International Standard

ISO 19901-2

Specific requirements for offshore structures —

Part 2:
Seismic design

Exigences spécifiques relatives aux structures en mer —

Partie 2: Conception sismique

Fourth edition
2026-07

Reference number
ISO 19901-2:2026(en)

Contents

Page

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 fourth edition cancels and replaces the third edition (ISO 19901-2:2022), which has been technically revised.

The main changes are as follows:

— the scope has been expanded to cover offshore wind and other renewable energy offshore structures;

— requirements from common industry specifications (IOGP JIP 35) have been incorporated;

— the seismic hazard maps have been updated.

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 for offshore structures prepared by ISO TC 67/SC 7 comprise:

— ISO 19900, the unifying International Standard for offshore structures;

— the ISO 19901 series, providing specific requirements for offshore structures;

— ISO 19902, ISO 19903, ISO 19904-1, the ISO 19905 series and ISO 19906, “structure type” standards.

Figure 1 illustrates the relationships between the International Standards for offshore structures prepared by ISO TC 67/SC 7.

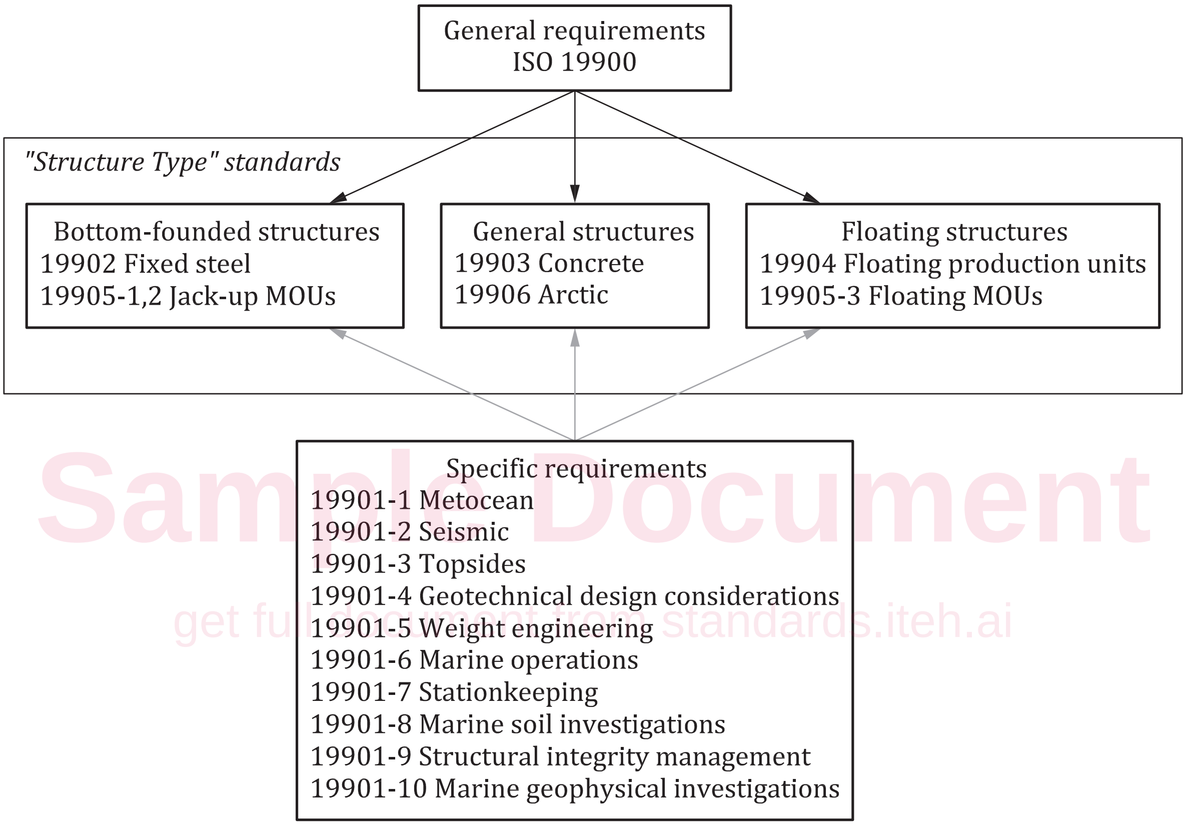


Figure 1 — Relationship of International Standards for offshore structures prepared by ISO/TC 67/SC 7

Seismic conditions vary widely around the world, and the design criteria depend primarily on observations of historical seismic events together with consideration of seismotectonics and local soil conditions. Additional information and guidance are given in Annex A, where the clause numbering mirrors the normative clauses to facilitate cross referencing.

