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Your ref: Docket No. 52-006
Our ref: DCP/NRC2479

May 15, 2009

Subject: AP1000 Response to Request for Additional Information (TR03)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on Technical Report 03. 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-TR03-010 R4
RAI-TR03-015 R4
RAI-TR03-016 R2
RAI-TR03-017 R4
RAI-TR03-024 R1
RAI-TR03-025 R1
RAI-TR03-026 R2
RAI-TR03-027 R2
RAI-TR03-028 R2
RAI-TR03-029 R2
RAI-TR03-030 R2
RAI-TR03-031 R2

After further review, Westinghouse found it was not necessary to modify RAI-TR03-14 and -19.

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,

Robert Sisk

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Request for Additional Information on Technical Report 03

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DO63
NRO

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	P. Jacobs	-	Florida Power & Light	1E
	C. Pierce	-	Southern Company	1E
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ENCLOSURE 1

Response to Request for Additional Information on Technical Report 03

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-010
Revision: 4

Question:

The staff's review of Tables 4.4.1-1A and 4.4.1-1B found that Westinghouse used three soil/rock degradation models in its parametric studies for selecting site conditions: Seed and Idriss 1970 soil/rock degradation curves, Idriss 1990 soil degradation curves, and EPRI 1993 soil degradation curves. For example, Westinghouse used Seed and Idriss 1970 model for two horizontal motions and EPRI 1993 soil degradation model for two rocking motions when the parametric studies were performed for the AP1000 site selection. Westinghouse is requested to provide reasons and bases for using different soil degradation models for its parametric studies.

Westinghouse Response:

Soil structure interaction analyses on rock sites for both AP600 and AP1000 use the rock degradation curve recommended by Seed and Idriss in Reference 1. This was applied in SSI analyses for the hard rock, firm rock and soft rock sites.

Soil structure interaction analyses on soil sites for the AP1000 used the latest soil degradation curve recommended by EPRI in Reference 2. This was applied in SSI analyses for the upper bound soft to medium, soft to medium and soft soil sites. Two sets of degradation curves were used in the AP600 studies. The early analyses used the degradation recommended by Seed and Idriss in Reference 1. Later AP600 analyses performed to address NRC questions used the later soil degradation curve recommended by Idriss in Reference 3.

Westinghouse used one degradation model for soil and one for rock for the AP1000 parametric studies consistent with the latest models recommended for soil and rock sites. The soil profiles used in the generic analyses are added in DCD subsection 3.7.1.4, see APP-GW-GLR-134, Technical Report 134 (TR134).

In the meeting of April 16 – 20, 2007, NRC Staff requested additional clarification of how to confirm that a specific site is enveloped by the generic seismic design basis. This clarification is provided in revisions to DCD subsection 2.5.2. These revisions are provided in RAI-SRP-2.5-RGS1-01 to RAI-SRP-2.5-RGS1-6, as well as TR134.

In the NRC meeting of May 19 - 23, 2008 it was agreed to remove DCD Chapter 2 from Section 5.0 of TR03. Reference to DCD Chapter 2.0 for AP1000 site requirements is made in Section 5.0. Further, the following was agreed that shear wave velocity should be based on low-strain minimum measured values, and a criterion should be given to define acceptable variation in shear wave velocity that show inversion characteristics. These items are addressed in RAI-SRP 2.5-RGS1-15.

During the NRC audit the week of May 12, 2009, it was requested that Westinghouse provide clarification in the DCD concerning limitations on the use of 2D SASSI analyses to address site-specific deviations from the certified design site parameter envelope. Section 2.5.2.3 will be modified to provide this clarification in the next revision to the DCD. See Design Control Document (DCD) Revision section given below.

References:

1. Seed, H.B. and I.M. Idriss, "Soil Moduli and Damping Factors for Dynamic Response Analysis," Report No. EERC 70-14, Earthquake Engineering Center, University of California, Berkeley, CA., 1970.
2. EPRI TR-102293, "Guidelines for Determining Design Basis Ground Motions, 1993.
3. Idriss, I.M., "Response of Soft Soil Sites during Earthquakes," H. Bolton Seed Memorial Symposium Proceedings, May 1990.

Design Control Document (DCD) Revision:

~~None~~ Revise Section 2.5.2.3 in Revision 18 as follows:

The Combined License applicant may identify site-specific features and parameters that are not clearly within the guidance provided in subsection 2.5.2.1. These features and parameters may be demonstrated to be acceptable by performing site-specific seismic analyses. If the site-specific spectra at foundation level at a hard rock site or at grade for other sites exceed the certified seismic design response spectra in Figures 3.7.1-1 and 3.7.1-2 at any frequency (or Figures 3I.1-1 and 3I.1-2 for a hard rock site), or if soil conditions are outside the range evaluated for AP1000 design certification, a site-specific evaluation can be performed. ~~These analyses may be either 2D or 3D.~~ Where 2D or 3D analyses apply are as follows:

- The 3D SASSI analyses will be used to quantify the effects of exceedances of site-specific GMRS compared to the CSDRS, or the HRHF GMRS at a hard rock site (DCD Figures 3I.1-1 and 3I.1-2), or in cases where the site specific velocity soil profiles do not fall within the range evaluated for the standard design.
- The 2D analyses are preformed for parameter studies.

Results will be compared to the corresponding 2D or 3D generic analyses.

PRA Revision: None

Technical Report (TR) Revision:
No change to TR03 except that DCD Chapter 2 is removed from TR03 Section 5.0. Reference is made to DCD Chapter 2 in this section.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-015
Revision: 4

Question:

In Page 48 of 154, Westinghouse illustrated that some effects (water table, soil layering, soil degradation model, etc.) are not significant to the seismic response of the nuclear island (NI) structures. Because these results are applied for the AP1000 design, the staff requests Westinghouse provide technical basis for making these conclusions. In addition, Westinghouse needs to demonstrate the combination of these effects is also insignificant to the seismic response of the NI structures.

Westinghouse Response:

Section 4.4.1.1 is amplified as shown below to provide additional technical basis for the selection of the soil parameters used in the AP1000 3D SASSI design cases. The soil cases selected for the AP1000 utilize the same parameters on depth to bedrock, depth to water table and variation of shear wave velocity with depth as those used in the AP600 design analyses. The selection of these parameters for the AP1000 is based on the results and conclusions from the AP600 soil studies summarized in Table 4.4.1-1A. These AP600 soil studies considered variations of the parameters and combinations thereof in establishing the design soil profiles. The conclusions of the AP600 soil studies are applicable to the AP1000 due to the identical footprint to the AP600 and the similarity in overall mass. The height of the shield building is increased by about 20'. The total weight of the nuclear island increases by about 10%.

Parametric analyses of the AP1000 were performed for six soil cases as described in Section 4.4.1.2. These analyses used the same assumptions for depth to bedrock, depth to water table and variation of shear wave velocity with depth as were used in the AP600 and AP1000 3D SASSI design analyses. These analyses confirm that the response of the AP1000 is similar to that of the AP600 for these soil cases with the AP1000 fundamental response occurring at lower frequencies due to the increased height and mass of the nuclear island. Based on the similar response in these analyses, it is concluded that the governing parameters obtained for the AP600 soil studies are also applicable to the AP1000.

Westinghouse has addressed soil degradation in RAI-TR03-10. Tables of strain-iterated shear wave velocity used in the generic analyses are shown in Table 4.4.1-3 of Technical Report 03. Figure RAI-TR03-15-1 shows the bounds of these strain-iterated shear wave velocity profiles. The combination of effects of the different soil parameters is reflected in these bounds. Figure RAI-TR03-15-2 shows how a COL applicant could demonstrate that the site is enveloped by generic seismic design basis. The applicant would define its site geotechnical parameters as defined in DCD Section 2.5 and would justify why the site is within the bounds of the AP1000 generic analyses that have been considered in this technical report. These parameters would include the soil profiles used in the PSHA (probabilistic seismic hazard analysis) analyses, which could then be compared to Figure RAI-TR03-15-1. Subsequent discussions between the COL applicant and the NRC may uncover a parameter for which more justification is required to show that the impact of this parameter on the response is small. This justification could be done with the AP1000 2D model (See RAI-TR03-010, Rev. 4 for clarification of the use of 2D analyses). An example of how a 2D parametric study would be used is shown in Figure RAI-TR03-15-3 and RAI-TR03-15-4. If the parametric 2D SASSI studies show that the effect could be significant (e.g., 90% of the design spectrum, see Figure RAI-TR03-15-4) when compared to the 2D design spectra, a 3D SASSI study would then be performed. If the 3D SASSI analyses show some exceedances at the critical locations, the applicant would then proceed to show that sufficient margin exists in the design to accommodate these exceedances.

The effect of water table on the seismic response of the nuclear island structures is shown in figures RAI-TR03-15-5 through RAI-TR03-15-7. Case 1 (SM) shows the results for the soft-to-medium generic case profile which assumes water table at grade. Case 2 (SM-NW) results are for the same soil condition except the water table is below the bottom of the soil profile at 120' below grade. As can be seen there is negligible difference between the two cases for the horizontal response. The vertical response due to the design profile with the water table at grade (Case 1) is more conservative than that for the dry soil profile (Case 2). This result is similar to the results in the AP600 study which are summarized in section 4.4.1.1 which states:

> "These studies showed that the change of water table elevations had insignificant effect on the horizontal results. Comparison of the vertical responses showed that the water table at the grade level controlled the responses in the frequency range of 2 to 8 hertz."

Thus, the generic analyses are conservative for sites with a lower water table.

The arrow in Figure RAI-TR03-15-2 related to COL Application was reversed.

