Westinghouse

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

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

Direct tel: 412-374-6206
Direct fax: 724-940-8505
e-mail: sisk1rb@westinghouse.com

Your ref: Docket No. 52-006
Our ref: DCP_NRC_003037

September 3, 2010

Subject: AP1000 Response to Request for Additional Information (SRP 3)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 3. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAI(s):

RAI-SRP3.8.3-SEB1-03 R3
RAI-SRP3.8.4-SEB1-04

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,

R. A. Lindgren /FOR

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

/Enclosure

1. Response to Request for Additional Information on SRP Section 3

D063
NRO

cc:	D. Jaffe	-	U.S. NRC	1E
	E. McKenna	-	U.S. NRC	1E
	S. Sanders	-	U.S. NRC	1E
	T. Spink	-	TVA	1E
	P. Hastings	-	Duke Energy	1E
	R. Kitchen	-	Progress Energy	1E
	A. Monroe	-	SCANA	1E
	P. Jacobs	-	Florida Power & Light	1E
	C. Pierce	-	Southern Company	1E
	E. Schmiech	-	Westinghouse	1E
	G. Zinke	-	NuStart/Entergy	1E
	R. Grumbir	-	NuStart	1E
	D. Lindgren	-	Westinghouse	1E

ENCLOSURE 1

Response to Request for Additional Information on SRP Section 3

RAI Response Number: RAI-SRP3.8.3-SEB1-03
Revision: 3

Question:

DCD Section 3.8.3.4.1 covers the seismic analyses of the containment internal structures (CIS). Subsection 3.8.3.4.1.1 describes the development of the 3D lumped-mass stick model of the CIS based on the structural properties obtained from a 3D finite element model using 3D shell elements. Subsection 3.8.3.4.1.2 describes the stiffness assumptions for local seismic analyses of the in-containment refueling water storage tank (IRWST). No description is provided for the model development and analysis, including the stiffness assumptions, for the global seismic analysis of the CIS. Prior revisions of the DCD did provide a description of this subject in a separate subsection; however, DCD Rev. 16 removed all of this information. Westinghouse is requested to provide a description of the CIS model, the stiffness assumptions utilized, and basis for the selection of the stiffness for the CIS and auxiliary building modules. In addition, DCD Table 3.8.3-2 was revised to utilize the "Monolithic Case 3" concrete stiffness representation of the CIS in the 3D finite element analysis using the equivalent static and response spectra analyses. Westinghouse is requested to explain why the CIS stiffness values were revised from the monolithic case 1 to monolithic case 3, and what is the technical basis for not evaluating the range of possible stiffness values between Cases 1 to 3.

If your response to this request for additional information will reference Revision 17 to the AP1000 DCD, please provide an exact reference.

Additional Request (Revision 1):

NRC Staff requests that in the Structural Modules for CIS DCD section that the information removed from DCD Section 3.8 be returned to the DCD and revised stiffness values be included in the DCD.

Additional Request (Revision 2):

In DCD Revision 16, the applicant removed Section 3.8.3.4.1.2 – Stiffness Assumptions for Global Seismic Analyses in the previous certified DCD. This section discussed the stiffness properties used in the seismic analyses of the containment internal structures (CIS) and the auxiliary building modules. Reference was made to DCD Table 3.8.3-1 which contained the various stiffness cases for the concrete filled steel plate modules used for structures inside containment and the auxiliary building.

The staff reviewed the Westinghouse response to RAI-SRP3.8.3-SEB1-03 Rev.1 and determined that the response did not address the two remaining concerns related to the appropriate concrete stiffness used for reinforced concrete structures as well as the concrete-filled steel plate modules. Provide the following:

1. The information presented in the proposed markup to DCD Table 3.8.3-2 (and associated text in the DCD) does not provide the technical basis for utilizing the stiffness reduction factor of

0.8 for the CIS. As noted in the proposed RAI markup to Section 3.8.3.4, the use of 0.8 is valid for a relatively small degree of cracking. The level and extent of cracking to justify the use of 0.8 should be provided for the current AP1000 evaluation. Also, the RAI response indicates that the NI model of the concrete structures (beyond the concrete-filled CIS modules) is based on the gross concrete section stiffness reduced by a factor of 0.8 to consider the effect of cracking "as recommended in Table 6-5 of FEMA 356." The staff finds that Table 6-5 of FEMA 356 indicates that the factor of 0.8 is only applicable to flexural rigidity for concrete walls which are uncracked when inspected, and for walls that are cracked the reduction factor is 0.5. For shear rigidity, the FEMA table indicates that the reduction factor is 0.4 for both uncracked and cracked conditions. Therefore, Westinghouse may have inappropriately referenced the FEMA standard for its use of the value of 0.8 for reinforced concrete structures as well as the concrete-filled steel plate module structures. Provide a completed justification supporting your assumptions that stresses in concrete are low and concrete is rarely cracking during SSE, as discussed.

2. State the technical basis for not evaluating the range of possible stiffness values for reinforced concrete structures as well as the concrete-filled steel plate module structures, as requested in the original RAI.

3. It was requested by the NRC during the June 28 – 30, 2010 audit, that the following information be provided.

1. Describe methodology for generation of FRS at 5 locations (3 applicable key locations (ASB control room floor, ASB fuel building roof at shield building, ASB shield building roof area) and 2 additional locations at Aux building that include highly stressed regions).
    - Abaqus
    - ANSYS
2. Compare the FRS from both methods at the 5 locations (3 applicable key locations and 2 additional locations at Aux building that include some higher stressed region).
3. Provide stress strain time history curves at 2 locations (1 Shield building and 1 Aux building). Show that no significant energy absorption occurs.
4. SC/RC connection
    - Describe methodology for modeling/analysis (accounting for current connection design).
    - Show that varying stiffness values does not significantly affect the response of the SB.
5. Provide discussion of the results and justification.

Additional Request (Revision 3):

The staff noted that on page 2 of 33, WEC did not incorporate the updated Path Forward list of items that was transmitted to WEC.

1. In accordance with the updated Path Forward, the staff expected that WEC would provide comparisons of the ABAQUS linear model to the ANSYS linear model, both using the 0.8

stiffness reduction factor. The staff requests WEC to add the corresponding ANSYS response spectra to Figures RAI-SRP3.8.3-SEB1-03-04 through RAI-SRP3.8.3-SEB1-03-21 in the RAI response, and to discuss any differences between the ANSYS linear results and the ABAQUS linear results. This is needed to ensure the adequacy of the ABAQUS linear model.

2. On page 4 of 33, the staff noted the following statement, in response to the staff's request for information about the modeling of the RC/SC connection in the ABAQUS analysis:

> "The non-linear model includes a benchmarked RC/SC connection using the existing shell and solid elements of the NI20 linear model. This connection was modified to match the testing performed at Purdue University, with the in-plane shear being the governing case. The purpose of including benchmarked non-linear RC/SC connection was to show what effects the RC/SC material properties have on the building response spectra and local stresses."

The staff requests the applicant to clarify and expand on this statement, to provide the following information:

(a) Describe how the shell elements on both sides of the juncture were modified to match the test results, including how the size difference between the actual connection design configuration and the elements was treated.

(b) Clarify the statement: "‥, with the in-plane shear being the governing case." Were extensional, bending, out-of-plane shear, and in-plane shear behavior of the RC/SC connection all considered? Compare the test stiffness values to the ABAQUS connection model values.

3. For the ANSYS linear analysis, the ABAQUS linear analysis, and the ABAQUS nonlinear analysis provide the following information:

(a) the time step used to define the synthetic time history input; the maximum input frequency that can be represented using this time step; and the method used to determine the maximum input frequency.

(b) the integration time step used in solution; the maximum response frequency that can be represented using this time step; and the method used to determine the maximum response frequency.

Westinghouse Response:

Section 3.8.3.4.1.2 was removed since stiffness assumptions for global seismic analyses are part of Section 3.7, Seismic Design. Description is provided for model development and analysis for the containment internal structures (CIS) in DCD Section 3.7.2.3.1 (Rev. 16 &17). Further, Technical Report 03 (Reference 1) was written to provide more details of the seismic analyses for soil sites than provided in the DCD. It is noted that DCD subsection 3.8.3.4.1.1 (Rev. 17), Finite Element Model is not up to date since it discusses 3D lumped-mass stick model of the CIS that is no longer used, a shell model is now used. The first sentence of the first paragraph of this subsection is removed, and reference is made to DCD Section 3.7 and 3G.

The stiffness assumptions for the global seismic analysis of the CIS and auxiliary building modules is discussed in DCD Section 3.7.2.3 (Rev. 16 & 17) and DCD Section 3.7.2.3.1 (Rev. 16 & 17). It is stated in DCD Section 3.7.2.3:

> "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 reduced by a factor of 0.8 to consider the effect of cracking as recommended in Table 6-5 of FEMA 356 (Reference 5)."

In DCD Section 3.7.2.3 it is stated:

> "The properties of the concrete-filled structural modules are computed using the combined gross concrete section and the transformed steel face plates of the structural modules. The modulus is reduced by a factor of 0.8 to consider the effect of cracking."

The concrete stiffness was changed to Monolithic Case 3 to be consistent with the local seismic analyses of in-containment refueling water storage tank discussed in DCD Section 3.8.3.4.1.2 (Rev. 16 & 17). Foot note 2 was added to Table 3.8.3-2 to refer to DCD Section 3.7 for the specifics related to the global containment internal structures seismic analyses.

Westinghouse Response (Revision 1):

The first paragraph of DCD subsection 3.8.3.4.1.1 is changed in the Revision 0 response to reflect that the three dimensional lumped mass stick model of the CIS is no longer used. The structural modules are modeled within the 3D finite element shell models described in DCD subsection 3.7 and Appendix 3G. For consistency with DCD Section 3.7.2.3 a sentence will be added related to the reduction of concrete modulus by a factor of 0.8 to reflect cracking.

Westinghouse Response (Revision 2):

The information to address items 1 and 2 is provided in the response to RAI-SRP3.7.1-SEB1-19. Provided below is the response to information requested by the NRC during the June audit.

Additional Audit Request:

Westinghouse performed a new time history analysis with the ABAQUS NI20 model in order to demonstrate the stability of the non-linear NI20 model, in which the concrete behavior is described by the Concrete Damaged Plasticity model. The acceleration time histories associated with the envelope of response spectra for all soil sites at foundation level (Elevation 60.5') at 5% critical damping was used as the input. This was performed as an implicit dynamic analysis in ABAQUS using specific alpha-beta damping values for each material property. An ANSYS comparison is not provided in this response since the NI20 model does not typically use the all soil input time history for analysis and has not currently been run. This is a sensitivity study between linear and non-linear concrete material properties.

The response spectra at several locations of the Nuclear Island (NI) were calculated. They agree with and are enveloped by the ones produced by the time history analysis with the linear elastic ABQAUS NI20 model, in which the stiffness is reduced to 80% to reflect the concrete crack effect. It can be concluded that the non-linear ABAQUS NI20 model is capable of better simulating the seismic response of the AP1000 NI to the different levels of the seismic excitation.

The non-linear ABAQUS NI20 model adopts the Concrete Damaged Plasticity (CDP) model to describe the mechanical behavior of the concrete. The material parameters in the CDP model were benchmarked with the testing performed by Purdue University. The linear ABAQUS model used the 80% Young's Modulus of concrete to address the effect of concrete cracking. In both non-linear and linear time history analyses, the input time histories are associated with the envelope of response spectra for all generic soil sites at the foundation level (Elevation 60.5').

The non-linear model includes a benchmarked RC/SC connection using the existing shell and solid elements of the NI20 linear model. This connection was modified to match the testing performed at Purdue University, with the in-plane shear being the governing case. The purpose of including benchmarked non-linear RC/SC connection was to show what effects the RC/SC material properties have on the building response spectra and local stresses.

The all soils input time history was developed by taking the enveloped CSDRS at elevation 60.5', and creating a statistically independent time history. In Figures RAI-SRP3.8.3-SEB1-03-01 through RAI-SRP3.8.3-SEB1-03-03, the enveloped Response Spectra (RS) for all soil sites at Elevation 60.5' are presented and compared against the AP1000 Certified Seismic Design Response Spectra (CSDRS) at 5% damping in the directions of North-South (X), East-West (Y) and Vertical (Z), respectively.

The Response Spectra (RS) at 5% critical damping are produced for 6 locations of the AP1000 NI shown in Table RAI-SRP3.8.3-SEB1-03-01 when subjected to the enveloped RS for all soil sites at El. 60.5'.

Node	Location
1750	Shield Building (SB) West Wall at El. 99'
1574	Auxiliary Building (AB) East Wall at El. 100'
2078	Auxiliary Building (AB) NE Corner at Control Room Floor at El. 116.5'
2505	Auxiliary Building (AB) Roof at El. 160'
2675	Auxiliary Building (AB) Corner of Fuel Building Roof at Shield Building at El. 179.19'
3329	Shield Building (SB) Roof at El. 327.41'

Table RAI-SRP3.8.3-SEB1-03-01

The Response Spectra at 5% critical damping produced by the non-linear and linear time history analyses of ABAQUS NI20 model for the nodes listed above are presented in Figures RAI-SRP3.8.3-SEB1-03-04 through RAI-SRP3.8.3-SEB1-03-21, respectively. It is shown that the RS calculated with the non-linear time history analysis matches and is enveloped by the RS produced by the linear time history analysis. The RC/SC connection effect can be seen at node 1750 and is negligible when modeled with non-linear benchmarked material properties.

A sample load deflection curve is provided in Figure RAI-SRP3.8.3-SEB1-03-22 to show the elastic and plastic behavior of these non-linear material properties. Maximum Principle Stress-strain curves in concrete for two high stress regions of the Auxiliary and Shield buildings have been provided in Figures RAI-SRP3.8.3-SEB1-03-23 through RAI-SRP3.8.3-SEB1-03-26. The plots contain a time history stress-strain curve at the Auxiliary East Wall and Shield Building West Wall for the linear and non-linear model analyses. The testing at Purdue University resulted in complete in-plane yielding in the concrete at a strain of roughly 0.003. These plots show the non-linear elements are acting linearly for the most part, under SSE loading.

The linear plots show higher stresses in these regions because the elements are unable to crack and redistribute stresses to surrounding elements. The non-linear results show lower stresses and that the material property still acting linearly under this loading. High stresses are redistributed in the non-linear concrete elements once these elements begin to crack so the overall magnitude is less than a linear material property with 80% stiffness.

