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Your ref: Docket No. 52-006
Our ref: DCP/NRC2225

August 20, 2008

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

Westinghouse is submitting a response to the NRC request for additional information (RAI) on APP-GW-S2R-010, Technical Report Number 3 (TR03). This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in the response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

A revised response is provided for TR03-010,-015,-017,-021,-022,-032, and -034. These responses complete all requests received to date for Technical Report Number 3. Revision 2 responses for TR03-010,-015,-017,-020, and -022 were provided under DCP/NRC2082 dated January 29, 2008. Revision 1 responses were provided for RAI-TR03-015 and -022 under DCP/NRC1987 dated August 31, 2007. A Revision 1 response for RAI-TR03-010 and a Revision 0 response for RAI-TR03-034 were provided under DCP/NRC1954 dated July 5, 2007. Revision 1 responses for RAI-TR03-017 and -020 were provided under DCP/NRC1942 dated June 15, 2007. A Revision 0 response for RAI-TR03-020 was provided under DCP/NRC1857 dated March 29, 2007. A Revision 0 response for RAI-TR03-022 was provided under DCP/NRC1822 dated January 29, 2007. Revision 0 responses for RAI-TR03-010,-015, and -017 were provided under DCP/NRC1814 dated January 18, 2007.

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
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D063
NRO

/Enclosure

1. Response to Request for Additional Information on Technical Report Number 3

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ENCLOSURE 1

Response to Request for Additional Information on Technical Report Number 3

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-010
Revision: 3

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.

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

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.

RAI Response Number: RAI-TR03-015
Revision: 3

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. 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.

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

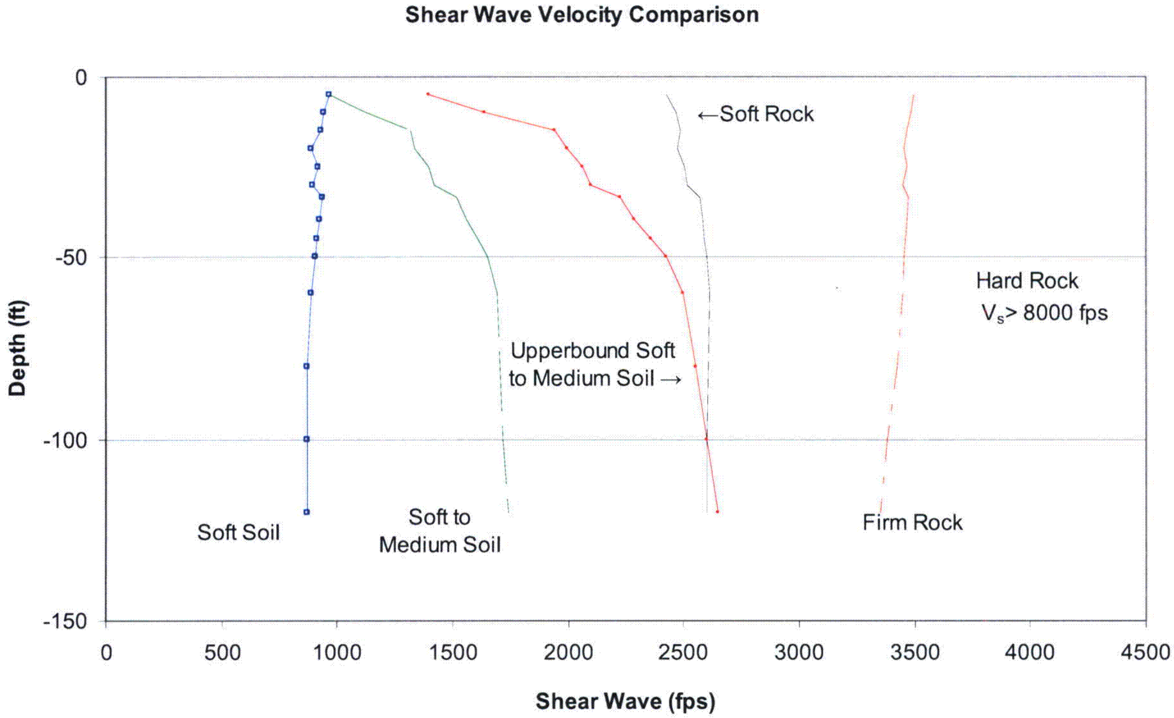


Figure RAI-TR03-15-1-Strain-iterated shear wave velocity profiles

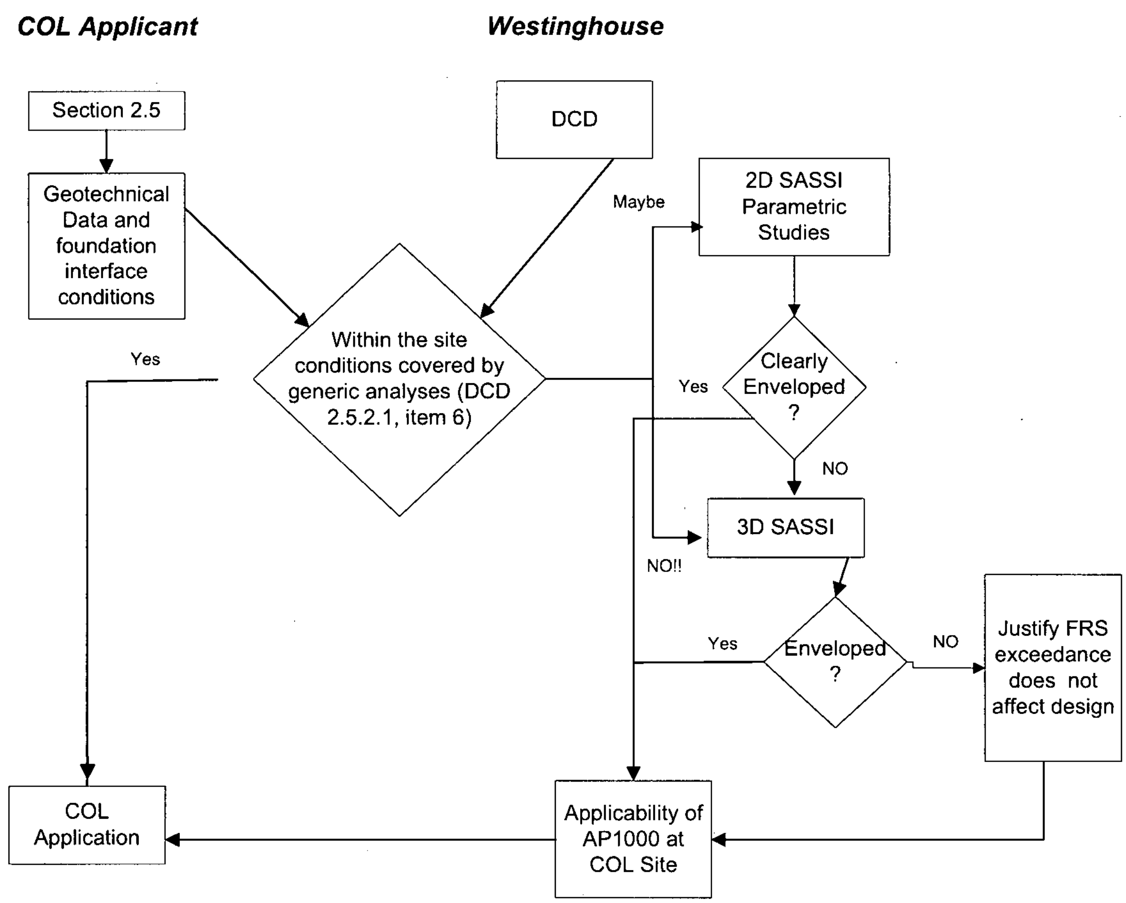


Figure RAI-TR03-15-2-COL Application process for generic design

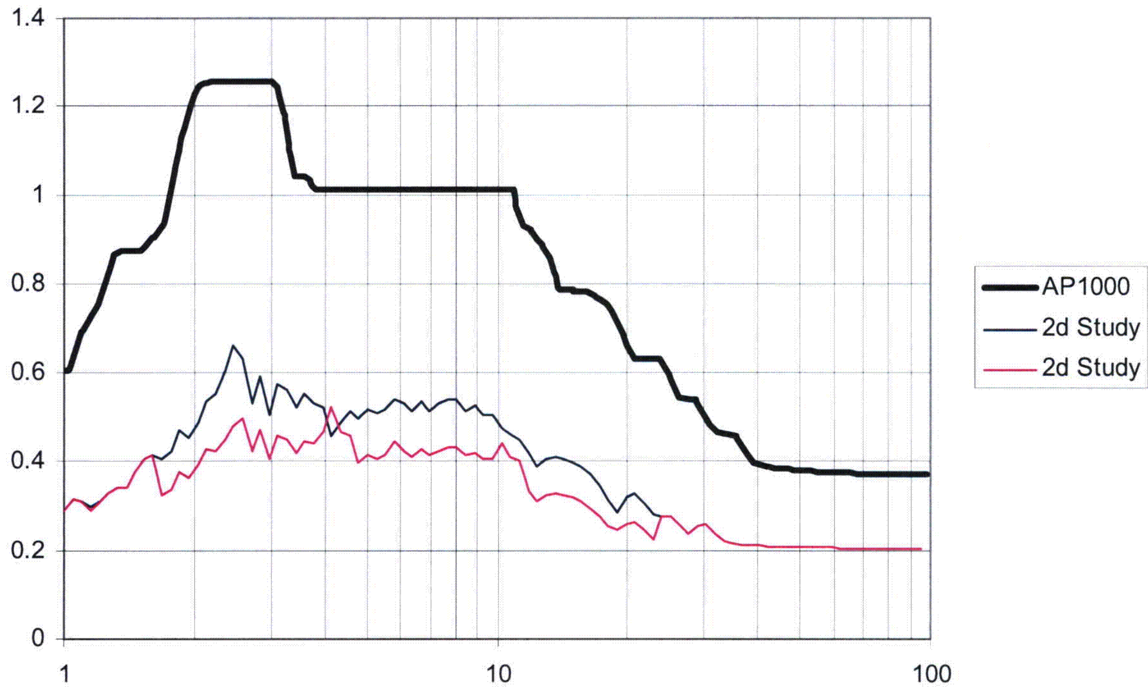


Figure RAI-TR03-15-3- 2D parametric studies demonstrate site is clearly enveloped by 2D design spectra