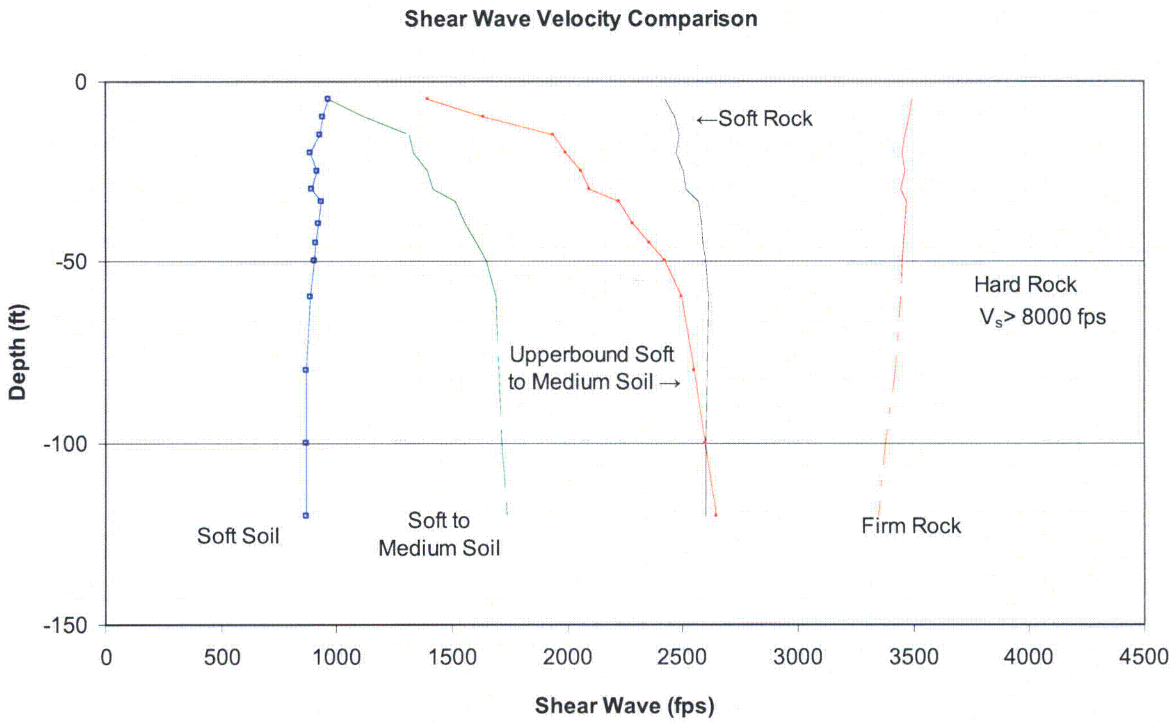


Figure RAI-TR03-15-1-Strain-iterated shear wave velocity profiles

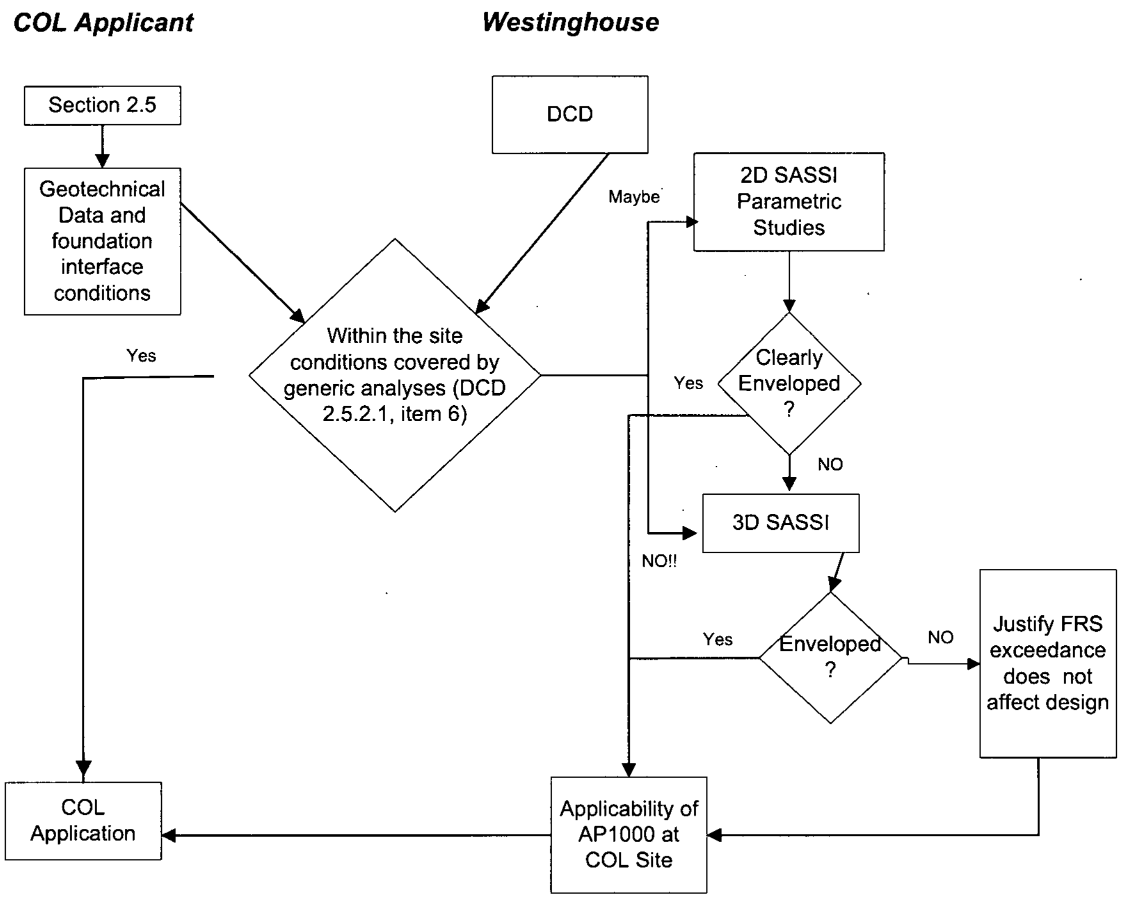


Figure RAI-TR03-15-2-COL Application process for generic design

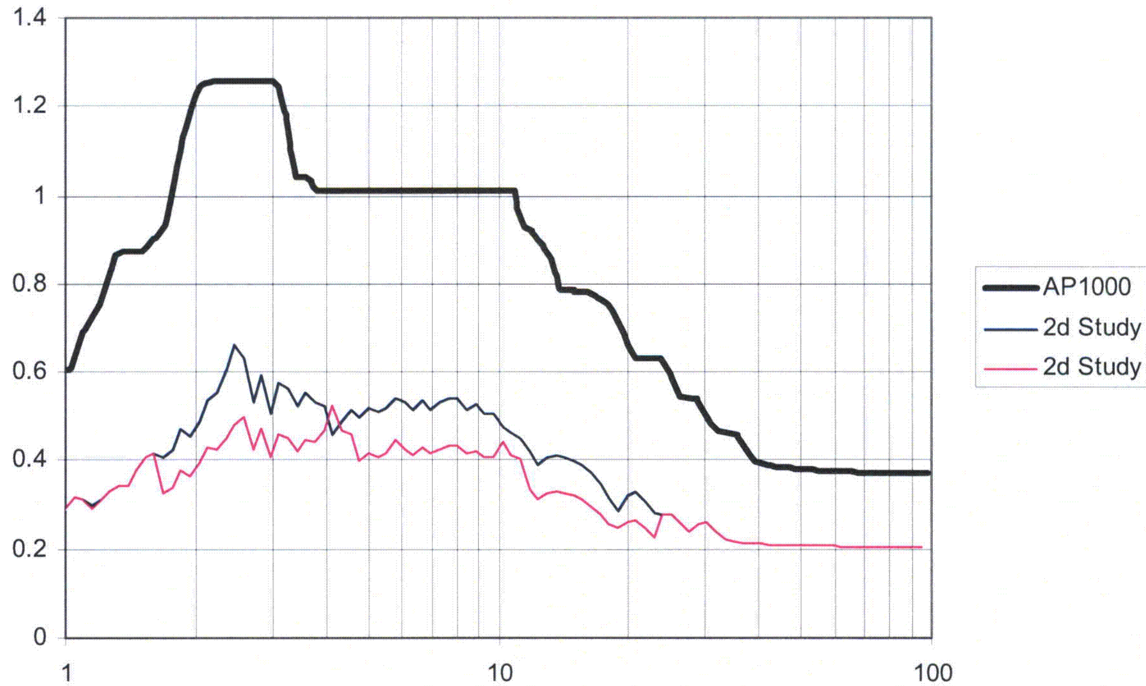


Figure RAI-TR03-15-3- 2D parametric studies demonstrate site is clearly enveloped by 2D design spectra

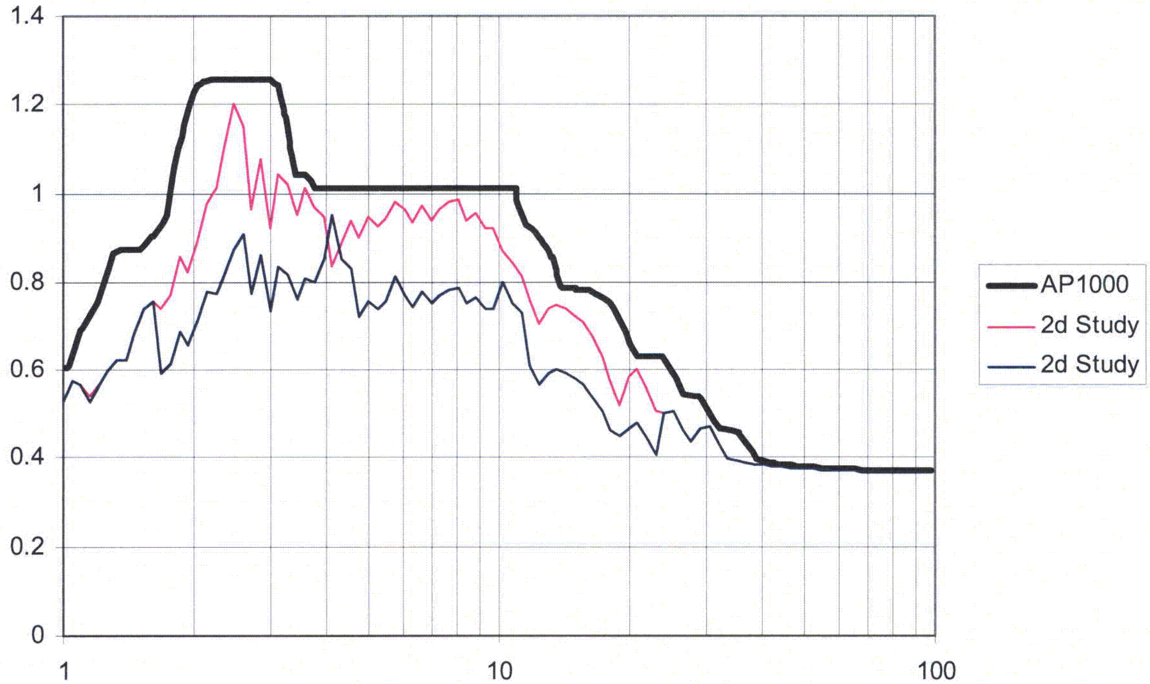


Figure RAI-TR03-15-4- 2D parametric study demonstrate that further studies may be required

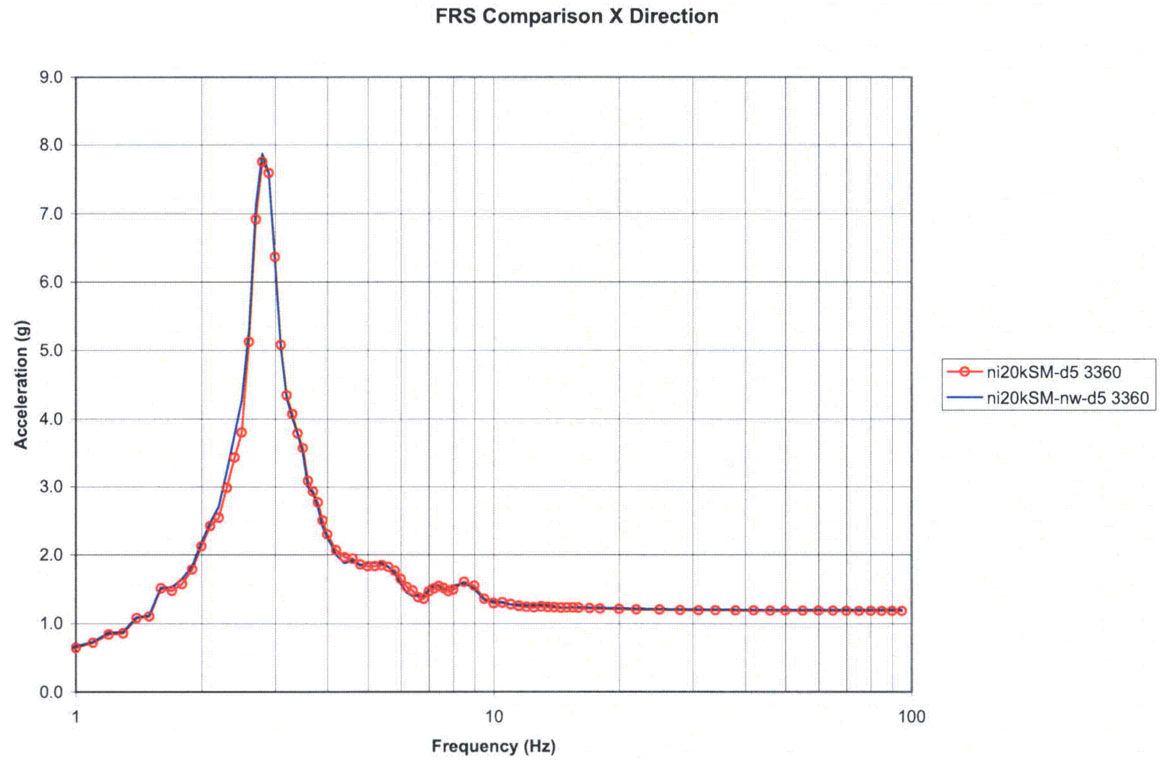


Figure RAI-TR03-15-5- Effect of water table variation in horizontal direction (X)

