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Oil and gas industries including lower carbon energy — Specific requirements for offshore structures — Part 4: Geotechnical design considerations

FDIS stage

Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO ~~documents~~document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

~~Attention is drawn~~ISO draws attention to the possibility that ~~some of~~ the ~~elements~~implementation of this document may ~~be~~involve the ~~subject~~use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents~~.~~. ISO shall not be held responsible for identifying any or all such patent rights. ~~Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see).~~

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Oil and gas industries including lower carbon energy*, Subcommittee SC 7, *Offshore structures*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 12, ~~Materials, equipment~~*Oil and* ~~offshore structures for petroleum, petrochemical and natural~~ *gas industries including lower carbon energy*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 19901-4:2016), which has been technically revised.

The main changes ~~compared to the previous edition~~ are as follows:

— guidance extended on representative and design values for soil parameters (Clause 5);

— guidance added for geotechnical design of intermediate foundations for fixed structures and clause renamed to ‘Design of shallow and intermediate foundations’ (Clause 7);

— requirements added on installation resistance, yield envelope approaches for ultimate limit state, and performance- based design for shallow skirted and intermediate foundations (Clause 7);

— new unified CPT method for axial capacity in sands to replace the former main text method, new TZ curve definition in sands, new unified CPT method for clays introduced into the annex Clause A.8, new PY curve methodology for clays to replace the existing method (Clause 8);

— new requirements added clause foronon reassessment of pile capacity for existing structures (Clause 9);

— a new clause for pipelines, conductors and risers, previously only informative (Clause 10);

— references have been reviewed, updated and reduced where possible.

A list of all parts in the ISO 19901 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The International Standards on offshore structures prepared by TC 67 (i.e. ISO 19900, the ISO 19901 series, ISO 19902, ISO 19903, ISO 19904-1, the ISO 19905 series, ISO 19906~~),~~) constitute a common basis covering those aspects that address design requirements and assessments of all offshore structures used by the oil and gas industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for offshore structures, whatever the type of structure and the nature of the materials used. Application specific requirements for different energy industries are given in the relevant standards. For example, for the offshore wind industry ~~the IEC standards~~, IEC 61400-1 and IEC 61400-3-1 outline the ~~normative~~ design requirements (e.g. return periods) for offshore wind turbine support structures.

This document may be applied for the design of foundations used in the offshore wind industry. In this case, it should be verified that the type and dimension of the foundation, as well as the type of actions acting upon it, are consistent with those used in the development of the design methods. For example, the pile design methods of Clauses 8 are not necessarily applicable to the design of monopiles for which *L/D* is less than 10 and their validity for such cases should be assessed. Offshore wind structures can also have other requirements, such as a characterisation of foundation stiffness, that are beyond the scope of this document. Reference should be made to the overarching application specific codes and standards such as IEC 61400-3-1.

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

For geotechnical design (engineering science dealing with the properties of soil: ~~Sand~~sand, silt, clay and rock), some additional considerations apply. These include the time, frequency and rate at which actions are applied, the method of installation, the properties of the surrounding soil, the overall behaviour of the seabed, effects from adjacent structures and the results of drilling into the seabed. All of these, and any other relevant information, should to be considered in relation to the overall reliability of the structure.

The International Standards on offshore structures prepared by TC 67 are intended to provide wide latitude in the choice of structural configurations, materials and techniques without hindering innovation. Geotechnical design practice for offshore structures has proved to be an innovative and evolving process over the years. This evolution is expected to continue and is encouraged. Therefore, circumstances can arise when the procedures described in this document or the International Standards on offshore structures prepared by TC 67 (or elsewhere) are insufficient on their own to ensure that a safe and economical design is achieved.

Seabed soils vary. Experience gained at one location is not necessarily applicable at another. Extra caution is necessary when dealing with unconventional soils or unfamiliar foundation concepts. Sound engineering judgment is therefore necessary in the use of this document.

Some background to and guidance on the use of this document is provided in Annex A.

