US-APWRRAIsPEm Resource

From:	Buckberg, Perry
Sent:	Friday, November 15, 2013 12:06 PM
To:	'us-apwr-rai@mhi.co.jp'; US-APWRRAIsPEm Resource
Cc:	Dixon-Herrity, Jennifer; Galvin, Dennis; Tegeler, Bret; Shams, Mohamed
Subject:	PROPRIETARY US-APWR Design Certification Application RAI 1060-7285 (Section 3.7.2)
Attachments:	Non-PROP US-APWR DC RAI 1060 SEB1 7285.pdf

MHI,

The Non-PROP attachment contains the redacted subject request for additional information (RAI). This RAI was sent to you in draft form on October 28, 2013. Your licensing review schedule assumes technically correct and complete responses within 60 days of receipt of RAIs.

The attached version of the RAI will be made publicly available.

Please submit your RAI response to the NRC Document Control Desk.

Thanks,

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REQUEST FOR ADDITIONAL INFORMATION 1060-7285

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Application Title: US-APWR Design Certification - Docket Number 52-021
Operating Company: Mitsubishi Heavy Industries

Docket No. 52-021

Review Section: 03.07.02 – Seismic System Analysis
Application Section: 3.7.2

QUESTIONS:

03.07.02-231

The applicant submitted information in support of the adequacy of the design-basis ACS-SASSI soil-structure interaction (SSI) analysis model using the Modified Subtraction Method (MSM) in the response to RAI 812-5983, Question 03.07.02-109. The RAI response does not provide sufficient information for the staff to make a definitive determination of the acceptability of the applicant's implementation of the MSM for the US-APWR SSI analyses. To assist the staff in its review, the applicant is requested to provide the following additional information:

(1) The RAI response indicates there are “minor differences” between the model of the Reactor Building (R/B) complex used in the two comparison studies described therein, and the model documented in technical report MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant," Revision 3. However, there is no discussion of the differences in the RAI response. Describe the model differences and explain why they are judged to be not significant for the comparison studies.

(2) Identify the S-wave passing frequencies for each of the models used in the two comparison studies described in the RAI response. Passing frequencies and corresponding layer/mesh sizes for vertical and horizontal East-West and North-South directions should be clearly identified for all the soil layers.

(3) For all six (6) soil cases described in technical report MUAP-10006, Revision 3, identify the fundamental natural frequency of the excavated soil mesh used to define the embedded SSI model of the R/B complex. Since prior staff experience indicates that any anomalies in the MSM analysis are likely to appear at or above these natural frequencies, discuss whether any identifiable anomalies exist in the computed transfer functions, at or above the natural frequency of the excavated soil mesh, in any of the comparison studies or design basis analyses performed, including the additional study requested in item (5) below.

(4) The bonding of the embedded structure to the side soil differs in the studies described in the RAI response and in the design basis analysis described in the technical report MUAP-10006, Revision 3. The comparison study denoted “study 1” in the RAI response considers both unbonded and fully bonded cases, but the comparison study denoted “study 2” considers only the unbonded case. In MUAP-10006, Revision 3, on the other hand, only fully bonded conditions are considered. To assess the impact of the unbonded vs. bonded assumption, provide additional figures that compare the results for the unbonded vs. bonded cases that correspond to Figures 1 through 4 in the RAI response (study 1).

(5) The comparison studies described in the RAI response consider only soil cases 270-200 and 560-500. Provide the results of an additional MSM vs. Direct Method (DM) comparison study that considers soil case 900-100 and the fully-bonded model used in study 1 (kinematic interaction

model). The shear wave passing frequency in this additional study should be at least as high as the passing frequency in the design basis analysis for this soil case (approx. 40 Hz).

