

Integrity of offshore structures

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Foreword	4
Introduction	4
1 Scope	5
2 Normative and informative references	5
2.1 Normative references	5
2.2 Informative references	6
3 Terms, definitions and abbreviations	7
3.1 Terms and definitions	7
3.2 Abbreviations	9
4 General provisions and design principles	9
4.1 Regulations, standards and design premises	9
4.2 General requirements relating to personnel qualifications and organisation	10
4.3 Risk assessment	10
4.4 Assessment of existing facilities	10
4.5 Design and assessment by testing	11
4.6 Disposal	11
4.7 Robustness assessment	12
5 Documentation and verification	12
5.1 Documentation	12
5.2 Verification	12
6 Actions and action effects	15
6.1 Standards and guidelines	15
6.2 Partial action factors	15
6.3 Action combinations	17
6.4 Special considerations	17
7 General structural design	18
7.1 Design objectives	18
7.2 Special design considerations	18
7.3 Selection of materials and fabrication control	22
7.4 Corrosion protection of structures	22
7.5 Condition monitoring of structures	23
7.6 Standards and guidelines for design of steel structures	23
7.7 Design of aluminium structures	23
7.8 Design of concrete structures	24
7.9 Soil investigation and geotechnical design	24
7.10 Subdivision, stability and freeboard	25
7.11 Station keeping systems	26
7.12 Marine operations	26
8 Design of various types of structures	27
8.1 Fixed steel structures	27
8.2 Fixed concrete structures	27
8.3 Tension leg platforms	27
8.4 Column-stabilised units	27
8.5 Self-elevating units	27
8.6 Ship shaped units	27
8.7 Other floating units	28
8.8 Topsides structures	28
8.9 Helicopter decks	28
8.10 Flare towers	28
8.11 Subsea facilities	28

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 for most 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), The Federation of Norwegian Industry, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

Introduction

This NORSOK standard is the principle standard for offshore structures. The standard especially refers to ISO 19900, *Petroleum and natural gas industries - General requirements for offshore structures*.

It is the intention to revise this NORSOK standard as soon as the International Standards covering the scope of this NORSOK standard have been published.

1 Scope

This NORSOK standard specifies general principles and guidelines for the design and assessment of offshore facilities, and the verification of load bearing structures subjected to foreseeable actions and related maritime systems.

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

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

This NORSOK standard is applicable to all structural parts of a facility including substructures, topside structures, vessel hulls, foundations, mooring systems, and subsea facilities. The standard is also applicable to crane pedestals, living quarters, maritime systems, helicopter decks, module support frames and lifeboats.

This NORSOK standard specifies principles that are applicable also to the successive stages in construction (i.e. fabrication, transportation and installation), to the use of the facility during operation, and to its final disposal.

This NORSOK standard also specifies principles applicable to the assessments of existing facilities, as required when

- the structure and related maritime systems has experienced damage or deterioration,
- changes deviate from the original design basis. Such changes would include
 - changes in manning,
 - changes to facilities,
 - modifications of existing facility,
 - more onerous environmental criteria,
 - more onerous component or foundation resistance criteria,
 - physical changes to the design basis such as scour and subsidence,
 - inadequate freeboard.
- extension of intended design service life.

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 the requirements of the referenced standards.

2.1 Normative references

DNV-OS-C501,	Composite Components
EN 1990,	Eurocode – Basis of structural design
EN 1999 (all parts),	Eurocode 9: Design of aluminium structures
EN 1999-1-3,	Eurocode 9: Design of aluminium structures – Part 1-3: Structures susceptible to fatigue
ISO 19900,	Petroleum and natural gas industries – General requirements for offshore structures
ISO 19901-4,	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations
ISO 19901-5,	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 5: Weight control during engineering and construction
ISO 19901-7,	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 7: Station keeping systems for floating offshore structures and mobile offshore units

ISO 19903, MARPOL, MEPC.139(53),	Petroleum and natural gas industries – Fixed concrete offshore structures Consolidated edition of 2006, Annex I, Reg. 19.3.1 and 19.3.2 Guidelines for the application of the revised MARPOL Annex I. Requirements to floating production, storage and offloading facilities (FPSOs) and floating storage units (FSUs)
NORSOK G-001,	Marine soil investigations
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 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-002,	Working environment
NORSOK Z-001,	Documentation for operation (DFO)
NMD: Regulations of 4 September 1987 No. 857,	Regulations concerning anchoring /positioning on mobile offshore units (issued with amendments 1997)
NMD: Regulations of 20 December 1991 No. 878,	Regulations concerning stability, watertight subdivision and watertight/weathertight closing means on mobile offshore units
NMD: Regulations of 20 December 1991 No. 879,	Regulations concerning ballast systems on mobile offshore units
NMD: Regulations of 10 February 1994 No. 123,	Regulations for mobile offshore units with production plants and equipment
NMD: Regulations of 1 April 1996 No. 320,	Regulations concerning certificates of competency and qualification requirements for the manning of mobile offshore units
NS 3472,	Steel structures – Design rules
NS 3473,	Concrete structures – Design and detailing rules
Petroleum Act,	The Norwegian parliament: Act 29 November 1996 No. 72 relating to petroleum activities
PSA: Information Duty Regulations,	,Petroleum Safety Authority Norway (PSA), Norwegian Pollution Control Authority (SFT) and Norwegian Social and Health Directorate (NSHD): Regulations relating to material and information in the petroleum activities
PSA: The Facility Regulations,	Regulations relating to design and outfitting of facilities etc. in the petroleum activities
PSA: The Management Regulations,	Regulations relating to management in the petroleum activities
Royal Decree (Norway),	Royal Decree 31 August 2001: Regulations relating to health, the environment and safety in the petroleum activities
Working Environment Act,	The Norwegian parliament: Act of 17 June 2005 No. 62 relating to working environment, working hours and employment protection, etc.

