BS EN ISO 19903:2019

BSI Standards Publication

Petroleum and natural gas industries – Concrete offshore structures (ISO 19903:2019)

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee B/525/12, Design of offshore structures.

A list of organizations represented on this committee can be obtained on request to its secretary.

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NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 19903

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English Version

Petroleum and natural gas industries - Concrete offshore structures (ISO 19903:2019)

Industries du pétrole et du gaz naturel - Structures en mer en béton (ISO 19903:2019)

Erdöl- und Erdgasindustrie - Offshore-Betonkonstruktionen (ISO 19903:2019)

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European foreword

This document (EN ISO 19903:2019) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” the secretariat of which is held by NEN.

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Industries du pétrole et du gaz naturel — Structures en mer en béton

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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).

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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 second edition replaces the first edition (ISO 19903:2006). The main changes compared to the previous edition are:

— udpate of the document to reflect the updated editions of the International Standards on offshore structures prepared by TC 67;

— clarifications on the use of reference standards for design;

— extension of scope to design of floating concrete offshore structures, including removing “fixed” from the title of this document;

— clarfications on the selection of soil parameters for soil-structure interaction in 7.3.3;

— Additional information on the dynamic aspects pertaining to floating concrete structures in 7.4.2.1.

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.

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Introduction

The International Standards on offshore structures prepared by TC 67 (i.e. ISO 19900, the ISO 19901 series, ISO 19902, ISO 19903, ISO 19904-1, the ISO 19905 series and ISO 19906) constitute a common basis covering those aspects that address design requirements and assessments of all offshore structures used by the petroleum and natural gas industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for manned and unmanned offshore structures, whatever the type of structure and 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 such modifications, therefore, need to be considered in relation to the overall reliability of all offshore structural systems.

The International Standards on offshore structures prepared by TC 67 are intended to provide 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 documents.

This document was developed based on experience gained from the design, execution and use of a number of fixed concrete platforms, in particular from more than 40 years of experience with such structures in the North Sea. The background documents used for developing this document are from the following types:

— national regulations and other requirements from the authorities;

— regional standards;

— national standards;

— operator's company specifications;

— scientific papers and reports;

— reports from inspection of structures in use.

This document applies the concept of a reference standard for design. The text that previously referred to NS 3473.E, the former Norwegian standard for concrete design that was widely used for the design of fixed offshore concrete platforms, has been amended in this document, since, as part of the Eurocode programme, NS 3473.E has been withdrawn and is no longer maintained.

This document now draws on the experience gained with fixed and floating concrete offshore structures. This experience shows that concrete offshore structures perform well and are durable in the marine environment. These structures are all unique, one-of-a-kind structures, purpose-made for a particular location and a particular set of operating requirements. This document reflects, in particular, the experience and the conditions in the North Sea and the east coast of Canada, and the design rules and practices used there, but is intended for worldwide application.

In order to provide a standard that will be useful to the industry, a comprehensive treatment of some topics is provided where there is currently no other relevant reference. For such well-known topics as the design formulae for concrete structural members, this document is intended to be used in conjunction with a suitable reference standard for basic concrete design (see 8.1.1). The designer can use suitable national or regional design standards that provide the required level of safety.

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Petroleum and natural gas industries — Concrete offshore structures

1 Scope

This document specifies requirements and provides recommendations applicable to fixed, floating and grounded concrete offshore structures for the petroleum and natural gas industries and for structures supporting nationally-important power generation, transmission or distribution facility. This document specifically addresses

— the design, construction, transportation and installation of new structures, including requirements for in-service inspection and possible removal of structures,

— the assessment of structures in service, and

— the assessment of structures for reuse at other locations.

This document is intended to cover the engineering processes needed for the major engineering disciplines to establish a facility for offshore operation.

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 4463-1, *Measurement methods for building — Setting-out and measurement — Part 1: Planning and organization, measuring procedures, acceptance criteria*

ISO 16204, *Durability — Service life design of concrete structures*

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

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

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

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

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

ISO 22966, *Execution of concrete structures*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19900 and the following 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 design situation
design situation in which conditions exceed conventionally specified design conditions and which is used to mitigate against very remote events

Note 1 to entry: Abnormal design situations are used to provide robustness against events with a probability of typically 10^{-4} per annum or lower by avoiding, for example, gross overloading.

3.2
abnormal level earthquake
ALE
intense earthquake of abnormal severity under the action of which the *structure* (3.51) should not suffer complete loss of integrity

Note 1 to entry: The ALE event is comparable to the abnormal event in the design of structures which are described in ISO 19901-2 and ISO 19902. When exposed to the ALE, a manned structure is supposed to maintain structural and/or floatation integrity for a sufficient period of time to enable evacuation to take place.

3.3
accidental design situation
design situation involving exceptional conditions of the *structure* (3.51) or its exposure

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

3.4
action
external load applied to the *structure* (3.51) (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

[SOURCE: ISO 19900:2019, 3.3]

3.5
action effect
result of *actions* (3.4) on structural components or on the structure

EXAMPLE Internal force, moment, stress or strain; deflection rotation

[SOURCE: ISO 19900:2019, 3.4]

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3.6
addition
finely divided material used in *concrete* (3.12) in order to improve certain properties or to achieve special properties

Note 1 to entry: This document deals with two types of inorganic additions:

— nearly inert additions (type I);

— pozzolanic or latent hydraulic additions (type II).

3.7
admixture
material added during the mixing process of *concrete* (3.12) in small quantities related to the mass of cement to modify the properties of fresh or hardened concrete

3.8
aggregate
granular mineral material suitable for use in *concrete* (3.12)

Note 1 to entry: Aggregate can be natural, artificial or recycled from material previously used in construction.

3.9
air cushion
air pumped into underbase compartments of the *structure* (3.51)

Note 1 to entry: The air cushion is normally applied in order to reduce the draft and increase the freeboard of the structure and/or to alter the structural loading.

3.10
atmospheric zone
part of the load-bearing *structure* (3.51) that is above the *splash zone* (3.50)

3.11
caisson
major portion of *concrete* (3.12) offshore *structure* (3.51), providing buoyancy whilst afloat and the possibility of oil storage within the structure

Note 1 to entry: The caisson is generally divided into watertight compartments, which can be subdivided into intercommunicating cells for structural reasons. The caisson can also be filled, or partly filled, with ballast water and *solid ballast* (3.49).

