
**Petroleum and natural gas
industries — Specific requirements
for offshore structures —**

**Part 2:
Seismic design procedures and
criteria**

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*Industries du pétrole et du gaz naturel — Exigences spécifiques
relatives aux structures en mer —*

Partie 2: Procédures de conception et critères sismiques

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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 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 to the possibility that some of the elements of this document may be the subject of patent rights. 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 www.iso.org/patents).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html. (standards.iteh.ai)

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This second edition cancels and replaces the first edition (ISO 19901-2:2004), which has been technically revised.

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

Introduction

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

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

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

The overall concept of structural integrity is described above. Some additional considerations apply for seismic design. These include the magnitude and probability of seismic events, the use and importance of the offshore structure, the robustness of the structure under consideration and the allowable damage due to seismic actions with different probabilities. All of these, and any other relevant information, need to be considered in relation to the overall reliability of the structure.

Seismic conditions vary widely around the world, and the design criteria depend primarily on observations of historical seismic events together with consideration of seismotectonics. In many cases, site-specific seismic hazard assessments will be required to complete the design or assessment of a structure.

This document is intended to provide general seismic design procedures for different types of offshore structures, and a framework for the derivation of seismic design criteria. Further requirements are contained within the general requirements standard, ISO 19900, and within the structure-specific standards, ISO 19902, ISO 19903, ISO 19904 and ISO 19906. The consideration of seismic events in connection with mobile offshore units is addressed in ISO 19905.

Some background to and guidance on the use of this document is provided in [Annex A](#). The clause numbering in [Annex A](#) is the same as in the normative text to facilitate cross-referencing.

Regional information on expected seismic accelerations for offshore areas is provided in [Annex B](#).

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Petroleum and natural gas industries — Specific requirements for offshore structures —

Part 2: Seismic design procedures and criteria

1 Scope

This document contains requirements for defining the seismic design procedures and criteria for offshore structures; guidance on the requirements is included in [Annex A](#). The requirements focus on fixed steel offshore structures and fixed concrete offshore structures. The effects of seismic events on floating structures and partially buoyant structures are briefly discussed. The site-specific assessment of jack-ups in elevated condition is only covered in this document to the extent that the requirements are applicable.

Only earthquake-induced ground motions are addressed in detail. Other geologically induced hazards such as liquefaction, slope instability, faults, tsunamis, mud volcanoes and shock waves are mentioned and briefly discussed.

The requirements are intended to reduce risks to persons, the environment, and assets to the lowest levels that are reasonably practicable. This intent is achieved by using:

- a) seismic design procedures which are dependent on the exposure level of the offshore structure and the expected intensity of seismic events;
- b) a two-level seismic design check in which the structure is designed to the ultimate limit state (ULS) for strength and stiffness and then checked to abnormal environmental events or the abnormal limit state (ALS) to ensure that it meets reserve strength and energy dissipation requirements.

Procedures and requirements for a site-specific probabilistic seismic hazard analysis (PSHA) are addressed for offshore structures in high seismic areas and/or with high exposure levels. However, a thorough explanation of PSHA procedures is not included.

Where a simplified design approach is allowed, worldwide offshore maps, which are included in [Annex B](#), show the intensity of ground shaking corresponding to a return period of 1 000 years. In such cases, these maps may be used with corresponding scale factors to determine appropriate seismic actions for the design of a structure.

For design of fixed steel offshore structures, further specific requirements and recommended values of design parameters (e.g. partial action and resistance factors) are included in ISO 19902, while those for fixed concrete offshore structures are contained in ISO 19903. Seismic requirements for floating structures are contained in ISO 19904, for site-specific assessment of jack-ups and other MOUs in ISO 19905 (all parts), for arctic structures in ISO 19906 and for topsides structures in ISO 19901-3.

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 19901-8, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 8: Marine soils Investigation*

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

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

3 Terms and definitions

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

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

- ISO Online browsing platform: available at <http://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 abnormal level earthquake

ALE

intense earthquake of abnormal severity with a very low probability of occurring during the life of the structure

Note 1 to entry: The ALE event is comparable to the abnormal event in the design of fixed structures which are described in ISO 19902 and ISO 19903.

