REQUEST FOR ADDITIONAL INFORMATION 776-5851 REVISION 3

7/6/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.07.02 - Seismic System Analysis
Application Section: 3.7.2

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

03.07.02-68

In Section 1.0 of the MUAP-11001 (R0), the last sentence in the 4th paragraph states, "The certified seismic design response spectra (CSDRS) and the CSDRS compatible time histories that were developed in Section 5.2 of MHI TR MUAP-10001 (Reference 7.1) define the ground motion for the standard design of the A/B."

The staff is unable to determine where the CSDRS is applied to the A/B structure in conducting the seismic responses described in this Report. The Applicant is requested to specify where the CSDRS is located for the standard design of the A/B.

03.07.02-69

In Subsection 2.2 of the MUAP-11001 (R0), "Material Properties," (page 6) the last sentence states "The critical damping ratio of 7% is for bolted steel structures at SSE stress level per Regulatory Guide 1.61(Reference 7.13)."

The staff noticed that 7% is allowed only if "Bolted Steel with Bearing Connections," are used. Otherwise, damping is limited to 4% (e.g., welded or bolted with friction joints). The Applicant is requested to provide a confirmatory statement in the Report that "Bolted Steel with Bearing Connections," are used.

03.07.02-70

In Subsection 2.3.1 of the MUAP-11001 (R0), "Structural Discretization and Finite Element Types," the third paragraph (page 7) states, "In order to ensure an appropriate transfer of high frequency seismic waves through the soil-structure interface, two dynamic FE models are developed with maximum element sizes in the horizontal direction of 9 feet and 13 feet."

In MHI technical report, MUAP-10006 (R1), the Applicant presents Equation (1b) on p.4 for the size of the FE mesh. For the cut-off frequency chosen to be that of the ZPA (50 Hz), the element size of 9 feet and 13 feet does not meet this equation for the 270-200 soil profile. The Applicant is requested to provide a technical basis and justification for not satisfying the element size requirement of equation (1b), in MUAP-10006(R1) in the current analysis for the A/B.

03.07.02-71

In Subsection 2.3.2.1of MUAP-11001 (R0), “Reduction of Stiffness for Concrete Cracking,” the paragraph (page 7) states, “The elastic modulus and wall/slab thicknesses of the shell elements are modified so that the out-of-plane flexural stiffness is reduced by 50% while the in-plane shear and axial stiffness remains unchanged.”

The Applicant is requested to provide technical basis and justification for not reducing the shear stiffness.

03.07.02-72

Subsection 2.3.3 of MUAP-11001 (R0), “Equivalent Dynamic Mass,” states that “The equivalent mass consists of permanent equipment self-weight, 25% live load and piping load (or 75% snow load for roof, whichever is greater). The loads including equipment self-weight, piping load and live load for the A/B are obtained from "Load Distribution Auxiliary Building" and “Component Weight List Auxiliary Building” (References 7.5, 7.6 respectively).”

Per SRP Acceptance Criteria D of SRP 3.7.2, in addition to the structural mass, the mass equivalent to a floor load of 50 pounds per square foot (psf) should be included in the equivalent dynamic mass. Since the staff does not have access to References 7.5 and 7.6 mentioned in the above quoted sentences, the Applicant is requested to confirm that the mass equivalent to a floor load of 50 pounds per square foot (psf) is included in the model for analyses. If this 50 psf mass is not included, the Applicant is requested to provide the technical basis and justification for its exclusion from the seismic analysis.

03.07.02-73

Subsection 3.2 of MUAP-11001 (R0), states that “Table 3.2-1 summarizes the results of the modal analyses of the three different FE models for the dominant natural frequencies in horizontal N-S and E-W directions.”

Table 3.2-1 did not show the results of the modal analyses for the vertical direction excitation. Applicant is requested to provide in Table 3.2-1 the corresponding data for the vertical direction so that the staff can assess the accuracy of the model in the vertical direction.

