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MFN 06-416
Supplement 1

Docket No. 52-010

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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 61 – Seismic, Structural and Piping Analyses – RAI Number 3.7-59S1**

Enclosure 1 contains a supplemental response to the subject RAI resulting from the November 2006 NRC Seismic Audit. GE's original response was transmitted via the Reference 1 letter. There are no changes to any of the remaining RAI responses contained in the Reference 1 letter.

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

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Reference:

1. MFN 06-416, Letter from David Hinds to U.S. Nuclear Regulatory Commission , *Response to Portion of NRC Request for Additional Information Letter No. 61 – Seismic, Structural and Piping Analyses – RAI Numbers 3.7-59 and 3.8-107*, November 7, 2006

Enclosures:

1. MFN 06-416, Supplement 1 – Response to Portion of NRC Request for Additional Information Letter No. 61 – Seismic, Structural and Piping Analyses – RAI Number 3.7-59S1

cc: AE Cubbage USNRC (with enclosures)
GB Stramback GE/San Jose (with enclosures)
eDRF 0000-0060-8449

ENCLOSURE 1

MFN 06-416

SUPPLEMENT 1

Response to Portion of NRC Request for

Additional Information Letter No. 61

Seismic, Structural and Piping Analyses

RAI Number 3.7-59S1

Original Response previously submitted under MFN 06-416 is included to provide historical continuity during review.

NRC RAI 3.7-59

Based on information obtained by the staff during the review and audit of ESBWR DCD Sections 3.7 and 3.8 in June and July 2006, the staff determined that General Electric (GE) developed the seismic stick models for the reactor building (RB)/fuel building (FB) and control building (CB) and the static NASTRAN finite element models for the RB/FB and CB directly from design information, without conducting any comparison/correlation of the static and dynamic responses of these models. The staff has concluded that comparison/correlation is required before the staff can complete its assessment of the adequacy of the stick models and the static NASTRAN finite element models. Consequently, the staff requests the applicant to provide the following additional information:

(A) Comparison/correlation between the seismic stick models and the static NASTRAN models for both the RB/FB and the CB, based on static analysis –

(i) Total reaction force/moment at the base (assume fixed base) due to a 1g static load applied separately in each horizontal direction and in the vertical direction.

(ii) Deflection at the top of model in each direction.

(iii) Total mass.

(iv) Calculation of first mode frequency in each direction.

The static analysis comparisons should be done for the complete model, and, if feasible, for each individual stick of the seismic model. Deflections at the top of the NASTRAN model should be representative values, based on engineering judgment.

(B) Comparison/correlation between the seismic stick models and the static NASTRAN models for both the RB/FB and the CB, based on dynamic analysis –

(i) Free vibration analyses (frequencies and mode shapes) for fixed base.

(ii) Seismic time history analyses or response spectrum analyses for fixed base.

The free vibration analysis (frequencies and mode shapes) results should demonstrate that the stick models reasonably include all significant frequencies and mode shapes that would affect the response to the design basis safe shutdown earthquake (SSE).

The time history analysis or response spectrum analysis results should confirm the adequacy of the method currently employed by GE to apply the seismic loads to the static NASTRAN models.

The time history analysis or response spectrum analysis results should demonstrate that any differences arising from the comparisons based on static analysis and free vibration analysis have minimal effect on the response to the design basis SSE.

(C) An explanation for all significant discrepancies, and the technical basis for concluding that the discrepancies are acceptable.

GE Response

In order to assess the adequacy of the stick models and the static NASTRAN finite element models, static and dynamic comparative analyses were performed both for the RBFB and the CB. Details are contained in the following:

- Attachment SER-ESB-043, *Comparative Analysis between Seismic Stick Model and Static FEM Model for RBFB, Rev. 0.*
- Attachment SER-ESB-044, *Comparative Analysis between Seismic Stick Model and Static FEM Model for CB, Rev. 0.*

The results show that the stick model is consistent with the finite element model in predicting static and dynamic responses. The stick model adequacy is therefore confirmed.

No DCD change was required in response to this RAI.

NRC RAI 3.7-59, Supplement 1

NRC Assessment Following the November 2, 2006 Audit

a. Revise Report SER-ESB-043 to address audit comments regarding torsional modes.

b. Address the adequacy of the design methods that apply the seismic loads to the static NASTRAN model.

GE Response

a. The following updated reports are being re-submitted to include stick model results for pure translational responses without contribution from rotation/torsion and to address the adequacy of design methods that apply seismic loads to the static NASTRAN models:

- Attachment SER-ESB-043, *Comparative Analysis between Seismic Stick Model and Static FEM Model for RBFB, Rev.1.*
- Attachment SER-ESB-044, *Comparative Analysis between Seismic Stick Model and Static FEM Model for CB, Rev.1.*

b. As shown in Attachment SER-ESB-043, it was confirmed from time history analysis that the design methods that apply the seismic loads to the static NASTRAN models are adequate.

No DCD change will be made in response to this RAI Supplement.

ATTACHMENT SER-ESB-043, REV. 1

Comparative Analysis between Seismic Stick Model and Static FEM Model for RBFB

Shimizu Engineering Report

Project	General Electric Company ESBWR Project	Shimizu Document No.	SER-ESB-043
Title	Comparative Analysis between Seismic Stick Model and Static FEM Model for RBFB	Rev.	1
		Issued Date	10/23/06
		Revised Date	11/30/06

NOTE:

In response to NRC RAI 3.7-59, in order to assess the adequacy of the stick models and the static NASTRAN finite element models, static and dynamic comparative analyses were performed for the RBFB.

Rev.	Date	Note	Approve	Review	Prepare
1	11/30/06	Issue for use	Y.O	N.M	S.O
0	10/23/06	Issue for use	Y.O	N.M	S.O

Shimizu Corporation	Prepared by	S. Oguri	10/23/06
	Reviewed by	N. Miura	10/23/06
	Approved by	Y. Orito	10/23/06

TABLE OF CONTENTS

1. Scope 5
2. Analysis Model 5
3. Static Analysis Results 5
4. Eigenvalue Analysis Results 6
5. Time History Analysis Results 6
6. Application of Stick Model Results to Static FEM Analysis 6
7. Conclusion 7

LIST OF TABLES

Table 1 Total Reaction Force/Moment at Base 8
Table 2 Deflection at Top of Model 8
Table 3 Calculated First Mode Frequency 8
Table 4 Eigenvalue Analysis Results 9
Table 5 Maximum Response Accelerations 10

LIST OF FIGURES

Figure 1 FEM Analysis Model 11
Figure 2 Seismic Stick Model 12
Figure 3 RBFB Stick Model 13
Figure 4 RCCV Stick Model 14
Figure 5 Pedestal Stick Model 15
Figure 6 Mode Shape - Y direction 1st Mode 16
Figure 7 Mode Shape - X direction 1st Mode 17
Figure 8 Mode Shape - Torsion 1st Mode 18
Figure 9 Mode Shape - Z direction 1st Mode 19
Figure 10 Selected Points for FRS 20
Figure 11 Response Spectra X-dir at RBFB EL34.0m 21
Figure 12 Response Spectra Y-dir at RBFB EL34.0m 21
Figure 13 Response Spectra Z-dir at RBFB EL34.0m 22
Figure 14 Response Spectra X-dir at RCCV EL27.0m 23
Figure 15 Response Spectra Y-dir at RCCV EL27.0m 23
Figure 16 Response Spectra Z-dir at RCCV EL27.0m 24
Figure 17 Response Spectra X-dir at V/W Top EL17.5m 25
Figure 18 Response Spectra Y-dir at V/W Top EL17.5m 25
Figure 19 Response Spectra Z-dir at V/W Top EL17.5m 26
Figure 20 Response Spectra X-dir at FB Top EL22.5m 27
Figure 21 Response Spectra Y-dir at FB Top EL22.5m 27
Figure 22 In-plane Shear Forces, Nxy, in X direction SSE Input 28
Figure 23 Vertical Axial Forces, Ny, in X direction SSE Input 29
Figure 24 In-plane Shear Forces, Nxy, in Y direction SSE Input 30
Figure 25 Vertical Axial Forces, Ny, in Y direction SSE Input 31
Figure 26 Vertical Axial Forces, Ny, in Z direction SSE Input 32
Figure 27 Comparison of In-plane Shear Forces, Nxy, in X direction SSE Input 33
Figure 28 Comparison of Vertical Axial Forces, Ny, in X direction SSE Input 34
Figure 29 Comparison of In-plane Shear Forces, Nxy, in Y direction SSE Input 35
Figure 30 Comparison of Vertical Axial Forces, Ny, in Y direction SSE Input 36
Figure 31 Comparison of Vertical Axial Forces, Ny, in Z direction SSE Input 37

1. Scope

This document is to describe the comparative analysis between seismic stick model and static NASTRAN finite element model for the Reactor/Fuel Building Complex (RBFB). This analysis was performed to respond to NRC RAI 3.7-59 regarding the adequacy of the stick models and the static NASTRAN finite element models.

2. Analysis Model

FEM analysis model is shown in Figure 1. Stick model is shown in Figures 2 through 4. Both models are the same as the design basis models in DCD Revision 1 with the following exceptions:

a. The Reactor Shield Wall (RSW) is excluded from the FEM model used in this study (Note: the RPV is not included in the design basis NASTRAN FEM).

b. The FEM model for the Vent Wall (VW) and Diaphragm Floor (DF) are simplified.

c. Stick model are based on the revised model described in MFN 06-278.

d. The RSW and the RPV are excluded also from the stick model used in this study.

e. The floor vertical oscillators are excluded from the stick model used in this study.

Analysis model is fixed at the top of basemat.

3. Static Analysis Results

Static load, 1 g, is applied to the both models separately in each horizontal direction and in the vertical direction. Locations where results are obtained are shown in Figure 1 for the FEM analysis model and in Figure 2 for the stick model.

(i) Total reaction force/moment at the base is shown in Table 1.

(ii) Deflection at the top of model in each direction is shown in Table 2.

(iii) Total mass is shown as each axial force in Table 1.

(iv) Calculated first mode frequency in each direction is shown in Table 3

4. Eigenvalue Analysis Results

Eigenvalue analysis results for FEM analysis model and stick model are shown in Table 4 and their mode shapes are shown in Figures 6 through 10. Natural frequencies and mode shapes of significant modes predicted from the stick model compare reasonably well with those from the FEM analysis model.

5. Time History Analysis Results

Seismic time history analyses are performed using the "Single Envelope" ground motions, described in response to RAIs 3.7-5 and 3.7-30, with simultaneous X, Y and Z direction input. Modal damping ratio of the model is 7.0% constant for both analysis models.

Table 5 shows comparison of maximum response accelerations at each level. The maximum accelerations from the stick model are evaluated both with and without considering the coupling effects between vertical and rocking and between lateral and torsion motions.

Figures 11 through 21 show comparison of Floor Response Spectra (FRS) at selected points shown in Figure 10. The FRS obtained from the both models show reasonable agreement. The FRS from the stick model is evaluated considering the coupling effects between vertical and rocking and between lateral and torsion motions.

6. Application of Stick Model Results to Static FEM Analysis

According to the current DCD design procedure, the maximum forces and moments from the stick model are applied to the static FEM analysis model. The obtained element stress distributions are compared with the dynamic FEM analysis results in the following contour figures.

- Figure 22 In-plane Shear Forces, Nxy, in X direction SSE Input
- Figure 23 Vertical Axial Forces, Ny, in X direction SSE Input
- Figure 24 In-plane Shear Forces, Nxy, in Y direction SSE Input
- Figure 25 Vertical Axial Forces, Ny, in X direction SSE Input
- Figure 26 Vertical Axial Forces, Ny, in Z direction SSE Input

- Figure 27 Comparison of In-plane Shear Forces, Nxy, in X direction SSE Input
- Figure 28 Comparison of Vertical Axial Forces, Ny, in X direction SSE Input
- Figure 29 Comparison of In-plane Shear Forces, Nxy, in Y direction SSE Input

- Figure 30 Comparison of Vertical Axial Forces, Ny, in X direction SSE Input
- Figure 31 Comparison of Vertical Axial Forces, Ny, in Z direction SSE Input

It is confirmed from these figures that the stress distribution pattern is very close to each other.

7. Conclusion

In view of the results obtained, it can be concluded that the stick model is consistent with the finite element model in predicting static and dynamic responses. The stick model adequacy is therefore confirmed.

Table 1 Total Reaction Force/Moment at Base

		Reaction Forces				
		Shear (MN)		Moment (MN·m)		Axial Force
		X-dir	Y-dir	X-dir	Y-dir	(MN)
Stick Model (DAC3N)	RBFB	1337	1332	33432	32716	1081
	RCCV	378	382	11347	13043	580
	Pedestal	155	156	1874	2023	209
	Total	1870	1870	46653	47783	1869
FEM (NASTRAN)	RBFB	1297	1230	34207	32612	1071
	RCCV	437	485	9522	10911	595
	Pedestal	136	155	2055	2394	204
	Total	1871	1871	45785	45917	1871

Table 2 Deflection at Top of Model

EL52.4m	Deflection (mm)		
	X-dir	Y-dir	Z-dir
Stick Model (DAC3N)	18.3	22.6	3.07
FEM (NASTRAN)	17.1	19.2	2.64

Table 3 Calculated First Mode Frequency

	Frequency (Hz)		
	X-dir	Y-dir	Z-dir
Stick Model (DAC3N)	3.7Hz	3.3Hz	9.0Hz
FEM (NASTRAN)	3.8Hz	3.6Hz	9.7Hz

Note: First mode frequency is calculated by the following equation from "Vibration Theory and Applications" William T. Thomson.

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta}}$$

where,

g : Gravity acceleration (9.807m/sec^2)

Δ: Static deflection at building top (m)

Table 4 Eigenvalue Analysis Results

(a) Stick Model (DAC3N)

Mode	Frequency (Hz)	MODAL PARTICIPATION FACTORS						Note
		X	Y	Z	XX	YY	ZZ	
1	4.0	-0.08	1.67	0.05	-1111.62	-51.99	-1015.44	Y-dir 1st mode
2	4.5	1.66	0.07	0.09	-50.06	1021.83	70.52	X-dir 1st mode
3	6.2	-0.01	0.04	0.01	-231.70	-22.57	1620.63	Torsion 1st mode
4	8.1	-0.04	-0.89	0.17	-1281.20	121.61	-874.40	
5	8.8	-0.69	0.07	0.53	93.37	1677.71	90.35	
6	11.2	-0.31	-0.05	-1.00	85.91	150.04	81.81	Z-dir 1st mode

(b) FE Model (NASTRAN)

Mode	Frequency (Hz)	MODAL PARTICIPATION FACTORS						Note
		X	Y	Z	XX	YY	ZZ	
1	4.3	-0.30	10.87	0.01	-303.09	-9.20	4.82	Y-dir 1st mode
2	4.7	-10.93	-0.32	-0.31	8.57	-309.39	0.72	X-dir 1st mode
3	7.7	0.15	-1.30	0.00	34.99	0.04	-281.83	Torsion 1st mode
4	8.4	0.13	-4.37	0.00	-41.20	-0.51	-33.01	
5	8.8	-5.01	-0.15	0.04	-1.12	60.04	-8.33	
6	10.0	0.04	-0.58	-0.01	-5.25	1.19	-11.98	
7	10.8	0.12	0.46	-1.13	3.91	3.56	8.08	
8	11.1	0.48	-0.07	-10.65	-2.15	22.79	-2.69	Z-dir 1st mode

Table 5 Maximum Response Accelerations

(a) RBFB

Elevation	FEM (g)			Stick Model with Rotation (g)			Stick Model without Rotation (g)		
(m)	X	Y	Z	X	Y	Z	X	Y	Z
52.40	1.23	1.24	1.29	1.46	1.56	1.76	1.43	1.51	1.24
34.00	0.98	0.81	0.94	1.20	0.98	1.31	1.18	0.94	0.82
27.00	0.86	0.72	0.86	1.01	0.89	1.24	0.98	0.80	0.68
22.50	0.81	0.65	0.80	1.01	0.85	1.16	0.98	0.75	0.69
17.50	0.73	0.65	0.75	1.00	0.81	1.06	0.98	0.75	0.70
13.57	0.67	0.62	0.71	0.99	0.78	1.00	0.97	0.72	0.70
9.06	0.64	0.57	0.69	0.86	0.79	0.92	0.83	0.72	0.70
4.65	0.57	0.52	0.72	0.74	0.74	0.88	0.72	0.66	0.76
-1.00	0.53	0.50	0.64	0.70	0.68	0.86	0.68	0.63	0.75
-6.40	0.52	0.46	0.52	0.62	0.64	0.74	0.61	0.62	0.68

(b) RCCV

Elevation	FEM (g)			Stick Model with Rotation (g)			Stick Model without Rotation (g)		
(m)	X	Y	Z	X	Y	Z	X	Y	Z
34.00	0.95	0.92	1.00	1.20	0.97	1.67	1.18	0.94	0.85
27.00	0.85	0.80	0.94	1.00	0.83	1.51	0.98	0.81	0.84
17.50	0.76	0.76	0.80	0.99	0.78	1.24	0.98	0.76	0.71
13.57	0.65	0.68	0.75	0.98	0.75	1.20	0.97	0.73	0.77
9.06	0.58	0.62	0.74	0.85	0.74	1.02	0.83	0.72	0.62
4.65	0.54	0.56	0.68	0.73	0.69	0.98	0.72	0.67	0.68
-1.00	0.50	0.54	0.54	0.69	0.63	0.76	0.68	0.62	0.56
-6.40	0.50	0.49	0.49	0.61	0.60	0.65	0.61	0.60	0.59

(c) V/W and Pedestal

Elevation	FEM (g)			Stick Model with Rotation (g)			Stick Model without Rotation (g)		
(m)	X	Y	Z	X	Y	Z	X	Y	Z
17.50	0.75	0.77	0.91	0.98	0.77	1.90	0.98	0.77	1.10
14.50	0.71	0.71	0.91	1.40	1.07	1.60	1.40	1.06	1.04
11.50	0.67	0.67	0.91	1.42	1.14	1.28	1.42	1.14	0.92
8.50	0.66	0.65	0.91	0.98	0.86	1.05	0.98	0.86	0.77
4.65	0.72	0.66	0.90	0.72	0.67	0.90	0.72	0.67	0.62
-1.00	0.60	0.60	0.68	0.68	0.62	0.70	0.68	0.62	0.55
-6.40	0.58	0.51	0.46	0.61	0.60	0.53	0.61	0.60	0.48

