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**Erdöl- und Erdgasindustrie –
Feststehende Offshore-Betonkonstruktionen (ISO 19903:2006);
Englische Fassung EN ISO 19903:2006**

Petroleum and natural gas industries –
Fixed concrete offshore structures (ISO 19903:2006);
English version EN ISO 19903:2006

Industries du pétrole et du gaz naturel –
Structures en mer fixes en béton (ISO 19903:2006);
Version anglaise EN ISO 19903:2006

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Nationales Vorwort

Diese Europäische Norm wurde vom Technischen Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ (Sekretariat: Frankreich) erstellt. Es handelt sich dabei um die unveränderte Übernahme von ISO 19903:2006, erarbeitet von ISO/TC 67 „Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries“, Subkomitee SC 7 „Offshore-Konstruktionen“ (Sekretariat: England).

Diese Europäische Norm enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 13/1983 nur die englische Originalfassung der ISO-Norm.

English Version

Petroleum and natural gas industries - Fixed concrete offshore
structures (ISO 19903:2006)

Industries du pétrole et du gaz naturel - Structures en mer
fixes en béton (ISO 19903:2006)

Erdöl- und Erdgasindustrie - Feststehende Offshore-
Betonkonstruktionen (ISO 19903:2006)

This European Standard was approved by CEN on 25 November 2006.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Foreword

This document (EN ISO 19903:2006) has been prepared by Technical Committee ISO/TC 67 “Materials, equipment and offshore structures for petroleum and natural gas industries” in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2007, and conflicting national standards shall be withdrawn at the latest by June 2007.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 19903:2006 has been approved by CEN as EN ISO 19903:2006 without any modifications.

Introduction

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

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

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

International Standard ISO 19903 was developed based on experience gained from the design, execution and use of a number of fixed concrete platforms, in particular from more than 30 years of experience with such structures in the North Sea. The background documents when developing this International Standard are from the following types of documents:

- 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 International Standard draws on the experience gained with fixed concrete offshore structures. This experience shows that fixed 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 is reflected in ISO 19903 by the fact that the standard gives guidance rather than detailed prescriptive rules. This International Standard 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.

1 Scope

This International Standard specifies requirements and provides recommendations applicable to fixed concrete offshore structures for the petroleum and natural gas industries, and specifically addresses

- a) the design, construction, transportation and installation of new structures, including requirements for in-service inspection and possible removal of structures,
- b) the assessment of structures in service, and
- c) the assessment of structures for reuse at other locations.

This International Standard is intended to cover the engineering processes needed for the major engineering disciplines to establish a facility for offshore operation. It can also be used for the design of floating concrete structures as specified in ISO 19904-1 ^[11] (and the future ISO 19904-2 ^[12] when published) and for arctic structures (as specified in the future ISO 19906 ^[7] when published).

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 relevant reference. For such well-known topics as the design formulas for concrete structural members, this International Standard is intended to be used in conjunction with a suitable reference standard for basic concrete design (see 8.2.1). The designer can use suitable national or regional design standards that provide the required level of safety. Only other ISO documents will be referenced directly in the text.

2 Normative references

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

ISO 1920-3, *Testing of concrete — Part 3: Making and curing test specimens*

ISO 1920-4, *Testing of concrete — Part 4: Strength of hardened concrete*

ISO 2394, *General principles on reliability for structures*

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

ISO 6934 (all parts), *Steel for the prestressing of concrete*

ISO 6935 (all parts), *Steel for the reinforcement of concrete*

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 19901-4, *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 operations¹⁾*

1) To be published.

ISO 19902, *Petroleum and natural gas industries — Fixed steel offshore structures* ³⁾

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19900 and the following apply.

NOTE Terms and definitions relevant for the use of this International Standard are also found in ISO 19901-1, ISO 19901-2, ISO 19901-4 and ISO 19901-6 and in ISO 19902.

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 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.

[ISO 19901-2]

3.2

abnormal level earthquake

ALE

intense earthquake of abnormal severity under the action of which the structure should not suffer complete loss of integrity

NOTE The ALE event is comparable to the abnormal event in the design of fixed structures which are described in ISO 19902 and ISO 19903. 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.

[ISO 19901-2]

3.3

accidental design situation

design situation involving exceptional conditions of the structure 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 (direct action) or an imposed deformation or acceleration (indirect action)

NOTE 1 An imposed deformation can be caused by fabrication tolerances, settlement, temperature change or moisture variation.

NOTE 2 An earthquake typically generates imposed accelerations.

[ISO 19900]

3.5

action effect

effect of action on structural components

EXAMPLE Internal force, moment, stress or strain.

[ISO 19900]

3.6

addition

finely divided material used in concrete in order to improve certain properties or to achieve special properties

NOTE This International Standard 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 in small quantities related to the mass of cement to modify the properties of fresh or hardened concrete

3.8

after-damage design situation

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

3.9

aggregate

granular mineral material suitable for use in concrete

NOTE Aggregate can be natural, artificial or recycled from material previously used in construction.