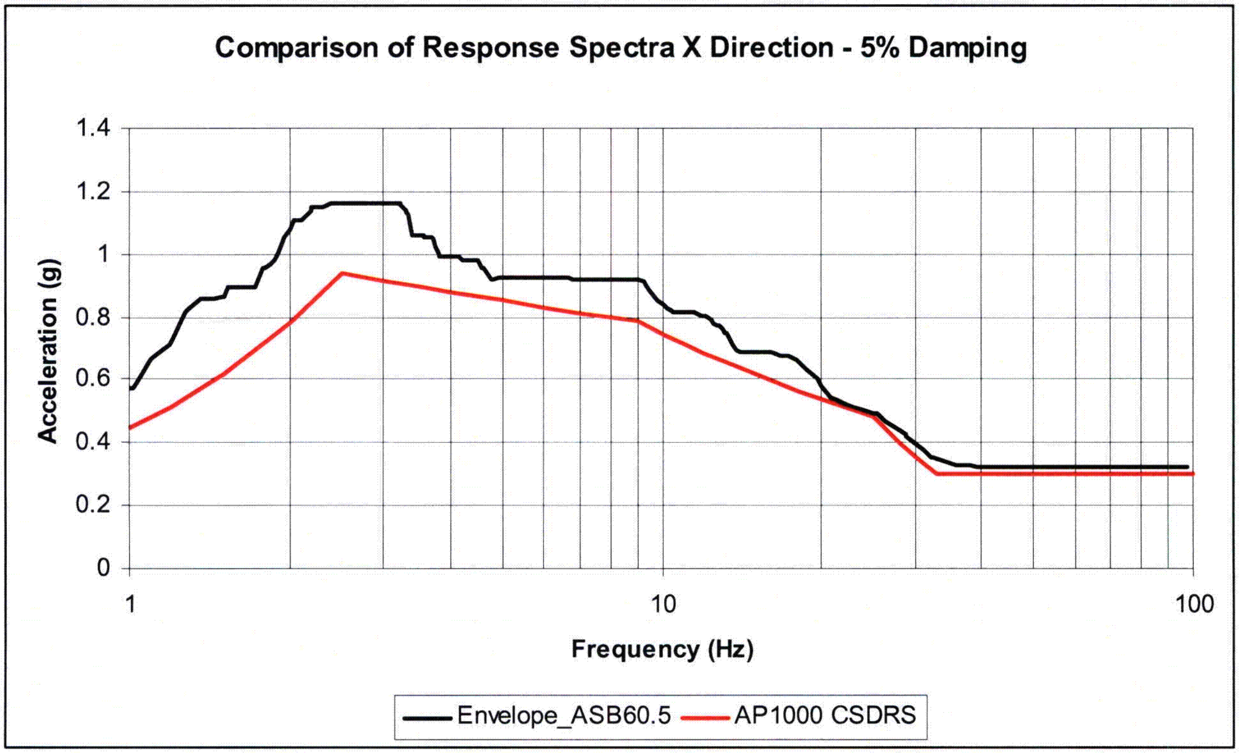

Figure RAI-SRP3.8.3-SEB1-03-01: Enveloped RS at El. 60.5' and AP1000 CSDRS in X direction

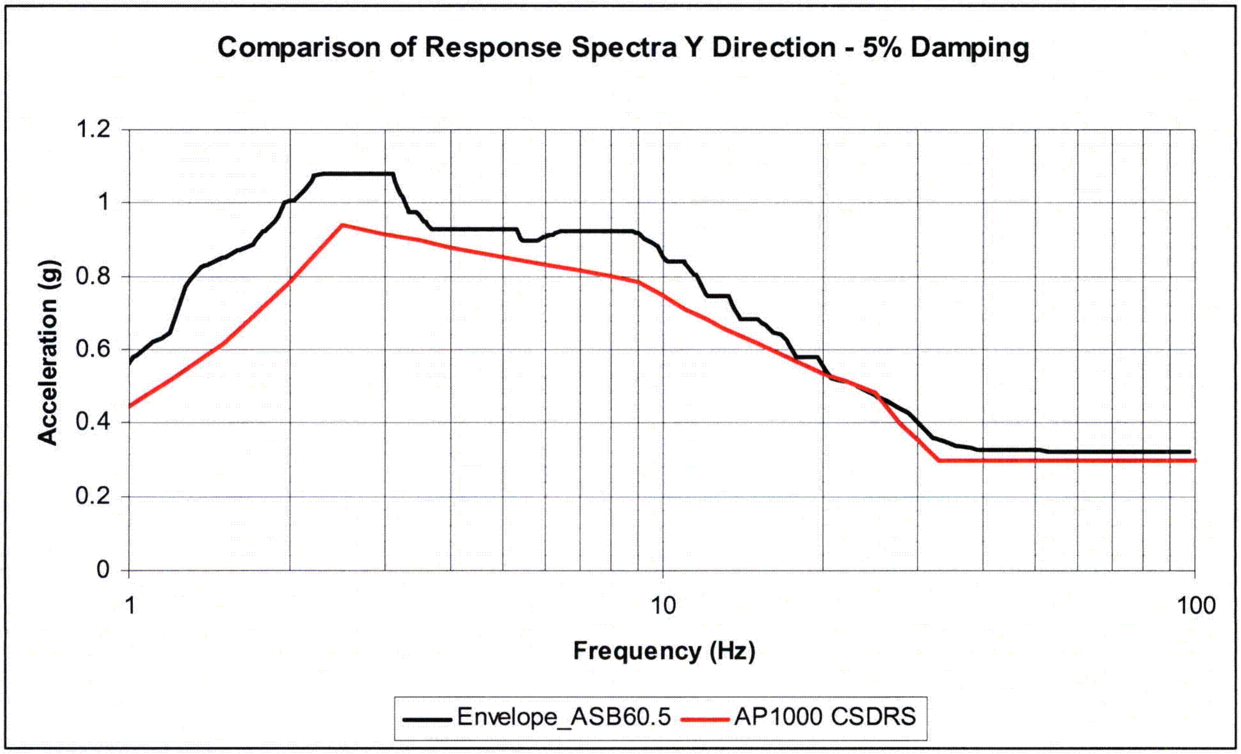

Figure RAI-SRP3.8.3-SEB1-03-02: Enveloped RS at El. 60.5' and AP1000 CSDRS in Y direction

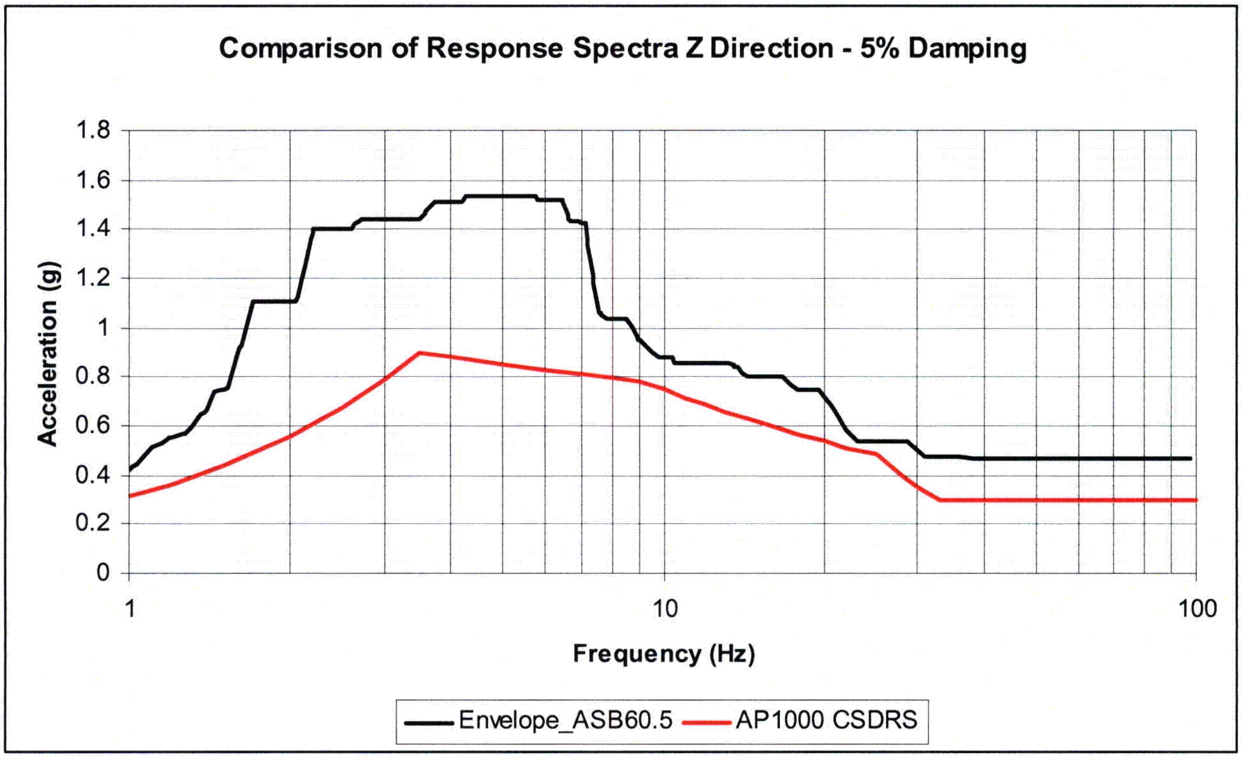

Figure RAI-SRP3.8.3-SEB1-03-03: Enveloped RS at El. 60.5' and AP1000 CSDRS in Z direction

The Figures RAI-SRP3.8.3-SEB1-03-04 through RAI-SRP3.8.3-SEB1-03-21 from Revision 2 of this response have been updated to include the ANSYS linear comparison and are presented in Revision 3 Figures RAI-SRP3.8.3-SEB1-03-27 through RAI-SRP3.8.3-SEB1-03-44.

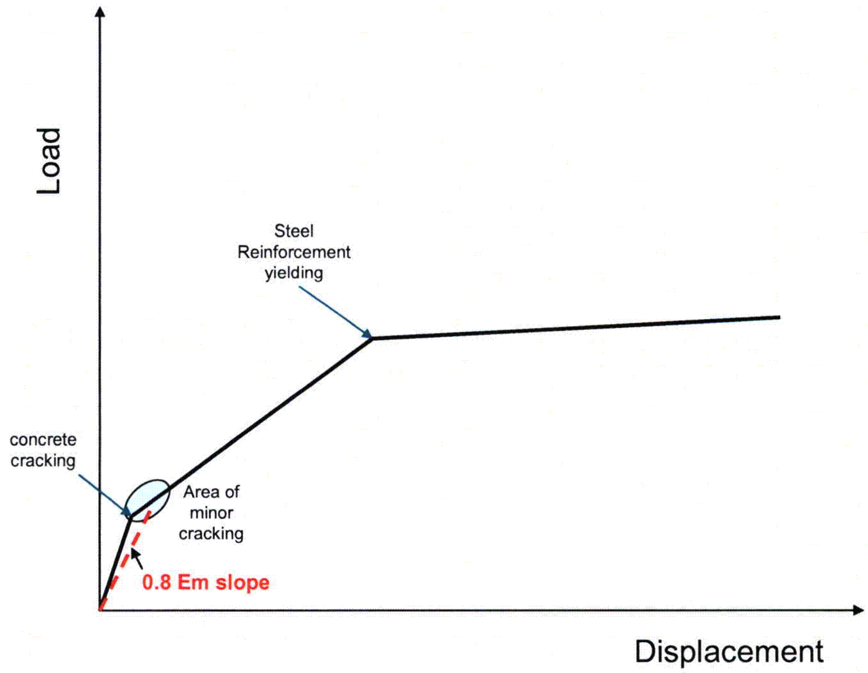

Figure RAI-SRP3.8.3-SEB1-03-22: Sample In-Plane Shear Load Deformation Behavior

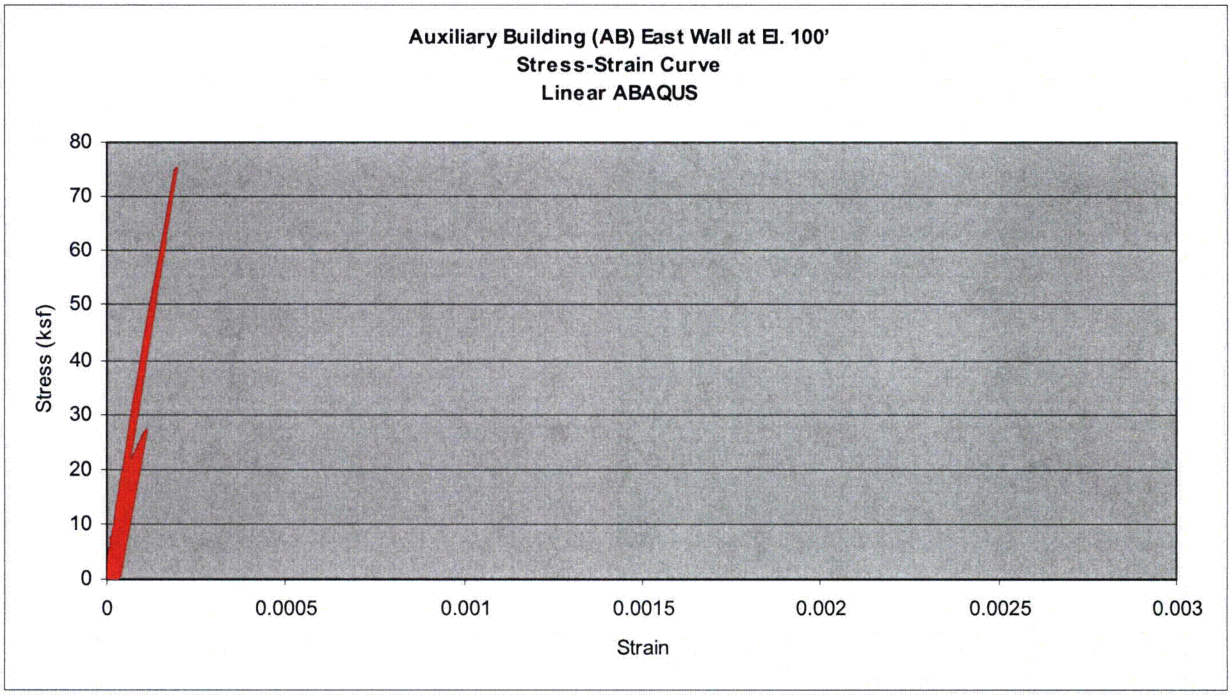

Figure RAI-SRP3.8.3-SEB1-03-23: Linear Stress/Strain Curve at RC AUX East Wall

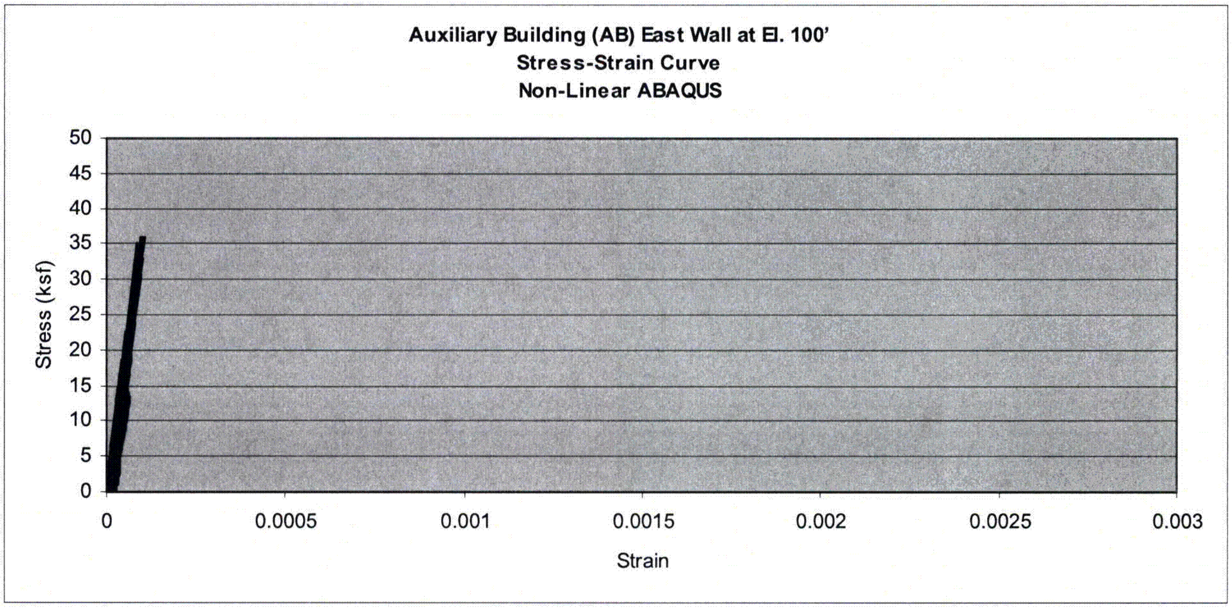

Figure RAI-SRP3.8.3-SEB1-03-24: Non-Linear Stress/Strain Curve at RC AUX East Wall

