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MFN 06-191
Supplement 2

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Subject: **Response to Portion of RAI Letter No. 38 Related to ESBWR Design Certification Application - Seismic Category I Structures – RAI Numbers 3.8-3, 3.8-13, 3.8-25, 3.8-41, 3.8-48, 3.8-51, 3.8-64, and 3.8-91- Supplement 2**

Enclosure 1 contains supplemental responses to the subject NRC RAIs resulting from post audit actions associated with the Structural Audit conducted July 11 through 14, 2006. There are no changes to any of the remaining RAIs transmitted via the Reference 1 or Reference 2 letters.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Enclosure:

1. MFN 06-191, Supplement 2 - Response to Portion of RAI Letter No. 38 Related to ESBWR Design Certification Application - Seismic Category I Structures – RAI Numbers 3.8-3, 3.8-13, 3.8-25, 3.8-41, 3.8-48, 3.8-51, 3.8-64, and 3.8-91- Supplement 2

Reference:

1. MFN 06-191, Letter from David H. Hinds to U. S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application – Structural Analysis - RAI Numbers 3.8-3, 3.8-6, 3.8-13, 3.8-14, 3.8-18, 3.8-19, 3.8-20, 3.8-23, 3.8-25, 3.8-26, 3.8-27, 3.8-40, 3.8-41, 3.8-46, 3.8-47, 3.8-48, 3.8-49, 3.8-51, 3.8-56, 3.8-63, 3.8-64, 3.8-82, 3.8-83, 3.8-87, 3.8-90, 3.8-91, 3.8-100, 3.8-104, 3.8-105 and 3.8-106,* June 28, 2006
2. MFN 06-191, Supplement 1, Letter from David H. Hinds to U. S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 38 Related to ESBWR Design Certification Application – Structural Analysis - RAI Numbers 3.8-3, 3.8-6, 3.8-13, 3.8-14, 3.8-18, 3.8-25, 3.8-27, 3.8-46, 3.8-48, 3.8-63, 3.8-64, 3.8-82, 3.8-87, 3.8-90, 3.8-91, 3.8-100, 3.8-104, and 3.8-106* - Supplement 1, September 14, 2006

cc: AE Cubbage USNRC (with enclosures)
GB Stramback GE/San Jose (with enclosures)
eDRF 0000-0058-8398

Enclosure 1

MFN 06-191, SUPPLEMENT 2

Response to Portion of RAI Letter No. 38

Related to ESBWR Design Certification Application

Seismic Category I Structures

RAI Numbers 3.8-3, 3.8-13, 3.8-25, 3.8-41, 3.8-48, 3.8-51,

3.8-64, and 3.8-91- Supplement 2

Original response and Supplement 1 previously submitted under MFNs 06-191 and 06-191, Supplement 1 are included to provide historical continuity during review. DCD updates previously submitted are not included in this package.

NRC RAI 3.8-3

Provide additional information (description, plans, and sections) for the following structural elements. These include the reinforcement details around major reinforced concrete containment vessel (RCCV) piping penetrations, equipment hatches, and personnel airlocks; structural attachments to the containment internal wall (such as pipe restraints); containment external supports if any, attached to the wall to support external structures/elements; reactor pressure vessel (RPV) stabilizer (referred to in App. 3G.1.3.1.4); reactor building (RB) floor slabs made of composite sections (referred to in App. 3G.1.3.1.1); roof trusses and their supporting columns (referred to in App. 3G.1.3.1.1); and the basaltic concrete at the bottom of the containment. In addition, to facilitate the review, Figure 3.8-1 should be improved to identify a number of elements in the ESBWR containment structure which are not shown. These elements include: the shield wall, RPV stabilizer, RPV skirt, RPV insulation, equipment hatches, wetwell hatch, personnel airlocks, refueling seal, major equipment platforms, quenchers, representative vent pipe and safety relief valve (SRV) downcomer pipe with sleeve (from the drywell into the suppression pool).

GE Response

A global structural analysis has been completed in the ESBWR DCD. The purpose of the global analysis is to prove that there are no safety issues unresolved. GE believes that sufficient level of civil-structural detail has been provided in the DCD for plant certification. The construction level design details requested are not available at this stage.

The detail structural design is intimately connected among several disciplines and depends on them for final resolution, such as piping analysis results, equipment sizes, layout and routing of commodities such as cable trays, ducts, etc. It is an iterative process between disciplines.

Among the various structural elements identified in this RAI, GE will provide to the NRC the details of reinforcement around MS/FW penetrations and a representative hatch through the RCCV, which will be included in the response to RAI 3.8-17 in the release on Oct. 31, 2006. They represent an example of the detail structural design. DCD Figure 3.8-1 is intended to depict only the containment boundary. Other items can be found in the following figures.

a. Shield wall. See DCD Figure 3G.1-58.
b. RPV Stabilizers. See DCD Figure 5.3-3.
c. RPV skirt (it is termed sliding support in the ESBWR DCD). See DCD Figure 5.3-3.
d. RPV insulation. Detailed design phase.
e. Equipment hatches. See DCD Figure 3G.1-52.
f. Wetwell hatch. See DCD Figure 3G.1-53.
g. Personnel airlocks. See DCD Figure 3G.1-54.
h. Refueling seal. See DCD Figure 5.3-3.

i. Major equipment platforms. Detailed design phase.

j. Quenchers. See DCD Figure 6.2-1.

k. Representative vent pipe and safety relief value (SRV) downcomer pipe with sleeve (from the drywell into the suppression pool). See DCD Figure 3G.1-57.

No DCD changes will be made in response to this RAI.

NRC RAI 3.8-3, Supplement 1

Additional topics discussed at audit

a) *Describe embedded plates to support steel members inside containment and show sketch of interaction with liner plate.*

b) *Describe embedded plate support steel members (from pipe whip restraints; piping supports; etc) outside containment and show sketches with anchors into concrete containment.*

c) *Describe diaphragm connection to containment and reference DCD figures as appropriate. Indicate whether fixed ended or simply supported and type of weld to be used (FP;FW; etc)*

d) *Provide description and sketch of a typical embedded plate outside containment that supports commodity items like ducts, trays, conduits, etc.*

GE Response

a) Regarding steel members such as structural steel shapes, piping supports or commodity supports inside containment, Figure 3.8-3 (1) below shows a typical support plate with anchors embedded in the concrete containment. The dimensions of the plate and the number of anchors depend on the loads for each support. They are designed in accordance with ANSI/AISC N690 and ACI 349 Appendix B.

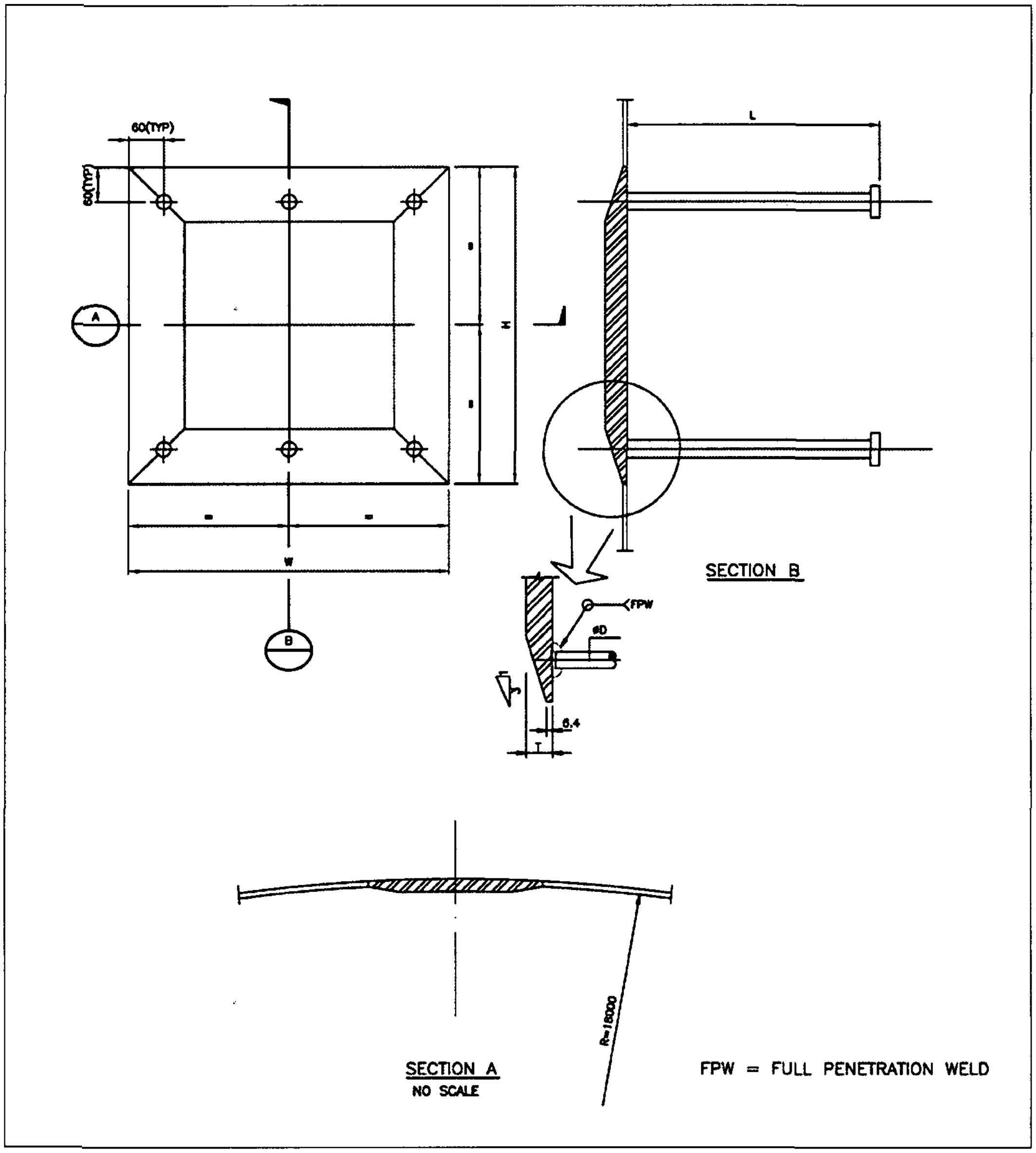


Figure 3.8-3 (1)

b) Regarding other steel members such as structural steel shapes, pipe whip restraints, piping supports, etc, outside the containment, Figure 3.8-3 (2) presents a typical support plate with anchors embedded in the concrete containment. See also response to a) above.

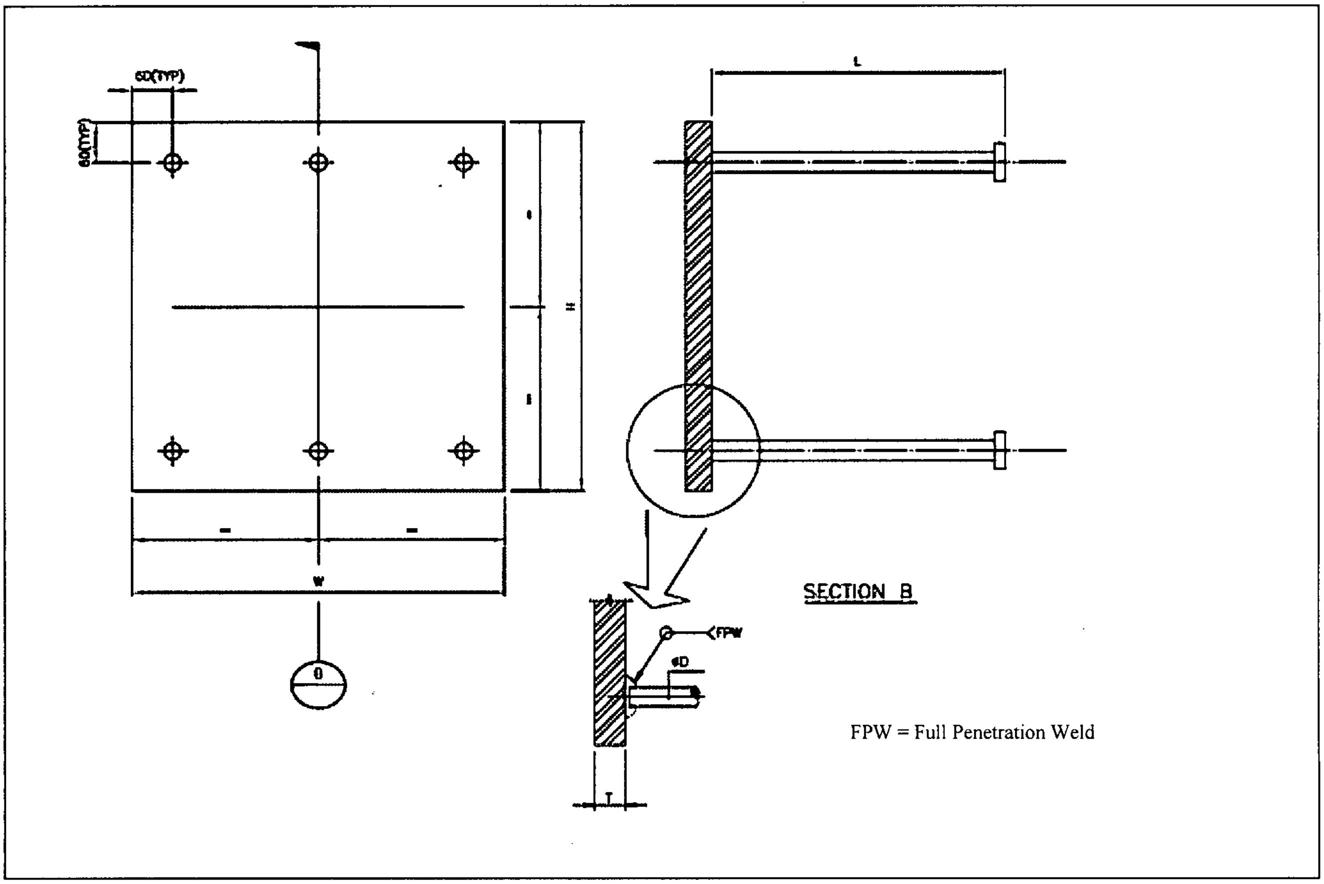


Figure 3.8-3 (2)

c) The top plate, bottom plate and support beam of diaphragm floor are welded to thickened RCCV liner plate, therefore this end is fixed. The reference drawings are Figures 3G.1-55 and –56 of DCD Appendix 3G. Type of weld will be decided in detail design, however, it is expected that the full penetration weld or the partial penetration with fillet weld may be applied to ensure the required strength.

d) The same type of support shown in Figure 3.8-3 (2) above is applicable in these cases. The design is based on ANSI/AISC N690 for the steel plates and ACI 349 Appendix B for the embedded anchors.

No DCD changes were identified for this response supplement.

NRC RAI 3.8-3, Supplement 2

GE Additional Post Audit Action

a. Provide conceptual design detail of RPV stabilizer.

b. Provide conceptual design detail of Refueling Seal.

GE Response

a. See RAI 3.7-27, Supplement 1.

b. See Fig. 3.8-3 (3) for conceptual design details of the Refueling Seal.

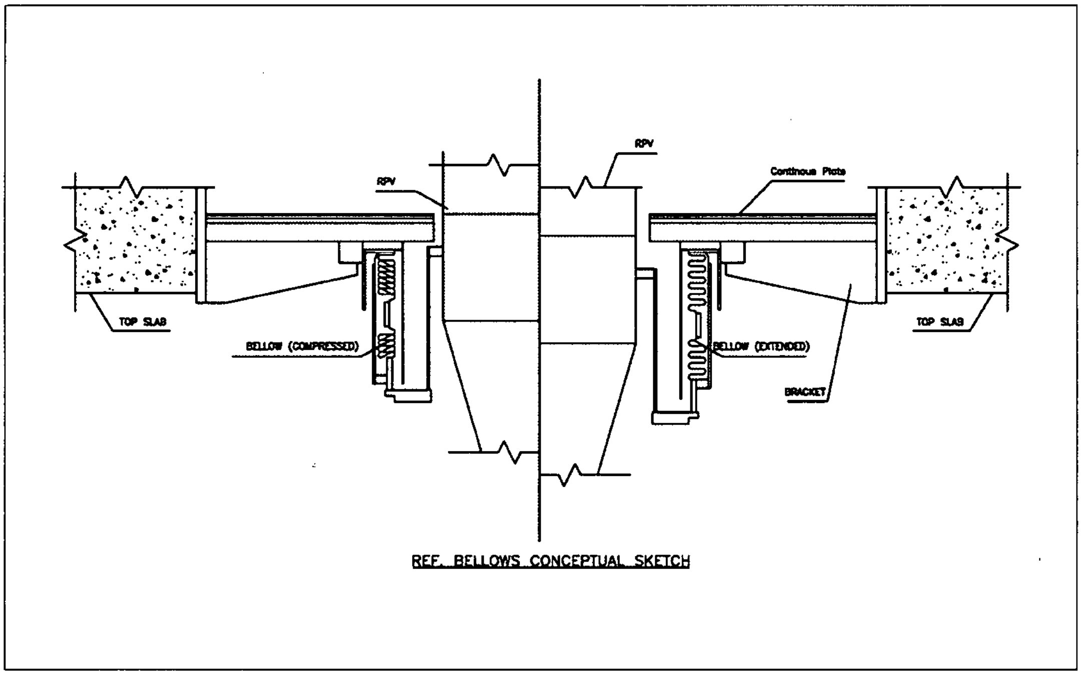


Figure 3.8-3 (3) - Refueling seal: Comparison of compressed and extended bellows.

No DCD changes were identified for this response supplement.

NRC RAI 3.8-13

For the soil springs used in the containment and RB model (DCD Section 3.8.1.4.1.1 and Appendix 3G):

a) Explain why the foundation soil springs for rocking and translation are determined based on soil parameters corresponding to the "Soft Site" conditions for seismic and other loads. Include a discussion of the conservatism of this assumption and the basis for the conclusion.

b) Explain how the soil springs for the non-seismic loads were determined. If the springs are modeled as having perfectly elastic stiffness, then explain why these stiffness values are so much smaller than the seismic soil springs.

In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

a) The deformations of buildings are greater for the case of Soft soil than for Hard rock. Therefore, it leads to larger section forces for member design. Hence, the Soft soil condition is used. Note that the enveloped seismic loads of all soil cases as described in DCD Section 3A.9 were conservatively applied to the soft soil condition.

b) The pressures acting on the foundation soil in the vertical direction differ in character between horizontal earthquake loads and other loads. When horizontal earthquake loads are excluded, vertical pressures are produced according to the force in the vertical direction, and the foundation soil resists them by vertical stiffness of the soil springs. For this reason, vertical soil springs, kv_1, can be estimated as follows:

$$kv_1 = Kv/A \qquad (3.8\text{-}13\text{-}1)$$

where,

Kv: stiffness of vertical soil spring (used in seismic response analysis)

A: area of basemat

On the other hand, for the horizontal seismic loads, vertical pressures are produced due to overturning moments, and the foundation soil resists them by its rotational rigidity. So, vertical soil springs, kv_2, under seismic loading conditions can be estimated as follows:

$kv_2 = Kr/I$ (3.8-13-2)

where,

Kr: stiffness of rotational soil spring (used in seismic response analysis)

I: moment of inertia of basemat bottom surface

The inherent rotational stiffness of the soil is larger than its vertical stiffness as shown in DCD Table 3A.5-1. That is why soil springs are larger in stiffness than that of the non-seismic case.

(1) The applicable detailed report/calculation that will be available for NRC audit is 26A6651, RB Structural Design Report, Revision 1, November 2005, containing the structural design details of the Reactor Building.

(2) Since this information exists as part of GE internal tracking system, it is not necessary to add it to the DCD submittal to the NRC.

No DCD changes will be made in response to this RAI.

NRC RAI 3.8-13, Supplement 1

Additional topics discussed at audit

a) *The part (a) response needs clarification and possible revision of the DCD to describe/explain how the dynamic stick model results for multiple soil cases were used to develop the statically applied seismic loads used in the NASTRAN model. How was conservatism verified?*

   It was shown that under load combination of DL+LOCA+SSE there is a small uplift on the south side of the mat. This means that the soil springs in this area are in tension, which is not possible. GE needs to re-run this analysis without the soil springs in this area taking uplift and demonstrate that this effect is not significant. Cut end springs to check uplift effects at end of mat for soft and hard soil conditions.

b) *Add note to RAI to indicate that differential settlement criteria accounts for horizontal soil variations under the mat. Indicate more clearly that the envelop of all loads was used for design and soil springs were used for soft soil case.*

GE Response

a) The seismic design load envelops the results obtained from all soil conditions in the seismic response analysis. In NASTRAN analysis the soil springs provided underneath of the basemat are estimated for the soft soil condition. The following sections explains the reason why the soft soil condition has been applied to the NASTRAN model by comparing the deformation and stresses of the basemat in both soft soil and hard soil conditions. In this comparison, pressure and thermal loads are not considered per NRC's request:

1. Basemat design under soft soil and hard rock condition

In order to confirm the appropriateness of the basemat design under "Soft Site" condition, basemat deformations and sectional moments are compared between the soft soil case (Vs=300m/sec) and the hard rock case (Vs=1700m/sec). The load combinations are shown in Table 3.8-13 (1). Seismic loads in North to South direction and South to North direction are considered.

Figure 3.8-13 (1) shows the sectional deformations of the basemat. Figures 3.8-13 (2) and (3) compare the bending moments generated in the basemat. Basemat deformation for the soft soil condition is much larger than that of the hard rock condition. As for bending moments, their magnitudes for the soft soil are larger than those for the hard rock, in general. The higher bending moments at few locations for the hard rock site has no impact on the design since they are much less than the maximum moments of the soft soil site on which rebar sizing is based.

Therefore, the basemat design envelops the worst conditions.

(Note that there is a small uplift on the south side of the basemat under the soft soil condition.)

Table 3.8-13 (2) shows calculation of Soil Springs for the soft soil condition.

Table 3.8-13 (1) Load Combinations

Label		Load		
Soft	Hard	Dead	Seismic(Hor.)	Seismic(Ver.)
SNS	HNS	1.00*DOL	1.0*EQNS	0.40*EQZ
SSN	HSN	1.00*DOL	-1.0*EQNS	0.40*EQZ

Table 3.8-13 (2) Calculation of Soil Springs

Soil Spring in Seismic Model				Basemat Dimension *1		A *2	I *3	Soil Spring Stiffness k			Note
				X (m)	Y (m)	(m^2)	(m^4)	($t/m/m^2$)	($MN/m/m^2$)		
(RBFB Model)											
X-dir	Khx	(t/m)	2.968E+06	68.0	47.0	3196.0		928.7	**9.107**		Horizontal X-dir.
Y-dir	Khy	(t/m)	3.146E+06	68.0	47.0	3196.0		984.4	**9.654**		Horizontal Y-dir.
Z-dir	Kv	(t/m)	4.453E+06	68.0	47.0	3196.0		1393.3	**13.66**		Vertical (Other Loads)
										Average	
X-X Rotation	Krxx	(t•m/rad)	2.516E+09	68.0	47.0		5.8833E+05	4276.5	41.94	**38.35**	Vertical (Horiz. Seismic Loads)
Y-Y Rotation	Kryy	(t•m/rad)	4.365E+09	68.0	47.0		1.2315E+06	3544.4	34.76		
(CB Model)											
X-dir	Khx	(t/m)	1.349E+06	29.4	22.9	673.3		2003.7	**19.650**		Horizontal X-dir.
Y-dir	Khy	(t/m)	1.399E+06	29.4	22.9	673.3		2077.9	**20.378**		Horizontal Y-dir.
Z-dir	Kv	(t/m)	2.003E+06	29.4	22.9	673.3		2975.1	**29.177**		Vertical (Other Loads)
										Average	
X-X Rotation	Krxx	(t•m/rad)	2.558E+08	29.4	22.9		2.9422E+04	8694.2	85.264	**79.174**	Vertical (Horiz. Seismic Loads)
Y-Y Rotation	Kryy	(t•m/rad)	3.614E+08	29.4	22.9		4.8495E+04	7452.3	73.085		

