessed;

— phase of life, i.e. construction (fabrication, transportation, installation), in-service (drilling, production, and other operational activities), decommissioning and removal;

— design/assessment situation considered.

ISO 19901-1 covers metocean basic variables and representative values:

— water depth, tides and storm surges;

— wind;

— waves;

— currents;

— marine growth;

— tsunamis;

— seiches;

— sea ice and icebergs;

— snow and ice accretion.

ISO 19901-2 covers seismic actions and design/assessment requirements to resist earthquakes.

ISO 19906 and ISO 35106[13] covers the following topics as well as supplementing some of those covered in ISO 19901-1, ISO 19901-2 and ISO 19901-4:

— daylight hours;

— air temperature;

— wind chill;

— precipitation and snow;

— ice accretion;

— visibility;

— polar lows;

— dissolved oxygen;

— sea temperature and salinity;

— sea ice and icebergs;

— permafrost;

— ice gouge;

— strudel scours.

Air and sea temperatures, accumulation of snow on horizontal and vertical surfaces (thickness and density), and the possibility of ice build-up through freezing of sea spray, rain or fog can affect the actions on the structure and the material selection of structural components.

Maximum, average and minimum air and sea temperatures should be determined for the field location, fabrication site and during transport, and estimates made of the probability distributions of the air and sea temperatures that are likely encountered during the total service life of the structure. Lowest anticipated service temperature can be important, particularly for material selection, for determining the temperature for impact testing of steel, and for winterization in arctic and cold regions.

In most offshore areas, marine growth can occur on submerged structural components. Marine growth increases surface roughness, mass, and diameter of tubular components, which in turn affect actions caused by waves, earthquakes and structural motions.

For the physical environment, evidence of climate change has been documented by various scientific organizations around the world, including the United Nations Intergovernmental Panel on Climate Change. Apparent effects could include changes in sea level and changes in frequency of environmental events.

Effects seem particularly noticeable in arctic regions, and include increasing annual average arctic temperature, and decreasing arctic sea ice extent in summer. Decreasing arctic sea ice extent in summer and the consequential retreat of the ice edge has resulted in increased fetch for waves in some locations, and therefore increased wave heights in summer storms.

ISO 19901-4 covers foundations, including:

— fault planes,

— seafloor instability,

— scour and sediment mobility,

— shallow gas,

— seabed subsidence, and

— carbonate soils.

ISO 19901-4 also covers supplementing topics, including the installation of shallow foundations, driven piles and various types of anchors, and the soil-structure interaction for auxiliary subsea structures, risers and flowlines.

ISO 19901-8 covers geotechnical investigations including marine soil investigations, but not rock investigations or geophysical investigations. Geophysical investigations will be covered by ISO 19901-10.

Usually it is necessary to establish several sets of conditions that take into consideration the following:

— day-to-day physical environmental conditions that are expected to occur frequently during the total service life of the structure: these conditions are required in order to develop environmental actions associated with particular operational, serviceability or fatigue design/assessment verifications;

— short duration physical environmental conditions: these conditions are required in order to plan field operations such as load-out, mating, transportation, installation, and hook-up;

— extreme environmental events and abnormal environmental events arising from physical environmental conditions that recur with a given return period or annual probability of exceedance or occurrence.

Periodicity of actions can cause dynamic effects. Therefore, it can be beneficial to establish the range of possible conditions for each of the above. For example, two different sea state conditions could have the same composite return period, but the sea state having lower wave heights or a longer or shorter associated period could cause more severe action effects on some structures or structural components.

A.6.4 Geotechnical and geophysical conditions

The presence of shallow gas can be determined by high resolution geophysical investigations. It can also be determined from 3D seismic data at deep water sites within certain limits assuming 3D seismic data are of sufficient resolution and appropriately processed, or reprocessed, for the purpose (see Reference [12]).

