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.:	**1-7827**
SRP Section:	**02.05.04 - Stability of Subsurface Materials and Foundations**
Application Section:	**2.5.4**
Date of RAI Issued:	**04/13/2015**

Question No. 02.05.04-1

In accordance with 10 CFR Parts 50, 52.47 and 100 and SRP 2.5.4, regarding APR 1400 DCD Subsections 2.5.4.2 and 2.5.4.3, please provide or properly cross-reference the soil or rock uniformity requirements needed for the foundation of Safety Related Structures. Uniformity requirements as it pertains to subgrade stiffness, shear wave velocity and other static and dynamic properties for the APR 1400 foundation need to be included in appropriate sections of 2.5.4. Please propose changes and/or updates to appropriate sections in 2.5.4 and Table 2.01 with this information.

Response

In the APR1400 standard design, there is no requirement for soil uniformity except that the dip angle in the soil layer be less than 20 degrees as described in DCD Section 2.5.2.7. The soil - structure interaction (SSI) analysis of APR1400 was performed using nine (9) generic site profiles and one fixed-base support condition as standard design. It is the responsibility of COL applicant to perform site-specific SSI analysis and to verify that site-specific variations from the generic layered profiles are enveloped by the Seismic Category I structures standard design. The maximum dip angle will be incorporated in Table 2.0-1.

Impact on DCD

DCD Table 2.0-1 and Tier 1 Table 2.1-1 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical and Environmental Reports.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Table 2.0-1 (3 of 4)

Parameter Description	Parameter Value
Certified Seismic Design Response Spectra (CSDRS) Referencing SSE	See Figures 2.0-1 and 2.0-2
Hard Rock High Frequency (HRHF) Response Spectra(4)	0.46g peak ground acceleration See Figures 2.0-3 and 2.0-4
Fault Displacement Potential (yes/no)	No
Minimum Allowable Static Bearing Demand	718.2 kPa (15 ksf)(3)
Minimum Allowable Dynamic Bearing Demand	2,872.8 kPa (60 ksf)(3)
Minimum Shear Wave Velocity	304.8 m/s (1,000 ft/s)
Liquefaction Potential (yes/no)	No
Maximum Differential Settlement inside Building	12.7 mm (0.5 in) per 15.24 m (50 ft) in any direction
Maximum Differential Settlement between Buildings	12.7 mm (0.5 in)
Minimum Soil Angle of Internal Friction	35 degrees
Slope Failure Potential (yes/no)	No
Backfill Material Density	137 pcf
Backfill Material Dynamic Poisson's Ratio	0.33
Backfill Material Dynamic Properties (Minimum Dynamic Shear Modulus, kg/cm^2) - Shear strain 1 % 0.1 % 0.01 % 0.001 % 0.0001 %	 0.05 0.22 0.54 0.85 1.00
Maximum Dip Angle for Soil Uniformity	20 degrees

Table 2.1-1 (2 of 3)

Tornado	
Maximum Tornado Wind Speed	102.8 m/s (230 mph)
Translational Speed	20.6 m/s (46 mph)
Maximum Rotational Speed	82.2 m/s (184 mph)
Radius of Maximum Rotational Speed	45.7 m (150 feet)
Pressure Drop	8.274 kPa (1.2 psi)
Rate of Pressure Drop	3.447 kPa/s (0.5 psi/s)
Missile Spectra	Table 2 (Region I) of NRC RG 1.76 (2007)
Hurricane	
Maximum 3-Second Wind Gust Speed	116 m/s (260 mph)
Missile Spectra	Table 1 of NRC RG 1.221 (2011)
Soil Properties	
Minimum Allowable Static Bearing Demand	718.2 kPa (15 ksf) (3)
Minimum Allowable Dynamic Bearing Demand	2,872.8 kPa (60 ksf) (3)
Minimum Shear Wave Velocity	304.8 m/s (1,000 ft/sec)
Liquefaction Potential (yes/no)	No
Maximum Differential Settlement inside Building	12.7 mm (0.5 in) per 15.24 m (50 ft) in any direction
Maximum Differential Settlement between Buildings	12.7 mm (0.5 in)
Minimum Soil Angle of Internal Friction	35 degrees
Slope Failure Potential (yes/no)	No
Fault Displacement Potential (yes/no)	No
Backfill Material Density	137 pcf
Backfill Material Dynamic Poisson's Ratio	0.33
Backfill Material Dynamic Properties (Minimum Dynamic Shear Modulus, kg/cm^2) - Shear Strain	
• 1% • 0.1% • 0.01% • 0.001% • 0.0001%	0.05 0.22 0.54 0.85 1.00
Maximum Dip Angle for Soil Uniformity	20 degrees

