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Petroleum and natural gas industries — General requirements for offshore structures

Industries du pétrole et du gaz naturel — Exigences générales pour les 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

ISO 19900 was prepared by Technical Committee ISO/TC 67, *Petroleum and natural gas industries*, Subcommittee SC 7, *Offshore structures*.

This first edition of ISO 19900 cancels and replaces ISO 13819-1:1995, which has been editorially revised.

ISO 19900 is one of a series of standards for offshore structures. The full series consists of the following International Standards:

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

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*

The following International Standards are under preparation:

ISO 19901-1, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Meteocean 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 19901-6, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 6: Marine operations*

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

ISO/TS 19903, *Petroleum and natural gas industries — Fixed concrete offshore structures*

ISO 19904, *Petroleum and natural gas industries — Floating offshore structures including stationkeeping*

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

ISO/TR 19905-2, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 2: Jack-ups commentary*

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

Introduction

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

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

The offshore structures International Standards are intended to provide a wide latitude in the choice of structural configurations, materials and techniques without hindering innovation. Sound engineering judgement is therefore necessary in the use of these International Standards.

ISO 19900 applies to offshore structures and is in accordance with the principles of ISO 2394 (see Reference [1] in the Bibliography). It includes, where appropriate, additional provisions that are specific to offshore structures.

Petroleum and natural gas industries — General requirements for offshore structures

1 Scope

This International Standard specifies general principles for the design and assessment of structures subjected to known or foreseeable types of actions. These general principles are applicable worldwide to all types of offshore structures including bottom-founded structures as well as floating structures and to all types of materials used including steel, concrete and aluminium.

This International Standard specifies design principles that are applicable to the successive stages in construction (namely fabrication, transportation and installation), to the use of the structure during its intended life and to its decommissioning. Generally, the principles are also applicable to the assessment or modification of existing structures. Aspects related to quality control are also addressed.

This International Standard is applicable to the design of complete structures including substructures, topsides structures, vessel hulls, foundations and mooring systems.

2 Terms and definitions

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

2.1
action
external load applied to the structure (direct action) or an imposed deformation or acceleration (indirect action)

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

NOTE An earthquake typically generates imposed accelerations.

2.2
action effect
effect of actions on structural components

EXAMPLE Internal force, moment, stress or strain.

2.3
air gap
clearance between the highest water surface that occurs during the extreme environmental conditions and the lowest exposed part not designed to withstand wave impingement

2.4
appurtenance
part of the structure that is installed to assist installation, to provide access or protection, or for transfer of fluids

2.5
basic variable
one of a specified set of variables representing physical quantities which characterize actions, environmental influences, geometrical quantities, or material properties including soil properties

2.6
catenary mooring
mooring system where the restoring action is provided by the distributed weight of mooring lines

2.7
characteristic value
value assigned to a basic variable associated with a prescribed probability of not being violated by unfavourable values during some reference period

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

2.8
compliant structure
structure that is sufficiently flexible that applied lateral dynamic actions are substantially balanced by inertial reactions

2.9
conductor
tubular pipe extending upward from the sea floor or below containing pipes that extend into the petroleum reservoir

2.10
decommissioning
process of shutting down a platform and removing hazardous materials at the end of its production life

2.11
design criteria
quantitative formulations that describe the conditions to be fulfilled for each limit state

2.12
design service life
assumed period for which a structure is to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary

2.13
design situation
set of physical conditions representing real conditions during a certain time interval for which the design will demonstrate that relevant limit states are not exceeded

2.14
design value
value derived from the representative value for use in the design verification procedure

2.15
exposure level
classification system used to define the requirements for a structure based on consideration of life safety and of environmental and economic consequences of failure

NOTE The method for determining exposure levels are described in ISO 19902[2]. An exposure level 1 platform is the most critical and exposure level 3 the least. A normally manned platform which cannot be reliably evacuated before a design event will be an exposure level 1 platform.

2.16
fit-for-purpose
meeting the intent of an International Standard although not meeting specific provisions of that International Standard in local areas, such that failure in these areas will not cause unacceptable risk to life-safety or the environment

2.17
fixed structure
structure that is bottom founded and transfers all actions on it to the seabed

2.18
floating structure
structure where the full weight is supported by buoyancy

2.19
jack-up
mobile offshore unit that can be relocated and is bottom founded in its operating mode

NOTE A jack-up reaches its operational mode by lowering legs to the sea floor and then jacking the hull to the required elevation.

2.20
mobile offshore unit
MOU
structure intended to be frequently relocated to perform a particular function

2.21
limit state
state beyond which the structure no longer fulfils the relevant design criteria

2.22
nominal value
value assigned to a basic variable determined on a non-statistical basis, typically from acquired experience or physical conditions

2.23
platform
complete assembly including structure, topsides and, where applicable, foundations

2.24
reference period
period of time used as basis for determining values of basic variables

2.25
reliability
ability of a structure or a structural component to fulfil the specified requirements

2.26
representative value
value assigned to a basic variable for verification of a limit state

2.27
resistance
capacity of a component, or a cross-section of a component, to withstand action effects without failure

2.28
return period
reciprocal of the probability of exceeding an event during a particular period of time

NOTE The return period is the average time (usually in years) between occurrences of an event exceeding a specified magnitude.