3.2 attenuation

decay of seismic waves as they travel from the earthquake source to the site under consideration

3.3 directional combination

combination of response values due to each of the three orthogonal components of earthquake-induced ground motions

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3.4 escape and evacuation system

system provided on the offshore structure to facilitate escape and evacuation in an emergency

EXAMPLE Passageways, chutes, ladders, life rafts and helidecks.

3.5 extreme level earthquake

ELE

strong earthquake with a reasonable probability of occurring during the life of the structure

Note 1 to entry: The ELE event is comparable to the extreme environmental event in the design of fixed structures which are described in ISO 19902 and ISO 19903.

3.6 fault movement

movement occurring on a fault during an earthquake

3.7 ground motion

accelerations, velocities or displacements of the ground produced by seismic waves radiating away from earthquake sources

Note 1 to entry: A fixed offshore structure is founded in or on the *seabed* (3.17) and consequently only seabed motions are of significance. The term ground motions is used rather than seabed motions for consistency of terminology with seismic design for onshore structures.

Note 2 to entry: Ground motions can be at a specific depth or over a specific region within the seabed.

3.8**liquefaction**

fluidity of soil due to the increase in pore pressures caused by earthquake action under undrained conditions

3.9**modal combination**

combination of response values associated with each dynamic mode of a structure

3.10**mud volcano**

diapiric intrusion of plastic clay causing high pressure gas-water seepages which carry mud, fragments of rock (and occasionally oil) to the surface

Note 1 to entry: The surface expression of a mud volcano is a cone of mud with continuous or intermittent gas escaping through the mud.

3.11**probabilistic seismic hazard analysis****PSHA**

framework permitting the identification, quantification and rational combination of uncertainties in earthquakes' intensity, location, rate of recurrence and variations in *ground motion* (3.7) characteristics

3.12**probability of exceedance**

probability that a variable (or that an event) exceeds a specified reference level given exposure time

EXAMPLE Example of probability of exceedance during a given exposure time is the annual probability of exceedance of a specified magnitude of ground acceleration, ground velocity or ground displacement.

3.13**response spectrum**

function representing the peak elastic response for single degree of freedom oscillators with a specific damping ratios in terms of absolute acceleration, pseudo velocity, or relative displacement values against natural frequency or period of the oscillators

3.14**safety system**

systems provided on the offshore structure to detect, control and mitigate hazardous situations

EXAMPLE Gas detection, emergency shutdown, fire protection, and their control systems.

3.15**sea floor**

interface between the sea and the *seabed* (3.17)

3.16**seabed slide**

failure of *seabed* (3.17) slopes

3.17**seabed**

material below the *sea floor* (3.15) in which a structure is founded

3.18**seismic risk category****SRC**

category defined from the exposure level and the expected intensity of seismic motions

3.19

seismic hazard curve

curve showing the annual *probability of exceedance* (3.12) against a measure of seismic intensity

Note 1 to entry: The seismic intensity measures can include parameters such as peak ground acceleration, *spectral acceleration* (3.22), or *spectral velocity* (3.23).

3.20

seismic reserve capacity factor

factor indicating the structure's ability to sustain ground motions due to earthquakes beyond the level of the *ELE* (3.5)

Note 1 to entry: The seismic reserve capacity factor is a structure specific property that is used to determine the *ELE* acceleration from the *ALE* (3.1) acceleration.

3.21

site response analysis

wave propagation analysis permitting the evaluation of the effect of local geological and soil conditions on the *ground motions* (3.7) as they propagate up from depth to the surface at the site

3.22

spectral acceleration

maximum absolute acceleration response of a single degree of freedom oscillator subjected to *ground motions* (3.7) due to an earthquake

3.23

spectral velocity

maximum pseudo velocity response of a single degree of freedom oscillator subjected to *ground motions* (3.7) due to an earthquake

Note 1 to entry: The pseudo velocity spectrum is computed by factoring the displacement or acceleration spectra by the oscillator's circular frequency or the inverse of its frequency, respectively. The pseudo spectrum is either relative or absolute, depending on the type of response spectra that is factored.

