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.:	**255-8285**
SRP Section:	**03.08.05 - Foundations**
Application Section:	**03.08.05**
Date of RAI Issue:	**10/19/2015**

Question No. 03.08.05-4

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) 3.8. 5, Section I.1.A, “Containment Structure Foundation,” states “If waterproofing membranes are used, the review addresses their effect on the shear resistance of the foundation.”

In DCD Tier 2, Section 3.8.5.1, “Description of Foundations,” the applicant did not provide any description whether waterproofing membranes are used. Therefore, the applicant is requested to address the following, and include this information in DCD Section 3.8.5:

Applicant is requested to descript, whether waterproofing membranes are used in APR1400 design, and if used, provide effects on the shear resistance of the NI common basemat.

Response – (Rev. 1)

Waterproofing membranes are used for exterior horizontal and vertical surfaces of structures in APR1400 design. The incorrect sentence in “e” of DCD Tier 2, Section 3.4.1.2 will be deleted.

A typical detail for installation of the waterproofing membranes is shown in Figure 1. Because the membranes are installed between lower and upper lean concrete beneath the basemat, they affect the shear resistance of the NI common basemat.

The sliding by shear transfer may be considered across the interfaces between dissimilar materials, i.e., foundation concrete on lean concrete, lean concrete and waterproofing membrane, lean concrete and the supporting medium (soil or rock), and within the supporting medium.

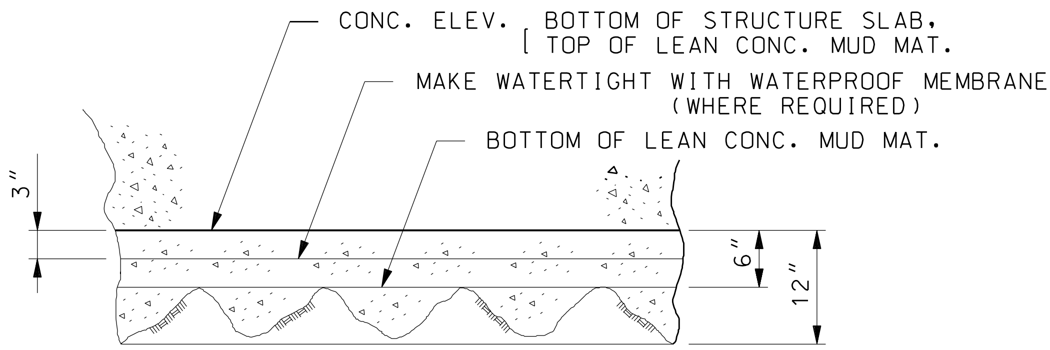

Figure 1 Typical Detail for Installation of Waterproofing Membrane

The coefficient of friction between the lean concrete and waterproofing membrane is bounded by 0.55 as described in COL 3.8(13). This value is compared with the coefficients of friction between other interfaces, and the minimum value among them is used for stability check of the basemat.

Impact on DCD

DCD Tier 2, Subsections 3.4.1.2 and 3.8.5.1 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.

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3.4.1.2 Flood Protection from External Sources

The flood protection measures for seismic Category I SSCs are designed in accordance with NRC RG 1.102 (Reference 3).

Seismic Category I structures identified in Table 3.2-1 are designed for flood protection. Seismic Category I structures are designed to protect safety-related equipment from flooding by incorporating the following safeguards into their construction:

a. No exterior access openings are lower than 0.41 m (1 ft 4 in) above plant grade (yard grade) elevation.

b. The finished yard grade adjacent to the safety-related structures is maintained at least 0.41 m (1 ft 4 in) below the ground floor elevation, except where ramps or steps are provided for access.

c. Waterstops are used in all horizontal and vertical construction joints in all exterior walls up to flood-level elevation.

d. Water seals are provided for all penetrations in exterior walls up to flood-level elevation. The water seals are designed for the static pressure of water at the flood elevation. Water seals in safety-related structures are designed to maintain integrity in the event of an SSE.

e. All below-grade exterior walls and basemats of seismic Category I structures are thickened by more than or equal to 0.6 m (2 ft) to protect against water seepage, as required in SRP Section 14.3.2. ~~Waterproofing systems are not used under the basemats or on the below-grade exterior walls of seismic Category I structures as a provision against external flooding.~~

Penetrations below the external flood level in the external walls of the auxiliary building include component cooling water, radwaste, and diesel fuel oil system piping and cable penetrations. Additional penetrations may be identified when layouts are finalized for systems such as sewage, demineralized water, station air, and security. All penetrations

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3.8.5 Foundations

3.8.5.1 Description of the Foundations

The foundation basemat is a reinforced concrete common basemat structure for the nuclear island that consists of the reactor containment building and auxiliary building.