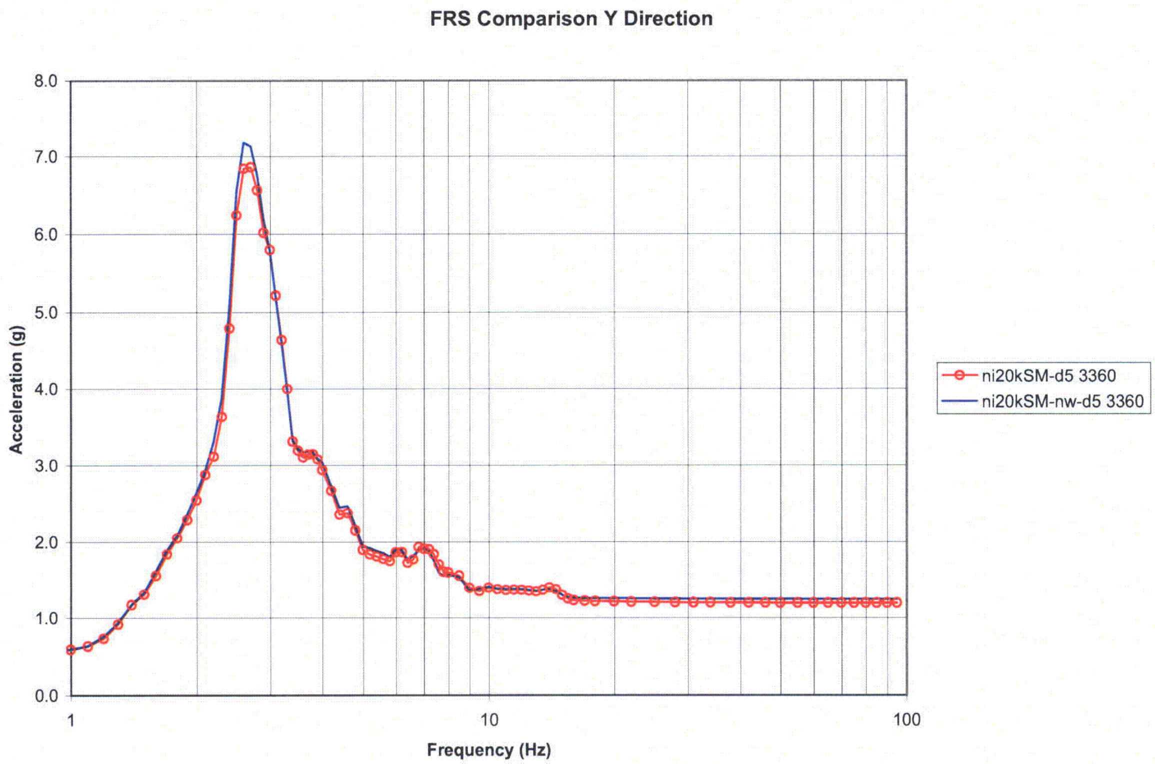


Figure RAI-TR03-15-6-Effect of water table variation in horizontal direction (Y)

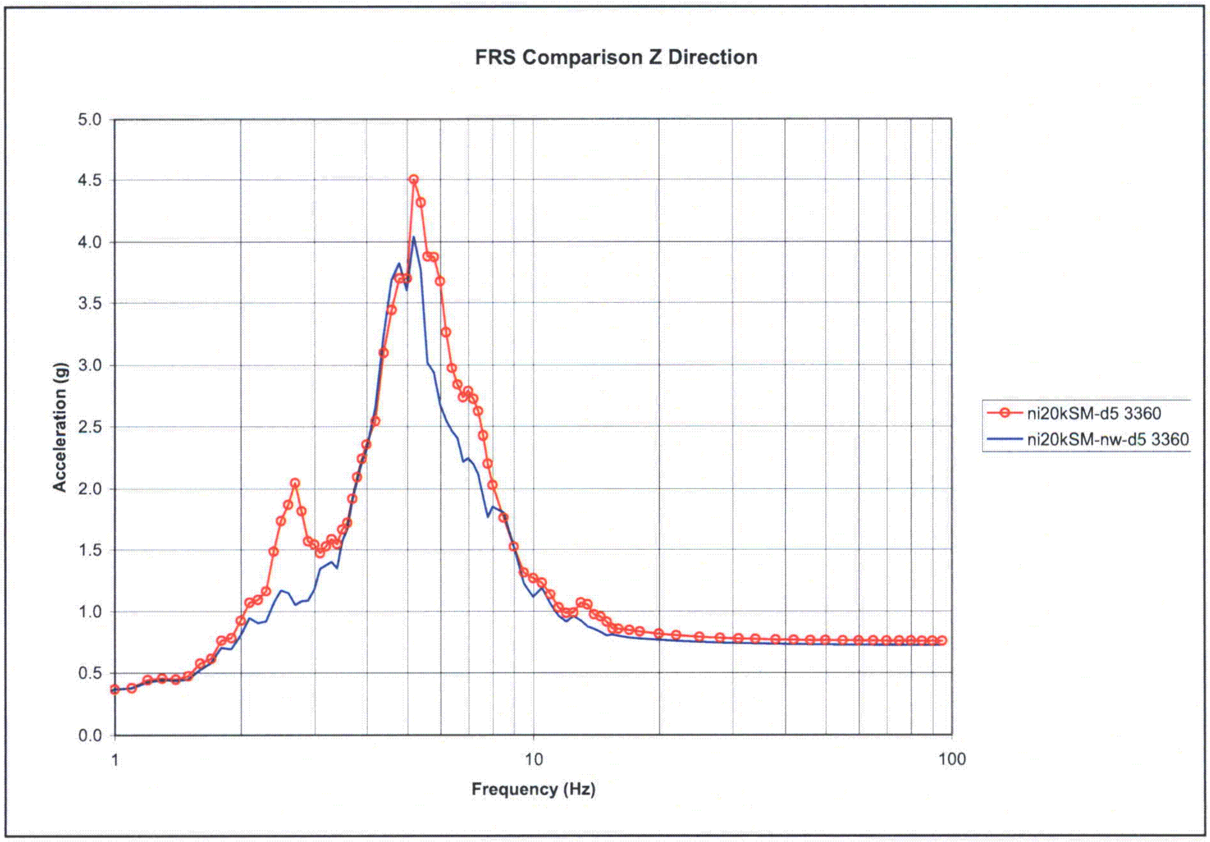


Figure RAI-TR03-15-7- Effect of water table variation in horizontal direction (Z)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:

Sections 4.4.1 and 4.4.1.1 have been revised as shown below in Revision 1 of the Technical Report.

Revision to Figure 4.4.1-1 will be made in Rev. 3 of report as shown below.

4.4 Soil Cases and SSI Analyses

4.4.1 2D SASSI Analyses and Parameter Studies

This section describes the parametric analyses performed using 2D models in SASSI to select the design soil cases for the AP1000. The AP1000 footprint, or interface to the soil medium, is identical to the AP600. The AP1000 containment and shield building are 20' 6" taller than AP600. Results and conclusions from the AP600 soil studies are summarized since the behavior of the AP1000 is expected to be similar and results from AP600 provide guidance in the selection of the generic cases for the AP1000. Five soil and rock cases are selected as follows: hard rock; firm rock; soft rock; upper bound soft to medium soil, soft to medium soil, and soft soil. These are the same as the cases analyzed for the AP600 except that the soft soil case is added and the soft rock case (v_s =2500 feet per second) for the AP600 has been replaced by firm rock (v_s = 3500 feet per second) since the 2D SASSI parametric analyses show that the firm rock case is more significant than on AP600 due to the additional height of the shield building.

4.4.1.1 AP600 Soil Studies

The AP600 studies are summarized below. They are described in Appendices 2A and 2B of the AP600 DCD (Reference 7).

A survey of 22 commercial nuclear power plants in the United States was conducted to identify the subsurface soil profiles and the range of soil properties at these plants as part of the AP600 design certification. The survey included nuclear power plants sites both east and west of the Rocky Mountains. Based on this survey five generic soil profiles (soft soil, soft to medium soil, soft rock and step profile in Figure 4.4.1-1 plus hard rock) were established ranging from soft soil to hard rock. Using these soil profiles, 2D soil-structure interaction analyses were performed to determine site geotechnical variables which induced the highest nuclear seismic response during an earthquake.

The series of parametric studies performed using 2D SASSI models for AP600 certification is shown in Table 4.4.1-1A. Note that for AP1000, 2D SASSI parametric studies were performed and they are shown in Table 4.4.1-1B. These SASSI models consisted of 2D lumped mass stick models coupled with a 2D model of the foundation. The conclusions made based on these parametric studies for the AP600 configuration are given below.

Soil properties were specified to a depth of 240 feet below grade. Analyses were performed for various depths to base rock. In each case, the soil properties above the base rock were those of the soil and the base rock was assumed to have shear wave velocity of 8000 feet per second. The analyses performed for a depth to base rock of 240 feet are described in Table 4.4.1-1A as a deep soil site and results would also be representative of deeper soil sites. Soil sites were found to control the AP600 nuclear island response at frequencies below about 4 hertz for horizontal response and 8 hertz for vertical response while the hard rock site controls the response at higher frequencies. The studies of depth to base rock showed that the response was not very sensitive to the depth. The depth-to-base rock of 120 ft generally gave the higher response for each of the soil profiles and was therefore specified for the 3D SASSI design cases. The shallower depth models gave a higher building response at high frequencies, but these responses were lower than those for hard rock. The deeper models had greater radiation damping reducing the overall response. The dominant AP1000 building mode shapes are similar to the AP600 and the frequencies are lower. Since the response of the AP600 was relatively insensitive to depth and the dominant modes of the AP600 and AP1000 are similar, using a depth-to-base rock of 120 ft is also appropriate for the AP1000.

The soil properties associated with the lower and upper bound sandy soils (soft-to-medium soil profile) bound the range of properties associated with clays with plasticity indices from 10 to 70 as shown in Figure 2B-13 of the AP600 DCD. SSI analyses were performed for clay profiles and concluded that the responses for clay profiles were bounded by those for the design soil profiles.

