Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, D.C. 20555

Direct tel: 412-374-6306
Direct fax: 412-374-5005
e-mail: sterdia@westinghouse.com

Your ref: Project Number 740
Our ref: DCP/NRC1987

August 31, 2007

Subject: AP1000 COL Response to Requests for Additional Information (TR 3)

In support of Combined License application pre-application activities, Westinghouse is submitting responses to NRC requests for additional information (RAIs) on AP1000 Standard Combined License Technical Report 3, APP-GW-S2R-010, Extension of Nuclear Island Seismic Analysis to Soil Sites. These RAI responses are submitted as part of the NuStart Bellefonte COL Project (NRC Project Number 740). The information included in the responses is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification.

Revised responses are provided for TR3-15, TR3-19, TR3-22, and TR3-33. Revision 0 responses to TR3-15 and TR3-33 were submitted on January 18, 2007 under Westinghouse letter DCP/NRC1814. The revision 0 response to TR3-22 was submitted on January 29, 2007 under Westinghouse letter DCP/NRC1822. The revision 0 response to TR3-19 was submitted on February 26, 2007 under Westinghouse letter DCP/NRC1840. All of these revision 0 responses were revised as detailed in the May 22, 2007 NRC letter, "Summary of April 16 through 20, 2007, Open and Closed Meeting with Westinghouse to Discuss AP1000 Seismic Analyses."

A revision 2 response is provided for TR3-32. The purpose of this revision is to incorporate enhancements in the shield building design. Revision 1 of TR3-32 was submitted on June 15, 2007 under Westinghouse letter DCP/NRC1942.

A revision 0 response is provided for RAI-TR3-36, transmitted in NRC letter dated May 15, 2007, from Mike Miernicki to Andrea Sterdis, Subject: Westinghouse AP1000 Combined License Pre-Application Technical Report 3 - Request for Additional Information (TAC NO. MD2358).

These responses complete all requests received to date for Technical Report 3.

Pursuant to 10 CFR 50.30(b), the responses to the requests for additional information on Technical Report 3, is submitted as Enclosure 1 under the attached Oath of Affirmation.

Questions or requests for additional information related to the content and preparation of these responses 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,

Monte D Bartley FOR

A. Sterdis, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Attachment

1. "Oath of Affirmation," dated August 31, 2007

/Enclosure

1. Responses to Requests for Additional Information on Technical Report No. 3

cc:	D. Jaffe	-	U.S. NRC	1E	1A
	E. McKenna	-	U.S. NRC	1E	1A
	S. Adams	-	Westinghouse	1E	1A
	G. Curtis	-	TVA	1E	1A
	P. Grendys	-	Westinghouse	1E	1A
	P. Hastings	-	Duke Power	1E	1A
	C. Ionescu	-	Progress Energy	1E	1A
	D. Lindgren	-	Westinghouse	1E	1A
	A. Monroe	-	SCANA	1E	1A
	M. Moran	-	Florida Power & Light	1E	1A
	C. Pierce	-	Southern Company	1E	1A
	E. Schmiech	-	Westinghouse	1E	1A
	G. Zinke	-	NuStart/Entergy	1E	1A
	B. LaPay	-	Westinghouse	1E	1A

ATTACHMENT 1

"Oath of Affirmation"

ATTACHMENT 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:)

NuStart Bellefonte COL Project)

NRC Project Number 740)

APPLICATION FOR REVIEW OF
"AP1000 GENERAL COMBINED LICENSE INFORMATION"
FOR COL APPLICATION PRE-APPLICATION REVIEW

W. E. Cummins, being duly sworn, states that he is Vice President, Regulatory Affairs & Standardization, for Westinghouse Electric Company; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission this document; that all statements made and matters set forth therein are true and correct to the best of his knowledge, information and belief.

W. E. Cummins
Vice President
Regulatory Affairs & Standardization

Subscribed and sworn to
before me this 31st day
of August 2007.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Patricia S. Aston, Notary Public
Murrysville Boro, Westmoreland County
My Commission Expires July 11, 2011
Member, Pennsylvania Association of Notaries

Notary Public

ENCLOSURE 1

Responses to Requests for Additional Information on Technical Report No. 3

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-015
Revision: 1

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. 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 in a foundation interface report in which the applicant would make its case of 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 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. 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.

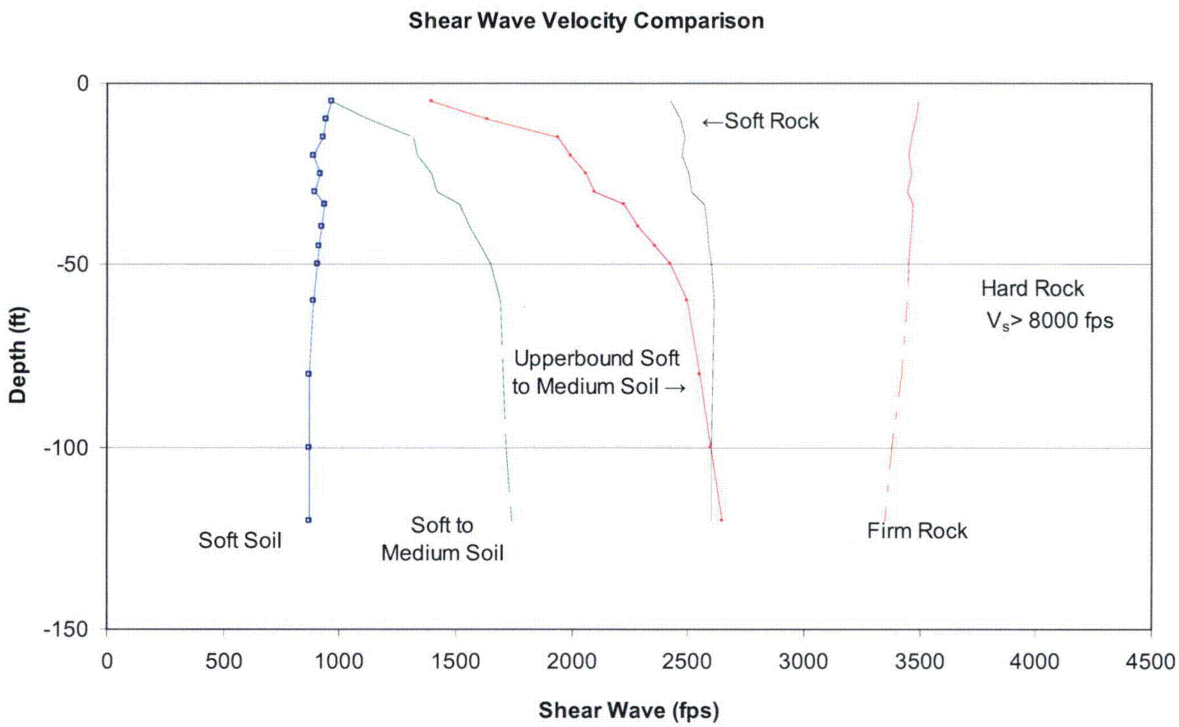


Figure RAI-TR03-15-1-Strain-iterated shear wave velocity profiles

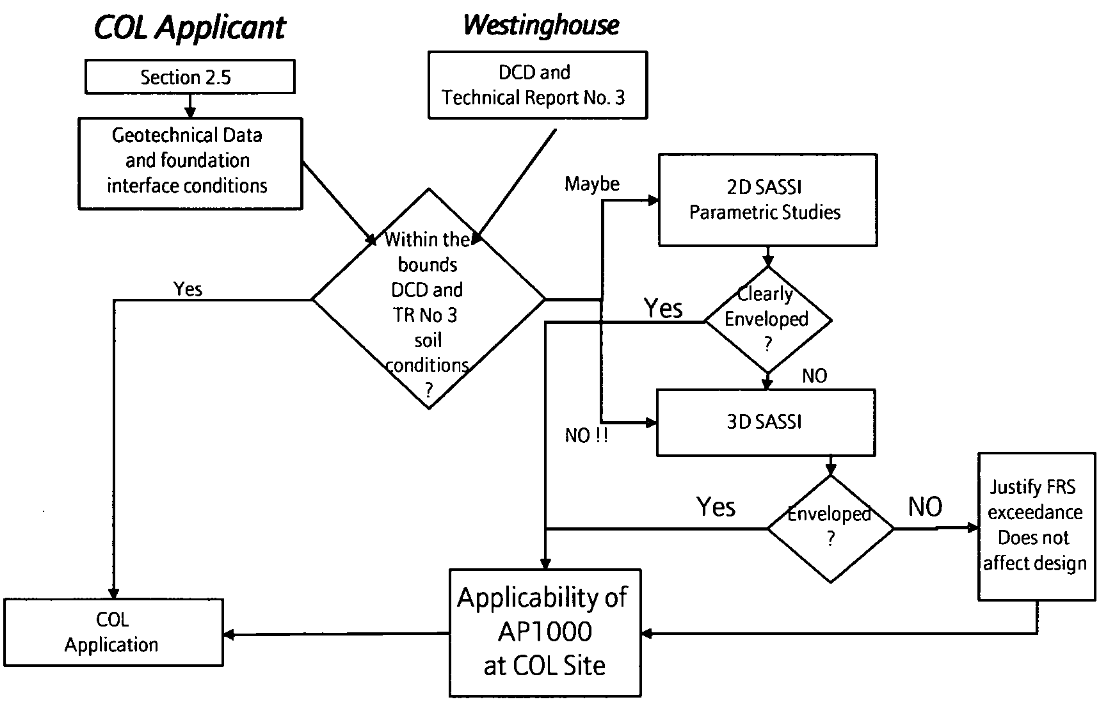


Figure RAI-TR03-15-2-COL Application process for generic design

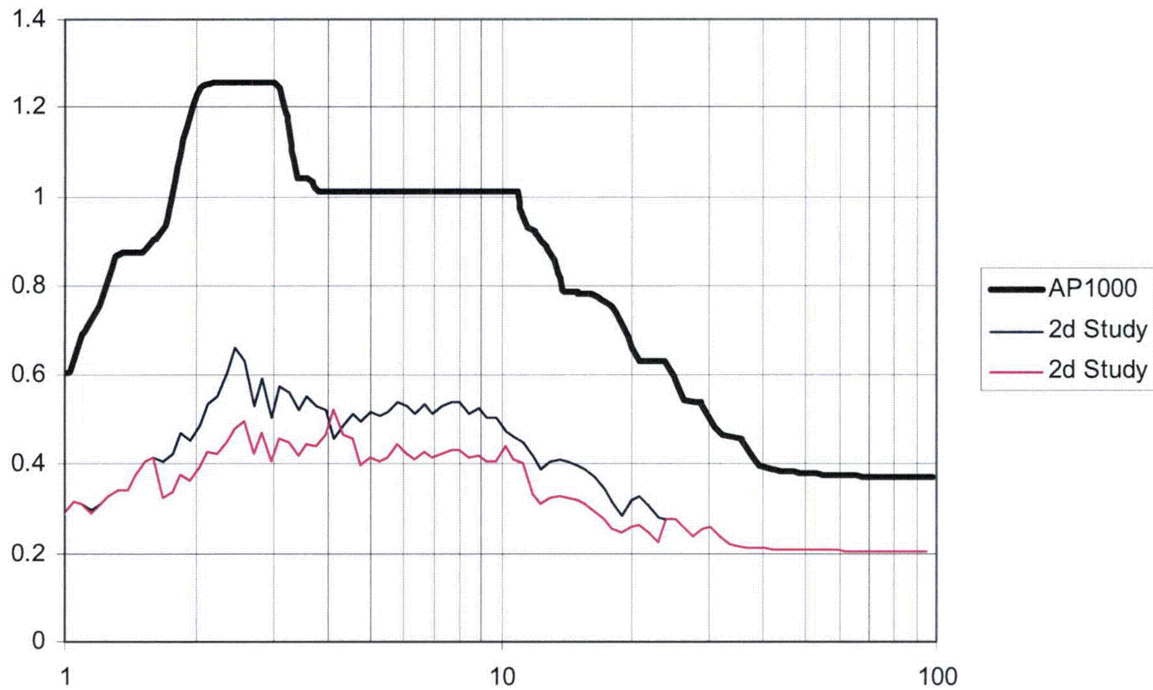


Figure RAI-TR03-15-3- 2D parametric studies demonstrate site is clearly enveloped by 2D design spectra

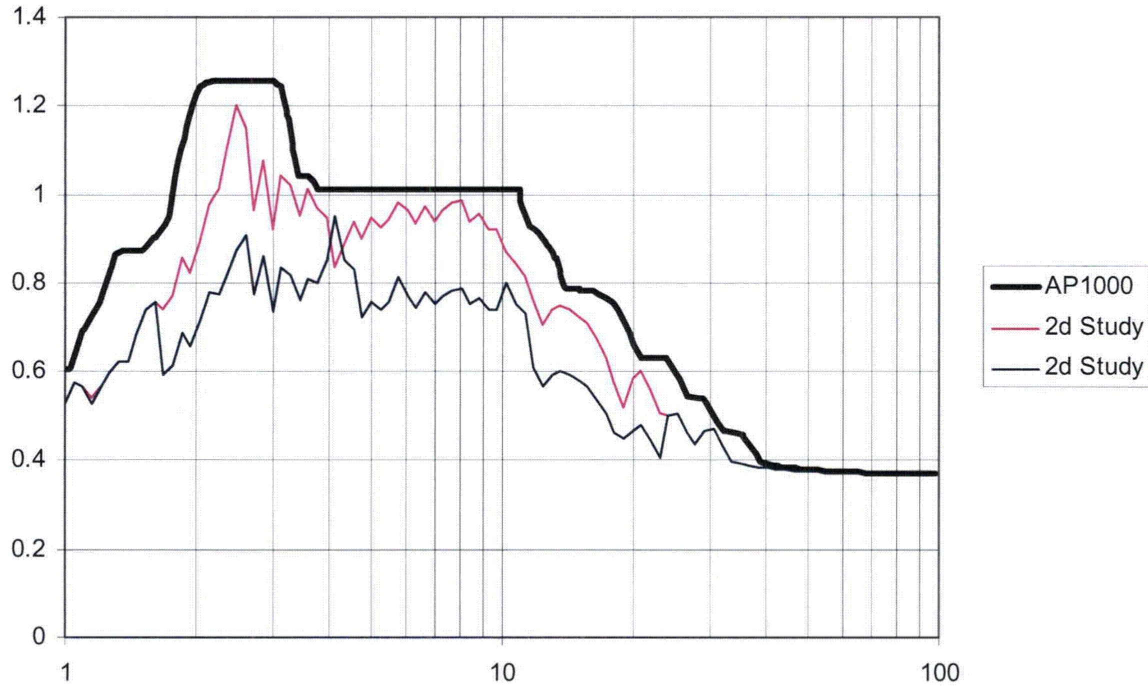


Figure RAI-TR03-15-4- 2D parametric study demonstrate that further studies may be required

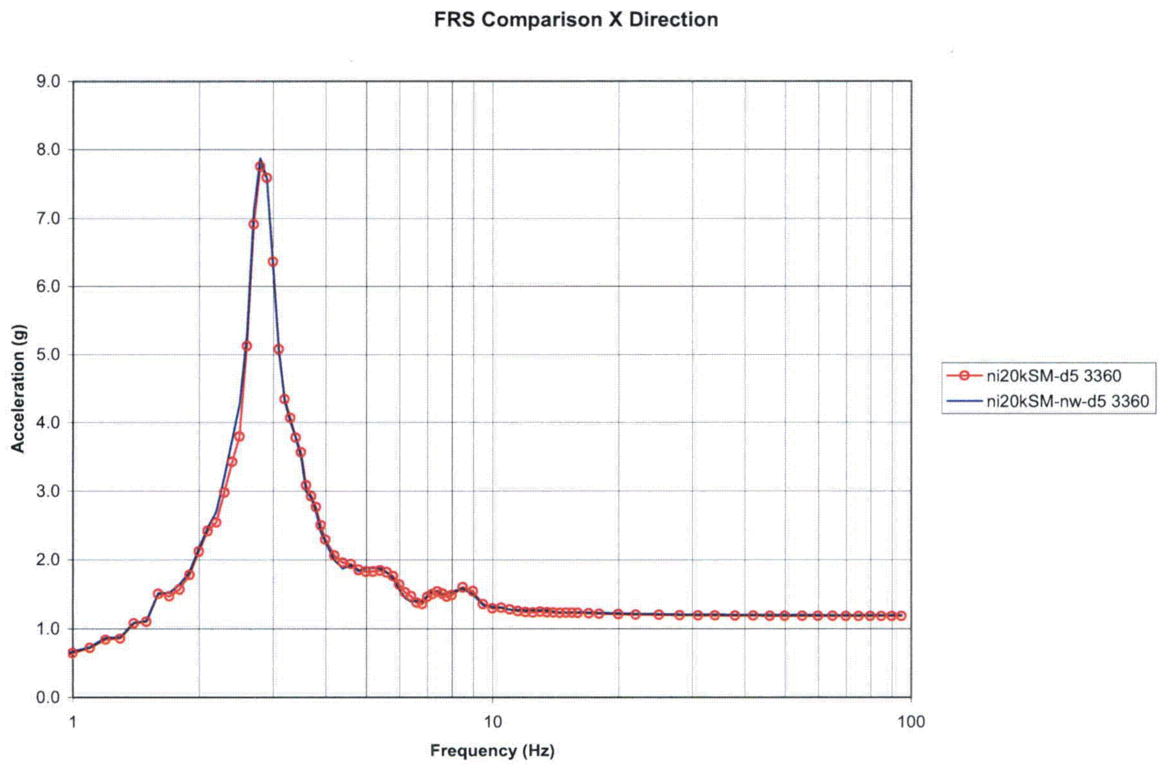


Figure RAI-TR03-15-5- Effect of water table variation in horizontal direction (X)