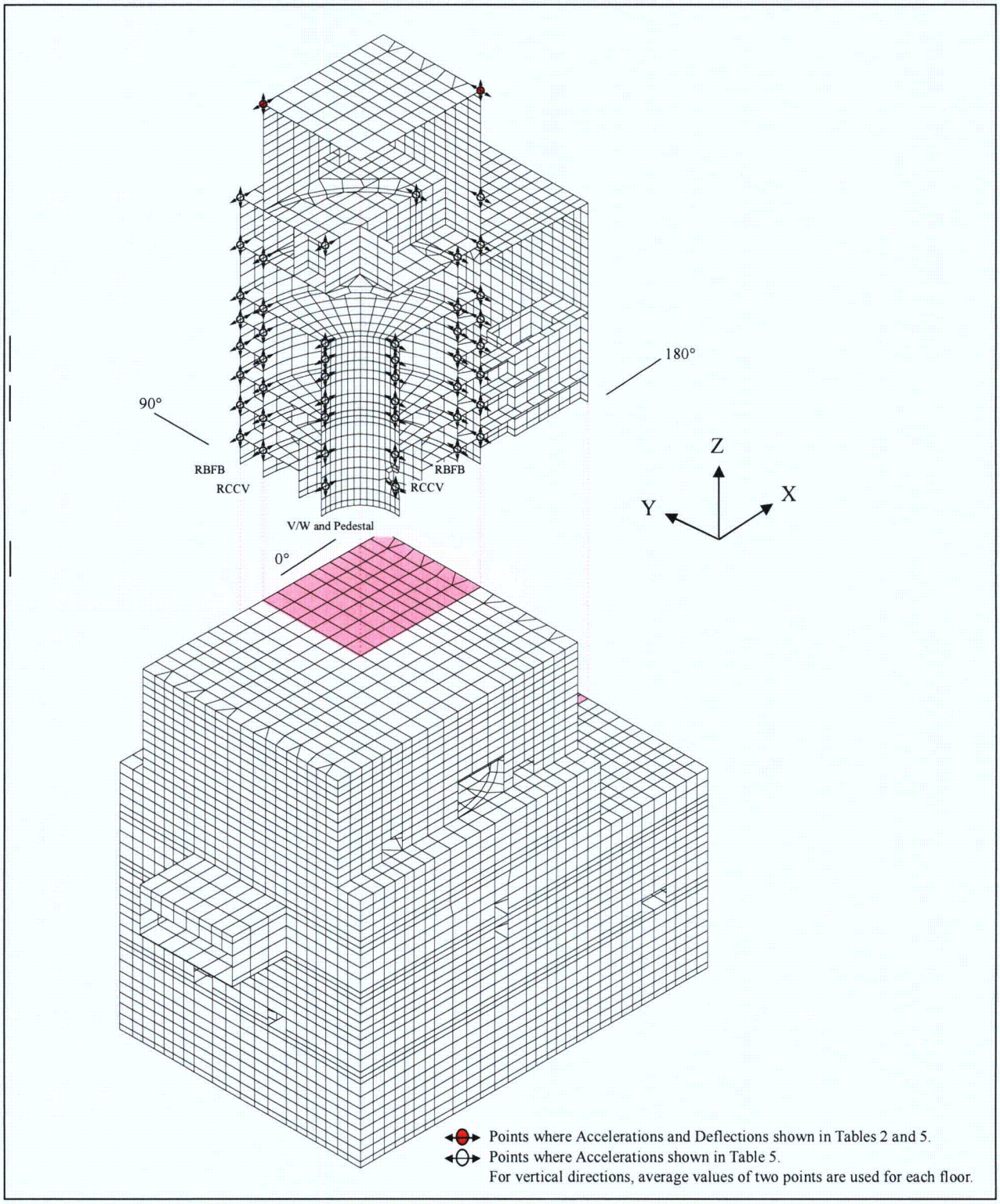


Figure 1 FEM Analysis Model

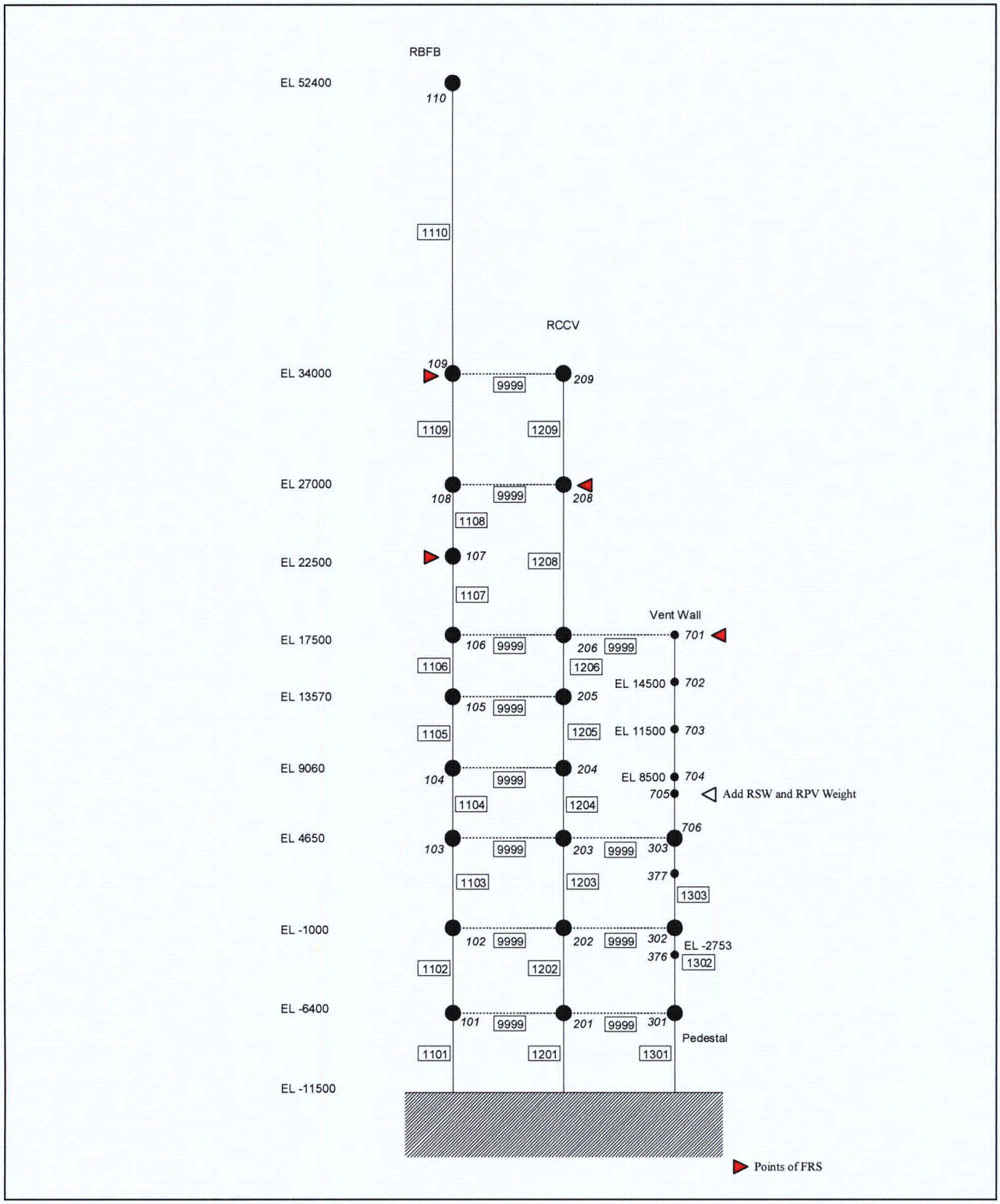


Figure 2 Seismic Stick Model

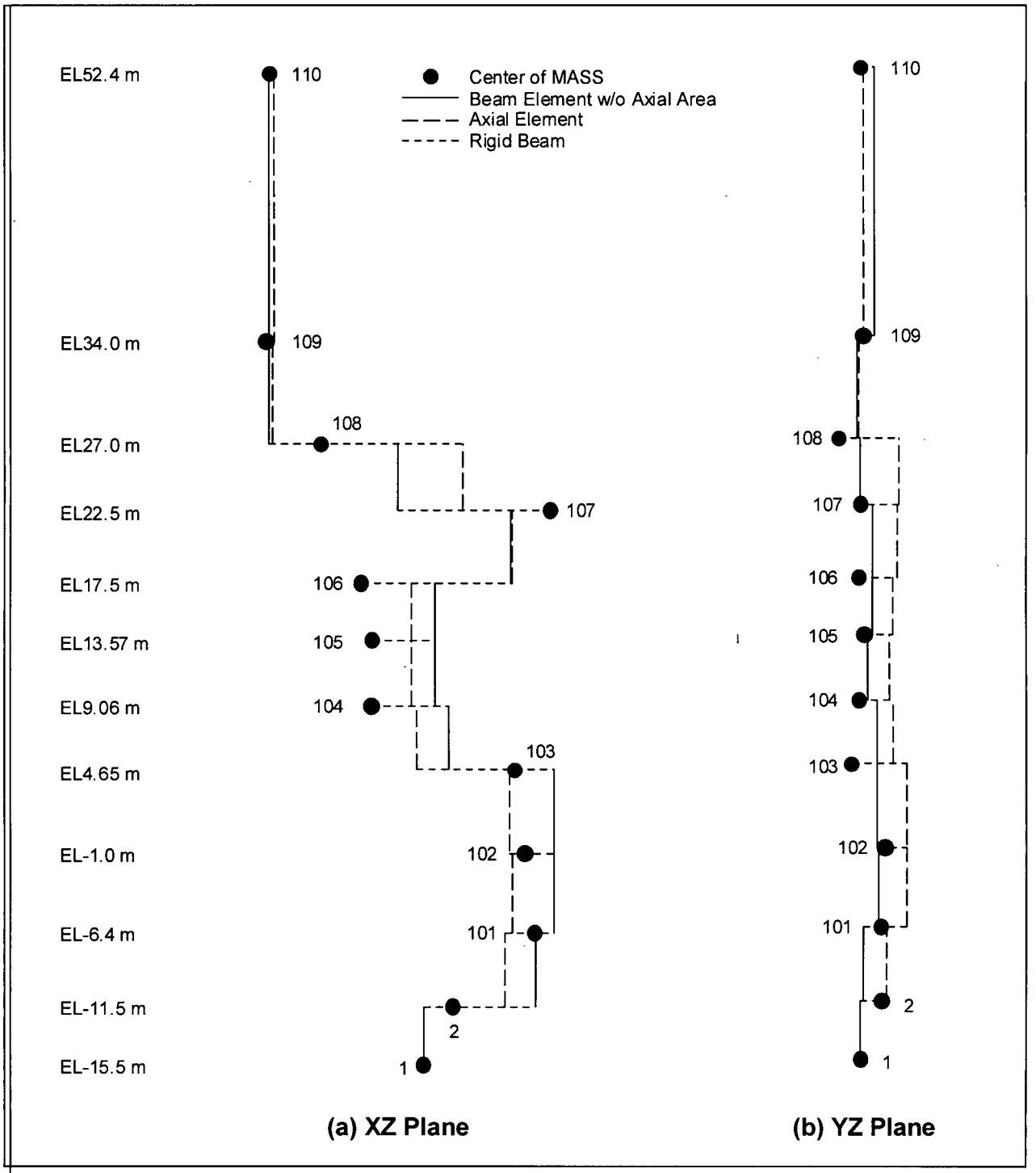


Figure 3 RBFB Stick Model

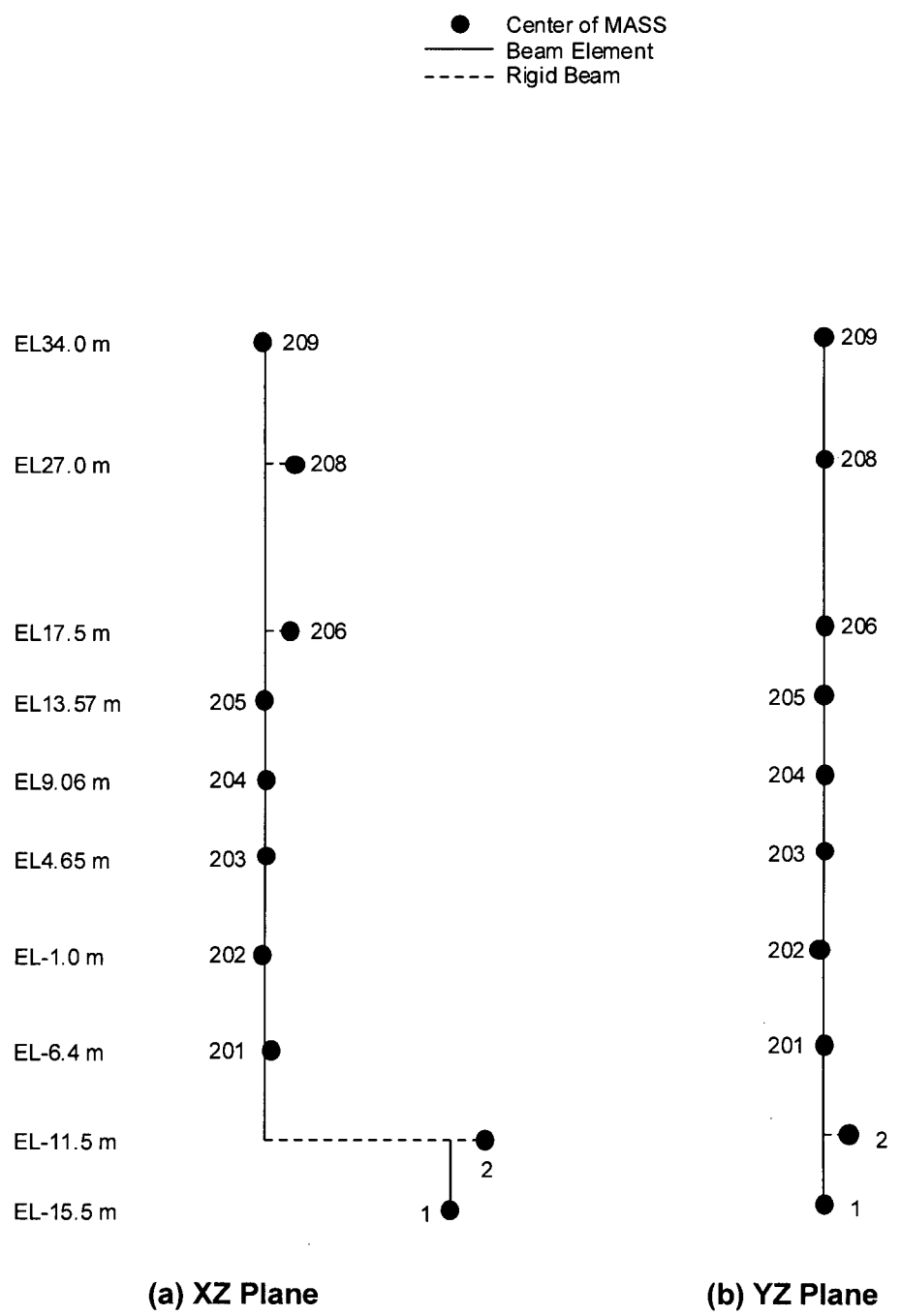


Figure 4 RCCV Stick Model

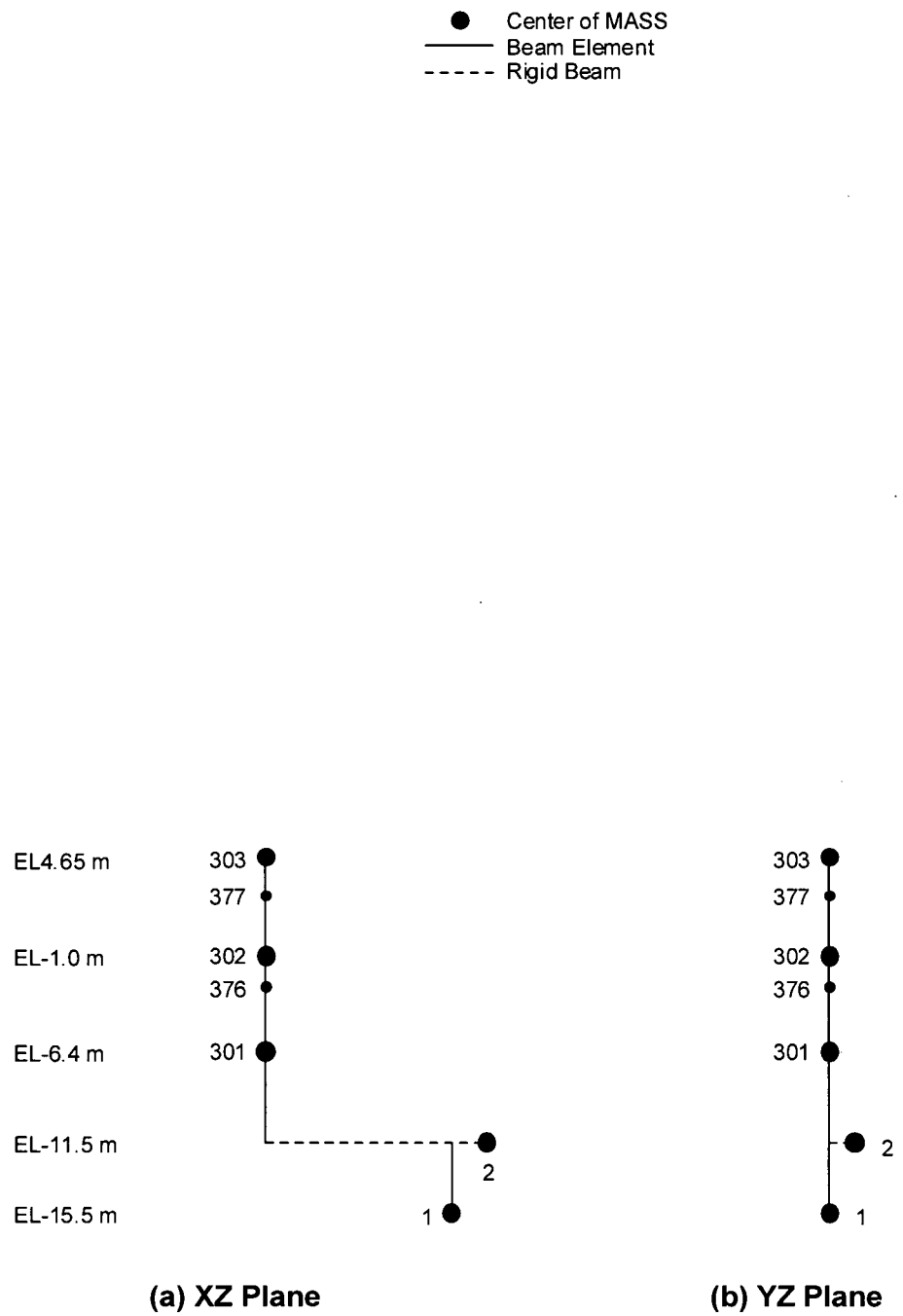
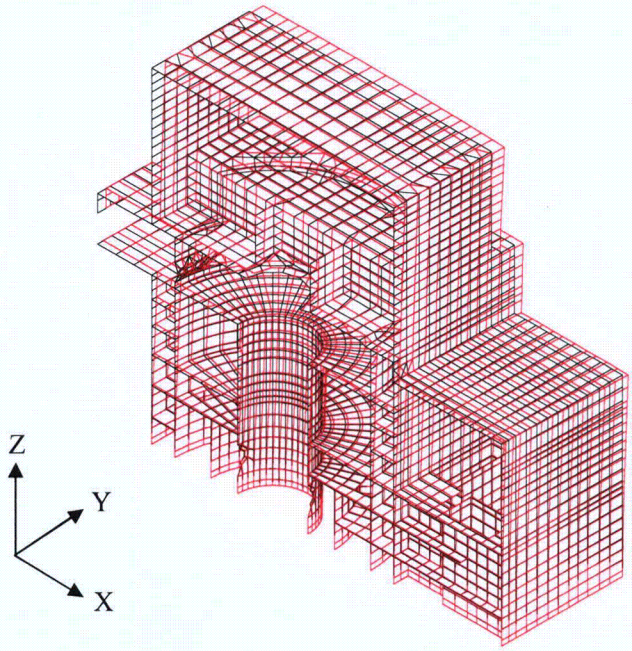