3.8.5.1.1 Reactor Containment Building Foundation

The reactor containment building basemat is reinforced at the top and bottom with layers of reinforcing steel bars. The reinforcing bars are arranged in radial and hoop directions for top layers and orthogonal directions for bottom layers. In addition, the reinforcing bars at the floor of the reactor pit below the liner are arranged in orthogonal directions for the top and bottom layers.

The steel liner plate for the containment basemat is 6.0 mm (0.25 in) thick except for embedments in local areas where it is thickened. The liner is anchored by welding on the top of the structural steel rolled sections embedded in the concrete.

Interior structural concrete is poured over the basemat liner to provide support for the reactor coolant loop (RCL) equipment, RCL piping, and the interior concrete walls. Tensile loads generated from analyses are carried by anchorage through the liner plate and into the basemat, if required. Tensile loads from internal concrete walls are transferred from the wall reinforcement to a thickened liner plate using mechanical splices and are then transferred to the base slab through steel reinforcement dowels welded to the underside of the thickened liner plate.

3.8.5.1.2 Auxiliary Building Foundation

The foundation of the auxiliary building is a reinforced concrete mat and rests on competent material with a thickness of 3.05 m (10 ft). The bottom of the basemat is located at elevation 40 ft 0 in and 45 ft 0 in, below the finished grade elevation.

Waterproofing membranes are used for exterior horizontal and vertical surfaces of structures. The waterproofing membranes are installed between lower and upper lean concrete beneath the basemat. The COL applicant is to verify that the coefficient of friction between the lean concrete and waterproofing membrane is bounded by 0.55 (COL 3.8(13)).

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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.

COL 3.8(13) The COL applicant is to verify that the coefficient of friction between the lean concrete and waterproofing membrane is bounded by 0.55.

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.

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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: 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.
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(13) The COL applicant is to verify that the coefficient of friction between the lean concrete and waterproofing membrane is bounded by 0.55.

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Question No. 03.08.05-14

10 CFR 50.55a and Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50, provide the regulatory requirements for the design of the containment internal structures. Standard Review Plan (SRP) 3.8.5, Section II specifies analysis and design procedures applicable to the foundation of seismic Category I structures.

Technical Report (TR) APR1400-E-S-NR-14006-P, Rev. 1, “Stability Check for NI Common Basemat,” Section 4.2.2, “Sliding Check,” states that, “The resistance forces against sliding of the common basemat are checked for the driving shear forces generated for the seismic load. The basemat friction force is considered to resist the sliding of the common basemat.” The applicant further stated that coefficient of friction for sliding check is 0.7. The applicant’s approach for evaluating the sliding analyses of the Category I structures is not clear to the staff. SRP 3.8.5 II.4.G and B provides the criteria for determining the sliding forces and overturning moment of the Category I structures subject to seismic loads. Per 10 CFR 50.55a; Appendix A to 10 CFR Part 50, General Design Criteria 1, 2, 4, 16 and 50; and SRP 3.8.5, the applicant is requested to provide a detail description of the method used to determine the sliding check of the Category I structures; and to justify that the coefficient of friction of 0.7 represents the minimum coefficient of friction considering the various sliding interfaces including concrete to soil, waterproofing to soil, and concrete basemat to concrete mudmat.

Response – (Rev. 1)

In the design of the APR1400, the stability check against sliding of Seismic Category I structures is based on the factor of safety specified in Table 3.8-10 of the DCD. The maximum shear forces induced by the safe shutdown earthquake are greater than those induced by the wind load. The wind load is not considered in the calculation for the sliding check since the seismic force and the wind load are not in the same load combination.

The factor of safety (FOS) against sliding is calculated at each time step (t = 0 ~ 20.48 seconds with an interval of 0.005 seconds) for each soil case (S01 ~ S09; S10 is a fixed base case), i.e., by linear time history method. The final result is shown in Table 1 and Figure 1 below.