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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Docket No. 52-046

RAI No.: **1-7827**

SRP Section: **02.05.04 - Stability of Subsurface Materials and Foundations**

Application Section: **2.5.4**

Date of RAI Issued: **04/13/2015**

Question No. 02.05.04-2

In accordance with 10 CFR Parts 50 and 100 and SRP 2.5.4, regarding APR 1400 DCD Subsection 2.5.4.10 and Table 2.0-1, please cross-reference or provide more details on the determination of the dynamic bearing capacity. Information related to the design load combination considered (e.g. shutdown earthquake loads) and Factor of Safety is absent from the discussion in 2.5.4.10. Please propose appropriate changes to the section and updates to Table 2.0-1.

Response

The details on the dynamic bearing capacity and settlement will be added in Subsections 2.5.4.10.1 and 2.5.4.10.2, respectively. Also, Subsection 2.5.4.11 will be revised to clarify a Factor of Safety for the bearing capacity of soil under foundation.

The design load combination and a Factor of Safety were provided in Subsection 3.8.5. In addition, the details of stability can be found in Subsection 3.8.5.5 along with Table 3.8-10 and Table 3.8A-15.

Impact on DCD

DCD Sections 2.5.4.10, 2.5.4.11 and relevant subsections will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical and Environmental Reports.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

2.5.4.8 Liquefaction Potential

As specified in Table 2.0-1, no potential for liquefaction is allowed for seismic Category I structures. The potential liquefaction under non-seismic Category I structures is a site-specific issue to be addressed by combined operating license applicants.

2.5.4.9 Earthquake Site Characteristics

The earthquake site-specific characteristics are described in Subsection 2.5.2.

2.5.4.10 Static Stability

Bearing capacity analysis and settlement computation using stratigraphic conditions, strength, and elastic parameters of the rock mass, building loads, and structural interfaces are provided.

and factor of safety (FOS) of stability

An evaluation of lateral earth pressures and hydrostatic groundwater loads acting on plant facilities is provided. Foundation information on seismic Category I structures is provided in Subsection 3.8.5.

An analysis is conducted using a two-dimensional or three-dimensional model.

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2.5.4.11 Design Criteria

The criteria for the factor of safety (FS) for the safety analysis of foundation rock and slope that may affect seismic Category I facilities are as follows:

Criterion	Factor of Safety
Bearing Capacity	
Ultimate capacity	FS ≥ 3.0
Transient loading	FS ≥ 2.0
Maximum localized stress	FS ≥ 1.2
Slope	
Static condition	FS ≥ 1.5
Dynamic condition	FS ≥ 1.2

The design criteria used in the stability studies of all safety-related facilities, including a description of the computer programs used in the analyses and the soil loads, are provided.

2.5.4.10.1 Bearing Capacity

The maximum bearing pressure under static loading conditions for the foundation basemat beneath the Seismic Category I structure (reactor containment building, auxiliary building, emergency diesel generator building and diesel fuel oil tank) is 641.5 kPa (13,397 lb/ft^2), which includes the dead weight of the structure and components and live load. The maximum bearing pressure under safe shutdown earthquake loads combined with static loads, as described in Subsection 3.8.5, is 1415.9 kPa (29,572 lb/ft^2) (Reference 8). The maximum bearing pressure is smaller than the maximum bearing demands specified in Table 2.0-1.

The COL applicant will evaluate the allowable bearing capacity of the subsurface based on the site-specific properties of the underlying materials, including appropriate laboratory test data to evaluate strength, and considering local site effects, such as fracture spacing, variability in properties, and evidence of shear zones. If the site-specific allowable bearing capacity is outside the range evaluated for APR1400 design certification or smaller than the maximum bearing demands specified in Table 2.0-1, a site-specific evaluation shall be performed by a COL applicant using the APR1400 basemat model and methodology described in subsection 3.8.5(COL 2.5(11)).

2.5.4.10.2 Settlement

The safety-related structures of APR1400 are reactor containment building, auxiliary building, emergency diesel generator building, and diesel fuel oil tank. Based on the distributed arrangement of safety-related systems and components, there are some restricted interfaces between systems which communicate between or within buildings. The effect of total settlement and differential settlement will be considered where these interfaces occur.

