
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

1/31/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.: NO. 659-5133 REVISION 2
SRP SECTION: 03.07.01 – Seismic Design Parameters
APPLICATION SECTION: 3.7.1
DATE OF RAI ISSUE: 11/15/10

QUESTION NO. RAI 03.07.01-11 (03.07.01-17):

This request for additional information (RAI) is necessary for the staff to determine if the application meets the requirements of 10 CFR Part 50, Appendix A, General Design Criteria 2; 10 CFR Part 50 Appendix S; and 10 CFR Part 100; as well as the guidance in NUREG-0800, 'Standard Review Plan for the Review of Safety Analysis for Nuclear Power Plants,' Chapter 3.7.1, "Seismic Design Parameters."

Section 3.2 of MHI's Topical Report, MUAP-10006 (R0), addresses site conditions and states that Tables 3-3A through 3-3H present the input material properties of the subgrade. However, the basis for the values in these tables is not discussed. In order to conduct a technical evaluation of the supporting media used for the seismic analysis, the staff requests that the applicant provide the following information:

1. The origin of the information in the tables
2. A description of how and to what extent the information does or does not relate to the data shown in Tables 5.2-3 through 5.2-11 of MUAP-10001 (R1)
3. A statement as to whether the properties shown are low-strain or strain-iterated properties
4. If the properties are strain-iterated properties, a description of which time histories (i.e. horizontal H1, horizontal H2, vertical, or some combination) were used to generate the properties
5. A description of how the compressional wave speeds and damping used in the vertical seismic analysis were developed.

ANSWER:

This answer revises and replaces the previous MHI answer that was transmitted by letter UAP-HF-11186 of (ML11178A071).

Technical Report MUAP-10001 is superseded and the relevant information has been incorporated into Technical Report MUAP-10006, Rev. 3.

1. Section 03.3.1 of Technical Report MUAP-10006, Rev. 3, presents the strain compatible soil/rock properties used as input for the revised set of soil-structure interaction (SSI) and

structure-soil-structure interaction (SSSI) analyses of the US-APWR standard plant. These revised site-independent seismic response analyses use as input the generic strain compatible soil/rock properties listed in Tables 03.3.1-1 through 03.3.1-6 of Technical Report MUAP-10006 that are developed based on the results of site response analyses presented in Section 01.5.2.1 of Technical Report MUAP-10006. Since the standard seismic design has been updated to consider embedded SSI models, these generic profiles represent the properties of the soil/rock layers supporting the foundation as well as the in-situ embedment soil surrounding the US-AWPR standard plant buildings. The median strain compatible soil/rock properties presented in Tables 01.5.2.2-1 through 01.5.2.2-6 are the origin of the generic soil/rock properties used as input for the site-independent SSI and structure-soil-structure interaction analyses.

2. As described in Section 03.3.1 of Technical Report MUAP-10006, Rev. 3, the site profiles used as input for the revised set of seismic response analyses are derived from the median strain-compatible soil properties (listed in Tables 01.5.2.2-1 through 01.5.2.2-6 and shown in Figures 01.5.2.2-1 through 01.5.2.2-6 of Technical Report MUAP-10006) by adjusting the layering to match the mesh of the structural models and to ensure the passage of short waves with high frequency (short wavelengths). The median values of shear wave velocities, compression wave velocity and shear wave material damping obtained from the results of site response analyses of randomized generic small strain soil profiles are used as input for the SSI and SSI analyses presented in Part 3 of Technical Report MUAP-10006, Rev. 3. As described in Section 01.5.2.2 of Technical Report MUAP-10006, Rev. 3, the median values of shear wave damping are used in the SSI models 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.
3. The seismic response analyses of the US-APWR standard plant use shear wave velocities and soil material damping that are compatible with the strains generated in the soil/rock media by ground motions for which its spectra, as full column response spectra, at foundation bottom are enveloped by the US-APWR certified seismic design response spectra (CSDRS). As described in Section 01.4.2.2 of Technical Report MUAP-10006, Rev. 3, shear modulus reduction and hysteretic damping curves from EPRI TR-102293 are used to represent the stiffness and damping properties of the generic soil/rock materials as function of strain. These degradation curves are appropriate for generic soils comprised of gravels, sands, and low PI clays. These curves also provide realistic strain compatible properties for the generic rock materials when subjected to low intensity strains generated by ground motions that are consistent with the CSDRS.

