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:	**3.8.5**
Date of RAI Issue:	**10/19/2015**

Question No. 03.08.05-9

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.II.4.H.E, states, “Detailed explanation of how settlement is evaluated, including potential effects of static or dynamic differential settlement, dependence on time (i.e., short term vs. long term), effect of the soil type (i.e., granular vs. cohesive), and effect of the foundation type and size (e.g.,basemats, spread footings). Evaluation of the effects of settlement on construction procedures. Evaluation of the allowable settlement (total and differential) that can be accommodated in the foundation/structures.” Also, SRP Section 3.8.5.II.4.H.J, states, “Explanation of how loads attributable to construction are evaluated in the design. Some examples of items to be discussed include the excavation sequence and loads from the construction sequence of the mat foundation and walls, as well as the potential for loss of subgrade contact (e.g., because of loss of cement from a mud mat) that may lead to a differential pressure distribution on the mat.” SRP Section 3.8.5.II.4.H.K, states “An essential aspect of the design and analysis procedures for seismic Category I foundations is the stiffness modeling of the soil material under and to the sides of the structures. Soil stiffness can be represented by means of analytical or numerical (e.g., solid finite elements, distributed springs) formulations that are appropriate for the loading conditions as well as for the soil type, foundation type and size, and time scale being considered.”

In DCD Tier 2, Section 3.8.5.4.2, “Analysis of Settlement during Construction,” the applicant provided limited description as to how settlement is evaluated. In the applicant’s technical report (TR) APR1400-ES-NR-14006-P, Rev 1, “Stability Check for NI Common Basemat,” the applicant describes the evaluation of the settlement of the NI basemat; however, Section 3.8.5.4 of the DCD does not reference the report. Furthermore, it is not clear to the staff how the criteria in SRP 3.8.5.II.4 E, J, and K are implemented.

Therefore, the applicant is requested to describe the design and analysis procedures to explain how the elements described in SRP 3.8.5.II.4 E, J and K are incorporated in APR14000 design, and include this information in DCD Section 3.8.5.

Response - (Rev. 2)

According to SRP Section 3.8.5.II.4.E, the settlement was evaluated as follows:

(1) Effects of static and dynamic differential settlement

The detailed explanation of the analysis procedure is discussed in RAI 255-8285, Question 03.08.05-7.

(2) Short term and long term

Short term settlement is evaluated as a construction sequence analysis limited to the NI common basemat. The considered sequence was based on the concrete pouring sequence with the basemat. The analysis result is summarized in the Technical Report Table 5-3. In addition, we checked the differential settlement under the loads (Dead + Live) in as-built. Also, the detailed construction sequence analysis with superstructure refers to RAI 255-8285, Question 03.08.05-7.

The detailed explanation regarding long term settlement refers to RAI 255-8285, Question 03.08.05-18.

For the case of a settlement monitoring program throughout construction, the COL applicant will be able to modify the construction sequences of adjacent buildings to conform to the site's settlement characteristics and minimize differential settlement. Accordingly, the COL item (COL 3.8(8)) will be changed as shown in the attachment to this response to incorporate various settlement (Maximum vertical settlement, tilt, differential settlement between structures, and angular distortion) based on actual deformation in accordance with RAI 255-8285 Question 03.08.05-7.

(3) Effect of soil type

Three generic site soil profiles (S1: Soft, S4: Medium, S8: Hard) are used to consider the effects of soil conditions on settlement. The selected profiles have been chosen to be a representative sample.

(4) Effect of foundation type and size

In order to represent soil stiffness, the compression-only soil spring to each direction (X, Y, Z) on basemat nodes is considered. The subgrade modulus used in spring stiffness was calculated using the method described in Technical Report APR1400-E-S-NR-14006-P/NP, Rev.1 Subsection 2.3. To achieve the subgrade modulus used in soil spring, the 3D FE foundation model was considered and applied to unit pressure. The size of these foundation media model with uniform soil stiffness each layer throughout the soil is enough to capture the shape of deformed soil.

