## KHNPDCDRAIsPEm Resource

**From:** Ciocco, Jeff
**Sent:** Tuesday, October 20, 2015 2:04 PM
**To:** KHNPDCDRAIsPEm Resource
**Subject:** FW: APR1400 Design Certification Application RAI 252-8299 (03.07.02 - Seismic System Analysis)
**Attachments:** APR1400 DC RAI 252 SEB1 8299.pdf

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**Sent:** Monday, October 19, 2015 8:24 AM
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**Subject:** APR1400 Design Certification Application RAI 252-8299 (03.07.02 - Seismic System Analysis)

KHNP,

The attachment contains the subject request for additional information (RAI). This RAI was sent to you in draft form. Your licensing review schedule assumes technically correct and complete responses within 30 days of receipt of RAIs. However, KHNP requests, and we grant, a 60 day response to the RAI. We may adjust the schedule accordingly.

Please submit your RAI response to the NRC Document Control Desk.

Thank you,


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# REQUEST FOR ADDITIONAL INFORMATION 252-8299

Issue Date: 10/19/2015
Application Title: APR1400 Design Certification Review – 52-046
Operating Company: Korea Hydro & Nuclear Power Co. Ltd.
Docket No. 52-046
Review Section: 03.07.02 - Seismic System Analysis
Application Section: 3.7.2

QUESTIONS

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.

03.07.02-8

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. SRP Section 3.7.2.II.11states that to account for accidental torsion, an additional eccentricity of ± 5% of the maximum building dimension shall be assumed for both horizontal directions.

Regarding the consideration of accidental torsion, DCD Section 3.7.2.10 states that additional eccentricity of 5 % of the maximum building dimension, perpendicular to load direction that results in an accidental torque, is applied to the static finite element structural model to calculate element forces due to accidental torsion. To assist the staff in evaluating the adequacy of the consideration of accidental torsion, the staff requests the applicant to clarify how the accidental torsion effects are combined with the computed seismic response, including a numerical example that shows the process.

03.07.02-9

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.

DCD Figures 3.7A-24 and 3.7A-25 show the ISRS in the E-W and N-S directions respectively at EL 191'-0" for the PSW. The staff notes that the N-S ISRS in Figure 3.7A-25 corresponds to the out-of plane direction for the PSW, and shows a large difference in the amplitude of the response (e.g. at the ZPA and PSA) compared to the E-W ISRS in Figure 3.7A-24, which is the in-plane direction. The staff also observes a similar response in Figures 3.7A-42 and 3.7A-43 which show the ISRS in the E-W and N-S directions respectively at EL 191'-0" for the SSW. To assist the staff in reviewing the adequacy of the analysis methods used for seismic Category I structures and the use of the respective analysis results, the applicant is requested to expand the presentation of the ISRS to include the individual soil profiles (including the fixed-base condition) and both concrete stiffness cases, that contribute to determination of the envelope ISRS. , In presenting the expanded results, only 5% damping curves need to be provided, and the ISRS corresponding to cracked and uncracked concrete cases should be provided in separate figures to facilitate readability.

This information is requested for the E-W, N-S, and Vertical directions at representative nodal points for the following locations:

- PSW, El. 191'-0"
- SSW, El. 191'-0"
- Top and Foundation level of CS
- Top and Foundation level of IS
- Top and Foundation level of AB
- Top and Foundation level of EDGB
- Top and Foundation level of DFOT

03.07.02-10

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.

a) *Flexible Floors and Walls*

(i) Section 4.2.6 in APR1400-E-S-NR-14002-P describes the approach used to demonstrate that the ANSYS coarse model is capable of accurately capturing out-of-plane flexibility of floor slabs. The report is silent about out-of-plane flexibility of walls. The staff needs additional information to verify the adequacy of the ANSYS fine and coarse model mesh to accurately capture out-of-plane response of both floor slabs and walls. Therefore, for the most flexible floor slabs and walls, the staff requests the applicant to compare the fundamental frequencies obtained from the ANSYS fine and coarse mesh models with those predicted based on local floor slab and wall models with additional mesh refinement or with frequencies calculated based on classical plate vibration formulas, as applicable. For this comparison, the staff requests the applicant to provide the floor slab and wall fundamental frequencies corresponding to both cracked and uncracked concrete stiffness.

(ii) The staff requests the applicant to clarify the following information in APR1400-E-S-NR-14002-P related to the comparison of the fine model and coarse model fundamental frequencies for floor slabs. Section 4.2.6 of the Report states: "*If the fundamental frequency of the fine isolated model is lower than 50 Hz and is 5% greater than that of the coarse isolated model, the modulus of elasticity of the panel in the coarse model is adjusted*…" Additionally, in comparing the fine and coarse model fundamental frequencies prior to any adjustment, Table 4-8 of the Report shows the coarse model frequencies to be lower than the fine model frequencies. This behavior conflicts with the staff's expectation that as the mesh size increases, the model becomes stiffer and therefore should result in higher frequencies. Based on this staff observation, the staff requests the applicant to explain why the fundamental frequencies are lower for the coarse mesh than for the fine mesh. As applicable, correct any inaccuracies and revise APR1400-E-S-NR-14002-P accordingly.

b) *RCB and AB Fundamental Frequencies*

In DCD Tables 3.7-10, 3.7-11, and 3.7-12, the lowest reported vibration mode numbers for the containment structure (CS), internal structure (IS), and auxiliary building (AB) are 11, 18, and 75, respectively. The staff requests the applicant to describe the nature and mass participation of the modes lower than those reported in the aforementioned DCD Tables. Further, the staff finds inconsistent information regarding the reported frequencies and mass ratios between these DCD Tables and Tables 5-1, 5-2, and 5-3 in APR1400-E-S-NR-14002-P, which also report the vibration mode information for the CS, IS, and AB. Therefore, the staff requests the applicant to clarify and correct any inconsistency between the aforementioned DCD tables and the tables in the technical report.