~~In this document, the following verbal forms are used:~~

~~— "shall" indicates a requirement;~~

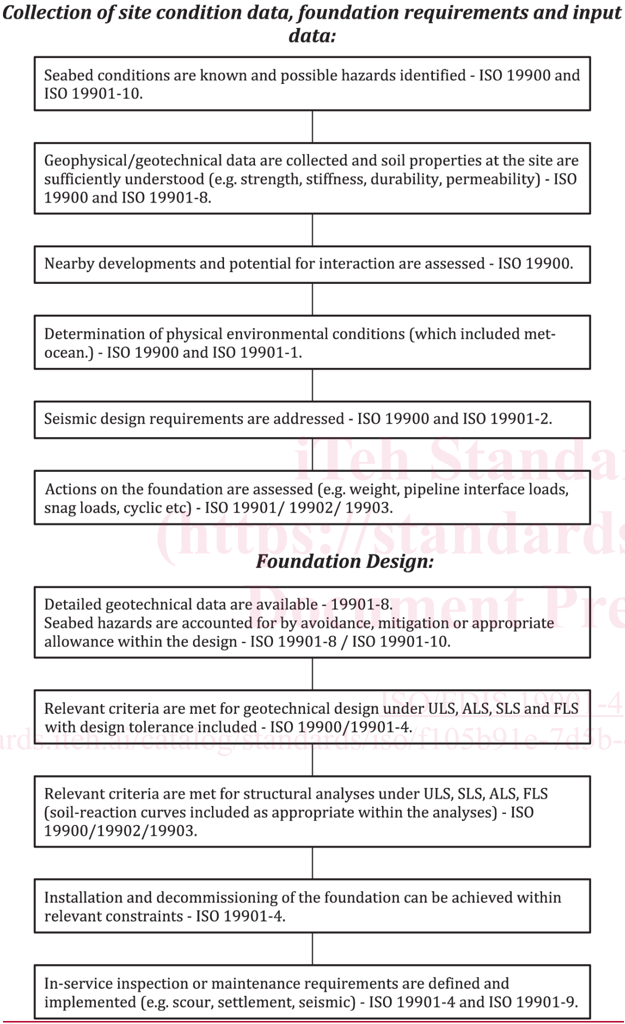
~~— "should" indicates a recommendation;~~

~~— "can" indicates a possibility or a capability;~~

~~— "may" indicates a permission.~~

ISO 19905 provides requirements and detailed guidance on foundations for mobile offshore units.

Figure 1 set outs a typical workflow for design of offshore foundations with reference to other relevant International Standards.



NOTE Specific design and installation constraints can apply for structures in arctic regions (see ISO 19906), for mobile offshore units, especially for jack-ups (see ISO 19905) and for anchors for floating units (see ISO 19901-7 Design can be an iterative process from concept (initial feasibility and applicability study), basic to final design. Different level of details and objectives are required in the various design stages.

Figure 1 — Flowchart showing typical design process for offshore foundations

Oil and gas industries including lower carbon energy — Specific requirements for offshore structures — Part 4: Geotechnical design considerations

1 Scope

This document contains provisions for geotechnical engineering design that are applicable to a broad range of offshore structures, rather than to a particular structure type. This document outlines methods developed for the design of shallow foundations with an embedded length (L) to diameter (D) ratio L/D < 0,5, intermediate foundations, which typically have 0,5 ≤ L/D ≤ 10 (see Clause 7), and long and flexible pile foundations with L/D > 10 (see Clauses 8 and 9).

This document also provides guidance on soil-structure interaction aspects for flowlines, risers and conductors (see Clause 10) and anchors for floating facilities (see Clause 11). This document contains brief guidance on site and soil characterization, and identification of hazards (see Clause 6).

NOTE ISO 19901-8 and 19901-10 provide requirements and detailed guidance on the performance of marine soil investigations and geophysical investigations for acquiring or defining the soil parameters required for design.

This document may be applied for foundation design for offshore structures used in the lower carbon energy industry. For example, this document may be applied for the design of foundations used in the offshore wind industry. In this case, it shall be verified that the type and dimension of the foundation, as well as the type of actions acting upon it, are consistent with those used in the development of the design methods. For example, the pile design methods of Clauses 8 are not necessarily applicable to the design of monopiles for which L/D is less than 10 and their validity for such cases shall be assessed.This document can be applied for foundation design for offshore structures used in the lower carbon energy industry.

Offshore wind structures can also have other requirements, such as a characterisation of foundation stiffness, that are beyond the scope of this document. Reference should be made to the overarching application specific codes and standards such as IEC 61400-3-1.

