## 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 03.07.01-30:**

In Subsection 5.2.2 of MUAP-10001(R3), "Strain Compatible Properties," the paragraph (Page 5-21) states, "For the eight combinations of profile categories and depths to hard or soft rock material (Table 5.2-1) strain compatible properties are developed reflecting median (best estimate) and ±1σ (upper and lower range) estimates over the thirty (30) realizations of profiles and G/Gmax and hysteretic damping curves (Section 4.2.2). The strain compatible properties are summarized in Tables 5.2-4 to 5.2-11, with Figures 5.2-6 to 5.2-14 showing the median and ±1σ_ estimates for the shear and compressional wave velocities and associated damping."

The applicant is requested to provide information that addresses the following:

1. Per Regulatory Guide 1.208, subsection 4.2 of Part C. Regulatory Position (Page 17 of RG 1.208), at least 60 convolution analyses should be performed to define the mean and the standard deviation of the site response. However, in the above quoted paragraph from the Report, only 30 were used. The applicant is requested to provide numerical data to justify that the mean and the standard deviation of the site response are stabilized after 30 simulations.

2. The applicant is requested to provide information for the computer code used in this study. Since the damping curves presented in Figure 4.2-2 are for shear strains, the applicant is requested to provide information on how the hysteretic damping for compression waves is calculated.

3. In Tables 5.2-4 through 5.2-11 of MUAP-10001 (R3), separate damping values are provided for shear waves and compression waves. However, in Tables 3-3A through 3-3H of MUAP-10006 (R1), the same damping is used for both compression waves and shear waves, which appear to be the damping ratios associated with shear waves in Tables 5.2-4 through 5.2-11 of MUAP- 10001 (R3). The applicant is requested to provide the basis and justification for assuming that the compression wave damping is the same as shear wave damping, especially when applied to the saturated soil that is assumed to be at the elevation of plant grade according to Subsection 4.2.1 of MUAP-10001 (R3).

4. Normally shear wave and compression wave speeds in elastic media are related by and are consistent with the Poisson's ratios for the media. In the case of saturated soil, the applicant has used the approach of enforcing a minimum compression wave speed of approximately 5,000 feet/second as evidenced by Tables 5.2-4 through 5.2-11 of MUAP-10001 (R3) and the note to Figure 5.2-1 of MUAP-10001 (R3). The applicant is requested to discuss whether this enforcement of the compression wave speed in saturated soil leads to inconsistencies in the relationships between the shear wave speeds, the compression wave speeds, and the Poisson's ratios. If it does result in inconsistencies, the applicant is requested to provide the basis and technical justification for the validity of the approach.

---

**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 information incorporated into Technical Report MUAP-10006, Rev. 3.

1. In Appendix 1-A of MUAP-10006, Rev. 3, MHI has provided detailed information that supports the use of 30 realizations for development of strain compatible properties of generic profiles.

2. The RASCAL computer code used for site response analyses described in Section 01.4.2.2 of MUAP-10006, Rev. 3 is described in Section 6.B.3.2 of EPRI Report TR-102293, Vol. 2 (Reference 1). The RASCAL code accounts for the non-linear response of the soil by implementing the equivalent-linear formulation (Seed and Idriss, Reference 2) to one-dimensional site response analysis. The RASCAL code provides a frequency domain solution for the site response problem by propagating the point-source outcrop power spectral density through a one-dimensional soil column. The random vibration theory is used to predict peak shear strains based upon the power spectrum defined controlled motion. In this sense, the procedure is analogous to the program SHAKE (Reference 3) except that peak shear strains in SHAKE are calculated using acceleration time history as input control motion. In the random vibration theory approach, the estimates of peak shear strain are fundamentally probabilistic in nature. The random vibration theory equivalent-linear methodology for one dimensional wave propagation site response analyses was validated in References 1 and 4.