Note *1: Size of basemat in FE analysis model

Note *2: Area of basemat

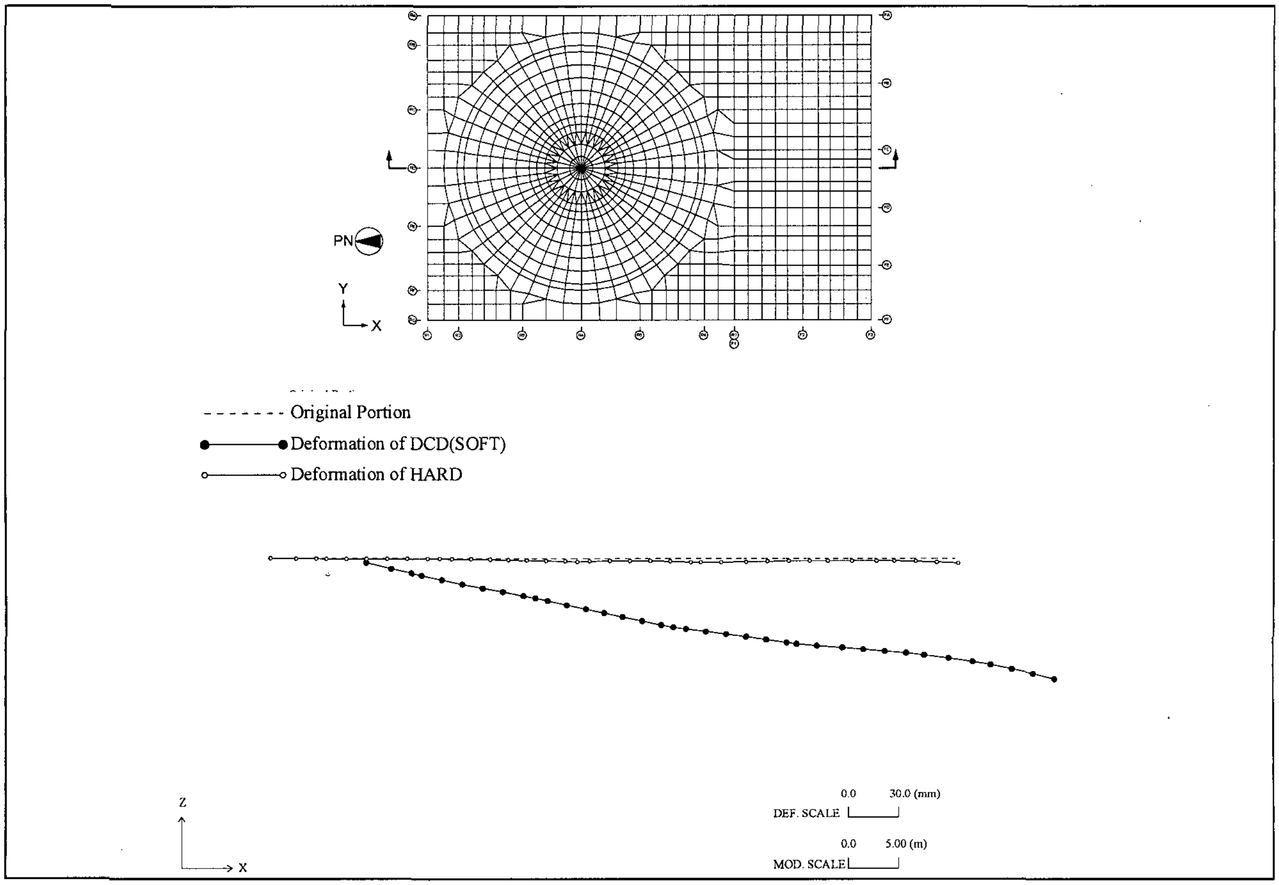
Note *3: Moment of inertia of basemat bottom surface

2. Cut off soil springs in tension

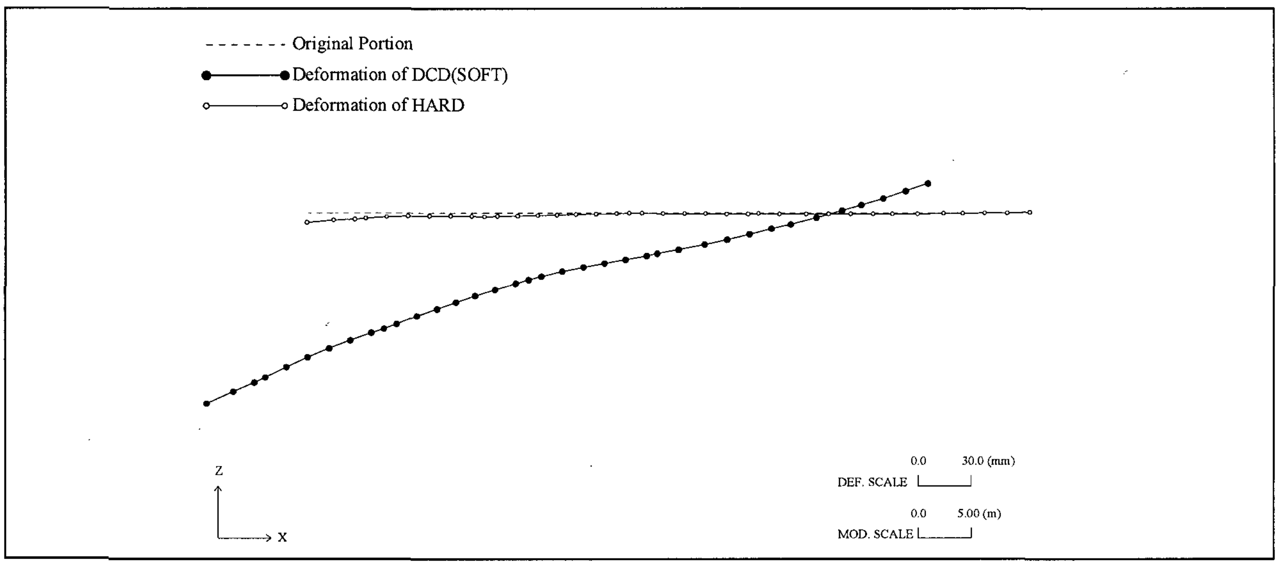
There are some soil springs present in Figure 3.8-13 (1) that are in tension for the South to North seismic case. This section evaluates the impact on basemat stresses without these soil springs in tension under the soft soil condition.

An iterative approach was used. Based on the result from the initial analysis, the tension capability is removed in the next iteration for those springs that are in tension. This iterative process is continued until there are no more springs in tension.

Figures 3.8-13 (4) and (5) show the comparison of the sectional deformations of the basemat and the bending moments generated in the basemat respectively at the final step of iteration. In the area close to the RCCV wall, bending moments are higher than that of the DCD design; however the resulting stresses in the concrete and reinforcement are still below the code allowables with large margins as shown in Table 3.8-13 (3).

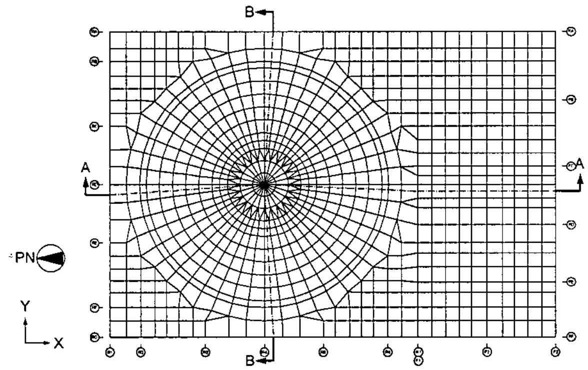


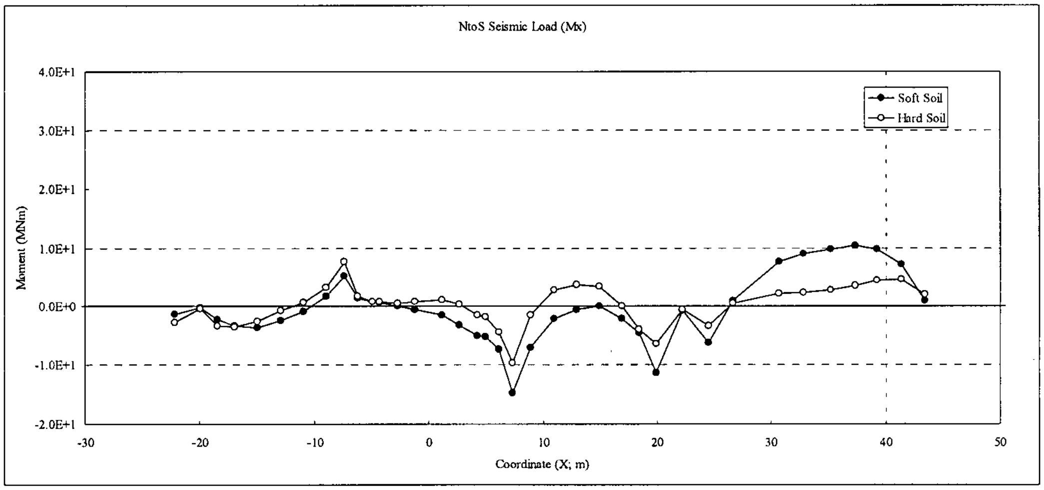
a) North to South



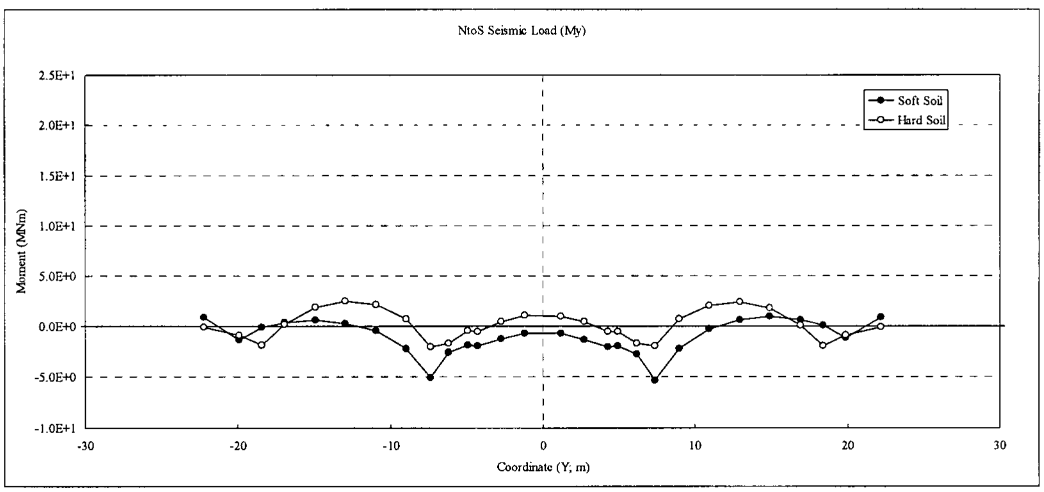
b) South to North

Figure 3.8-13 (1) Comparison of Basemat Deformation for Dead Load



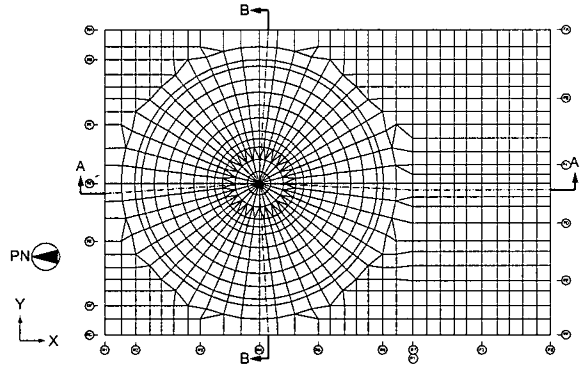


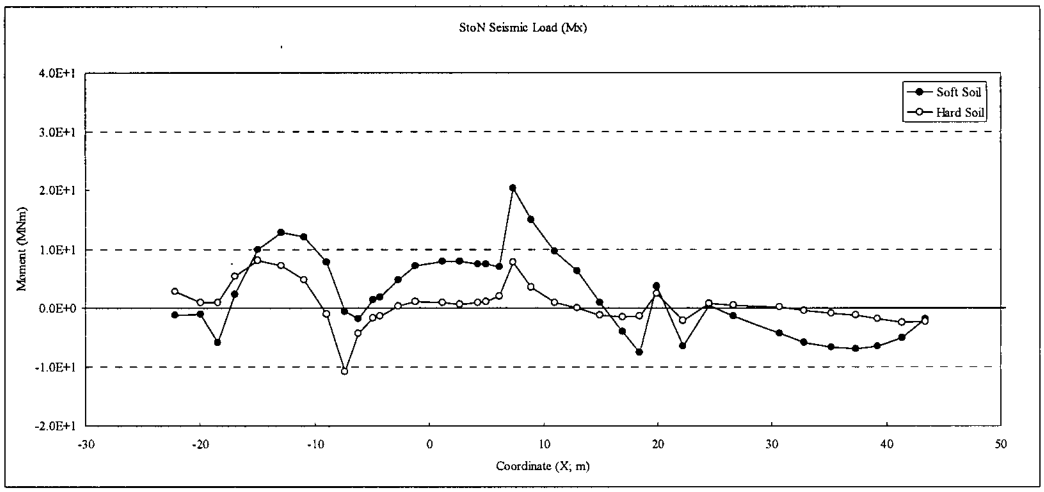
(a) Mx in A-A Section



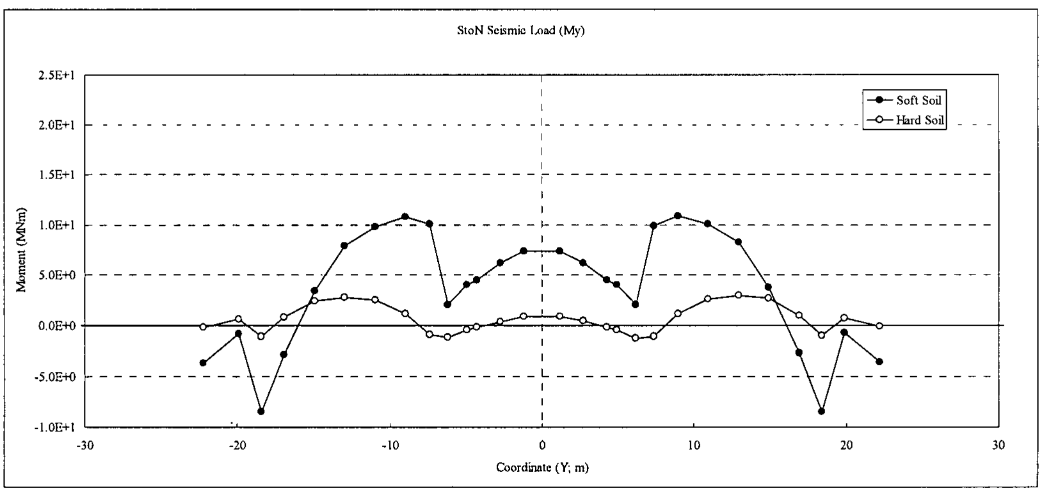
(b) My in B-B Section

Figure 3.8-13 (2) Comparison of Basemat Sectional Moments (N to S)



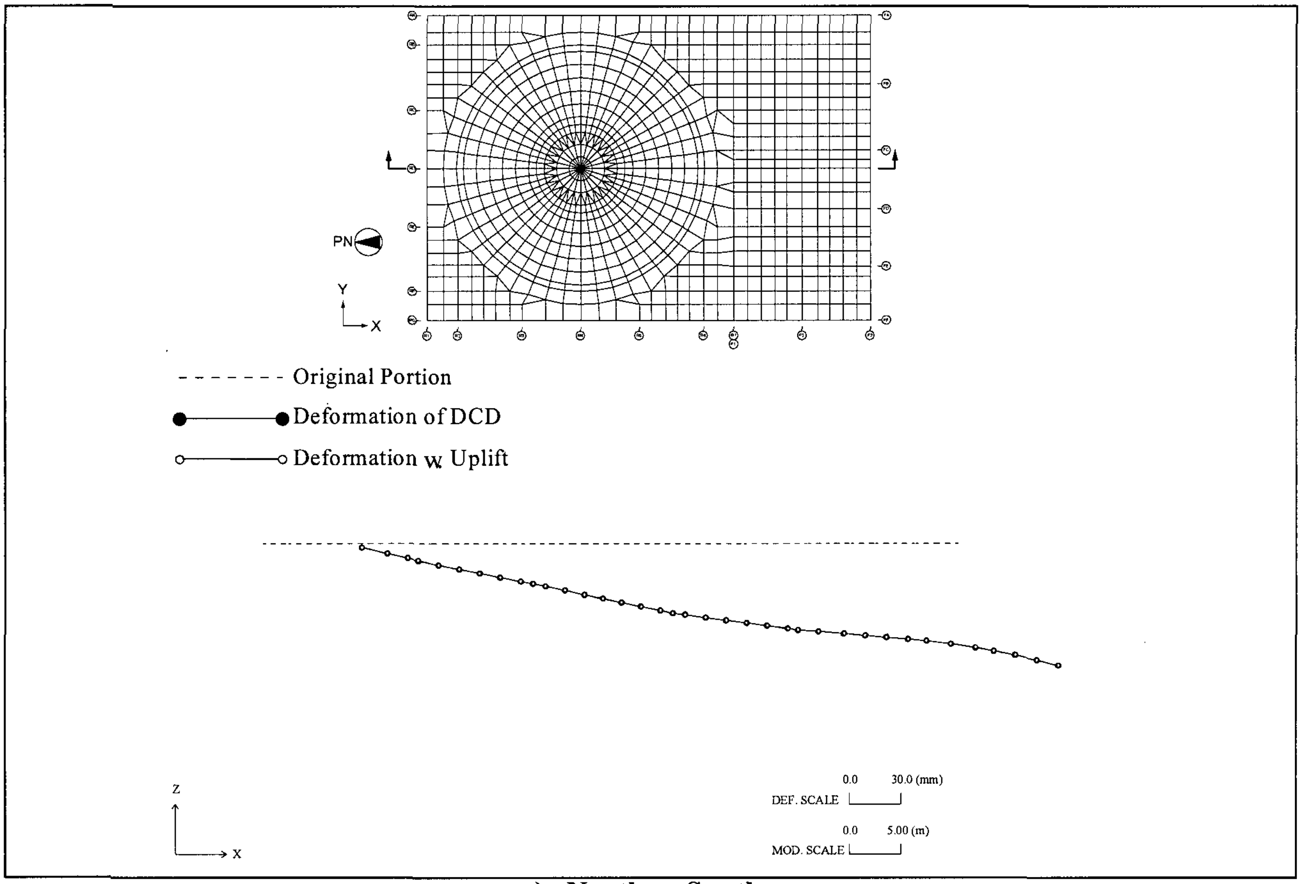


(a) Mx in A-A Section

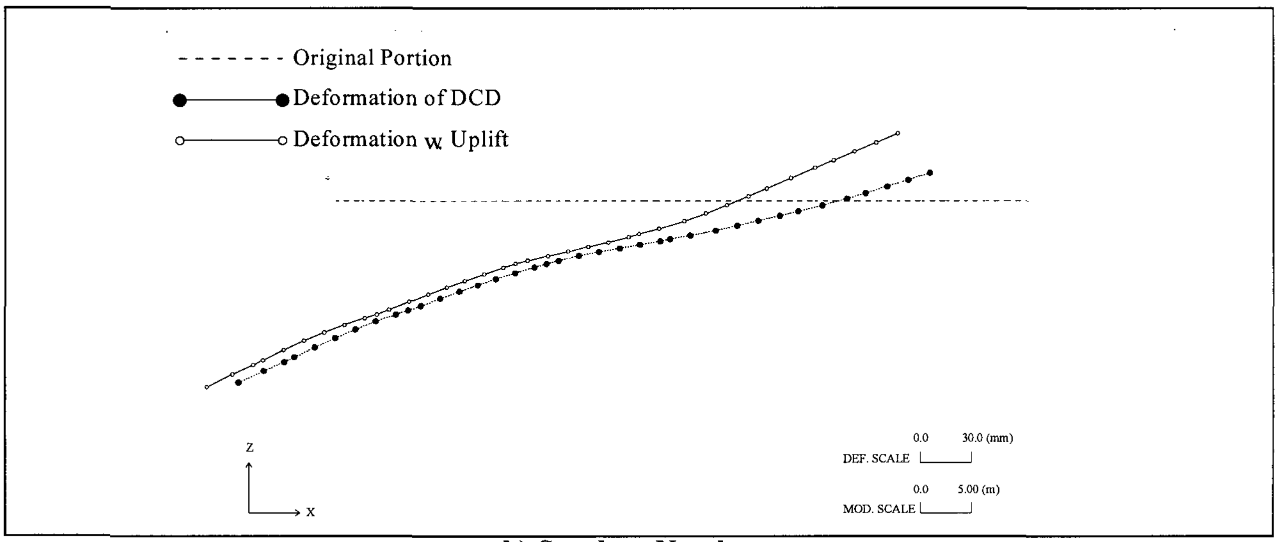


(b) My in B-B Section

Figure 3.8-13 (3) Comparison of Basemat Sectional Moments (S to N)

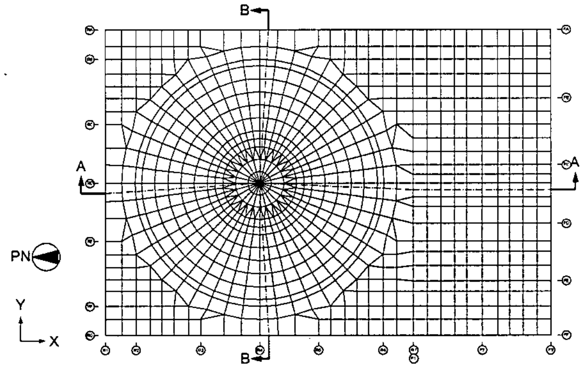


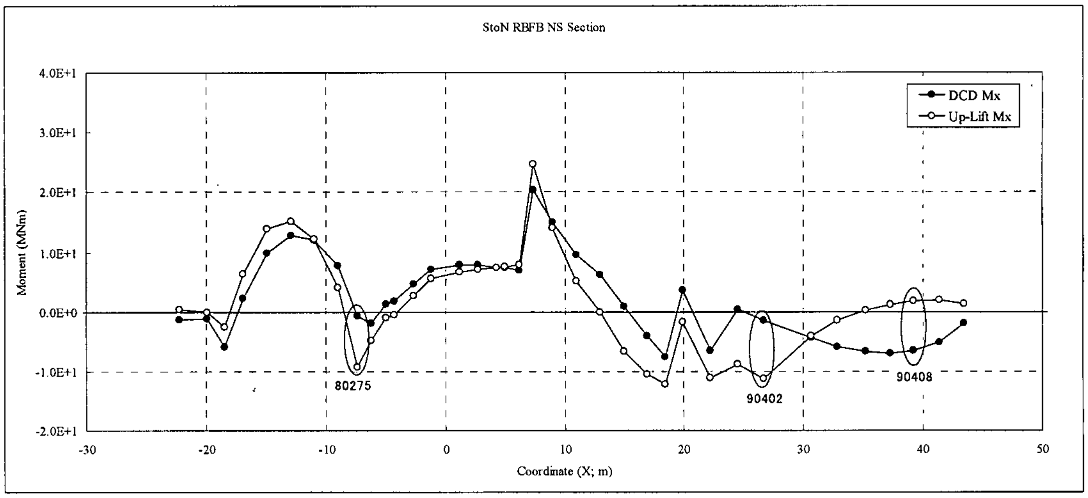
a) North to South



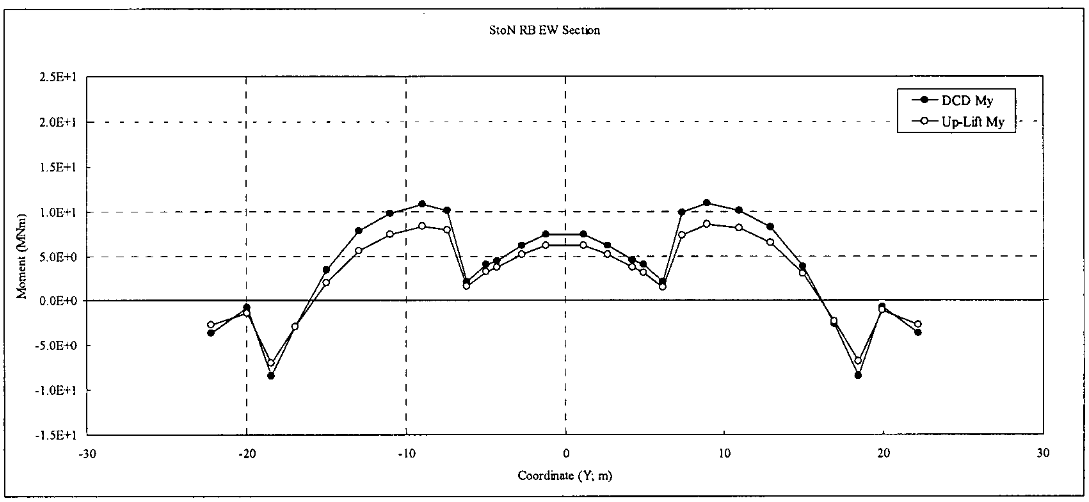
b) South to North

Figure 3.8-13 (4) Comparison of Basemat Deformation without tension springs





(a) Mx in A-A Section



(b) My in B-B Section

Figure 3.8-13 (5) Comparison of Basemat Sectional Moments (S to N)

Table 3.8-13 (3) Concrete and Rebar stresses

[DCD Design]

Seismic Force Direction	Soil Condition	Element ID	Load	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated	Allowable	Radial		Circumferential		Allowable
						Top	Bottom	Top	Bottom	
S to N	Soft	80275	SSE+LOCA 6min	-5.3	-23.5	-35.4	-10.9	2.2	4.2	372.2
			SSE+LOCA 72h	-6.4	-23.5	-40.7	-7.6	0.9	8.7	372.2
		90402	SSE+LOCA 6min	-5.9	-23.5	177.7	-10.5	213.8	23.7	372.2
			SSE+LOCA 72h	-6.6	-23.5	187.6	-13.4	220.1	24.2	372.2
		90408	SSE+LOCA 6min	-10.2	-23.5	-51.7	133.2	99.7	116.7	372.2
			SSE+LOCA 72h	-10.7	-23.5	-54.9	137.4	101.4	119.8	372.2

[Cut-off Soil Springs in tension]

Seismic Force Direction	Soil Condition	Element ID	Load	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated	Allowable	Radial		Circumferential		Allowable
						Top	Bottom	Top	Bottom	
S to N	Soft	80275	SSE+LOCA 6min	-7.8	-23.5	-45.2	8.6	-7.2	17.2	372.2
			SSE+LOCA 72h	-8.8	-23.5	-49.8	15.4	-8.2	28.1	372.2
		90402	SSE+LOCA 6min	-5.0	-23.5	-27.0	17.7	54.5	42.9	372.2
			SSE+LOCA 72h	-4.0	-23.5	-18.9	10.1	58.3	40.2	372.2
		90408	SSE+LOCA 6min	-3.0	-23.5	19.0	-10.3	51.6	-3.2	372.2
			SSE+LOCA 72h	-3.0	-23.5	17.5	-10.5	51.7	-3.0	372.2

Note: For the locations of elements, see Figure 3.8-13 (5).

b) The discussion about differential settlement criteria will be provided in response to RAI 3.8-92, which is due to the NRC by October 31, 2006. In the NRC audit discussion about the response to RAI 3.8-90 a parametric study was requested to consider the non-uniform soil conditions under the basemat. Because additional analytical work is required for this parametric study, the response to RAI 3.8-94 will address this issue. RAI 3.8-94 is also due to the NRC by October 31, 2006.