2.29
riser
tubular used for the transport of fluids between the sea floor and a termination point on the platform

NOTE For a fixed structure the termination point is usually the topsides. For floating structures the riser may terminate at other locations of the platform.

2.30
scour
removal of seabed soils caused by currents and waves

NOTE Such erosion can be due to natural processes or can be due to interruption of the natural flow regime near the sea floor by structural elements.

2.31
splash zone
area of a structure that is frequently wetted due to waves and tidal variations

2.32
structural system
load-bearing components of a structure and the way in which these components function together

2.33
structural component
physically distinguishable part of a structure

EXAMPLE Column, beam, stiffened plate, tubular joint, or foundation pile.

2.34
structural model
idealization of the structural system used for design or assessment

2.35
structure
organized combination of connected parts designed to withstand actions and provide adequate rigidity

2.36
structure orientation
position of a structure in plan referenced to a fixed direction such as true north

2.37
taut-line mooring
mooring system where the restoring action is provided by elastic deformation of mooring lines

2.38
topsides
structures and equipment placed on a supporting structure (fixed or floating) to provide some or all of a platform's functions

NOTE 1 For a ship-shaped floating structure, the deck is not part of the topsides.

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

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

3 Symbols and abbreviated terms

3.1 Symbols

A accidental action

a_d design value of geometrical parameter

a_k characteristic value of geometrical parameter

C constraint (see 5.1.4 and 8.1)

E environmental action

F_d design value of action

F_r representative value of action

f_d design value of material property, for example strength

f_k characteristic value of material property, for example strength

G permanent action

G_k characteristic value of permanent action

Q variable action

Q_k characteristic value of variable action

R_d design value of component resistance

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

γ_d factor related to model uncertainty or other circumstances that are not taken into account by the other γ values

γ_f partial action factor of which the value reflects the uncertainty or randomness of the action (see 8.2.2)

γ_m partial material factor of which the value reflects the uncertainty or variability of the material property (see 8.3.2)

γ_n factor by which the importance of the structure and the consequences of failure, including the significance of the type of failure, may be taken into account and of which the value of γ_n depends on the design situation under consideration

γ_R partial resistance factor of which the value reflects the uncertainty or variability of the component resistance including those of material properties (see 8.5)

Δ_a additive partial geometrical quantity of which the value reflects the uncertainties of the geometrical parameter (see 8.4.2)

Ψ_0 reduction factor to account for reduced probability of simultaneous independent actions (see 8.2.3)

Ψ_1, Ψ_2 factors relating characteristic values to representative values for variable actions (see 8.2.1)

3.2 Abbreviated terms

ALS accidental limit state

FLS fatigue limit state

SLS serviceability limit state

ULS ultimate limit state

4 General requirements and conditions

4.1 Fundamental requirements

A structure and its structural components shall be designed, constructed and maintained so that it is suited to its intended use. In particular, it shall, with appropriate degrees of reliability, fulfil the following performance requirements:

a) it shall withstand actions liable to occur during its construction and anticipated use (ULS requirement);

b) it shall perform adequately under all expected actions (SLS requirement);

c) it shall not fail under repeated actions (FLS);

d) in the case of hazards (accidental or abnormal events), it shall not be subsequently damaged disproportionately to the original cause (ALS);

e) appropriate degrees of reliability depend upon:

- the cause and mode of failure;
- the possible consequences of failure in terms of risk to life, environment and property;
- the expense and effort required to reduce the risk of failure;
- different requirements at national, regional or local level.

This International Standard provides criteria so that the above requirements are fulfilled during the intended life of the structure.

A structure designed and constructed in accordance with this International Standard may be assumed to comply with the above requirements.

4.2 Durability, maintenance and inspection

The durability of the structure in its environment shall be such that the general state of the structure is kept at an acceptable level during its life.

Maintenance shall include the performance of regular inspections, inspections on special occasions (e.g. after an earthquake or other severe environmental event), the upgrading of protection systems and repair of structural components.

Durability of the structure shall be achieved by either

a) a maintenance program, or

b) by designing the structure so as to allow for deterioration in those areas which cannot be, or are not expected to be, maintained during the planned life of the structure.

In the case of a), the structure shall be designed and constructed so that no significant degradation is likely to occur within the time intervals between the inspections. The necessity of relevant parts of the structure being available for inspection, without unreasonably complicated dismantling, shall be considered during design. Degradation may be reduced or prevented by providing a suitable protection system.

The rate of deterioration may be estimated on the basis of calculations, experimental investigations, experience from other structures or a combination of these.

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

4.3 Hazards

4.3.1 General

Hazardous circumstances, that alone or in combination with normal conditions could cause the SLS or ULS to be exceeded, shall be taken into account.