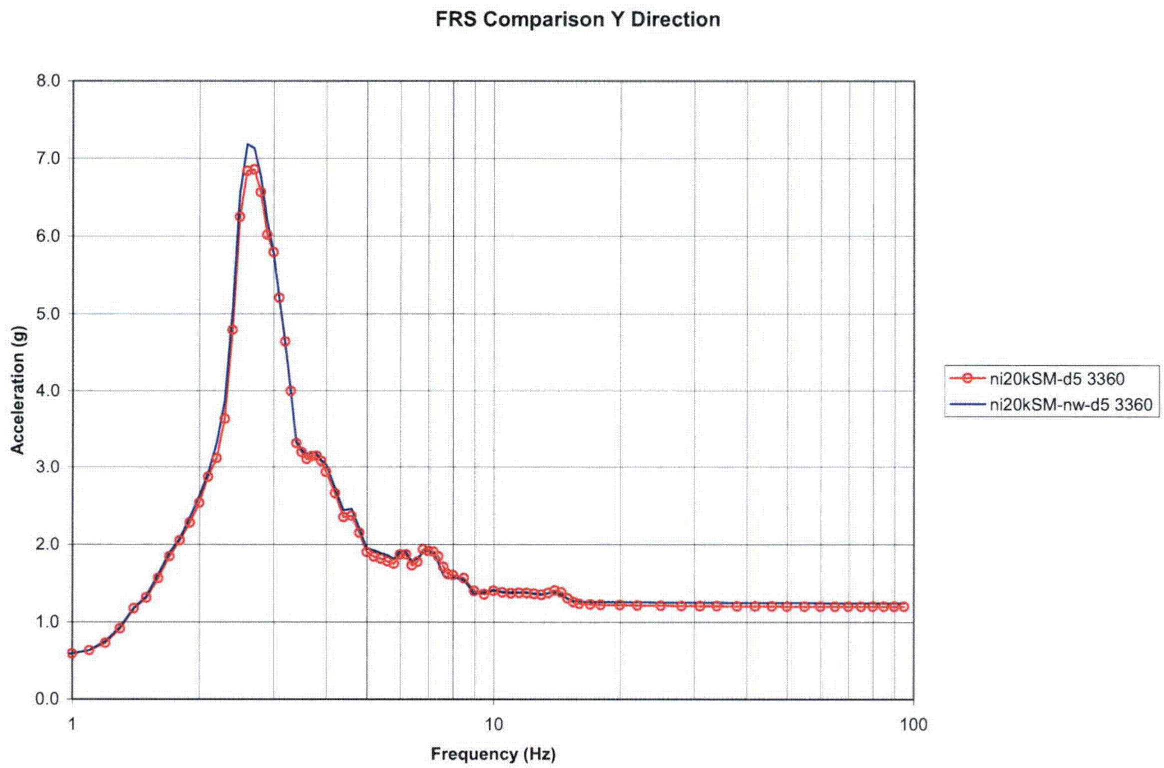


Figure RAI-TR03-15-6-Effect of water table variation in horizontal direction (Y)

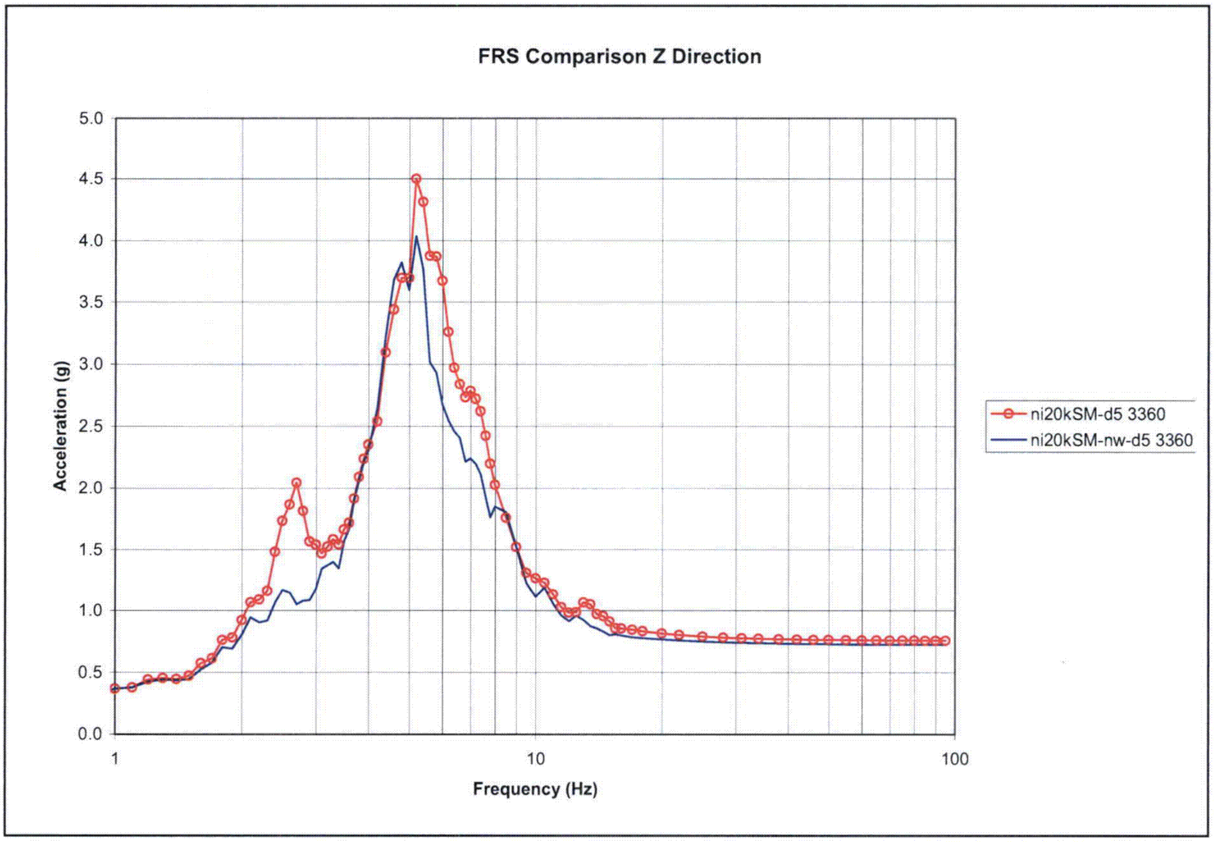


Figure RAI-TR03-15-7- Effect of water table variation in horizontal direction (Z)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:

The Technical Report will be revised to include the RAI responses in an appendix. Thus the proposed DCD revisions will also become a part of the technical report. Also, revise section 4.4.1 and 4.4.1.1 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.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-019
Revision: 1

Question:

The section of "DCD Subsection 2.5.2.3 - Sites with Geoscience Parameters Outside the Certified design" states that final design verifications were based on 3D SASSI results with 2D results used to test sensitivity only. The final verification for a site not satisfying the site criteria should be based on 3D SASSI results. Westinghouse should justify how does one judge the adequacy of 2D SASSI results without performing 3D computations.

Westinghouse Response:

Westinghouse has expanded the number of soil cases it evaluates in its 3D SASSI generic analyses so that no justification is required using AP1000 2D SASSI sensitivity cases. The 3D SASSI results that are enveloped to develop the generic design are for six design cases whose strain-iterated shear wave velocities, the shear wave velocities used in the SASSI analyses, have been shown in TR03-15. These six generic cases have been identified for convenience as hard rock (HR), firm rock (FR), soft rock (SR), upper bound soft to medium (UBSM), soft to medium (SM), and soft soil (SS).

In RAI-TR03-15 Westinghouse has provided clarification and shown examples as to when 2D SASSI analyses are appropriate to demonstrate that local features are bounded by the design cases.

Design Control Document (DCD) Revision:

<u>Changes to DCD Section 2.5.2</u>

Revisions to DCD Section 2.5 were included in the response to RAI-TR03-010, Rev .1. These changes have been incorporated in DCD Rev 16. The revision marks show revisions from DCD Rev 16.

2.5.2 Vibratory Ground Motion

The AP1000 is designed for a safe shutdown earthquake (SSE) defined by a peak ground acceleration (PGA) of 0.30g and the design response spectra specified in subsection 3.7.1.1, and Figures 3.7.1-1 and 3.7.1-2. The AP1000 design response spectra were developed using the Regulatory Guide 1.60 response spectra as the base and modified to include additional high frequency amplification at a control point at 25 Hz. The peak ground accelerations in the two horizontal and the vertical directions are equal.

The AP1000 is also evaluated for a safe shutdown earthquake (SSE) defined by a peak ground acceleration (PGA) of 0.30g and the design response spectra specified in Appendix 3I, and Figures 3I.1-1 and 3I.1-2. These design response spectra are applicable to certain east coast rock sites.

2.5.2.1 Combined License Seismic and Tectonic Characteristics Information

Combined License applicants referencing the AP1000 certified design will address the following site-specific information related to the vibratory ground motion aspects of the site and region:

- Seismicity
- Geologic and tectonic characteristics of site and region
- Correlation of earthquake activity with seismic sources
- Probabilistic seismic hazard analysis and controlling earthquakes
- Seismic wave transmission characteristics of the site
- SSE ground motion

The site-specific ground motion response spectra (GMRS) are determined in the free-field on the ground surface. For sites with soil layers that will be completely excavated to expose competent material, the GMRS is specified on an outcrop or a hypothetical outcrop that will exist after excavation. Motions at this hypothetical outcrop are developed as a free-surface motion, not as an in-column motion. Competent material may be defined as in-situ material having a shear wave velocity equal to or greater than 1000 fps. The Combined License applicant must demonstrate that the proposed site meets the following requirements:

1. The free field peak ground acceleration at the finished grade level is less than or equal to a 0.30g SSE.

2. The site-specific ground motion response spectra (GMRS) at the finished grade level in the free-field are less than or equal to the AP1000 certified seismic design response spectra (CSDRS) given in Figures 3.7.1-1 and 3.7.1-2.

3. In lieu of (1) and (2) above, for a site where the nuclear island is founded on competent rock with shear wave velocity greater than 8,000 feet per second, the site-specific ground motion may be defined at the foundation level as the foundation input response spectrum (FIRS) and shown to be less than or equal to the CSDRS given in Figures 3.7.1-1 and 3.7.1-2.

4. In lieu of (1) and (2) above, for a site where the nuclear island is founded on competent rock with shear wave velocity greater than 8000 feet per second and there are thin layers of soft material overlying the rock, the site-specific peak ground acceleration and spectra may be developed at the top of the competent

rock and shown at the foundation level to be less than or equal to those given in Figures 3I.1-1 and 3I.1-2

5. Foundation material layers are approximately horizontal (dip less than 20 degrees), and the median estimate of the low strain shear wave velocity of the soil below the foundation of the nuclear island is greater than or equal to 1000 feet per second.

6. For sites where the nuclear island is founded on soil, the median estimate of the strain-compatible soil shear modulus and hysteretic damping is compared to the values used in the AP1000 generic analyses shown in Table 3.7.1-4 and Figure 3.7.1-17. Properties of soil layers within a depth of 120 feet below finished grade are compared to those in the generic soil site analyses (soft soil, soft-to-medium soil, and upper bound soft-to-medium soil).

7. In lieu of (1) to (5) above, a site-specific evaluation can be performed as described in subsection 2.5.2.3.

Where features of the site are not within the parameters specified for the AP1000, site-specific soil structure interaction analyses may be performed using the 2D SASSI models described in Appendix 3G for variations in site conditions that can be represented in these models. Results should be compared to the results of the 2D SASSI analyses described in Appendix 3G. Such analyses may be used to demonstrate that local features, such as soil degradation properties or backfill, are well within the bounds established by the design cases. If the results are not clearly enveloped then a 3D SASSI analysis may be required.

2.5.2.2 Site-Specific Seismic Structures

The AP1000 includes all seismic Category I structures, systems and components in the scope of the design certification.

2.5.2.3 Sites with Geoscience Parameters Outside the Certified Design

If the site-specific spectra at foundation level exceed the response spectra in Figures 3.7.1-1 and 3.7.1-2 at any frequency, or if soil conditions are outside the range evaluated for AP1000 design certification, a site-specific evaluation can be performed. This evaluation will consist of a site-specific dynamic analysis and generation of in-structure response spectra to be compared with the floor response spectra of the certified design at 5-percent damping. The site design response spectra at the foundation level in the free-field given in Figures 3.7.1-1 and 3.7.1-2 were used to develop the floor response spectra. They were applied at foundation level for the hard rock site and at finished grade level for the soil sites. The site is acceptable for construction of the AP1000 if the floor response spectra from the site-specific evaluation do not exceed the AP1000 spectra for each of the locations identified below:

Containment internal structures at elevation of reactor vessel support	Figures 4.4.3-1 to 4.4.3-3* Figure 3G.4-5
Containment operating floor	Figures 4.4.3-4 to 4.4.3-6* Figure 3G.4-6
Auxiliary building NE corner at elevation 117' 6"	Figures 4.4.3-7 to 4.4.3-9* Figure 3G.4-7
Shield building at fuel building roof	Figures 4.4.3-10 to 4.4.3-12* Figure 3G.4-8
Shield building roof	Figures 4.4.3-13 to 4.4.3-15* Figure 3G.4-9
Steel containment vessel at polar crane support	Figures 4.4.3-16 to 4.4.3-18* Figure 3G.4-10

** DCD Section 2.5 will reference the figures in Appendix 3G. The Figures in 3G are the same as those in Section 4.4 of the technical report. Both figure numbers are shown for information in this draft revision of DCD Section 2.5. It is noted that Figures 3G.4-5 to 3G.4-10 will be added in Appendix 3G and will be the same as Figures 4.4.3-1 to 4.4.3-18.*

Site-specific soil structure interaction analyses are performed using the 3D SASSI models described in Appendix 3G. The site-specific soil structure interaction analyses use the site-specific soil conditions (including variation in soil properties in accordance with Standard Review Plan 3.7.2). The three components of the site-specific ground motion time history must satisfy the regulatory requirements for statistical independence and enveloping of the site design spectra at 5% damping. Floor response spectra determined from the site-specific analyses should be compared against the design basis of the AP1000 described above. These evaluations and comparisons will be provided and reviewed as part of the Combined License application.

If the site-specific spectra at foundation level at a rock site exceed the response spectra in Figures 3I.1-1 and 3I.1-2 at any frequency, a site-specific evaluation can be performed similar to that described in Appendix 3I.

PRA Revision:
None

Technical Report (TR) Revision:

The Technical Report will be revised to include the RAI responses in an appendix. Thus the proposed DCD revisions will also become a part of the technical report. Also, revise the proposed changes to the DCD in section 5.0 as follows:

DCD Subsection 2.5.2 Vibratory Ground Motion

The AP1000 is designed for a safe shutdown earthquake (SSE) defined by a peak ground acceleration (PGA) of 0.30g and the design response spectra specified in subsection 3.7.1.1, and Figures 3.7.1-1 and 3.7.1-2. The AP1000 design response spectra were developed using the Regulatory Guide 1.60 response spectra as the base and modified to include additional high frequency amplification at a control point at 25 Hz. The peak ground accelerations in the two horizontal and the vertical directions are equal.

DCD Subsection 2.5.2.1 Combined License Seismic and Tectonic Characteristics Information

Combined License applicants referencing the AP1000 certified design will address the following site-specific information related to the vibratory ground motion aspects of the site and region:

- Seismicity
- Geologic and tectonic characteristics of site and region
- Correlation of earthquake activity with seismic sources
- Probabilistic seismic hazard analysis and controlling earthquakes
- Seismic wave transmission characteristics of the site
- SSE ground motion

The site-specific ground motion response spectra (GMRS) are determined in the free-field on the ground surface. For sites with soil layers that will be completely excavated to expose competent material, the GMRS is specified on an outcrop or a hypothetical outcrop that will exist after excavation. Motions at this hypothetical outcrop are developed as a free-surface motion, not as an in-column motion. Competent material may be defined as in-situ material having a shear wave velocity equal to or greater than 1000 fps. The Combined License applicant must demonstrate that the proposed site meets the following requirements:

1. The free field peak ground acceleration at the finished grade level is less than or equal to a 0.30g SSE.

2. The site-specific ground motion response spectra (GMRS) at the finished grade level in the free-field are less than or equal to the AP1000 certified seismic design response spectra (CSDRS) given in Figures 3.7.1-1 and 3.7.1-2.

3. In lieu of (1) and (2) above, for a site where the nuclear island is founded on competent rock with shear wave velocity greater than 8,000 feet per second, the site-specific ground motion may be defined at the foundation level as the

foundation input response spectrum (FIRS) and shown to be less than or equal to the CSDRS given in Figures 3.7.1-1 and 3.7.1-2.

4. In lieu of (1) and (2) above, for a site where the nuclear island is founded on competent rock with shear wave velocity greater than 8000 feet per second and there are thin layers of soft material overlying the rock, the site-specific peak ground acceleration and spectra may be developed at the top of the competent rock and shown at the foundation level to be less than or equal to those given in Figures 3I.1-1 and 3I.1-2

5. Foundation material layers are approximately horizontal (dip less than 20 degrees), and the median estimate of the low strain shear wave velocity of the soil below the foundation of the nuclear island is greater than or equal to 1000 feet per second.

6. For sites where the nuclear island is founded on soil, the median estimate of the strain-compatible soil shear modulus and hysteretic damping is compared to the values used in the AP1000 generic analyses shown in Table 3.7.1-4 and Figure 3.7.1-17. Properties of soil layers within a depth of 120 feet below finished grade are compared to those in the generic soil site analyses (soft soil, soft-to-medium soil, and upper bound soft-to-medium soil).