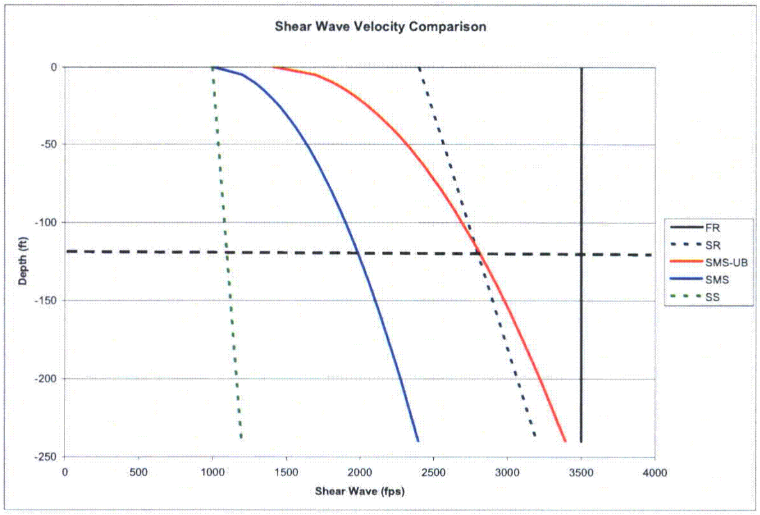
The effect of depth to water table was studied for the soft-to-medium soil case with the depth to base rock of 120 feet. Cases were analyzed for water table at grade, for water table at the foundation level (40 foot depth) and for a dry site. For cases where the water table was below grade, the Poisson's ratio for soil above the water table was also varied from 0.25 to 0.35. These studies showed that the change of water table elevations had insignificant effect on the horizontal results. Comparison of the vertical responses showed that the water table at the grade level controlled the responses in the frequency range of 2 to 8 hertz. The increase in response was mainly due to an increase in foundation effective motion, which results from an increase in the P-wave velocity in conjunction with the SSI frequency for this case. Thus, the water table was specified at grade for the 3D SASSI design cases. Since the mass of the AP1000 is similar to that of the AP600 the vertical SSI frequency and response are similar. Thus, the specification of the water table at grade is also appropriate for the AP1000 soil sites.

The change in degradation curves between the 1970 Idriss and Seed and 1990 Seed degradation curves was not significant. The AP1000 uses the EPRI 93 degradation curves. These degradation curves have been used in AP1000 2D SASSI parametric analyses and do not significantly affect the SSI response, and thus should not result in a change in the selection of the generic soil profiles.

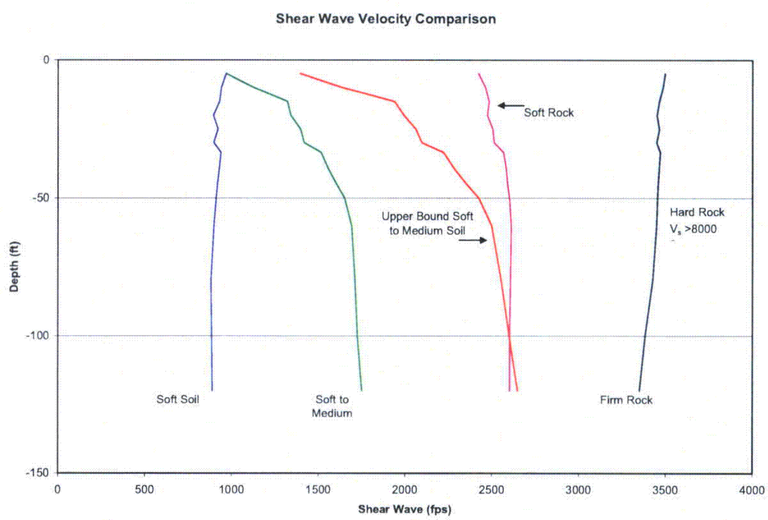
Analyses were also performed for a layered soil profile with step-wise change in shear wave velocity. The step-wise layered soil profile had a layered profile with shear wave velocity of 1000 feet per second to a 40-foot depth, 1800 feet per second between 40-foot and 80-foot depth, and 4300 feet per second for depth greater than 80 feet. The response for this profile is enveloped by the soft rock, soft-to-medium, and rigid base response. In addition the cases previously described in the depth to base rock studies showed that the sharp contrast in shear wave velocity (layering) was enveloped by the design cases with depth to base rock at 120 feet. Based on this study and the studies of depth to base rock, the step-wise layered soil profile was not included as a design case for AP600 nor need it be included for AP1000.

Analyses including adjacent buildings showed that the effect of the adjacent buildings on the nuclear island response was small. Based on this, the 3D SASSI analysis of the nuclear island can be performed without adjacent buildings. The nuclear island does affect the response of the adjacent buildings and the results of the 2D SASSI analyses are used for design of the adjacent buildings for both the AP600 and AP1000.

SASSI analyses for hard rock sites were compared to fixed base results. A fixed base analysis is adequate for sites in excess of 8000 fps.



Initial Properties



Strain-Iterated Shear Wave Velocity Profiles

Note: Fixed base analyses were performed for hard rock sites. These analyses are applicable for shear wave velocity greater than 8000 feet per second.

Figure 4.4.1-1- Generic Soil Profiles

(Revision to Figure 4.4.1-1 to be made in Revision 3 of Technical Report)

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-016
Revision: 2

Question:

The first sentence of the fourth paragraph in Page 50 of 154 states that maximum member forces are shown in Figures 4.4.1-2 through 4.4.1-5. These figures indicate that the equivalent static analysis always results in highest member forces when compared with SASSI results based on other site conditions. The staff requests Westinghouse to identify which site condition was selected to develop the equivalent static acceleration profile used to perform the equivalent static analysis.

In addition, the staff's review of the report APP-GW-GLR-009, "Containment Vessel design Adjacent to Large Penetrations," found that the containment vessel was designed for seismic loads by applying equivalent static accelerations at each elevation based on the maximum acceleration from the fixed-base NI stick models tabulated in DCD Table 3.7.2-6. Based on the ZPAs shown in Table 4.4.1-2 and seismic loads shown in Figures 4.4.1-2 through 4.4.1-7, Westinghouse should demonstrate that the seismic loads used for the containment vessel design are the worst loading condition.

Additional Request (Revision 2):

Westinghouse should demonstrate that the adequacy of using results from equivalent static acceleration analyses for the SSE response in the evaluation of the large penetrations.

Westinghouse Response:

The equivalent static acceleration profile used in the parametric studies described in subsection 4.4.1.2 with member force results designated as EQ in Figures 4.4.1-2 to 4.4.1-5 is based on the maximum acceleration values obtained from the 2D ANSYS time history modal analyses of the same stick model on hard rock described in Section 7.1 of the report. These ANSYS analyses used the same model as the 2D SASSI analyses. The accelerations in Table 4.4.1-2, the member forces shown in Figures 4.4.1-2 to 4.4.1-5, and the floor response spectra in Appendix D are all from the 2D parametric analyses and are evaluated in the selection of the design soil cases as described in the fourth paragraph on page 50 of 154.

The equivalent static acceleration profiles specified for the design of the nuclear island structures are described in subsection 6.2 of the technical report. The accelerations given in Table 6.2-4 for the containment vessel are the envelope of the maximum accelerations obtained from the updated nuclear island analyses for the four design soil cases described in the technical report. The design analyses of the containment vessel were initially performed during the hard rock design certification using equivalent static accelerations tabulated in DCD Table 3.7.2-6 (based on fixed base stick models). The reconciliation of the design of the containment vessel for seismic input for soil sites is described in report APP-GW-GLR-005, "Containment Vessel Design Adjacent to Large Penetrations," (Reference 1). As discussed in the April 16-20 meeting, this reconciliation should be considered as part of the review of Reference 1.

Reference:

1. APP-GW-GLR-005, "Containment Vessel Design Adjacent to Large Penetrations," Rev. 1.

Westinghouse Response (Revision 2):

The equivalent static acceleration analyses of the containment vessel are described in Reference 1. These analyses use a finite element shell model with a refined mesh in the area adjacent to the large penetrations (Figure 2-6 of Reference 1). A re-analysis has been performed using the same methodology on the coarse-mesh model of the steel containment vessel.

Additionally, a time history analysis has been performed selecting information for the regions immediately surrounding the large penetrations as shown in Figure RAI-TR03-016-001. The purpose of this analysis is to verify that the loads from equivalent static analysis are conservative to time history using a representative study. The effects of the missing mass in the time history analysis have been incorporated by an algebraic sum of the stress intensities from a run with the left out mass accelerated at ZPA and the modal superposition time history analysis.

Figures RAI-TR03-016-002 through RAI-TR03-016-005 compares the stress intensity for individual elements surrounding the major penetrations. These results show that equivalent static analysis consistently produces higher stresses than the generally accepted time history results.