Possible hazards to the structure and its components include

a) an error caused by lack of information, omission, misunderstanding, etc.,

b) effects of abnormal actions, or

c) operation malfunction that could lead to fire, explosion, capsizing, etc.

The measures taken to counter such hazards basically consist of

— careful planning at all phases of development and operation,

— avoiding the structural effects of the hazards by either eliminating the source or by bypassing and overcoming them,

— minimizing the consequences, or

— designing for the hazards.

In considering a specific hazard, a design situation shall be defined (see 5.2.2). This design situation will normally be dominated by one hazardous occurrence with expected concurrent normal operating conditions.

4.3.2 Accidental events

The possibility of accidental events shall be considered, and suitable criteria shall be established, when appropriate. Possible accidental events include, for example, vessel collision, dropped objects, explosion, fire and unintentional flooding. Design requirements shall be established taking account of the operational conditions and the type, function and location of the structure.

4.4 Design basis

The influences arising from the intended use of the structure and the environmental conditions shall be described as the design situations associated with normal use of the structure. The influences arising during construction of the structure and the associated environmental conditions shall also be covered by suitable design situations (see 5.2.2).

All relevant influences and conditions shall be considered in order to establish the design basis for the structure. The principal influences and conditions that should be considered to establish the design basis for offshore structures are described in 4.5 to 4.12.

4.5 Service requirements

The service requirements and the expected service life shall be specified. The structure may be used for drilling, producing, storage, personnel accommodation, or other function or combination of functions.

4.6 Operating requirements

4.6.1 Manning

The manning level for each phase of the structure's life shall be specified.

4.6.2 Conductors and risers

The number, location, size, spacing and operating conditions of all conductors and risers shall be specified and taken into account in the structural design. The design and/or layout shall provide protection to conductors and risers from accidental damage.

The design should have provisions to mitigate the consequences of accidental damage to conductors and risers.

4.6.3 Equipment and material layouts

Equipment and material layouts and their associated weights, centres of gravity and exposure to environmental actions shall be specified. Consideration should be given to planned future operations.

4.6.4 Personnel and material transfer

Plans for transferring personnel and materials shall be specified, for example

a) the types, sizes and weights of helicopters,

b) the types, sizes and displacements of supply and other service vessels,

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

d) planned emergency personnel evacuation.

4.6.5 Motions and vibrations

Structures and parts of structures shall be designed so that accelerations, velocities and displacements do not impair safety and serviceability within defined limits.

4.7 Special requirements

All special operational, construction and maintenance requirements not covered under 4.6.1 to 4.6.5 that can affect the safety of the structure shall be specified, together with their expected concurrent environmental conditions.

The limiting environmental conditions specific to certain operations should be specified.

NOTE This will normally apply to floating units (e.g. limiting environmental conditions for certain drafts) or MOUs (e.g. limiting environmental conditions for a jack-up when the cantilever is fully extended).

4.8 Location and orientation

The site location and structure orientation shall be specified. For structures designed to be relocatable, the range of limiting environmental conditions, water depths and soil conditions should be provided.

The site for the structure in latitude and longitude should be identified early in order that the appropriate environmental conditions and soil conditions can be identified.

4.9 Structural configuration

4.9.1 General

The choice of the structural system shall be made such that the primary structure is able to maintain adequate structural integrity during normal service and after specified situations that apply actions on the structure. The choice of materials, detailing and method of construction as well as quality control can influence structural integrity.

4.9.2 Deck elevation

The topsides structure shall normally have adequate clearance above the design wave crest. Any topsides structure or piping not having adequate clearance (air gap) shall be designed for actions caused by waves and currents. Minor structure or components may be excluded from this requirement.

The deck elevation and air gap shall be determined taking into account the values of and uncertainties in the following parameters as applicable:

a) water depth;

b) tides and surges;

c) crest elevation of extreme waves;

d) wave-structure interaction;

e) structure motion and draft;

f) initial and long-term settlements and inclination;

g) subsidence.

4.9.3 Splash zone

The splash zone extent shall be established taking into account the values of the platform elevation, motions of floating vessels, tidal ranges, wave crests and wave troughs.

For floating structures with possibilities for draft adjustment, the splash zone shall be defined relative to the extreme draft levels expected.

NOTE The splash zone is that part of a structure that is intermittently exposed to air and immersed in the sea. The splash zone is important in relation to inspection and maintenance considerations and can have an impact on the design to resist corrosion and fatigue.

4.9.4 Stationkeeping systems

Floating structures shall be provided with a stationkeeping system, which may be either passive or active or a combination of both passive and active.

The stationkeeping system shall be designed to maintain adequate position reference as well as directional control when orientation is important for safety or operational considerations.

Passive stationkeeping systems include catenary mooring, taut-line mooring, spring buoy, articulated leg and tension leg systems. Active systems include dynamic positioning based on thrusters or catenary systems based on changing mooring line tensions.