3.12
concrete
material formed by mixing cement, coarse and fine *aggregate* (3.8) and water, with or without the incorporation of *admixtures* (3.7) and *additions* (3.6), which develops its properties by hydration of the cement

3.13
condition monitoring
evaluation of the condition and behaviour of the load-bearing *structure(s)* (3.51) in service using data from design, *inspection* (3.29) and *instrumentation* (3.31)

3.14
construction afloat
fabrication, construction and related activities taking place on a *structure* (3.51) that is afloat, normally at an inshore location and restrained by a temporary mooring system

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3.15
deck mating
marine operation (3.35) in which the platform *topsides* (3.55) is floated into position and connected to the substructure

Note 1 to entry: This operation is normally conducted by ballasting and deballasting of the substructure.

3.16
deep water construction site
site for construction of the *structure* (3.51) while afloat

Note 1 to entry: The use of a deep water site might not always be required, depending on the construction method. It might or might not be the same location as that where mating of *topsides* (3.55) to the substructure takes place.

3.17
design rule
rule in accordance with the chosen reference standard for *concrete* (3.12) design

Note 1 to entry: See 8.2.

3.18
design wave
deterministic wave used for the design of an offshore *structure* (3.51)

Note 1 to entry: The design wave is an engineering abstraction. Most often it is a periodic wave with suitable characteristics (e.g. height *H*, period *T*, steepness, crest elevation). The choice of a design wave depends on:

— the design purpose(s) considered;

— the wave environment;

— the geometry of the structure;

— the type of *action(s)* (3.4) or *action effect(s)* (3.5) pursued.

Note 2 to entry: Normally, a design wave is only compatible with design situations in which the action effect(s) are quasi-statically related to the associated wave action on the structure.

[SOURCE: ISO 19901-1:2015, 3.5]

3.19
dynamic amplification factor
ratio of a dynamic *action* (3.4) effect to the corresponding static *action effect* (3.5)

Note 1 to entry: An appropriately selected dynamic amplification factor can be applied to static actions to simulate the effects of dynamic actions.

3.20
extreme level earthquake
ELE
earthquake with a severity which the *structure* (3.51) should sustain without major damage

Note 1 to entry: The ELE event is comparable to the extreme environmental event in the design of structures which are described in ISO 19901-2 and ISO 19902. When exposed to an ELE, a structure is supposed to retain its full capacity for all subsequent conditions.

3.21
execution
activities carried out for the physical completion of the *works* (3.55), including procurement, *inspection* (3.29) and documentation thereof

Note 1 to entry: The term covers work on site; it might also signify the fabrication of components off-site and their subsequent erection on site.

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3.22
exposure level
classification system used to establish relevant criteria for a *structure* (3.51) based on consideration of life-safety and of environmental and economic consequences of failure

Note 1 to entry: The method for determining exposure levels is described in ISO 19900. An exposure level 1 platform is the most critical and an exposure level 3 the least. A normally manned platform that cannot be reliably evacuated before a design event will be an exposure level 1 platform.

[SOURCE: ISO 19900:2019, 3.20, modified — "consideration of life-safety and of environmental and economic" has been added to the definitions and the Note 1 to entry has been added.]

3.23
finite element analysis
analysis method whereby a *structure* (3.51) or a part thereof is subdivided into small elements of known or assumed behaviour, then analyzed by numerical matrix methods to determine *action* (3.4) effects, static or dynamic

3.24
fixed concrete offshore structure
concrete (3.12) *structure* (3.51) designed to rest on the sea floor

Note 1 to entry: Sufficient structural stability can be achieved through its own weight, or in combination with suction in skirt compartments, or founding of the structure on piles into the seabed. It includes the mechanical outfitting of the structure.

3.25
fixed structure
structure (3.51) that is bottom founded and transfers most *actions* (3.4) on it to the seabed

[SOURCE: ISO 19900:2019, 3.24, modified — "all" has been changed to "most".]

3.26
floating concrete offshore structure
concrete *structure* (3.51) where the full weight is supported by buoyancy

3.27
float-out
transfer of a major assembly from a dry construction site to a self-floating condition

Note 1 to entry: Typically, it is the transfer of the lower part of the *concrete* (3.12) *structure* (3.51) from a flooded drydock.

3.28
global analysis
determination of a consistent set of either internal forces and moments or of stresses for a complete *structure* (3.51) usually resulting from the *finite element analysis* (3.23).

3.29
inspection
conformity evaluation by observation and judgement accompanied, as appropriate, by measurement, testing or gauging to verify that the *execution* (3.21) is in accordance with the *project work specification* (3.44)

3.30
installation
marine operation (3.35) in which the platform is positioned and set down on the sea floor at the *offshore site* (3.38)

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3.31
instrumentation
outfitting of a *concrete* (3.12) offshore *structure* (3.51) with instruments for data measurement and recording

3.32
interface manual
document defining all interfaces between the various parties and disciplines involved in the design and construction, ensuring that responsibilities, reporting and information routines, as appropriate, are established and maintained

3.33
lightweight aggregate
aggregate (3.8) of mineral origin having an oven-dry particle density 2 000 kg/m^3 or a loose oven-dry bulk density 1 200 kg/m^3

3.34
local analysis
determination of a consistent set of internal forces and moments, or stresses, in a cross-section of a structural component, or in a subset of structural components forming part of the structural system, that are in equilibrium with the boundary conditions

3.35
marine operation
planned and controlled vertical or horizontal movement of a *structure* (3.51) or component thereof over, in or on water

3.36
method statement
document stating the methods and *procedures* (3.42) used to perform the *work* (3.56)

3.37
normal-weight aggregate
aggregate (3.8) with an oven-dry particle density between 2 000 kg/m^3 and 3 000 kg/m^3

3.38
offshore site
offshore location where the *structure* (3.51) is installed for its operational life

3.39
operations manual
document giving the requirements and restrictions related to a safe operation of the *concrete* (3.12) *structure* (3.51) and all its systems

3.40
owner
representative of the companies which own a development

Note 1 to entry: The owner will normally be the operator on behalf of co-licensees.

3.41
primary structure
all main structural components [*concrete* (3.12) or steelwork] that provide the *structure's* (3.51) main strength and stiffness

3.42
procedure
document that describes a specified way to carry out an activity or a process, the detailed sequence and interrelationships required for the completion of a particular task

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3.43
project specification
document giving the overall technical requirements provided by the *owner* (3.40)

3.44
project work specification
information and technical requirements necessary for the *execution* (3.21) of the *works* (3.56), including documents and drawings, etc., as well as references to relevant regulations, specifications, etc.