Movements of the seabed can be caused by ocean wave pressures, earthquakes, weight of seabed soils, mud volcanoes or a combination of these phenomena. Weak under-consolidated sediments can be unstable at very shallow angles of slope. Earthquakes can induce failure of sea floor slopes that are otherwise stable under existing forces.

Scour is removal of seabed soils by currents and waves. Such erosion can be a geological process or can be caused by structural components or mounds from drilling operations interrupting the natural fluid flow near the sea floor.

A.6.5 Specific design/assessment requirements

Stationkeeping systems can be categorized as active, semi-active, semi-passive, and passive.

Active stationkeeping systems involve continuous or defined condition adjustments. Active stationkeeping systems include dynamic positioning based on thrusters or catenary systems based on dynamic adjustment of mooring line tensions.

Passive stationkeeping systems do not require real-time or active control. Passive stationkeeping systems include catenary mooring, taut-line mooring, spring buoy, catenary-anchored buoy, articulated leg and tension leg systems.

The design/assessment and specification of certain key components, such as risers, can typically involve engineers and suppliers outside the structural engineering disciplines. Consequently, the interface with the relevant discipline engineers is particularly important and information needed for both structural and other disciplines should be planned to be shared in a timely manner.

A.7 Development of design/assessment situations

A.7.1 Hazards

The test of 'reasonably foreseeable' is required when identifying hazards. All hazards that can be 'reasonably foreseeable' should be identified and documented regardless of probability, before being evaluated and screened for relevance for structural design/assessment or risk management.

Examples of hazards that can be relevant for an offshore structure include

— human error or negligence,

— unplanned or unexpected operational activity,

— unexpected events during personnel and material transfer and movement,

— inadequate topsides weight management,

— failure of a supporting system (such as a control system to manage thruster-assisted stationkeeping systems),

— vandalism and malicious attacks,

— environmental conditions, such as storms, earthquakes, and ice features,

— vessels, such as supply vessels and general shipping traffic,

— objects that can drop (for topsides, substructures, and appurtenances),

— fires and explosions,

— shallow geohazards and other geological processes, and

— scour and ice gouge.

Inherent or hidden defects such as possibly created during fabrication could also be considered as within the definition of hazards. Such hazards can impact the resistance assumptions, but do not cause actions. The extent to which they are foreseeable is usually uncertain.

A.7.2 Hazardous events

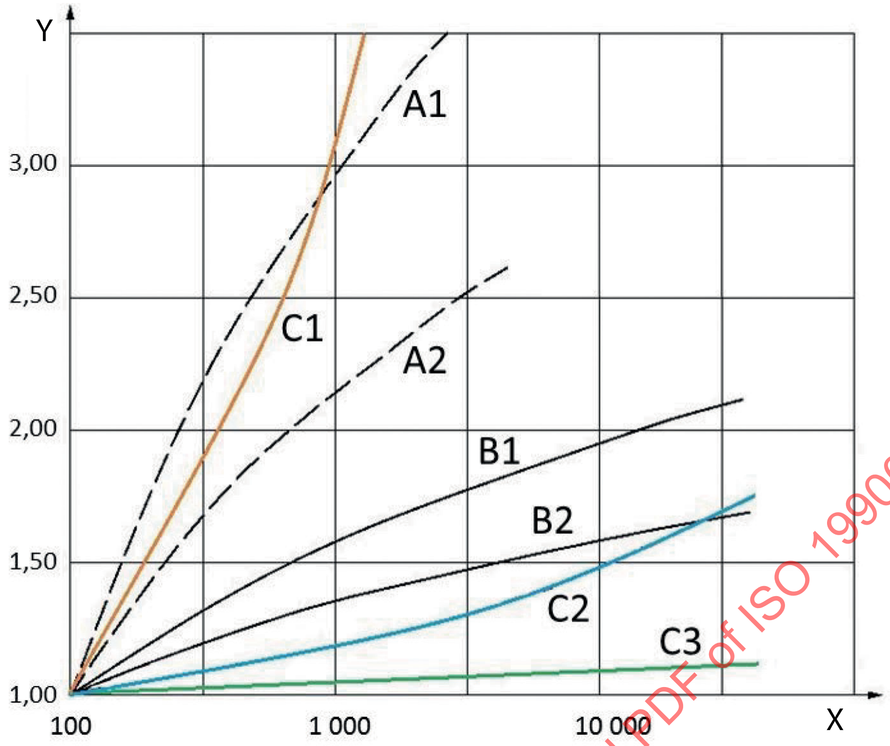
While hazards cover the full set of potential sources of harm to offshore structures, the term 'hazardous event' is used to cover the subset of hazards that can be reasonably foreseeable to interact with the structure under consideration, during any phase of the life of the structure including decommissioning. Thus, while an iceberg is a hazard to an offshore structure, the possible impact of an iceberg with a jacket structure in an equatorial region is not a hazardous event with a probability sufficient to be considered for that structure.