Table 1 Factor of Safety against Sliding

Soil Case	Minimum Factor of Safety
S01	1.516
S02	1.585
S03	1.483
S04	1.375
S05	1.411
S06	1.259
S07	1.247
S08	1.360
S09	1.333

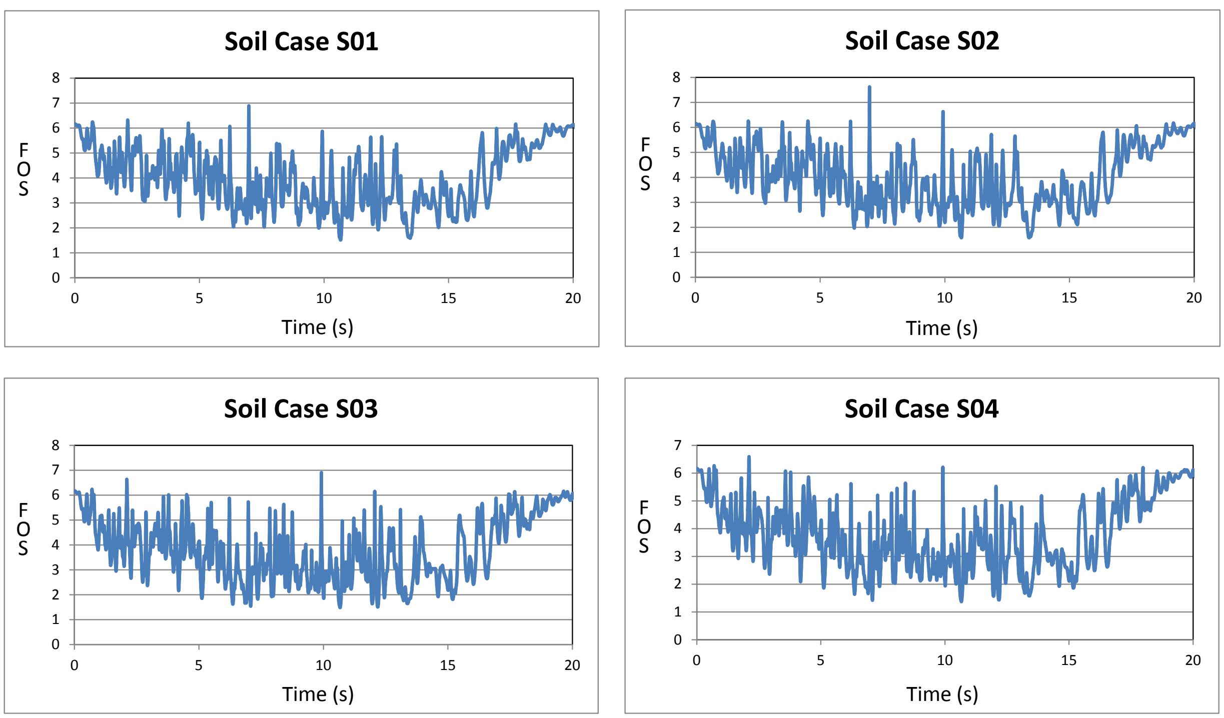

Figure 1 Factor of Safety against Sliding at Each Time Step

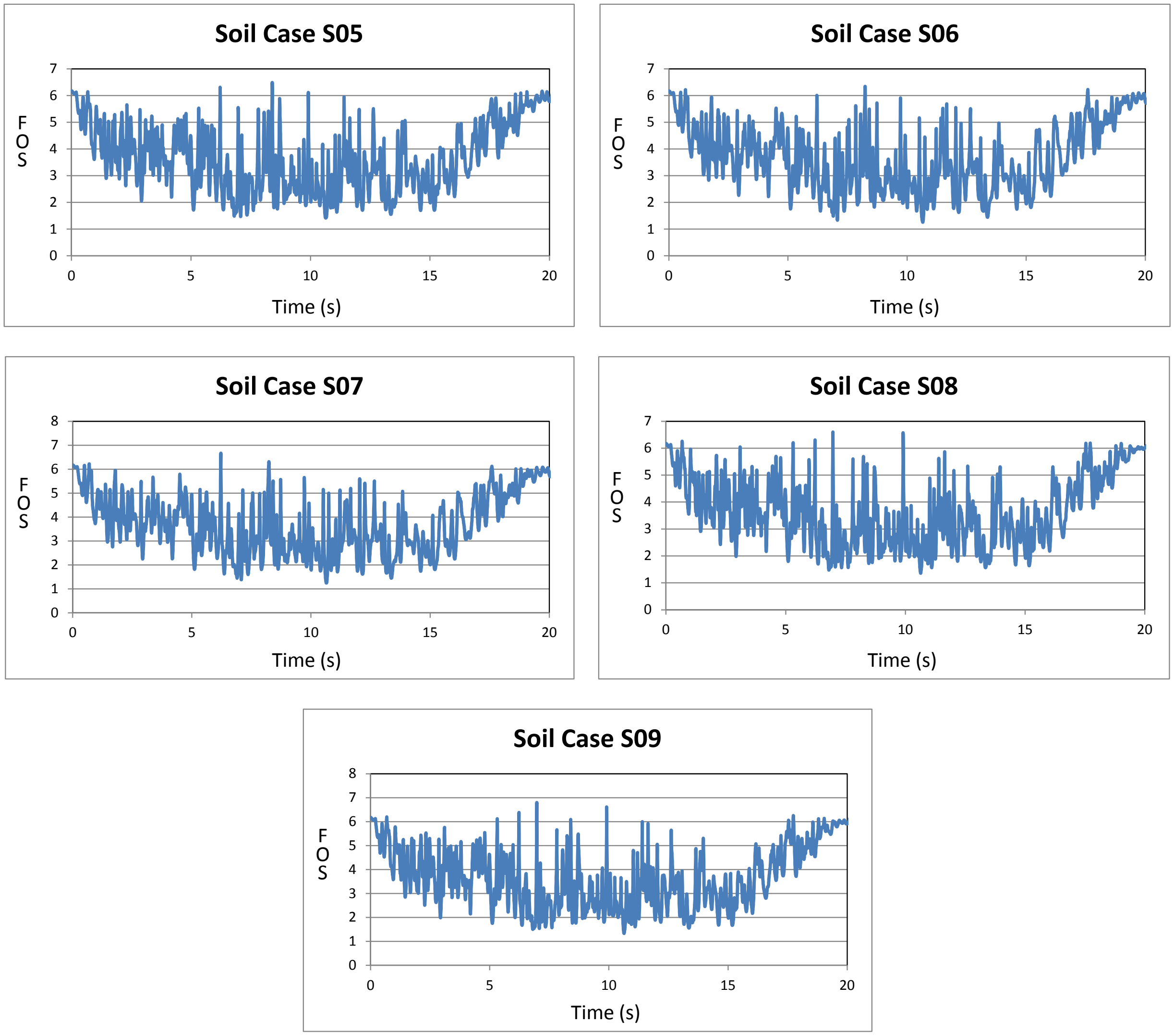

Figure 1 Factor of Safety against Sliding at Each Time Step (continued)

The FOS against sliding is calculated by the ratio of resisting force to driving force. The driving force is calculated from seismic horizontal force of the NI structure. From the time history analysis result, the total sum of seismic horizontal force of the NI structure is obtained for E-W and N-S direction, respectively. At each time step, resultant horizontal driving force is calculated from the E-W and N-S direction forces by square root of sum of their squares.

The resisting force consists of two categories: resisting force by base friction and resisting force by shear keys.

In the calculation of the base friction, the effective dead weight of the NI structure is multiplied with the coefficient of friction (COF) of 0.55. For the calculation of the effective dead weight, the buoyant force from design ground water level is subtracted from the total dead weight of the NI structure. This subtraction is applied at all the time steps. Then, the total vertical seismic force obtained from the time history analysis is algebraically summed at each time step to consider probable adverse effect of seismic uplift. That is, the seismic forces of E-W, N-S, and vertical directions are simultaneously considered in the evaluation.

The COF of 0.55 is based on the value between the lean concrete and waterproofing material. In the design of APR1400, there are upper and lower lean concrete layers between the supporting medium and the foundation concrete, as shown in Figure 1of the response to RAI 255-8285, Question 03.08.05-4. Because the waterproofing membranes are installed between the lower and upper lean concrete layers beneath the basemat, the sliding by shear transfer may be considered across the interfaces between dissimilar materials, i.e., foundation concrete on lean concrete, lean concrete and waterproofing membrane, lean concrete and the supporting medium (soil or rock), and within the supporting medium.