3.10

air cushion

air pumped into underbase compartments of the structure

NOTE Normally applied in order to reduce the draft and increase the freeboard of the structure and/or to alter the structural loading.

3.11

atmospheric zone

part of the load-bearing structure that is above the splash zone

3.12

caisson

major portion of fixed concrete offshore structure, providing buoyancy during floating phases and the possibility of oil storage within the structure

NOTE 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.

3.13

characteristic value of a material property

value of a material or product property having a prescribed probability of not being attained in a hypothetical unlimited test series, a nominal value being used as the characteristic value in some circumstances

NOTE The characteristic material property generally corresponds to a specified fractile of the assumed statistical distribution of the particular property of the material or product. Characteristic strength is normally defined as the value of the strength below which 5 % of the population of all possible strength determinations of the material under consideration are expected to fall or, alternatively, 95 % if an upper value is more severe.

3.14

critical shear zone

zone in which the shear stress is at a maximum in relation to the shear strength

3.15

concrete

material formed by mixing cement, coarse and fine aggregate and water, with or without the incorporation of admixtures and additions, which develops its properties by hydration of the cement

3.16**condition monitoring**

evaluation of the condition and behaviour of the load-bearing structure(s) in service using data from design, inspection and instrumentation

3.17**construction afloat**

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

3.18**deck mating**

marine operation in which the platform topsides is floated into position and connected to the substructure

NOTE This operation is normally conducted by ballasting and deballasting of the substructure.

3.19**deep water construction site**

site for construction of the structure while afloat

NOTE 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 to the substructure takes place.

3.20**design rules**

rules in accordance with the chosen reference standard for concrete design

NOTE See 8.2.

3.21**dynamic amplification factor****DAF**

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

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

3.22**extreme level earthquake****ELE**

earthquake with a severity which the structure should sustain without major damage

NOTE The ELE event is comparable to the extreme environmental event in the design of fixed structures which are described in ISO 19902 and ISO 19903. When exposed to an ELE, a structure is supposed to retain its full capacity for all subsequent conditions.

[ISO 19901-2]

3.23**execution**

all activities carried out for the physical completion of the work including procurement, inspection and documentation thereof

NOTE The term covers work on site; it might also signify the fabrication of components off-site and their subsequent erection on site.

3.24**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 is described in ISO 19902. 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.

[ISO 19900]

3.25
finite element analysis
FEA

analysis method whereby a structure or a part thereof is subdivided into small elements of known or assumed behaviour, then analysed by numerical matrix methods to determine action effects, static or dynamic

3.26
fixed concrete offshore structure
FCS

concrete structure designed to rest on the sea floor

NOTE 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.

3.27
fixed structure

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

[ISO 19900]

3.28
float-out

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

NOTE Typically, it is the transfer of the lower part of the concrete structure from a flooded drydock.

3.29
global analysis

determination of a consistent set of either internal forces and moments or of stresses in a structure that are in equilibrium with a defined set of actions on the entire structure and which depend on geometrical, structural and material properties

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

3.30
inspection

conformity evaluation by observation and judgement accompanied, as appropriate, by measurement, testing or gauging to verify that the execution is in accordance with the project work specification

3.31
installation

marine operation in which the platform is positioned and set down on the sea floor at the offshore site

3.32
instrumentation

outfitting of a fixed concrete offshore structure with instruments for data measurement and recording

3.33
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

3.34**lightweight aggregate**

aggregate of mineral origin having an oven-dry particle density $\leq 2\,000\text{ kg/m}^3$ or a loose oven-dry bulk density $\leq 1\,200\text{ kg/m}^3$

3.35**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

3.36**marine operation**

planned and controlled vertical or horizontal movement of a structure or component thereof over, in or on water

3.37**method statement**

document stating the methods and procedures to be used to perform the work

3.38**normal-weight aggregate**

aggregate with an oven-dry particle density between $2\,000\text{ kg/m}^3$ and $3\,000\text{ kg/m}^3$

3.39**offshore site**

offshore location where the structure is to be installed for its operational life

3.40**operations manual**

document giving the requirements and restrictions related to a safe operation of the concrete structure and all its systems

3.41**owner**

representative of the companies which own a development

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

3.42**primary structure**

all main structural components (concrete or steelwork) that provide the structure's main strength and stiffness

3.43**procedure**

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

3.44**project specification**

document giving the overall technical requirements provided by the owner

3.45**project work specification**

all information and technical requirements necessary for the execution of the works, includes documents and drawings, etc. as well as references to relevant regulations, specifications, etc.

3.46**quality plan**

document specifying which procedures and associated resources shall be applied by whom and when, covering the entire project or defined parts of the project and all relevant products, processes or contracts

3.47

secondary structure

structural components that do not contribute significantly to the overall strength and stiffness of the structure but which support individual items of equipment, transferring the actions thereon onto the primary structure

3.48

shaft

compartment extending from the caisson of the fixed concrete offshore structure to the topsides

NOTE 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.