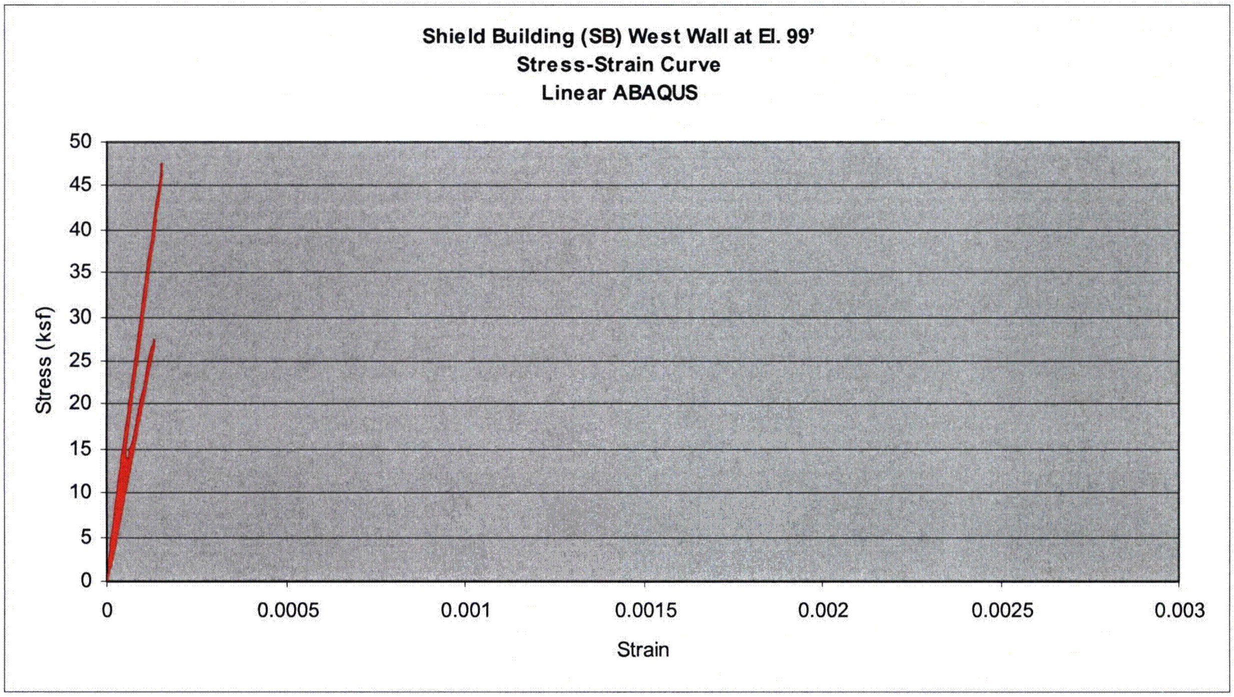

Figure RAI-SRP3.8.3-SEB1-03-25: Linear Stress/Strain Curve at SC Shield Building West Wall

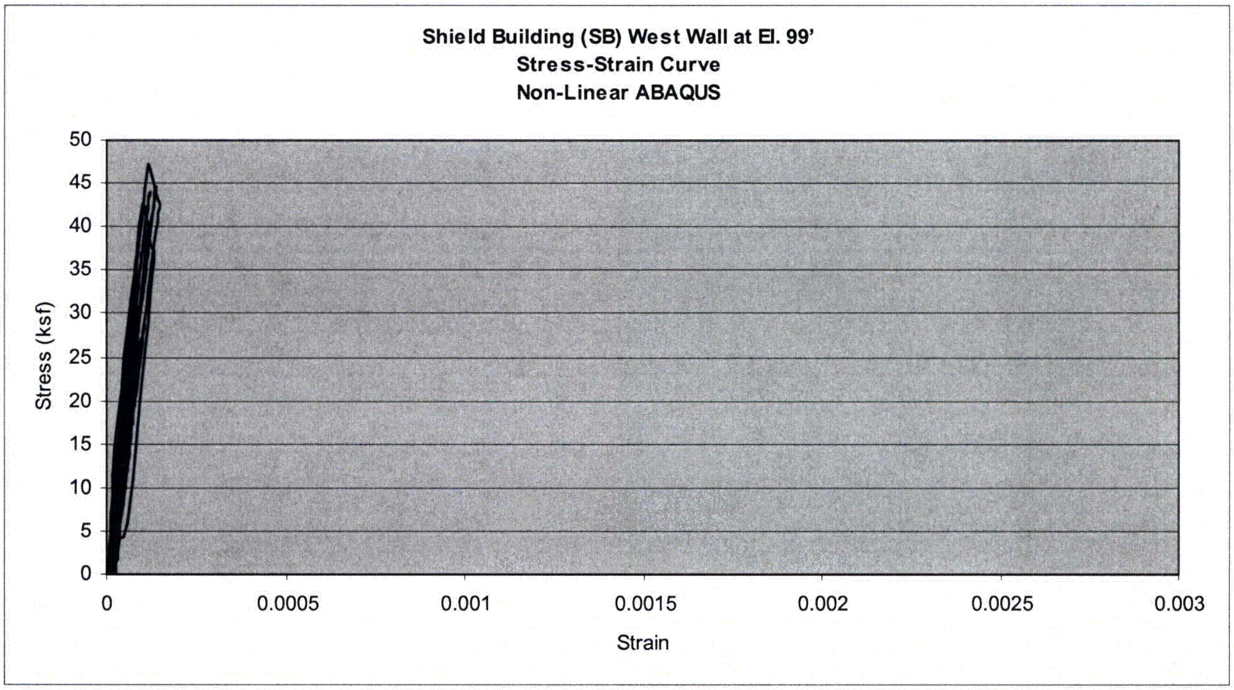

Figure RAI-SRP3.8.3-SEB1-03-26: Non-Linear Stress/Strain Curve at SC Shield Building West Wall

Westinghouse Additional Response (Revision 3):

1. A list of critical nodes compared in this analysis is provided in Table RAI-SRP3.8.3-SEB1-01 in the Westinghouse Revision 2 response of this RAI. The FRS comparisons from the previous Revision of this RAI response have been updated to include additional information. These plots now show a comparison between the NI20 ANSYS linear, ABAQUS linear and ABAQUS non-linear models, and are provided in Figures RAI-SRP3.8.3-SEB1-03-27 through RAI-SRP3.8.3-SEB1-03-44.

The minor differences between the ABAQUS and ANSYS results are caused by a combination of the software's element calculation discrepancies as well as modeling modifications made to account for the limitations in FEM programs. The differences in results between the linear ABAQUS and ANSYS models are considered negligible when using the model for structural parametric studies. The FRS comparisons show good agreement up to 10 Hz where most of the structural damage is present. Two differences that affect the results, especially at the higher frequencies, are:

- Alpha Beta Damping - Leads to under damped frequency ranges in the model
- No CIS modeled in ABAQUS

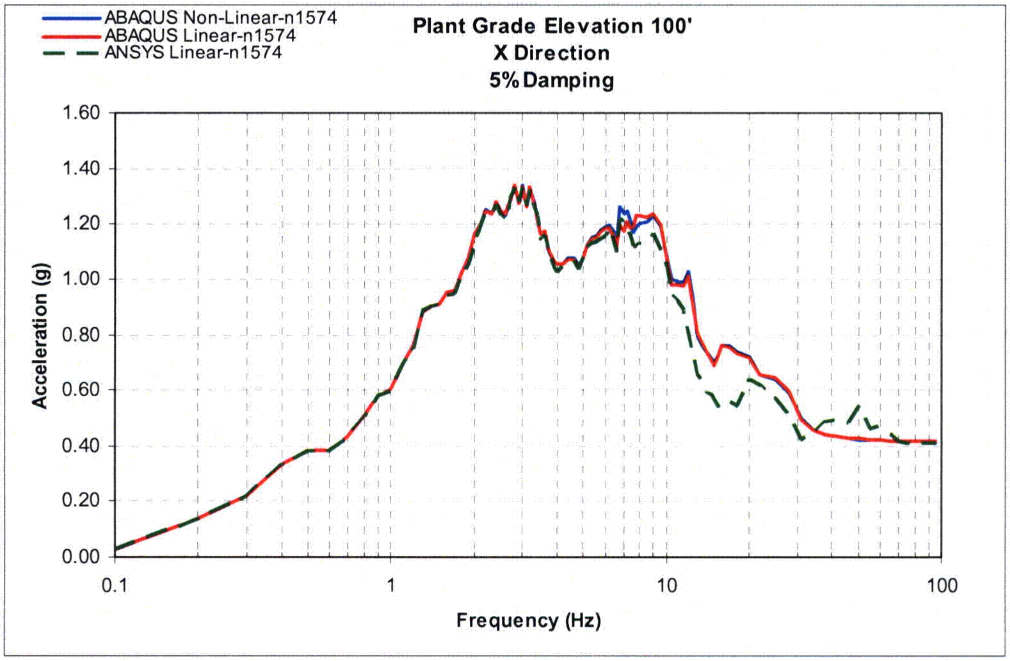

Figure SRP3.8.3-SEB1-03-27: RS of Aux. Bldg. East Wall at El. 100' Subjected to Enveloped RS in X Direction

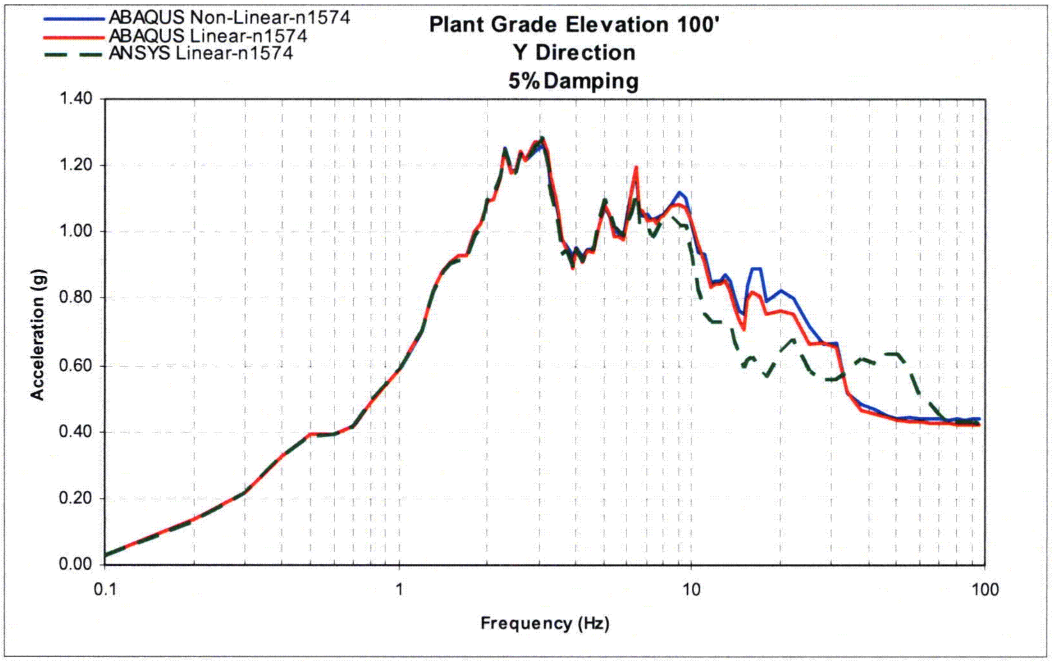

Figure SRP3.8.3-SEB1-03-28: RS of Aux. Bldg. East Wall at El. 100' Subjected to Enveloped RS in Y Direction

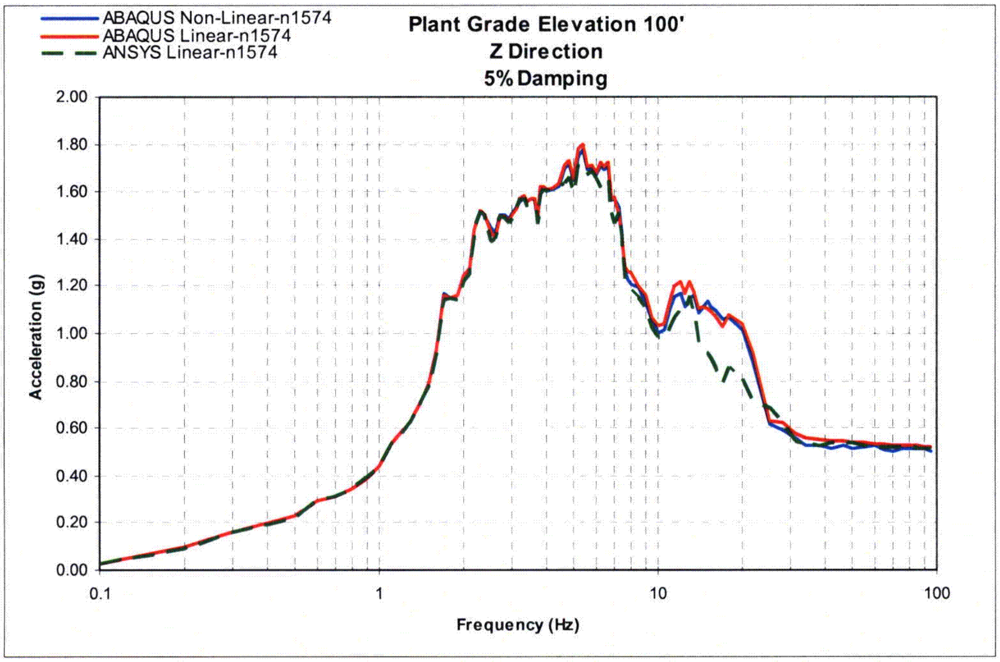

Figure SRP3.8.3-SEB1-03-29: RS of Aux. Bldg. East Wall at El. 100' Subjected to Enveloped RS in Z Direction

