REQUEST FOR ADDITIONAL INFORMATION 853-6029 REVISION 3

10/24/2011

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)

03.07.02-139

In Section 1.0 MUAP-11006 (R0), the applicant states that the lumped mass stick models (LMSM) will be used in studies of base reactions, effects of embedment, and structure-soil-structure interaction (SSSI) studies. The applicant is requested to provide justification for how validating the models in the fixed-base condition using ANSYS provides sufficient evidence that the LMSM models will provide responses comparable to those that a properly benchmarked and validated detailed SASSI model would predict.

In particular, the validation process does not benchmark the SSI capabilities of either model. For example, the capability of the LMSM model for performing embedment, seismic stability, and SSSI studies is not addressed in the validation process. Results of each of these studies depends on having proper seismically induced lateral wall pressures, but the validation process for the lumped mass models does not benchmark this feature.

The applicant's justification for the use of the SASSI and LMSM should also include a description of the damping implemented in both ANSYS and SASSI. If the damping formulations are different in the two computer codes, the applicant is requested to provide justification for how benchmarking in a fixed-base condition with a different damping formulation in ANSYS provides validation for a SASSI SSI model.

03.07.02-140

In the second paragraph of Section 1.0 of MUAP-11006 (R0), the applicant states that "The models use complex damping formulation in ACS SASSI (Reference 2) to model the dissipation of energy due to material damping of the structural members and the soil." In Section 2.0 of the report, it is stated that "The results of the soil-structure interaction (SSI) analyses performed on this model benchmark base reactions resulting from the FE model that serve for evaluation of seismic stability of the R/B complex." Similarly, in Section 3.0, it is stated that "The models use complex damping formulation in ACS SASSI (Reference 2) to model the dissipation of energy due to material damping of the structural members and the soil."

The models described in this report are all ANSYS models and the staff understands that all the ANSYS models were analyzed in the fixed-base condition. In particular, SASSI models were not utilized in this report (other than as a basis for benchmarking),

SSI analyses were not conducted as part of the benchmarking of the LMSM, and complex damping does not appear to have been used in the ANSYS models. The applicant is requested to explain the relevance of the above statements to the benchmarking described in this report.

03.07.02-141

In Section 1.0 of MUAP-11006 (R0) regarding the CIS, the applicant states, “Due to the complexity of the CIS, different stiffness and damping values are assigned to different types of structural components for the two bounding stiffness and damping conditions as described in Appendix A of MUAP-10001.”

The staff noted that the applicant has issued a report MUAP-11018 (R0), “Containment Internal Structure: Stiffness and Damping for Analysis,” in August 2011. The applicant is requested to confirm that the CIS stiffness and damping information presented in Appendix A of MUAP-10001 (R3), that is used in the validation analysis reported in MUAP- 11006 (R0), is not superceded by information in MUAP-11018 (R0); otherwise identify all changes made to the CIS stiffness and damping. The staff has not completed its evaluation of MUAP-11018 (R0); further questions and requests for additional information may be generated with respect to Appendix A of MUAP-10001 (R3).

03.07.02-142

In Section 3.0 of MUAP-11006 (R0), the applicant states, in part, that, “a set of validation analyses are performed to demonstrate the ability of the R/B Complex LMSM to adequately represent the global dynamic properties of the structure.” The applicant is requested to define what constitute the global dynamic properties; provide the criteria for determining the adequacy of the global dynamic properties; and state how the criteria is met.

03.07.02-143

In Section 4.0 of MUAP-11006 (R0), the applicant states that, “Based on the decoupling criteria of Standard Regulatory Plan (SRP) 3.7.2 (Reference 3), with the exception of the RCL, the subsystems and components inside the containment and in the R/B are included in the coupled model by lumping their masses and neglecting their stiffness.”

The applicant is requested to provide a technical justification for the dynamic decoupling (frequency or mass ratios) of representative subsystems and components thereby neglecting their stiffness in the models.

03.07.02-144

In the fourth paragraph of Section 4.0 of MUAP-11006 (R0) related to the CIS, the applicant states, “In addition, uniform 5% structural damping was assigned to the models for validation purposes.” In numerous places in the report, the applicant states that validation is performed in ANSYS using full transient time history analysis. The staff understands that for full transient time history analysis, uniform structural damping is not

an option available in ANSYS; rather globally applied mass proportional damping, and stiffness proportional damping (applied either globally or at the material level) is considered for such analysis. The applicant is requested to explain the damping formulation used in the validation and what effect it has on the validation results.

03.07.02-145

In the fourth paragraph of Section 4.0 of MUAP-11006 (R0), the applicant states that, "In addition, uniform 5% structural damping was assigned to the models for validation purposes." However, the applicant did not specify what damping is used for the SSCs other than the CIS. Thus, the applicant is requested to provide details of how damping was implemented in all the SSCs used in the ANSYS models for the validation process.

03.07.02-146

In the second paragraph of Section 5.2 of MUAP-11006 (R0), the applicant states that, "For validation purposes, the lumped-mass stick model is separated into three parts: R/B-FHA (including the common basemat), PCCV, and CIS. Static and dynamic analyses using ANSYS solvers are performed on each of the three components of the lumped-mass stick models by establishing fixed boundary conditions at the base of each structure, respectively. An identical set of fixed base analyses are also performed on the Dynamic FE models of the R/B, PCCV, and CIS. The results obtained from the Lumped Mass Stick Models and Dynamic FE models are compared to demonstrate the ability of Lumped Mass Stick Models to adequately capture the global dynamic behavior of the corresponding Dynamic FE models."

