Westinghouse

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U.S. Nuclear Regulatory Commission
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Your ref: Project Number 740
Our ref: DCP/NRC1954

July 5, 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 the 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 TR3-7, TR3-10, and TR3-31. Revision 0 of RAI-TR03-007 was transmitted to the NRC via DCP/NRC1822 on January 29, 2007. Revision 0 of RAI-TR03-010 and RAI-TR03-031 were sent on January 18, 2007 via DCP/NRC1814. In addition, reponses are provided for TR3-34 and TR3-35 transmitted in NRC letter dated May 15, 2007 from Mike Miernicki to Andrea Sterdis, Subject: Westinghouse AP1000 Combined License (COL) Pre-application Technical Report 03 – Request for Additional Information (TAC No. MD2358).

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,

D. F. Hakling for

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

00195psa.doc

D063
D079
NRO

/Attachment

1. "Oath of Affirmation," dated July 5, 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
	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
	R. Orr	-	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

D. S. Lipman, being duly sworn, states that he is Senior Vice President, Nuclear Power Plants, 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.

D. S. Lipman
Senior Vice President
Nuclear Power Plants

Subscribed and sworn to
before me this 5 day
of July 2007.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Katherine W. McGinnett, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Jan. 4, 2009
Member, Pennsylvania Association of Notaries

Notary Public

ENCLOSURE 1

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

RAI-TR03-007, Revision 1
RAI-TR03-010, Revision 1
RAI-TR03-031, Revision 1
RAI-TR03-034, Revision 0
RAI-TR03-035, Revision 0

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-007
Revision: 1~~0~~

Question:

The fourth sentence of the fourth paragraph in Page 10 of 154 states that since the water in the PCCS tank responds at a very low frequency (sloshing) and does not affect building response, the PCCS tank water mass is reduced to exclude the low frequency water sloshing mass. The staff requests Westinghouse to provide its detailed technical basis, with references and/or numerical results, for excluding the low-frequency, water sloshing mass. Westinghouse also needs to quantify the percentage of water mass in the PCCS tank that was excluded.

Westinghouse Response:

Sloshing of the water in the AP1000 PCS tank was analyzed using a formula for toroidal tanks (Reference 1). The fundamental sloshing frequency given by the formula is 0.136 hertz with a modal mass equal to 65% of the water mass. **Key dimensions, frequencies and effective masses of the AP600 and AP1000 tanks are shown below.**

Parameter	AP600	AP1000	Units
Inside radius of tank	**17.5**	**17.5**	**feet**
Outside radius of tank	**38.0**	**42.5**	**feet**
Average water depth	**20.85**	**22.7**	**feet**
Sloshing frequency	**0.139**	**0.136**	**Hertz**
Ratio of sloshing to total mass	**0.66**	**0.65**	

The increase in tank capacity was provided by increases in both the external radius and depth. The AP600 analyses by formula gave frequencies and effective masses similar to those in the AP1000 analyses. The sloshing formula was confirmed for the AP600 by analyses of a 3D finite element model of the water in a rigid tank. The AP600 ANSYS analyses gave the same frequency but a lower modal mass of about 60% in the first two modes. In both the AP600 and AP1000 stick models of the Auxiliary and Shield Building (ASB) 60% of the water mass was considered to be sloshing. This was included in the stick model at the elevation of the tank with two masses each with 2 horizontal degrees of freedom. The sloshing mode at 0.136 hertz appears in the first four modes of the ASB stick model given in DCD Table 3.7.2-1. The total sloshing mass is 2.6% of the mass of the ASB.

The seismic analyses of the stick model show a maximum absolute acceleration of the sloshing masses of 0.13g. This occurs at a much lower frequency of 0.136 hertz than the fundamental frequency of the ASB which is between 2 and 3 hertz. The maximum acceleration of the sloshing mass of 0.13g is much lower than the 1.1 g of the structure at the base of the tank. Therefore the low frequency sloshing mode is not significant to the response of the nuclear

island away from the shield building roof. The horizontal mass participating in the sloshing mode was therefore excluded from the 3D shell dynamic model of the shield building. Sloshing is considered in the hydrodynamic loads in the design calculations for the walls of the tank.