A mooring system for floating structures may be designed to be disconnectable to mitigate the effects of severe storms, if the disconnection can be accomplished in a controlled manner without

a) impairing the safety of personnel on board the unit or a neighbouring infrastructure, or

b) creating undue risk to the environment.

4.9.5 Compartmentation of structures

Floating structures or structures for which buoyancy is important shall normally be subdivided into compartments to limit the consequences of unintended flooding (see 5.1.6).

The amount of compartmentation should be determined after considering special conditions and protection measures that can be used to prevent flooding. Fewer compartments may be justified, if buoyancy is only needed in temporary phases or if the consequences of flooding have only minor effects on the overall reliability.

4.10 Environmental conditions

4.10.1 Meteorological and oceanographical information

4.10.1.1 General

The phenomena listed in 4.10.1.2 through 4.10.1.9 shall, where appropriate to the region, be taken into account in the design.

These phenomena shall be described by physical characteristics and, where available, statistics. The joint occurrence of different values of parameters should also be defined when suitable data are available. From this information, appropriate environmental design conditions shall be established that will consider the following:

a) the type of structure being designed;

b) the phase of development (e.g. construction, transportation, installation, drilling, production, etc.);

c) the limit-state considered.

Usually two sets of conditions have to be established that take into consideration the following:

— Consideration for normal meteorological and oceanographical conditions that are expected to occur frequently during the life of the structure. These conditions are needed to plan field operations such as installation and to develop the actions caused by the environment associated with particular operations or serviceability checks.

— Consideration for extreme meteorological and oceanographical conditions that recur with a given return period or probability of occurrence.

Extreme, normal and other meteorological and oceanographical parameters shall be determined from actual measurements at the site or by suitable validated model data such as from hindcast models.

NOTE 1 Environmental actions are generally derived from design environmental conditions. The extreme environmental conditions normally have a specified return period for the in-service condition (see 8.2.1). Alternatively, the action associated with extreme environmental conditions can be defined to have a specified return period, if adequate data exist to reliably determine the specified return period, allowing for the joint occurrence of extreme meteorological and oceanographical conditions occurring at the site and further provided that the partial factors are selected accordingly.

NOTE 2 Normally the structure's response to actions caused by the environment are investigated for a range of potential combinations of environmental parameters and consideration is given to the relationship considering the closeness of the wave period compared to the natural response period of motion or vibration. For example, for two different sea-state conditions, each having the same composite return period, it is possible that the sea-state having lower wave heights but a longer or shorter associated period will develop more severe action effects on some components.

NOTE 3 Compliant or floating structures are generally sensitive to more environmental parameters than fixed or bottom-founded structures, since dynamic effects are more significant for such structures.

NOTE 4 Normally consideration is given to specific problems such as the tuning of a characteristic dimension of the structure with respect to wavelengths, for example

a) the distance between the main legs of gravity-based structures or semi-submersible units, or

b) the length of the hull of a ship-shaped barge.

4.10.1.2 Wind

Actions caused by wind acting on a structure shall be considered for both the global and local design. Site-specific information on wind speed, direction and duration shall be determined.

Wind is usually characterized by the mean value of its velocity over a given time interval at a given elevation above the mean water level. In specific cases (for example, design of flexible structures such as flare-towers and compliant structures with periods of motion that are large), the frequency content is of importance and should be taken into account.

The variability with elevation and the spatial coherence should be considered.

NOTE Generally, the sustained wind speed at the time of peak actions caused by waves is used for global design in conjunction with wave actions. Maximum gust conditions during the design storm are used to design topsides and individual members.

4.10.1.3 Waves

Actions caused by waves acting on a structure shall be considered for both the global and the local design. Site-specific information shall be established to consider the following:

a) sea state characteristics in terms of wave height, period, duration, directions and spectra, and

b) the long-term statistics of these characteristics.

4.10.1.4 Water depth and sea level variations

The water depth shall be determined. The magnitude of the low and high tides and positive and negative storm surges shall be determined.

The possibility of ground subsidence shall be considered when determining the water depth.

4.10.1.5 Currents

Phenomena such as tidal, wind driven, global circulation, loop and eddy currents shall be considered when relevant.

Currents shall be described by their velocity (magnitude and direction), variability with water depth and persistence.

The occurrence of fluid motion caused by internal waves should be considered.

NOTE Global circulation currents are driven by large-scale global effects. Loop currents are associated with major ocean current circulation patterns as they conform to the landmasses, e.g. Gulf of Mexico loop current. Eddy currents are meso-scale circulatory features shed from loop or other major circulation currents. Eddy currents can persist for several months or more. Internal waves are propagating waves that can occur at the interface between layers of fluids having different densities.

4.10.1.6 Marine growth

Marine growth shall be considered and defined by its thickness, roughness, density and variation with depth.

The design may rely on periodic marine growth cleaning or anti-fouling systems during the platform life. Any such reliance shall be documented and the cleaning program defined over the life of the platform. The consequences of not maintaining this program should be determined and reported.

