

## Structural design

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## Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for petroleum industry developments and operations. Furthermore, NORSOK standards are as far as possible intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary to fill the broad needs of the Norwegian petroleum industry. Where relevant, NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable standards work and according to established procedures defined in NORSOK A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF) and Federation of Norwegian Manufacturing Industries (TBL).

NORSOK standards are administered and published by Standards Norway.

## Introduction

The principle standard for offshore structures is ISO 19 900 *Petroleum and natural gas industries. General requirements for offshore structures* has been approved as a European standard, and has been published as EN-ISO 19 900.

Below is a list of international standards published or under preparation. It is the intention to revise the present NORSOK N-001 as soon as the ISO standards have been published.

ISO 19901 consists of the following parts, under the general title *Petroleum and natural gas industries — Specific requirements for offshore structures*:

- *Part 1: Metocean design and operating considerations*
- *Part 2: Seismic design procedures and criteria*
- *Part 4: Geotechnical and foundation design considerations*
- *Part 5: Weight control during engineering and construction*

The following parts of ISO 19901 are under preparation:

- *Part 3: Topsides structure*
- *Part 6: Marine operations*
- *Part 7: Stationkeeping systems for floating offshore structures and mobile offshore units*

ISO 19901 is one of a series of standards for offshore structures. The full series consists of the following International Standards:

- ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*
- ISO 19902, *Petroleum and natural gas industries — Fixed steel offshore structures*
- ISO 19903, *Petroleum and natural gas industries — Fixed concrete offshore structures*
- ISO 19904, *Petroleum and natural gas industries — Floating offshore structures*
- ISO 19905-1, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 1: Jack-ups*
- ISO/TR 19905-2, *Petroleum and natural gas industries — Site-specific assessment of mobile offshore units — Part 2: Jack-ups commentary*
- ISO 19906, *Petroleum and natural gas industries — Arctic offshore structures*

## 1 Scope

This NORSOK standard specifies general principles and guidelines for the structural design and the structural design verification of load bearing structures subjected to foreseeable actions.

This NORSOK standard is applicable to all types of offshore structures used in the petroleum activities, including bottom founded structures as well as floating structures.

This NORSOK standard is applicable to different types of materials used including steel, concrete, aluminium, etc.

This NORSOK standard is applicable to the design of complete structures including substructures, topside structures, vessel hulls, foundations, mooring systems and subsea installations.

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

## 2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements and guidelines of the standards referenced below.

BS 8118	Structural use of Aluminium, Part 1, Code practice for the design of Al-structures
DIN 4131	Antennentragwerke aus stahl
DIN 4133	Schorsteine aus stahl
DNV	DNV OS-C101, Design of Offshore Steel Structures, General (LRFD-method)
DNV	DNV OS-C102, Structural Design of Offshore Ships
DNV	DNV OS-C103, Structural Design of Column Stabilised Units (LRFD-method)
DNV	DNV OS-C104, Structural Design of Self Elevating Units
DNV	DNV OS-C105, Structural Design of TLPs (LRFD-method)
DNV	DNV OS-E401 Helicopter Decks
DNV	Classification note no. 30.5 "Environmental conditions and environmental loads"
DNV	Veritas Marine Operations, Standard for insurance warranty surveys in marine operations
IMO	Code for the construction and equipment of mobile offshore drilling units (MODU CODE)
ISO 19 900	Petroleum and natural gas industries. General requirements for offshore structures
ISO 19 901-4	Petroleum and natural gas industries. Specific requirements for offshore structures - Part 4: Geotechnical and foundation design considerations
ISO 19 901-5	Petroleum and natural gas industries. Specific requirements for offshore structures - Part 5: Weight control during engineering and construction
NORSOK G-CR-001	Marine Soil investigations (next revision will be renumbered G-001)
NORSOK J-003	Marine operations
NORSOK M-001	Materials selection
NORSOK M-101	Structural steel fabrication
NORSOK M-102	Structural aluminium fabrication
NORSOK M-120	Material data sheets for structural steel
NORSOK M-121	Aluminium structural materials
NORSOK M-501	Surface preparation and protective coating
NORSOK M-503	Cathodic protection
NORSOK M-CR-505	Corrosion monitoring design (will be renumbered M-505)

NORSOK N-002	Collection of metocean data
NORSOK N-003	Actions and action effects
NORSOK N-004	Design of steel structures
NORSOK N-005	Condition monitoring of load bearing structures
NORSOK S-001	Technical safety
NORSOK S-002	Working environment
NORSOK U -001	Subsea structures and piping system
NORSOK Z-001	Documentation for operation (DFO)
NS 3420	Descriptions for construction and building
NS 3472	Steel structures. Design rules
NS 3473	Concrete structures. Design rules

NOTE The reference to DNV Rules applies to the technical provisions therein. Any requirement therein for classification, certification or third party verification is not part of this NORSOK standard and may be considered as a separate service. Wherever the terms: agreement, acceptance or consideration etc. appear in the DNV Rules they shall be taken to mean agreement, acceptance or consideration by the Client/Purchaser or any other specifically designated party. Likewise, any statement such as: to be submitted to DNV, shall be taken to mean: to be submitted to Client /Purchaser or any other specifically designated party.

### 3 Terms, definitions and abbreviations

#### 3.1 Terms and definitions

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

##### 3.1.1

###### **can**

verbal form used for statements of possibility and capability, whether material, physical or casual.

##### 3.1.2

###### **design premises**

set of project specific design data and functional requirements which are not specified or are left open in the general standard

##### 3.1.3

###### **may**

verbal form used to indicate a course of action permissible within the limits of the standard

##### 3.1.4

###### **normative references**

shall mean normative in the application of NORSOK standards

##### 3.1.5

###### **Norwegian petroleum activities**

petroleum activities where Norwegian regulations apply

##### 3.1.6

###### **operator**

company or an association that through the granting of a production licence is responsible for the day to day activities carried out in accordance with the licence

##### 3.1.7

###### **petroleum activities**

offshore drilling, production, treatment and storage of hydrocarbons

##### 3.1.8

###### **principal standard**

standard with higher priority than other similar standards. Similar standards may be used as supplements, but not as alternatives to the Principal Standard

**3.1.9****recognised classification society**

classification society with recognised and relevant competence and experience from the petroleum activities, and established rules and procedures for classification/certification of installations used in the petroleum activities

**3.1.10****shall**

verbal form used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted, unless accepted by all involved parties

**3.1.11****should**

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

**3.1.12****verification**

examination to confirm that an activity, a product or a service is in accordance with specified requirements

**3.2 Abbreviations**

ALS	Accidental damage Limit State
API	American Petroleum Institute
BSI	British Standards Institution
DC	Design Class
DNV	Det Norske Veritas
DP	Dynamic Positioning
EN	European Standard
FLS	Fatigue Limit State
IMO	International Maritime Organisation
ISO	International Organisation for Standardisation
MDS	Material Data Sheet
NMD	Norwegian Maritime Directorate
NS	Norsk Standard
PSA	Petroleum Safety Authority Norway <sup>1</sup>
SLS	Serviceability Limit State
ULS	Ultimate Limit State

**4 General provisions and design principles****4.1 Regulations, standards and design premises**

Load bearing structures used in the petroleum activities shall comply with relevant national and international regulations. The Principal Standard for design of offshore structures is ISO 19 900.