This document shall not be applied to onshore structures where it is expected that other codes and standards provide more specific requirements or practice.

ISO 19905 provides requirements and detailed guidance on foundations for mobile offshore units.

set outs a typical workflow for design of offshore foundations with reference to other relevant International Standards.

Collection of site condition data, foundation requirements and input data:

Seabed conditions are known and possible hazards identified - ISO 19900 and ISO 19901-10.

Geophysical/geotechnical data are collected and soil properties at the site are sufficiently understood (e.g. strength, stiffness, durability, permeability) - ISO 19900 and ISO 19901-8.

Nearby developments and potential for interaction are assessed - ISO 19900.

Determination of physical environmental conditions (which included met-ocean.) - ISO 19900 and ISO 19901-1.

Seismic design requirements are addressed - ISO 19900 and ISO 19901-2.

Actions on the foundation are assessed (e.g. weight, pipeline interface loads, snag loads, cyclic etc) - ISO 19901/ 19902/ 19903.

Foundation Design:

Detailed geotechnical data are available - 19901-8.
Seabed hazards are accounted for by avoidance, mitigation or appropriate allowance within the design - ISO 19901-8 / ISO 19901-10.

Relevant criteria are met for geotechnical design under ULS, ALS, SLS and FLS with design tolerance included - ISO 19900/19901-4.

Relevant criteria are met for structural analyses under ULS, SLS, ALS, FLS (soil-reaction curves included as appropriate within the analyses) - ISO 19900/19902/19903.

Installation and decommissioning of the foundation can be achieved within relevant constraints - ISO 19901-4.

In-service inspection or maintenance requirements are defined and implemented (e.g. scour, settlement, seismic) - ISO 19901-4 and ISO 19901-9.

~~NOTE Specific design and installation constraints can apply for structures in arctic regions (see ISO 19906), for mobile offshore units, especially for jack-ups (see ISO 19905) and for anchors for floating units (see ISO 19901-7 Design can be an iterative process from concept (initial feasibility and applicability study), basic to final design. Different level of details and objectives are required in the various design stages.~~

Figure — Flowchart showing typical design process for offshore foundations

72 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 19901 (all parts), *Petroleum -7, Oil and natural gas industries including lower carbon energy — Specific requirements for offshore structures — Part 7: Station-keeping systems for floating offshore structures and mobile offshore units*

ISO 19901-8, *Oil and gas industries including lower carbon energy — Offshore structures — Part 8: Marine soil investigations*

ISO 19901-9, *Oil and gas industries including lower carbon energy — Specific requirements for offshore structures — Part 9: Structural integrity management*

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

ISO 19903, *Petroleum and natural gas industries — Concrete offshore structures*

ISO ISO 19904-1, *Petroleum and natural gas industries — Floating offshore structures — Part 1: Ship-shaped, semi-submersible, spar and shallow-draught cylindrical structures*

ISO 19905 (all parts), *PetroleumOil and natural gas industries including lower carbon energy — Site-specific assessment of mobile offshore units*

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

ISO 3421, *Petroleum and natural gas industries – Drilling and production equipment - Offshore conductor design, setting depth, and installation*

DNV-RP-F110, *Global buckling of submarine pipelines*

DNV-RP-F114, *Pipe-soil interaction for submarine pipelines*

83 Terms and definitions

For the purposes of this document, the following terms and definitions given in ISO 19900, the ISO 19901 series and the following shall apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
action
external loading applied to the structure (direct action) or an imposed deformation or acceleration (indirect action)

Note 1 to entry: EXAMPLE An imposed deformation can be caused by fabrication tolerances, differential *settlement*, (3.18), temperature change or moisture variation. An imposed acceleration can be caused by an earthquake.

[SOURCE: ISO 19900:2019, 3.3]

3.2
action factor
partial action factor thewhose value of which reflects the uncertainty or randomness of the action

[SOURCE: ISO 19900:2019, 4.1]

3.4
basic variable
variable representing physical quantities which characterize actions, and environmental influences, geometric quantities, or material properties including soil properties

[SOURCE: ISO 19900:2019, 3.7], modified — Note 1 to entry has been removed.]

