APPENDIX 5D

Seismic Design of SD2 Platforms and Onshore Facilities

1. SDB Platforms Seismic Loads and Seismic Design Criteria

1.1 Design Criteria

The seismic design will be carried out in accordance with the recommendations of ISO 19901-2. Draft ETP GP 66-02 will also be consulted for guidance.

The ISO guidelines for seismic design are based on a two level design check following the concept of balanced strength and ductility. An Extreme Level Earthquake (ELE) is used to demonstrate sufficient component strength without damage and an Abnormal Level Earthquake (ALE) is used to demonstrate sufficient system capacity with possible component damage. The ALE spectral accelerations are determined from the site-specific hazard curve for the ISO target annual probability of failure. The ELE spectral acceleration is estimated from the ALE based on the platform system ductility. For a balanced design the ELE analysis provides assurance that the design will meet the ALE performance requirements.

In addition to the two levels specified in ISO, a third return period of seismic activity will be considered as an additional risk reduction assessment with aim of meeting the intent of draft GP 66-02.

1.2 Design Seismic Conditions

The design seismic conditions cover the following seismic events:

- Firstly, the offshore platforms are designed against an earthquake that has a relatively low likelihood of occurrence during the life of the platform, referred to as the ELE. Structures are expected to sustain little or no damage and economic viability should be ensured. This is interpreted to mean that the facilities can be placed in a safe state, structural capacity will be unaffected, hydrocarbon containment shall be ensured and production systems can be re-started after the earthquake. The return period of ELE is 240 years.

- Secondly, the offshore platforms are checked against a rare earthquake that has a very low likelihood of occurrence during the platform life. This event is referred to as ALE. The platforms can sustain local damage; however, it should not collapse or have high Health, Safety or Environmental consequences. Command and control functions are to be maintained to ensure the facilities can be placed in a defined safe-state, platform collapse through direct or secondary fire effects will be avoided, Temporary Refuge (TR) will remain available and orderly evacuation accomplished. The return period of ALE is 3,400 years.

- Finally, performance of the platforms in terms of global and local response to a 10,000 year return period earthquake is assessed in accordance with draft GP 66-02. Structure should not suffer complete loss of integrity for sufficient time to enable emergency evacuation. Global collapse of the platform is not permitted, although local damage, such as member buckling is allowed. Hinging of piles must be limited and structures supporting safety critical deck systems, such as the living quarters, must remain intact. Damage at critical load transfer points, such as skirt pile to jacket framing and top of jacket to deck leg connections should be limited.

1.3 Seismic Analysis

Seismic criteria were developed based on a site-specific probabilistic seismic hazard analysis (PSHA) performed by EQE International and a non-linear site response analysis performed by a specialist consultant (D'Appolonia). These site-specific ELE, ALE and extrapolated 10,000-yr seismic loads (spectral accelerations and time history data from seven suitable earthquakes) have been quality checked by the BP UEC subject matter expert and independently verified by a competent third party (Energo).

The effects of soil liquefaction on ground motions have been included in the time histories provided. The accelerations traces supplied by D'Appolonia have been baseline corrected for liquefied behaviour by KBR prior to use in structural analyses. The analysis will be carried out in accordance with the seismic loading as defined in ISO 19902.

Table 1 and Figure 1 below present the ELE, ALE and 10,000-year horizontal acceleration spectra at mudline. Following ISO recommendations, the vertical spectral accelerations may be taken as 50% of the horizontal value.

Table 1. 5% Damped Horizontal ELE, ALE & 10,000yr Design Spectra at Mudline

		Horizontal Spectral Acceleration (g)		
Frequency (Hz)	**Period (Sec)**	**ELE**	**ALE**	**10,000yr**
PGA	PGA	0.116	0.155	0.159
20	0.050	0.161	0.219	0.215
13.33	0.08	0.208	0.250	0.278
10	0.10	0.236	0.298	0.310
6.67	0.15	0.308	0.364	0.390
5	0.2	0.329	0.360	0.387
3.33	0.3	0.348	0.369	0.388
2	0.5	0.314	0.439	0.479
1.33	0.75	0.247	0.510	0.514
1	1.0	0.231	0.436	0.508
0.67	1.5	0.145	0.356	0.429
0.5	2.0	0.131	0.298	0.398
0.33	3.0	0.094	0.250	0.321
0.25	4.0	0.048	0.170	0.284
0.10	10.0	0.004	0.023	0.057