c) *Comparison of ANSYS and SASSI ISRS*

Figures 5-30 to 5-38, and Figures 5-46 to 5-65 show comparisons of ISRS corresponding to the ANSYS coarse mesh model and the SASSI model for the RCB and AB, respectively. These comparisons are performed to demonstrate equivalence between the SASSI model and the ANSYS coarse mesh model. Staff review identified instances where the ANSYS response exceeds the SASSI response by as much as 25% (see Figure 5-29 for example), at the peak spectral acceleration. Considering that the SASSI model results are used to obtain seismic demands for subsequent design analyses, the staff requests the applicant to provide the technical basis for differences such as that indicated above, and discuss whether it is necessary to make any corrections to the SASSI results.

03.07.02-11

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.

Per SRP Section 3.7.2.II.4, to ensure proper implementation of SSI methodologies, the staff reviews sensitivity studies performed by the applicant to evaluate the effects of important parameters such as potential foundation uplift, separation and sliding of soil from sidewalls, non-symmetry of embedment, and location of boundaries. Further, the staff reviews the applicant's use of appropriate benchmark problems that demonstrate the applicant's proper implementation of SSI methodologies. To assist the staff in reviewing the applicant's proper implementation of SSI methodologies, the staff requests the applicant to provide a description of its consideration of the aforementioned sensitivity studies and use of benchmark problems.

03.07.02-12

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.

DCD Sections 3.8A.2.3.1 and 3.8A.3.3.1, for the AB and EDGB respectively, indicate that an equivalent static method of analysis is performed to obtain the member forces for these structures. Per SRP Section 3.7.2.II.1, the use of equivalent static load method is acceptable provided it can be demonstrated that the method produces conservative results in terms of responses. Therefore, to assist the staff in its evaluation of the conservatism of the equivalent static method implemented by the applicant, the staff requests the applicant to provide comparisons of maximum member forces obtained from the equivalent static method to corresponding results from the time history analysis method (i.e. SASSI analysis), or to RSA results using foundation ISRS from the time history analysis.

03.07.02-13

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. DCD Table 3.7-14, 3.7-17, and 3.7-20 report maximum response acceleration values for the CS, IS and AB, respectively. Staff review did not find a clear description whether the values are taken from the ISRS computed from SASSI or the peak of the response time histories computed from SASSI. To assist the staff in assessing the adequacy of these maximum response acceleration values, the staff requests the applicant to indicate the source of these values. If these values were computed from the SASSI ISRS, the staff requests the applicant to provide comparison of the values in the aforementioned Tables and the peak values of the corresponding acceleration time histories.

03.07.02-14

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. Per SRP Section 3.7.2.II.8, to ensure an adequate evaluation of the seismic Category I SSCs in a DC application, it is necessary to determine that they are not vulnerable to collapse or interaction with adjacent non-seismic Category I structures. Consequently, DC applicants should provide sufficient analysis and design information concerning interaction of the non-seismic Category I structures with seismic Category I SSCs for staff review.

DCD Section 3.7.2.7.1, describes three alternate criteria related to providing reasonable assurance that the failure of non-seismic Category I structure under the effect of a seismic event does not impair the integrity of an adjacent seismic Category I structures. Additionally, this DCD section references APR1400-E-S-NR-14005, which contains the details of the structure-soil-structure interaction (SSSI) analysis of the NI structures, EDGB/DFOT, the seismic Category II turbine generator building (TGB), and the seismic Category II compound building (CB).  Staff review did not find a clear description of the specific criterion out of the three aforementioned criteria that apply to the evaluation of interaction effects of the TGB and CB with the seismic Category I structures. The staff needs additional information regarding these buildings, to ensure that the NI and EDGB/DFOT are not vulnerable to damage caused by collapse of the TGB or CB. As a minimum, the staff requests the applicant to provide the specific criteria out of the three criteria mentioned above that applies to the TGB and CB;  a definition of the seismic input used for the design of these structures, and how the SSSI effects are accounted for in such seismic input; a description of the method of seismic design and analysis applicable to these structures: the maximum relative displacements between these structures and adjacent seismic Category I structures considering out-of-phase motion; and a description of how the potential effects of sliding and uplift have been considered for these structures.

03.07.02-15

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.

(a) COL Items 3.7(3) and 3.8(1) in DCD Sections 3.7.5 and 3.8.4 respectively, identify the seismic Category I essential service water building and the seismic Category I component cooling water heat exchanger building as site-specific structures. However DCD Section 1.2.14 and Figure 1.2-1 identify these structures as being within the scope of the design certification for APR1400. The staff finds the information in DCD Section 1.2.14 and Figure 1.2-1 to be inconsistent with the aforementioned COL Items. Therefore, the staff requests the applicant to confirm that the aforementioned structures are site-specific and correct any inconsistencies presented in any other sections of the DCD.

(b) DCD Section 1.2.14 and Figure 1.2-1 identify the seismic Category II alternate alternating current (AAC) gas turbine generator building as being within the scope of the design certification for APR1400. However the staff did not find information in Section 3.7.2.7.1 concerning the seismic analysis and design methods for this building, or the treatment of seismic Category I and non-seismic Category I interaction considerations. Therefore, the staff requests the applicant to clarify which of the interaction criteria from DCD Section 3.7.2.7.1 applies to this building, and to provide a description of the applicable seismic analysis and design methods, consistent with the applicable criterion from DCD Section 3.7.2.7.1.

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