Action factors, material factors, design fatigue factors and rules for combination of actions shall be determined on the basis of relevant national or international requirements with regard to reliability. When the rules of a classification society are used as basis for design and documentation, possible additional requirements necessary to fulfil relevant national regulations shall be identified and implemented. A Class Notation should be specified with the objective to minimise the need for additional requirements.

A Design Premises document shall be prepared and used as basis for design and documentation, stating all project specific regulations, standards, and functional requirements.

<sup>1</sup> On 2004-01-01 the Petroleum Safety Authority Norway (PSA) was established as an independent, government supervisory body under the Ministry of Labour and Government Administration. The PSA will be the authority in charge of safety, emergency preparedness and working environment in the petroleum activities. The responsibility was taken over from the Norwegian Petroleum Directorate (NPD).

## 4.2 General requirements relating to personnel qualifications and organisation

Personnel engaged in activities covered by the scope of this standard, see clause 1, shall have necessary qualifications and practical training. The organisation of the activity shall be such that it will ensure that the work is carried out safely and properly.

The party carrying out the design shall have a person who is professionally responsible. This person shall have extensive experience in design work and shall be given adequate opportunity to follow up the technical side of the work. The position for this person should be identified in the project organization chart.

The designer shall have adequate opportunity to carry out design work satisfactorily.

The Operator shall stipulate requirements to training and experience for personnel who are professionally responsible and for personnel carrying out design and verification. Documentation for the qualifications of personnel shall be available.

The designer should be able to carry out simplified and clearly set out calculations of all structural parts where faults may entail major consequences.

In the guidelines for selection of materials and fabrication of steel structures, reference is made to recognised standards for personnel qualifications.

Personnel who will be carrying out and checking concrete work, should meet the requirements of NS 3420 (1986) Chapter L item 06.2.

A number of maritime operations such as anchoring, dynamic positioning, crane operations, stability management and ballasting require a high degree of reliability from the personnel involved. Reference is made to NORSOK J-003.

NOTE Special provisions relating to the Norwegian petroleum activities:

1. The NMD: Regulations of 1 April 1996 No. 320 is recognised standard for personnel handling ballasting systems.
2. The NMD guidelines and notices No. 23 of 15 June 1993 relating to certification of DP operators is recognised standard for qualifications for dynamic positioning (DP) operators.

## 4.3 Risk assessment

Risk assessments shall be carried out in order to identify accidental events that may occur in the activities, and the consequences of such events for people, for the environment and for assets and financial interests. The extent of risk assessments and the risk assessment methods shall be determined by the Operator, taking into account the type of structure and relevant accumulated experience.

NOTE For the Norwegian petroleum activities risk analysis shall comply with PSA: Regulations relating to management in the petroleum activities. "The management regulations"

## 4.4 Assessment of existing structures

The principles for assessment of existing structures are given in ISO 19 900. Structural analysis and verification should be carried out in accordance with the relevant design standards and guidelines, taking into consideration the accumulated operational experience and the standard to which the structure was originally designed.

## 4.5 Abandonment and disposal

The abandonment and final disposal of the facilities and structures shall be considered at the design stage, to the extent required by the Operator. An abandonment dossier, containing details of the installation and other aspects that may influence the final disposal of the facilities, should be prepared. Ref. NORSOK Z-001.

NOTE For the Norwegian petroleum activities reference is made to Ch. 5 of the Petroleum Act and Royal Decree 31 August 2001: Regulations relating to health, the environment and safety in the petroleum activities. "The framework regulations"

## 5 Documentation and verification

### 5.1 Documentation

Documentation shall be prepared and submitted as basis for consents and decisions in accordance with relevant national regulations.

Sufficient documentation shall be prepared to ensure and to document that the activities are carried out in accordance with the regulations.

The Operator shall assess the need for documentation in the various phases of the activities. The Operator may in his documentation system make use of the documentation and the documentation systems already established with the various contractors and suppliers.

During the operational phase, documentation may be limited to what is required in order to be able to give an overall assessment of possible damage, repairs and modifications, and to be able to set up and carry out condition monitoring rationally. What documents are required has not been specified, and must consequently be considered in each separate case. This implies that possible incidents and the need for documentation must be considered thoroughly. Measures shall be taken for procreation of necessary documentation at short notice.

NOTE For the Norwegian petroleum activities reference is made to PSA: Regulations relating to material and information in the petroleum activities. "The duty of information regulations".

### 5.2 Verification

#### 5.2.1 General requirements

The Operator has the responsibility to have the verification carried out. The verification cannot be delegated to the contractor who is responsible for the work that is to be verified.

It shall be verified that provisions contained in relevant national and international regulations or decisions made pursuant to such regulations, have been complied with.

The extent of the verification and the verification method in the various phases shall be assessed. The consequences of any failure or defects that may occur during construction of the structure and its anticipated use shall receive particular attention in this assessment. The party carrying out the verification must be given opportunity to carry out the verification in a satisfactory manner. «All phases» also comprise soil investigations, preparing specifications, calculations, concreting, testing and similar. If work that is difficult to check later is carried out, such as soil investigations and concreting, the requirement implies that the party carrying out the verification shall witness the work when it is carried out.

The verification shall confirm whether the structure satisfies the requirements for the specific location and method of operation, taking into consideration the design, including material selection and corrosion protection, and the analyses methods used.

There shall be organisational independence between those who carry out the design work, and those who verify it. Special consideration should be given to the organisation of verification activities in cases where new project execution models and/or information technology systems are introduced.

If an operator takes over a specification from another operator, verification may be omitted if this specification has previously been verified pursuant to the present regulations, and the specifications are otherwise applicable to the location in question and to the installation concerned.

