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.:	**320-8383**
SRP Section:	**03.08.05 – Foundations**
Application Section:	**3.8.5**
Date of RAI Issue:	**11/24/2015**

Question No. 03.08.05-19

10 CFR 50.55a and Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4 and 5, provide the regulatory requirements for the design of the mat foundation for the prestressed concrete containment. Standard Review Plan (SRP) 3.8.5, Section II specifies analysis and design procedures applicable to the foundation of seismic Category I structures.

On October 5, 2015, the applicant presented an overview of its seismic analysis approach of the APR1400 to the staff. During the presentation, the applicant stated that a 3-feet lean concrete will be placed beneath the bottom of the basemat and that the lean concrete is classified as a non-safety related structure. The staff reviewed the DCD Tier 2, Section 3.8 along with the technical report (TR), APR1400-ES-NR-14006-P, “Stability Check for NI Common Basemat,” Revision 1, and noted that the applicant did not provide any description on the use of lean concrete in its design of the APR1400. Per 10 CFR 50.55a, Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 5, and SRP 3.8.5, the applicant is requested to describe in detail the following:

a. What is the design criteria for the lean concrete?

b. How is it used in the soil-structure-interaction analysis model?

c. Is the “lean concrete” being used for all Category I structures?

d. Is the lean concrete 3 feet thick throughout the NI? Why 3 feet?

e. Is the lean concrete reinforced?

Also, the applicant is requested to update applicable portion of Section 3.8 of the DCD Tier 2, and the TR accordingly.

Response - (Rev. 1)

DCD Tier 2, Subsection 3.8.5 and technical report (TeR) APR1400-ES-NR-14006-P, "Stability Check for NI Common Basemat," provide methodologies and results of structural analysis and design for basemats of seismic category I structures above the lean concrete. Information regarding the lean concrete will be provided in applicable sections of DCD Tier 2, and the TeR as discussed below.

a. The design criteria for the lean concrete are a compressive strength of 2000 psi, a Poisson's ratio of 0.17, and a density of 0.137 kcf. DCD Tier 2, Subsection 2.5.4.5 will be revised to state the required compressive strength, as indicated in the attachment associated with this response. The required Poisson's ratio and density are presented in Table 5-2 of Technical Report APR1400-E-S-NR-14003-P, "SSI Analysis Methodology and Results of NI Buildings."

   Based on ACI 318-08, the in-plane shear strength at the surface of lean concrete is 1,021,931 kips. Applying a 0.75 strength reduction factor for shear, results in a lean concrete in-plane shear strength of 766,448 kips. The maximum base shear at basemat is 408,146 kips, which is less than 766,448 kips. Therefore, the lean concrete has enough strength to resist base shear and transfer it to the ground.

   The bearing pressure at the bottom of the NI basemat considered the bousinessque effect and was calculated by the spring reaction under the static loading case (Dead+Live). Table 1 summarizes the bearing pressure corresponding to each soil profile.

Table 1. Bearing Pressure at Bottom of NI Basemat

Site Profile	Average Bearing Pressure (ksf)
S1	10.6
S4	11.03
S8	11.21

b. Section 6.4, "Bottom Lean Concrete and Side Soil Backfill with SFG," of TeR APR1400-E-S-NR-14002-P, "Finite Element Seismic Models for SSI Analyses of the NI Buildings," describes the three feet of lean concrete backfill as being modeled between the bottom of the basemat and the top surface of soil below the excavation. ACS SASSI solid elements are used to model the lean concrete. TeR APR1400-E-S-NR-14002-P, Subsection 6.4 will be revised, as indicated in the attachment associated with this response.

c. The three feet of lean concrete backfill is used for all seismic Category I structures. DCD Tier 2, Subsections 2.5.4.5, 2.5.6, and the associated COL Table 1.8-2 will be revised to state three feet of lean concrete backfill is used for all seismic Category I structures, as indicated in the attachment associated with this response.

d. The three foot thickness is consistent throughout the SSI model. Since the APR1400 standard design considers nine generic soil profiles, including soft soil conditions, the inclusion of three feet of lean concrete below the basemat of the seismic Category I structures is selected based on consideration of the worst soil conditions of other previously-constructed NPPs.

e. Since the lean concrete is not considered as a structural member, the lean concrete is not reinforced.

Impact on DCD

DCD Tier 2, Subsections 2.5.4.5, 2.5.6, and COL Table 1.8-2 will be revised, as indicated in the attachment associated with 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, Subsection 6.4 will be revised, as indicated in the attachment associated with this response.

RAI 8-7847 - Question 02.05.04-5

RAI 320-8383 - Question 03.08.05-19

6 COMBINED NI SASSI MODEL

The combined NI SASSI model for the APR1400 SSI analysis consists of the RCB and AB. These two buildings are founded on a common foundation basemat. Above the basemat, the two buildings are separate and to not have structural connections. In the plant layout, the AB is separated by 3 ft gaps from the emergency diesel generator building, the turbine generator building, and the compound building.