NOTE In most offshore areas, marine growth will occur on submerged platform members. Marine growth increases surface roughness, member diameter and mass, which in turn affects actions caused by waves and earthquakes and structural motions.

4.10.1.7 Ice and snow

Ice and snow accumulations shall be considered when relevant to the region. The accumulation of snow on horizontal and vertical surfaces (thickness and density) shall be defined. The maximum wind, waves and current to consider at the same time shall be stated. In addition, the possibility of ice build-up through freezing of sea spray, rain or fog shall also be considered.

Sea ice and iceberg occurrences shall be considered when relevant.

4.10.1.8 Temperatures

The maximum, average and minimum air and sea temperatures at the site shall be determined when temperatures are likely to be relevant to structural design.

NOTE Air and sea temperatures can affect the characteristics of materials.

4.10.1.9 Other meteorological and oceanographical information

Other environmental information such as precipitation, fog, wind chill and variability of the density and oxygen content of the sea water shall be determined when relevant.

4.10.2 Active geological processes

4.10.2.1 General

The nature, magnitude and return periods of potential seabed movements shall be evaluated by

a) site investigations and analysis, or

b) model testing.

Seabed behaviour and its influence on the overall integrity of the structure and foundation shall be documented. Information should include such items as relic permafrost in cold regions, the potential for subsidence, etc.

NOTE In most offshore areas, geological processes associated with movement of the near surface sediments can occur within time periods relevant to platform design. Due to the uncertainty associated with definition of these processes, a parametric approach to studies can be helpful in development of design criteria.

4.10.2.2 Earthquakes

Actions resulting from seismic activity shall be considered in the structure design for regions that are considered to be seismically active.

The seismic hazard may be determined on the basis of previous records of seismic activity, both in magnitude and probability of occurrence. If there are insufficient data, seismicity may be determined by detailed site-specific investigations. The latter should include

a) seismotectonic and site characterization, including location of potential causative faults and fault slip history, if available,

b) seismic exposure assessment, including long-term event occurrence probabilities,

c) ground motion characterization, including attenuation, and

d) definition of the design ground motion.

4.10.2.3 Faults

Siting of facilities in close proximity to faults shall be avoided, if at all possible. If siting near potentially active features cannot be avoided, the magnitude and time scale of expected movements shall be estimated on the basis of a geological study and demonstrated to lead to acceptable consequences and/or low risk of occurrence.

NOTE In some offshore areas, faults can extend to the sea floor with potential for either vertical or horizontal movement. Fault movement can occur as a result of seismic activity, removal of fluids from deep reservoirs or long-term creep related to large-scale sedimentation or erosion.

4.10.2.4 Shallow gas

The presence of shallow gas shall be determined as part of the site-specific investigations.

NOTE If either biogenic or petrogenic gas is present in the pore-water of near-surface soils, it can have a serious effect on the foundation behaviour and drilling operations. The presence of shallow gas can be determined by means of shallow seismic measurements.

4.10.3 Geotechnical information

4.10.3.1 Soil properties

Site investigations shall be performed to define the various soil strata, their corresponding physical and engineering properties and potential hazards to the structure.

The site investigations shall provide adequate information to characterize soil properties throughout the depth and area that will affect or be affected by the structure foundation.

Site investigations should include one or more soil borings to provide samples and/or *in situ* test data suitable for defining engineering properties at the platform site. The number and depths of borings required depend on the soil variability in the vicinity of the site, the platform configuration and expected actions.

Geophysical surveys should usually be part of the site investigations and should generally be carried out before soil borings are taken. In order to develop the required foundation design parameters, data obtained during the investigations should be considered in combination with an evaluation of the shallow geology of the region.

If practical, the soil sampling and testing program should be defined after reviewing the geophysical results.

NOTE Previous site investigations and experience at the site can reduce or eliminate the number and extent of investigations or studies needed for additional structures.

4.10.3.2 Seabed instability

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

a) identification of metastable geological features surrounding the site, and

b) definition of the geotechnical properties required for modelling and estimating seabed movement.

NOTE Movements of the seabed can be caused by ocean wave pressures, earthquakes, weight of seabed soils 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 due to the weight of seabed soils and wave conditions.

4.10.3.3 Scour

The possibility of scour shall be accounted for in the design. The extent of scour shall be determined:

a) on the basis of previous records from sites with similar seabed features,

b) from model tests, or

c) from calculations calibrated by prototype or model tests.

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

4.11 Construction

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. Design requirements shall be established taking into account the type of structure and its location, the environmental conditions, the construction equipment and the nature and duration of the construction operations.

4.12 Decommissioning and removal

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

5 Principles of limit states design

5.1 Limit states

5.1.1 General

The structural performance of a whole structure or part of it shall be described with reference to a specified set of limit states beyond which the structure no longer satisfies the design requirements.

5.1.2 Categories of limit states

The limit states are divided into the following four categories which, in turn, may be subdivided:

a) the ultimate limit states (ULS) that generally correspond to the resistance to maximum applied actions;

b) the serviceability limit states (SLS) that correspond to the criteria governing normal functional use;

c) the fatigue limit states (FLS) that correspond to the accumulated effect of repetitive actions;

d) the accidental limit states (ALS) that correspond to situations of accidental or abnormal events.