#### 5.2.2 Verification during the design phase

Verification of design should include checking:

- a) that specifications are in compliance with the applicable rules and regulations etc.
- b) personnel qualifications and organisation of the design
- c) calculations of actions and responses
- d) that accidental actions are in compliance with the results from the risk analyses

- e) the usefulness of computer software, and that the programmes are adequately tested and documented. This is of particular importance when programmes are used in dealing with new problems, constructions or new software
- f) that methods used in respect of geometry, actions, resistance calculations and manner of operation are suitable by carrying out alternative calculations
- g) that equipment and procedures for control of actions has adequate reliability, and by carrying out random checks
- h) that measuring requirements are complied with, see also NORSOK N-002
- i) that deviations during fabrication and installation are assessed and if necessary corrected
- j) that drawings are in accordance with calculations and specifications
- k) corrosion and erosion protection
- l) that a design review is carried out by different professional sectors co-operating in solving problems
- m) the design of important structural details.

With regard to the design of concrete structures, verification may in addition be carried out on the basis of NS 3473.

The design of structures or structural parts of significance to the overall safety should be verified by means of independent calculations. Such verification may be carried out by manual calculations or by computer calculations. When computer calculations are used, it is normally assumed that the person carrying out the verification uses another software programme than the designer. It shall be documented that computer software used in verifications has been tested for the purpose in question.

The calculations should be sufficiently accurate and extensive so as to demonstrate clearly that the dimensions are adequate.

The verification may be carried out as a combination of documentation review and audit. It is in particular organisation and personnel qualifications that can be verified during an audit.

### **5.2.3 Verification during the fabrication phase**

The person who verifies fabrication should, inter alia, check the following:

- a) that the specifications are in accordance with public regulations/provisions and safety requirements
- b) that satisfactory work instructions and procedures are prepared
- c) that personnel qualifications are in accordance with the requirements
- d) that the methods and equipment of suppliers and at the construction site are satisfactory with regard to control of dimensions and quality of structural parts and materials
- e) that dimensions, materials, surface protection and work performance are in accordance with the basic assumptions made during design
- f) the actual production, if for instance casting makes it difficult to assess the quality later
- g) that deviation procedures are adequate during fabrication
- h) that the transportation and storage of materials and fabricated assemblies is adequate.

A certification scheme for production of steel plates may replace the operator's verification in view of the authority regulations. The certification shall then include an acceptance of the equipment used for the steel making and production of plates, acceptance of technical specifications, procedures and work instructions, extensive testing of the steel products in delivery condition, and an evaluation of the quality assurance system. A follow-up of the steel mill shall be executed in accordance with defined plans and include audit of the quality assurance system, review of documentation, inspection of production testing and surveillance of the processes. The certification scheme representative must have relevant competence within steel materials and steel making in order to execute the verification described above.

With regard to fabrication of concrete structures, verification should be carried out according to NS 3473.

## **6 Actions and responses**

### **6.1 Standards and guidelines**

Actions to be considered are defined and classified in ISO 19 900. Actions are classified according to the variation of their magnitude with time, according to their variation in space and according to the structural response.

The Principal Standard for calculation of actions and responses is NORSOK N-003. Design data should be determined from actual measurements at the site or by suitable validated model data such as from hind cast models. Such design data shall be stated in the Design Premises.

Other standards and guidelines such as DNV: Classification note No. 30.5 and API RP 2N may be used as supplements to the Principal Standard. The use of such supplementary standards should depend on type of structure, location and relevant accumulated experience.

## 6.2 Action factors

### 6.2.1 General

The principles of the design format of partial factors are given in ISO 19 900.

When checking the serviceability limit states, the action factor shall be 1.0 for all actions. When checking the fatigue failure limit states, the action factor shall be 1.0 for all actions. The ultimate limit states shall be checked for two action combinations, a and b, with action factor according to Table 1.

**Table 1 – Action factor for the ultimate limit states**

Action combinations	Permanent actions	Variable actions	Environmental action
a	1.3	1.3	0.7
b	1.0	1.0	1.3

The actions are to be combined in the most unfavourable way, provided the combination is physically feasible and permitted according to the action specifications. For permanent actions, an action factor of 1.0 in action combination 'a' shall be used where this gives the most unfavourable response.

For the weight of soil, an action factor of 1.0 is to be used.

For calculation of the action carrying capacity of the soil during cyclic actions, the design response shall be stipulated in the following two cases:

1. action factor equal to 1.0 for the cyclical actions and 1.3 for the largest environmental action;
2. action factor larger than 1.0 for the cyclical actions in the total action history. The value of the action factor shall be determined based on an evaluation of the uncertainty attached to the cyclical actions in the action history.

Where the action is a result of high counteracting and independent hydrostatic pressures, the action factor shall be multiplied by the pressure difference. For installations with the shape of a ship, the action factor for environmental actions (Table 1) may be reduced to 1.15 (action combination b) when calculating bending moment in the longitudinal extent, if the still water moment represents between 20 % and 50 % of the total moment. In the accidental damage limit state for progressive collapse, the load coefficients shall be 1.0 for all loads.

### 6.2.2 Conditions and special considerations

When determining the action factors, the following has been taken into consideration:

1. the possibility that the actions may deviate from the characteristic actions;
2. the reduced possibility that different actions contributing to the response analysed, will reach their characteristic value at the same time;
3. possible inaccurate calculation of responses, to the extent that such inaccuracies may be assumed to be independent of the construction material.

If conditions other than those mentioned take effect, the action factor shall be adjusted accordingly.

Uncertainties in fatigue calculations have been taken into account through the implementation of design fatigue factors.

The action factor 1.3 (action combination a) for permanent actions in Table 1 can be reduced to 1.2 if actions and responses are determined with great accuracy. A reduced action factor of 1.2 will normally be acceptable for external hydrostatic fluid pressures, if the responses can be determined with normal accuracy. If there is a significant uncertainty with regard to determining the water level, e.g. due to reservoir subsidence, the factor 1.3 shall nevertheless be used. With regard to structures where effects of the second order are significant, the factor 1.3 shall normally be used. If there is doubt as to whether the actions and the responses have been determined with adequate accuracy, the use of 1.2 for such actions may be substantiated according to the provisions of clause 7.2.2. The analysis must then be sufficiently accurate to be able to differentiate between different phases, structural parts and failure types, and to take into account accuracy in maritime operations.

The action factor 1.3 (action combination b) for wave, current and wind actions in Table 1 can be reduced to 1.15 if the installation is unmanned during storms. This will be based on an evaluation as to whether a collapse will entail:

- a) danger of loss of human life;
- b) significant pollution;
- c) major financial consequences.