Statements containing requirements (“shall” and “shall not”), recommendations (“should” and “should not”) or permissions (“may”) are collectively referred to as provisions.

Specific requirements for offshore structures —

Part 2:
Seismic design

1 Scope

This document contains requirements for seismic design and assessment of offshore structures.

This document includes recommendations for the effects of seismic events on floating structures.

This document addresses specifically the design and assessment of offshore structures subjected to earthquake-induced ground motions. It also covers briefly other geologically induced hazards such as liquefaction, slope instability, fault surface displacement, tsunamis, mud volcanoes and shock waves.

This document provides requirements for site-specific probabilistic seismic hazard analysis for offshore structures in high seismic areas and for offshore structures with high consequence levels.

2 Normative references

The following documents are referred to in the text in such a way that some or all 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, *Oil and gas industries including lower carbon energy — General requirements for offshore structures*

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

IOGP S-631-11, *Supplementary Specification for Fixed Steel Offshore Structures, International Oil & Gas Producers Association, Version 2, 8 February 2021*

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 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
abnormal level earthquake
ALE
ground motion (3.6) due to a rare intense earthquake with a very low probability of occurrence during the life of the structure

Note 1 to entry: Typically, having an annual *probability of exceedance* (3.10) of one in a few thousand years.

3.2
active fault
fault likely to have another earthquake in the future

3.3
attenuation
decay of seismic waves as they travel from the earthquake source to the site under consideration

3.4
deaggregation
separation of seismic hazard contributions from different faults and seismic source zones

3.5
extreme level earthquake
ELE
ground motion (3.6) due to an earthquake with a reasonable probability of occurring during the life of the structure

Note 1 to entry: Typically having an annual *probability of exceedance* (3.10) of one in a few hundred years.

3.6
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 and consequently only seabed motions or motions along the length of piles are of significance. The expression "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.

3.7
liquefaction
fluidity of soil due to the increase in pore pressures caused by earthquake action under undrained conditions

3.8
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.

3.9
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* (3.6) characteristics

3.10
probability of exceedance
P_e
probability that a variable (or an event) exceeds a specified reference level within a given exposure period

EXAMPLE The annual probability of exceedance of a specified magnitude of ground acceleration, ground velocity or ground displacement.

3.11
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

3.12
response spectrum
maximum responses of a series of single-degree-of freedom systems subjected to a given base motion, plotted as a function of natural frequencies for specific values of damping

3.13
safety system
system provided on the offshore structure to detect, control and mitigate hazardous situations

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

3.14
seabed slide
failure of seabed slopes

Note 1 to entry: The seabed is defined as the soil material below the sea floor (ISO 19900:2019, 3.47).

Note 2 to entry: The effective seabed is defined in 8.3.2; typically, being the upper 30 m of seabed material.

3.15
seismic hazard curve
curve showing the annual *probability of exceedance* (3.10) against a measure of *ground motion* (3.6) or response of the single degree of freedom oscillator

Note 1 to entry: The seismic measures can include parameters such as peak ground acceleration, *spectral acceleration* (3.19), spectral velocity or spectral displacement.

3.16
seismic reserve capacity factor
C_r
factor indicating the structure's ability to sustain *ground motions* (3.6) due to earthquakes beyond the level of the *extreme level earthquake* (3.5)

3.17
seismic risk category
SRC
category defined from the consequence level and the intensity of seismic motions

3.18
site response analysis
wave propagation analysis permitting the evaluation of the effect of local geological and soil conditions on the *ground motions* (3.6) as they propagate up from depth to the surface at the site

3.19
spectral acceleration
maximum acceleration response of a single degree of freedom oscillator subjected to *ground motions* (3.6) due to an earthquake

3.20
tsunami
long period sea waves caused by rapid vertical movements of the sea floor

Note 1 to entry: The vertical movement of the sea floor is often associated with fault rupture during earthquakes or with *seabed slides* (3.14).

