REQUEST FOR ADDITIONAL INFORMATION 850-6002 REVISION 3

10/21/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.07.01 - Seismic Design Parameters
Application Section: 3.7.1

QUESTIONS for Structural Engineering Branch 1 (AP1000/EPR Projects) (SEB1)

03.07.01-19

Section 4.2 of MUAP-10001(R3), “Development of Soil Profiles and Strain Compatible Properties” (Page 4-5) states that a whole new suite of soil properties were developed for the new seismic analysis reported herein. The last two sentences in the first paragraph states, “The number of available profiles generally decreases rapidly with depth as noted in "Surface Geology Based Strong Motion Amplification Factors for the San Francisco Bay and Los Angeles Areas" (Reference 7). Therefore, judgment has to be used to extend the generic profiles at the deeper depths.”

The staff believed that the US-APWR seismic analyses are to be applicable to a large number of sites in the Central and Eastern United States (CEUS), nonetheless, the reference cited (Reference 7) is meant for the Western US regions (specifically California). The Applicant is requested to explain: (1) how the material in Reference 7 in MUAP-10001(R3) is applied to the CEUS sites; and (2) describe the nature, extent, and the basis of the judgment that was necessary to determine the soil profiles that are applicable to and representative of the CEUS sites.

03.07.01-20

Section 4.2.1 of MUAP-10001(R3), states, “soft soil (270 m/s) with a depth of 100 feet was deemed not to be representative of conditions at candidate sites within the continental United States and therefore was not included in the SSI analysis.”

At a number of current sites considered for placement of new plants (e.g. Vogtle, Calvert Cliffs and Levy sites), soft surficial soils are removed and replaced with well-compacted materials to form the basis of the plant foundation support. The measured velocities of these well-compacted soils still fall within this soft soil characterization. To ensure that the design for generic sites is adequate over a large range of site conditions, soft soil sites need to be considered in selecting the generic profiles. Thus, the applicant is requested to provide the technical basis for not considering soft soil conditions as illustrated above in the SSI analysis.

03.07.01-21

In Section 4.2.1 of MUAP-10001(R3), “Selection of Profiles,” the second paragraph (page 4-6) states that “For compressional-waves, a water table depth at the plant

surface of each profile was assumed. The US-APWR DCD specifies a water table depth of 1 foot below the plant grade which, for the development of vertical motions, is equivalent to the surface. Due to the absence of fluids over the top 1 foot, the lower compressional-wave velocity has a very minor impact on vertical motions for the softer profiles."

The applicant did not provide any data in the report to support the statement that the "lower compressional-wave velocity has a very minor impact on vertical motions for the softer profiles." The P-wave velocity for the saturated soil will be increased to a minimum of 5000 ft/s irrespective of the soil profile. It is expected that this increase in velocity will have an impact on the vertical motions in the high frequency range. The applicant is requested to provide technical basis and justification that supports the statement that the lower compressional-wave velocity has a very minor impact on vertical motions for the softer profiles. This information is required by the staff to evaluate the effects of the high water table on the seismic response of the SSCs and the results of the SSI analyses.

03.07.01-22

In Subsection 4.2.2 of MUAP-10001(R3), "Development of US-APWR CSDRS Strain Compatible Properties Equivalent Dynamic Mass," the first paragraph (page 4-6) states, "To characterize the range in strain compatible properties for each profile and depth to hard or soft rock conditions in a fully probabilistic manner, each base-case profile is randomized in velocity as well as nonlinear dynamic material properties. Thirty realizations were generated for each profile category and depth to hard or soft rock."

Section 4.2 of Regulatory Guide 1.208 stipulates that 60 realizations should be performed for a Monte Carlo simulation. Thus, the applicant is requested to provide the technical basis for concluding that 30 realizations are sufficient, especially when SSI analyses must consider uncertainties in the procedures. In addition, the applicant needs to describe the criteria for making this determination.

03.07.01-23

In Subsection 4.2.2 of MUAP-10001(R3), "Development of US-APWR CSDRS Strain Compatible Properties Equivalent Dynamic Mass," the second paragraph (page 4-7) states, "Control motions reflect a representative magnitude of **M**7.5 for CEUS hazard and are consistent with the overall spectral shape of the CSDRS."

The staff noticed that the criteria used in generating CSDRS compatible ground motion time histories are for a **M**6.5 earthquake (See footnote to Tables 5.1-2 and 5.1-3). The applicant is requested to provide an explanation as to why CSDRS represents a **M**7.5 earthquake; whereas, the CSDRS compatible motions only match a **M**6.5 earthquake.

