

GENERAL SPECIFICATION

SURVEYS

GS EP GEO 601

Seismic Hazard Assessment for Offshore Structures

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1. Scope

The aim of this General Specification is to detail the Company minimum-requirements for the performance of a Seismic Hazard Assessment (SHA) study of any offshore site.

This document is applicable to any offshore oil & gas structures to be permanently or temporarily installed in seismically active areas, including but not limited to **jacket platforms, pipelines, subsea infrastructures** and **mobile units**.

This General Specification covers the requirements regarding the SHA stricto sensu, the site response analysis, the identification of earthquake-related geohazards and the subsequent reporting and deliverables.

Would Company consider that any aspects of the works require more refinement, further Particular Technical Specifications will be applied.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
API RP 2A LRFD / WSD	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Load and Resistance Factor Design / Working Stress Design
ISO 19901-2	Petroleum and natural gas industries - Specific requirements for offshore structures - Part 2: Seismic design procedures and criteria
ISO 19902 (§ 11.3)	Petroleum and natural gas industries - Fixed steel offshore structures
ISO 19905-1	Petroleum and natural gas industries - Site-specific assessment of mobile offshore units - Part 1: Jack-ups

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP GEO 101	Offshore Geotechnical Survey
GS EP GEO 401	GIS requirements for engineering site surveys and studies

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Acronyms

ALE	Abnormal Level Earthquake
ASCR	Active Shallow Crustal region
Cr	Seismic reserve capacity factor
DSHA	Deterministic Seismic Hazard Assessment
ELE	Extreme Level Earthquake
GMPE	Ground Motion Prediction Equation (attenuation law)
KOM	Kick Off Meeting
MCE	Maximum Credible Earthquake
PGA	Peak Ground Acceleration
PGD	Peak Ground Displacement
PGV	Peak Ground Velocity
PSHA	Probabilistic Seismic Hazard Assessment
RIE	Rare Intense Earthquake
SA	Spectral Acceleration
SCR	Stable Continental Region
SHA	Seismic Hazard Assessment
SLE	Strength Level Earthquake
SZ	Subduction Zone
UHRS	Uniform Hazard Response Spectra

Units

Unless otherwise mentioned, the units of measurements shall be expressed in agreement with the **International System of Units (SI)**.

Acceleration	unit in g or in m/s^2
Velocity	unit in m/s
Displacement	unit in m
Return periods	unit in years
Spectral period	unit in seconds
Spectral frequency	unit in Hz
Slip rate	unit in mm/year

3. Seismic Hazard Assessment Approach

The SHA is aimed at defining and characterizing the seismic hazard affecting a specific project-location and at quantifying the seismic ground-motions to be used in the design basis of the project.

The adopted regulatory framework of the SHA is the [ISO 19901-2](#).

3.1 Approach

Two detail-levels of SHA are considered as a function of the anticipated type of structure, the anticipated soil conditions and the anticipated ground motions:

- Simplified level
- Detailed level.

Both types of SHA include the following similar tasks but at different level of details:

- Data collection and database organisation
- Development of the seismic catalogue
- Development of seismo-tectonic models
- Selection of ground motion prediction equations (GMPE)
- SHA computations
- Reporting.

The type of SHA to be conducted (detailed or simplified) is specified in the scope of works provided within the Particular Technical Specifications.

3.2 Design ground-motion levels

The seismic ground-motions to be used for the structure design are developed in the [ISO 19901-2](#). Three design earthquakes are considered:

- Abnormal Level Earthquake (ALE)

The ALE is associated with an intense ground motion of abnormal severity with a **very low probability of occurrence** during the structure service-life. The ALE can cause considerable damage to the structure, which however shall maintain an overall structural integrity (no collapse requirement). The ALE is comparable to the Rare Intense Earthquake (RIE) or Ductility Level Earthquake (DLE) defined in the [API RP 2A - LRFD / WSD](#).

- Abnormal Level Earthquake (ALE2)

The ALE2 is associated with an intense ground motion of abnormal severity with an **extremely low probability of occurrence** during the structure service-life. The ALE2 may only be used to check and ensure the non-collapse of the structure.

- Extreme Level Earthquake (ELE)

The ELE is associated with an intense ground motion of extreme severity with a **probable occurrence** during the structure service-life. The structure shall sustain the ELE event

with no major damage and remain operational. The ELE is comparable to the Strength Level Earthquake (SLE) defined in the [API RP 2A - LRFD / WSD](#).

3.2.1 Permanent structures

For permanently (i.e. during field life duration or more than several years) installed structures, the design ground-motion levels shall be as per the following requirements.

ALE event

ALE response spectrum shall be computed following the [ISO 19901-2](#) detailed seismic action procedure (section 8.4) as a function of (1) the **exposure level**, of (2) the **dominant modal periods of the structure** T_{dom} and of (3) the **slope of the seismic hazard curve** α_R (site specific).

The site-specific seismic hazard-curve is determined in terms of the annual exceedance probability of a spectral acceleration corresponding to a period that is equal to the dominant modal period of the structure.

Unless otherwise mentioned in the Particular Technical Specification, an **exposure level L1** associated to an annual probability of failure $P_f = 4 \times 10^{-4}$ shall be used. The dominant modal period(s) of the intended structure(s) is specified in the Particular Technical Specification.

ALE2 event

Unless otherwise mentioned in the Particular Technical Specification, the ALE2 response spectrum shall be computed for a minimal return period of 5000 years

ELE event

The ELE response-spectrum shall be directly computed from the ALE response-spectrum following [ISO 19901-2](#) detailed seismic action procedure (section 8.4).