According to SRP Section 3.8.5.II.4.G, the evaluation of stiff and soft spots should be considered in basemat analysis. The stiff and soft spots are not predictable before the site survey or site excavation for the specific site. So, if these are found during excavation, the COL applicant shall perform basemat analysis considering stiff and soft spots (RAI 255-8285 Question 03.08.05-7, COL item, COL 3.8(12)).

According to SRP Section 3.8.5.II.4.J, the evaluation of settlement during the construction sequence of superstructure will be performed and reflected design as described in RAI 255-8285 Question 03.08.05-7. If the actual soil status and loss of cement from mud mat is expected after the site survey or site excavation, the site-specific evaluation is performed by COL applicant as shown RAI 255-8285 03.08.05-7, COL item, COL3.8 (12)).

According to SRP Section 3.8.5.II.4.K, the two soil stiffness parameters are applied to the NI common basemat analysis corresponding to which loads are considered. In the stability evaluation (Settlement, Bearing capacity) under static loading cases and load combination (LC01~07) for member forces, the soil springs possessed the subgrade moduli are used to represent soil. Each vertical subgrade modulus on bottom of NI common basemat considers the vertical variation of soil. For the load combination included in seismic load for member forces, the foundation media are used to represent soil. The foundation media model's properties are applied to dynamic elastic modulus calculated from strain-compatible shear wave velocity used in SASSI analysis to keep consistent with the magnitude of soil strains. Detailed explanation of applied soil stiffness refers to RAI 255-8285 Question 03.08.05-8, Attachment.

Impact on DCD

DCD Tier 2, Table 1.8-2, Subsection 3.8.5.7 and 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: 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.

Replace by the contents described in page 4 of Attachment.

~~COL 3.8 (11) The COL applicant is to perform a foundation evaluation including stiff and soft spots using the methodology described in DCD Tier 2, Section 3.8.5.4.~~

~~COL. 3.8 (12) The COL applicant is to evaluate the loss of subgrade contact due to loss of cement from the mud mat using site specific data and the methodology described in DCD Tier 2, Section 3.8.5.4.~~

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))~~.

Replace by the contents described in page 4 of Attachment.

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.

Replace by the contents described in page 4 of Attachment.

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 (11) The COL applicant is to perform a foundation evaluation including stiff and soft spots using the methodology described in DCD Tier 2, Section 3.8.5.4.~~

~~COL. 3.8 (12) The COL applicant is to evaluate the loss of subgrade contact due to loss of cement from the mud mat using site specific data and the methodology described in DCD Tier 2, Section 3.8.5.4.~~

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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~~The COL applicant is to provide a site-specific monitoring program and to monitor differential settlement, tilt, and angular distortion are bounded by following values during construction and plant operation.~~
~~Allowable differential settlement associated with tilt: 1/1200~~
~~Allowable differential settlement associated with angular distortion: 1/750~~

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The COL applicant is to provide a site-specific monitoring program and to monitor various settlements (Maximum vertical settlement, tilt, angular distortion, differential settlement between structures) are bounded by allowable values provided in DCD Tier 2 Table 2.0-1.

REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

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SRP Section:	**03.08.05 - Foundations**
Application Section:	**3.8.5**
Date of RAI Issue:	**10/19/2015**

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. 2)

In the design of the APR1400, the stability check against sliding, overturning, and flotation of Seismic Category I structures is based on the factor of safety specified in Table 3.8-10 of the DCD. There are four (4) load combinations for the stability check as follows:

(LC1) D + H + W (Wind)
(LC2) D + H + E' (SSE)

(LC3) D + H + Wt (Tornado)
(LC4) D + F' (Flood)

The review results of Nuclear Island (NI) common basemat for each load combination are as the following:

(LC1) Because the maximum forces induced by the SSE are much larger than those by wind/tornado, the wind/tornado load is not necessary to be considered in the stability evaluation of the NI structure. However, the allowable factor of safety (FOS) for wind is 1.5 different from that for seismic load. The wind load combination LC1 is evaluated for overturning and sliding of the NI structure for justification. Overturning and sliding FOS in wind load combination LC1 is shown in Table 1 below. As shown in Table 1, both overturning and sliding FOS exceeds the allowable FOS of 1.5. In wind load combination LC1, buoyancy at normal design groundwater elevation is used.