2.2 Informative references

API RP 2A,	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms
BS 8100-1,	Lattice towers and masts – Part 1: Code of practice for loading
DNV-OS-C101,	Design of Offshore Steel Structures, General (LRFD-method)
	Structural Design of Offshore Ships
DNV-OS-C102,	Structural Design of Offshore Ships
DNV-OS-C103,	Structural Design of Column Stabilised Units (LRFD-method)
DNV-OS-C104,	Structural Design of Self Elevating Units
DNV-OS-C502,	Offshore Concrete Structures
DNV-OS-E401,	Helicopter Decks
DNV-RP-H102,	Marine operations during Removal of Offshore Installations
DNV Rules for Planning and Execution of Marine Operations	
DNV Classification Note No. 30.4,	Foundations
IMO MODU Code,	Code for the construction and equipment of mobile offshore drilling units

	(MODU CODE)
ISO 19904-1,	Petroleum and natural gas industries – Floating offshore structures – Part 1: Monohulls, semi-submersibles and spars
Maritime Directorate's regulations,	Norwegian Maritime Directorate's regulation for Mobile Offshore Units, InfoMediaHuset, Oslo, 2003
NORSOK N-006,	Assessment of structural integrity for existing offshore load-bearing structures (to be issued)
NORSOK S-001,	Technical safety
NORSOK U-001,	Subsea structures and piping system
NS 3465,	Execution of concrete structures – Common rules
NS 3481,	Soil investigations and geotechnical design for marine structures
PSA: The Framework Regulations,	Petroleum Safety Authority Norway (PSA), Norwegian Pollution Control Authority (SFT) and Norwegian Social and Health Directorate (NSHD): Regulations relating to health, environment and safety in the petroleum activities

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

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

3.1 Terms and definitions

3.1.1

action

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

3.1.2

action effect

effect of actions on structural components

3.1.3

can

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

3.1.4

characteristic value

value of a basic variable, an action or a strength model having a prescribed probability of not being violated by unfavourable values

3.1.5

design premises

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

3.1.6

design service life

assumed period for which a structure or a structural component is to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary

NOTE On the NCS the design service life will be limited to the planned design service life in plan for development and operation and the DFI résumé as described in PSA: Information Duty Regulations.

3.1.7**design value**

value of a basic variable, action or strength model derived from a representative value for use in a design verification procedure

NOTE For a design check in accordance with the partial factor design format, a design value for a strength variable or model is found by dividing the representative value of strength by a partial resistance factor, and for an action variable by multiplying the representative value of the action effect by a partial action factor.

3.1.8**limit state**

state where a structure or part of a structure no longer meets the requirements laid down for its performance or operation

3.1.9**may**

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

3.1.10**mobile offshore unit**

structure intended to be relocated to perform a particular function

3.1.11**Norwegian petroleum activities**

petroleum activities where Norwegian regulations apply

3.1.12**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

3.1.13**petroleum activities**

offshore drilling, production, treatment and storage of hydrocarbons

3.1.14**principal standard**

standard with higher priority than other similar standards

NOTE Similar standards may be used as supplements, but not as alternatives to the principal standard.

3.1.15**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

3.1.16**representative value**

value of a basic variable, action or strength model, for verification of a limit state

NOTE The representative value can be equal a characteristic value, a nominal value, or other rationally determined value.

3.1.17**resistance**

capacity of a structure, component or cross-section of a component to withstand action effects without exceeding a limit state

3.1.18**shall**

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

3.1.19**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

3.1.20**verification**

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

3.1.21**warranty surveyor**

independent third party ensuring that the terms of the marine insurance warranty clauses are complied with

3.2 Abbreviations

ALS	accidental damage limit state
API	American Petroleum Institute
BS	British Standard
DFF	design fatigue factor
DFI	design, fabrication and installation
DNV	Det Norske Veritas
DP	dynamic positioning
EN	European Standard
FLS	fatigue limit state
FPSO	floating production, storage and offloading structure
FSO	floating storage and offloading structure
IMO	International Maritime Organisation
ISO	International Organisation for Standardisation
MARPOL	International Convention for the Prevention of Pollution from Ships
MODU	mobile offshore drilling unit
MPI	magnetic particle inspection
NCS	Norwegian Costal Shelf
NDE	non-destructive examination
NMD	Norwegian Maritime Directorate
NPD	Norwegian Petroleum Directorate
NS	Norsk Standard
PSA	Petroleum Safety Authority Norway ¹
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.

Action factors, material factors, DFFs 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.

¹ 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 NPD.

4.2 General requirements relating to personnel qualifications and organisation

Personnel engaged in activities covered by the scope of this NORSOK 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 with safe and sound engineering judgement.

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 party carrying out the design shall ensure that the combined qualifications of the group of involved engineers are appropriate.

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

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

The designer shall be qualified to make simplified modelling and perform corresponding calculations of relevant structural parts where faults may entail major consequences.