The Operator should then discuss the three items above and include an evaluation in a statement in the Design Premises. Such evaluations may be relevant for, inter alia, loading buoys, separate flare towers, stability during installation, subsea installations and other installations which are unmanned during storms.

### **6.3 Action combinations**

The principles for combination of actions are given in ISO 19 900.

A detailed and specific description of how actions of different values shall be combined is given in NORSOK N-003.

### **6.4 Special considerations**

#### **6.4.1 Deck elevation**

The topside structure shall normally have adequate clearance above the design wave crest. When determining the deck elevation and air gap in accordance with ISO 19 900, the non-Gaussian structure of surface waves shall be accounted for. Any topside structure or piping not having adequate clearance shall be designed for actions caused by waves and currents. Impact actions should be verified by properly designed model tests. Minor structure or components may be excluded from this requirement.

#### **6.4.2 Repetitive actions and possible fatigue damage in topside structures**

The possibility for fatigue damage in topside structures due to repetitive actions shall be considered.

Repetitive actions and fatigue damage may be significant, e.g. in case of:

- Interaction between topside structures and multishaft fixed concrete substructures
- Interaction between topside structures and column/pontoon type floating substructures
- Interaction between topside structures and monohulls (global hull bending)
- Wave induced motions and accelerations of floating structures
- Direct wave actions (slamming).

Flare towers, drilling towers, bridges, crane pedestals, etc. should be given special attention.

#### **6.4.3 Weights engineering and weight control**

The weight and centre of gravity shall be checked at regular intervals on installations that are sensitive to alterations.

The requirement relating to checking weight applies to all phases from design to operation of the installation.

For floating installations weights engineering and weight control shall be considered in relation to stability criteria and stability control, see clause 7.10.

An inclining test should be carried out immediately after installation, and also if major weight increases are carried out, or in the event of a redistribution of the weight on the installation. If a floating installation is placed on a location over a longer period of time, regular inclining tests should be carried out, if no other weight follow-up is carried out.

Recognised standard for weights engineering and weight control is ISO 19 901-5.

#### **6.4.4 Actions caused by moored vessels**

Operational limitations related to mooring of vessels to an installation shall be documented by specifying where mooring actions may take place, under which conditions vessels are permitted to be moored, and the allowable size of the vessels to be permitted to be moored. Based on these restrictions the installation shall be designed for the most probable maximum action in this condition. Measures should be taken to avoid damage to the installation in the event of overloading. When maximum action is calculated in a potentially weak link, a high characteristic value for the resistance of the link should be used. The calculation of mooring actions should take into account the fact that the mooring arrangement's action-displacement characteristics may be changed during use (e.g. synthetic rope).

#### **6.4.5 Accidental actions and protection against accidental actions**

Structures shall be designed with due consideration to fire, explosions, impacts, flooding and other relevant accidental events with associated effects. In assessing the risk for accidental events, technical, operational and/or organisational risk reducing measures should be considered, see also clause 7.2.6 and NORSOK S-001.

#### **6.4.6 Anomalous dynamic effects**

Ringing and springing dynamic effects need to be carefully taken into account in design of e.g. tension leg platforms and gravity based structures. Where analytical approaches are not fully developed/acknowledged, it is a requirement to perform model testing at appropriate scale.

## **7 General structural design**

### **7.1 Design objectives**

A structural system, its components and details shall be designed to comply with ISO 19 900 and the following listed principles:

- Structures and structural elements shall normally be designed with ductile resistance
- Structures shall be designed such that an unintended event does not escalate into an accident of significantly greater extent than the original event
- Structures shall be designed with the objective to minimise overall dynamic stress concentrations and provide a simple stress path
- Structures shall be designed such that fabrication, including surface treatment, can be accomplished in accordance with relevant recognised techniques and practices
- Design of structural details, selection of structural profiles and use of materials shall be done with the objective to minimise corrosion and the need for special precautions to prevent corrosion
- Adequate access for inspection, surveillance, maintenance and repair shall be provided
- Satisfy functional requirements as given in the Design Premises.

Active operation (such as draft adjustment, re-location of cargo, etc.) may be taken into consideration on the condition that it can be demonstrated that the operations have an acceptable degree of reliability. Active operation in an emergency situation should consequently not depend on a high degree of reliability of operations personnel.

The installation may be designed on the assumption that individual components may be replaced in such a way that an acceptable overall safety is maintained for the installation. Replacement procedures should be prepared during the design phase.

## 7.2 Special design considerations

### 7.2.1 Limit states design

The principles of the limit states design method and the definitions of the four limit states categories are given in ISO 19 900. The term limit state shall be understood to mean that state where a structure or part of a structure no longer meets the requirements laid down for its performance or operation. All identified forms of fault shall be checked within the respective groups of limit states (ultimate limit state, serviceability limit states, fatigue limit states and accidental damage limit states). It must be checked that the structure has sufficient ductility to develop the relevant failure mechanism.

Methods based on permissible stresses can only be used if it can be demonstrated that they provide results that are on the safe side compared to the limit states design method.

Commonly used design methods are based on the assumption that design values for response and resistance can be calculated separately. In cases where integrated non-linear analyses are used, care should be taken to ensure that intended levels of safety are obtained.

### 7.2.2 Check of limit states

The purpose of the calculations or the testing, on which the design is to be based, is to maintain the probability of reaching a limit state below a specified value.

In cases where a high resistance is unfavourable for the structure, the characteristic resistance shall be determined so as to give a low probability of failure. This probability shall be of the same level as the probability of a lower value. For geotechnical analyses «low probability» will in most cases mean a conservatively estimated mean value. The wording has been chosen to cover a number of special structures. It is consequently expected of the designer to consider the relevant cases.

When the response is increased with the material resistance, the design should be based on an upper characteristic strength, e.g. based on 95 % fractile.

Design against fatigue failure in steel, aluminium and concrete may be based on S-N curves. Fracture mechanics analyses of crack propagation can be used in special cases.

Design responses and resistances may be calculated by using deterministic computational models. Normal uncertainties in the computational models are assumed covered by the partial coefficients.

The design may be based on a more complete reliability design method, provided it can be documented that the method is suitable from a theoretical point of view, and that it provides adequate safety in typical, known cases. This opens for use of reliability methods which entail calibration of action and material coefficients against a given failure probability level, or direct design by means of such methods. The safety level can be calibrated directly against the safety of known structure types and be based on corresponding assumptions. When reliability methods are used, it shall be documented that the results are on the safe side.

### 7.2.3 Ultimate limit states (ULS)

The principles of the design format of partial factors are given in ISO 19 900.

In respect of steel structures the material coefficient shall be 1.15 and in respect of aluminium structures the material coefficient shall be 1.2.

