DEP SPECIFICATION

EARTHQUAKE DESIGN FOR ONSHORE FACILITIES – SEISMIC HAZARD ASSESSMENT

DEP 34.00.01.10-Gen.

February 2011

(DEP Circular 93/11 has been incorporated)

(DEP Circular 53/12 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

DEM1

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1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements for seismic hazard quantification and seismic design of onshore facilities.

This DEP covers all steel and concrete structures, storage tanks, refrigerated liquefied gas (RLG) storage tanks. It specifically excludes plant equipment and piping though the philosophy described within this DEP in respect of performance levels can also be applied to them.

The requirements in this DEP are based on European and American best practice. The seismic design of foundations is covered in DEP 34.11.00.12-Gen.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in oil refineries, chemical plants, gas plants, onshore exploration and production facilities and supply/distribution installations. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

Amended per
Circular 53/12
A number of editorial (non-technical) changes have been made throughout this DEP.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

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1.3.2 Abbreviations

ALS	Accident Limit State
DLS	Damage Limitation State
DSHA	Deterministic Seismic Hazard Assessment
EPA	Effective Peak Acceleration
GMPE	Ground Motion Predictive Equation
MCE	Maximum Considered Earthquake

NOTE: In the seismological community an MCE is also referred to as the Maximum Capable Earthquake, which is that largest possible earthquake (see 1.3.2).

OBE	Operating Basis Earthquake
PGA	Peak Ground Acceleration
PGD	Peak Ground Displacement
PGV	Peak Ground Velocity
PSHA	Probabilistic Seismic Hazard Assessment
RLG	Refrigerated Liquefied Gas (storage tanks)
SSE	Safe Shutdown Earthquake
ULS	Ultimate Limit State

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (8).

1.5 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal http://sww.shell.com/standards and on the main page of the DEPs DVD-ROM.

1.6 DUAL UNITS

Amended per

Circular 93/11

Dual units have been incorporated throughout this DEP.

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

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2. GENERAL

2.1 OBJECTIVES

The design of all onshore facilities shall consider earthquake loading in accordance with this DEP.

The extent of work required to determine the seismic design parameters usually depends on the severity of the earthquake ground motion and the potential consequence of the various hazards due to earthquake-induced transient and permanent ground movements.

The object of this DEP is to highlight seismic design requirements in addition to the design requirements outlined in EN 1998 and ASCE 7.

2.2 BACKGROUND DATA

The seismic design activities required to evaluate the level of seismic risks for an LNG Facility appropriate to the IDENTIFY and ASSESS, the SELECT and the DEFINE phases are summarised in the flowchart given in Figure 1.