In the guidelines for selection of materials and fabrication of structures, reference is made to recognised standards for personnel qualifications, e.g. NS 3465 for personnel who will be carrying out and checking concrete work.

A number of maritime operations (e.g. anchoring, DP, crane operations, stability management and ballasting) require highly qualified and experienced personnel.

Special provisions

For special provisions relating to the Norwegian petroleum activities, see NMD: Regulations of 1 April 1996 No. 320.

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 facility and relevant accumulated experience.

For the Norwegian petroleum activities risk analysis shall comply with PSA: The Management Regulations.

4.4 Assessment of existing facilities

Assessment of existing facilities is required when

- the structure and related maritime systems has experienced damage or deterioration,
- intended design service life is extended,
- changes may be more onerous than in the original design basis. Such changes would include
 - changes in manning,
 - changes to facilities,
 - modifications of existing facility,
 - changes in environmental criteria,
 - changes in component or foundation resistance criteria,
 - physical changes to the design basis such as scour and subsidence,
 - inadequate freeboard.

Assessment of existing facilities shall be performed taking the following elements into account:

- relevant information from design, fabrication and installation, e.g. design basis, specifications and as-built information;
- historic performance and operational experience of the structure with respect to incidents, accidents, degradation, repair and inspection results;

- as-is condition;
- an evaluation of expected future degradation of the structure based on the historic performance;
- planned modifications and mitigations to the structure and facility;
- new developments in knowledge and technology.

Assessment, analysis and verifications to verify that the structure is sufficiently safe in the planned service life should be carried out in accordance with NORSOK N-006, taking these elements into account. Further, technical and operational modifications found necessary to obtain such safety should be described, including plan for necessary inspection and maintenance. New structural elements introduced as a result of modifications or mitigations should be designed according to this NORSOK standard.

NOTE On the Norwegian continental shelf analysis and verification of the existing structures may be carried out in accordance with the same design standards and guidelines to which the facility was originally designed with respect to technical minimum requirements.

This NORSOK standard also specifies principles applicable to conversion of mobile offshore units. Important areas to be addressed during conversions are

- pre-conversion survey,
- effects of prior service,
- corrosion protection and material suitability,
- inspection and maintenance.

Special attention shall be given to a detailed "close up" visual inspection of crack prone structural details, including a related significant level of non-destructive testing in order to identify existing fatigue-related problems. A corrosion protection management philosophy shall be prepared and taken into considerations in structural design, taking into account

- effects of prior service and current condition related to coating degradation and corrosion wastage,
- future corrosion protection management system and potential future corrosion rates.

General guidance related to conversions is given in the normative part of ISO 19904-1.

4.5 Design and assessment by testing

Design by testing of resistance is in general to be supported by analytical design methods.

Structural resistance and resistance against degradation may be established by means of testing of structural components. To the extent that testing is used as basis for design, the testing shall be verifiable, see also EN-1990, 5.2.

Reference is made to EN-1990, Annex D, for guidance on determination of characteristic values from the testing to be used for design. For new types of materials and/or where the failure mode(s) of the structural components are not well defined the characteristic value should be determined based on procedure for "unknown" coefficient of variation in test data. Number of test data applies to one and the same failure mode only. In case of well known failure mechanisms, where similar test data are frequently available, the characteristic values can be determined from statistics with coefficient of variation in test data assumed as "known".

For testing of new types of structural components, reference is also made to DNV-OS-C501, Section 10.

Tests shall be conducted whenever uncertainties about action levels, action effects and corresponding freeboard requirements are present, e.g. in wind tunnel, wave tank or ice tank. This applies in particular to all new concepts. Towing tank tests shall be conducted, when relevant.

4.6 Disposal

Final disposal of the facilities shall be considered at the design stage, to the extent required by the operator. A removal dossier, containing details of the facility and other aspects that may influence the final disposal of the facilities, should be prepared.

For the Norwegian petroleum activities, reference is made to the Petroleum Act, Ch. 5, and Royal Decree (Norway).

4.7 Robustness assessment

Load bearing structures shall have sufficient robustness to prevent that local damage or failure gives unacceptable consequences. Maritime systems shall have sufficient robustness to prevent that local damage or single technical or operational failures gives unacceptable consequences.

Checking robustness covers an evaluation of the vulnerability of a structure or a maritime system in addition to the ALS check for accidental loads as described in a risk analysis. It should include an evaluation of the vulnerability of the structure or the maritime system for

- local errors in design, fabrication and operation,
- damages or human errors in installation and operation.

It is normally assumed that such errors and damages are restricted to a local area, or to a single event. This check is not intended to cover fundamental or systematic failures in the design, fabrication or operation.

Basis for check of local damage and failure of structures shall be based on the ALS principle as stated in 6.2. All maritime systems shall be categorized with regards to safety criticality, redundancy and robustness. Proper maintenance- and spare part philosophy shall be demonstrated for all essential maritime systems.

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 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. In his documentation system the operator may 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. The documents that are required have not been specified, and shall consequently be considered in each separate case. This implies that possible incidents and the need for documentation shall be considered thoroughly. Measures shall be taken for procreation of necessary documentation at short notice.

The designer shall carry out additional simplified calculations of relevant structural parts where failure may entail major consequences of the structural integrity.

For the Norwegian petroleum activities, reference is made to PSA: Information Duty 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 facility and its anticipated use shall receive particular attention in this assessment. The party carrying out the verification shall 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 (e.g. soil investigations and concreting), the requirement implies that the party carrying out the verification shall witness the work when it is carried out.