The effect of the low frequency sloshing mode was confirmed to be negligible by performing an analysis of the nuclear island stick model without the low frequency mass. The results were compared against the results with the lower frequency masses provided in revision 15 of the DCD. Comparisons were made to the maximum absolute accelerations, member forces and floor response spectra. There were no significant changes in any of the responses.

Reference:

1. J.S. Meserole, A. Fortini, "Slosh Dynamics in a Toroidal Tank," Journal Spacecraft Vol. 24, Number 6, November-December 1987.

Design Control Document (DCD) Revision:

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

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-010
Revision: ~~0~~1

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 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 as shown below.**

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 the revisions to DCD subsection 2.5.2 shown below.

Reference:

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:

Changes to DCD Section 2.5

Revisions to DCD Section 2.5 were included in APP-GW-GLR-044, Rev 0, "Nuclear Island Basemat and Foundation", October 2006. These revisions to subsection 2.5.2 were further revised in the responses to RAI-TR03-018 and RAI-TR03-019. The following revision shows all changes from DCD Revision 15. These changes have been incorporated in 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**~~address~~ high frequency amplification **at a control point at 25 Hz**~~effects observed in eastern North America earthquakes~~. The peak ground accelerations in the two horizontal and the vertical directions are equal.

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 ~~foundation~~ **finished grade** level is less than or equal to a 0.30g SSE.

2. The site-**specific ground motion** ~~design~~ response spectra **(GMRS)** at the ~~foundation~~ **finished grade** level in the free-field are less than or equal to th~~ese~~ **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. **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.**

5. **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).**

6. **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 bounded by the design cases.

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 135'**	**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.*

Site-specific soil structure interaction analyses are performed using the 3D SASSI models described in Appendix 3G. The s~~S~~ite-specific soil structure interaction analyses ~~must be performed by the Combined License applicant to demonstrate acceptability of sites that have seismic and soil characteristics outside the site parameters in Table 2-1. These analyses would~~ 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**~~enveloping criteria of Standard Review Plan 3.7.1 for the response spectrum for damping values of 2, 3, 4, 5, and 7 percent and the enveloping criterion for power spectral density function~~. Floor response spectra determined from the site-specific analyses should be compared against the design basis of the AP1000 described above. ~~Member forces in each of the sticks should be compared against those given in Tables 3.7.2-11 to 3.7.2-13.~~ These evaluations and comparisons will be provided and reviewed as part of the Combined License application.

Changes to DCD Section 3.7

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

Add paragraph at end of subsection 3.7.1.4, references in 3.7.6, and Table 3.7.1.4 and Figures 3.7.1-15 and 3.7.1-16 as follows:

For the design of seismic Category I structures, a set of five design soil profiles of various shear wave velocities is established from parametric studies as described in Appendix 3G. These five profiles are sufficient to envelope sites where the shear wave velocity of the supporting medium at the foundation level exceeds 1000 feet per second (see subsection 2.5.2). The design soil profiles include a hard rock site, a firm rock site, an upper bound soft-to-medium soil site, a soft-to-medium soil site, and a soft soil site. The shear wave velocity profiles and related governing parameters of the five sites considered are as follows:

- **For the hard rock site, an upper bound case for rock sites using a shear wave velocity of 8000 feet per second.**
- **For the firm rock site, a shear wave velocity of 3500 feet per second to a depth of 120 feet and base rock at the depth of 120 feet.**
- **For the upper bound soft-to-medium soil site, a shear wave velocity of 1414 feet per second at ground surface, increasing parabolically to 3394 feet per second at 240 feet, base rock at the depth of 120 feet, and ground water at grade level. The initial soil shear modulus profile is twice that of the soft-to-medium soil site.**
- **For the soft-to-medium soil site, a shear wave velocity of 1000 feet per second at ground surface, increasing parabolically to 2400 feet per second at 240 feet, base rock at the depth of 120 feet, and ground water is assumed at grade level.**
- **For the soft soil site, a shear wave velocity of 1000 feet per second at ground surface, increasing linearly to 1200 feet per second at 240 feet, base rock at the depth of 120 feet, and ground water is assumed at grade level**

The strain-dependent shear modulus curves for the foundation materials, together with the corresponding damping curves are taken from References 37 and 38 and are shown in Figures 3.7.1-15 and 3.7.1-16 for rock material and soil material respectively. The different curves for soil in Figure 3.7.1-16 apply to the range of depth within a soil column below grade. The strain-dependent soil material damping is limited to 15 percent of

critical damping. The strain-dependent properties used in the SSI analyses for the safe shutdown earthquake are shown in Table 3.7.1-4 for the firm rock, upper bound soft-to-medium soil, soft-to-medium soil, and soft soil properties.