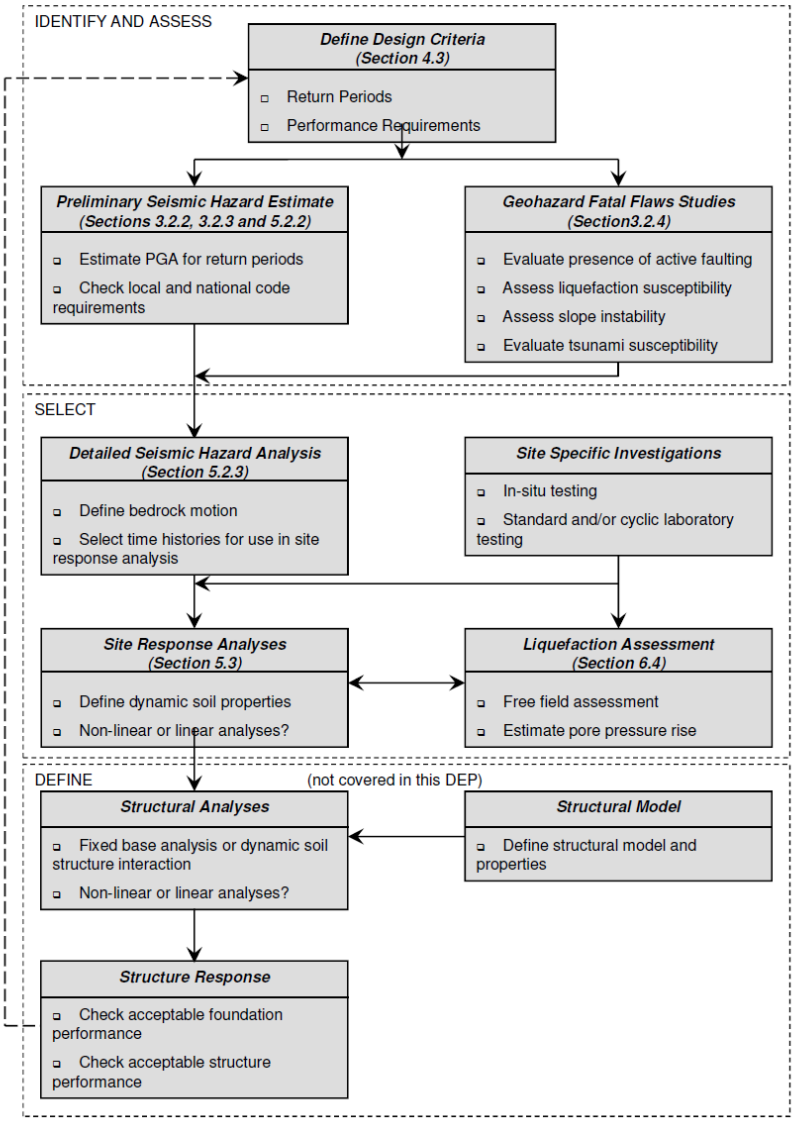

Figure 1 Seismic Design flowchart

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3. SEISMIC DESIGN FOR SHELL PROJECTS

3.1 GENERAL

This section summarises the steps required to define the seismic hazard and seismic performance requirements at both the IDENTIFY and ASSESS phase and the SELECT phase.

3.2 IDENTIFY AND ASSESS PHASE (SCOUTING)

3.2.1 General

The Seismic Design objectives of the IDENTIFY and ASSESS are to:

- Identify the potential seismic hazards;
- Estimate the extent or severity of each hazard;
- Indicate those hazards that are serious fatal flaws, potentially leading to abandonment of the site (see Table 2);
- Identify investigations that are considered necessary to evaluate their impact.

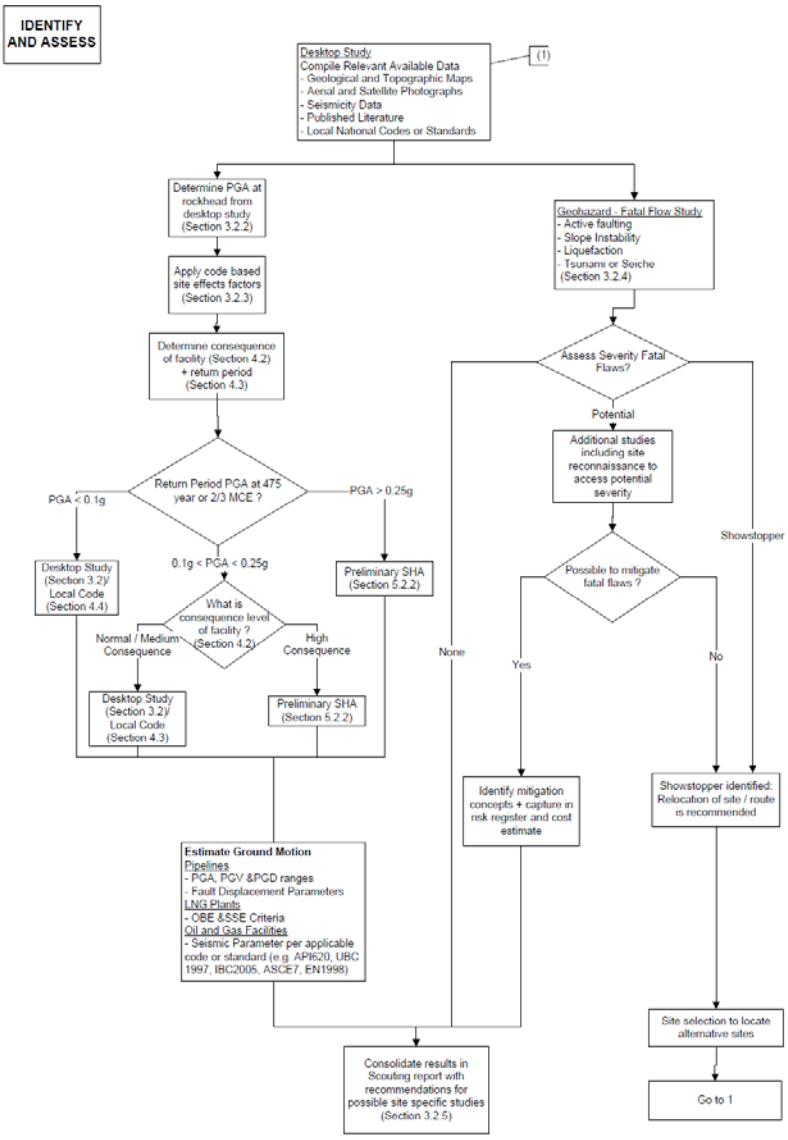

Figure 2 Requirements for the Seismic Hazard Assessment for IDENTIFY and ASSESS Phase

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The flowchart presented in Figure 2 summarises the necessary steps for the IDENTIFY and ASSESS phase. Further details are given in the sections below.