7. In lieu of (1) to (5) above, a site-specific evaluation can be performed as described in subsection 2.5.2.3.

Where features of the site are not within the parameters specified for the AP1000, site-specific soil structure interaction analyses may be performed using the 2D SASSI models described in Appendix 3G for variations in site conditions that can be represented in these models. Results should be compared to the results of the 2D SASSI analyses described in Appendix 3G. Such analyses may be used to demonstrate that local features, such as soil degradation properties or backfill, are well within the bounds established by the design cases. If the results are not clearly enveloped then a 3D SASSI analysis may be required.

2.5.2.2 Site-Specific Seismic Structures

The AP1000 includes all seismic Category I structures, systems and components in the scope of the design certification.

Subsection 2.5.2.3 Sites with Geoscience Parameters Outside the Certified Design

If the site-specific spectra at foundation level exceed the response spectra in Figures 3.7.1-1 and 3.7.1-2 at any frequency, or if soil conditions are outside the range evaluated for AP1000 design certification, a site-specific evaluation can be performed. This evaluation will consist of a site-specific dynamic analysis and generation of in-structure response spectra to be compared with the floor response spectra of the certified design at 5-percent damping. The site design response spectra at the foundation level in the free-field given in Figures 3.7.1-1 and 3.7.1-2 were used to develop the floor response spectra. They were applied at foundation level for the hard rock site and at finished grade level for the soil sites. The site is acceptable for construction of the AP1000 if the floor response spectra from the site-specific evaluation do not exceed the AP1000 spectra for each of the locations identified below:

Containment internal structures at elevation of reactor vessel support	Figures 4.4.3-1 to 4.4.3-3* Figure 3G.4-5
Containment operating floor	Figures 4.4.3-4 to 4.4.3-6* Figure 3G.4-6
Auxiliary building NE corner at elevation 117' 6"	Figures 4.4.3-7 to 4.4.3-9* Figure 3G.4-7
Shield building at fuel building roof	Figures 4.4.3-10 to 4.4.3-12* Figure 3G.4-8
Shield building roof	Figures 4.4.3-13 to 4.4.3-15* Figure 3G.4-9
Steel containment vessel at polar crane support	Figures 4.4.3-16 to 4.4.3-18* Figure 3G.4-10

** DCD Section 2.5 will reference the figures in Appendix 3G. The Figures in 3G are the same as those in Section 4.4 of the technical report. Both figure numbers are shown for information in this draft revision of DCD Section 2.5. It is noted that Figures 3G.4-5 to 3G.4-10 will be added in Appendix 3G and will be the same as Figures 4.4.3-1 to 4.4.3-18.*

Site-specific soil structure interaction analyses are performed using the 3D SASSI models described in Appendix 3G. The site-specific soil structure interaction analyses use the site-specific soil conditions (including variation in soil properties in accordance with Standard Review Plan 3.7.2). The three components of the site-specific ground motion time history must satisfy the regulatory requirements for statistical independence and enveloping of the site design spectra at 5% damping. Floor response spectra determined from the site-specific analyses should be compared against the design basis of the AP1000 described above. These evaluations and comparisons will be provided and reviewed as part of the Combined License application.

If the site-specific spectra at foundation level at a rock site exceed the response spectra in Figures 3I.1-1 and 3I.1-2 at any frequency, a site-specific evaluation can be performed similar to that described in Appendix 3I.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-022
Revision: 1

Question:

Section 6.3 states "The maximum seismic deflections that were obtained from the time history analyses and SASSI analyses given in Tables 6.3-1 to 6.3-3 for the auxiliary and shield building, containment internal structure, and steel containment vessel." For the staff to properly evaluate this information, the following additional information is needed:

a. Are the deflections in the tables a consistent set, based on the worst-case time history result, or are they an envelope of maximum deflections from all the time history results?

b. How do these tabulated deflections compare to the corresponding deflections obtained from the equivalent static acceleration analyses? Please provide a tabulated comparison, and an explanation of any significant differences.

Westinghouse Response:

a. Deflections have been developed using the model with the robust shield building design. These displacements for the soil and hard rock cases have been obtained relative to the translation of a reference node at the bottom of the foundation and near the center of the basemat. Coordinates of this reference node are x= 993.00 ft, y= 986.00 ft and z= 60.50 ft. The deflections have been revised to remove drift. The absolute displacement time histories are calculated from the nodal time histories accelerations. When the relative displacements are plotted there is a constant slope as shown in Figure RAI-TR03-022-1. To correct this drift, the slope of the relative displacement multiplied by the time is subtracted from the relative displacement at each time step. Presented in Figure RAI-TR03-022-2 is the drift corrected relative displacement.

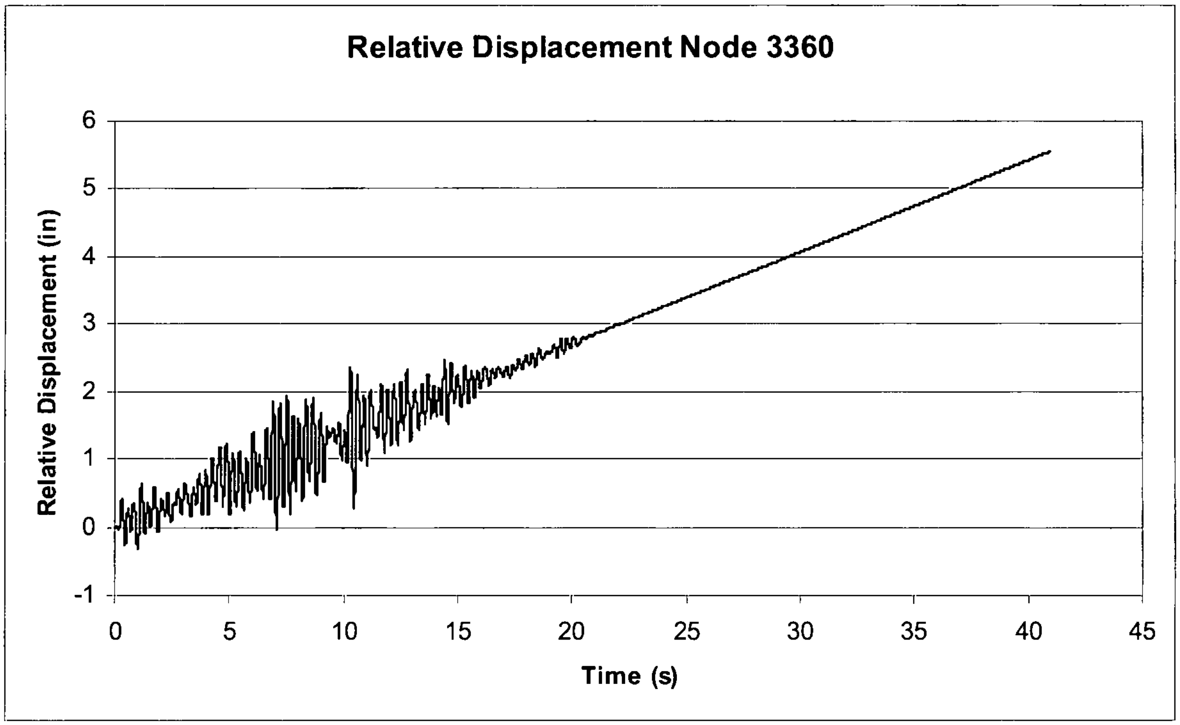


Figure RAI-TR03-022-1-Relative Displacement of Node 3360, top of Shield Building

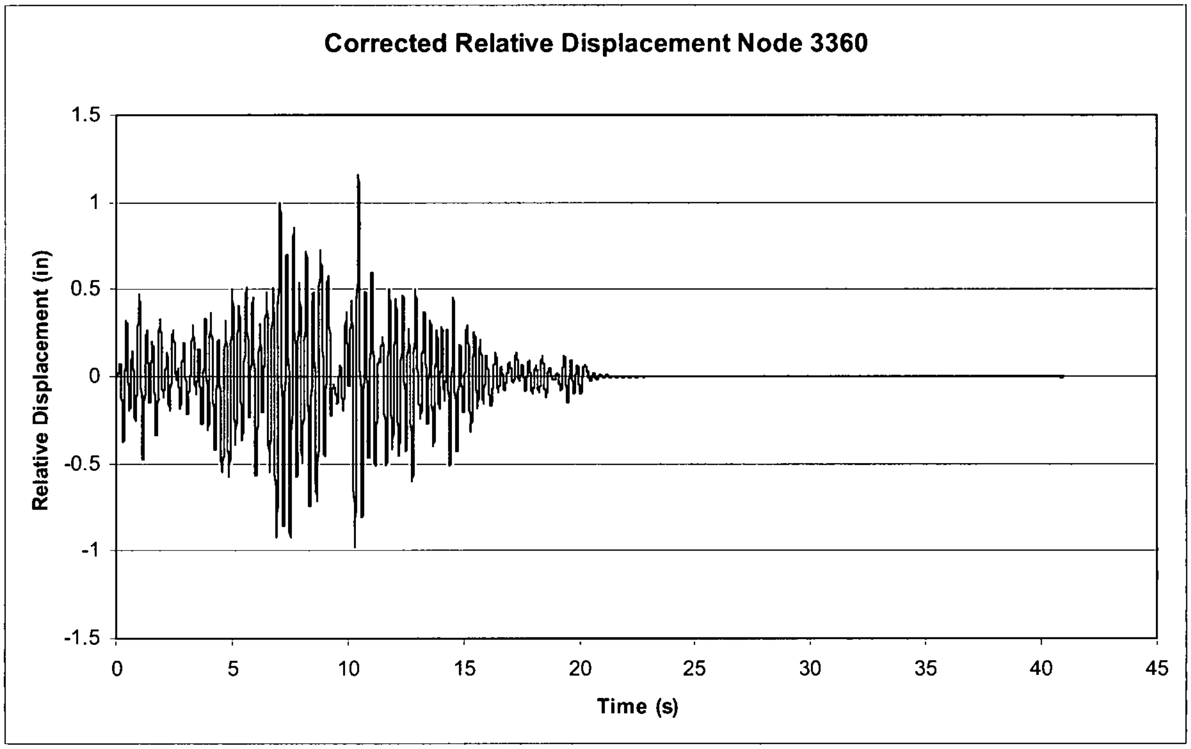
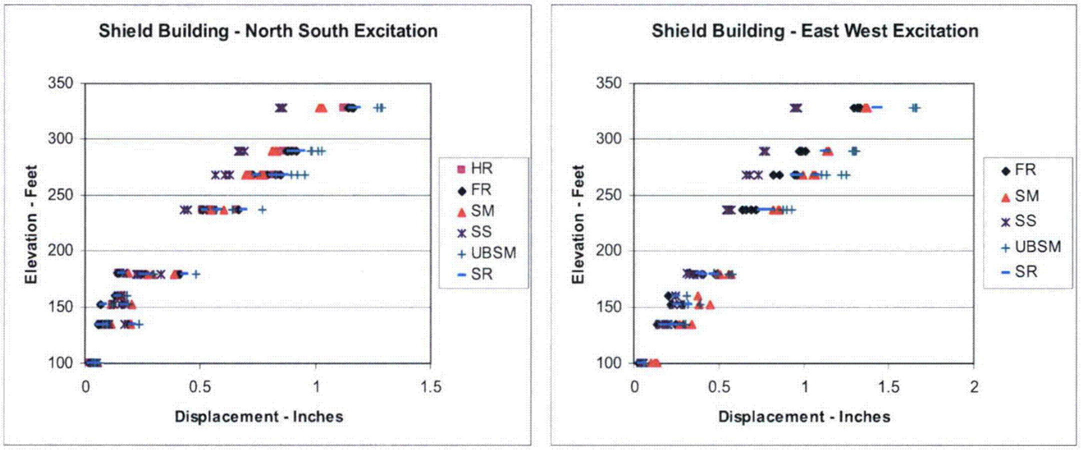


Figure RAI-TR03-022-2 - Corrected Relative Displacement of Node 3360, top of Shield Building

Figures RAI-TR03-022-3 and RAI-TR03-022-4 show the maximum deflection plots for the shield building and steel containment vessel for each of the soil cases (firm rock, FR; soft to medium, SM; soft soil, SS; Upper bound soft to medium, UBSM; and soft rock, SR) and hard rock site (HR). Figures RAI-TR03-022-5 and RAI-TR03-022-6 show deflections for the NW corner of the pressurizer compartment and the SE corner of the East steam generator compartment.