Table 1 Stability FOS of NI Structure for Wind

Item	FOS for Wind	Allowable FOS
Overturning	16.46	1.5
Sliding	8.30	1.5

(LC2) The evaluation result for the SSE load combination LC2 is provided in DCD Tier 2, Table 3.8A-15. In SSE load combination LC2, the buoyancy at normal design ground water elevation is used.

(LC3) In the stability check, the seismic load governs over wind/tornado load. The allowable FOS of both SSE load combination LC2 and tornado load combination LC3 are same. Therefore, the load combination LC3 is governed by SSE load combination LC2.

(LC4) The evaluation result for the flood load combination LC4 is provided in DCD Tier 2, Table 3.8A-15. The buoyancy at extreme ground water elevation is used.

In conclusion, overturning and sliding of the NI common basemat are governed by SSE load combination LC2 and flotation is governed by flood load combination LC4.

Similarly, the review results of Emergency Diesel Generator Building (EDGB) and Diesel Fuel Oil Tank (DFOT) for each load combination are as the following:

(LC1) The EDGB is a low-rise building and the DFOT is a buried building except entrance. Therefore, wind loads should not govern in overturning and sliding. Nevertheless, the wind load combination LC1 is evaluated for overturning and sliding of EDGB for justification. Overturning and sliding FOS in wind load combination LC1 is tabled in Table 2 below. As shown in Table 2, both overturning and sliding FOS exceeds the allowable FOS of 1.5. In wind load combination LC1, buoyancy at normal design groundwater elevation is used.

Table 2. Stability FOS of EDGB for Wind

Item	FOS for Wind	Allowable FOS
Overturning	10.67	1.5
Sliding	5.41	1.5

(LC2) The evaluation result for the SSE load combination LC2 is provided in DCD Tier 2, Table 3.8A-38. In SSE load combination LC2, the buoyancy at normal design ground water elevation is used.

(LC3) In the stability check, the seismic load governs over wind/tornado load. The allowable FOS of both SSE load combination LC2 and tornado load combination LC3 are same. Therefore, the load combination LC3 is governed by SSE load combination LC2.

(LC4) The evaluation result for the flood load combination LC4 is provided in DCD Tier 2, Table 3.8A-38. The buoyancy at extreme ground water elevation is used.

In conclusion, overturning and sliding of the EDGB and DFOT are also governed by SSE load combination LC2 and flotation is governed by flood load combination LC4.

The stability check methodology of NI structure against sliding is different from that of EDGB and DFOT, in that the sliding evaluation of the NI common basemat against seismic force is based on the time history method instead of the static method. The detailed description of the method and result are as follows.

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 3 and Figure 1 below.