03.07.02-232

Part 1

Figure 03.3.4.1-3, "Excavated Soil Volume Elements," of technical report MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant," Revision 3, shows the finite element mesh used to model the excavated soil volume of the embedded Reactor Building (R/B) complex. The staff notes that under the Pre-stressed Concrete Containment Vessel (PCCV) there are regions where the mesh is irregular and the elements are highly distorted. To ensure the ACS SASSI soil-structure interaction (SSI) solution is not sensitive to such irregularly meshed regions, the applicant is requested to provide the following additional information:

(1) What is the value of the parameter “R” (radius of the central zone in the point load solution) used in the design basis analysis, how was it determined, and how does it compare to the generic SASSI recommendations for a uniform mesh?

(2) Provide the results of a comparison study that demonstrates the ACS SASSI SSI solution is insensitive to the mesh irregularity noted above. The two SSI analyses to be compared should have (a) the irregular mesh and the parameter “R” used in the design basis analysis, and (b) a uniform mesh and the parameter “R” that satisfies the generic SASSI recommendations. For the purpose of this study, soil case 900-100 should be used; the superstructure may be represented by a lumped-mass stick model. The S-wave passing frequency should be at least as high as the passing frequency in the design basis analysis for soil case 900-100 (approx. 40 Hz). The Modified Subtraction Method (MSM) may be used and the results should be provided in terms of transfer functions and In-Structure Response Spectra (ISRS) at the following locations: four (4) corners, both top and bottom, of the excavated volume; center of bottom of the excavated volume; center of PCCV, at the top of the excavated volume; and top of the PCCV (11 locations total).

Part 2

Table 03.3.5-1, "Matrix of ACS SASSI Runs," of technical report MUAP-10006, Revision 3, indicates the cut-off frequency of the SSI analysis is 40 Hz for generic soil profiles 270-200 and 270-500, and 50 Hz for generic soil profiles 560-500, 900-100, 900-200 and 2032-100. However, the staff notes that the passing frequency of several SSI model soil profiles are lower than the analysis cut-off frequency. Based on layer thickness, the S-wave passing frequency for cases 270-200, 270-500, and 560-500 is indicated as 36.2 Hz, 33.6 Hz, and 38.2 Hz, respectively (Tables 03.3.1-1, "Input 270-200 Soil Properties," 03.3.1-2, Input 270-500 Soil Properties 03.3.1-3, "Input 560-500 Soil Properties," and 03.3.4.1-1, "S-Wave Vertical Mesh Passage Frequencies of the Excavated Volume Element"). Based on average horizontal dimension of the excavated volume mesh in the East-West direction, the passing frequencies for cases 270-200, 270-500, 560-500, 900-100, and 900-200 are indicated as 32.7 Hz, 31.9 Hz, 29.1 Hz, 41.4 Hz, and 42.7 Hz, respectively (Table 03.3.4.1-3, "EW Wave Passage Frequencies of the Excavated Volume Element"; slightly larger values are given in Table 03.3.4.1-2, "NS Wave Passage Frequencies of the Excavated Volume Element," for the North-South direction). Below the basemat, the passing frequencies for cases 270-200, 270-500, and 560-500 isare indicated as 32.5 Hz, 34.3 Hz, and 44.5 Hz, respectively (Table 03.3.5-2, "Wave Passage Frequencies of the Model Below Foundation").

Section 03.3.5 of the report indicates that passing and cutoff frequencies below 50 Hz for the soil sites are acceptable because (a) for the soil sites, the relatively softer soil will filter out high frequency content of the input motion propagated from the hard rock basement (supporting reference identified); and (b) cases 270-200 and 270-500 control the seismic response, in terms of the ISRS at various locations, only at frequencies far below 30 Hz.

However, the report provides no justification for the acceptability of the passing frequencies for cases 560-500, 900-100, and 900-200 (29.1 Hz, 41.4 Hz, and 42.7 Hz, respectively), which are all below 50 Hz.

To assist the staff in determining the adequacy of the SSI models developed for the analysis of the six (6) generic soil profiles, the applicant is requested to provide the following additional information:

(1) Revise Section 03.3 of MUAP-10006, Revision 3, (e.g., pgs. 3.3-6 and 3.3-9) to clarify the distinction between model passing frequencies and analysis cutoff frequencies.