03.07.02-74

Subsection 3.4 of MUAP-11001 (R0), states that “Figure 3.4-1 and Figure 3.4-2, respectively, compare the transfer function amplitudes computed for the horizontal NS and EW seismic responses at the roof elevation (El. 75.9 ft). As indicated from these figures, the correlation between the dynamic properties of the fixed-base lumped-mass stick model and that of the fixed-base FE model are reasonable for the fundamental-mode responses.”
The Applicant is requested to address the following staff comments:

- The staff noticed that the information presented in Figures 3.4-1 and 3.4-2 are for the two horizontal directions. In order for the staff to assess the accuracy of the lump mass stick model in the vertical direction, the Applicant is requested to provide a figure showing the corresponding comparison of the transfer function amplitudes for the vertical direction.
- The lumped mass stick model is used to generate the in-structure response spectra at the top of the basemat for the structural design; therefore, the accuracy of the lumped mass stick model is essential for the structural design. In the above quoted sentence, the Applicant stated that the lumped mass stick model is reasonable for the fundamental-mode response. The Applicant is requested to provide the technical basis and justification to demonstrate that the contribution from the higher modes is negligible and the result is conservative.
- In order for the staff to assess the accuracy of the lumped mass stick model, the Applicant is requested to provide a table comparing the modal properties for the lumped mass stick model and the FEM model in the x, y and z directions. The data should include the modal frequencies, mass participation factors, and the cumulative modal participating mass in percentage of the total mass up to the 90 percent of the total mass.

03.07.02-75

In Subsection 4.1 of MUAP-11001 (R0), “Methodology,” the fourth paragraph (page 41) states, “Table 4.2-1 provides a summary of the dynamic models, site profiles, number of frequencies of analyses and cut-off frequency of analyses used for the different SSI analyses presented in this report. The horizontal size of the FE mesh of the basemat is also presented in the table together with the maximum frequency of the waves that can be transmitted through the soil-foundation interface based on the criterion that the basemat FE size is not more than 20% of the minimum wave length.”

The ZPA for the CSDRS is 50 Hz. The staff noticed that for several soil profiles, the data for the maximum wave passage frequency presented in Table 4.2-1 are much less than 50 Hz. The SRP Acceptance Criteria 1.A(1) of SRP 3.7.2 states, “all modes with frequencies less than the ZPA (or PGA) frequency of the corresponding spectrum are adequately represented in the dynamic solution.” Both the lumped mass stick model and the FE model used in the report do not meet this criterion for soft soil profiles. The Applicant is requested to revise their methodology or to provide the technical basis and justification to demonstrate that their approach is conservative.

03.07.02-76

In Subsection 4.3 of MUAP-11001 (R0), “Results of Dynamic FE Model SSI Analyses,” the third paragraph (page 55) states, “These SASSI models are shown in Figure 2.3-1 through Figure 2.3-3 for the 9-ft-mesh model, which is used for the critical 270-500 site profile case, and in Figure 2.3-4 through Figure 2.3-12 for the 13-ft-mesh model, which is used for the critical 900-100, 900-200, and 2032-100 site profile cases.”

The data shown in Table 4.2-1 of the report indicate that the maximum wave passage frequency for the 9-ft-mesh model is 27.9 Hz which is less than the ZPA frequency of 50

Hz. The Applicant is requested to provide the technical basis and justification to demonstrate that the contribution from the higher modes is negligible and the result is conservative.

03.07.02-77

In Subsection 4.3 of MUAP-10001 (R0), "Results of Dynamic FE Model SSI Analyses," the fifth paragraph (page 55) states, "Figure 4.3-1 shows that the maximum displacement relative to the free-field ground surface is 0.92 inches in the East-West direction."

The staff is not able to determine whether or not 0.92 inches includes the contribution from the SSE motions in the North –South (NS) and East –West (EW) directions including the displacement in NS direction caused by the SSE motion in the EW direction, and the displacement in EW direction caused by the SSE motion in the NS direction. The Applicant is requested to provide detailed information that shows how the various components of the horizontal seismic displacements are combined.

03.07.02-78

In Subsection 5.1.5 of MUAP-11001 (R0), "SSE Loads (E_{ss})," the third paragraph (page 59) states, "Therefore, in addition to the earthquake forces derived from RSA analyses, the effects of accidental torsion is also considered. A torsion moment equal to the larger of the torsions resulting from the product of the base shears times 5% of the building dimension that is perpendicular to the direction of the base shear force is applied to the analytical model."

The Applicant is requested to confirm that the effect of accidental torsion is included in the calculation of the displacement relative to the free-field ground motion. If this torsional effect was not included, the Applicant is requested to provide the technical basis and justification for its exclusion in determining the maximum relative displacements.