According to DCD Tier 2, Table 2.0-1 and KHNP's response to RAI 149-8147, Question 02.05.04-12, the minimum angle of internal friction of supporting medium is 35 degrees, which leads to a COF of 0.7, and this is to be confirmed by the COL applicant (COL 2.5(15)). This value is applicable to the internal friction of the supporting medium, i.e., soil-on-soil interface. For the case of a cohesionless soil site, the COL applicant should confirm that the soil below the structures will have a friction angle in excess of 35 degrees. For a cohesive soil site, the COL applicant should confirm that the soil will have an undrained strength equivalent to or exceeding a drained strength of 35 degrees, yielding a coefficient of friction greater than 0.7.

The Design Manual 7.02 of Naval Facility Engineering Command (1986) states the COF is 0.7 between mass concrete on rock media, representing the friction angle of 35 degrees. This is applicable to the interface between the lean concrete and supporting medium at a rock site. The Design Manual 7.02 also shows the range of 0.55 to 0.60 for coefficient of friction between mass concrete and gravel, gravel-sand mixture, or coarse sand. This is applicable to the basemat design of APR1400. Although it recommends the range of 0.45 to 0.55 for the interface between mass concrete and fine to medium sand, the value of 0.55 is reasonable because the fine sand is not appropriate as supporting medium for nuclear power plant and because the friction between the lean concrete and the supporting medium may be higher due to the interlocking of lean concrete and the soil or rock as shown in in Figure 1of the response to RAI 255-8285, Question 03.08.05-4. The COL applicant is to verify that the COF between the lean concrete and the supporting medium at the site is equal to or higher than 0.55 (COL 3.8(14)).

The COF between the lean concrete and foundation concrete may be used as 1.0 or higher. The Provision 11.7.4.3 of ACI 349 states that the COF shall be taken as 1.0 for concrete placed against hardened concrete with surface intentionally roughened. This is applicable to the interface between the foundation concrete and the lean concrete of APR1400 because Standard Drawing 1-300-C118-001 of APR1400 states: "Construction joints shall be intentionally roughened to a full amplitude of approximately 1/4 inches unless noted otherwise."

From the above discussion, the COF of 0.55 as a minimum among the interfaces is used for the calculation of resisting force by base friction.

For the resisting force by shear keys, partial concave and convex areas of the basemat that are expected to play a role as shear keys are considered. Shear keys may be used to provide additional resistance against basemat sliding. In this sliding evaluation, the difference of passive soil pressure and active soil pressure are considered as the additional resistance, as shown in Figure 2. Because the direct shear strength on the sliding soil face is larger than the force by passive soil, this approach is reasonable. The configuration of the shear keys considered in this evaluation is shown in Figure 3. Only the smaller resistance of E-W or N-S direction side is conservatively calculated against the resultant horizontal driving force from the two directions.