3.49

skirts

structural components constructed in concrete and/or steel that extend from the foundation downwards and penetrate into the seabed

NOTE Skirts are used to increase the capacity of the foundation to resist vertical and horizontal actions and improve erosion resistance. Skirts can also be needed to form compartments facilitating the under-base grouting.

3.50

solid ballast

non-structural material added to a structure

NOTE 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.

3.51

splash zone

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

[ISO 19900]

3.52

structure

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

[ISO 19900]

3.53

submerged zone

part of the structure that is normally submerged and exposed to the constant influence of sea water

3.54

subsidence

that part of the settlement of the structure that results from extraction of reservoir hydrocarbons and factors other than the weight of the structure

3.55

summary report

document including the most important assumptions on which the design, construction and installation work is based with regard to the load-bearing structure

3.56

topsides

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

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

[ISO 19900]

3.57**tow to field**

marine operation in which the complete platform or structure is moved from the dry dock or inshore construction site to the offshore site

3.58**works**

construction work described in the project work specification

3.59**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 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
C_a	total current capacity of the anodes
D	action due to imposed deformation
E	environmental action
E_a^o	design closed-circuit anode potential
E_c^o	design protective potential
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
$I_{c,initial}$	initial current demand
$I_{c,final}$	final current demand
L	lap length

M_x, M_y, M_{xy} six force components giving stresses in the plane of the member
 N_x, N_y, N_{xy}

R	radius
R_a	anode resistance
Q	variable action
a	mass content of the active addition (type II)
c	cement mass content
c_a	current capacity of an anode
f_c	coating breakdown factor for any coated surfaces ($f_c = 1$ for bare steel)
f_{cd}	design compressive strength of concrete
f_{ck}	characteristic compressive strength of concrete
f_{cn}	nominal compressive strength of concrete
f_{yk}	characteristic strength of steel
i_c	design current density
k	factor which takes into account the activity of a type II addition
m	effective water/cement ratio
m_T	total net anode mass
n	number of anodes
t	thickness
u	utilization factor of the anode
w	water mass content in concrete
t_f	design life of the cathodic protection system
ε	anode material's electrochemical efficiency
ν	Poisson ratio
γ_F	partial factor for action taking account of model and geometrical uncertainties
γ_M	partial factor for material resistance properties taking account of material, model and geometric uncertainties
γ_G	partial factor for permanent actions, also accounting for dimensional variations
γ_Q	partial factor for variable actions
γ_E	partial factor for environmental actions
γ_D	partial factor for actions resulting from imposed deformations

γ_A partial factor for accidental actions

4.2 Abbreviated terms

AAR	alkali aggregate reaction
ALE	abnormal level earthquake
ALS	accidental limit state
CCTV	closed-circuit television
CFD	computational fluid dynamics
ELE	extreme level earthquake
FCS	fixed concrete offshore structure
FLS	fatigue limit state
GRP	glass-fibre reinforced plastic
HAT	highest astronomical tide
HAZOP	hazard and operability analysis
HISC	hydrogen-induced stress cracking
HVAC	heating, ventilation and air conditioning
IC	inspection class
LAT	lowest astronomical tide
MIC	microbiologically induced corrosion
ROV	remotely operated vehicle
SCC	self-compacting concrete
SLS	serviceability limit state
SRB	sulfate-reducing bacteria
ULS	ultimate limit state

5 General requirements

5.1 General

Fixed concrete offshore structures shall be designed in accordance with ISO 19900, this International Standard 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 2394.

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

5.2 National requirements

National regulations and standards applicable in the place where a structure will be used can be different from those given in this International Standard. In such cases it shall be ensured that the requirements of safety, reliability and durability implicit from the requirements of this International Standard are met. This applies to all phases of planning, design, construction, transportation, installation, service in-place and possible removal.

5.3 Overall planning requirements

5.3.1 General

A fixed concrete offshore structure shall be planned in such a manner that it can meet all requirements related to its functions and use, as well as to its structural safety, reliability and durability. Adequate planning shall be done before design is started in order to have sufficient basis for the engineering to obtain a safe, workable and economical structure that will fulfil the required functions.

The initial planning shall include determination and description of all functions the structure shall fulfil, and all requirements and criteria that the design of the structure shall meet. 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. All functional and operational requirements in temporary and in-service phases, as well as robustness against accidental situations that can influence the layout and the structural design, shall be considered.

All functional requirements 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.

Investigation of site-specific data such as seabed topography, soil conditions and environmental conditions shall be carried out in accordance with the requirements of ISO 19901-1 and ISO 19901-4.

5.3.2 Quality systems

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

All work performed in accordance with this document shall be subject to quality control in accordance with an implemented quality plan. The quality plan shall be in accordance with an internationally accepted quality system, for example, the ISO 9000 series. There can be one quality plan covering all activities or one overall plan with separate plans for the various phases and activities to be 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.