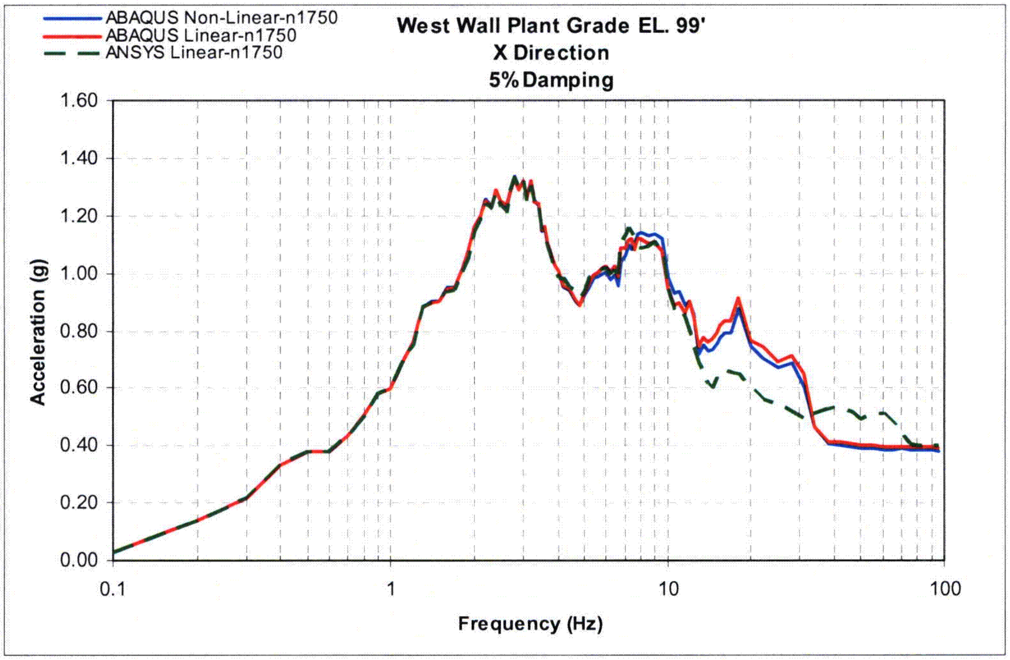

Figure SRP3.8.3-SEB1-03-30: RS of SB West Wall at El. 99' Subjected to Enveloped RS in X Direction

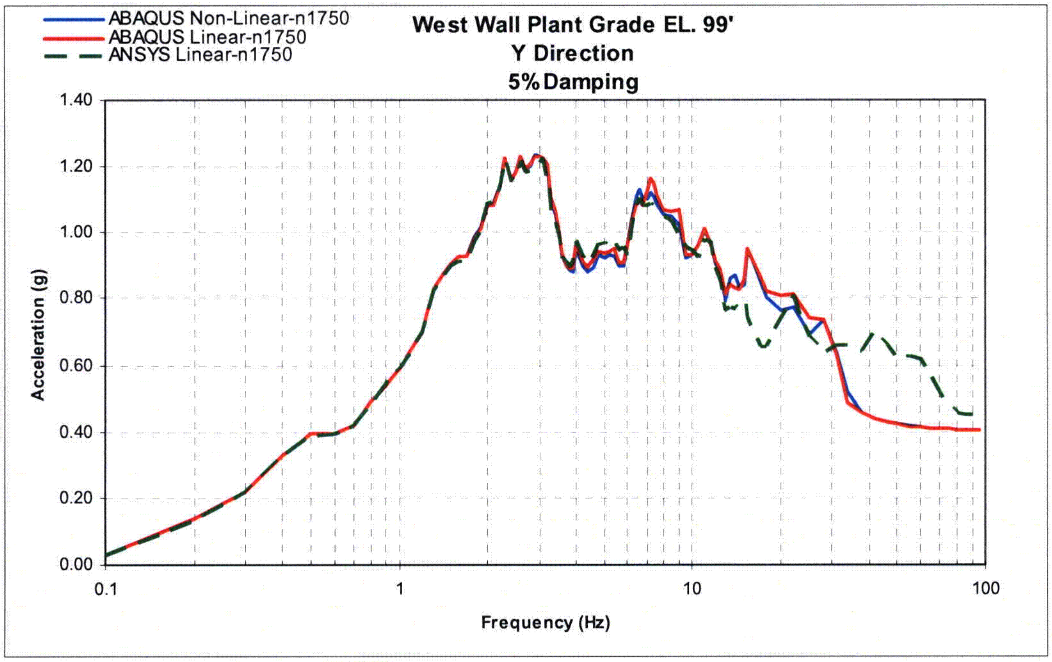

Figure SRP3.8.3-SEB1-03-31: RS of SB West Wall at El. 99' Subjected to Enveloped RS in Y Direction

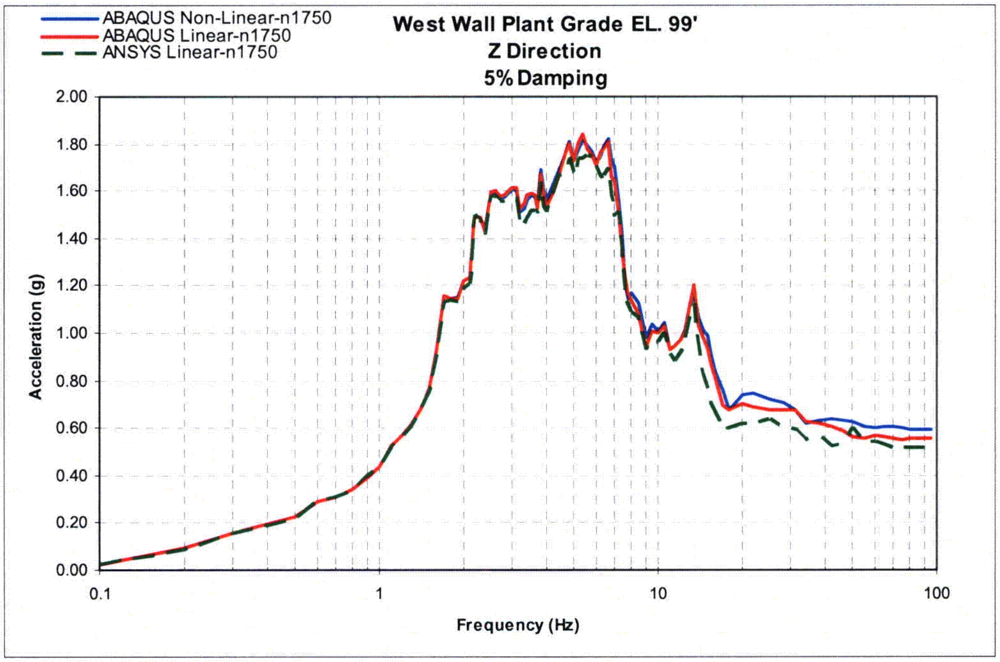

Figure SRP3.8.3-SEB1-03-32: RS of SB West Wall at El. 99' Subjected to Enveloped RS in Z Direction

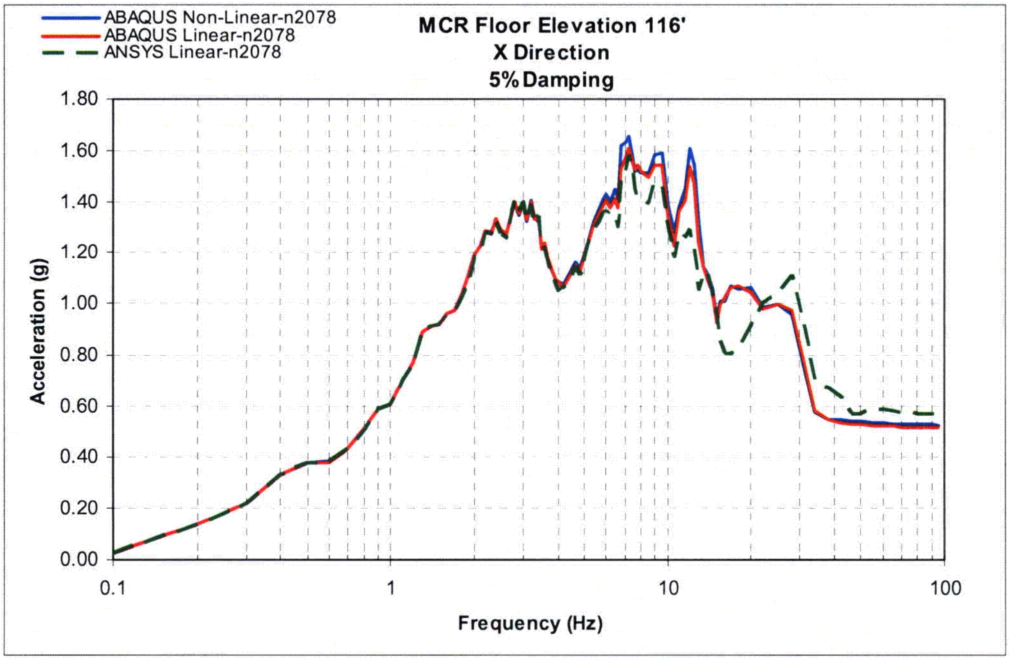

Figure SRP3.8.3-SEB1-03-33: RS of Aux. Bldg. Main Control at El. 116.5' Subjected to Enveloped RS in X Direction

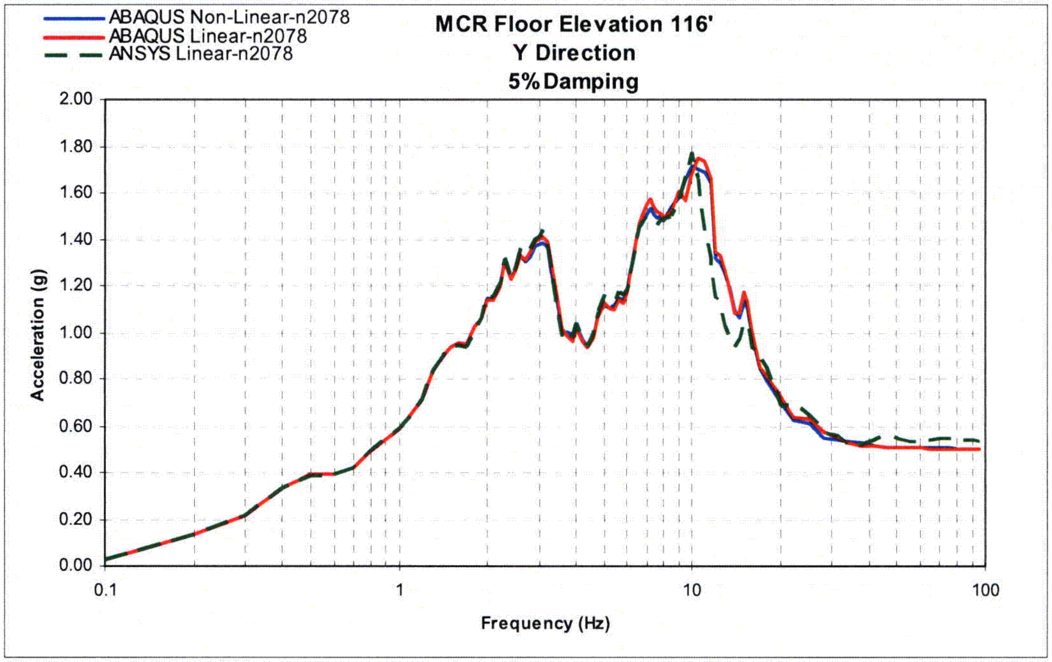

Figure SRP3.8.3-SEB1-03-34: RS of Aux. Bldg. Main Control at El. 116.5' Subjected to Enveloped RS in Y Direction

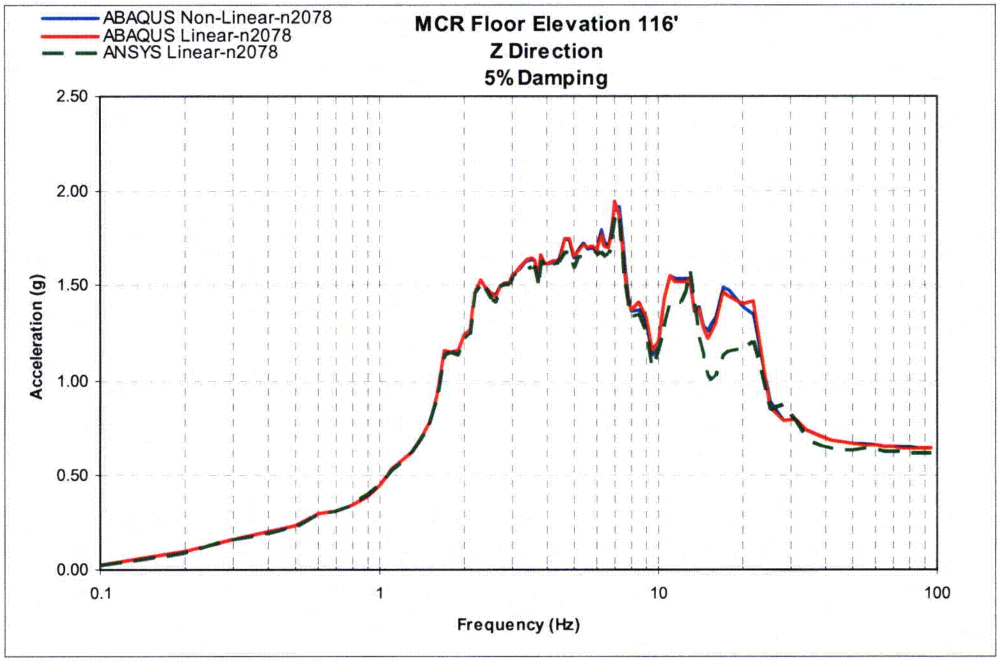

Figure SRP3.8.3-SEB1-03-35: RS of Aux. Bldg. Main Control at El. 116.5' Subjected to Enveloped RS in Z Direction