Figure 5 Pedestal Stick Model



FEM 1st Mode (Y-dir)

Stick Model 1st

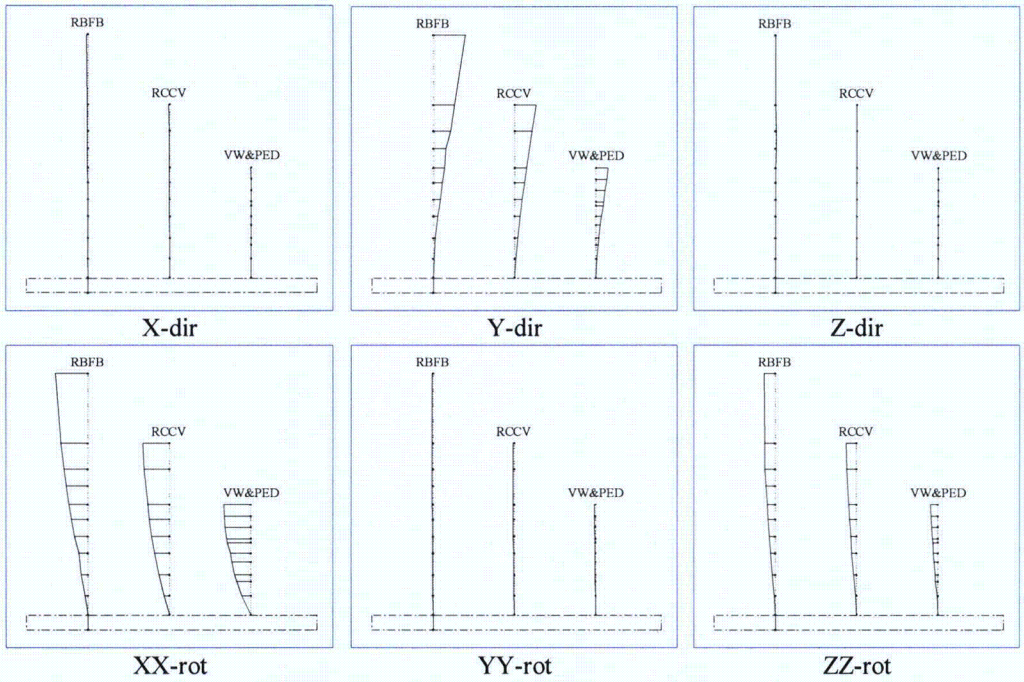
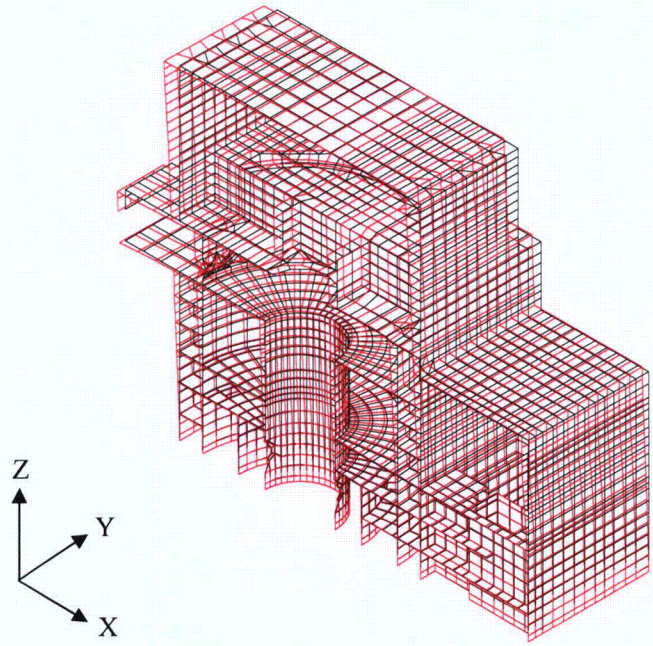


Figure 6 Mode Shape - Y direction 1st Mode



FEM 2nd Mode (X-dir)

Stick Model 2nd

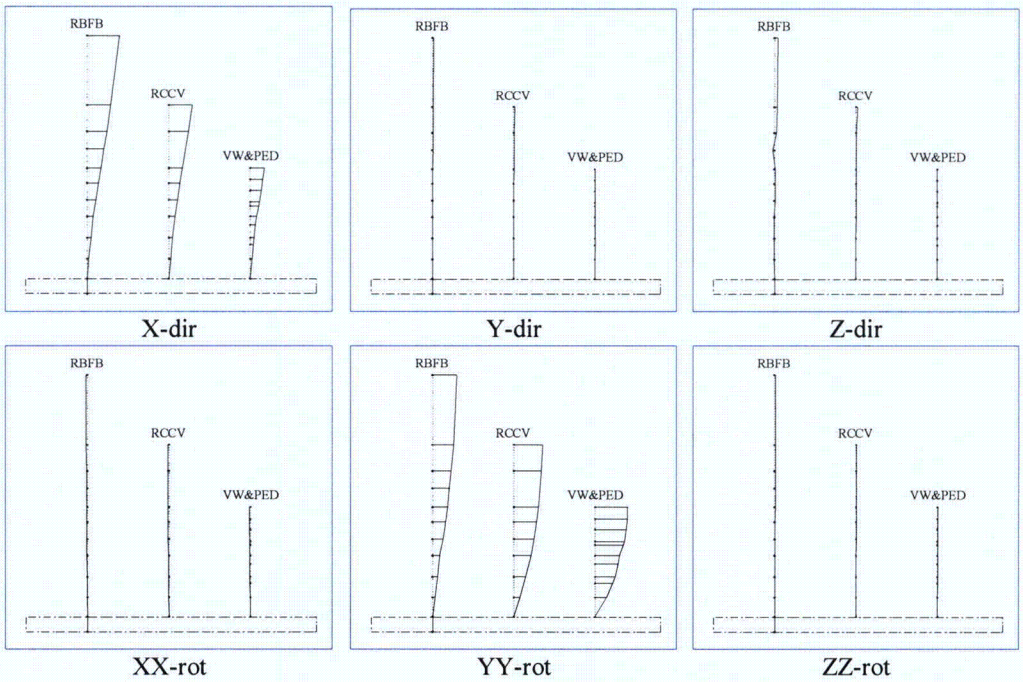
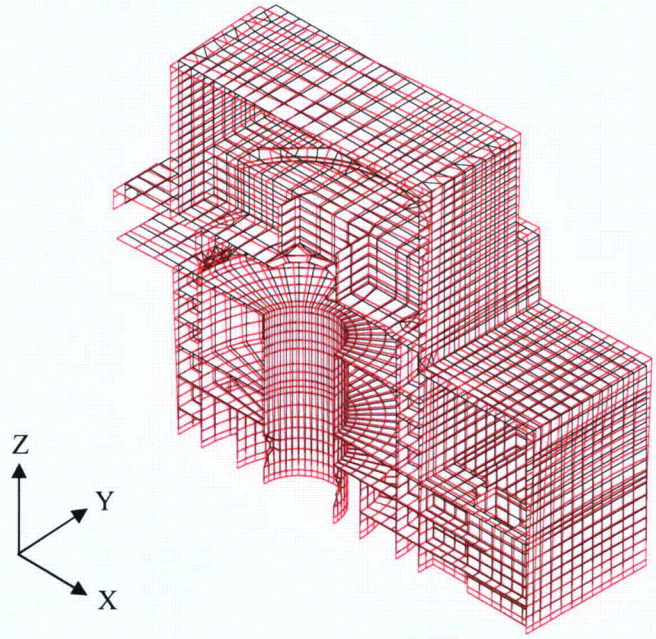


Figure 7 Mode Shape - X direction 1st Mode



FEM 3rd Mode (ZZ-rot)

Stick Model 3rd

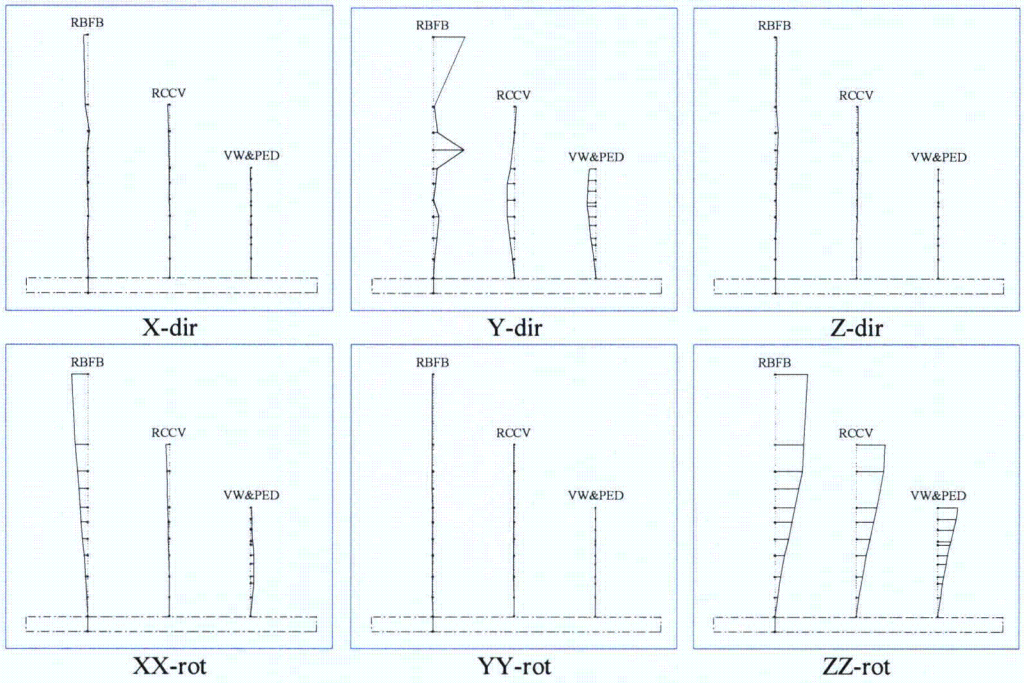
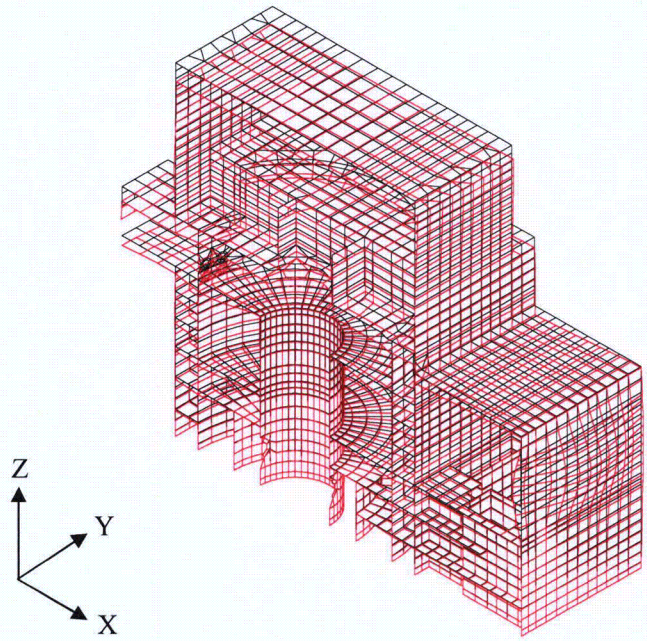


Figure 8 Mode Shape - Torsion 1st Mode



FEM 8th Mode (Z-dir)