Total settlement and differential settlement is dependent on site-specific conditions, construction sequence, loading condition, and excavation plans. It is expected that most of this settlement occurs during civil construction prior to final installation of the equipment. Site-specific considerations for the predicted settlement will be taken into account. Site-specific considerations include the effects of excavation, foundation material preparation, sequence of concrete placement of the basemat, and site-specific construction sequence of the superstructure.

The COL applicant will verify whether the predicted settlement exceeds the maximum differential settlement within building specified in Table 2.0-1 or not. If the predicted settlement exceeds the maximum value in Table 2.0-1, a detailed site specific evaluation shall be performed by a COL applicant using the APR1400 basemat model and methodology described in subsection 3.8.5 to demonstrate acceptable (COL 2.5(12)).

2.5.4.11 Design Criteria

The criteria for the factor of safety (FOS) for the safety analysis of foundation soil and slope that may affect seismic Category I facilities are shown in Table 2.0-1.

For bearing capacity of soil under foundation, the required FOS is greater than or equal to 3.0 for static condition and the required FOS is greater than or equal to 2.0 for dynamic condition including SSE load.

For slope, the required FOS is greater than or equal to 1.5 for static condition and the required FOS is greater than or equal to 1.2 for dynamic condition including SSE load.

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 Components Sensitive to High Frequency Vibratory Motions" (Reference 6), if COL 2.5(4) is not met.

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.

2.5.7 References

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 Plant

3. Regu
Engi
Regu

4. Regu
Earth

5. NRC
Seism
Regu

COL 2.5(11) The COL applicant will evaluate the allowable bearing capacity of the subsurface based on the site-specific properties of the underlying materials, including appropriate laboratory test data to evaluate strength, and considering local site effects, such as fracture spacing, variability in properties, and evidence of shear zones. If the site-specific allowable bearing capacity is outside the range evaluated for APR1400 design certification or smaller than the maximum bearing demands specified in Table 2.0-1, a site-specific evaluation shall be performed by a COL applicant using the APR1400 basemat model and methodology described in subsection 3.8.5.

COL 2.5(12) The COL applicant will verify whether the predicted settlement exceeds the maximum differential settlement within building specified in Table 2.0-1 or not. If the predicted settlement exceeds the maximum value in Table 2.0-1, a detailed site specific evaluation shall be performed by a COL applicant using the APR1400 basemat model and methodology described in subsection 3.8.5 to demonstrate acceptable.

6. “Seismic Screening of Components Sensitive to High Frequency Vibratory Motions,” EPRI White Paper, June 2007.

7. NUREG/CR-0693, "Seismic Input and Soil-Structure Interaction," U.S. Nuclear Regulatory Commission, February 1979.

8. APR1400-E-S-NR-14006-P, "Stability Check for NI Common Basemat" Rev.1, KHNP, February 2015.

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
COL	
COL	
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 Components Sensitive to High Frequency Vibratory Motions," if COL 2.5(4) is not met.
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 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 that 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.

COL 2.5(11) The COL applicant will evaluate the allowable bearing capacity of the subsurface based on the site-specific properties of the underlying materials, including appropriate laboratory test data to evaluate strength, and considering local site effects, such as fracture spacing, variability in properties, and evidence of shear zones. If the site-specific allowable bearing capacity is outside the range evaluated for APR1400 design certification or smaller than the maximum bearing demands specified in Table 2.0-1, a site-specific evaluation shall be performed by a COL applicant using the APR1400 basemat model and methodology described in subsection 3.8.5.

COL 2.5(12) The COL applicant will verify whether the predicted settlement exceeds the maximum differential settlement within building specified in Table 2.0-1 or not. If the predicted settlement exceeds the maximum value in Table 2.0-1, a detailed site specific evaluation shall be performed by a COL applicant using the APR1400 basemat model and methodology described in subsection 3.8.5 to demonstrate acceptable.

APR1400 DCD TIER 2

The allowable static bearing capacity, including a factor of safety 3.0, shall be greater than or equal to the maximum static bearing demand.

