# 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

The static and dynamic cases are considered in the differential settlement evaluation. Differential settlement is evaluated in the static loading case (D+L) in technical report APR 1400-E-S-NR-14006-P, Rev1. With regard to differential settlements by seismic loading, the displacement results from the seismic analysis calculation were used (refer to Figures 4-6 through 4-14 regarding displacements of the basemat due to seismic loading in the technical report). Note that the differential settlement by seismic loading was obtained from the time-history analysis which does not consider any other loads.

In DCD Tier 2, Section 3.8.5.4 and technical report APR 1400-E-S-NR-14006-P, Rev.1, the construction sequence analysis considers the pouring and hardening stages and is evaluated for 19 basemat segments. 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.

According to SRP 3.8.1, 3.8.3, 3.8.4 and 3.8.5, the Seismic Category I Structures including 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.

To accomplish the construction sequence analysis, the generic geotechnical parameters are used. Among soil profiles #1, #4, and #8, soil profile #1 is the most critical soil profile for the settlement, and is to be considered. The given data of generic geotechnical parameters for soil profile #1 are;

1) Type of soil and layer which is sand, soft rock, and rock.

2) Shear wave velocity of sand, soft rock, and rock: 1173~3789ft/s for sand, 5778~6325ft/s for soft rock, and 9200ft/s for rock.

3) Unit weight of sand, soft rock, and rock: 0.125~0.130k/ft$^3$ for sand, 0.135k/ft$^3$ for soft rock, and 0.155k/ft$^3$ for rock.

When considering the characteristics of settlement for sand, and the relationship between settlement and applied load, the settlement of sand is controlled by immediate settlement, and the settlement is dependent upon the amount of load applied. So, the settlement during construction will be smaller than the settlement described in the technical report, which is for after construction.

Based on the soil properties of DCD Table 3.7A-1, the generic geotechnical parameters which are assumed for the construction sequence analysis are below;

1) The soil layer of DCD Table 3.7A-1 will be considered.

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

3) The analysis will refer to the construction sequence of the building structures of Shin-Kori units 3&4, instead of using the actual construction sequence.

4) The effect of the design for Seismic Category I structures due to the actual construction sequence will not be 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 procedures for the construction sequence analysis are below,

1) The concrete used in this analysis is normal weight concrete with the compressive strength of 5,000 psi at 91 days. The concrete strength is assumed at the three

hardening conditions to consider the change of the strength due to the concrete pouring sequence.

2) The relation between the age and the strength of the 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 by the equation, $57{,}000\sqrt{f_{ck}}$, as given in ACI-349. The tensile strengths of concrete will be considered.

3) Based on the construction techniques, the mat foundation is divided by concrete pour zones. The segments of concrete block are added to the construction-site according to the order of the prescribed concrete pouring. The concrete pour sequences and hardening condition of each segment are considered. Construction sequence analysis will be performed by a finite element method using a computer program. The number of analyses is the number of concrete pouring stages and an additional 3 analyses to consider the completion of hardening of all the concrete segments.

4) 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.

In the COL stage, the construction sequence analysis will be conducted corresponding to the actual construction schedule and soil profile parameters, as described 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 (11)) will be added to the DCD, as indicated in the attachment associated with this response.

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**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.

Table 1.8-2 (5 of 29)

| Item No. | Description |
|---|---|
| COL 3.8(7) | The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1. |
| COL 3.8(8) | The COL applicant is to provide the necessary measures for foundation settlement monitoring considering site-specific conditions. |
| COL 3.8(9) | The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation and to monitor groundwater chemistry. |
| COL 3.8(10) | The COL application is to provide the following soil information for APR1400 site:<br>1) Elastic shear modulus and Poisson's ratio of the subsurface soil layers,<br>2) Consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots,<br>3) Moisture content, Atterberg limits, grain size analyses, and soil classification,<br>4) Construction sequence and loading history, and<br>5) Excavation and dewatering programs. |
| COL 3.9(1) | The COL applicant is to provide the inspection results for the APR1400 reactor internals classified as non-prototype Category I in accordance with RG 1.20. |
| COL 3.9(2) | The COL applicant is to provide a summary of the maximum total stress, deformation, and cumulative usage factor values for each of the component operating conditions for ASME Code Class 1 components except for ASME Code Class 1 nine major components. For those values that differ from the allowable limits by less than 10 percent, the contribution of each loading category (e.g., seismic, deadweight, pressure, and thermal) to the total stress is provided for each maximum stress value identified in this range. The COL applicant is to also provide a summary of the maximum total stress and deformation values for each of the component operating conditions for Class 2 and 3 components required to shut down the reactor or mitigate consequences of a postulated piping failure without offsite power (with identification of those values that differ from the allowable limits by less than 10 percent). |
| COL 3.9(3) | The COL applicant is to identify the site-specific active pumps. |
| COL 3.9(4) | The COL applicant is to confirm the type of testing and frequency of site-specific pumps subject to IST in accordance with the ASME Code. |
| COL 3.9(5) | The COL applicant is to confirm the type of testing and frequency of site-specific valves subject to IST in accordance with the ASME Code. |
| COL 3.9(6) | The COL applicant is to provide a table listing all safety-related components that use snubbers in their support systems. |

COL. 3.8 (11) The detailed construction sequence analysis for the basemat and superstructure shall be performed according to the actual construction schedule. The differential settlement of the basemat shall be checked to demonstrate acceptability.

COL 3.8(7) The COL applicant is to confirm that uneven settlement due to construction sequence of the NI basemat falls within the values specified in Table 2.0-1.

COL 3.8(8) The COL applicant is to provide the necessary measures for foundation settlement monitoring considering site-specific conditions.

COL 3.8(9) The COL applicant is to provide testing and inservice inspection program to examine inaccessible areas of the concrete structure for degradation and to monitor groundwater chemistry.

COL 3.8.(10) The COL applicant is to provide the following soil information for the APR1400 site: 1) elastic shear modulus and Poisson's ratio of the subsurface soil layers, 2) consolidation properties including data from one-dimensional consolidation tests (initial void ratio, Cc, Ccr, OCR, and complete e-log p curves) and time-versus-consolidation plots, 3) moisture content, Atterberg limits, grain size analyses, and soil classification, 4) construction sequence and loading history, and 5) excavation and dewatering programs.



## 3.8.7 References

1. 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” U.S. Nuclear Regulatory Commission.

2. ASME Section III, Subsection NE, “Class MC Components,” The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

3. ASME Section III, Division 2, “Code for Concrete Containments,” Subsection CC, American Society of Mechanical Engineers, 2001 Edition with 2003 Addenda.

4. Regulatory Guide 1.35, “Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containment,” Rev. 3, U.S. Nuclear Regulatory Commission, July 1990.

5. Regulatory Guide 1.35.1, “Determining Prestressing Forces for Inspection of Prestressed Concrete Containments,” U.S. Nuclear Regulatory Commission, July 1990.

COL. 3.8 (11) The detailed construction sequence analysis for the basemat and superstructure shall be performed according to the actual construction schedule. The differential settlement of the basemat shall be checked to demonstrate acceptability.