37. H.B. Seed, and I.M. Idriss, "Soil Moduli and Damping Factors for Dynamic Response Analysis," Report No. EERC-70-14, Earthquake Engineering Research Center, University of California, Berkeley, 1970.

38. EPRI TR-102293, "Guidelines for Determining Design Basis Ground Motions, 1993.

PRA Revision:

None

Technical Report (TR) Revision:

Revise subsection 4.4.1.2 to include the description and table of ~~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.~~ **degraded properties for each soil profile as shown in the DCD revision.**

Revise subsection 5.0 to show the proposed changes to DCD subsection 2.5.2.

Table 3.7.1.4 (Sheet 1 of 4)

STRAIN COMPATIBLE SOIL PROPERTIES

Depth to Bottom of Layer (ft)	Thickness of Layer (ft)	Layer Number	Total Unit Weight (kcf)	Initial G (ksf)	Initial Vs (fps)	Final G (ksf)	Final Vs (fps)	Damping
Firm Rock								
0.0								
5.0	5.0	1	0.15	57422	3500	57030	3499	0.015
10.0	5.0	2	0.15	57422	3500	56579	3485	0.016
15.0	5.0	3	0.15	56963	3486	55961	3466	0.014
20.0	5.0	4	0.15	56963	3486	55731	3459	0.015
25.0	5.0	5	0.15	56442	3470	54894	3433	0.016
30.0	5.0	6	0.15	56442	3470	55260	3444	0.014
33.5	3.5	7	0.15	55922	3454	54564	3422	0.015
39.5	6.0	8	0.15	55922	3454	54395	3417	0.015
45.0	5.5	9	0.15	55406	3438	53708	3395	0.016
60.0	15.0	10	0.15	55406	3438	53462	3388	0.017
70.0	10.0	11	0.15	54763	3418	52285	3350	0.018
80.0	10.0	12	0.15	54763	3418	51561	3327	0.020
90.0	10.0	13	0.15	53647	3383	49794	3269	0.021
100.0	10.0	14	0.15	53647	3383	49236	3251	0.022
Bedrock			0.15	300000	8000	298137	8000	0.000

Table 3.7.1.4 (Sheet 2 of 4)

STRAIN COMPATIBLE SOIL PROPERTIES

Depth to Bottom of Layer (ft)	Thickness of Layer (ft)	Layer Number	Total Unit Weight (kcf)	Initial G (ksf)	Initial Vs (fps)	Final G (ksf)	Final Vs (fps)	Damping
Soft Rock								
0								
10	10.0	1	0.15	27214	2417	27050	2402	0.007
20.0	10.0	2	0.15	27962	2450	27533	2424	0.009
30.0	10.0	3	0.15	28720	2483	28162	2451	0.009
40.0	10.0	4	0.15	29512	2517	28865	2481	0.010
60.0	20.0	5	0.15	30696	2567	29940	2527	0.010
80.0	20.0	6	0.15	32295	2633	31422	2589	0.011
120.0	40.0	7	0.15	34795	2733	33772	2684	0.011
160.0	40.0	8	0.15	38290	2867	37094	2813	0.011
200.0	40.0	9	0.15	41925	3000	40584	2942	0.011
240.0	40.0	10	0.15	45725	3133	44259	3073	0.011
Base	-	11	0.15	47702	3200	-	-	0.011

Table 3.7.1.4 (Sheet 3 of 4)