Table 3 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

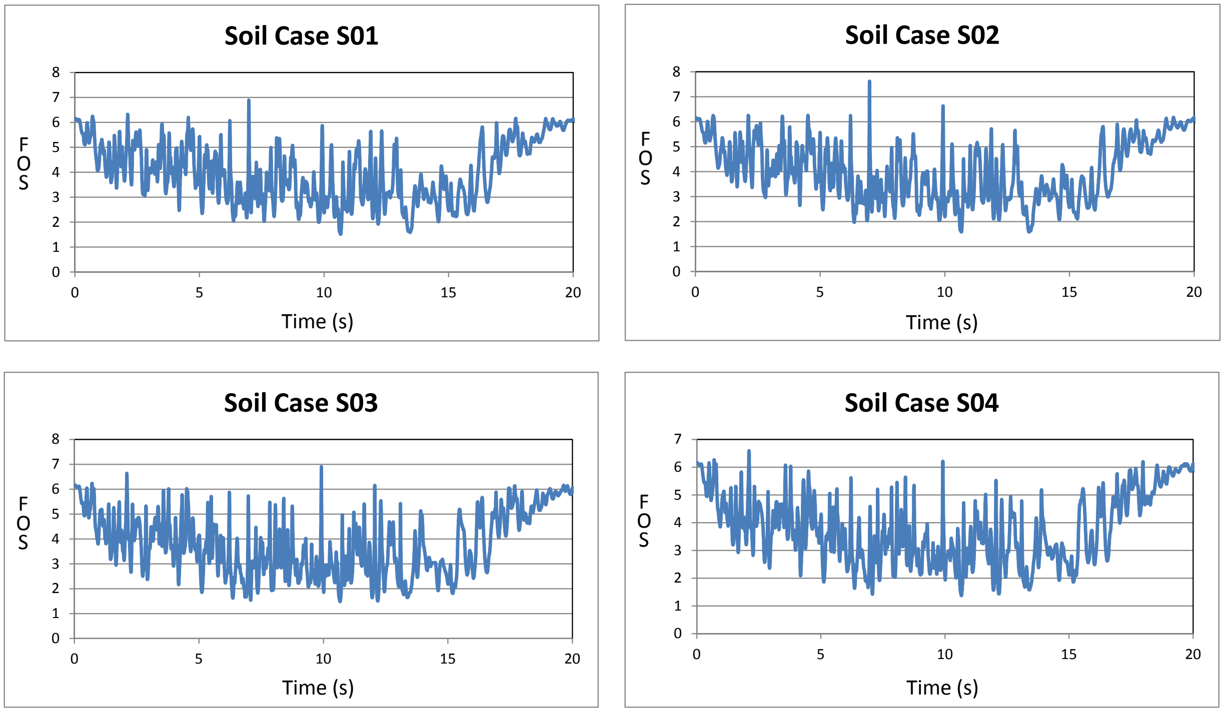

Figure 1 Factor of Safety against Sliding at Each Time Step

