REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**252-8299**
SRP Section:	**03.07.02 – Seismic System Analysis**
Application Section:	**3.7.2**
Date of RAI Issue:	**10/19/2015**

Question No. 03.07.02-7

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. In accordance with 10 CFR 50 Appendix S, the staff reviews the adequacy of the seismic analysis methods used to demonstrate that SSCs can withstand seismic loads and remain functional. To assist the staff in assessing adequacy of the finite element models used for seismic analysis, the applicant is requested to provide additional information related to the following modeling aspects.

a) Conversion of ANSYS Coarse Model to SASSI

Section 2 in APR1400-E-S-NR-14002-P states that the ANSYS coarse 3-D FEM of NI structures is converted to SASSI for a 3-D SSI analysis of NI structures. However the staff did not find a description of how this conversion was performed. The applicant is requested to describe in the report whether this conversion was performed with the ACS SASSI translator or, if not, describe the conversion process used. This description should include a discussion of how the attachment of the superstructure elements to the basemat elements was implemented and how the ability of the resulting FEM model to translate and rotate in a rigid body mode on the supporting soil was verified.

b) Representation of Floor Loads, Live Loads, and Major Equipment in Dynamic Model

SRP Section 3.7.2.II.3D provides the acceptance criteria regarding the representation of floor loads, live loads, and major equipment in a dynamic model. In addressing these SRP criteria, DCD Section 3.7.2.3.3 includes a description of masses that are assumed to contribute to the inertial forces in the seismic analyses. However, this DCD section did not specify the magnitude of such masses. For example, based on the description in DCD Section 3.7.2.3.3, it could be inferred that 100% of the live load is used in the seismic load case. The staff review finds that Section 3.2.5 and Table 4-7 in APR1400-E-S-NR-14002-P, for the RCB and AB, respectively,

provide additional information on the magnitude of the masses described in DCD Section 3.7.2.3.3. Section 3.2.5 in APR1400-E-S-NR-14002-P states that 25 % of floor live load or 75% of snow load are applied on the roof of the containment which appears to conflict with DCD Section 3.7.2.3.3. Based on these two statements it is not clear to the staff what floor live load has been considered on all floors of the reactor containment building. Therefore the staff request the applicant to clarify in the DCD how the SRP Section criteria regarding floor loads is addressed in the models used for seismic analysis.

c) Shell Elements in Primary Shield Wall

As described in Section 3.2.10 and shown Figure 3-3 in APR1400-E-S-NR-14002-P, shell elements are used to model the shield wall portion of the primary shield wall (PSW) from EL 130' to EL 191.' Given the geometry of the PSW, the use of thick shell elements may be more appropriate for this portion of the PSW. he geometry of the PSW, the use of thick shell elements may be more appropriate for this portion of the PSW. Additionally, based on Figure 3-3, a portion of these walls modeled with shell elements, appears to be not in plane with respect to the plane of each respective wall. Therefore to assist the staff in evaluating the adequacy of the FEM for the PSW, the staff requests the applicant to clarify why the shell element selected for the PSW model is appropriate as opposed to using a thick shell element formulation. Additionally, please describe the modeling approach and the basis of the shell portion of the walls including the location of plates oriented in non-parallel planes.

d) Transitions between Beam and Solid Elements

Staff review of APR1400-E-S-NR-14002-P finds that the nuclear island finite element model includes locations at which beam elements connect with solid elements (e.g. connections between the reactor coolant system model and the containment internal structure model). However, the staff did not did not find a description of how the degree of freedom compatibility is addressed for transitions between beam and solid elements. Therefore the staff requests the applicant to provide such description, including a graphical representation of the transition between beam and solid elements.

e) Poisson's Ratio Used in SSI Analyses

DCD Tables 3.7A-1 and 3.7A-2 show Poisson's ratios in the S1 and S2 soil profiles used for SSI analysis as great as 0.47 and 0.48 respectively. Based on staff experience, use of Poisson's ratio approaching these values may result in numerical instability of the SSI analysis results. Therefore, to assist the staff in evaluating the adequacy of the SSI analysis results based on the aforementioned soil profiles, the staff request the applicant to provide a demonstration (e.g. sensitivity study) that the assumed Poisson's ratio values do not produce numerical instabilities in the SSI results based on these profiles.