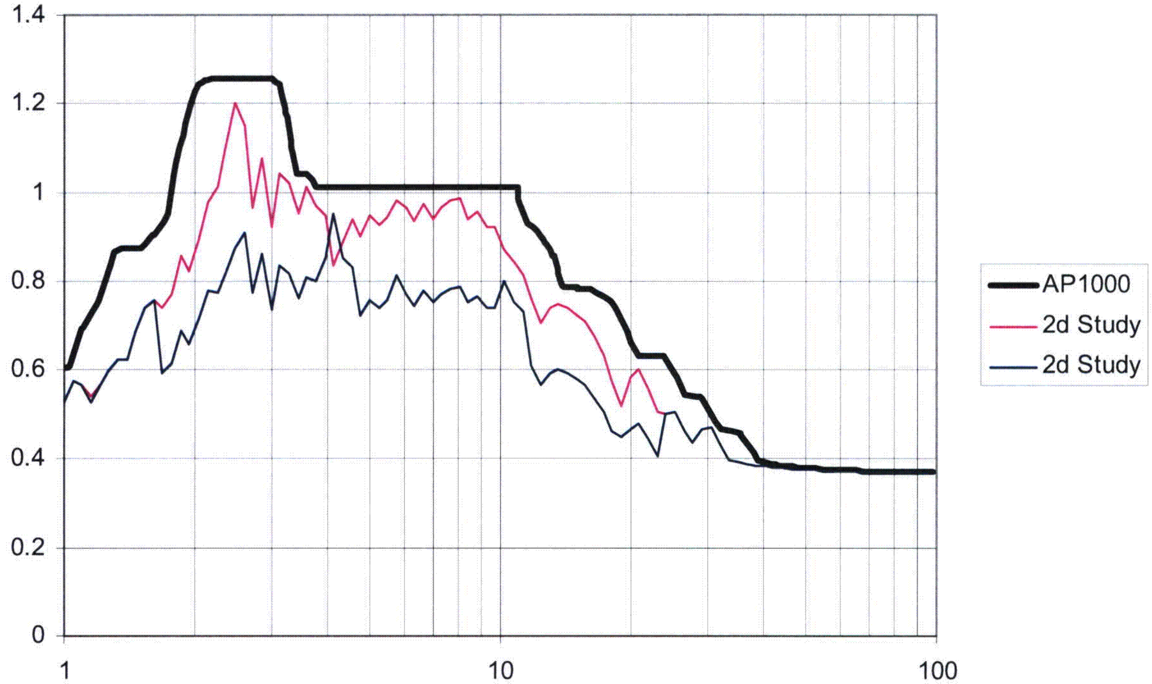


Figure RAI-TR03-15-4- 2D parametric study demonstrate that further studies may be required

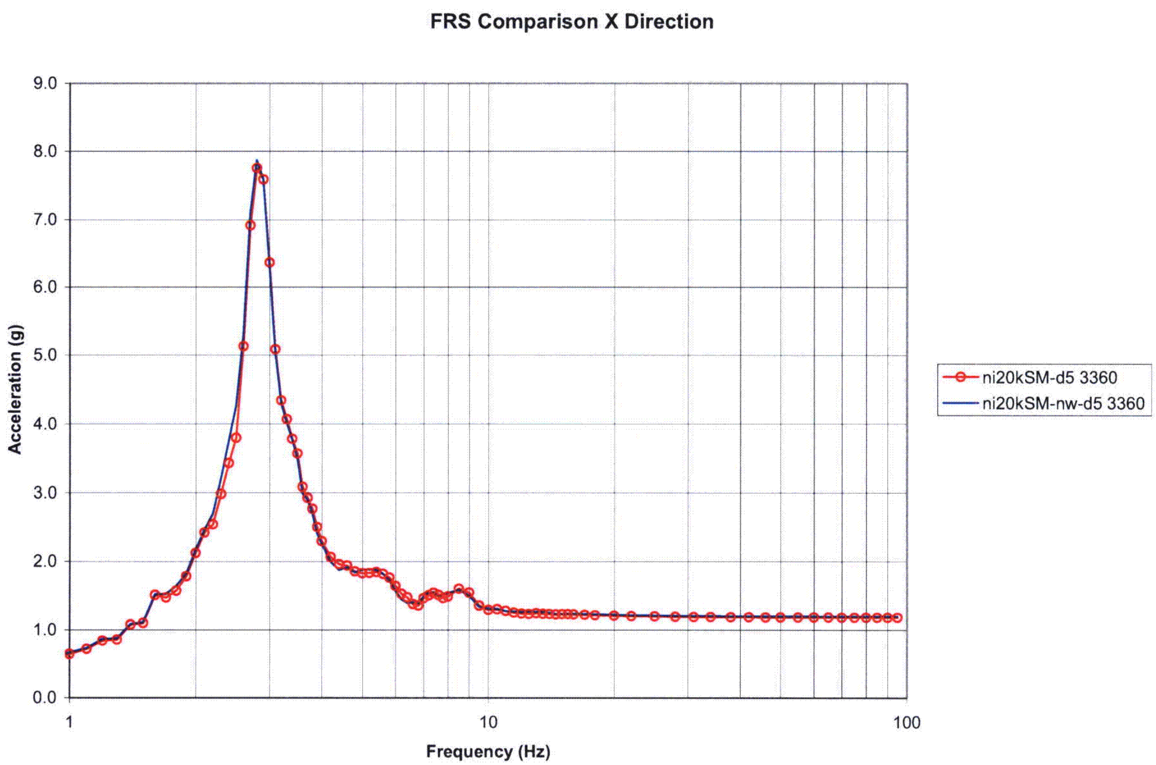


Figure RAI-TR03-15-5- Effect of water table variation in horizontal direction (X)

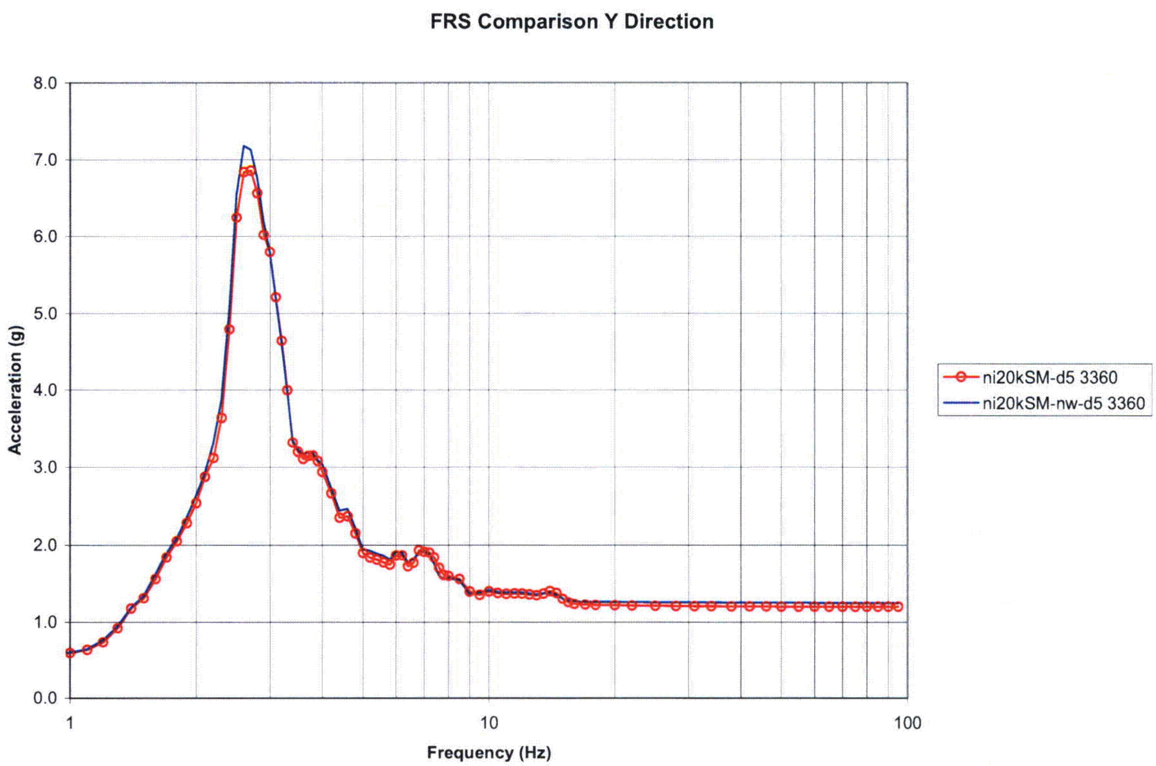


Figure RAI-TR03-15-6-Effect of water table variation in horizontal direction (Y)

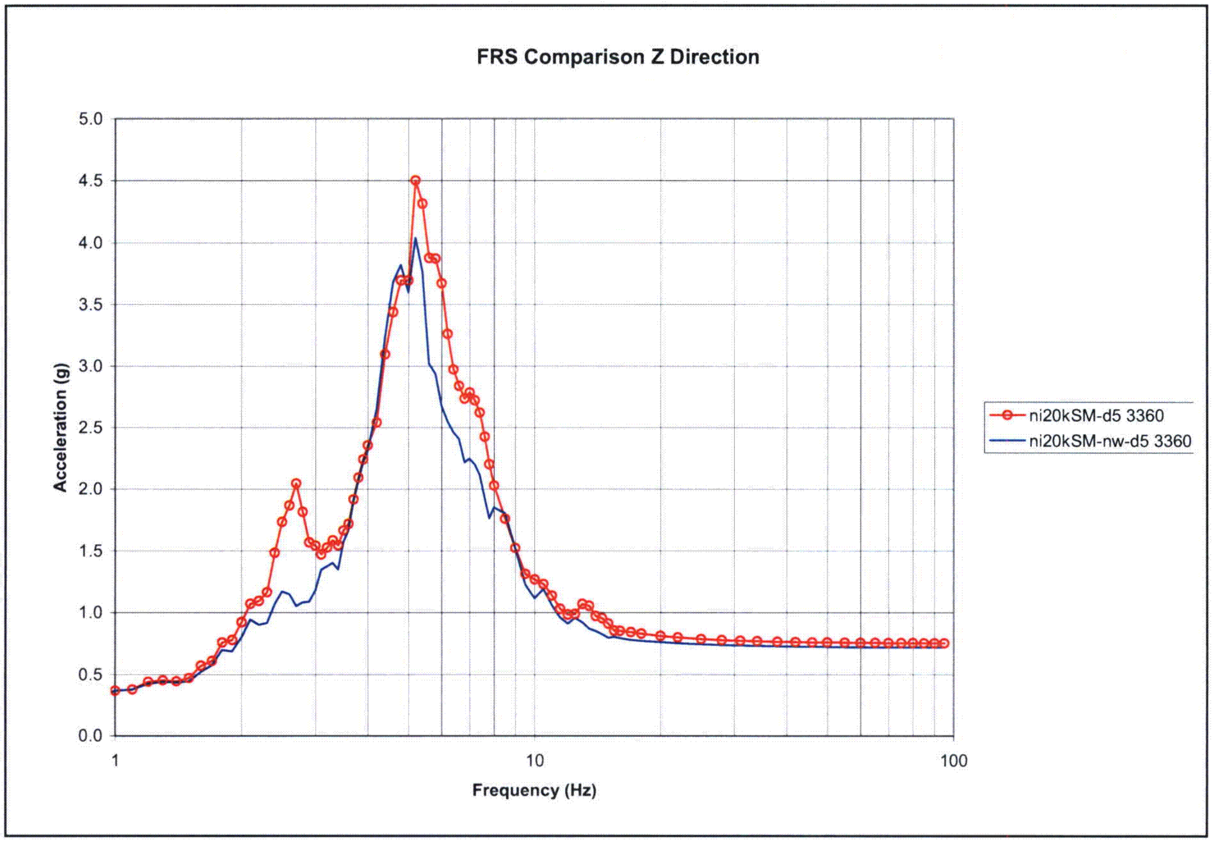


Figure RAI-TR03-15-7- Effect of water table variation in horizontal direction (Z)

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.