For structures of reinforced concrete, the material factor shall be 1.25. For reinforcement steel and steel for prestressed concrete, the material factor shall be 1.15.

In the case of geotechnical analyses, the material factor shall normally not be lower than 1.25. For piles and anchors the material factor for soil shall be 1.3. The material factor applies to the group of piles. A material factor lower than 1.3 is permitted for individual piles if it can be documented that this will not result in adverse behaviour.

If necessary, the safety level shall be adjusted to the desired value through the use of factors. The factors shall take into account any conditions deviating from the conditions on which the material factors were based. Reference is made to NORSOK N-004 for steel and BS 8118 for aluminium.

When determining the material factors, the following has been taken into consideration:

- a) the possibility that the strength of the sample may deviate from the characteristic values
- b) the possibility of local strength change in the structure caused by the construction process
- c) possible inaccurate calculation of the resistance, including the effect of dimensional tolerances.

#### 7.2.4 Serviceability limit states (SLS)

Serviceability limit states for offshore steel structures are associated with:

- Deflections which may prevent the intended operation of equipment
- Deflections which may be detrimental to finishes or non-structural elements
- Vibrations which may cause discomfort to personnel, ref. NORSOK S-002.
- Deformations and deflections which may spoil the aesthetic appearance of the structure

Serviceability requirements will normally be defined by the operator for the specific project. In absence of project specific requirements the provisions given in Table 2 shall be used.

Limitations with regard to deflections, displacements, vibrations and operation of the installation shall be defined during the design and stated in the Design Premises.

For calculations in the serviceability limit states the material coefficient shall be 1.0.

**Table 2 – Limiting values for vertical deflections**

Condition	Limit for $\delta_{max}$	Limit for $\delta_2$
Deck beams	L/200	L/300
Deck beams supporting plaster or other brittle finish or non- flexible partitions	L/250	L/350

L is the span of the beam. For cantilever beams L is twice the projecting length of the cantilever.

The maximum vertical deflection is:

$$\delta_{max} = \delta_1 + \delta_2 - \delta_0 \quad (1)$$

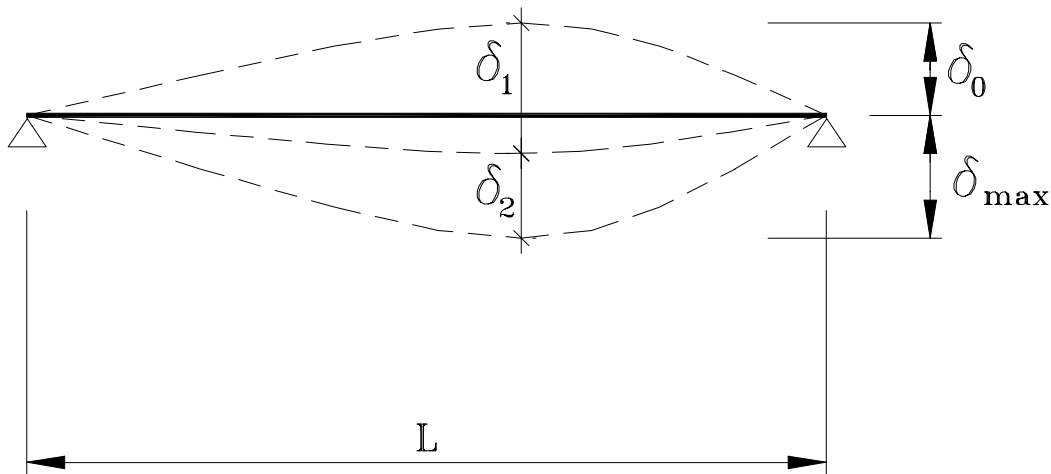
Where:

$\delta_{max}$  = the sagging in the final state relative to the straight line joining the supports.

$\delta_0$  = the pre-camber

$\delta_1$  = the variation of the deflection of the beam due to the permanent loads immediately after loading

$\delta_2$  = the variation of the deflection of the beam due to the variable loading plus any time dependent deformations due to the permanent load



**Figure 1 – Definitions of vertical deflections**

Installations with extensive movements shall be designed so that equipment that is of significance to safety is not rendered non-functional as a result of the movements. The provisions given in the IMO MODU Code relating to machinery installations for all types of units should be complied with when relevant. For installations with extensive movements maximum permissible movements shall also be stipulated based on working environment considerations.

NOTE For installations in the Norwegian petroleum activities which are covered by the scope of application of the Working Environment Act, design criteria shall be stipulated based on working environment considerations, cf. the Working Environment Act, Section 8 subsection 1, literas e) and f). Further guidance is provided in PSA: Regulations relating to design and outfitting of facilities etc. in the petroleum activities. "The facility regulations"

**7.2.5 Fatigue limit states (FLS)**

Structures shall be designed to withstand the presupposed repetitive (fatigue) actions during the life span of the structure. Design fatigue factors shall be applied for safety and with the objective to minimise life cycle costs, taking into account the need for in-service inspection, maintenance and repair, see NORSOK N-005.

Minimum values for the design fatigue factors are given in Table 3

**Table 3 - Design fatigue factors**

Classification of structural components based on damage consequence	Not accessible for inspection and repair or in the splash	Accessible for inspection, change or repair and where inspection or change is assumed.	
		Below splash zone	Above splash zone or internal
Substantial consequences	10	3	2
Without substantial consequences	3	2	1

The selection of design fatigue factors shall then be based on an assessment of damage consequences and accessibility for inspection and repair.

Assumptions made regarding damage consequences, accessibility and design fatigue factors shall be stated in the Design Premises.

A distinction is made between «substantial consequences» and «without substantial consequences». «Substantial consequences» in this context means that a collapse of the structural part will entail:

- a) danger of loss of human life;
- b) significant pollution;
- c) major financial consequences.

«Collapse of the structural part» means that adequate safety in damaged condition must be demonstrated according to clause 7.2.6.

With regard to accessibility for inspection and repair distinction is made between the terms «no access or in the splash zone», «below splash zone» and «above splash zone or internal». In this connection «below and above splash zone» of an installation is related to the programme for condition monitoring that is prepared for that specific installation, see NORSOK N-005. In the event of 4-5 years of dry docking the entire installation may be regarded as being above the splash zone. The splash zone for fixed platforms can be taken from 4 m below the lowest tide to 5 m above the highest tide.

### **7.2.6 Accidental damage limit states (ALS)**

The ALS check ensures that the accidental action does not lead to complete loss of integrity or performance of the structure, as described in ISO 19 900.