3.45
quality plan
document specifying the *procedures* (3.42) and associated resources to be applied, and by whom and when, covering the entire project or defined parts of the project and all relevant products, processes or contracts

3.46
secondary structure
structural components that do not contribute significantly to the overall strength and stiffness of the *structure* (3.51) but which support individual items of equipment, transferring the *actions* (3.4) thereon onto the *primary structure* (3.41)

3.47
shaft
compartment extending from the *caisson* (3.11) of the *concrete* (3.12) offshore *structure* (3.51) to the *topsides* (3.55)

Note 1 to entry: A shaft is generally used to house and support the wells (drill shaft), mechanical systems (utility shaft) and risers and J-tubes (riser shaft). The part of a shaft extending above a caisson is also often referred to as a leg.

3.48
skirt
structural component constructed in *concrete* (3.12) and/or steel that is part of the foundation and penetrates into the seabed

Note 1 to entry: Skirts are used to increase the capacity of the foundation to resist vertical and horizontal *actions* (3.4) and improve erosion resistance. Skirts can also be needed to form compartments facilitating the under-base grouting.

3.49
solid ballast
non-structural material added to a *structure* (3.51)

Note 1 to entry: Solid ballast is normally applied in order to increase the self-weight of the structure or to lower the centre of gravity for floating stability purposes.

3.50
splash zone
area of a *structure* (3.51) that is frequently wetted due to waves and tidal variations

3.51
structure
combination of physically connected structural components designed to withstand *actions* (3.4) and provide adequate rigidity

[SOURCE: ISO 19900:2019, 3.53, modified — added text from "designed".]

3.52
submerged zone
part of the *structure* (3.51) that is normally submerged and exposed to the constant influence of sea water

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3.53
subsidence
part of the settlement of the *structure* (3.51) that results from extraction of reservoir hydrocarbons and factors other than the weight of the structure

3.54
summary report
document including the most important assumptions on which the design, construction and *installation* (3.30) work is based with regard to the load-bearing *structure* (3.51)

3.55
topsides
structure (3.51) and equipment placed on a supporting *structure* (3.51) (fixed (3.25) or floating (3.26)) to provide some or all of a platform's functions

Note 1 to entry: A separate fabricated deck or module support frame is part of the topsides.

[SOURCE: ISO 19900:2019, 3.54, modified — Notes 1 and 2 to entry have been omitted.]

3.56
works
construction work described in the *project work specification* (3.44)

3.57
works certificate
mill certificate
document issued by the manufacturer or a testing institute certifying the materials delivered, and giving

— test method, specifications and criteria (e.g. test standard used),

— all relevant test data,

— certification that the tests have been carried out on samples taken from the delivered products, and

— all necessary information for identification of product, producer and purchaser.

Note 1 to entry: A works certificate is normally required for construction materials that are not subject to an accepted certification scheme.

4 Symbols and abbreviated terms

4.1 Symbols

A	accidental action
A_c	actual surface area to be protected
a	mass content of the active addition (type II)
C_a	total current capacity of the anodes
c	cement mass content
c_a	current capacity of an anode
D	action due to imposed deformation
d	depth from the compressive side of the cross section to the centre of the tensile longitudinal reinforcement on the opposite side

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E	environmental action
E^{o}_{a}	design closed-circuit anode potential
E^{o}_{c}	design protective potential
f_c	coating breakdown factor for any coated surfaces (f_c = 1 for bare steel)
F_{ck}	characteristic compressive strength of concrete
F_{cn}	nominal compressive strength of concrete
F_{yk}	characteristic strength of steel
G	permanent action
I_a	anode current output
$I_{a,initial}$	initial current output
$I_{a,final}$	final current output
I_c	current demand
$I_{c,average}$	average current demand
$I_{c,final}$	initial current demand
$I_{c,final}$	final current demand
i_c	design current density
k	factor which takes into account the activity of a type II addition
L	lap length
M_x, M_x, M_{xy}, N_x, N_y, N_{xy}	six force components giving stresses in the plane of the member
m	effective water/cement ratio
m_T	total net anode mass
n	number of anodes
Q	variable action
R	radius
R_a	anode resistance
t	thickness
t_f	design life of the cathodic protection system
u	utilization factor of the anode
w	water mass content in concrete
X	distance from the support
γ_A	partial factor for accidental actions

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γ_D	partial factor for actions resulting from imposed deformations
γ_E	partial factor for environmental actions
γ_F	partial factor for action taking account of model and geometrical uncertainties
γ_G	partial factor for permanent actions, also accounting for dimensional variations
γ_M	partial factor for material resistance properties taking account of material, model and geometric uncertainties
γ_Q	partial factor for variable actions
ε	anode material's electrochemical efficiency
ν	Poisson's ratio

4.2 Abbreviated terms

ALS	accidental limit state
CFD	computational fluid dynamics
FLS	fatigue limit state
GRP	glass-fibre reinforced plastic
HAZOP	hazard and operability analysis
HVAC	heating, ventilation and air conditioning
MIC	microbiologically induced corrosion
ROV	remotely operated vehicle
SLS	serviceability limit state
SRB	sulphate-reducing bacteria
ULS	ultimate limit state

5 General requirements

5.1 General

Concrete offshore structures shall be designed in accordance with ISO 19900, this document and the requirements given in the project specification.

The structure shall be designed, constructed, transported and installed in such a way that

— the installed structure meets the intended reliability level, and

— all functional and structural requirements are met.

General principles for the verification of the reliability of the structure shall be in accordance with ISO 19900.

This document assumes that the owners will operate an organization that supervises and monitors the project, and will ensure that an appropriate level of independent verification of design and construction is performed.

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This document is intended to be used in conjunction with a suitable reference standard for basic concrete design. The designer may use suitable national or regional design standards that provide the required level of safety and structural reliability.

5.2 Overall planning requirements

5.2.1 General

A concrete offshore structure shall be planned in such a manner that it meets all requirements related to its functions and use, while at the same time providing adequate levels of structural safety, reliability and durability.

All functional requirements, including operational issues and environmental conditions affecting the layout and design of the structure, shall be established in a clear format such that these can form the basis for the engineering process and the structural design. All functional requirements in temporary and operational design situations, as well as robustness against accidental situations that can influence the layout and the structural design, shall be considered. The exposure level shall be defined according to 6.6.

Site-specific data, such as water depth, environmental conditions and soil properties, shall be sufficiently known and documented to serve as a basis for the design.