3.21
zero pad
technique used in signal processing particularly when analysing earthquake recordings using the fast Fourier transformation

4 Symbols and abbreviated terms

4.1 Symbols

a_R	tail slope of the seismic hazard curve
C_a	correction factor for 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
C_v	correction factor for the velocity part (longer periods) of a response spectrum
d	thickness of soil layer
D	scaling factor for damping
G_{max}	initial (small strain) shear modulus of the soil
g	acceleration due to gravity
H	horizontal spectral accelerations
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_{ELE}	annual probability of exceedance for the ELE event
P_e	annual probability of exceedance
$P_{ULS_{DL}}$	annual probability of exceeding the ULS_{DL}
$P_{ULS_{NC}}$	annual probability of exceeding the ULS_{NC}
q_c	cone penetration resistance of soil
q_{cl}	normalized cone penetration resistance of soil
$\bar{q}_{cl}$	average normalized cone penetration resistance of sand in the effective seabed
R_k	representative capacity
$S_a(T)$	spectral acceleration (associated with single degree of freedom oscillator period, T)
$S_{a,ALE}(T)$	ALE spectral acceleration
$S_{a,ALE}(T_{dom})$	ALE spectral acceleration at T_{dom}
$S_{a,ELE}(T)$	ELE spectral acceleration
$S_{a,ELE}(T_{dom})$	ELE spectral acceleration at T_{dom}
$S_{a,map}(T)$	1 000-year bedrock spectral acceleration obtained from seismic maps

$S_{a,site}(T)$	site spectral acceleration corresponding to a return period of 1 000 years
$\bar{S}_{a,P_e}(T)$	spectral acceleration having an annual probability of exceedance (P_e) obtained from a PSHA.
$S_{a,P_{ULS_{DL}}}(T_{dom})$	site-specific spectral acceleration at T_{dom} having an annual probability $P_{ULS_{DL}}$ of exceeding the ULS_{DL}
$S_{a,P_{ULS_{NC}}}(T_{dom})$	site-specific spectral acceleration at T_{dom} having an annual probability $P_{ULS_{NC}}$ of exceeding the ULS_{NC}
s_u	undrained shear strength of the soil
$\bar{s}_u$	average undrained shear strength of the soil in the effective seabed
T	natural period of a simple, single degree of freedom oscillator
T_{dom}	dominant modal period of the structure
T_{return}	return period
V	vertical spectral accelerations
v_s	representative shear wave velocity
$\bar{v}_s$	average 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}	in situ vertical effective stress of soil

4.2 Abbreviated terms

DL	damage limitation state (specified in 6.2.3 and 6.2.4)
DSHA	deterministic seismic hazard analysis
DSRA	dynamic site response analysis
L1, L2, L3	consequence levels (see ISO 19900)
NC	near collapse state (specified in 6.2.1 and 6.2.2)
NPA	nonlinear pushover analysis
NTHA	nonlinear time history analysis
RSA	response spectrum analysis
SDOFS	single degree of freedom
SLS	serviceability limit state
SPA	static pushover analysis

ULS ultimate limit state

5 Seismic hazards

5.1 Seismic design and assessment of offshore structures shall include the effect of ground motions due to earthquakes.

5.2 In addition to the effect of ground motion, design and assessment of offshore structures shall also include the effects of the following seismic hazardous events, as developed by specialists in geologic site hazards:

a) soil liquefaction,

b) seabed slide,

c) fault surface displacement,

d) tsunamis,

e) mud volcanoes,

f) velocity pulse from directivity effects (earthquake-induced shock wave in the water column typically associated with volcanic eruptions).

NOTE Provisions for seismic design and assessment of floating structures is covered in Clause 10.

6 Performance objectives and limit states

6.1 General

6.1.1 The risks, due to the structure being exposed to seismic hazardous events, shall be demonstrated to be tolerable by stake holders in accordance with 6.1.2 to 6.1.4.

NOTE The requirements in this document ensure that the structure has sufficient strength and ductility such that the risks (life-safety, environmental-pollution, and business-disruption) are tolerable when the structure is exposed to seismic hazardous events, as defined by the seismic hazard curve for the site.

6.1.2 Demonstration that the structure meets the performance objectives shall be by limit state verification in accordance with ISO 19900.