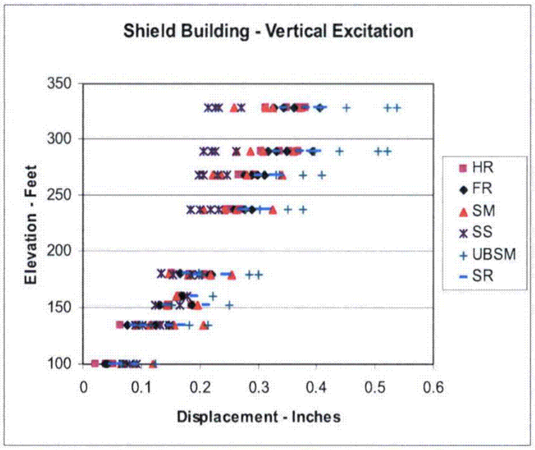


Figure RAI-TR03-022-3 – Deflection Plots of Shield Building for all Soil Cases

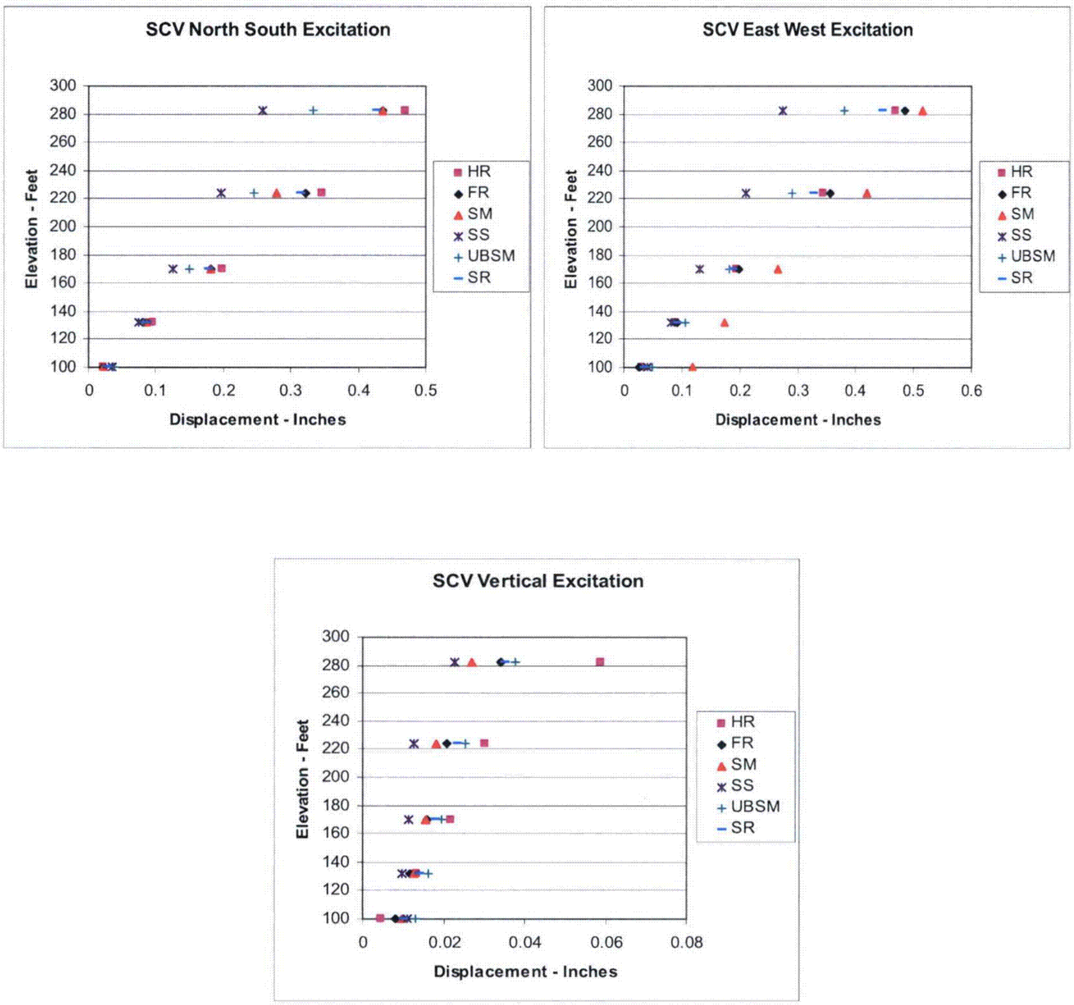


Figure RAI-TR03-022-4 – Deflection Plots of SCV for all Soil Cases

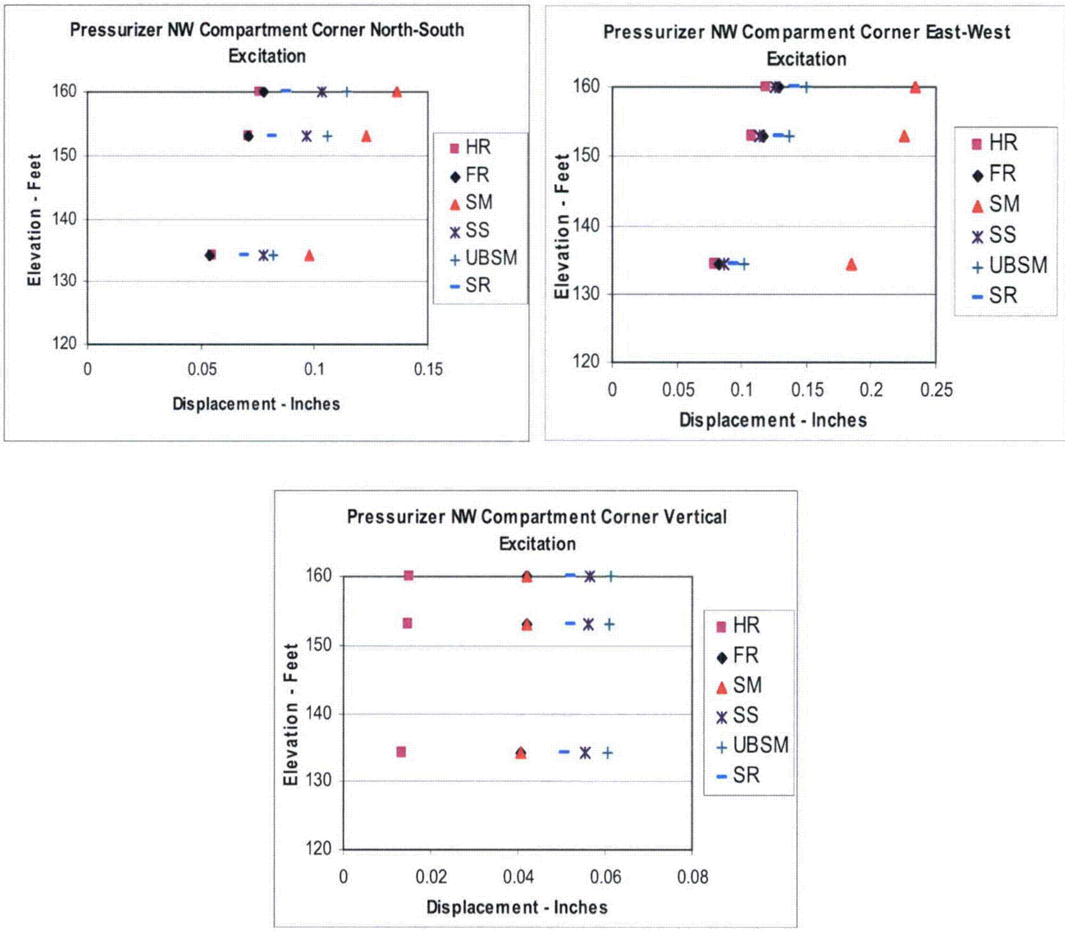


Figure RAI-TR03-022-5 – Deflection Plots of Pressurizer Compartment NW Corner

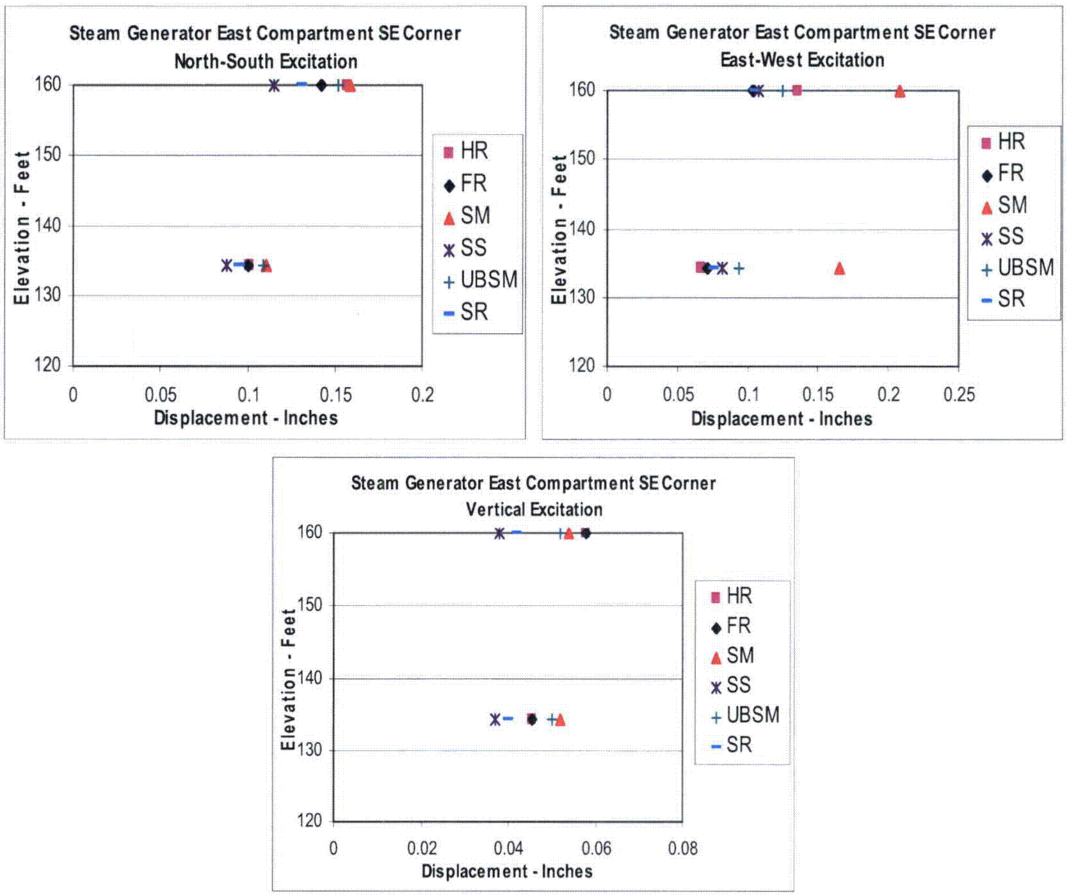


Figure RAI-TR03-022-6 – Deflection Plots of East SG Compartment SE Corner

b. Westinghouse has switched to a seismic response spectrum analysis and is not using equivalent static analyses. The responses for this request for additional information are no longer applicable.

Reference:

None

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

Section 6.3 will be replaced by the response given in the Westinghouse Response (part a).

-Deflections have been developed using the model with the robust shield building design. These displacements for the soil and hard rock cases have been obtained relative to the translation of a reference node at the bottom of the foundation and near the center of the basemat. Coordinates of this reference node are x= 993.00 ft, y= 986.00 ft and z= 60.50ft. The deflections have been revised to remove drift. The absolute displacement time histories are calculated from the nodal time histories accelerations. When the relative displacements are plotted there is a constant slope as shown in Figure 6.3-1. To correct this drift, the slope of the relative displacement multiplied by the time is subtracted from the relative displacement of each time step. Presented in Figure 6.3-2 is the drift corrected relative displacement.

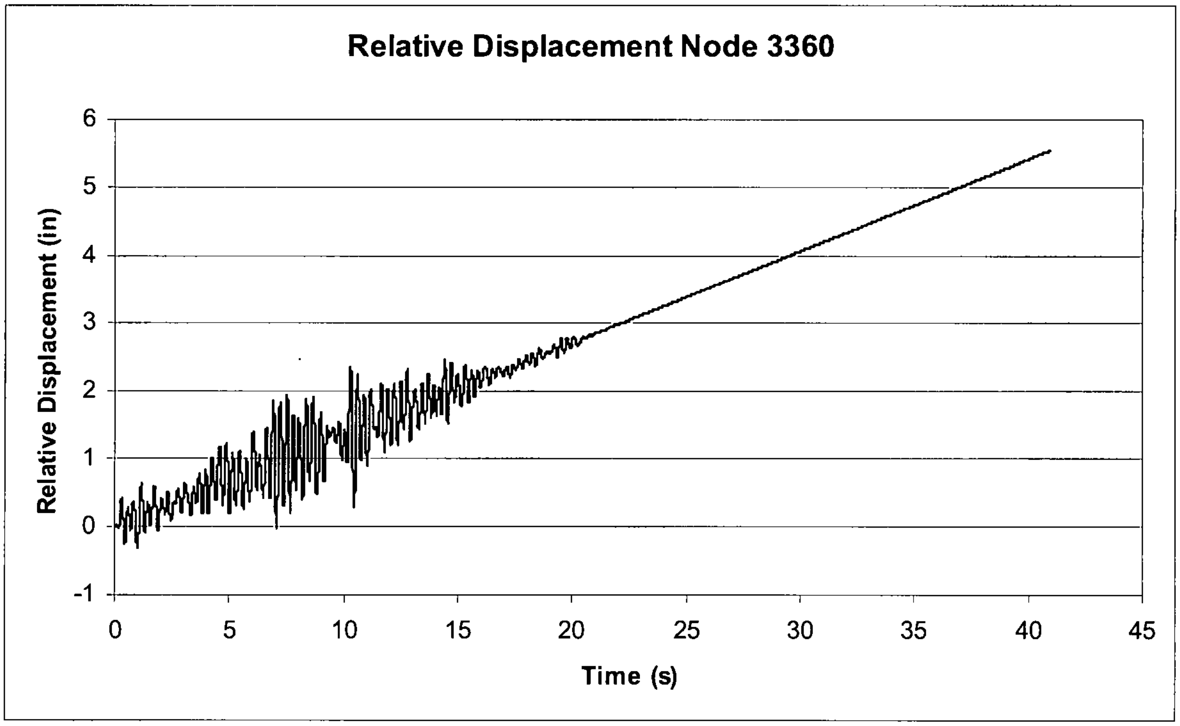


Figure 6.3-1 - Relative Displacement of Node 3360, top of Shield Building

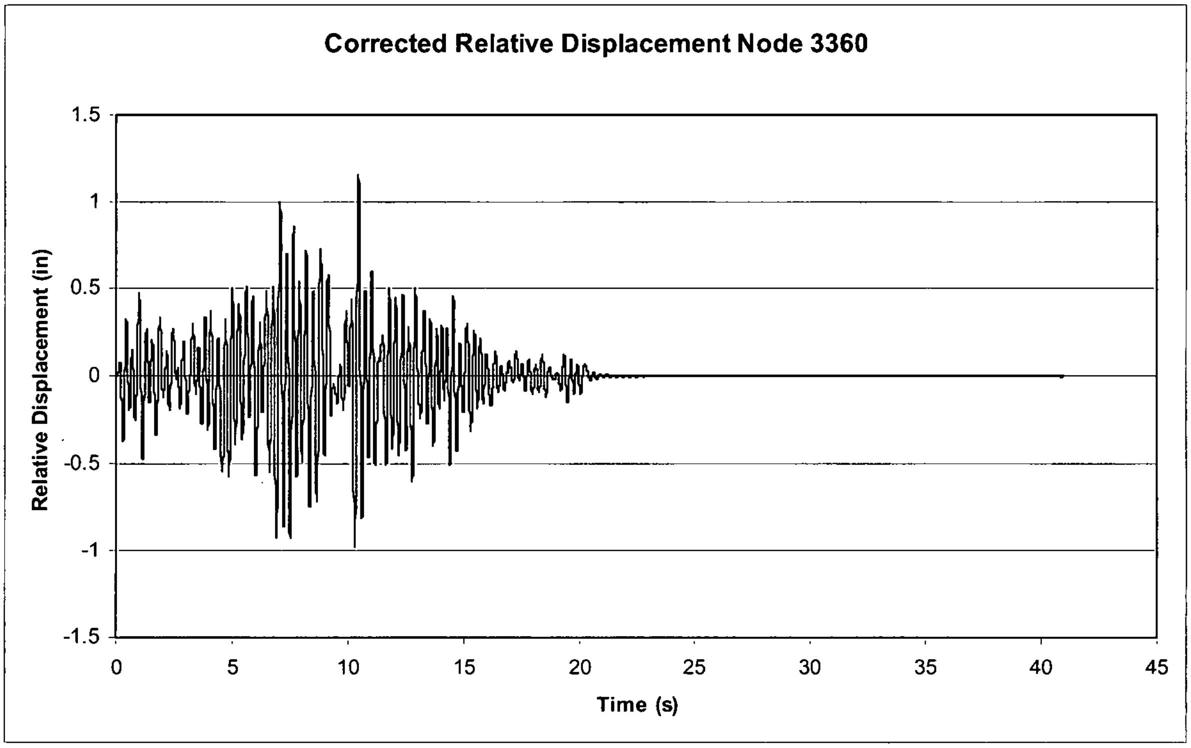


Figure 6.3-2 - Corrected Relative Displacement of Node 3360, top of Shield Building

Figures 6.3-3 and 6.3-4 show the maximum deflection plots for the shield building and steel containment vessel for each of the soil cases (firm rock, FR; soft to medium, SM; soft soil, SS; Upper bound soft to medium, UBSM; and soft rock, SR) and hard rock site (HR). Figures 6.3-5 and 6.3-6 show deflections for the NW corner of the pressurizer compartment and the SE corner of the East steam generator compartment.