Investigation of site-specific data, such as seabed topography, geo-hazards (shallow gas, boulders, etc.), soil conditions and environmental conditions including sea ice and icebergs, as appropriate, shall be carried out in accordance with the requirements of ISO 19901-1, ISO 19901-2, ISO 19901-4, ISO 19901-8 and ISO 19906.

5.2.2 Quality system

The quality system shall conform with the requirements of ISO 19900 and the specific requirements quoted for the various engineering disciplines in this document.

All work performed in accordance with this document shall be subject to quality control in accordance with an implemented quality plan. There can be one quality plan covering all activities or one overall plan with separate plans for the various phases and activities that are performed.

The quality plan shall ensure that all responsibilities are defined. An interface manual should be developed that defines all interfaces between the various parties and disciplines involved, and ensures that responsibilities, reporting and information routines are established as appropriate.

5.2.3 Qualifications of personnel

The qualifications of personnel shall conform with the requirements of ISO 19900 and specific requirements quoted for the various engineering disciplines in this document.

5.2.4 Documentation

Documentation shall be prepared for all activities that are performed in the engineering, design, construction, transportation, installation and possible removal of concrete offshore structures.

This documentation shall be sufficient to give complete information about the structure including the following:

— investigations establishing data on which the design is based;

— design briefs for major elements of design, such as concrete, mechanical outfitting, foundation, etc.;

— engineering reports, design reports and calculations;

— drawings, specifications, etc.

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Documentation shall also be prepared showing records of all inspection and control of materials used and execution work performed that has an impact on the quality of the final product. This documentation shall be in accordance with the requirements in ISO 22966. ISO 22966:2009, Annex A provides guidance to the project team to determine the minimum list of documents and content of execution specification required from contractors and suppliers.

Necessary procedures and manuals shall be prepared to ensure that the construction, transportation, installation and in-service inspection are performed in a controlled and safe manner in full conformity with all assumptions of the design.

The assumptions on which the design, construction and installation work is based with regard to the load-bearing structures shall be presented in a summary report. The summary report shall be available and suitable for use in connection with operation, maintenance, alterations and possible repair work.

An operations manual shall be prepared giving all necessary information for the safe operation of the concrete offshore structure including all systems.

5.3 Functional requirements

5.3.1 General

The engineering of a concrete offshore structure shall be performed in such a way that all functional and operational requirements relating to its safety and its operation as an offshore platform are met.

The functional requirements affect the layout of the structure as well as the design situation that shall be considered in the design of the structure. The functional requirements are related both to the site-specific conditions and to the structure as a production or storage facility for the production of hydrocarbons, or any other activities in the operation of a field.

5.3.2 Position on site

The structure shall be positioned and oriented on site taking into account the reservoir, construction requirements, other platforms in the vicinity, operations, accessibility by ships and helicopters, and safety in case of fire or leakages of hydrocarbons. Position tolerance shall be defined by the owner.

5.3.3 Environmental considerations

There shall be a site-specific evaluation of all types of environmental conditions that can affect the layout and design of the structure, including rare events with a low probability of occurrence.

The deck elevation shall be determined such that it provides an adequate air gap or clearance, based on site-specific data, allowing the passage of wave crests higher than the design wave crest and icebergs or sea ice, in accordance with ISO 19901-1 and ISO 19906, as appropriate.

Green water effects on the deck of floating structures shall be in accordance with ISO 19904-1.

Due account shall be taken of wave crest modifications caused by the structure, caisson effect, local or regional features of the sea floor, storm surge, uncertainty in water depth including platform placement tolerance, wave diffraction by nearby structures, and wave run-up along the shafts.

It can be impractical to set the deck elevation to avoid impact from wave run-up along the shafts of multi-leg structures or up the sides of caissons. Potential detrimental effects of wave run-up along shafts of multi-leg structures or up the sides of caissons may be mitigated by use of wave deflectors or other structural components that can resist those actions.

The water depth used in establishing layout and in design shall be based on site-specific data taking due account of potential settlements, including subsidence, etc.

A wave model test early in the design phase may be used to determine the air gap.

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5.3.4 Platform operational requirements

The functional requirements related to the production system shall be determined by the owner and could include the following:

— design life;

— layout of production wells, risers and pipelines, etc.;

— storage volume, compartmentalization, densities, temperatures, etc., in the case of stored products;

— safeguards against hydrocarbon spillage, leakage and contamination;

— access requirements, both internal and external, for operation, inspection and condition monitoring, etc.;

— interface to topsides;

— requirements for supply boats and other vessels servicing the platform;

— future tiebacks;

— hydrocarbon loading or offloading systems.

All hazards (fire, explosions, loss of intended pressure differentials, flooding, leakages, rupture of pipe systems, falling objects, ship impacts, etc.) that can be reasonably foreseen during operations shall be established and evaluated.

5.4 Structural requirements

5.4.1 General

Structures and structural members shall perform satisfactorily during all design situations, with respect to structural strength, ductility, durability, displacements, settlements and vibrations. The structure and its layout shall be such that it serves as a safe and functional base for all the mechanical and other installations that are needed for it to operate. Adequate performance shall be demonstrated in design documentation.

5.4.2 Structural concept requirements

The structural concept, details and components shall be such that the structure fulfils the following requirements:

— has adequate robustness (reserve strength, ductility) where local damage (dropped objects, vessel collision) will neither impair overall structural integrity nor hydrocarbon containment;

— can be constructed in a controlled and efficient manner;

— is adequately protected from corrosion and other degradation throughout the design life;

— is suitable for condition monitoring, maintenance and repair, if required;

— fulfils requirements for decommissioning and removal, if required;

— maintains deflections and motions within acceptable limits both during floating conditions and at permanent location;

— meets water/oil leak-tightness requirements.

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5.4.3 Materials requirements

The selected materials shall be suitable for the purpose and meet requirements of the design standard. The material properties and the verification that these materials fulfil the requirements shall be documented.

It shall be ensured that the specified quality of the materials, all structural components and the physical structure itself is maintained during all stages of construction.

5.4.4 Execution requirements

Requirements for execution, testing and inspection of the various parts of the structure shall be specified on the basis of the significance of the various parts with regard to the overall safety of the completed and installed structure as well as to the structure in temporary phases.

5.4.5 Temporary phases requirements

The structure shall be designed for all phases with the same intended reliability as for the final condition unless otherwise agreed. This applies also to temporary moorings or anchorage systems used during those construction phases when the structure is afloat.