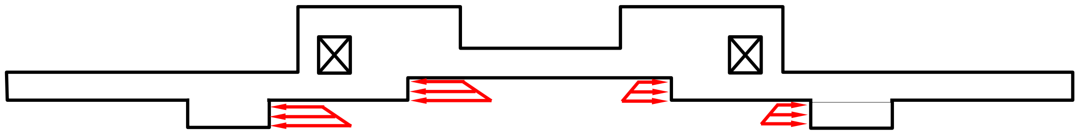

Figure 2 Resisting Force by Shear Keys

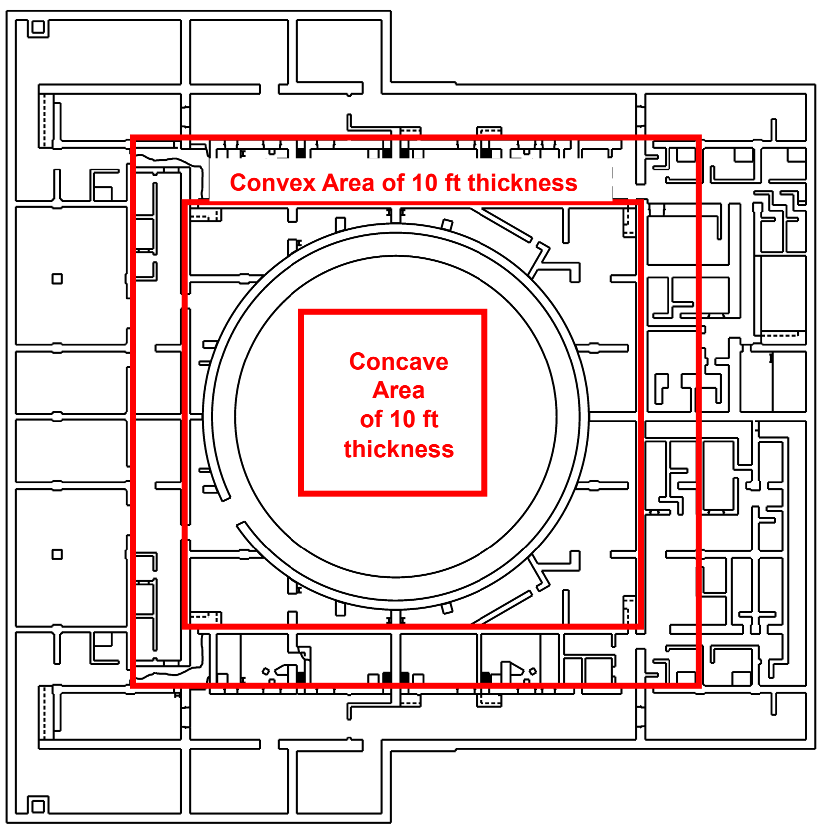

Figure 3 Configuration of Shear Keys considered in Evaluation

Finally, the minimum FOS against sliding during the entire time period and for all soil cases is obtained as 1.25, as shown in Table 1.

In addition, the evaluation of FOS against overturning is performed based on the static method using the maximum seismic moments and forces of each direction. That is, when 100% of maximum driving moments and 100% of maximum vertical uplift force are used together with 100% of maximum horizontal seismic forces, the FOS is decreased from 1.36 into 1.24 which still exceeds the acceptable value of 1.1 in Table 3.8-10 of the DCD.

Impact on DCD

DCD Tier 2, Subsections 3.8.5.5.2, 3.8.6, and Tables 1.8-2, 3.8A-15 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-14006-P/NP, Rev. 1 Section 4.2, Subsections 4.2.1 and 4.2.2 will be revised, as indicated in the attachment associated with this response.

The acceptance criteria for overturning, sliding, and flotation are described in Table 3.8-10. The factor of safety to design load combinations is calculated as stated below and compared to the minimum factors to provide reasonable assurance of the stability of the basemats.

3.8.5.5.1 Overturning Acceptance Criteria

The factor of safety against overturning is identified as the ratio of the resisting moment on overturning (M_r) to the overturning moment (M_o). Therefore,

FS_o = [M_r / M_o], not less than the factor of safety determined from Table 3.8-10.

Where:

FS_o = structure factor of safety against overturning caused by the design basis wind, tornado, hurricane, or earthquake load

M_r = resisting moment determined as the dead load of the structure minus buoyant force from normal design groundwater table, multiplied by the distance from the structure edge to the structure center of gravity provided there is no overstress at the edge of the structure

M_o = overturning moment caused by earthquake

Resistance moment due to passive soil pressure is not included in M_r. Therefore, active and overburden soil pressures are also not considered.

3.8.5.5.2 Sliding Acceptance Criteria

The factor of safety against sliding caused by earthquake is identified by the following ratio:

FS_s = [F_s]/[F_d], not less than the factor of safety determined from Table 3.8-10

Where:

FS_s = structure factor of safety against sliding caused by earthquake

F_s = sliding resistance along bottom of the basemat determined as the dead load of the structure minus the buoyant force from the normal design groundwater table and sliding resistance by shear key effect

F_d = earthquake load

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The sliding resistance is based on the friction force developed between the basemat and the foundation with a coefficient of friction of 0.7 calculated with an internal friction angle of 35 degrees in the soil below the basemat. Resistance force due to passive soil pressure is not included in F_s. Therefore, active and overburden soil pressures are also not considered.

