REQUEST FOR ADDITIONAL INFORMATION 340-2004 REVISION 0

4/21/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 03.08.05 - Foundations
Application Section: 3.8.5

QUESTIONS for Structural Engineering Branch 1 (AP1000/EPR Projects) (SEB1)

03.08.05-1

3.8.5-1

In DCD Subsection 3.8.5.1.1, the second sentence (Page 3.8-69) states that, “The basemat of the R/B is a rectangular reinforced concrete mat....” The rectangular shape agrees with the shape shown in DCD Figure 3.8.5-5 (Page 3.8-219), but it differs from the shape shown in DCD Figure 3.8.5-6 (Page 3.8-220). The applicant is requested to explain this discrepancy.

03.08.05-2

3.8.5-2

In DCD Subsection 3.8.5.4.1, the first paragraph (Page 3.8-71) states that: “For purposes of the US-APWR standard design, the SSI effects are captured by considering three generic subgrade types utilizing frequency independent springs.” It further states: “Subsection 3.7.2.4 provides further discussion relating to SSI and the selection of subgrade types.”

ASCE 4-98 is referenced in DCD Subsection 3.7.2.4 for SSI analysis. Per ASCE 4-98 subsection 1.1.1, for SSI of a sub-grade type, three cases are analyzed using different soil modulus values (see subsection 3.3.1.7 of ASCE 4-98) and the envelope of the SSI analyses from these three cases is to be used for design. This means that for each of the three soil types, three cases are to be analyzed: (1) Best Estimate; (2) Upper Bound; and, (3) Lower Bound. So, for US-APWR, a total of 9 cases should be analyzed for SSI. The analyses presented in DCD Subsection 3.7.2 of US-APWR did not follow this recommendation. Provide the technical basis for not following the ASCE 4-98 recommendation.

03.08.05-3

3.8.5-3

In DCD Subsection 3.8.5.4.1, the first paragraph (Page 3.8-71) states, “For purposes of the US-APWR standard design, the SSI effects are captured by considering three generic subgrade types utilizing frequency independent springs. A fourth subgrade condition is also considered, that of a foundation resting on hard rock. For the fourth condition, it is not necessary to consider SSI effects because the foundation is considered to be resting on a fixed base that is rigid.” The second paragraph states “The four supporting media (subgrade) conditions for the US-APWR design are provided in Table 3.8.5-3.” In Table 3.8.5-3, these four media are denoted as soft soil, stiff soil (Medium 1), soft rock (Medium 2), and hard rock (Fixed). The shear wave velocities for these four media are given in DCD Subsection 3.7.2.4 (Page 3.7-29). They are 1,000 ft/s, 3,500 ft/s, 6,500 ft/s, and 8,000 ft/s, respectively.

The applicant is requested to provide the following information:

(a) Traditionally, the shear wave velocity is not specified for the fixed-base condition. Explain why is the shear wave velocity of 8,000 ft/s specified? Is 8,000 ft/s the minimum shear wave velocity for the fixed-base condition?

(b) In subsection 1.2 of ASCE 4-98, “Rock” is defined as material with a shear wave velocity of 3,500 ft/s or more. In subsection 3.3.1 of ASCE 4-98, item (a) states that SSI need not be considered if the structure is supported by a rock. Therefore, in accordance with the ASCE 4-98, SSI effects need not be considered for three out of four subgrade conditions that the applicant had chosen. Then there are only two subgrade conditions considered in the US-APWR, soft soil and fixed-base conditions. Provide the rationale for selecting the range of soils with their corresponding shear wave velocities for SSI analyses.

03.08.05-4

3.8.5-4

In DCD Subsection 3.8.5.4.1, the third paragraph (Page 3.8-71) states, “For the generic subgrade having a shear wave velocity of 1,000 ft/s, the shear modulus is reduced in accordance with Subsection 3.7.2.4 to account for changes in shear modulus due to relatively large strains.” DCD Subsection 3.7.2.4.1 (Page 3.7-31) indicates that the soil degradation curves should be used to account for changes in shear modulus due to relatively large strains; however, no information that pertains to the soil degradation curves is given in the DCD. In DCD Subsection 3.7.2.4.1 (Page 3.7-31), the lower bound and the upper bound values of the initial shear modulii are established from the best estimated soil shear modulus, and the value of C_v.

The applicant is requested to provide the following information:

(a) Provide the soil degradation curves used in your analyses to account for changes in shear modulus due to relative large strains. Also, provide the technical basis for your selection of these curves.
(b) Provide the value or values of C_v used in the calculation for the upper and lower bound of the soil shear modulii.