No DCD changes were identified for this response supplement.

NRC RAI 3.8-13, Supplement 2

GE Additional Post Audit Action

Supplement 1 showed only seismic loading in N-S direction. Provide results for seismic loading in 3 directions.

GE Response

Uplift analyses described here were additionally performed for the following conditions:

EW_uplift = DL + SSE (1.0EW + 0.4V)

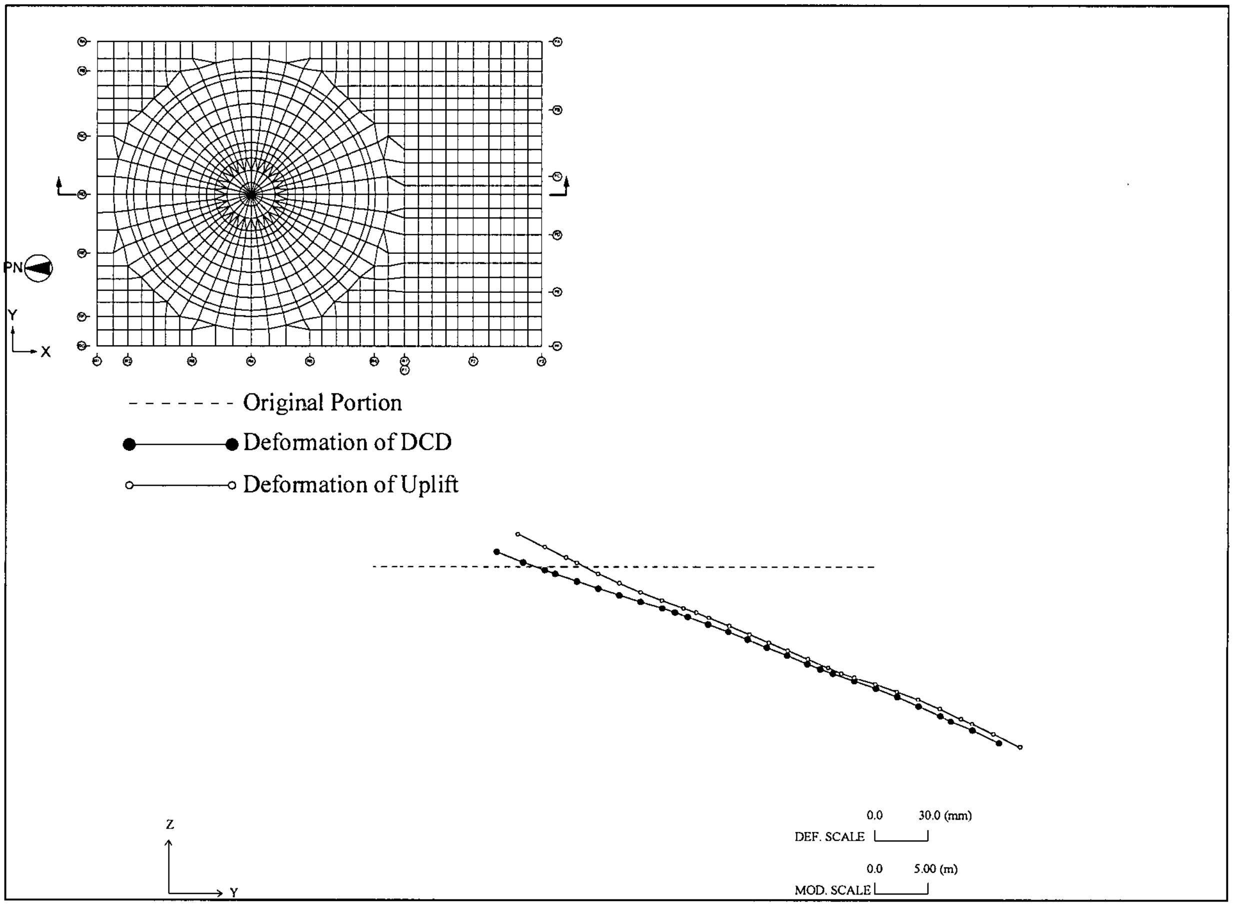
WE_uplift = DL + SSE (1.0WE + 0.4V)

Figures 3.8-13 (6), (7) and (8) show the comparison of the sectional deformations of the basemat and bending moments generated in the basemat respectively at the final step of iteration. In the area close to the cylindrical wall below the RCCV wall, bending moments are higher than that of DCD design; however the resulting stresses in the concrete and reinforcement are still below the code allowables with large margins as shown in Table 3.8-13 (4). Stress calculations in Table 3.8-13 (4) were performed for the following combinations to consider the effects of three directional inputs:

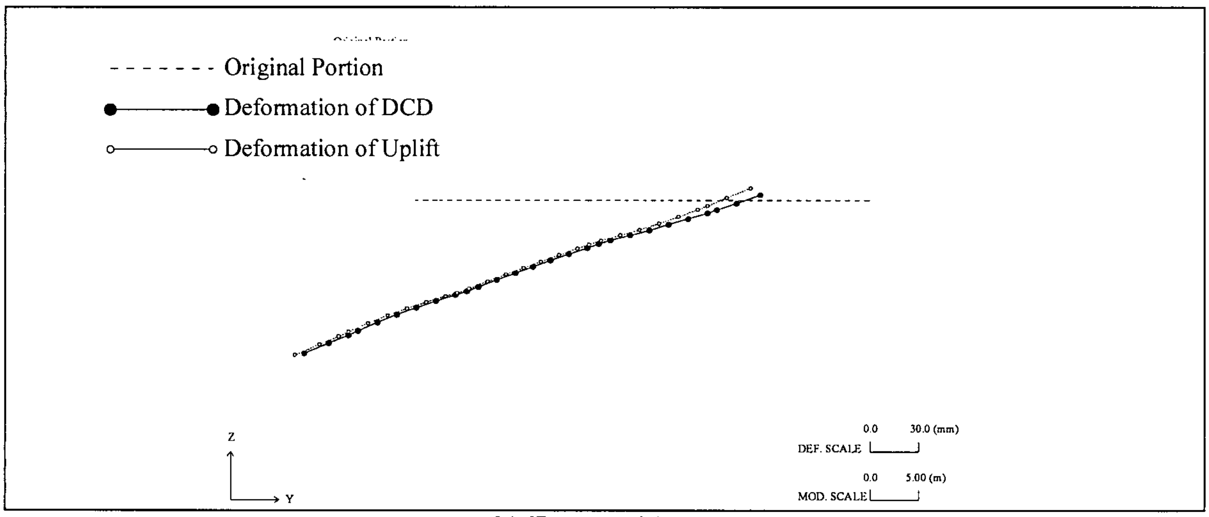
1) 1.0EW_uplift +/- 0.4NS_linear + Other loads (excluding DL)
2) 1.0WE_uplift +/- 0.4NS_linear + Other loads (excluding DL)

In the above combinations, linear analysis results that do not consider the basemat uplift are used for the NS direction earthquake. However, since significant uplift will not occur for 0.4NS, the results are considered to be acceptable.

No DCD changes were identified for this response supplement.

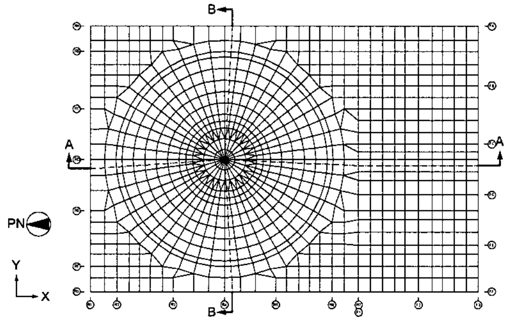


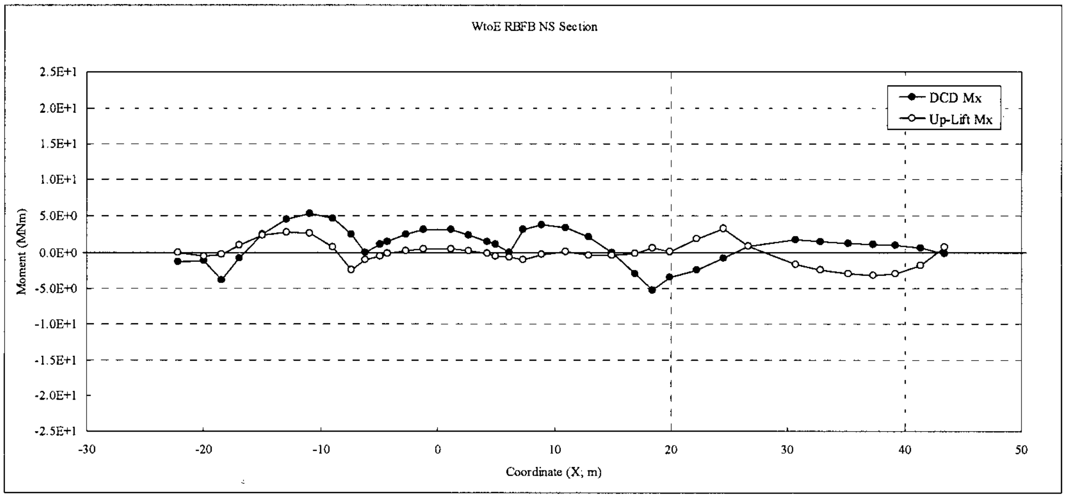
a) **West to East**



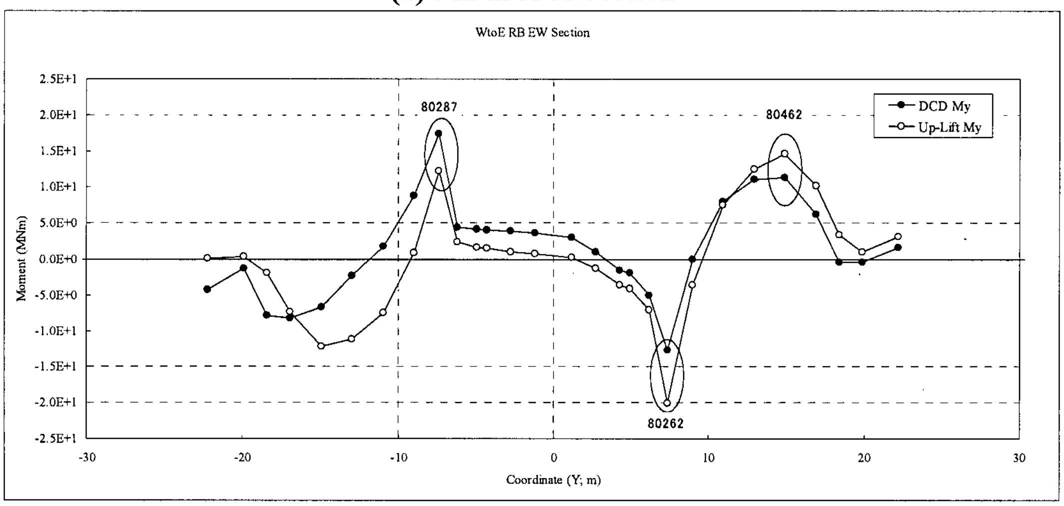
b) East to West

Figure 3.8-13 (6) Comparison of Basemat Deformation without Tension Springs



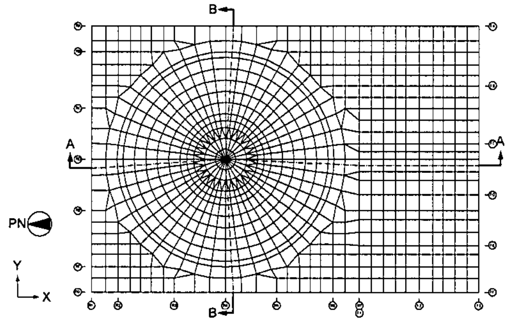


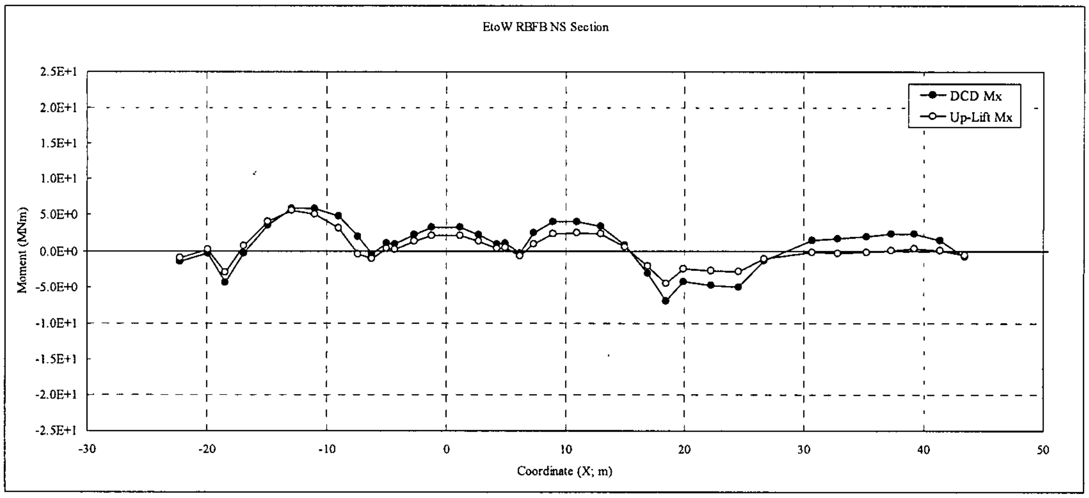
(a) Mx in A-A Section



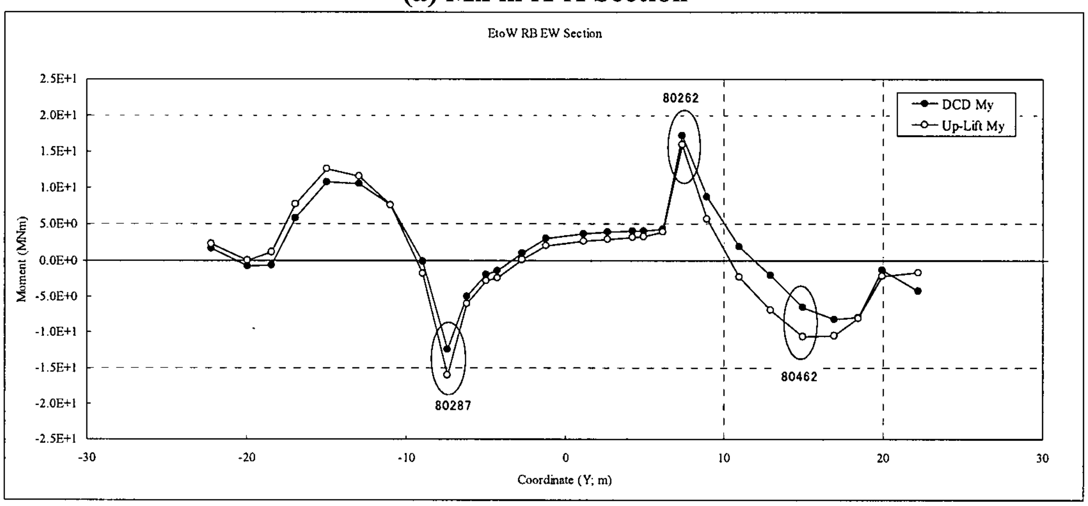
(b) My in B-B Section

Figure 3.8-13 (7) Comparison of Basemat Sectional Moments (W to E)





(a) Mx in A-A Section



(b) My in B-B Section

Figure 3.8-13 (8) Comparison of Basemat Sectional Moments (E to W)

Table 3.8-13(4) Concrete and Rebar stresses

[DCD Design]

Seismic Force Direction	Soil Condition	Element ID	Load	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated	Allowable	Radial		Circumferential		Allowable
						Top	Bottom	Top	Bottom	
EW	Soft	80262	SSE+LOCA 6min	-7.5	-23.5	-35.1	89.6	-0.4	43.6	372.2
			SSE+LOCA 72h	-5.6	-23.5	-32.9	-7.4	16.1	11.8	372.2
		80287	SSE+LOCA 6min	-6.2	-23.5	-32.0	75.2	0.6	21.6	372.2
			SSE+LOCA 72h	-4.8	-23.5	-31.0	-9.2	28.0	-15.3	372.2
		80462	SSE+LOCA 6min	-3.8	-23.5	46.6	2.8	-1.4	-17.9	372.2
			SSE+LOCA 72h	-7.3	-23.5	106.1	-14.8	75.7	-27.6	372.2

[Cut-off Soil Springs in tension]

Seismic Force Direction	Soil Condition	Element ID	Load	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
				Calculated	Allowable	Radial		Circumferential		Allowable
						Top	Bottom	Top	Bottom	
W to E	Soft	80262	SSE+LOCA 6min	-17.9	-23.5	-58.7	175.6	-20.4	191.1	372.2
			SSE+LOCA 72h	-18.4	-23.5	-60.8	183.5	-20.2	193.4	372.2
		80462	SSE+LOCA 6min	-12.0	-23.5	227.7	-9.8	11.5	-48.2	372.2
			SSE+LOCA 72h	-11.5	-23.5	225.6	-8.4	-11.5	-47.2	372.2
E to W	Soft	80287	SSE+LOCA 6min	-14.6	-23.5	-49.1	140.8	-14.6	149.7	372.2
			SSE+LOCA 72h	-15.3	-23.5	-52.1	147.2	-15.4	150.4	372.2
		80462	SSE+LOCA 6min	-8.5	-23.5	-43.9	166.6	71.4	113.5	372.2
			SSE+LOCA 72h	-9.0	-23.5	-43.9	175.4	64.9	123.6	372.2

Note: For the locations of elements, see Figure 3.8-13 (7) and (8).

NRC RAI 3.8-25

Describe how the analysis of a typical liner plate-to-RCCV attachment is performed using the NASTRAN model results. Include this information in DCD Section 3.8.1 and/or Appendix 3G.

In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

Rigid bar elements connect the corresponding grid points of the liner elements and concrete elements as described in DCD Appendix 3G.1.4.1. They are schematically shown in Figure 3.8-25 (1). To represent the anchor, rigid bar elements are placed in the radial direction for the liners of the RCCV cylinder wall and the RPV pedestal. They are placed vertically for the basemat, the suppression pool slab, and the top slab.

Using this modeling technique, the design forces of liner plates are obtained from the analysis directly, and the anchorage design is performed in accordance with ACI 349-01 Appendix B.

(1) The applicable detailed report/calculation that will be available for NRC audit is 26A6651, RB Structural Design Report, Revision 1, November 2005, containing the structural design details of the Reactor Building.

(2) Since this information exists as part of GE internal tracking system, it is not necessary to add it to the DCD submittal to the NRC.

No DCD changes will be made in response to this RAI.

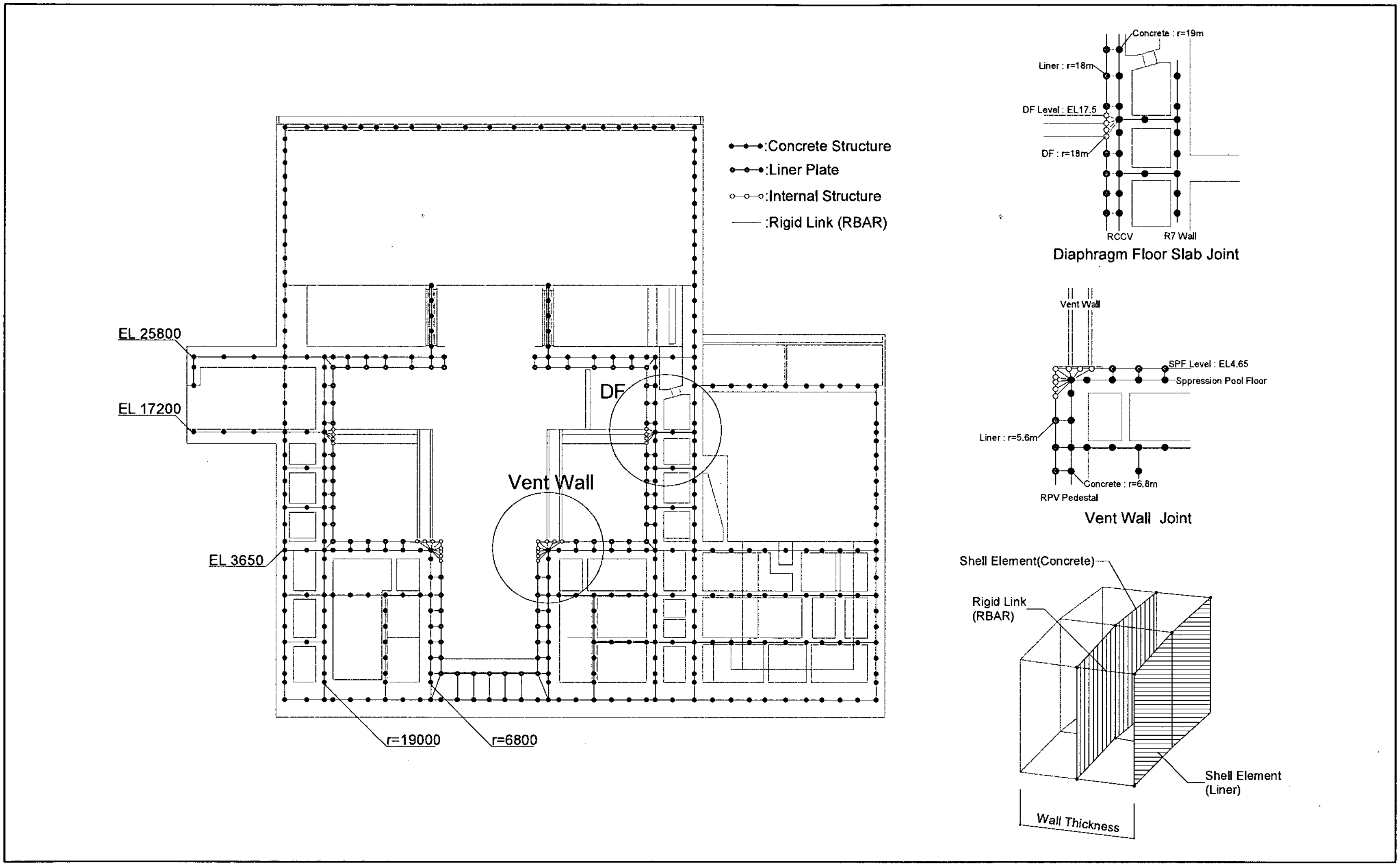


Figure 3.8-25 (1) Rigid Bar Elements between Concrete and Liner

NRC RAI 3.8-25, Supplement 1

Additional topics discussed at audit

a) Add Reference to ACI 349-01 in Table 3.8-9 and in the body of DCD text.

b) Consider adding RG's No. 1.142 and 1.199 to Table 3.8-9

GE Response

a) DCD Section 3.8.1.1.2 will be revised in the next update as noted in the markup provided under MFN 06-191S1.

b) Please refer to the response to RAI 3.8-14, Supplement 1 provided under MFN 06-191S1.

NRC RAI 3.8-25, Supplement 2

GE Additional Post Audit Action

Evaluate the concerns identified at structural audit in July 2006 related to the potential for the liner to penetrate the concrete surface, and the liner grid spacing versus the actual spacing, and also explain how the forces on the anchors are determined if 1/10,000 E is used for the liner in the NASTRAN model.

GE Response

In NASTRAN analysis of the RBFB global FE model, Young's modulus for the RCCV steel liners is set to a small value, 1/10000 of the normal value, for non-thermal loads so that they do not bear any stresses. For thermal loads the normal Young's modulus for the liner is used in the model to account for the effect of differential thermal expansion between steel and concrete.

The liner is modeled in global FEM model with rigid bar elements placed between RCCV wall element and liner element as described in DCD Appendix 3G.1.4.1. The positions of these rigid bar elements do not match the layout of liner anchors.

The following sections provide justification for the adequacy of the modeling technique to correctly predict the behavior of the liner attached to the RCCV wall. Therefore, calculated strains and anchor forces for the liner plate design are acceptable.

FEM ANALYSIS FOR LINER PLATES

1. Scope

This analysis provides justification for the adequacy of the modeling technique to correctly predict the behavior of the liner attached to the RCCV wall.

2. Analysis Cases and Model

Two models are provided to predict the behavior of non-anchored region of liner plate supported by its anchorage. The non-anchored portion of plate is coupled to the concrete by rigid link element or contact element. The parameters for the analysis are shown on Table 3.8-25 (1).

2.1 Analysis cases

Analysis cases are shown in Table3.8-25 (1). Case 1 is provided to simulate the DCD design technique and Case 2 permits non-anchored region of liner plate to move in any direction except the RCCV wall direction.

Table 3.8-25 (1) Analysis conditions

No.	Model	Coupling with Concrete	Load	Stiffness of Liner
1-a	Glued	Rigid Link	Pressure	E/10000
1-b			Thermal	E
2-a	Contact	Contact spring*1	Pressure	E/10000
2-b			Thermal	E

*1; depends on the function of NASTRAN

2.2 Model

The width of the model is twice the Liner anchor pitch (2 x 5.14 degrees) and the height is the half of width. Six degrees of freedom of nodes provided for liner are subordinations to these of RC wall. Figure 3.8-25 (2) shows the analysis models.

Coordinate System : Cylindrical、radius = 18m
Size : Liner plate = 6 mm
: Concrete wall thickness = 2 m
Boundary Conditions :
vertical edges : axi-symmetric condition
bottom : simple support [θ, z], but [r] is free
top : for Pressure Load: Same as bottom
: for Thermal Load: Rigid Link
Division : divide the width of Liner anchor pitch (5.14 degrees) into 4 elements

2.3 Material properties

Refer to Table 3.8-25 (2). The Young's Modulus is set to a very small value, i.e. 1/10,000 of the standard value, for pressure loads so that the liner resistance to pressure loads will be discounted. For thermal loads, the standard Young's Modulus value is used to account for the effect of differential thermal expansion between steel and concrete.

