

**Oil and gas industries including lower carbon energy -
Specific requirements for offshore structures -
Part 4: Geotechnical design considerations
(ISO 19901-4:2025)**

EESTI STANDARDI EESSÕNA

NATIONAL FOREWORD

See Eesti standard EVS-EN ISO 19901-4:2025 sisaldab Euroopa standardi EEN ISO 19901-4:2025 ingliskeelset teksti. Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 26.02.2025. Standard on kättesaadav Eesti Standardimis- ja Akrediteerimiskeskusest.	This Estonian standard EVS-EN ISO 19901-4:2025 consists of the English text of the European standard EN ISO 19901-4:2025. This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation and Accreditation. Date of Availability of the European standard is 26.02.2025. The standard is available from the Estonian Centre for Standardisation and Accreditation.
--	---

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile standardiosakond@evs.ee.

ICS 31.220.10

Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardimis- ja Akrediteerimiskeskusele. Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardimis- ja Akrediteerimiskeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardimis- ja Akrediteerimiskeskusega: Koduleht www.evs.ee; telefon 605 5050; e-post info@evs.ee

The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation and Accreditation. No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation and Accreditation.

If you have any questions about copyright, please contact Estonian Centre for Standardisation and Accreditation: Homepage www.evs.ee; phone +372 605 5050; e-mail info@evs.ee

English Version

**Oil and gas industries including lower carbon energy -
Specific requirements for offshore structures - Part 4:
Geotechnical design considerations (ISO 19901-4:2025)**

Industries du pétrole et du gaz y compris les énergies à
faible teneur en carbone - Exigences spécifiques
relatives aux structures en mer - Partie 4: Bases
conceptuelles géotechniques (ISO 19901-4:2025)

Öl und Gasindustrie einschließlich kohlenstoffarmer
Energieträger-Besondere Anforderungen an Offshore-
Bauwerke-Teil 4: Geotechnische Auslegungsmerkmale
(ISO 19901-4:2025)

This European Standard was approved by CEN on 10 February 2025.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and United Kingdom.



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

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

This document (EN ISO 19901-4:2025) has been prepared by Technical Committee ISO/TC 67 "Oil and gas industries including lower carbon energy" in collaboration with Technical Committee CEN/TC 12 "Oil and gas industries including lower carbon energy" the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2025, and conflicting national standards shall be withdrawn at the latest by August 2025.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN ISO 19901-4:2016.

Any feedback and questions on this document should be directed to the users' national standards body/national committee. A complete listing of these bodies can be found on the CEN website.

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

Endorsement notice

The text of ISO 19901-4:2025 has been approved by CEN as EN ISO 19901-4:2025 without any modification.

Contents

Foreword	vi
Introduction.....	vii
1 Scope	1
2 Normative references	1
3 Terms and definitions.....	2
4 Symbols and abbreviated terms	4
4.1 Symbols for shallow and intermediate foundation design	4
4.2 Symbols for pile foundation design	6
4.3 Symbols for soil-structure interaction for auxiliary subsea structures, risers and flowlines	9
4.4 Symbols for design of anchors for stationkeeping systems	9
4.5 Abbreviated terms	12
5 General requirements.....	12
5.1 General	12
5.2 Design cases and partial factors.....	13
5.3 Representative and design values of geotechnical parameters	13
5.3.1 Guidelines.....	13
5.3.2 Determination of representative and design values of soil parameters.....	14
5.4 Reliability-based geotechnical design	16
5.5 Testing and instrumentation	16
6 Site investigation, identification of geohazards and carbonate soils	17
6.1 General	17
6.2 Geological modelling and identification of hazards	17
6.2.1 General	17
6.2.2 Assessment of site geohazards	17
6.3 Carbonate soils	18
6.3.1 General	18
6.3.2 Characteristic features and properties of carbonate soils	18
6.3.3 Foundations in carbonate soils	18
7 Design of shallow and intermediate foundations for fixed structures	19
7.1 General	19
7.2 Principles.....	19
7.2.1 General principles.....	19
7.2.2 Foundation embedment.....	20
7.2.3 Sign conventions, nomenclature and action reference point.....	21
7.3 Acceptance criteria	21
7.3.1 Material and action factors	21
7.3.2 Use of partial factors in design	22
7.4 Design considerations	23
7.4.1 Adjusting for soil plug weight	23
7.4.2 Skirt spacing	23
7.4.3 Foundation base perforations	23
7.4.4 Skirtless foundations penetrating soft soils	23
7.4.5 Tensile stresses beneath foundations	23
7.4.6 Omni-directional actions	24
7.4.7 Interaction with other structures.....	24
7.4.8 Multiple foundations.....	24
7.4.9 Hydraulic stability.....	24
7.4.10 Unconventional soils or soil profiles.....	25
7.4.11 Selection of soil parameter values for design	25
7.5 Ultimate limit state (stability)	25
7.5.1 Assessment of bearing capacity of shallow foundations.....	25
7.5.2 Assessment of sliding capacity of shallow foundations.....	28