(2) In light of a passing frequency of 29.1 Hz for soil case 560-500, confirm that this soil case does not control the seismic response at frequencies above 29.1 Hz, and supplement the justification provided in Section 03.3.5 of the report to cover this soil case.

(3) Revise DCD Tier 2, Section 3.7 to be consistent with the revisions to MUAP-10006, Revision 3, indicated in items (1) and (2) above.

(4) The stiff profiles 900-100 and 900-200 appear to control the seismic response in the frequency range of 30-50 Hz; however, the passing frequency for these two cases is only slightly above 40 Hz. Provide the results of a study that demonstrates the sensitivity of seismic response for the 900-100 case when the passing frequency is increased from 40 Hz to 50 Hz. It is not necessary to consider the 900-200 case because its seismic response is expected to be very similar to the 900-100 case. The simplified model described in Part (1) of this RAI should be used to perform this study, with the uniform mesh for the excavated volume and the MSM. The results should be provided in terms of transfer functions and ISRS at the locations identified in Part (1). Add a statement to MUAP-10006, Revision 3, documenting that the SSI models for the 900-100 and 900-200 profiles are adequate up to 50 Hz, if the study results support such a conclusion.

03.07.02-233

Part 1

The soil-structure interaction (SSI) and structure-soil-structure interaction (SSSI) models described in the technical report MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant," Revision 3, include solid brick elements connecting the free field soils and the basement structural elements, in order to simulate the near field backfill material that is expected to surround the structures. In the case of the SSSI analysis, backfill elements are also utilized in the volume between the Reactor Building (R/B) Complex and Turbine Building (T/B) basements. These backfill elements are shown in Figures 03.3.4.1-4, "R/B Complex with Backfill Soil Elements," through 03.3.4.2-3, "SSSI Model with Backfill and Free Field Soils (Looking East)."

The applicant is requested to provide the following additional information related to modeling of backfill:

(1) Tables 03.3.1-8, "Backfill Small-Strain Properties for Profiles 270-200, 270-500 and 560-500," and 03.3.1-9, "Backfill Small-Strain Properties for Profiles 900-100, 900-200 and 2032-100," indicate small-strain P-wave velocities between 1350 ft/s and 2500 ft/s, which implies the backfill is not saturated. Since the SSI analysis assumes saturated conditions for the free field soils up to grade elevation, explain the technical basis for the unsaturated assumption for the backfill. Revise MUAP-10006, Revision 3, to address this inconsistency.

(2) Clarify whether stresses in the backfill elements, as computed from the SSI analysis, are used to estimate dynamic soil pressures for design of embedded walls. If this is not the case then revise MUAP-10006, Revision 3, to add this clarification.

(3) Revise DCD Section 3.7 to be consistent with the revisions to MUAP-10006, Revision 3, indicated in items (1) and (2) above.

Part 2

The guidance in SRP 3.7.2, Revision 3, SRP Acceptance Criterion 4, “Soil Structure Interaction,” indicates that sensitivity studies should be performed to identify the effects of potential separation of soil from sidewalls, to assist in judging the adequacy of the SSI analysis results. Similar guidance is indicated in the ASCE 4-98 standard.

MUAP-10006, Revision 3, does not include results of such sensitivity studies. Therefore, the applicant is requested to provide the results of sensitivity studies performed to investigate the effect of potential separation of the lateral soil from the embedded sidewalls of the R/B Complex. The results should be provided in terms of transfer functions and In-Structure Response Spectra (ISRS) at key locations throughout the structure.

03.07.02-234

Each nonlinear sliding analysis described in MUAP-12002, "Sliding Evaluation and Results," Revision 1, is based on the simultaneous input of three perpendicular input acceleration time histories in the X, Y and Z directions. The analysis is for only 1 of 8 possible combinations of the X, Y, and Z input motions (i.e., +x+y+z; +x+y-z; +x-y+z; +x-y-z; -x+y+z; -x+y-z; -x-y+z; -x-y-z). Because nonlinear sliding analyses may be affected by the phasing between the three input motions, particularly between the vertical and horizontal directions, the effect of phasing between the three input motions should be considered. Therefore, the applicant is requested to evaluate all 8 combinations, for the time history case that produced the largest sliding response, in order to ensure that the worst case sliding displacement has been determined.

