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.:	**183-8197**
SRP Section:	**03.07.02 – Seismic System Analysis**
Application Section:	**3.7.2**
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Question No. 03.07.02-4

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. In accordance with 10 CFR 50 Appendix S, the staff reviews the adequacy of the seismic analysis methods used to demonstrate that SSCs can withstand seismic loads and remain functional. Per the guidance in SRP Section 3.7.2.II.4, the staff reviews the calculation of the ground contact ratio to ensure that linear 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, computed in each time step throughout the SSI analysis. The acceptance criterion is that linear SSI analysis methods are appropriate provided the ground contact ratio is equal to or greater than 80 percent. The ground contact ratio can be calculated from the linear SSI analysis using the minimum basemat area that remains in compression with the soil. If the ratio is less than 80 percent, then the effect of the nonlinearity due to the foundation uplift should be evaluated.

In Sections 4.1.1 and A.4.1.1 in APR1400-E-S-NR-14006-P, Rev. 1 the applicant described its ground contact ratio calculation for the nuclear island (NI) common basemat and EDGB/DFOT basemat respectively. Further, Tables 4-1 and A-2 of the report provide the calculated ground contact ratios for the NI common basemat and EDGB/DFOT basemat, respectively. Per the guidance in SRP Section 3.7.2.II.4, in order to assist the staff in its review of the adequacy of the calculated ground contact ratios, the applicant is requested to clarify whether the specified ground contact ratios represent the minimum ratio of the area of the foundation in contact with the soil to the total area of the foundation, computed in each time step throughout the SSI analysis time history. If not, provide the technical basis for the adequacy of the alternate method used to calculate the ground contact ratio as applicable.

Response

The specified ground contact ratios in Tables 4-1 and A-2 of technical report APR1400-E-S-NR-14006-P, Rev. 1, “Stability Check for NI Common Basemat” for the NI common basemat and the emergency diesel generator building / diesel fuel oil tank (EDGB/DFOT) room basemat, respectively, are not calculated directly from the SSI analysis results of each time step.

The ground contact ratios are calculated from the structural analysis models and their results, instead of the seismic analysis models and the SSI analysis results in order to include all the applicable load cases that are considered in the uplift check.

When combining the load cases, the reactions from the response spectrum analyses of the reactor containment building (RCB) shell and dome and the RCB internal structure using in-structure response spectra, and the equivalent static analyses of the auxiliary building (AB) and the EDGB/DFOT are applied as the seismic loads (maximum SSI analysis results) in their basemat models.

Because the maximum values of individual modes occur simultaneously in the response spectrum analysis, the individual modal responses are summed algebraically. Three directional reaction forces from the seismic analysis of superstructures in each seismic excitation are combined using the 100-40-40 rule. All possible seismic load sign ($\pm$) combinations of the three directional reactions are considered. These calculations and combination sequences give the most critical condition in the uplift check.

To obtain a more accurate ground contact ratio, the calculation is performed using SSI time history results as the seismic loads in accordance with the guidance in SRP Section 3.7.2.II.4. The same site profiles (S01, S04, and S08) with both uncracked and cracked concrete stiffness conditions are considered. The contact area is calculated by checking the stress of the rigid spring elements which connect the NI basemat and the underlying soil in the ACS SASSI model. In order to obtain the stresses, the z-directional force components of the spring elements computed at 4,096 time steps (0.005 sec. interval) throughout the ACS SASSI analysis of NI structures are divided by their tributary areas.

Load combinations consider all possible permutations of the z-directional forces resulting from the three directional seismic inputs (total of eight combinations) as follows:

- Seismic directional combination #1: $+1.0 \cdot SSE_{EW} + 1.0 \cdot SSE_{NS} + 1.0 \cdot SSE_{VT}$
- Seismic directional combination #2: $+1.0 \cdot SSE_{EW} + 1.0 \cdot SSE_{NS} - 1.0 \cdot SSE_{VT}$
- Seismic directional combination #3: $+1.0 \cdot SSE_{EW} - 1.0 \cdot SSE_{NS} + 1.0 \cdot SSE_{VT}$
- Seismic directional combination #4: $+1.0 \cdot SSE_{EW} - 1.0 \cdot SSE_{NS} - 1.0 \cdot SSE_{VT}$
- Seismic directional combination #5: $-1.0 \cdot SSE_{EW} + 1.0 \cdot SSE_{NS} + 1.0 \cdot SSE_{VT}$
- Seismic directional combination #6: $-1.0 \cdot SSE_{EW} + 1.0 \cdot SSE_{NS} - 1.0 \cdot SSE_{VT}$
- Seismic directional combination #7: $-1.0 \cdot SSE_{EW} - 1.0 \cdot SSE_{NS} + 1.0 \cdot SSE_{VT}$
- Seismic directional combination #8: $-1.0 \cdot SSE_{EW} - 1.0 \cdot SSE_{NS} - 1.0 \cdot SSE_{VT}$