The material coefficient shall be 1.0 in the ALS check.

The ALS shall be checked in two steps:

- a) resistance to accidental actions. The structure should be checked to maintain the prescribed load carrying function for the defined accidental actions.
- b) resistance in damaged condition. Following local damage which may have been demonstrated under a), or following more specifically defined local damage, the structure shall continue to resist defined environmental conditions without suffering extensive failure, free drifting, capsizing, sinking or extensive damage to the external environment.

The methodology implies that minor damage is accepted for the ALS. This also applies to damage that cannot be repaired, e.g. in connection with the foundation.

The ALS check may be omitted if an overall evaluation shows that a collapse (by «collapse» is meant collapse of the entire installation) will not entail:

- a) danger of loss of human life;
- b) significant pollution;
- c) major financial consequences.

The Operator shall then discuss the three items above and include the evaluation in a statement in the Design Premises. This may be relevant for, inter alia, loading buoys, separate flare towers, stability during installation, subsea installations and other installations which are unmanned during storms.

### **7.3 Selection of materials and fabrication control**

When selecting materials, the following shall, inter alia, be taken into account:

- a) consequences of possible material defects;
- b) operations temperature for the structure;
- c) weldability for metallic materials;
- d) stress level;
- e) detrimantation or corrosion;
- f) maintenance.

The Principal Standard for selection of materials is NORSOK M-001.

Simple and minor repairs may be carried out in accordance with a general procedure. Major repairs should be carried out according to special procedures that describe how control and documentation of the result is to be carried out.

## **7.4 Corrosion protection of structures**

The site specific conditions and the planned degree of weather protection shall be considered with regard to corrosion, and a suitable corrosion protection system shall be designed. If the conditions differ significantly from previous experience, field measurements should be carried out.

Adequate accessibility for corrosion protection and maintenance shall be allowed for in the design.

The Principal Standards for planning and implementation of a corrosion protection system for load bearing structures are NORSOK M-001, NORSOK M-501, NORSOK M-503 and M-CR-505.

Other design standards and guidelines may be used as supplements to the Principal Standards specified above. The use of such supplementary standards should depend on type of structure, area of location and relevant accumulated experience.

Consistency between structural design criteria, technical solutions and applied corrosion protection system shall be documented.

## **7.5 Condition monitoring of structures**

The Principal Standard for planning and implementation of a condition monitoring system of load bearing structures is NORSOK N-005. Special consideration shall be given to critical components identified on the basis of risk assessment, operating experience and failure statistics. Reference is also made to NORSOK N-002.

A Design, Fabrication and Installation resume (DFI-resume) shall be prepared in accordance with NORSOK Z-001.

## **7.6 Design of steel structures**

### **7.6.1 Standards and guidelines**

Principal Standards for design of steel structures are NORSOK N-004 Design of steel structures, NS 3472 and Eurocode 3.

Principal Standards for material selection and for structural steel fabrication are NORSOK M-001, M-101 and M-120 respectively.

## **7.7 Design of aluminium structures**

### **7.7.1 Standards and guidelines**

Principle Standard for design of aluminium structures is: BS 8118, Part 1 Code of practice for design.

The designer should be aware of the reduced strength and ductility in the welds and the heat affected zones in hardened aluminium materials. Plastic hinges shall be avoided at or in the vicinity of welds.

Exceptions from the Principal Standard are:

- a) Action factors, material factors and design fatigue factors shall comply with NORSOK N-001. However, the material factors of BS 8118 Table 3.3 shall still apply for joints.
- b) Guidelines for selection of recommended materials according to clause 7.7.2
- c) Inspection categories for welds according to clause 7.7.3
- d) Mechanical data given in material standards referred in Material Data Sheet in NORSOK M-121 shall be used. Limiting stresses in Table 4.1 and 4.2 in BS 8118 Part 1 shall not be used, they shall be calculated as shown in Appendix D in BS 8118 Part 1.

The following items shall when relevant be decided by the designer, and be noted on the drawings:

- Quality of all materials
- Type and dimension of welds
- Inspection Category for welds
- Restricted areas for temporary cut-outs
- Overall weld geometry requirements
- Areas of welds with mandatory NDT

### 7.7.2 Selection of aluminium materials

Principal Standard for specification of aluminium materials is NORSOK M-121.

### 7.7.3 Fabrication of aluminium structures

The welds should be divided into four Inspection Categories as defined in Table 4.

Principal Standard for welding and non-destructive testing is NORSOK M-102.

**Table 4 - Determination of inspection categories for joints subjected to static and fatigue loads**

Consequence	High fatigue utilisation <sup>c</sup>	Low fatigue utilisation	
		High tensile stresses <sup>d</sup>	Low tensile stresses
Substantial Consequences <sup>a</sup>	A	B	C
Substantial Consequences but with reserve strength <sup>b</sup>	B	C	D
Non-Substantial Consequences	C	D	D

<sup>a</sup> "Substantial consequences" in this context means that failure of the joint or member will entail:

- Danger of loss of human life;
- Significant pollution;
- Major financial consequences.

<sup>b</sup> Residual strength means that the structure meets requirements corresponding to the damaged condition in the check for Accidental Damage Limit States, with failure in the actual joint or component as the defined damage.

<sup>c</sup> High fatigue utilisation means connections with calculated fatigue life less than 3 times the required fatigue life (Design fatigue life multiplied with the Design Fatigue Factor DFF).

<sup>d</sup> High tensile stresses mean ULS tensile stresses in excess of 0.75 of design stress.

## 7.8 Design of concrete structures

The Principal Standards for design of concrete structures is NS 3473.

Functional requirements relevant to a special design shall be stated in the Design Premises.

Other design standards and guidelines, such as DNV: Rules for classification of fixed offshore installations, may be used as supplements to the Principal Standards specified above. The use of such supplementary standards should depend on type of structure, location and relevant accumulated experience.

## 7.9 Soil investigation and geotechnical design for marine structures

### 7.9.1 Soil investigation

The Principal Standard for soil investigation is ISO 19 901-4, and the Principal Standard relating to requirements to equipment, testing and reporting of soil investigations and laboratory work is NORSOK G-CR-001.

If anchoring system failure for a floating installation does not cause danger to the installation itself or to neighbouring installations, the requirement to soil investigations can be considered met on the basis of interpretation of seismic data and general knowledge about the soil conditions in the area.

Soil investigation for jack-up structures shall be carried out when:

- a) soil seismic show or one may expect a pronounced stratification of the soil
- b) no soil investigations have been carried out in the vicinity that can be linked up with the soil seismic
- c) there is a possibility for dangerous soil conditions, e.g. uncontrolled subsidence due to erosion or weak underlying layers.