5.1.3 Ultimate limit states (ULS)

ULS for offshore structures include

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

b) failure of critical components of the structure caused by exceeding the ultimate strength (in some cases reduced by repetitive actions) or the ultimate deformation of the components,

c) transformation of the structure into a mechanism (collapse or excessive deformation),

d) loss of structural stability (buckling, etc.),

e) loss of stationkeeping (free drifting), and

f) sinking.

5.1.4 Serviceability limit states (SLS)

SLS for offshore structures include

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

b) excessive vibrations producing discomfort or affecting non-structural components or equipment (especially if resonance occurs),

c) local damage (including cracking) that reduces the durability of a structure or affects the use of structural or non-structural components,

d) corrosion that reduces the durability of the structure and affects the properties and geometrical parameters of structural and non-structural components, and

e) motions that exceed the limitations of equipment.

To control SLS by design, it is often necessary to use one or more constraints (C) that describe acceptable deformations, accelerations, crack widths, etc. (see 8.1).

5.1.5 Fatigue limit states (FLS)

FLS for offshore structures refer to cumulative damage due to repeated actions typically from wave action.

5.1.6 Accidental limit states (ALS)

The ALS check ensures that local damage or flooding does not lead to complete loss of integrity or performance of the structure.

The intention of this limit state is to ensure that the structure can tolerate specified accidental and abnormal events and, where damage occurs, subsequently maintains structural integrity for a sufficient period under specified environmental conditions to enable evacuation to take place. This requirement is sometimes called the progressive collapse limit state (PLS).

5.2 Design

5.2.1 General design requirements

All relevant limit states shall be considered in design. A calculation model should be established that will address each relevant limit state. This model should incorporate all appropriate variables and also allow for

a) the uncertainties with respect to actions,

b) the response of the structure as a whole,

c) the behaviour of individual components of the structure, and

d) the effect on the environment.

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.

5.2.2 Design situations

For any structure it is generally necessary to consider several distinct design situations. Corresponding to each of these design situations, there may be different structural systems, different design values, different environmental conditions, etc.

The design situations may be classified as

a) persistent situations, having a duration of the same order as the life of the structures,

b) transient situations, having a shorter duration and varying levels of intensity, e.g. construction, load-out, transportation and installation phases, and

c) accidental situations (during and after an accident), normally of short duration and low probability of occurrence.

6 Basic variables

6.1 General

The calculation model expressing each limit state considered shall contain a specified set of basic variables. In general, the basic variables correspond to measurable physical quantities.

Normally, the basic variables characterize

a) actions,

b) properties of materials and soils, and

c) geometrical parameters.

6.2 Actions

6.2.1 Classification of actions

6.2.1.1 General

Actions may be classified by their variation with time, by their point of application and by a structure's response to them. Different partial action factors apply depending on their classification and hence a description of each classification is necessary.

6.2.1.2 Permanent actions (G)

These actions are likely to act throughout a given design situation and for which variations in magnitude with time are

a) negligible in relation to the mean value, or

b) attain some limiting value.

Permanent actions generally include

— self weight of structures,

— weight of topsides permanent fixtures and functional equipment,

— actions resulting from earth pressure,

— deformations imposed during construction,

— actions resulting from shrinkage of concrete or distortions due to welding,

— actions resulting from external hydrostatic pressure,

— actions resulting from support and/or subsidence, and

— prestressing.

6.2.1.3 Variable actions (Q)

These actions are likely to act throughout a given design situation, but do not include environmental actions.

Variable actions generally include

— actions due to use and occupancy, including actions caused by crane loads, drilling hook loads, variable ballast, helicopter loads, etc.,

— self weight of temporary structures and equipment,

— actions caused during erection,

— all moving actions such as for movable drilling derricks, and

— functional temperature changes, as they can induce actions or affect material properties.

6.2.1.4 Environmental actions (E)

These actions can be repeated, sustained or both repeated and sustained.

Environmental actions generally include

— actions caused by wind,

— actions caused by waves,

— actions caused by current,

— actions resulting from marine growth, snow and accumulated ice and their indirect effects on variable actions and other environmental actions,

— actions caused by ice (direct),

— environmental temperature changes as they can induce actions or affect material properties, and

— actions caused by earthquakes.

6.2.1.5 Repetitive actions

These actions whose variation in magnitude with time is significant and occurs repeatedly, can lead to possible fatigue effects.

6.2.1.6 Accidental actions (A)

These actions can occur and can have minor consequences (more frequent) or can cause severe structural damage (very rare).

Accidental actions generally result from

— collisions,

— dropped objects,

— fire,

— explosions,

— unexpected subsidence of subsoil,

— unexpected erosion or scour, and

— unexpected flooding.

