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Our ref: DCP/NRC2507

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Subject: AP1000 Response to Request for Additional Information (TR 85)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on Technical Report No. 85. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-TR85-SEB1-04 R2

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

D. A. Lindgren /FOR

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/Enclosure

1. Response to Request for Additional Information on Technical Report No. 85

DD63
NRO

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ENCLOSURE 1

Response to Request for Additional Information on Technical Report No. 85

RAI Response Number: RAI-TR85-SEB1-04
Revision: 2

Question:

Sections 2.3.1, 2.4.1, 2.4.2, and 2.6.1 indicate that equivalent static nonlinear analysis (not clear whether 2D or 3D), 2D SASSI analysis, 2D ANSYS linear dynamic analysis, 2D ANSYS nonlinear time history analysis, 3D ANSYS equivalent static non-linear analysis, etc. were performed. Westinghouse needs to develop a table (or tables) similar to AP1000 DCD Tables 3.7.2-14 and 3.7.2-16 to show: (1) the purpose of the analysis; (2) the model type(s); (3) analysis method(s); (4) soil condition(s); (5) loads, load combinations, combination method (for combining loads and directional combination for SSE); (6) governing design loads; and (7) reference location in this technical report or other report for the detailed description.

Additional Request (Revision 1):

The RAI response provided revised DCD Tables 3G.1-1 and 3G.1-2. These tables were revised to address the information requested in this RAI and to reflect the changes in methodology described in other RAI responses. Three entries in these detailed tables, related to the basemat design analyses, soil bearing reactions, and stability evaluation, were also included separately in the RAI response.

Based on this and other RAI responses it appears that a number of the seismic models and analyses have been substantially revised. Therefore, Westinghouse is requested to confirm the staff's understanding that the current seismic analyses of the basemat are based on the following:

(1) <u>Maximum dynamic bearing pressure calculations</u> due to seismic loading are still based on the 2D finite element stick model, using time history analysis with ANSYS, non-linear soil springs (with lift-off), for two soil cases performed previously - hard rock and soft to medium soil (1000 kcf) and two new confirmatory soil cases (1340 kcf and 780 kcf) to be completed. This is further revised by response to RAI TR85-SEB1-22, which states that for this 2D ANSYS analysis, six soil cases shown in the proposed revision to Table 2.6-1 (left hand column) are used. The staff still has concerns with the use of 2D instead of 3D seismic inputs (addressed in RAI TR85-SEB1-03), the use of a simplified stick model (addressed in RAI-TR85-03), and why lower subgrade modulus values of the order of 80 kcf (addressed in RAI-TR85-SEB1-05) were not considered.

(2) <u>Stability evaluations</u> (for sliding and overturning) are based on a new 3D NI20 model response spectrum (linear no lift-off) analysis, enveloping all soil cases, using ANSYS. Westinghouse is requested to provide a full description of this model, range of soil springs used, analysis approach, and results. Since this model assumes no lift-off, Westinghouse is requested to confirm the adequacy of the existing stability evaluations by comparing the set of shear and overturning loads to those from one of the other seismic analyses that include the non-linear soil springs which permit lift-off effects. There is some inconsistency identified with

which model is being used for stability evaluations (addressed under item a below, and RAI TR85-SEB1-34).

(3) New equivalent static accelerations are calculated based on the 3D NI20 model, mode superposition time history analysis, ANSYS, linear, for hard rock and also calculated for the 3D NI20 model, time history analysis, SASSI, for five soil cases (values need to be defined). These are only developed to be used in a confirmatory analysis described below.

(4) The basemat design is still based on the 3D NI05 model (prior to the design change to enhance the shield building), equivalent static analysis, ANSYS, with non-linear soil springs for lift-off from the basemat and for the connections between basemat/containment vessel/CIS basemat, and only one soil case for springs (520 kcf), using the prior equivalent static accelerations from the prior global seismic analyses on hard rock and considering all soil cases. The adequacy of using these accelerations, existing model, and existing design was confirmed by comparing the total base reactions and bearing pressures from the above analysis with a new 3D NI20 updated model for the shield building, fixed base, time history analysis. The time history used for the new fixed base analysis is developed so that it envelops the basemat response given by the 3D SASSI analyses at the corners and center of the basemat for all soil cases.