The soil investigation should consist of at least one borehole drilled to 30 metres or to a penetration depth twice the diameter of the spudcan, depending on which is the deeper. If there is a great variation in the substrata layers in the area, several boreholes shall be drilled. In particular cases, a cone penetration test can replace drilling fully or in part.

NOTE Special conditions relating to the Norwegian petroleum activities:

1. Geotechnical data submitted to the PSA are public. By geotechnical data is meant results from examination of soil conditions on the continental shelf carried out for safety reasons.
2. When soil investigations have been carried out to evaluate the foundation, it is recommended that they are placed at the disposal of Norges geologiske undersøkelser (The Geological Survey of Norway).

### **7.9.2 Characteristic properties of the soil**

The characteristic values of soil properties are to account for the variability of the property values and the extent of the zone of ground governing the limit state being considered.

The results of both laboratory tests and in-situ tests shall be evaluated and corrected on the basis of recognised practice and experience. Such evaluations and corrections shall be documented. Possible effects of installation activities on the soil properties should be considered.

The characteristic values of a soil parameter shall be selected such that the probability of a less favourable value governing the occurrence of the limit state is small. When the limit state is governed by a large soil volume, the characteristic mean value for the soil parameter or the characteristic depth profile for the same soil parameter shall be selected such that the probability of having a less favourable mean value governing the occurrence of the limit state is small.

### **7.9.3 Geotechnical design for marine structures**

The geotechnical design for marine structures shall comply with the principles given in ISO 19 900. The Principal Standard for geotechnical design is ISO 19 901-4.

Other design standards and guidelines, such as API RP 2A and DNV: Rules for Classification of fixed offshore installations, may be used as supplements to the Principal Standards specified above. The use of such supplementary standards should depend on type of structure, location and relevant accumulated experience.

### **7.9.4 Slope stability**

In connection with slope stability calculations, minimum safety factors shall be evaluated both for global and local slope failures. This evaluation shall include:

- Environmental loads (earthquake, shallow gas, pore pressure etc)
- Loads imposed from human activities (trenching, rock filling, installation of structures ets)
- The possibility that local slope failures can develop to large global failures
- The possibility that human activities may reduce the safety both for local and global slopes.

Selection of safety factor for global and local slope stability must be based on a total risk evaluation considering both soil type, triggering mechanisms, loads and consequences. Regarding human activity, the main objective must be not to worsen the safety if the calculated safety already is marginal.

### **7.10 Subdivision, stability and freeboard**

General requirements relating to subdivision of structures are given in ISO 19 900. For surface units (ship- or barge-type displacement hull of single or multiple hull construction), self-elevating units and column-stabilised units the detailed provisions of the IMO MODU Code relating to subdivision, stability and freeboard should be complied with.

NOTE Special provisions relating to the Norwegian petroleum activities:

1. The individual technical provisions for new units in the NMD: Regulations of 20 December 1991 No. 878 concerning stability, watertight subdivision and watertight/weathertight closing means on mobile offshore units, are recognised standards for stability.
2. Any space adjacent to the sea should be calculated to be able to be flooded if:
  - a) the space has penetrations to the sea;
  - b) the space may become flooded as a result of a system or operation failure;
  - c) relevant accidental events entail significant leakage.
3. If a dimensioning accidental event may entail damage to the bulkheads between two spaces, the possibility of flooding of both spaces should be taken into account.
4. If a risk analysis shows that the greatest relevant accidental event with regard to collision is a drifting vessel with a displacement which does not exceed 5000 tons, the extent of damage indicated in the Maritime Directorate's regulations can be used.
5. The walls of concrete structures adjacent to the sea should, if failure or leakages may entail loss of human life, significant pollution or major economical consequences, be designed for a pressure differential equal to at least 1.0 MPa, and the thickness should be at least 0.5 m (The 1.0 MPa should be used in the ALS check).
6. The individual technical provisions for new units in the NMD: Regulations of 20 December 1991 No. 879, concerning ballast systems on mobile offshore units, are recognised standards for ballasting.

## 7.11 Station keeping systems

General requirements relating to station keeping systems are given in ISO 19 900. The requirements are functionally oriented. General guidelines for design of station keeping systems are given in API RP 2SK. For station keeping in relation to marine operations reference is made to clause 7.12.

Specific design conditions and criteria shall be established in relation to the type of structure, the type of operation, the operating philosophy, the consequences of failure etc. A description of the specific design conditions and criteria shall be included in the Design Premises.

When calculating mooring systems of catenary type intact condition is considered as ULS. For ALS the number of line failures and location of failure are to be determined in relation to an annual probability of exceedance of  $10^{-4}$ . Alternatively two line failures may be taken as basis when combined in the most unfavourable way.

The Principal Standards for design of station keeping systems are the technical provisions for new units in NMD: Regulations of 10 February 1994 No. 123 for mobile offshore units with production plants and equipment, and the technical provisions for new units in NMD: Regulations of 4 September 1987 No. 857 concerning anchoring/positioning systems on mobile offshore units.

However, the structural and geotechnical design of pile anchors and suction anchors in the condition shall be based on the action factors and material factors defined previously

In the ALS condition the geotechnical design of such anchors shall be based on a load factor equal to 1.0 and a material factor equal to 1.0. Generally for one and two line failure an environmental load with an annual probability of exceedance of  $10^{-2}$  should be applied. For two line failures an environmental load with an annual probability of exceedance of  $10^{-1}$  can be applied in the geotechnical design, in this case a material factor equal to 1.25 shall be used.

Provided all conditions given in clause 7.2.2 are fulfilled, the design of station-keeping systems may be based on a reliability based design method. The damage condition (the number of line failures and the failure locations) and the storm condition to be considered for the ALS check should then be based on risk analyses.

Actual dimensions of permanent mooring chain in service are not to be smaller than the dimensions presupposed in the analysis.

NOTE For design of Dynamic Positioning Systems and for Thruster Assist Systems for the Norwegian petroleum activities, the technical provisions for new units in the NMD: Regulations of 4 September 1987 No. 857 concerning anchoring/positioning systems on mobile offshore units shall be complied with and Guideline No. 28 to the NMD regulations and Appendix B to Guideline No. 28, are recognised standards.

## 7.12 Marine operations

The Principal Standard for marine operations is NORSOK J-003.

For operations where a Marine Warranty Surveyor has been appointed to fulfil the clauses in the insurance policy, all requirements given by the Marine Warranty Surveyor shall be complied with. For operations where a Marine Warranty Surveyor has not been appointed the DNV: Veritas marine operations, Standard for insurance warranty surveys in marine operations should be applied.