6.2.2 Classification of actions according to their variation in space

Actions may also be classified according to their variation in space into two groups

a) fixed actions that have a spatial distribution over the entire structure, such that the position, magnitude and orientation of the actions are constant, and

b) free actions that can act at various positions on the structure.

Actions that cannot be defined as belonging to either of these two groups may be considered to consist of a fixed part and a free part.

The treatment of free actions requires the consideration of different arrangements of the actions. A design situation is determined by fixing the positions of each of the free actions (see 5.2.2).

6.2.3 Classification of actions according to the structural response

Actions may be further classified according to the way in which the structure responds to an action:

a) static actions that produce static response without causing significant acceleration of the structure or component, and

b) dynamic actions that cause significant acceleration of the structure or component, thereby a dynamic response.

NOTE Whether or not the action is regarded as dynamic is dependent on the structure and the nature of the source of the action. For simplicity, dynamic actions can often be treated as equivalent static actions in which the dynamic effects, which depend on the behaviour of the structure, are taken into account by either an appropriate increase in the magnitude of the primary static action or by the addition of a representative set of inertial actions as appropriate for the type of structure.

6.3 Properties of materials and soils

The values describing the properties of materials and their variability shall be based on either specific qualification tests or *in situ* observations in conjunction with other sources of information. Properties relating to special test specimens should be converted to the relevant properties of the actual material in the structure by the use of conversion factors or functions that should take account of any scale effects and any dependence on time and temperature. The uncertainty in the properties of the material in the structure or of the soil should be derived from the uncertainties of the standard test results and of the conversion factor or function.

For additional soil considerations, see 4.10.2 and 4.10.3.

6.4 Geometrical parameters

Geometrical parameters that define the shape, size and overall arrangement of structures, components and cross-sections shall be described (see 8.4). When the deviation of any of the geometrical parameters from its prescribed value has a significant effect on the structural behaviour and the resistance of the structure, the magnitude and variability of the deviation shall be taken into account by prescribed tolerance limits.

NOTE In many cases, the random variability of the geometrical parameters can be considered to be small in comparison with the variability of the actions and of material properties. In such cases, the geometrical parameters can be assumed to be non-random and as specified in the design.

7 Analyses — calculations and testing

7.1 General

Generally the design procedure consists of:

a) global behaviour analysis that gives the global action effects (forces, moments, accelerations, displacements) for the structure;

b) structural analysis that gives the action effects (forces and moments) in the cross-sections;

c) analysis of cross-sections, joints, etc., that gives their resistance and more generally their behaviour in greater detail;

d) analysis of localized features and details, for example, at discontinuities in cross-sections at connections.

For the analysis of ALS, the design procedure includes:

e) selection of relevant actions (see 6.2.1.6) and the corresponding level of accepted damage (see 4.1); in addition, after an accident, the structure shall be able to withstand environmental actions in relation to the accepted delay for evacuation of personnel and for protection of the environment.

For fatigue analysis, the design procedure includes:

f) analysis of localized features and details, for example, at discontinuities in cross-sections and at connections.

For floating structures the design procedure also includes:

g) marine stability analysis.

The analysis of a structure may be carried out by calculation, model testing or prototype testing. A combination of these methods may also be used.

Features of the structure that have an important influence on its overall stability and integrity shall be maintained and checked throughout all stages of the structure's life.

Where similar structures have been designed in similar conditions, a simplified procedure may be used, if this can be shown to meet the requirements outlined in this International Standard.

7.2 Calculation

Calculation models and basic assumptions for the calculation shall express the actions and the structural response according to the limit state under consideration.

For the purpose of analysis, a structure may generally be described by a model consisting of one-dimensional components (beams, columns, cables), two-dimensional components (plates and shells) and three-dimensional components (solids).

For the SLS, ULS and FLS, linear elastic methods of analysis will usually be appropriate. However, sometimes non-linear methods need to be used, for example for mooring systems and pile-soil interaction.

For ALS analysis, proven theories using unconventional representation of actions or resistances may be considered when appropriate (plastic deformation, reserve strength analysis etc.), providing the results are reasonably insensitive to minor modifications in the definition of the event considered.

In treating free actions, simplified spatial models for each action shall be defined and used in order to define different action arrangements. For a given structure, the action arrangement that is the most unfavourable shall be selected.

The influence of the environmental conditions on the behaviour of materials shall be considered in the analysis when appropriate.

EXAMPLE Environmental conditions that may be expressed directly in the analysis include the influence of environmental humidity conditions on the shrinkage and creep deformations of concrete and the influence of high temperature during a fire on the strain distribution and the strength of structural components.

7.3 Model testing

A structure or part of it may be designed on the basis of results from appropriate model testing coupled with the use of model analysis to predict the behaviour of the actual structure. Examples are centrifuge testing of foundation-structure interaction, wave basin testing for vessel motions, wind tunnel testing for floating vessels, etc.

Validity of the conversion of model test results to full scale shall be ensured. Designs based on testing should account for the inherent uncertainties in the tests by using appropriate partial safety factors.