Verification activities shall be carried out by competent personnel.

The verification shall confirm whether the facility 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 which involve a new type of facility, new project execution models or information technology systems.

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 facility concerned.

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 or computer calculations. When computer calculations are used, it is normally assumed that the person carrying out the verification uses another programme than the designer. Special care and attention to simplified additional calculations should be evaluated when this is not fulfilled. Further, the computer models shall be independent. Possible discrepancies between the initial calculations and verification analyses shall be clarified on the basis of the differences in the method applied in the respective software and the models applied to ensure that conservative estimates are used for the design.

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

5.2.2 Verification during the design phase

Verification of design should include checking of the following:

- a) that specifications are in compliance with the applicable rules and regulations etc.;
- b) personnel qualifications and organization of the design;
- c) calculations of actions and action effects;
- d) that accidental actions are in compliance with the results from the risk analyses;
- e) the applicability of computer software, and that computer programmes are adequately validated and documented with respect to theory and use. This is of particular importance when programmes are used in dealing with new problems, structures or new software;
- f) that simplifications made in manual or computer based analyses, are conservative;
- g) that methods used in respect of geometry, actions, resistance calculations and manner of operation are suitable by carrying out alternative calculations;
- h) that equipment and procedures for control of actions has adequate reliability, and by carrying out random checks;
- i) that the boundary conditions are representative;
- j) that metocean data collection requirements are complied with, see also NORSOK N-002;
- k) that deviations during fabrication and installation are assessed and, if necessary, corrected;
- l) that drawings are in accordance with calculations and specifications;
- m) corrosion and erosion protection;
- n) that a design review is carried out by different professional sectors co-operating in solving problems;
- o) the design of important structural details.

With regard to the design of concrete structures, verification of the design should meet the requirements of NS 3473.

The verification of organisation and personnel qualifications can be carried out as a combination of documentation review and audit.

5.2.3 Verification during fabrication and installation phases

Persons verifying fabrication and installation activities should i.a. check the following:

- a) that the specifications are in accordance with public regulations/provisions and safety and health requirements;
- b) that satisfactory work instructions, procedures and plans 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, tolerances, materials, surface protection and work performance are in accordance with the basic assumptions made during design;
- f) that operations undertaken (i.a. load-outs, transportations, lifts) satisfy relevant assumptions and criteria utilized in the design;
- g) the actual production, where for instance it is difficult to assess the quality post fabrication;
- h) that deviation procedures are adequate;
- i) that the transportation and storage of materials and fabricated assemblies is adequate;
- j) that deviations during fabrication and installation are assessed and if necessary corrected.

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 shall 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 of the execution of the concrete works should meet the requirements of NS 3473.

5.2.4 Verification during service life

Verification of structures and related maritime systems during service life should include checking

- a) the relevance of analysis and technical documentation used as basis for the integrity management,
- b) that the maintenance-, design- and fabrication philosophy in combination forms a sufficient basis for ensuring sufficient integrity,
- c) that the actual maintenance strategy meets the principles described in the maintenance philosophy,
- d) the methods and the development of the inspection programme,
- e) the inspection methods and whether these are sufficient to meet the maintenance philosophy and strategy,
- f) that data collection and experience from inspections are adequately evaluated, used for updating of the inspection programme and are stored for later use,
- g) that trends in data are adequately evaluated,
- h) the integrity of the facility,
- i) that mitigating measures are implemented to obtain sufficient integrity of structure and related maritime systems in case of deficiencies,
- j) the emergency preparedness procedures following a failure of a structure, a structural part or a related maritime system, including the criteria for when these are triggered,
- k) the personnel qualifications of personnel involved in the integrity management and inspection.

For flagged units the certificates from the flag state and the certification authorities can be used as documentation for performed verification.

5.2.5 Verification of assessment of existing facilities

Verification of existing facilities for service life extensions should include verification in line with the verification in design phase as described in 5.2.2 and 5.2.6 for site specific mobile offshore units, and should also include

- a) the conditions of the as-built and installed facility, including soil conditions,
- b) changes to structure, maritime systems and corresponding battery limits during operation,
- c) the inspection and repair history of the structure and related maritime systems,
- d) the effect of damages of structure and related maritime systems,
- e) that foreseeable aging effects are included,
- f) condition of corrosion protection systems,
- g) water level, scour, marine growth, metocean data,
- h) that the need for measurement of action and action effects are evaluated.

NOTE Information duty regulation § 5 and § 6 should be complied with in Norwegian petroleum activities. For flagged mobile offshore units the NPD letter of semi submersibles as of 01.04.2003 and the PSA letter on jack-ups as of 05.01.2006 should be complied with for units exceeding 19 years of age.

5.2.6 Verification of site specific mobile offshore units

Verification of a mobile offshore unit for a site specific location can be based on the certificates issued by the flag and classification authority, with due consideration of the limitations of the certificates and deviations from the flag requirements. It should be verified whether national requirements are more restrictive than those according to the certificates.

In addition the site specific verification should include

- a) review of specifications to check their quality, adequacy and compliance with the applicable rules and regulations etc.,
- b) evaluation of methods and results of actions and action effects for the site specific operation,
- c) check that accidental actions are in compliance with the results from the risk analyses,
- d) the applicability of computer software, and that computer programmes are adequately validated and
- e) documented with respect to theory and use. This is of particular importance when programmes are used in dealing with new problems, structures or new software,
- f) the procedure and quality of results of the soil investigations,
- g) whether the relevant unit can comply with the national requirements and operate within the limits of the
- h) unit and its equipment with respect to water depth, minimum temperature, anchor holding capacity, soil conditions etc.