Since so many of the seismic models and analyses are being substantially updated, it is not clear how the current evaluations and to what extent the previous evaluations will be deleted. Therefore, to facilitate the resolution of this and other RAIs, Westinghouse is requested to provide a revised

This revised technical report should contain in each subsection a complete description of all of the updated models, specific soil cases considered (if qualitative terms are used (e.g., soft soil), then include the corresponding specific soil subgrade modulus values to avoid any misunderstanding), analysis approach, and results, and also should delete the superseded analyses. If any prior analyses remain in TR85, because certain aspects of the design or study are still based on the prior analyses, then the technical report should clearly describe why they remain in the report and should clearly demonstrate that the new evaluations confirm the adequacy of the prior analyses/designs. Note if any soil cases within the entire range of properties are not being considered in all of the analyses, then the technical basis should be provided.

In addition, Westinghouse is requested to clarify the following specific items related to the information presented in Tables 3.G.1-1 and 3.G.1-2 in the RAI response:

a. The 3D finite element analysis model [NI20], listed on page 1 of 7 of the RAI response, indicates that it was used in a response spectrum analysis with seismic input enveloping all soil cases for overturning and stability evaluation. Explain an apparent inconsistency with the analyses in the proposed revision to DCD Table 3G.1-1 in the RAI response.

b. The revised DCD Table 3G.1-2, fifth row, indicates that the "Equivalent static analysis using nodal accelerations from shell model" was used in the "3D finite element model of the nuclear island basemat (NI05)." Explain to what "shell model" this refers and where is it described, and indicate to which specific model these acceleration values are applied in Table 3G.1-1 because no NI basemat NI05 model could be identified. This should be clarified within this Table 3G.1-2. Also, are these the same acceleration values identified in Table 2.6-2(a) in RAI-TR85-SEB1-22? Explain how Westinghouse can derive a single acceleration value at each elevation if it came from a 3D "shell model" that contains many nodes over a range of elevations?

Additional Request (Revision 2):

Although information has been provided in this RAI response and TR85, Rev. 1, to describe the evaluations performed for the bearing pressure demand, foundation stability, and design of the basemat, the staff could not identify where a description of the evaluations for bearing pressure demand and foundation stability are presented in the DCD. Some limited information on the factors of safety for sliding and overturning is provided; however a complete summary of the evaluations, as described in TR85 Rev. 1, is not included in the DCD. Therefore, Westinghouse is requested to include in the DCD a description of the evaluations performed for the bearing pressure demand and foundation stability which consists of a summary of the analyses presented in TR85, Rev. 1.

During the May 4 to 8 basemat technical audit Westinghouse committed to include a summary of the TR85 information (on bearing pressure and stability) into the DCD via a revised RAI response that includes new DCD pages + including a summary of 2D non-linear evaluation.

Westinghouse Response:

DCD Tables 3.7.2-14 and 3.7.2-16 in Revision 15 were moved to Appendix 3G and renumbered to Tables 3G.1-1 and 3G.1-2. These Tables were included in TR03, Rev 1 and in TR134. The tables have been edited as shown in the DCD Revisions below to show additional information requested in this RAI as well as revisions due to changes in methodology described in other RAI responses.

Portions of these tables related to the basemat design analyses, soil bearing reactions, and stability evaluation are shown below including reference to the location in this technical report for the detailed description.