7.4 Prototype testing

A structure or part of it may also be designed on the basis of results from testing prototype units relevant to the particular design situation under consideration, for example, inclining tests for floating stability. Designs based on testing shall account for the inherent uncertainties in the tests by using appropriate partial safety factors.

7.5 Existing reference

A structure or part of it may also be designed on the basis of results from an existing structure relevant to the particular design situation under consideration.

8 Design format of partial factors

8.1 Principles

The partial factor format separates the influence of uncertainties and variabilities originating from different causes by means of partial factors.

The principles of the method are described in this clause. However, in practical application, slight modifications are sometimes necessary or desirable (see 8.2.2 and 8.3.2).

In the verification procedure the values assigned to the basic variables are called design values.

The design values for actions, F_d (see 8.2.2) shall be determined from:

$$F_d = \gamma_f F_r \qquad (1)$$

Strengths of materials shall be expressed by their design values f_d (see 8.3) determined from:

$$f_d = f_k / \gamma_m \qquad (2)$$

Alternatively to Equation (2), the design resistances of components may be determined directly from:

$$R_d = R_k / \gamma_R \qquad (3)$$

Other relevant properties may be treated in a similar way or by introducing an additive safety margin.

Geometrical parameters shall be expressed by their design values a_d (see 8.4.2) defined by the equation:

$$a_d = a_k \pm \Delta a \qquad (4)$$

See 8.2.1, 8.3.1 and 8.4.1 for explanation of representative and characteristic values of actions, resistances and geometrical parameters.

The condition for a limit state not to be exceeded may be expressed in the following general form:

$$\theta\left(F_d, f_d, R_d, a_d, C, \gamma_n, \gamma_d\right) > 0 \qquad (5)$$

The parameter C refers to constraints (see 5.1.4) while γ_d and γ_n are factors defined in 3.1. The factors γ_d should take on different values depending on the degree of confidence in the design model as an accurate representation of the real structure or structural component.

NOTE Many sources of variability have been identified in design and construction, such as imperfect mathematical modelling, standards of construction, the difference between test and *in situ* material properties and workmanship. A common feature of these uncertainties is that, while it is possible to identify them qualitatively, it is not always possible to quantify them.

8.2 Actions and their combinations

8.2.1 Representative values

For different design situations, different values may be assigned to each action. These values are called representative values.

The main representative value is the characteristic value, which is a value associated with a prescribed probability of not being exceeded by unfavourable values during some reference period. In some design situations, an action can have two characteristic values, an upper and a lower value. In situations where the effect of a reduction in an action is more dangerous for the structure, the lower value shall be taken as the more unfavourable.

The other representative values shall be chosen with regard to some features of the situation, for example duration of exposure and geological phenomena, and may be expressed as a particular part of the characteristic value by using a factor $\Psi_i < 1$.

Whenever possible, actions and their random variations should be established on the basis of observations, laboratory tests or field data.

Other sources of information, such as judgement on the basis of experience with the type of use or physical constraints, may also be taken into account. Values obtained within this group of information are termed “nominal values”.

A permanent action G has, in general, a unique representative value. When the action consists of the self weight of the structure, the value G_k shall be obtained from the intended values of the geometrical parameters (in general, taken from drawings) and the mean density of the material.

In cases where the uncertainties in the permanent actions are important, the characteristic values should be used. In such cases, both upper and lower characteristic values shall be defined, if necessary.

Variable actions Q shall be defined by the following representative values:

a) the characteristic value Q_k,

b) the frequent value $\Psi_1 Q_k$,

c) the sustained value (quasi-permanent value) $\Psi_2 Q_k$, or

d) the expected repeated action history (for fatigue analysis).

For special purposes, other representative values may be specified.

If characteristic values for variable or accidental actions cannot be determined from statistical data or where appropriate data are not available, the corresponding values may then be estimated on the basis of available information. The characteristic value is then a nominal value.

The characteristic values of environmental actions are normally defined by an annual exceedance probability of the environmental conditions. Alternatively, the environmental action itself may be defined to have a specified return period if adequate data on the joint occurrence of meteorological and oceanographic conditions so permit (see 4.10.1.1, Note 1) and provided that the partial factors are selected accordingly.

In treating repetitive actions for fatigue analysis, rather than determining a single representative value, it is necessary to establish their variation in magnitude with time in order to determine the number of repeated actions of each magnitude.

8.2.2 Design values

An action shall be introduced into calculation by its design values, which are obtained from the representative values by multiplication with partial factors γ_f (see 8.1).

Different design values shall be used corresponding to the different representative values, for example

— γ_f multiplied by the characteristic value,

— γ_f multiplied by the frequent value, or

— γ_f multiplied by the sustained value (quasi-permanent value).

The partial factors γ_f shall take account of

a) the possibility of unfavourable deviations of the actions from their representative values, and

b) uncertainty in the calculations of actions.

The partial factor γ_f should depend on the limit state considered. In particular, the factors for ULS and for SLS should be different. Also, the partial factors γ_f may be different for different action sources within an action type (see 6.2).

