REQUEST FOR ADDITIONAL INFORMATION 894-6270 REVISION 3

1/25/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.08.03 - Concrete and Steel Internal Structures of Steel or Concrete Containments
Application Section: 3.8.3

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

03.08.03-56

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), page vii, states "However, some aspects of SC specific behavior can cause slight deviations from RC behavior. For example: … (iii) The steel reinforcement ratios for SC walls are much higher (about 2-4%)." Since this range of steel ratios for SC members is very high, the staff requests that the applicant explain what is the technical basis for accepting these higher values. In addition, the staff requests that the applicant provide sufficient test data to show that the steel-concrete (SC) composite member performance is equal to or better than reinforced concrete (RC) members. This should be demonstrated by comparison of performance parameters that include stiffness, ultimate strength, cyclic behavior, and ductility in all member directional loadings (i.e., membrane, bending, shear in and out of plane, and combination of these loadings).

03.08.03-57

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), page vii, (as well as other sections of the report), presents a table which summarizes the equations for stiffness developed for SC Category 1 and RC members for load condition A - seismic plus operating thermal loading (Ess+To) and different equations for load condition B - seismic plus accident thermal loading (Ess+Ta).

1. The stiffness and damping values for each of these load conditions are developed separately depending on the level of cracking that would occur for the applicable load combination. Because predicting the level of cracked concrete is uncertain and because concrete cracking may occur for some of the loading conditions, all of the loads and load combinations should be analyzed for the range of uncracked and cracked conditions.

   Based on the MUAP-11013 report, it appears that the enveloping approach (for the two levels of cracking) is being utilized for developing the US-APWR in-structure response spectra (ISRS). However, it is not clear to the staff whether the enveloping approach is also being utilized for developing member forces for design. Therefore, the staff requests that the applicant clarify whether (1) for seismic loading, the stiffness values (and damping values) corresponding to load condition A and the stiffness values (and damping values) corresponding to load condition B for all members are analyzed; (2) the same approach is also used for the other loads that appear in the various load combinations for design; (3) then, for each load combination used to design the RC and SC members, total member forces are determined separately for the two levels of stiffness conditions, and the envelope of these two cases is used for the design of the members. If different levels of cracking are used for various members or regions in the model within a loading condition, then also clarify how the effects of reduced stiffness values (and corresponding damping values) due to cracking of the concrete will be considered in the finite element model. For example, explain whether each finite element in the seismic SSI models and design models is checked for stress levels and the corresponding stiffness values and damping values are used based on the stress level, or a single stiffness value and a single damping value are used for all finite elements within the SC category and RC type members based on the load condition A or B being evaluated. If it is the latter, provide the basis for this approach.

2. Loading condition A provides the stiffness equations for shear and flexure. Explain why the equations for in-plane membrane are not provided. Also, provide the basis for the stiffness values being used for the in-plane membrane direction.

03.08.03-58

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), presents two tables on page viii, which indicates that the flexural stiffness (E_cI_{ct}) of Category I SC walls under loading condition A is the same as that under loading condition B. Several places of the report explain that, with the lower load condition A, this is due to the fact that SC walls tend to crack early in flexure due to locked in shrinkage strains and lower degree of composite action. Section 5 of the report, which was intended to evaluate stiffness and damping for load condition A, does not provide an evaluation for SC Category 1 flexural stiffness. Therefore, the applicant is requested to provide the technical justification for the use of E_cI_{ct} for loading condition A and to demonstrate that the values of the SC member flexural stiffness for load conditions A and B are the same.

03.08.03-59

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), first table on page viii, shows that for loading condition A, the uncracked shear stiffness and the cracked flexural stiffness are being utilized for SC Category 1 members. According to ASCE 43-05, which is referenced and shown in Table 4-1 (page 4-15), if walls are cracked, then both the flexural and shear stiffnesses should use a factor of 0.5. Explain why the shear stiffness is based on uncracked properties while cracked stiffness is assumed for flexural behavior. This same issue appears in the second table on page ix for RC Category 4; however, the uncracked and cracked conditions in this case appear for loading condition B.