For all floating phases during marine operations or construction, sufficient positive stability and reserve buoyancy shall be ensured. Both intact and damaged stability shall be evaluated on the basis of an accurate geometric model for each condition. Adequate freeboard shall be provided. One-compartment damage stability should normally be provided. For short transient phases, the one-compartment damage stability may be waived, provided this can be justified by a risk analysis.

Weight control required for temporary phases should be performed by means of a well-defined, documented, robust and proven weight control method. Procedures shall be in accordance with ISO 19901-5. The system should provide up-to-date weight reports containing the necessary data for all operations.

5.5 Design requirements

5.5.1 General

The structural design of a concrete offshore structure and its foundation design shall be in accordance with this document. The design shall be performed according to the principles of limit state design as defined in ISO 19900.

The design shall provide adequate strength and serviceability in all design situations, such that the assumptions made are conformed with.

The design of structural steel components shall be in accordance with ISO 19902 and ISO 19901-3, as applicable.

5.5.2 Design actions

The representative values of actions shall be selected according to 6.2.

The partial factors for actions shall be chosen with respect to the limit states and the combination of actions concerned. Values are given in 6.4.

5.5.3 Design resistance

The characteristic resistance of a cross-section or a member shall be derived from characteristic values of material properties and nominal geometrical dimensions.

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The design resistance is obtained by amending the characteristic values by the use of appropriate partial factors for materials.

5.5.4 Characteristic values for material strength

The characteristic strength of materials shall be determined according to the relevant design standards and recognized standards for material testing.

For concrete, the 28 days characteristic compressive strength F_{ck} is defined as a 5 % fractile value (5th percentile) found from statistical analysis of testing 150 mm × 300 mm cylindrical specimens.

NOTE 1 In some standards, a nominal compressive strength F_{cn} is used, which is less than F_{ck}; this considers transition of test strength into in situ strength and ageing effects due to high sustained stresses. If this nominal value is used for the calculation of design strength, reduced partial factors for materials reflecting this can be applied.

NOTE 2 In some design standards, limits are placed on the upper characteristic strength, which can reflect local construction practice. Such limits can be relaxed if adequate justification can be provided, including testing of the concrete mix and aggregates, where appropriate.

For reinforcement steel, the specified minimum yield stress shall be taken as the characteristic strength F_{yk}; for prestressing, the 0,1 % proof stress may be applied.

Values for geotechnical analyses shall be determined in accordance with ISO 19901-4. Any deteriorating effects during the operation design situation shall be taken into consideration.

For the fatigue limit state (FLS), the characteristic material strength shall be determined statistically as a 5 % fractile for reinforcement, prestressing assemblies, couplers, welded connections, etc., unless other values are specified in the reference standard for design. For concrete, normally a design reference strength shall be used. For other materials, acceptance criteria shall be specified which offer a safety level equivalent to that of the requirements in this document. The reference standard used for design should give key fatigue parameters for concrete, reinforcement and prestressing in the marine environment.

Where high resistance of a member is unfavourable (e.g. in weak link considerations), an upper value of the characteristic resistance shall be used in order to give a low probability of failure of the adjoining structure. The upper value shall be chosen with the same level of probability of exceedance as the probability of lower values being underscored. In such cases, the partial factor for material shall be 1,0 for calculating the resistance that is used when actions are applied on adjoining members.

5.5.5 Partial factors for structural materials

The partial factors for the materials in reinforced concrete shall be chosen in accordance with the reference standard for the design and for the limit state considered.

For structural steel members in the mechanical outfitting, embedment, skirts, etc., the partial resistance factor shall be in accordance with ISO 19902.

5.5.6 Design by testing

Where actions acting on a structure or the resistance of materials or structural members cannot be determined with reasonable accuracy, model tests should be considered.

Characteristic resistances of structural details, structural members or parts may be verified by a combination of tests and calculations.

A test structure, a test structural detail or a test model shall be sufficiently similar to the structure to be considered representative of the actual structure. The results of the tests shall provide a basis for a reliable interpretation in accordance with a recognized standard. Scale effects shall be taken into account where relevant.

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6 Action and action effects

6.1 General

6.1.1 Classification of actions

In accordance with ISO 19900, actions are classified as the following:

— environmental actions (E) (6.2);

— permanent actions (G) (6.3.1);

— variable actions (Q) (6.3.2);

— accidental actions (A) (6.3.4).

Although ISO 19900 defines actions resulting from imposed deformation (D) as permanent actions, in this document they are treated differently (see 6.3.3).

The actions shall include the corresponding external reactions. The representative actions shall be chosen according to the design situation under investigation. The following design situations are distinguished:

— operational situations;

— temporary and transient situations including construction (dry-dock and deep water site) transportation, and installation;

— accidental and abnormal situations;

— damaged situations;

— decommissioning situations.

6.1.2 Determination of action effects

Action effects shall be determined by means of recognized methods that take into account the variation of the action in time and space, the configuration and stiffness of the structure, relevant soil conditions and the limit state that is under consideration. For floating structures, reference may be made to ISO 19904-1 for the determination of action effects.

Dynamic or non-linear action effects shall be considered where appropriate.

Hydrodynamic and aerodynamic actions, and the associated action effects, shall be determined by methods which take the kinematics of the liquid or air into account. For hydrodynamic actions, the interaction between liquid, structure and soil shall be considered. For calculation of overall action effects from wind, simplified methods normally suffice.

Seismic actions shall be considered in accordance with ISO 19901-2 and 7.5.7.

When determining the soil reactions used in the calculation of action effects in the structure, the soil-structure interaction shall be accounted for. An appropriate range of design parameters should be used to ensure that all realistic patterns of action effect distribution are included, considering long- and short-term effects, unevenness of the sea floor, degrees of elasticity and plasticity in the soil and, if relevant, in the structure.

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6.2 Environmental actions

6.2.1 General

Wind, wave, tide and current are important sources of environmental actions (E) on many structures located offshore. In addition, seismic actions (see 6.2.4) and ice actions (see 6.2.5) can be significant actions, depending on location.

The determination of actions due to wind, wave and current requires an appropriate description of the physical environment in the form of sea state severity and direction, associated wind speed and direction, and relevant current descriptions in terms of current velocity profiles through the depth and associated directional information. The derivation of wind, wave and current combinations required for the calculation of actions is described in ISO 19901-1.