STRAIN COMPATIBLE SOIL PROPERTIES

Depth to Bottom of Layer (ft)	Thickness of Layer (ft)	Layer Number	Total Unit Weight (kcf)	Initial G (ksf)	Initial Vs (fps)	Final G (ksf)	Final Vs (fps)	Damping
Upper Bound Soft-to-Medium Soil								
0								
5	5.0	1	0.11	6440	1373	6272	1355	0.018
10.0	5.0	2	0.11	6440	1373	5894	1313	0.027
15.0	5.0	3	0.11	8626	1589	7741	1505	0.030
20.0	5.0	4	0.11	8626	1589	7310	1463	0.037
25.0	5.0	5	0.11	11415	1828	10323	1738	0.026
30.0	5.0	6	0.11	11415	1828	10071	1717	0.029
33.5	3.5	7	0.11	13231	1968	11683	1849	0.029
39.5	6.0	8	0.11	13231	1968	11478	1833	0.031
45.0	5.5	9	0.11	15659	2141	14303	2046	0.023
52.5	7.5	10	0.11	16012	2165	14444	2056	0.025
60.0	7.5	11	0.11	16012	2165	14228	2041	0.026
66.0	6.0	12	0.11	18850	2349	16841	2220	0.026
73.0	7.0	13	0.11	18850	2349	16665	2209	0.027
80.0	7.0	14	0.11	18850	2349	16495	2197	0.028
90.0	10.0	15	0.11	22179	2548	19544	2392	0.027
100.0	10.0	16	0.11	22179	2548	19326	2379	0.028
120.0	10.0	17	0.11	22179	2548	19024	2360	0.030
130.0	10.0	18	0.11	22179	2548	18698	2340	0.032
Base			0.15	298137	8000	298137	8000	0.000

Table 3.7.1.4 (Sheet 4 of 4)

STRAIN COMPATIBLE SOIL PROPERTIES

Depth to Bottom of Layer (ft)	Thickness of Layer (ft)	Layer Number	Total Unit Weight (kcf)	Initial G (ksf)	Initial Vs (fps)	Final G (ksf)	Final Vs (fps)	Damping
Soft-to-Medium Soil								
0								
10	10.0	1	0.11	3617	1029	3074	946	0.032
20.0	10.0	2	0.11	4044	1088	2989	933	0.056
30.0	10.0	3	0.11	4486	1146	2859	912	0.077
40.0	10.0	4	0.11	4952	1204	2843	909	0.089
60.0	20.0	5	0.11	5702	1292	2977	931	0.100
80.0	20.0	6	0.11	6772	1408	3453	1002	0.102
120.0	40.0	7	0.11	8560	1583	4764	1177	0.093
160.0	40.0	8	0.12	12304	1817	7343	1399	0.085
200.0	40.0	9	0.12	15661	2050	9277	1573	0.086
240.0	40.0	10	0.12	19424	2283	11490	1750	0.086
Base	-	11	0.12	21466	2400	-	-	0.093

Soft Soil								
0								
10	10.0	1	0.11	3444	1004	2925	922	0.033
20	10.0	2	0.11	3506	1013	2472	848	0.063
30	10.0	3	0.11	3561	1021	2044	771	0.089
40	10.0	4	0.11	3617	1029	1750	713	0.108
60	20.0	5	0.11	3709	1042	1484	657	0.128
80	20.0	6	0.11	3824	1058	1530	667	0.130
120	40.0	7	0.11	4007	1083	1603	683	0.136
160	40.0	8	0.11	4262	1117	1705	704	0.150
200	40.0	9	0.11	4518	1150	1807	725	0.150
240	40.0	10	0.11	4781	1183	1912	746	0.150
Base		11	0.11	6708	1200			0.150