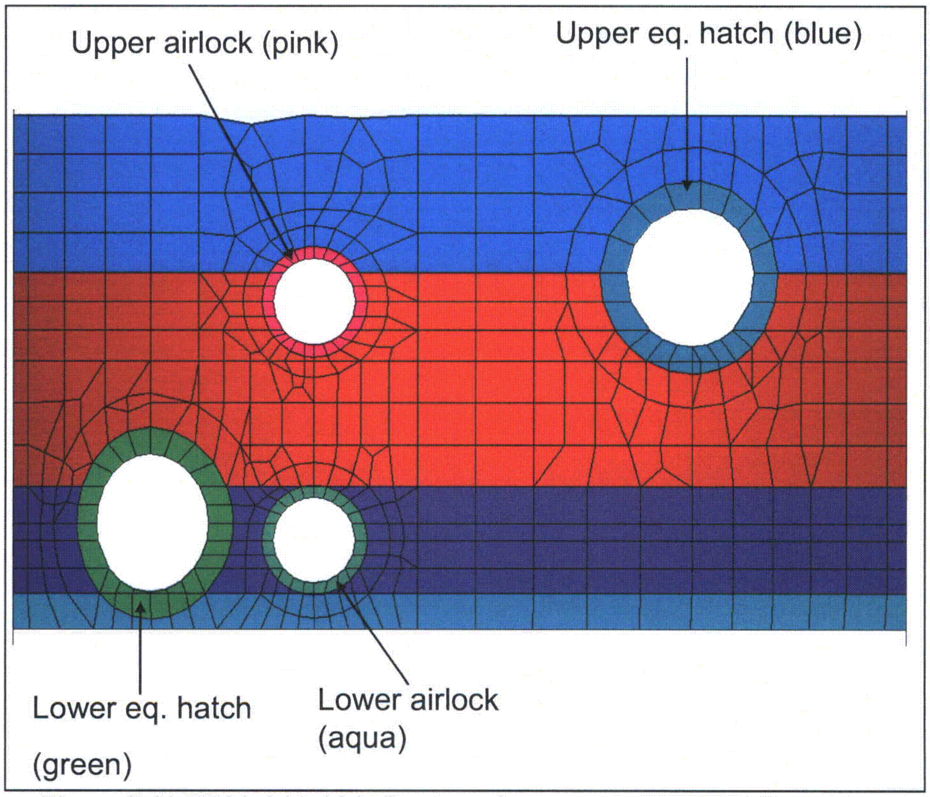


Figure RAI-TR03-016-001: Regions Surrounding Major Penetrations

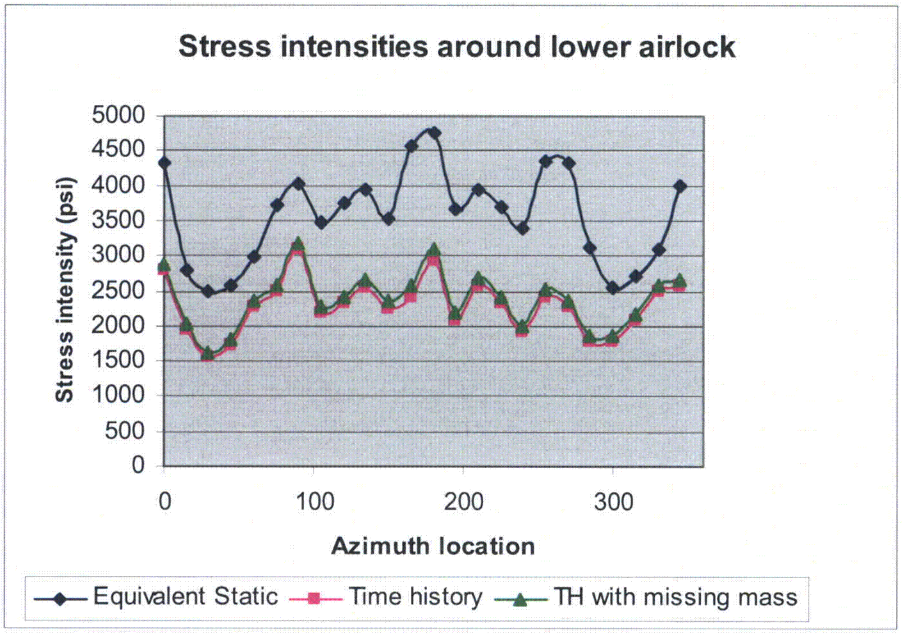


Figure RAI-TR03-016-002: Stress Intensity Comparison for Lower Airlock

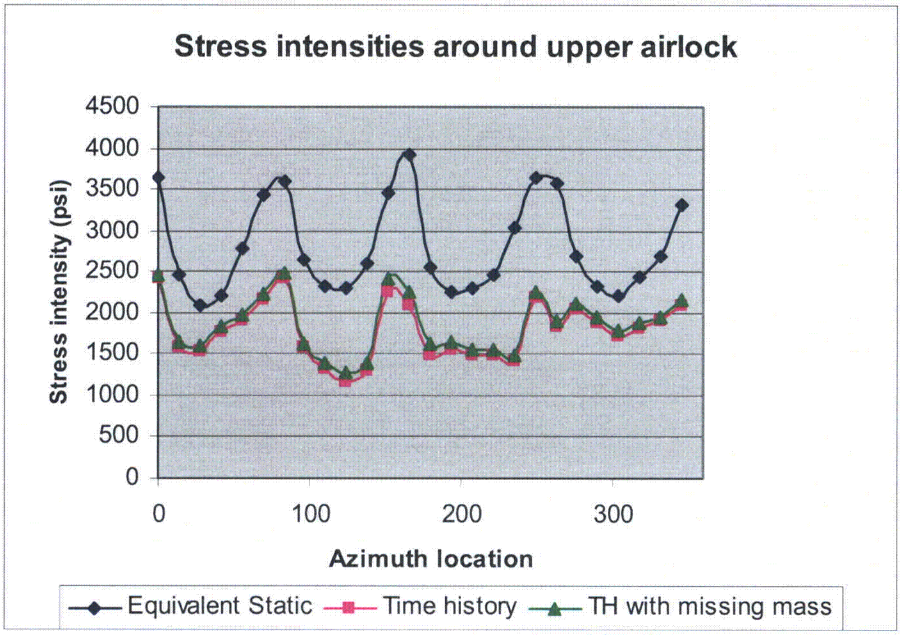


Figure RAI-TR03-016-003: Stress Intensity Comparison for Upper Airlock

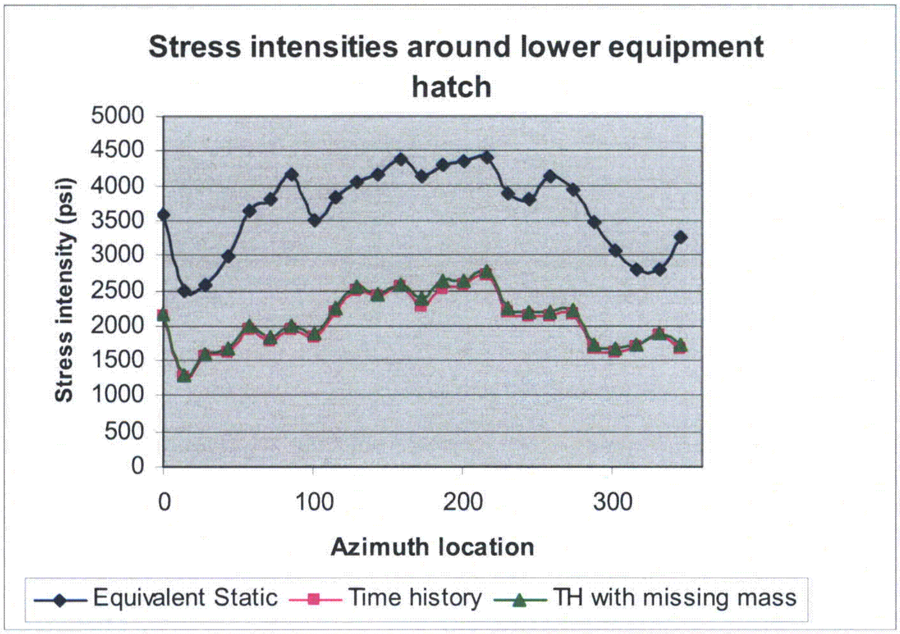


Figure RAI-TR03-016-004: Stress Intensity Comparison for Lower Equipment Hatch

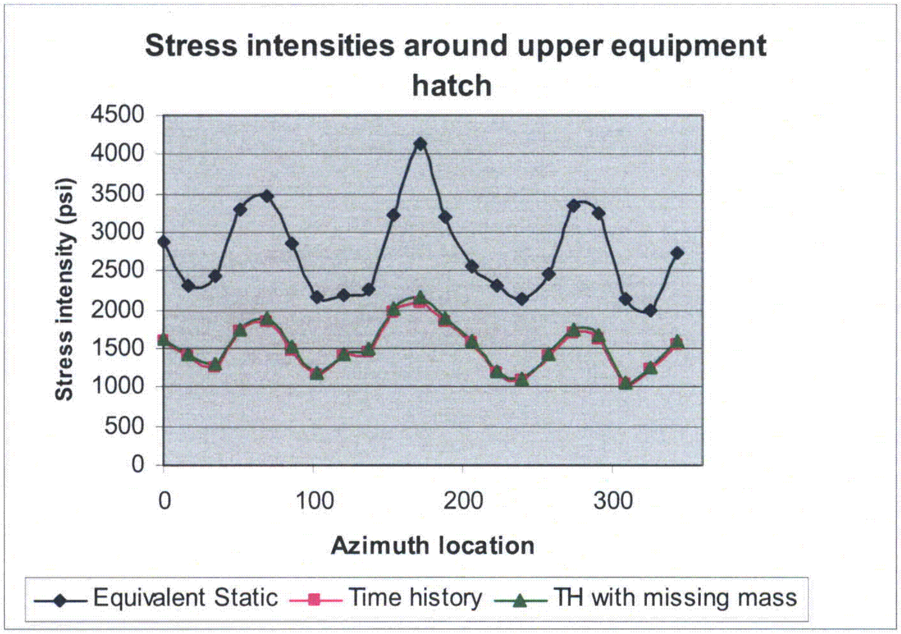


Figure RAI-TR03-016-005: Stress Intensity Comparison for Upper Equipment Hatch

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:

The revisions shown in Revision 1 of this response were included in the revised TR03.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-017
Revision: 4

Question:

Wording in DCD Table 2-1 "Site Parameters" indicates that best estimate low-strain shear wave velocity shall be greater than 1,000 fps and that variability across the site shall be less than 100 fps (10%). It is presumed that this DCD commitment is based on SASSI results for a uniform half-space below the plant basemat. Westinghouse is requested to a include statement on maximum acceptable change in velocity profile within a depth equal to the width of the basemat in the definition of "Site Parameters."

Westinghouse Response:

The variability in shear wave velocity of 10% across the site was established to limit variability in the soil pressures used in design of the basemat. This was based on AP600 basemat analyses. The analyses for the AP1000 are described in the "Nuclear Island Basemat and Foundation" report (Reference 1) submitted in October 2006. The variability specified for the AP600 is retained for the AP1000. Section 5 of Reference 1 shows proposed revisions to DCD Chapter 2. Subsection 2.5.4.5.3, Site Foundation Material Evaluation Criteria, describes the evaluation of the variability in each layer. If the shear wave velocity at the foundation level varies in plan, the minimum value must satisfy the requirement that the best estimate low-strain shear wave velocity shall be greater than 1,000 fps.

The maximum acceptable change in velocity profile within a depth equal to the width of the basemat is evaluated by the comparison against the AP1000 generic soil profiles as required by item 6 of DCD subsection 2.5.2.1 (see RAI-TR03-010, Rev ~~2~~4). It is noted that if there is a property inversion (i.e. stiff soil above soft soil) at a specific site, then a site specific analysis will be performed for this case. Six design soil profiles are analyzed. Four of these are the same profiles as were analyzed for the AP600. For the AP600 a number of soil profiles were included in parametric studies including soil with various depths to rock and a "stepped" profile. Responses on the nuclear island for these cases were bounded by the four AP600 design soil profiles. Further discussion is given related to the applicability of these studies to the AP1000 plant in the responses to RAI-TR03-014 and RAI-TR03-015.

See RAI-TR03-010, Rev. ~~3~~4.

Reference:

1. APP-GW-GLR-044 Revision 0, "Nuclear Island Basemat and Foundation", October, 2006.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-024
Revision: 1

Question:

The description of Section 7.1 does not indicate whether the vertical spring/damper values were based on the rocking site stiffness value or the vertical site stiffness value and whether the horizontal/vertical parameters were determined from an assumed uniform half-space. Westinghouse should explain what are the differences in these parameters and how significant are these parameters on the computed results.

Westinghouse Response:

The material in Section 7.1 is a summary of material submitted and accepted during the hard rock design certification.

The spring and damping values were calculated for an equivalent rectangular foundation on a uniform half space having a shear wave velocity of 8000 feet per second. The vertical stiffness was based on vertical loading rather than rocking.

The value of the assumed soil spring was not significant in the lift off analyses on hard rock. This was shown by varying the stiffness (minus 50% and plus 50%). Use of soil springs based on the rocking site stiffness and damping values rather than the vertical values would not affect the conclusions of the analysis.

Additional results on liftoff and subgrade pressure from the hard rock analyses described in Section 7.1 are provided in the nuclear island basemat and foundation report (Reference 1).

In the NRC meeting of May 19 - 23, 2008, it was agreed to remove the discussion of nonlinear liftoff analyses from Section 7.0 of TR03. This material was moved to APP-GW-GLR-044 (TR85), "Nuclear Island Basemat and Foundation." As agreed in the AP1000 NRC Audit of April 13-16, 2009, a reference is given to the location of the TR03 Section 7 information in TR85, Rev. 1. The information for this RAI is in Sections 2.4.1 and 2.4.2. It was agreed in a telecom with the NRC on May 11, 2009 that the seismic response spectra associated with uplift and Review Level Earthquake be documented since it does not appear in TR85. For documentation purposes it is placed in this response below.

Nuclear Island Liftoff Analyses

Hard rock site

The effect of liftoff during the safe shutdown earthquake of 0.3g on a hard rock site was described in the response to DSER Open Item 3.7.2.3-1 (Reference 2). The effect of liftoff during the review level earthquake of 0.5g on a hard rock site was described in the response to DSER Open Item 19A.2-8 (Reference 3).

Lift off was evaluated using an East-West lumped-mass stick model of the nuclear island structures supported on a rigid basemat with nonlinear springs. This model is shown in Figure RAI-TR03-024-1. The liftoff analysis model consists of the following two elements:

1. The nuclear island (NI) combined stick model (ASB, CIS and SCV). The three sticks are concentric and the reactor coolant loop is included as mass only.
2. The rigid basemat model with horizontal and vertical rock springs

Analyses at the safe shutdown earthquake (SSE) level were performed on a model with an equivalent rectangular basemat of 140.0' × 234.5'. Analyses at the review level earthquake (RLE) level were performed initially with the same rectangular basemat. Later analyses used the actual footprint of the basemat. The overall width is 161' whereas the equivalent rectangle only had a width of 140'. Both have the same overturning resistance in linear analyses where soil springs take tension. Both models have the same eccentricity between the center of mass of the nuclear island and the centroid of the basemat.