Response

a) The ANSYS fine-mesh and coarse-mesh finite element (FE) models for the fixed-base Reactor Containment Building (RCB) and the Auxiliary Building (AB) were first developed and analyzed with the fixed-base condition to (1) generate 1-g lateral static-load response

displacements, (2) extract fixed-base dynamic modal properties (natural frequencies and associated mode shapes and participation factors, and (3) develop fixed-base 5%-damped in-structure response spectra (ISRS) at selected sufficiently representative structure locations. The ANSYS coarse-mesh models were verified against their corresponding ANSYS fine-mesh FE models to ensure that the model properties of the ANSYS coarse-mesh models are dynamically adequate as compared to the ANSYS fine-mesh FE models.

When the ANSYS coarse-mesh models of the RCB and the AB are verified, the two models are combined to create an ANSYS coarse-mesh FE model of the NI structures.

Then, the fixed-base ANSYS coarse-mesh FE model of the NI structures was converted to the fixed-base SASSI structure model using the ACS SASSI model translator. The converted SASSI structure model was checked manually to ensure that the SASSI structure model was appropriately converted from the ANSYS model.

Then, the converted SASSI fixed-base structure model was analyzed for the fixed-base condition to develop fixed-base seismic acceleration response transfer functions and the corresponding 5%-damped ISRS at the same selected representative structure locations as those selected for the ANSYS model. These ISRS results were compared with the corresponding results obtained from the fixed-base ANSYS structure model to verify that the converted fixed-base SASSI structure model produces results which are sufficiently similar to the corresponding results of the fixed-base ANSYS structure model.

The SASSI foundation model which is combined with the SASSI structure model consists of a common basemat structure model, an excavated soil volume model for the structure embedment developed to use the SASSI Direct Method (DM), and a backfill soil model which was treated as a part of the structure model. The SASSI foundation model for the NI structures was so developed and checked manually.

The common basemat for the AB and the RCB was modeled separately by 4-node shell elements for the AB at the bottom surface of concrete foundation (EL. 45'-0") to specially account more closely for the soil-structure interaction effects, and by 8-node solid elements for the RCB concrete foundation, respectively. To ensure continuity of rotational deformation at the interface of the AB shell elements and the RCB solid elements, a dummy massless ring of shell elements was extended from the outside edge to the inside of the RCB, beneath the solid elements. To simulate the relatively rigid 10-ft basemat between the top (EL. 55'-0") and the bottom (EL. 45'-0") surfaces of the concrete foundation for the AB, the AB walls and columns were extended from EL. 55'-0" to EL. 45'-0" with massless rigid beam elements.

The ability of the resulting SASSI FE SSI model to translate and rotate was demonstrated by observing that the resulting seismic response transfer functions are able to translate and rotate as a rigid body on the supporting soil.

Technical report APR1400-E-S-NR-14002-P, Rev. 0, "FEM for SSI Analyses of NI Buildings" will be revised, as indicated in Attachment 1 to this response, to incorporate the procedures described above for development of the ACS SASSI models for the NI structures.

b) In general, in addition to the mass of the tributary structure dead load, additional mass equivalent to 25% of the specified floor live load or 75% of the specified snow load, where

applicable; 50 psf, the equivalent of the miscellaneous dead load supported on the floors; and 10 psf, the equivalent of the attachment load on each face of the walls are included in the calculation of the inertia forces of the model. However, there are some exceptions, for example, 25% of floor live load is not considered in the RCB floors, and the roof material dead load is considered only for the AB roof. The magnitudes of masses on the floors are presented in the following table.

Masses that are considered to contribute to the inertial forces			
Description	Value (psf)	RCB	AB
Misc. dead load (Minor equipment, piping, race ways)	50.00	Applied	Applied
Seismic live load(1) (25% of floor design load 200 psf)	50.00	Not Applied	Applied
Roof snow load (75% of roof design snow load 75 psf)	56.25	Applied	Applied
Roofing material dead load(2)	50.00	Not Applied	Applied
Raised floor dead load(3)	20.00	Not Applied	Applied

(1) Seismic live load is not considered for floors in the RCB. The design floor live load inside the RCB is generated by movable heavy equipment during construction and maintenance of plant. During normal operation, the live load is negligible since equipment removal is not allowed in the RCB. Also, the seismic load is considered not to occur during the construction and maintenance of the plant. Therefore, the seismic inertial floor live load is not applied to the seismic analysis for the RCB.