NOTE For units operating on the NCS the PSA: The Framework Regulations, § 3, should be complied with.

6 Actions and action effects

6.1 Standards and guidelines

Actions to be considered are defined and classified in ISO 19900. Actions are classified according to the variation of their magnitude with time, according to their variation in space and according to the structural action effect.

The principal standard for calculation of actions and action effects is NORSOK N-003. Design data should be determined from actual measurements at the site or by suitable validated model data, e.g. from hind cast models. Such design data shall be stated in the design premises.

6.2 Partial action factors

6.2.1 General

The principles of the design format of partial factors are given in ISO 19900.

When checking the ULS, the SLS, the ALS and the FLS, the action factors shall be used according to Table 1.

Table 1 – Partial action factor for the limit states

Limit state	Action combinations	Permanent actions (G)	Variable actions (Q)	Environmental actions (E) ^d	Deformation actions (D) ^e
ULS	a ^a	1,3	1,3	0,7	1,0
ULS	b	1,0	1,0	1,3	1,0
SLS		1,0	1,0	1,0	1,0
ALS	Abnormal effect ^b	1,0	1,0	1,0	1,0
ALS	Damaged condition ^c	1,0	1,0	1,0	1,0
FLS		1,0	1,0	1,0	1,0

^a For permanent actions and/or variable actions, an action factor of 1,0 shall be used where this gives the most unfavourable action effect

^b Actions with annual probability of exceedance = 10⁻⁴

Limit state	Action combinations	Permanent actions (G)	Variable actions (Q)	Environmental actions (E) ^d	Deformation actions (D) ^e
^c Environmental actions with annual probability of exceedance = 10^{-2}					
^d Earthquake shall be handled as environmental action within the limit state design for ULS and ALS (abnormal effect)					
^e Applicable for concrete structures					

The actions are to be combined in the most unfavourable way, provided the combination is physically feasible and permitted according to the action specifications.

Certain actions, which can be classified as either permanent or variable, may be treated as imposed deformations (D). Load effects caused by imposed deformations shall be treated in the same way as load effects from other normal loads 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,
- pre-stressing effects,
- creep and shrinkage effects,
- differential settlement of foundation components.

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 action shall be stipulated in the following two cases:

Case 1: Action factor equal to 1,0 for the cyclical actions and 1,3 for the largest environmental action.

Case 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 facilities with the shape of a ship, the action factor for environmental actions (E) (see 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.

6.2.2 Conditions and special considerations

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

- a) the possibility that the actions may deviate from the characteristic actions;
- b) the reduced possibility that different actions contributing to the action effect analyzed, will reach their characteristic value at the same time;
- c) possible inaccurate calculation of action effects, 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.

A number of parameters in fatigue assessments contribute to uncertainty in the calculated fatigue life of structures. To account for this uncertainty, and include issues like consequence of damage and accessibility for inspection and repair DFFs are introduced such that fatigue analysis performed according to standard procedure result in structures with acceptable safety.

A reduced action factor of 1,2 for ULS action combination "a" for permanent actions in Table 1 will normally be acceptable for external hydrostatic fluid pressures, if the action effects 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 be used.

If there is doubt as to whether the actions and the action effects have been determined with adequate accuracy, action factors for such actions may be substantiated according to the provisions of 7.2.2. The

analysis shall then be sufficiently accurate to be able to differentiate between different phases, structural parts and failure types, and to take into account accuracy in relevant 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 facility is unmanned during storms. This will be based on an evaluation as to whether a collapse will

- a) entail danger of loss of human life,
- b) cause significant pollution,
- c) have 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 i.a. loading buoys, separate flare towers, stability during installation, subsea facilities and other facilities which are unmanned during storms. Documentation of a facility being unmanned during storms shall include an assessment showing that the probability of personnel being on the facility simultaneous with environmental actions damaging main safety functions is less than 10^{-4} per year.

6.3 Action combinations

The principles for combination of actions are given in ISO 19900.

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. Determination of wave crest elevation shall be in accordance with ISO 19901-1. Facilities not having sufficient deck clearance to the wave crest elevation shall be designed for actions caused by waves and currents. Local exposed structures and piping not having adequate clearance shall in addition be assessed. 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

- a) interaction between topside structures and multishaft fixed concrete substructures,
- b) interaction between topside structures and column/pontoon type floating substructures,
- c) interaction between topside structures and monohulls (global hull bending),
- d) wave induced motions and accelerations of floating facilities,
- e) direct wave actions (slamming).

Flare towers, drilling towers, bridges, crane pedestals and other fatigue exposed structures 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 facilities that are sensitive to alterations.

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

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

An inclining test shall be carried out after topside completion for newbuildings (before tow-out) and after major conversions performed inshore for existing floating facilities. After major conversions performed offshore or after major weight increases, a displacement test shall be performed for floating facilities.

Weight engineering and weight control shall be performed in accordance with ISO 19901-5.

6.4.4 Actions caused by moored vessels

Operational limitations related to mooring of vessels to a facility 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 facility shall be designed for the most probable maximum action in this condition. Measures should be taken to avoid damage to the facility 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

Facilities shall be designed with due consideration to fire, explosions, impacts, flooding, loss of heading (dead ship scenario) 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 7.2.6 and NORSOK S-001.