3.24

spectral displacement

maximum relative displacement response of a single degree of freedom oscillator subjected to *ground motions* (3.7) due to an earthquake

3.25

static pushover method

static pushover analysis

application and incremental increase of a global static pattern of actions on a structure, including equivalent dynamic inertial actions, until a global failure mechanism occurs

3.26

tsunami

long period sea waves caused by rapid vertical movements of the *sea floor* (3.15)

Note 1 to entry: The vertical movement of the sea floor is often associated with fault rupture during earthquakes or with *seabed slides* (3.16).

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4 Symbols and abbreviated terms

4.1 Symbols

a_R	slope of the seismic hazard curve
C_a	site coefficient, a correction factor applied to the acceleration part (shorter periods) of a response spectrum
C_c	correction factor applied to the spectral acceleration to account for uncertainties not captured in a seismic hazard curve
C_r	seismic reserve capacity factor; see Formulae (7) and (10)
C_v	site coefficient, a correction factor applied to the velocity part (longer periods) of a response spectrum
s_u	undrained shear strength of the soil
\bar{s}_u	average undrained shear strength of the soil in the effective seabed
D	scaling factor for damping
G_{\max}	low amplitude shear modulus of the soil
g	acceleration due to gravity
M	magnitude of an earthquake measured by the energy released at its source
N_{ALE}	scale factor for conversion of the site 1 000-year acceleration spectrum to the site ALE acceleration spectrum
p_a	atmospheric pressure
P_{ALE}	annual probability of exceedance for the ALE event
P_e	probability of exceedance
P_{ELE}	annual probability of exceedance for the ELE event
P_f	target annual probability of failure
q_c	cone penetration resistance of sand
q_{cl}	normalized cone penetration resistance of sand
\bar{q}_{cl}	average normalized cone penetration resistance of sand in the effective seabed
$S_a(T)$	spectral acceleration associated with a single degree of freedom oscillator period, T
$\bar{S}_a(T)$	mean spectral acceleration associated with a single degree of freedom oscillator period, T ; obtained from a PSHA
$S_{a,ALE}(T)$	ALE spectral acceleration associated with a single degree of freedom oscillator period, T
$\bar{S}_{a,ALE}(T)$	mean spectral acceleration associated with a single degree of freedom oscillator period, T ; obtained from a PSHA
$S_{a,ELE}(T)$	ELE spectral acceleration associated with a single degree of freedom oscillator period, T

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$\bar{S}_{a,ELE}(T)$	mean ELE spectral acceleration associated with a single degree of freedom oscillator period, T ; obtained from a PSHA
$S_{a,map}(T)$	1 000-year rock outcrop spectral acceleration obtained from maps associated with a single degree of freedom oscillator period, T NOTE The maps included in Annex B are for oscillator periods of 0,2 s and 1,0 s.
$\bar{S}_{a,Pe}(T)$	mean spectral acceleration associated with a probability of exceedance, P_e , and a single degree of freedom oscillator period, T , obtained from a PSHA
$\bar{S}_{a,Pf}(T)$	mean spectral acceleration associated with a target annual probability of failure, P_f , and a single degree of freedom oscillator period, T , obtained from a PSHA
$S_{a,site}(T)$	site spectral acceleration corresponding to a return period of 1 000 years and a single degree of freedom oscillator period, T
T	natural period of a simple, single degree of freedom oscillator
T_{dom}	dominant modal period of the structure
T_{return}	return period
u_i	code utilization in time history analysis, i
\hat{u}	median code utilization
V_s	representative shear wave velocity
\bar{V}_s	average of representative shear wave velocity in the effective seabed
ρ	mass density of soil
η	per cent of critical damping
σ_{LR}	logarithmic standard deviation of uncertainties not captured in a seismic hazard curve
σ'_{v0}	<i>in situ</i> vertical effective stress of soil

4.2 Abbreviated terms

ALE	abnormal level earthquake
ALS	abnormal limit state
ELE	extreme level earthquake
L1, L2, L3	exposure level derived in accordance with the International Standard applicable to the type of offshore structure ¹⁾
MOU	mobile offshore unit
PGA	peak ground acceleration
PSHA	probabilistic seismic hazard analysis

1) International Standards applicable to types of offshore structure include ISO 19902, ISO 19903, ISO 19904 (all parts), ISO 19905 (all parts) and ISO 19906.