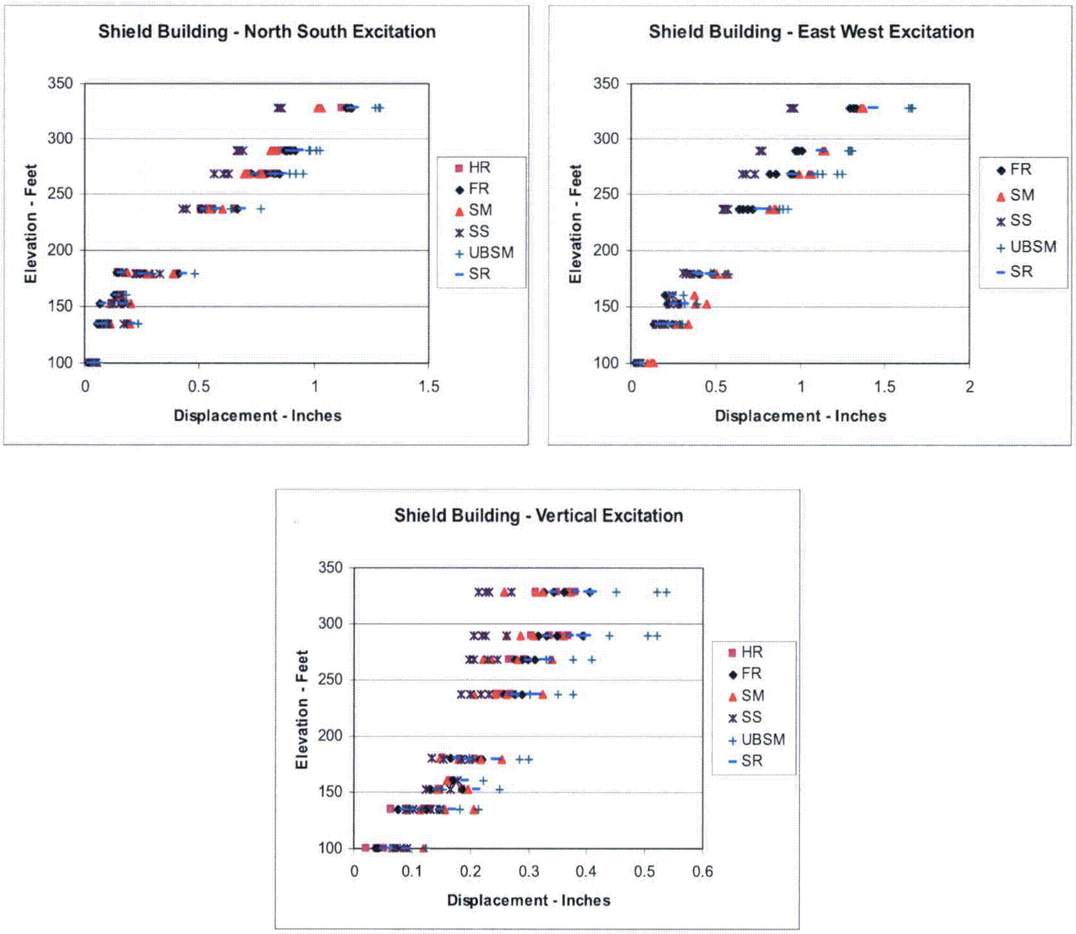


Figure 6.3-3 – Deflection Plots of Shield Building for all Soil Cases

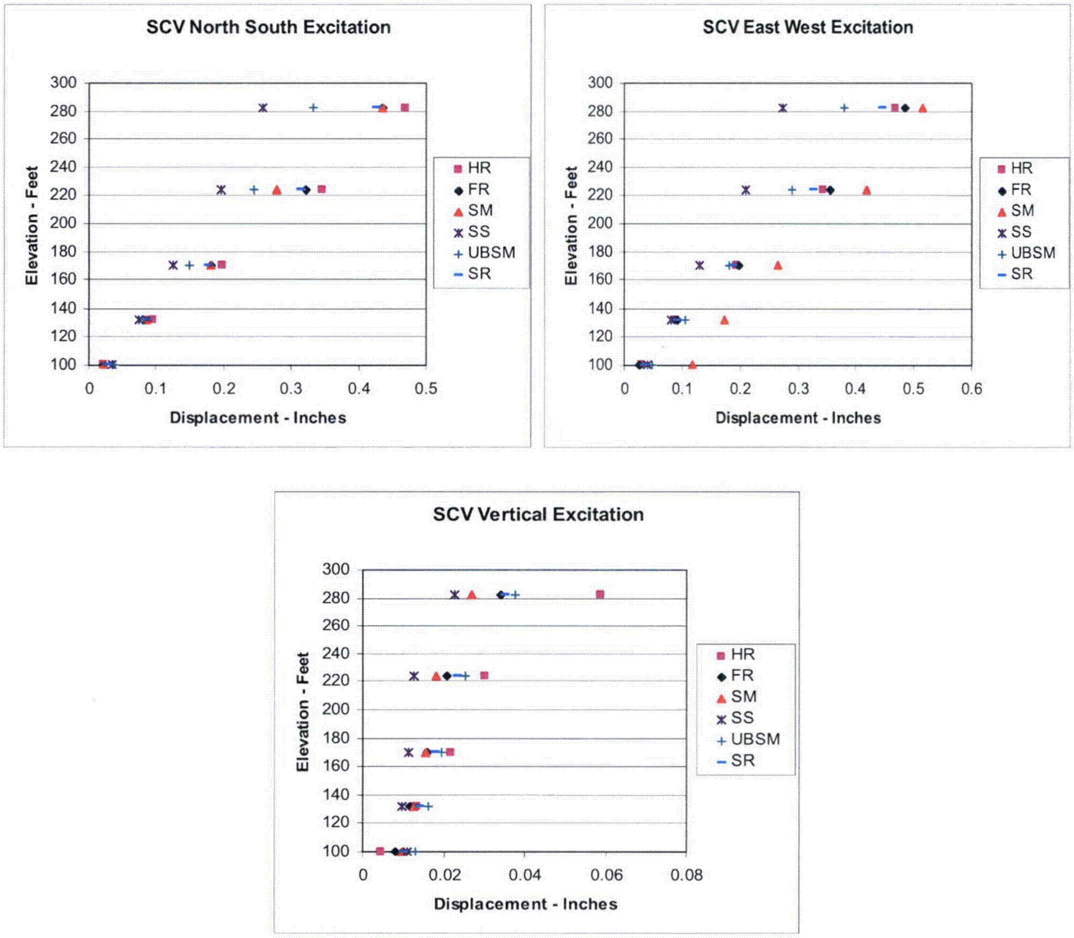
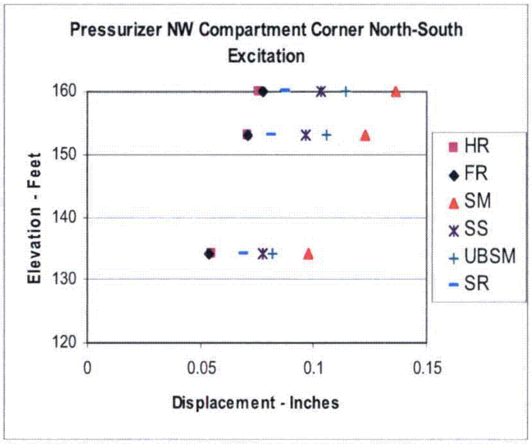
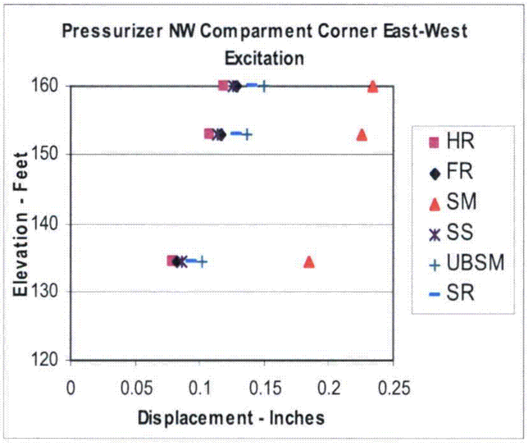


Figure 6.3-4 – Deflection Plots of SCV for all Soil Cases





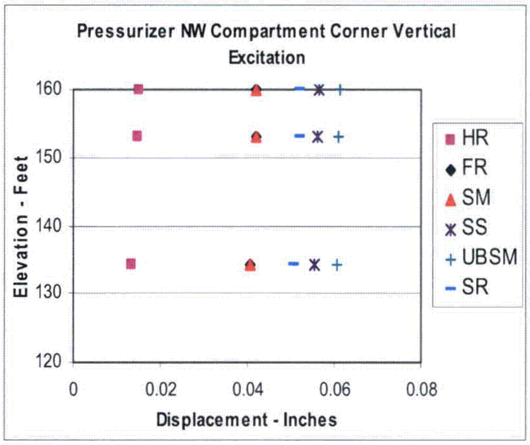


Figure 6.3-5 – Deflection Plots of Pressurizer Compartment NW Corner

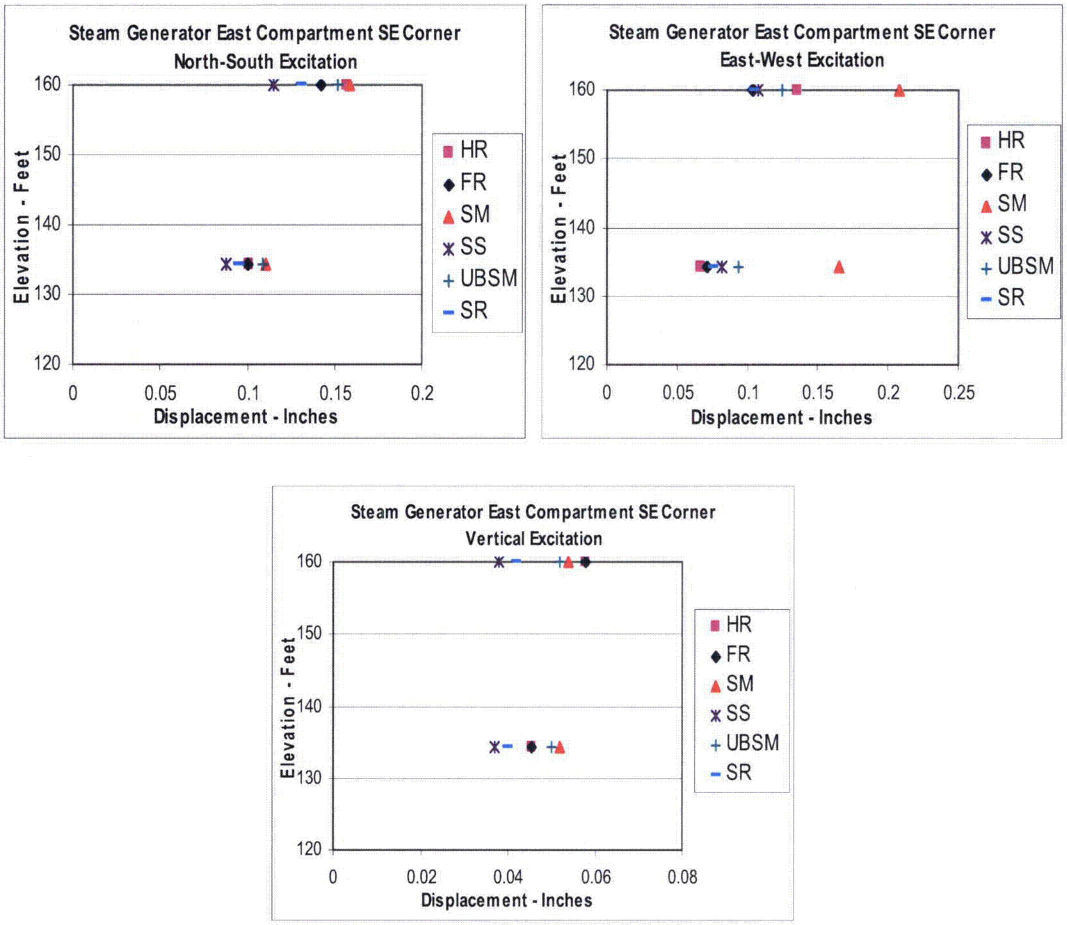


Figure 6.3-6 – Deflection Plots of East SG Compartment SE Corner

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-032
Revision: 2

Question:

The staff's review of the text and figures in Appendix C of AP1000 Document No. APP-GW-S2R-010, Revision 0, June 2006, "Extension of Nuclear Island Seismic Analyses to Soil Sites," identified the need for a number of clarifications and explanations of the results presented. The staff requests Westinghouse to address the following:

a. In paragraphs 4 and 5, an explanation is provided why the SASSI NI20 model produces higher results in the high frequency region than the ANSYS NI20 model, for a hard rock site condition. The explanation would appear to apply on a generic basis. However, comparison of Figures C-1 through C-6 to Figures C-7 through C-12, respectively, indicates that this effect is not generically demonstrated. Only the first three of the six locations demonstrate this behavior. Please (a) provide a detailed explanation why this effect occurs only at three locations, and not at all six locations; (b) describe how it was determined that the explanation provided in paragraph 4 and 5 is accurate; and (c) confirm that all other potential sources for the differences (e.g., modeling error) have been investigated and eliminated as the source of the difference.

b. Paragraph 2 states:

> "Both finite element models give comparable results below 10 hertz. However, the results from the coarse model are not as good at high frequencies (above about 15 hertz). Therefore the hard rock FRS were generated from the fine NI10 model, and the coarse NI20 model was used for the soil site analyses where frequencies of interest are below 10 hertz."

Paragraph 6 states:

> "In a few cases it is found that the soil cases analyzed in SASSI using the NI20 model give higher results than the hard rock case using the NI10 model for frequencies above 10 Hz (see for example Figure 4.4.3-9). Although these cases <u>are believed to be</u> due to conservatism in the SASSI results at high frequency, the SASSI results are used in developing the broadened envelope design response spectra."

Apparently, the hard rock results obtained from the NI10 ANSYS model do not always envelop the soil site results obtained from the SASSI NI20 model at frequencies above 10 hertz, as one might easily conclude from paragraph 2. From paragraph 6, it appears that there is considerable uncertainty about the validity of the SASSI results above 10 hertz. This is in contrast to the "matter-of-fact" statements made in paragraphs 4 and 5. Please clarify the Westinghouse position, including the technical basis, on the validity of SASSI

NI20 model results above 10 hertz for all site conditions, including a hard rock site. Is the NI20 grid sufficiently refined to accurately predict response above 10 hertz? Have any SASSI soil site analyses been performed using a refined grid comparable to the NI10 model, to study the effect of element size on the solution results?

c. Explain what studies were performed to establish that the NI10 model refinement is sufficient to accurately account for high frequency response effects at all critical locations. It is not obvious from the results shown in Figure C-1 that convergence with element size has been achieved.

Westinghouse Response:

a) The NI20 model uses solid elements for the mass concrete below grade inside the shield building. Other parts of the model use shell elements. The difference in ANSYS and SASSI results is most noticeable at the three lowest elevations where the response is most affected by the solid elements below grade.

The explanation provided in Paragraphs 4 and 5 were based on detailed checking of the models and on a series of studies. The explanation was confirmed by a study comparing the SASSI and ANSYS responses using a reduced model with only the solid elements in the NI20 model.

b) Paragraph 2 does not imply that NI10 ANSYS model envelopes the soil site results obtained from the SASSI NI20 model at frequencies above 10 hertz. It is discussing the comparison of the NI10 and NI20 models on hard rock. The paragraph states explicitly that the results of the NI20 model on hard rock are not as good at high frequencies.

The RAI is correct when it says that the hard rock results obtained from the NI10 ANSYS model do not always envelop the soil site results obtained from the SASSI NI20 model at frequencies above 10 hertz. This can be seen by review of the floor response spectra in Figures 4.4.3-1 to 4.4.3-18. The higher SASSI responses are generally responses in the vertical direction. An extreme example is seen in Figures 4.4.3-9 where the firm rock exhibits a higher response at about 25 hertz. As seen in Figure C-3 on hard rock the NI20 model has a similar higher response so this higher response is due to the coarser modeling of NI20; however, the higher SASSI results were conservatively enveloped in developing the broadened envelope design response spectra.

The comparisons of the NI10 and NI20 results in Figures C-1 to C-6 show the NI20 model is acceptable for responses above 10 hertz. However, as stated in paragraph 2, the NI10 model gives more accurate results and is used in the fixed base analyses for hard rock. The comparisons of NI10 to NI20 were performed in ANSYS. Analyses have not been performed in SASSI with more refined models than the NI20 model.

The FRS for the NI10, NI20 (ANSYS & SASSI) given in Appendix C are compared on the same plots in Figures RAI-TR03-032-1 to RAI-TR03-032-6. The node numbers are the same as shown in Table C1 of the technical report (Revision 1). The pertinent information from Table C1 is reproduced in Table RAI-TR03-032-1. The NI10 ANSYS FRS are used as the design basis for hard rock.

c) The NI10 model is described in DCD subsection 3.7.2 (Item 5) and is the basis for the vertical floor response spectra for hard rock. The model was reviewed and accepted as part of the hard rock design certification. During development of the model detail studies with greater element refinement were performed for the floor above the control room and the adjacent bays to confirm the adequacy of the model.

Table RAI-TR03-032-1– Key Nodes at Location

Location	NI10 Node	NI20 Sassi	Figure ANSYS & SASSI FRS Comparaison	General Area	Elevation (feet)
CIS at Reactor Vessel Support Elevation	130401	1761	RAI-TR03-032-1	RPV Center	100.00
CIS at Operating Deck	105772	2199	RAI-TR03-032-2	SG West compartment, NE	134.25
ASB NE Corner at Control Room Floor~~Ceiling~~	4724	2078	RAI-TR03-032-3	NE Corner	116.50
ASB Corner of Fuel Building Roof at Shield Building	574~~54~~	2675	RAI-TR03-032-4	NW Corner of Fuel Bldg	179.19
ASB Shield Building Roof Area	8573	3329	RAI-TR03-032-5	South side of Shield Bldg	327.40
SCV Near Polar Crane	130412	2788	RAI-TR03-032-6	SCV Stick Model	224.00

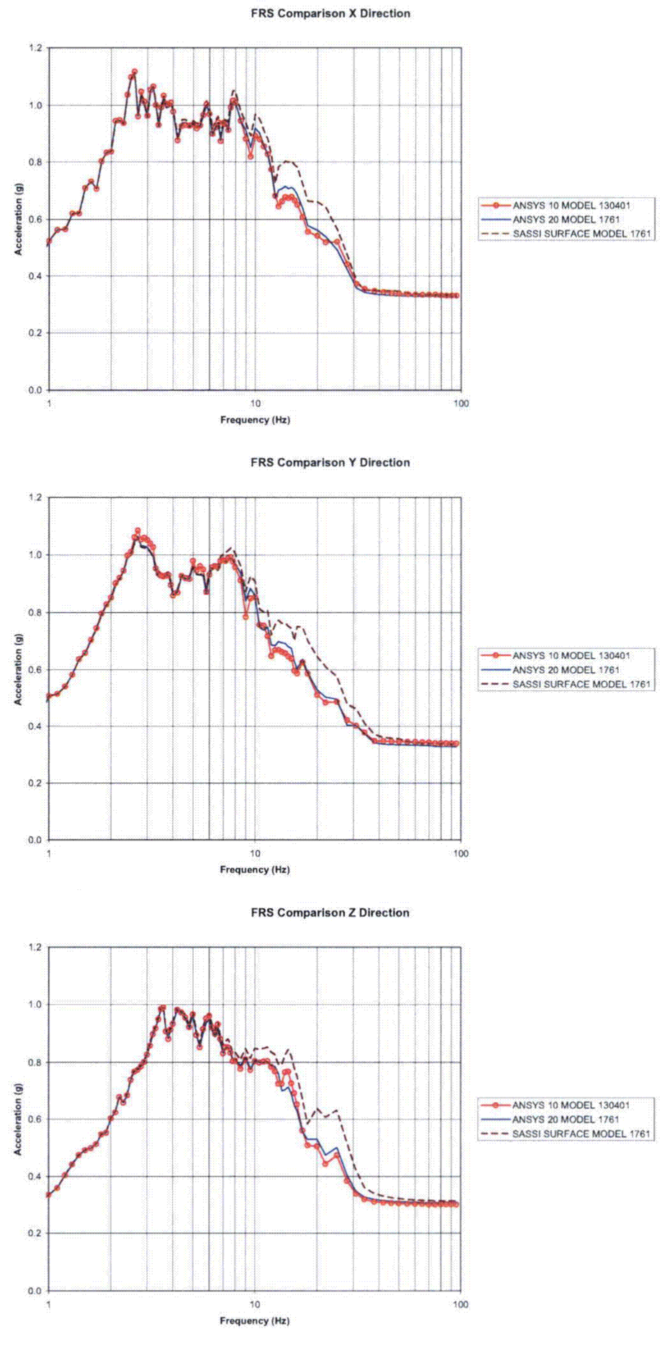


Figure RAI-TR03-032-1 — FRS Comparison at Base of SCV on CIS at RPV Center

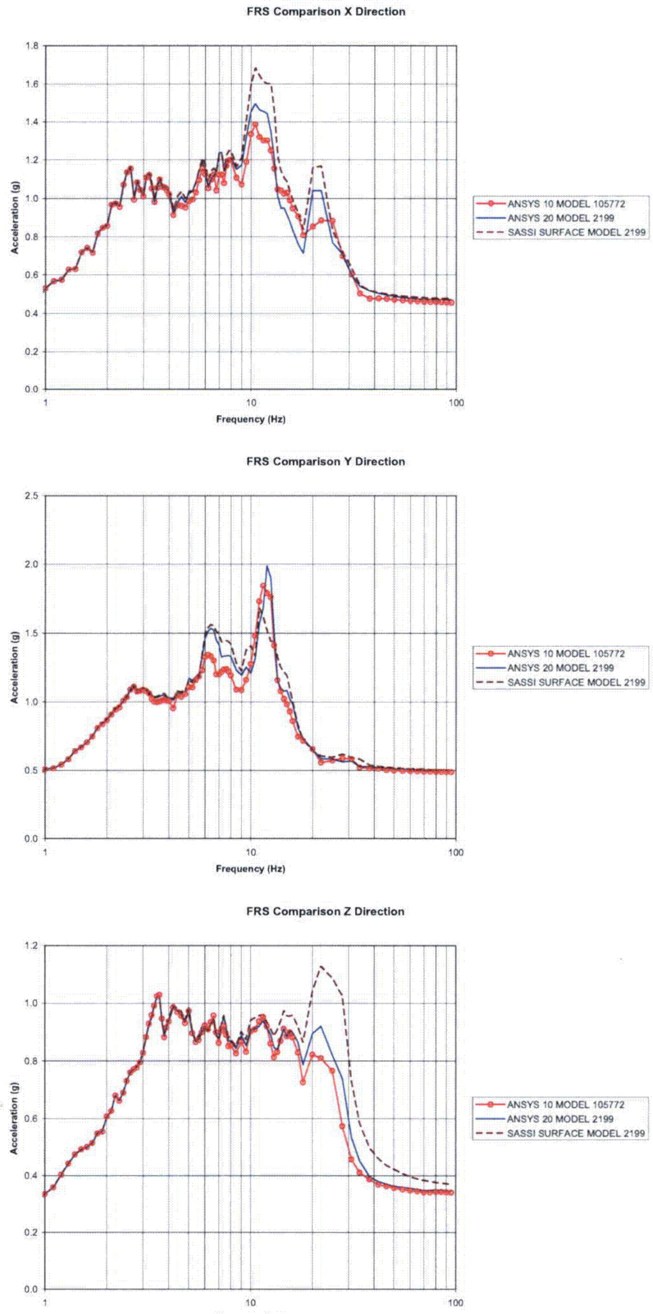


Figure RAI-TR03-032-2 - FRS Comparison at NE Corner of SG West Compartment, El. 134'