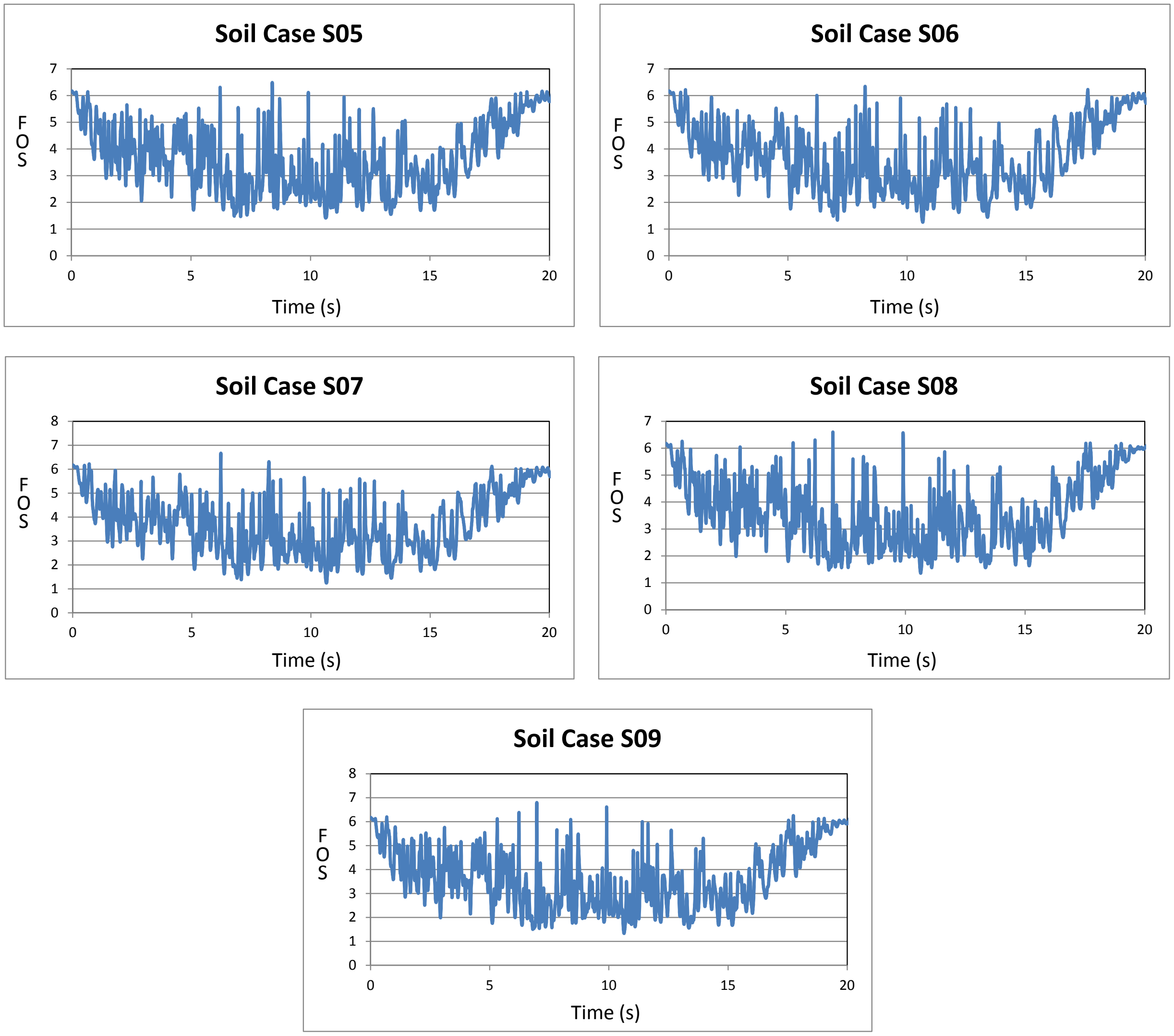

Figure 1 Factor of Safety against Sliding at Each Time Step (continued)

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.