6.4.6 Anomalous dynamic effects

Ring 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, model testing shall be performed at an appropriate scale.

7 General structural design

7.1 Design objectives

A structural system, its components and details shall be designed to comply with ISO 19900 and the following principles:

- structures and structural elements shall normally be designed with ductile resistance behaviour;
- an unintended event shall not escalate into an accident of significantly greater extent than the original event;
- structures shall be designed to minimise overall stress concentrations and provide a well defined stress path;
- the design shall secure that fabrication, including surface treatment, can be accomplished in accordance with relevant recognised techniques and practices;
- the design of details, selection of profiles and use of materials shall be done with the objective to minimise corrosion, degradation, and the need for special precautions to prevent corrosion and degradation;
- adequate access for inspection, surveillance, maintenance and repair shall be provided;
- satisfy functional requirements as given in the design premises.

Active operation (e.g. 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 personnel.

The facility may be designed on the assumption that individual components may be replaced to maintain an acceptable overall safety. 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 19900. All identified failure modes shall be checked within the respective groups of limit states, i.e. ULS, SLS, FLS and ALS. It shall 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 actions 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. The main definitions for limit state controls are given in EN 1990 and ISO 19900.

In cases where a high resistance is unfavourable for the structure, the characteristic resistance shall be determined as an upper characteristic resistance. This probability shall be of the same level as the probability of a lower value, e.g. 5 % vs. 95 % fractile. 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 action effect is increased with the material resistance, the design should be based on an upper characteristic resistance, e.g. based on 95 % fractile.

Design against fatigue failure in steel, aluminium and concrete should be based on S-N curves with characteristic resistance based on 2,3 % fractile. Fracture mechanics analyses of crack propagation can be used in special cases.

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

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 factors 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)

For steel structures the material factors shall be 1,15 and for aluminium structures the material factor shall be 1,2.

For structures of reinforced concrete, the material factor shall be 1,25. For reinforcement steel and steel for pre-stressed concrete, the material factor shall be 1,15.

For composite glass reinforced plastic and fibre reinforced plastic load bearing structures, partial resistance factors shall be taken from DNV-OS-C501, Section 8, B700, table B8 and B9. For lifeboats, table B8 shall be used in combination with a high safety class.

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 EN 1999 (all parts) for aluminium.

The material factor in this NORSOK standard is a partial factor for a material property, also accounting for model uncertainties and dimensional variations, see also ISO 19900, 8.3.2.

7.2.4 Serviceability limit states (SLS)

SLSs for offshore steel structures are associated with

- a) deflections which may prevent the intended operation of equipment,
- b) deflections which may be detrimental to connections or non-structural elements,
- c) vibrations which may cause discomfort to personnel, see NORSOK S-002,
- d) 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. Limitations with regard to deflections, displacements, settlements, water tightness, vibrations and operation of the facility shall be defined during the design and stated in the design premises. In absence of project specific requirements the provisions given in Table 2 shall be used.

For calculations in the SLSs the material factor shall be 1,0.

Table 2 – Limiting values for vertical deflections

Condition	Limit for $\delta_{\max}$	Limit for δ_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

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

δ_0 is the pre-camber

δ_1 is the variation of the deflection of the beam due to the permanent actions immediately after loading

δ_2 is the variation of the deflection of the beam due to the variable actions plus any time dependent deformations due to the permanent load

Contribution from environmental actions shall also be considered when calculating the maximum deflection.

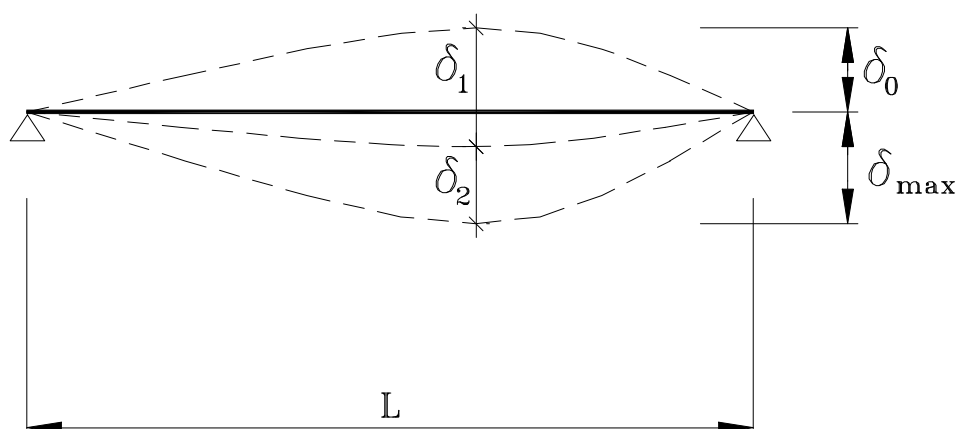


Figure 1 – Definitions of vertical deflections

Structures with extensive deflections, velocities and accelerations 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 structures with extensive deflections, velocities and accelerations maximum permissible deflections, velocities and accelerations shall also be stipulated based on working environmental considerations.

For facilities 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 requirements are provided in PSA: The Facility Regulations.