Algebraic summation is applied at each time step to consider the combined effect of input motions in the x-, y-, and z-directions. The final resultant stress time histories are combined with the stresses obtained from the z-directional springs of the static load analysis. The stiffness of the LINK180 element used to model the z-directional spring is defined to represent the entire

soil column below the basemat. Here, the static loads include the dead load (D), the seismic live load (SLL, 25% of live loads), and the buoyancy load (Lh) due to groundwater. Using these load combinations (D + SLL + Lh + seismic time history loads), the minimum contact ratios of the area of the basemat in contact with the soil to the total area of the basemat are determined as follows:

Table 1 Ground Contact Ratios of NI Common Basemat

Site Profile	Concrete Stiffness	Ground Contact Ratio (%)	Seismic Directional Combination Number
S1	Uncracked	95.74	1
	Cracked	95.62	1
S4	Uncracked	90.90	1
	Cracked	92.11	7
S8	Uncracked	85.40	1
	Cracked	88.90	8

The ground contact ratios re-calculated using SSI time history results with static analysis results are less than the current ground contact ratios described in Tables 4-1 of technical report APR1400-E-S-NR-14006. Since the former is more accurate than the latter, DCD Tier 2 and the associated technical report will be revised using the re-calculated ground contact ratios.

With the same procedure which is used for NI structures, the minimum contact ratios of the area of the basemat for EDGB/DFOT are determined as follows:

Table 2a Ground Contact Ratios of EDGB & DFOT Room Basemat (Calculated Using Rigid Spring Stiffness of 1×10^7 kips/ft)

	Site Profile	Concrete Stiffness	Ground Contact Ratio (%)	Seismic Directional Combination Number
EDGB	S1	Uncracked	86.01	6
		Cracked	86.49	6
	S4	Uncracked	84.94	5
		Cracked	87.76	1
	S8	Uncracked	64.45	4
		Cracked	63.08	6
DFOT	S1	Uncracked	51.65	1
		Cracked	60.15	6
	S4	Uncracked	51.36	7
		Cracked	47.94	6
	S8	Uncracked	46.72	8
		Cracked	57.33	5

Similar to the NI structures, the rigid spring elements which connect the EDGB and DFOT basemat with underlying soil in the SSI model are used to calculate the contact stresses indirectly. Because the rigid spring forces from the SSI analysis of EDGB and DFOT are relatively larger than the corresponding reaction forces from their fixed-base analysis results, the ground contact ratios are underestimated for all site profiles. From the expectation that the spring forces by which the ground contact ratio is influenced directly are sensitive to their stiffness values in a certain range, a stiffness change of the spring elements from their original value of 1×10^{7} kips/ft to the increased value of 1×10^{8} kips/ft are made. The minimum contact ratios calculated with this stiffness change are summarized as follows:

Table 2b Ground Contact Ratios of EDGB & DFOT Room Basemat (Calculated Using Rigid Spring Stiffness of 1×10^{8} kips/ft)

	Site Profile	Concrete Stiffness	Ground Contact Ratio (%)	Seismic Directional Combination Number
EDGB	S1	Uncracked	100.00	1
		Cracked	100.00	1
	S4	Uncracked	100.00	1
		Cracked	98.81	1
	S8	Uncracked	97.97	2
		Cracked	98.46	1
DFOT	S1	Uncracked	92.53	7
		Cracked	94.22	2
	S4	Uncracked	95.47	6
		Cracked	95.24	5
	S8	Uncracked	92.10	6
		Cracked	93.21	1

Section A.4.1.1 and Table A-2 of technical report APR1400-E-S-NR-14006-P, Rev. 1 will be revised using the re-calculated ground contact ratios of EDGB & DFOT room basemat.

Impact on DCD

DCD Tier 2, Table 3.8A-16 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, “Stability Check for NI Common Basemat,” Rev.1 will be revised, as indicated in the attachment associated with this response.