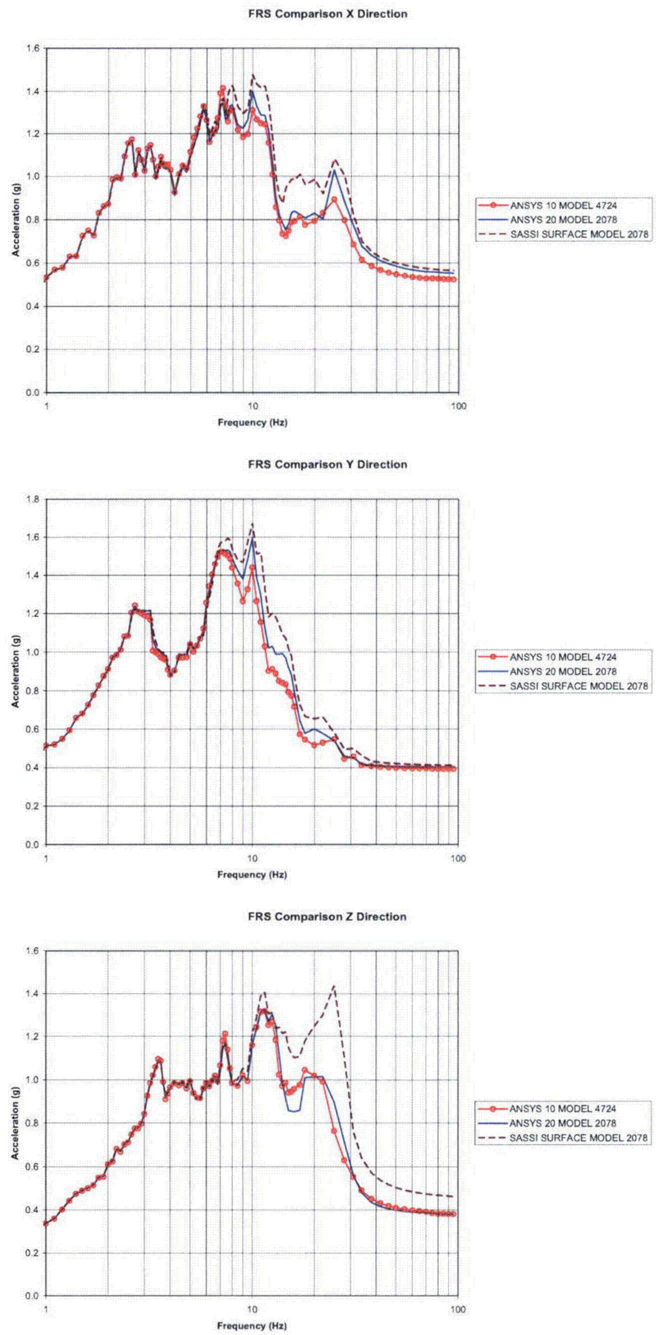


Figure RAI-TR03-032-3 - FRS Comparison at NE Corner of Control Room Floor

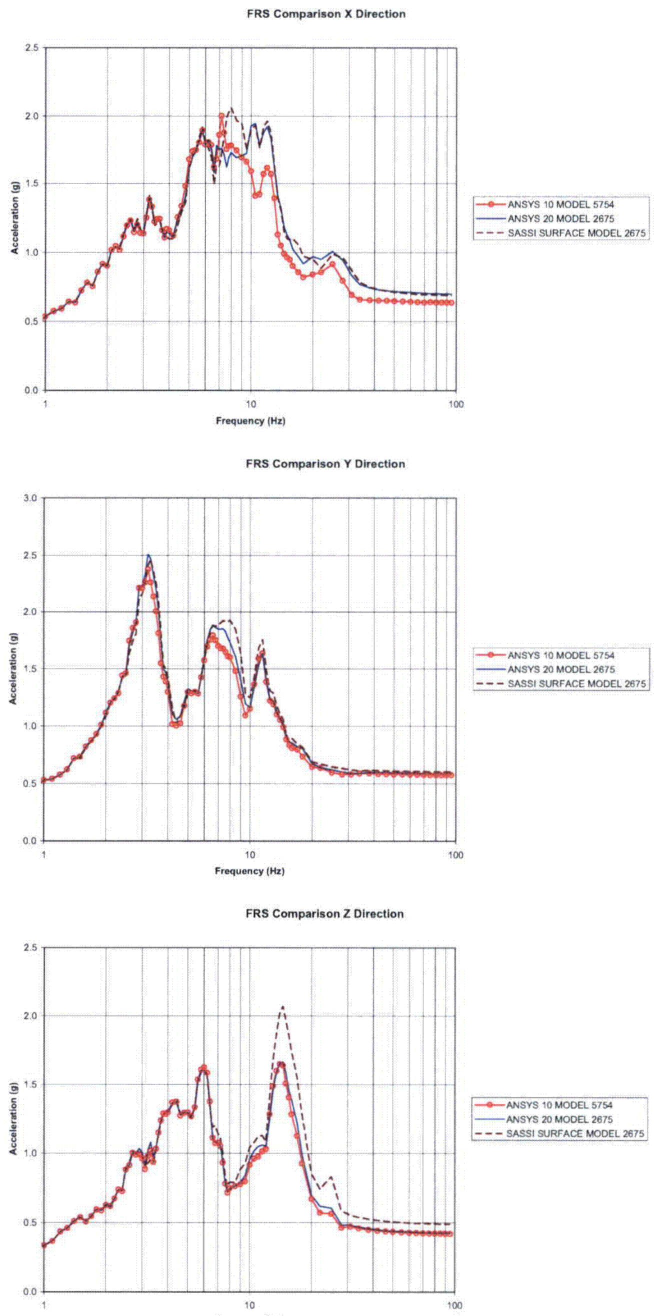


Figure RAI-TR03-032-4 - FRS Comparison at NW Corner of Fuel Building Roof

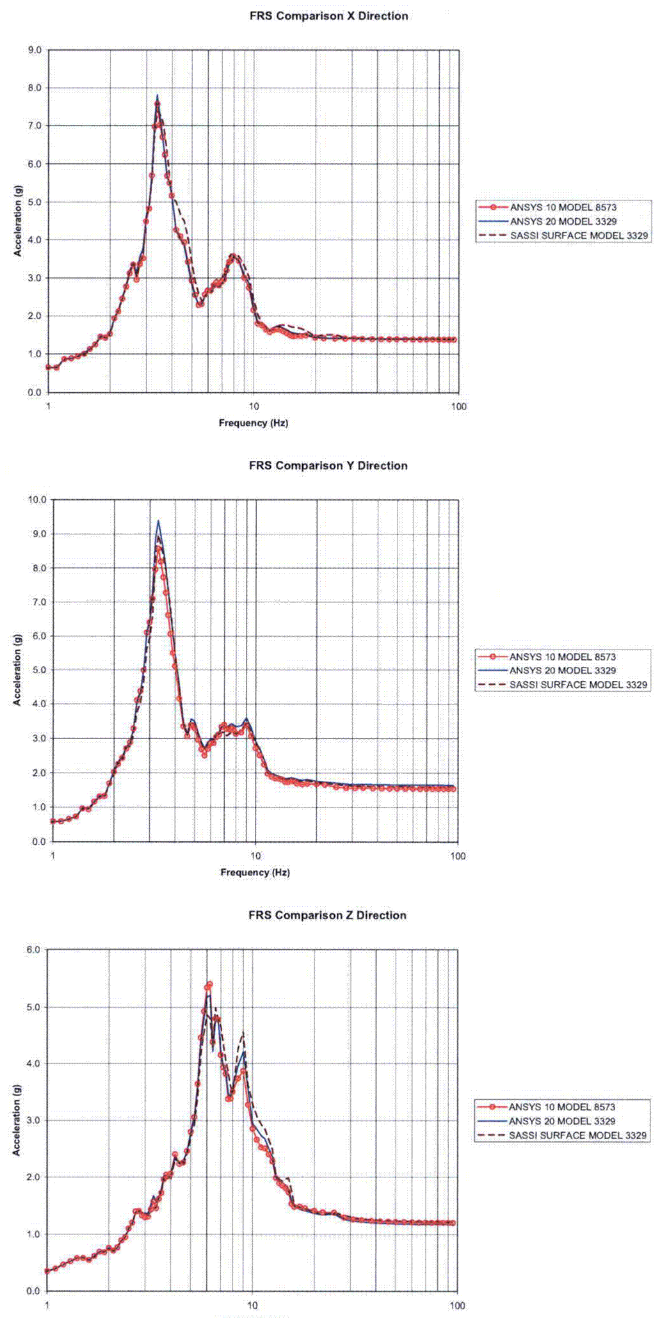


Figure RAI-TR03-032-5 - FRS Comparison at South Side of Shield Building at El. 327.41'

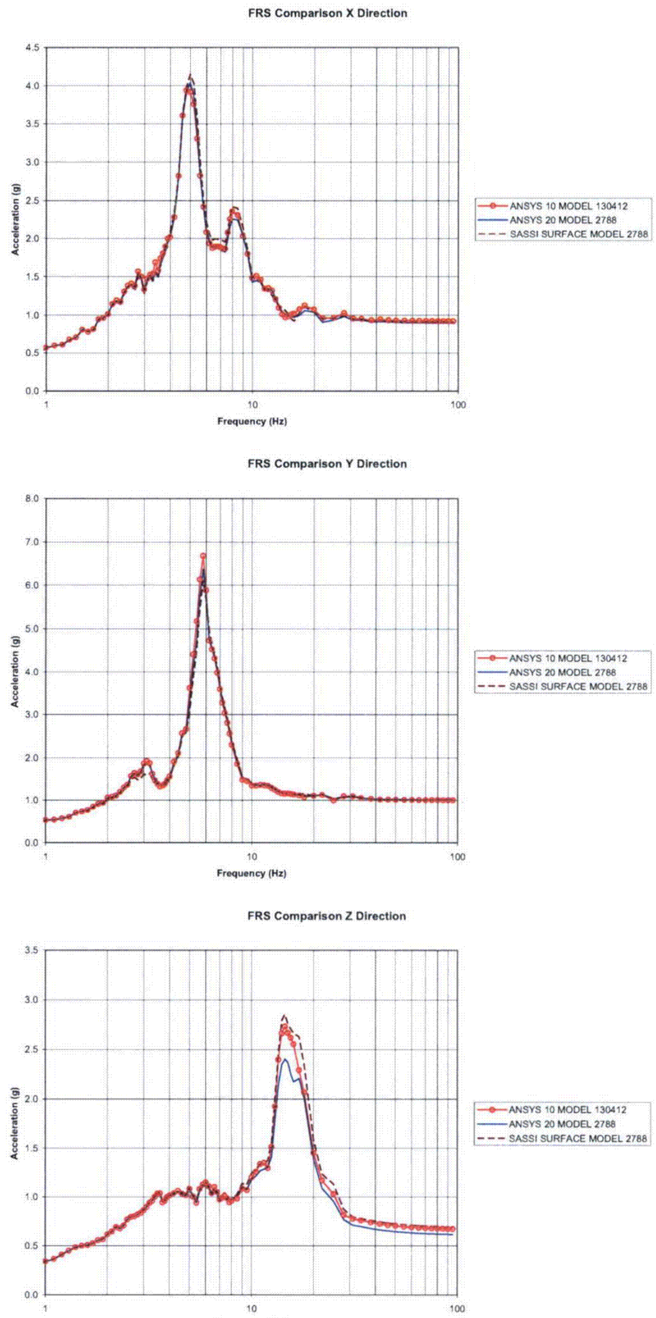


Figure RAI-TR03-032-6 - FRS Comparison on SCV near Polar Crane, El. 224'

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

Revise Appendix C as shown below:

Appendix C - Comparison of NI10 and NI20 Responses

In this appendix the fine (NI10) and coarse (NI20) model seismic responses are compared. Seismic response spectra were developed for both models using a fixed base (hard rock) case. Also in this section the NI10 and NI20 ANSYS is compared to the SASSI analysis results.

Figures C-1 to C-6 compare response spectra for ANSYS analyses of the NI10 and NI20 models at the interface seismic response key nodes (see Section 4.4.3). These locations are given in Table C-1. Also shown in this table are the figures where the comparison spectra are given. Both finite element models give comparable results below 10 hertz. However, the results from the coarse model are not as good at high frequencies (above about 15 hertz). Therefore the hard rock FRS were generated from the fine NI10 model, and the coarse NI20 model was used for the soil site analyses where frequencies of interest are below 10 hertz.

A Time History Analysis for the Nuclear Island SASSI Surface Structure Model and the Embedded Structure Model is carried out with the seismic input in three orthogonal directions. The acceleration response spectra for 5% damping are generated at the interface locations identified in Table C-1. The nodes chosen for "SASSI Surface Model " in Figures C-1 to C-6 compare the Nuclear Island SASSI Surface Structure Model and the Embedded Structure Model results with the Nuclear Island ANSYS Coarse Model (NI20) results for hard rock conditions.

As seen from the comparison (see Figures C-1 to C-6), for the horizontal response, the SASSI and ANSYS results for NI20 are very similar to about 15 Hz horizontal and about 10 Hz vertical. At the higher frequencies SASSI calculates higher accelerations. The NI20 model uses solid elements for the mass concrete below grade inside the shield building. Other parts of the model use shell elements. The difference in ANSYS and SASSI results is most noticeable at the three lowest elevations where the response is most affected by the solid elements below grade. This behavior was investigated in a study comparing the SASSI and ANSYS responses using a reduced model with only the solid elements in the NI20 model. One reason for this conservatism in the SASSI results is the different formulation in the solid elements. Another difference is due to the different way the two computer programs calculate the dynamic response. ANSYS performs the dynamic response in the time domain. SASSI converts the time history input (time domain) to the frequency domain, solves the response in the frequency domain, and then converts the output back to the time domain.

SASSI also needs to specify key frequencies to perform its transfer function calculations. For such a large model, resting on a very stiff soil (hard rock), SASSI gives conservative results at high frequencies. The significant responses for soil cases occur at less than 10 Hz. Therefore, the SASSI Model is adequate for the AP1000 Soil-Structure Interaction analyses to be performed.

In a few cases it is found that the soil cases analyzed in SASSI using the NI20 model give higher results than the hard rock case using the NI10 model for frequencies above 10 Hz (see for example Figure 4.4.3-9). The reason for this is two-fold: mesh size and SASSI approximation. The NI20 SASSI model is a much coarser model than the NI10, at higher frequencies it cannot capture the local behavior as well as the NI10 and this causes some of the response to be higher. SASSI uses a limited number of transfer functions to obtain the dynamic response. This limited number (up to 100 frequencies) is an adequate approach when the medium that you are considering is soil, where only a few significant modes need to be captured to obtain the building response. At higher frequencies, in a shell models, many modes (or transfer frequencies) are required to obtain the building response. Although these cases are due to conservatism in the SASSI results at high frequency, the SASSI results are used in developing the broadened envelope design response spectra.