(2) The roof of the RCB, i.e. containment dome, does not use roofing material.

(3) The raised floor dead load is only applicable for the floor at EL. 156’-0” of the AB.

DCD Tier 2, Subsection 3.7.2.3.3 and technical report APR1400-E-S-NR-14002-P will be revised as indicated in Attachment 2 to this response to incorporate brief descriptions of the masses considered in the seismic analyses.

In the seismic analysis model of the RCB, the slabs at EL. 114’-0”, 136’-6”, and 156’-0” between the secondary shield wall (SSW) and the containment shell are not modeled in accordance with the decoupling criteria presented in the USNRC SRP 3.7.2. All the masses of those slabs considering the self-weight, the 50 psf of misc. attachment dead load, and the major equipment loads are lumped onto the SSW. The SSW is considered the main supporting structure of these weights. All other slabs, which exist in the RCB, are modeled in the seismic analysis model of the RCB.

Since the slabs in the RCB are not large, and the increase of the weight due to the addition of the seismic live load 50 psf (total 1,650 kips) is not great compared to the existing weight of the walls and slabs (total 183,000 kips) the effect of the seismic live load on the seismic responses of the RCB is expected to be very small.

To evaluate the effect of seismic live load which is not considered in the RCB, a study is performed using the ANSYS coarse model of the RCB. The transient time history analyses are performed with the fixed-base condition using two ANSYS models. One is the original ANSYS coarse model of the RCB, and the other is modified model considering the seismic live load of all slabs in the RCB, whether the slabs are modeled or not. For the slabs which are not modeled, the masses equivalent to the seismic live loads which are applied to the slabs are added to the SSW of the modified model. For the slabs in the model, the lumped masses equivalent to the seismic live loads are added to the nodes of the slabs in the modified model. Then, the 4%-damped ISRS of SSW are compared between two models as presented in Figures 1 through 3. Since the SSW supports one end side of most slabs in the RCB, comparisons of ISRS at the only SSW are conducted. The nodes, which were used for enveloping the APR1400 ISRS of the SSW, are identically used to generate the enveloped ISRS for the comparisons. As shown in the comparison figures, the variation of ISRS due to the consideration of the seismic live load in the RCB seismic analysis model is negligibly small. Therefore, it can be concluded that the effect of seismic live load on the RCB seismic response is insignificant.

TS

Figure 1. Comparison of ISRS at SSW EL. 114'-0"

TS

Figure 2. Comparison of ISRS at SSW EL. 136'-6"

TS

Figure 3. Comparison of ISRS at SSW EL. 156'-0"

c) The original SASSI program was developed in the 1980's and has only the LCCT9 thin shell element, which was adopted from the SAP IV structural analysis program. This same version of the SASSI code was adopted by many company-specific versions of SASSI. ACS SASSI 2.3 also has only the LCCT9 thin shell element. Many versions of SASSI, including ACS SASSI 2.3, do not have thick shell element available for structural modeling. This is the reason why thick shell elements have not been used for modeling the PSW by the ANSYS program.

Use of thick or thin shell elements does not significantly affect the overall structural stiffness since the main stiffness of the shell structures (containment shell, PSW, SSW, etc.) are primarily due to in-plane stiffness.

The thickness and center axis of the PSW section are changed over EL. 147'-9" through EL. 154'-0", as shown in Figure 4. The portion of wall which is not in plane with respect to the plane of respective walls in Figure 3-3 of APR1400-E-S-NR-14002-P was intentionally modeled to represent the contour of the PSW.