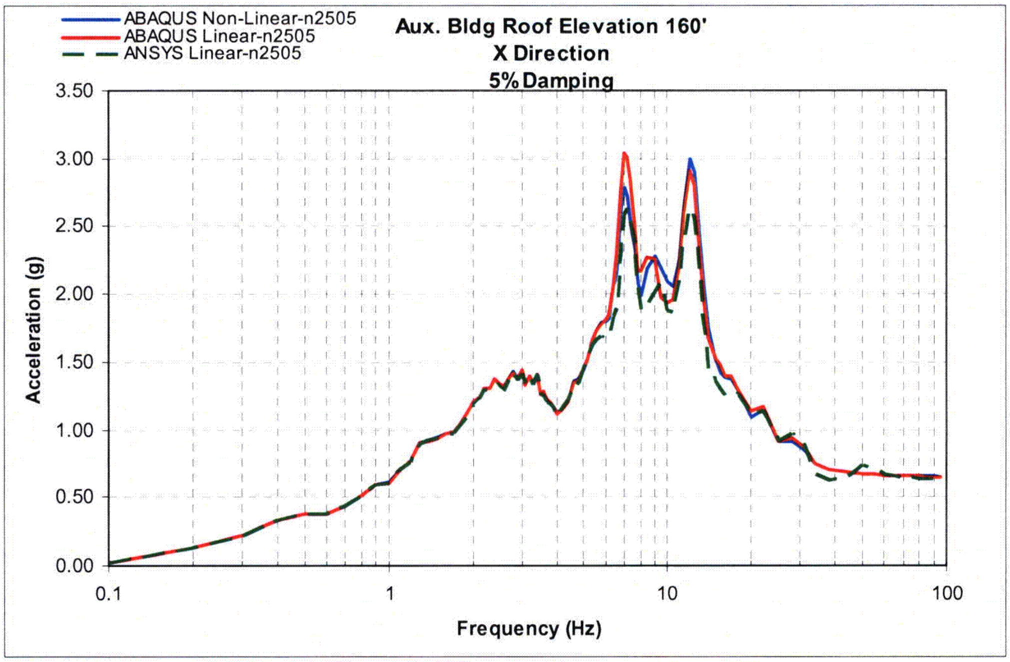

Figure SRP3.8.3-SEB1-03-36: RS of Aux. Bldg. Roof at El. 160' Subjected to Enveloped RS in X Direction

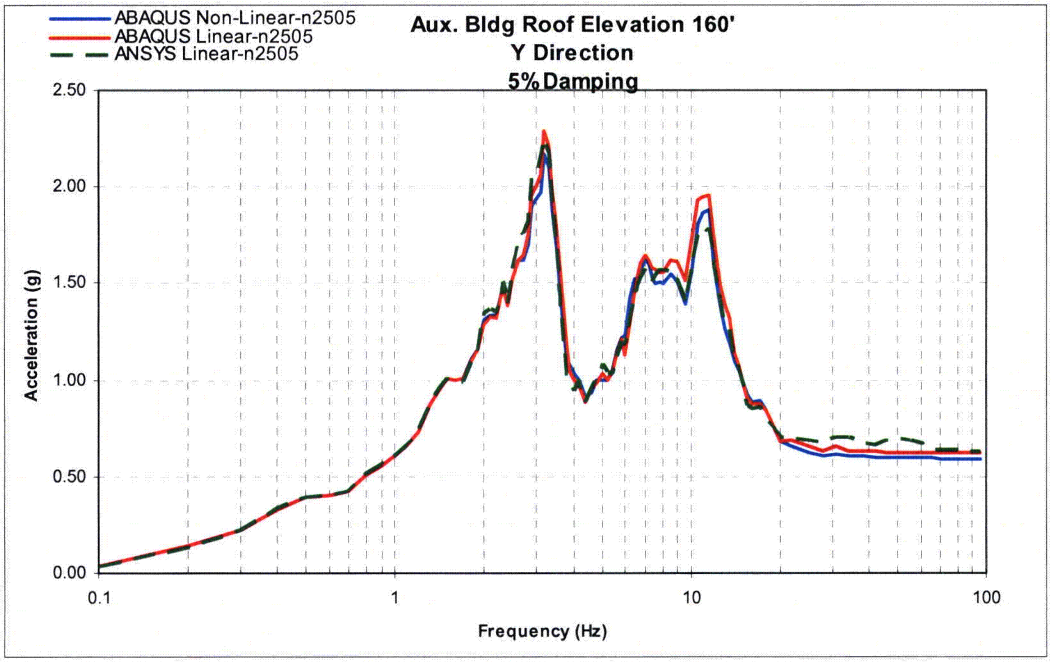

Figure SRP3.8.3-SEB1-03-37: RS of Aux. Bldg. Roof at El. 160' Subjected to Enveloped RS in Y Direction

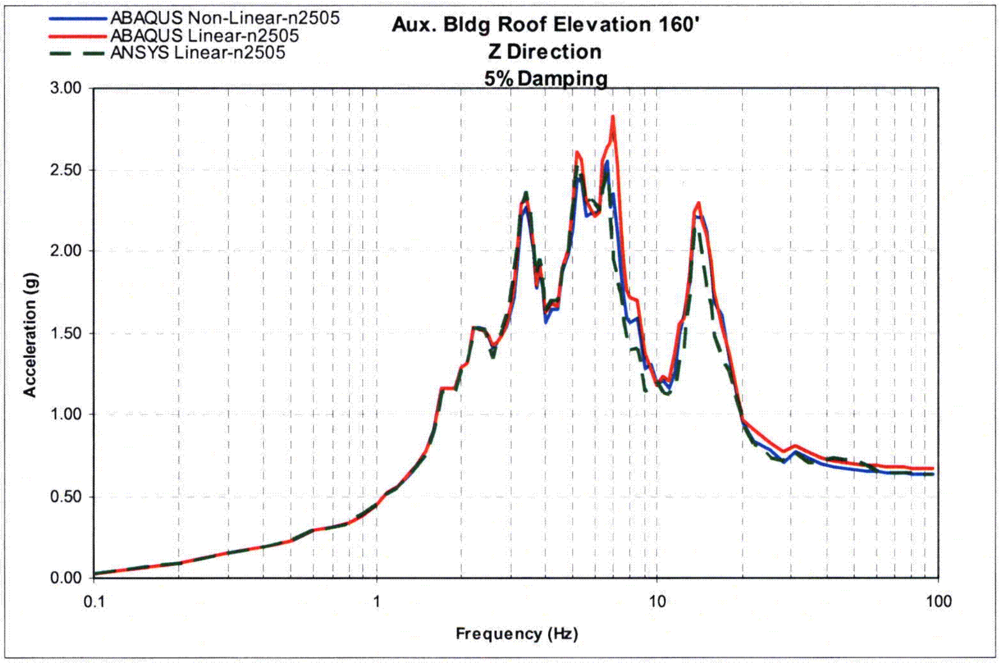

Figure SRP3.8.3-SEB1-03-38: RS of Aux. Bldg. Roof at El. 160' Subjected to Enveloped RS in Z Direction

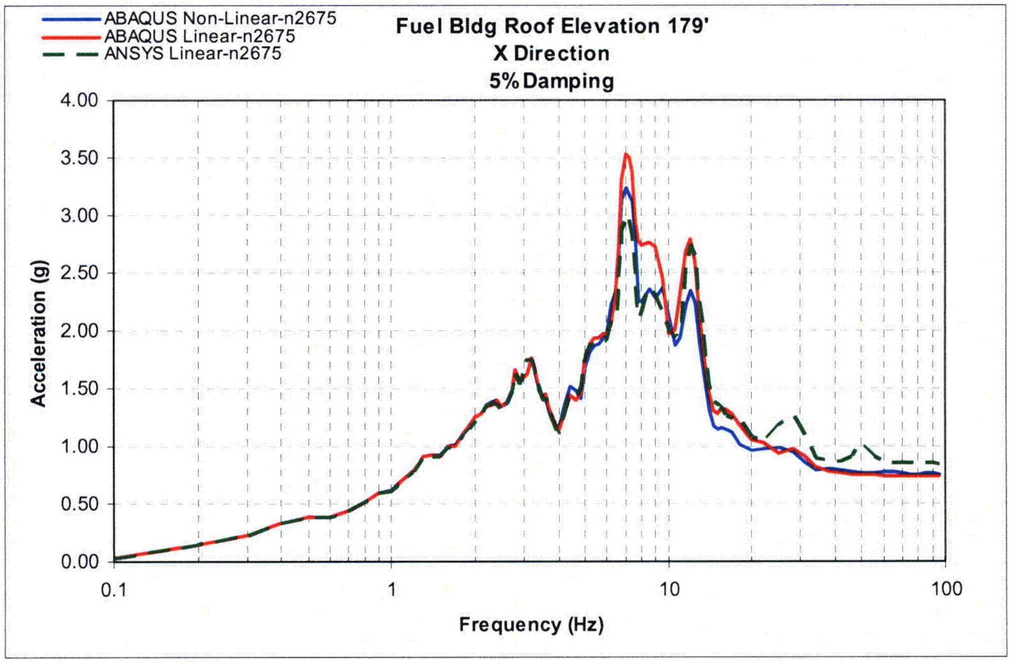

Figure SRP3.8.3-SEB1-03-39: RS of Aux. Bldg. Corner of Fuel Bldg. Roof at SB at El. 116.5' Subjected to Enveloped RS in X Direction

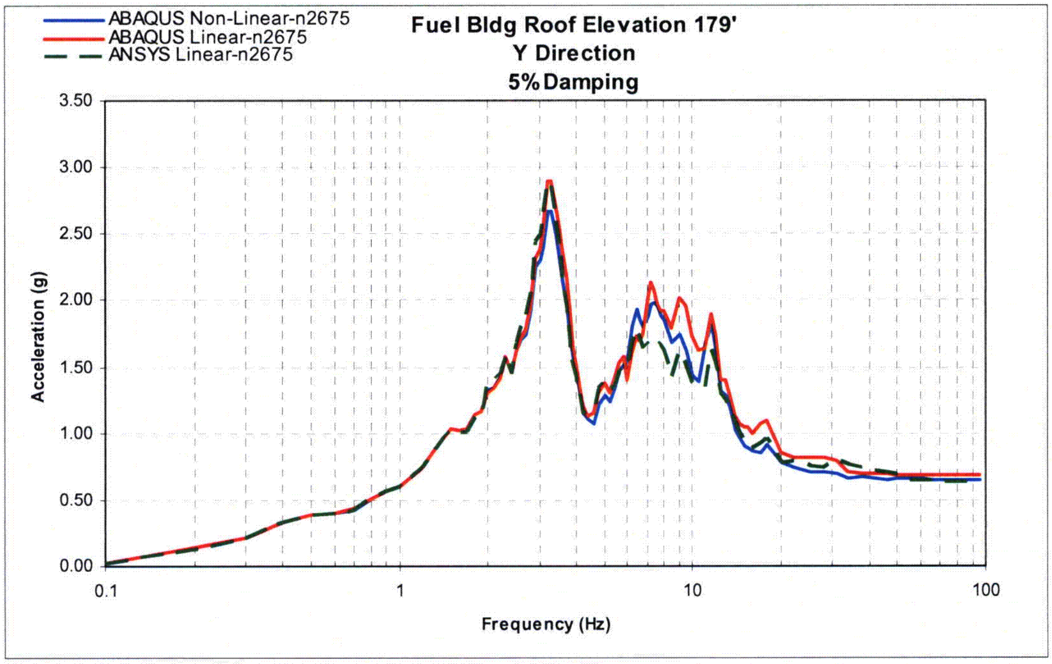

Figure SRP3.8.3-SEB1-03-40: RS of Aux. Bldg. Corner of Fuel Bldg. Roof at SB at El. 116.5' Subjected to Enveloped RS in Y Direction

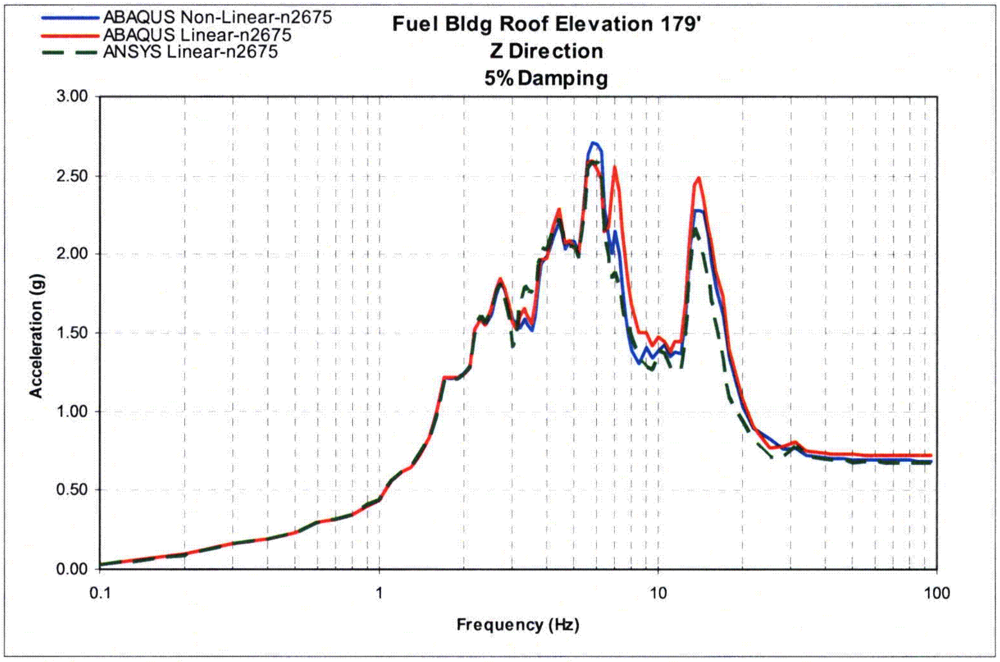

Figure SRP3.8.3-SEB1-03-41: RS of Aux. Bldg. Corner of Fuel Bldg. Roof at SB at El. 116.5' Subjected to Enveloped RS in Z Direction

