RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/27/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 1045-7141 REVISION 3**
SRP SECTION:	**03.08.05 – Foundations**
APPLICATION SECTION:	**3.8.5**
DATE OF RAI ISSUE:	**07/08/2013**

QUESTION NO. 03.08.05-54:

On April 3, 2013, the applicant submitted a markup of DCD Tier 2 Section 3.8 to provide updated information related to a seismic design change.

In Subsection 3.8.5.4.3, "Boundary Condition of Basemat," the first paragraph (Page 3.8-99) states, "For basemat analysis, the equivalent static seismic accelerations are linearly reduced such that for each soil profile, the maximum shear produced by an earthquake in a given direction is 10% greater than the corresponding maximum shear values produced in the SSI [soil-structure interaction] analysis."

The information presented above is not clear to the staff. The staff requests the applicant to describe clearly how the earthquake design loads for the basemat are obtained.

ANSWER:

The following methodology was used to transfer the seismic response loads determined from the dynamic model (SASSI) to the structural model (ANSYS) used in the detailed design analysis to comply with Standard Review Plan (SRP) 3.7.2, Acceptance Criteria II.3.E.

Earthquake design loads are computed as a function of applied static seismic accelerations multiplied by the self-weight, lumped masses, and that portion of live load (25 percent) attributed as seismic mass. The following steps were taken in the development of the equivalent static load used in the seismic design of the basemat:

<u>Step 1, Development of Acceleration Values from SASSI</u>

1.1 The results of SASSI time-history analysis were obtained from the 12 cases that included six independent soil types under cracked and uncracked concrete conditions. Refer to MHI Technical Report MUAP-10006, Rev. 3, for further information on the results of soil-structure interaction (SSI) analysis.

1.2 The maximum absolute nodal accelerations in the global X, Y, and Z directions were extracted for each node on each nominal floor elevation in each structure of the reactor building (R/B) complex regardless of time-step.

1.3 Maximum nodal accelerations were averaged (using a weighted average) over each floor slab to generate a single equivalent static acceleration for each nominal floor slab elevation within the R/B complex structure. Weighted average accelerations were performed in using Equation 03.3.7-1 of MHI Technical Report MUAP-10006, Rev. 3.

Step 2, Application of Equivalent Static Accelerations

2.1 The acceleration values for cracked and uncracked concrete conditions computed in Step 1.3 were enveloped for each R/B complex structure individually for each of the two specific soil profiles modeled. Refer to MHI response to RAI No. 1045-7141, Question 03.08.05-56 for a description of the two soil profiles (270-500 and 2032-100) that were selected from the six generic soil profiles to perform the structural analyses.

2.2 Accelerations were applied to the R/B complex structure mass individually in each axis.

2.3 The affect of the acceleration on wall elements was accounted for in the ANSYS finite element (FE) model by averaging the Step 2.1 accelerations from the floors above and below the wall element, and then applying this average acceleration to the mid-height of the wall.

Step 3, Basemat Bottom Shear Comparison and Reduction of Seismic Shear Forces

3.1 The base shear acting at the bottom of the basemat and the overturning moment forces were computed using the ANSYS FE analysis model.

3.2 The base shear acting at the bottom of the basemat computed in Step 3.1 was compared with the base shear force acting at the bottom of the basemat as computed from the SASSI time-history analysis. The SASSI time-history analysis results provided in Table 1 for the maximum base shear and overturning moment reaction forces are computed considering the time-history domain. [Note: Although this approach results in different values than the results described in Section 03.4.3 and associated Table 03.4.3-7 of Technical Report MUAP-10006 Rev. 3, they are bounded by the MUAP-10006 Rev.3]

3.3 Horizontal acceleration values from Steps 2.2 and 2.3 were factored (reduced) so that the resulting shear and overturning moment from the SASSI analysis continued to be bounded by the results of the ANSYS FE analysis used in the basemat design. A summary of the resulting base shear comparison made in Steps 3.2 and 3.3 is provided in Table 1 of this response.

All of the base shear and moment reactions computed in the ANSYS FE analysis model for the basemat were greater than those values computed in the SSI time-history analysis. If the resulting base shear (Fx and Fy) in the FE analyses exceeded the SSI shear values by more than 10 percent, a reduction factor was applied to the shear forces of each structure in the FE model to limit the base shear load to a 10 percent margin above the SSI time history shear. Table 1 identifies the three individual shear forces that were reduced along with the margin between the SSI and FE analysis. The 10 percent margin was chosen because the resultant shear forces envelopes all base shears from all other soil sites. A margin still remains in the overturning moment as shown in Table 1.

3.4 The process described in Step 3.3 was repeated independently in each direction (Global X, Y and Z) for each evaluated soil type prior to application of the 100-40-40 rule for directional combined loading.

3.5 No reduction factors were directly applied to overturning moments computed in the ANSYS basemat structural analysis model. The factored shear loads were applied to the structural model with consideration to location and orientation and the resulting moments were applied to the foundation. The FE moments were confirmed to be equal to or greater than the overturning moments computed from the SASSI time-history analysis. The FE analysis overturning moments are provided in Table 1 of this response.

Step 4, Application of Seismic Accelerations

The enveloped seismic accelerations were applied to the self-weight, lumped masses and that portion of live load (25 percent) acting as seismic mass at the provided elevations in the R/B complex model to produce the earthquake design loads for the basemat structural analysis. Seismic loading on the FE analysis model was performed utilizing the 100-40-40 rule to account for the directional combinations. Directional combinations of the seismic loading resulted in 24 permutations as shown in Table 2. These directional combinations shown in Table 2 were applied to each of the two evaluated soil conditions separately.