03.08.05-5

3.8.5-5

In DCD Subsection 3.8.5.4.1, the second paragraph (Page 3.8-71) states, "The four supporting media (subgrade) conditions for the US-APWR design are provided in Table 3.8.5-3", and the fourth paragraph (Page 3.8-71) states, "An average subgrade bearing capacity of 15,000 psf is utilized for static load cases, while an average dynamic soil bearing capacity of 95,000 psf is used for Normal plus SSE loads."

The applicant is requested to provide the following information:

(a) There are four supporting media (soil) conditions shown in DCD Table 3.8.5-3. Are 15,000 psf and 95,000 psf the average bearing capacities (static and dynamic respectively) of these four types of soils? If not, define what "an average subgrade bearing capacity" is, and how these two numbers were derived or obtained.
(b) Explain the rationale for the increase by 6.3 times (95,000/15,000) for the dynamic soil bearing capacity.
(c) Provide the rationale for using an average subgrade bearing capacity for static load cases and an average dynamic bearing capacity for dynamic loads in the design of structures.
(d) Provide the maximum dynamic pressure on soils under the basemat during the SSE for the four supporting media considered.

03.08.05-6

3.8.5-6

In DCD Subsection 3.8.5.4.2, the second paragraph states, "The combined global FE model of the R/B, PCCV, and containment internal structure, including basemat, is presented on Figures 3.8.5-5 through 3.8.5-10."

The applicant is requested to provide the following information:

In DCD Figure 3.8.5-10, it is indicated in the figure caption that solid elements were used to model the basemat, and in DCD Table 3.8.1-4 it is indicated that shell elements were used to model the PCCV. Also, in DCD Subsection 3.8.3.4.1, it states that the SC modules were modeled by the shell elements. Since the shell element has six degrees of freedom and the solid element has only three translational degrees of freedom for every node, explain how shell elements are connected to the solid elements.

03.08.05-7

3.8.5-7

In DCD Subsection 3.8.5.4.2, the first paragraph (Page 3.8-72) states, “The vertical spring at each node in the analytical model act in compression only. The horizontal springs are active when the vertical spring is in compression and inactive when the vertical spring lifts off.”

The application is requested to provide the following information:

(a) Describe how the vertical and horizontal spring constants were calculated.
(b) Are there horizontal springs for every node? Are the spring constants for the vertical springs and the horizontal springs used in the analyses for the NASTRAN FE model the same for both the static and dynamic loadings?
(c) DCD Figure 3.8.5-3 (Page 3.8-217) shows that the bottom of the basemat for the reactor building is not all at the same elevation. The elevation of the bottom of the central region of the basemat is about 10 feet above that of the peripheral portion of the basemat. Provide answers for the following bounding conditions for analysis:
    (1) It is conceivable that the soil in the central region under the PCCV could consolidate, or settle, such that the central slab would not be in complete, or effective, contact with the soil.
    (2) On the other hand, it is also conceivable that since the soil column in the central region has a higher degree of confinement, it may have higher vertical stiffness than the soil in the peripheral region. As a result, some or all of the whole structure would be supported on the central soil column.

    Have these two bounding cases (1) and (2) above considered in the foundation design? If not, provide technical basis for not considering these two cases.

03.08.05-8

3.8.5-8

In DCD Subsection 3.8.5.4.2, the first paragraph (Page 3.8-72) states, “Soil springs are assigned in the model to determine the interaction of the basemat with the overlying structures and with the subgrade. The model is capable of determining the possibility of uplift of the basemat from the subgrade during postulated SSE events. The vertical spring at each node in the analytical model act in compression only.”

1. In DCD Subsection 3.8.4.4.1, the fourth paragraph (Page 3.8-56) states, “Seismic forces are obtained from the dynamic analysis of the three-dimensional lumped-mass stick model described in Subsection 3.7.2.”
2. In DCD Subsection 3.7.2.4, the second paragraph (Page 3.7-29) states “The lumped parameters representing the stiffness and damping properties of the SSI are calculated from the formulas presented in Table 3.3-3 that are in accordance with Subsection 3.3.4.2 of ASCE 4-98 (Reference 3.7-9).”

The stiffness and damping properties of the SSI presented in Table 3.3-3 of ASCE 4-98 (statement 2 above) assume that there is no separation between the foundation and the soil. This assumption is inconsistent with the FE model described in DCD Subsection 3.8.5.4.2 where the vertical springs may separate from the foundation (Statement 1 above).

The applicant is requested to explain this apparent inconsistency in the assumptions used for the mathematical models.

03.08.05-9

3.8.5-9

In DCD Subsection 3.8.5.4.2, the first paragraph (Page 3.8-72) states, “Horizontal bearing reactions on the side walls below grade are conservatively neglected for the analysis of the basemat. However, horizontal forces are considered in the analysis of the wall.”