5.3.3 Qualifications of personnel

All activities that are performed in the engineering, design, construction, transportation, installation, inspection and maintenance of offshore structures according to this International Standard shall be performed by competent personnel with the qualifications and experience necessary to meet the objectives of this International Standard. Qualifications and relevant experience shall be documented for all key personnel and for personnel performing tasks that normally require special training or certificates.

National requirements on qualifications of personnel such as engineers, operators, welders, divers, etc. in the place of use apply. Additional requirements can be given in the project specification.

5.3.4 Documentation

Documentation shall be prepared for all activities that are to be performed in the engineering, design, construction, transportation, installation and possible removal of fixed concrete offshore structures. This includes investigations establishing data on which the design is based, engineering reports, design reports and calculations, drawings, specifications, etc., sufficient to give complete information about the structure. 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.

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 compliance 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 fixed concrete offshore structure including all systems.

5.4 Functional requirements

5.4.1 General

The engineering of a fixed 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 load cases that have to 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.

5.4.2 Site-related functional requirements

5.4.2.1 Position on site

The structure shall be positioned and oriented on site such that its orientation takes account of the reservoir, construction requirements, other platforms in the vicinity, accessibility by ships and helicopters, and safety in case of fire or leakages of hydrocarbons. Position tolerance is to be defined by the owner.

5.4.2.2 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, based on site-specific data, allowing the passage of extreme wave crests higher than the design wave crest, in accordance with ISO 19901-1. Due account shall be taken of wave crest modifications caused by the structure, caisson effect, local or regional features of the sea floor and wave run-up along the shafts.

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.

5.4.3 Platform operational requirements

The functional requirements to be considered that are related to the production system include

- a) layout of production wells, risers and pipelines, etc.,
- b) storage volume, compartmentalization, densities, temperatures, etc. in case of stored products,

- c) safeguards against spillage and contamination,
- d) access requirements, both internal and external, for operation, inspection and condition monitoring, etc.,
- e) interface to topsides, and
- f) provisions for supply boats and other vessels servicing the platform.

All hazards (fire, explosions, loss of intended pressure differentials, flooding, leakages, rupture of pipe systems, falling objects, ship impacts, etc.) that can be anticipated during operations shall be established and evaluated. The structure shall be designed to give adequate safety to personnel, safety against damage to the structure or pollution of the environment.

5.5 Structural requirements

5.5.1 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.

5.5.2 Structural concept requirements

The structural concept, details and components shall be such that the structure

- a) has adequate robustness with low sensitivity to local damage,
- b) can be constructed in a controlled manner,
- c) provides simple stress paths that limit stress concentrations,
- d) is adequately protected from corrosion and other degradation,
- e) is suitable for condition monitoring, maintenance and repair, if required, and
- f) fulfils requirements for decommissioning and removal if required.

5.5.3 Materials requirements

The materials selected for the load-bearing structures shall be suitable for the purpose. 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.

5.5.4 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.

5.5.5 Temporary phases requirements

The structure shall be designed for all phases with the same intended reliability (per annum) as for the final condition unless otherwise agreed. This applies also to temporary moorings or anchorage systems applied to 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 a complete

geometric model. 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.

5.6 Design requirements

5.6.1 General

The structural design of a fixed concrete offshore structure and its foundation design shall be in accordance with this International Standard. 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 tightness in all design situations such that the assumptions made are complied with.

The design of structural steel components shall be in accordance with ISO 19902.

5.6.2 Design actions

The representative values of actions shall be selected according to 6.5.

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.

5.6.3 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.

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

5.6.4 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 In some standards (e.g. NS 3473.E [2]), 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.

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.

For geotechnical analyses, the characteristic material resistance shall be determined so that the probability of more unfavourable materials occurring to any significant extent is low. Any deteriorating effects during the operation phase 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 soil, the characteristic 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 International Standard.

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.

5.6.5 Partial factors for 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 steel members in the mechanical outfitting, embedment, skirts, etc., the partial resistance factor shall be in accordance with ISO 19902.

Foundation design shall be performed in accordance with Clause 9. The partial factor for soil material shall normally not be lower than 1,25.

5.6.6 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. 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.

6 Actions and action effects

6.1 General

6.1.1 Classification of actions

In accordance with ISO 19900, actions are classified as

- permanent actions (G),
- variable actions (Q),
- environmental actions (E), and
- accidental actions (A).

In this International Standard, an additional category is distinguished, being

- actions resulting from imposed deformations (D).

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:

- normal operations;
- temporary situations;
- accidental situations;

- abnormal situations;
- damaged 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.

Simplified methods for computing actions may be applied if it can be verified that they produce conservative results.

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

Hydro- 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 models 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. Parameters shall be varied with upper and lower bound values to ensure that all realistic patterns of distribution are enveloped, 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.

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, depending on location, seismic actions (6.2.6) or ice actions (6.2.7) or both can be significant environmental actions.