Table C-1 – Key Nodes at Location

Location	NI10 Node	NI20 Sassi	Figure ANSYS & SASSI FRS Comparaison	General Area	Elevation (feet)
CIS at Reactor Vessel Support Elevation	130401	1761	C-1	RPV Center	100.00
CIS at Operating Deck	105772	2199	C-2	SG West compartment, NE	134.25
ASB NE Corner at Control Room Floor	4724	2078	C-3	NE Corner	116.50
ASB Corner of Fuel Building Roof at Shield Building	5744	2675	C-4	NW Corner of Fuel Bldg	179.19
ASB Shield Building Roof Area	8573	3329	C-5	South side of Shield Bldg	327.40
SCV Near Polar Crane	130412	2788	C-6	SCV Stick Model	224.00

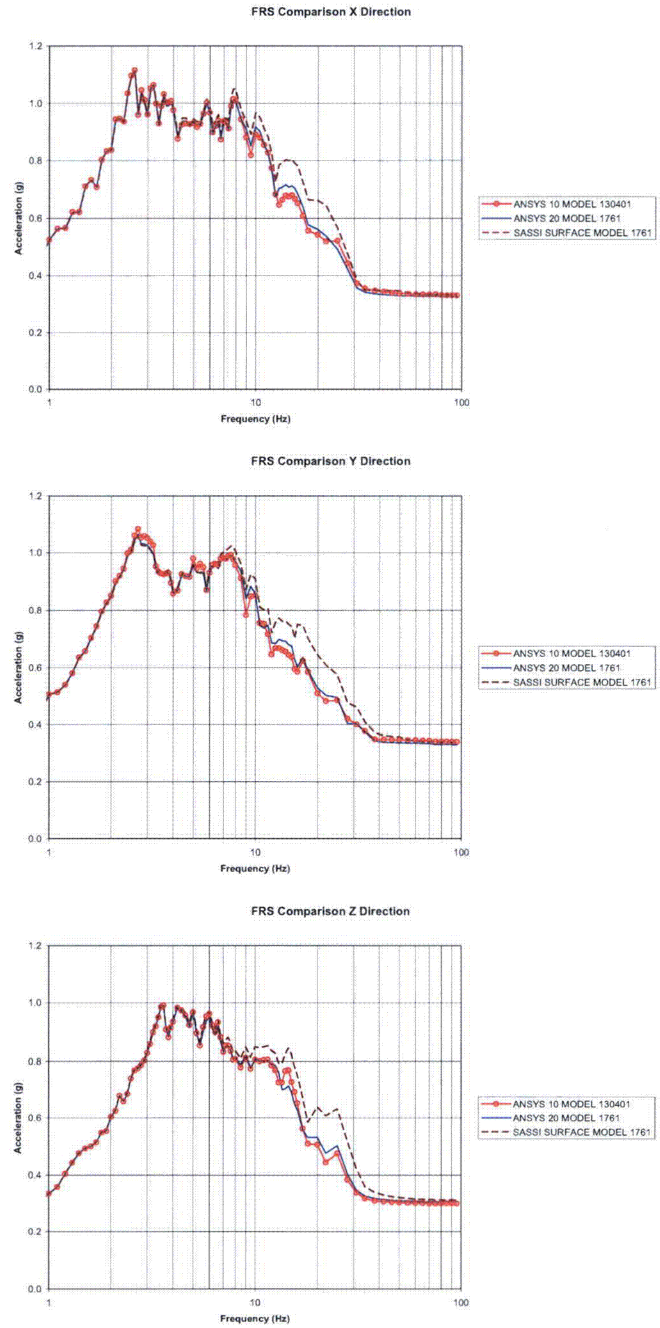


Figure C-1 – FRS Comparison at Base of SCV on CIS at RPV Center

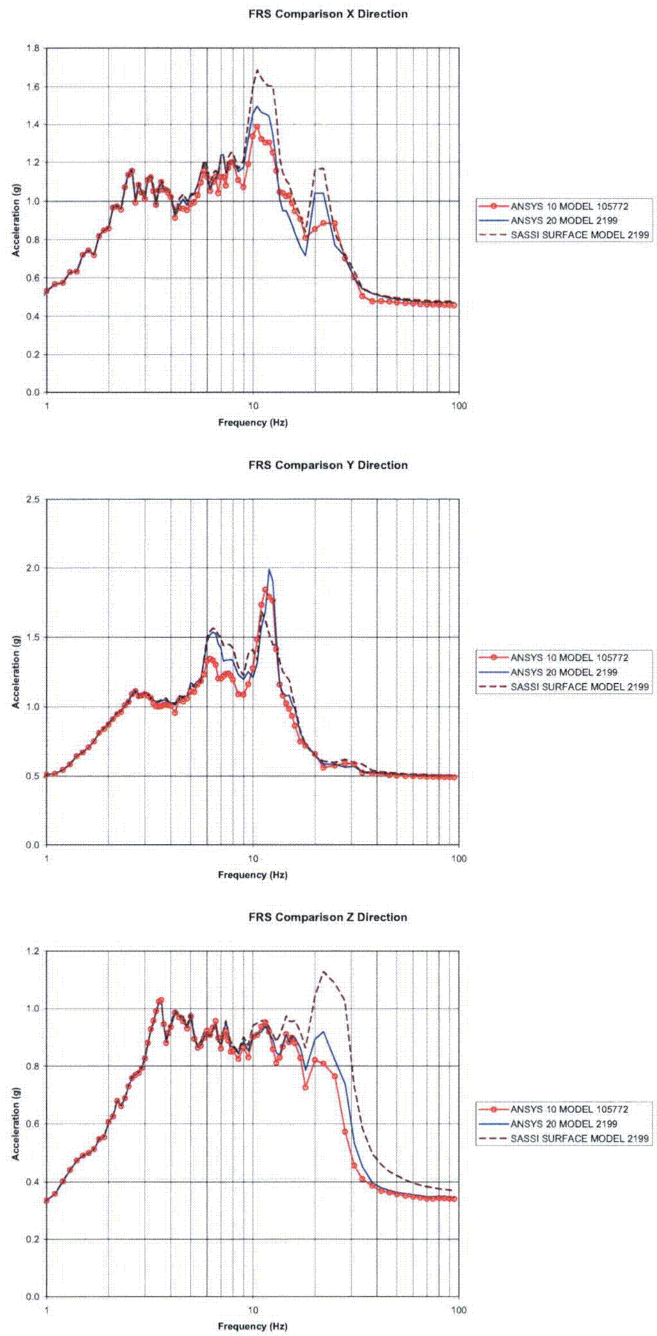


Figure C-2 – FRS Comparison at NE Corner of SG West Compartment, El. 134'

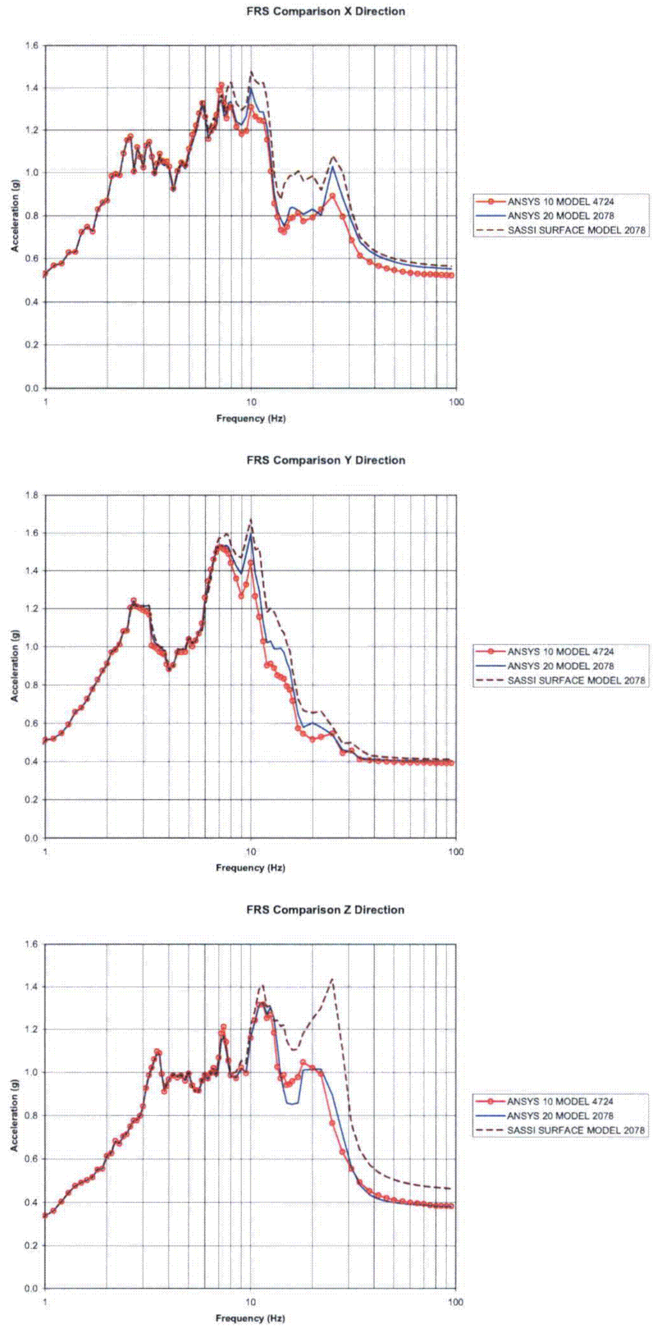


Figure C-3 – FRS Comparison at NE Corner of Control Room Floor

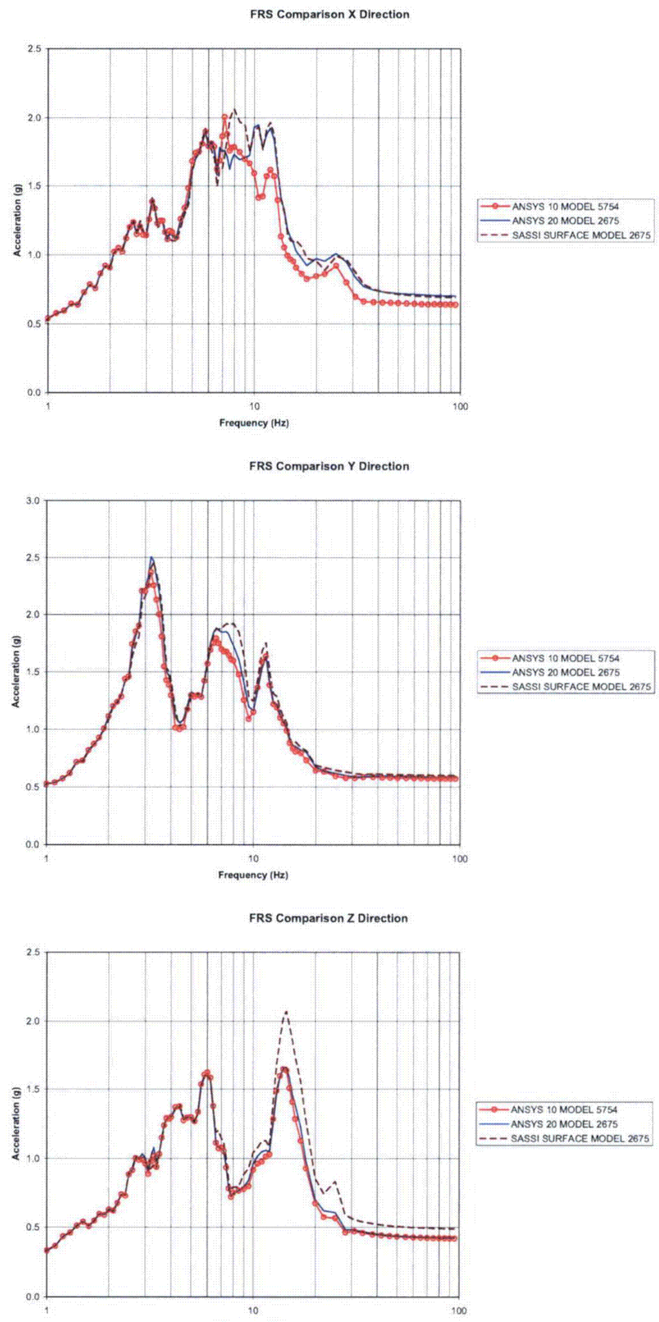


Figure C-4 – FRS Comparison at NW Corner of Fuel Building Roof

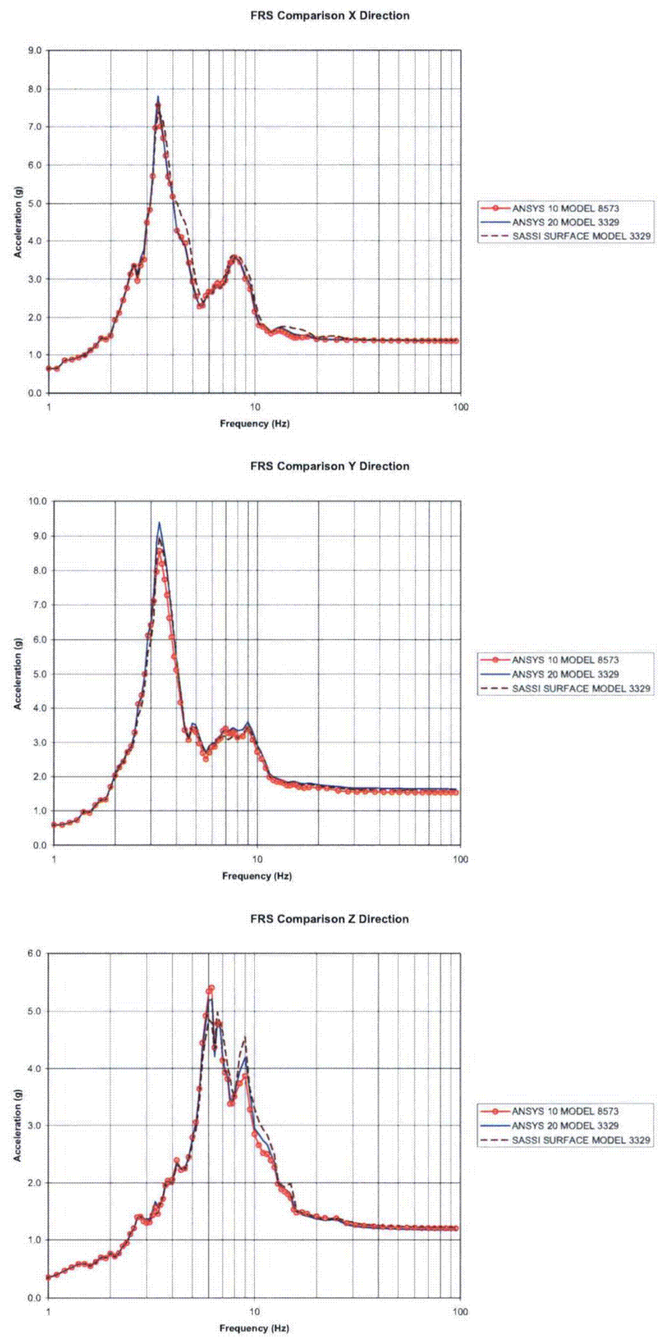


Figure C-5 – FRS Comparison at South Side of Shield Building at El. 327.41'

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-033
Revision: 1

Question:

The staff's review of Appendix E identified a number of items in need of clarification or explanation. The staff requests Westinghouse to address the following:

a. Please explain why the MAX horizontal acceleration profiles shown in Figure E-2, for the Auxiliary Building, exhibit an erratic pattern of acceleration with increasing elevation, while the stick model results do not exhibit this behavior. Also explain why a vertical acceleration profile is not included in Figure E-2. Identify which acceleration profiles are used for the final design of the Auxiliary Building.

b. Please explain the very significant differences shown in Figure E-4, for the CIS, between the MAX horizontal and vertical acceleration profiles and the stick model acceleration profiles at the top of the CIS. Identify which acceleration profiles are used for the final design of the CIS.

c. Please explain why the ASB vertical acceleration profile for both MAX and stick model, shown in Figure E-1, exhibit essentially rigid behavior above elevation 290 ft. Also provide a detailed technical explanation for the significant reduction in the MAX vertical acceleration, compared to the stick model vertical acceleration, between elevations 260 ft and 290 ft. Identify which acceleration profiles are used for the final design of the ASB.

d. The last paragraph of Appendix E discusses accelerations used for overturning. The staff noted that no comparison figure is included in Appendix E, and also is not sure which acceleration profiles are used for the overturning case. Please provide this figure and also identify which acceleration profiles are used for the final design-basis overturning analysis.

Westinghouse Response:

Westinghouse is now using seismic response spectrum analysis and not equivalent static analyses; therefore, these additional requests for additional information no longer apply.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
Appendix E has been removed in Revision 1 to TR-03.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-036
Revision: 0

Question:

Following its review of the applicant's response to RAI-TR03-023, the staff determined that it needs to conduct a more in-depth evaluation of how the equivalent static seismic acceleration method was implemented to calculate internal forces and moments needed for detailed design. The staff requests the applicant to provide the following additional information:

a. The detailed step-by-step description of how the equivalent static accelerations applied to the NI05 model were derived from the multiple NI20 time history analyses.

b. For each soil condition case, a set of 3 tables corresponding to revised Tables 6.4-1 through 6.4-3, which were included in the response to RAI-TR03-023 for the fixed base case.

c. An additional set of 3 tables, corresponding to revised Tables 6.4-1 through 6.4-3, that compares the NI05 equivalent static acceleration results with the envelope of the NI20 equivalent static acceleration results, and with the envelope of the NI20 time history results.

d. A detailed explanation, including quantitative data as appropriate, why significant differences (>10% under-prediction) between the design-basis NI05 static analysis results and the envelope of the NI20 time history results are considered acceptable.

e. A discussion of the extent of significant differences at locations that are NOT presented in the tables, including an explanation of the basis for acceptability.

Westinghouse Response:

Westinghouse has switched to a seismic response spectrum analysis and is not using equivalent static analysis to obtain member forces for the design of the auxiliary and shield building or the containment internal structures. The responses for this request for additional information are no longer applicable.

The input spectra are envelopes of the design ground motion spectra (DCD Figures 3.7.1-1 and 3.7.1-2) which are applicable for hard rock, and of the basemat response spectra for 5 soil types (Firm Rock, Soft Rock, Upper Bound Soft to Medium, Soft to Medium and Soft Soil) obtained from SASSI analyses. The soil input spectra is the envelope of the center, edge, and corner nodes of the ASB basemat at elevation 60.5'. The nodes enveloped are shown in Figure RAI-TR03-36-1. The input spectra are applied at the Nuclear Island basemat.

Composite modal damping is calculated for each mode of the building model. The spectra input in the response spectrum analyses are interpolated from the spectra at variable damping based on the composite modal damping at each frequency. The design spectrum varies between 5% and 7% of critical damping in both horizontal and vertical directions. The design spectra based on composite modal damping for the AP1000 Auxiliary and Shield Building are shown in Figures RAI-TR03-036-2 through RAI-TR03-036-4.