Actions from wind, wave and current occur as a result of various mechanisms. The most important sources of action are the following:

— viscous or drag effects, which are generally of most importance for relatively slender bodies;

— inviscid effects due to inertia of the water particles and wave diffraction, which are generally of most importance in terms of global effects for relatively large-volume bodies.

For fixed concrete offshore structures, static analyses can be adequate, but the possibility that dynamic analysis is required for local behaviour of components or for the global behaviour of the whole platform shall be investigated. In the specific case of wave action, the possibility that non-linear effects can lead to responses at frequencies either above or below the frequency range in the wave spectrum shall be investigated. This applies to fixed and floating structures.

Possible ringing effects shall be included in the considerations of wave actions on particular types of concrete offshore structures, normally single-shafted. When a steep, high wave encounters a shaft, non-linear, higher-order frequency components of wave actions can coincide with natural frequencies of the structure causing resonant transient response. Such ringing effects are only of significance in combination with extreme first order wave frequency effects. Computational fluid dynamics (CFD) analysis procedures may be used to evaluate the magnitude of the wave actions.

Potential dynamic effects due to local or global actions from wind and current shall also be investigated.

Environmental actions shall also be considered for temporary design situations of the structure during construction, tow and installation, including any inertial actions resulting from accelerations of the structure. The complete life cycle of the structure, from initial construction to removal, shall be considered and appropriate combinations of actions shall be determined to define design situations.

6.2.2 Wave actions

6.2.2.1 General

Wave actions shall be determined by means of an appropriate analysis procedure and supplemented by a model test programme, if required. Global actions on the structure and local actions on various appurtenances, attachments and components shall be determined.

Impulsive global and local wave actions shall be considered, e.g. slamming. These action effects can be significant for structures where the water depth above the caisson is small compared to the wave-height.

The appropriate analysis procedure for computing wave actions generally depends on the ratio of wavelength to a characteristic dimension of the structure, such as the diameter of a cylinder or caisson. For ratios less than approximately five, a procedure that accounts for the interaction of the structure with the incident wave-field, such as diffraction analysis, shall be applied. For higher ratios, a slender-body theory, such as the Morison equation, may be used. Where drag forces are important in global actions, both procedures should be applied in combination. In some cases, such as in the computation of local actions on various external attachments to a structure, both procedures can be required.

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Model testing and CFD analyses should be considered for supplementing analytical results, particularly in cases where it is anticipated that non-linear effects can be significant, or where previous experience is not directly applicable because of the configuration of the structure.

6.2.2.2 Slender-body theory

The Morison equation can be appropriate for application to determine wave actions on slender members. The local wave kinematics are considered to be unaffected by the presence of the structural component under investigation, but local kinematics can be significantly influenced by adjacent structures.

The required inertia and drag coefficients for application in the Morison equation shall be based on recognized procedures, such as those given in ISO 19902.

The Morison equation shall be applied:

— with a regular (single-period) design wave;

— with irregular sea states in the time domain;

— with spectral representations in the frequency domain using appropriate linearization of the drag term.

The Morison equation may also be applied to calculate local actions from the kinematics around a global structure derived from diffraction theory.

The Morison equation does not account for various non-linear or higher order interactions between wave and structure, such as slamming or ringing.

6.2.2.3 Diffraction analyses

6.2.2.3.1 General

Global actions on large-volume bodies shall generally be determined by applying a validated diffraction analysis procedure. In addition, the design of various appurtenances shall be evaluated, including incident kinematics, diffraction and (if necessary) radiation effects.

The fundamental assumption of diffraction analysis is that the fluid is inviscid and that the oscillatory motions of both the waves and of the structure are sufficiently small to permit the assumption of linearity. The hydrodynamic interaction between waves and a structure can then be predicted based on linearized three-dimensional potential theory.

CFD analysis procedures may be employed on shallow water structures, on surface-piercing structures that will be overtopped by the progressing wave or on structures with significantly varying cross-section near the waterline, within the likely wave-affected zone. The CFD analysis may either complement or replace the diffraction analysis.

6.2.2.3.2 Methods

Diffraction procedures shall generally be implemented through well-verified computer programs, typically based on source/sink (Green's function) panel methods or similar procedures.

6.2.2.3.3 Special considerations for panel methods

Diffraction analysis using panel methods shall be executed with an adequate grid density to provide a solution with the required accuracy.

Diffraction models shall be combined with Morison models in the assessment of various relatively slender attachments to large-volume structures. Diffraction methods provide the required kinematics field, the Morison equation may be applied to compute resulting actions on slender attachments.

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The proximity of additional relatively large-volume structures shall be included in assessing actions. Disturbances to the kinematics field around two or more structures can interact and this interaction shall be accounted for in the analysis.

Careful consideration shall be given to possible pressure fluctuations on the underside of a structure during the passage of a wave. If the foundation conditions are such that pressure fluctuations are expected to occur, then such pressure fluctuations shall be included in the analysis.

Diffraction analysis programs may be used to determine coefficients required in the evaluation of various non-linear effects, typically involving sum and/or difference frequencies.

6.2.2.4 Additional requirements for dynamic analysis

In cases where the structure can respond dynamically, the additional effects associated with the motions of the structure shall be determined. Typically, these additional effects shall be captured in additional inertia and damping terms in the dynamic analysis. Structures can, for example, respond dynamically in the as-installed situation due to wave or seismic actions, or in floating situations due to wave or wind actions.

The effects of motions of the structure on internal fluids, such as ballast water in tanks, shall also be evaluated. Sloshing in tanks generally affects the pressures, particularly near the free surface of the fluid.

6.2.2.5 Model testing

6.2.2.5.1 Role of model testing

Model testing should be considered in the following circumstances:

— Verification of analytical procedures: to confirm the results of analytical procedures, particularly for cases with structures of unusual shape, for structures in shallow water with steep or breaking waves, for the assessment of potential for sea-bed scouring or for any other case where known limitations of analytical procedures are present.

— Complementing analytical procedures: where various effects, such as ringing, wave run-up, potential occurrence of slamming are suspected, or in cases where the higher order terms that are neglected in analytical procedures can be important.

6.2.2.5.2 Scaling of model tests

Froude scaling is normally appropriate for typical gravity-driven processes, such as waves acting on large-volume structures. However, in any decision to apply Froude scaling, the possible influence of viscosity and Reynolds number effects should be considered.

6.2.2.5.3 Validation of model tests

Actions determined by model test shall be validated by comparison with analytical solutions or with the results of prior appropriate test programmes.

