RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

1/31/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No.52-021

RAI NO.:	**NO. 852-6003 REVISION 3**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**10/24/11**

QUESTION NO. RAI 03.07.02-113:

With respect to Section 4.3 of MUAP 10001 (R3), “ACS SASSI Dynamic Finite Element Model of R/B Complex,” and Section 4.4 of MUAP 10001 (R3), “ACS SASSI Dynamic Finite Element Model of PS/B, ” the applicant is requested to provide the following additional information:

(i) Section 4.3.1 of MUAP 10001(R3), the applicant discussed the SASSI problem of connecting different element types having differing end conditions together at a common node. It has been found that the improper definition of constraint conditions at the free degrees-of-freedom can lead to potential improper restraint to the entire model when considering SSI responses. The Applicant is requested to provide descriptions of the connectivity used in SASSI between beam and shell elements and between beam and brick elements, and examples of computed responses using the defined connectivity.

(ii) In Figures 4.3.1.1-6 and 4.3.1.1-7, massless rigid beams and massless surface beams are used to connect structural beams to shell elements. It appears that the rigid beams would be adequate for this purpose. Explain why surface beams are needed and how the stiffness of these surface beams is determined.

(iii) In section 4.3.1.2, the maximum mesh size for concrete was determined to be 20 ft, in order to transfer a shear wave up to 70 Hz, based on a calculation of shear wave propagation. This is not necessarily adequate to accurately capture local out-of-plane vibration modes of walls and floors up to 70 Hz. How have the local out-of-plane modes been incorporated in the dynamic model? Is the detailed model refined enough to adequately represent these modes up to 70 Hz? Have the dynamic and detailed models been compared to confirm the sufficiency of the dynamic model?

(iv) On page 4-28, it is stated that “the effective width of concrete (before transformation to steel section) is based on AISC 360-05, Section I3. The requirements in AISC 360-05 are applicable when the flange of the composite section is in compression. When the flange is in tension, smaller values of ‘be’ could be used.

Since the flange (concrete slab of the composite floor) may be in both tension and compression during earthquake excitation, a smaller ‘be’ would appear to be appropriate. AISC 360-05, Section A1 refers to the provisions of ANSI/AISC N690 or ANSI/AISC N690L for nuclear safety-related structures.

The applicant is requested to confirm whether it has considered provisions of ANSI/AISC N690 or ANSI/AISC N690L in the calculation of 'b_e'.

ANSWER:

Technical Report MUAP-10001 has been incorporated into Technical Report MUAP-10006, Rev. 3.The seismic methodology has been updated to perform soil-structure interaction (SSI) analyses of the US-APWR reactor building (R/B) complex, which now consists of the R/B, prestressed concrete containment vessel (PCCV), containment internal structure (CIS), east power source building (PS/B),west PS/B,auxiliary building (A/B), and essential service water pipe chase(ESWPC) all on a common basemat, using a dynamic finite element (FE) model.

(i)Section 02.4.1.1.1 of Technical Report MUAP-10006, Rev. 3corresponds to and supersedes Section 4.3.1.1 of Technical Report MUAP-10001.The text of Section 02.4.1.1.1 has been expanded as follows to explain the connectivity between the various elements:

The development of the model ensures that the connection between two different element types is such that an adequate transfer of forces and/or moments from one structural component to the other is enabled. The nodes of the solid elements have only three translational degrees of freedom and therefore do not transfer the moments from shell or beam elements. In order to enable the transfer of bending moments from the walls modeled by shell elements to the basemat and massive concrete sections of the CIS modeled by solid elements, the shell elements are extended into or overlaid on the solid elements as shown in Figure 02.4.1.1.1-5.In SASSI, the translational degrees of freedom (DOF) of the common nodes are shared by the solid element and the extended shell element, but the rotational DOFs are associated only with the extended shell elements. The extended shell elements are assigned with the same stiffness as the shell element of the wall. By doing so, a proper rotational constraint is imposed on the connection.A preliminary study was performed on a flexible wall panel that is located in the basement of the west PS/B to investigate the effect of the rotational stiffness on its out-of-plane dynamic properties. The flexible wall panel dimension is approximately 30 ft (high) x 55 ft (long) x1.5 ft (thick). In the study, the panel is assumed to be simply supported by the ground slab at top and other basement walls at the two ends. Compared to the fixed condition at intersection of the wall and the basemat, which doesn't allow rotation of the wall at the top of the basemat, with the arrangement described above, the difference on the fundamental frequencies of the out-of-plane vibration is insignificant.