7.2.5 Fatigue limit states (FLS)

Structures shall be designed to withstand the presupposed repetitive (fatigue) actions during the service life of the facility. The principal standard for fatigue design of steel structures is NORSOK N-004, for concrete structures NS 3473 and aluminium structures EN 1999-1-3.

DFFs shall be applied taking into account damage consequences and the need for in-service inspection, maintenance and repair, see NORSOK N-005. Minimum values for the DFFs are given in Table 3.

Table 3 - Design fatigue factors (DFFs)

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

Assumptions made regarding damage consequences, accessibility and DFFs 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 shall be demonstrated according to 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 a facility is related to the programme for condition monitoring prepared for that specific facility, see NORSOK N-005. If regular dry docking is performed each fifth year for mobile offshore units, the entire facility may be regarded as being above the splash zone. The splash zone for fixed facilities can be taken from 4 m below the lowest tide to 5 m above the highest tide.

7.2.6 Accidental limit states (ALS)

The ALS check ensures that the accidental action does not lead to complete loss of integrity or performance of the structure and related maritime systems, as described in ISO 19900.

The material factor shall be 1,0 in the ALS check. For concrete structures the material factor shall be in compliance with NS 3473.

The ALS shall be checked in the following two steps:

Step 1: Resistance to accidental actions

The structure and related maritime systems should be checked to maintain the prescribed load carrying function for the defined accidental actions.

Step 2: Resistance in damaged condition

Following local damage which may have been demonstrated under a), or following more specifically defined local damage, the facility 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 facility) 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 i.a. loading buoys, separate flare towers, stability during installation, subsea facilities and other facilities which are unmanned during storms.

7.3 Selection of materials and fabrication control

When selecting materials, the following shall i.a. be taken into account:

- a) consequences of possible material defects;
- b) operating temperature;
- c) weldability for metallic materials;
- d) stress level;
- e) degradation 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 work is to be carried out.

7.4 Corrosion protection of structures

The site specific conditions and the planned 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.

A proper corrosion management and a corresponding corrosion protection system shall be implemented for internal zones of load bearing structural parts of mobile offshore units, taking into consideration i.a. the design service life of the facility, the maintenance philosophy, steel temperature and single or double side exposure. Special attention shall be given to corrosion protection of the ballast tank, the crude oil storage tank, and related systems.

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 and NORSOK M-503.

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 DFI resume shall be prepared in accordance with NORSOK Z-001.

7.6 Standards and guidelines for design of steel structures

Principal standards for design of steel structures are NORSOK N-004 and NS 3472.

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

7.7 Design of aluminium structures

7.7.1 Standards and guidelines

The principle standard for design of aluminium structures is EN 1999 (all parts).

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 as follows:

- a) action factors, material factors and DFFs shall comply with this NORSOK standard;
- b) guidelines for selection of recommended materials according to 7.7.2;
- c) inspection categories for welds according to 7.7.3;
- d) mechanical data given in material standards referred in Material Data Sheet in NORSOK M-121 shall be used.

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

- a) material strength, grade and mechanical properties;
- b) type and dimension of welds;
- c) inspection category for welds;
- d) restricted areas for temporary cut-outs;
- e) overall weld geometry requirements;
- f) mandatory NDE.

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 ^c	Low fatigue utilisation	
		High tensile stresses ^d	Low tensile stresses
Substantial consequences ^a	A	B	C
Substantial consequences but with reserve strength ^b	B	C	D
Non-substantial consequences	C	D	D

^a "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.

^b Residual strength means that the structure meets requirements corresponding to the damaged condition in the check for ALS, with failure in the actual joint or component as the defined damage.

^c High fatigue utilisation means connections with calculated fatigue life less than 3 times the required fatigue life (design fatigue life multiplied with the DFF).

^d High tensile stresses are ULS tensile stresses in excess of 0,75 of design stress.

7.8 Design of concrete structures

The principal standards for design, execution and material selection for concrete structures are ISO 19903 with NS 3473 as the reference standard for the structural design.

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

Other design standards and guidelines (e.g. DNV-OS-C502), may be used as supplements to the principal standards specified above. The use of supplementary standards should depend on type of structure, location and relevant accumulated experience.

7.9 Soil investigation and geotechnical design

7.9.1 Soil investigation

The on site soil investigations shall extend throughout the depth and area extent of soil that will be affected by the installation and use of the foundation. The extent of the soil investigations shall be determined by competent geotechnical personnel. The investigation shall be in accordance with the principal standard ISO 19901-4, and the principal standard relating to requirements to equipment, testing and reporting of soil investigations and laboratory work is NORSOK G-001. Other standards and guidelines (e.g. DNV Classification Note No. 30.4), may be used as supplements to the principal standards specified above.

Due to potential hazards from shallow gas, it should be evaluated to perform the investigation outside the foundations.

Special conditions relating to the Norwegian petroleum activities are as follows:

- geotechnical data submitted to the PSA are public;
NOTE By geotechnical data is meant results from examination of soil conditions on the continental shelf carried out for safety reasons.
- 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 - NGU (The Geological Survey of Norway), see PSA: Information Duty Regulations, § 10.

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 secure 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

The principal standard for geotechnical design is ISO 19901-4.

Other design standards and guidelines (e.g. NS 3481, API RP 2A and DNV Classification Note No. 30.4), may be used as supplements to the principal standards. 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

- a) environmental loads, e.g. earthquake, shallow gas, pore pressure etc.,
- b) loads imposed from human activities, e.g. trenching, rock filling, installation of structures etc.,
- c) the possibility that local slope failures can develop to large global failures,
- d) the possibility that human activities may reduce the safety both for local and global slopes,
- e) accidental situations as uncontrolled release of fluids, e.g. blow-outs, water fountains etc.