Table 2.0-1 (3 of 4)

Parameter Description	Parameter
Certified Seismic Design Response Spectra (CSDRS) Referencing SSE	See Figures 2.0-1 and 2.0-2
Hard Rock High Frequency (HRHF) Response Spectra(4)	0.46g peak ground acceleration See Figures 2.0-3 and 2.0-4
Fault Displacement Potential (yes/no)	No
~~Minimum Allowable~~ Static Bearing Demand	718.2 kPa (15 ksf)(3)
~~Minimum Allowable~~ Dynamic Bearing Demand	2,872.8 kPa (60 ksf)(3)
Minimum Shear Wave Velocity	304.8 m/s (1,000 ft/s)
Liquefaction Potential (yes/no)	No
Maximum Differential Settlement inside Building	12.7 mm (0.5 in) per 15.24 m (50 ft) in any direction
Maximum Differential Settlement between Buildings	12.7 mm (0.5 in)
Minimum Soil Angle of Internal Friction	35 degrees
Slope Failure Potential (yes/no)	No
Backfill Material Density	137 pcf
Backfill Material Dynamic Poisson's Ratio	0.33
Backfill Material Dynamic Properties (Minimum Dynamic Shear Modulus, kg/cm^2) - Shear strain 1 % 0.1 % 0.01 % 0.001 % 0.0001 %	 0.05 0.22 0.54 0.85 1.00
Minimum Factor of Safety for Slope on Static condition	1.5
Minimum Factor of Safety for Slope on Dynamic condition (SSE)	1.2

Maximum

The allowable dynamic bearing capacity, including a factor of safety 2.0, shall be greater than or equal to the maximum dynamic bearing demand.

Table 2.1-1 (2 of 3)

Tornado	
Maximum Tornado Wind Speed	102.8 m/s (230 mph)
Translational Speed	20.6 m/s (46 mph)
Maximum Rotational Speed	82.2 m/s (184 mph)
Radius of Maximum Rotational Speed	45.7 m (150 feet)
Pressure Drop	8.274 kPa (1.2 psi)
Rate of Pressure Drop	3.447 kPa/s (0.5 psi/s)
Missile Spectra	Table 2 (Region I) of NRC RG 1.76 (2007)
Hurricane	
Maximum 3-Second Wind Gust Speed	116 m/s (260 mph)
Missile Spectra	Table 1 of NRC RG 1.221 (2011)
Soil Properties	
~~Minimum Allowable~~ Static Bearing Demand	718.2 kPa (15 ksf) (3)
~~Minimum Allowable~~ Dynamic Bearing Demand	2,872.8 kPa (60 ksf) (3)
Minimum Shear Wave Velocity	304.8 m/s (1,000 ft/sec)
Liquefaction Potential (yes/no)	No
Maximum Differential Settlement inside Building	12.7 mm (0.5 in) per 15.24 m (50 ft) in any direction
Maximum Differential Settlement between Buildings	12.7 mm (0.5 in)
Minimum Soil Angle of Internal Friction	35 degrees
Slope Failure Potential (yes/no)	No
Fault Displacement Potential (yes/no)	No
Backfill Material Density	137 pcf
Backfill Material Dynamic Poisson's Ratio	0.33
Backfill Material Dynamic Properties (Minimum Dynamic Shear Modulus, kg/cm^2) - Shear Strain	
• 1% • 0.1% • 0.01% • 0.001% • 0.0001%	0.05 0.22 0.54 0.85 1.00
Minimum Factor of Safety for Slope on Static condition	1.5
Minimum Factor of Safety for Slope on Dynamic condition (SSE)	1.2

The allowable static bearing capacity, including a factor of safety 3.0, shall be greater than or equal to the maximum static bearing demand.

Maximum

The allowable dynamic bearing capacity, including a factor of safety 2.0, shall be greater than or equal to the maximum dynamic bearing demand.

FAC	flow-accelerated corrosion
FACT	fuel assembly compatibility test
FAP	fuel alignment plate
FATT	fracture appearance transition temperature
FC	fully closed
FCAW	flux cored arc welding
FCI	fuel-coolant interaction
FCR	field change request
FDS	floor drain system
FDT	1) floor drain tank 2) functional definition table
FEI	fluid-elastic instability
FEM	finite element model
FF	flash fraction
FHA	1) fuel handling accident 2) fuel handling area 3) fire hazards analysis
FHAEES	fuel handling area emergency exhaust system
FHEVAS	fuel handling area emergency ventilation actuation signal
FHS	fuel handling system
FIDAS	fixed in-core detector amplification system
FIRS	foundation input response spectra
FIV	flow-induced vibration
FLB	feedwater line break
FLC	factored load category
FLEX	diverse and flexible coping strategies
FME	foreign material exclusion
FMEA	failure modes and effects analysis
FO	fully open
FOM	fiber optic modem
FP	fire protection

FOS factor of safety