The compression wave velocities used as input for the seismic response analyses are developed assuming linear constrained modulus of the soil/rock materials that is strain independent. As described in Section 01.5.2.1 of Technical Report MUAP-10006, Rev. 3, linearity of the constrained modulus and compression wave velocity is a realistic assumption for vertical motions with incident inclined P-SV waves which magnitudes are compatible with the vertical CSDRS.

4. The strain compatible properties used as input for the site-independent SSI and structure-soil-structure interaction analyses are obtained from a set of site response analyses of randomized profiles that use input control motions that reflect contributions of multiple site conditions and earthquakes of varying sizes that define the CSDRS as broadband design spectra. As described in Section 01.4.2.2 of Technical Report MUAP-10006, Rev. 3 a point-source model and the outcrop power spectral density defined control motions are used as input for the site response analyses. Random vibration theory was used with equivalent-linear site response (EPRI, 1993; Silva, et al., 1996) to develop the strain compatible properties. Random process theory does not require time history inputs to estimate peak cyclic shear strains. Source distances (loading levels) are

adjusted such that the median 5% damped response spectrum developed for each profile and depth to baserock approaches, but does not exceed, the CSDRS. Refer to Sections 01.4.2.2 and 01.5.2.1 of Technical Report MUAP-10006, Rev. 3 for more information on the point-source model used to generate the ground motions used as input for the random vibration theory based site-response analyses.

As discussed in Section 01.4.2.2 of Technical Report MUAP-10006, Rev. 3, the implemented approach of using input control motions that represent a single earthquake ensures that the site response analyses provide appropriate strain compatible properties of the generic soil profiles reflecting realistic strains in the soil columns. The broad band nature of the CSDRS can be taken to reflect the envelope of motions from a single earthquake and a range in site conditions. With this approach, shear strain levels and associated strain compatible properties reflect realistic loading conditions for CEUS sites and are appropriate for use as input in the site-independent seismic response analyses. The standard design basis time histories documented in Section 01.5.1.2 are not used as input for developing the strain compatible soil properties because the use of a broad band CSDRS excitation would result in a condition known as overdriving (i.e., unrealistically high values for the strain compatible soil damping that will overestimate the dissipation of energy in the SSI system due to soil material damping).

5. Section 01.4.2 of Technical Report MUAP-10006, Rev. 3 presents the methodology used for development of the generic strain compatible soil/rock properties listed in Tables 01.5.2.2-1 through 01.5.2.2-6. A set of generic small strain soil/rock profiles is developed based on a database of measured initial small-strain site properties representing a range of generic site conditions that may exist across the continental US. The strain compatible properties are developed in a fully probabilistic manner from the results of site response analyses where each generic small-strain soil/rock profile is randomized as well as the degradation curves representing the dynamic properties of generic soil and rock materials as function of strain. Thirty realizations are generated for the site response analyses of each generic profile category. Equivalent-linear site response analyses are performed on each random profile for horizontal motions to calculate strain compatible shear wave velocities and damping. For vertical motions, linear site response analyses are performed by assuming that the soil/rock compression wave velocities are not strain dependent. The 5% damped spectrum of the full column outcrop motion in vertical and horizontal directions is computed for each randomized profile at the reactor building (R/B) complex foundation bottom elevation. Figures 01.5.2.1-1 and 01.5.2.1-2 of Technical Report MUAP-10006 respectively, compare for each generic profile the horizontal and vertical median spectra to the horizontal and vertical CSDRS. The comparisons show that the developed generic soil/rock properties provide realistic representation of the conditions at candidate sites.

References:

Silva, W.J. (1997). "Characteristics of Vertical Strong Ground Motions for Applications to Engineering Design." Proc. of the FHWA/NCEER Workshop on the Nat=I Representation of Seismic Ground Motion for New and Existing Highway Facilities, I.M. Friedland, M.S Power and R. L. Mayes eds., Technical Report NCEER-97-0010.

Silva, W. J., S. Li, B. Darragh, and N. Gregor (1999). "Surface Geology Based Strong Motion Amplification Factors for the San Francisco Bay and Los Angeles Areas." A PEARL Report to PG&E/CEC/Caltrans, Award No. SA2120-59652.

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.