The applicant is requested to clarify whether or not these validation analyses are performed separately for the R/B-FHA, PCCV, and CIS, or if they are performed simultaneously with the R/B-FHA, PCCV, and CIS active in the models at the same time. If three systems are analyzed separately, the applicant is requested to provide a justification for neglecting any potential dynamic interaction between the three components of the lumped-mass stick models. The applicant is also requested to provide the details as to how the R/B-FHA, PCCV, and CIS are evaluated separately in the detailed dynamic model; and how it is determined that the individual SSCs lead to the same responses in both the LMSM and detailed dynamic models.

03.07.02-147

The staff has reviewed the verification results for the PCCV, R/B and FHA, and the CIS that are reported in Section 5.2 of MUAP-11006 (R0). The staff has noted several inconsistencies shown below. The applicant is requested to describe the effects each of these inconsistencies have on the validation results of the LMSMs of the PCCV, R/B-FHA, and CIS.

1. The third sentence of third paragraph of Subsection 5.2.1.1 of MUAP-11006 (R0) states that the total mass of the dynamic FE model of the PCCV is 2,447 kip-s^2/ft and that the difference between the mass of the dynamic FE model and the LMSM is less than 0.2%. In contrast, Table 5.1.1-1 of MUAP-11006

(R0) shows the mass of the LMSM of the PCCV to be 2.311 kip-s^2/ft. However the sum of the masses shown in Table 5.1.1-1 is 2.439 kip-s^2/ft, which is different than both of the values above.

2. In Section 5.2.2.1 of MUAP-11006 (R0), it is stated that the total weight of the LMSM of the R/B and FHA is 372,000 kips, which is based on the weight of the FE model given in that Subsection. 372,000 kips appears to represent the weight of the model without the basemat. In contrast, Table 5.1.1-3 of MUAP-11006 (R0) shows the total weight of the LMSM of the R/B and basemat to be 766,760 kips. The applicant is requested to explain the interpretation of the two different weights.
3. The sum of the masses in Table 5.1.1-3 is 340.24 x 10^3 kip-s^2/ft, not the value of 2,882 kips shown in the table.
4. The weight of 766,760 kips shown in Table 5.1.1-3 is inconsistent with either the mass of 2882 kips shown in the table, or the mass of 340.24 x 10^3 kip-s^2/ft arrived at by summing the values in the table. The applicant is requested explain this inconsistency.
5. In Subsection 5.2.3.1 of MUAP-11006 (R0), it is stated that the total mass of the CIS from the dynamic FE model is 3,120 kip-s^2/ft or 100,383 kips and that the difference between the mass of the LMSM and the dynamic FE model is 5.3%. However the mass of the CIS from the LMSM is shown as 2,882 kip-s^2/ft in Table 5.1.1-2 with a difference of more than 5.3%. The applicant is requested to provide the acceptance criteria , explain this inconsistency, and to provide the proper masses and interpretation for the values shown in the report and supporting tables identified above.

03.07.02-148

In Subsection 5.2.4 of MUAP-11006 (R0), "Base Shear Verification Results," it states that, "A dynamic Time-History response analysis using explicit time integration is performed to calculate the base shear of the combined R/B Complex LMSM. For this purpose, the three individual lumped mass stick structures, namely PCCV, R/B and FHA, as well as CIS (uncracked model), are constrained at the top of their basemats and an explicit time integration is performed on each model. The resulting time histories of base shear for each of the three LMSMs are added together to calculate the time history of base shear for the combined R/B Complex LMSM."
In order for the staff to better evaluate the characteristics of the LMSM, the applicant is requested to provide the following information:

1. Identify source(s) and provide justification of conservatism in the base shears predicted by LMSM relative to the base shears from the detailed dynamic model as shown in Figures 5.2.4-1, and 5.2.4-2 of MUAP-11006 (R0).
2. Calculate and compare the maximum base overturning moments (in all three directions) predicted by LMSM relative to the maximum base overturning moments from the detailed dynamic model to show that the overturning moments due to LMSM are conservative.

03.07.02-149

In Subsection 5.2 of MUAP-11006 (R0), the applicant states that transient dynamic analysis was used for validation of the various LMSMs and that "ARS indicate that the LMSM captures the global structure response to dynamic loads in all direction properly." The ARS presented in the report do not support the applicant's conclusion. The staff observed that in many cases, the ARS from the LMSM are significantly lower than the ISRS from the dynamic FE models, particularly in the frequency band of 1-8 Hz. A few examples of this are shown in Figures 5.2.2.3-51, 5.2.2.3-52, 5.2.2.3-54, 5.2.2.3-55, and 5.2.3.3-5. The applicant is requested to (1) state the acceptance criteria and justification used in drawing the conclusion that the LMSMs properly capture the structural response to dynamic loading, and (2) discuss the impact of the deficiencies of the LMSM ARS on the validity of the embedment, sliding, and structure-soil-structure interaction studies performed using LMSMs.

03.07.02-150

In reviewing the Applicant's technical report, MUAP-11006(R0), the staff found several areas which need further clarification, additional information, or editorial revision. The applicant is requested to address the following requests and questions:

In the fifth paragraph of Section 4.0 of MUAP-11006 (R0), the applicant refers to Figure 4-1 in the context of refining stick elements of the R/B-FHA model. Figure 4-1 shows a finite element model plot of floor slabs. The applicant is requested to explain the relevance of Figure 4-1 to the refinement of stick elements.

In the first sentence of Section 5.2 of MUAP-11006 (R0), the applicant uses Reference 12 to refer to the ANSYS computer program. This reference appears as Reference 11 in the Reference section of the document. The applicant is requested to correct this discrepancy.

In numerous places in MUAP-11006 (R0), the applicant refers to MUAP-10001 (R3) as the basis for the properties of the dynamic FE models used as the benchmark for validating the LMSMs. However, the reference section of MUAP-11006 (R0) refers to Revision A of MUAP-10001. The applicant is requested to correct this discrepancy.