RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

3/27/2014

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 1050-7218 REVISION 3**
SRP SECTION:	**03.07.02 – Seismic System Analysis**
APPLICATION SECTION:	**3.7.2**
DATE OF RAI ISSUE:	**08/30/2013**

QUESTION NO. 03.07.02-228:

In accordance with SRP Section 3.7.2, the staff performs a review of all soil-structure interaction (SSI) analyses to ensure that uncertainties in the phenomenon, such as coupling of the soil and structure are considered.

DCD Section 3.7.2 identifies that ACS SASSI is used to analyze the SSI response of the reactor building (R/B) Complex. The staff notes that the SASSI analysis code is based on linear theory, in which full contact between the bottom of the foundation basemat and the supporting soil is assumed. As such, a review of the tendency to uplift during the transient seismic response is important. The tendency to uplift would be indicated by tensile forces between the bottom of the foundation basemat and the supporting soil.

The staff requests the applicant to describe how the potential for uplift of the foundation basemat from the underlying soil/rock was evaluated for the generic cases considered. In addressing this, for each case considered, quantify the minimum area of the basemat that remains under compression at all times during the transient response (considering the simultaneous effect of the three design-basis ground motions and all applicable gravity loads), as a percentage of the total basemat area. In evaluating potential uplift, assess the acceptability of the uplift relative to acceptable engineering practice. An acceptable method for assessing the potential for basemat uplift is described in SRP (Rev 4), Section 3.7.2.

ANSWER:

The potential for uplift analysis begins with a quasi-static R/B Complex foundation uplift screening analysis to find the critical case that produces the minimum contact area ratio and the critical time step when this occurs. All six generic subgrade profiles are analyzed with Ground Water Level (GWL) at one foot below the plant grade. Both cracked and uncracked concrete section properties are considered. Since the R/B Complex is an asymmetric structure, all 8 permutations of the seismic load directional combinations (±X, ±Y, ±Z) are considered in the calculation.

The screening method for the maximum R/B Complex foundation uplift (minimum contact ratio) is described below.

- The analysis model has a rigid basemat and is placed on rigid subgrade. Compression only contact elements are used for the basemat-subgrade interface.
- Nodal acceleration time histories obtained from SSI SASSI analyses and corresponding nodal masses are used to compute the seismic inertia forces and overturning moments.
- Gravity loads include the self-weight of the R/B Complex and 25% Live Load.
- Buoyancy forces, corresponding to the maximum groundwater level (one foot below grade) are applied at the basemat level.
- Only the static soil pressure (at-rest lateral earth pressure) is considered at the resisting side of the R/B Complex.
- Dynamic soil pressure is conservatively applied only at the driving side, in addition to static at rest pressure, to produce the minimum contact area ratio.
- In addition to the static and dynamic soil pressures described above, a lateral soil pressure due to surcharge of 450 psf is conservatively applied at the driving side.
- The contact area ratio (uplift) is calculated at each time step of the design basis time histories for all six subgrade profiles, two types of concrete sections (cracked and uncracked) and eight permutations of the seismic load directional combinations. During the analysis, when a spring indicates that tensile stresses have developed, the soil/foundation contact area is reduced by removing the spring, and the pressures are then adjusted to maintain force and moment equilibrium. This process is iteratively continued until all tensile stresses are removed without violating equilibrium.

The screening results concluded that minimum contact area ratio is produced by the 900-200 subgrade profile case with uncracked concrete section properties and “-X+Y-Z” seismic load directional combination. This is the identified critical case for uplift. The minimum contact area was found to occur at time T=10.9 seconds from the start of the earthquake.

Next, a time history analysis is performed using ANSYS for the critical case to obtain the foundation dynamic uplift, using the LMSM developed and validated for sliding analysis (Reference 1). The method for this analysis is described below:

- The validated LMSM model for the sliding analysis of R/B Complex with uncracked concrete properties is used. This model has a rigid surface at the bottom of the basemat and a rigid surface modeling the top of the subgrade. These two rigid surfaces are connected to each other using flexible contact elements. The contact elements model Coulomb friction, to simulate sliding, but (unlike in the sliding analyses discussed in Reference 1) can develop both tension and compression forces. Therefore, sliding at the interface is allowed, but no separation or uplift is permitted. In this case, the forces between the structure basemat and the subgrade could be in tension, which is in accord with the requirements described in Section II.4 of SRP 3.7.2 Revision 4 (Reference 2).

- In column motions consistent with the CSDRS were obtained at foundation bottom level from soil-structure interaction analyses performed with ACS-SASSI for the R/B Complex with uncracked concrete properties placed on subgrade profile 900-200 and using the combination “-X+Y-Z” of the three components of the design input motion.
- The In-column motions are applied to the rigid plane representing the subgrade simultaneously in all three directions to perform the time history analyses.