3. Loads

Pressure and thermal loads are considered as shown bellow:
Pressure: 45 psig = 0.31 MPa (LOCA after 72 hr)
Thermal: Average temperatures to concrete wall and liner are assigned
Concrete = 20°C
Liner =170°C
Initial temperature = 15.5°C

4. Results

Figures 3.8-25 (3) and (4) show the strains. The strains are the same for Case 1 and Case 2. Therefore the modeling technique of DCD is acceptable.

Table 3.8-25 (2) Material Properties

		Reinforced Concrete	Liner
		f'c=5000psi 34.5MPa	Carbon Steel
Young's Modulus (MPa)	Temperature	2.78×10^{4}	2.00×10^{5}
	Pressure	2.78×10^{4}	2.00×10^{1}
Poisson's Ratio		0.17	0.3
Thermal Expansion (m/m°C)		9.90×10^{-6}	1.17×10^{-5}

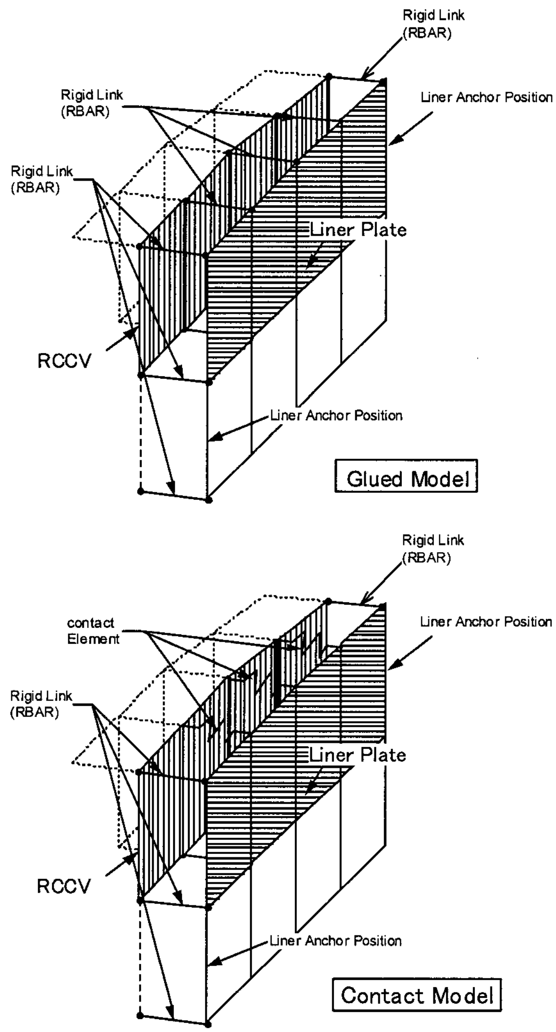
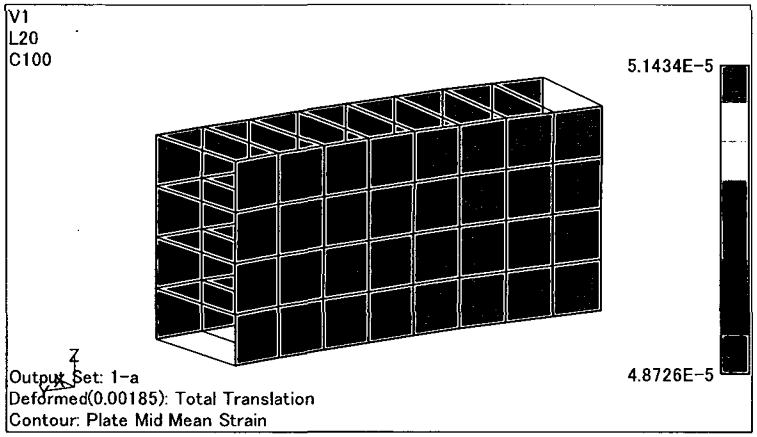
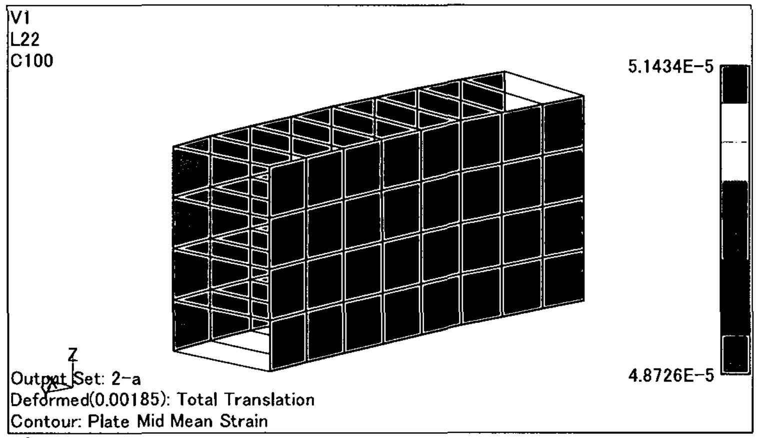


Figure 3.8-25 (2) Analysis Models

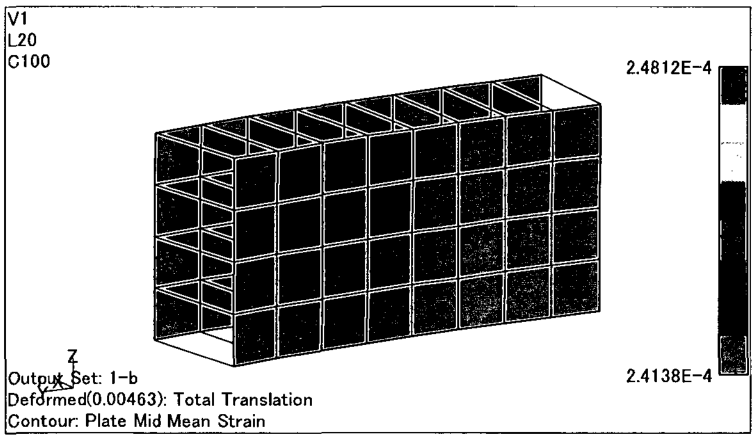


a) Glued Model

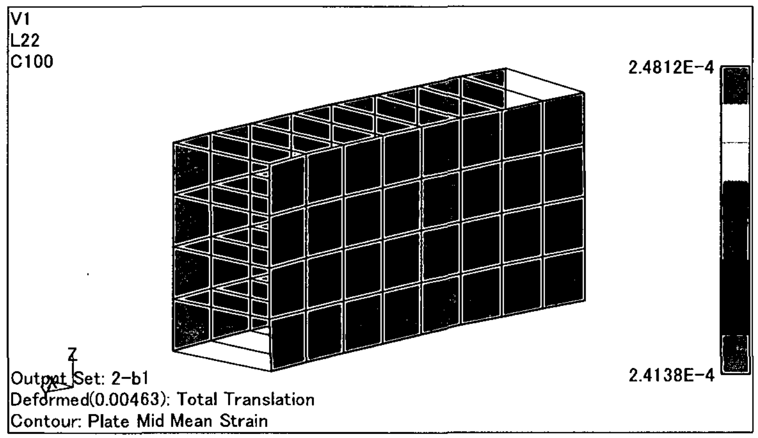


b) Contact Model

Figure 3.8-25 (3) Liner Strains (Pressure)



a) Glued Model



b) Contact Model

Figure 3.8-25 (4) Liner Strains (Thermal)

CONVERSION OF LINER STRAIN TO ANCHOR FORCES

For the displacement evaluation of liner anchor, the NASTRAN results of liner strain is converted to liner anchor load. In this conversion process, the normal value (i.e. E itself, not divided by 10,000) of steel Young's modulus is used.

For the pullout of liner anchor, the negative pressure load is used. NASTRAN results are not used for this evaluation.

Liner strains for each load are obtained directly from NASTRAN analysis results (strain of liner element) except the thermal loads. NASTRAN does not output the thermal stress (stress of liner element) directly, so the output of stress is converted to strain using normal Young's modulus.

No DCD changes were identified for this response supplement.

NRC RAI 3.8-41

DCD Sections 3.8.3.1.1 and 3.8.3.1.4 indicate that the diaphragm floor (DF) and vent wall (VW) are constructed from steel plates filled with concrete. Section 3G.1.4.1 of Appendix 3G indicates that the infill concrete is conservatively neglected in the analysis model. Neglecting the mass and stiffness of the concrete may not be conservative. Therefore, provide more information which explains how the infill concrete is considered in the analysis and design of these structures. Describe how the mass, stiffness, and strength are considered when analyzing the DF and VW structures for each applicable loading condition. For analysis of thermal transients, how was the infill concrete modeled in heat transfer analyses, and how was the constraint to thermal growth/contraction of the steel plates considered in the thermal stress analyses?

Include this information in DCD Section 3.8.3 and/or Appendix 3G. In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

Concrete strength and stiffness are conservatively neglected in both the structural analysis model and the seismic analysis model. The mass of concrete is considered in the seismic analysis model and in the structural analysis model.

For the linear thermal analysis, concrete strength and stiffness are neglected and thus the constraint to thermal expansion or contraction of the steel plates from the infill concrete is not considered. However, for the non linear analyses, the infill concrete in VW and DF is explicitly included as brick elements with strain compatibility between the steel and concrete interfaces and using the respective values for the coefficient of thermal expansion for concrete and steel. This modeling includes the effect of the constraint to thermal expansion or contraction to both the concrete and steel components. Note that concrete cracking is also included, and this would relieve some of the thermal induced stress. The effect of this infill concrete on thermal constraint from the nonlinear model is then transferred to the linear thermal-stress design model through scaling via thermal ratios. Concrete cracking effects due to thermal loads are obtained by a nonlinear, concrete cracking analysis using ABAQUS/ANACAP program as described in DCD Appendix 3C.

Thermal transients in the heat transfer analysis done to determine temperature distribution, the heat transfer coefficient of concrete is neglected in the DF and WW for the linear analysis but concrete is included in the non linear model. Through the use of the thermal ratios to account for the thermal stresses, the effect of infill concrete on the heat transfer is implicitly addressed in the linear analysis.

Therefore, for the non-thermal and non-seismic loads, neglecting the strength of the infill concrete in the design of the VW and DF structures is conservative, because the steel sections must then resist all these type of loads (under the bending of the VW or DF, the concrete could resist significant load in compression, if not neglected). For seismic load, neglecting the strength and stiffness of the concrete but including the mass is conservative because the mass can add significant dynamic load without the benefit of any stiffness or strength to resist this load. For the thermal loads, the stiffness, strength, and associated constraint due to thermal expansion or contraction of the infill concrete is included in the nonlinear modeling. In addition, concrete cracking due to thermal induced stress and the associated reduction and redistribution of thermal load is also included. The effect of concrete expansion or contraction and cracking of the infill concrete in the steel composite structures (VW, DF) associated with thermal loads is incorporated into the design through the use of thermal ratios that scale results of the design basis model that use linear thermal stress analysis neglecting the infill concrete.

(1) The applicable detailed report/calculation that will be available for NRC audit is 26A6625, Cracking Analysis of Containment Structure for DBA Thermal Loads, Revision 1, October 2005. This report documents the non-linear analyses for the thermal loads taking into account of concrete cracking and the redistribution of section forces due to concrete cracking.

(2) Since this information exists as part of GE internal tracking system, it is not necessary to add it to the DCD submittal to the NRC.

No DCD changes will be made in response to this RAI.

NRC RAI 3.8-41, Supplement 1

None submitted.

NRC RAI 3.8-41, Supplement 2

GE Additional Post Audit Action

Since concrete properties were not used in the stick model for the VW and DF, indicate what is the effect on frequency shift when considering concrete, even if cracked, in the spectrum curves generated for equipment and piping design.

GE Response

To address the effect of in-fill concrete on the frequency shift for the VW and DF, the stiffness properties of the two structures in the seismic model were adjusted to include contribution of concrete stiffness. Since the in-fill concrete is unreinforced, it would likely to crack under SSE. An effective concrete stiffness equal to 50% of the nominal uncracked stiffness was thus assumed. The resulting fundamental frequency was found to be 113% higher for the VW and 26% higher for the DF than that of the base model without consideration of the in-fill concrete stiffness. (See Table 3.8-41 (1))

The effect of frequency shift on the floor response spectra was evaluated by additional parametric SSI analysis for generic uniform sites with single envelope ground motion input. The results were compared with the enveloping results obtained from Report SER-ESB-033, *Parametric Evaluation of Effects on SSI Response, Rev. 0,* submitted to NRC as Enclosure 2 to MFN 06-274. As shown in Figs. 3.8-41 (1) through 3.8-41 (25) for spectra comparison at selected locations, the existing site-envelope spectra without the in-fill concrete stiffness consideration do not completely bound. (In these figures, U-3 means the case without concrete stiffness (base model), and U-5 means with 50% concrete stiffness.) In view of this comparison, the results of the in-fill concrete stiffness parametric evaluation will be included in the site-envelope seismic design loads.

It should be noted that additional parametric seismic analysis is being performed to address the effect of containment LOCA flooding (see response to RAI 3.8-8) and the effect of updated modeling properties of containment internal structures for more consistency with the design configuration.

Final seismic loads will be documented in next update of DCD Appendix 3A.

Table 3.8-41 (1) Effect of concrete rigidity for natural frequencies for VW and DF

Structure		Modulus of elasticity of concrete	
		0% (E=0MPa)	50% (E=13900MPa)
Vent Wall	Frequency (Hz)	21.6	46.0
	Ratio	1	2.13
Diaphragm Floor	Frequency (Hz)	13.5	17.0
	Ratio	1	1.26

Material properties:

(1) Concrete
Modulus of elasticity: E=13900MPa (50%)
Poison's ratio : v=0.17

(2) Steel
Modulus of elasticity: E=200000MPa
Poison's ratio : v=0.3

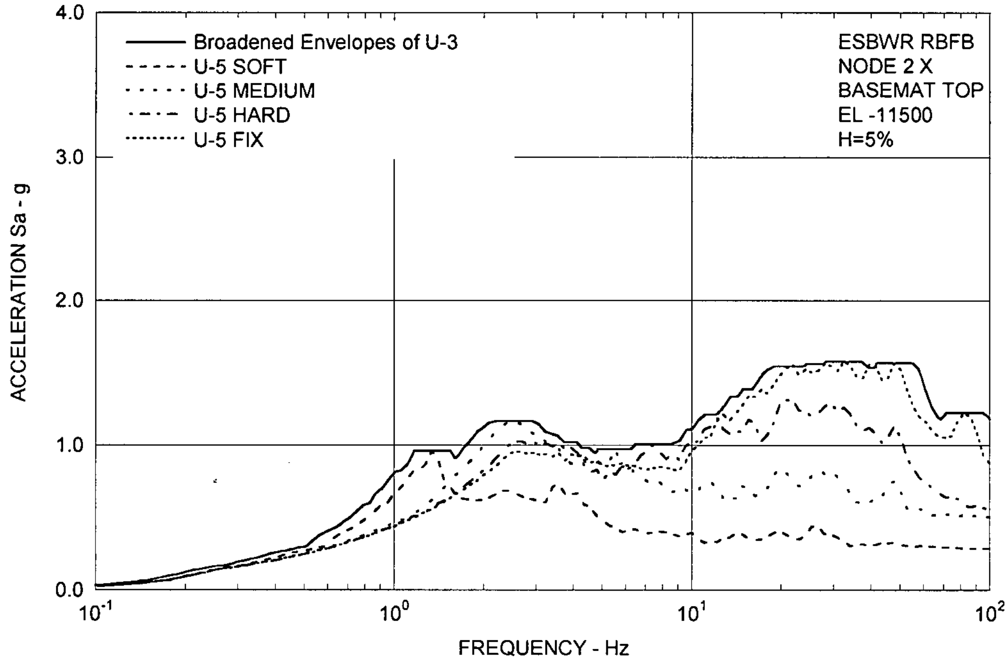


Figure 3.8-41 (1) Floor Response Spectra - RBFB Basemat X

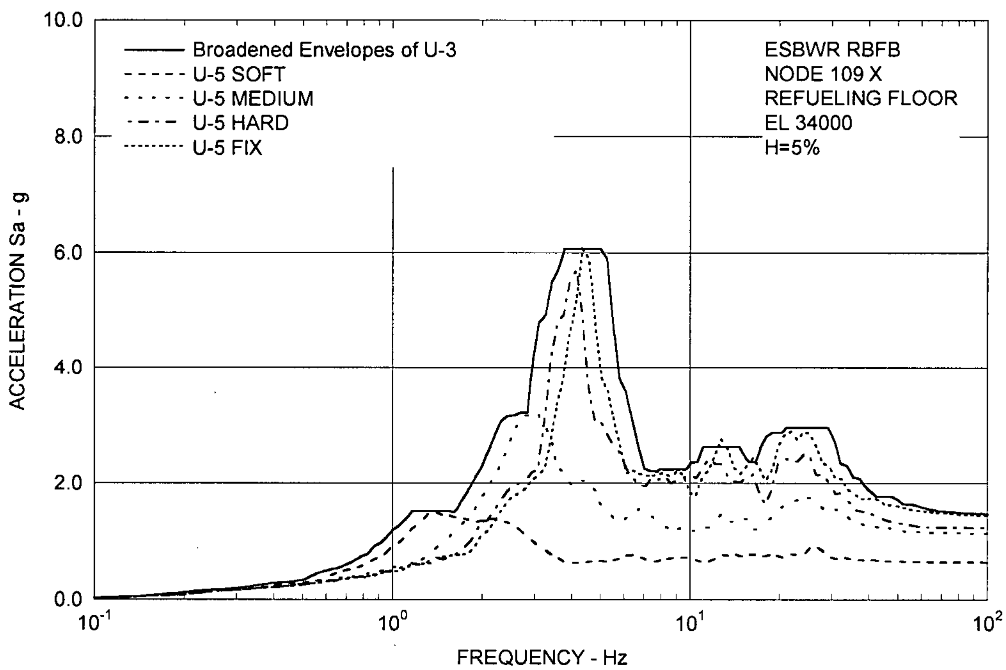


Figure 3.8-41 (2) Floor Response Spectra - RBFB Refueling Floor X

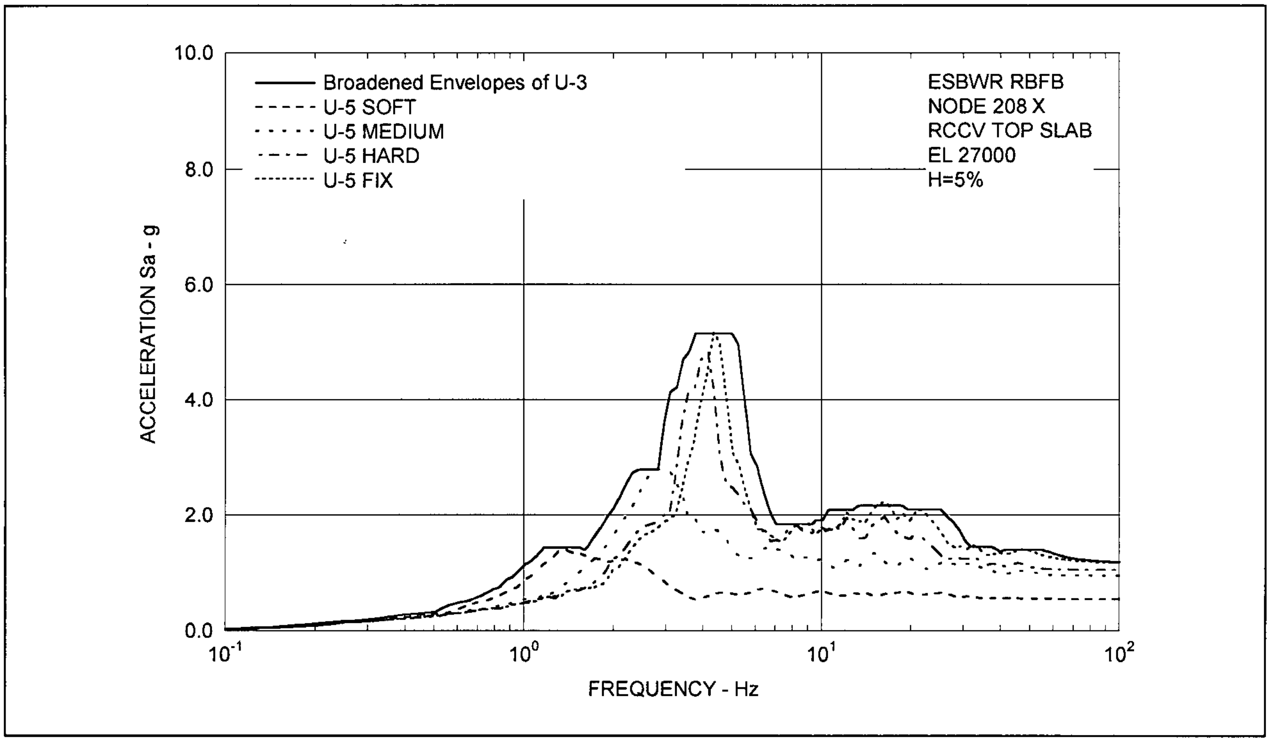


Figure 3.8-41 (3) Floor Response Spectra - RCCV Top Slab X

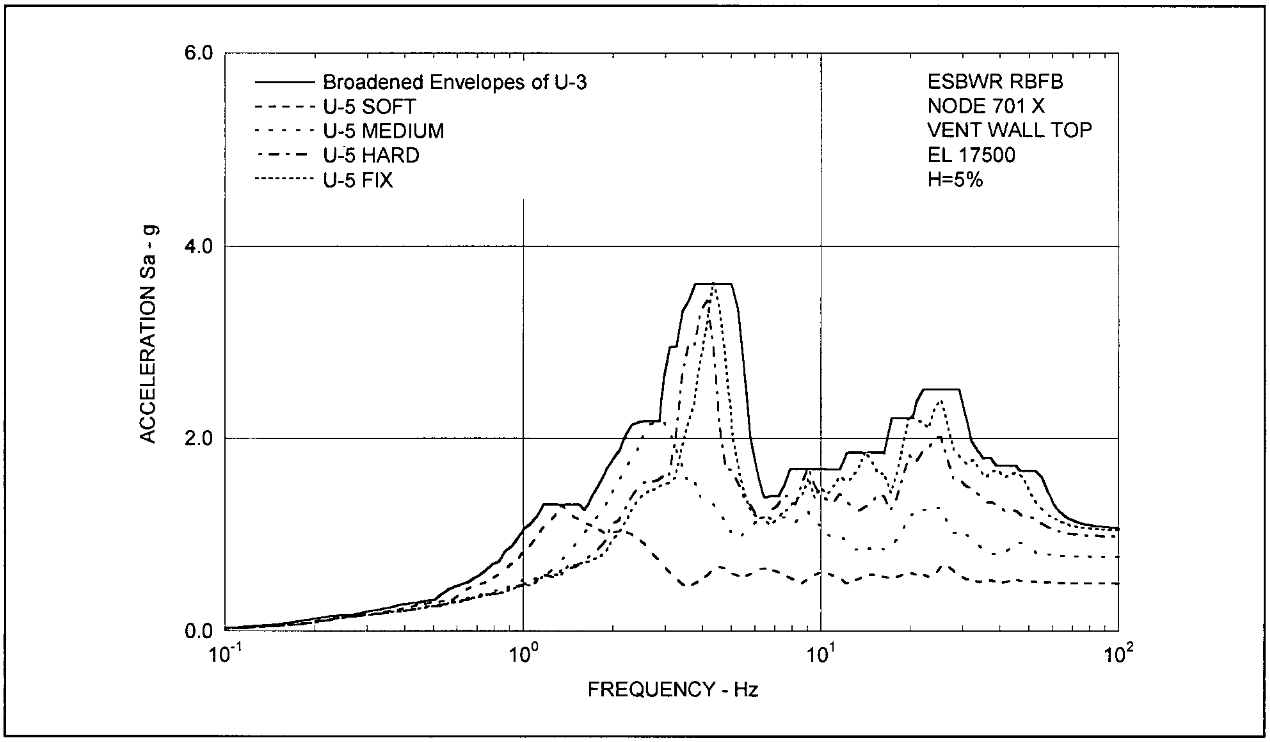


Figure 3.8-41 (4) Floor Response Spectra - Vent Wall Top X

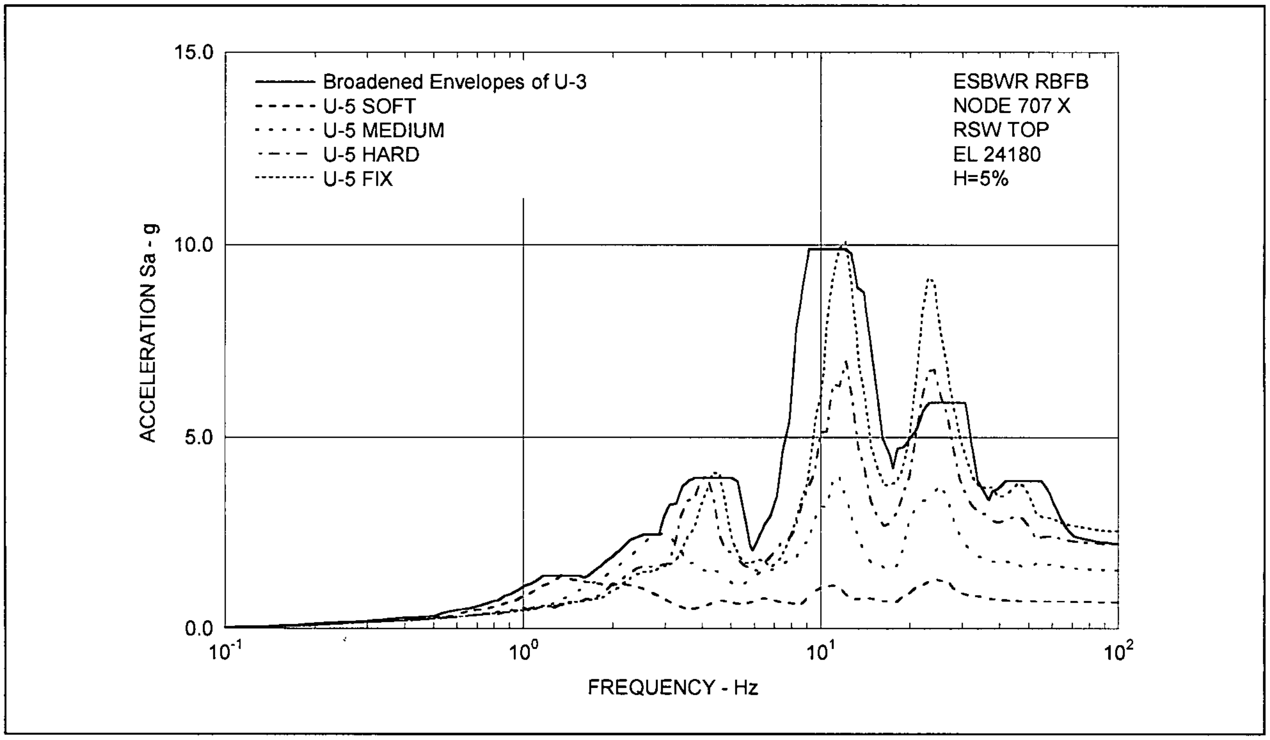


Figure 3.8-41 (5) Floor Response Spectra - RSW Top X

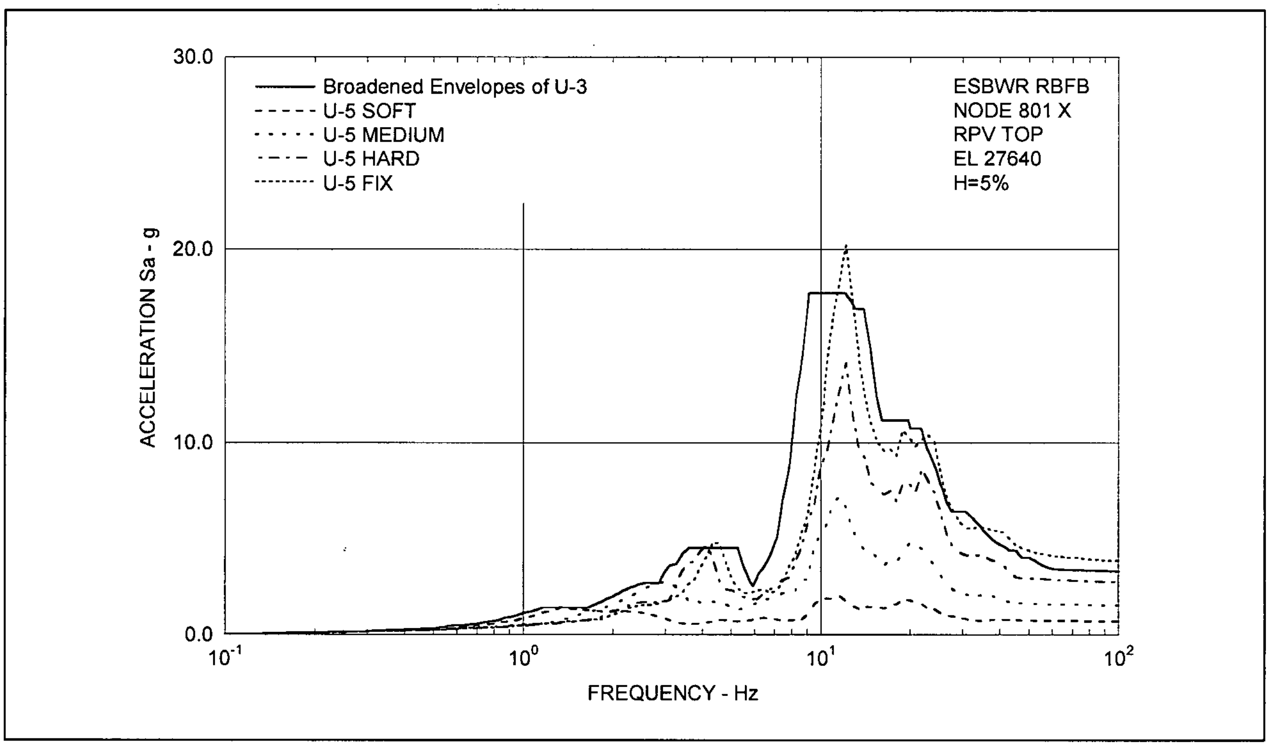


Figure 3.8-41 (6) Floor Response Spectra - RPV Top X

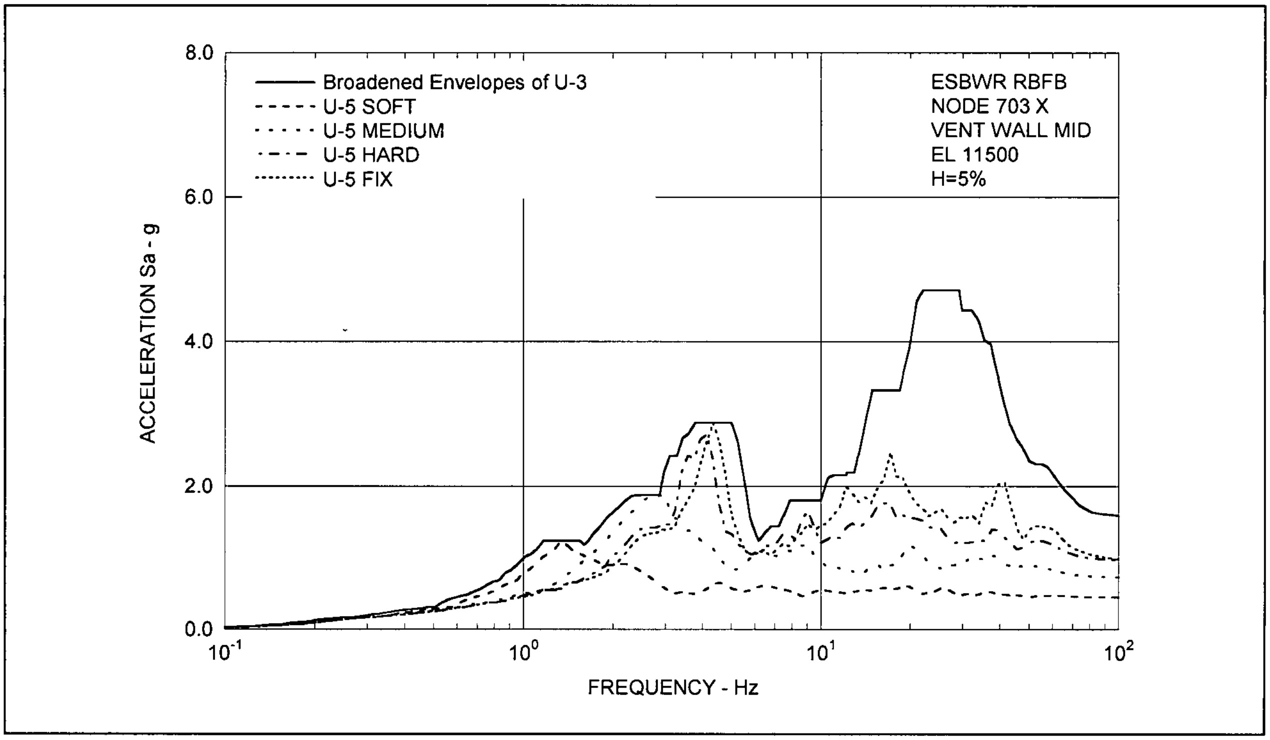


Figure 3.8-41 (7) Floor Response Spectra - Vent Wall Middle X

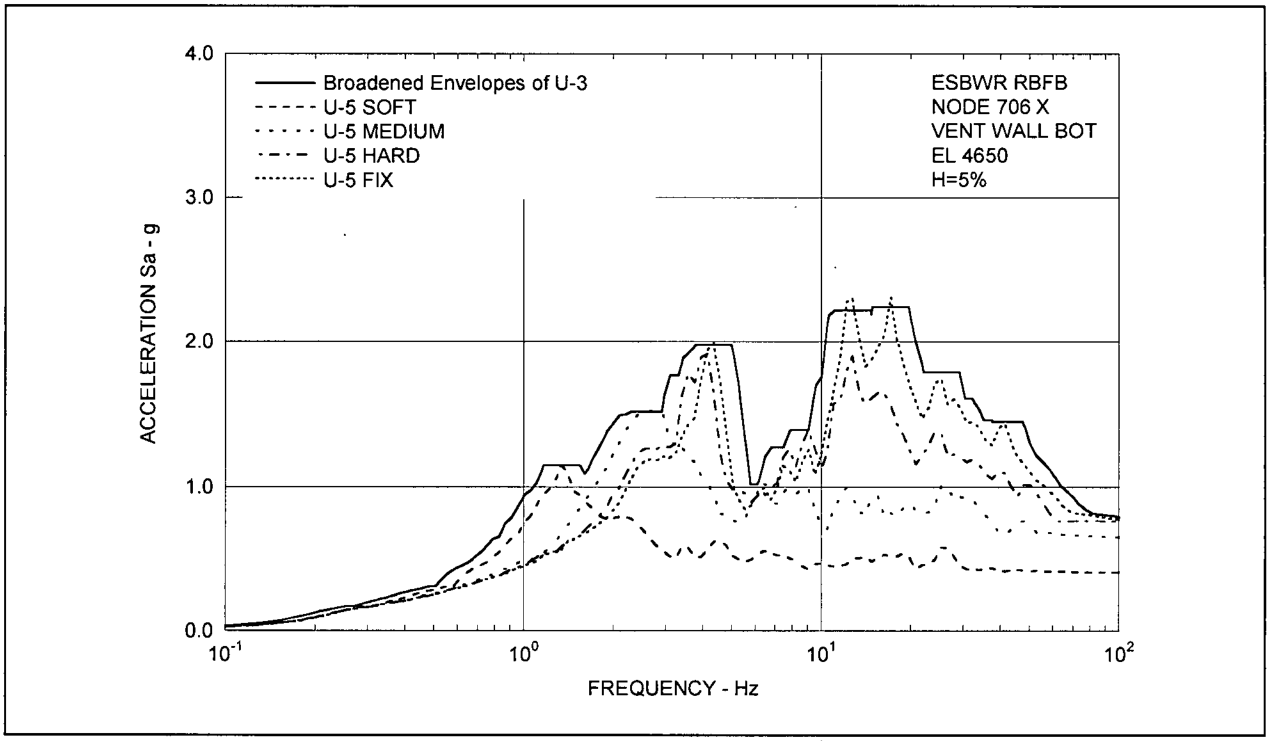


Figure 3.8-41 (8) Floor Response Spectra - Vent Wall Bottom X

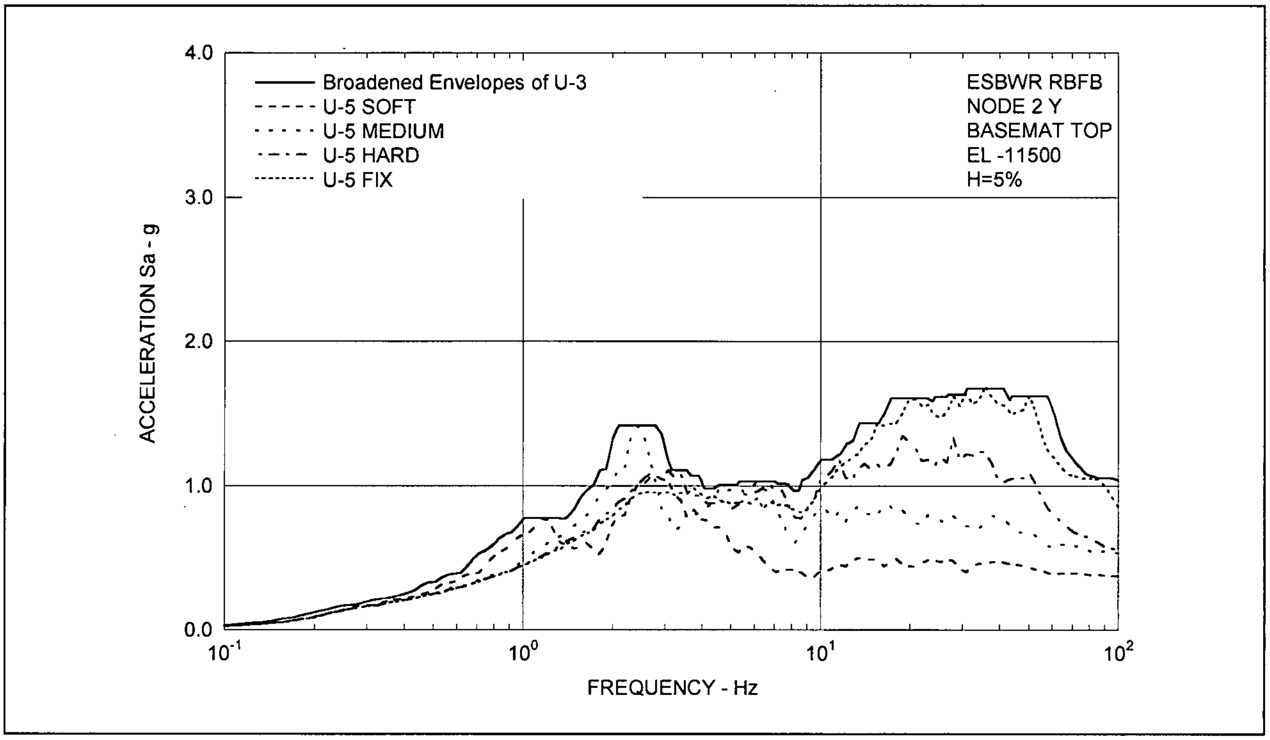


Figure 3.8-41 (9) Floor Response Spectra - RBFB Basemat Y

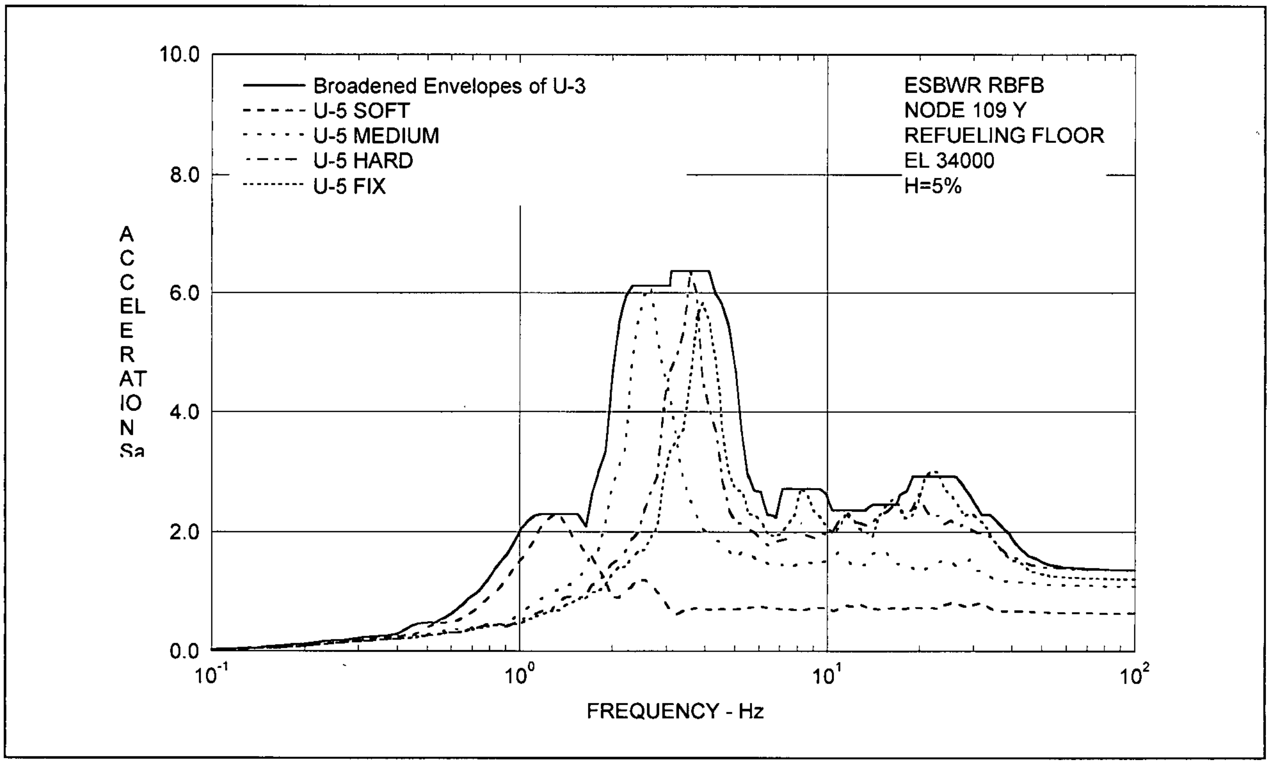


Figure 3.8-41 (10) Floor Response Spectra - RBFB Refueling Floor Y

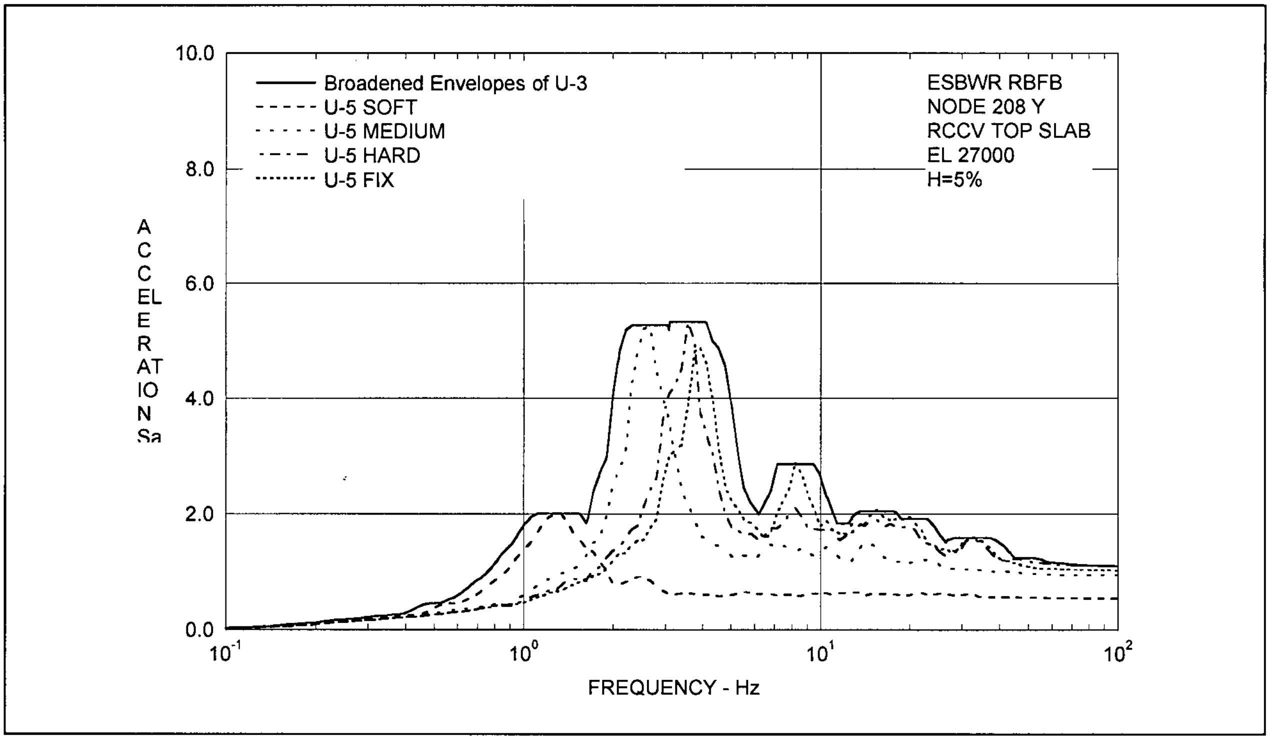


Figure 3.8-41 (11) Floor Response Spectra - RCCV Top Slab Y

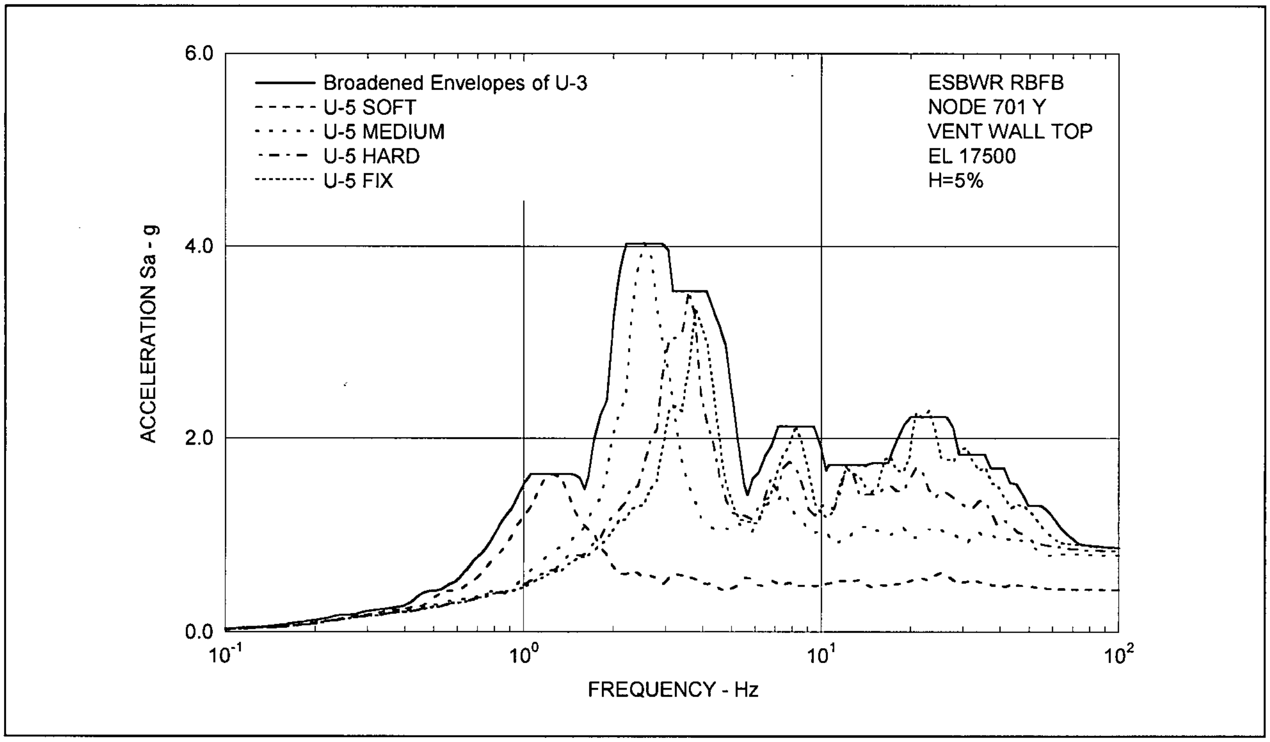


Figure 3.8-41 (12) Floor Response Spectra - Vent Wall Top Y

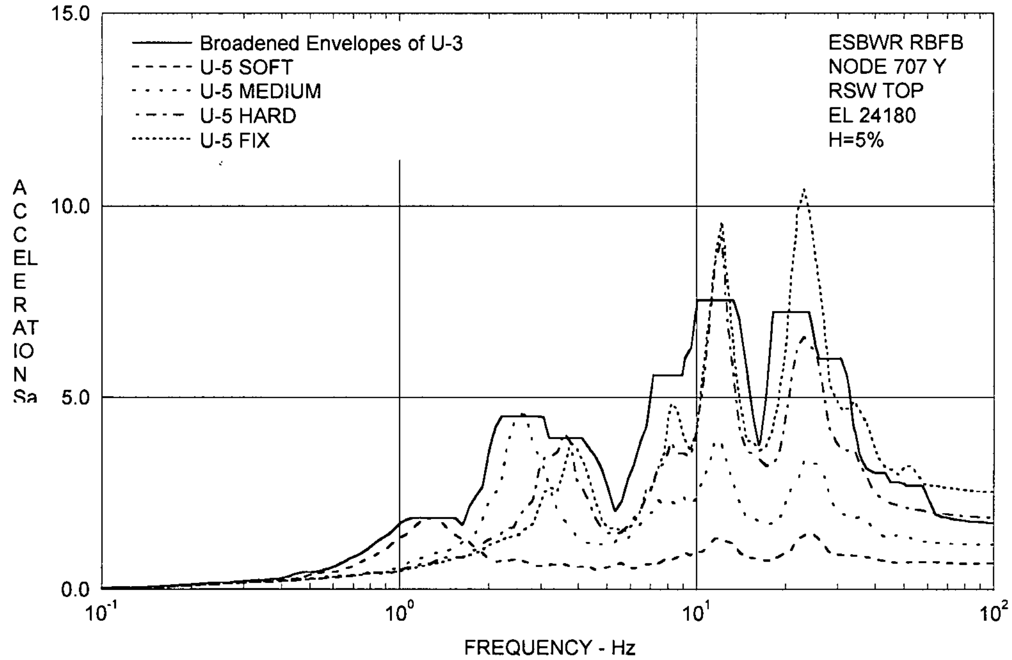


Figure 3.8-41 (13) Floor Response Spectra - RSW Top Y

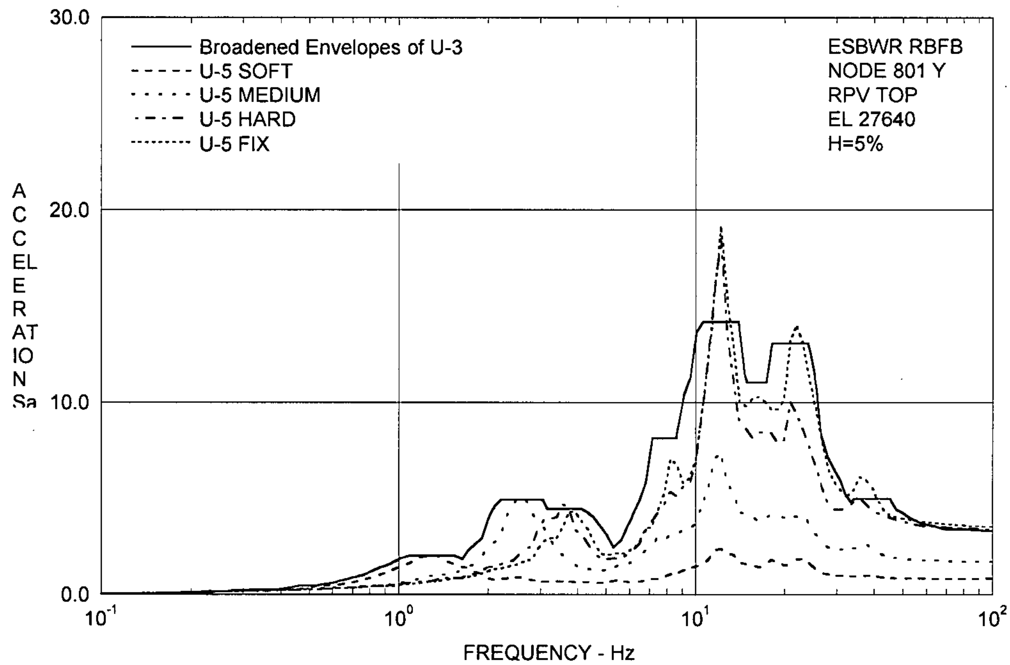


Figure 3.8-41 (14) Floor Response Spectra - RPV Top Y

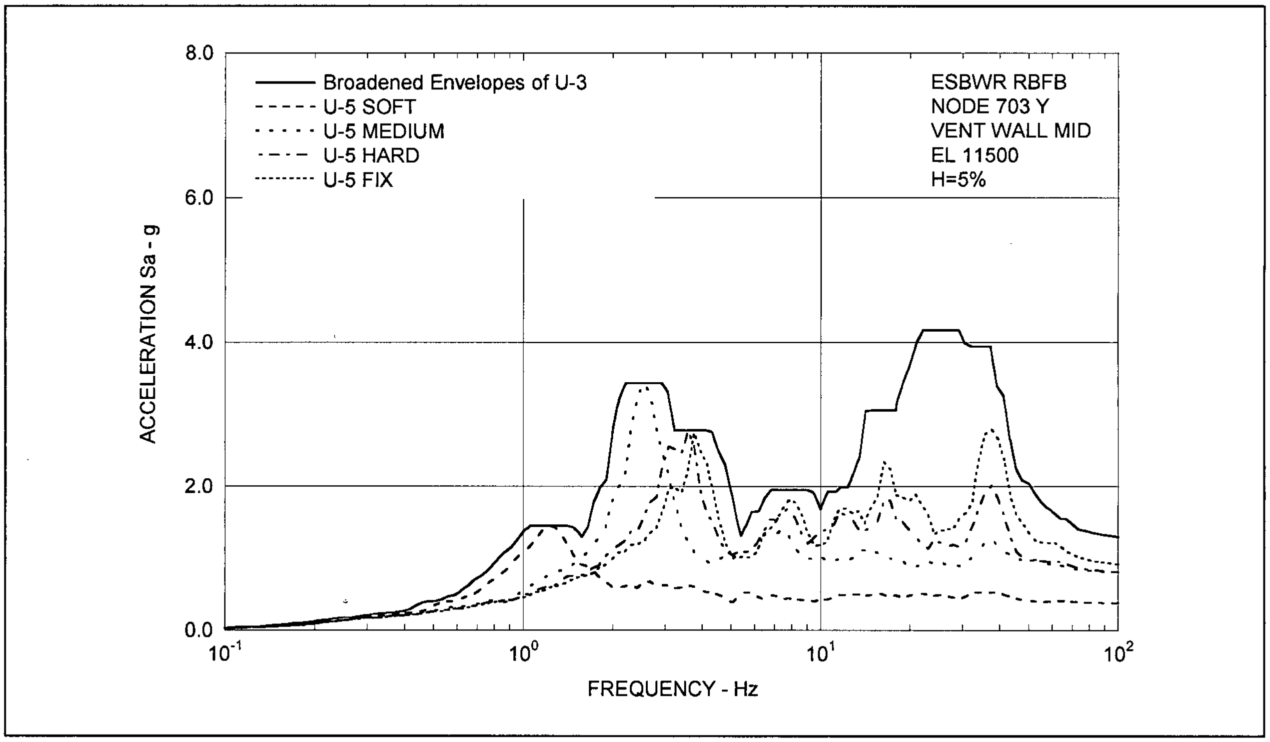


Figure 3.8-41 (15) Floor Response Spectra - Vent Wall Middle Y

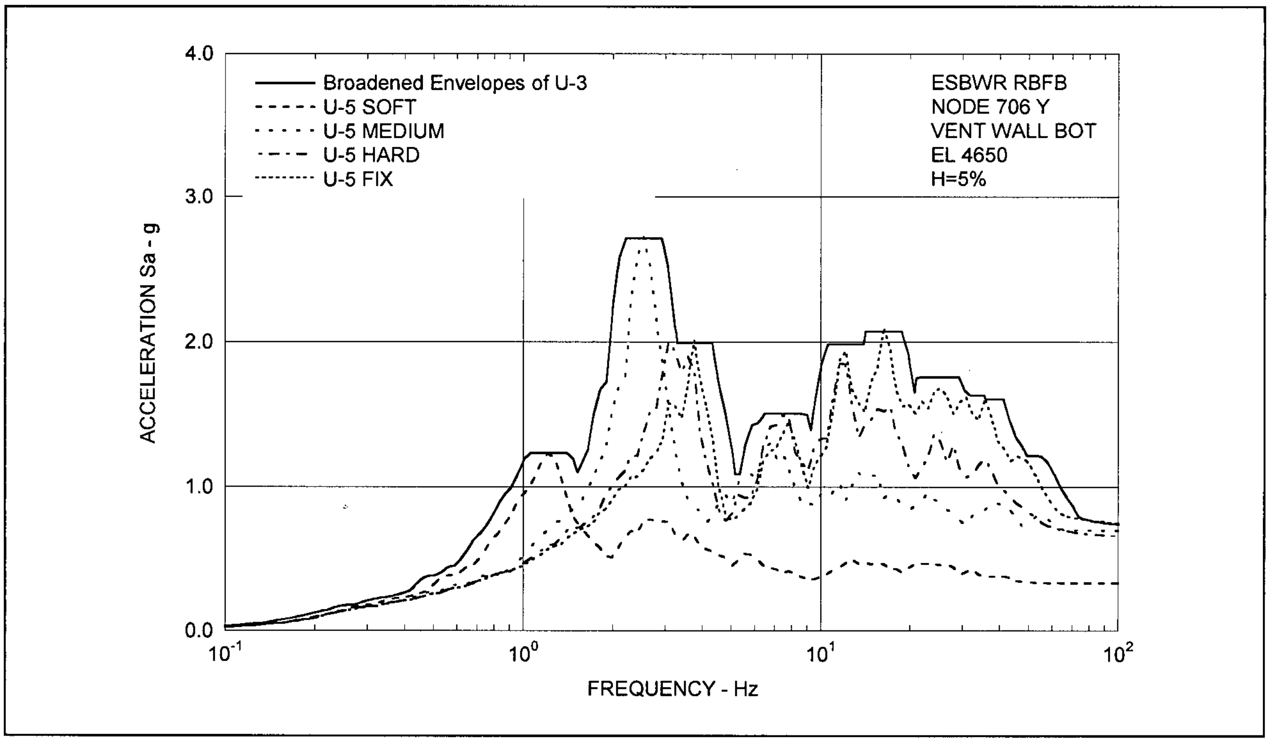


Figure 3.8-41 (16) Floor Response Spectra - Vent Wall Bottom Y

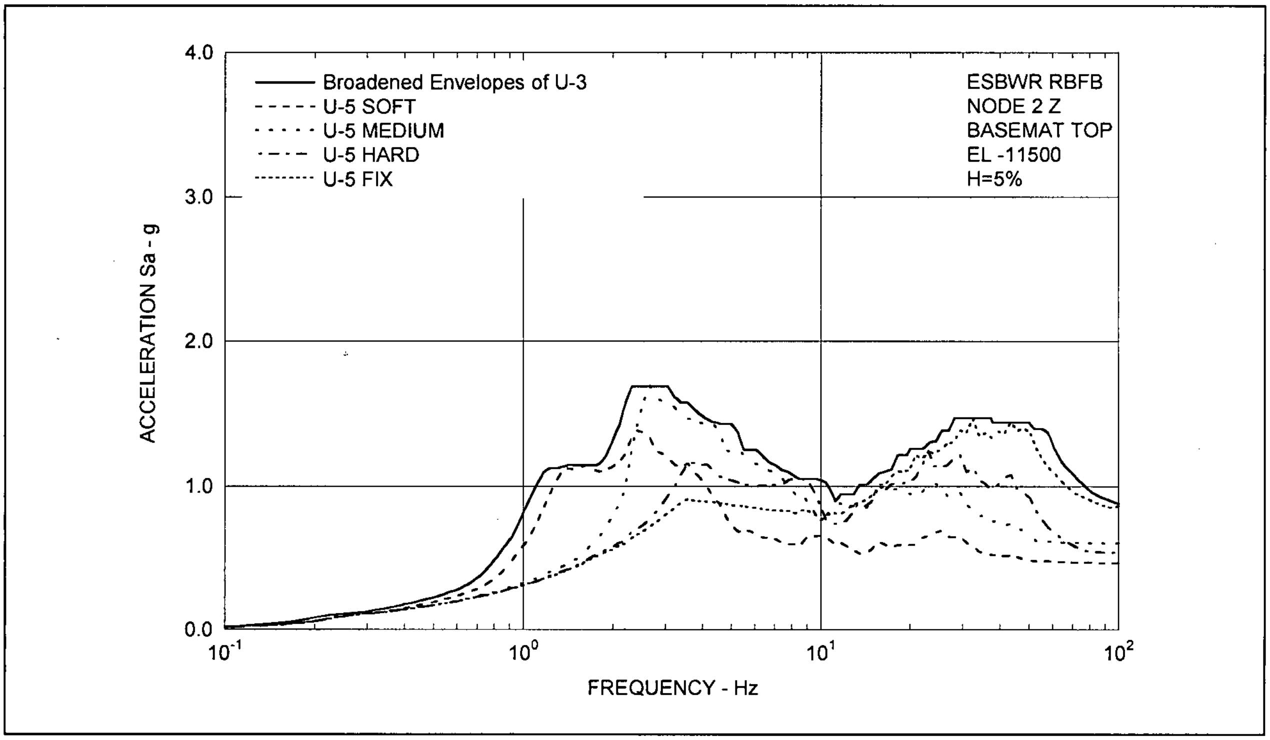


Figure 3.8-41 (17) Floor Response Spectra - RBFB Basemat Z

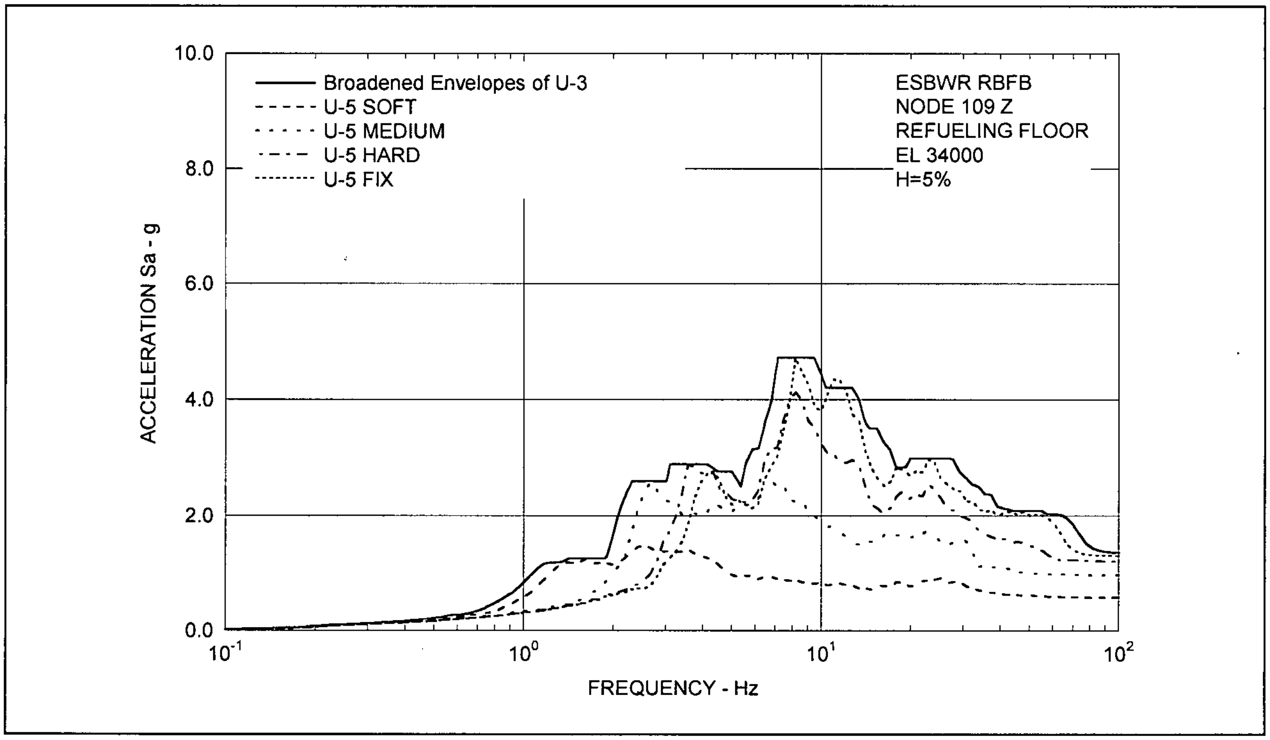


Figure 3.8-41 (18) Floor Response Spectra - RBFB Refueling Floor Z

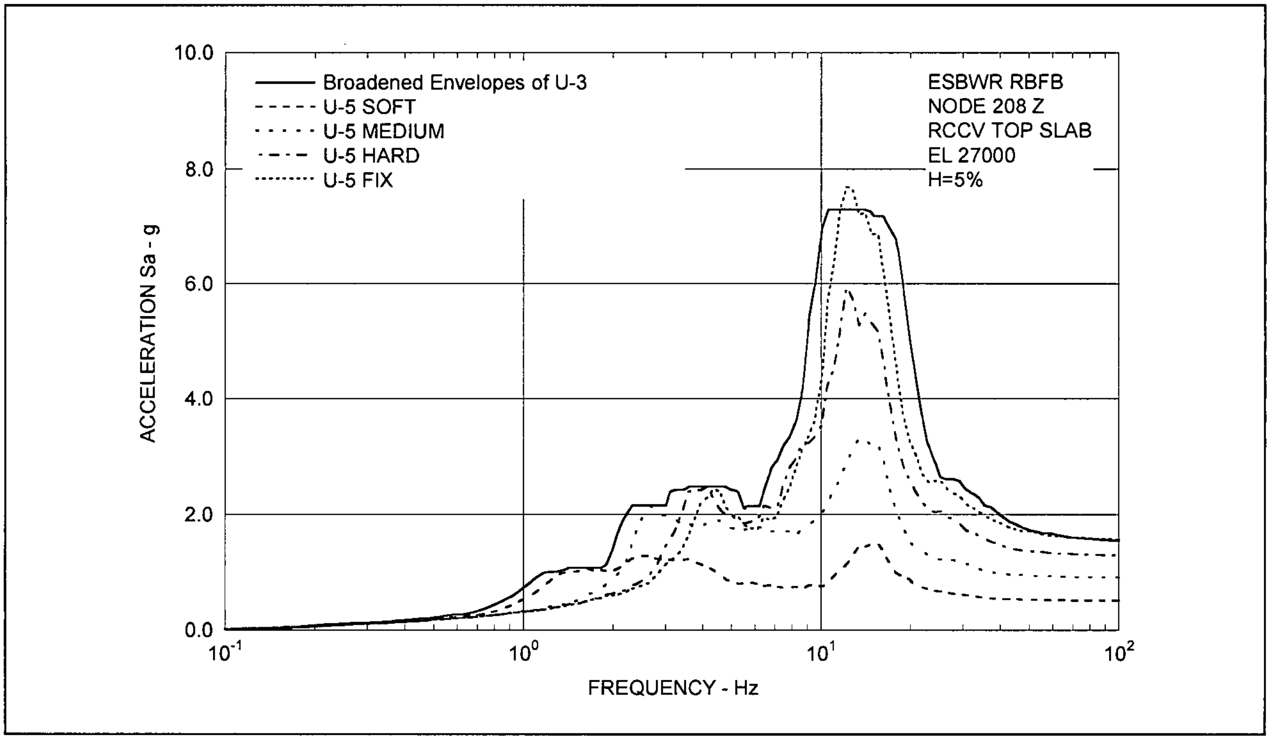


Figure 3.8-41 (19) Floor Response Spectra - RCCV Top Slab Z

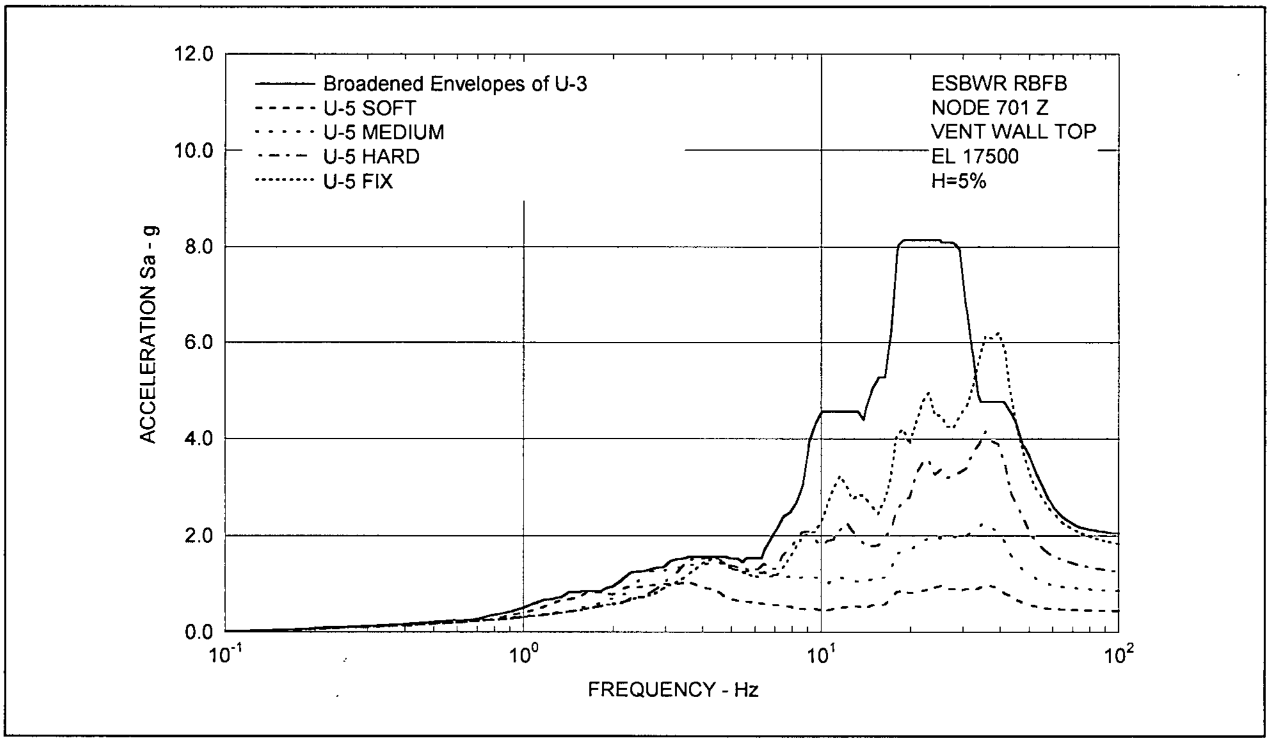


Figure 3.8-41 (20) Floor Response Spectra - Vent Wall Top Z

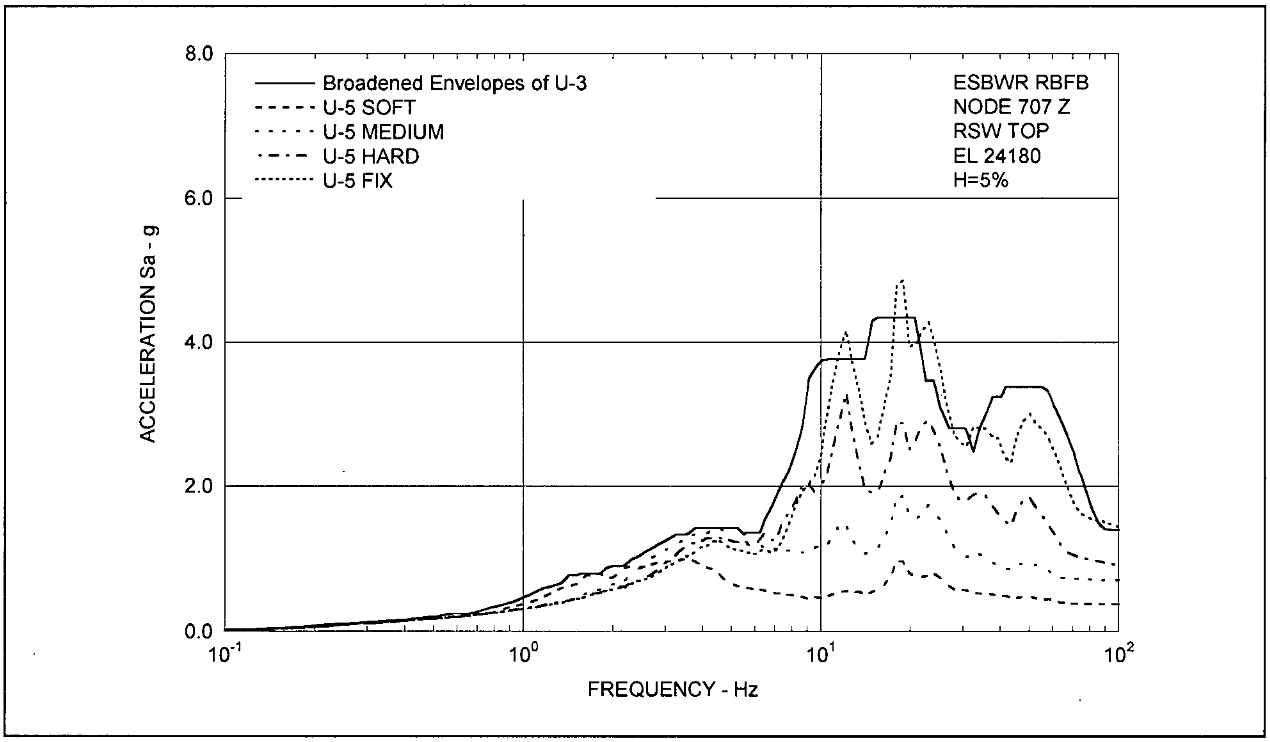


Figure 3.8-41 (21) Floor Response Spectra - RSW Top Z

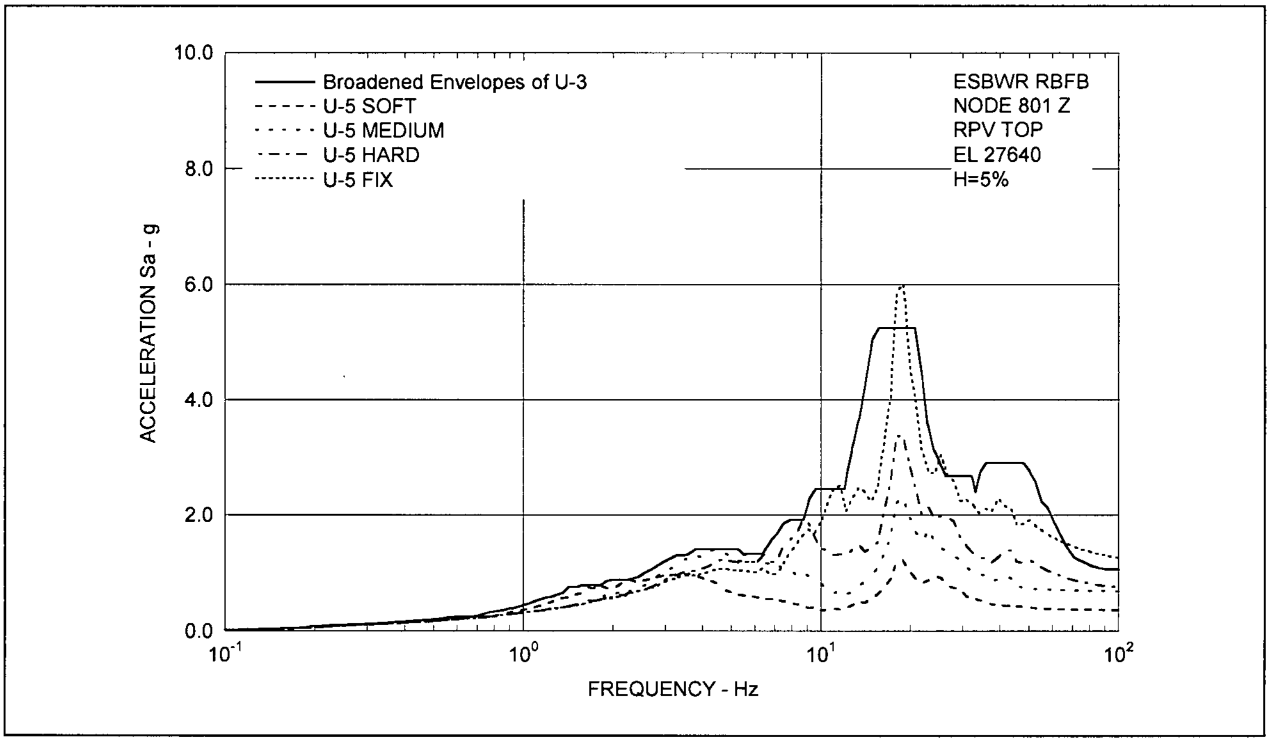


Figure 3.8-41 (22) Floor Response Spectra - RPV Top Z

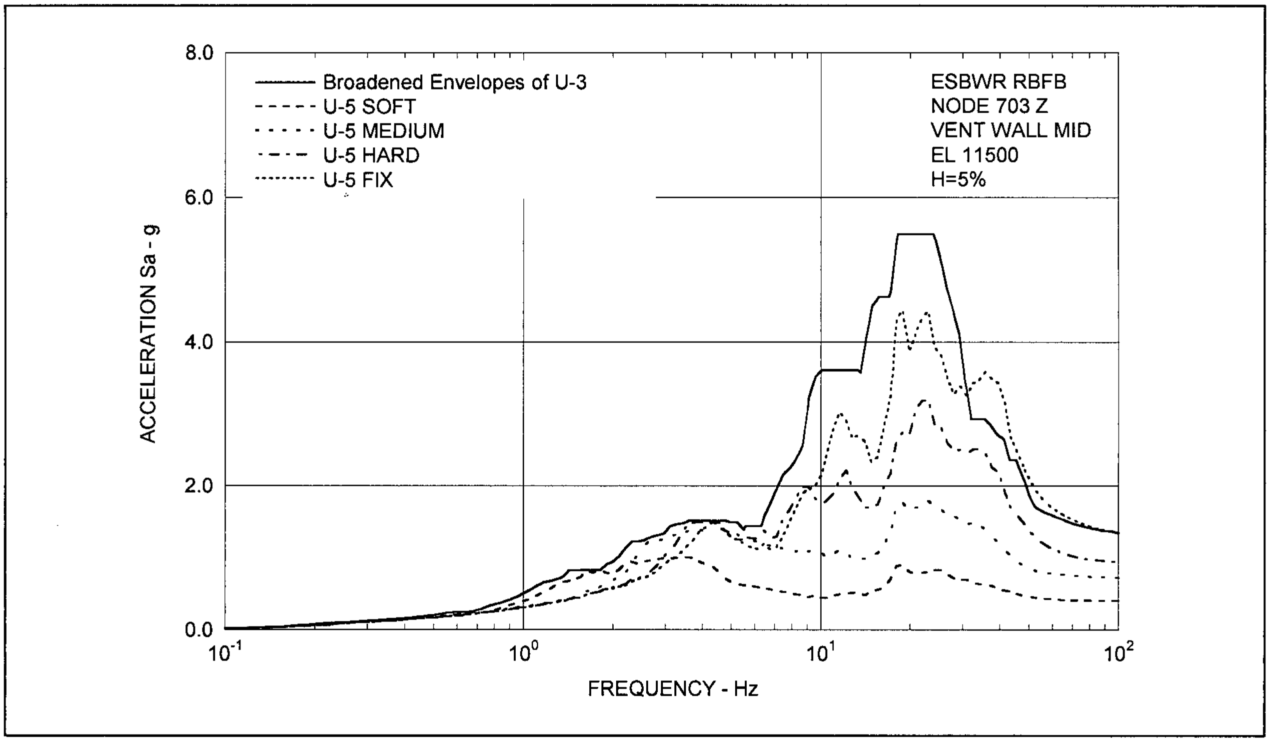


Figure 3.8-41 (23) Floor Response Spectra - Vent Wall Middle Z

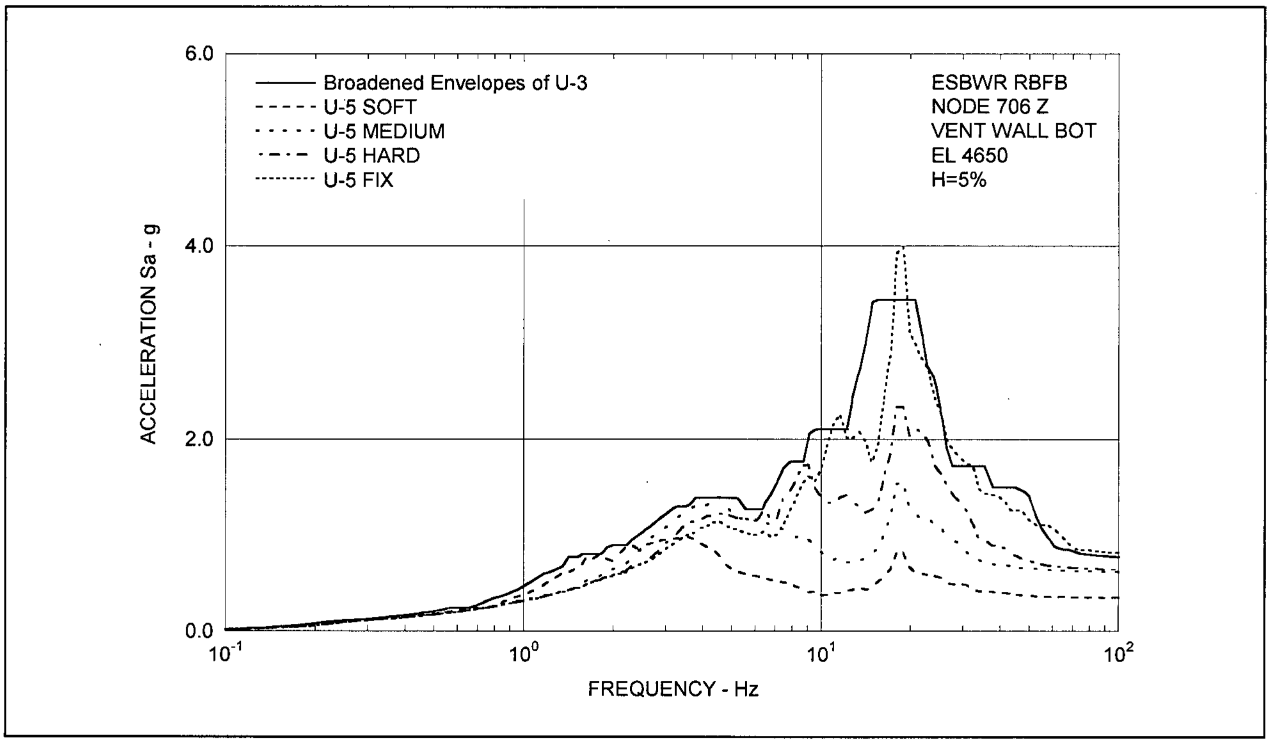


Figure 3.8-41 (24) Floor Response Spectra - Vent Wall Bottom Z

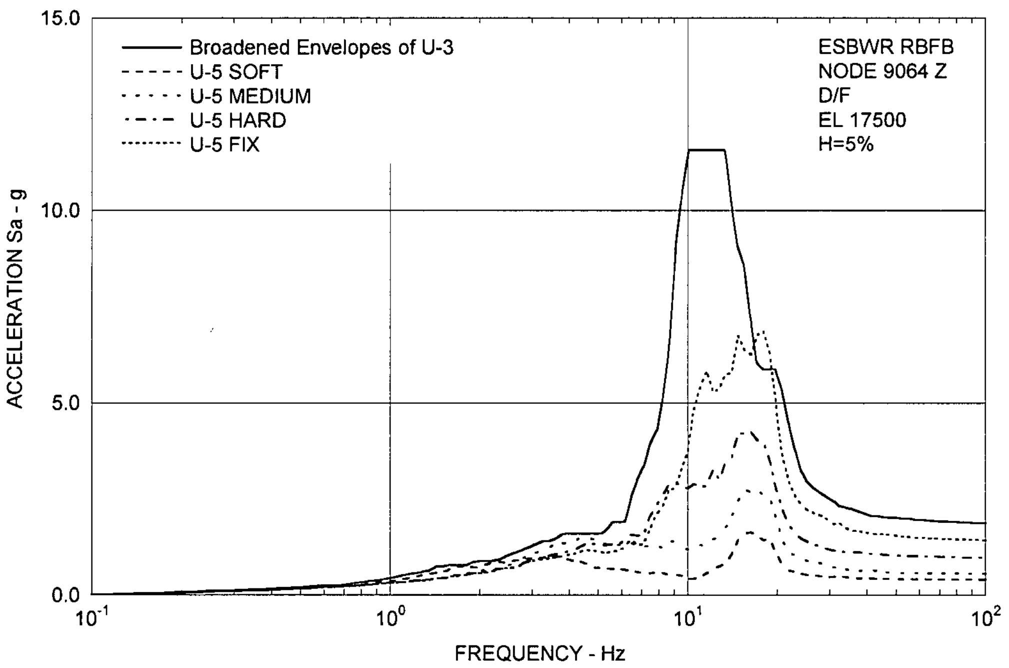


Figure 3.8-41 (25) Floor Response Spectra - D/F Oscillator

NRC RAI 3.8-48

DCD Section 3.8.3.4 indicates that the containment internal structures are included in the NASTRAN finite element model described in DCD Subsection 3.8.1.4.1.1. The finite element model described in DCD Subsection 3.8.1.4.1.1 includes the containment, containment internal structures (CIS), reactor building (RB), and fuel building (FB). This subsection also indicates that for LOCA and SRV loadings, the hydrodynamic pressures, as described in Appendix 3B, are applied as equivalent static pressures equal to the dynamic peak value times a dynamic load factor.

Appendix 3F "RESPONSE OF STRCTURES TO CONTAINMENT LOADS" states that this appendix specifies the design for safety-related structures, systems, and components as applicable due to dynamic excitations originating in the primary containment in the event of operational transients and LOCA. The input containment loads are described in Appendix 3B.

The containment loads considered for structural dynamic response analysis are (1) Hydrodynamic Loads which are Condensation Oscillation(CO), Pool Chugging (CH), Horizontal Vent Chugging (HVL), Local Condensation Oscillation (LCO) and Safety Relief valve discharge (SRV) in the Suppression Pool (SP), and (2) Pipe break Loads which consist of Annulus Pressurization (AP) in the annulus between the Reactor Shield Wall (RSW) and Reactor Pressure Vessel (RPV), nozzle jet, jet impingement and pipe whip restraint loads.

The staff notes that Appendix 3F is not reference anywhere in DCD Section 3.8 or Appendix 3G. Therefore, the staff requires additional information to clarify how the dynamic effects of the hydrodynamic loadings were analyzed and how the results were included in the design calculations for the affected structures.

(a) What computer code was used for the hydrodynamic analyses described in Appendix 3F?

(b) Provide detailed information on how the symmetric and asymmetric hydrodynamic loads are applied in the time history analysis.

(c) In Appendix 3F, horizontal and vertical floor response spectra are presented for 4 locations. What is the significance of these 4 locations, compared to any other location? Were response spectra generated at additional locations for future use in subsystem analyses?

(d) From the response spectral plots, it appears that the zero period acceleration (ZPA) frequency is above 100 Hz for several of the loadings; however, the plot is truncated at 100 Hz. Please explain this.

(e) Describe how the hydrodynamic response spectra were/will be utilized in the ESBWR detailed design.

(f) Describe how the structure responses to the hydrodynamic loadings were incorporated into the design evaluation of the affected structures, for load combinations that include hydrodynamic loads.

Include this information in DCD Section 3.8 and/or Appendix 3G, as applicable. In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

a) ANSYS software is used for the hydrodynamic load analysis. DCD Section 3C.6 adresses ANSYS documentation.

b) Symmetric loads have an axisymmetric pressure distribution on the SP walls and floors. Asymmetric loads have cosine pressure distribution on the SP walls and floor.

c) The 4 locations for floor response spectra included in DCD Appendix 3F are intended to be representative. Response floor response spectra are generated at all locations of interest for use in the subsystem analysis.

d) The Fourier spectra (amplitude) have been obtained for loads that contain high frequencies (CO and CH loads). The spectra obtained show a rapid reduction of amplitude with frequency. The energy content of the wave at a given frequency is a function of the square of the Fourier amplitude. For CH loads at 100 Hz, the energy content is 36 times less than at frequencies < 10 Hz and 20 times less than for frequencies < 20 Hz. For CO loads, the factors are even higher. Consequently, the truncation at 100 Hz in response spectra is conservative since the actual ZPA values are at higher frequencies.