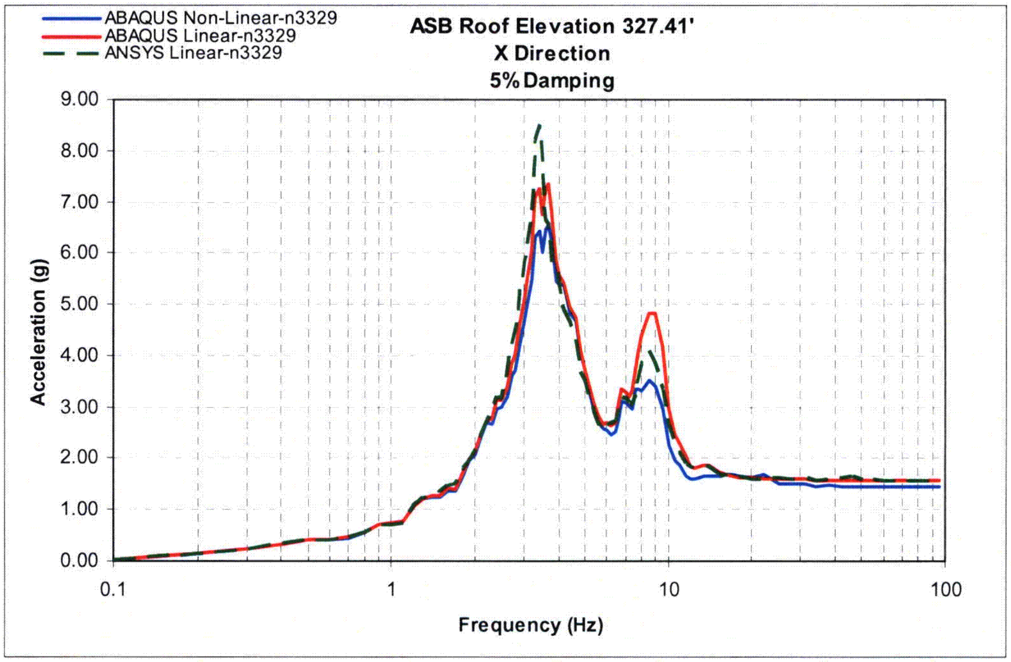

Figure SRP3.8.3-SEB1-03-42: RS of SB Roof at El. 327.41' Subjected to Enveloped RS in X Direction

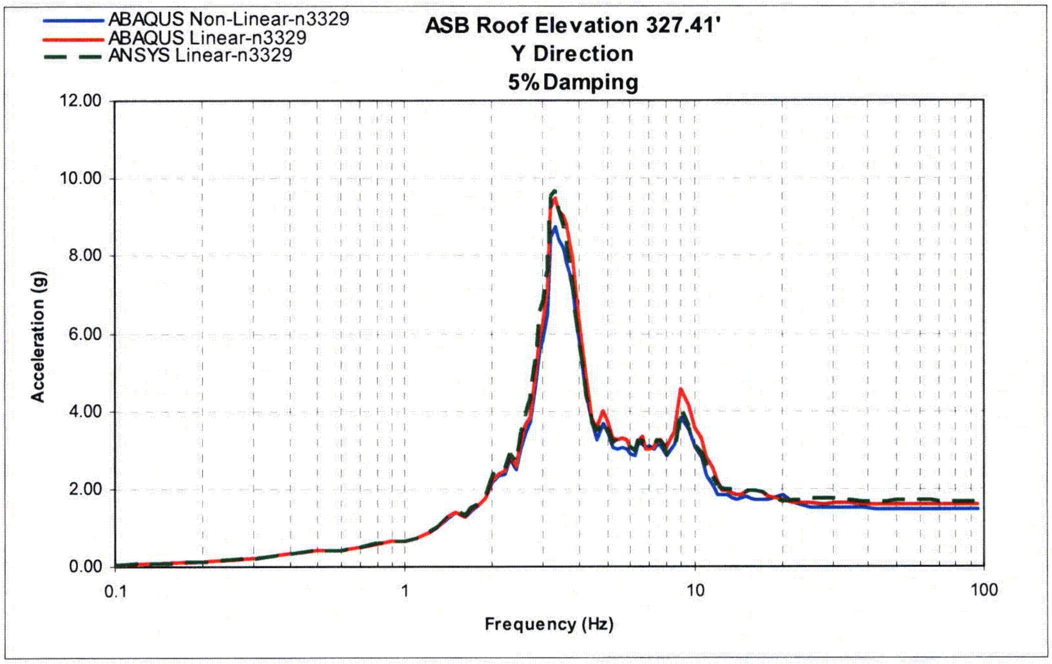

Figure SRP3.8.3-SEB1-03-43: RS of SB Roof at El. 327.41' Subjected to Enveloped RS in Y Direction

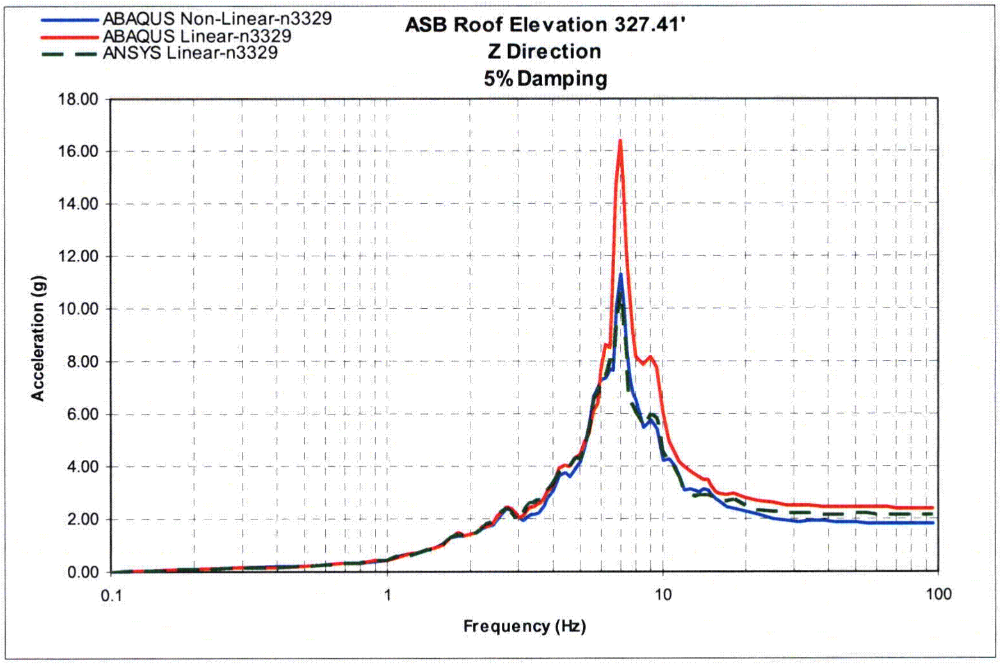

Figure SRP3.8.3-SEB1-03-44: RS of SB Roof at El. 327.41' Subjected to Enveloped RS in Z Direction

2. The connection detail between reinforced concrete and the steel composite shield building wall was benchmarked to test results from the Level 3 Shield Building analyses. The in-plane shear results were used as the target results for this analysis since that is the behavior that controls the dynamic response of the shield building. After the in-plane shear was benchmarked to the Level 3 analysis, the section was checked for tension and out-of-plane shear to ensure that section had not been increased in stiffness under the other loading cases.

To benchmark the NI20 ABAQUS model with non-linear materials, a section of the West Wall RC/SC connection is selected from the model and given the same loading case as the Level 3 analyses. The section of the model used for this analysis is shown in Figure RAI-SRP3.8.3-SEB1-03-45, with an enlarged view in Figure RAI-SRP3.8.3-SEB1-03-46. The Level 3 in-plane analyses use a detailed finite element model which includes tie bars and reinforcement steel within the steel composite structures, shown in Figure RAI-SRP3.8.3-SEB1-03-47 and RAI-SRP3.8.3-SEB1-03-48. This provides very accurate model representation and benchmarked materials. The Level 1 analyses do not model the reinforcement because of the model refinement and are therefore inherently weaker than the actual structure. An in-plane shear load is applied to the model and analyzed as an explicit time based displacement load for both Level 1 and Level 3 analyses.

The Level 1 model contains three shell geometries and one solid geometry used to represent reinforced concrete, steel-composite, and modeling aids used to transfer forces between solid and shell elements. In order to benchmark the NI20 model, the stiffness of the interface shell elements, used to transfer the wall element moments to the solid elements in the basemat, were changed to match the in-plane behavior of the more detailed model. These properties were modified to show the failure in the Shield Building wall elements occurred before the CIS reinforced concrete, which match the Level 3 analyses. The non-linear concrete and SC material properties of the shield building wall and CIS base were not modified.

To determine the level of accuracy needed for the benchmarking of the RC/SC connection, the maximum displacement between the top and bottom of the section was calculated in the time history analysis. Figure RAI-SRP3.8.3-SEB1-03-49 shows the relative displacement between the two points for an in-plane shear motion.

Figure RAI-SRP3.8.3-SEB1-03-50 provides a Load-Displacement curve comparing the two in-plane shear analyses. From the figure and the maximum relative displacement, the connection is most acting linearly up to 0.1 inch where the Level 1 benchmarked material properties provide conservative in-plane shear results.

These material properties were also analyzed for a tension loading, as well as an out-of-plane load (OOP) case. These analyses were similarly compared to the Level 3 analyses to make sure the section did not over predict in tension or OOP. The maximum relative displacement at the RC/SC connection for the tension load case is provided in Figure RAI-SRP3.8.3-SEB1-03-51. The load-displacement curve and comparison is shown in Figure RAI-SRP3.8.3-SEB1-03-52. Similarly, the relative displacements and load-displacement curves for the out-of-plane shear analysis are provided in Figures RAI-SRP3.8.3-SEB1-03-53 and RAI-SRP3.8.3-SEB1-03-53. Both analyses show conservative comparisons to the Level 3 detailed analyses.

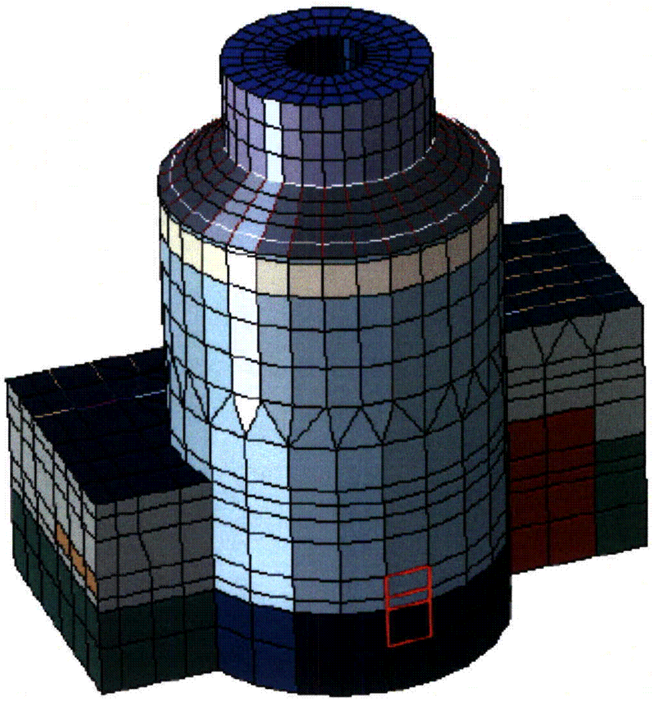

Figure RAI-SRP3.8.3-SEB1-03-45: RC/SC Structural Section in the West Wall

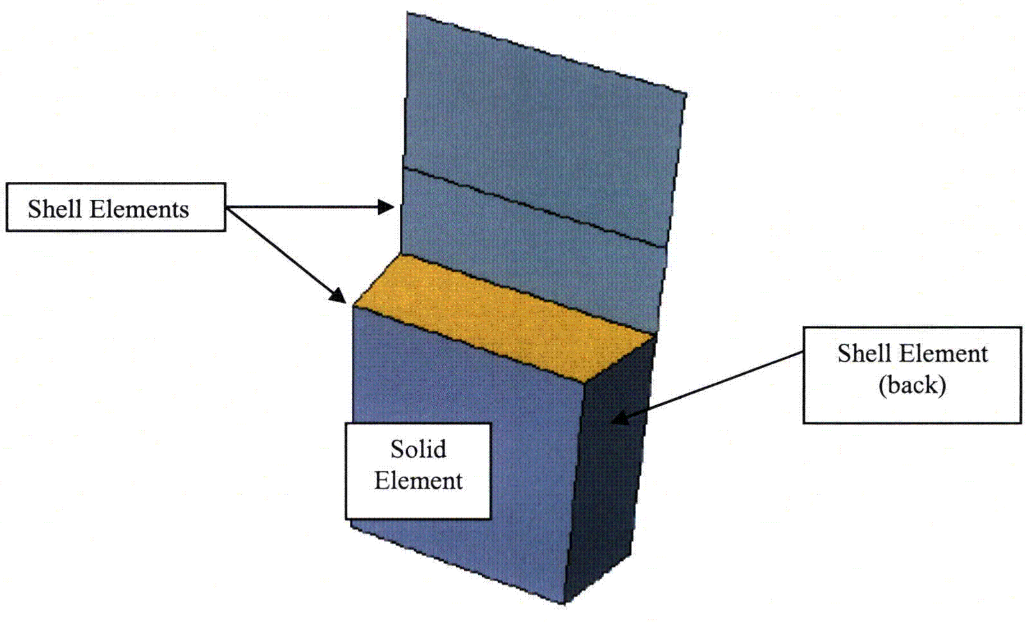

Figure RAI-SRP3.8.3-SEB1-03-46: RC/SC Structural Section in the West Wall, Enlarged