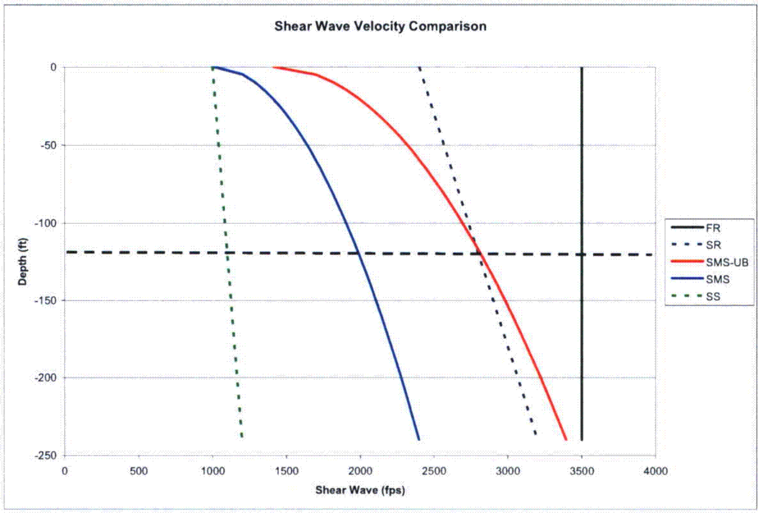
The effect of depth to water table was studied for the soft-to-medium soil case with the depth to base rock of 120 feet. Cases were analyzed for water table at grade, for water table at the foundation level (40 foot depth) and for a dry site. For cases where the water table was below grade, the Poisson's 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.

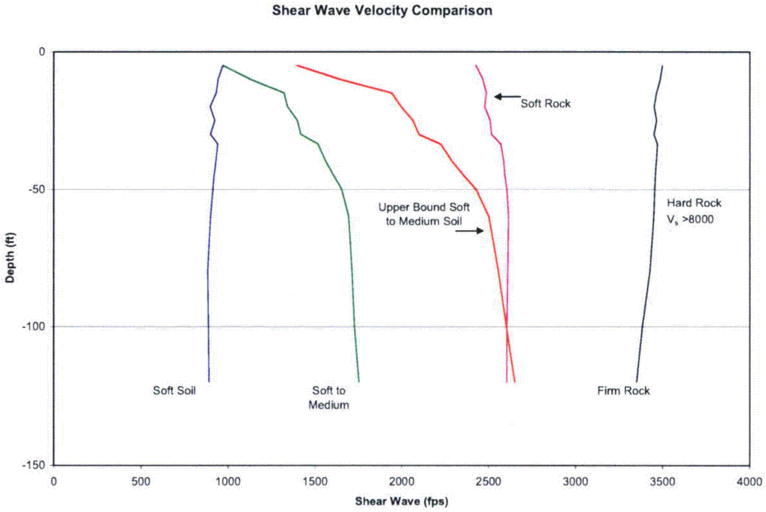
Analyses were also performed for a layered soil profile with step-wise change in shear wave velocity. The step-wise layered soil profile had a layered profile with shear wave velocity of 1000 feet per second to a 40-foot depth, 1800 feet per second between 40-foot and 80-foot depth, and 4300 feet per 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-TR03-017
Revision: 3

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). 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.

<u>See RAI-TR03-010, Rev. 3.</u>

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-TR03-021
Revision: 3

Question:

The staff's review of Section 6.2 identified a number of items in need of clarification or explanation. The staff requests Westinghouse to address the following:

a. The fourth paragraph of page 91 of 154 states "In Section 6.3 a comparison of member forces obtained from seismic static and time history analyses is given." Please confirm that the reference should be to Section 6.4.

b. The last paragraph of page 91 of 154 states "For those local flexible structures that are amplified, apply an additional acceleration to these structures equal to the difference between the average uniform amplified component accelerations and rigid body component equivalent static accelerations. These accelerations are to be considered in local design of the flexible portion of the structure but do not need to be considered in areas of the structure away from the local flexibility. They can be applied in a series of individual load vectors." It is not obvious to the staff how this methodology has been implemented, and whether the effects of increased accelerations on locally flexible structures can be ignored in areas of the structure away from the locally flexible structures. The sum total of all the flexible masses times the corresponding acceleration increments may impose non-negligible additional loads on the overall structure, in the two horizontal directions and in the vertical direction. Therefore, Westinghouse is requested to (1) describe in greater detail the implementation of this methodology, including a numerical example; and (2) provide a quantitative technical basis for the conclusion that the effects of increased accelerations on locally flexible structures can be ignored in areas of the structure away from the locally flexible structures.

c. The top paragraph of Page 93 of 154 states "The vertical equivalent static seismic accelerations at (Shield Bldg) elevations 294.93 ft and 333.13 ft are obtained directly from the maximum time history results by taking the average of locations at opposite ends of a diameter. The vertical accelerations from the 3D finite element model at the shield building edges at these elevations are significantly influenced by the horizontal loading. If they are used for the vertical equivalent accelerations, the horizontal response would be double counted in the vertical direction." It is not obvious to the staff how this methodology has been implemented, and whether it is even appropriate. Therefore, Westinghouse is requested to submit a numerical example, based on elevation 333.13 ft of the Shield Building, to demonstrate the implementation of this methodology. In this example, please also include the vertical acceleration value that would be obtained if this methodology was NOT implemented.

d. Confirm that in Table 6.2-7, the referenced table numbers should be 6.2-3, 6.2-4, 6.2-5, and 6.2-6.

e. In Page 99, under the heading "Seismic Accelerations for Evaluation of Building Overturning," states "The dynamic response of the structure affecting overturning and basemat lift off is primarily the first mode response at about 3 hertz on hard rock. This reduces to about 2.4 hertz on soil sites as shown in the 2D ANSYS and SASSI analyses. The higher auxiliary building accelerations of Table 6.2-2 are not considered in overturning since they are from higher frequency modes greater than 2.4 hertz. Amplified response of individual walls in the Auxiliary Building and the IRWST need not be considered since they are local responses that do not effect overturning." For the overturning analysis, the staff is concerned that the methodology employed may not predict an overall moment on the basemat that envelops the maximum overturning moment for all site conditions. Westinghouse is requested to provide its technical basis for the conservatism of the methodology employed.

Westinghouse Response:

a. It is confirmed that the reference should be Section 6.4 and not Section 6.3.

b. Equivalent static analyses are no longer being used for the design of the auxiliary building, shield building, and containment internal structure. Seismic response spectrum analysis is being performed to develop the seismic design loads for these buildings (see RAI-TR03-036). Therefore, the loads generated include the amplified load due to flexibility and the distribution of this load to the surrounding structures.

   In the NRC meeting of May 19 - 23, 2008 it was requested to demonstrate that the conservatism in the seismic response spectrum analysis using the fixed base 3D NI20 shell model is sufficient to reflect rocking. It was agreed with the NRC at this meeting that it would be sufficient to compare loads at the top of the shield building. Comparison is made of the bending moments in the beams that are at the top of the shield building in Figure RAI-TR03-021-1. In Figure RAI-TR03-021-2 is shown the comparison of the forces and moments in the PCS vertical wall. In all cases the response spectra analysis is conservative when compared to the time history analysis confirming the conservatism in the response spectrum analyses that will account for rocking.

c. Since seismic response spectrum analysis is being used (see RAI-TR03-036), this part of the question is no longer applicable.

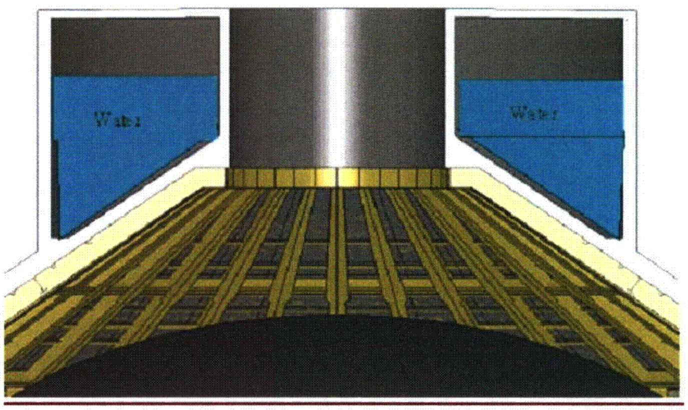
In the NRC meeting of May 19 - 23, 2008 it was requested to show that the NI20 is adequate to reflect the floor flexibility. In Figure RAI-TR03-21-4 is shown a comparison of vertical response spectra (5% damping) associated with the roof in the fuel building area (see Figure-TR03-21-3). The vertical response spectra closely match demonstrating the adequacy of the NI20 model.

d. It is confirmed that in Table 6.2-7, the referenced table numbers should be 6.2-3, 6.2-4, 6.2-5, and 6.2-6. However, it is noted that Section 6.2 will be revised to remove the auxiliary building, shield building, and containment internal structure since equivalent static analysis is no longer used for the design of these buildings.

e. The conservatism of the overall moment on the basemat is addressed in Section 2.6.1.2 of the Nuclear Island Basemat and Foundation report (Reference 1). This part of the RAI should be considered during the review of this report.

Reference:

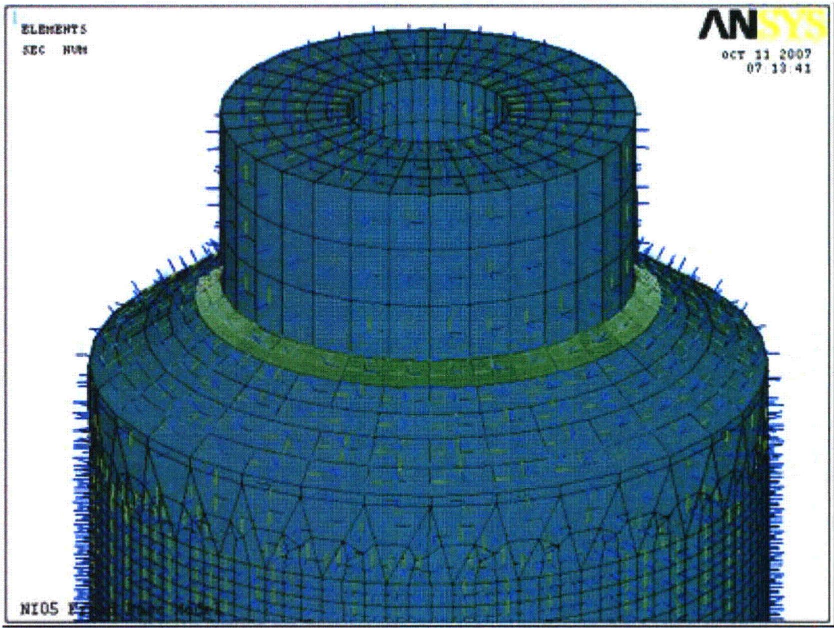
1. APP-GW-GLR-044, Rev 0, "Nuclear Island Basemat and Foundation", October, 2006



Beams Bending Moments:

SASSI Time History: 3887 k-ft
ANSYS Response Spectra: 4761 k-ft

Figure RAI-TR03-021-1 - Beams at the top of the Shield Building



Analysis	TX	TY	TXY	MX	MY	MXY
All Medium CQC	65	53	53	5	30	1
SASSI Time History	59	47	51	4	28	1

Note: Results are in kip/ft and kip-ft /ft

Figure RAI-TR03-021-2 - Loads in PCS Tank Vertical Wall

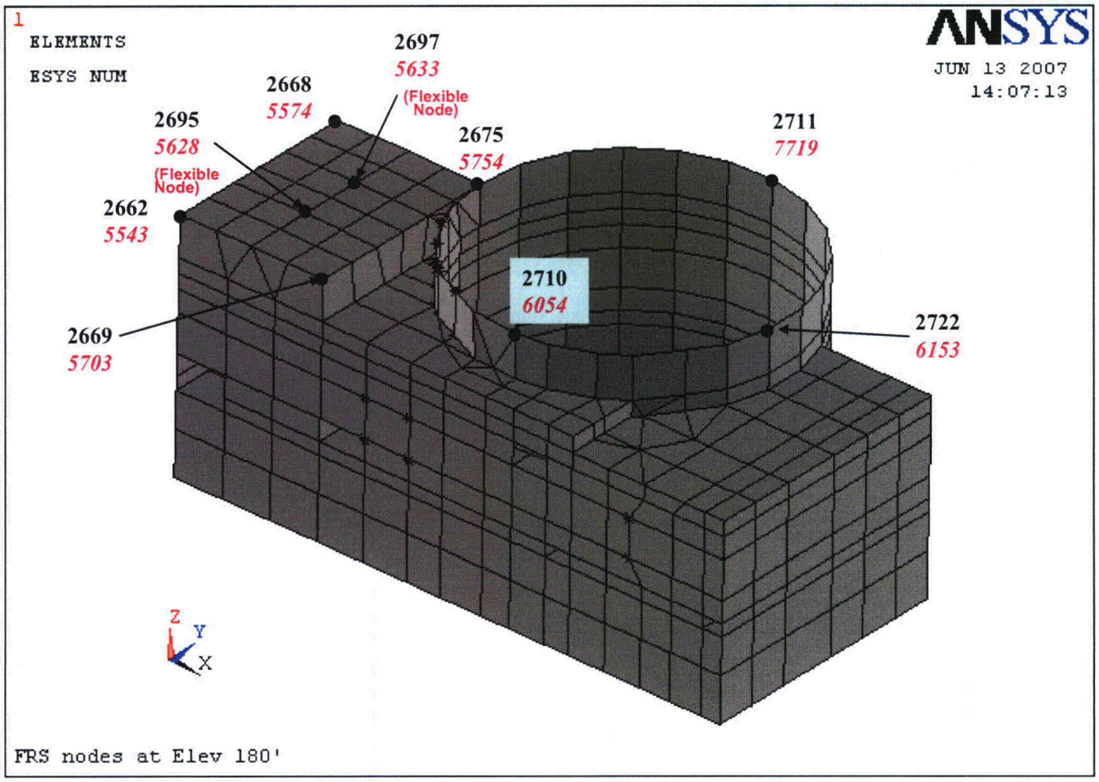


Figure RAI-TR03-021-3 - Shell Model Showing Flexible Node Locations 2697 (NI20) and 5633 (NI10)

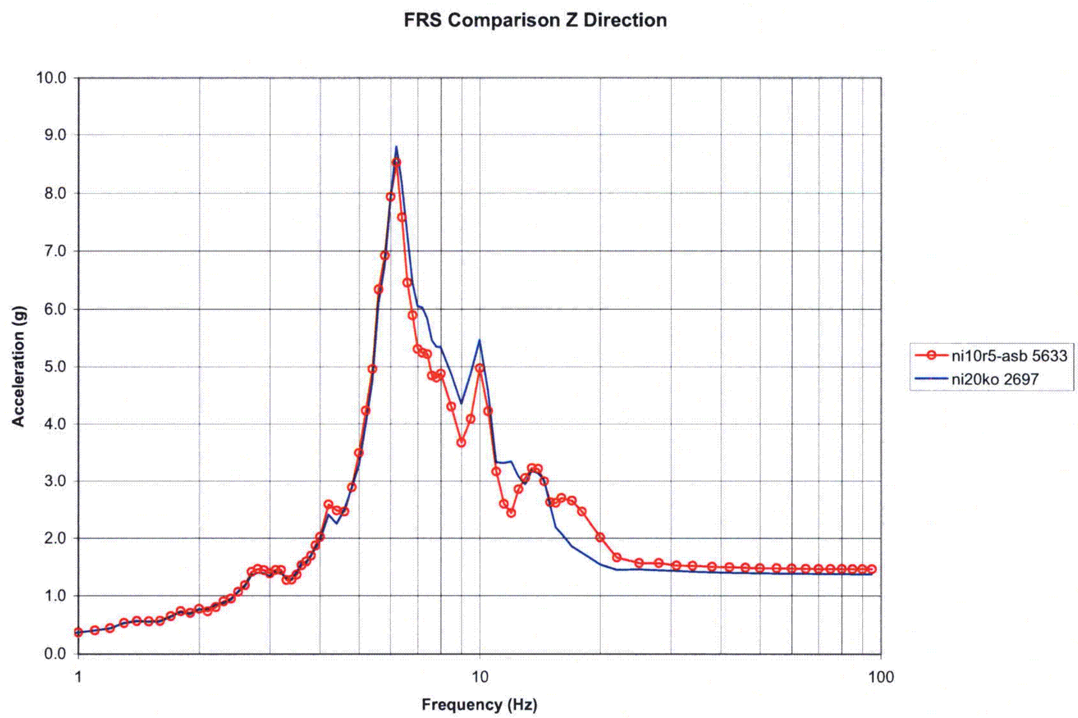


Figure RAI-TR03-021-4 - NI10 and NI20 Vertical Response Spectra Comparisons at Node Locations 2697 (NI20) and 5633 (NI10)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:

Section 6.2 will be revised to remove the auxiliary building, shield building, and containment internal structure since equivalent static analysis is no longer used for the design of these buildings. The comparison of equivalent static results to time history results will be removed from Section 6.4 since seismic response spectrum analysis is being used. The fourth paragraph of page 91 of 154 that states "In Section 6.3 a comparison of member forces obtained from seismic static and time history analyses is given" has been removed. Therefore, there is no need to change the reference to be Section 6.4. Section 6.4 will be revised to add a description of the response spectrum analyses.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-022
Revision: 3

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. During the October 8-12, 2007 audit, the NRC requested that Westinghouse consider adjusting the deflections obtained from SSI analyses for drift in the frequency domain, and not use a baseline correction that subtracts the slope of the relative displacement multiplied by the time from the relative displacement at each time step. Westinghouse has adopted the recommended approach by calculating displacements internally within the SASSI program based on an analytical complex frequency domain approach that uses inverse fast-fourier transforms (FFT) to compute relative displacement histories instead of double numerical integration in the time domain for computing absolute displacement time histories from absolute acceleration time histories. The analytical approach is more accurate than a typical baseline correction (time integration) algorithm.

<u>During the May 19-23 NRC review, Westinghouse was requested to revise Section 6.3, Seismic Displacement Calculation, of the technical report adding more detail of the analysis methodology. The following words are added:</u>

> <u>"The relative displacement time history is calculated using ACS SASSI RELDISP module. The complex acceleration transfer functions (TF) are computed for reference and all selected output nodes. The relative acceleration transfer function is calculated by subtracting the reference node TF from the output node TF. The relative displacement transfer function is obtained by dividing the circular frequency square (ω^2) for each frequency data point. The relative displacement time history is obtained by taking the inverse FFT."</u>

In Figure RAI-TR03-022-01 is presented a comparison for the baseline double integration(old, Dbl Int) method compared to the FFT (new method) shown for the soft to medium soil case at the top of the shield building.

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.

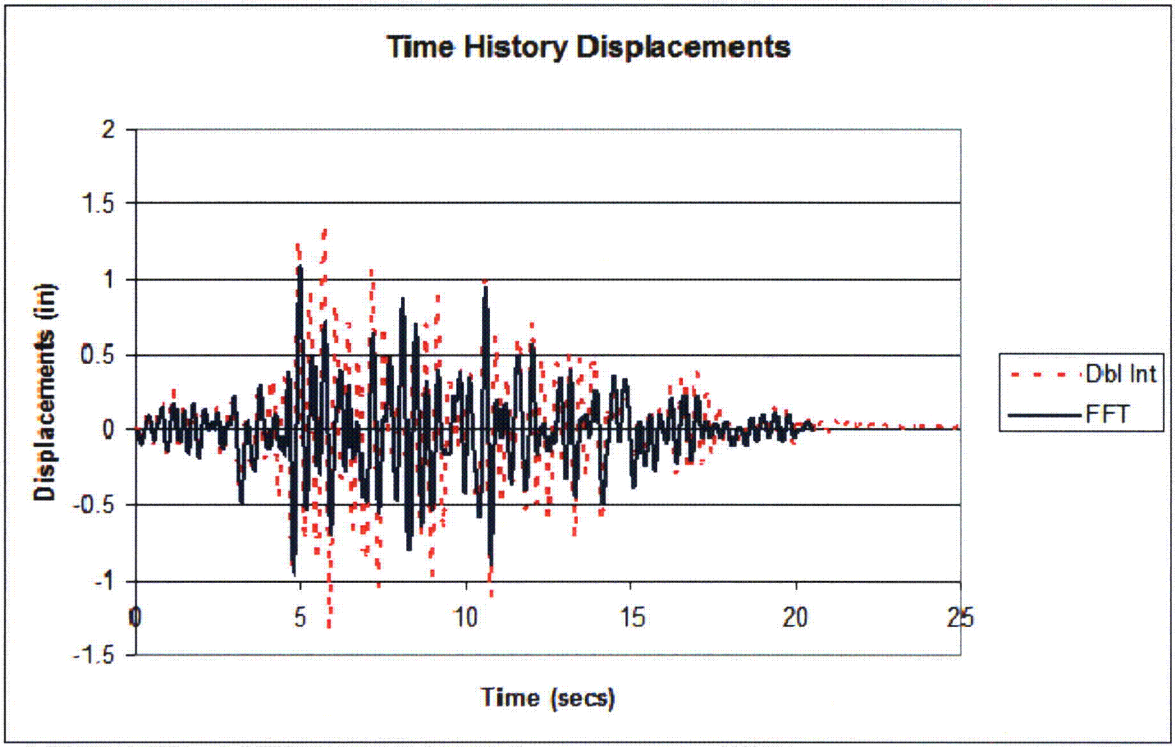


Figure RAI-TR03-022-01 – Comparison of Time History Displacements using Double Integration and Fast Fourier Transforms

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:

Section 6.3 is modified as given in the Westinghouse Response (part a).