The responses to DSER Open Items 3.7.2.3-1 (Reference 2) and 19A.2-8 (Reference 3) show the floor response spectra in the horizontal and vertical directions at representative elevations of the auxiliary and shield building. Typical results are shown in Figures RAI-TR03-024-2 and RAI-TR03-024-3 for the SSE and RLE spectra at elevation 116.5' in the ASB. The SSE figure also shows results with the soil springs reduced to 50% of the hard rock spring. The results show that the liftoff and rock stiffness have insignificant effect on the SSE response and a small increase at high frequencies for the RLE.

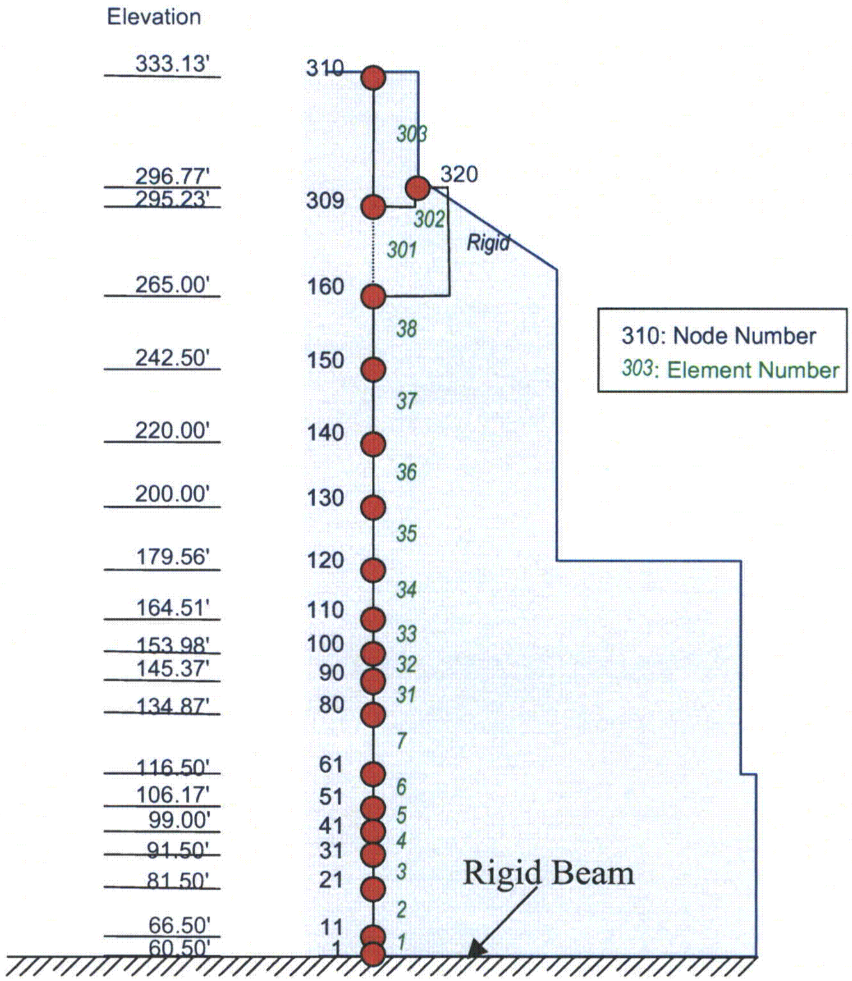
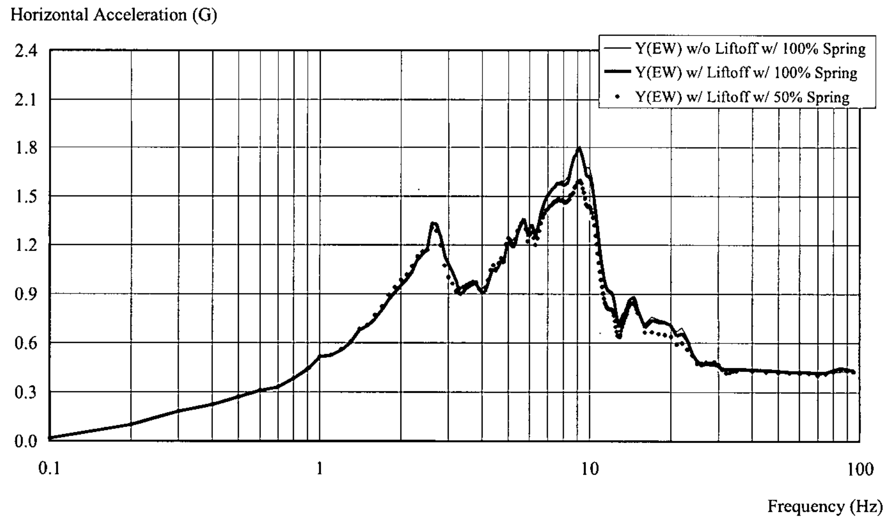


Figure RAI-TR03-024-1 - ASB Stick Portion of NI Combined Model



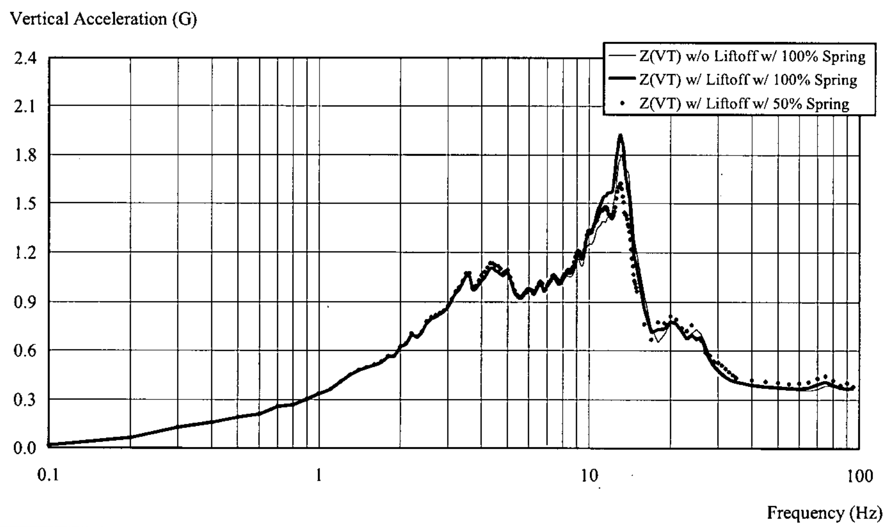


Figure RAI-TR03-024-2 - SSE Floor Response Spectra at 5 % Damping – Node 61 (EL. 116.50')

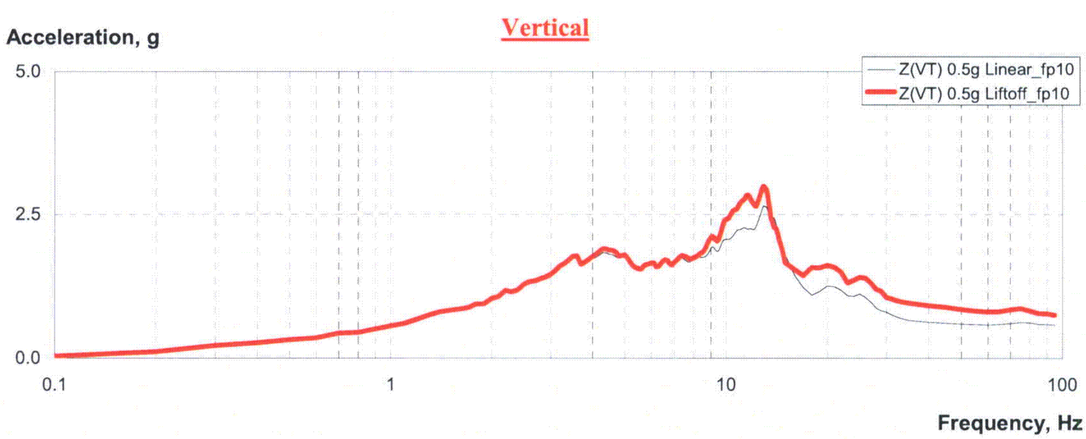


Figure RAI-TR03-024-3 - RLE Floor Response Spectra of ASB Node at EL. 116.50'

Soil Sites

The effect of liftoff during the safe shutdown earthquake of 0.3g and the review level earthquake of 0.5g was evaluated using the same approach described for the hard rock site. The analyses used the East-West lumped-mass stick model of the nuclear island structures supported on a rigid basemat with nonlinear springs. The H2 (East-West direction) and vertical components of the time histories were used to generate liftoff response in the 2D analyses. They were applied simultaneously. The actual footprint of the basemat was used in the analyses of the East-West model.

Linear analyses of the ANSYS models showed that the soft-to-medium soil case gave the maximum base shear force and overturning moment. Hence, a non-linear lift off analysis was performed for the soft-to-medium soil case. Linear and non-linear (liftoff) analyses were performed for the SSE input of 0.3g and the RLE (review level earthquake) input of 0.5g. The linear analysis uses linear soil springs, and the non-linear (liftoff) analysis uses non-linear soil springs that are inactive when a basemat node is higher than its initial location without loads.

Figure RAI-TR03-024-4 compares the SSE FRS between linear and non-linear (liftoff) analyses. The lift off effect on FRS is similar with those for the hard rock case; it is visible but insignificant. Figure RAI-TR03-024-5 compares RLE FRS between linear and non-linear (liftoff) analyses. The liftoff effect on FRS is similar with those for the hard rock case; it is insignificant in the horizontal direction and visible in the vertical direction at high frequency range.