03.07.02-79

In Section 1.0 of the MUAP-11001 (R0), it is stated that response spectrum analysis (RSA) is used to obtain static and dynamic demands of the major representative structural members of A/B. The ISRS at A/B basemat resulting from lumped-mass stick model SSI analysis is used as the input response spectrum for RSA.

In Subsection 5.2.1 of MUAP-11001 (R0), "Determination of the Input Response Spectrum," (page 63) the Applicant listed five steps used for calculating the In-Structure Response Spectra (ISRS). The staff reviewed the five-step procedure and was not able to identify the step that includes the base rocking motion in the ISRS generation. SRP Acceptance Criteria 1.A.iii of Section 3.7.2 requires consideration of rocking response of site structures and their foundations. As a result of soil-structure interaction, the superstructure experiences an additional rocking motion at its base, and the effect of this rocking motion should be considered in the generation of ISRS.

The Applicant is requested to provide technical details that show how this rocking motion is included in generating the ISRS. If this rocking motion is not included, the Applicant is requested to provide the technical basis and justification that demonstrates that the seismic displacements and design forces of A/B structure based on the analyses using the ISRS (that are generated excluding the rocking motion) are conservative.

03.07.02-80

In Subsection 5.2.3 of MUAP-11001 (R0), "Combined Modal Responses: Lindley-Yow Method," the paragraph (page 63) states, "The periodic response portion of the Lindley-Yow method is implemented by using ANSYS "Grouping Method" and the rigid response portion is implemented by using "Static ZPA Method" per Regulatory Position 1.4.2 of RG 1.92, Rev. 2. The directional effect from each direction is combined by 100-40-40 method."

The staff noticed that so far the Applicant has not reported the use of the Lindley-Yow method for combining modal responses in the DCD (Rev. 3) and in seismic analyses reports of various category I structures and the Turbine building. The applicant is requested to discuss the unique circumstances and aspects of the A/B seismic analyses that require the use of Lindley-Yow method for combining modal responses. In RG. 1.92, one limitation on the use of Lindley-Yow's method is specified, "The Lindley-Yow's method should not be used for SSCs that have natural frequencies less than the frequency of the lowest-frequency spectral acceleration peak."

Thus, the applicant is requested to discuss the effect of the Lindley-Yow's method limitation on the seismic analyses responses. The Applicant is also requested to discuss how the periodic response component is combined with the rigid response portion and provide the technical basis and justification for the combination used.

03.07.02-81

In Section 5.5 of MUAP-11001 (R0), "Structural Integrity Evaluation Results," the second paragraph (page 70) states, "The required reinforcement due to out-of-plane bending moments and in-plane forces are calculated by program "WALL" and is shown in Table 5.5-2. Similarly, the required reinforcement due to out-of-plane bending moments and out-of plane shear force in slabs are calculated by program "SLAB". These required reinforcements are calculated in element level and are defined as "Demands."

The Applicant is requested to clarify how the effect of concrete cracking are considered in the calculation of the design forces and moments.

03.07.02-82

In Table 5.5-3 of MUAP-11001 (R0), "Typical Structural Demands," (page 78) the second item states that, "1< DCR [Demand/Capacity Ratio] <2 for wall above and below 3rd floor."

Since the demand exceeds the capacity for this wall, the wall will need to be redesigned. The Applicant is requested to show how these exceedances are factored into the design, and in the calculation of the relative displacements between the A/B and R/B and the A/B and PS/B; and in demonstrating that the relative displacement is within the acceptable limits.

03.07.02-83

On Page A1 of Appendix A of the MUAP-11001 (R0) under Key Features, the second bullet states, “Program Checks Minimum Reinforcement in Accordance with Section 7.12 of ACI 349-01.”

Requirements for minimum reinforcement are also specified in Section 14.3 of ACI 349-01. The Applicant is requested to confirm that the program also checks for minimum reinforcement requirements in Section 14.3 of ACI 349-01, and that the A/B design meets the ACI code requirements.

03.07.02-84

In Subsection 5.1.3 of MUAP -11001 (R0), the Applicant stated that to simplify the calculations, the groundwater level is conservatively taken as at grade level for determination of hydrostatic pressure.
However, the Applicant did not address the effect of water table on the SSI seismic analysis of the A/B. The applicant is requested to include the effects of water table in seismic analyses or provide the technical bases including supporting analyses for neglecting the effects of the high water table on the seismic design and analyses for the A/B.