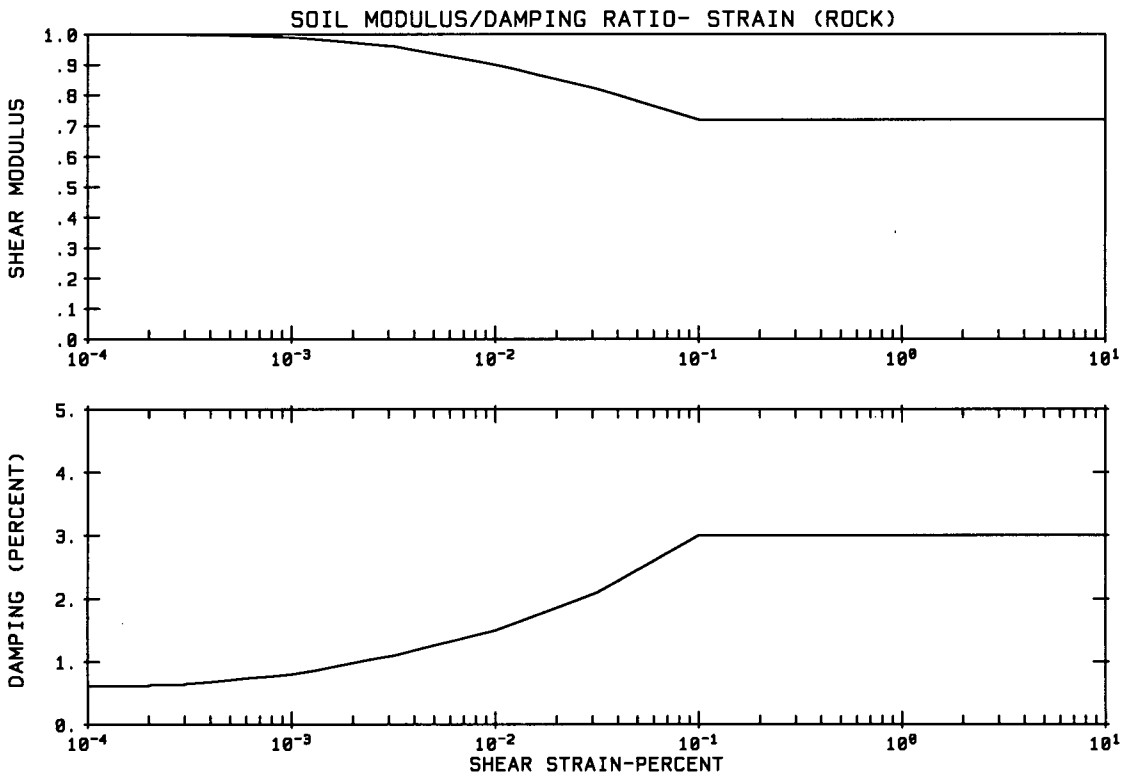
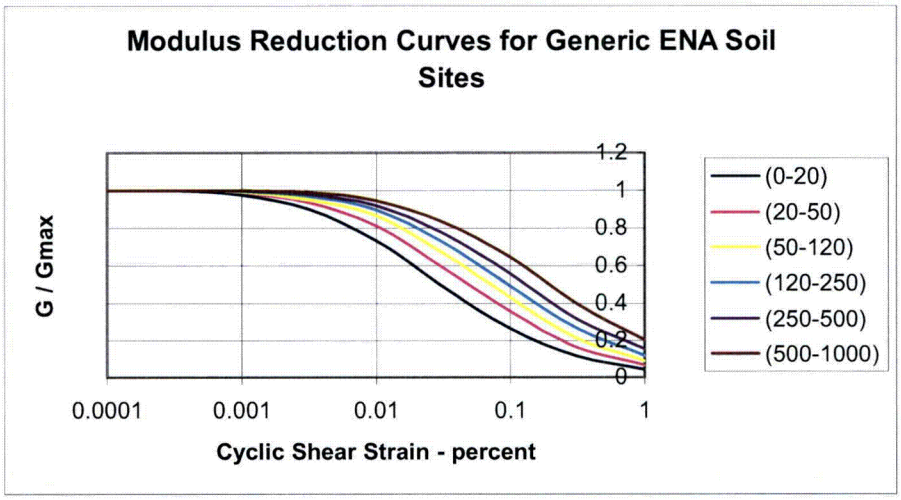