The response spectrum methodology used in the AP1000 design employs the Complete Quadratic Combination (CQC, Section 1.1 of Reference 1) grouping method for closely spaced modes with the Der Kiureghian Correlation Coefficient (Section 1.1.3 of Reference 1) used for correlation between modes. The Lindley-Yow (Section 1.3.2, Reference 1) spectral analysis methodology is employed for modes with both periodic and rigid response components. The modal analysis performed to develop composite modal participation is used to develop input for the response spectrum analysis. Modes ranging from 0 to 33 Hz or higher are considered. For modes above the cutoff frequency, the Lindley-Yow is used. The Static ZPA Method (Section 1.4.2, Reference 1) is employed for the residual rigid response component of each mode as outlined in NRC Reg. Guide 1.92 (Reference 1). The complete solution is developed via Combination Method B (Section 1.5.2, Reference 1). The combined effects, considering three spatial components of an earthquake (N-S, E-W, and Vertical), are combined by square root sum of the squares method (Section 2.1, Reference 1).

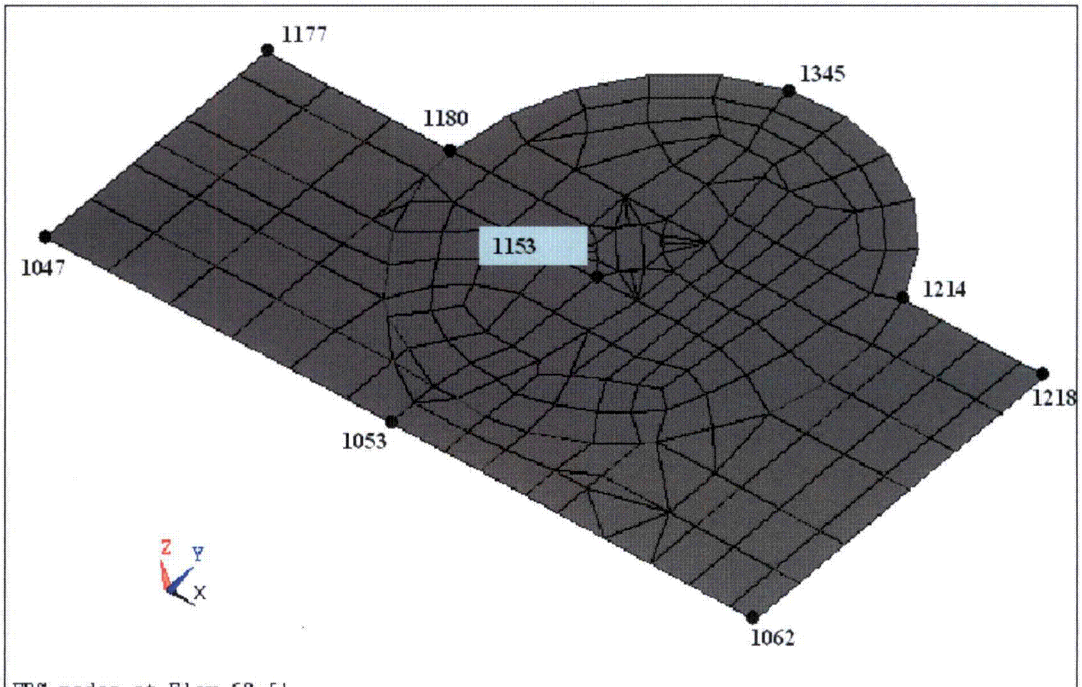


Figure RAI-TR03-36-1– Nodes Enveloped for AP1000 Basemat Spectral Input

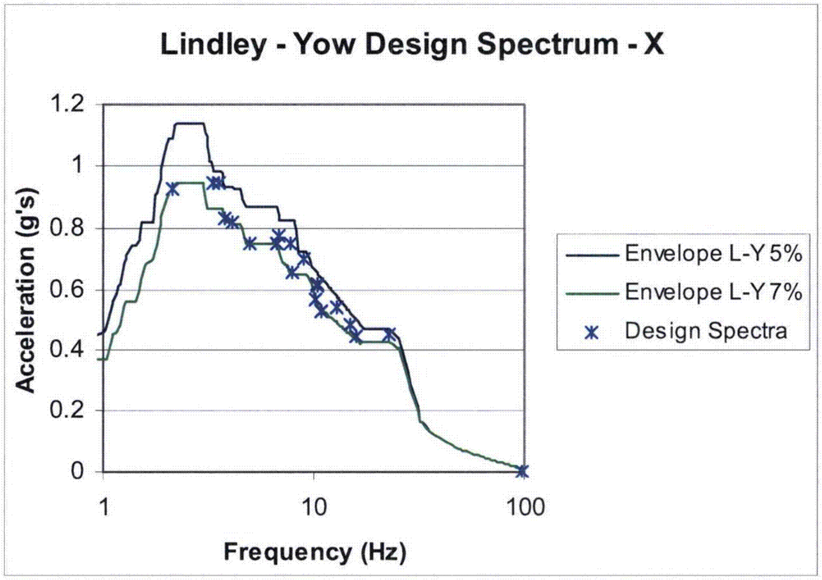


Figure RAI-TR03-36-2– AP1000 North-South Direction Design Response Spectra

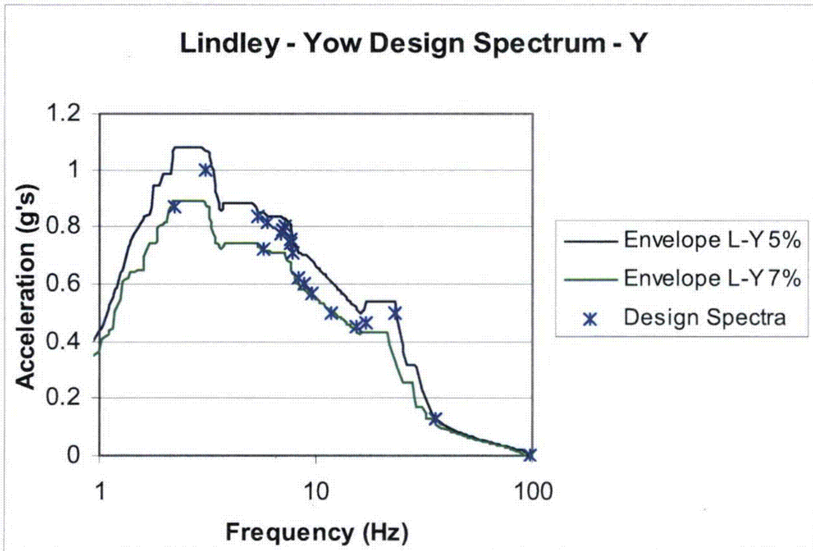


Figure RAI-TR03-36-3– AP1000 East-West Direction Design Response Spectra

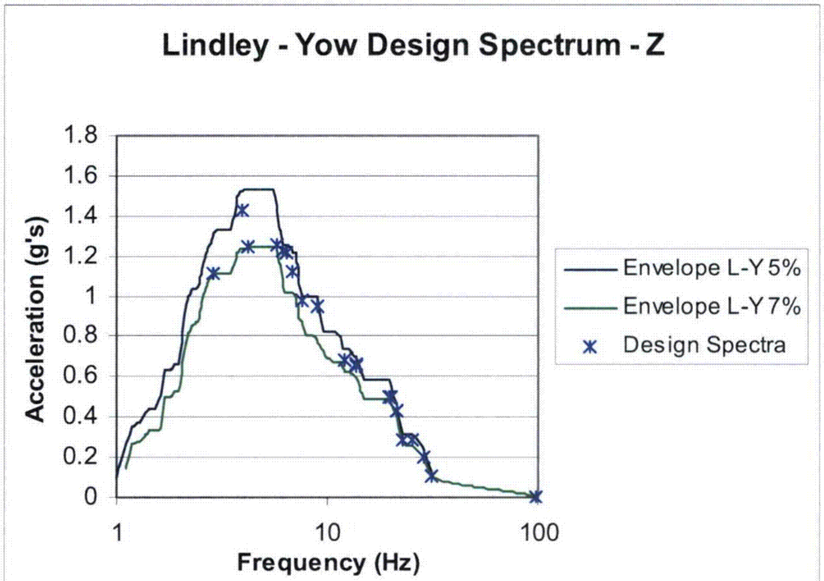


Figure RAI-TR03-36-4– AP1000 Vertical Direction Design Response Spectra

References:

1. US NRC Regulatory Guide 1.92, Rev. 2, "Combining Modal Responses and Spatial Components in Seismic Response Analysis."

Design Control Document (DCD) Revision:

None.

PRA Revision:

None.

Technical Report (TR) Revision:

Section 6.4 will be revised removing the discussion of equivalent static results, and the description of the response spectrum analysis presented in the Westinghouse response will be added.

6.4 Response Spectrum Analysis

The input spectra are envelopes of the design ground motion spectra (Figures 2.1-1 and 2.1-2) which are applicable for hard rock, and of the basemat response spectra for 5 soil types (Firm Rock, Soft Rock, Upper Bound Soft to Medium, Soft to Medium and Soft Soil) obtained from SASSI analyses. The soil input spectra is the envelope of the center, edge, and corner nodes of the ASB basemat at elevation 60.5'. The nodes enveloped are shown in Figure 6.4-1. The input spectra are applied at the Nuclear Island basemat.
Composite modal damping is calculated for each mode of the building model. The spectra input in the response spectrum analyses are interpolated from the spectra at variable damping based on the composite modal damping at each frequency. The design spectrum varies between 5% and 7% of critical damping in both horizontal and vertical directions. The design spectra based on composite modal damping for the AP1000 Auxiliary and Shield Building are shown in Figures 6.4-2 through 6.4-4.

The response spectrum methodology used in the AP1000 design employs the Complete Quadratic Combination (CQC, Section 1.1 of Reference 12) grouping method for closely spaced modes with the Der Kiureghian Correlation Coefficient (Section 1.1.3 of Reference 12) used for correlation between modes. The Lindley-Yow (Section 1.3.2, Reference 12) spectral analysis methodology is employed for modes with both periodic and rigid response components. The modal analysis performed to develop composite modal participation is used to develop input for the response spectrum analysis. Modes ranging from 0 to 33 Hz or higher are considered. For modes above the cutoff frequency, the Lindley-Yow is used. The Static ZPA Method (Section 1.4.2, Reference 12) is employed for the residual rigid response component of each mode as outlined in NRC Reg. Guide 1.92 (Reference 12). The complete solution is developed via Combination Method B (Section 1.5.2, Reference 12). The combined effects, considering three spatial components of an earthquake (N-S, E-W, and Vertical), are combined by square root sum of the squares method (Section 2.1, Reference 12).

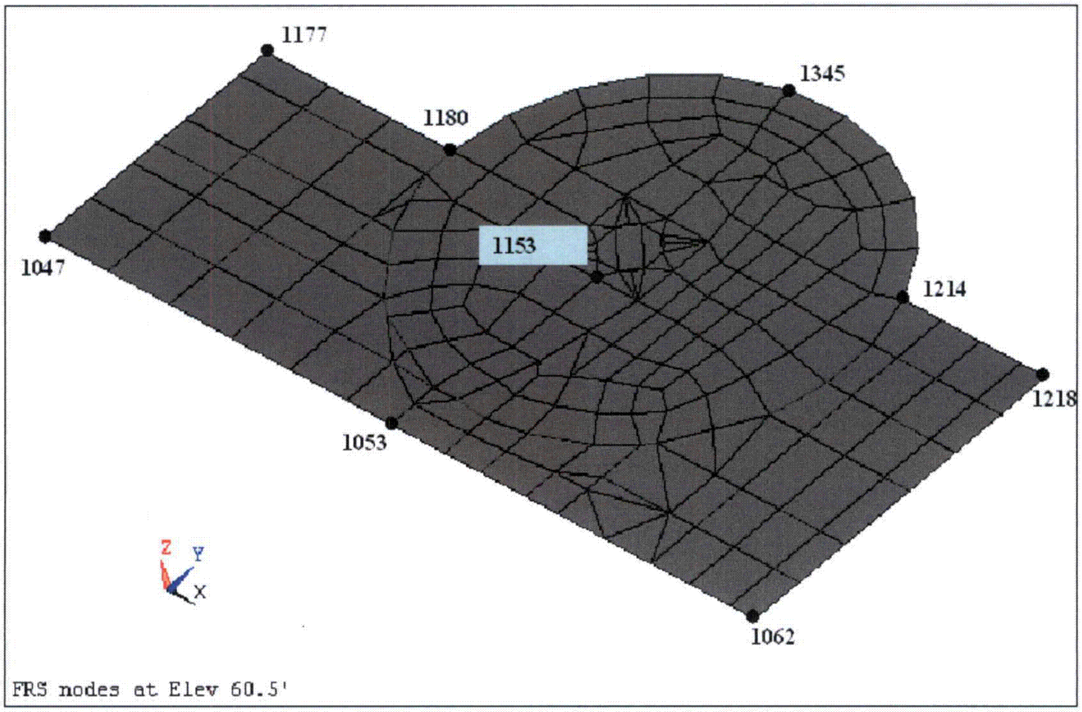


Figure 6.4-1– Nodes Enveloped for AP1000 Basemat Spectral Input

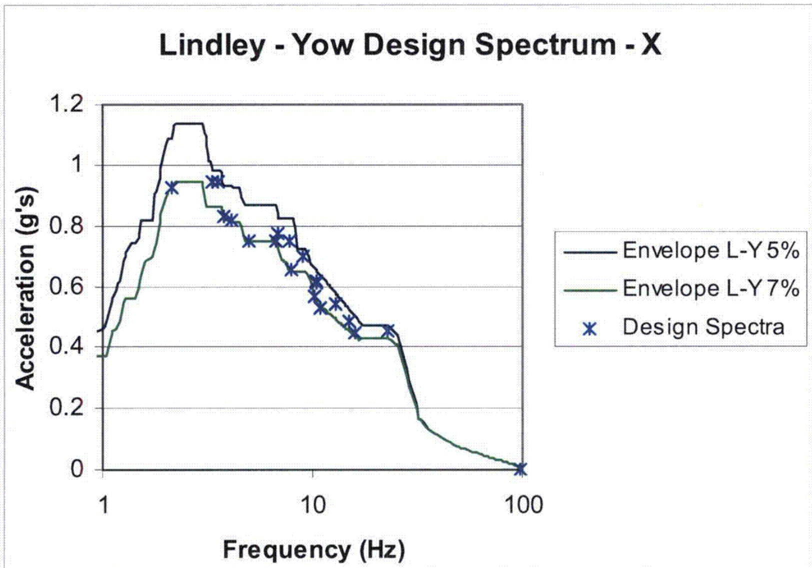


Figure 6.4-2– AP1000 North-South Direction Design Response Spectra

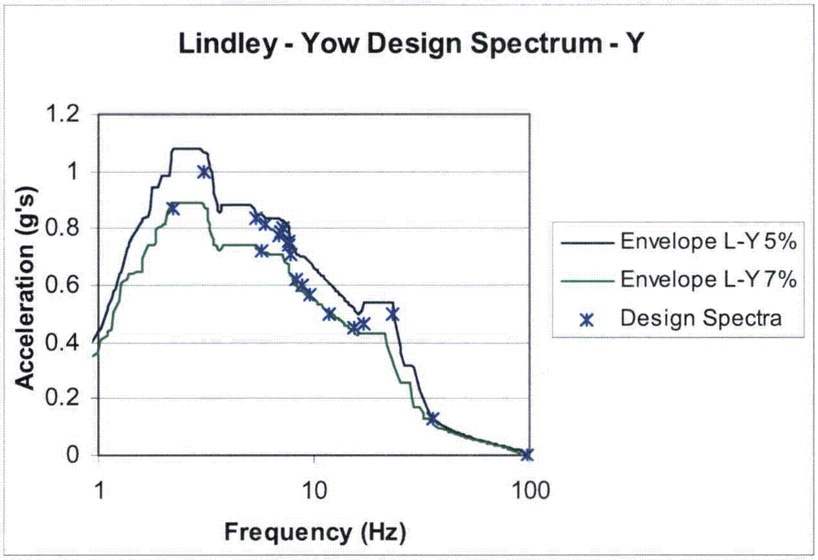


Figure 6.4-3– AP1000 East-West Direction Design Response Spectra

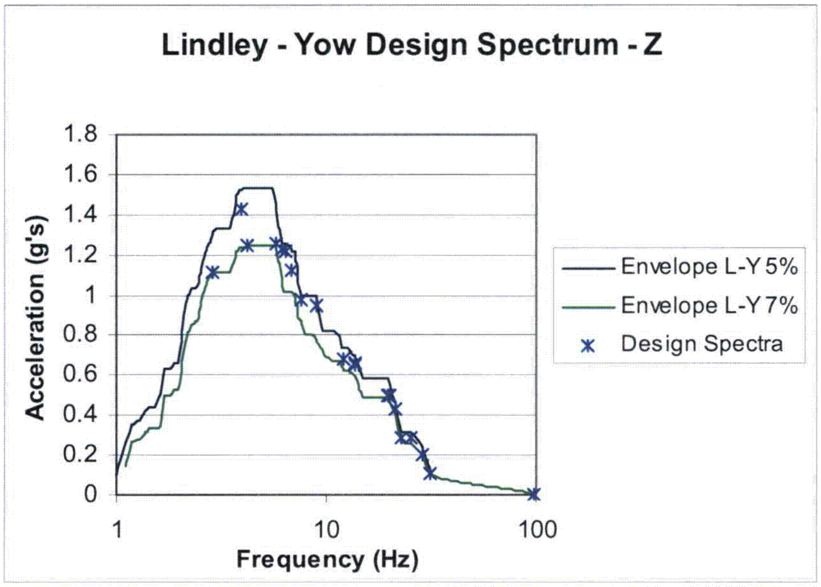


Figure 6.4-4– AP1000 Vertical Direction Design Response Spectra