3D finite element refined shell model of nuclear island (NI05)	Equivalent static non-linear analysis using accelerations from time history analyses;	ANSYS	To obtain SSE member forces for the nuclear island basemat. See section 2.6 as modified by response to RAI-TR85-SEB1-21
3D finite element coarse shell model of auxiliary and shield	Response spectrum analysis with seismic	ANSYS	To obtain total basemat reactions for overturning and stability evaluation.

building and containment internal structures [NI20] (including steel containment vessel, polar crane, RCL, and pressurizer)	input enveloping all soils cases		To obtain total basemat reactions for comparison to reactions in equivalent static analyses using NI05 model. See section 2.6.1.2 as modified by response to RAI-TR85-SEB1-07 and 22
Finite element lumped mass stick model of nuclear island	Time history analysis	ANSYS	Performed 2D linear and non-linear seismic analyses to evaluate effect of lift off on Floor Response Spectra and bearing. See section 2.4.2

Westinghouse Response (Revision 1):

(1) Westinghouse will base its 35 ksf limit on the SASSI 3D results given in RAI-TR85-SEB1-3. The ANSYS 2D analyses will be used to support that the 35 ksf limit is a reasonable value. The bearing pressures have been obtained from the 3D SASSI analyses. The maximum bearing pressures obtained from the various soil cases are listed in Table RAI-TR85-SEB1-03-1. See RAI-TR85-SEB1-05, Rev.1, for a discussion of the 80 kcf subgrade modulus.

(2) The stability evaluations (for sliding and overturning) are based on a 3D NI20 model time history analysis (linear no lift-off), and not a response spectrum modal analysis. This is consistent with Table 3G1-1 given in DCD Appendix 3G, Revision 17 (see also response to RAI-TR85-SEB1-34). The model used is shown in Figure RAI-TR85-SEB1-04-1. As noted in Section 2.4.2 to Technical Report 85, "Comparison of floor response spectra and the maximum member forces and moments for these two cases show that the liftoff has insignificant effect on the SSE response." Therefore, it has been concluded that liftoff will have insignificant effect on the forces and moments that are being used for seismic stability evaluation.

In an effort to reduce the reliance on passive pressure to resist sliding, Westinghouse is no longer using a time history that envelopes all of the soil cases since it is too conservative. The seismic analysis was performed using the time history inputs as defined in DCD subsection 3.7.1.2, Revision 17. The analysis considered the hard rock case. All the base nodes were constrained to a single node, which in turn was fixed. This allowed the total Nuclear Island reaction forces to be taken from a single node location (node 1153). Node 1153 was selected as the central location, because it is located under the Center of Gravity (CG) for the NI structure. Shown in Figure RAI-TR85-SEB1-04-2 are the elements in the basemat at elevation 60'-6". Key nodes at the Elevation 60' 6" for the basemat of the NI20 model are shown for reference. Node 1153 is centrally located, and all the nodes in the basemat at this elevation are rigidly fixed to this node for the analysis.

The shear and vertical loads obtained from the 2D SASSI analyses given in the response to RAI-TR85-SEB1-07 were used to adjust the hard rock (HR) forces and moments to reflect the change in seismic response due to the other soil cases. These loads are given in Table RAI-TR85-SEB1-04-1. As seen from this table the upper bound soft to medium (UBSM) and soft to medium (SM) soil cases along with the hard rock case are the controlling generic soil cases. Therefore, it is not necessary to consider the other soil cases. The hard rock time history analysis base reactions are adjusted using the factors shown in Table RAI-TR85-SEB1-04-2. In order to confirm the adequacy of the loads being used for the stability evaluations, a comparison is made of the shear and vertical reactions for the UBSM soil case using 3D SASSI results. This comparison is given in Table RAI-TR85-SEB1-04-3. The UBSM case is used since it has the largest shear loads. As seen from this comparison the 3D SASSI results are lower.

(3) See Table 3G.1-1, DCD Revision 17, along with response given in RAI-TR85-SEB1-03.

(4) See Table 3G.1-1, DCD Revision 17, along with response given in RAI-TR85-SEB1-03.