3.5
design actions
combination of representative actions and partial safety factors representing a design situation for use in checking the acceptability of a design

3.6
design value
value derived from the *representative value* (3.11) for use in *limit state* (3.9) verification

Note 1 to entry: Design values can be different in different design/assessment situations due to different partial factors.

Note 2 to entry: The term “characteristic value” used in ISO 19900 is not used in this standarddocument; and both terms “characteristic value” and “representative value” are considered equivalent for geotechnical and foundation design.

[SOURCE: ISO 19900:2019, 3.14], modified — Note 2 to entry has been added.]

3.7
drained condition
condition whereby the applied stresses and stress changes are supported entirely by the soil skeleton and do not cause a change in pore pressure

[SOURCE: ISO 19901--8:2023, 3.9]

3.8
effective foundation area
reduced foundation area having its geometric centre at the point where the resultant action vector intersects the foundation base level

3.9
limit state
state beyond which the structure or structural component no longer satisfies the design/assessment criteria

[SOURCE: ISO 19900:2019, 3.31]

3.10

material factor
partial factor applied to the representative *strength* (3.19) of the soil, the value of which reflects the uncertainty or variability of the material property

Note 1 to entry: See ISO 19900.

3.11
representative value
value assigned to a *basic variable* (3.4) for verification of a *limit state* (3.9) in a design/assessment situation

[SOURCE: ISO 19900:2019, 3.40], modified — Note 1 to entry has been removed.]

3.12
resistance
ability of a structure, or a structural component, to withstand action effects

[SOURCE: ISO 19900:2019, 3.41]

3.13
partial resistance factor
factor used for *limit state* (3.9) verification, the value of which reflects the uncertainty or variability of the foundation *resistance* (3.12) including those of material properties

3.14
scour
removal of *seabed* (3.15) material caused by currents, waves or ice

[SOURCE: ISO 19900:2019, 3.45], modified — "or ice" has been added.]

3.15
seabed
materials at or below the *seafloor*, (3.16), whether soils such as sand, silt and clay, cemented materials or rock

Note 1 to entry: Offshore foundations are most commonly installed in soils, and the terminology in this document reflects this. However, the requirements equally apply to cemented seabed materials and rock. Thus, the term 'soil' does not exclude any other material at or below the seafloor.

3.16
seafloor
interface between the sea and the *seabed* (3.15)

3.17
serviceability
ability of a structure or structural member to perform adequately for normal use under all expected actions

[SOURCE: ISO 2394:2015, 2.1.32]

3.18
settlement
permanent downward movement of a structure as a result of its own weight and other actions

3.19
strength

mechanical property of a material indicating its ability to resist actions, usually given in units of stress

Note 1 to entry: See ISO 19902.

3.20
suction under steel catenary riser
refers to a net upward force acting on the seabed, accompanied by a decrease in pore pressure relative to ambient conditions

3.21
undrained condition
condition whereby the applied stresses and stress changes are supported by both the soil skeleton and the pore fluid and do not cause a change in volume

[SOURCE: ISO 19901-‑8:2023, 3.4244]

3.2221
undrained shear strength
maximum shear stress at yielding or at a specified maximum strain in an *undrained condition* (3.20)

Note 1 to entry: Yielding is the condition of a material in which a large plastic strain occurs at little or no stress increase.

[SOURCE: ISO 19901-‑8:2023, 3.4445]

94 Symbols and abbreviated terms

9.14.1 Symbols for shallow and intermediate foundation design

A actual (cross-sectional plan) foundation area

A' effective foundation area depending on eccentricity of actions

A_h vertical projected area of the foundation in the direction of sliding

A_p projected area of skirt tip

A_s side surface area of skirt embedded at a particular penetration depth

$A_{idealized}$ idealized rectangular foundation area, for irregular foundation shapes

b_c, b_q, b_γ bearing capacity correction factors related to foundation base inclination

B minimum lateral foundation dimension (also foundation width)

B' minimum effective lateral foundation dimension (also foundation effective width)

C compression index of soil over loading range consideredeffective cohesion

c'

c' effective cohesion

d_c, d_q, d_γ bearing capacity correction factors related to foundation embedment depth

D foundation diameter (for circular foundations)

D_b depth below seafloor to foundation base level

e eccentricity of action

e_0 initial void ratio of the soil