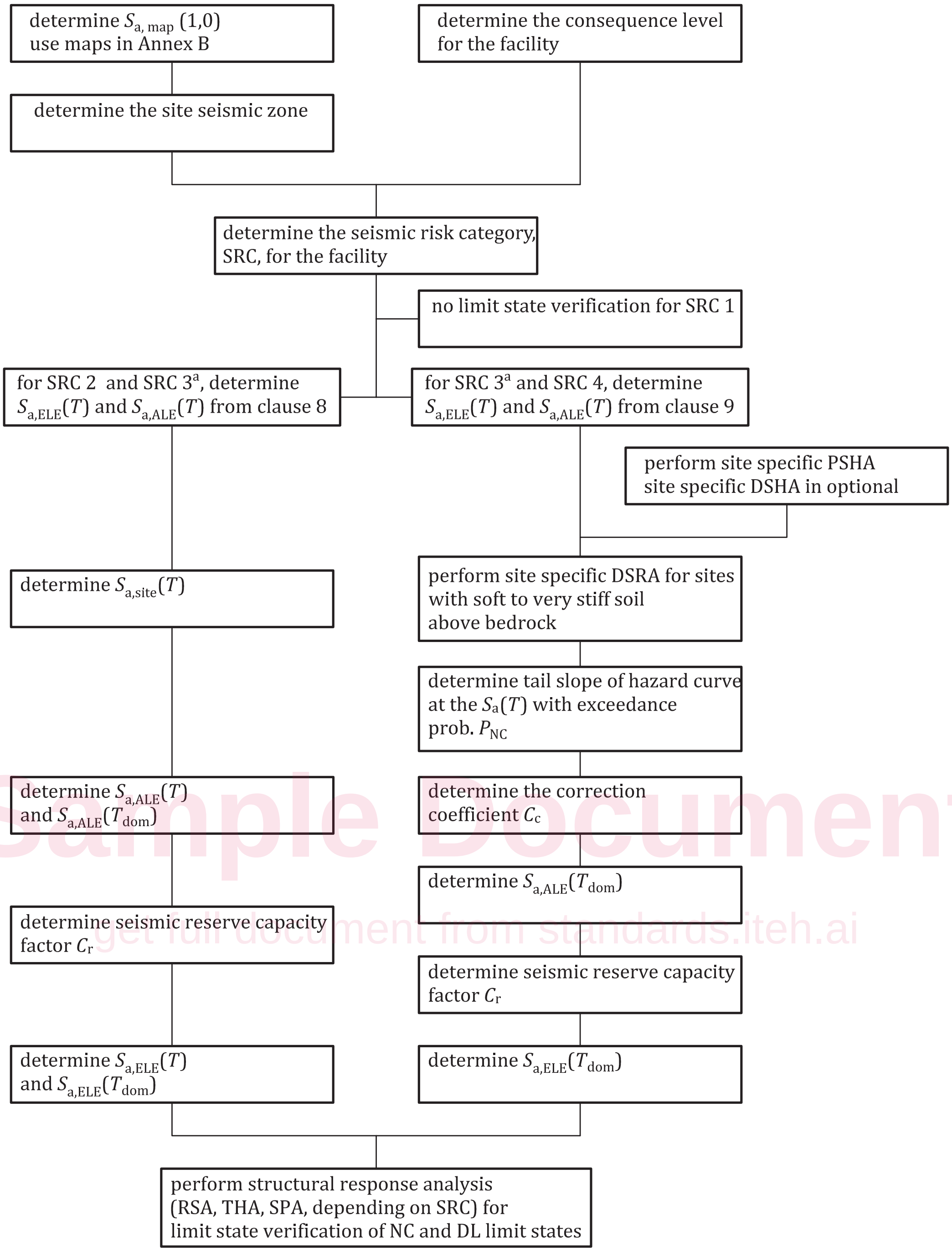
6.1.3 The performance objective for life-safety and environmental risks, typically associated with an ALE, shall specify the maximum tolerable annual probability that the (damaged) state of structure can exceed ULS_{NC}.

NOTE 1 Life-safety risk refers to the potential for injury or loss of life during an earthquake.

NOTE 2 ULS_{NC} is described in 6.2.1. When the state of the structure exceeds ULS_{NC} one or more components can have failed and the structure can be near to collapsing.

6.1.4 The performance objective for business-disruption risk, typically associated with an ELE, shall specify the maximum tolerable annual probability that the (damaged) state of structure can exceed ULS_{DL}.

NOTE ULS_{DL} is described in 6.2.3. When the state of the structure exceeds ULS_{DL}, the structural system remains stable, but the lateral system of the structure (braces, joints, and piles) can have plastic strains that result in permanent deformation that can affect the functionality of the structure. The permanent deformation is likely repairable and thus the functionality of the facility can be restored.



Key

a SRC 2 structures can alternatively be designed using the detailed seismic action procedure similar to SRC 3 and SRC 4 structures (see Table 4).

Figure 2 — Steps for limit state verification

6.2 Ultimate limit states

6.2.1 The state of the structure at the ULS_{NC}, typically due to hazardous events with intensity $S_{a,ALE}(T)$, shall not include:

a) collapse of the structure's gravity load resisting system (i.e. legs, pile to leg joints, pile-soil resistance) or collapse of the gravity sub-system that supports the living quarters;

b) damage to safety systems, escape routes, and evacuation systems that prevent their functionality;

c) loss of supports for critical hydrocarbon equipment that could lead to escalation by loss of process containment;

d) collapse of the living quarters, masts, derricks, flare structures and other safety critical structures.

