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Your ref: Project Number 740
Our ref: DCP/NRC1814

January 18, 2007

Subject: AP1000 COL Response to Request 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 (RAI) on AP1000 Standard Combined License Technical Report 3, APP-GW-S2R-010, Rev. 0, Extension of Nuclear Island Structures Seismic Analysis. These RAI responses are submitted as part of the NuStart Bellefonte COL Project (NRC Project Number 740). The information included in the response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification.

Responses are provided for request TR3-1 through TR3-6, TR3-8 through TR3-12, TR3-14, TR3-15, TR3-17, TR3-24 through TR3-31, and TR3-33, transmitted in NRC letter dated December 5, 2006 from Steven D. Bloom to Andrea Sterdis, Subject: Westinghouse AP1000 Combined License (COL) Pre-application Technical Report 3 – Request for Additional Information (TAC No. MD2358).

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

It is expected that when the RAIs on Technical Report 3 are complete, the technical report will be revised as indicated in the response and submitted to the NRC. The RAI response will be included in the document.

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,

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

D079

00048-psa.doc

/Attachment

1. "Oath of Affirmation," dated January 18, 2007

/Enclosure

1. Response to Request for Additional Information on Technical Report No. 3

cc:	S. Bloom	-	U.S. NRC	1E	1A
	S. Coffin	-	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

ATTACHMENT 1

"Oath of Affirmation"

ATTACHMENT 1

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:	)
NuStart Bellefonte COL Project	)
NRC Project Number 740	)

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

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

W E Cummins

W. E. Cummins
Vice President
Regulatory Affairs & Standardization

Subscribed and sworn to
before me this 22 day
of January 2007.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Debra McCarthy, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Aug. 31, 2009
Member, Pennsylvania Association of Notaries

Debra McCarthy
Notary Public

ENCLOSURE 1

Response to Request for Additional Information on Technical Report No. 3

RAI-TR3-1 through TR3-6, TR3-8 through TR3-12, TR3-14, TR3-15, TR3-17, TR3-24 through TR3-31, and TR3-33

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-001
Revision: 0

Question:

The Introduction (p.1, paragraph 5) states "This document addresses seismic response spectra, soil sites, dynamic models, minor structural changes that are significant, seismic results and their impact on seismic design loads for the building structures." The staff notes that only the pressurizer compartment redesign is described in the report. Please describe in detail all the other "minor structural changes that are significant", and why these changes to the AP1000 design are necessary. Also identify the auditable documents that contain the applicable design/analysis calculations for each change.

Westinghouse Response:

The seismic analysis models have been revised from those reviewed during the hard rock design certification for two types of changes. Firstly, there are design changes to the AP1000 which include the shorter pressurizer, an increase in spent fuel storage within the existing pit and a revision to the bracing of the shield slab below the discharge stack. Secondly are changes to the finite element model to better reflect the structural configuration. The changes that have been incorporated into the dynamic models in addition to the redesign of the pressurizer compartment described in the report are discussed further below. All are described in the associated design calculation documenting parts of the finite element model (auxiliary and shield building, containment internal structures, dish below containment vessel, polar crane, core makeup tank).

Design changes

- A design change was made in the spent fuel pool area to permit heavier fuel racks. Masses reflecting the racks and spent fuel were updated. In addition, the water in the fuel pits was modeled as lumped masses instead of solid elements.

  Auditable document: APP-1000-S2C-032, Rev 2, Auxiliary and Shield Building Finite Element Models
  Technical Report: APP-GW-GLR-033, "Spent Fuel Racks Design and Structural Analysis."

- The shield building roof slab bracing was modified from tie rods to cross bracing to improve the seismic response.

  Auditable documents: APP-1000-S2C-032, Rev 2, Auxiliary and Shield Building Finite Element Models

Model improvements

- The dish model was modified to incorporate changes in the annulus configuration included in existing DCD figures. The annulus tunnel on the west side was deleted and replaced by concrete. In addition nodes and elements were modified in the lower shield building and upper CIS basemat to be compatible with the revised Dish model.

  Auditable documents: APP-1010-S2C-002, Rev 3, Finite Element Model of Dish
  Technical Report: APP-GW-GLR-044, "Nuclear Island Basemat and Foundation"

- The core makeup tanks were added as stick models.

  Auditable documents: APP-MV20-S2C-001, Rev 1, Core Makeup Tank Dynamic Model

- Floors in the CIS model were refined to provide better member force results for use in design.

  Auditable document: APP-1100-S2C-034, Rev 4, Finite Element Solid-Shell Model of Containment Internal Structures

- Polar Crane Model – Changes made to the model weight (3% reduction), updated SCV local stiffness, and inclusion of polar crane truck stiffness.

  Auditable documents: APP-MH01-S2C-001, Rev 2.

These changes listed above are considered minor since the nuclear island building basic configuration is not modified. They reflect structural and model changes that are made during design development.

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:
None

Technical Report (TR) Revision:

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.

The additional structural changes that are described in this RAI will be added to the next revision of the technical report. This addition to the Technical Report will be made at the end of Section 3.0, and is provided below.

Additional structural changes are reflected in the models used for the soil and hard rock cases along with modeling improvements. These are summarized below:

- A design change was made in the spent fuel pool area to permit heavier fuel racks. Masses reflecting the racks and spent fuel were updated. In addition, the water in the fuel pits was modeled as lumped masses instead of solid elements.
- The shield building roof slab bracing was modified from tie rods to cross bracing to improve the seismic response.
- The dish model was modified to incorporate changes in the annulus configuration included in existing DCD figures. The annulus tunnel on the west side was deleted and replaced by concrete. In addition nodes and elements were modified in the lower shield building and upper CIS basemat to be compatible with the revised Dish model.
- The core makeup tanks were added as stick models.
- Floors in the CIS model were refined to provide better member force results for use in design.
- Polar Crane Model – Changes made to the model weight (3% reduction), updated SCV local stiffness, and inclusion of polar crane truck stiffness.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-002
Revision: 0

Question:

The last second sentence of Item 2 in Page 3 of 154 states that the walls and basemat inside containment for this model is shown in DCD Figure 3.7.2-2. Since the height of the pressurizer cubical walls was reduced, this statement is no longer valid. Clarification is needed.

