## RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**1/31/2013**

**US-APWR Design Certification**

**Mitsubishi Heavy Industries**

**Docket No. 52-021**

| | |
|---|---|
| **RAI NO.:** | **NO. 850-6002 REVISION 3** |
| **SRP SECTION:** | **03.07.01 – Seismic Design Parameters** |
| **APPLICATION SECTION:** | **3.7.1** |
| **DATE OF RAI ISSUE:** | **10/21/11** |

---

**QUESTION NO. RAI 03.07.01-28:**

In Section 5.2.1 of MUAP-10001(R3), "Site Response Analysis," the last sentence in the 2nd paragraph (Page 5-16) states, "For applications to sites with a water table at or very near the surface, linearity of the constrained modulus is also a realistic assumption as compressional waves control the high-frequencies in vertical motions (Refer to "Properties of Vertical Ground Motions," Reference 19), where nonlinearity has its largest effect."

The applicant is requested to explain whether the assumption of linearity of the constrained modulus is still realistic for applications to sites with a water table at or near the bottom of the R/B basemat (or even lower), and to provide the basis and technical justification for the assumption. If the assumption is not realistic then the applicant is requested to describe the anticipated behavior of the modulus for these water table conditions. Additionally, the applicant is requested to provide the details of the sensitivity of the water table location to demonstrate that the seismic SSI response of the standard plant SSCs is enveloped for all potential water table locations.

This information is required by the staff in order to assess the effects of the location of the water table on the seismic SSI response of the SSCs.

---

**ANSWER:**

This answer revises and replaces the previous MHI answer that was transmitted by letter UAP-HF-11417 (ML11339A013). Technical Report MUAP-10001, Rev. 3 has been superseded and the relevant content incorporated into Technical Report MUAP-10006, Rev. 3.

This RAI question is related to the subject of Technical Report MUAP-11007, Rev. 2, which addresses soil-structure interaction (SSI) sensitivity to variations in the ground water for the US-APWR standard plant. Technical Report MUAP-11007, Rev. 2 considers profiles denoted as 270-200Dry and 270-500Dry that represent soil sites with a nominal $V_s$ of 270 m/s over the top 30 meters (see Section 01.4.2 of Technical Report MUAP-10006, Rev. 3, for a description of this nomenclature), a groundwater level at 200 ft below plant grade, and an overburden depth of 200 ft and 500 ft, respectively. The 560-500Dry profile also considered represents a generic soil site with a nominal $V_s$ of 560 m/s over the top 30 meters, a groundwater level at 100 ft below plant grade, and an overburden depth of 500 ft. The SSI analyses of unsaturated soil conditionsin

Technical Report MUAP-11007, Rev. 2, produced some instances and locations where the in-structure response spectra (ISRS) and base reaction results are not enveloped by the SSI results corresponding to the saturated soil conditions. Technical Report MUAP-11007, Rev. 2, concludes that the effects of groundwater level variation on the seismic design basis response for the R/B complex are minor and that the use of saturated soil profiles will result in a standard plant design that envelops the seismic demands at a majority of candidate sites within the central and eastern United States (CEUS).

The constrained modulus defines the soil resistance against deformation and depends on both states of relative stress as well as the magnitude of stress in the primary vertical direction of loading. At soil sites, nonlinearity of the constrained modulus for unsaturated conditions may require special consideration due to low compressional-wave velocity, where vertical motions are controlled by compressional-waves at higher-frequency (≥ 10 Hz, Beresnev et al., 2002, Reference 1; Silva, 1997, Reference 3). However, as Technical Report MUAP-10006, Rev.3, Section 01.5.2.1, and (Abrahamson and Silva (1997), Reference 2) illustrate, vertical motions are significantly below the corresponding horizontal motions at all frequencies when the source is beyond about 50 km. At close rupture distances and large magnitude, high-frequency vertical motions can exceed the horizontal motions by a significant degree (Silva, 1997, Reference 3).

Even in these cases any nonlinearity of the constrained modulus would be dependent on the dilation due to inclined compressional-waves. Because the compressional-wave velocity is typically much greater than the shear-wave velocity, the resulting dilation would be small along with any change in constrained moduli.

As a result, the assumption of linearity (effective) for the constrained modulus in unsaturated soils reflects a realistic assumption for the levels of horizontal motion of the certified seismic design response spectra (CSDRS) shown in Figure 3-1 of Technical Report MUAP-11007, Rev. 2. That is, the horizontal CSDRS in spectral shape represents a magnitude M of about 7.5 and, in terms of absolute levels, reflects distances exceeding 50 km (Section 01.5.2.1 of Technical Report MUAP-10006, Rev. 3). For these conditions vertical motions are expected to be much lower (Technical Report MUAP-10006, Rev. 3, Section 01.5.2.1) than horizontal motions at all frequencies and remain linear in constrained modulus.

Therefore, the assumption of linearity of the constrained modulus is realistic for applications to sites with a water table at or near the bottom of the reactor building (R/B) complex basemat. For site specific conditions where water table elevations are even lower than the bottom of the R/B basemat, per COL Item 3.7 (25) the COL Applicant will perform confirmation SSI analyses of the standard plant structures to consider the site specific profile conditions including the effects of the water table elevation.

References:


1) Properties of vertical ground motions, Bulletin of the Seismological Society of America, 92(2), pages 3152-3164, Beresnev, I.A, Nightengale, A.M. Silva, W.J., 2002.
2) Empirical Response Spectral Attenuation Relations for Shallow Crustal Earthquakes, Seismological Research Letter, 68(1), pages 94-127, Abrahamson, N.A. and Silva, W.J., 1997.
3) Characteristics of Vertical Strong Ground Motions for Applications to Engineering Design, NCEER-97-0010, Proceedings of the FHWA/NCEER Workshop on the National Representation of Seismic Ground Motion for New and Existing Highway Facilities, I.M. Friedland, M.S Power and R. L. Mayes eds., Silva, W.J., 1997.


**Impact on DCD**

There is no impact on the DCD

**Impact on R-COLA**

There is no impact on the R-COLA.

**Impact on S-COLA**

There is no impact on the S-COLA.

**Impact on PRA**

There is no impact on the PRA.

**Impact on Technical/Topical Report**

There is no impact on a Technical/Topical Report.

---

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