Stick Model 6th

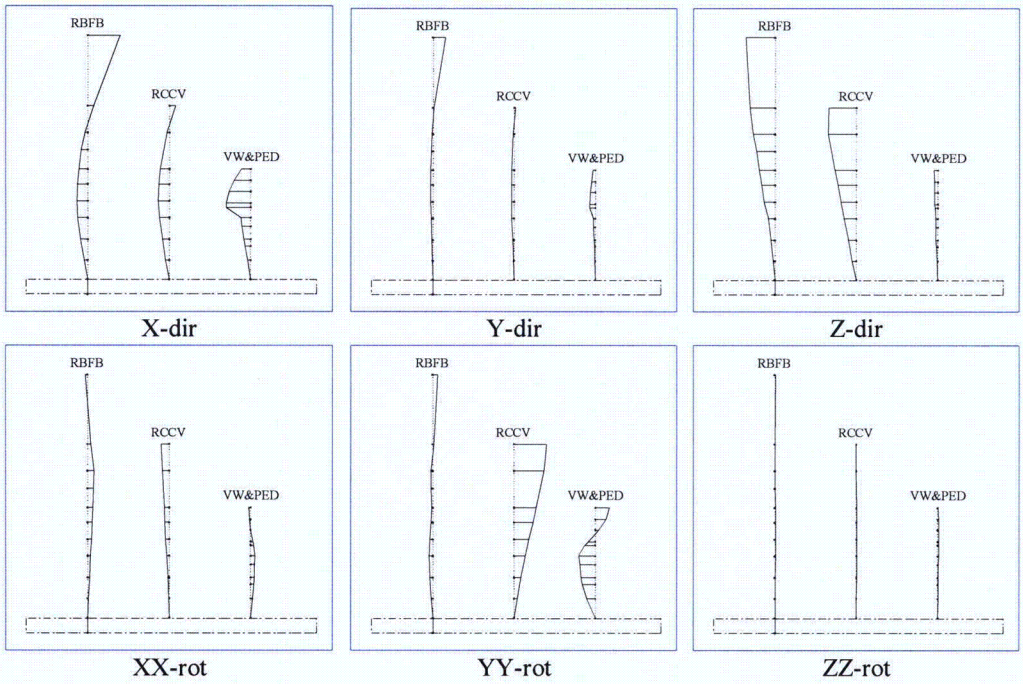


Figure 9 Mode Shape - Z direction 1st Mode

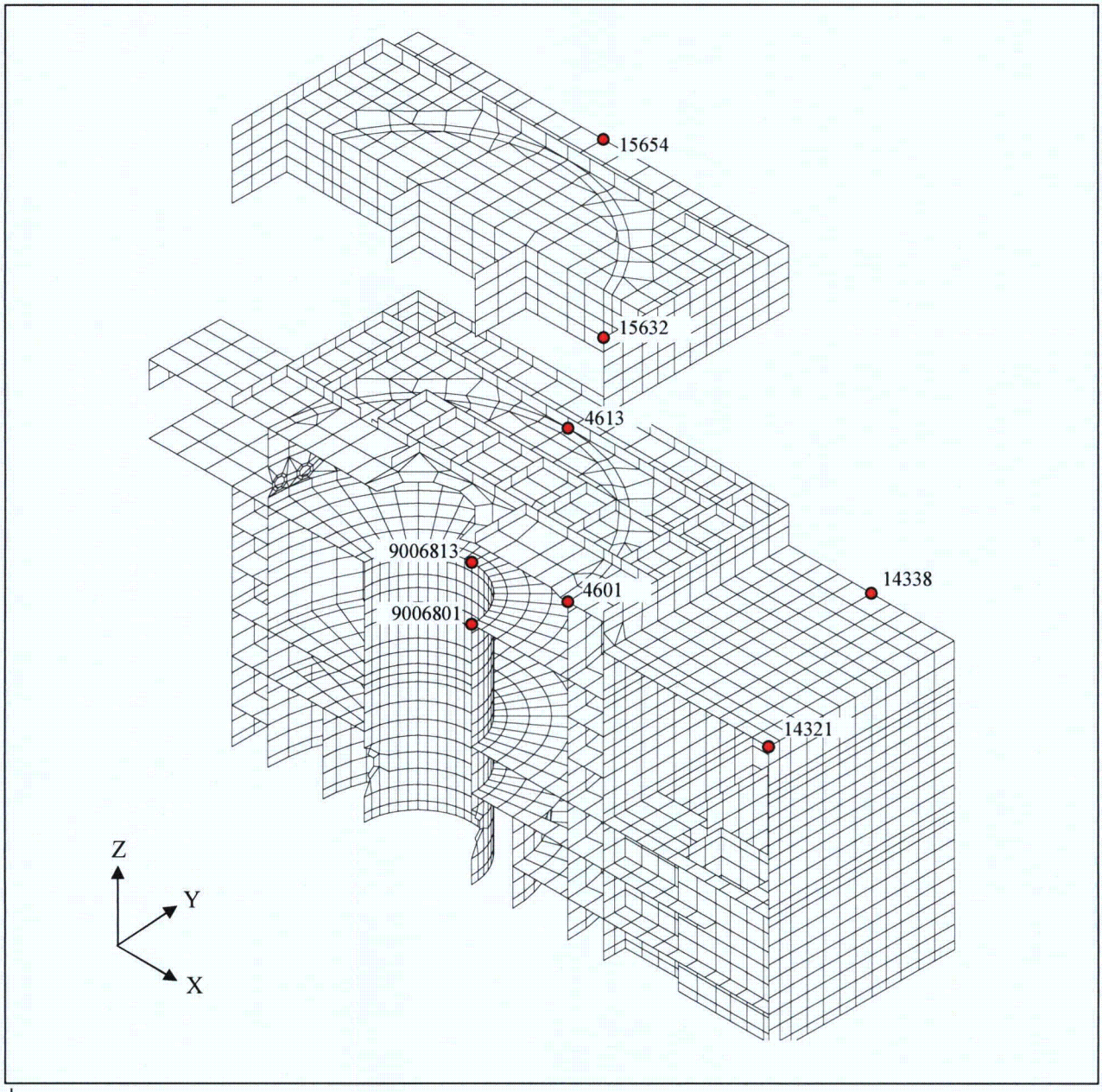


Figure 10 Selected Points for FRS

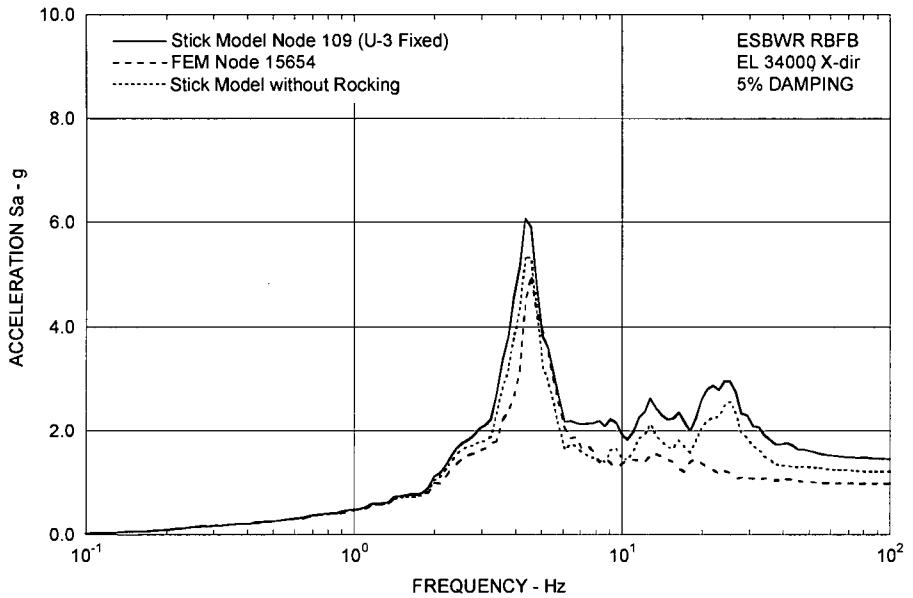


Figure 11 Response Spectra X-dir at RBFB EL34.0m

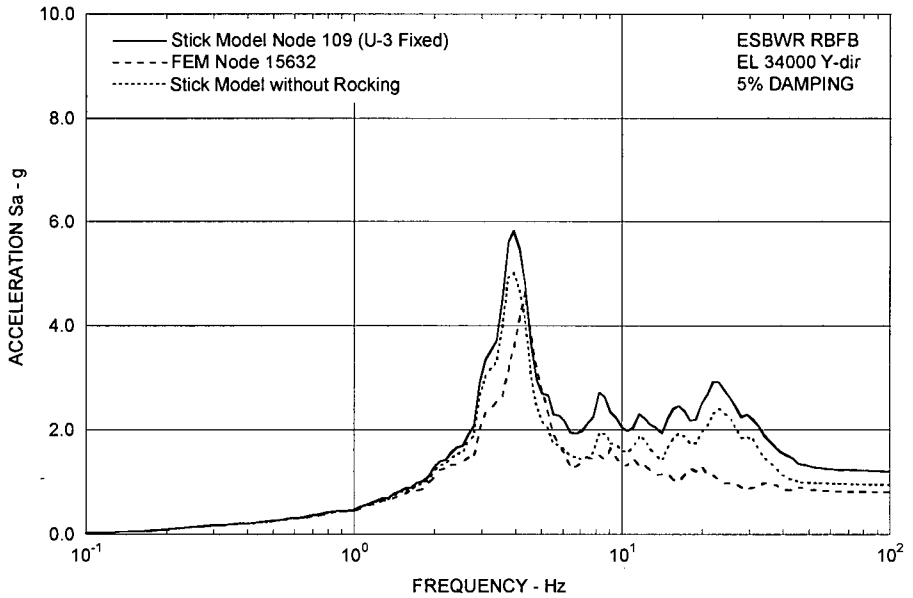


Figure 12 Response Spectra Y-dir at RBFB EL34.0m

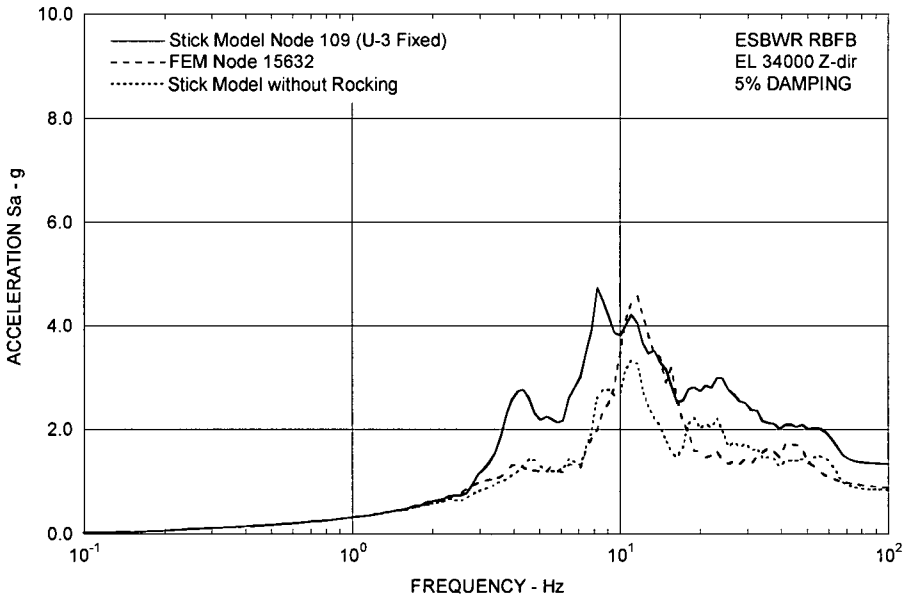


Figure 13 Response Spectra Z-dir at RBFB EL34.0m

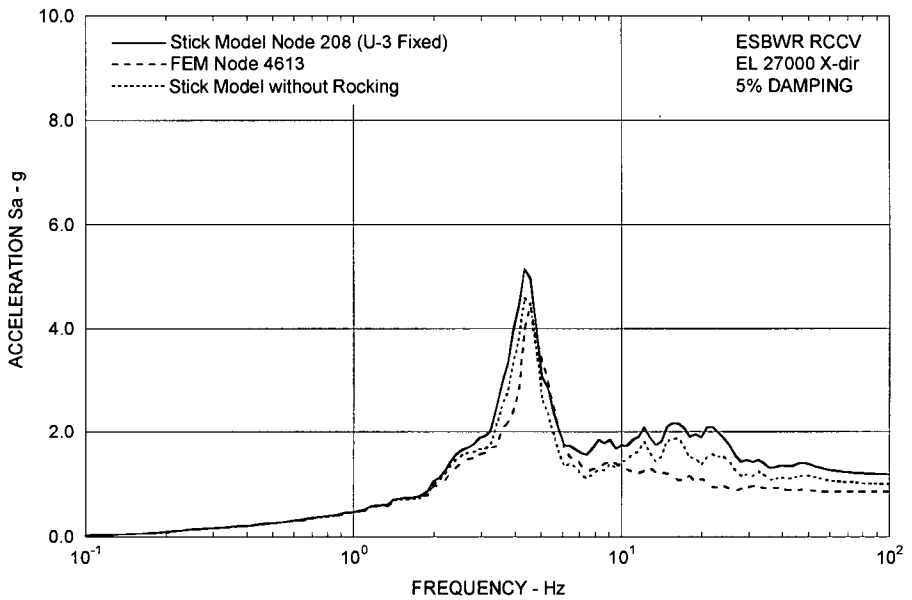


Figure 14 Response Spectra X-dir at RCCV EL27.0m

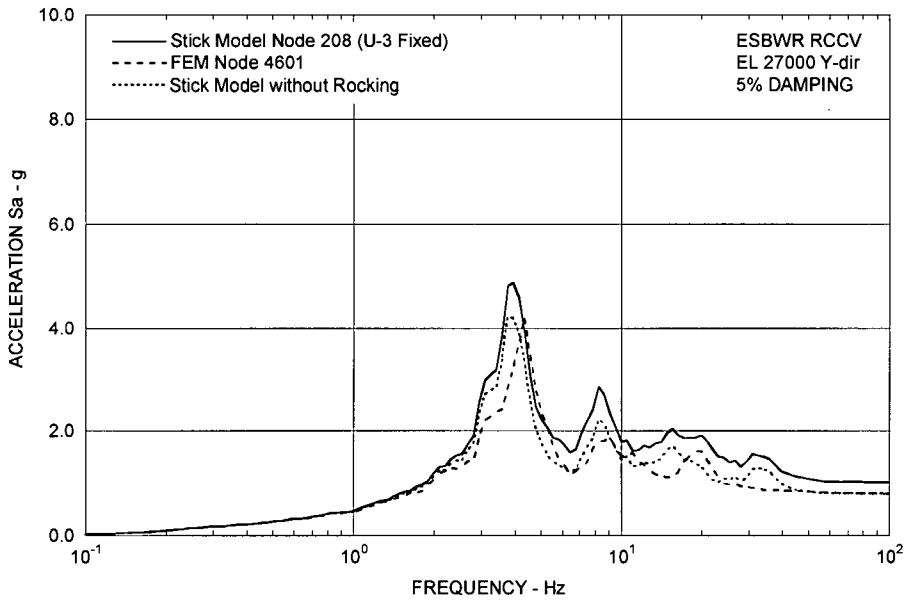


Figure 15 Response Spectra Y-dir at RCCV EL27.0m

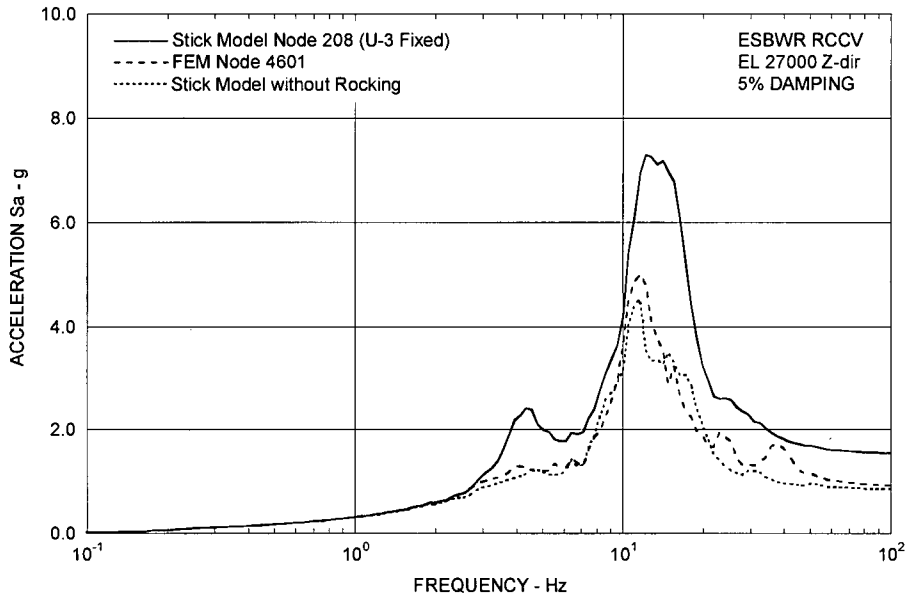


Figure 16 Response Spectra Z-dir at RCCV EL27.0m

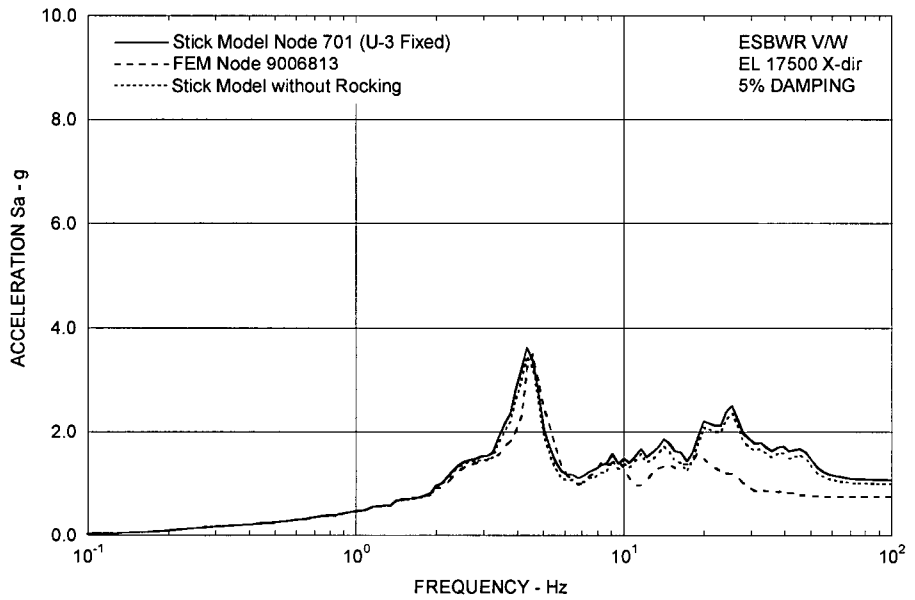


Figure 17 Response Spectra X-dir at V/W Top EL17.5m

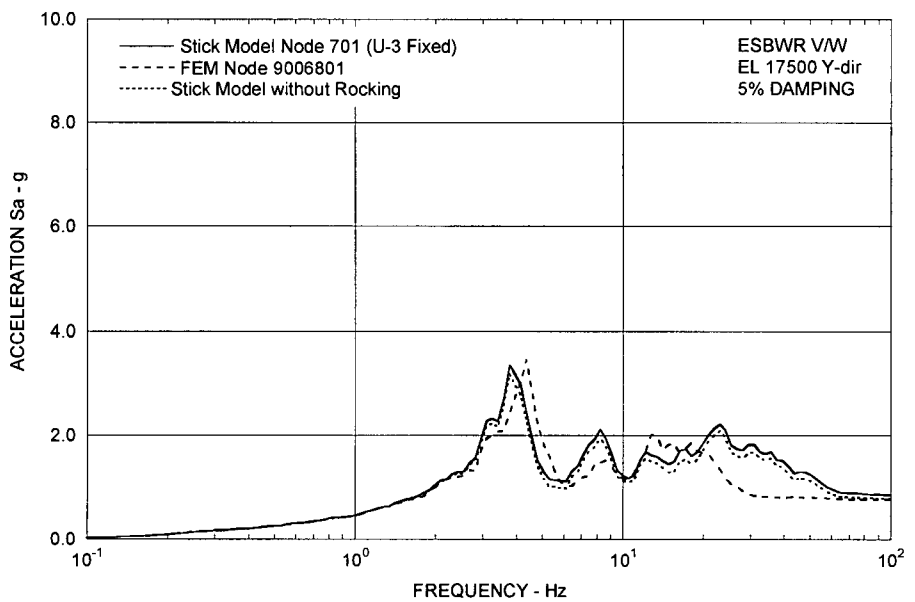


Figure 18 Response Spectra Y-dir at V/W Top EL17.5m

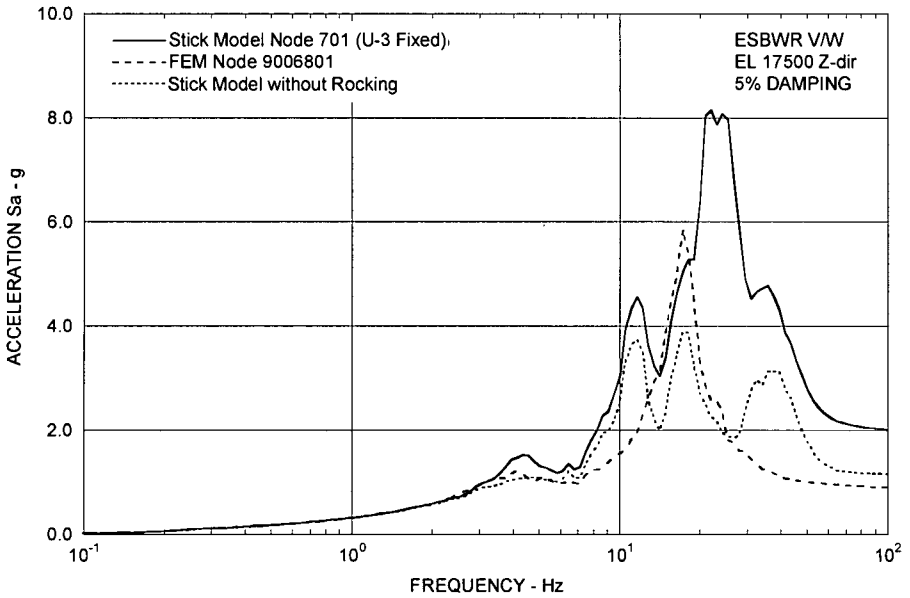


Figure 19 Response Spectra Z-dir at V/W Top EL17.5m

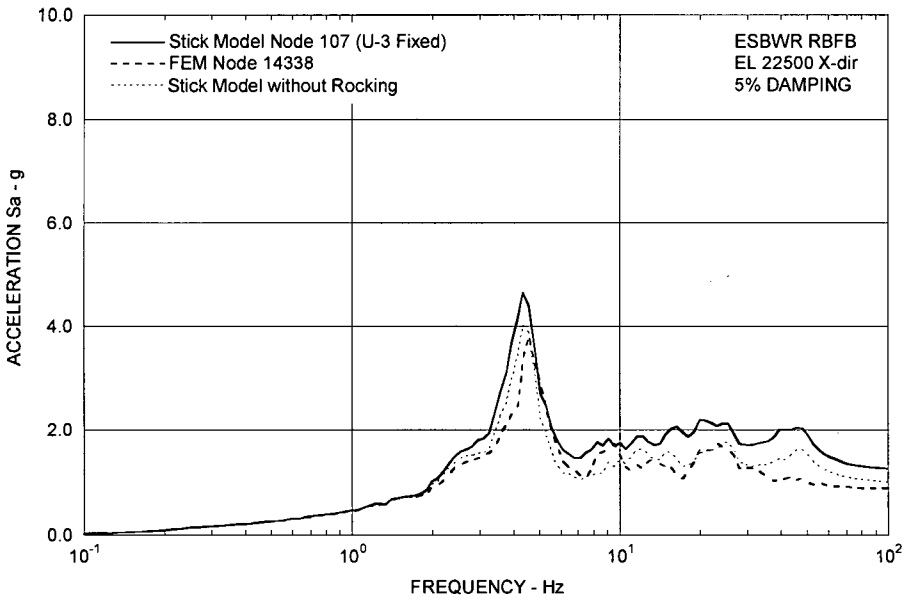


Figure 20 Response Spectra X-dir at FB Top EL22.5m

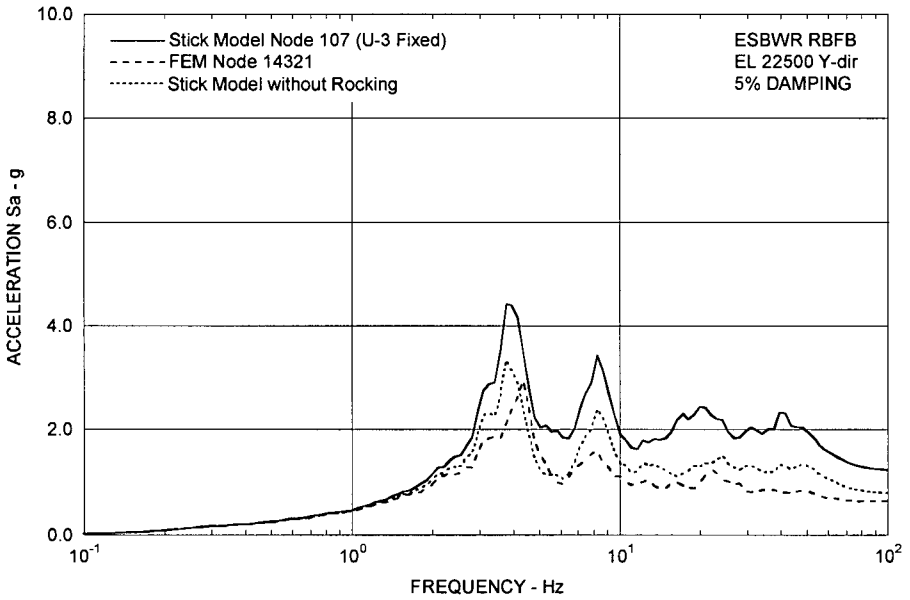
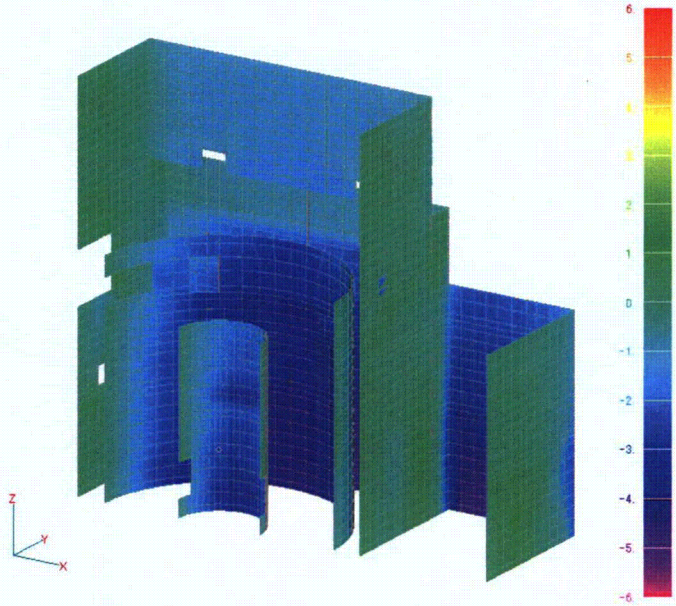
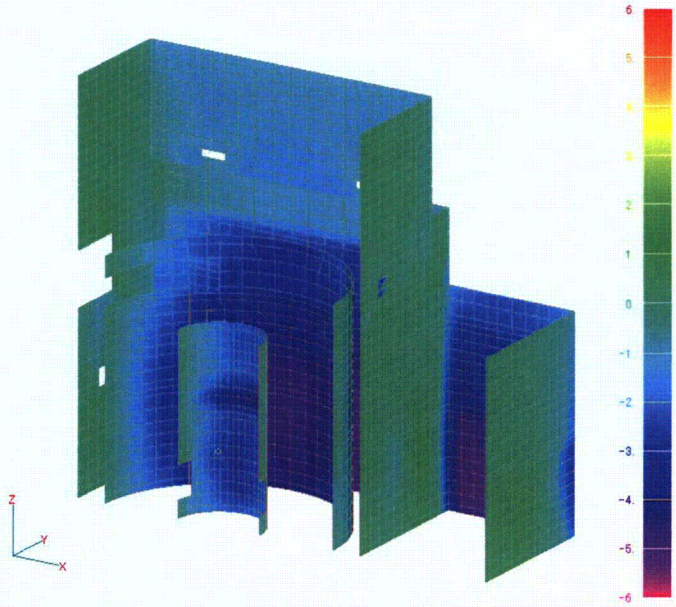