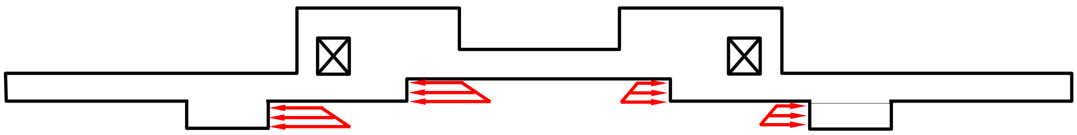

Figure 2 Resisting Force by Shear Keys

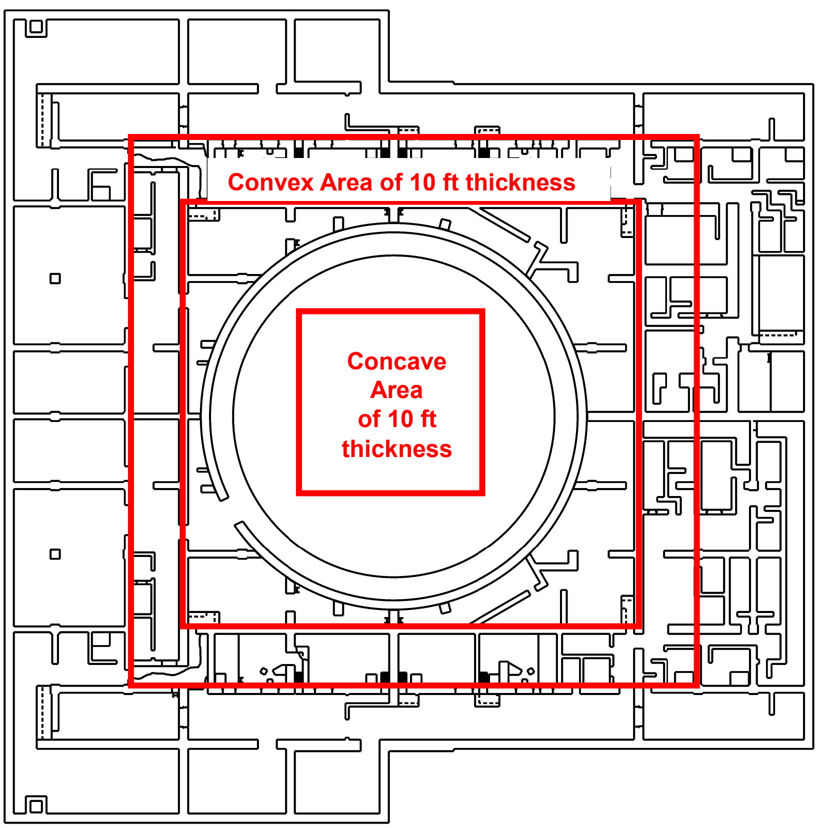

Figure 3 Configuration of Shear Keys considered in Evaluation

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 3.

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 3.8.5.5.1, 3.8.5.5.2, 3.8.6, 3.8A.1.4.2.3.2, 3.8A.3.4.1, and Tables 1.8-2, 3.8A-15, 3.8A-38 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.

 RAI 255-8285 - Question 03.08.05-14_Rev.1

RAI 255-8285 - Question 03.08.05-14_Rev.2

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 [wind, tornado, or] 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 [wind, tornado, or] 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 [wind, tornado, or] 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 = [sliding force caused by wind, tornado, or] earthquake load

Replace : next page

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)).

RAI 255-8285 - Question 03.08.05-14_Rev.1

RAI 255-8285 - Question 03.08.05-14_Rev.2

of NI common basemat

caused by earthquake

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.

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(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 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(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.

3.8A.1.4.2.3.2 Stability Check

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 load combinations meet the criteria of Section II of SRP 3.8.5 as shown in Table 3.8A-14.

wind load (W),

The sliding and overturning factors of safety are determined using load combination containing dead load (D), SSE (E_s), and buoyant load at normal (H_e). The floatation factor of safety is determined based on dead load (D) and buoyant force at flood (H_s).

The normal design groundwater elevation is El. 96 ft 8 in. The extreme groundwater elevation is the same as plant grade level (El. 98 ft 8 in.) considering probable maximum flood.

tornado

In the earthquake load, axial force, shear force, and moment due to horizontal and vertical excitation of the structure are obtained from seismic analysis. Since seismic load governs over ~~wind~~ load, ~~stability checks are not considered under wind load~~. A summary of overturning, sliding, and flotation check is provided in Table 3.8A-15.

3.8A.1.4.2.3.3 Basemat Uplift Check

The ground contact uplift ratio between the basemat and soils is carried out to provide reasonable assurance that the linear soil-structure interaction (SSI) analysis remains valid. The ground contact ratio is defined as the minimum ratio of the area of the foundation in contact with the soil to the total area of the foundation. Among the results from the NI common basemat analysis, the load combination cases, which are shown, the uplift phenomena are considered for uplift check. Table 3.8A-16 shows the uplift area ratios of NI common basemat. The APR1400 NI common basemat has an 80 percent or more contact area during basemat uplift, and it can be concluded that the contact area would be acceptable.

3.8A.1.4.2.3.4 Settlement Check

Differential settlements are divided by the differential settlement within the NI common basemat and the differential settlement between the NI basemat and the turbine generator

the tornado load is not necessary to be considered in the stability evaluation. The wind load combination (D + He + W) in Table 3.8A-14 is considered though the seismic load governs over the wind load, because the allowable factor of safety for wind is 1.5, which is different from 1.1 for the seismic load.