e) The use of hydrodynamic and AP load response spectra in combination with others loads will be included in the system and equipment design specifications in the detailed design.

f) The design evaluation of the affected structures for hydrodynamic loads was performed using equivalent static pressure input equal to a dynamic load factor (DLF) of two times the peak dynamic pressure. The resulting forces or stresses were combined with those due to other loads in the most conservative manner by systematically varying the signs associated with dynamic loads.

(1) The applicable detailed report/calculation that will be available for NRC audit is 092-134-F-C-00006, Dynamic Response Analysis of Containment Loads, Revision 3, June 2006, containing the RBFB dynamic analysis and results under AP, SRV and LOCA hydrodynamic loads.

(2) Since this information exists as part of GE internal tracking system, it is not necessary to add it to the DCD submittal to the NRC.

Some changes to DCD Appendix 3F have been identified. DCD Appendix 3F will be revised in the next update as noted in the markup submitted under MFN 06-191. DCD Subsections 3.8.1.4.1.1.1 and 3.8.1.4.1.1.2 will also be revised to add DCD Appendix 3F reference in the next update as noted in the markup submitted under MFN 06-191.

NRC RAI 3.8-48, Supplement 1

Additional topics discussed at audit

Provide additional clarification for asymmetric load application.

GE Response

For the analysis of the asymmetric loads, only the first two terms in the Fourier series were considered.

$F(\theta) = A0 + A1 \cos\theta$

They were analyzed up to the first harmonic because the structure of the containment is of very thick concrete and is constrained horizontally at different levels by the slabs of the Reactor Building, and so the contribution of the higher order harmonics around the circumference is not significant. Furthermore, the assumption of asymmetric load with discharge of all the valves is conservative since it encompasses the asymmetric load associated with the actuation of one or two valves.

For clarity purposes, editorial changes to part (d) and (e) of the original response are as follows:

Part (d): The last sentence is revised to read "Consequently, the truncation at 100 Hz in response spectra is conservative since the actual spectrum values beyond 100 Hz are lower than that at the 100 Hz cut-off frequency."

Part (f): The last sentence is revised to read "The resulting forces or stresses were combined with those due to other loads in the most conservative manner by systematically varying the sign (+ or -) associated with dynamic loads.

No DCD changes were identified for this response supplement.

NRC RAI 3.8-48, Supplement 2

GE Additional Post Audit Action

a. *GE to explain how the correct asymmetric pressure distribution can be applied to the ANSYS axi-symmetric model using only the n=1 harmonic. This produces negative pressure (i.e., external pressure) on one side of the axi-symmetric structure.*

b. *GE does not have examples of design specifications for distributions systems and equipment. These would be developed at a later date following the criteria contained in the DCD. GE to confirm that a COL item is needed.*

GE Response

a. ANSYS allows the use of axi-symmetric structural elements with harmonic loads (non axi-symmetric) just specifying the number of waves (harmonic order) and the symmetry/ no symmetry condition (cosine / sine term). Using only the n=1 harmonic is a simulation of asymmetric pressure loading over the entire suppression pool boundary following the cosine spatial distribution with the peak pressure at 0 degree (positive) and 180 deg (negative). This is a conservative analysis consideration since the actual asymmetric loads are localized to portions of the pool boundary.

b. Besides seismic loads, other appropriate hydrodynamic loads such as Condensation Oscillation (CO) and Annulus Pressurization (AP) loads are enveloped and are imposed on vendors supplying equipment to GE by means of procurement specifications. This is typical for Seismic Category I procured equipment subject to dynamic loads. Vendors use these loads for analysis and/or testing of the equipment being furnished. Since these loads are in compliance with the DCD, an open COL item is not deemed necessary.

   Examples of GE design specifications for equipment procured for recent BWR projects are available for NRC audit at GE offices.

No DCD changes were identified for this response supplement.

NRC RAI 3.8-51

From the information presented in DCD 3.8.3.4 and Appendix 3G, it is not clear how the individual member forces from thermal, seismic, hydrodynamic, and other loads are obtained from the finite element model.

- *a) Provide a description of what type of analyses (static, response spectra, time history, etc.) are used with the finite element model for each of the applicable loads in order to obtain individual member forces for design.*
- *b) For thermal loading consideration, define the transient and steady state thermal loads, nonlinear temperature distributions, analysis approach, model, and design approach utilized for the major containment internal structures.*

Include this information in DCD Section 3.8.3 and/or Appendix 3G. In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

a) The type of analyses for various loads considered for the containment internal structures, such as Diaphragm Floor (DF), Vent Wall (VW), RPV Support Bracket (RPVSB), Reactor Shield Wall (RSW) and GDCS Pool (GDCSP) are:

(i) Dead Load

Static analysis was performed for the dead load to all containment internal structures. Hydrostatic loads of pool water were also applied statically to VW and GDCSP.

(ii) Pressure load

Static analysis was performed for the pressure load (Po and Pa) applied to DF and VW.

(iii) Thermal load

Static analysis was performed for the thermal load (To and Ta) to all internal structures.

(iv) Seismic load

Static analysis was performed for the seismic load on DF, VW, RPVSB and RSW in the integral NASTRAN model, while response spectra analysis was performed for GDCSP local model.