6.3 Seismic Displacement Calculation

Westinghouse has adopted the approach that calculates displacements internally within the ACS SASSI program based on an analytical complex frequency domain approach that uses inverse Fast-Fourier Transforms (FFT) to compute relative displacement histories instead of double numerical integration in the time domain that computes absolute displacement time histories from absolute acceleration time histories. ~~The analytical approach is more accurate than a typical baseline correction (time integration) algorithm.~~

The relative displacement time history is calculated using ACS SASSI RELDISP module. The complex acceleration transfer functions (TF) are computed for reference and all selected output nodes. The relative acceleration transfer function is calculated by subtracting the reference node TF from the output node TF. The relative displacement transfer function is obtained by dividing the circular frequency square (ω^2) for each frequency data point. The relative displacement time history is obtained by taking the inverse FFT.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-032
Revision: 3

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.

Based on discussions in the NRC meeting on May 19-23, 2008, revisions to wording in Appendix C of the technical report was modified to state that the NI20 model has higher (conservative) results in the high frequencies compared to the NI10 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	4724	2078	RAI-TR03-032-3	NE Corner	116.50
ASB Corner of Fuel Building Roof at Shield Building	5744	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

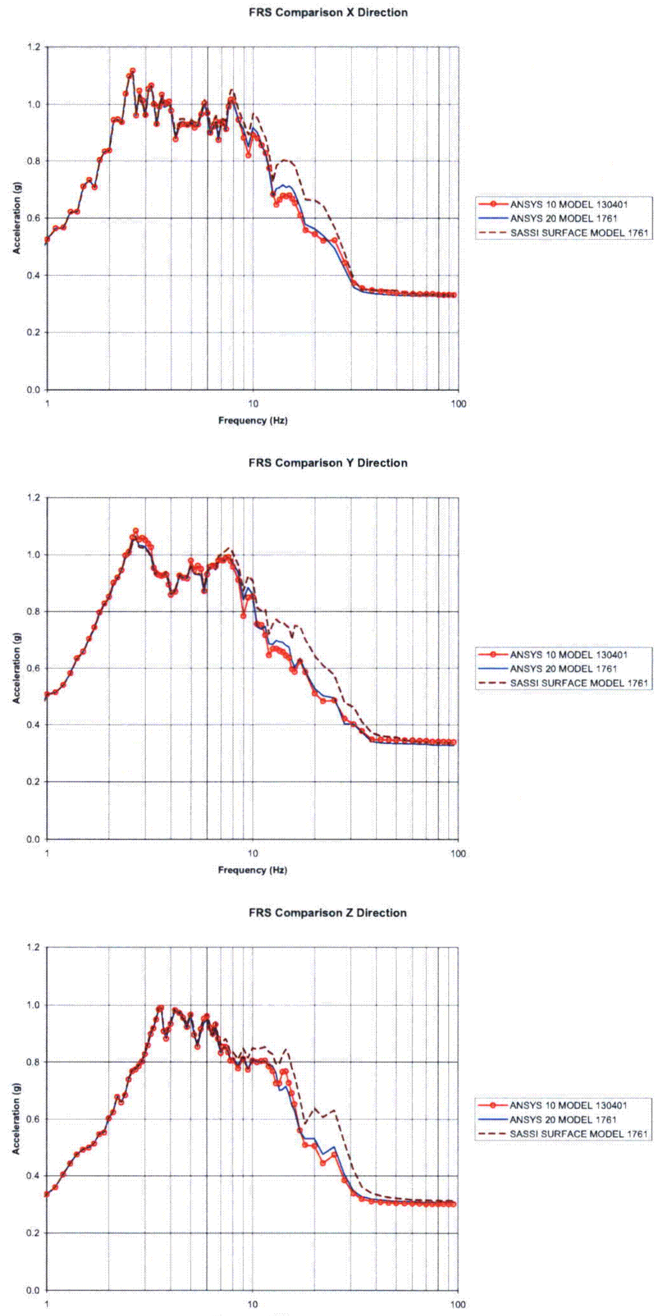


Figure RAI-TR03-032-1 — FRS Comparison at Base of SCV on CIS at RPV Center

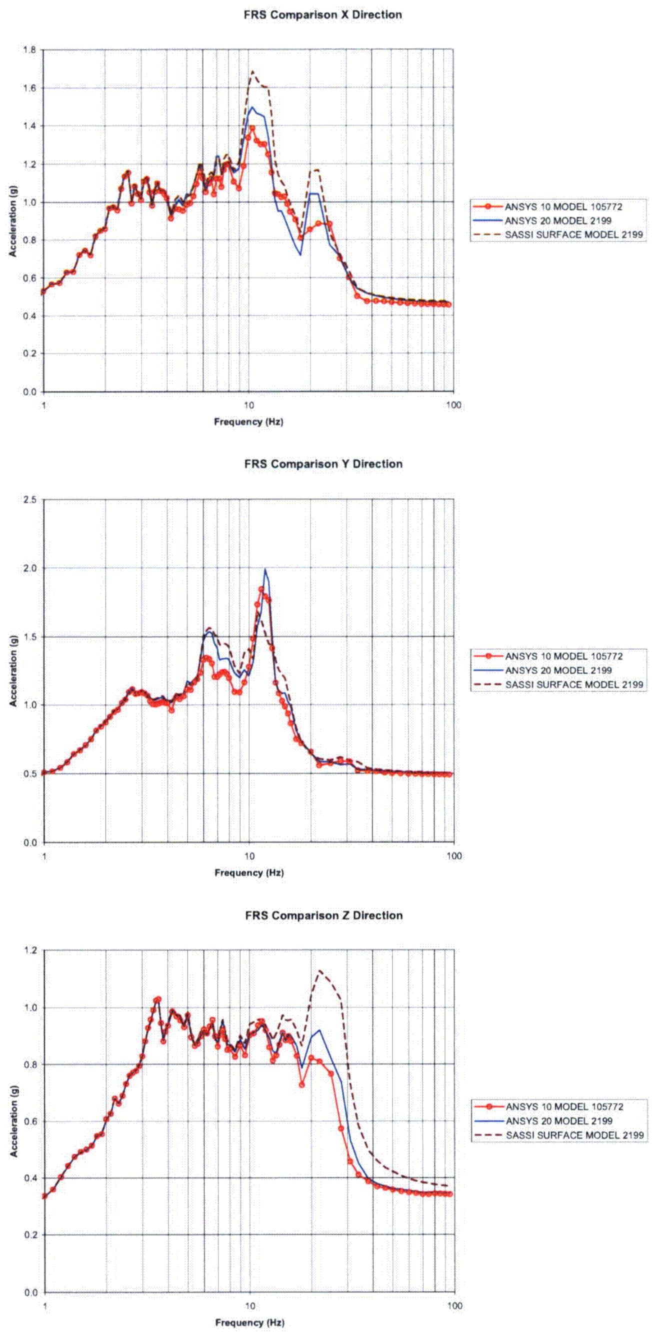


Figure RAI-TR03-032-2 - FRS Comparison at NE Corner of SG West Compartment, El. 134'