The technical report is being revised to reflect the models and analyses being used. See RAI-TR85-SEB1-03 and RAI-TR85-SEB1-05.

a. As noted in item (2) above, time history analyses are used and not seismic response spectrum analyses for the overturning and stability evaluation. This is consistent with Table 3G1-1 given in DCD Appendix 3G, Revision 17.

b. In Table 3G.1-2, DCD Revision 17, the NI05 model is identified in the third and fourth rows. The basemat is modeled in the NI05 model. In Table 3G.1-1, DCD Revision 17. NI05 is identified on sheet 1, 5^{th} row, and on sheet 3 the 7^{th} row.

   Single acceleration values at each elevation are an average of the accelerations of each node at an elevation from the 3D shell model. This is acceptable since this will result in representative load acting on the basemat.

Westinghouse Response (Revision 2):

As requested, the changes to the DCD providing more detail on bearing pressure taken from TR85 are given below in the section Design Control Document (DCD) Revision. This information is added to Appendix 3G of the DCD (subsection 3G.4.3.4).

The changes to the DCD related to stability are given in a revision to RAI-TR85-SEB1-10, along with a summary of the 2D non-linear sliding evaluation.

Table RAI-TR85-SEB1-04-1 - 2D Shears and Vertical Loads
Units: 1000 kips

Seismic Reaction	2D SASSI Hard Rock	2D SASSI Firm Rock	2D SASSI Soft Rock	2D SASSI Upper Bound Soft to Medium	2D SASSI Soft to Medium	2D SASSI Soft
Shear NS	123.75	116.49	118.65	121.48	113.61	73.11
Shear EW	112.31	113.55	121.88	128.11	124.94	74.34
Vertical	98.76	98.65	99.63	104.55	112.30	94.48

Table RAI-TR85-SEB1-04-2 – Factors to Apply to Hard Rock Analysis Base Reactions

Seismic Excitation	Upper Bound Soft to Medium	Soft to Medium
NS	0.98	0.92
EW	1.14	1.11
Vertical	1.06	1.14

Table RAI-TR85-SEB1-04-3 – Shear and Vertical Load Comparisons
Units: 1000 kips

Seismic Reactions at Base	3D ANSYS UBSM	3D SASSI UBSM
Shear NS	91.7	73.7
Shear EW	108.4	95.9
Vertical	111.3	83.9

