Attachment 17
NRC3-13-0036

Sargent & Lundy Report SL-011956, Rev. 1
(85 pages)

DTE Electric Company
Fermi 3 – ESBWR

SSI Analyses of Reactor Building/Fuel Building and Control Building with Engineered Backfill Summary Report

SL-011956

Nuclear Safety-Related
Revision 1
December 10, 2013

Prepared by: Surendra Singh 12/10/2013

Reviewed by: Ming S. Yang 12/10/2013

Reviewed by James W. McIntyre 12/10/2013

Approved by: Javad Moslemian 12/10/2013

Sargent & Lundy LLC

Project No.: 12583-201

Table of Contents

List of Figures

Executive Summary

This report presents the summary of Fermi 3 Soil-Structure Interaction (SSI) analyses performed for the Reactor Building/Fuel Building (RB/FB) and Control Building (CB), with engineered backfill above the top of the Bass Islands Group bedrock. These SSI analyses address the related questions in (i) NRC Letter No. 77 (Reference 1), regarding the impact of the Central and Eastern United States (CEUS) Seismic Source Characterization (SSC) model for Fermi 3 Site; (ii) NRC RAI letter No. 79 (Reference 2), regarding previously submitted SSI analyses; and (iii) the April 2012 Audit Summary for the Fermi 3 Combined License Application Seismic Analysis (Reference 3).

The results from these analyses demonstrate that the in structure responses obtained from these analyses are bounded by the corresponding responses presented in ESBWR Design Control Document (Reference 4), with substantial margin. The lateral soil pressures have been calculated and the adequacy of the wall designs for the lateral soil pressures are evaluated in Report SL-012018, "Evaluation of Reactor Building/Fuel Building and Control Building Dynamic Bearing Capacity, Foundation Stability, and Wall Seismic Soil Pressures Summary Report".

1.0 Introduction

The scope of this report is to present the summary of Fermi 3 Soil-Structure Interaction (SSI) analyses performed for the Reactor Building/Fuel Building (RB/FB) and Control Building (CB), with engineered backfill above the top of the Bass Islands Group bedrock. These SSI analyses address the related questions in (i) NRC Letter No. 77 (Reference 1), regarding the impact of the Central and Eastern United States (CEUS) Seismic Source Characterization (SSC) model for Fermi 3 Site; (ii) NRC RAI letter No. 79 (Reference 2), regarding previously submitted SSI analyses; and (iii) the April 2012 Audit Summary for the Fermi 3 Combined License Application Seismic Analysis (Reference 3). The results from these analyses are used to demonstrate that the responses obtained from these analyses are bounded by the corresponding responses presented in the ESBWR Design Control Document (Reference 4).

2.0 SSI Models, Input Motions, and Method of Analyses

The following provides general descriptions of the RB/FB and CB SSI models, seismic input motions, and specific information regarding the method of analyses.

- The SSI models are prepared to be analyzed using SASSI2010 computer code (Reference 5).
- Each SSI model consists of two parts: (1) structural portion and (2) rock-engineered backfill (i.e., engineered backfill and the underlying bedrock) profile portion.
- The structural portion of each model is based on the verified ESBWR seismic model information provided in Reference 6.
- The foundation mat and exterior walls up to the grade elevation of the respective buildings are modeled by thin plate (shell) elements (same as in DCD model). The maximum aspect ratio of the shell elements is less than 3.0.
- The interior portions of the buildings and the exterior walls above grade are modeled by lumped mass beam (stick) model.
- Operating Basis Earthquake (OBE) damping values are used for the structural parts of the model.
- Two rock-engineered backfill profiles are used in the model; upper bound (UB) and lower bound (LB). These rock profile properties are based on Reference 7, which considers the impact of acceleration time histories based upon CEUS SSC model.
- The UB rock-engineered backfill layer thicknesses are adjusted to be capable of transmitting shear waves with a frequency of at least 50 Hz (thickness not greater than 20 percent of the corresponding layer shear wave length).
- The LB rock-engineered backfill layer thicknesses are kept the same as for the UB rock-engineered backfill layer.

- The excavated volume is from the bottom of the building basemat to the grade (top of the engineered backfill).
- Excavated volume is modeled using 8-node solid elements. To meet SASSI2010 (Reference 8) requirements, the maximum horizontal and vertical mesh dimensions in the excavated volume for the UB rock-engineered backfill profile are limited to less than 20% of the subsurface material (rock-engineered backfill) shear wave length at frequency of 50 Hz.
- The in-column acceleration time histories represent the SSI Foundation Input Response Spectra (FIRS) for the respective rock-engineered backfill profiles (UB and LB) are applied at the elevation of the bottom of each building's basemat. These time histories are from Reference 7 and include the impact of the CEUS SSC model. Input motions in the three directions of excitation are statistically independent (absolute value of correlation coefficient between each pair of motions does not exceed 0.16).
- The SSI analyses are performed using direct (flexible volume) method (DM) for CB and modified subtraction method (MSM) for RB/FB.
- The SSI analyses for the three directions of excitation are performed separately. The co-directional responses for the three directions of excitation are combined using either square root of sum of squares (SRSS) method or using algebraic sums in time domain. Both methods are acceptable per ESBWR DCD (Reference 4).

The details of the SSI models, input motions, and SSI analyses for the RB/FB and CB with engineered backfill are described in the following sections.