SRC	seismic risk category
TLP	tension leg platform
ULS	ultimate limit state

5 Earthquake hazards

Actions and action effects due to seismic events shall be evaluated in the structural design of offshore structures in seismically active areas. Areas are considered seismically active on the basis of previous records of earthquake activity, both in frequency of occurrence and in magnitude. [Annex B](#) provides maps of indicative seismic accelerations; however, for many areas, depending on indicative accelerations and exposure levels, seismicity shall be determined on the basis of detailed seismic hazard investigations (see [Clause 8](#)).

Evaluation of seismic events for seismically active regions shall include investigation of the characteristics of ground motions and of the acceptable seismic risk for structures. Structures in seismically active regions shall be designed for ground motions due to earthquakes. However, other seismic hazards shall also be considered in the design and, when warranted, should be addressed by special studies (e.g. mudflow loading, seabed deformation). The following hazards can be caused by a seismic event:

- soil liquefaction;
- seabed slide;
- fault movement;
- tsunamis;
- mud volcanoes;
- shock waves.

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Effects of seismic events on subsea equipment, pipelines and in-field flowlines shall be addressed by special studies (e.g. simultaneous seabed and structure excitation, spatially varying motions).

6 Seismic design principles and methodology

6.1 Design principles

This clause addresses the design of structures against base excitations, i.e. accelerations, velocities and displacements caused by ground motions.

Structures located in seismically active areas shall be designed to the ultimate limit state (ULS) for low-intensity frequent earthquakes and to the abnormal limit state (ALS) for high-intensity rare earthquakes.

The ULS requirements are intended to provide a structure which is adequately sized for strength and stiffness to ensure that no significant structural damage occurs for a level of earthquake ground motion with an adequately low likelihood of being exceeded during the design service life of the structure. The seismic ULS design event is the extreme level earthquake (ELE). The structure shall be designed such that an ELE event will cause little or no damage. It is recommended that the structure be inspected subsequent to an ELE occurrence.

The ALS requirements are intended to ensure that the structure and foundation have sufficient reserve strength, displacement and/or energy dissipation capacity to sustain large inelastic displacement reversals without complete loss of integrity, although structural damage can occur. The seismic ALS design event is the abnormal level earthquake (ALE). The ALE is an intense earthquake of abnormal

severity with a very low probability of occurring during the structure's design service life. The ALE can cause considerable damage to the structure; however, the structure shall be designed such that overall structural integrity is maintained to avoid structural collapse causing loss of life and/or major environmental damage.

Both ELE and ALE return periods depend on the exposure level and the expected intensity of seismic events. The target annual failure probabilities given in 6.4 may be modified to meet targets set by owners in consultation with regulators, or to meet regional requirements where they exist.