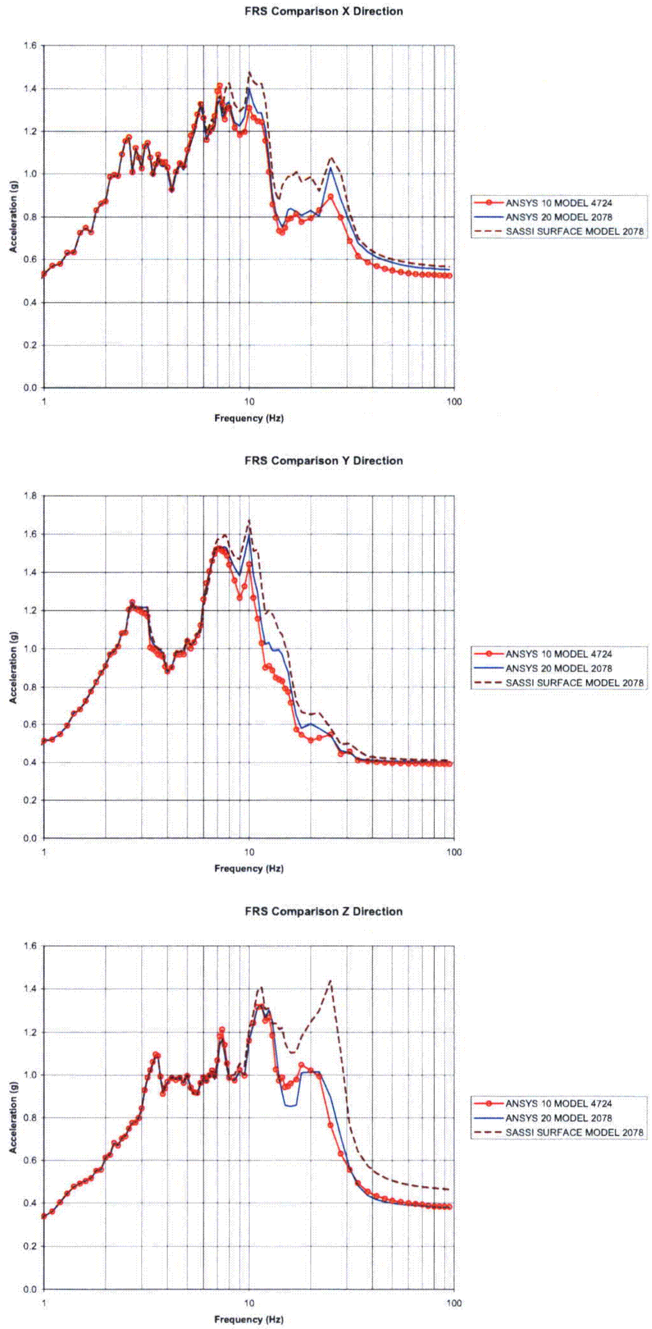


Figure RAI-TR03-032-3 - FRS Comparison at NE Corner of Control Room Floor

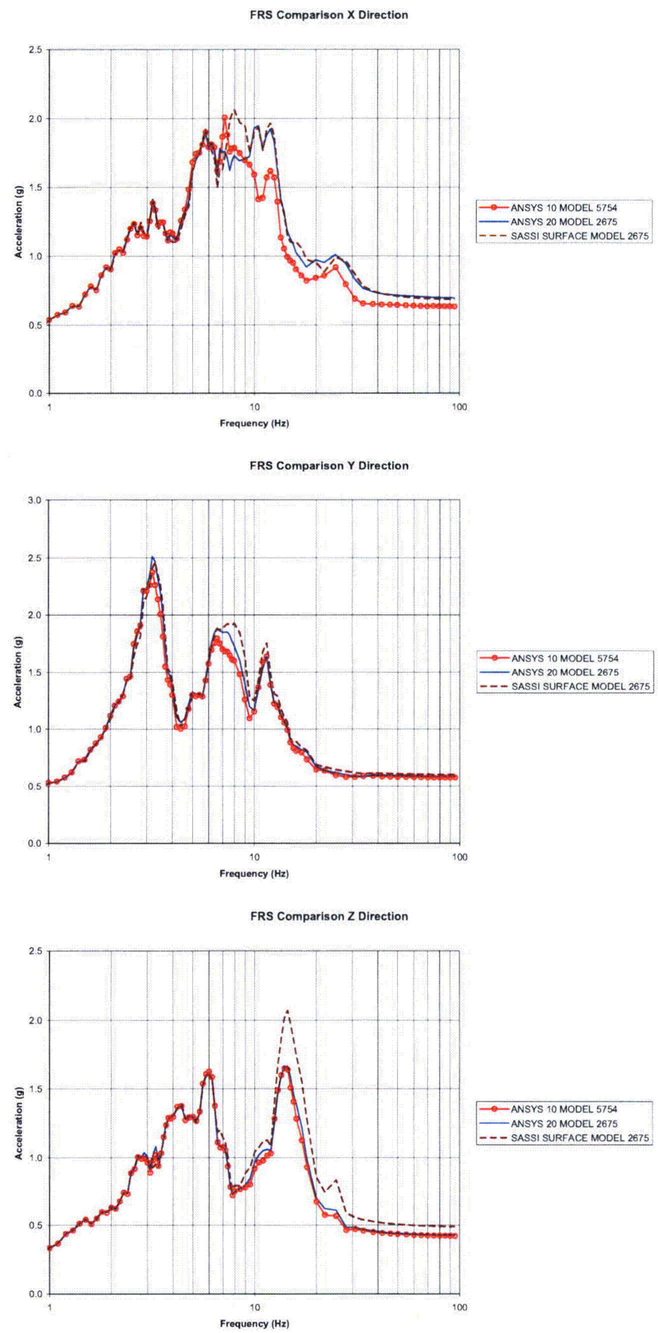


Figure RAI-TR03-032-4 - FRS Comparison at NW Corner of Fuel Building Roof

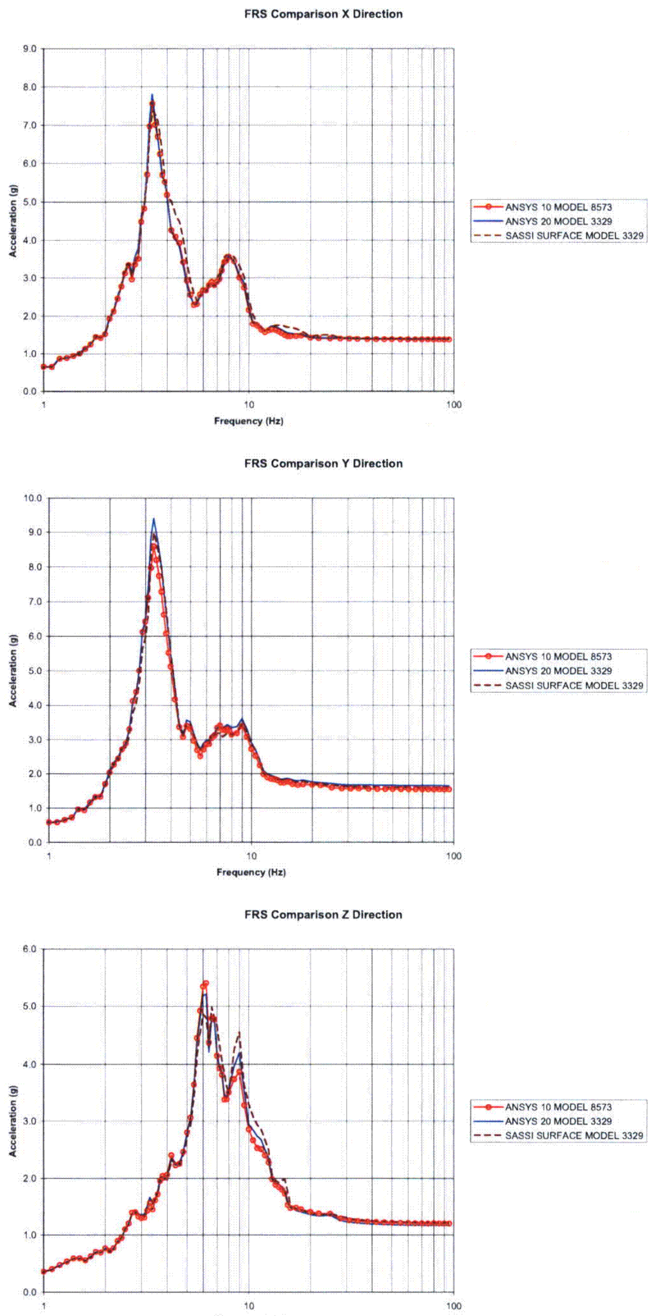


Figure RAI-TR03-032-5 - FRS Comparison at South Side of Shield Building at El. 327.41'

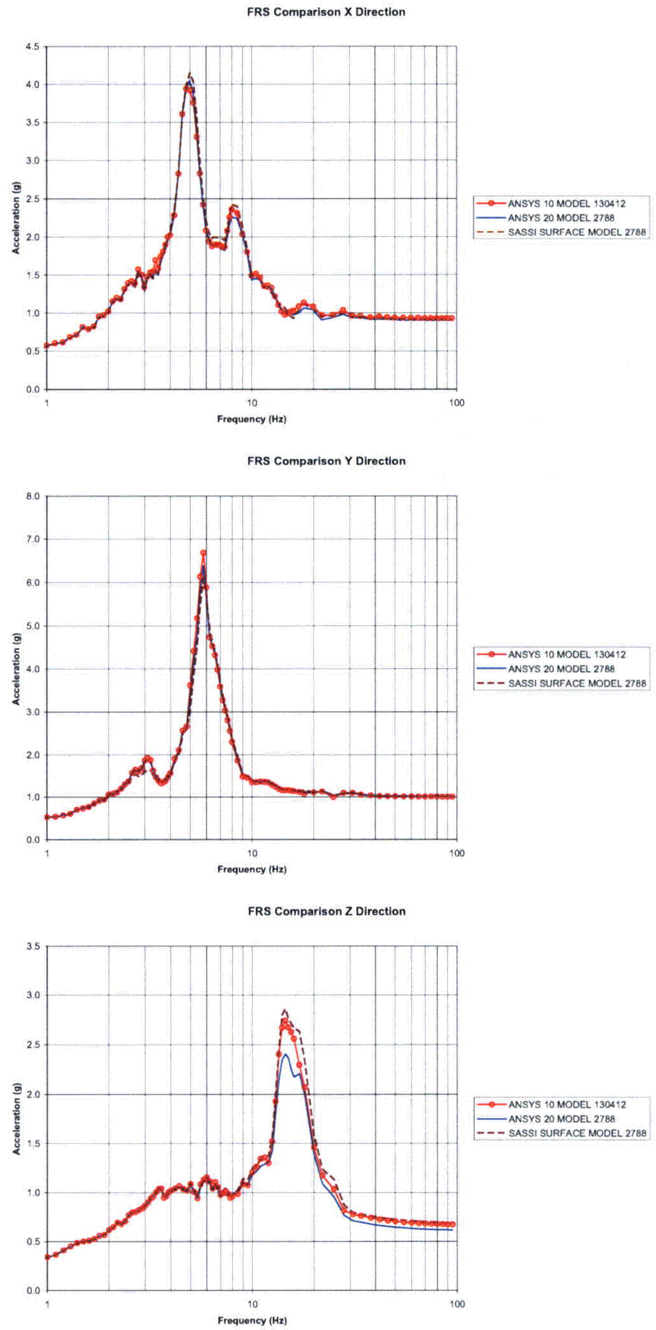


Figure RAI-TR03-032-6 - FRS Comparison on SCV near Polar Crane, El. 224'

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~~ models are compared ~~to~~ using 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~~higher (conservative) 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