6.2.2 Wind, wave and current actions

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 velocity 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:

- 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 the as-installed situation at the permanent location as well as to temporary floating situations. Potential dynamic effects due to local or global actions from wind and current shall also be investigated.

The influence of the structure on the instantaneous water surface elevation shall be investigated. The possibility of direct impact of greenwater on topsides or shafts shall also be investigated. Total water surface elevation depends on storm surge and tide, on the crest height of incident waves, and on the interaction of the incident waves with the structure.

Environmental actions due to wind, wave and current relate particularly to ultimate limit state requirements. In addition, these actions can contribute to the fatigue, serviceability, and accidental limit states. Environmental actions due to wind, wave and current shall also be considered for temporary configurations of the structure during construction, tow and installation. The complete design life cycle of the structure, from initial construction to removal, shall be considered and appropriate combinations of wind, wave and current shall be determined to define design situations for all phases.

6.2.3 Extreme wave action

6.2.3.1 General

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

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 such as diffraction analysis shall be applied that accounts for the interaction of the structure with the incident wave-field. For higher ratios, a slender-body theory such as the Morison equation may be used. Where drag forces are important in this regime, both methods 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.

Model testing 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.

6.2.3.2 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) extreme 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.

6.2.3.3 Diffraction analysis

6.2.3.3.1 General

Global actions on large-volume bodies shall generally be determined by applying a validated diffraction analysis procedure. In addition, local kinematics, required in 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.

6.2.3.3.2 Methods

Analytical procedures shall generally be implemented through well-verified computer programs, typically based on source/sink (Green's Function) panel methods or similar procedures. Alternative procedures including classical analytical or semi-analytical methods and the finite element method may be considered in specialized cases. Programs should be validated by comparisons with model tests and/or verified with published data.

6.2.3.3.3 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. The grid density shall be sufficient to adequately capture fluctuations in parameters such as pressure. In zones of relatively high gradients, denser grids shall be employed. By way of example, in the vicinity of the free surface grid densities will generally need to be increased. Grid densities shall also be related to the wave period in order to provide an adequate description of fluctuations over the wavelength. In general, convergence tests with grids of variable density shall be carried out to confirm the adequacy of any proposed panel model.

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.

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.

Structures with significantly varying cross-section near the waterline, within the likely wave-affected zone, call for additional consideration. Structures that are not wall-sided across the waterline are not consistent with the underlying assumptions of linear diffraction theory; both local and global actions as well as action effects can be significantly non-linear relative to the magnitude of the sea state.

The calculation of actions caused by waves on surface-piercing structures that will be overtopped by the progressing wave need special attention and validation of the calculation method is necessary.

Careful consideration shall be given to possible pressure fluctuations on the base of a structure during the passage of a wave field. If the foundation conditions are such that pressure fluctuations are expected to occur on the base, 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.

6.2.3.4 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 temporary floating situations due to wave or wind actions.

Ringling can control the extreme dynamic response of particular types of fixed concrete offshore structures. A ringling response resembles that generated by an impulse excitation of a linear oscillator; it features a rapid build-up and slow decay of the response at the resonant period of the structure. Ringling is excited by non-linear (second, third and higher order) processes in the actions due to waves that are only a small part of the total applied environmental actions on a structure.

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.

6.2.3.5 Model testing

6.2.3.5.1 The role of model testing

The necessity of model tests to determine extreme wave actions shall be determined on a case-by-case basis. Generally, model tests shall be considered when the following is required.

- Verification of analytical procedures: model tests should be performed to confirm the results of analytical procedures, particularly for cases with structures of unusual shape, for structures in shallow water with steep extreme waves, or for any other case where known limitations of analytical procedures are present.
- Complementing analytical procedures: model tests should be performed where various effects such as ringling, wave run-up, potential occurrence of deck slamming are suspected, or in cases where the higher order terms that are neglected in analytical procedures can be important. These effects cannot normally be assessed by the basic analytical procedure.

6.2.3.5.2 Scaling of model tests

Froude scaling is normally appropriate for typical gravity-driven processes like 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.

6.2.3.5.3 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.

6.2.3.5.4 Estimation of actions

When model tests are performed, appropriate test data shall be recorded to facilitate computation of wave actions. Data that can be appropriate include

- 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, and
- 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.

6.2.3.5.5 Limitations of model testing

It shall be recognized that, analogous with analytical procedures, model test results have inherent limitations. These limitations 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 generally allowed for in model test programme definition and can be significant particularly where large-scale factors are applied.
- Viscous effects: the Reynolds number is not generally accurately scaled 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 depend on this phenomenon such as slamming actions will not in general be accurately scaled in typical Froude-scale-based model tests.

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

- 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, and
- difficulties in the inclusion of wind or currents in association with wave fields.

6.2.4 Current action

6.2.4.1 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 fixed structure shall be accounted for.