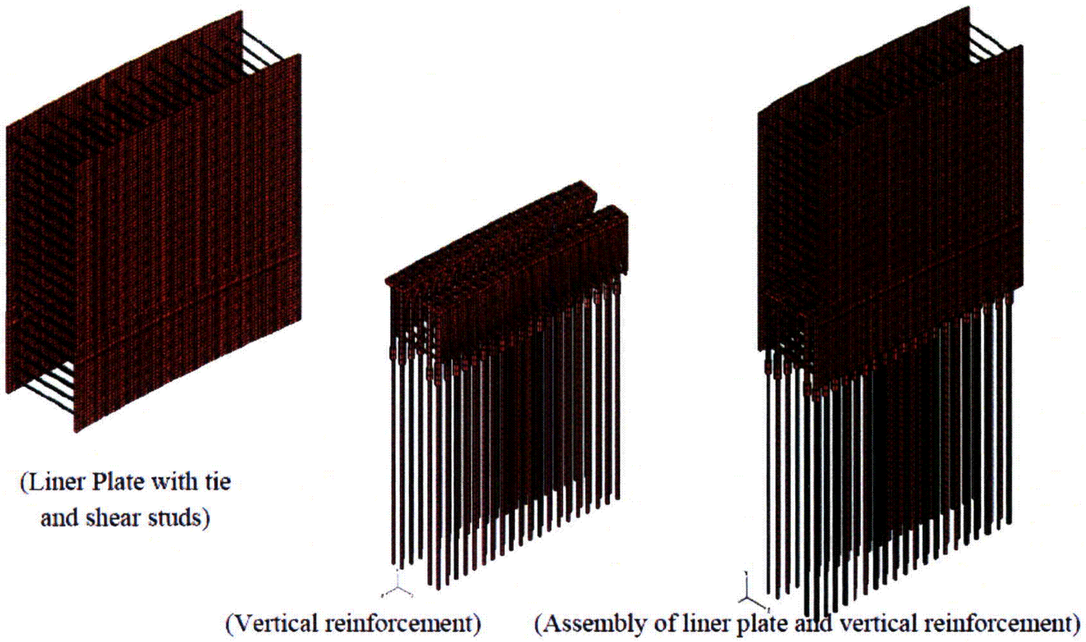

Figure RAI-SRP3.8.3-SEB1-03-47: Level 3 RC/SC Reinforcement Layout

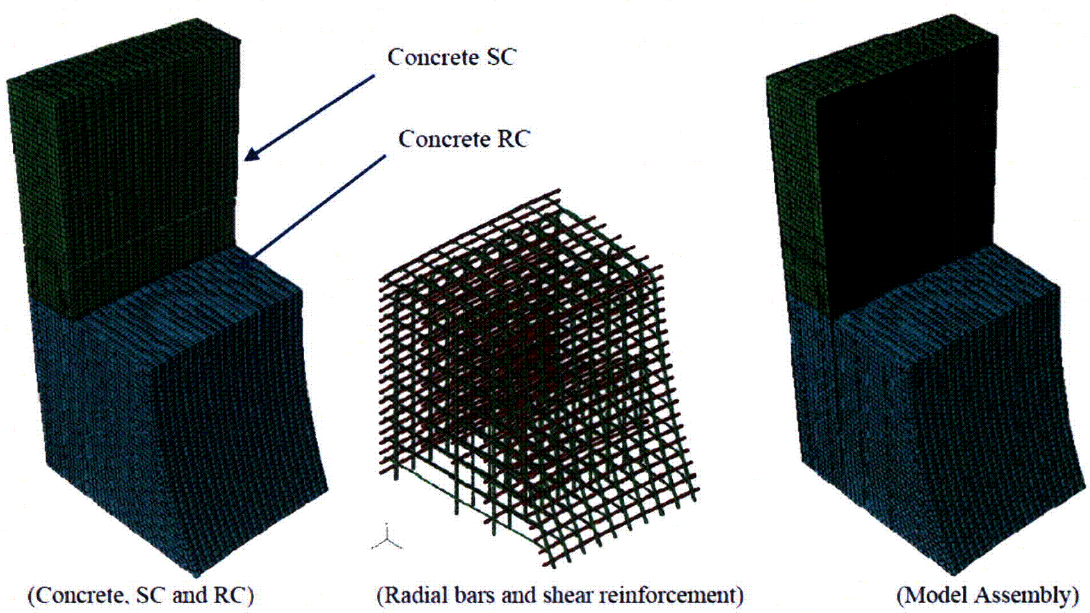

Figure RAI-SRP3.8.3-SEB1-03-48: Level 3 RC/SC Model Assembly

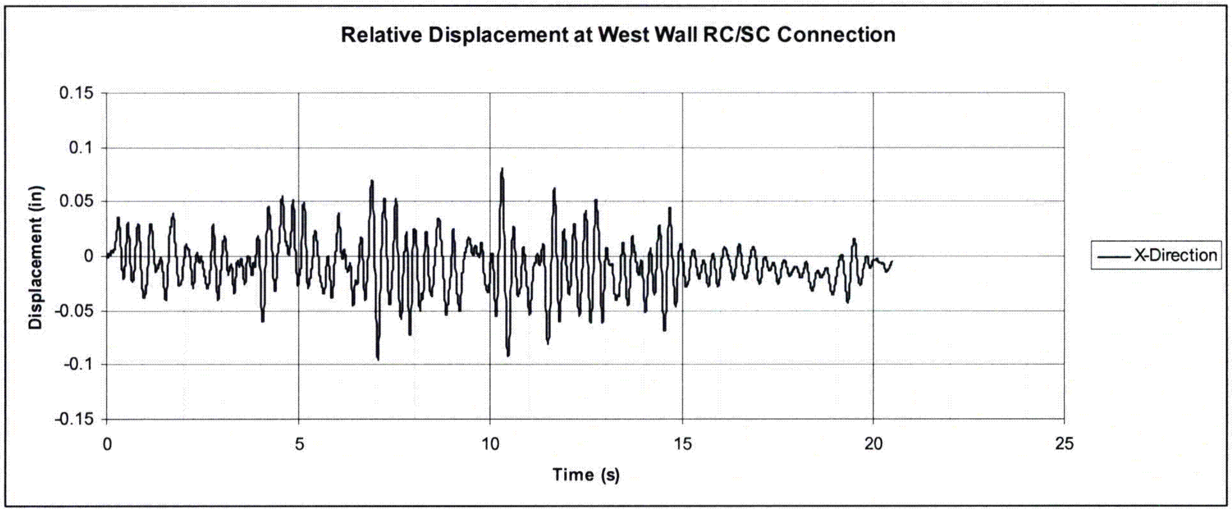

Figure RAI-SRP3.8.3-SEB1-03-49: Relative Displacement at RC/SC connection, In-Plane Shear

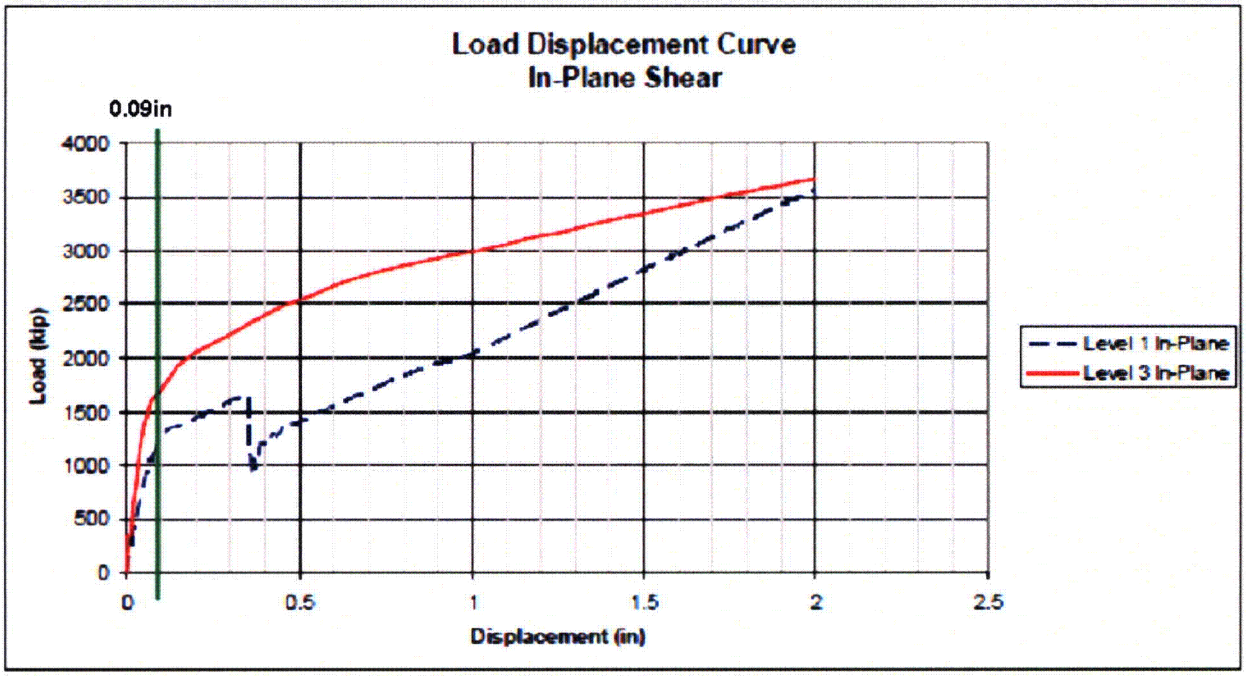

Figure RAI-SRP3.8.3-SEB1-03-50: Load-Displacement Comparison between Level 1 and Level 3 In-Plane Shear Benchmarking

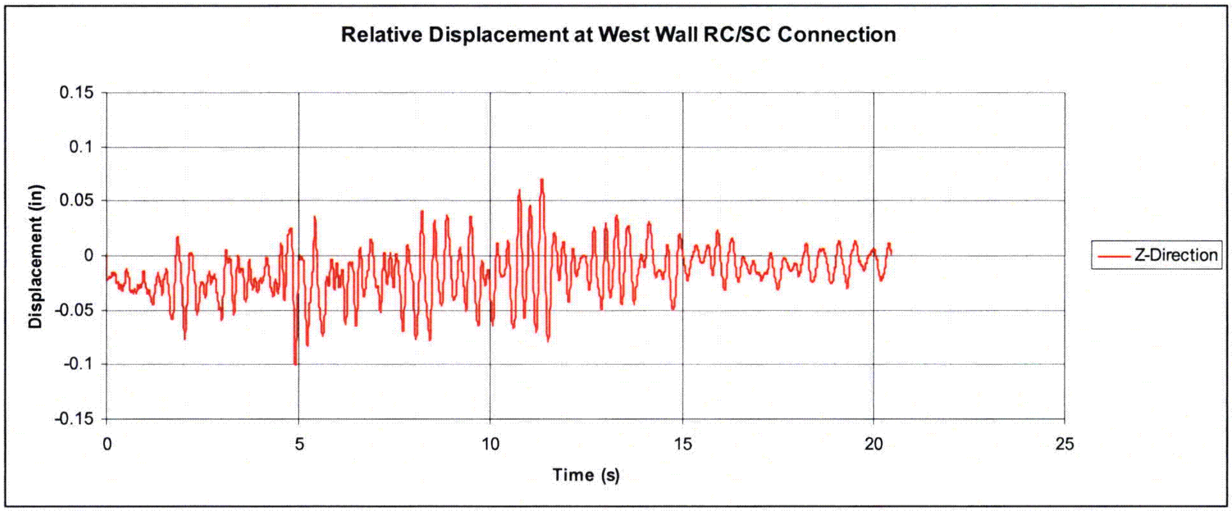

Figure RAI-SRP3.8.3-SEB1-03-51: Relative Displacement at RC/SC connection, Tension

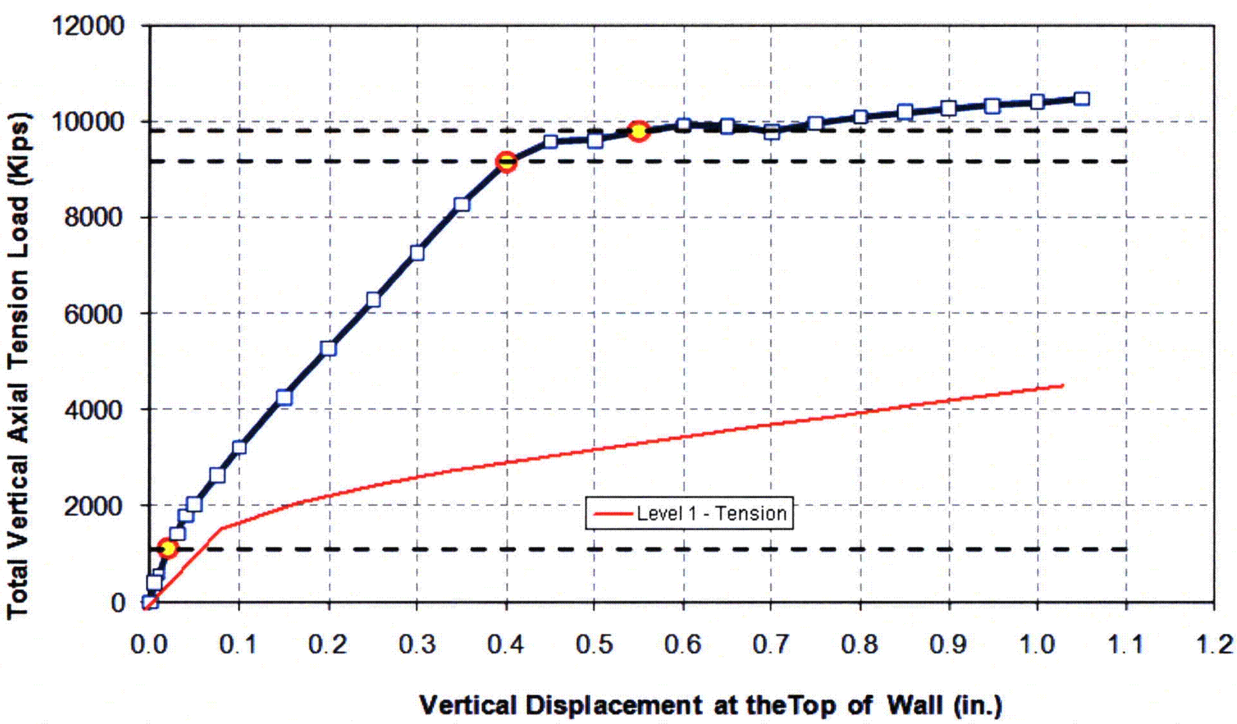

Figure RAI-SRP3.8.3-SEB1-03-52: Load-Displacement Comparison between Level 1 and Level 3 Tension Analysis

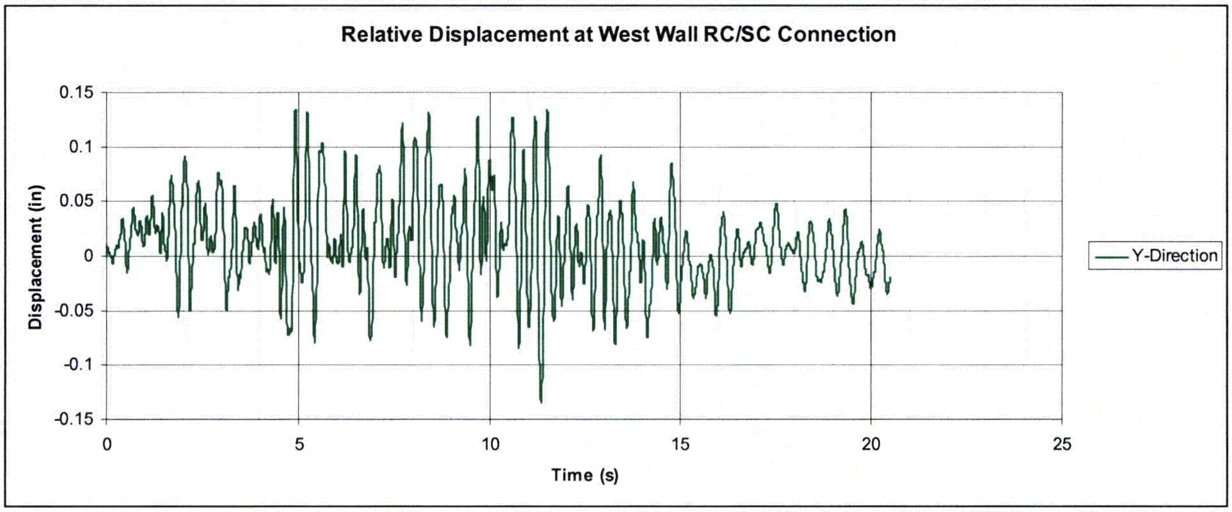

Figure RAI-SRP3.8.3-SEB1-03-53: Relative Displacement at RC/SC connection, Out-of-Plane Shear