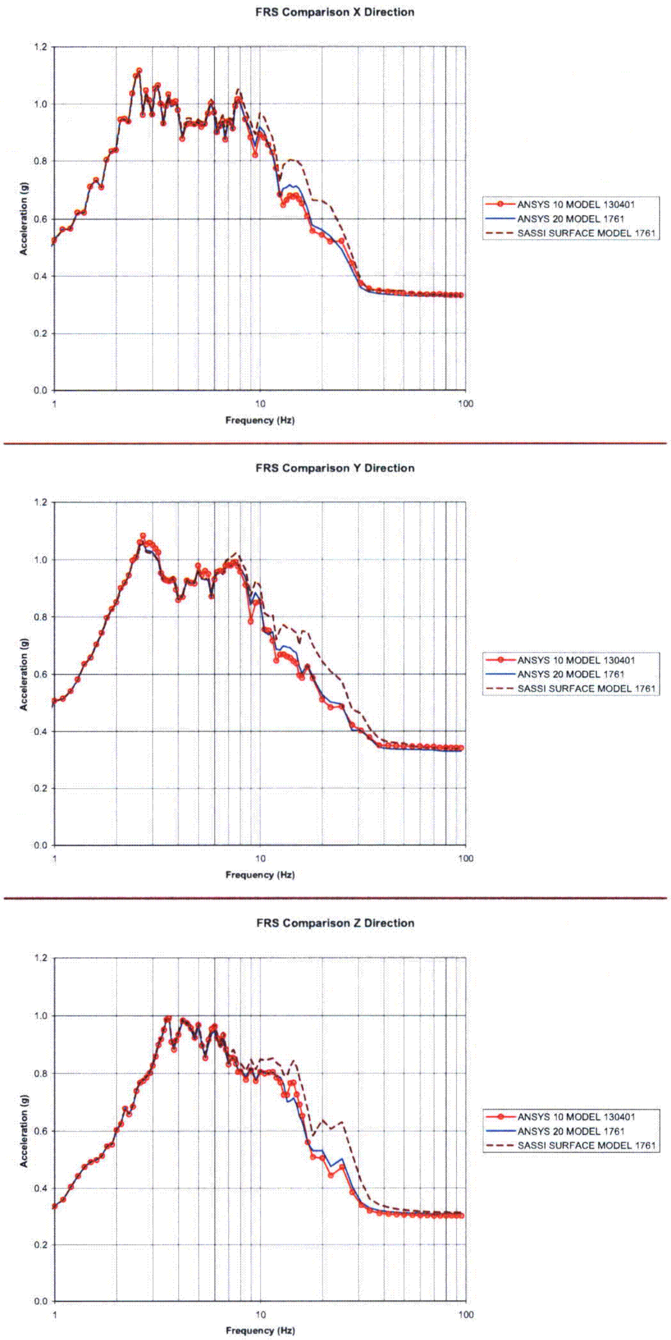


Figure C-1 – FRS Comparison at Base of SCV on CIS at RPV Center

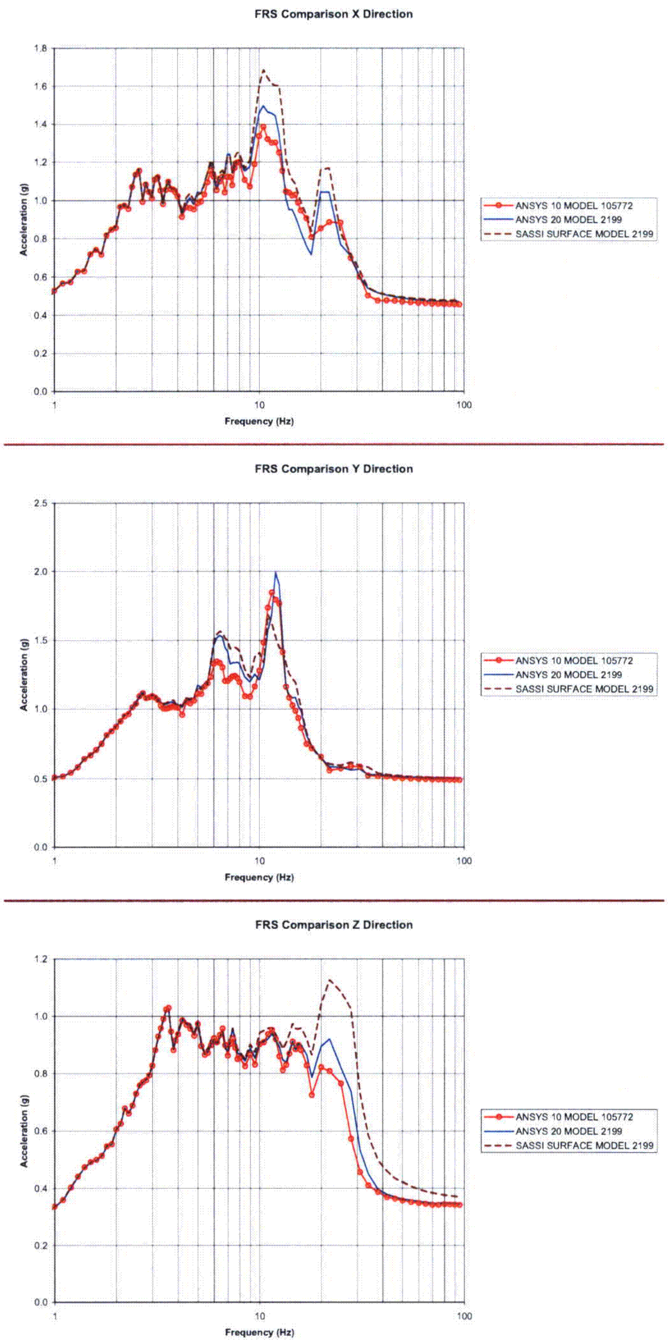


Figure C-2 – FRS Comparison at NE Corner of SG West Compartment, El. 134’

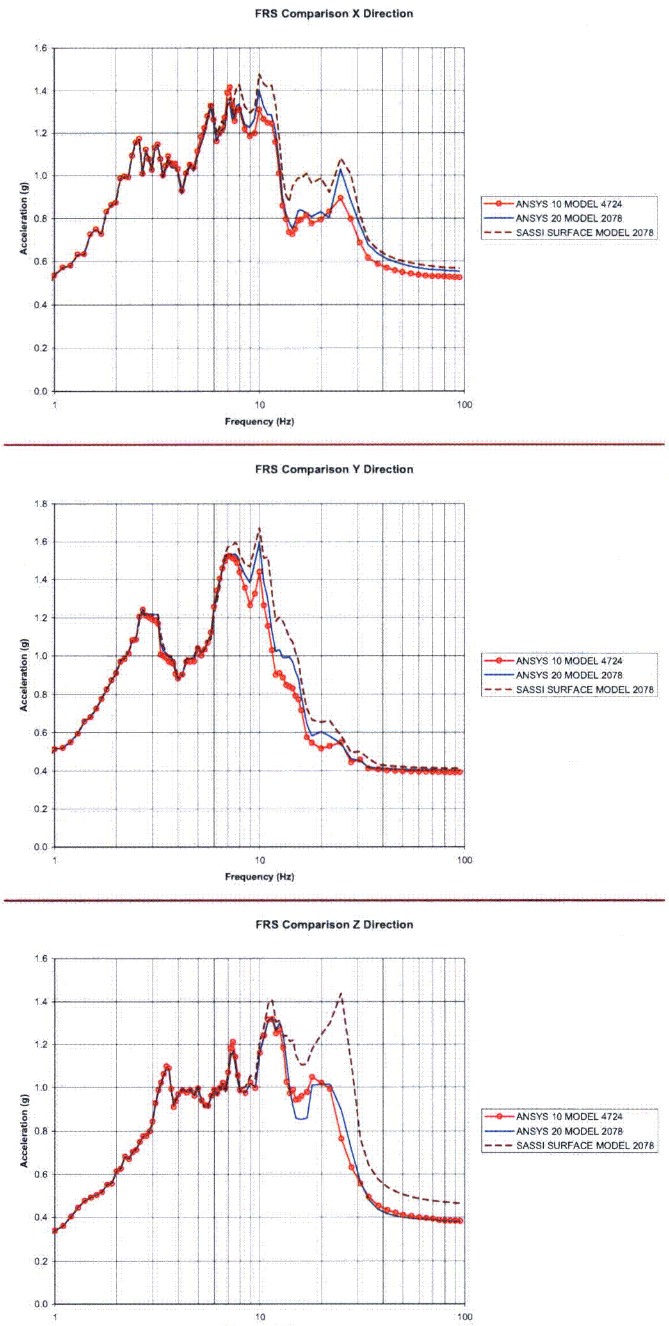


Figure C-3 – FRS Comparison at NE Corner of Control Room Floor

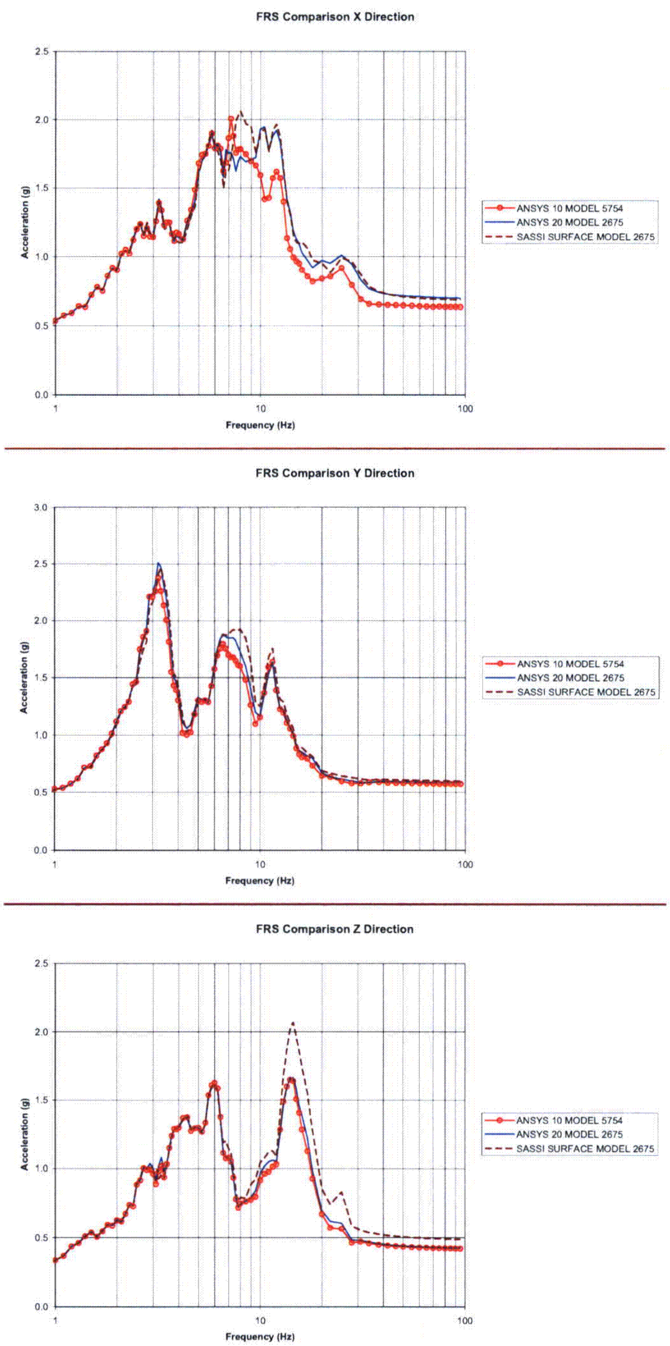


Figure C-4 – FRS Comparison at NW Corner of Fuel Building Roof

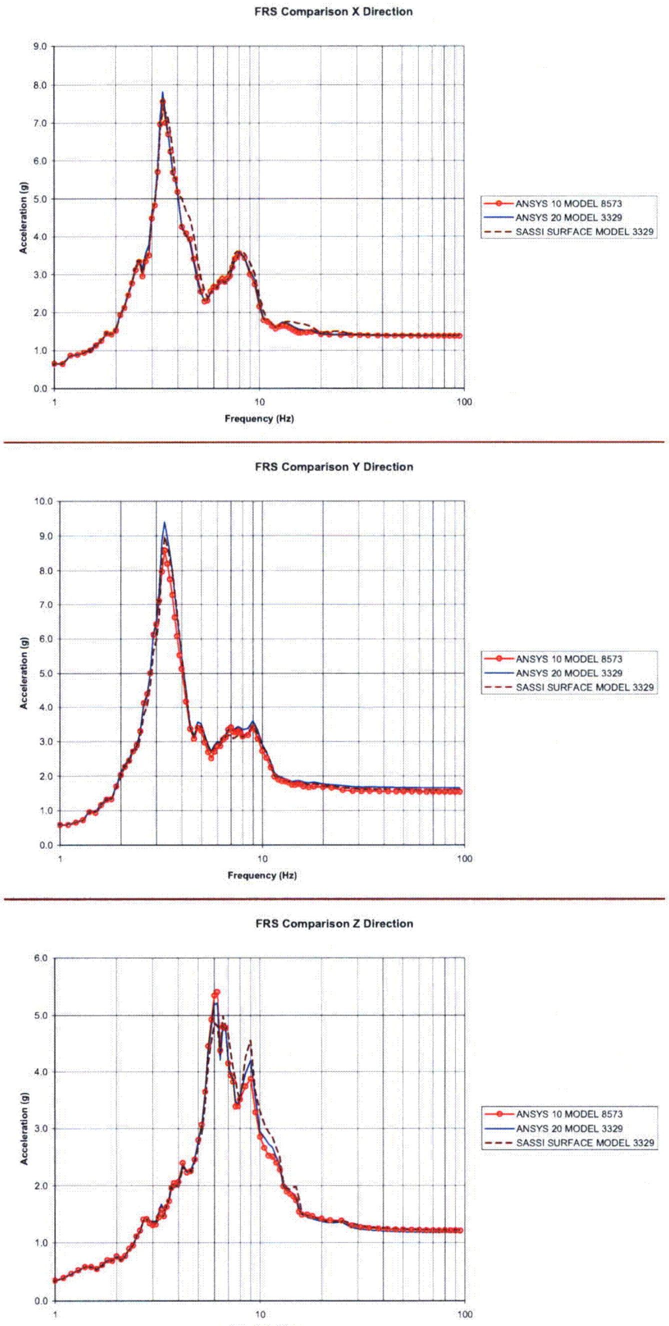


Figure C-5 – FRS Comparison at South Side of Shield Building at El. 327.41'