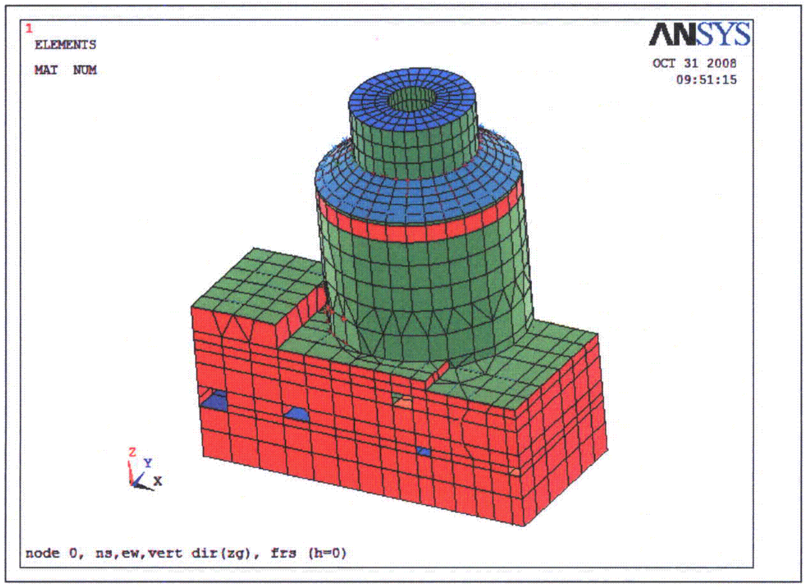

Figure RAI-TR85-SEB1-04-1 – ANSYS NI20 Model

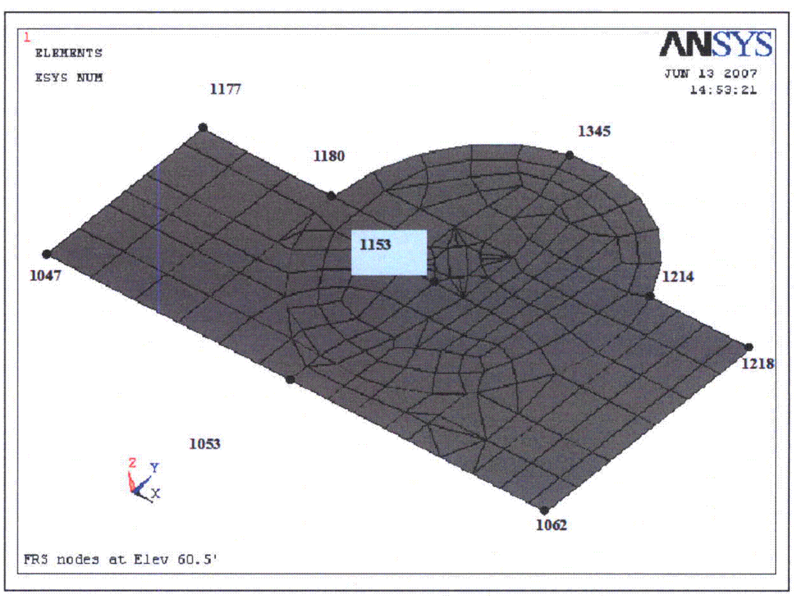

Figure RAI-TR85-SEB1-04-2 – Basemat Elements at Elevation 60'6"

Design Control Document (DCD) Revision:

The revisions to the DCD identified in Revision 0 of this response have been incorporated in DCD Revision 17.

Table 3G.1-1, Sheet 2 and Sheet 3, are modified Post Revision 17 as shown below.

Table 3G.1-1 (Sheet 2 of 4)

SUMMARY OF MODELS AND ANALYSIS METHODS

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
Finite element lumped-mass stick model of nuclear island	Time history analysis	SASSI	Performed 2D parametric soil studies to help establish the bounding generic soil conditions., and to develop adjustment factors to reflect all generic site conditions for seismic stability evaluation.
Finite element lumped-mass stick model of nuclear island	Direct integration time history analysis	ANSYS	Performed 2D linear and non-linear seismic analyses to evaluate effect of lift off on Floor Response Spectra and bearing.
3D finite element coarse shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel, polar crane, RCL, and pressurizer)	Time history analysis	SASSI	Performed for the five soil profiles of firm rock, soft rock, upper bound soft-to-medium soil, soft-to-medium soil, and soft soil. To develop time histories for generating plant design floor response spectra for nuclear island structures. To obtain maximum absolute nodal accelerations (ZPA) to be used in equivalent static analyses. To obtain maximum displacements relative to basemat. To obtain SSE bearing pressures for all generic soil cases. To obtain maximum member forces and moments in selected elements for comparison to equivalent static results.

3D shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel)	Mode superposition time history analysis	ANSYS	Performed to develop loads for seismic stability evaluation.
3D shell of revolution model of steel containment vessel	Modal analysis; equivalent static analysis using accelerations from time history analyses	ANSYS	To obtain dynamic properties. To obtain SSE stresses for the containment vessel.
3D lumped-mass stick model of the SCV	-	ANSYS	Used in the NI10 and NI20 models.

Table 3G.1-1 (Sheet 4 of 4)

SUMMARY OF MODELS AND ANALYSIS METHODS

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
3D finite element coarse shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel, polar crane, RCL, and pressurizer)	Mode superposition time history analysis with seismic input enveloping all soil cases	ANSYS	~~To obtain total basemat reactions for overturning and stability evaluation.~~ To obtain total basemat reactions for comparison to reactions in equivalent static linear analyses using NI05 model.