Westinghouse Response:

Item 2 on page 3 of 154 is describing the ANSYS finite element shell model of the containment internal structure that was used for analysis during the hard rock licensing phase. Therefore, this statement is valid for this section of the report. It is correct that the pressurizer cubicle walls height was reduced and this is reflected in the models described in Section 4 of the report.

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:
None

Technical Report (TR) Revision:

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-TR03-003
Revision: 0

Question:

The fourth sentence of Item 4 in Page 4 of 154 states that plant design response spectra were developed from these analyses along with equivalent static accelerations for analysis of the building structures. Westinghouse is requested to define the term "plant design response spectra." Are these the response spectra at different floor levels?

Westinghouse Response:

The plant design floor response spectra described in Item 4 in Page 4 of 154 were developed for the nuclear island building structures to be used for design during the hard rock licensing phase. They are developed from the seismic time history analyses, using the models described in the DCD that are applicable to hard rock sites, at different floor levels associated with the individual buildings (auxiliary shield building, containment internal structure, and steel containment vessel).

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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.

The sentence in the middle of item 4 on page 4 of 154 is changed to read: "Plant design floor response spectra were developed from these analyses along with equivalent static seismic accelerations for analysis of the building structures."

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-004
Revision: 0

Question:

The first sentence of the last paragraph in Page 8 of 154 should read "Key dimensions, such as the foundation size and thickness of the basemat, floor slabs, roofs and walls, of the seismic Category I building structures are shown in DCD Figures 3.7.1-14 and 3.7.2-12."

Westinghouse Response:

Westinghouse agrees.

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

The first sentence of the last paragraph in Page 8 of 154 will be revised to read "Key dimensions, such as the foundation size and thickness of the basemat, floor slabs, roofs and walls, of the seismic Category I building structures are shown in DCD Figures 3.7.1-14 and 3.7.2-12." 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-TR03-005
Revision: 0

Question:

The second sentence of the third paragraph in Page 9 of 154 states that the (concrete) modulus of elasticity is reduced to 80% of its value to reduce stiffness to simulate cracking. Westinghouse is requested to clarify whether this reduced stiffness was used in both the dynamic seismic response analyses for generation of floor response spectra, and the equivalent static acceleration analyses for design of the structural members. If different stiffness assumptions were used, provide the technical basis for this decision. Also provide the technical basis for using 80%. Discuss this in relation to current industry guidance (e.g., ASCE 43-05, ASCE 4-98). Were any sensitivity studies conducted to determine the effect of varying the concrete stiffness on (1) the floor response spectra, and (2) the design of structural members?

Westinghouse Response:

The reduction to 80% is described in DCD subsection 3.7.2.3 as shown below and was reviewed during the hard rock Design Certification. This reduction is applied in both the updated dynamic ANSYS analyses on hard rock sites as well as in the SASSI analyses on soil sites. The reduction is also applied in the equivalent static acceleration analyses for design of the structural members and the nuclear island basemat.

> *The finite element models of the coupled shield and auxiliary buildings, and the containment internal structures are based on the gross concrete section with the modulus based on the specified compressive strength of concrete. When the finite element or stick models of these buildings are used in time history or response spectrum dynamic analyses, the stiffness properties are reduced by a factor of 0.8 to consider the effect of cracking as recommended in Table 6-5 of FEMA 356 (Reference 5).*

Section 3.7.2.3 (page 3-81) of the FSER accepts this approach and states:

> *The use of FEMA recommendations to modify the member stiffness of the seismic model of the NI structures is consistent with current industry practice and is reasonable and acceptable.*

Reference:

5. FEMA 356, "Prestandard and Commentary for the Seismic Rehabilitation of Buildings," Federal Emergency Management Agency, November 2000.

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-006
Revision: 0

Question:

The last sentence of the fourth paragraph in Page 9 of 154 states that the decision to move away from the use of the combined stick model is predicated on the use of the shell model for soil-structure interaction analyses, and to reflect the improvement in technology where the use of the shell models are reflective of the state of the art. Westinghouse needs to clarify which reinforced concrete structural model was used for calculate seismic responses of nuclear island structures founded on hard rock site: stick model or shell model?

Westinghouse Response:

The lumped mass stick models of the nuclear island were used for the hard rock licensing phase of the AP1000 plant. With the inclusion of soil sites with the hard rock case, the seismic analyses performed use shell models. The hard rock analyses that are reported in the DCD were redone with these shell models. The only lumped mass stick model of a building that was included with the shell models is that associated with the steel containment vessel with the polar crane. Stick models are also used for the reactor coolant loop, pressurizer, and core make up tank (see DCD Section 3.7.2.1.2).

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-008
Revision: 0

Question:

The first column of the third row of Table 4.2.4-1 in Page 40 of 154 provides a description of the seismic building model as "3D finite element coarse shell model of auxiliary and shield building (including steel containment vessel, polar crane, RCL, and pressurizer)." Westinghouse should clarify why the containment internal structures (superelement?) was excluded.