Principles and strategies both to prevent the occurrence of hazardous events and to limit the possible consequences are provided in ISO 17776[4].

For hazards arising from the physical environment, a hazard curve can describe the variation in the magnitude of the action caused by hazardous events with return period or annual probability of exceedance. Figure A.1 shows example hazard curves covering wave actions (for steel offshore platforms that are drag dominated), earthquake actions, and actions from different types of ice feature.

NOTE Hazard curves can also be presented with return period or probability of exceedance on the vertical axis.

In the examples given in Figure A.1, the "slope" of the hazard curve is relatively mild for sea ice actions, steeper for wave actions on drag dominated structures and significantly steeper for earthquake and iceberg actions.



Key

Y E_{RP}/E_{100}, ratio of the environmental action E_{RP} at different return periods to the 100-year action E_{100}.
X Return Period (years)
A1 earthquake action, high slope, see ISO 19901-2
A2 earthquake action, low slope, see ISO 19901-2
B1 wave actions representative of Gulf of Mexico, see Reference [9]
B2 wave actions representative of Central North Sea, see Reference [9]
C1 ice actions, icebergs, Grand Banks, Canada, from data in Reference [7]
C2 ice actions, 5 % multiyear ice, Beaufort Sea, from data in Reference [7]
C3 ice actions, first year ice ridges, Sakhalin, from data in Reference [7]

Figure A.1 — Example action hazard curves

Very unlikely hazardous events have occurrence probabilities lower than those for which a design/assessment situation is required to be established, i.e. return periods greater than 10 000 years. Actions and action effects for very unlikely hazardous events are not required to be quantified. Therefore, a very unlikely hazardous event, for which the structure is not designed, could cause collapse. This would be a risk event for which the risk can be assessed. The risk event can be considered for inclusion on a risk matrix as a risk to the structure for which it is not designed.

The significance with respect to the risk profile of the structure could be an issue that the operator chooses to assess, based on risk management policy and planning, as pertaining to the likelihood of economic loss and other consequences. The operator in discussion with other stakeholders could choose to determine contingency plans, equipment, processes, and resources to manage the response to the approaching hazard and to mitigate any consequences of a very unlikely hazardous event. Care should be taken in how reliability targets are interpreted when assessing the relative risk (see for example References [6] and [11]).

A.7.3 Exposure levels

Exposure level is a measure of exposure to risk events in terms of severity of consequences. Targets for structural reliability vary with exposure level in order to take account of the consequences of structural failure or collapse.

The philosophy for offshore structures is that manned platforms should be designed and built to the most stringent criteria irrespective of the number of personnel accommodated. However, simply differentiating a platform as either ‘manned’ or ‘unmanned’ is not sufficient.

For some unlikely but potentially high consequence hazardous events that can be forecast and tracked well in advance of interacting with the structure, e.g. large cyclones and icebergs, it is recognized that personnel can be evacuated or a floating structure disconnected and moved from its normal operating location, so that life-safety risk due to the potential hazardous event is mitigated. This relies on adequate information, procedures, resources, and correct decision making; these factors are largely outside the scope of structural standards. Furthermore, evacuation or relocation are not risk free, e.g. helicopter flights or personnel transfer onto support vessels, failure of mooring and riser disconnect systems.