Add new section to Appendix 3G.

3G.4.3.4 Bearing Pressure Demand

Bearing pressure demand was calculated using both 2D and 3D analyses. Both linear and non-linear analyses are performed with the 2D Nuclear Island model. The maximum bearing pressures calculated include the effect of dead, live, and seismic loading.

The 2D model was used to evaluate the effect of lift off on the bearing pressure. Since the largest bearing pressure will result from the East-West seismic excitation because of the smaller width of the basemat in this direction, lift off was evaluated using an East-West stick model of the nuclear island structures, supported on a rigid basemat with non-linear springs. Direct integration time history analyses were performed. The bearing pressures calculated from these analyses are summarized in Table 3G.4-2. The pressures are at the edge of the basemat. Results are given for the three cases that result in the highest bearing pressure (hard rock (HR), upper bound soft to medium (UBSM) soil and soft to medium (SM) soil). The linear results show maximum bearing pressures on the west side of 31 to 33 ksf. Lift off increases the subgrade pressure close to the west edge by 4 to 6% with insignificant effect beneath most of the basemat.

The SASSI Soil-Structure Interaction analyses are performed based on the Nuclear Island 3D SASSI Model for the hard rock and five soil conditions established from the AP1000 2D SASSI analyses. The SASSI Model of the Nuclear Island is based on the NI20 Finite Element model. The bearing pressures from the 3D SASSI analyses have been obtained by combining the time history results from the North-South, East-West, and vertical earthquakes. The maximum soil bearing pressure demand is obtained from the hard rock (HR) case equal to 35 ksf. It is noted that a maximum localized peak is obtained on the west edge of 38 ksf; a limit of 35 ksf for maximum bearing seismic demand is obtained by averaging the soil pressure over 335 ft^2 of the west edge of the shield building where the maximum stress occurs.

Table 3G.4-2 – Maximum Bearing Pressure from 2D Time History Analyses

Soil Case	Analysis	East Edge (ksf)	West Edge (ksf)
Hard Rock	Linear	17.18	32.77
	Lift off	17.38	34.85
Upper-bound Soft to Medium	Linear	19.46	31.69
	Lift off	18.42	33.51
Soft to Medium	Linear	15.84	30.82
	Lift off	17.06	32.18

PRA Revision:

None

Technical Report (TR) Revision:

~~None~~ The following paragraph is added at the beginning of Section 2.9. See also Modifications made to Section 2.9 in RAI-TR85-SEB1-10.

The 2D SASSI reactions (NS and EW shear, and vertical) are used to obtain seismic response factors between the hard rock case to the upper-bound-soft-to-medium (UBSM) soil case, and the soft-to-medium (SM) soil case. These factors are used to adjust the hard rock (fixed base) NI20 ANSYS seismic time history analysis base reactions to reflect the seismic response for the other two potential governing soil cases UBSM and SM. The shear and vertical loads obtained from the 2D SASSI analyses given in Table 2.4-2 are used to adjust the hard rock (HR) reaction forces and moments obtained from the time history ANSYS analysis to reflect the change in seismic response due to the other soil cases. As seen from this table the upper bound soft to medium (UBSM) and soft to medium (SM) soil cases along with the hard rock case are the controlling generic soil cases. Therefore, it is not necessary to consider the other soil cases. The hard rock time history analysis base reactions are adjusted using the NS, EW, and vertical factors shown in Table 2.9-2.

Passive soil resistance is not considered for overturning seismic stability evaluation. For sliding, the amount of passive soil resistance, if required, is calculated to obtain the minimum factor of safety of 1.1. The deflection necessary to obtain the required passive pressure is then determined to show that it is reasonable (e.g., less than 2").

Table 2.9-2 – Factors to Apply to Hard Rock Analysis Base Reactions

Seismic Excitation	Upper Bound Soft to Medium	Soft to Medium
NS	0.98	0.92
EW	1.14	1.11
Vertical	1.06	1.14