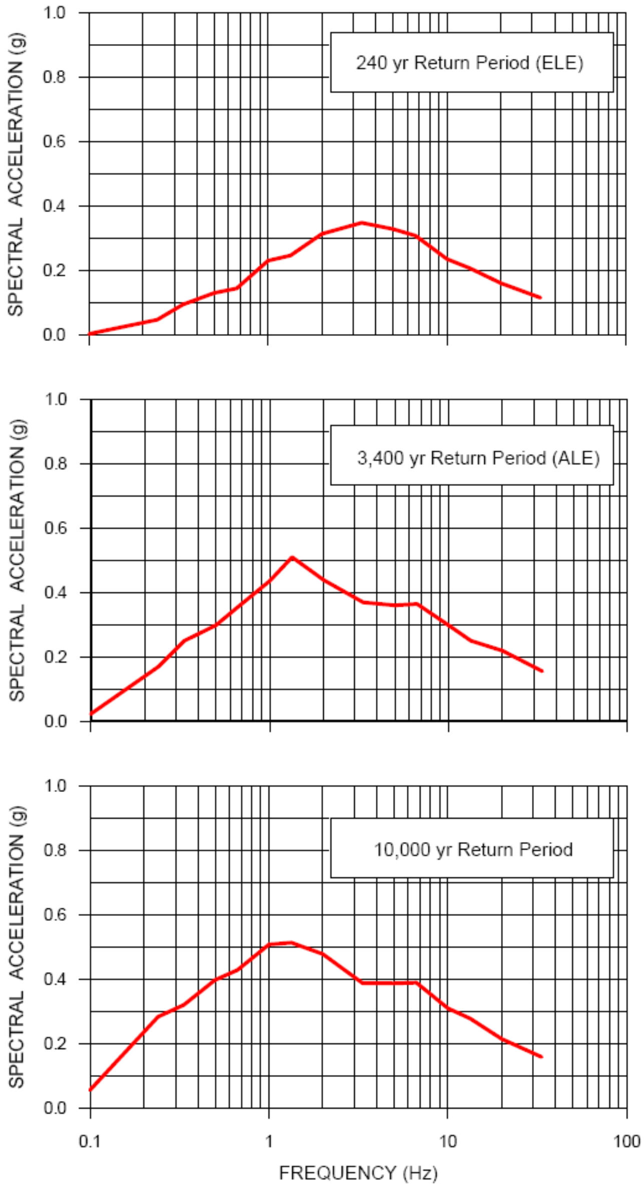

Figure 1. SDB Platform Location - Mudline Response Spectra

2. Onshore Facilities Seismic Loads and Seismic Design Criteria

2.1 Design Criteria

The seismic design and seismic design criteria shall be in accordance with ASCE 7-10.

2.2 Design Seismic Conditions

The Onshore safety Philosophy identifies the following seismic design requirements:

- All facilities to be fully functional after a 475-year return period event (Design Earthquake: DE),
- Essential Facilities shall provide containment of significant hydrocarbon inventories, ensure safe plant shutdown and facilitate emergency response after a 2,475-year event (Maximum Considered Earthquake: MCE), and,
- Critical Facilities shall achieve containment of the incoming pipeline inventories and large hydrocarbon storage tanks, avoid immediate collapse of manned buildings during a 10,000-year event and after it for a time commensurate with emergency response actions (Extreme Earthquake: EE).

2.3 Seismic Analysis

Sangachal Terminal specific seismic DE, MCE and EE design criteria have been developed by a specialist consultant (Arup) in accordance with ASCE 7-10 and best international practice. Figures 2 and 3 below show horizontal acceleration response spectra corresponding to the 475-year (DE), 2475-year (MCE), and 10000-year (EE) return period events at the Sangachal Terminal site.

Due to the collapsible nature of the existing soils at Sangachal Terminal when saturated, response spectra were developed based upon dry and wet soil conditions for the DE and MCE events, and upon dry soil conditions for the EE event.

Figure 2 – Surface Response Spectra for DE and MCE (Dry Soils)

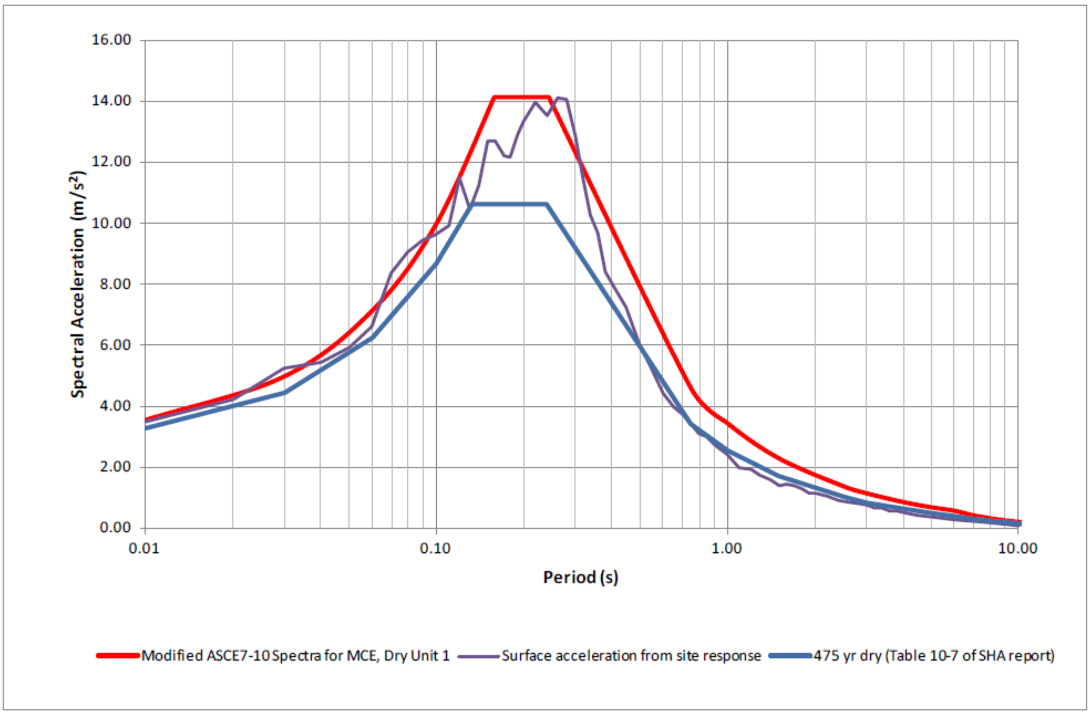

Figure 3 – Surface Response Spectra for EE (Dry Soils)