Consequently, a risk assessment is specified herein to ensure that any actions triggered in response, such as evacuation or relocation, do not lead to a higher risk to the personnel during the total service life of the platform than the risk from remaining aboard the platform or remaining on-site. This recognizes that the threshold to trigger a response, such as evacuation or relocation, should be well below the threshold likely to cause major structural failure or complete loss of the platform and the likely loss of life from the various failure scenarios.

Risk assessment should include consideration of the following activities associated with potential or actual hazardous events, as appropriate:

a) risk to personnel from additional evacuation activities (both de-manning and re-manning the platform), e.g. additional helicopter flights, or specific floating platform relocation activities (see also Reference [8]);

b) risk to personnel on adjacent platform/vessel from the failed or damaged platform;

c) risk to temporary maintenance personnel on a failed or damaged platform during the hazardous event;

d) risk to personnel who would typically be engaged in any activity to decommission, salvage, or repair a damaged platform.

Inspection and maintenance personnel can be on otherwise unmanned platforms for extended periods of time. Of particular concern could be personnel making many offshore visits to unmanned platforms. Unless there are plans for evacuation when a hazardous event is foreseeable, their risk of being on one specific platform during the hazardous event can be modest, but their risk of being on any one of the platforms can be significant.

A.7.4 Design/assessment situations

Each design/assessment situation is established so that the structure or structural component can be verified to satisfy the design/assessment criteria for a specified limit state when subject to design action effects which result from the specified actions. Various physical conditions and other criteria can be specified for each design/assessment situation, such as the following:

— category of design/assessment situation;

— hazardous event or dominating source of action;

— applicable exposure level(s) (includes aspects such as manning and inventory risk);

— structural configuration (such as under construction and in-place, and specific component configurations such as original or in-service defects, damage, and deterioration);

— structural system (parts resisting event and actions);

— operational measures (e.g. ice management, disconnection criteria, evacuation and shutdown criteria);

— facility operational configuration (e.g. drilling, temporary works);

— principal and companion actions;

— combination of action types, with partial action factors;

— partial material and/or resistance factors;

— limit state (specific criteria for SLS, ULS, ALS and/or FLS);

— choice of structural modelling and preferred method of analysis.

If a hazard curve has been developed for a series of hazardous events arising from that hazard, different design/assessment situations can be selected at different points on the hazard curve (see also A.7.2).

An overview of the different design/assessment situations with a simplified summary of key criteria is provided in Table A.1.

Table A.1 — Simplified summary of key criteria for design/assessment situations

Category of design/ assessment situation	Type of principal action (see 9.2)	Basis for value of principal action[a]	Typical partial factors for actions	Modelling and analysis	Limit states
Operational (see 7.4.2)	G and/or Q	Nominal[b], maximum[c], or representative[a,c]	γ	linear elastic[d]	ULS_1 and ULS_2
Extreme (see 7.4.3)	E	Typically 100 yr (10^{-2} p.a.)[d] (see 7.2)	γ varies with exposure level	linear elastic[d]	ULS_1 and ULS_2
Abnormal (see 7.4.4)	E	Up to 10 000 yr (to 10^{-4} p.a.)[d] — varies with exposure level (see 7.2)	1,0	non-linear[d] (or lin. elastic[d])	ULS_2 and ALS
Accidental (see 7.4.5)	A	Up to 10 000 yr (to 10^{-4} p.a.)[d] — varies with exposure level (see 7.2)	1,0	non-linear[d] (or lin. elastic[d])	ULS_2 and ALS
Short duration (see 7.4.6)	G and/or Q, or E	Nominal[b], maximum[c], or extreme[d], subject to specification of d/a situation	γ or 1,0	linear elastic[d]	ULS_1, ULS_2, and ALS
Serviceability (see 7.4.7)	G and/or Q, or E	Nominal[b] or maximum[c]	1,0	linear elastic[d]	SLS

NOTE For earthquakes, see ISO 19901-2.

