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 3**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**11/15/2013**

QUESTION NO. 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. [

] 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.

ANSWER:

Methodology

As presented in MUAP-11002, the factor of safety (FOS) against overturning is the sum of the resisting moments divided by the sum of the overturning moments about the same overturning axis. The resisting moment, overturning moment and resulting FOS about each axis are calculated at each time step (4417 time steps) for each subsurface profile. After the FOS have been calculated for all 4417 time steps, the minimum FOS about each axis is determined for each subsurface profile and is shown in Table 6.2-1 of MUAP-11002.

The overturning FOS for the combined Turbine Building and Electrical Room foundation is calculated at each time step for the following load combination with effects of buoyancy included:

- $D + H + E_s$.

The total resisting moment at each time step, M_{rx} or M_{ry}, is the sum of the:

- Superstructure and substructure dead loads multiplied by their respective orthogonal moment arms about the overturning axis for that direction. The 50 psf superimposed dead load is not included because it is not considered to be a reliable dead load. The total resisting moment is reduced by the moment due to buoyancy.
- Vertical seismic forces multiplied by their respective orthogonal moment arms about the overturning axis for that direction. The vertical seismic force is included in the total resisting moment only if it is acting downward.

The total overturning moment at each time step, M_{ox} or M_{oy}, is the sum of the:

- Horizontal seismic forces multiplied by their respective orthogonal moment arms about the overturning axis for that direction.
- Vertical seismic forces multiplied by their respective orthogonal moment arms about the overturning axis for that direction. The vertical seismic force is included in the total overturning moment only if it is acting upward.
- Overturning moments due to unbalanced static and dynamic lateral earth pressures.

The seismic forces applied at each node of the model are calculated by multiplying the nodal accelerations (X, Y and Z) for that time step obtained from the ACS SASSI SSI analysis by its corresponding nodal mass.

Discussion

Attached Table 1 provides the total resisting moment, the total overturning moment, the minimum FOS, and its associated time step about each axis for each subsurface profile for SSI cracked and uncracked conditions. It should be noted that the minimum FOS in Table 6.2-1 occur at different time steps about the X- (East-West) and Y- (North-South) axes for each subsurface profile. Those different time steps for the X- and Y-axes are shown in Table 1.

The total resisting moments about the X-axis are larger than about the Y-axis, which is consistent with the difference between the X and Y dimensions of the TI substructure. The substructure basemat has dimensions of 342 feet 8 inches by 265 feet 6 inches and has corresponding uncracked resisting moments of 31,758,155 ft-kips (M_{rx}) and 23,780,413 ft-kips (M_{ry}) (see Table 1). The substructure basemat's length-to-width ratio is 1.29. The ratio of the resisting moments, M_{rx}/M_{ry}, is 1.34 which is consistent with the length-to-width ratio.

The minimum FOS about the X- and Y-axes have similar values because the relative difference between the resisting moments are nearly the same as the relative difference between the overturning moments. The influence of the above relationship is seen in Table 1, rounded to the nearest hundredth to show the numerical differences more clearly.

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
There is no impact on the Technical/Topical Report.

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

Table 1
Turbine Building and Electrical Room Minimum SSI Cracked and Uncracked Overturning Factors of Safety (FOS)

Subsurface Profile	Overturning about the E-W Direction (X-Axis)				Overturning about the N-S Direction (Y-Axis)			
	Time Step (sec.)	Total Resisting Moment M_{rx}[1, 2] (ft-kip)	Total Overturning Moment M_{ox} (ft-kip)	Minimum FOS = M_{rx}/M_{ox}	Time Step (sec.)	Total Resisting Moment M_{ry}[1, 2] (ft-kip)	Total Overturning Moment M_{oy} (ft-kip)	Minimum FOS = M_{ry}/M_{oy}
CRACKED SSI								
270-200	9.710	31,740,465	17,812,477	1.78	10.185	23,772,596	13,725,338	1.73
270-500	9.705	31,740,465	17,723,166	1.79	10.185	23,772,596	13,223,450	1.80
560-500	9.685	31,740,465	20,385,001	1.56	11.580	23,772,596	15,028,165	1.58
900-100	9.705	31,740,465	21,755,584	1.46	11.575	23,772,596	16,486,080	1.44
900-200	9.705	31,740,465	21,698,143	1.46	11.575	23,772,596	16,483,745	1.44
2032-100	9.680	31,740,465	22,311,222	1.42	11.570	23,772,596	16,718,363	1.42
UNCRACKED SSI								
270-200	9.685	31,758,155	19,041,177	1.67	11.580	23,780,413	15,090,437	1.58
270-500	9.685	31,758,155	19,074,612	1.66	11.580	23,780,413	15,358,209	1.55
560-500	9.685	31,758,155	21,026,827	1.51	11.580	23,780,413	17,399,471	1.37
900-100	9.685	31,758,155	21,944,341	1.45	11.575	23,780,413	17,624,621	1.35
900-200	9.685	31,758,155	21,456,946	1.48	11.570	23,780,413	17,790,666	1.34
2032-100	9.680	31,758,155	22,476,132	1.41	11.570	23,780,413	17,550,101	1.36

Notes:
1. The respective resisting moments about the X-axis or the Y-axis are the same for all subsurface profiles because the vertical seismic forces are acting upward, at those time steps, and contribute to the overturning moment not to the resisting moment.
2. The differences of resisting moments between cracked and uncracked SSI cases are due to the slight buoyancy difference between two revisions of the buoyancy calculation. Since the difference is insignificant, the cracked case was not updated.