7.5.3	Assessment of capacity of intermediate foundations.....	31
7.6	Serviceability limit state (displacements and rotations)	31
7.6.1	General	31
7.6.2	Serviceability of shallow foundations under static loading.....	31
7.6.3	Serviceability of intermediate foundations	33
7.6.4	Serviceability in response to dynamic and cyclic actions.....	33
7.7	Alternative methods of design.....	34
7.7.1	Yield surface approach	34
7.7.2	Risk-informed decision making.....	34
7.8	Installation.....	34
7.8.1	General	34
7.8.2	Skirt penetration resistance.....	35
7.8.3	Required and allowable under-pressure.....	35
7.9	Relocation, retrieval and removal.....	36
8	Pile foundation design.....	36
8.1	Pile capacity for axial compression	36
8.1.1	General	36
8.1.2	Axial pile capacity.....	37
8.1.3	Skin friction and end bearing in clay soils.....	38
8.1.4	Skin friction and end bearing in sands	40
8.1.5	Skin friction and end bearing in gravels	42
8.1.6	Skin friction and end bearing of grouted piles in rock	42
8.1.7	Skin friction and end bearing of driven piles in intermediate soils.....	42
8.2	Pile capacity for axial tension	42
8.3	Axial pile performance	43
8.3.1	Static axial behaviour of piles	43
8.3.2	Cyclic axial behaviour of piles.....	43
8.4	Soil reaction for piles under axial actions.....	43
8.4.1	Axial shear transfer t - z curves	43
8.4.2	End bearing resistance-displacement, Q - z curve	45
8.5	Soil reaction for piles under lateral actions	45
8.5.1	General	45
8.5.2	Lateral soil reaction for clay.....	46
8.5.3	Lateral capacity for sand.....	53
8.5.4	Lateral soil resistance - displacement p - y curves for sand	55
8.5.5	p - y curves for fatigue actions for sands	55
8.5.6	Refined assessment of lateral pile response	56
8.5.7	Lateral soil resistance-displacement curves in calcareous soil, cemented soil and weak rock	56
8.6	Pile group behaviour.....	56
8.6.1	General	56
8.6.2	Axial behaviour	56
8.6.3	Lateral behaviour	56
8.7	Pile installation assessment.....	57
8.7.1	General	57
8.7.2	Drivability studies.....	57
8.7.3	Obtaining required pile penetration.....	58
8.7.4	Driven pile refusal.....	58
8.7.5	Pile refusal remedial measures.....	58
8.7.6	Selection of pile hammer and stresses during driving	59
8.7.7	Use of hydraulic hammers.....	60
8.7.8	Drilled and grouted piles.....	61
8.7.9	Grouting pile-to-sleeve connections.....	61
8.7.10	Pile installation data	61
8.7.11	Installation of conductors and shallow well drilling.....	62
9	Assessment of pile capacity for existing structures.....	63

9.1	General	63
9.2	Geotechnical and foundation data.....	63
9.2.1	Geotechnical data	63
9.2.2	Design data	63
9.2.3	Installation data	63
9.2.4	Condition data	63
9.2.5	Operational data	64
9.3	Evaluation	64
9.4	Assessment	64
9.4.1	General	64
9.4.2	Pushover response of pile foundation systems	64
9.5	Time-dependent effects on pile foundations.....	65
10	Geotechnical design input to subsea structures, risers and flowlines	66
10.1	General	66
10.2	Geotechnical investigation.....	66
10.3	Foundations for subsea production structures	66
10.4	Steel catenary risers.....	67
10.4.1	General	67
10.4.2	Seabed characterisation.....	67
10.4.3	Design for ultimate limit state	67
10.4.4	Design for fatigue limit state	67
10.5	Geotechnical design for jetted conductors and top tension risers	69
10.5.1	General	69
10.5.2	Jetted conductors.....	70
10.5.3	Soil-structure interaction for well integrity assessment	72
10.5.4	Geotechnical input to well strength assessment.....	72
10.5.5	Geotechnical input to well fatigue assessment.....	72
10.5.6	Geotechnical considerations in conductor driving analysis.....	77
10.6	Foundation design for riser towers	77
10.6.1	General	77
10.6.2	Foundation options.....	77
10.6.3	Loading actions and safety factors	78
10.6.4	Design challenges	78
10.7	Offshore pipelines and flowlines	78
10.7.1	Geotechnical pipe-soil interaction (PSI) analysis.....	78
10.7.2	Submarine slides and density flows: simulation and pipeline impact analysis	80
11	Design of anchors for floating structures	80
Annex A (informative)	Additional information and guidance	81
Bibliography		204

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 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).