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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

Replace this table with Table 3.8A-15 in the next page.

Table 3.8A-15

Results on Factor of Safety for Basemat Stability

NI Common Basemat	FOS(1)	Allowable FOS	Remark
Overturning by Wind	16.46	1.5	
Overturning by Earthquake	1.24	1.1	
Sliding by Wind	8.30	1.5	
Sliding by Earthquake	1.25	1.1	Time history method
Flotation	3.39	1.1	

FOS = Factor of Safety

Table replaced

shear wall in the EDG building. The computed member forces are used in the structural design. All fixed boundary conditions are imposed in the basemat and the dead, live, wind, seismic force, and soil pressure are applied.

The additional load is buoyant. This analysis used spring element to consider the influence of soil. All fixed boundary conditions are imposed at the end node of spring element. Figure 3.8A-34 shows the full FEM for the global structural analysis, and Figure 3.8A-35 shows the basemat model of the EDG building. The design forces and moments for the EDG building basemat are summarized in Table 3.8A-34.

The structural design for the EDG building basemat is performed in accordance with all requirements of ACI 349. Required reinforcements are calculated based on the governing required capacities obtained from FE analysis.

Design Summary

For the EDG building area, the maximum required moment capacities obtained from the basemat analysis are 947.3 k-ft/ft for the N-S direction and 794.8 k-ft/ft for the E-W direction. Upon the required design moment capacities, the EDG building basemat is provided with 2-#11 bar at 305 mm (12 in.) spacing in each direction at each face and shear bar #5 at 305 mm (12 in.) spacing is provided to a 1.21 m (4 ft) thick area. Figure 3.8A-54 shows the typical sections of the EDG building basemat. The basemat reinforcement and margins of safety are shown in Table 3.8A-37. The margin of safety is the ratio of required reinforcement and provided requirement.

Stability Check

EDG and DFOT basemat structure is evaluated for stability against overturning, sliding, and floatation. The calculated factors of safety against overturning, sliding, and floatation for the load combinations meet the criteria of Section II of SRP 3.8.5, as shown in Table 3.8A-14.

wind load (W),

The sliding and overturning factors of safety are determined using load combination containing dead load (D), SSE (E_s), and buoyant load at normal (H_e). The floatation factor of safety is determined based on dead load (D) and buoyant force at flood (H_s).

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The normal design ground water elevation is EL. 96 ft 8 in. The extreme ground water elevation is the same as plant grade level (EL. 98 ft 8 in.) considering probable maximum flood.

In the earthquake load, axial force, shear force, and moment due to horizontal and vertical excitation of the structure are obtained from seismic analysis. Since seismic load governs over ~~wind~~ tornado load, ~~stability checks are not considered under wind load.~~ the tornado load is not necessary to be considered in the stability evaluation. The wind load combination (D + He + W) in Table 3.8A-14 is considered for the EDG building though the seismic load governs over the wind load, because the allowable factor of safety for wind is 1.5, which is different from 1.1 for the seismic load. Because the DFOT building is a buried structure and the wind load is not applicable to the overturning and sliding check. A summary of overturning, sliding, and flotation check is shown provided in Table 3.8A-38.

Settlement Check

Differential settlements are divided by the differential settlement within the EDG building basemat and the differential settlement within DFOT building. For the differential settlements within the each basemat, the static (dead and live loads) loading case is calculated.

The nodes within a distance of approximately 15.24 m (50 ft) are selected to check the different settlement. Table 3.8A-39 shows the differential settlements at site profiles 1, 4, and 8.

3.8A.3.4.2 Shear Walls

Description

The shear walls and slabs of the EDG building representing the primary lateral load-resisting system are designed against seismic or extreme wind-related loads. The concrete slab distributes lateral forces through diaphragm action to the shear walls as in-plane loads in proportion to the relative stiffness of the shear walls. These in-plane shear forces are transferred down to the basemat foundation as in-plane shear forces and moments of the shear walls.