03.07.02-235

In Section 02.5.1.5, “Validation of the Dynamic Model Translation into SASSI Format,” of MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant," Revision 3, the ACS SASSI acceleration transfer functions (ATFs) are used to identify a limited number of low-frequency modes that are close to those identified in the ANSYS modal analyses. However, this validation approach, which compares the two structural models at only a few frequencies, does not cover the entire frequency range of interest and does not compare the magnitude of amplification. To assist the staff’s evaluation of the conversion of the ANSYS dynamic model to the ACS SASSI model, the staff requests that the applicant submit a comparison of the results of the harmonic analysis of the ANSYS dynamic model and the ATFs from the ACS SASSI analysis, at representative locations throughout the Reactor Building (R/B) complex, including the roof, an intermediate elevation, and at the bottom of buildings on the common R/B complex basemat.

03.07.02-236

Section 02.4.1.1.4, “Modeling of Mass,” of MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant," Revision 3, and Figure 02.4.1.1.4-1 “Example of Hydrodynamic Masses”, show that the impulsive mass is separated into two parts: impulsive mass and constrained mass. Section 02.4.1.1.4 states:

> "The impulsive mass is rigidly fastened to the walls as it moves with the walls responding to the seismic excitation. Depending on the ratio of the water depth to the pit width, the lower portion of the impulsive part can be considered as fully constrained which responds as a rigid body. The impulsive pressure is evenly and uniformly divided into a pressure force on the wall accelerating into the fluid, and a suction force on the opposite wall accelerating away from the fluid.”

From the paragraph above, it is unclear how the constrained and impulsive components of the impulsive mass are calculated and how each is incorporated into the dynamic finite element (FE) model. What is the significance of the “impulsive pressure” in this context? The staff requests the applicant to clarify in Section 02.4.1.1.4 of MUAP-10006, Revision 3, how the water mass is incorporated in the dynamic FE model.

03.07.02-237

Section 02.4.1.1.1 , “Finite Element Modeling,” of MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant,” Revision 3, states in part:

> “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 as shown in Figure 02.4.1.1.1-7 and Figure 02.4.1.1.1-8 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 model, the effect of adding torsional stiffness to the slab and wall shell elements (Allman in-plane rotational stiffness in ANSYS SHELL63 element) is evaluated and the impact on the results is found to be negligible.”

The staff reviewed the cited figures, and is unable to completely understand the modeling techniques used to enforce moment transfer between beams and shells and between beams and solids. In Figures 02.4.1.1.1-7, "Connection of Beam to Solid Elements," and 02.4.1.1.1-8, "Connection of Beam to Shell Elements," rigid massless beams, called a massless tripod in the figures, connect the beam element to the shell or solid element, creating an eccentric constraint with respect to the beam element axis. The rigid massless beams are shown to be attached to the beam element at a finite distance along the beam axis, away from the beam/shell or beam/solid intersection point.

The staff requests the applicant to perform a simple analysis of a typical beam-to-solid connection utilizing the massless tripod approach. Describe the tripod model properties, and show that the desired moment transfer is accomplished.

03.07.02-238

Section 02.5.1.5 “Validation of the Dynamic Model Translation into SASSI Format,” of MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant," Revision 3, first paragraph, states:

> “Since the ANSYS FE formulation implementation is not identical with the SASSI FE formulation implementation, a few modifications were applied to the SASSI FE model to improve its numerical conditioning for the SASSI analysis. These FE model modifications were related to the introduction of appropriate boundary condition constraints for the node rotational degree of freedoms of the SOLID and SHELL elements, to avoid potential stiffness matrix singularities due to zero rotational terms.”