6.2.2.5.4 Estimation of actions

Sufficient data shall be gathered to perform reliable statistical analysis to determine wave actions. Data can include the following:

— the time history of the local instantaneous air/water surface elevation at various locations;

— local particle kinematics;

— global actions, such as base shear, vertical load or overturning moment, as well as local actions in the form of the pressure distribution on individual components;

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— structural response, such as displacements and accelerations, particularly if dynamic response occurs.

Model test data shall be converted to full scale by appropriate factors consistent with the physical scaling procedures applied in the test programme.

6.2.2.5.5 Limitations of model testing

Analogous with analytical procedures, model test results have inherent limitations that shall be considered in assessing the validity of resulting actions. The primary sources of inherent limitations include the following:

— Surface tension effects: these are not allowed for in model test programme definition in general and can be significant, particularly where large-scale factors are applied.

— Viscous effects: the Reynolds number is not accurately scaled in general, and these effects are important where viscosity is significant, such as in the prediction of drag or damping effects.

— Air/water mixing and air entrainment: various actions that are influenced by this phenomenon, such as slamming actions, will not be accurately scaled in typical Froude-scale-based model tests in general.

The influence of particular effects on actions determined in model tests shall be assessed and steps shall be taken in the testing programme to reduce or minimize them. Such effects can be as follows:

— wave reflections from the ends of model test basins;

— scattering of waves from large-volume structures;

— reflection of spurious scattered waves from model basin sidewalls interfering with target design wave conditions;

— breakdown of wave trains representing the target design wave due to various instabilities leading to an inaccurate realization of design wave conditions;

— difficulties in the inclusion of wind or currents in association with wave fields.

6.2.3 Current actions

6.2.3.1 General

Currents, including directionality over the water column, shall be combined with the design wave conditions.

The disturbance of the incident current field due to the presence of the structure shall be accounted for.

6.2.3.2 Methods

Current actions shall be determined using recognized procedures. Typical methods are based on the use of empirical coefficients accounting for area, shape, shielding, etc. Such empirical coefficients shall be validated. Model tests or analytical procedures or both shall be considered to validate computed current actions.

Analytical procedures based on CFD may be used in the evaluation of current actions or other effects associated with current. Only well-validated implementations of the CFD procedure shall be used in the computation of current effects. The method can provide a more economic and reliable procedure for predicting drag forces than physical modelling techniques.

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6.2.3.3 Local effects

Disturbances of the incident current field lead to modifications in the local current velocity in the vicinity of the structure. Actions on local attachments to the structure shall be computed based on the modified current field. The possibility of vortex-induced vibrations on various attachments shall be investigated.

6.2.3.4 Scour around the base

The presence of water motions in the vicinity of the base of a structure can lead to scour or sediment transport around the base. The potential for sediment transport shall be investigated. Typical procedures require the computation of fluid velocities using either CFD or model test results. In general, these velocities are evaluated with empirical procedures to predict scouring or sediment transport.

NOTE There is a substantial body of mostly empirical data (including data related to coastal and port engineering fields) that can be consulted for additional insight into sediment transport processes and the prevention of scour.

6.2.3.5 Wind action

Wind actions on a concrete offshore structure consist of two parts:

— wind actions on the topsides;

— wind actions on the concrete offshore structure above sea level.

Global wind actions shall either be determined based on the appropriate design wind velocity in combination with recognized calculation procedures or by wind tunnel testing. In a typical case, global wind action may be estimated by simplified procedures, such as a block method.

In this type of procedure, wind actions may be based on calculations that include empirical coefficients for simple shapes for which data are available, an appropriate exposed area and a pressure that is a function of the square of the wind speed normal to the exposed area.

The wind action on the exposed part of the concrete offshore structure is normally small compared to the wind action on the topsides and to wave actions. A simplified method of applying the effect of wind to the concrete structure is using the wind actions on the topsides only.

NOTE For a more complete description of wind actions, see ISO 19901-1 and ISO 19902.

Global dynamic effects of wind action shall be investigated if relevant. By way of example, a structure that is afloat or in a temporary condition during the construction, transportation or installation phases can be susceptible to wind dynamics. An appropriate description of the wind field, such as a wind spectrum, shall be included to determine global dynamic effects of wind action.

6.2.4 Seismic actions

Procedures for the determination of seismic actions and minimum return periods are provided in ISO 19901-2 at two levels, ELE and ALE. For the ELE event the structure shall meet the ULS requirements.

Seismic actions at ALE level may be considered as an abnormal design situation.

The action factors for ELE and ALE are specified in Table 1.

6.2.5 Ice actions

The computation of ice actions (sea ice and icebergs) and action effects, such as vibration or impact, is highly specialized and location-dependent and shall be in accordance with ISO 19906.

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6.3 Other actions

6.3.1 Permanent actions

Permanent actions (*G*) are actions that do not vary in magnitude, position or direction during the time period considered. These include the following:

— self-weight of the structure, including topsides;

— weight of permanent ballast;

— weight of permanently installed parts of mechanical outfitting, including risers, etc.;

— external hydrostatic pressure up to the mean water level;

— prestressing.

The expected variation in the centre of gravity position shall be accounted for.

NOTE Prestressing can alternatively be considered as actions from imposed deformations.

6.3.2 Variable actions

Variable actions (*Q*) change on magnitude, position and direction during the time period considered. They include actions from the following:

— personnel;

— temporary equipment, any mechanical outfitting and structure planned to be added or removed during the operational design situation;

— weight of gas and liquid in pipes and process plants;

— stored goods, tanks, etc.;

— weight and pressure in storage compartments and ballasting systems;

— temperatures;

— actions caused by drilling, workover or enhanced oil recovery operations, etc.;

— low energy boat impact, fendering and mooring;

— tidal variation about mean water level;

— external hydrostatic pressure experienced due to heave, pitch and roll in floating conditions.

NOTE Variable actions from temperatures can also be considered as actions from imposed deformations.

The assumptions that are made concerning variable actions shall be reflected in the summary report (see 5.2.4) and shall be conformed with in the operations. Possible deviations shall be evaluated and, if appropriate, shall be considered in the assessment of accidental actions.

6.3.3 Actions from imposed deformations

Certain actions, which can be classified as either permanent or variable, may be treated as resulting from imposed deformations (*D*). Action effects caused by imposed deformations shall be treated in the same way as action effects from normal actions or by demonstration of strain compatibility and equilibrium between applied actions, deformations, and internal forces.