6.2.4.2 Methods

Current actions on platforms 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 computational fluid dynamics (CFD) may be used in the evaluation of current actions or other effects associated with current. These procedures are based on an exact solution of the equations of motion of viscous fluids (the Navier Stokes equations). 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.

6.2.4.3 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.

6.2.4.4 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 velocity using either CFD or model test results. These velocities are generally combined 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.

6.2.5 Wind action

Wind actions on a fixed 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 be determined based on the appropriate design wind velocity in combination with recognized calculation procedures. 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 and 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.

6.2.6 Seismic actions

Procedures for the determination of seismic actions are provided in ISO 19901-2 at two levels, ELE and ALE respectively. For the ELE event the structure shall meet the normal ultimate limit state requirements. Seismic actions at ALE level may be considered as an abnormal event in the design. Unless otherwise specified in the project specification, the return periods should be as specified in 6.5, the annual probability of exceedance as specified in Table 2, and the action factors as specified in Table 1 of this International Standard.

6.2.7 Ice actions

The computation of ice actions is highly specialized and location-dependent and is not covered by this International Standard; see ISO 19906 ^{[7], 2)} for pertinent information.

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

- 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, and
- prestressing.

2) Under preparation. Until published, see the specialist literature.

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

6.3.2 Variable actions

Variable actions (Q) originate from normal operations of the structure in the different phases and vary in magnitude, position and direction during the time period considered. They include actions from

- personnel,
- modules, parts of mechanical outfitting and structural parts planned to be added or removed during the operational phase,
- 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 installation and drilling operations, etc., and
- ordinary boat impact, fendering and mooring.

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

The assumptions that are made concerning variable actions shall be reflected in the summary report, see 5.3.4, and shall be complied 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

- thermal effects,
- prestressing effects (including effects of prestressing sequences etc.),
- creep and shrinkage effects,
- differential settlement of foundation components, and
- 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, maloperation or accident. The accidental actions to be 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. Concerning evaluations of risk related to fire and explosions, see ISO 13702^[6].

Primary sources of accidental actions include

- rare occurrences of abnormal environmental events,
- fires,
- explosions,
- flooding,
- dropped objects,
- collisions, and
- unintended changes in pressure differences.

6.3.4.2 Rare occurrences of abnormal environmental events

These include abnormal environmental events such as the 10 000 year return period wave condition and the ALE seismic event, as well as other abnormal environmental events when relevant.

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, among others, 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 or 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.

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 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 FCS 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 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.

6.3.4.5 Flooding

Flooding of compartments in temporary and operational phases shall be considered in the design. In phases where 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.

6.3.4.6 Dropped objects

Actions due to dropped objects should, for instance, 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 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.

6.3.4.7 Collisions

The effect of a vessel impact shall be evaluated if the probability of collision is not negligible. In such an evaluation the nature of all vessel operations in the platform vicinity shall be taken into account. These can include

- vessels in service to and from the installation, including supply vessels,
- tankers loading at the field,
- floating installations, such as flotels, and

- 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 LAT and 13 m above 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

- avoiding weak elements in the structure,
- selecting materials with sufficient toughness, and
- 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. The collision events shall represent both a fairly frequent condition, during which the structure should only suffer insignificant damage, and a rare event where the emphasis is on avoiding a complete loss of integrity of the structure.

Two energy levels shall be considered:

- 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.
- 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.

Level a) represents a serviceability limit state to which the owner can set his own requirements based on practical and economical considerations. Level b) represents an ultimate limit state in which the structure is damaged but progressive collapse shall not occur. In both cases the analysis shall account for the vessel's mass, its added mass, orientation and velocity. The possibility of leaks due to damages in the impact zone and flooding shall be assessed.

The collision energy can be determined on the basis of relevant masses, velocities and directions of vessels that can collide with the structure. All traffic in the relevant area shall be mapped and possible future changes in vessel operational pattern shall be accounted for. Design values for collisions are determined based on an overall evaluation of possible events.

The mass of supply ships selected should normally be not less than 5 000 tonnes. A hydrodynamic (added) mass of 40 % for sideways and 10 % for bow and stern impact can be assumed. For low energy impacts, a vessel velocity of 0,5 m/s is commonly used, representing a minor "bump" during normal manoeuvring of the vessel while loading or unloading or while standing alongside the platform. For high energy conditions, a vessel velocity of 2 m/s is commonly used, representing a vessel drifting out of control in a sea state with significant wave height of approximately 4 m.

6.3.4.8 Unintended changes in pressure difference

Changes in intended pressure differences or buoyancy caused for instance by defects in, or wrong use of, separation walls, valves, pumps or pipes connecting separate compartments, as well as safety equipment to control or monitor pressure, shall be considered.

Unintended distribution of ballast due to operational or technical faults shall also be considered.

6.3.4.9 Floating structures in damaged condition

Floating structures that experience buoyancy loss or flooding have an abnormal floating position. The corresponding abnormal variable and environmental actions shall be considered.

Adequate global structural strength shall be documented for the abnormal floating conditions considered in the damage stability check, as well as tightness or ability to handle potential leakages in the tilted condition.