A preliminary seismic hazard assessment shall be carried out in the IDENTIFY and ASSESS phase for all Facilities in highly seismic areas and High Consequence facilities in Areas of Moderate and High Seismicity.

3.2.2 Preliminary assessment of seismic hazard

In the IDENTIFY and ASSESS phase, unless site-specific seismic data are available, a preliminary study to estimate the seismic hazard level shall be carried out through means of a literature review of global, regional and local seismic hazard studies that are published.

The hazard criteria shall be determined for the return period(s) appropriate to the type of facility being assessed. Appropriate return periods are discussed in (Section 4.3).

3.2.3 Preliminary assessment of site effects

The seismic hazard criteria derived for rock conditions shall be amended to account for the overlying soil conditions, as the amplitude of the ground motion is expected to increase as the seismic waves approach the ground surface.

Table 1 shall be used to determine the Ground type when assessing site effects.

Table 1 Soil categories

EN 1998 Ground type	NEHRP Ground Type	Generic Description	Parameters		
			$v_{s,30}$		N_{SPT} (blows/30 cm [ft])
			m/s	*ft/s*	
A	A	Hard Rock	> 1500	> 4900	
	B	Rock	760 to 1500	2500 to 4900	-
B	C	Very Dense Sand or Very Stiff Clay	360 to 760	1180 to 2500	> 50
C	D	Dense Sand or Stiff Clay.	180 to 360	590 to 1180	15 to 50
D	E	Loose to Medium dense sand or Soft to Firm Clay.	< 180	< 590	< 15
E	N/A[(a)]	5 m to 20 m (16 ft to 65 ft) EN 1998 Type C or D soils overlaying rock	-		-
S_1[(b)]	F [(b)]	Soft Clay or Silt with High Plasticity Index and Water Content	< 100 (indicative)	< 330 (indicative)	-
S_2[(b)]		Liquefiable Soils or Sensitive Clays	-		-

(a) Not considered in NEHRP soil categories

(b) Requires site-specific evaluation

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Potential errors in assessing site effects

Due to the contradiction between the code amplification values the following procedure should be considered during the Identify and Assess phase:

- The spectral shape shall be modified using the NEHRP amplification factors for soil classes A to E (according to NEHRP) or soil classes A to D (according to EN 1998).
- Where shallow (5-20 m [16-65 ft]) soil layers exist over rock (i.e. soil class E according to EN 1998), the effect of the EN 1998 amplification factor shall be considered.
- For special soil classes S_1 or S_2 (according to EN 1998) or soil class F (according to NEHRP) further analyses are required as described in Section 5.3.

The resulting response spectrum shall also be checked against local code requirements.

3.2.4 Preliminary assessment of geo-hazards

3.2.4.1 Fatal flaw identification and assessment

The potential geo-hazard issues to be addressed in the fatal flaw evaluations are listed below:

Table 2 Potential fatal flaw issues during Identify and Assess phase

Hazard	Potential issues
Active fault at the site see (Section 6.2)	Significant fault-rupture displacement at ground surface
Slope instability – see (Section 6.3)	Movement of portion of slope underneath facility or pipeline, or movement of slide mass into facility or pipeline
Liquefaction potential – see (Section 6.4)	Significant permanent ground displacement due to lateral spreading or flow failure, foundation settlement, floatation or toppling
Tsunamis/Seiches – see (Section 6.5)	Flooding of site or inertial impact of water waves and debris

NOTE: A fatal flaw is considered to be any hazard that would affect the economic viability of a proposed facility.

Each of the four potential hazards in Table 2 shall be addressed regardless of the site location. During the initial work, the hazards will be designated as low, moderate, or high with a description of the hazard, its location or extent, and some discussion of possible impacts and mitigation concepts, if feasible.

NOTE: The completeness of this exercise will depend on the quality and quantity of available information.

The terms, low, moderate or high, refer to the severity of the hazard or its likelihood of being present and affecting the siting or design. This qualitative assessment should be verified by a suitably qualified expert. The assessment of each of these issues is discussed in more detail in (Section 6).

If a hazard listed in Table 2 is identified, then a limited site reconnaissance may be necessary to delineate its potential severity before concluding whether or not it is a fatal flaw. This site reconnaissance shall be focused based on the results of the data collection studies and in particular the satellite imagery.