Potential imposed deformations are derived from sources that include the following:

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— prestressing effects (including effects of prestressing sequences, etc.);

— creep and shrinkage effects;

— differential settlement of across the foundation;

— locked-in deformations due to construction stages.

6.3.4 Accidental actions

6.3.4.1 General

Accidental actions (*A*) can occur from abnormal environmental events, malfunction, mal-operation or accident. The accidental actions considered in the design shall be based on an evaluation of the operational conditions for the structure, due account being taken of factors such as personnel qualifications, operational procedures, facilities and equipment, safety systems and control procedures. Evaluations of risk related to fire and explosions are covered in ISO 13702.

Primary sources of accidental actions include the following:

— abnormal environmental events;

— fires;

— spillage of refrigerated liquefied gas;

— explosions;

— flooding;

— dropped objects;

— collisions;

— unintended changes in pressure differences.

6.3.4.2 Abnormal environmental events

Abnormal environmental events include events such as the 10 000-year return period wave condition, when appropriate, and the ALE seismic event.

6.3.4.3 Fires

The principal fire and explosion events are associated with hydrocarbon leakage from flanges, valves, equipment seals, nozzles, etc.

The following types of fire scenarios shall at least be considered, where relevant:

— burning blowouts in wellhead area;

— fires related to releases from leaks in risers, manifolds, loading/unloading or process equipment, or storage tanks, including jet fire and fire ball scenarios;

— burning oil on sea;

— fires in equipment or electrical installations;

— pool fires on deck, in shafts or on the sea.

The fire action intensity may be described in terms of thermal flux as a function of time and space or, simply, as a standardized temperature-time curve for different locations.

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The fire thermal flux may be calculated on the basis of the type of hydrocarbons, release rate, combustion, time and location of ignition, ventilation and structural geometry, using simplified conservative semi-empirical formulae or analytical/numerical models of the combustion process.

6.3.4.4 Spillage of refrigerated liquefied gas

Where relevant, leakage of refrigerated liquefied gas from process or equipment onto the concrete structure shall be considered during design in accordance with international standards for liquefied natural gas storage tanks, ACI 376, EEMUA 207[16].

6.3.4.5 Explosions

The following types of explosions shall be considered:

— ignited gas clouds;

— explosions in enclosed spaces, including machinery spaces and other equipment rooms, as well as shafts and storage tanks.

The overpressure action due to expanding combustion products may be described by the pressure variation in time and space. It is important to ensure that the rate of rise, peak overpressure and area under the pressure-rise curve are adequately represented. The spatial correlation over the relevant area that affects the action effect should also be accounted for. Equivalent constant pressure distributions over panels could be established based on more accurate methods.

The damage due to explosion should be determined with due account of the dynamic character of the action effects. Simple, conservative single degree of freedom models may be applied. If necessary, non-linear time domain analyses based on numerical methods, such as the finite element method, should be applied.

Fire and explosion events that result from the same scenario of released combustibles and ignition should be assumed to occur at the same time, i.e. to be fully dependent. The fire and blast analyses should be performed by taking into account the effects of one on the other.

Damage done to the fire protection by an explosion preceding the fire should be considered.

6.3.4.6 Flooding

Unless otherwise mitigated, flooding of compartments in temporary and operational design situations shall be considered in the design. When the structure is afloat, the effect on tilt and waterline shall be considered. If mechanical systems are used to minimize the structural effects, these systems shall be designed to operate under the relevant conditions.

6.3.4.7 Dropped objects

Actions due to dropped objects should include the following types of incidents:

— cargo dropped from lifting gear;

— falling lifting gear;

— unintentionally swinging objects;

— loss of drilling equipment, pipes, etc.

The impact energy from the lifting gear shall be determined based on lifting capacity and lifting height, and on the expected weight distribution in the objects being lifted.

Unless more accurate calculations are carried out, the actions from falling objects may be based on the safe working action for the lifting equipment. The action shall be assumed to be due to objects falling from lifting gear from the highest specified height and at the most unfavourable place. Sideways

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movements of the dropped object due to possible motion of the structure and the crane hook should be considered.

The trajectories and velocities of objects dropped in water should be determined on the basis of the initial velocity, impact angle with water, effect of water impact, possible current velocity and the hydrodynamic resistance.

The impact effect of long objects, such as pipes and drill stem equipment, shall be subject to special consideration.

6.3.4.8 Collisions

The effect of a vessel impact shall be evaluated if the annual probability of collision is greater than 10^{-4}. In such an evaluation, the nature of all vessel operations in the platform vicinity shall be taken into account. These can include the following:

— vessels in service to and from the installation, including supply vessels;

— tankers loading at the field;

— floating installations, such as flotels;

— ships and fishing vessels passing the installation.

Where appropriate, impacts from sea ice or icebergs and from aircraft servicing the field shall be treated in the same manner as impacts from vessels.

The most probable impact locations and impact geometry shall be established, based on the dimensions and geometry of the structure and vessel. This shall account for tidal changes, operational sea states, and motions of the vessel and structure in free vibration modes. Potential vessel impact on the structure's waterline members, risers and external wells shall be considered. Effective operational restrictions on vessel approach sectors can limit the exposure to impacts in some areas of the structure. Unless more detailed investigations are done for the relevant vessel and structure, the impact zone for supply vessels may be considered to be between 10 m below lowest astronomical tide (LAT) and 13 m above highest astronomical tide (HAT). Barge bumpers, boat landings and other external fendering may be used as protection.

Depending on the risk of collision and the consequences for the structural integrity of the structure, an analysis of vessel impact conditions can be required. Irrespective of whether an analysis is required, robustness in relation to vessel collisions should be incorporated into the design by indirect means, such as the following:

— avoiding weak elements in the structure;

— selecting materials with sufficient toughness;

— ensuring that critical components are not placed in vulnerable locations.

Impact actions are characterized by kinetic energy, impact geometry and the relationship between action and indentation. In a rigorous impact analysis, if required, accidental design situations shall be established representing bow, stern and beam-on impacts on all exposed components.

Two energy levels shall be considered:

a) Low energy level: representing the frequent condition, based on the type of vessel which would routinely approach alongside the platform (e.g. a supply boat) with a velocity representing normal manoeuvring of the vessel approaching, leaving or standing alongside the platform.

b) High energy level: representing a rare condition, based on the type of vessel that would operate in the platform vicinity, drifting out of control in the worst sea state in which it is allowed to operate close to the platform.

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