Table 1: Base Shear and Overturning Moment Comparison

Notes:

1.) Basemat model uses the enveloped values of equivalent static accelerations of both the cracked and uncracked SSI models.

2.) Definitions:

Fx: Shear Force in North-South Direction — Mx: Overturning Moment in North-South Direction

Fy: Shear Force in East-West Direction — My: Overturning Moment in East-West Direction

Fz: Force in Vertical Direction — Mz: Torsional Moment, Moment in the Z-Direction

R_f: Coefficient applied to shear forces (Fx and Fy directions) to limit the base shear load to a 10 percent margin above the SSI time-history shear. R_f = 1.0 provides no adjustment to shear values in the model. The three instances where a reduction was applied contain a $R_f \leq$ 1.0 and are indicated by cells with bold borders.

3.) $\%_M$: Margin of the ANSYS FE analysis basemat model seismic loading as compared to the values in the SSI analysis.

Table 2: Seismic Load Combinations Employed Using 100-40-40 Newmark Method

Permutation No.	Component Load Factors		
	E_{NS} (Global X - Direction)	E_{EW} (Global Y - Direction)	E_{V} (Global Z - Direction)
1	1	0.4	0.4
2	1	-0.4	0.4
3	1	0.4	-0.4
4	1	-0.4	-0.4
5	-1	0.4	0.4
6	-1	-0.4	0.4
7	-1	0.4	-0.4
8	-1	-0.4	-0.4
9	0.4	1	0.4
10	-0.4	1	0.4
11	0.4	1	-0.4
12	-0.4	1	-0.4
13	0.4	-1	0.4
14	-0.4	-1	0.4
15	0.4	-1	-0.4
16	-0.4	-1	-0.4
17	0.4	0.4	1
18	0.4	-0.4	1
19	-0.4	0.4	1
20	-0.4	-0.4	1
21	0.4	0.4	-1
22	0.4	-0.4	-1
23	-0.4	0.4	-1
24	-0.4	-0.4	-1

Impact on DCD

DCD Subsection 3.8.5.4.3 is revised as indicated in Attachment 1 of this RAI.

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

There is no impact on a Technical/Topical Report.

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

Attachment 1

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The upper portion of tendon gallery is conservatively modeled using a concrete strength of 5,000 psi to simplify design while providing for the potential in variation of construction joints.

The R/B complex basemat is simulated with solid elements (ANSYS SOLID45 elements) that are defined by eight nodes having three degrees of freedom at each node; translations in the nodal x, y, and z directions. The R/B complex basemat is divided into six layers in the vertical dimension for areas away from the PCCV. The area below the PCCV is divided into 12 layers in the vertical direction. The portion modeled to simulate the reactor cavity is divided into ten layers in the vertical direction.

The R/B complex basemat is modeled with element divisions in the horizontal direction in a rectangular grid pattern, in areas away from the PCCV. The element divisions in the horizontal direction within the PCCV boundaries, mainly between the primary shield wall and the secondary shield wall, are mostly in a rectangular grid pattern. The element divisions between the secondary shield wall and the PCCV exterior wall are generally in a polar grid pattern as shown in Figure 3.8.5-5.

3.8.5.4.3 Boundary Conditions of Basemat

The basemat subgrade is included in the FE models used for structural design by meshing a sufficiently large volume of soil/rock below and around the basemat. For seismic load cases, the stiffness of the backfill soil is only activated along the face of the R/B complex basemat in the opposite direction of the applied earthquake load. The activation of soil stiffness allows the backfill soil to contribute compression to the exterior walls of the R/B complex basemat during the earthquake load condition. Dynamic lateral soil pressure at applicable locations was superimposed on seismic loads to account for soil–to–structure interactions. ~~For basemat analysis, the equivalent static seismic accelerations are linearly reduced such that for each soil profile, the maximum shear produced by an earthquake in a given direction is 10% greater than the corresponding maximum shear values produced in the SSI analysis.~~ The backfill and side soil are modeled from elevation 2'-7" to elevation -42'-8". Backfill soil ranges from approximately 11' to 14' in width while the side soil extends from the edge of the backfill soil to the extremities of the subgrade soil. The backfill properties used for the standard design are discussed in Subsection 3.7.2.4.1. To increase computational efficiency for the non-linear analyses, the soil subgrade portion of the FE model is condensed into a super element. For all linear analyses, soil layers are modeled explicitly. The properties of the subgrade layers used in the FE model of the subgrade are established based on several profiles selected from the ge… -10006 (Reference 3. …ntative nuclear power plant …

The base shear and moment reaction forces computed in the ANSYS FE analysis model for the basemat are equal to or greater than those values computed in the SSI time-history analysis. The shear forces applied to the FE analyses consider orientation and location within the structure. If the resulting base shear exceeded the SSI shear values then a factor was applied to the shear forces in the FE analysis to limit the base shear load to a 10% margin above the SSI time-history shear. This reduction was applied to the shear values within the model and because these loads consider location and orientation the overturning moment would be affected. The moments in each principal axis computed in the ANSYS FE analysis model are confirmed to bound the overturning moments computed at the basemat in the SSI time-history analysis.

3.8.5.4.4 Analy…

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