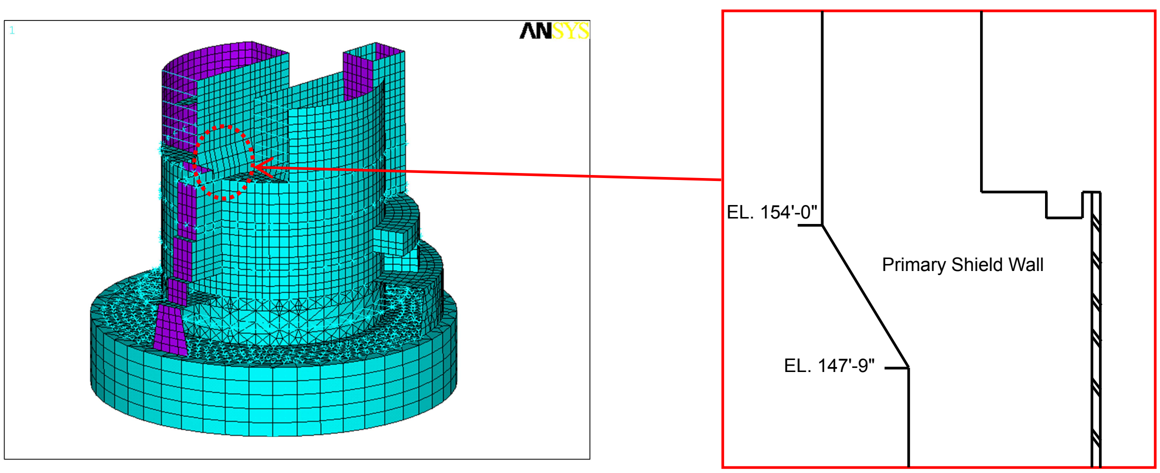

Figure 4. Tapered Section in Primary Shield Wall

d) The degrees of freedom compatibility condition between the beam elements of the reactor coolant system (RCS) and solid elements of the primary shield wall (PSW) and the secondary shield wall (SSW) was satisfied by using the rigid beam elements at the beam-to-wall support points covering the footprint of the RCS support brackets. The RCS supports are modeled as rigid beam elements and connected with other rigid beam elements in the solid elements which represent the PSW and the SSW.

Figure 5 shows the connection between the RCS supports (rigid beam) and the building model (solid elements). Technical report APR1400-E-S-NR-14002-P will be revised, as indicated in Attachment 3 to this response to incorporate the description of the beam-to-solid element connection.

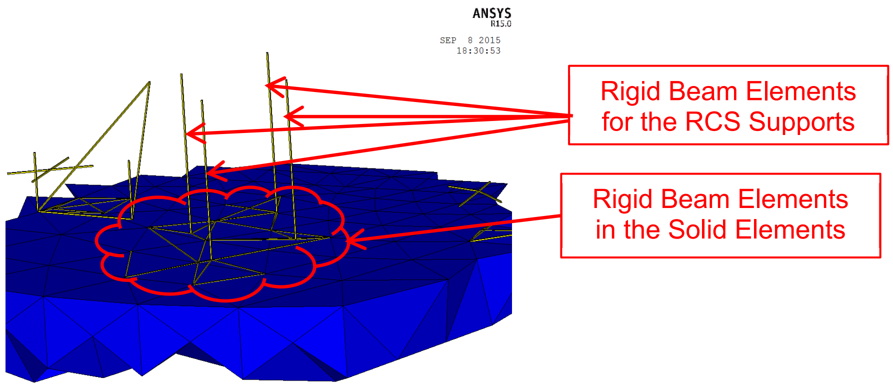

Figure 5. Connection between RCS Supports and Solid Elements

e) It is generally known that a dynamic Poisson's ratio value approaching 0.5 will cause numerical sensitivity problems in SSI analyses using the SASSI program. In the SSI analysis of the APR1400, the dynamic Poisson's ratio of the soil is limited to not greater than 0.48 in order to avoid numerical sensitivity problems. To demonstrate that the Poisson's ratio values used do not produce numerical instabilities in the SSI results, a sensitivity study will be performed using the S1 and S2 soil profiles, and the results will be provided by September 30, 2016.

Impact on DCD

DCD Tier 2, Subsection 3.7.2.3.3 will be revised, as indicated in Attachment 2 to this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Technical report APR1400-E-S-NR-14002-P/NP will be revised, as indicated in Attachments 1, 2, and 3 to this response.