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NOTE: This should be part of a larger geo-hazard desk study consisting of, but not limited to, the following hazards; flooding; kaarst topography; loess and collapsible/ sensitive soils; old mine workings; dune migration; landslide and rockfall; volcanism and lahar etc (Refer Section 5 of DEP 34.11.00.10-Gen).

If there is limited or no information for the proposed site, then this shall be considered a potential fatal flaw**.** This shall be mitigated by a site reconnaissance and data gathering mission to ensure sufficient data is obtained so that an appropriate assessment can be made.

3.2.4.2 Mitigation strategy

A risk matrix shall be developed containing all possible geohazards, their likelihood of occurrence, proposed mitigation stategy and recommendations for further work. Key risks shall be identified in the project risk register.

Where hazards exist appropriate geohazard mitigation strategies shall be identified to proceed further beyond the identification phase. If mitigation is potentially feasible and economical, then from a seismic standpoint, the project may proceed and more detailed investigations performed to provide the input data for the design.

Mitigation strategies shall include the following:

- Identification of possible triggering scenarios, the associated hazard levels and return periods.
- Analysis of possible consequences for the different scenarios.
- Assessment of possible measures to reduce and/or eliminate the potential consequences of the hazard.
- Recommendation of specific remedial measures and if relevant reconstruction and rehabilitation plans.

Mitigation strategies need to be adapted for different natural hazards and different parts of the world.

3.2.5 Scouting report

The Scouting Report shall compile together the results of the IDENTIFY and ASSESS phase which shall include the following information (Section 4):

1. Seismic Code(s) to be used for the design. This will depend on a number of factors that include:
    - Type of plant being developed
    - Local building code requirements
    - Relevant national and international codes
2. The appropriate return periods for design (Section 4.3). They will depend on:
    a) The type of structure
    b) Consequences of any potential failure
    c) The hazardous nature of any materials contained
    d) The local code requirements
    e) The recommended return periods for Shell facilities.
3. The ground-motion criteria which have been assessed from the desk study/site-specific studies:

    <u>LNG Facilities</u>

    - OBE and SSE Criteria

    <u>Pipelines</u>

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- Peak ground acceleration (PGA), peak ground velocity (PGV) and Peak Ground Displacement (PGD).
- Permanent ground Displacement and fault displacement.

Oil and Gas Facilities

- Design response spectra for various damping ratios.
- Seismic Parameter per Applicable Code or Standard.

4. Geo-hazard Issues
   - Geo-hazards identified during the Identify and Assess phase and the mitigation strategy.
   - The location of known active and potentially active faults and fault systems.
   - Recommendations for Further Studies.

The SELECT phase should only proceed if:

- No fatal flaws are identified during the IDENTIFY and ASSESS phase.
- Mitigation measures are available to offset all identified potential flaws. Refer Section 3.2.4 for discussion on mitigation strategy for geo-hazards.

3.3 SELECT PHASE

3.3.1 General

The Seismic Design objectives of the SELECT phase are to:

a) Evaluate the potential geohazards at the location of the proposed facility or routing and select the preferred mitigation option (Chapter 6).

b) Determine ground-motion criteria from site-specific studies as required by Table 8.

c) Define seismic performance requirements.

d) Develop seismic response spectra for design.

e) Define Codes and Standards to be used for Design.

Site-specific seismic studies are nearly always required for high hazard facilities (as defined in Table 3). For less critical facilities located in areas of low seismic hazard the risks of ground-motion and ground-failure effects will be smaller. In such cases, where national codes or standards are available that clearly define the seismic ground motion, site-specific seismic studies may not be warranted.

The requirements for the SELECT phase of the Seismic Hazard Assessment are summarised in Figure 3.

3.4 DEFINE PHASE

The following information should be included in the BDP Document:

- Definition of Seismic Performance Requirements (Chapter 4);
- Ground-motion criteria which have been assessed from the desk study/site-specific studies:

  LNG Facilities

  - OBE and SSE Criteria and Return Period;
  - Seismic Response Spectra for Design (Chapter 5) determined from detailed seismic hazard assessment.

  Pipelines

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- Peak ground acceleration (PGA), peak ground velocity (PGV) and Peak Ground Displacement (PGD);
- Permanent ground Displacement and fault displacement.

Oil and Gas Facilities

- Design response spectra for various damping ratios;
- Seismic Parameter per Applicable Code or Standard.

- Seismic Response Spectra for Design (Chapter 5) determined from code based requirements, preliminary seismic hazard assessment or detailed seismic hazard assessment (Table 8);
- List of Codes and Standards to be used for Design (Chapter 4);
- Detailed Geohazard Report of the Facility Location or Pipeline Routing identifying potential geohazards and the preferred mitigation (Chapter 6).

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