Westinghouse Response:

It was not intended to exclude the containment internal structures. The first column of the third row of Table 4.2.4-1 on Page 40 of 154 should read:

> "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)"

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

Table 4.2.4-1 (first column of last row on first page of table – Page 39 of 1540 and of the third row on second page of table - Page 40 of 154) of the topical report will be modified as "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)".

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-TR03-009
Revision: 0

Question:

The core make-up tank is mentioned in Section 4.3. Westinghouse needs to provide a description of this tank in the report.

Westinghouse Response:

A description of the core makeup tank was not given in the report since it is given in subsections 5.4.13 and 6.3.2.2.1 of the DCD. There are two core makeup tanks located inside containment at elevation 107' 2". The first paragraph of subsection 5.4.13.2 states:

> The core makeup tank is a low-alloy steel vessel with 308L stainless steel internal cladding. The minimum free internal volume for the core makeup tank is 2500 cubic feet. The normal full-power temperature and pressure in the core makeup tank are 70° to 120°F and 2250 psia, respectively. The tank is designed to withstand the design environment of 2500 psia and 650°F. The core makeup tank is a vertically mounted, cylindrical pressure vessel with hemispherical top and bottom heads.

The core make-up tanks are modeled in the nuclear island fine (NI10) model as stick models using 7 nodes. The two stick models of the tanks are shown in Figure RAI-TR03-009-1.

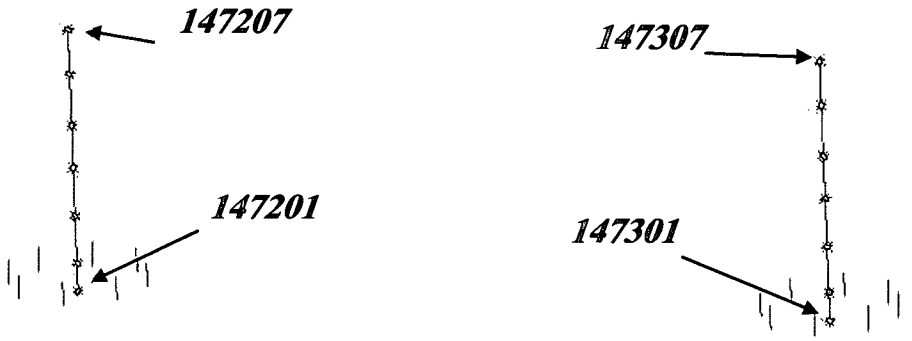


Figure RAI-TR03-009-1– Core Make-Up Tank

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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

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.

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:

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 and figures as follows:

The strain-dependent shear modulus curves for the foundation materials, together with the corresponding damping curves 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.

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.

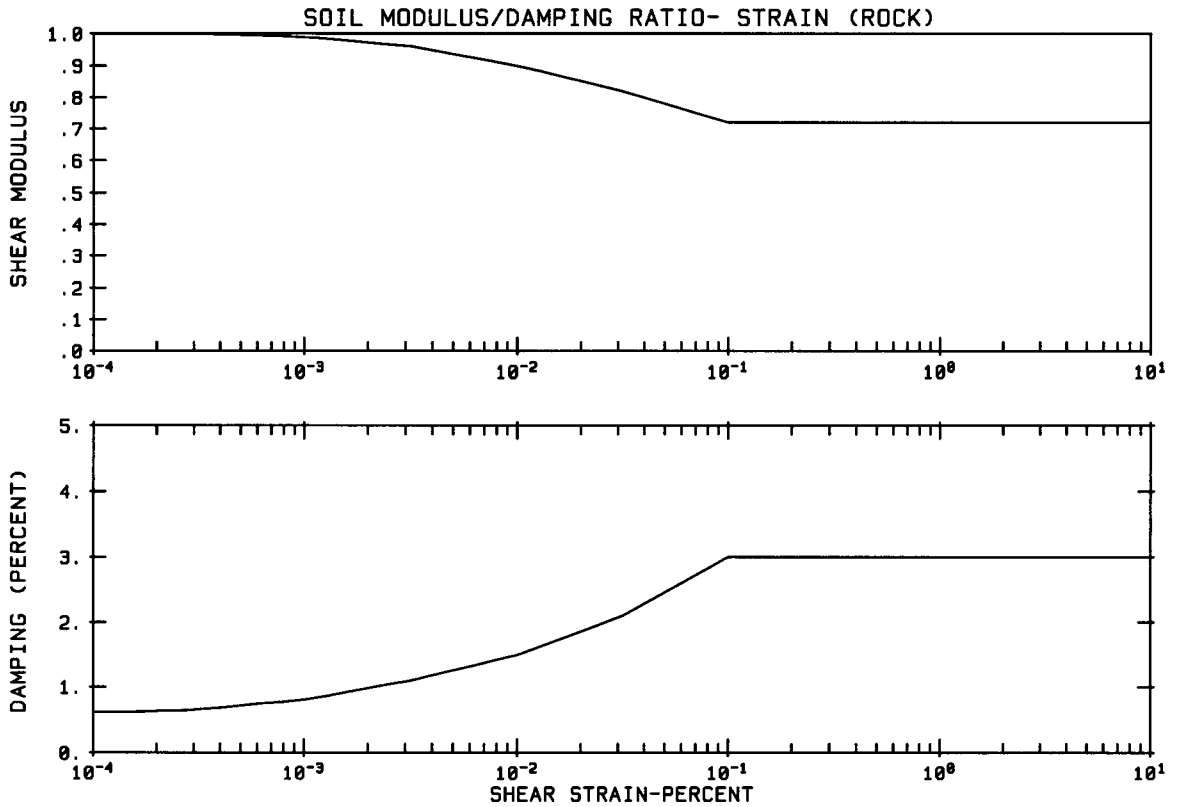
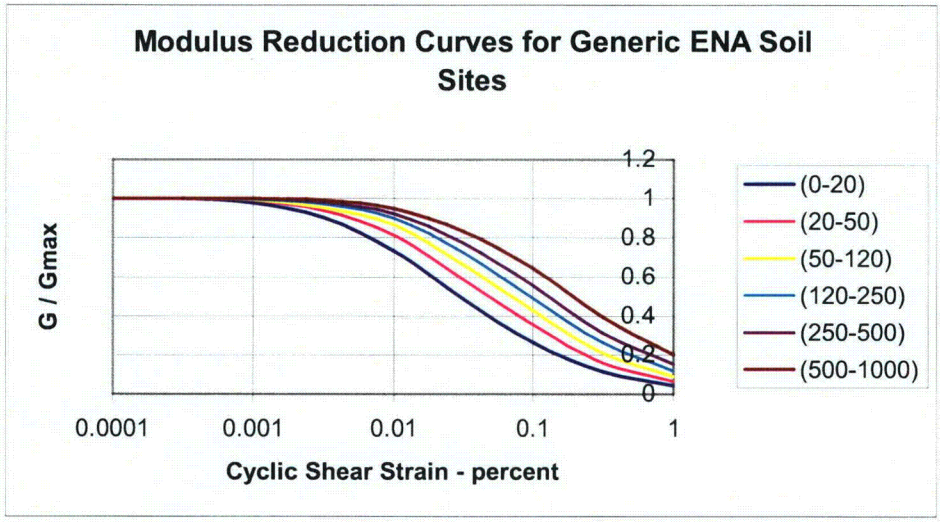