6.2.2 The state of the structure at the ULS_{NC} may include damage to the structure's lateral system (i.e. braces and their joints, and pile lateral deformation) as follows:

a) severed braces (by fracture or low-cycle fatigue, with or without strain ratcheting);

b) plastic local buckling of braces or global buckling of braces;

c) permanent deformation of joints, and collapse or fracture of joints;

d) permanent lateral deformation of piles;

e) spalling of reinforced concrete.

6.2.3 The state of the structure at the ULS_{DL}, typically due to hazardous events with intensity $S_{a,ELE}$, shall not include:

a) permanent deformation of the components comprising the structure's gravity load resisting system (i.e. legs, pile to leg joints, and pile-soil resistance);

b) permanent deformation to the components comprising the structure's lateral system (i.e. braces and their joints, and pile lateral deformation);

c) damage to safety systems, escape routes, and evacuation systems that prevent their functionality;

d) damage to pipelines, conductors, risers, and other safety-critical components due to displacements at mudline elevation of the structure;

e) damage due to toppling of topsides equipment and cable trays;

f) damage to masts, derricks, and flare structures;

g) damage to sliding supports that prevent their functionality;

h) damage to piping systems that prevents their functionality due to differential displacement of supports.

6.2.4 The state of the structure at the ULS_{DL} should not include damage that will result in dropped objects.

6.3 Performance objectives

6.3.1 ULS_{NC} verification shall be demonstrated for hazardous events with intensity $S_{a,ALE}$ in accordance with 6.3.2.

6.3.2 The annual probability of the structure exceeding the ULS_{NC} (defined in 6.2.1) shall not be larger than the value of P_f listed in Table 1.

Table 1 — Maximum tolerable annual probability of exceeding P_f

Consequence level	P_f
L1	$4 \times 10^{-4} = 1/2\,500$
L2	$1 \times 10^{-3} = 1/1\,000$
L3	$2{,}5 \times 10^{-3} = 1/400$

NOTE 1 P_f values in Table 1 account for epistemic uncertainty due to the use of the mean hazard curve and the mean fragility curve in Clause 9.

NOTE 2 Reference [22] describes the calibration of the simplified procedure in Clause 8 to the probabilities listed in Table 1.

6.3.3 The maximum tolerable annual probability of exceeding the ULS_{NC} may be less than listed in Table 1 if specified by the operator or regulator, provided the structural response with probability of exceedance in Table 1 is also demonstrated to be acceptable.

NOTE The lower probability event with its higher motions can result in nonlinear soil response which can effectively reduce seismic demands on the structure.

EXAMPLE 1×10^{-4} p.a. (1/10 000) for L1 facilities.

6.3.4 ULS_{DL} verification shall be demonstrated for hazardous events with intensity $S_{a,ELE}$ in accordance with 6.3.5.

6.3.5 The annual probability of the structure exceeding the ULS_{DL}, as defined in 6.2.3, shall not be larger than P_{ELE} or $P_{ULS_{DL}}$ as listed in Table 2.

Table 2 — Maximum tolerable annual probability of exceeding ULS_{DL}

Consequence level	$P_{ULS_{DL}}$	P_{ELE}
L1	$5{,}0 \times 10^{-3} = 1/200$	P_{ELE} is the annual probability of exceedance of the spectral acceleration value, $S_{a,ELE}$ given by the hazard curve in Figure 6.
L2	$1{,}0 \times 10^{-2} = 1/100$	
L3	$2{,}0 \times 10^{-2} = 1/50$	

6.4 Seismic risk category

6.4.1 The facility shall be assigned a seismic risk category (SRC) in accordance with Table 3.

6.4.2 Site seismic zone shall be determined from the 1,0 s horizontal spectral acceleration maps in Annex B or from a site-specific seismic hazard study (PSHA).

Table 3 — Seismic risk category

$S_{a,map}(1{,}0)$ (see Annex B)	Site seismic zone	Consequence level (see ISO 19900)		
		L1	L2	L3
<0,03 g	0	SRC 1	SRC 1	SRC 1
0,03 g to <0,10 g	1	SRC 3	SRC 2	SRC 2
0,10 g to <0,25 g	2	SRC 4	SRC 2	SRC 2
0,25 g to <0,45 g	3	SRC 4	SRC 3	SRC 2
≥0,45 g	4	SRC 4	SRC 4	SRC 3

6.4.3 For seismic design situations, a facility with environmental consequence level greater than L3, shall not be classified as consequence level L2 unless it is normally unoccupied (e.g. limited to inspection and maintenance visits).

NOTE No reliable forewarning of seismic actions is feasible and, consequently, it is not possible to evacuate prior to an earthquake.