

GENERAL SPECIFICATION

SURVEYS

GS EP GEO 602

Seismic hazard assessment for onshore structures

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General Specification		GS EP GEO 602
Seismic hazard assessment for onshore structures		
Rev.: 02	Effective date: 11/2019	Page: 2 of 35

Contents

1. Scope	4
2. Reference documents.....	4
3. Applicability.....	5
4. Definition of Terms	5
5. Seismic Hazard Assessment Approach.....	6
5.1 National codes	6
5.2 Approach	6
5.3 Design ground-motion levels.....	7
5.4 Ground classification	9
6. Seismic Hazard Assessment	10
6.1 Detailed Analysis vs. Simplified Analysis	10
6.2 Methodology	10
6.3 Data Collection	14
6.4 Earthquake catalogue.....	15
6.5 Seismo-tectonic modelling	17
6.6 GMPE.....	18
6.7 Uncertainty propagation.....	20
6.8 SHA.....	20
7. Site response analysis	24
7.1 Geotechnical ground model	24
7.2 Data requirements	25
7.3 Dynamic soil response analysis	26
7.4 Soil-structure interaction	29
8. Associated geohazards	29
8.1 Active faulting	29
8.2 Liquefaction	30
8.3 Slope instability.....	30
8.4 Tsunami.....	31



General Specification		GS EP GEO 602
Seismic hazard assessment for onshore structures		
Rev.: 02	Effective date: 11/2019	Page: 3 of 35

9. Reporting & deliverables	31
9.1 Reporting time-frame	31
9.2 Report organization	31
9.3 Results format	33
9.4 Deliverables	34
9.5 Peer Review	34
10. Bibliography	35



General Specification		GS EP GEO 602
Seismic hazard assessment for onshore structures		
Rev.: 02	Effective date: 11/2019	Page: 4 of 35

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 onshore site.

This document is applicable to any onshore oil & gas installation to be permanently or temporarily installed in seismically active areas, including but not limited to **LNG plants, refineries, process facilities, and pipelines.**

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

This document is the TOTAL E&P transposition of the TOTAL S.A. Harmonized GS GR GEO 602.

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 addendums, is the latest revision published at the effective date of this document.

Reference	Title
EN 1998-1	Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for building
EN 1473	Installation and equipment for liquefied natural gas - Design of onshore installations

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 102	Onshore Geotechnical Investigation
GS EP GEO 210	Onshore Geophysical Site Survey: Crosshole geophysical survey
GS EP GEO 211	Onshore Geophysical Site Survey: Seismic refraction geophysical survey
GS EP GEO 212	Onshore Geophysical Site Survey: Multichannel surface waves geophysical survey
GS EP GEO 401	GIS Requirements for Engineering Site Surveys and Studies

3. Applicability

This specification is applicable to onshore sites.

4. Definition of Terms

For the purpose of this document, the following terms and definitions apply:

ASCR	Active Shallow Crustal region
DSHA	Deterministic Seismic Hazard Assessment
GMPE	Ground Motion Prediction Equation
KOM	Kick Off Meeting
LNG	Liquefied Natural Gas
MCE	Maximum Credible Earthquake
OBE	Operating Basis Earthquake
PGA	Peak Ground Acceleration
PGD	Peak Ground Displacement
PGV	Peak Ground Velocity
PSHA	Probabilistic Seismic Hazard Assessment
SA	Spectral Acceleration
SCR	Stable Continental Region
SHA	Seismic Hazard Assessment
SSE	Safe Shutdown Earthquake
SZ	Subduction Zone
UHRs	Uniform Hazard Response Spectra

General Specification		GS EP GEO 602
Seismic hazard assessment for onshore structures		
Rev.: 02	Effective date: 11/2019	Page: 6 of 35

Units

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

- 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.

5. 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.

Unless otherwise specified, the regulatory framework adopted for the SHA is the [EN 1998-1](#).

5.1 National codes

It is part of the Contractor's task to identify any national codes, applicable to the seismic design of the intended project.

Applicable national codes shall be reviewed by Contractor and their quality commented.

Ultimately, Contractor shall provide a full gap analysis between applicable National codes, the [EN 1998-1](#) and the present General Specification.

5.2 Approach

Two detail-levels of SHA are considered as a function of the anticipated type of structure, the anticipated ground 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.

5.3 Design ground-motion levels

The seismic ground-motions to be used for the design are named following the terminology developed in [EN 1473](#) for LNG plants but are applied for any type of installations.

Three design earthquakes shall be considered:

- Safe Shutdown Earthquake (SSE): the SSE is associated with an intense ground motion of extreme severity with a very low probability of occurrence during the structure service-life.
- Safe Shutdown Earthquake (SSE2): the SSE2 is associated with an intense ground motion of extreme severity with an extremely low probability of occurrence during the structure service-life.
- Operating Basis Earthquake (OBE): the OBE is associated with an intense ground motion of extreme severity with a probable occurrence during the structure service-life.

5.3.1 Permanent structures

For permanently (i.e. during Field life duration or at least several years) installed structures and unless otherwise mentioned in the Particular Technical Specifications, the design ground-motion levels shall be associated to the following minimum return periods.

Table 1 - Minimum return-period for seismic design

	Design ground-motion levels		
	OBE	SSE	SSE2
Return Period (years)	475	2475	5000

5.3.2 Temporary structures

For temporary facilities (i.e. for a few years at maximum) and unless otherwise mentioned in the Particular Technical Specifications, the SHA shall be conducted for the design earthquake associated with the two following return periods:

- T1 = 50 years
- T2 = 100 years.



General Specification		GS EP GEO 602
Seismic hazard assessment for onshore structures		
Rev.: 02	Effective date: 11/2019	Page: 8 of 35

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

5.4 Ground classification

The site classification in terms of ground conditions shall be done following the [EN 1998-1](#) (section 5.1), which is summarized in Table 2 here after.

Table 2 - Ground type determination ([EN 1998-1](#))

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	—	—
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with v_s values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with $v_s > 800$ m/s.			
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index ($PI > 40$) and high water content	< 100 (indicative)	—	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1			

The geotechnical data available at time of study will be specified within the Particular Technical Specifications.

General Specification		GS EP GEO 602
Seismic hazard assessment for onshore structures		
Rev.: 02	Effective date: 11/2019	Page: 10 of 35

If no soil data is available at time of study and if no soil data can be found in literature (e.g. geological map), the SHA shall preliminary be done considering the worst case scenario, i.e. in two phases:

- (1) SHA first conducted with an estimated ground type B or C and
- (2) followed by Site response analysis when dedicated geotechnical data are available.

6. Seismic Hazard Assessment

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

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

6.1 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.

6.2 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.



General Specification		GS EP GEO 602
Seismic hazard assessment for onshore structures		
Rev.: 02	Effective date: 11/2019	Page: 11 of 35

The DSHA shall:

- Be conducted for the SSE design ground-motion level and
- 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.