6.3.4.10 Combination of accidental actions

Where accidental actions occur simultaneously, the annual probability level (10^{-4}) applies to the combination of these actions. Unless the accidental actions are caused by the same phenomenon (like hydrocarbon gas fires and explosions), the occurrence of different accidental actions may be assumed to be statistically independent.

NOTE While, in principle, the combination of two different accidental actions with exceedance probability of 10^{-2} , or one at 10^{-3} and the other at a 10^{-1} level, corresponds to a 10^{-4} event, individual accidental actions at a probability level of 10^{-4} will normally be most critical.

6.4 Partial factors for actions

Partial factors for actions to be applied with representative actions according to Table 2 are given in Table 1. The factors should be adjusted as required for consistency with the reference standard used to provide an equivalent level of safety.

NOTE The recommended factors are consistent with the use of NS 3473.E [2] as the reference standard.

The ultimate limit state shall be checked for two sets of combinations of actions, ULS (A) and ULS (B) (see Table 1).

Table 1 — Partial factors γ_F for actions for different limit states

Limit state	Classification of action				
	γ_G	γ_Q	γ_E	γ_D	γ_A^a
ULS (A)	1,3	1,3	0,7 ^b	1,0	0
ULS (B)	1,0	1,0	1,3 ^b	1,0	0
SLS	1,0	1,0	1,0	1,0	0
FLS	1,0	1,0	1,0	1,0	0
ALS	1,0	1,0	1,0	1,0	1,0
^a A value of 0 for a partial factor for actions means that the action is not applicable to the design situation.					
^b These values may have to be adjusted for areas with long-term distribution functions that differ from those for North Sea conditions.					

The actions shall be combined in the most unfavourable way, provided that the combination is physically possible and permitted according to the action specifications. Combinations of actions that are physically possible but not intended or permitted to occur in operations shall be included by assessing their probability of occurrence and shall be accounted for either as an accidental design situation in the accidental limit state (ALS) or shall be treated as part of the ordinary design situations included in the ULS. Such conditions may be omitted in cases where the annual probability of occurrence can be determined to be less than 10^{-4} .

For permanent actions, a partial factor for action of 1,0 in action combination ULS (A) shall be used where this gives a more unfavourable action effect.

For external hydrostatic pressure, and for internal pressures resulting from a free surface, an action factor of 1,2 may normally be used, provided that the action effect can be determined with normal accuracy. Where second order effects are important, a partial factor for action of 1,3 shall be used. Where an action is the result of the difference between independent and counteracting hydrostatic pressures, the pressure difference shall be multiplied by the partial factor for action. The pressure difference shall be taken as no less than the smaller of either one tenth of the highest pressure or 100 kPa. This does not apply when the pressure is balanced by direct flow communication.

Prestressing actions may be considered as actions resulting from imposed deformations. Due account shall be taken of the time-dependent effects in calculation of effective internal forces. The more conservative value of 0,9 or 1,1 shall be used as a partial factor for action in the design.

A partial factor for action of 1,0 shall be applied to the weight of soil included in the geotechnical calculations.

For calculation of the soil capacity during cyclic actions, the design action effect shall be determined for the following two cases:

- a) using a partial factor for action equal to 1,0 for the cyclic actions and 1,3 for the largest environmental action;
- b) using a partial factor for action larger than 1,0 on the cyclic actions throughout the load history, including the greatest environmental action. Appropriate values of the partial factor for action shall be determined on the basis of an evaluation of the uncertainties associated with the cyclic action history.

The load history shall represent the wave conditions affecting the pore pressure build-up in a design storm, with respect to the distribution of load cycles, and their magnitude and number, prior to the time considered in the analysis. When the method in case b) is employed, a partial factor for action of 1,15 has been considered appropriate in a number of cases.

6.5 Combinations of actions

Table 2 gives a more detailed description of how actions shall be combined. When environmental and accidental actions are acting together, the given probabilities apply to the combination of these actions.

Table 2 — Representative actions and combinations of actions

	Representative actions and combinations of actions									
	Temporary phases					Normal operations				
	Serviceability limit state (SLS)	Fatigue limit state (FLS)	Ultimate limit state (ULS)	Accidental limit state (ALS)		Serviceability limit state (SLS)	Fatigue limit state (FLS)	Ultimate limit state (ULS)	Accidental limit state ALS	
Abnormal situation				Damaged situation	Abnormal situation				Damaged situation	
Permanent actions	Representative value									
Variable functional actions	Specified value									
Environmental actions	Dependent on operational requirements	Representative action history	Dependent on measures taken ^a			Dependent on operational requirements	Representative action history	Annual probability of exceedance = 10 ⁻²	Annual ^b probability of exceedance = 10 ⁻⁴	Annual probability of exceedance = 10 ⁻²
Deformation actions	Representative extreme value									
Accidental actions	Not applicable		Dependent on operational requirements		Not applicable				Annual probability of exceedance = 10 ⁻⁴	Not applicable

^a See 6.5.2 and Table 3.