3.8.5.5.3 Flotation Acceptance Criteria

The factor of safety against flotation is identified as the ratio of the total dead load of the structure including basemat (D_r) to the buoyant force (F_b). Therefore, $FS_f = D_r / F_b$, not less than the factor of safety determined from Table 3.8-10.

Where:

FS_f = structure factor of safety against flotation caused by the maximum design basis flood or groundwater table

D_r = total dead load of the structure including basemat

F_b = buoyant force caused by the design basis flood or high groundwater table, whichever is greater

3.8.5.6 Material, Quality Control, and Special Construction Techniques

The materials, quality control, and special construction techniques for foundations conform with those set forth for the superstructures as discussed in Subsections 3.8.1.6 and 3.8.4.6 and Appendix 3.8A.

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

3.8.5.7 Testing and Inservice Inspection Requirements

Testing and inservice surveillance of the basemat are performed in accordance with the requirements described in Subsections 3.8.1.7 and 3.8.4.7.

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

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The factor of safety against sliding is calculated by the ratio of resisting force to driving force. The factor of safety against sliding may be calculated at each time step for each soil case, i.e., by linear time history method. In this case, the minimum value is selected as the factor of safety.

The driving force is calculated from seismic horizontal force of the structure. From the time history analysis result, the total sum of seismic horizontal force of the structure is obtained for E-W and N-S direction, respectively. At each time step, resultant horizontal driving force is calculated from the E-W and N-S direction forces by square root of sum of their squares.

The resisting force consists of two categories: resisting force by base friction and resisting force by shear keys. The resisting force by base friction is based on the minimum friction force between the sliding interfaces. In the calculation of the resistant force, the coefficient of friction of 0.55 is used (COL 3.8(13)). It is based on that the coefficient of friction between waterproofing membrane and lean concrete is the minimum value among the interfaces of dissimilar materials.

The COL applicant is to verify that the coefficient of friction between the lean concrete and the supporting medium at the site is equal to or higher than 0.55 (COL 3.8(14)). The minimum angle of internal friction of supporting medium is 35 degrees, which leads to a coefficient of friction of 0.7, and this is to be confirmed by the COL applicant (COL 2.5(15)). The coefficient of friction between the lean concrete and foundation concrete may be used as 1.0 or higher because construction joints of APR1400 shall be intentionally roughened.

The resisting force by base friction is calculated by multiplication of effective dead weight and coefficient of friction. For the calculation of the effective dead weight, probable adverse effects of the buoyant force from design ground water level and seismic uplift force are considered.

For the resisting force by shear keys, partial concave and convex areas of the basemat that are expected to play a role as shear keys are considered. Shear keys may be used to provide additional resistance against basemat sliding. In this sliding evaluation, the difference of passive soil pressure and active soil pressure are considered as the additional resistance provided the direct shear strength on the sliding soil face is larger than the force by passive soil.

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COL 3.8(14) The COL applicant is to verify that the coefficient of friction between the lean concrete and the supporting medium at the site is equal to or higher than 0.55.

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.

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Table 1.8-2 (5 of 29)

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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.
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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(14)	The COL applicant is to verify that the coefficient of friction between the lean concrete and the supporting medium at the site is equal to or higher than 0.55.

Table 3.8A-15

Results on Factor of Safety for Basemat Stability

	FOS(1)	Allowable FOS	Remark
Overturning	~~1.36~~ 1.24	1.10	
Sliding	~~1.51~~ 1.25	1.10	
Flotation	3.39	1.10	

FOS = Factor of Safety

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The maximum probable differential settlements of the APR1400 NI common basemat are 0.18 and 0.1 in. for the static (D+L) and seismic (Es) loading conditions, respectively. Therefore, it is concluded that the critical criterion for differential settlement, is 0.5 in. differential settlement per 50 ft.

In addition, the differential settlement between the NI basemat and the other buildings is checked. Additional FE analyses for the turbine generator building (TGB), which is the building adjacent to the NI common basemat are performed for the differential settlement between the NI basemat and other buildings. The superstructure of the TGB consists of braced steel frames, and the basemat of the TGB is located at El. 73 ft 0 in.. The subgrade moduli for the TGB analysis corresponding to S1, S4, and S8 are 28.52 kcf, 121.37 kcf, and 877.20 kcf, respectively (see Table 2-4). The settlement analyses for the TGB basemat are carried out using the GTSTRUDL program. Figure 4-15 shows the FE model for the TGB basemat analysis. The maximum settlements of the NI and TGB basemats are used for calculating the differential settlement. Table 4-3 shows the differential settlement between the NI basemat and the TGB basemat. From the analysis results, it is concluded that the criterion for the differential settlement between the NI basemat and the other buildings, which is 0.5 in., is acceptable.