6.1 Modeling of Structural Components of Combined NI

Models of RCB and AB structural components are first created in the ANSYS and then converted to SASSI. A total of 32,778 nodes are created (23,524 structural nodes and 9,254 soil interaction nodes), and a total of 59,030 elements are generated (including 35,113 solid elements, 4,037 beam elements, 17,974 shell elements, and 1,906 spring elements). A total of 1,452 concentrated masses are included in the model.

At the junction of shell and solid elements, massless shell elements are used to extend shell elements into solid elements for a finite distance to make the shell rotational deformation at the junction continuous with solid elements. Figure 6-1 shows the structural model of the SASSI 3-D FEM for the combined NI structures.

6.2 Common Foundation Basemat

The common foundation basemat is a 10 ft thick slab at an embedment of 53.5 ft at its bottom surface. The basemat is modeled by shell elements at its bottom surface (El. 45'-0"). With rigid properties and massless densities, structural walls and columns are extended vertically from the top surface (El. 55'-0") of the basemat to connect to the shell elements at the bottom surface.

6.3 Soil Excavation

A soil excavation model is created with the dimensions of the AB plus extensions in two horizontal directions as well as vertically downward for soil and lean concrete backfill. A total of 9,254 interaction nodes are created with the Flexible Volume Method for this model. A mesh size of 12 ft is used for an average cut-off frequency of 50 Hz among the nine (9) soil profiles for the upper 98.5 ft of soil layers. The SASSI 3-D FEM of the excavated soil volume for the combined NI structure foundation is shown in Figure 6-2.

6.4 Bottom Lean Concrete and Side Soil Backfilled with SFG

An extra 3 ft deep excavation beneath the bottom concrete surface of the basemat is used for the lean concrete backfill. An extra side excavation varies from 12 ft wide at the bottom to 24 ft wide at the top of the soil and 3 ft wide backfill between adjacent buildings. The extra side soil excavations are backfilled with structural fill granular (SFG). The SASSI 3-D FEM of the SFG and lean concrete backfill[, which are modeled using solid elements,] for combined NI structures is shown in Figure 6-3.

6.5 Connections between Structural Concrete and Soil

The SASSI model has two sets of nodes at the soil-structure interface boundary. One set consists of structural concrete nodes for external walls and basemat, and the other set consists of soil interaction nodes for soil excavation and soil backfill. The two sets of nodes are coincident nodes at the same locations, and are connected by a set of rigid spring elements. With this rigid spring connection, the concrete foundation is connected to the free-field soil. The SASSI 3-D FEM of the combined NI structures with soil backfill solid elements is shown in Figure 6-4.

RAI 8-7847 - Question 02.05.04-5

RAI 320-8383 - Question 03.08.05-19

2.5.4.4 Geophysical Surveys

A description is provided of the geophysical investigations performed at the site to determine the dynamic characteristics of the soil or rock, including geophysical methods used to determine foundation conditions. The results of compressional and shear wave velocity surveys and electric resistivity surveys performed to evaluate the occurrence and characteristics of the foundation soils and rocks are provided in tables and profiles.

~~and compressive strength of lean concrete under the nuclear island basemat~~

and the compressive strength of lean concrete

2.5.4.5 Excavations and Backfill

Site-specific information is provided for excavation and backfill, including properties of borrow and backfill materials, extent (horizontally and vertically) of all seismic Category I excavations, compaction specifications, dewatering, excavation methods, and control measures of groundwater during excavation. Minimum requirements of structural fill granular (SFG) for dynamic properties are described in Table 2.0-1. The typical APR1400 site arrangement is shown in Figure 1.2-1 and the typical profile of basemat and SFG is shown in Figure 2.5-1.

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The COL applicant is to confirm that the dynamic properties of SFG to be used in construction of the APR1400 seismic Category I structures satisfy the SFG requirements provided in Table 2.0-1 (COL 2.5(8)).

and minimum compressive strength of 140 kg/cm² (2,000 psi) for lean concrete

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2.5.4.6 Groundwater Conditions

Basic groundwater conditions are described in Section 2.4. In this subsection, the groundwater conditions relative to foundation stability of the safety-related facilities, plans for dewatering during construction, and plans for analysis of seepage and potential piping conditions during construction are provided. Records of field and laboratory permeability tests and history of groundwater fluctuations are provided.

2.5.4.7 Response of Soil and Rock to Dynamic Loading

Site-specific information is provided on the response of soil and rock to dynamic loading, including investigations to determine the effects of prior earthquakes on the soils and rocks, compressional and shear wave velocity profiles determined from field seismic surveys, and the results of dynamic tests in the laboratory on samples of the soil and rock. The methodology of site response analysis is described in Appendix 3.7A.

basemat of seismic Category I structures

Under the ~~nuclear island common basemat,~~ a layer of approximately 0.91m (3 ft) thick lean concrete with a minimum compressive strength of 140 kg/cm² (2,000 psi) is backfilled between the bottom of the basemat and the ~~base of the excavation pit~~.

top surface of soil below the excavation

RAI 8-7847 - Question 02.05.04-5

RAI 320-8383 - Question 03.08.05-19

COL 2.5(5) The COL applicant is to perform a site-specific seismic analysis to generate in-structure response spectra at key locations using the procedure described in Appendix 3.7A if COL 2.5(2) and COL 2.5(3) above are not met. In addition, the COL applicant is to confirm that the site-specific in-structure response spectra so generated are enveloped by the corresponding in-structure response spectra provided in Appendix 3.7A.