Figure 21 Response Spectra Y-dir at FB Top EL22.5m

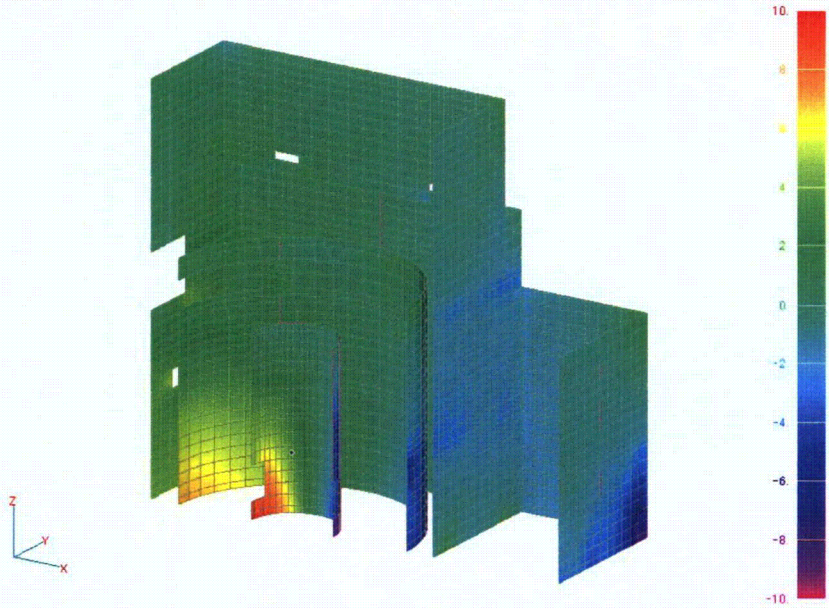


(a) Dynamic Analysis Results (Unit : MN/m)

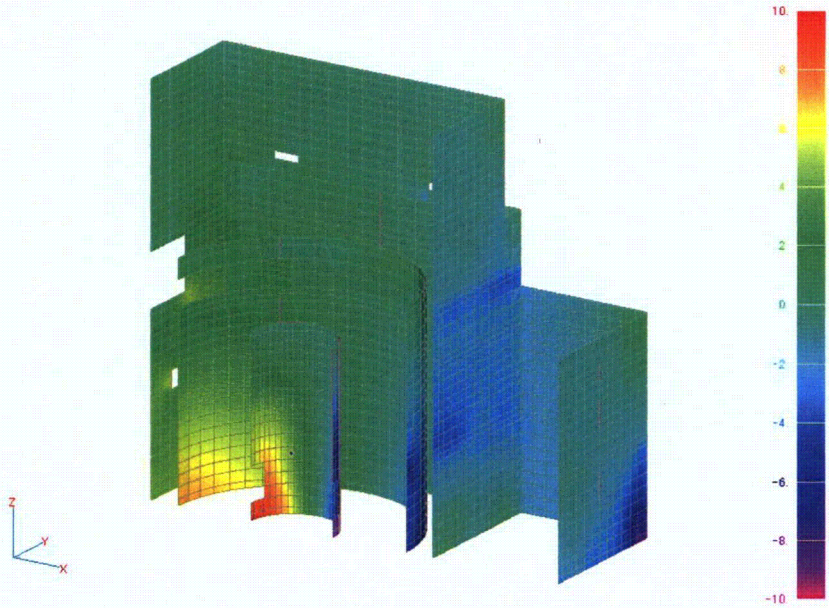


(b) Static Analysis Results (Unit : MN/m)

Figure 22 In-plane Shear Forces, Nxy, in X direction SSE Input

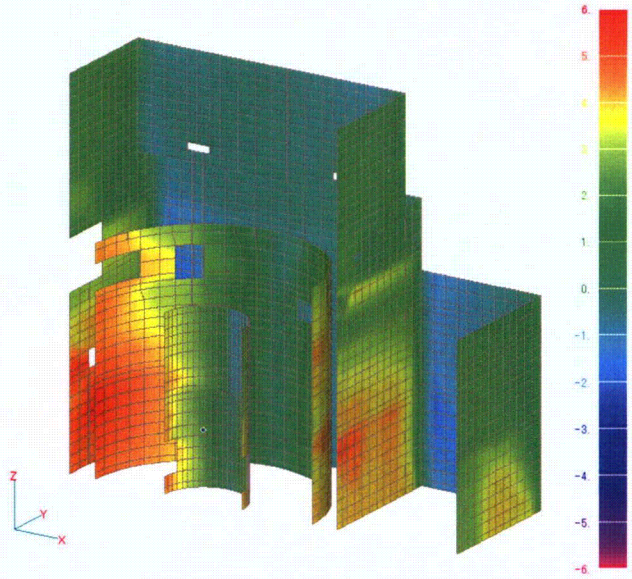


(a) Dynamic Analysis Results (Unit : MN/m)

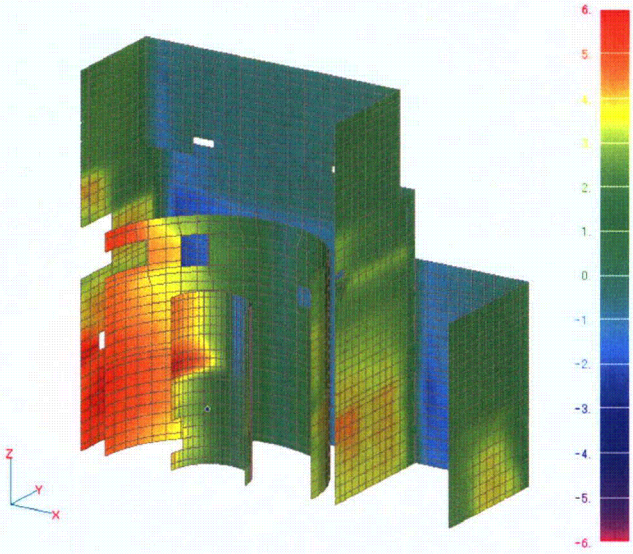


(b) Static Analysis Results (Unit : MN/m)

Figure 23 Vertical Axial Forces, Ny, in X direction SSE Input

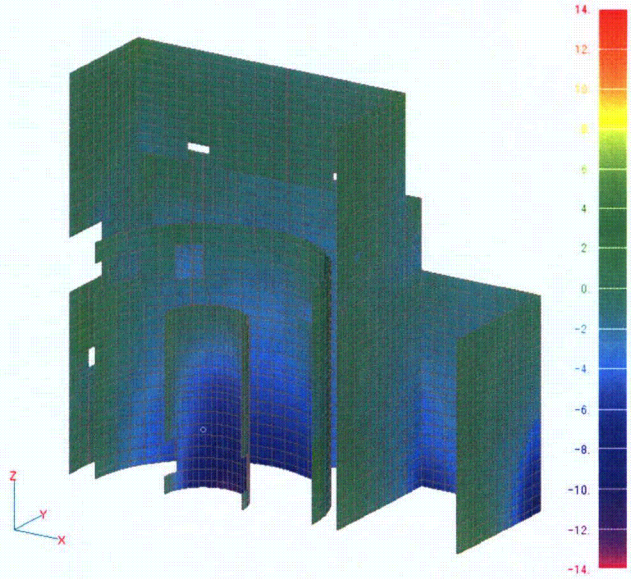


(a) Dynamic Analysis Results (Unit : MN/m)

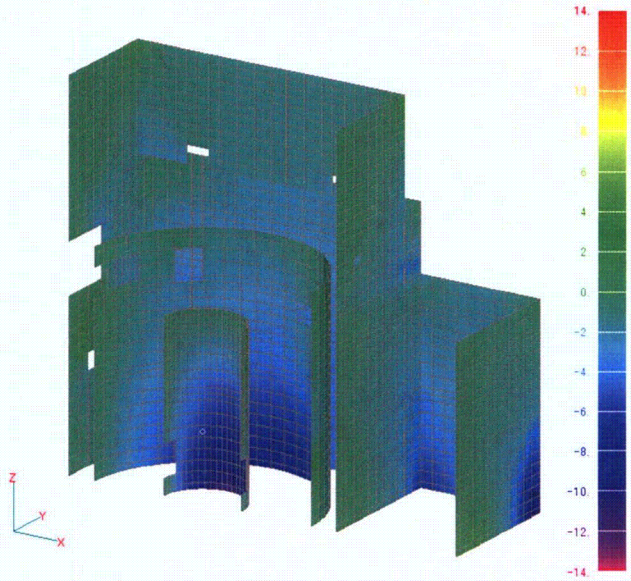


(b) Static Analysis Results (Unit : MN/m)

Figure 24 In-plane Shear Forces, Nxy, in Y direction SSE Input

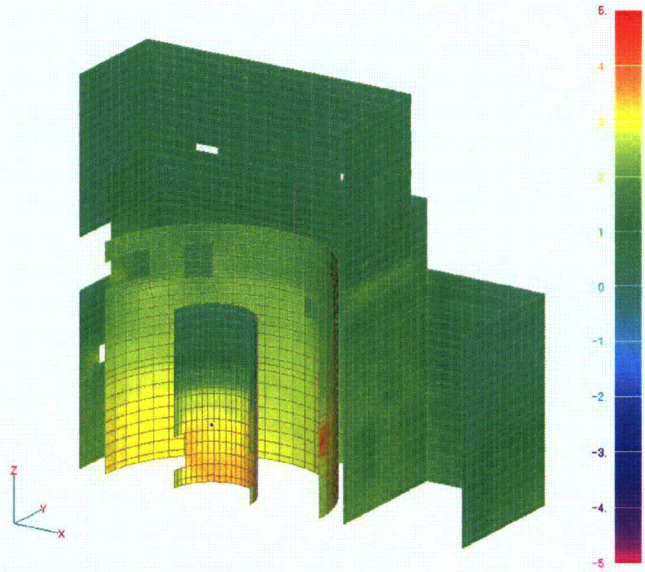


(a) Dynamic Analysis Results (Unit : MN/m)

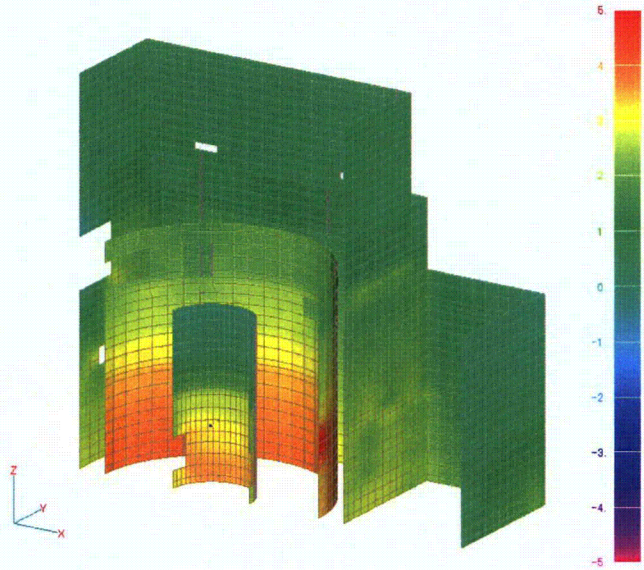


(b) Static Analysis Results (Unit : MN/m)

Figure 25 Vertical Axial Forces, Ny, in Y direction SSE Input

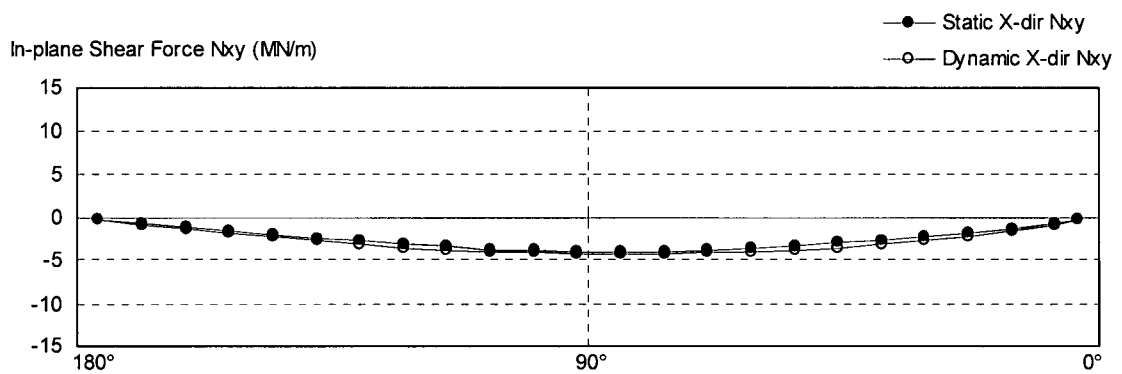


(a) Dynamic Analysis Results (Unit : MN/m)

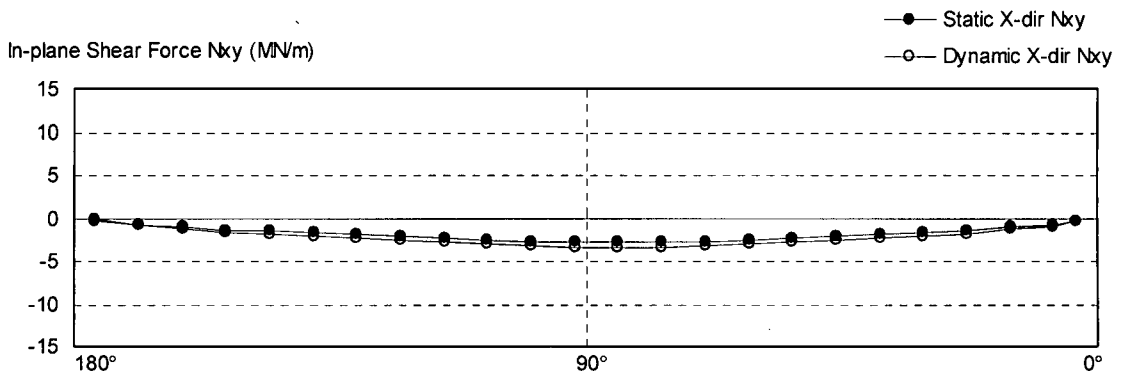


(b) Static Analysis Results (Unit : MN/m)

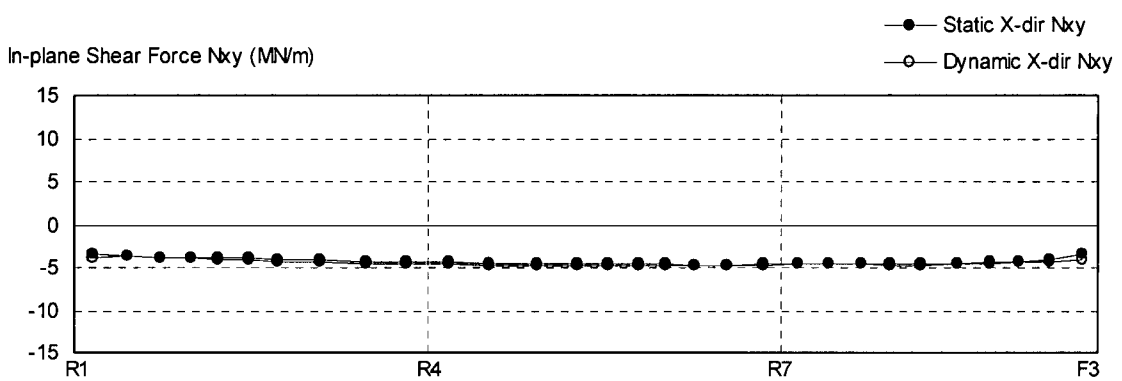
Figure 26 Vertical Axial Forces, Ny, in Z direction SSE Input