## 8 Design of various types of structures

### 8.1 Fixed steel structures

Fixed steel structures (steel jackets) should be designed and verified in accordance with NORSOK N-004.

### 8.2 Fixed concrete structures

Fixed concrete structures should be designed and verified in accordance with clauses 4 - 7 of this standard.

The soil-structure interaction shall be carefully assessed in the calculation of soil reactions for the design of the structure including skirts, dowels etc. Realistic upper and lower bounds of soil parameters shall be assumed so as to ensure that all realistic patterns of soil reactions are enveloped in an appropriate manner. As part of this degree of mobilisation both locally and globally shall be considered as well as plasticity at stress peaks and time dependent effects. Skirt compartments that in the design are assumed to rely on pore pressure higher than ambient, shall be documented to have the appropriate tightness for all limit states.

### 8.3 Tension leg platforms

Tension leg platforms including topside structures and tether system, should be designed and verified in NORSOK N-004, Annex N. See section 7.8 in case of concrete.

With regard to the extent of damage in relation to loss of buoyancy, reference is made to clause 7.10.

### 8.4 Column-stabilised units

Column-stabilised units (semi submersibles) including topside structures and station keeping system, should be designed and verified in accordance with NORSOK N-004, Annex M. See section 7.8 in case of concrete.

The IMO MODU Code should be complied with. If the rules of a classification society are to be applied, the relevant Class Notation shall be stated in the Design Premises.

NOTE 1 For the Norwegian petroleum activities the DNV OS-C103, Structural Design of Column Stabilised Units should be applied for units that are to have maritime certificates.

NOTE 2 For non-Norwegian petroleum activities the rules of a selected recognised classification society should be complied with.

### 8.5 Self-elevating units

Self-elevating units (jack-ups) including topside structures, should be designed and verified in accordance with clauses 4 - 7 of this standard. The IMO MODU Code should be complied with. If the rules of a classification society are to be applied, the relevant Class Notation shall be stated in the Design Premises.

NOTE 1 For the Norwegian petroleum activities the DNV OS-C104, Structural Design of Self Elevating Units should be applied for units that are to have maritime certificates. For units involved in Norwegian petroleum activities that are not to have maritime certificates, the technical provisions in DNV OS-C104, Structural Design of Self Elevating Units should be used as a supplement.

NOTE 2 For non-Norwegian petroleum activities the rules of a selected recognised classification society should be complied with.

### 8.6 Surface units

Surface units (ship- or barge-type displacement hull of single hull construction) including topside structures, should be designed and verified in accordance with NORSOK N-004, Annex L. The IMO MODU Code should be complied with. If the rules of a classification society are to be applied, the relevant Class Notation shall be stated in the Design Premises.

NOTE 1 For the Norwegian petroleum activities the DNV OS-C102, Structural Design of Offshore Ships should be applied for units that are to have maritime certificates, see also clause 5.1.4.

NOTE 2 For non-Norwegian petroleum activities the rules of a selected recognised classification society should be complied with.

### 8.7 Topside structures

Topside structures (integrated decks, module support frames, modules and equipment skids) should be designed and verified in accordance with NORSOK N-003, N-004 and relevant Annexes, or the relevant rules of a recognised classification society, as stated in clauses 8.4 - 8.6 of this standard.

Subcontractors responsible for design of modules and equipment skids should receive design premises that outline relevant design conditions and criteria.

### 8.8 Helicopter decks

Helicopter decks for installations used in the petroleum activities shall be designed and verified in accordance with relevant national or international regulations.

The technical provisions in DNV OS-E401 *Helicopter Decks* may be used as a supplement.

### 8.9 Flare towers

Flare towers should be designed and verified in accordance with NORSOK N-003 and N-004. Other design standards and guidelines, such as BS 8100: part 1 Lattice towers and masts, DIN 4131 Antennentragwerke aus Stahl, DIN 4133 Schorsteine aus Stahl or technical provisions in rules issued by a recognised classification society may be used as supplements.

Displacements and fatigue damage caused by vortex induced vibrations, including wake interactions, local frame vibrations and global vibrations, should be considered.

Flare towers should preferably be designed with the objective to avoid vortex induced vibrations. Permissible design ranges based on critical velocities may be utilised.

Alternatively, flare towers may be designed according to relevant fatigue criteria, taking into account the accumulated damage caused by vortex induced local vibrations and global dynamic response.

In special cases, e.g. temporary phases, the use of vortex reducing devices may be considered.

### 8.10 Buoys

Buoys should be designed and verified in accordance with clauses 4 - 7 of this standard. The IMO MODU Code should be complied with. If the rules of a classification society are to be applied, the relevant Class Notation shall be stated in the Design Premises.

NOTE 1 For the Norwegian petroleum activities the DNV OS-C101, Design of Offshore Steel Structures should be applied for units that are to have maritime certificates, see also clause 5.1.4. For units involved in Norwegian petroleum activities that are not to have maritime certificates, the technical provisions in DNV OS-C101, Design of Offshore Steel Structures should be used as a supplement.

NOTE 2 For non-Norwegian petroleum activities the rules of a selected recognised classification society should be complied with.

### 8.11 Subsea structures

Subsea structures should be designed and verified in accordance with the principles for general design of structures NORSOK N-003, N-004 and NORSOK U-001.

Dynamic loading and fatigue should in particular be considered in the design of subsea structures that are connected to surface structures by mooring lines, cables or risers.

## Bibliography

- API RP 2A Recommended practice for planning, designing and constructing fixed offshore platforms.
- API RP 2N Recommended practice for planning, designing and constructing fixed offshore structures in ice environments.
- API RP 2SK Recommended practice for design and analysis of station keeping systems for floating structures.
- BS 8100 Lattice towers and masts, Part 1.
- NMD Regulations of 4 September 1987 No. 857 concerning anchoring/positioning on mobile offshore units (issued with amendments 1997).
- NMD Regulations of 20 December 1991 No. 878 concerning stability, watertight subdivision and watertight/weathertight closing means on mobile offshore units.
- NMD Regulations of 20 December 1991 No. 879 concerning ballast systems on mobile offshore units.
- NMD Regulations of 10 February 1994 No. 123 for mobile offshore units with production plants and equipment.
- NMD Regulations of 1 April 1996 No. 320 concerning certificates of competency and qualification requirements for the manning of mobile offshore units.
- PSA Royal Decree 31 August 2001: Regulations relating to health, the environment and safety in the petroleum activities. "The framework regulations".
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