The staff is aware that there are incompatibilities between ANSYS and SASSI that require special consideration in the conversion of an ANSYS model to a SASSI model. However, the staff finds the explanation provided in the subsequent paragraphs of Section 02.5.1.5 to be confusing, and in need of clarification. To assist the staff in its evaluation of the SASSI structural model, the staff requests the applicant to revise Section 02.5.1.5, to clarify the approaches used to eliminate rotational singularities.

03.07.02-239

In Section 02.4.1.1.2 “Discretization Considerations: Mesh Size,” of MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant," Revision 3, the applicant presents an adequate description of its approach to ensuring that the ANSYS dynamic model is capable of accurately picking up out-of-plane slab vibration modes up to 70 Hz, for uncracked concrete properties. However, the staff needs additional information relating to modeling of flexible walls before it can complete its evaluation of the adequacy of the ANSYS dynamic model. To assist the staff, the applicant is requested to submit comparisons between fundamental frequencies based on classical plate vibration formulas and those computed using the ANSYS detailed model and the ANSYS dynamic model, for all walls that have out-of-plane fundamental frequencies below 70 Hz, in order to demonstrate that the ANSYS dynamic model discretization is adequate to predict the out-of-plane flexural deformation. If the element mesh for a particular wall is not adequate, discuss how the additional amplification at the center of the wall will be calculated.

03.07.02-240

Section 02.5.1.1, “Development of the Reactor Building Complex Dynamic FE Model,” of MUAP-10006, "Soil-Structure Interaction Analysis and Results for the US-APWR Standard Plant," Revision 3, states:

> “The global origin is located at the center of the PCCV and top of the basement with the X axis pointing North, Y axis pointing West, and Z axis pointing upward. Once the model is translated into SASSI format, the global coordinate system is rotated 180 degrees about the Z axis so that the X axis is pointing South and the Y axis pointing East.”

The use of two different coordinate systems in the models creates confusion in interpreting the results and can potentially become a source for misapplication of the data in detailed design certification (DC) design and combined operating license (COL) applications. Therefore, the applicant is requested to revise MUAP-10006, Revision 3, to provide clarification of the orientation of the coordinate system used in the figures and tables. The clarification should address whether the coordinate system shown on each figure relates to either the ANSYS or the SASSI coordinate system.

03.07.02-241

The staff issued RAI 1018-7083, Question 03.07.02-224, as a result of the acceptance review of MUAP-11002, "Turbine Building Model Properties, SSI Analyses, and Structural Integrity Evaluation," Revision 2. The applicant's response to RAI 1018-7083, Question 03.07.02-224, indicates that the proximity of the larger and heavier Reactor Building (R/B) Complex to the Turbine Building (T/B) induces higher structural demands on the T/B and Electrical Room structures during the design basis earthquake. **PROPRIETARY information has been removed**{

}**PROPRIETARY information has been removed** The applicant also considered both cracked and uncracked concrete properties, as compared to only cracked concrete properties as described in MUAP-11002, Revision 2. The new results are incorporated in MUAP-11002, Revision 3.

In Table 6.2-1, "Turbine Building and Electrical Room Minimum Overturning Factor of Safety for each Subsurface Profile," of MUAP-11002, Revision 3, prior to the application of the SSSI correction factors, the minimum overturning factors of safety are identical in both the N-S and E-W directions, except for a slight difference for soil profile 270-500. The staff finds this unusual, considering that the plan dimensions of the T/B differ substantially in the two horizontal directions. In addition, considering the geometry of the building and the vertical mass distribution (steel braced-frame superstructure and massive concrete substructure), the reported factors of safety appear to be low.

Section 6, "Stability Evaluation," of MUAP-11002, Revision 3, does not provide sufficient information for the staff to understand how the reported results were derived. To assist the staff in its evaluation, the applicant is requested to provide a detailed description of and the technical basis for the methodology used to calculate the overturning factors of safety; if feasible, provide a sample calculation demonstrating the methodology.