(a) RCCV Bottom

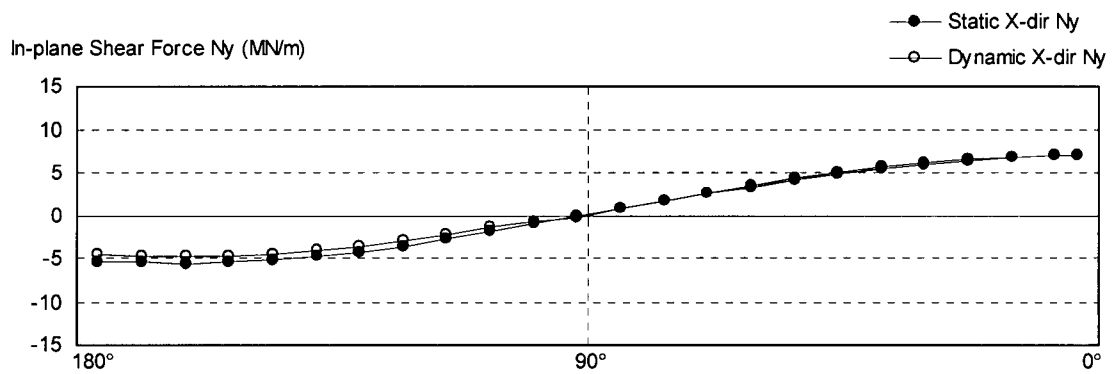


(b) Pedestal Bottom

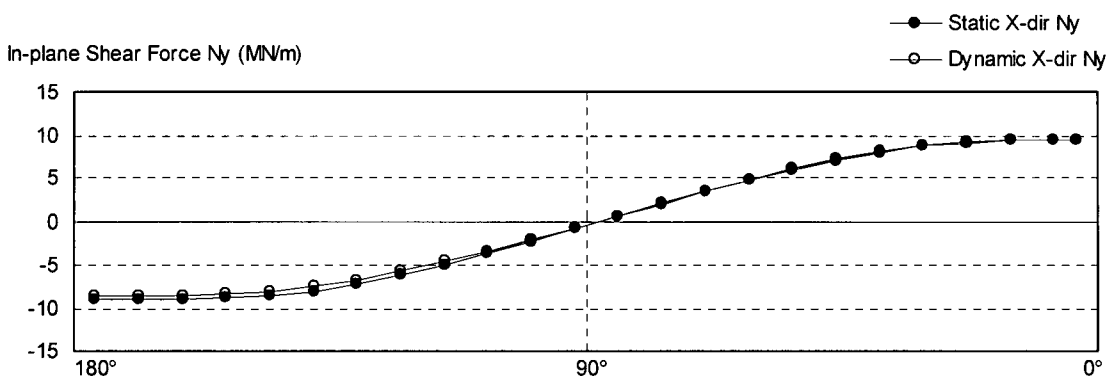


(c) Outer Wall on RA and FA Bottom

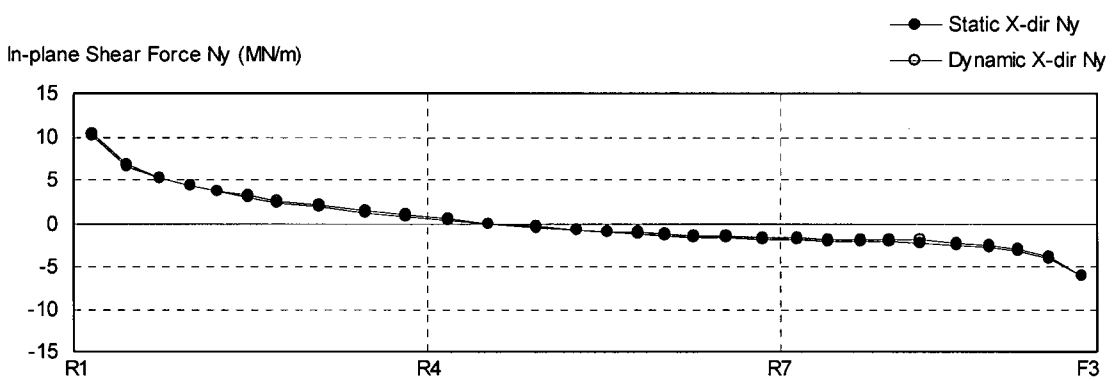
Figure 27 Comparison of In-plane Shear Forces, Nxy, in X direction SSE Input



(a) RCCV Bottom



(b) Pedestal Bottom



(c) Outer Wall on RA and FA Bottom

Figure 28 Comparison of Vertical Axial Forces, Ny, in X direction SSE Input

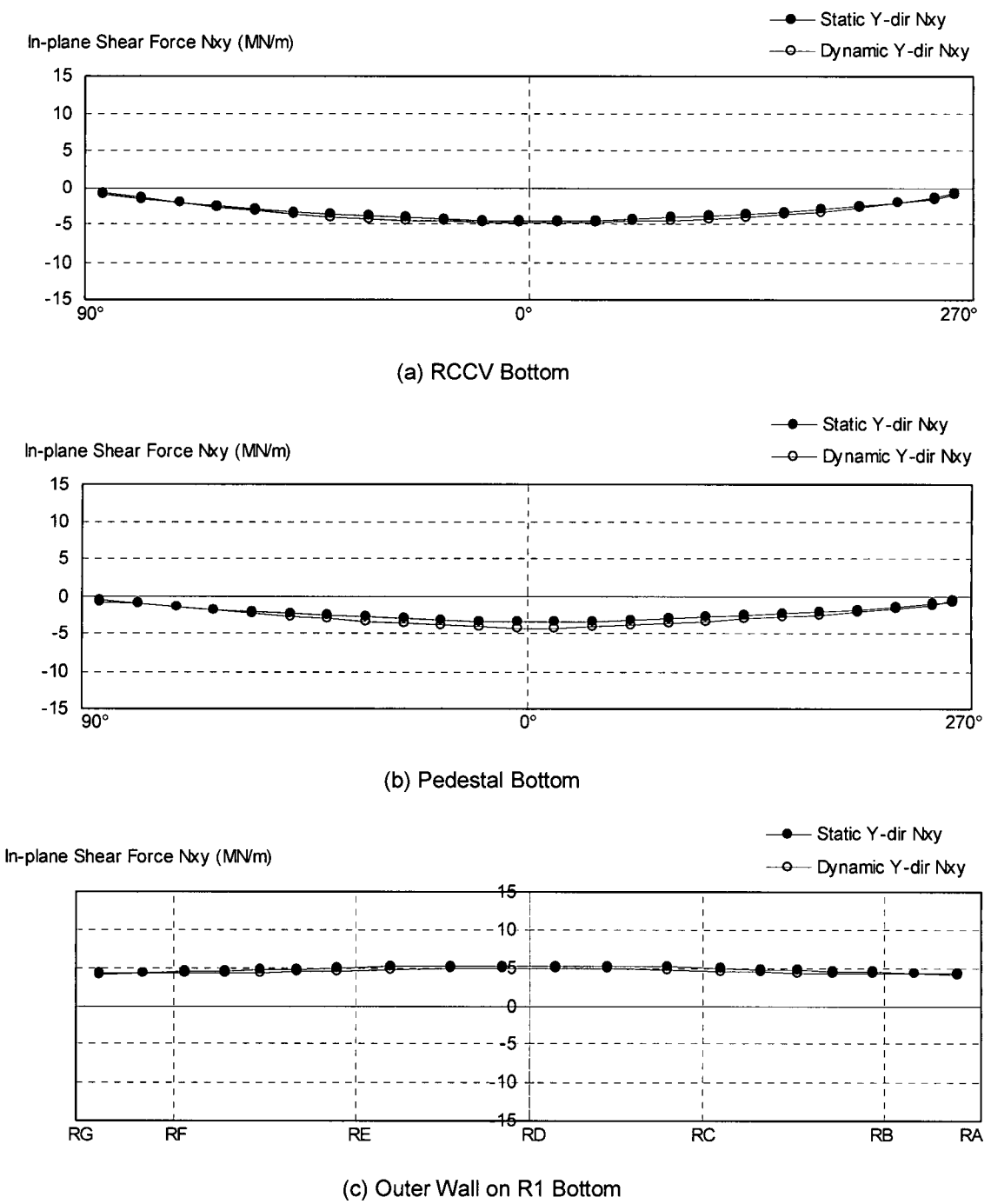
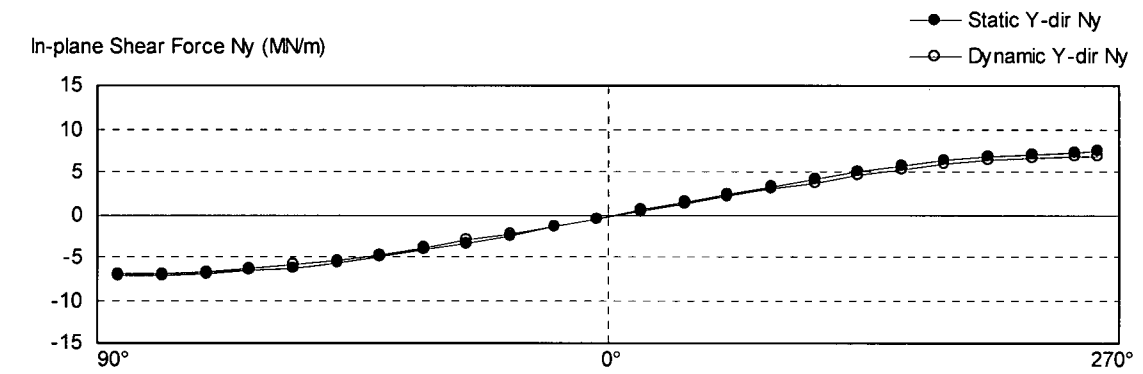
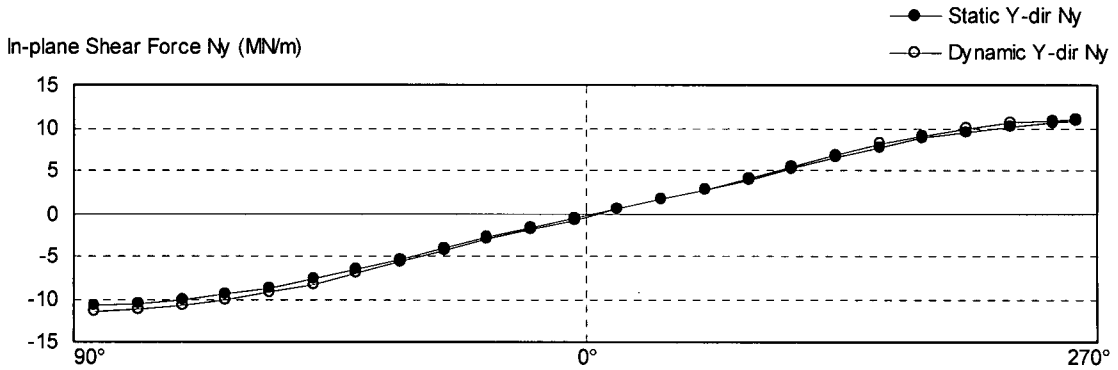


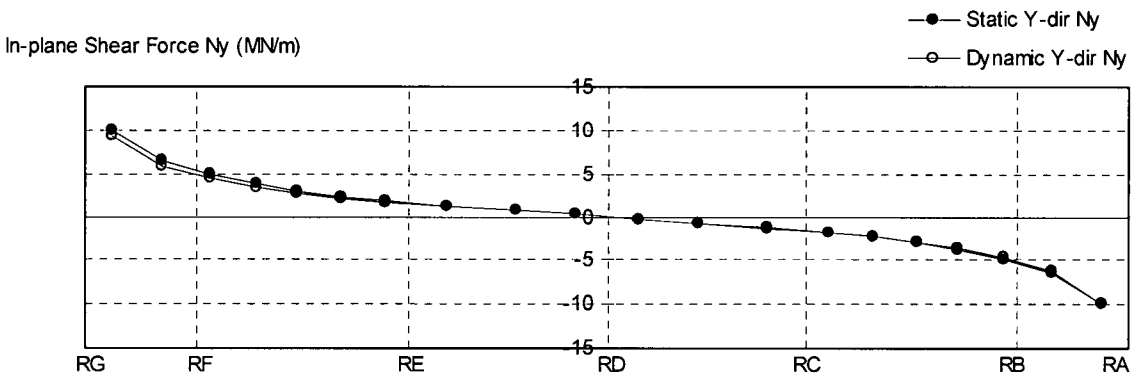
Figure 29 Comparison of In-plane Shear Forces, Nxy, in Y direction SSE Input



(a) RCCV Bottom

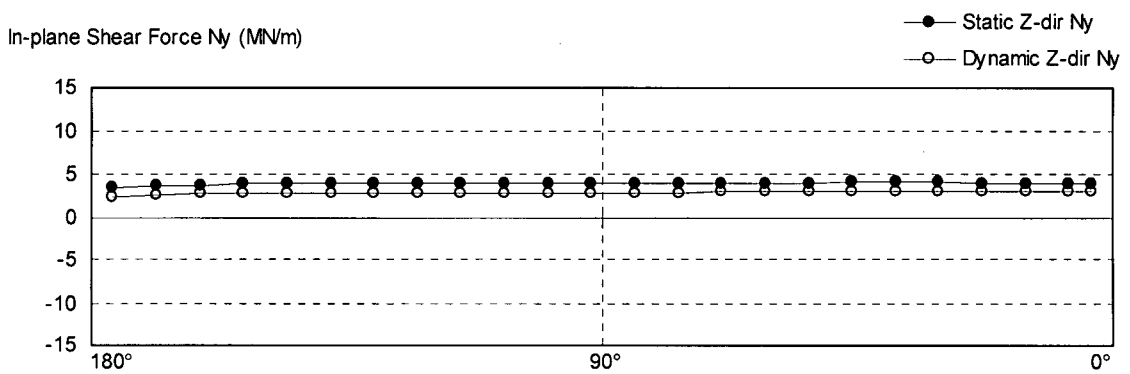


(b) Pedestal Bottom

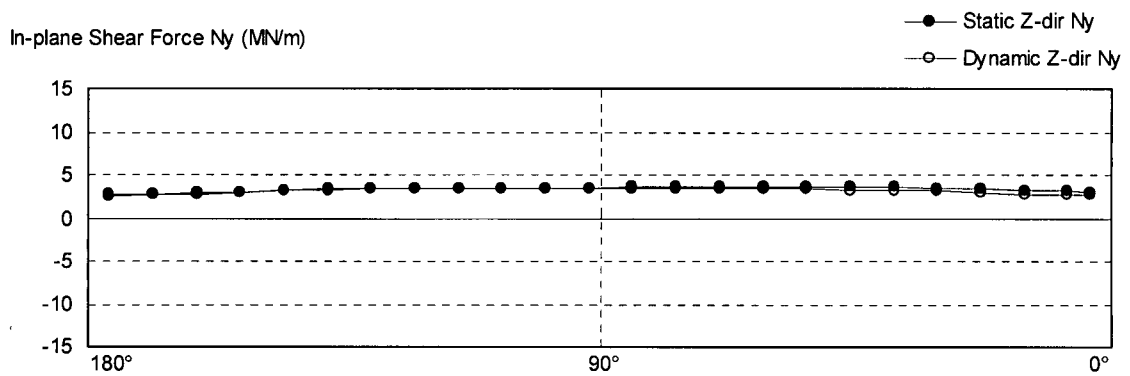


(c) Outer Wall on R1 Bottom

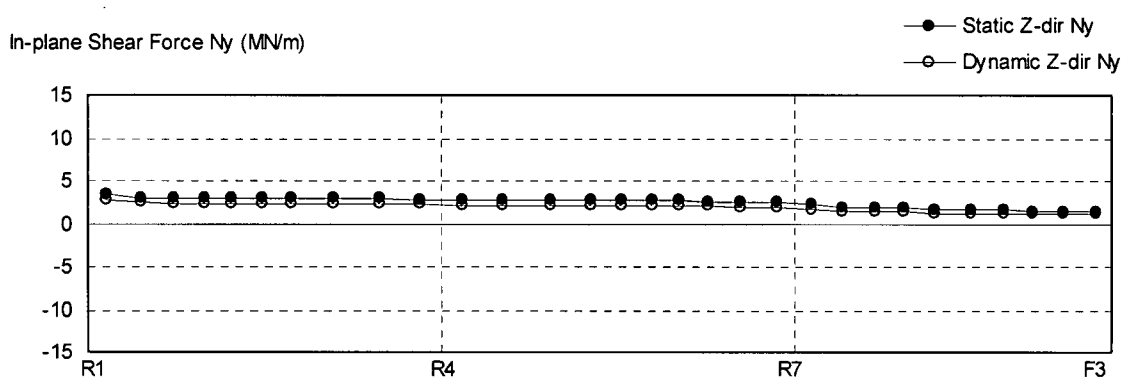
Figure 30 Comparison of Vertical Axial Forces, Ny, in Y direction SSE Input



(a) RCCV Bottom



(b) Pedestal Bottom



(c) Outer Wall on RA and FA Bottom

Figure 31 Comparison of Vertical Axial Forces, Ny, in Z direction SSE Input

ATTACHMENT SER-ESB-044 REV. 1

Comparative Analysis between Seismic Stick Model and Static FEM Model for CB

Shimizu Engineering Report

Project	General Electric Company ESBWR Project	Shimizu Document No.	SER-ESB-044
Title	Comparative Analysis between Seismic Stick Model and Static FEM Model for CB	Rev.	1
		Issued Date	10/23/06
		Revised Date	11/30/06

NOTE:

In response to NRC RAI 3.7-59, in order to assess the adequacy of the stick models and the static NASTRAN finite element models, static and dynamic comparison analyses were performed for the CB.

Rev.	Date	Note	Approve	Review	Prepare
1	11/30/06	Issue for use	Y.O.	N.M	S.O
0	10/23/06	Issue for use	Y.O.	N.M	S.O

Shimizu Corporation	Prepared by	S. Oguri	10/23/06
	Reviewed by	N. Miura	10/23/06
	Approved by	Y. Orito	10/23/06

TABLE OF CONTENTS

1. Scope 5
2. Analysis Model 5
3. Static Load Analysis Results 5
4. Eigenvalue Analysis Results 5
5. Time History Analysis Results 6
6. Application of Stick Model Results to Static FEM Analysis 6
7. Conclusion 6

LIST OF TABLES

Table 1 Total Reaction Force/Moment at Base 7
Table 2 Deflection at Top of Model 7
Table 3 Calculated First Mode Frequency 7
Table 4 Eigenvalue Analysis Results 8
Table 5 Maximum Response Accelerations 9

LIST OF FIGURES

Figure 1 FEM Analysis Model 10
Figure 2 Seismic Stick Model 11
Figure 3 Mode Shape - Y direction 1st Mode 12
Figure 4 Mode Shape - X direction 1st Mode 13
Figure 5 Mode Shape - Torsion 1st Mode 14
Figure 6 Mode Shape - Z direction 1st Mode 15
Figure 7 Selected Point for FRS 16
Figure 8 Response Spectra X-dir at EL9.06m 17
Figure 9 Response Spectra Y-dir at EL9.06m 17
Figure 10 Response Spectra Z-dir at EL9.06m 18

1. Scope

This document is to describe the comparative analysis between seismic stick model and static NASTRAN finite element model for the Control Building. This analysis was performed to respond to NRC RAI 3.7-59, regarding the adequacy of the stick models and the static NASTRAN finite element models.

2. Analysis Model

FEM analysis model and stick model are shown in Figure 1 and Figure 2, respectively. Both models are the same as the design basis models in DCD Revision 1 with the following exceptions:

a. Stick model are based on the revised model described in MFN 06-251.

b. The floor oscillators are excluded from the stick model used in this study.

Analysis model is fixed at the top of basemat.

3. Static Load Analysis Results

Static load, 1 g, is applied to the both models separately in each horizontal direction and in the vertical direction. Locations where results are obtained are shown in Figure 1 for the FEM analysis model and in Figure 2 for the stick model.

(i) Total reaction force/moment at the base is shown in Table 1.