Figure 3.7.1-15
Strain Dependent Properties of Rock Material



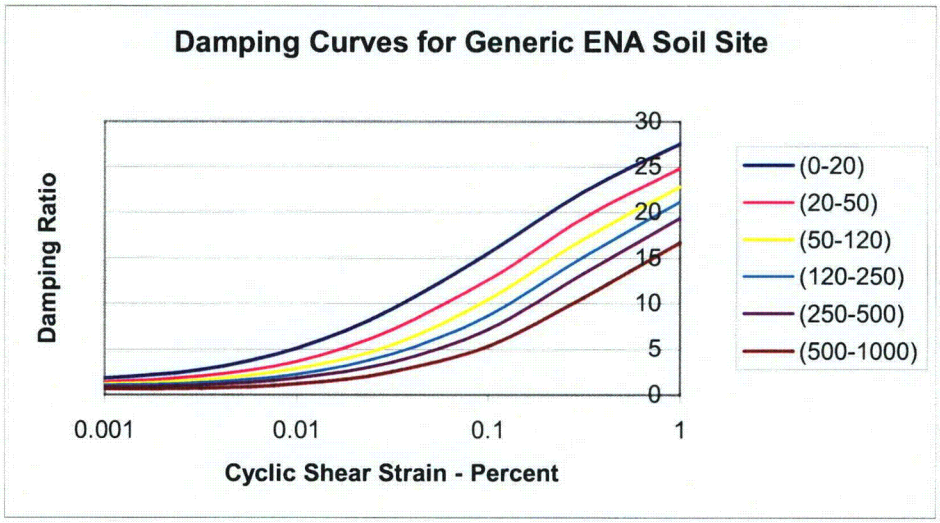


Figure 3.7.1-16
Strain Dependent Properties of Soil Material

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-011
Revision: 0

Question:

The last sentence of the third paragraph in Page 48 of 154 states that since the dominant AP1000 building frequencies are lower than for AP600, the shallower depth conditions would provide even less of an effect and thus using a depth-to-base rock of 120 ft is also appropriate. However, the last sentence of the first paragraph (Section 4.4.1) in Page 47 of 154 states that the soft rock case (V_s = 2500 ft/sec) for the AP600 has been replaced by firm rock (V_s = 3500 ft/sec) 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. Westinghouse needs to explain why the conclusion drawn for the AP1000 (the nuclear island structures with lower dominant building frequencies result in higher seismic response when founded on firm rock than on soft rock) is contradict to the conclusion drawn for the AP600 (the nuclear island structures with higher dominant building frequencies result in lower seismic response when founded on firm rock than on soft rock).

Westinghouse Response:

The third paragraph on Page 48 is rewritten as shown in the response to RAI-TR03-015 to clarify the conclusions of the AP600 depth-to-base rock analyses and to discuss the validity of these conclusions for the AP1000. The paragraph addresses the response on soil sites.

The second part of the question relates to the response on firm rock sites. Results of analyses of the AP600 response on firm rock sites are shown in Figure 2B-3 of Appendix 2B of the AP600 DCD. This showed the response at the firm rock site to be very similar to the response on a hard rock site and to be bounded by the envelope of the four design cases. With the additional height of the AP1000 the response at the firm rock site is slightly higher than that at the hard rock site as shown in Appendix D of the report (see for example Figure D-6). This response would not be bounded by the envelope of the same four design cases as for the AP600. Since the soft rock case did not generally control the maximum response, Westinghouse replaced the AP600 soft rock case by the firm rock case for the AP1000 design analyses.

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

See response to RAI-TR03-015 where change to technical report is given. Also, 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-TR03-012
Revision: 0

Question:

The fifth paragraph of section 4.2.3 in Page 19 of 154 provides a description of how the grouping method was applied to define the seismic design response spectra. Appendix B provides tables showing the node grouping for various elevations of ASB and CIS. As indicated in Figures 4.2.3.3 and 4.2.3.4, and Table B-1, the grouping method was applied to the outside nodal points, but not the inside nodes. Westinghouse is requested to demonstrate that the resulted vertical seismic design response spectra are more conservative than those that would be obtained by grouping all of the nodes, including inside nodes.

