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.:	**255-8285**
SRP Section:	**03.08.05 – Foundations**
Application Section:	**03.08.05**
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Question No. 03.08.05-7

10 CFR 50.55a and 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 1, 2, 4 and 5 provide the regulatory requirements for the design of the seismic Category I structures. Standard Review Plan (SRP) Section 3.8.5.I.3, “Load and Load Combinations,” states, “These should also include the loads that are induced by the construction sequence and by the differential settlements of the soil under and to the sides of the structures.” Furthermore, SRP Section 3.8.5.I.4, “Design and Analysis Procedures,”, states, “Where a single mat foundation is used for multiple plant structures, attention is given to bending, shear, and similar factors in the basemat that are attributable to uneven settlement, construction sequence, and mat flexibility.”

In DCD Tier 2, Section 3.8.6.4, “Design and Analysis Procedures,” the applicant stated “The maximum differential settlement of foundation is 12.7 mm per 15.24 m (0.5 in per 50 ft) within NI common basemat. The maximum differential settlement between buildings is 12.7 mm (0.5 in) based on enveloping properties of subsurface materials. ” However, it is not clear to the staff how the construction sequence and differential settlement of foundations were considered in the load and load combinations. Therefore, the applicant is requested to describe how the construction sequence and differential settlement of foundations were considered in the load and load combinations. Also, DCD Section 3.8.5 should be updated accordingly.

Response

For maximum differential settlement of buildings, KHNP considered the limited construction sequence, as-built state for the static loading case (Dead + Live), and the dynamic loading case.

1) As-build State for the Static Loading Case (Refer to Technical Report APR1400-E-S-NR-14006-P, Rev. 1, Subsection 4)

   To check the differential settlement of the as-built state for the static loading case (Dead + Live), nodes within a distance of approximately 50 ft for soil profile S1, S4, S8 were chosen

as shown Figure 4-4 of the technical report (TeR). In the analysis, the soil stiffness was considered in the soil springs applied to the subgrade modulus, as specified in TeR Table 2-4. A detailed explanation on the calculation of the subgrade modulus is provided in TeR subsection 2.3.

2) Construction Sequence Based on Concrete Pouring and Hardening Stage Within the Basemat (Refer to TeR Subsection 5)

The purpose of the analysis is to check the stress changes of the concrete and settlement distribution corresponding to the construction sequence. The applied loads are the self–weight of the NI common basemat without any other loads.

To check the differential settlement due to the 24-stage process of concrete pouring and hardening, the difference between maximum and minimum displacements for soil profiles 1 and 8 was used as described in TeR Table 5-3. In contrast to the analysis described in response to item 1 previously, the foundation model including soil stiffness specified in TeR Table 2-3 was used. The soil stiffness values were addressed in RAI 255-8285 Question 03.08.05-16.

3) As-build State for the Dynamic Loading Case.

With regard to differential settlements due to seismic loading, the displacement results from the seismic analysis calculation were used, (refer to the TeR Figures 4-6 through 4-14 on the displacements of the basemat due to seismic loading). The differential settlement by seismic loading was generated from the time-history analysis which does not consider any other loads. The detailed discussion was included in the response to RAI 255-8285 Question 03.08.05-17.

According to DCD Table 3.7A-1 which provides the characteristics of soil profiles S1 thru S8, the soil layers consist of sand, soft rock or rock. The settlement during construction are not to be governed by sand and/or rock sites. Since the total amount of applied loads on the soil profiles S1 thru S8 during construction is less than as-built case, the differential settlement for limited soil profiles described in Table 1 was checked.

Table 1. The summary of Differential Settlement inside building

Table 1. Differential Settlement of Buildings			
Status	As-built	As-built	Construction sequence based on pouring and hardening stage
Applied Load	Dead+Live	Seismic Loading	Self-weight corresponding the sequence of the basemat
Soil model	Soil spring (S1, S4, S8)	3D Full Model (All Soil profiles)	3D Full Model (S1, S8)

Based on the soil properties in DCD Table 3.7A-1, the assumptions of the construction sequence analysis due to the uncertainty of the generic geotechnical parameters are below:

1) The soil layers specified in DCD Table 3.7A-1 were considered.

2) Based on the sand soil characteristics, settlement will occur immediately; therefore, analysis of long-term settlement is not required.

3) The analysis referred to the construction sequence of Shin-Kori Units 3 & 4, rather than using the estimated construction sequence.

4) The effect of the design for seismic Category I structures due to the construction sequence analysis are not accounted for due to the uncertainty of the generic geotechnical parameters and construction sequence if the settlements do not exceed the allowable settlements in DCD Table 2.0-1.

The process for the construction sequence analysis is provided below:

1) The concrete used in the analysis is normal weight concrete with the compressive strength of 5,000 psi at 91 days. The concrete strength is assumed at three hardening conditions to account for the change of strength due to the concrete pouring sequence.

2) The relation between age and strength of concrete complies with the relationship for moist-cured concrete made with normal portland cement proposed by ACI Committee 209. The modulus of elasticity for concrete is calculated using the equation, $57{,}000\sqrt{f'_c}$ as given in ACI-349. The tensile strength of concrete will be checked during construction to determine whether the tensile strength is exceeded or not.

3) The mat foundation is divided by each concrete pour zone based on the construction techniques used. The segments of concrete block are added to the construction site according to the order of the prescribed concrete pouring. The concrete pour sequence and hardening condition of each segment are considered. Construction sequence analysis is performed using a finite element method computer program. The number of analyses corresponds to the number of concrete pouring stages and an additional three analyses to account for the complete hardening of the basemat concrete segments.

4) The construction sequences analysis of superstructures, such as the containment building, internal structures, and auxiliary building, will be conducted by the COL applicant. The COL applicant re-performs the construction sequence analysis of the basemat in accordance with actual site profiles using the same methodology specified in technical report APR 1400-E-S-NR-14006-P, Rev. 1, section 5.0. After hardening of all basemat concrete segments, the construction sequences analysis of superstructures, such as the containment building, internal structures, and auxiliary building, will be conducted. The superstructures are also divided by each concrete segment.

According to SRP 3.8.1, 3.8.3, 3.8.4 and 3.8.5, the seismic Category I structures including the foundation and superstructures should be designed to take into account the additional member forces and moments induced by the effects of the construction sequence and the short term and long term settlement of the soil under the foundation. Though the Standard Review Plan

describes the above explanation, the settlements during construction shall not be governed for sand and/or rock site because the total amount of applied loads on the soil profiles S1 through S8 during construction is less than that after construction. Therefore, the design of building structures is not affected by the results of the construction sequence analysis if the settlement does not exceed DCD Table 2.0-1 values. If the settlement exceeds the acceptance criteria of DCD Table 2.0-1, the COL applicant will modify the construction sequence to meet the specified acceptance criteria. Therefore, the construction sequence analysis is not necessary in the DC application stage.

In the COL stage, the construction sequence analysis will be conducted corresponding to the actual construction schedule and soil profile parameters provided in DCD COL 3.8(10). The differential settlement of the basemat will be checked and the construction sequence analysis results will be provided.

A COL information item (COL 3.8 (13)) will be added to the DCD to ensure that the COL applicant performs a detailed construction sequence analysis that is based on the construction plan, as indicated in the attachment associated with this response.

Impact on DCD

DCD Tier 2, Table 1.8-2 and Subsection 3.8.6 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

There is no impact on any Technical, Topical, or Environmental Report.