(ii) Deflection at the top of model in each direction is shown in Table 2.

(iii) Total mass is shown as each axial force in Table 1.

(iv) Calculated first mode frequency in each direction is shown in Table 3

4. Eigenvalue Analysis Results

Eigenvalue analysis results for FEM analysis model and stick model are shown in Table 4 and their mode shapes are shown in Figures 3 through 6. Natural frequencies and mode shapes of significant modes predicted from the stick model compare reasonably well with those from the FEM analysis model.

5. Time History Analysis Results

Seismic time history analyses are performed using the "Single Envelope" ground motions, described in response to RAIs 3.7-5 and 3.7-30, with simultaneous X, Y and Z direction input. Modal damping ratio of the model is 7.0% constant for both analysis models.

Table 5 shows comparison of maximum response accelerations at each level.

Figures 8 through 10 show comparison of Floor Response Spectra (FRS) at selected points shown in Figure 7. The FRS obtained from the both models show reasonable agreement.

The maximum accelerations and FRS from the stick model are evaluated considering the coupling effects between vertical and rocking and between lateral and torsion motions.

6. Application of Stick Model Results to Static FEM Analysis

In the current DCD design procedure, the maximum forces and moments from the stick model are applied to the static FEM analysis model. This methodology is exactly same as the RBFB. The adequacy of this methodology is confirmed by using the RBFB model. The results are described in the following report in detail.

- SER-ESB-043 Comparative Analysis between Seismic Stick Model and Static FEM Model for RBFB, Rev. 1

7. Conclusion

In view of the results obtained, it can be concluded that the stick model is consistent with the finite element model in predicting static and dynamic responses. The stick model adequacy is therefore confirmed.

Table 1 Total Reaction Force/Moment at Base

	Reaction Forces				
	Shear (MN)		Moment (MN·m)		Axial Force (MN)
	X-dir	Y-dir	X-dir	Y-dir	
Stick Model (DAC3N)	104	104	1181	1181	105
FEM (NASTRAN)	105	105	1142	1154	105

Table 2 Deflection at Top of Model

EL9.06m	Deflection (mm)		
	X-dir	Y-dir	Z-dir
Stick Model (DAC3N)	2.3	2.6	0.45
FEM (NASTRAN)	2.2	2.5	0.43

Table 3 Calculated First Mode Frequency

	Frequency (Hz)		
	X-dir	Y-dir	Z-dir
Stick Model (DAC3N)	10.3Hz	9.8Hz	23.6Hz
FEM (NASTRAN)	10.5Hz	10.0Hz	24.0Hz

Note: First mode frequency is calculated by the following equation from "Vibration Theory and Applications" William T. Thomson.

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta}}$$

where,

g : Gravity acceleration (9.807m/sec^2)

Δ: Static deflection at building top (m)

Table 4 Eigenvalue Analysis Results

(a) Stick Model (DAC3N)

Mode	Frequency	MODAL PARTICIPATION FACTORS						Note
		X	Y	Z	XX	YY	ZZ	
1	10.3	0.18	1.29	0.01	-186.88	43.03	-22.63	Y-dir 1st mode
2	10.9	1.25	-0.18	0.01	21.01	248.03	28.02	X-dir 1st mode
3	16.7	0.00	0.00	0.00	0.25	0.33	-44.43	Torsion 1st mode
4	25.0	-0.13	-0.11	1.02	-181.06	330.84	1.84	Z-dir 1st mode

(b) FE Model (NASTRAN)

Mode	Frequency	MODAL PARTICIPATION FACTORS						Note
		X	Y	Z	XX	YY	ZZ	
1	9.4	0.02	-2.85	0.01	19.32	0.03	-41.74	Y-dir 1st mode
2	10.1	-2.93	-0.02	0.00	0.09	-19.62	32.20	X-dir 1st mode
3	16.9	0.28	-0.01	0.00	0.08	1.51	-36.00	Torsion 1st mode
4	18.8	1.17	-0.08	0.00	-0.32	-7.34	-10.92	
5	19.1	0.11	0.87	0.00	3.65	-0.75	11.61	
6	21.7	0.47	-0.01	0.00	-0.07	-4.44	-5.53	
7	24.7	0.00	-0.04	0.25	3.80	-3.72	-0.62	
8	26.1	0.00	-0.04	3.01	35.02	-43.70	-0.40	Z-dir 1st mode

Table 5 Maximum Response Accelerations

Elevation	FEM (g)			Stick Model with Rotation (g)			Stick Model without Rotation (g)		
(m)	X	Y	Z	X	Y	Z	X	Y	Z
9.06	0.84	0.79	1.33	1.05	1.10	1.69	1.05	1.10	1.17
4.65	0.64	0.66	1.05	0.94	0.94	1.43	0.94	0.94	1.03
-2.00	0.53	0.62	0.62	0.84	0.81	0.84	0.84	0.80	0.67

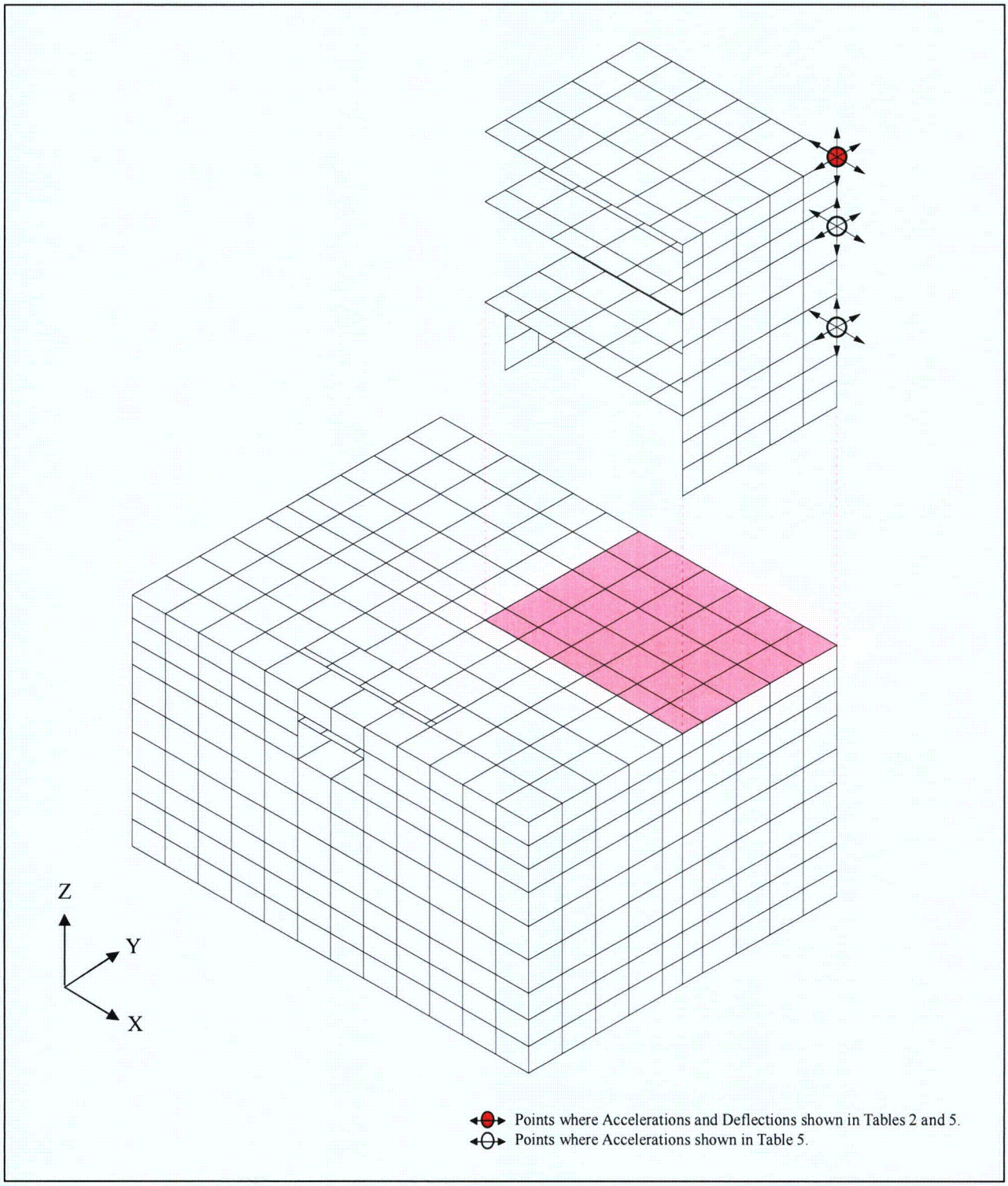


Figure 1 FEM Analysis Model

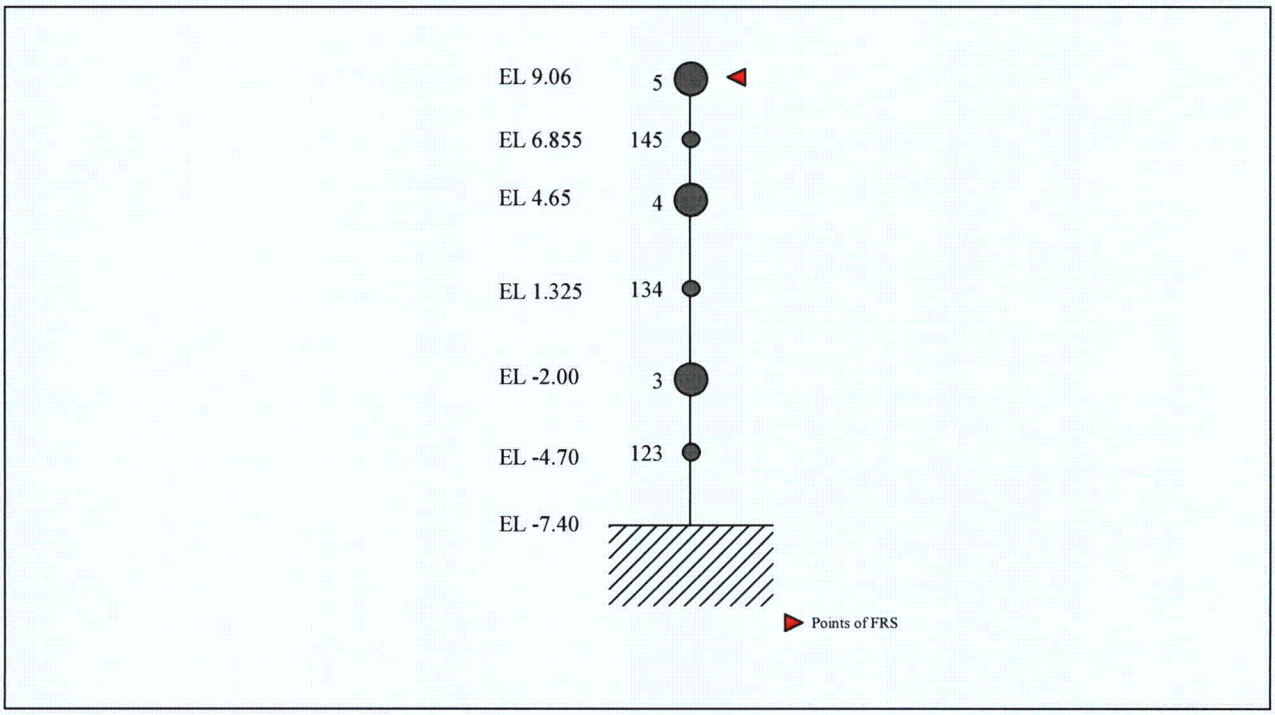
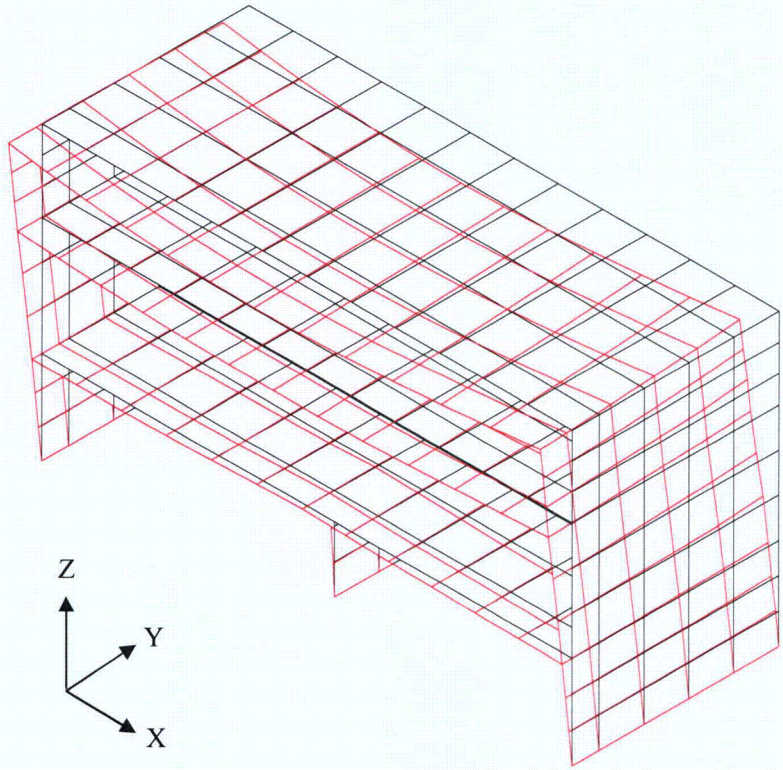


Figure 2 Seismic Stick Model



FEM 1st Mode (Y-dir)

Stick Mode 1st

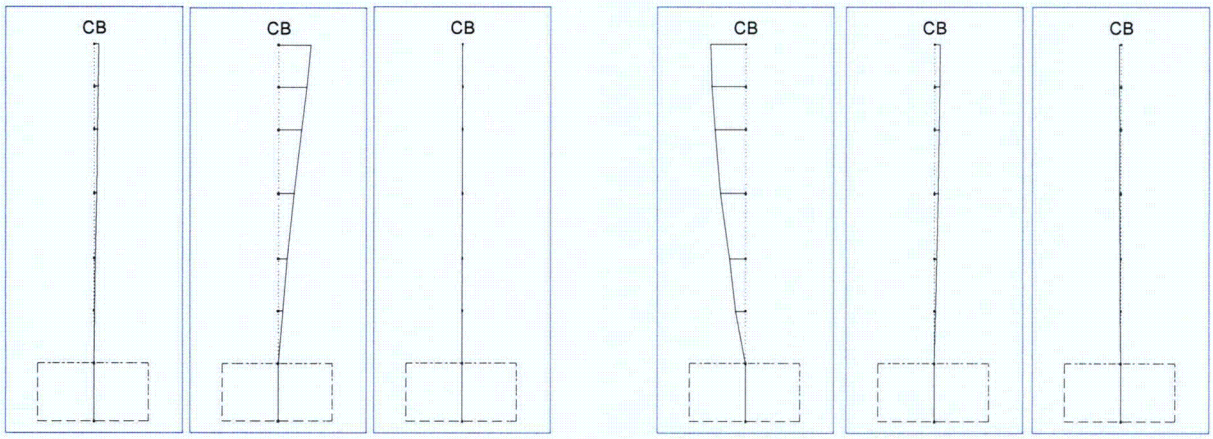
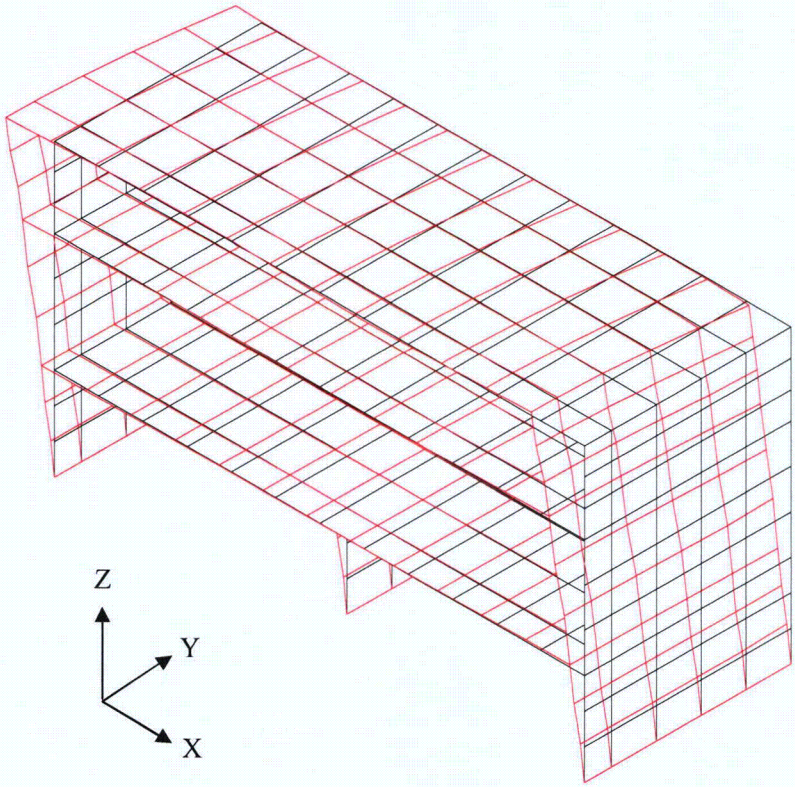


Figure 3 Mode Shape - Y direction 1st Mode



FEM 2nd Mode (X-dir)