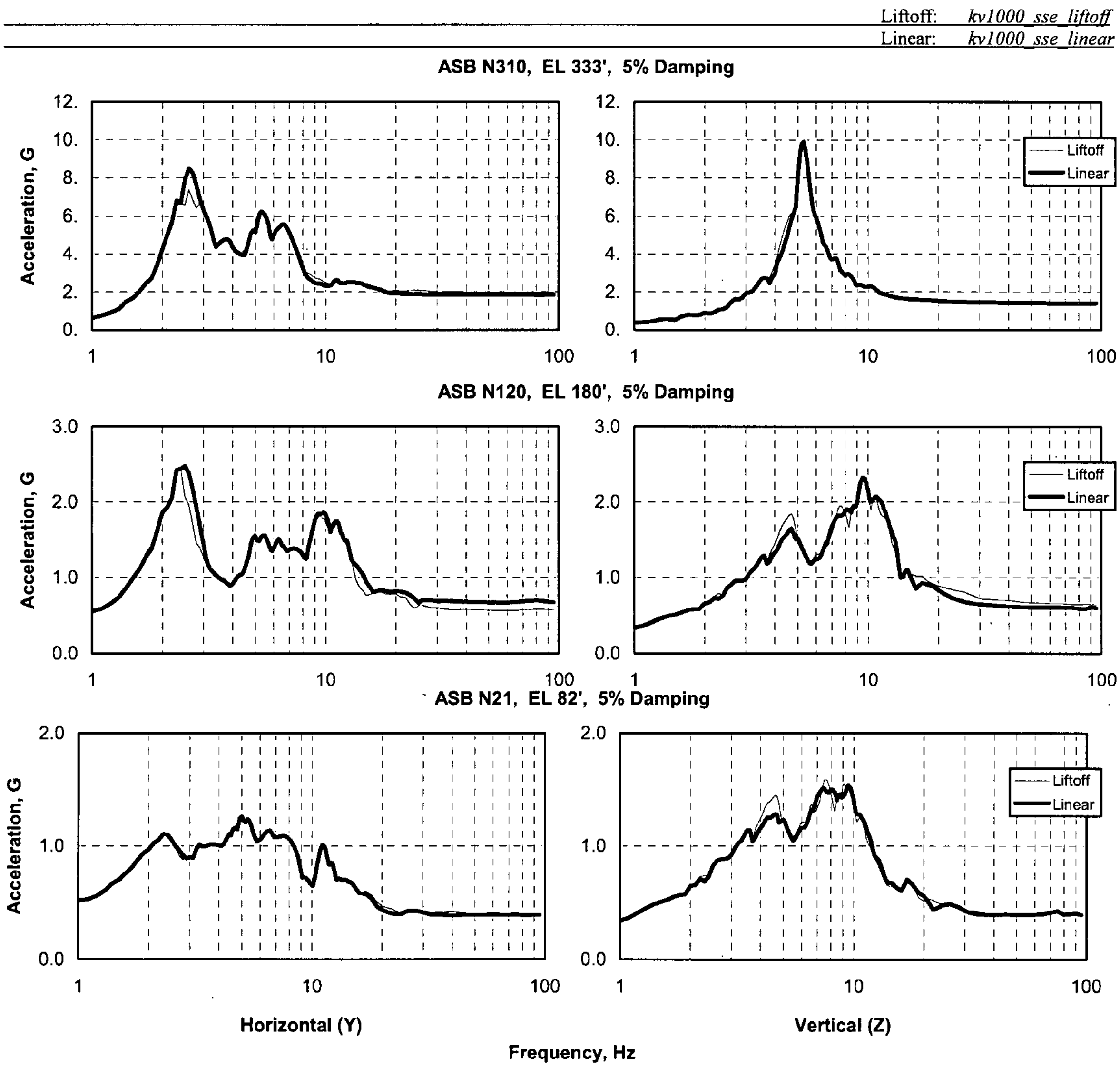


Figure RAI-TR03-024-4 - ANSYS Liftoff Effects on FRS (SSE) Soft to Medium Soil

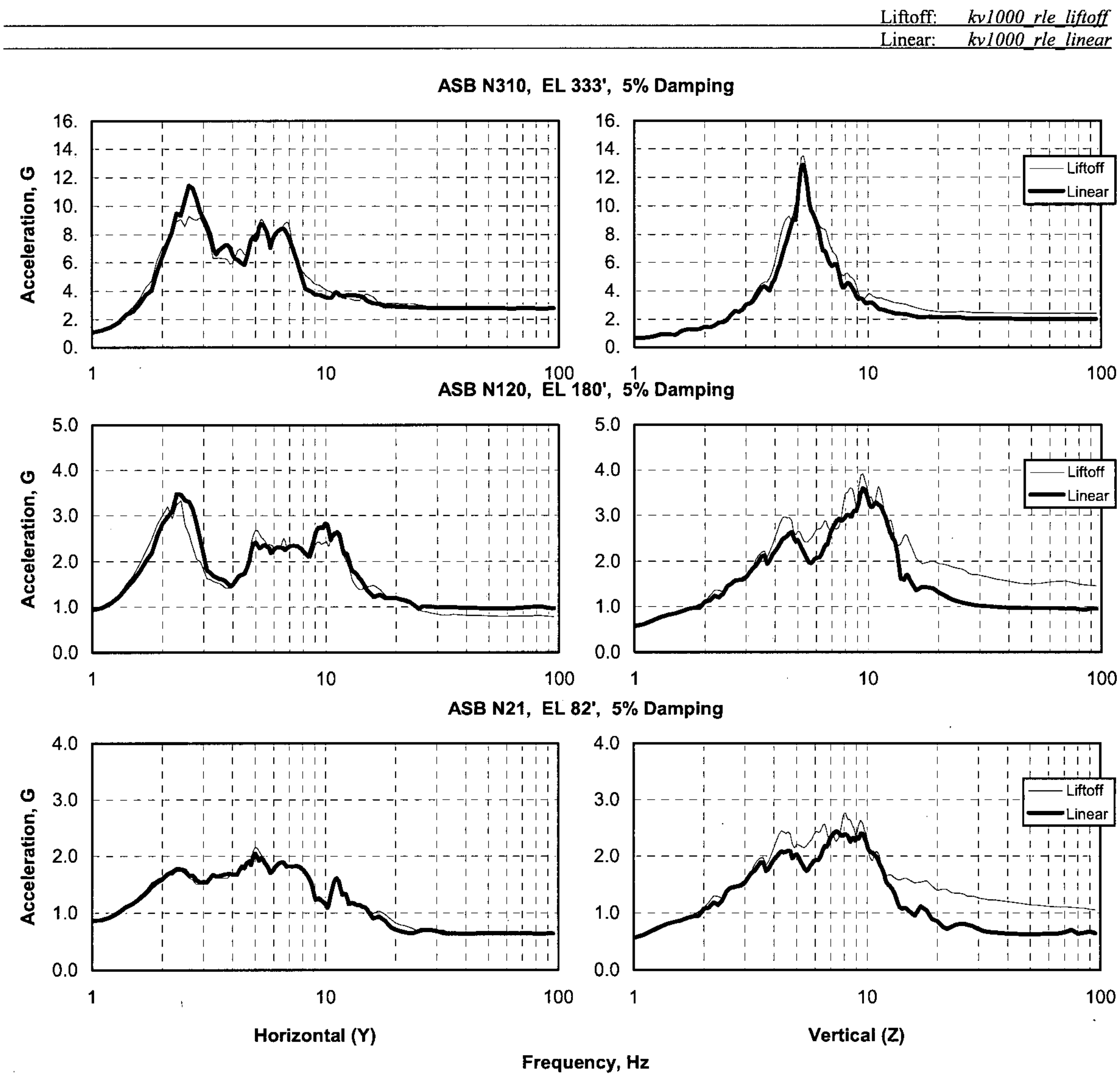


Figure RAI-TR03-024-5 - ANSYS Liftoff Effects on FRS (RLE) Soft to Medium Soil

Reference:

(1) APP-GW-GLR-044, Nuclear Island Basemat and Foundation, Rev 0, October, 2006.
(2) DSER Open Item 3.7.2.3-1, Rev. 1, Transmitted in DCP/NRC 1625, September 11, 2003.
(3) DSER Open Item 19A.2-8, Transmitted in DCP/NRC 1599, June 24, 2003.

Design Control Document (DCD) Revision:

DCD revisions are not shown for each RAI. A single set of proposed revisions is given in the response to RAI-TR03-013. The revisions are based on the material in the technical report as well as in the RAI responses. The revisions include changes to Section 3.7 and the addition of a new Appendix 3G providing a summary of the seismic analyses.

PRA Revision:

None

Technical Report (TR) Revision:

None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-025
Revision: 1

Question:

It is not obvious from the description provided in Section 7.1 if the nonlinear (zero tension) cases were run with the basemat width of 140 ft or 161 ft and if the runs were 2D or 3D cases.

Westinghouse Response:

This has been clarified in Reference 1. The second paragraph in Section 2.4.2 describes the SSE analyses as follows:

> Section 7.0 of Reference 3 (APP-1000-S2R-010, Rev 0) describes analyses to investigate the effect of liftoff during the safe shutdown earthquake of 0.3g on a hard rock and a soft to medium soil site using an East-West lumped-mass stick model of the nuclear island structures supported on a rigid basemat with nonlinear springs. Analyses for the hard rock site were performed on a model with an equivalent rectangular basemat of 140.0' × 234.5'. Analyses for the soft to medium soil site were performed on a model with the actual footprint of the basemat. The overall width is 161' whereas the equivalent rectangle only had a width of 140'. Both have the same overturning resistance in linear analyses where soil springs take tension. Both models have the same eccentricity between the center of mass of the nuclear island and the centroid of the basemat.

Analyses were also performed for the review level earthquake of 0.5g on both hard rock and soft to medium soil. These analyses used the actual footprint with width of 161'.

Reference:

1. APP-GW-GLR-044 Revision 0, "Nuclear Island Basemat and Foundation", October, 2006.

In the NRC meeting of May 19 - 23, 2008, it was agreed to remove the discussion of nonlinear liftoff analyses from Section 7.0 of TR03. This material was moved to APP-GW-GLR-044 (TR85), "Nuclear Island Basemat and Foundation." As agreed in the AP1000 NRC Audit of April 13-16, 2009, a reference is given to the location of the TR03 Section 7 information in TR85, Rev. 1. The information for this RAI is in Section 2.4.2.

Design Control Document (DCD) Revision: None

PRA Revision: None

Technical Report (TR) Revision: None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-026
Revision: 2

Question:

The description provided in Section 7.2 indicates that spring/dashpot values were selected based on parameters for a uniform half-space. However, for a soil site with hard rock located at a depth of 120 ft below the basemat, the resulting SSI radiation damping value would be expected to be significantly lower than that for a uniform half-space solution. Westinghouse should evaluate what is the impact of this difference on the computed seismic response?

Westinghouse Response:

The vertical springs were not selected based on a uniform half space. As stated in the second paragraph of Section 7.2 the springs were calculated for elastic layers of finite depth by means of the Steinbrenner approximation. The soil properties were those used in the SASSI analyses described in Section 4.4.1.2 of the report with hard rock located at a depth of 120 feet below grade.

The horizontal springs were calculated from the vertical springs assuming the ratio of horizontal to vertical springs was equal to that for a uniform half space.

For a soil site with hard rock located at a depth of 120 ft below the basemat, the resulting SSI radiation damping value would be lower than that for a uniform half-space solution. Soil spring stiffness was calculated using the Steinbrenner approximation, which does not provide a damping value. Preliminary time history analyses were performed with the identified soil spring stiffness with zero soil spring damping. Comparison of these preliminary time history analysis results to those from the 2D SASSI analyses confirmed the soil spring stiffness. Member forces/moments in these preliminary analyses were higher than the 2D SASSI results due to the neglect of soil damping. Since the SASSI analyses account for the soil damping including the effect of embedment and the hard rock at elevation 120', damping in the soil springs in the ANSYS analyses was selected by iterative modal analyses to match the overturning member forces in the SASSI analyses. The resulting damping values are shown in Table 7-1 of the report. The 30% value for damping for soft soil was the value obtained to match the 2D SASSI results. This value was not used in any subsequent analyses since the overall response on a soft soil site is significantly lower than on the soft to medium soil case selected for the non-linear liftoff analyses.

The soft to medium soil case analyzed for the AP1000 assumes bedrock at a depth of 120 feet. This depth was established based on the parametric studies described in section 4.4.1.1 of the technical report and in the response to TR03-RAI-015.

In the NRC meeting of May 19 - 23, 2008, it was agreed to remove the discussion of nonlinear liftoff analyses from Section 7.0 of TR03. This material was moved to APP-GW-GLR-044

(TR85), "Nuclear Island Basemat and Foundation." As agreed in the AP1000 NRC Audit of April 13-16, 2009, a reference is given to the location of the TR03 Section 7 information in TR85, Rev. 1. The information for this RAI is in Sections 2.4.2, 2.6.1.1, 2.7.2 and Table 2.4-4.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:

Revision 1

Revise section 7.2 as shown below.

7.2 Soil sites

The effect of liftoff during the safe shutdown earthquake of 0.3g and the review level earthquake of 0.5g was evaluated using the same approach described in section 7.1 for the hard rock site. The analyses used the East-West lumped-mass stick model of the nuclear island structures supported on a rigid basemat with nonlinear springs. The actual footprint of the basemat was used in the analyses of the East-West model (see Figure 7.2-3).

Table 7-1 summarizes the properties of soil springs and dampers used in this calculation. The stiffness of the soil springs in the vertical direction in the ANSYS models were calculated for elastic layers of finite depth by means of the Steinbrenner approximation. This same approach was used for calculation of the soil springs in the AP600 nuclear island basemat analyses. The depth to bedrock was 120 feet. The stiffness of soil springs in the horizontal direction was calculated from that in the vertical direction assuming that the ratio of horizontal and vertical stiffness for the layered site has the same relationship as for a semi-infinite medium.

