RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

07/08/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 939-6334 REVISION 3**
SRP SECTION:	**03.07.01 – Seismic Design Parameters**
APPLICATION SECTION:	**3.7.1**
DATE OF RAI ISSUE:	**06/12/2012**

QUESTION NO. 03.07.01-38:

In its response to RAI 850-6002, Question 03.07.01-28, the applicant states, in part, that "The vertical CSDRS (Figure 5.2-4) reflects extremely conservative levels of motion and is inconsistent with current observations as well as the community understanding of strong ground motions."

The staff finds that there is evidence that the influence of high water table level, as well as the degree of ground saturation, can have very significant influence on the seismic response, especially in the higher frequencies. For example, in Yang and Sato (2000 a,b), the authors point out that, in measurement in a borehole array during the 1995 Hyogo-ken Nanbu (Kyoto) earthquake, "the vertical motions were greatly amplified at the surface, with peak value of 556 cm/sec^2, which was about 1.5 to 2.0 times larger than the horizontal components." Further, in that same paper, the authors state that "Vertical component motions may be significantly affected by the pore-water saturation of shallow soil layers, suggesting that we may need to carefully examine the condition of saturation in the study of vertical site amplification." These papers indicate that the water table at the grade level with the soil fully saturated may not be the critical case concerning the vertical motions.

The applicant is requested to clarify and confirm that for the soil profiles considered in the US-APWR standard design, the effects on the vertical seismic response component resulting from varying levels of the groundwater, including the degree of groundwater saturation, have been explicitly considered in the design basis seismic analysis. In particular, the applicant is requested to confirm that these effects will not result in significant increase of the vertical component of ground shaking, and that the US-APWR design remains conservative.

References:

Yang, J. and T. Sato (2000a),"Interpretation of Seismic Vertical Amplification Observed at an Array Site," Bulletin of the Seismological Society of America, 90, 2, p. 275-286.

Yang, J. and T. Sato (2000b), "Effects of Pore-water Saturation on Seismic Reflection and Transmission from a Boundary of Porous Soils," Bulletin of the Seismological Society of America, 90, 5, p. 1313-1317.

ANSWER:

The cited statement from MHI response to RAI 850-6002, Question 03.07.01-28 was concluded based on the condition that “The horizontal CSDRS in spectral shape represents a Magnitude M of about 7.5 and, in terms of absolute levels, reflects (source) distances exceeding 50 km”. For these conditions vertical motions are expected to be significantly lower than the horizontal motions at all frequencies and the vertical certified seismic design response spectra (CSDRS) using Regulatory Guide RG 1.60 V/H ratios are conservative.

It has been observed that vertical motions can exceed horizontal motions at short period and near-source distance. At very close distances (≤ 15 km) for large magnitude (M ≥ 5) earthquakes, high-frequency (≥ 10 Hz) 5% damped response spectra of the vertical motions are expected to exceed horizontal motions, at soft rock and soil sites with V/H ratios (vertical over horizontal component ratio) exceeding one (References 1, 2, 3 and 4). The exceedence is due to the dominance of compressional-waves over shear-waves for vertical components at high-frequencies, resulting from converted shear-waves (≥ 10 Hz) (Reference 1 and 3). The exceedence of the vertical component over the horizontal component is larger for soils due to the nonlinear site response in the horizontal direction, decreasing the high-frequency spectral levels (Reference 2 and 5). For vertical components, any nonlinear effect at high-frequency in unsaturated soils would involve the constrained modulus with associated dilatational strains. The dilatational strains would be lower than any shear-strains at similar loading levels due to the much higher compressional-wave velocity, reducing the potential for non-linear effects to reduce high-frequency vertical motions. For saturated soils, the constrained modulus remains largely linear as the bulk modulus is controlled by the fluids. As a result, for both saturated and unsaturated soils, at close distances, vertical motions are expected to exceed horizontal motions at high-frequency. For distances exceeding approximately 15 km, high-frequency vertical motions are expected to be lower than corresponding motions by a significant amount that depends on frequency (References 1, 2 and 4).

The Yang, J. and T. Sato paper referenced in the RAI question reported the strong ground motions that were recorded at Port Island , Kobe, by a borehole array during the 1995 Hygogo-ken Nanbu (Kobe) earthquake. The distance from the borehole site to the source is less than 15 km. The CSDRS design spectra are not intended to reflect near-source conditions. The design spectra are appropriate for a majority of site locations across the US not sited adjacent to large magnitude active sources. Furthermore, as reported in the Yang, J. and T. Sato paper (2000a), the soil profile at the borehole site consists of a twenty meter thick reclaimed sandy gravel surface layer. The shear wave velocity of the top eighty meter soils varies from 170 m/sec to 320 m/sec. The average shear wave velocity of the soils over the top thirty meter is approximately 195 m/sec or 640 ft/sec. The US-APWR Standard Plant design does not consider such soils with low strength and high susceptibility to liquefaction as supporting media of the structures. The US-APWR Standard Plant design considers the ground water table as being one foot below plant finished grade. Accordingly, the six generic soil profiles were developed to represent fully saturated soil conditions and site independent design basis soil-structure interaction (SSI) analyses were performed for the standard plant structures. In order to assess the effects of water table fluctuations, SSI sensitivity analyses were performed on the reactor building (R/B) complex structure for soil profiles that are developed to represent unsaturated soil conditions. The water table effects on seismic response of the Standard Plant structures were determined by comparing the structural responses for two set of bounding subgrade soil cases (i.e., fully saturated soils, which serves as design-basis vs. unsaturated soils) on which SSI sensitivity analyses were performed. Technical Report MUAP-10006, Rev. 3 documents site independent design basis SSI analyses for standard plant structures, and Technical Report MUAP-11007, Rev. 2

presents the sensitivity study of water table fluctuation effect. The two reports provide detailed information regarding development of saturated and unsaturated soil profiles and the corresponding SSI analysis.

References:

1) Silva, W. J., "Characteristics of Vertical Strong Ground Motions for Applications to Engineering Design," Proc. of the FHWA/NCEER Workshop on the Nat'l Rep. of Seismic Ground Motion for New and Existing Highway Facilities, Technical Report NCEER 97 0010, 1997.

2) Abrahamson, N. A and Shedlock, K. M., "Overview." Seismic Research Lett., 68(1), 9 23, 1997.

3) Beresnev, I. A,, Nightengale, A. M., and Silva, W. J., “Properties of Vertical Ground Motions.” Bull. Seism. Soc. Am., 92(2), 3152-3164, 2002.

4) Campbell, K. W., and Bozorgnia, Y., “Updated Near-Source Ground-Motion (Attenuation) Relations for the Horizontal and Vertical Components of Peak Ground Acceleration and Acceleration Response Spectra,” Bull. Seismic Soc. Am., 93(1), 314-331, 2003.

5) Power, M., Chiou, B., Abrahamson, N., Bozorgnia, Y., Shantz, T., and Roblee, C., “An Overview of the NGA Project,” Earthquake Spectra, 24(1), 3-21, 2008.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on the Technical Reports.

This completes MHI’s response to the NRC’s question.