Stick Mode 2nd

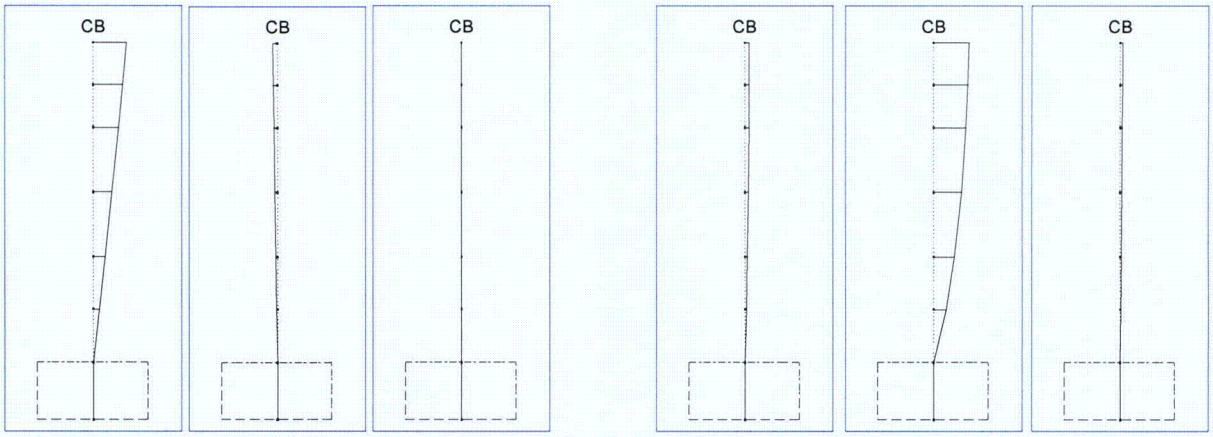
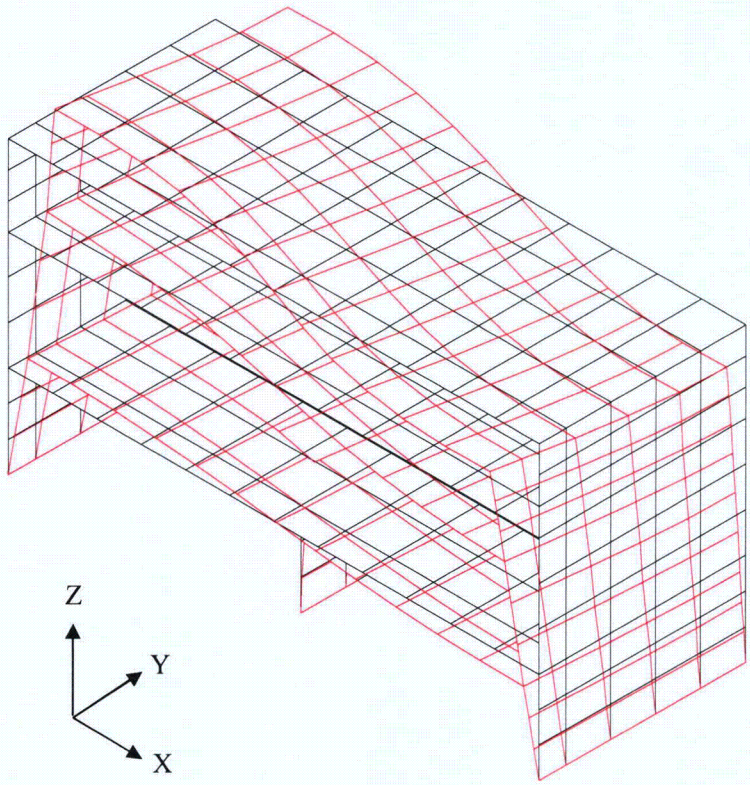
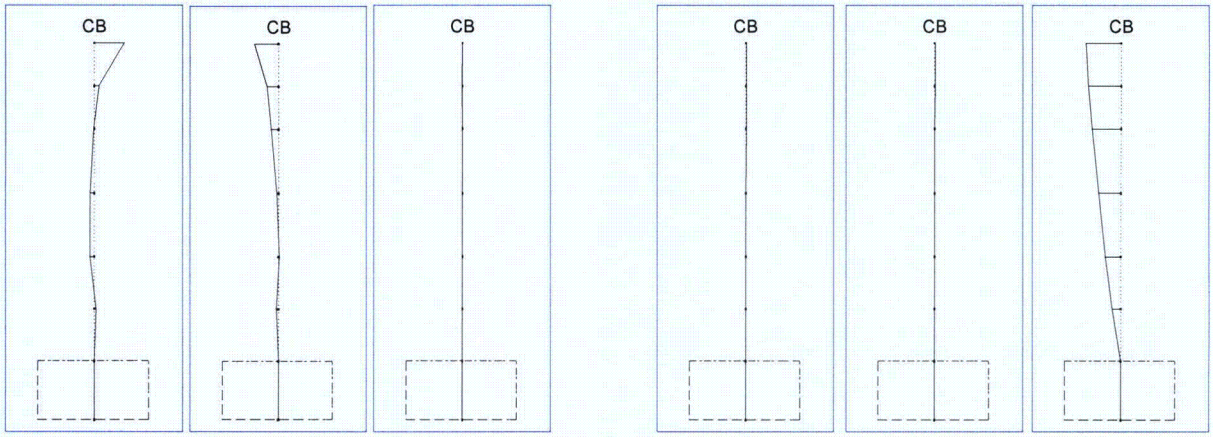


Figure 4 Mode Shape - X direction 1st Mode



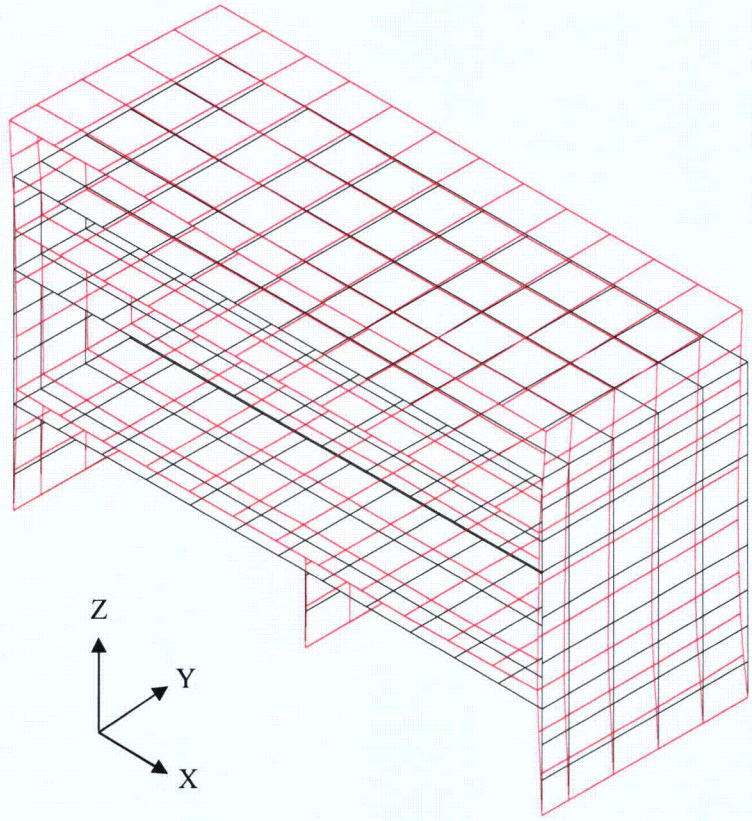
FEM 3rd Mode (ZZ-rot)

Stick Model 3rd



X-dir Y-dir Z-dir XX-rot YY-rot ZZ-rot

Figure 5 Mode Shape - Torsion 1st Mode



FEM 8th Mode (Z-dir)

Stick Model 4th

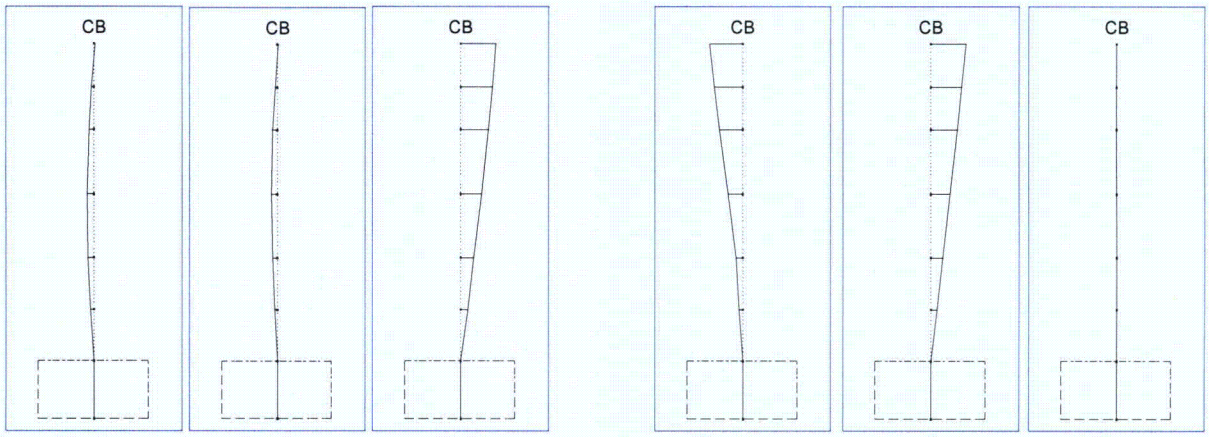


Figure 6 Mode Shape - Z direction 1st Mode

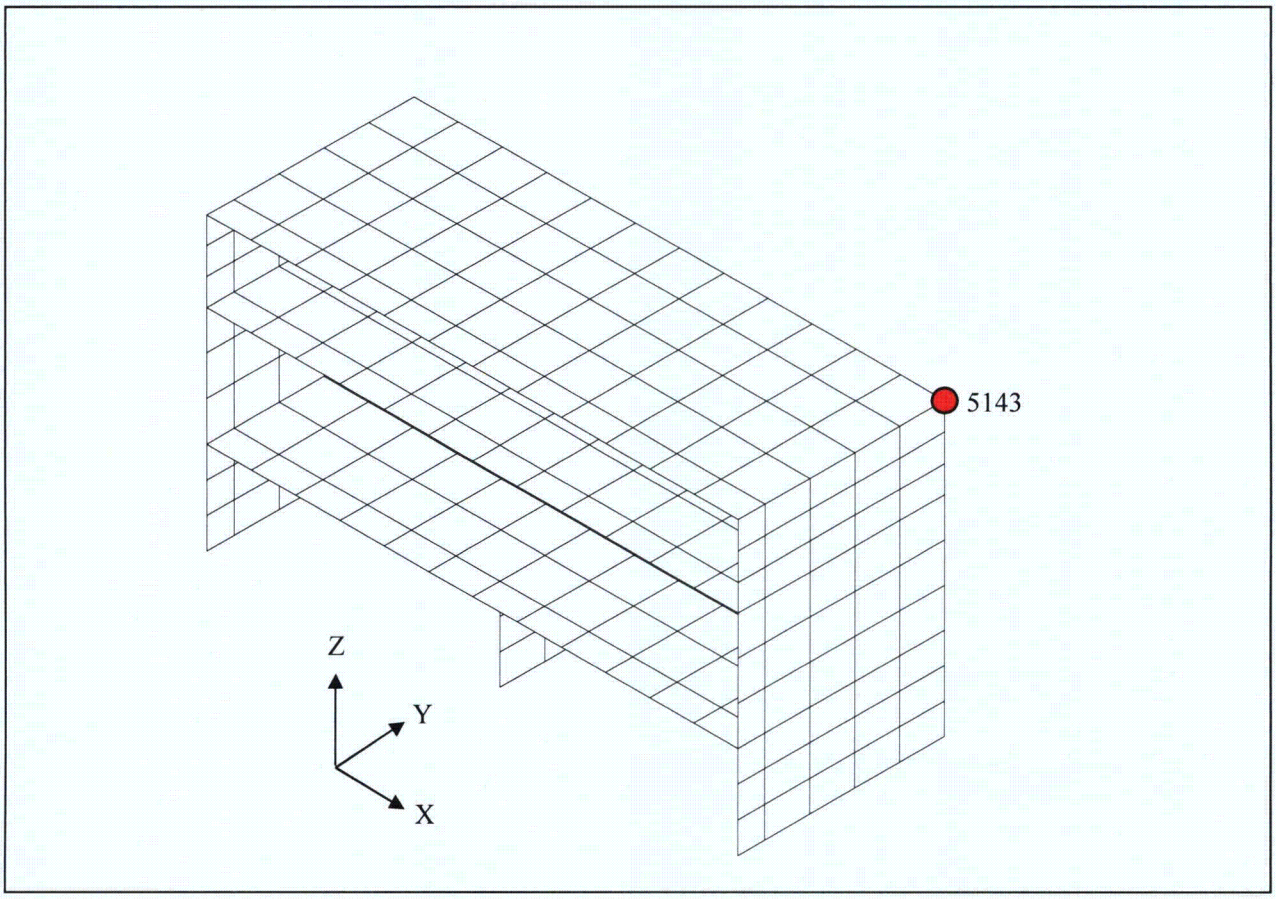


Figure 7 Selected Point for FRS

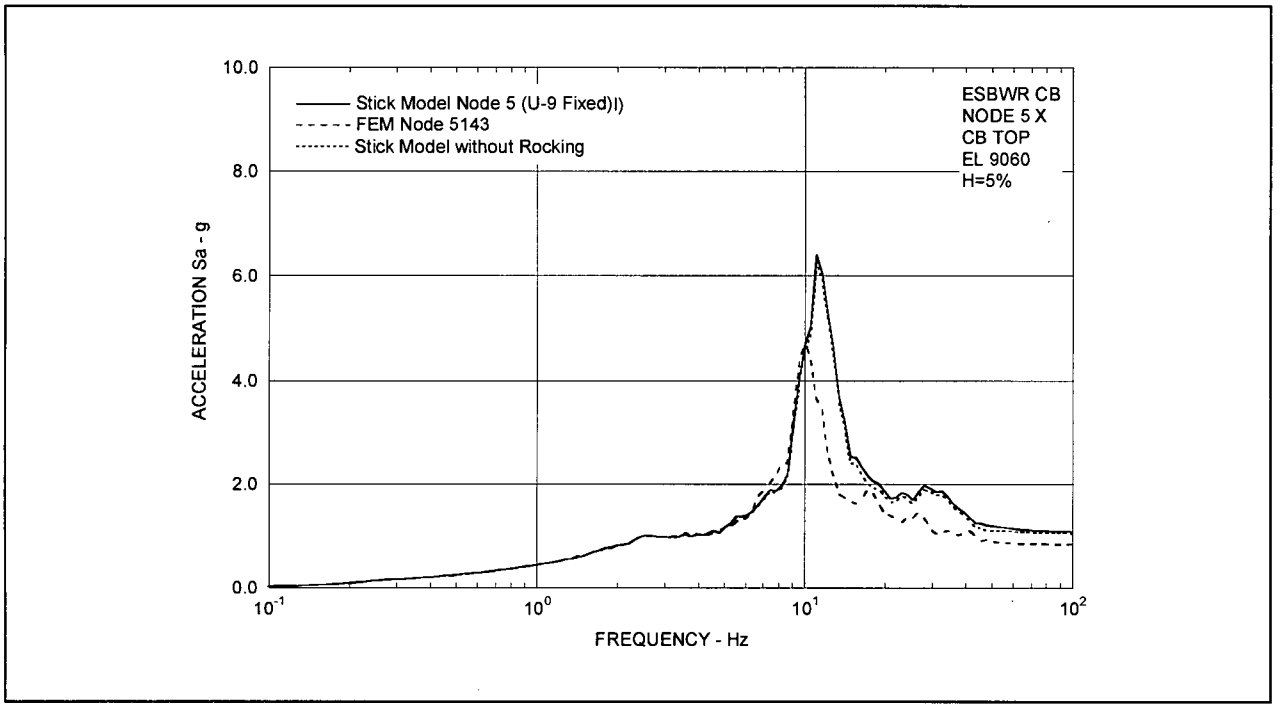


Figure 8 Response Spectra X-dir at EL9.06m

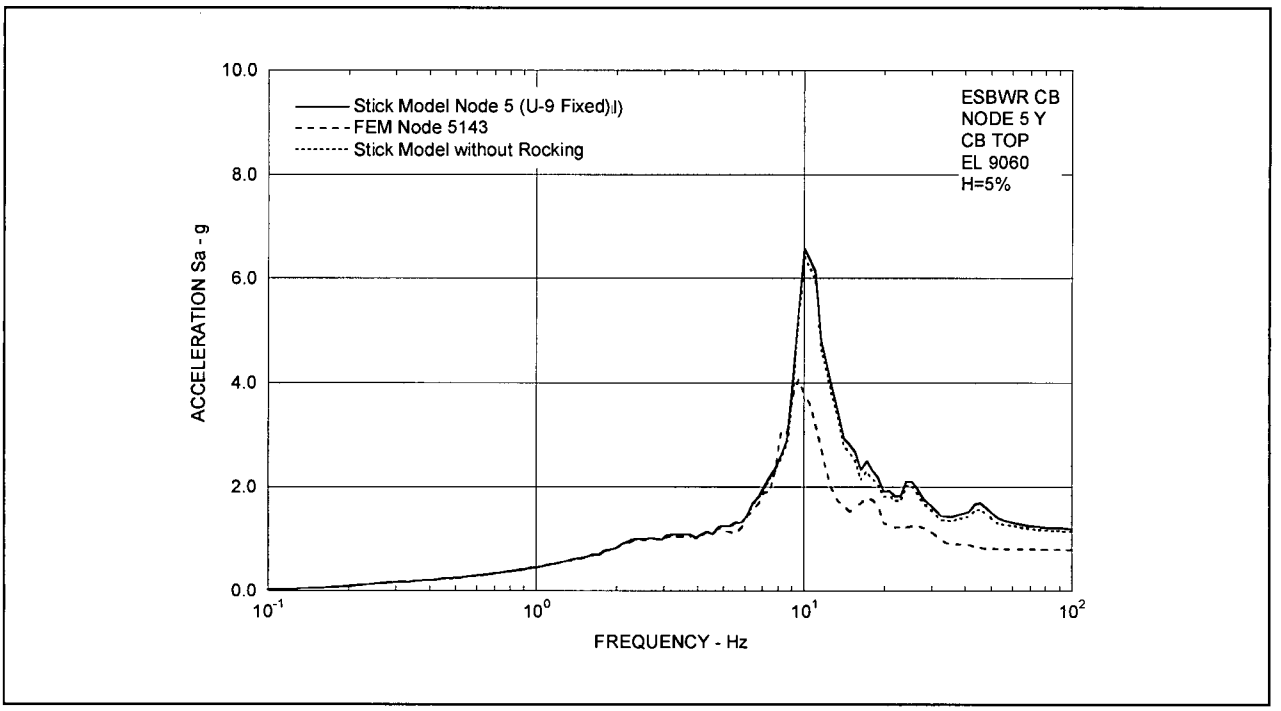


Figure 9 Response Spectra Y-dir at EL9.06m

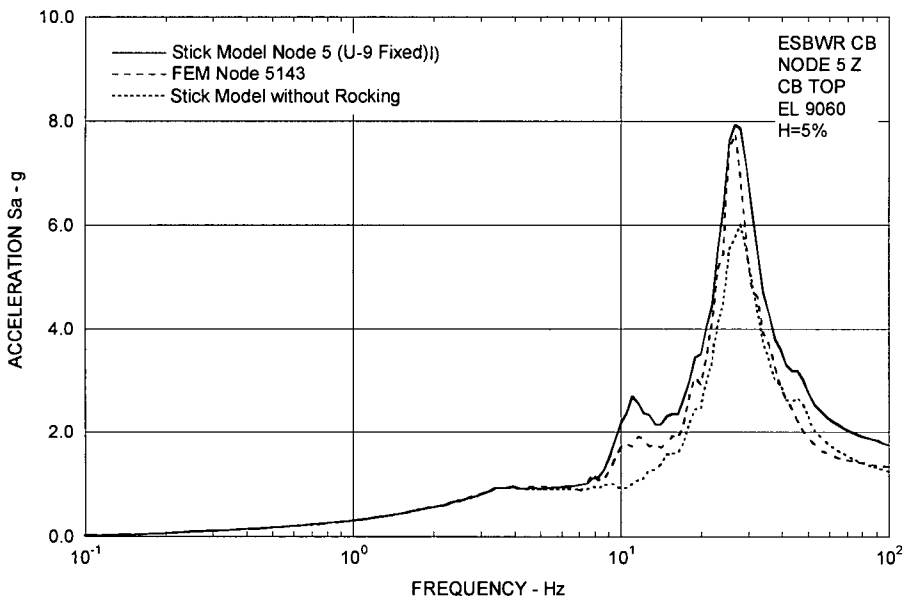


Figure 10 Response Spectra Z-dir at EL9.06m