ISO draws attention to the possibility that the implementation of this document may involve the 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.

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, *Oil and 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 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 Clause A.8, new PY curve methodology for clays to replace the existing method (Clause 8);
- new requirements added on reassessment of pile capacity for existing structures (Clause 9);
- a new clause for pipelines, conductors and risers (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, IEC 61400-1 and IEC 61400-3-1 outline the 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 Clause 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, 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 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.

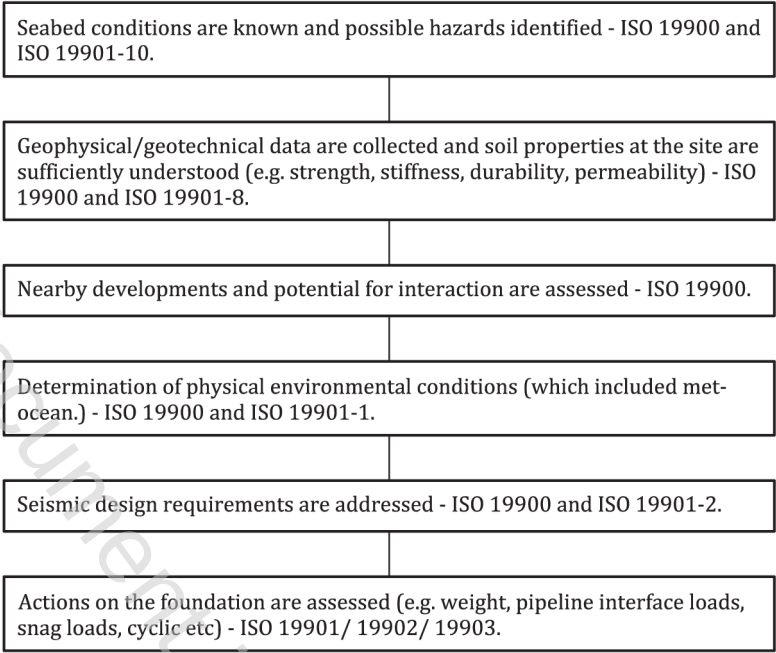
Seabed soils vary. Experience gained at one location is not necessarily applicable at another. Extra caution is necessary when dealing with unconventional soils or unfamiliar foundation concepts. Sound engineering judgment is therefore necessary in the use of this document.

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

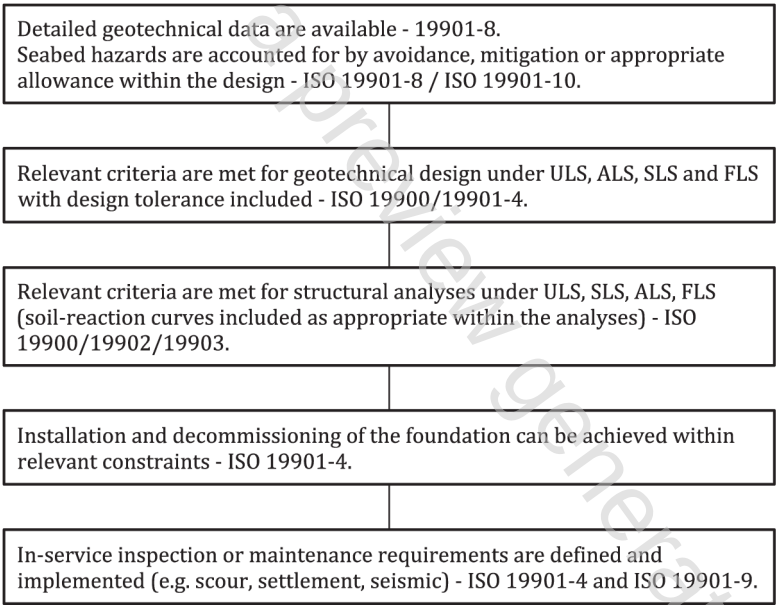
ISO 19905 provides requirements and detailed guidance on foundations for mobile offshore units.

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

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



Foundation Design:



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 $0,5 \leq L/D \leq 10$ (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).

This document can be applied for foundation design for offshore structures used in the lower carbon energy industry.

2 Normative references

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

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

ISO 19901-7, *Oil and 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 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), *Oil and gas industries including lower carbon energy — Site-specific assessment of mobile offshore units*

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

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

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