The applicant is requested to provide the following information:

(a) Do the words “analysis of the basemat” include the stability analysis, such as sliding and overturning of, and the strength of, the basemat? Provide a technical basis which demonstrates that it is conservative to neglect the soil reactions on the side walls below grade for both the stability and strength of the basemat.
(b) Explain how the horizontal forces considered in the analysis and design of the wall were calculated.

03.08.05-10

3.8.5-10

In DCD Subsection 3.8.5.4.2, the fifth paragraph (Page 3.8-72) states, “Linear analyses are performed for all specified load combinations assuming that the soil springs can not take tension. The results of the linear cases are then used to select critical load cases for non-linear analyses.”

The applicant is requested to provide the following explanation:

(a) Explain how the linear analyses (mentioned in the first sentence above) were performed while the soil springs were assumed to be nonlinear (cannot take tension).
(b) Explain what are the non-linear analyses (mentioned in the second sentence above) and how they were performed.

03.08.05-11

3.8.5-11

In DCD Subsection 3.8.5.4.3 (Page 3.8-73), the paragraph states: "The basemat subgrade is represented by springs. The spring constants for rotations and translations are determined based on the soil parameters. Springs are attached to the bottom of the basemat, and the constraints by side soil are not considered in the model. The values of the springs used in the analysis are shown below."

The applicant is requested to provide the following explanation:

(a) How the spring constants for rotations and translations are calculated, and where are the values of the springs presented in the DCD? If the values are not in the DCD, state the values.
(b) In DCD Subsection 3.8.5.4.2 (Page 3.8-72), only translational springs were mentioned. Is the FE model described in DCD Subsection 3.8.5.4.2 different from the one described in this DCD Subsection 3.8.5.4.3?
(c) The FE model uses solid element for the basemat. Explain how the rotational springs are connected to the solid element.
(d) The last sentence in the quote above states that the values of the springs used in the analysis are shown below. However, the staff could not find these spring values. Provide all spring values used for the analyses.

03.08.05-12

3.8.5-12

In DCD Section 3.8.5.4.4, the first paragraph (Page 3.8-73) states, "The potential for foundation subsidence, or differential displacement, is designed for a maximum 2 in. based on enveloping properties of subsurface materials."

The applicant is requested to provide the following information:

(a) How was the maximum value of 2 in. determined?

(b) Do the shear force and bending moments generated from the 2 in. differential displacement combine with those from load cases in DCD Subsections 3.8.1.3 and 3.8.4.3 for the design of the basemat and the super-structures?

03.08.05-13

3.8.5-13

In DCD Subsection 3.8.5.4.4, the third paragraph (Page 3.8-74) states, "The basemat FE model is analyzed for various phases of construction, including the determination of displacement."

The applicant is requested to provide the following information:

(a) Were both the immediate settlement and the settlement due to consolidation included in the displacement calculations?
(b) Describe how these settlements were calculated.
(c) Was the effect of nearby structures' weights included in the settlement calculation?

03.08.05-14

3.8.5-14

In DCD Subsection 3.8.5.4.4, the fourth paragraph (Page 3.8-74) states, "Subsequent to the placement of the concrete foundation, walls, and containment internal structure, the basemat is significantly stiffened, minimizing any further tendency of differential settlement."

Placing concrete for walls and containment structures imposes additional loads on the concrete foundation (basemat), and may create additional settlement and differential settlement for the basemat.

The applicant is requested to:

(1) describe its analytical method used to calculate the settlement and differential settlements of the basemat with respect to the proposed construction sequences, and
(2) provide the curves of the basemat settlement vs. different stages of construction, and differential settlements of the basemat vs. different stages of construction, for the four types of soil conditions assumed in the DCD.

Use the curves/data provided in response to (2) above to substantiate the claim that "...the basemat is significantly stiffened, minimizing any further tendency of differential settlement."

03.08.05-15

3.8.5-15

In DCD Subsection 3.8.5.4.5, the first paragraph (Page 3.8-74) states, "For the R/B Table 3.8.5-4 provides sectional thickness and reinforcement ratio of basemat used in the evaluation. Table 3.8.5-5 provides sectional thickness and reinforcement ratio of basemat used in the PS/B evaluation."

The applicant is requested to provide the following information:

In DCD Tables 3.8.5-4 and 3.8.5-5 add an extra column that provides information that identifies the control load case for each section listed. Please indicate in which revision of the DCD the revised tables will appear.

03.08.05-16

3.8.5-16

In DCD Subsection 3.8.5.5.1 (page 3.8-75), the Resisting moment, M_r, is defined as the dead load of the structure, minus the buoyant force created by the design ground water table, multiplied by the distance from the structure edge to the structure center of gravity.