Westinghouse Response:

The nodes associated with a specific elevation and building structure (i.e., ASB and CIS) are grouped. For the ASB where the floor at the elevation of interest is rigid (i.e. frequency $\geq$ 33 hertz), it is only necessary to envelop the response spectra at edge points and interior nodes at the shield wall to obtain the largest seismic response spectra because of rigid motion. The edge nodes reflect the largest rocking and translational response of the auxiliary building, and the response spectra associated with the nodes on the shield wall will reflect the shield wall dynamic response. It is not necessary to include any nodes between the shield wall and auxiliary building edge since the floor is rigid, and the response cannot be worse than those enveloped. This case is shown in Figure 4.2.3-1 where the response spectra at the edge and shield wall nodes are enveloped. If the floor is flexible, then response spectra for these interior nodes associated with this flexible area are enveloped. Such a case is shown in Figure 4.2.3-2 where the seismic response spectra associated with nodes 4548 (1756), 4570 (1764), and 4556 (1760) are enveloped.

If equipment or a structure is supported at more than one elevation, then the analysts of such equipment will define the seismic input as an envelope of multiple groups based on the support locations. Therefore, if the equipment or structure is supported on rigid and flexible floor areas the response spectra (horizontal and vertical directions) used by the analysts will be the envelope of the rigid and flexible areas that include inside and outside nodes.

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

The fifth paragraph of section 4.2.3 on Page 19 of 154 is revised as follows:

> Seismic response spectra are developed at the locations of the nodes. These response spectra are grouped and enveloped to define the seismic design response spectra. The nodes associated with a specific elevation and building structure (i.e., ASB and CIS) are grouped. For the ASB where the floor at the elevation of interest is rigid (i.e. frequency $\geq$ 33 hertz), it is only necessary to envelop the response spectra at edge points and interior nodes at the shield wall to obtain the largest seismic response spectra because of rigid motion. The edge nodes reflect the largest rocking and translational response of the auxiliary building, and the response spectra associated with the nodes on the shield wall will reflect the shield wall dynamic response. It is not necessary to include any nodes between the shield wall and auxiliary building edge since the floor is rigid, and the response cannot be worse than those enveloped. This case is shown in Figure 4.2.3-1 where the response spectra at the edge and shield wall nodes are enveloped. If the floor is flexible, then response spectra for these interior nodes associated with this flexible area are enveloped. Such a case is shown in Figure 4.2.3-2 where the seismic response spectra associated with nodes 4548 (1756), 4570 (1764), and 4556 (1760) are enveloped.
>
> If equipment or a structure is supported at more than one elevation, then the analysts of such equipment will define the seismic input as an envelope of multiple groups based on the support locations. Therefore, if the equipment or structure is supported on rigid and flexible floor areas the response spectra (horizontal and vertical directions) used by the analysts will be the envelope of the rigid and flexible areas that include inside and outside nodes.
>
> Appendix B provides tables showing the grouping for the ASB and the CIS. There is no grouping for the SCV since it is represented by a stick model.

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-TR03-014
Revision: 0

Question:

The third sentence of the first paragraph in Page 47 of 154 states that many results and conclusions from the AP600 soil studies are applicable for the AP1000. Westinghouse is requested to describe what results and conclusions from the AP600 soil studies, other than the three soil sites (the hard rock site, upper bound soft to medium soil, and soft to medium soil), are applicable to the AP1000.

Westinghouse Response:

The AP600 design is based on enveloped results from analyses for four soil conditions (hard rock, soft rock, upper bound soft-to-medium, and soft to medium). These four soil cases were selected from the parametric analyses summarized in Section 4.4.1 of the technical report. The AP600 soil studies demonstrated that these four cases would bound sites having soil with shear wave velocity exceeding 1000 feet per second. Parameters selected for the design soil cases from these analyses were:

- Depth to bedrock of 120 feet
- Water table for the upper bound soft to medium and soft to medium cases up to grade
- Parabolic variation of shear wave velocity with depth for the upper bound soft to medium and soft to medium 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. These parameters are discussed further in the response to RAI-TR03-015. The conclusions from the AP600 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 25'. 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 used in the AP600 and AP1000 3D SASSI design analyses. These analyses confirmed that the response of the AP1000 was 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.

Westinghouse has performed parametric analyses for the AP1000 to assess the effect of various soils. Westinghouse is supplementing these AP1000 studies using results and

conclusions from the AP600 soil studies to establish detailed parameters for each of the 3D SASSI design cases. This is discussed further in the response to RAI-TR03-015.

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-015
Revision: 0

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 25'. 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.

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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

4.4 Soil Cases and SSI Analyses

4.4.1 2D SASSI Analyses and Parameter Studies

This section describes the parametric analyses performed using 2D models in SASSI to select the design soil cases for the AP1000. The AP1000 footprint, or interface to the soil medium, is identical to the AP600. The AP1000 containment and shield building are 25' 6" taller than AP600. Many of the rResults and conclusions from the AP600 soil studies are described as well as their application to the AP1000 in establishing the design soil profilesapplicable to AP1000. Analyses of AP1000 are described similar to key soil cases analyzed for AP600. Four soil and rock cases are selected as follows: hard rock; firm rock; upper bound soft to medium soil and soft to medium soil. These are the same as the cases analyzed for the AP600 with the exception that 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 Rockies. 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, along with a discussion of their validity for the AP1000 configuration.