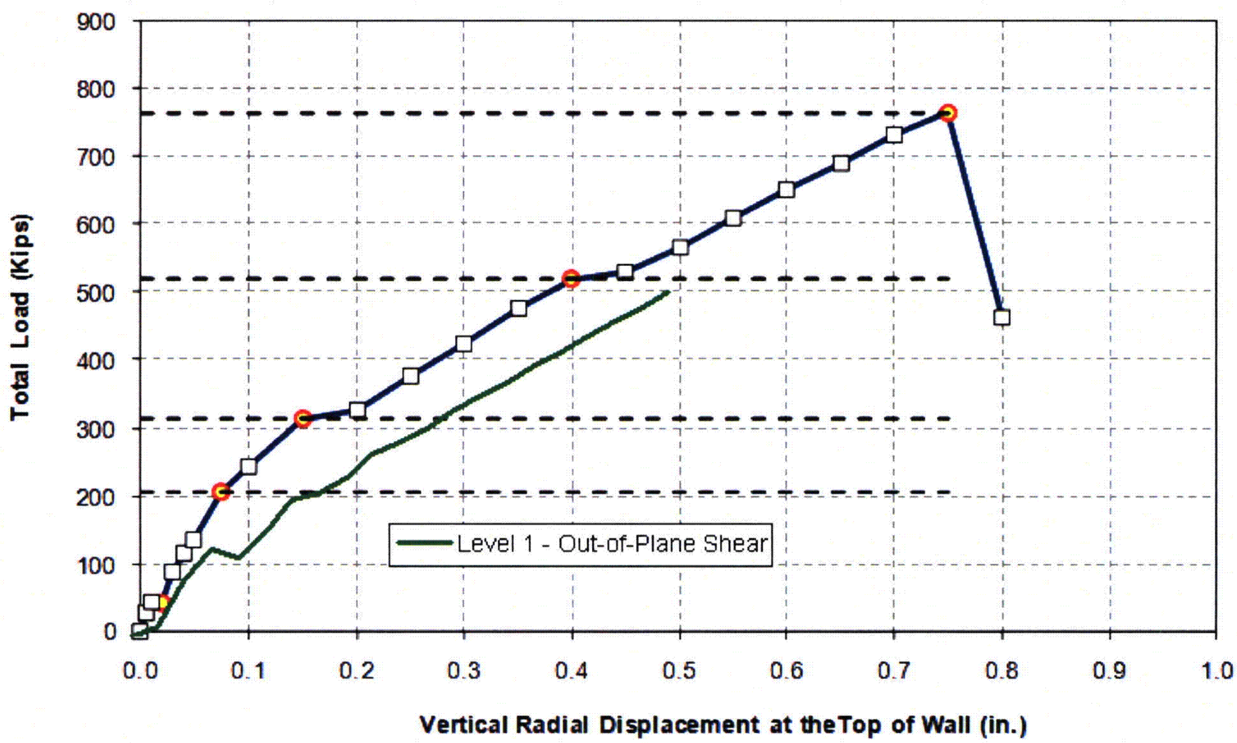

Figure RAI-SRP3.8.3-SEB1-03-54: Load-Displacement Comparison between Level 1 and Level 3 OOP Shear Analysis

3. Provided below in Table RAI-SRP3.8.3-SEB1-03-02 are the defining the parameters used for ANSYS linear, ABAQUS linear and ABAQUS non-linear time history analyses:

	ANSYS Linear	**ABAQUS Linear**	**ABAQUS Non-Linear**
Synthetic Time Step	0.01	0.01	0.01
Integration Time Step (Initial)	1.00E-06	0.0001	0.0001
Minimum Time Step	Auto	1.00E-15	1.00E-15
Maximum Time Step	Auto	0.02	0.02

Table RAI-SRP3.8.3-SEB1-03-02

Method Description from ANSYS:

Resolve the response frequency. The time step should be small enough to resolve the motion (response) of the structure. Since the dynamic response of a structure can be thought of as a combination of modes, the time step should be able to resolve the highest mode that contributes to the response. For the Newmark time integration scheme, it has been found that using approximately twenty points per cycle of the highest frequency of interest results in a reasonably accurate solution. That is, if f is the frequency (in cycles/time), the integration time step (ITS) is given by

$$ITS = 1/(20f)$$

References:

1. APP-GW-S2R-010 (Technical Report 03), "Extension of Nuclear Island Seismic Analyses to Soil Sites.

Design Control Document (DCD) Revision: (Revision 0, 1)

Modify the second paragraph of subsection 3.8.3.4 as shown below:

> Methods of analysis for the structural modules are similar to the methods used for reinforced concrete. Table 3.8.3-2 summarizes the finite element analyses of the containment internal structures and identifies the purpose of each analysis and the stiffness assumptions for the concrete filled steel modules. For static loads the analyses use the monolithic (uncracked) stiffness of each concrete element. The elastic modulus is taken as 0.80 times the value calculated based on the ACI Code. This reduced elastic modulus considers a small degree of cracking as described in the seismic analyses in subsection 3.7.2.3. For thermal and dynamic loads the analyses consider the extent of concrete cracking as described in later subsections. Stiffnesses are established based on analyses of the behavior and review of the test data related to concrete-filled structural modules. The stiffnesses directly affect the member forces resulting from restraint of thermal growth. The in-plane shear stiffness of the module influences the fundamental horizontal natural frequencies of the containment internal structures in the nuclear island seismic analyses described in subsection 3.7.2. The out-of-plane flexural stiffness of the module influences the local wall frequencies in the seismic and hydrodynamic analyses of the in-containment refueling water storage tank. Member forces are evaluated against the strength of the section calculated as a reinforced concrete section with zero strength assigned to the concrete in tension.

Modify the second bullet in the last paragraph of subsection 3.8.3.4 as shown below:

- Case 2 considers the full thickness of the wall as uncracked concrete. This stiffness value is shown for comparison purposes. It is applicable for loads that do not result in significant cracking of the concrete and is the basis for the stiffness of the reinforced concrete walls in the nuclear island seismic analyses (prior to the reduction in concrete stiffness by a factor of 0.8). This stiffness was used in the harmonic analyses of the internal structures described in subsection 3.8.3.4.2.2.

Modify the first paragraph of subsection 3.8.3.4.1.1 (Rev. 17) as shown below:

3.8.3.4.1.1 Finite Element Model

> ~~The three dimensional (3D) lumped mass stick model of the containment internal structure is developed based on the structural properties obtained from a 3D finite element model.~~ The structural modules are simulated within the finite element model using 3D shell elements.

Equivalent shell element thickness and modulus of elasticity of the structural modules are computed as shown below. The shell element properties are computed using the combined gross concrete section and the transformed steel faceplates of the structural modules. This representation models the composite behavior of the steel and concrete. The modulus of concrete, E_C, is reduced by a factor of 0.8 to consider the effect of cracking as recommended in Table 6-5 of FEMA 356 (Reference 5 given in DCD Section 3.7.6). See Section 3.7 and Appendix 3G for further discussion of the CIS finite element model.

Modify Table 3.8.3-2 as follows:

Table 3.8.3-2

SUMMARY OF CONTAINMENT INTERNAL STRUCTURES MODELS AND ANALYSIS METHODS

Computer Program and Model	Analysis Method	Purpose	Concrete Stiffness [1]
3D ANSYS finite element of containment internal structures	~~Equivalent static and Response Spectra analyses[2]~~ Static	To obtain the in-plane and out-of-plane mechanical ~~seismic~~ forces for the design of floors and walls (dead, live, hydrostatic, pressure)	Monolithic Case ~~3~~1 with Ec reduced by factor of 0.8.
3D ANSYS finite element of containment internal structures ~~fixed at elevation 98′-0″~~	Response Spectra analyses[2] ~~Static analyses~~	To obtain the in-plane and out-of-plane seismic forces for the design of floors and walls ~~To obtain member forces in boundaries of IRWST for static loads (dead, live, hydrostatic, pressure)~~	Monolithic Case 1 with Ec reduced by factor of 0.8.
3D ANSYS finite element of containment internal structures ~~fixed at elevation 98′-0″~~	Static analyses	To obtain the in-plane and out-of-plane member forces ~~in boundaries of IRWST~~ for thermal loads	Cracked Case 3
The following AP600 analyses are used as background to develop the AP1000 design loads.			
3D ANSYS finite element of containment internal structures fixed at elevation 103′-0″	Harmonic analyses	To evaluate natural frequencies potentially excited by hydrodynamic loads	Uncracked Case 2
	Time history analyses	To obtain dynamic response of IRWST boundary for hydrodynamic loads	Monolithic and cracked Cases 1 & 3

Note:

1. See Table 3.8.3-1 for stiffness case description.
2. See Section 3.7 for discussion of the containment internal structures seismic analyses.

PRA Revision:
None

Technical Report (TR) Revision:
None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.8.4-SEB1-04
Revision: 0

Question:

Westinghouse shall provide commitments for unique construction and inspection procedures. The NRC needs assurance that the COL applicant will develop and follow these procedures. The use of these procedures needs to be captured in a COL Information Item, ITAAC, or license condition.

Westinghouse Response (Revision 0)

Westinghouse will add information about construction procedures and inspection procedures for SC construction in Section 3.8 of the DCD. This information is derived from Chapter 9 of the Shield Building Report and includes information about concrete placement and inspection of the modules following placement of the concrete. The COL applicants will commit to this information by incorporating the DCD into their application.

The construction inspection activities will be done in accordance with the applicable codes required for those inspections. DCD Section 3.8.4.2 lists codes, standards and specifications that will be used for the shield building including other steel face plate concrete construction and has specific information for the welding and inspection activities that are required for Seismic Category I structural steel. Additional Codes and Standards that will be used in the construction and inspection of the shield building as described in Section 9 of the Shield Building report have been added to Section 3.8.4.2 of the DCD mark-up.

For the shield building a mock-up program will be used. The intent is to provide a mock-up program for each site but shared mock-up programs across the fleet may be evaluated for implementation. The mockups will represent sections of the design that present difficult construction issues. The proposed sections are the heavily reinforced lower section of the RC/SC interface, horizontal RC/SC connection, and the air inlet structures/tension ring. These mockups provide an opportunity to apply and evaluate alternate and innovative construction and inspection methods and procedures. They also provide training opportunities for construction and quality assurance personnel. Similar mock-ups will be performed on the structural modules and insights from the shield building mock-ups will be applied to those modules during construction.

Please see attached DCD mark-ups for the specific information related to construction and inspection procedures and information derived from Chapter 9 of the Shield Building Report.

Design Control Document (DCD) Revision: (below)

PRA Revision: None

Technical Report (TR) Revision: None

Design Control Document (DCD) Revision:

Table 1.8-2 (Sheet 4 of 13)

SUMMARY OF AP1000 STANDARD PLANT COMBINED LICENSE INFORMATION ITEMS

Item No.	Subject	Subsection	Addressed by Westinghouse Document	Action Required by COL Applicant	Action Required by COL Holder
3.8-2	Deleted Passive Containment Cooling System Water Storage Tank Examination	Deleted	APP-GW-GLR-021	N/A	N/A
3.8-3	Deleted As-Built Summary Report	Deleted	APP-GW-GLR-021	N/A	N/A
3.8-4	Deleted In-Service Inspection of Containment Vessel	Deleted	APP-GW-GLR-021	N/A	N/A
3.8-5	Structure Insepction Program	3.8.6.5	N/A	Yes	-
3.8-6	Construction Procedures Program	3.8.6.6	N.A	No	Yes

3.8.4.2 Applicable Codes, Standards, and Specifications

The following standards are applicable to the design, materials, fabrication, construction, inspection, or testing:

- [*American Concrete Institute (ACI), Code Requirements for Nuclear Safety Related Structures, ACI-349-01*]* (refer to subsection 3.8.4.5 for supplemental requirements)
- American Concrete Institute (ACI), ACI Detailing Manual, 1994
- American Concrete Institute (ACI), Self-Consolidating Concrete, ACI-237R-07
- American Concrete Institute (ACI) 211.1, Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete, 1991
- American Concrete Institute (ACI) 304R, Guide for Measuring, Mixing, Transporting and Placing Concrete, 2000

- American Society for Testing and Materials (ASTM) C94, Standard Specification for Ready-Mixed Concrete, 2009

[• *American Institute of Steel Construction (AISC), Specification for the Design, Fabrication and Erection of Steel Safety Related Structures for Nuclear Facilities, AISC-N690-1994*]* (refer to subsection 3.8.4.5 for supplemental requirements)

Rest of references in Section 3.8.4.2 are the same.

3.8.4.8 Construction Inspection

Construction inspection is conducted to verify the concrete wall thickness and quantity of concrete reinforcement. The construction inspection includes concrete wall thickness and reinforcement expressed in units of in^2/ft (linear length) equivalent when compared to standard reinforcement bar sections. Inspections will be measured at applicable sections excluding designed openings or penetrations. Inspections will confirm that each applicable section provides the minimum required reinforcement, steel plate thickness, and concrete thickness. The minimum required reinforcement, steel plate thickness, and concrete thickness represent the minimum values to meet the design basis loads. Appendix 3H also indicates the reinforcement provided which may exceed the minimum required reinforcement for the following reasons:

- Structural margin
- Ease of construction
- Use of standardized reinforcement sizes and spacing

A Shield Building construction mock-up program will be utilized to build full-scale replicas of areas of the Shield Building that present critical construction areas that are identified as challenging areas of construction. These mock-ups provide an opportunity to apply and evaluate alternate and innovative construction and inspection methods and procedures. The fabrication, assembly, and erection of a full-scale mockup provides the accurate physical representation needed to evaluate true working conditions, physical configuration, accessibility, and quality control issues that may be encountered in construction. Construction practices review and examination of the mockups will be used to confirm the adequacy of construction means, methods, and procedures. If defects are found, the procedures will be revised and the mockup repeated until the required result is obtained. The major tasks that will be performed on each mockup include the following: Field performance testing of the quality of concrete mixes, methods of concrete placement, inspections and surveillance and post-placement activities.

In addition to these important process control tasks performed on the mockups, an inspection program will be undertaken on the AP1000 construction site mockups that use the enhanced shield building design. Both visual inspection and non-destructive examination (NDE) will be performed for the purposes of assessing defects that may impact structural integrity such as crack distress, deterioriation caused by honeycomb, voids, and delaminations. The NDE inspection of the mockups will be performed at the first construction site of an AP1000 plant with an enhanced shield building design and mockups applicability will be evaluated for the subsequent AP1000 site.. This is to demonstrate the construction quality process control for concrete placement and develop and document insights and requirements for corrective action, if required to be used in the construction inspection program for all AP1000 plants.

3.8.6.6 Construction Procedures Program

Combined license holders referencing the AP1000 Design certification will develop construction and inspection procedure to implement the commitments for concrete filled steel plate modules. These procedures will address pre and post concrete placement, use of construction mock-ups and inspection of modules pre and post concrete placement.