The applicant is requested to provide the following information:

Is 100% of the dead load of the structure used in the calculation of the Resisting Moment? Per ACI 349-06 Section 9.2.3, 0.9D should be used. Provide an explanation if 0.9D is not used. This question also applies to D_r defined in DCD Subsection 3.8.5.5.3.

03.08.05-17

3.8.5-17

In DCD Subsection 3.8.5.5.2 (page 3.8-75), the notation F_s is defined as the shear (or sliding) resistance along the bottom of the structure basemat.

The applicant is requested to state how the F_s value was calculated. If the friction coefficient between the basemat and the supporting soils is used in the calculation, provide its value and the rationale for choosing that value.

03.08.05-18

3.8.5-18

In DCD Subsection 3.8.5.5, three factors of safety are defined. They are the factor of safety against overturning, FS_o, the factor of safety against sliding, FS_{sw} & FS_{se}, and the factor of safety against flotation, FS_f.

The applicant is requested to provide the following information:

Provide a table tabulating values of these factors for the four subgrade conditions defined in DCD Subsection 3.8.5.4.1 and DCD Table 3.8.5-3.

During the calculation of these factors of safety, was the passive soil pressure against the vertical face of the basemat and exterior walls that were embedded in soils utilized? If yes, describe how the passive soil pressure and its distribution along the vertical side of the embedded basemat and walls were calculated.

03.08.05-19

3.8.5-19

In DCD Subsection 3.8.5.4, the third paragraph (Page 3.8-71) states, "The reinforced concrete basemat for the PCCV and enveloped containment internal structure are designed in accordance with ASME Code Section III, Division 2, Subsection CC (Reference 3.8-2). Other seismic category I basemats of reinforced concrete are designed in accordance with ACI-349 (Reference 3.8-8) and the provisions of RG 1.142 (Reference 3.8-19) where applicable. Table 3.8.5-2 identifies the material properties of concrete and Figure 3.8.5-4 delineates the governing codes based on region of the R/B, PCCV and containment internal structure basemat."

The applicant is requested to provide the following information:

(a) DCD Table 3.8.5-2 (page 3.8-108) indicates that in the basemat, 7,000 psi concrete is used at the upper part of Tendon Gallery and 4,000 psi concrete is used for the remaining portions of the Tendon Gallery. Since the modulus of elasticity of concrete is proportional to the square root of the compressive strength of concrete. The shrinkage and creep are functions of the modulus of elasticity; therefore, the concrete at the upper part of Tendon Gallery and the periphery will have different behaviors in shrinkage and in creep. Provide information for the action taken to control possible concrete cracking at the interface of these two different strength concretes.

(b) As it is shown in DCD Figure 3.8.5-4 (page 3.8-218), the common basemat for the PCCV and R/B are governed by two different codes, ASME Code Section III, Division 2 and the ACI-349. Explain how the design was performed for the foundation at the interface of these two codes.

(c) In DCD Figure 3.8.5-10 (Page 3.8-224), it is shown that three-dimensional solid element was used for the modeling of the common basemat. Explain how the results obtained from the Finite-Element analysis were split into primary and secondary stresses when checking against the ASME Code.

03.08.05-20

3.8.5-20

In DCD Subsection 3.8.5.6, the paragraph (Page 3.8-76) states, “Subsection 3.8.1.6 provides testing and surveillance requirements relating to the PCCV basemat.”

The title for subsection 3.8.1.6 (Page 3.8-23) is “Material, Quality Control, and Special Construction Techniques” and that subsection does not have the information for testing and surveillance requirements. The required information is in DCD Subsection 3.8.1.7 (Page 3.8-27). The applicant is requested to correct this error.

03.08.05-21

3.8.5-21

DCD Subsection 3.8.5.4.2 (page 3.8-72), first paragraph, states: “The major seismic category I structures basemat analyses use 3-dimensional NASTRAN FE models of the major seismic category I structures, which are described in Subsection 3.7.2.3.”

Define the “major” structures cited in this subsection. Also, are there “minor” structures which have been analyzed?

03.08.05-22

3.8.5-22

In DCD Subsection 3.8.5.1,”Description of the Foundations”, the second paragraph (Page 3.8-69) states, "The COL Applicant is to determine if the site-specific zone of maximum frost penetration extends below the depth of the basemats for the standard plant, and to pour lean concrete under any basemat above the frost line so that the bottom of lean concrete is below the maximum frost penetration level." The applicant is requested to provide the material specification for the lean concrete used in the construction of US-APWR foundations, including the minimum compressive strength.