[a] For actions based on events, see 7.2. Action frequencies in this table are expressed in terms of return period in years (annual probability of exceedance/occurrence)

[b] See 8.2 and 9.2 for nominal values.

[c] See 9.3 for operational values.

[d] Simplification for clarity, refer to full text for details and variations.

The word 'operational' is used for a design/assessment situation for ULS, and later to describe the action type denoted by the symbol Q (see 9.3). This is firstly to differentiate the design/assessment situation for ULS from normal or day-to-day operating situations, and secondly to differentiate operational actions from environmental actions, both of which are variable. In other standards for structural and building engineering, both are described as variable actions, and the differentiation herein between operational and environmental is intended to improve consistency. The word 'operational' continues to be also used to describe procedures for operations, such as ice management, and for conditions prevailing during normal or day-to-day operation of a platform.

Operational and extreme design/assessment situations include partial factors or other ratios, the application of which result in adequate reliability for individual structural components and for the structure as a whole.

Abnormal and accidental design/assessment situations address the avoidance of complete loss of integrity of the structure or critical parts of the structure based on representative values with specified small exceedance probabilities, such that reliability of the structural system, i.e. of structure as a whole or a critical part of the structure, is adequate with application of partial factors of unity.

An alternative approach to ensure adequate system reliability of fixed steel offshore and similar structures in extreme metocean design/assessment situations is to calculate the reserve strength ratio (RSR). This approach replaces the limit state verification method for the ULS_1 design/assessment verification under extreme metocean design/assessment situations only. Because the analysis proceeds to overall collapse, local structural failure will occur. This alternative approach does not replace design/assessment verification in abnormal and accidental design/assessment situations.

Design/assessment situations involving abnormal or accidental events, such as ship collision, helicopter accident, or iceberg impact, usually follow a two-step procedure:

— establishing the abnormal or accidental design/assessment situation and verifying the structure to the ALS while estimating the relevant damage. This includes the local behaviour of the impacted area, and the global strength of the structural system against overall collapse;

— establishing post-damage design/assessment situations which account for the damaged configuration of the structure, and verifying its post-damage integrity for short duration as described in 7.4.6.

Energy absorption of the overall structural system arises from the combined effect of local and global deformation, with adequate structural continuity.

The structural integrity of the structural system with respect to progressive or disproportionate collapse due to failure of a critical structural component can be improved by providing that component with additional resistance, for example by applying partial factors greater than 1,0 for calculating local design action effects and verifying the design/assessment of that component. Such partial factors for abnormal and accidental design/assessment situations can be taken as those for operational or extreme design/assessment situations, or can be selected between 1,0 and the partial factors for operational or extreme design/assessment situations, e.g. by calibration.

Alternatively, a post-damage design/assessment situation can be established, and the structural integrity of the structural system can be assessed based on structural configurations for which one or more critical structural components have failed or been weakened. These damaged components can be removed from the analysis, or appropriately modelled to simulate their reduced strength and stiffness. Analysis is usually performed using linear static analysis.

Short-duration design/assessment situations are intended to include all types of operational and extreme events and actions but with representative actions suitably modified for the short duration. If the duration, or exposure to environmental events and actions is less than one year, representative values of actions are usually based on return periods less than (exceedance probabilities greater than) those for the extreme environmental action. This is justified by the probability of occurrence/exceedance over the short duration, including any seasonal variation, being similar to the annual probability of occurrence/exceedance of the extreme environmental action. It is also possible to include relevant abnormal and accidental events and actions suitably modified for the short duration design/assessment situation.

Consideration of post-damage design/assessment situations is important for the design and structure configuration. The rationale for design is that damage can develop due to a fault sequence of events, and it becomes important to establish a barrier to stop the escalation of events. For the structure, this