~~and compressive strength of lean concrete under the nuclear island basemat~~

COL 2.5(6) The COL applicant is to perform a site-specific seismic response analysis using the procedure described in Appendix 3.7B and the EPRI White Paper "Seismic Screening of Components Sensitive to High Frequency Vibratory Motions" (Reference 6), if COL 2.5(4) is not met.

and the compressive strength of lean concrete

COL 2.5(7) The COL applicant is to perform an evaluation of the subsurface conditions within the standard plant structure footprint based on the geologic investigation in accordance with NRC RG 1.132.

COL 2.5(8) The COL applicant is to confirm that the dynamic properties of SFG to be used in construction of the APR1400 seismic Category I structures satisfy the SFG requirements provided in Table 2.0-1.

and minimum compressive strength of 140 kg/cm² (2,000 psi)

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for the lean concrete

2.5.7 <u>References</u>

1. Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, June 2007.

2. Regulatory Guide 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Rev. 2, U.S. Nuclear Regulatory Commission, October 2003.

3. Regulatory Guide 1.138, "Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants," Rev. 2, U.S. Nuclear Regulatory Commission, December 2003.

4. Regulatory Guide 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion," U.S. Nuclear Regulatory Commission, March 2007.

5. NRC DC/COL-ISG-017, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses," U.S. Nuclear Regulatory Commission, August 2009.

RAI 8-7847 - Question 02.05.04-5

RAI 320-8383 - Question 03.08.05-19

Table 1.8-2 (2 of 29)

Item No.	Description
COL 2.5(1)	The COL applicant is to provide the site-specific information on geology, seismology, and geotechnical engineering as required in NRC RG 1.206.
COL 2.5(2)	The COL applicant is to confirm that the foundation input response spectra (FIRS) of the nuclear island are completely enveloped by the CSDRS-compatible free-field response motions at the bottom elevation of the nuclear island for a site with the low-strain shear wave velocity greater than 304.8 m/s (1,000 ft/s) at the finished grade in the free field. Alternately, the COL applicant is to confirm that FIRS of the nuclear island are completely enveloped by the CSDRS for a hard rock site with a low-strain shear wave velocity of supporting medium for the nuclear island greater than 2,804 m/s (9,200 ft/s).
COL 2.5(3)	The COL applicant is to confirm that the lower bound of the site-specific strain-compatible soil profile for a soil site is greater than the lower bound of the generic strain-compatible soil profiles used in the APR1400 seismic analyses.
COL 2.5(4)	The COL applicant is to confirm that the site-specific GMRS determined at the finished grade are completely enveloped by the hard rock high frequency (HRHF) response spectra for a site with a low-strain shear wave velocity of supporting medium for the nuclear island higher than 1,494 m/s (4,900 ft/s) overlaying a hard rock with a low-strain shear wave velocity greater than 2,804 m/s (9,200 ft/s).
COL 2.5(5)	The COL applicant is to perform a site-specific seismic analysis to generate in-structure response spectra at key locations using the procedure described in Appendix 3.7A if COL 2.5(2) and COL 2.5(3) above are not met. In addition, the COL applicant is to confirm that the site-specific in-structure response spectra so generated are enveloped by the corresponding in-structure response spectra provided in Appendix 3.7A.
COL 2.5(6)	The COL applicant is to perform a site-specific seismic response analysis using the procedure described in Appendix 3.7B and the EPRI White Paper, "Seismic Screening of Compo[illegible]" if COL 2.5(4) is not met.
COL 2.5(7)	The C[illegible]e conditions within the standa[illegible]ation in accordance with NRC R[illegible]
COL 2.5(8)	The COL applicant is to confirm that the dynamic properties of structural fill granular to be used in construction of the APR1400 seismic Category I structures satisfy the requirements of structural fill granular provided in Table 2.0-1.
COL 3.2(1)	The COL applicant is to identify the seismic classification of site-specific SSCs that should be designed to withstand the effects of the SSE.
COL 3.2(2)	The COL applicant is to identify the quality group classification of site-specific systems and components and their applicable codes and standards.
COL 3.3(1)	The COL applicant is to demonstrate that the site-specific design wind speed is bounded by the design wind speed of 64.8 m/s (145 mph).
COL 3.3(2)	The COL applicant is to demonstrate that the site-specific seismic Category II structures adjacent to the seismic Category I structures are designed to meet the provisions described in Subsection 3.3.1.2.
COL 3.3(3)	The COL applicant is to provide reasonable assurance the site-specific structures and components not designed for the extreme wind loads do not impact either the function or integrity of adjacent seismic Category I SSCs.

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and minimum compressive strength of 140 kg/cm² (2,000 psi)

for the lean concrete