In this response spectra analysis, it is assumed that all pool water mass is distributed uniformly on the GDCDP wall and RCCV wall. This is considered as a conservative assumption, therefore sloshing was not considered in GDCSP local model. For integral NASTRAN model, however, sloshing load was considered as the static pressure load on DF upper surface and static reaction load from GDCSP wall. The results from integral NASTRAN model due to these loads were used for the structural integrity evaluation of the structures other than GDCSP, while the results from GDCSP local model were used for evaluation of GDCSP itself.

(v) Hydrodynamic load

Static analysis was performed for the hydrodynamic load (CO, CH and SRV) on VW taking DLF = 2 into account.

(vi) Pipe Break loads consist of Annulus Pressurization (AP) load, jet impingement and pipe-whip restraint loads

(vii) These loads acting on the RSW were first analyzed for dynamic response using the NASTRAN beam model. The resulting maximum values of bending moment and shear force were then applied to the integral NASTRAN static analysis model.

b) All steel temperature is the same as atmospheric temperature. The temperature of the intermediate node of VW rib plate is the average value of outer and inner plate ones. Further discussion of thermal analysis is described in the response to RAI 3.8-41.

(1) The applicable detailed report/calculation that will be available for NRC audit is DC-OG-0053, Structural Design Report for Containment Internal Structures, Revision 2, October 2005, containing evaluation method and results for structural integrity of containment internal structures.

(2) Since this information exists as part of GE internal tracking system, it is not necessary to add it to the DCD submittal to the NRC.

DCD Section 3G.1.5.4.2 will be revised in the next update as noted in the markup submitted under MFN 06-191.

NRC RAI 3.8-51, Supplement 1

None submitted.

NRC RAI 3.8-51, Supplement 2

GE Additional Post Audit Action

Revise the DCD to describe application of impulsive and convective loads for all pools except the GDCS pool, where it was shown that the convective load was sufficiently small.

GE Response

The water mass in all pools was treated as impulsive mass rigidly attached to the pool structure in the stick model for seismic analysis. In the stress analysis for all pools, except for the GDCS pool and suppression pool, the seismic-induced hydrodynamic pressures were calculated for impulsive and convective components separately and the results then combined by the SRSS method. For the GDCS and suppression pools, the total pressure was conservatively considered to be all impulsive.

DCD Tier 2 Subsection 3.8.4.3.1.1 will be revised in the next update as noted in the attached markup.

NRC RAI 3.8-64

DCD Section 3.8.4.1.2 states that the CB frame members such as beams or columns are designed to resist vertical loads and to accommodate deformations of the walls in case of earthquake conditions. A similar statement appears in Section 3.8.4.1.3 for the Fuel building and Section 3.8.4.1.4 for the Emergency Breathing Air system (EBAS) Building. Provide the structural design criteria, including the deformation limits, used to design these frame members.

Include this information in DCD Section 3.8.4 and/or Appendix 3G. In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

Frame members are explicitly included in the 3D NASTRAN model. As a result, the interaction with building walls and slabs are automatically accounted for in the analysis. The criterion of frame members is presented in DCD Section 3.8.4.5 Structural Acceptance Criteria.

(1) The applicable detailed report/calculation that will be available for NRC audit is 26A6655, FB Structural Design Report, Revision 1, November 2005, containing the structural design details of the Fuel Building.

(2) Since this information exists as part of GE internal tracking system, it is not necessary to add it to the DCD submittal to the NRC.

No DCD changes will be made in response to this RAI.

NRC RAI 3.8-64, Supplement 1

Additional topics discussed at audit

a) *GE to include supplemental response given at the audit in this RAI response. GE needs to strengthen the response regarding why deformations for design loads are not strictly performed. Need to characterize the term "not so large" and broaden the response to address all frame members.*

b) *Clarify RAI response as follows:*

   - *Add a subsection to DCD under 3.8.4.5 describing the EBAS building.*
   - *Add note stating that Column deflection does not control the design.*

GE Response

a) Supplemental response is provided below regarding frame members and deformation under design loads:

Design Criteria for Frame Members

1. Reinforced Concrete Members

Structural design of reinforced concrete frame members is performed in accordance with ACI 349-01 "Code Requirements for Nuclear Safety Related Concrete Structures."

It is confirmed that section forces and moments generated in members for design load combinations do not exceed the design strengths specified in ACI 349-01 as follows including strength reduction factors:

- Strength reduction factor: ACI 349-01, Section 9.3
- Flexure and axial loads: ACI 349-01, Chapter 10
- Shear: ACI 349-01, Chapter 11

2. Steel Members

Structural design of steel frame members is performed in accordance with ANSI/AISC N690-1994s2 (2004) "Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities."

It is confirmed that stresses generated in members for design load combinations do not exceed the allowable stresses specified in ANSI/AISC N690-1994s2 (2004) as follows:

- Tension: ANSI/AISC N690-1994s2 (2004), Section Q1.5.1.1
- Shear: ANSI/AISC N690-1994s2 (2004), Section Q1.5.1.2
- Compression: ANSI/AISC N690-1994s2 (2004), Section Q1.5.1.3
- Bending: ANSI/AISC N690-1994s2 (2004), Section Q1.5.1.4
- Combined stresses: ANSI/AISC N690-1994s2 (2004), Section Q1.6

3. Deformation Limit

The RB, FB and CB are described in Section 3.8.4.1 of the DCD. Since they are relatively rigid shear-wall type of buildings, deformations due to basic design loads are small. Calculated deformations due to seismic loads are also very small, as shown in Figures 3.8-64 (1) and (2). Since the deformations are less than the allowable drift limits (see Table 5-2, ASCE 43-05), there is no need to perform any other analysis.

For concrete frame members, it is confirmed that their thicknesses satisfy the requirement for the minimum thickness specified in ACI 349-01, Section 9.5.1.1, Table 9.5 (b) for deflection control.