The seismic reserve capacity factor C_r ([ISO 19902](#), section 11.3) to be used in the ELE computation is specified in the Particular Technical Specification, as it is dependent on the intended structural design.

Minimum return periods

In order to enhance the level of safety against seismic hazard and in order to maintain coherency with Company current practice, the following **minimal design return-periods** shall be used in the SHA of any permanent structure (Table 1).

Table 1 - Minimum return-period for seismic design

Exposure Level	Minimum return periods (years)		
	ELE	ALE	ALE2
L1	475	2475	5000
L2	200	1000	n/a
L3	100	475	n/a

3.2.2 Temporary structures

As per [ISO 19905-1](#) (section 10.7), a design earthquake event associated to a 1000 year return period shall be considered for temporary-installed (i.e. for a few years at maximum) mobile units (i.e. Jack-Up platforms).

In case of **temporary critical structures**, longer return periods will be considered up to a maximum return period corresponding to the ALE event. In such a case, the design return period will be specified in the Particular Technical Specification.

3.3 Soil classification

The site classification in terms of soil conditions shall be done following the [ISO 19901-2](#) (section 7), which is summarized in Table 2 below.

Table 2 - Soil class determination (ISO 19901-2)

Site class	Soil profile name	Average properties in top 30 m of effective seabed		
		Soil shear wave velocity $\bar{v}_s$ m/s	Sand: normalized cone penetration resistance $\bar{q}_{cl}$ ^a	Clay: soil undrained shear strength $\bar{c}_u$ kPa
A/B	Hard rock/rock, thickness of soft sediments < 5 m	$\bar{v}_s > 750$	Not applicable	Not applicable
C	Very dense hard soil and soft rock	$350 < \bar{v}_s \leq 750$	$\bar{q}_{cl} \geq 200$	$\bar{c}_u \geq 200$
D	Stiff to very stiff soil	$180 < \bar{v}_s \leq 350$	$80 \leq \bar{q}_{cl} < 200$	$80 \leq \bar{c}_u < 200$
E	Soft to firm soil	$120 < \bar{v}_s \leq 180$	$\bar{q}_{cl} < 80$	$\bar{c}_u < 80$
F	—	Any profile, including those otherwise classified as A to E, containing soils having one or more of the following characteristics: $\bar{v}_s \leq 120$; soils vulnerable to potential failure or collapse under seismic actions such as liquefiable soils, highly sensitive clays, collapsible weakly cemented soils; ooze ^b with a thickness of more than 10 m; soil layers with high gas content or ambient excess pore pressure greater than 30 % of <i>in situ</i> effective overburden; layers greater than 2 m thick with sharp contrast in shear wave velocity (greater than ± 30 %) and/or undrained shear strength (greater than ± 50 %) compared to adjacent layers.		

^a $q_{cl} = (q_c / p_a) \times (p_a / \sigma'_{v0})^{0.5}$
where
 q_c is the cone penetration resistance;
 p_a is atmospheric pressure = 100 kPa;
 σ'_{v0} is the vertical effective stress.

^b Clay containing more than 30 % calcareous or siliceous material of biogenic origin.

The geotechnical soil data available at time of study are specified within the Particular Technical Specifications.

If no soil data is available at time of study, the SHA shall preliminary be done considering a worst case scenario, i.e. in two phases (1) SHA first conducted with an estimated Site class B, C or D and (2) Followed by Site response analysis when dedicated geotechnical data are available.

4. Seismic Hazard Assessment

The performance of a SHA study includes the achievement of the following tasks:

- Data collection
- Earthquake catalogue compilation

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- Seismo-tectonic modeling
- Ground motion prediction equations (GMPE) selection
- Logic Tree and Uncertainty propagation
- Soil classification
- Seismic hazard assessment (probabilistic and/or deterministic)
- De-aggregation
- Site effect evaluation
- Time histories compilation (optional)
- Reporting & deliverables.

4.1 Detailed Analysis vs. Simplified Analysis

The performance of a detailed analysis compared to a simplified analysis has consequences in terms of study refinement, level of details and performance of optional/additional works.

The flowcharts presenting the simplified and detailed SHA analysis requirements are presented in Figure 1 and Figure 2 respectively.

4.2 Methodology

Unless otherwise mentioned in the Particular Technical Specifications, the SHA shall be performed in a probabilistic way through a standard Probabilistic Seismic Hazard Assessment (PSHA) methodology.

For detailed SHA, the PSHA shall be complemented by a Deterministic Seismic Hazard Assessment (DSHA) in order to evaluate the hazard contribution of specific seismic sources and in order to check the relevance of PSHA results. The DSHA shall be conducted for all the design ground-motion levels and shall focus on the primary seismic sources.

For simplified SHA, the performance of a DSHA is optional. In case of very low seismicity area, it can be proposed to replace the PSHA by a DSHA, subject to Company approval.

4.3 Data Collection

The objective of the data collection is the development at a regional level of a comprehensive and integrated database of geological, geophysical, geotechnical and seismological information. The information shall be used to identify any earthquake-related geohazards, which may affect the site (e.g. active faults, tectonic plate relative motions...).

The extent of the regional level area depends on the seismo-tectonic context:

- A minimum radius of **300 km** around the site shall be considered for Stable Continental Region (SCR)
- A minimum radius of **400 km** around the site shall be considered for Active Shallow Crustal Region (ASCR)
- A minimum radius of **500 km** shall be used for Subduction Zone (SZ).