03.08.03-60

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), second table on page viii, provides the stiffness values for the SC and RC members. Explain why the shear stiffness value for the SC Category 1 wall under loading condition B, is smaller than that of the RC wall, considering the higher reinforcement ratio in the SC wall. Also, provide the specific reinforcement ratio for the RC wall used in the table, and explain what equations are used for calculating the reinforcement ratios for both SC and RC members in this report.

03.08.03-61

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), first table on page viii, indicates that the damping ratios of SC Category 1 walls under loading condition A and B are 4% and 5%, respectively. According to the report, the 5% damping ratio is based on test results of the 1/10th scale test. Since the 1/10th scale test is for the entire CIS structure which includes various SC category types, not just the SC Category 1 walls, the staff requests that the applicant provide additional justification/test data to justify the use of the 4% and 5% damping ratios for the SC Category 1 walls used in the US-APWR Containment Internal Structure (CIS).

03.08.03-62

For damping, MHI Technical Report MUAP-11018-P (R0) also references MHI Technical Report MUAP-10002-P (R0). Page 2-2 of MHI Technical Report MUAP-10002-P (R0) indicates that, in the test model, a significant portion of the steel plates on both surfaces were connected by web plates. The staff's understanding is that this web plate method will not be used in the design of the US-APWR SC structures. In addition, MHI Technical Report MUAP-11013-P (R1), page 1-2, indicates that the SC wall anchorage details of the 1/10th test model are different from those proposed for the US-APWR SC structures. Provide an explanation of the effects of the above construction differences, and any others that may exist, on the damping ratio.

03.08.03-63

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), page ix, presents a table which summarizes the equations developed for SC Categories 2 & 3 for load condition A (Ess+To) and different equations for load condition B (Ess+Ta). The technical basis for using RC equations for the SC Categories 2 & 3 does not appear to be adequate. For example, the SC to RC flexural ratio from the table on page viii of the technical report is 1.34, which shows that an SC member 48 inches thick is much stiffer than the corresponding RC member. Therefore, explain why would a 56 inch thick SC Category 2 member have the same stiffness as an RC member.

03.08.03-64

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), first table on page ix, indicates a damping ratio of 7% for SC Category 2 walls under loading condition B. The damping ratio is higher than the 5%, shown in the first table on page viii, for SC walls under loading condition B. Since the SC Category 2 member is still an SC type member, provide the technical basis for using a higher damping value. Generally, the damping value should be determined based on the stress level not the thickness of the section.

03.08.03-65

The Executive Summary of MHI Technical Report MUAP-11018-P (R0), page x, indicates that the stiffness and damping values for SC Category 6 steel structures with non-structural concrete infill are based on the stiffness of the steel structure alone. The mass of the non-structural concrete infill is included in the models. Provide a technical basis for only including the steel stiffness properties of this Category 6 structure. Even though the concrete is considered to be “nonstructural,” it may provide some stiffness to the members. Therefore, the potential range of stiffness values for such members should be considered or an acceptable technical basis needs to be provided for totally neglecting the stiffness contribution from the concrete.

03.08.03-66

Section 4.1 of MHI Technical Report MUAP-11018-P (R0), which describes how the in-plane shear stiffnesses for SC Category 1 walls are determined is extremely important. The uncracked and cracked in-plane shear stiffnesses for SC members are derived analytically. These equations rely on the combined monolithic behavior of the steel faceplates and concrete as if they act as an integrally connected unit, which is a key assumption. For the uncracked stiffness equation, reference is made to the Ozaki et al. testing. The referenced paper/report could not be located in the technical report(s). The staff requests that that applicant provide the test report/information along with a summary demonstrating its applicability (e.g., specimen configuration and design detail) to the SC members used in the US-APWR design and adequacy of its results.

For the cracked stiffness equation, reference is made to Appendices A through C, which derive the equations. These derivations are very complex with several assumptions. The equations have some parameters that are difficult to quantify (i.e., tensile strength of concrete and shrinkage strains), and therefore, the equations are calibrated to match experimental test data which makes the equations empirical. The staff requests that that applicant identify the test report used to calibrate the equations and provide the test report/information along with a summary demonstrating its applicability to the SC members used in the US-APWR design and adequacy of its results.