Figure 3.7.1-15
Strain Dependent Properties of Rock Material



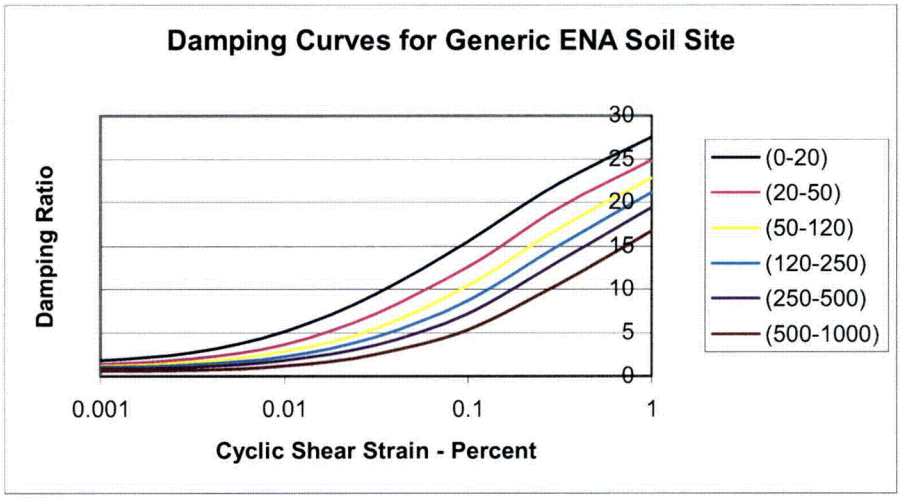


Figure 3.7.1-16
Strain Dependent Properties of Soil Material

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-031
Revision: 1~~0~~

Question:

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

Westinghouse Response:

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

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

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

Design Control Document (DCD) Revision:

~~DCD revisions are not shown for each RAI. A single set of proposed revisions is given in the response to RAI-TR03-013. The revisions are based on the material in the technical report as well as in the RAI responses. The revisions include changes to Section 3.7 and the addition of a new Appendix 3G providing a summary of the seismic analyses~~**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~~**None**.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-034
Revision: 0

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.

Reference:

None

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

Revise Table 4.2.4-1 to include the 2D models 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	Equivalent static analysis using accelerations from time history analyses	ANSYS	CIS portion of NI10 To obtain SSE member forces for the containment internal structures.
3D finite element shell model of nuclear island [NI10](coupled auxiliary/shield building shell model, containment internal structures, steel containment vessel , polar crane, RCL, pressurizer and CMTs)	Mode superposition time history analysis	ANSYS	Performed for hard rock profile for ASB with CIS as superelement and for CIS with ASB as superelement. To develop time histories for generating plant design 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 finite element coarse shell model of auxiliary and shield building [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
~~2D f~~Finite element lumped mass stick model of ~~auxiliary and shield building~~**nuclear island**.	Time history analysis	SASSI	Performed **2D** parametric soil studies to help establish the bounding generic soil conditions **and to develop loads for overturning and stability evaluation**.

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
Finite element lumped mass stick model of nuclear island.	**Time history analysis**	**ANSYS**	**Performed 2D linear and non-linear seismic analyses to evaluate effect of lift off on Floor Response Spectra and bearing.**
3D finite element coarse shell model of auxiliary and shield building [NI20] (including steel containment vessel , polar crane, RCL, and pressurizer)	Time history analysis	SASSI	Performed for the three soil profiles of firm rock, upper bound soft to medium soil, and soft to medium soil. To develop time histories for generating plant design 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 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 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		**ANSYS**	**Used in the NI10 and NI20 models**

Model	Analysis Method	Program	Type of Dynamic Response/Purpose
beam) model of the polar crane			
3D finite element shell model of containment vessel	**Mode superposition time history analysis** **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**
Static analyses			
3D finite element refined shell model of auxiliary and shield building (ASB05)	Equivalent static analysis using accelerations from time history analyses	ANSYS	To obtain SSE member forces for the auxiliary and shield building.
3D finite element model of the shield building roof	Equivalent static analysis using accelerations from time history analyses	GT STRUDL	To obtain SSE member forces for the shield building roof.
3D finite element refined shell model of nuclear island (NI05)	Equivalent static non-linear analysis using accelerations from time history analyses	ANSYS	To obtain SSE member forces for the nuclear island basemat

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-035
Revision: 0

Question:

Since Westinghouse is in the process of extending the AP1000 design certification, which assumes a hard rock foundation, to cover a full range of possible soil sites, DCD Tier 2 Section 3.7 is being revised. The site parameters in the geotechnical and seismic areas also need to be updated. Westinghouse should submit the required revisions to DCD Tier 2 Section 2.5 and DCD Tier 1 (design description, ITAAC, figures, and site parameters) for staff review.

Westinghouse Response:

The revisions to DCD Tier 2 Section 2.5 affected by Technical Report TR03 were included in Section 5 of the technical report. Additional revisions for the basemat and foundation were included in Technical Report APP-GW-GLR-044 "Nuclear island basemat and foundation". These proposed revisions have been modified by responses to RAIs. All proposed revisions have been included in Tier 2 Section 2.5 in DCD Revision 16. These changes have also been incorporated in DCD Tier 1 Chapter 5.

Reference:

None

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Technical Report (TR) Revision:

None