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. The depth-to-base rock of 120 ft is the governing soil profile and was therefore specified for the 3D SASSI design cases. At high frequencies the shallower depth models gave a higher building response, but a depth of 120 ft gave the highest overall response. Since the dominant AP1000 building frequencies are lower than for AP600, the shallower depth conditions would provide even less of an effect and thus using a depth-to-base rock of 120 ft is also appropriate.. 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. SHAKE and SSI analyses were performed for clay profiles and . concluded that the responses for clay profiles were bounded by those for the design soil profiles. This conclusion is also applicable to the AP1000. Based on this, no further work needs to be done with clay profiles for the generic design.

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. Thuis the specification of the water table at grade is also appropriate for the AP1000 soil sites.

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

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

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

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

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR03-017
Revision: 0

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. 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.

There is no limit on the maximum acceptable change in velocity profile within a depth equal to the width of the basemat. Four design soil profiles are analyzed. These are similar to the four cases 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 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.

Reference:

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

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-024
Revision: 0

Question:

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

Westinghouse Response:

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

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

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

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

Reference:

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

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-025
Revision: 0

Question:

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

Westinghouse Response:

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

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

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

Reference:

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

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-026
Revision: 0

Question:

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

Westinghouse Response:

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

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

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

Design Control Document (DCD) Revision:

DCD revisions are not shown for each RAI. A single set of proposed revisions is given in the response to RAI-TR03-013. The revisions are based on the material in the technical report as

well as in the RAI responses. The revisions include changes to Section 3.7 and the addition of a new Appendix 3G providing a summary of the seismic analyses.

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-027
Revision: 0

Question:

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

Westinghouse Response:

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

The basis for selection of the damping values is described in the response to RAI-TR03-026. The modal damping value in Table 7-1 for the soft soil is 30%. This exceeds the 20% limitation for composite modal damping in ASCE 4-98. The composite modal damping in the soft soil analysis would be lower than 30%. The 30% value for damping for soft soil was the value obtained to match the 2D SASSI results. This value was not used in any subsequent analyses since the overall response on a soft soil site is significantly lower than on the soft to medium soil case selected for the non-linear liftoff analyses.

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-028
Revision: 0

Question:

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

Westinghouse Response:

As stated in DCD subsection 3.7.1.2:

> Design horizontal time history, H1, is applied in the north-south (Global X or 1) direction; design horizontal time history, H2, is applied in the east-west (global Y or 2) direction; and design vertical time history is applied in the vertical (global Z or 3) direction.

The H2 and vertical components of the time histories were used to generate liftoff response in the 2D analyses. They were applied simultaneously.

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

The first paragraph in Section 7.2 is modified as follows:

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

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-TR03-029
Revision: 0

Question:

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

Westinghouse Response:

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

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

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-TR03-030
Revision: 0

Question:

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

Westinghouse Response:

The basis for selection of the damping value is described in the response to RAI-TR03-026. The damping of 30% was selected for the soft soil site for use in ANSYS analyses based on matching the overturning member forces in ANSYS time history modal analyses to those from the 2D SASSI analyses. This damping value includes a component of material damping as well as that due to radiation damping. The hysteretic material damping calculated using SHAKE for the soft soil case with base rock at a depth of 120 feet varies between 3 and 6%. For a semi-infinite half space the radiation damping would be larger than 30%. The 30% value for damping for soft soil was not used in any subsequent analyses since the overall response on a soft soil site is significantly lower than on the soft to medium soil case selected for the non-linear liftoff analyses.

Design Control Document (DCD) Revision:

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

PRA Revision:
None

Technical Report (TR) Revision:

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-TR03-031
Revision: 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.

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.

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-TR03-033
Revision: 0

Question:

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

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

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

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

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

Westinghouse Response:

a. The difference in the pattern of response from the stick model is due to the use of the more refined 3D finite element shell model and the difference in response between the south and north ends of the auxiliary building. The stick model represents the stiffness and mass properties with the south and north side of the auxiliary building combined. As seen in Table 6.2-2, the X and Y response of the south and north ends of the building are not erratic. The X and Y equivalent static acceleration plotted in Figure E-2 is the maximum response of the south and north sides of the auxiliary building. It is erratic because some of the values are from the south and some from the north end. The south side of the auxiliary building contains the spent fuel pool

and other related pools related to storage of spent fuel. Therefore, this area is more open than the north side of the building. The vertical acceleration profile that is used for design of the auxiliary building is shown in Figure E-1. The acceleration profile that is used for the design of the auxiliary building is that associated with the maximum accelerations (MAX) from the time history analyses of the different soil cases and the hard rock site. The MAX value is the envelop of the maximum accelerations of the time history analyses for the hard rock, firm rock, upper bound soft to medium, and soft to medium soil cases.

b. The difference is due to the improved representation of the CIS that is possible in the 3D finite element shell models, and also due to the structural change to the pressurizer compartment (lower pressurizer compartment height). The acceleration profiles associated with the 3D finite element model are not as conservative as those obtained from the stick model. They are more realistic with both the east and west side of the containment internal structures modeled. In the stick model the east steam generator compartment is represented by one stick above the operating deck, and the west steam generator compartment is combined with the pressurizer compartment as another stick above the operating deck. In the 3D finite element model it is possible to connect each support to its compartment wall. The response of the shell model shows that the outer edges of the steam generator compartment respond differently from the walls of the refueling canal at the operating floor. This was not permitted in the stick model. These modeling differences result in the differences shown in Figure E-4 for the CIS. The acceleration profile that is used for the design of the CIS is that associated with the maximum accelerations (MAX) from the time history analyses of the different soil cases and the hard rock site for the east and west side.

c. The ASB vertical acceleration profile for both MAX and stick model shown in Figure E-1 exhibit essentially rigid behavior above elevation 290 feet because of the passive cooling water storage tank in the center of conical roof of the shield building in this area. The tank is essentially a rigid body with the bottom of the tank supported by the shield building roof. The roof has a fundamental vertical frequency of about 5 hertz as shown by the floor response spectra in Figures 4.4.3-15 and 6.1-3. The wall of the tank is rigid vertically relative to this 5 hertz roof frequency. Therefore, the tank will respond as a rigid body excited by the shield building roof response.