^b When an abnormal environmental load is applied in ALS as accidental load, the annual probability of exceedance for an abnormal level earthquake ALE shall be agreed with relevant authorities typically 10⁻⁴ has been used for fixed concrete offshore structures in low to moderate seismic areas.

For temporary phases, where a progressive collapse in the installation does not entail the risk of loss of human life, injury, or damage to people or the environment, or of significant financial losses, a reduced return period for environmental actions may be considered. The return period to be considered should be related to the duration of the operation. As general guidance, the criteria given in Table 3 may be applied:

Table 3 — Environmental criteria

Duration of operation	Environmental conditions
Up to 3 days	Specific weather window
3 days to 1 week	1 year return period, seasonal
1 week to 1 month	10 year return period, seasonal
1 month to 1 year	100 year return period, seasonal
More than 1 year	100 year return period, all year

6.6 Exposure levels

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

Life-safety considers the manning situation in respect of personnel on the platform when the design environmental event occurs.

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

Three categories for each of life-safety and consequence can, in principle, be combined into nine different exposure levels. This results in three exposure levels, according to Table 4.

Table 4 — Determination of exposure level

Life-safety category	Exposure level (L1 to L3)		
	Consequence category		
	High consequence	Medium consequence	Low consequence
Manned—nonevacuated	L1	L1	L1
Manned—evacuated	L1	L2	L2
Unmanned	L1	L2	L3

The exposure level applicable to a structure shall be determined by the owner prior to the design of a new structure, and be agreed with the regulator where applicable.

NOTE The exposure levels are intended to have the same meaning as specified in greater detail in ISO 19902.

Structures in exposure level L1 shall be designed in accordance with the requirements of this International Standard for permanent, variable, environmental, deformation and accidental actions. Inspection of execution shall be according to inspection class 3, extended inspection, see 8.6.2.

For structures in exposure level L2 the same requirements apply as for L1 structures except that inspection of execution may be performed according to inspection class 2, normal inspection.

For structures in exposure level L3 the same requirements apply as for L2 structures except that accidental actions with a probability of less than 10^{-3} may be disregarded. Additionally, a reduction of the factor for environmental actions of not more than 10 % may be considered, if permitted by the project specification.

7 Structural analysis

7.1 General

Appropriate structural analyses shall be performed to determine the action effects within a structure. These analyses shall define the responses of the structure during each stage of its life in accordance with Clause 6.

Structural analysis refers to calculations based on numerical techniques including longhand calculations and/or computer-based methods. The development of action effects by model testing or by instrumentation of other similar structures is not precluded by this International Standard.

Complex or unusual structural types can require forms of analysis not described within this International Standard. If required, these shall be performed in accordance with the principle that a sufficient number of suitable analyses are carried out to accurately assess all significant action effects within the structure.

7.2 General principles

7.2.1 Planning

In order to ascertain that analysis of a fixed concrete offshore structure is successful, the following are required:

- all necessary analyses shall be performed on the basis of an accurate and consistent structural model that defines the structural system to the appropriate level of detail and enables the required corresponding actions on the structure to be assessed;
- these analyses shall be performed using appropriate methods, shall have relevant boundary conditions and shall be of suitable type;
- suitably verified results in the form of action effects shall be available in due time for use in design or reassessment.

Interfaces with structural designers, topsides designers, hydrodynamicists, geotechnical engineers and other relevant parties shall be set up. The schedule of supply of data on actions (including reactive actions) shall be determined and monitored. Interfaces shall ensure that these data are in the correct format, cover all necessary locations and are provided for all required limit states and for all appropriate stages in the lifetime of the structure.

7.2.2 Extent of analyses

Sufficient structural analyses shall be performed to provide action effects suitable for checking all parts and all structural components of the primary structure for the required design situations and limit states. At least one analysis should normally represent global behaviour of the structure during each relevant stage of its life.

The number and extent of analyses to be performed shall cover all parts and all structural components of the structure through all stages of its life, i.e. construction, transportation, installation, in-service conditions and removal/retrieval/relocation. However, if it can be clearly demonstrated and documented that particular stages in the life of the structure will not govern the design of a part of the structure or of a structural component, such stages need not be analysed explicitly for this part or component.

The simulation of a part of the structure or of a structural component shall, as a minimum, comprise a three-dimensional representation of the stiffness of all primary structure. In general, the stiffness of secondary structures may be omitted from structural analyses, although significant action effects due to secondary structure shall be incorporated. Secondary structure can provide such restraint to the primary structure that additional section forces are developed. Such effects shall be assessed and included where necessary.

Secondary components of the structure shall be assessed, by analysis if necessary, to determine their integrity and durability, and to quantify their contribution to action effects in the primary structure. Such analyses may be performed separately from analysis of the primary structure, but shall include deformations of the supporting primary structure, where relevant.