4.1.3 Site Interface for the Nuclear Island Common Basemat

The bearing pressures of the NI common basemat by static and seismic loadings are evaluated in this subsection.

For the bearing pressure, the D+L load (static) case and LC08 through LC15 (dynamic) cases are applied in the basemat and the maximum bearing pressures of the basemat are obtained from the ANSYS static analysis. Table 4-4 shows the bearing pressures by static and dynamic loadings. These bearing pressures are satisfied because the allowable bearing capacity is less than or equal to 15 ksf (static) and 60 ksf (dynamic).

4.2 Stability Check of the Nuclear Island Common Basemat

The NI common basemat structure is evaluated for stability against overturning, sliding, and flotation. The calculated factors of safety against overturning, sliding, and flotation for the applicable load combinations satisfy the criteria shown in Table 4-5.

The normal design groundwater elevation for the APR1400 is 96.67 ft. The extreme groundwater elevation (design basis flood level) is the same as the plant grade level (98.67 ft) for seismic Category I, II, and III structures considering the probable maximum flood level.

In the earthquake load, axial force, shear force, and moment due to horizontal and vertical excitation of the structure are obtained from seismic analysis. Table 4-6 shows the enveloped results of the seismic analysis corresponding to each site profile (S1 through S9). Since the seismic load governs the wind load, a stability check is not considered for the wind load condition. ~~In addition, the earth pressure effect is neglected for a conservative stability check.~~

4.2.1 Overturning Check

For the overturning check, the possible minimum resisting moment and maximum driving moment are conservatively calculated. In addition, when overturning is checked in combination with seismic forces (E_s), the hydrostatic force at the design water level (H_e) is used. ~~Minimum resisting moment is obtained by multiplying the effective dead load (D-H_e) by the minimum distance (d_{min}). Maximum driving moment consists of the overturning moments due to horizontal moments (M_x and M_y), seismic shear forces (F_x and F_y), and upward seismic force (V). The 100-40-40 method is used for upward seismic force.~~

- Minimum resisting moment = ~~125,666,760~~ 7.125×10^7 kips-ft

Minimum resisting moment is obtained by multiplying the effective dead load by the minimum distance. The effective dead load is calculated by subtraction of buoyant force and maximum seismic uplift force from dead weight. Maximum driving moment consists of the overturning moments due to maximum horizontal moments, maximum seismic shear forces. 100% of maximum moments and 100% of maximum forces for the three directions are used in the overturning check.

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- Maximum driving moment = 92,086,763 kips-ft
- Factor of safety (FOS) for D+He+Es load combination
  - minimum resisting moment / maximum driving moment = 1.36 > 1.1

4.2.2 Sliding Check

The resistance forces against sliding of the common basemat are checked for the driving shear forces generated from the seismic load. The basemat friction force is considered to resist the sliding of the common basemat. In the sliding check, the shear key and earth pressure effects are conservatively neglected. In addition, when sliding is checked in combination with seismic forces, the hydrostatic force at the design water level is used.

For the sliding check, the coefficient of friction (μ) is 0.7 that the internal friction angle is 35°. The resistance force is calculated by multiplying the coefficient of friction by the effective dead load. The X-directional (E-W) seismic forces are selected as the maximum driving shear forces.

- Resisting force = 617,310 kips
- Maximum driving force = 408,146 kips
- Factor of safety (FOS) for D+He+Es load combination
  - resisting force / maximum driving force = 1.51 > 1.1

4.2.3 Flotation Check

Flotation problems may be encountered during construction, operation, or flood condition. The deadweight of the structure is used to resist the hydrostatic uplift. For the flotation check, the hydrostatic force at flooding groundwater level (H_s) is used. Any skin friction between the subgrade exterior walls and backfill is conservatively neglected.

- Resisting force = 1,232,270 kips
- Maximum driving force = 364,029.4 kips
- Factor of safety (FOS) for D+He+Es load combination
  - resisting force / maximum driving Force = 3.39 > 1.1