Damping was modeled in the ANSYS analyses using Rayleigh damping to match modal damping at 3 and 25 hertz. The value of modal damping shown in Table 7.1 was selected to match member forces from the corresponding 2D SASSI analyses described in section 4.4.1. The soil damping is 5% for the soft to medium soil.

FRS comparisons of the ASB stick were performed to check the adequacy of the calculated soil spring properties. The peaks match reasonably for all cases. However, the 2D ANSYS results are significantly higher in the high frequency range compared with the 2D SASSI results. The calculated soil spring stiffness and damping are considered adequate because the results of the 2D ANSYS analyses match the peaks of FRS and member forces/moments reasonably to the 2D SASSI analyses.

Linear analyses of the ANSYS models showed that the soft-to-medium soil case gave the maximum base shear force and overturning moment. Hence, a non-linear lift off analysis was performed for the soft-to-medium soil case. Linear and non-linear (liftoff) analyses were performed for the SSE input of 0.3g and the RLE (review level earthquake) input of 0.5g. The linear analysis uses linear soil springs, and the non-linear (liftoff) analysis uses non-linear soil springs that are inactive when a basemat node is higher than its initial location without loads.

Basemat Displacements

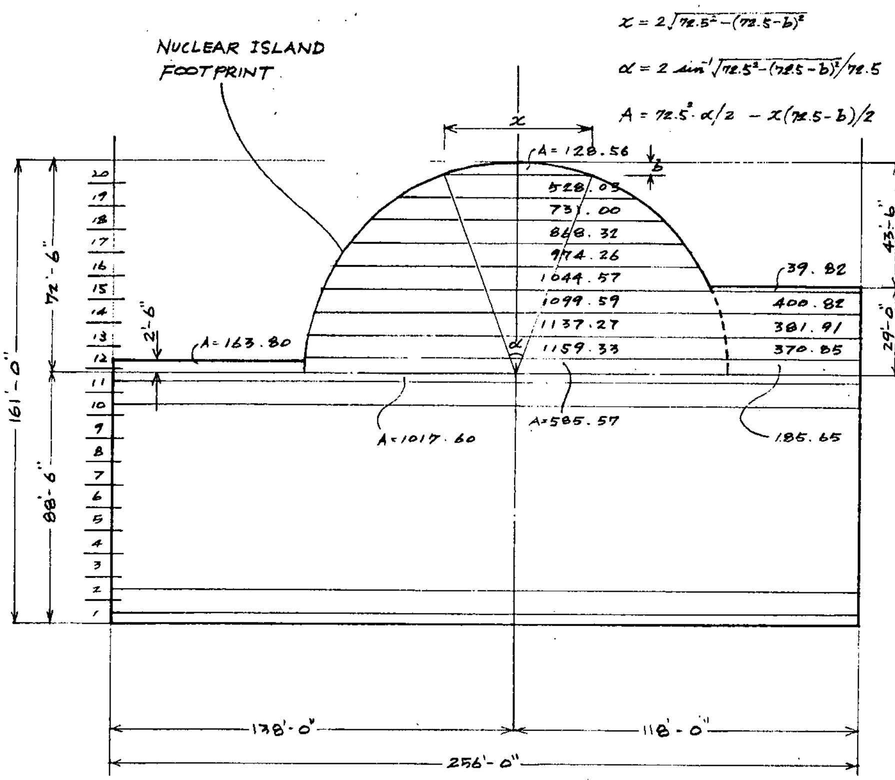
Figure 7.2-1 shows the time history of uplift displacements at the basemat edges. Maximum uplift at the east edge occurs at the time around 5 seconds for both linear and non-linear (liftoff) analyses. Maximum lift off is 0.31 inches. This is higher compared with the hard rock case result of 0.07 inches described in section 7.1. The increase ratio is about equal to the inverse of the soil spring stiffness (1000 versus 6267 kcf).

Floor Response Spectra

Figure 7.2-1 compares the SSE FRS between linear and non-linear (liftoff) analyses. The lift off effect on FRS is similar with those for the hard rock case; it is visible but insignificant. Figure 7.2-2 compares RLE FRS between linear and non-linear (liftoff) analyses. The liftoff effect on FRS is similar with those for the hard rock case; it is insignificant in the horizontal direction and visible in the vertical direction at high frequency range.

Table 7-1 - ANSYS Soil Spring Property

	Assumption of Soil Conditions				
	Soil Material Property		ANSYS Soil Spring Property		
	Density pcf	Poisson's Ratio	Stiffness kcf		Damping %
			Vertical	East-West	
Soft-to-medium Soil	110	0.35	1000	814	5



NODE	Y (ft)	AREA (ft²)
621	1072.50	128.6
620	1064.45	528.0
619	1056.40	731.0
618	1048.35	868.3
617	1040.30	974.3
616	1032.25	1084.4
615	1024.20	1500.4
614	1016.15	1519.2
613	1008.10	1530.2
612	1000.05	1952.6
611	992.00	2060.8
610	983.95	"
609	975.90	"
608	967.85	"
607	959.80	"
606	951.75	"
605	943.70	"
604	935.65	"
603	927.60	"
602	919.55	2060.8
601	911.50	1030.4

Σ AREA 32455.4

Σ Y × AREA 31726957.8

$\Sigma AY/\Sigma A = \underline{977.6}$

EQUAL WITH EQUIVALENT RECTANGULAR CENTER. OK

Figure 7.2-3 Modeling of Actual Footprint in East-West Model

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-027
Revision: 2

Question:

Section 7.1 indicates that direct integration was used to obtain computed results. Section 7.2 indicates that modal analysis was used to obtain solutions requiring the computation of equivalent modal damping accounting for both element and SSI damping. Westinghouse should describe how was the modal analysis method used to account for lift-off? Do the resulting modal damping values satisfy the limitations recommended in ASCE 4-98?

Westinghouse Response:

Non-linear lift-off analyses were performed in ANSYS using direct integration. Linear (no lift-off) time history modal analyses were performed to compare the ANSYS model on soil springs to the SASSI model on layered soil. These ANSYS analyses were also used to select a soil damping to match the ANSYS overturning member forces to the SASSI results. These damping values are shown in Table 7-1 of the report.

The basis for selection of the damping values is described in the response to RAI-TR03-026.

In the NRC meeting of May 19 - 23, 2008, it was agreed to remove the discussion of nonlinear liftoff analyses from Section 7.0 of TR03. This material was moved to APP-GW-GLR-044 (TR85), "Nuclear Island Basemat and Foundation." As agreed in the AP1000 NRC Audit of April 13-16, 2009, a reference is given to the location of the TR03 Section 7 information in TR85, Rev. 1. The information for this RAI is in Sections 2.4.2, 2.6 and 2.7.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-028
Revision: 2

Question:

Westinghouse is requested to describe in Section 7 of this report that were the three directions of motion (H1, H2 and V) used to generate liftoff responses in all cases analyzed?

Westinghouse Response:

The H2 component (east west direction) and the vertical component of the time histories were used to generate liftoff response in the 2D analyses of the East-West lumped mass stick model. They were applied simultaneously.

Reference:
None

In the NRC meeting of May 19 - 23, 2008, it was agreed to remove the discussion of nonlinear liftoff analyses from Section 7.0 of TR03. This material was moved to APP-GW-GLR-044 (TR85), "Nuclear Island Basemat and Foundation." As agreed in the AP1000 NRC Audit of April 13-16, 2009, a reference is given to the location of the TR03 Section 7 information in TR85, Rev. 1. The information for this RAI is in Section 2.4.2.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
The first paragraph in Section 7.2 is modified as follows:

The effect of liftoff during the safe shutdown earthquake of 0.3g and the review level earthquake of 0.5g was evaluated using the same approach described in section 7.1 for the hard rock site. The analyses used the East-West lumped-mass stick model of the nuclear island structures supported on a rigid basemat with nonlinear springs. The H2 and vertical components of the time histories were used to generate liftoff response in the 2D analyses. They were applied simultaneously. The actual footprint of the basemat was used in these analyses.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-029
Revision: 2

Question:

In section 7.1, Westinghouse should explain why are comparisons of 2D SASSI-ANSYS results used to judge adequacy of the liftoff analyses?

Westinghouse Response:

Comparisons of 2D SASSI-ANSYS results are used to judge adequacy of the soil springs and damping in the ANSYS model. As discussed in RAI-TR03-024, the damping values are sensitive to the depth to base rock. The depth to base rock is addressed directly in the 2D SASSI model. Soil damping is selected in the ANSYS linear analyses to match the maximum overturning member forces in SASSI. These modal damping values are shown in Table 7-1 of the report. This soil modal damping is then converted to Rayleigh damping in the non-linear direct integration analyses.

<u>In the NRC meeting of May 19 -23, 2008, it was agreed to remove the discussion of nonlinear liftoff analyses from Section 7.0 of TR03. This material was moved to APP-GW-GLR-044 (TR85), "Nuclear Island Basemat and Foundation." As agreed in the AP1000 NRC Audit of April 13-16, 2009, a reference is given to the location of the TR03 Section 7 information in TR85, Rev. 1. The information for this RAI is in Section 2.4.2.</u>

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-030
Revision: 2

Question:

Table 7.1 indicates that a damping of 30% was selected for the soft soil site. Westinghouse is requested to explain what is the basis for this selection? How does the viscous damping values shown in this table compare with the hysteretic material damping values typically found for iterated soils based on site responses?

Westinghouse Response:

Table 7.1 has been revised to remove the soft soil case as described in the response to TR03-RAI-026, Rev 1.

In the NRC meeting of May 19 - 23, 2008, it was agreed to remove the discussion of nonlinear liftoff analyses from Section 7.0 of TR03. This material was moved to APP-GW-GLR-044 (TR85), "Nuclear Island Basemat and Foundation." As agreed in the AP1000 NRC Audit of April 13-16, 2009, a reference is given to the location of the TR03 Section 7 information in TR85, Rev. 1. The information for this RAI is in Table 2.4-3 (soft soil case not used for non-linear analysis, see Section 2.4.2).

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-031
Revision: 2

Question:

As described in Section 7, if a soft/hard impedance mismatch occurs within the zone of influence of the basemat, the effective radiation damping may be severely reduced. Westinghouse should explain how would this impact computed responses?

Westinghouse Response:

A soft/hard impedance mismatch is considered in the soil cases with hard rock assumed below 120 feet. This depth to bed rock was established in the parametric studies performed for the AP600.

The soft to medium soil case analyzed for the AP1000 assumes bedrock at a depth of 120 feet. This depth was established based on the parametric studies described in section 4.4.1.1 of the technical report and in the response to TR03-RAI-015.

Comparisons of 2D SASSI-ANSYS results are used to judge adequacy of the soil springs and damping in the ANSYS model. As discussed in RAI-TR03-024, the damping values are sensitive to the depth to base rock. The depth to base rock is addressed directly in the 2D SASSI model. Soil damping is selected in the ANSYS linear analyses to match the maximum overturning member forces in SASSI. This damping includes both the material damping and the radiation damping. These modal damping values are shown in Table 7-1 of the report.

In the NRC meeting of May 19 - 23, 2008, it was agreed to remove the discussion of nonlinear liftoff analyses from Section 7.0 of TR03. This material was moved to APP-GW-GLR-044 (TR85), "Nuclear Island Basemat and Foundation." As agreed in the AP1000 NRC Audit of April 13-16, 2009, a reference is given to the location of the TR03 Section 7 information in TR85, Rev. 1. The information for this RAI is in Sections 2.4.1 and 2.4.2.

Design Control Document (DCD) Revision:

None.

PRA Revision:

None

Technical Report (TR) Revision:

None.