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

7.10 Subdivision, stability and freeboard

For surface units (e.g. 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.

FPSOs/FSOs (e.g. surface units of ship- or barge type hull intended for oil storage) shall have protection against pollution as specified in MEPC.139 (53). Provisions shall be made such that the ballast system is not contaminated in case of a leakage between a ballast tank and an oil storage tank.

Special provisions relating to the Norwegian petroleum activities are as follows:

- a) the individual technical provisions for new units in the NMD: Regulations of 20 December 1991 No. 878, are recognised standards for stability;
- b) any space adjacent to the sea should be calculated to be able to be flooded if
 - the space has penetrations to the sea,
 - the space may become flooded as a result of a system or operation failure,
 - relevant accidental events entail significant leakage.
- c) 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;
- d) 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 5 000 tons, the extent of damage required in the Maritime Directorate's regulations can be used. In other cases the damage has to be calculated based on the collision energy, see NORSOK N-003 and NORSOK N-004;
- e) 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);
- f) the individual technical provisions for new units in the NMD: Regulations of 20 December 1991 No. 879, are recognised standards for ballasting;
- g) FPSOs/FSOs (surface units of ship- or barge type hull intended for oil storage) intended for NCS shall have a double hull arrangement as specified in MARPOL, covering the entire storage tank length.

7.11 Station keeping systems

The principal standard for design of station keeping systems and analysis in survival conditions is ISO 19901-7. For station keeping in relation to marine operations reference is made to 7.12, and for soil investigations reference is made to 7.9.1. The anchor line analysis should be based on dynamic analysis.

Specific design conditions and criteria shall be established in relation to the type of facility, 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.

The strength of the fluke or plate anchor can be controlled either by pre-tensioning to the design action level or by analyzing

- a) that the anchor is able to take the design actions after dragging. The analyses shall be based on site specific soil data, with action and soil material factors according to this NORSOK standard,
- b) the consequences of dragging on the other lines, other infra structure and third parties. The drag length should be calculated, and the effect of dragging the most exposed line, on the other lines shall be calculated. The results shall be checked against the requirements in intact conditions.

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 at least two line failures may be taken as basis when combined in the most unfavourable way.

In the ALS condition the geotechnical design of pile anchors and suction 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 action 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 7.2.2 are fulfilled, the design of station-keeping systems may be based on a reliability based design method. The damage condition (i.e. 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.

If fatigue analysis is not performed, chains above 20 years should be inspected annually using MPI or similar test methods, on all available parts. Loose studs should be MPI tested before cold pressing.

Special provisions relating to the Norwegian petroleum activities are as follows:

- a) 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, and the technical provisions for new units in NMD: Regulations of 4 September 1987 No. 857. 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;
- b) NMD: Regulations of 4 September 1987 No. 857, § 8, shall be used for preloading of the anchors, based on the calculated 100 year actions;
- c) for design of DP systems and for thruster assist systems, the technical provisions for new units in the NMD: Regulations of 4 September 1987 No. 857, shall be complied with.

7.12 Marine operations

Guidance related to removal of facilities is given in DNV-RP-H102.

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 Rules for Planning and Execution of Marine Operations, should be applied.

Effects of sea spray icing shall be assessed specifically, where relevant.

8 Design of various types of structures

8.1 Fixed steel structures

Fixed steel structures (i.e. 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 clause 4 to clause 7.

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 local and global effects 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 accordance with NORSOK N-004 and relevant Annex. See also 7.8 in case of concrete.

With regard to the extent of damage in relation to loss of buoyancy, see 7.10.

8.4 Column-stabilised units

Column-stabilised units (i.e. semi submersibles) including topside structures and station keeping system, should be designed and verified in accordance with NORSOK N-004 and relevant Annex. See also 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 basis.

NOTE 1 For Norwegian petroleum activities DNV OS-C103, or equivalent standard achieving the same level of safety, 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 clause 4 to clause 7.

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 basis.

NOTE 1 For Norwegian petroleum activities DNV OS-C104, or equivalent standard achieving the same level of safety 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, or equivalent standard achieving the same level of safety 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 Ship shaped units

Ship shaped units including topside structures, should be designed and verified in accordance with NORSOK N-004 and relevant Annex.

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 basis.

NOTE 1 For Norwegian petroleum activities DNV OS-C102, or equivalent standard achieving the same level of safety 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.

8.7 Other floating units

Other floating units including topside structures, should be designed and verified in accordance with the relevant criteria as specified in clause 4 to clause 7 of this NORSOK standard, NORSOK N-003, NORSOK N-004 and relevant Annexes.

If the rules of a classification society are to be applied, the relevant class notation shall be stated in the design basis.

NOTE 1 For Norwegian petroleum activities DNV OS-C101, or equivalent standard achieving the same level of safety, 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-C101, or equivalent standard achieving the same level of safety, 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 as applicable.

8.8 Topside structures

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

8.9 Helicopter decks

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

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

8.10 Flare towers

Flare towers should be designed and verified in accordance with NORSOK N-003 and NORSOK N-004. Other design standards and guidelines (e.g. BS 8100-1), 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, shall 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 action effects.

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

8.11 Subsea facilities

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

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