The in-plane shear forces and moments, which are obtained from the seismic analysis results, are combined with the applicable out-of-plane loads to determine the quantity and distribution of vertical and horizontal reinforcing steel of the EDG building shear walls.

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Table 3.8A-38

Results on Factor of Safety for Basemat Stability

Building	Item	FOS(1)	Allowable FOS	Remark
EDG	Overturning	1.58	1.1	
	Sliding	1.82	1.1	
	Flotation	10.67	1.1	
DFOT	Overturning	1.19	1.1	
	Sliding	1.29	1.1	
	Flotation	1.81	1.1	

(1) FOS = Factor of Safety

Replace this table with Table 3.8A-38 in the next page.

Table 3.8A-38

Results on Factor of Safety for Basemat Stability

Building	Item	FOS(1)	Allowable FOS	Remark
EDG	Overturning by Wind	10.67	1.5	
	Overturning by Earthquake	1.58	1.1	
	Sliding by Wind	5.41	1.5	
	Sliding by Earthquake	1.82	1.1	
	Flotation	10.67	1.1	
DFOT	Overturning by Wind	N/A		Buried structure
	Overturning by Earthquake	1.19	1.1	
	Sliding by Wind	N/A		Buried structure
	Sliding by Earthquake	1.29	1.1	
	Flotation	1.81	1.1	

(1) FOS = Factor of Safety

Table replaced

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.

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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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In the design of the APR1400, the stability check against sliding, overturning, and flotation of NI common basemat is based on the factor of safety specified in Table 4.5. There are four (4) load combinations for the stability check as follows:

(LC1) D + H + W (Wind)
(LC2) D + H + E' (SSE)
(LC3) D + H + Wt (Tornado)
(LC4) D + F' (Flood)

The review results of Nuclear Island (NI) common basemat for each load combination are as the following:

(LC1) Because the maximum forces induced by the SSE are much larger than those by wind/tornado, the wind/tornado load is not necessary to be considered in the stability evaluation of the NI structure. However, the allowable factor of safety (FOS) for wind is 1.5 different from that for seismic load. The wind load combination LC1 is evaluated for overturning and sliding of the NI structure for justification. Overturning and sliding FOS in wind load combination LC1 is shown in the table below. As shown in the table, both overturning and sliding FOS exceeds the allowable FOS of 1.5. In wind load combination LC1, buoyancy at normal design groundwater elevation is used.

Stability FOS of NI Common Basemat for Wind

Item	FOS for Wind	Allowable FOS
Overturning	16.46	1.5
Sliding	8.30	1.5

(LC2) The evaluation result for the SSE load combination LC2 is provided in Subsections 4.2.1 and 4.2.2 against overturning and sliding, respectively. In SSE load combination LC2, the buoyancy at normal design ground water elevation is used.

(LC3) In the stability check, the seismic load governs over wind/tornado load. The allowable FOS of both SSE load combination LC2 and tornado load combination LC3 are same. Therefore, the load combination LC3 is governed by SSE load combination LC2.

(LC4) The evaluation result for the flood load combination LC4 is provided in Subsection 4.2.3. The buoyancy at extreme ground water elevation is used.

In conclusion, overturning and sliding of the NI common basemat are governed by SSE load combination LC2 and flotation is governed by flood load combination LC4.

- Maximum driving moment = ~~92,086,763~~ kips-ft [5.764 x 10^7]
- Factor of safety (FOS) for D+He+Es load combination
  - minimum resisting moment / maximum driving moment = ~~1.36~~ > 1.1 [1.24]

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~~ [considered]. 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~~

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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

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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 is 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. 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 minimum angle of internal friction of supporting medium is 35 degrees, which leads to a coefficient of friction of 0.7. 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.

Finally, the minimum factor of safety against sliding during the entire time period and for all soil cases is obtained as 1.25 which exceeds the acceptable value of 1.1, as shown in the table below.

Stability FOS of NI Common Basemat for Earthquake

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