6.2 Seismic design procedures

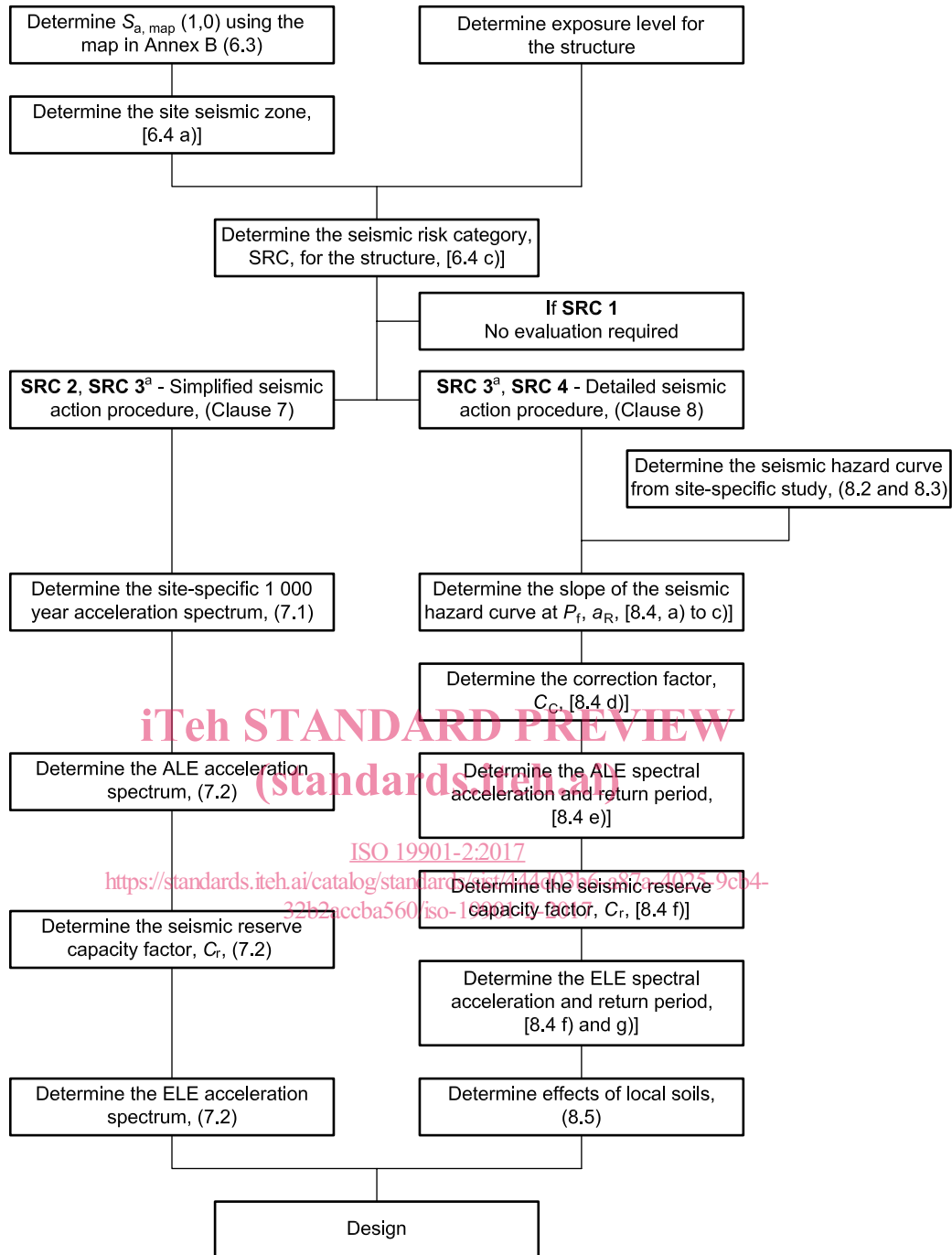
6.2.1 General

Two alternative procedures for seismic design are provided. The simplified method may be used where seismic considerations are unlikely to govern the design of a structure. The detailed method shall be used where seismic considerations have a significant impact on the design. The selection of the appropriate procedure depends on the exposure level of the structure and the expected intensity and characteristics of seismic events. The simplified procedure (see Clause 7) allows the use of generic seismic maps provided in Annex B; while the detailed procedure (see Clause 8) requires a site-specific seismic hazard study. In all cases, the simplified procedure may be used to perform appraisal and concept screening for a new offshore development.

When a structural design is asymmetric in geometric configuration or directional capacity, additional analyses shall be included to demonstrate suitable performance in weaker directions. For time history analyses, this may require different orientations of the earthquake horizontal records to demonstrate performance requirements (see Clause 9).

Figure 1 presents a flowchart of the selection process and the steps associated with both procedures.

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^a SRC 3 structures may be designed using either the simplified or the detailed seismic action procedure (see Table 4).

Figure 1 — Seismic design procedures

6.2.2 Extreme level earthquake design

During the ELE event, structural members and foundation components are permitted to sustain localized and limited non-linear behaviour (e.g. yielding in steel, tensile cracking in concrete). As such, ELE design procedures are primarily based on linear elastic methods of structural analysis with, for example, non-linear soil-structure interaction effects being linearized. However, if seismic isolation or passive energy dissipation devices are employed, non-linear time history procedures shall be used.