The contact pressure contours calculated at time instant T = 10.9 seconds are presented in Figure 1. The minimum contact area ratio was calculated “using the minimum basemat area that remains in compression with the soil” (Reference 2) and was found to be 82%.This satisfies the minimum 80 percent requirement as indicated in SRP 3.7.2 Acceptance Criteria II.4 Revision 4. It is therefore concluded that the linear SSI analysis methods used for US-APWR standard plant are acceptable.

As a result of the Public Meeting of October 31st, 2013, the following additional questions were raised:

1. How does MHI demonstrate that its nonlinear (uplift and sliding) analysis method is adequate and that the results are reasonable?

   ANSWER: The uplift calculation method discussed above is linear, and in accord with the requirements of Section II.4 of SRP 3.7.2, Revision 4 (Reference 2). The non-linear sliding analysis method used by MHI is discussed in the answer to Question 3.8.5-216(b) of RAI 960-6709.

2. Do MHI’s floor response spectra envelope the results from linear (no uplift and no sliding) and nonlinear (uplift and sliding) analyses?

ANSWER: The floor response spectra are based upon the results of the ACS-SASSI analyses (which are linear), and are using a broadened and enveloped response spectrum. As stated in Section II.4 of SRP 3.7.2, Revision 4 (Reference 2), “linear SSI analysis methods are acceptable if the ground contact ratio is equal to or greater than 80 percent.” As stated above, the minimum contact area ratio was calculated “using the minimum basemat area that remains in compression with the soil” (Reference 2) and was found to be 82%, which satisfies the minimum 80 percent requirement.

3. Are the peak shears, moments, torsions in structural members resulting from nonlinear analysis included or will be included in the design for sectional strength?

   ANSWER: Please see the Answer to Question #2.

4. Will MHI perform nonlinear analyses for the remaining balance of the four types of soils? If not, why not?

   Please refer to MHI Answer to RAI 1045-7141, Question 03.08.05-54.

   References:

   1. MHI Technical Report, MUAP-12002, Rev. 1. Jan. 2013.

2. NRC Standard Review Plan, 3.7.2, Rev. 4. Sept. 2013.

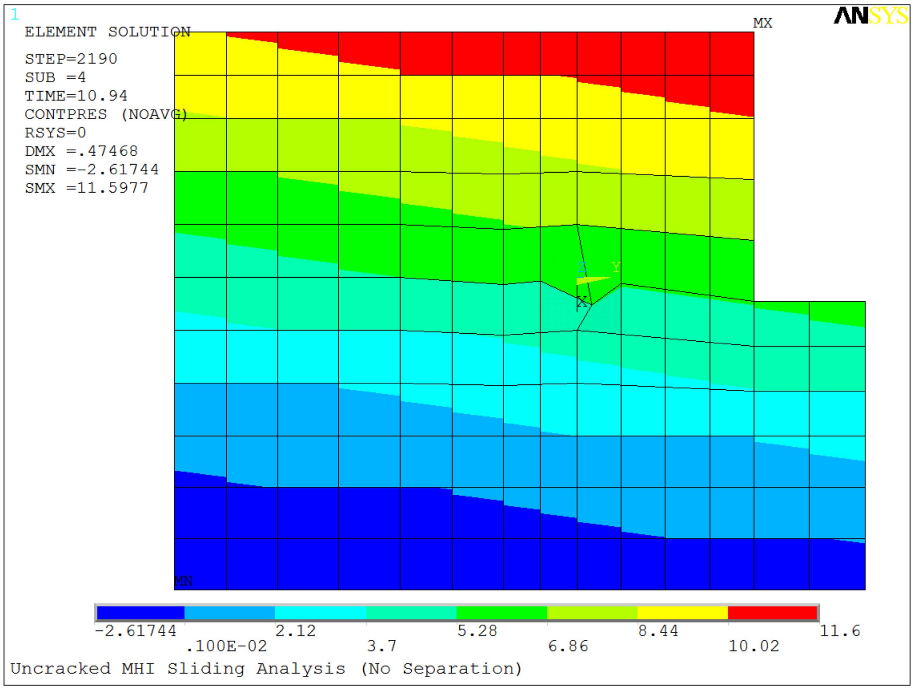

Figure 1 R/B Complex Contact Pressure Contours – Sliding is Allowed, but Separation is Not Allowed at the Foundation Subgrade Interface. Dark Blue Color Indicates the Area of the Interface that is in Tension (about 18% of total basemat surface).

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.