RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

3/24/2014

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 1060-7285 REVISION 4**
SRP SECTION:	**03.07.02 – SEISMIC SYSTEM ANALYSIS**
APPLICATION SECTION:	**3.7.2**
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QUESTION NO. 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 no 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 stiffnesses.

ANSWER:

MUAP-10006, Revision 3, Section 02.5.1.5, is revised to clarify the approach used to eliminate rotational stiffnesses as shown in Attachment 1. The second and third paragraphs of Section 02.5.1.5 are revised and the last two paragraphs are deleted. Tables 02.5.1.5-1 through 02.5.1.5-3 and Figures 02.5.1.5-2 through 02.5.1.5-3 are also deleted.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

MUAP-10006, Rev. 3 is revised as shown in Attachment 1.

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

02.5.1.5 Validation of the Dynamic Model Translation into SASSI Format

After the individual Dynamic FE models are validated against the Detailed FE models, the combined R/B complex Dynamic FE model is translated into SASSI (Reference 02-1) using the built in file converter. To confirm that the translation is accurate, a SASSI analysis is performed on the R/B complex model sitting on hard rock to simulate a fixed base condition. ATF are produced at prescribed locations presented in Figure 02.5.1.5-1 and compared with modal analysis results obtained from ANSYS to ensure that the structural response is accurate. The following Sections demonstrate that the integrated 3-D Dynamic SASSI model accurately represents the structural response of the combined Dynamic FE model developed in ANSYS.

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 SASSI software includes a 3-D four-node Plate/Shell element with three translational and three rotational degrees of freedom per node. The shell elements are similar to the SAP IV thin Kirchhoff shell/plate elements. There is no stiffness corresponding to the in-plane rotational (drilling) degree of freedom in the element coordinate system for this shell/plate element. In the analysis of flat plates the stiffness associated with the rotation normal to the shell surface is not defined; therefore, the rotation normal degree of freedom must not to be included in the analysis. In cases where the curvature is very small or for flat plates, the in-plane rotational degree of freedom should be restrained by the addition of a "Spring/Boundary element" with a small rotational stiffness to prevent a numerical instability. In the SAP IV User Manual, Bathe and Wilson (Reference 02-12) suggested the normal rotational stiffness should be less or about 10% of the element bending stiffness, so that there is no influence on the system behavior. ~~i~~In order to improve the numerical conditioning for the stiffness matrix, for the shell/plate elements that are oblique to global coordinate axes, small rotational stiffnesses around the normal axis to the shell elements were added to avoid the in-plane rotation singularity. The added rotational stiffnesses were equal to 10 kips-ft/rad. ~~that is 0.0001-0.000001 times the shell element out-of-plane bending stiffnesses~~. In the cases of shell elements that are all in the same plane that is parallel to one of the global coordinate axes (with no other element type with rotational stiffness around the normal of the shell common plane), then, the in-plane rotations were fixed for those elements.

~~Three nodes are selected for the R/B complex FE model for illustration; two nodes are on the PCCV shell at different elevations and one node is on the top floor of the CIS, as shown in Figure 02.5.1.5-2 and Figure 02.5.1.5-3. Their coordinates are listed in the Table 02.5.1.5-1. The nodes and corresponding equation numbers are listed in Table 02.5.1.5-2. The diagonal stiffness matrix elements for the selected finite elements are listed in Table 02.5.1.5-3. Compare the shell element bending values, kr_{xx}, kr_{yy} and kr_{zz} that have values of hundreds of thousands, or millions, with the spring rotational stiffnesses introduced to improve the system numerical conditioning that are slightly less than 10. Thus, the added numerical rotational stiffnesses are negligible in comparison with the shell stiffnesses.~~

~~All rotations for the nodes that belong to only solid elements were also fixed.~~

Delete

Table 02.5.1.5-1 Nodes Coordinates List

Node ID	Constraint ID						X	Y	Z	Location
43505	0	0	0	0	0	0	76.75	0	17.363	Containtment Wall – Low Elevation
56612	0	0	0	0	0	0	56.583	-6.75	75.417	Internal Structure Floor – High Elevation
61858	0	0	0	0	0	0	76.143	0	165	Containtment Wall – High Elevation

Delete

Table 02.5.1.5-2 Nodes Equation Numbers

Node Number	Equation Number for All Six DOFs (X, Y, Z, XX, YY, ZZ)					
43505	148925	148926	148927	148928	148929	148930
56612	212197	212198	212199	212200	212201	212202
61858	235425	235426	235427	235428	235429	235430

Delete

Table 02.5.1.5-3 Structural Stiffness on the Nodes

Node ID	Diagonal Stiffness Matrix Elements (Compare with Rotational Spring Stiffness of less than 10)					
	k_{xx}	k_{yy}	k_{zz}	kr_{xx}	kr_{yy}	kr_{zz}
43505	8379546	10309727.4	5983420	119052.4	57198349	92811478
56612	3935851.3	2981937.5	1895002	6095676	4413599	1945899
61858	3876490.3	7042790.5	4745087	875550.8	25236092	41467446

Attachment 1
RAI 1060-7285 Q3.7.2-238

~~Figure 02.5.1.5-2 Nodes on PCCV~~

~~Figure 02.5.1.5-3 Nodes on the Floor of the CIS~~