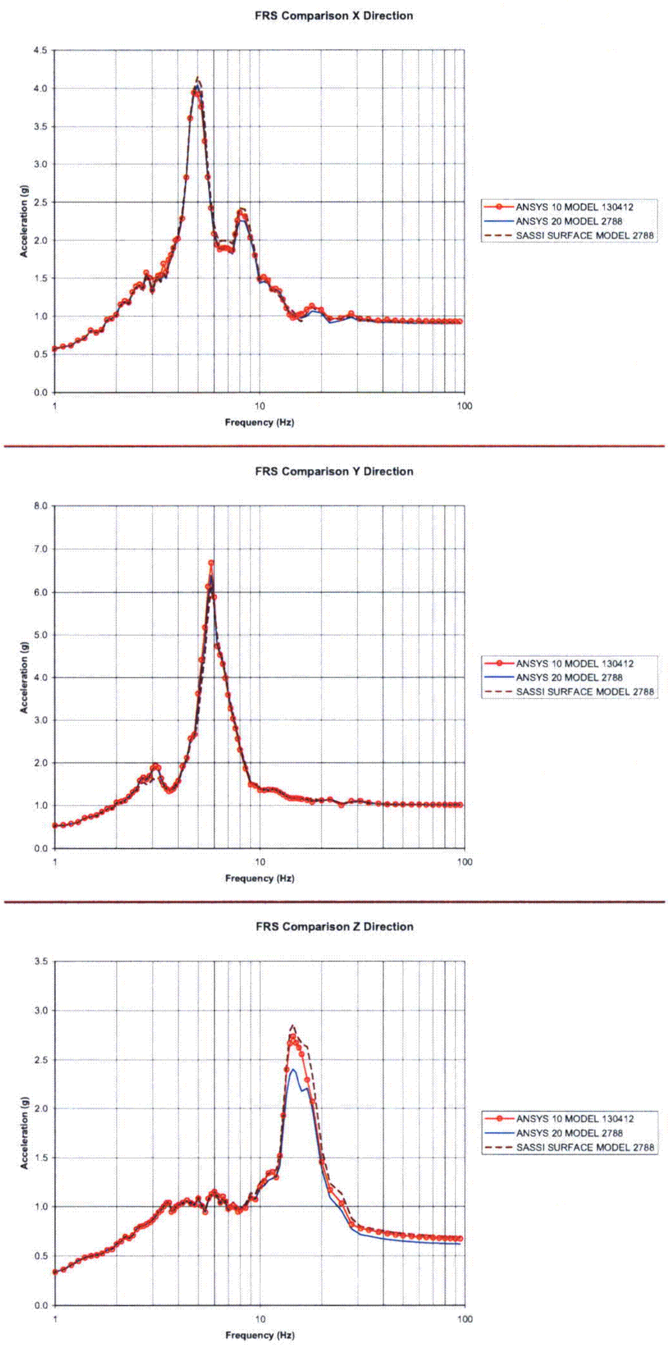


Figure C-6 – FRS Comparison on SCV near Polar Crane, El. 224'

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-034
Revision: 1

Question:

In Table 4.2.4-1, Westinghouse summarized the type of structural models (including models of soil foundation), analysis methods, and computer codes used in the task to extend the NI seismic analysis to soil sites. In the table, Westinghouse stated that the 2D finite element lumped-mass stick model of the auxiliary and shield building was analyzed, using the SASSI code, by time history analysis method for the purpose of parametric studies to establish the bounding generic soil conditions.

However, during its review of the response to RAI's, the staff noted that 2D seismic analyses were apparently used for other purposes also (e.g., 2D ANSYS time history analyses, 2D SASSI analyses based on 3D model (although it is not clear whether a finite element or a stick model was used), and 2D ANSYS time history analysis based on stick model, etc.).

Westinghouse is requested to clarify the information provided in table 4.2.4-1, and update this table as needed, to identify all applications of 2D seismic analysis and how results were utilized.

Westinghouse Response:

Table 4.2.4-1 has been revised to show the additional seismic models and analyses identified in this RAI. The revision to the table also adds the polar crane models and the containment vessel shell model included in the response to RAI-TR03-020, Rev 1.

In the NRC meeting on May 19 – 23 revisions to Table 4.2.4-1 were discussed. These changes are made to tables in Appendix 3G of the DCD and the Technical Report.

Design Control Document (DCD) Revision:

~~None~~Revise Table 3G.1-1 as shown below.

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

SUMMARY OF MODELS AND ANALYSIS METHODS

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
3D (ASB) solid-shell model	-	ANSYS	Creates the finite element mesh for the ASB finite element model
3D (CIS) solid-shell model	-	ANSYS	Creates the finite element mesh for the CIS finite element model
3D finite element model including shield building roof (ASB10)	-	ANSYS	ASB portion of NI10
3D finite element model including dish below containment vessel	-	ANSYS	CIS portion of NI10
3D finite element shell model of nuclear island [NI05](coupled auxiliary/shield building shell model, containment internal structures, steel containment vessel , polar crane, RCL, pressurizer and CMTs)	Mode superposition time history analysis and response spectra analysis	ANSYS	Performed for hard rock profile for ASB with CIS as superelement and for CIS with ASB as superelement. Floor and wall flexibility included in models. To develop time histories for generating plant design floor response spectra for nuclear island structures. To obtain maximum absolute nodal accelerations (ZPA) to be used in equivalent static analyses. To obtain maximum displacements relative to basemat.

3D finite element coarse shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel , polar crane, RCL, and pressurizer)	Mode superposition time history analysis	ANSYS	Performed for hard rock profile for comparisons against more detailed NI10 model

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

SUMMARY OF MODELS AND ANALYSIS METHODS

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

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

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

SUMMARY OF MODELS AND ANALYSIS METHODS

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
3D lumped mass stick model of the RCL	-	ANSYS	Used in the NI10 and NI20 models
3D lumped mass stick model of the Pressurizer	-	ANSYS	Used in the NI10 and NI20 models
3D lumped mass stick model of the CMT	-	ANSYS	Used in the NI10 model
3D lumped mass detailed model of the polar crane	Modal analysis	ANSYS	To obtain dynamic properties. Used with 3D finite element shell model of the containment vessel
3D lumped mass simplified (single beam) model of the polar crane.	-	ANSYS	Used in the NI10 and NI20 models

3D finite element shell model of containment vessel	Mode superposition time history analysis Equivalent static analysis	ANSYS	Used with detailed polar crane model to obtain acceleration response of equipment hatch and airlocks. To obtain shell stresses in vicinity of the large penetrations of the containment vessel
3D finite element refined shell model of nuclear island (NI05)	Equivalent static non-linear analysis using accelerations from time history analyses Response spectrum analysis with seismic input enveloping all soil cases	ANSYS	To obtain SSE member forces for the nuclear island basemat To obtain SSE member forces for the auxiliary and shield building and the containment internal structures. To obtain maximum displacements relative to basemat
3D finite element coarse shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel, polar crane, RCL, and pressurizer	Mode superposition time history analysis with seismic input enveloping all soil cases	ANSYS	To obtain total basemat reactions for overturning and stability evaluation. To obtain total basemat reactions for comparison to reactions in equivalent static linear analyses using NI05 model.

PRA Revision:
None

Technical Report (TR) Revision:

~~Revise Table 4.2.4-1 to include the 2D models~~Table 4.2.4-1 is revised as shown below.

Table 4.2.4-1- Summary of Models and Analysis Methods

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
3D (ASB) solid-shell model	-	ANSYS	Creates the finite element mesh for the ASB finite element model
3D (CIS) solid-shell model	-	ANSYS	Creates the finite element mesh for the CIS finite element model
3D finite element model including shield building roof (ASB10)	-	ANSYS	ASB portion of NI10
3D finite element model including dish below containment vessel	-	ANSYS	CIS portion of NI10
3D finite element shell model of nuclear island [NI05] (coupled auxiliary/shield building shell model, containment internal structures, steel containment vessel , polar crane, RCL, pressurizer and CMTs)	Mode superposition time history analysis and response spectra analysis	ANSYS	Performed for hard rock profile for ASB with CIS as superelement and for CIS with ASB as superelement. Floor and wall flexibility included in models. To develop time histories for generating plant design floor response spectra for nuclear island structures. To obtain maximum absolute nodal accelerations (ZPA) to be used in equivalent static analyses. To obtain maximum displacements relative to basemat.
3D finite element coarse shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel , polar crane, RCL, and pressurizer)	Mode superposition time history analysis	ANSYS	Performed for hard rock profile for comparisons against more detailed NI10 model
Finite element lumped mass stick model of nuclear island	Time history analysis	SASSI	Performed 2D parametric soil studies to help establish the bounding generic soil conditions.

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
Finite element lumped mass stick model of nuclear island	Direct Integration time history analysis	ANSYS	Performed 2D linear and non-linear seismic analyses to evaluate effect of lift off on Floor Response Spectra and bearing.
3D shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel, polar crane, RCL, and pressurizer)	Time history analysis	SASSI	Performed for the five soil profiles of firm rock, soft rock, upper bound soft to medium soil, soft to medium soil, and soft soil. To develop time histories for generating plant design floor response spectra for nuclear island structures. To obtain maximum absolute nodal accelerations (ZPA) to be used in equivalent static analyses To obtain maximum displacements relative to basemat. To obtain maximum member forces and moments in selected elements for comparison to equivalent static results.
3D shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel	Mode superposition time history analysis	ANSYS	Performed to develop loads for seismic stability evaluation.
3D shell of revolution model of steel containment vessel	Modal analysis; Equivalent static analysis using accelerations from time history analyses	ANSYS	To obtain dynamic properties. To obtain SSE stresses for the containment vessel.
3D lumped mass stick model of the SCV	-	ANSYS	Used in the NI10 and NI20 models
3D lumped mass stick model of the RCL	-	ANSYS	Used in the NI10 and NI20 models
3D lumped mass stick model of the Pressurizer	-	ANSYS	Used in the NI10 and NI20 models
3D lumped mass stick	-	ANSYS	Used in the NI10 model

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
model of the CMT			
3D lumped mass detailed model of the polar crane	Modal analysis	ANSYS	To obtain dynamic properties. Used with 3D finite element shell model of the containment vessel
3D lumped mass simplified (single beam) model of the polar crane	-	ANSYS	Used in the NI10 and NI20 models
3D finite element shell model of containment vessel [1]	Mode superposition time history analysis Equivalent static analysis	ANSYS	Used with detailed polar crane model to obtain acceleration response of equipment hatch and airlocks. To obtain shell stresses in vicinity of the large penetrations of the containment vessel
3D finite element refined shell model of nuclear island (NI05)	Equivalent static non-linear analysis using accelerations from time history analyses; response spectrum analysis	ANSYS	To obtain SSE member forces for the nuclear island basemat To obtain SSE member forces for the auxiliary and shield building and the containment internal structures. To obtain maximum displacements relative to basemat
3D finite element coarse shell model of auxiliary and shield building and containment internal structures [NI20] (including steel containment vessel, polar crane, RCL, and pressurizer	Mode superposition time history analysis with seismic input enveloping all soil cases	ANSYS	To obtain total basemat reactions for overturning and stability evaluation. To obtain total basemat reactions for comparison to reactions in equivalent static linear analyses using NI05 model.

Note: 1) The 3D finite element shell model of the containment vessel is described in report APP-GW-GLR-005, "Containment Vessel Design Adjacent to Large Penetrations."