   Figure 4.2-2 of Technical Report MUAP-10001, Rev. 3 has been replaced by Figure 01.4.2-2 of Technical Report MUAP-10006, Rev. 3 that shows the EPRI soil degradation curves used as input for the horizontal shear wave site response analyses. The soil strain compatible hysteretic damping for shear waves are obtained from the results of the equivalent linear horizontal site response analyses. The vertical site response motions are computed in Section 01.5.2.1 of Technical Report MUAP-10006, Rev. 3 from linear site response analyses with hysteretic damping for compression-waves taken as equal to the shear-wave low-strain damping (Johnson and Silva, 1981, Reference 4).

   References:

   1) "Guidelines for Determining Design Basis Ground Motions," TR-102293, Electric Power Research Institute, Palo Alto, CA, 1993.
      - Vol.1: "Methodology and Guidelines for Estimating Earthquake Ground Motion in Eastern North America"

- Vol. 2: “Appendices for Ground Motion Estimation”
- Vol. 3: “Appendices for Field Investigations”
- Vol. 4: “Appendices for Laboratory Investigations”
- Vol. 5: “Quantification of Seismic Source Effects”


2) Seed, H. B., and Idriss, I., M., "Influence of Soil Conditions on Ground Motions During Earthquakes," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 95, No. SM1, pp. 99-138, 1969.

3) Schnabel B., Lysmer, J., and Seed, H. B., SHAKE, "A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites," Report No. EERC 72-12, College of Engineering University of California, Berkeley, CA, 1972.

4) Johnson, L.R., and Silva, W., "The Effects of Unconsolidated Sediments Upon the Ground Motion During Local Earthquakes," Bull. Seism. Soc. Am., 71, pp. 127-142, 1981.


3. The strain compatible soil properties listed in Tables 5.2-4 through 5.2-11 of Technical Report MUAP-10001, Rev. 3 have been updated. Tables 01.5.2.2-1 through 01.5.2.2-6 of Technical Report MUAP-10006, Rev. 3 present the strain compatible soil properties obtained from the revised set of site response analyses. The soil properties used as input for the revised set of soil-structure interaction (SSI) analyses of the reactor building (R/B) complex are listed in Tables 03.3.1-1 through 03.3.1-6 of Technical Report MUAP-10006. The SSI analyses use the median values of shear wave damping calculated from the site response analyses for both shear and compression-wave damping in order to account in a more realistic manner for the dissipation of energy in the soil under the wave propagation pattern present in the SSI model. Section 01.5.2.2 of Technical Report MUAP-10006, describes the basis and justification for using the same compression wave damping as shear wave damping.

4. Tables 5.2-4 through 5.2-11 of Technical Report MUAP-10001, Rev. 3 have been replaced by Tables 01.5.2.2-1 through 01.5.2.2-6 of Technical Report MUAP-10006, Rev. 3. Section 01.4.2.1 of Technical Report MUAP-10006, Rev. 3 describes the methodology used for development of generic soil profiles for US-APWR standard design. Section 2.3 of Technical Report MUAP-11007, Rev. 2, describes in more detail the approach used to account for the effect of the ground water on the dynamic soil properties. The compression wave velocity the $V_p$ of the saturated soil in the design basis soil profiles are developed by:

    a. Setting the value of $V_p$ at or above 5,000 ft/s, which is the $V_p$ of water.

    b. Maintaining $V_p$ gradient that is considered realistic for saturated soil sites based on a database of measured $V_p$.

    c. Smoothing the resulting $V_p$ profile.

    This approach resulted in a more realistic representation of saturated site conditions than setting a profile of 5,000 ft/s. Figures 3-3 and 3-5 of Technical Report MUAP-11007 present the soil compression wave velocity and Poisson’s ratio profiles, respectively, for both saturated and unsaturated conditions. The plots show that the design basis saturated soil profiles are realistic reflecting measurements taken at sites with high groundwater level. Figure 3-5 of Technical Report MUAP-11007 indicates that the Poisson’s ratios of the softer strata of saturated soil approach values close to 0.48. This value is low enough not to compromise the numerical stability of the SASSI results.

**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 the Technical/Topical Report.

---

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