   The MAX vertical acceleration is approximately equal to the stick model vertical acceleration at elevation 260 ft and approximately 7% lower at elevation 290 ft in Figure E-1. This reduction in the MAX vertical acceleration compared to the stick model is due to the reduced response of the tank described above and to the refinement in the 3D finite element model. The additional refinement in the shell model results in multiple modes of the roof tank with combinations of vertical and

rocking response. This reduces the maximum response relative to the stick model which has primarily single mode vertical response.

The vertical acceleration values in Figure E-1 at elevations of 295' and 333' are for the hard rock case. It has been determined that the soft to medium soil case controls the vertical acceleration in this area. The MAX acceleration values have changed from 0.9g at 295' to 1.09g and from 0.95g at 333' to 1.10g. The revised plot of the vertical accelerations shown in Figure E-1 is shown in Figure RAI-TR03-033-1. The revised MAX vertical acceleration is approximately 10% higher at elevation 290 ft than the stick model. The acceleration profile that is used for the design of the ASB is that associated with the maximum accelerations (MAX) from the time history analyses of the different soil cases and the hard rock site.

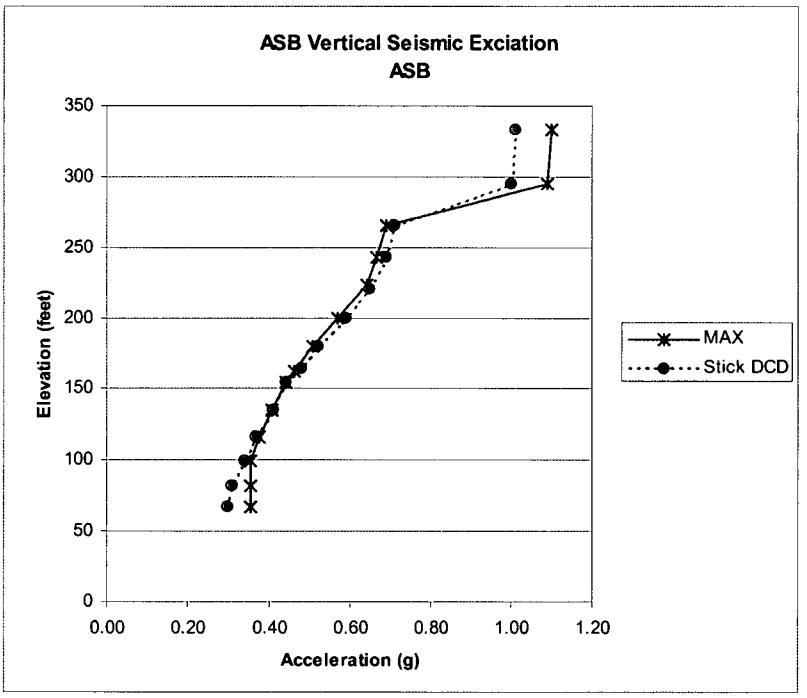


Figure RAI-TR03-033-1 – Comparison of ASB Vertical Seismic Accelerations

d. No comparison of acceleration profiles are given since comparisons are made of soil reactions on the basemat. For a discussion of this comparison see Nuclear Island Basemat and Foundation technical report, APP-GW-GLR-044, and also RAI-TR03-021e. In section 2.6.1.2 of technical report APP-GW-GLR-044 it is stated:

> *Table 2.6-2 compares the sum of the soil reactions on the basemat for the equivalent static accelerations applied in the design analyses of the basemat on soil springs to those obtained from linear time history analyses of the nuclear island. The values for the fixed base analyses are from the nuclear island stick model time history analyses documented in the AP1000 DCD for the hard rock analyses. The values for the soft to medium soil are from 2D SASSI analyses described in section 2.4.1. Comparison of the base reactions demonstrate the conservatism of the equivalent static accelerations applied in the basemat analyses.*

The nuclear island stability analysis (sliding and overturning) are calculated for each soil case for the base reactions shown in Table 2.4-2 of technical report APP-GW-GLR-044. It is stated in foot note 2 to this table:

> *Reactions for horizontal input are calculated from member forces at grade in 2D SASSI analyses plus maximum acceleration times mass below grade. Reactions due to vertical input are calculated from maximum accelerations in 3D ANSYS or SASSI analyses for HR, FR, UBSM and SM from 2D ANSYS analyses for SR and SS.*

Reference:

None

Design Control Document (DCD) Revision:

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

PRA Revision:

None

Technical Report (TR) Revision:

Tables 6.2-3 and 6.2-7 will be revised to reflect the higher vertical seismic accelerations at elevations 294.93' (1.09g) and 333.13' (1.10g) as shown below.