In addition, each node of the SASSI shell elements has five degrees of freedom that enable beam elements to transfer forces and bending moments to shell elements but not torsional moments. Therefore, massless beam elements are generated on the surface of the shell or solid elements in order to provide adequate transfer of moments from beams in all three rotational degrees of freedom. For beams or columns connecting to slabs or walls in the R/B complex model, the effect of adding torsional stiffness to the slab and wall shell elements is evaluated and the impact on the results is found to be negligible.

(ii) The previous Technical Report MUAP-10001, Rev. 3 Figures 4.3.1.1-6 and 4.3.1.1-7 correspond toFigures 02.4.1.1.1-7 and 02.4.1.1.1-8in Technical Report MUAP-10006, Rev. 3.As described in the last paragraph of Section 02.4.1.1.1 massless rigid beams and massless surface beams are used to connect structural beams to shell elements. Massless surface beams are necessary to simulate a rigid base and transfer the bending moments of the attached reactor coolant loop (RCL)structural members into walls or slabs by coupled forces transferred to nodes of the shell elements from the attaching surface beams. The surface beams are assigned wth axial stiffness (EA/L) and bending stiffness (EI) of ten times the corresponding wall element stiffness.The surface beams are then considered as rigid compared to the wall with this assumption. Their stiffness effect is local and does not significantly affect the global responses of seismic accelerations and in-structure response spectra (ISRS).

(iii) Section 02.4.1.1.2 of Technical ReportMUAP-10006, Rev. 3, which superseded the referenced Section 4.3.1.2 of Technical Report MUAP-10001, Rev. 3,determined that the mesh size needed to be equal to or less than 21 ft in order to be able to transfer shear waves with frequencies up to 70 Hz for modeling of concrete fill but does not address walls and slabs. The average mesh size of the solid elements representing the concrete fill in the dynamic model of 9 feet satisfies this requirement.To accurately capture local out-of-plane vibration modes of floors, which have lower frequencies than walls, Section 02.4.1.1.8 of Technical Report MUAP-10006, Rev. 3 addresses modeling of slabs, which need more refined mesh than walls to capture responses of the local out-of-plane modes up to 70 Hz for the uncracked model.In accordance with the requirements of SRP 3.7.2, the validation is based on comparison of responses obtained from a series of static and dynamic analyses performed on the dynamic FE models and detailed FE models with a more refined mesh that includes all important structural details such as eccentricities and openings in walls and slabs. Sections 02.5.1.3 and 02.5.1.5 of Technical Report MUAP-10006, Rev. 3 present the results of the validation analyses performed to confirm the sufficiency of the dynamic model. Thus, the detailed model is refined enough to adequately represent the dynamic properties of the US-APWR standard plant seismic category I structures.

(iv) The provisions of ANSI/AISC N690 have been considered in the calculation of 'b_e' in addition to the provisions of ANSI/AISC 360-05.The sentences of Section I3,which stated,"Above requirements are applicable when the flange of the composite section is in compression.When the flange is in tension, smaller values of 'be' could be used,"arenot included in Technical Report MUAP-10006, Rev. 3. Two bounding stiffness levels are modeled in the SSI analysis. For the full stiffness case (uncracked), the composite beam stiffness is represented by the 75% linear equivalent stiffness of the transformed section under positive moment, which corresponds to the slab under compressive load and without cracking. The 75% is required per the code to consider the difference in stiffness along the beam length. For the reduced stiffness case, no composite effect for the beams is considered and only stiffness of the steel beam is considered.

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 Technical/Topical Report.

This completes MHI's response to the NRC's question.