03.07.01-24

In Figure 4.2-2 of MUAP-10001 (R3), rock appears to have higher damping ratio than sand for comparable strain levels. To help the staff better understand the comparable damping ratios, the applicant is requested to provide the technical basis and identify the

corresponding references leading to this result. Additionally, is this relationship considered appropriate for hard rock as well as firm or soft rock?; and discuss whether the high rock damping is conservative or unconservative from an SSI perspective and provide the appropriate technical justification.

03.07.01-25

In Subsection 4.1 of MUAP-10001(R3), "CSDRS Compatible Ground Motion Time Histories," Item 2 of the first paragraph on Page 4-4 states:

"a. Run RSPMatch to simultaneously match the target for the five damping ratios defined in the target and multiple iterations.
b. Apply baseline correction to the matched time history motion.
c. Rerun RSPMatch to match only the 5% damped spectral target, only with a single iteration.
d. Apply baseline correction to that time history motion."

It is a general engineering practice that the spectrum from the artificial ground motion time history must envelop the free-field design response spectra for all damping values used in the seismic response analysis. The applicant is requested to clarify whether the time history obtained from step c stated above will simultaneously match the target spectra for the five damping ratios. The Applicant is also requested to provide graphical plots for the comparisons and to provide rationale for why step c is needed once step a is done.

03.07.01-26

In Subsection 5.1 of MUAP-10001(R3), "CSDRS Compatible Ground Motion Time Histories," the last sentence of the first paragraph (Page 5-1) states, "The time history motion plots of the ground acceleration, velocity, and displacement are shown together to demonstrate their non-stationary process."

The applicant did not provide any explanation as to how the time history motion plots of the ground acceleration, velocity, and displacement demonstrate the non-stationary process. The Applicant is requested to provide the required explanation.

03.07.01-27

The purpose of Section 5.2.1 of MUAP-10001(R3), "Site Response Analysis," for Standard plant structures is not clear to the staff. The Applicant is requested to explain its purpose and how the results presented have been used in conducting the SSI analyses for the CSDRS.

(i) The first paragraph on Page 5-16 states, "The site response analyses are conducted using the equivalent linear RVT approach (Reference 8, Reference 10, and NUREG/CR-6729 (Reference 17)) with the point-source model used to generate both the horizontal and vertical motions (References 8, 10, and 11)." The staff did not find the relevance of the equivalent linear RVT approach in the SSI analyses.

(ii) The last sentence of the 1st paragraph (Page 5-16), states: "Figure 5.2-3 also suggests a simple manner to update the CSDRS to reflect the expected spectral shape for CEUS strong ground motions." The Applicant is requested to explain the relevance of Figure 5.2-3 and how Figure 5.2-3 will is used in the SSI analysis and design of the standard plant SSCs.

The applicant is also requested to explain the different base rock definitions in the footnote to Table 5.2-1 on page 5-12 that defines the base rock differently for different soil profiles.

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.

03.07.01-29

Figure 5.2.1 of MUAP-10001(R3), shows that two soil sites with depth to hard rock of greater than 500' and two rock sites with depth to hard rock of 350' and 100' have been selected. Considering that the depth of the plant foundation is about 50', the distance from bottom of foundation to hard rock is greater than 450', 300' and 50'. These depths to hard rock would correspond approximately to frequencies of 2 Hz, 3 Hz and 20 Hz, respectively, assuming Vs is 1000 ft/sec. Considering the typical frequency range of interest for SSI effects, the applicant is requested to explain why an additional profile with an intermediate depth to hard rock (e.g., 150') was not selected.

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.

03.07.01-31

The site response analyses used to develop the subgrade properties use degradation curves for damping and shear modulus that are appropriate for the media considered. The applicant is requested to discuss whether the subgrade properties were developed using dry soils, saturated soils, or both. If both dry and saturated soils were used to develop the subgrade properties, the applicant is requested to discuss if different sets of degradation curves were used for dry and saturated soils, and if not, the applicant is requested to discuss the applicability of using the same degradation curves in each case.

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

03.07.01-32

In Subsection 5.1 of MUAP-10001(R3), "CSDRS Compatible Ground Motion Time Histories," the paragraph under the subtitle of "Duration of Motion" (Page 5-10) states, "The set of three statistically independent components of the artificial time history earthquake which are developed for design of the US-APWR seismic Category I buildings are characterized by the strong duration of motion times, listed in Table 5.1-2 and total duration of motion time of 22.085 seconds."

The staff noticed that the duration of 22.005 seconds is given in item (a) of the paragraph on Page 5-7 of MUAP-10001(R3); whereas it is 22.085 seconds in the above quoted sentence. Also, the US-APWR DCD (R3) states the duration as 22.005 seconds. The applicant is requested to clarify this discrepancy.