Table 6.2-3 - ASB Design Accelerations

Units: g

Elevation Feet	North South		East West		Vertical
	Shield Building	Auxiliary Building	Shield Building	Auxiliary Building	Shield and Auxiliary Building
333.13	1.25		1.36		0.951.10
294.93	0.98		1.07		0.901.09
265	0.79		0.85		0.69
242.5	0.74		0.78		0.66
222.75	0.69		0.72		0.64
200	0.62		0.64		0.57
180	0.55	0.86	0.56	0.73	0.51
162	0.52	0.71	0.51	0.69	0.46
153.98	0.51	0.71	0.49	0.58	0.44
134.88	0.47	0.58	0.43	0.58	0.41
116.5	0.41	0.43	0.38	0.43	0.37
99	0.35	0.42	0.37	0.40	0.36
81.5	0.32	0.36	0.37	0.37	0.36
66.5	0.32	0.32	0.37	0.37	0.36

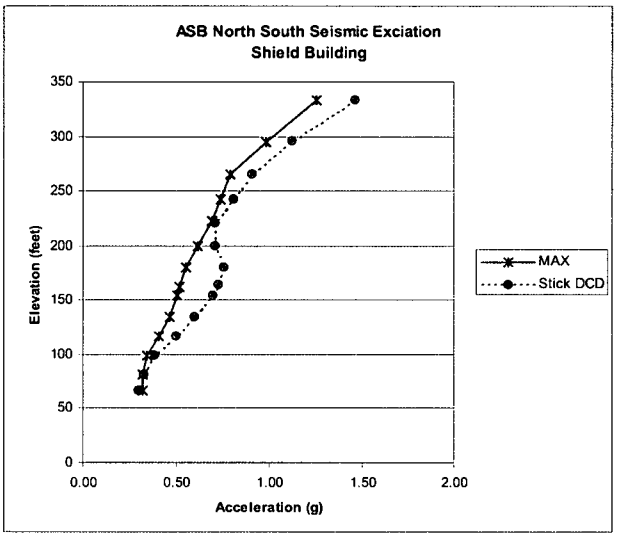
Table 6.2-7 – Equivalent Seismic Static Accelerations for Overturning Evaluation

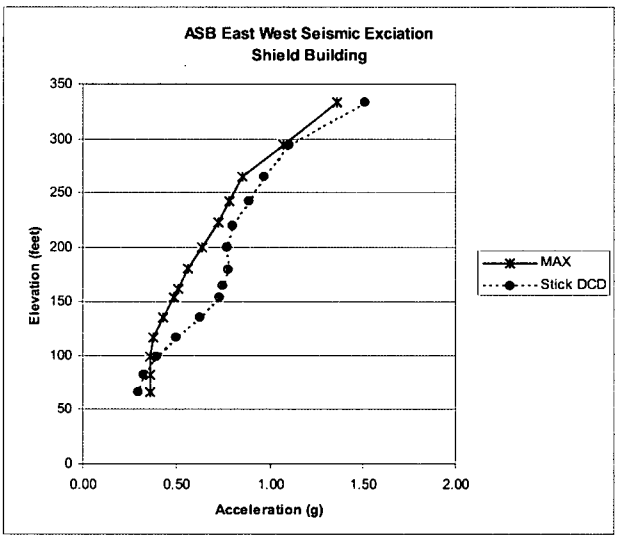
	Elevation	Equivalent Static Seismic Accelerations (1)			Notes
	feet	X	Y	Z	
ASB	66.5	0.32	0.37	0.36	Table 6.2-4 Shield Bldg
	81.5	0.32	0.37	0.36	
	99	0.35	0.37	0.36	
	116.5	0.41	0.40	0.38	
	134.88	0.47	0.43	0.41	
	179.19	0.55	0.56	0.51	
	222.75	0.69	0.72	0.64	
	265	0.79	0.85	0.69	
	294.93	0.98	1.07	0.901.09	
	333.13	1.25	1.36	0.951.10	
SCV	99.00	0.33	0.36	0.36	Table 6.2-5
	131.68	0.41	0.48	0.44	
	169.93	0.56	0.65	0.55	
	224.00	0.87	1.03	0.66	
	244.21	0.98	1.15	0.70	
	255.02	1.04	1.22	0.75	
	265.83	1.10	1.28	0.86	
	273.83	1.14	1.33	1.03	
	281.90	1.18	1.37	1.21	
Polar Crane	236.5	2.14	2.31	1.89	Table 6.2-6
CIS	66.5	0.33	0.36	0.36	Table 6.2-7 Average of East and West Sides
	82.5	0.33	0.36	0.36	
	99	0.35	0.36	0.36	
	103	0.36	0.37	0.36	
	107.17	0.37	0.38	0.37	
	134.25	0.58	0.56	0.39	
	153	0.73	0.62	0.39	
	164.95	0.85	0.83	0.41	

Notes to Table 6.2-7:

(1) X = North-South; Y = East-West; Z = Vertical
(2) Linear interpolation between elevations is acceptable.

Also Figure E-1 will be modified to reflect increased seismic acceleration values as shown below.





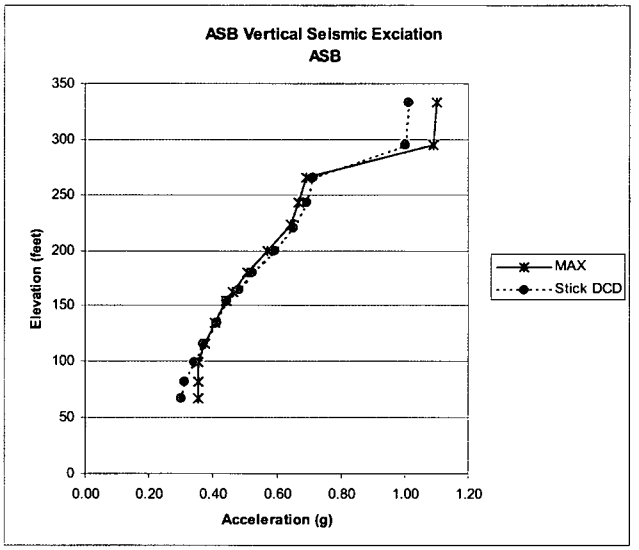


Figure E-1 – Comparison of ASB Response

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.