Column Row		Level EL (m)		Node ID		Displacement (NS; m)		Differential Disp.	Coodinate (Z; m)		Floor Hight	Basemat	Rotational Disp.	Actual Disp.	Angle
EW	NS	from	to	from	to	from	to	δd_0 (mm)	from	to	δh (m)	Rotation (rad)	δd_1 (mm)	$\delta d=\delta d_0-\delta d_1$ (mm)	$\delta d/\delta h$ (rad)
FD	F2	-11.50	-6.40	190205	91205	6.079E-02	6.900E-02	8.21	-11.50	-6.90	4.60	1.510E-03	6.95	1.26	1/3642
	F2	-6.40	-1.00	91205	92205	6.900E-02	7.863E-02	9.63	-6.90	-1.50	5.40	1.510E-03	8.16	1.47	1/3665
	F2	-1.00	4.65	92205	93205	7.863E-02	8.735E-02	8.71	-1.50	3.65	5.15	1.510E-03	7.78	0.94	1/5496
	F1	4.65	22.50	11829	14229	8.780E-02	1.237E-01	35.92	3.65	22.50	18.85	1.510E-03	28.47	7.45	1/2531
	F3	4.65	22.50	11918	14318	8.722E-02	1.234E-01	36.15	3.65	22.50	18.85	1.510E-03	28.47	7.68	1/2455

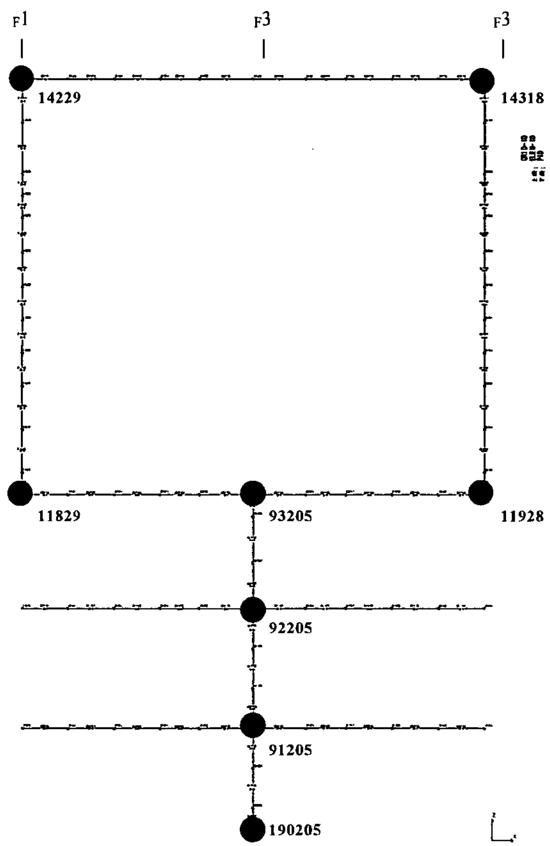


Figure 3.8-64 (1) Displacement of FB Frame Members due to Horizontal Seismic Load

Column Row		Level EL (m)		Node ID		Displacement (NS; m)		Differential Disp.	Coodinate (Z; m)		Floor Hight	Basemat	Rotational Disp.	Actual Disp.	Angle
EW	NS	from	to	from	to	from	to	δd_0 (mm)	from	to	δh (m)	Rotation (rad)	δd_1 (mm)	$\delta d=\delta d_0-\delta d_1$ (mm)	$\delta d/\delta h$ (rad)
C2	CB	-7.40	-2.00	582	2082	8.336E-03	1.211E-02	3.78	-7.40	-2.25	5.15	5.030E-04	2.59	1.19	1/4345
	CC	-7.40	-2.00	556	2056	8.339E-03	1.213E-02	3.79	-7.40	-2.25	5.15	5.030E-04	2.59	1.20	1/4293
	CB	-2.00	4.65	2082	3582	1.211E-02	1.732E-02	5.21	-2.25	4.30	6.55	5.030E-04	3.29	1.91	1/3423
	CC	-2.00	4.65	2056	3556	1.213E-02	1.732E-02	5.19	-2.25	4.30	6.55	5.030E-04	3.29	1.90	1/3451
	CB	4.65	9.06	3582	5082	1.732E-02	2.077E-02	3.45	4.30	8.81	4.51	5.030E-04	2.27	1.18	1/3818
	CC	4.65	9.06	3556	5056	1.732E-02	2.077E-02	3.45	4.30	8.81	4.51	5.030E-04	2.27	1.18	1/3827

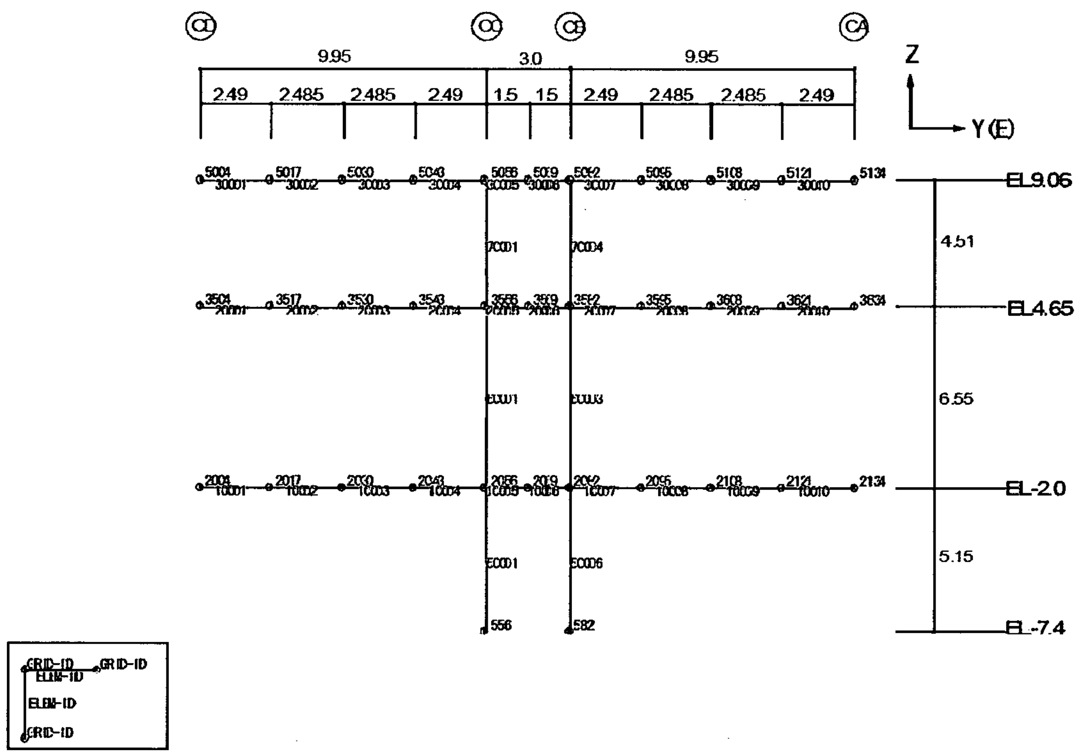


Figure 3.8-64 (2) Displacement of CB Frame Members due to Horizontal Seismic Load

b) Response to RAI 3.8-64 is clarified as shown below:

- New DCD subsections 3.8.4.2.6, 3.8.4.3.5, and 3.8.4.5.5 will be added and DCD subsection 3.8.4.4 will be revised in the next update as noted in the markups for EBAS descriptions provided under MFN 06-191S1.
- Column deflection is addressed in the supplemental response to Item a) above.

NRC RAI 3.8-64, Supplement 2

GE Additional Post Audit Action

Provide an evaluation of the RB/FB exterior walls for the automobile tornado missile.

GE Response

The evaluation of the automobile tornado missile was performed for the RB/FB exterior walls and roof slabs in accordance with SRP 3.5.1.4 to confirm that the walls and slabs are adequately designed to resist the tornado-generated automobile missile loads.

The impact load generated by an automobile missile was estimated by the method described in Reference 1. Using the estimated load, evaluations for punching shear and bending were performed.

As for punching shear, it was confirmed that shear due to the impact load is less than the punching shear strength calculated in accordance with ACI 349-01.

Bending moments due to the automobile missile were evaluated by the RB/FB global FE model analyses in which the impact loads were applied to several critical elements. The resulting bending moments in critical elements were combined with moments due to other loads including the tornado wind pressure, and it was confirmed that resultant moments do not exceed their bending capacities.

Therefore, it can be concluded that the RB/FB exterior walls and roof slab are adequately designed to resist the tornado-generated automobile missile loads.

Evaluation details are contained in Report SER-ESB-041, *Reactor Building/Fuel Building Automobile Tornado Missile Impact Assessment, Rev.0*, which is available for NRC review at GE offices.

No DCD changes were identified for this response supplement.

Reference 1: Topical Report BC-TOP-9A, *Design of Structures for Missile Impact, Revision 2*, Bechtel Power Corp., September 1974

NRC RAI 3.8-91

DCD Section 3.8.5.4 states that the foundations are analyzed using "well-established methods". Identify the references for and describe the "well-established methods" used to analyze the foundations. Demonstrate conformance of these methods with the requirements of SRP 3.8.5. Include this information in DCD Section 3.8.5.4.

In addition, (1) identify the applicable detailed report/calculation (number, title, revision and date, and brief description of content) that will be available for audit by the staff, and (2) reference this report/calculation in the DCD.

GE Response

As described in DCD Section 3.8.1.4.1.1, the linear elastic finite element (FE) model is used for the analyses of the building structures including the foundation mat, and the foundation soil is modeled with elastic springs in the FE model. The modeling method is the same as the ABWR standard design which was reviewed and approved by the NRC; hence it is considered to be a well-established method.

SRP 3.8.5 II 4.a. requires that the soil-structure interaction be considered in the seismic Category I foundation design, and the method mentioned above satisfies this SRP requirement.

(1) The applicable detailed report/calculation that will be available for NRC audit is 26A6651, RB Structural Design Report, Revision 1, November 2005, containing the structural design details of the Reactor Building.

(2) Since this information exists as part of GE internal tracking system, it is not necessary to add it to the DCD submittal to the NRC.

DCD Subection 3.8.5.4 will be revised in the next update as noted in the markup submitted under MFN 06-191.

NRC RAI 3.8-91, Supplement 1

Additional topics discussed at audit

a) *GE is requested to:*

- *Review details of mat design and determine what additional information to incorporate in the DCD to describe the "well-established" methods.*
- *Add supplemental response regarding Comment #3 under "RAI 3.8-12 SSDP Validation".*

In addition, in order to confirm the size and quantity of designed steel reinforcement, the total factored moment and shear forces are needed by the NRC audit team. This information was not included in RB Structural Design Report (26A6651 Rev. 1). Please:

- *Provide this information for the three identified critical elements and demonstrate how the individual load cases are combined to arrive at the total loads and how these total loads are applied to the critical sections.*

b) *GE to provide more description of how the mat is designed, including how the loads from walls are transferred to the mat.*

GE Response

a) See below:

- The "well-established methods" is an ambiguous statement, and it will be removed from the DCD. DCD Section 3.8.5.4 will be revised in the next update as noted in the markup provided under MFN 06-191S1.
- For supplemental response regarding Comment (a) second bullet, refer to the response to the new RAI 3.8-107 "SSDP Validation" due to the NRC by October 31, 2006.
- Information requested by NRC for its confirmatory analysis is shown below:

i. Combined Section Forces and Moments

Table 3.8-91 (1) shows the combined section forces and moments of the basemat elements, which was requested by NRC.

Table 3.8-91 (1) Combined Section Forces and Moments of Basemat Element

ELEM	90140	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
7511	OTHR	-3.415	-2.849	-0.232	-2.240	-1.158	2.916	-1.891	1.734
	TEMP	1.628	1.213	0.456	-8.677	-9.122	0.629	-0.482	0.827
	EQEW	0.415	4.638	2.888	0.033	3.216	-2.595	2.865	-5.032
	EQNS	0.034	1.460	-2.130	-6.707	-0.901	-0.370	-2.810	1.163
	EQZ	-0.060	0.480	0.263	1.419	0.971	-2.078	0.964	-1.107
	EQT	0.965	-0.447	0.984	0.658	0.012	-0.229	0.294	0.106
	SPKW	-0.052	-1.084	-0.003	-0.119	0.019	-0.123	-0.029	-0.213
	SPKN	-1.849	0.114	-0.120	-0.044	-0.045	0.049	-0.037	0.017
7111	OTHR	-3.187	-2.730	-0.181	-1.424	-0.643	1.411	-2.191	1.945
	TEMP	1.625	1.228	0.485	-8.737	-9.165	0.608	-0.528	0.838
	EQEW	0.415	4.638	2.888	0.033	3.216	-2.595	2.865	-5.032
	EQNS	0.034	1.460	-2.130	-6.707	-0.901	-0.370	-2.810	1.163
	EQZ	-0.060	0.480	0.263	1.419	0.971	-2.078	0.964	-1.107
	EQT	0.965	-0.447	0.984	0.658	0.012	-0.229	0.294	0.106
	SPKW	-0.052	-1.084	-0.003	-0.119	0.019	-0.123	-0.029	-0.213
	SPKN	-1.849	0.114	-0.120	-0.044	-0.045	0.049	-0.037	0.017
7431	OTHR	-2.939	-2.620	-0.036	-1.925	-0.968	1.516	-2.457	2.177
	TEMP	1.517	1.526	0.904	-9.928	-10.235	0.483	-1.089	1.095
	EQEW	0.415	4.638	2.888	0.033	3.216	-2.595	2.865	-5.032
	EQNS	0.034	1.460	-2.130	-6.707	-0.901	-0.370	-2.810	1.163
	EQZ	-0.060	0.480	0.263	1.419	0.971	-2.078	0.964	-1.107
	EQT	0.965	-0.447	0.984	0.658	0.012	-0.229	0.294	0.106
	SPKW	-0.052	-1.084	-0.003	-0.119	0.019	-0.123	-0.029	-0.213
	SPKN	-1.849	0.114	-0.120	-0.044	-0.045	0.049	-0.037	0.017
7441	OTHR	-2.939	-2.620	-0.036	-1.925	-0.968	1.516	-2.457	2.177
	TEMP	0.656	1.198	1.910	-1.176	-1.209	-0.620	-1.549	0.481
	EQEW	0.415	4.638	2.888	0.033	3.216	-2.595	2.865	-5.032
	EQNS	0.034	1.460	-2.130	-6.707	-0.901	-0.370	-2.810	1.163
	EQZ	-0.060	0.480	0.263	1.419	0.971	-2.078	0.964	-1.107
	EQT	0.965	-0.447	0.984	0.658	0.012	-0.229	0.294	0.106
	SPKW	-0.052	-1.084	-0.003	-0.119	0.019	-0.123	-0.029	-0.213
	SPKN	-1.849	0.114	-0.120	-0.044	-0.045	0.049	-0.037	0.017

Table 3.8-91 (1) Combined Section Forces and Moments of Basemat Element (Continued)

ELEM	90182	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
7221	OTHR	-2.103	-2.317	-0.223	-0.372	-1.614	0.181	0.061	1.376
	TEMP	2.148	0.503	0.511	-0.337	-3.646	0.149	-0.116	2.707
	EQEW	6.054	0.571	0.309	0.153	-0.445	-0.242	-0.046	-3.502
	EQNS	3.163	0.701	-1.456	-1.619	-0.476	1.390	-1.659	0.675
	EQZ	0.369	0.221	0.046	-0.592	1.442	0.238	-0.137	-0.399
	EQT	1.000	0.064	0.515	0.020	0.260	-0.335	0.346	-0.258
	SPKW	0.120	-1.176	-0.143	-0.170	-0.632	-0.021	0.026	-0.440
	SPKN	-1.507	0.096	0.137	-0.018	-0.210	0.106	-0.110	0.162
7431	OTHR	-2.241	-2.358	-0.196	-0.265	-1.324	0.195	0.018	1.146
	TEMP	1.042	0.028	-0.059	-8.769	-10.526	0.078	0.104	3.415
	EQEW	6.054	0.571	0.309	0.153	-0.445	-0.242	-0.046	-3.502
	EQNS	3.163	0.701	-1.456	-1.619	-0.476	1.390	-1.659	0.675
	EQZ	0.369	0.221	0.046	-0.592	1.442	0.238	-0.137	-0.399
	EQT	1.000	0.064	0.515	0.020	0.260	-0.335	0.346	-0.258
	SPKW	0.120	-1.176	-0.143	-0.170	-0.632	-0.021	0.026	-0.440
	SPKN	-1.507	0.096	0.137	-0.018	-0.210	0.106	-0.110	0.162

Table 3.8-91 (1) Combined Section Forces and Moments of Basemat Element (Continued)

ELEM	90111	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
7431	OTHR	-3.906	-1.826	0.005	-1.720	-0.144	-0.354	0.499	0.271
	TEMP	0.321	0.885	-0.123	-10.119	-9.107	-0.050	3.448	0.174
	EQEW	-0.250	0.765	-0.889	-0.470	0.409	1.439	-0.060	-2.916
	EQNS	1.027	5.920	-0.258	0.380	-1.228	0.393	-2.033	-0.131
	EQZ	0.246	0.490	-0.027	1.301	-0.708	0.327	-0.439	-0.071
	EQT	-0.052	0.035	-0.613	-0.075	0.084	0.414	0.010	-0.492
	SPKW	0.162	-1.308	0.049	-0.226	-0.098	0.013	0.201	-0.026
	SPKN	-1.233	0.065	-0.048	-0.638	-0.141	0.024	-0.484	0.020
7421	OTHR	-3.906	-1.826	0.005	-1.720	-0.144	-0.354	0.499	0.271
	TEMP	0.739	3.121	-0.053	-5.526	-1.300	0.126	3.843	0.163
	EQEW	-0.250	0.765	-0.889	-0.470	0.409	1.439	-0.060	-2.916
	EQNS	1.027	5.920	-0.258	0.380	-1.228	0.393	-2.033	-0.131
	EQZ	0.246	0.490	-0.027	1.301	-0.708	0.327	-0.439	-0.071
	EQT	-0.052	0.035	-0.613	-0.075	0.084	0.414	0.010	-0.492
	SPKW	0.162	-1.308	0.049	-0.226	-0.098	0.013	0.201	-0.026
	SPKN	-1.233	0.065	-0.048	-0.638	-0.141	0.024	-0.484	0.020
7321	OTHR	-3.906	-1.826	0.005	-1.720	-0.144	-0.354	0.499	0.271
	TEMP	0.639	2.711	-0.049	-4.654	-0.922	0.098	3.296	0.146
	EQEW	-0.250	0.765	-0.889	-0.470	0.409	1.439	-0.060	-2.916
	EQNS	1.027	5.920	-0.258	0.380	-1.228	0.393	-2.033	-0.131
	EQZ	0.246	0.490	-0.027	1.301	-0.708	0.327	-0.439	-0.071
	EQT	-0.052	0.035	-0.613	-0.075	0.084	0.414	0.010	-0.492
	SPKW	0.162	-1.308	0.049	-0.226	-0.098	0.013	0.201	-0.026
	SPKN	-1.233	0.065	-0.048	-0.638	-0.141	0.024	-0.484	0.020
7441	OTHR	-3.906	-1.826	0.005	-1.720	-0.144	-0.354	0.499	0.271
	TEMP	0.765	3.129	-0.048	-5.573	-1.340	0.131	3.888	0.160
	EQEW	-0.250	0.765	-0.889	-0.470	0.409	1.439	-0.060	-2.916
	EQNS	1.027	5.920	-0.258	0.380	-1.228	0.393	-2.033	-0.131
	EQZ	0.246	0.490	-0.027	1.301	-0.708	0.327	-0.439	-0.071
	EQT	-0.052	0.035	-0.613	-0.075	0.084	0.414	0.010	-0.492
	SPKW	0.162	-1.308	0.049	-0.226	-0.098	0.013	0.201	-0.026
	SPKN	-1.233	0.065	-0.048	-0.638	-0.141	0.024	-0.484	0.020

ii. Description of the Combination Method of Section Forces and Moments Utilized (example)

Reference 1: 26A6651 "Reactor Building Structural Design Report", Rev. 1

1. Section Forces and Moments

ELEM	90140	Nx (MN/m)	Ny (MN/m)	Nxy (MN/m)	Mx (MNm/m)	My (MNm/m)	Mxy (MNm/m)	Qx (MN/m)	Qy (MN/m)
7511	OTHR	-3.415	-2.849	-0.232	-2.240	-1.158	2.916	-1.891	1.734
	TEMP	1.628	1.213	0.456	-8.677	-9.122	0.629	-0.482	0.827
	EQEW	0.415	4.638	2.888	0.033	3.216	-2.595	2.865	-5.032
	EQNS	0.034	1.460	-2.130	-6.707	-0.901	-0.370	-2.810	1.163
	EQZ	-0.060	0.480	0.263	1.419	0.971	-2.078	0.964	-1.107
	EQT	0.965	-0.447	0.984	0.658	0.012	-0.229	0.294	0.106
	SPKW	-0.052	-1.084	-0.003	-0.119	0.019	-0.123	-0.029	-0.213
	SPKN	-1.849	0.114	-0.120	-0.044	-0.045	0.049	-0.037	0.017

Nomenclature:

OTHR: Loads other than thermal and seismic loads
TEMP: Thermal loads
EQEW: Horizontal seismic loads in the EW direction
EQNS: Horizontal seismic loads in the NS direction
EQZ: Vertical seismic loads
EQT: Torsional seismic loads
SPKW: Dynamic soil pressure during a horizontal earthquake in the EW direction
SPKN: Dynamic soil pressure during a horizontal earthquake in the NS direction
(Ref. 1, Section 6.3.3)

2. Combination of Section Forces and Moments

- Ref. 1, Table 6.3.2-2
- Combination of Seismic Loads: Ref. 1, Table 6.3.2-4

Example of combination of Nx for Load ID 7511, Seismic Case 1

1.0*OTHR + 1.0*EQEW + 0.4*EQNS + 0.4*EQZ + 1.0*EQT + 1.0*SPKW + 0.4*SPKN
= 1.0*-3.415 + 1.0*0.415 + 0.4*0.034S + 0.4*-0.06 + 1.0*0.965 + 1.0*-0.052 + 0.4*-1.849
= -2.837

Notes:

- Factors for seismic loads shall be in accordance with Ref. 1, Table 6.3.2-4
- Load factor for OTHR shall be 1.0. Factors of loads other than thermal and seismic loads, i.e., dead, live, pressure, wind, tornado, in Ref. 1, Table 6.3.2-2 have been already considered in calculations of section forces and moments for OTHR.
- Section forces and moments for thermal loads should be combined separately considering reduction due to concrete cracking.

b) Loads from the walls are transferred to the mat by means of rigid links as shown in Figure 3.8-87 (1) and is included in the global NASTRAN model. The stress resultants (forces, moments, etc) of the mat are extracted from the mat shell elements (see Table 3.8-91 (1)), and used as input to the concrete cracking analysis performed by the SSDP computer program. The output is a tabulation of stresses in concrete and rebars and a list of allowable stresses. The format of the output is similar to that of Table 3.8-82 (3).

NRC RAI 3.8-91, Supplement 2

GE Additional Post Audit Action

Demonstrate that adequate development length for the reinforcement is provided.

GE Response

In the basemat around the cylindrical wall below the RCCV wall, rebars in two coordinate systems, i.e., orthogonal and cylindrical coordinates, are installed. Circumferential rebars are continuous. Other rebars are terminated at the end after assuring required development length. (See Figure 3.8-91 (1).) In section design calculations, orthogonal rebars and radial rebars are evaluated for adequate development length.

No DCD changes were identified for this response supplement.

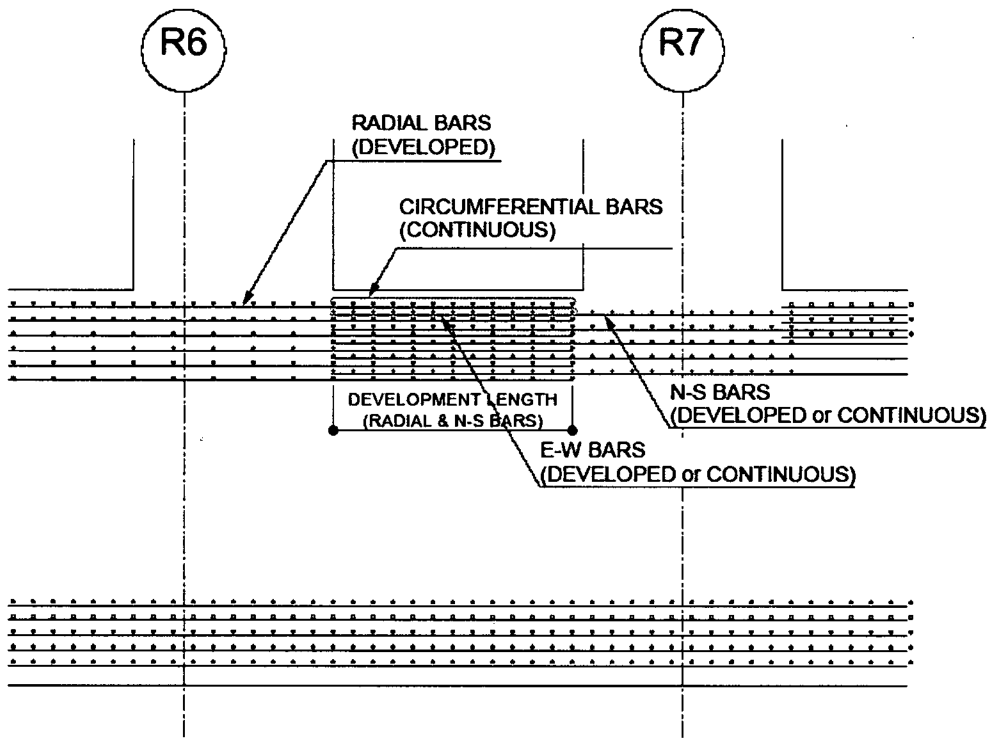


Figure 3.8-91 (1) Rebar Arrangement in Basemat around Cylindrical Wall below RCCV

Y_r = Equivalent static load on a structure generated by the reaction on the broken high-energy pipe during the postulated break and including a calculated dynamic factor to account for the dynamic nature of the load.

Y_j = Jet impingement equivalent static load on a structure generated by the postulated break and including a calculated dynamic factor to account for the dynamic nature of the load.

Y_m = Missile impact equivalent static load on a structure generated by or during the postulated break, like pipe whipping, and including a calculated dynamic factor to account for the dynamic nature of the load.

W = Wind force (Subsection 3.3.1)

W_t = Tornado load (Subsection 3.3.2) (tornado-generated missiles are described in Subsection 3.5.1.4, and barrier design procedures in Subsection 3.5.3.)

P_a = Accident pressure at main steam tunnel due to high energy line break.

F = Internal pressures resulting from flooding of compartments.

E' = Safe shutdown earthquake (SSE) loads as defined in Section 3.7 including SSE-induced hydrodynamic pressures in pools. The impulsive and convective pressures may be combined by the SRSS method.

T_o = Thermal effects — load effects induced by normal thermal gradients existing through the RB wall and roof. Both summer and winter operating conditions are considered. In all cases, the conditions are considered of long enough duration to result in a straight line temperature gradient. The temperatures are listed in Table 3.8-10. The stress free temperature for the design is 15.5°C.

T_a = Thermal effects (including T_o) which may occur during a design accident.

H = Loads caused by static or seismic earth pressures.

3.8.4.3.1.2 Load Combinations for Concrete Members

For the load combinations in this subsection, where any load reduces the effects of other loads, the corresponding coefficient for that load is taken as 0.9, if it can be demonstrated that the load is always present or occurs simultaneously with the other loads. Otherwise, the coefficient for that load is taken as zero.

The safety-related concrete structure is designed using the loads, load combinations, and load factors listed in Table 3.8-15. The maximum co-directional responses to each of the excitation components for seismic loads are combined by the 100/40/40 method as described in Subsection 3.8.1.3.6.

3.8.4.3.1.3 Load Combinations for Steel Members

The safety-related steel structure is designed using the loads, load combinations, and load factors listed in Table 3.8-16. The maximum co-directional responses to each of the excitation components for seismic loads are combined by the 100/40/40 method as described in Subsection 3.8.1.3.6.