3.0 Reactor Building/Fuel Building (RB/FB)

3.1 Structure Model

Figure 3.1-1 presents a 3D view of the RB/FB structural model. The structural model of the RB/FB is obtained from Reference 6. The length and width of the building are 70 m and 49 m, respectively. The structural model consists of thin plate elements and 3D lumped mass beam (stick) elements. The basemat and the exterior walls up to the grade elevation are modeled with thin shell elements. The interior of the RB/FB, Reinforced Concrete Containment Vessel (RCCV), Pedestal, Vent Wall, Reactor Shield Wall (RSW), and Reactor Pressure Vessel (RPV) and its internals are modeled by lumped mass beam elements. The shell elements have an aspect ratio not greater than 1:2 and their dimensions satisfy the requirement of a minimum passing frequency of 50 Hz in both the horizontal and vertical directions. For calculating the lateral soil pressure on the exterior walls, the embedded portions of the exterior walls have double nodes connected by 3D rigid springs. One end of each spring is connected to the wall node

and the other to the adjacent engineered backfill/rock layer. The pairs of the double nodes at the same elevation have the same location coordinates.

The damping values of the structural elements in RB/FB (obtained from Reference 6) were changed to OBE damping. The OBE damping values for RPV and its internals are provided in Reference 9. For other structural elements, per Regulatory Guide 1.61 (Reference 10), OBE damping values of 4.0% and 3.0% are used for reinforced concrete elements and welded steel elements, respectively.

3.2 Site-Specific Rock-Engineered Backfill Model

Two rock-engineered backfill profiles are considered in the RB/FB model; upper bound (UB) and lower bound (LB). The properties for the UB and LB rock-engineered backfill profiles are obtained from Reference 7. The layer thicknesses for each rock-engineered backfill profile are adjusted as needed to match the SSI structural model geometry and to maintain a minimum shear wave passing frequency of 50 Hz for the UB profile. In case the adjusted layering covers two or more layers provided in Reference 7, the shear wave and compression wave velocities of the adjusted layer are determined using the equivalent wave travel time procedure and the unit weights and damping ratios are determined using thickness weighted average procedure. Tables 3.2-1 and 3.2-2 provide the UB, and LB rock-engineered backfill properties, respectively, used in the model.

The excavated volume is from the bottom of the basemat (Elevation -15.5 m) to the grade elevation (Elevation 4.5 m). The excavated volume is modeled using 8-node solid elements. To meet SASSI2010 requirements, the maximum horizontal and vertical mesh dimensions in the excavated volume are limited to less than 20% of the subsurface material (for the UB profile) shear wave length at frequency of 50 Hz.

3.3 SSI Method of Analysis

The SSI analysis is performed using SASSI2010 computer code (Reference 5). Modified Subtraction Method (MSM) is used for the analysis. The selection of the interaction nodes is based on the conclusions of the RB/FB Benchmark Summary Report (Reference 11). The excavated rock-engineered backfill volume nodes at the top surface (El. 4.5 m) and at El. -2.00 m are added as interaction nodes, in addition to the nodes at the side and bottom boundaries of the excavated rock-engineered backfill. Separate analyses are performed for each of the two horizontal directions and the vertical direction.

3.4 Seismic Input Motion

The seismic input motions corresponding to UB and LB rock-engineered backfill profiles and in two horizontal directions (X- and Y-directions) and the vertical direction

(Z-direction) are FIRS in-column motions at the bottom of the basemat (at Elevation -15.5 m). These time histories are from Reference 7 and include the impact of the CEUS SSC model. The horizontal direction time histories are specified as vertically propagating shear waves and the vertical direction time history is specified as a vertically propagating compression wave.

3.5 Analyses Response Results and Comparisons with DCD Responses

<u>Transfer Functions</u>

Transfer functions are calculated at the key locations of the RB/FB. The key locations are the locations where the DCD provides enveloped floor response spectra (FRS). The key locations are:

- RB/FB Basemat
- RB/FB Refueling Floor
- RCCV Top Slab
- Vent Wall Top
- RSW Top
- RPV Top

Figures 3.5-1 through 3.5-36 show both calculated and interpolated transfer functions. These transfer functions are generally smooth. There are few spikes in the interpolated transfer functions (see Figures 3.5-6, 3.5-7, 3.5-16, 3.5-22. 3.5-25 and 3.5-31). Occasionally, these spikes occur in the interpolated transfer functions due to the interpolation scheme built into the SASSI2010 program. To check the real value of transfer function at the frequency of the spike, a frequency is added for the calculation of the transfer function at the particular frequency of the spike. The spike disappears at the particular frequency of the spike; however, sometimes it reappears at another frequency close to the added frequency. These unnatural spikes in the interpolated transfer functions are easily recognizable by their sharpness, i.e., a vertical line (e.g., Figures 3.5-7, 3.5-16 and 3.5-22). Furthermore, these sharp and isolated spikes do not impact the seismic response as seen by the corresponding response spectra plots that do not have sharp peaks or show unreasonable behavior at those frequencies.

A review of the transfer functions shows that for RSW top node (Node 707) and RPV top node (Node 801), there is a significant coupling in the X-direction due to the excitation in the vertical Z-direction (Figures 3.5-15 and 3.5-18 for UB case, and Figures 3.5-33 and Figure 3.5-36 for LB case). This coupling is not exhibited in the Y-direction due to the vertical Z-direction excitation. The reason for this coupling is that in the XZ-plane, some parts of the RB/FB model have some eccentricity between the mass centers and the centers of the rigidity. Hence, the vertical excitation produces X-direction response due to the beam bending of the RSW and RPV sticks. In the YZ-plane, the eccentricity between the mass center and the center of rigidity is very small

as compared to the corresponding eccentricity in the XZ-plane. Hence, the Y-direction transfer function due to Z-direction excitation does not show the coupling. Figures 3A.7-1 through 3A.7.3 of the ESBWR DCD show the eccentricities of the mass center and the center of rigidity of various parts of the model in the XZ-plane and YZ-plane.

Floor Response Spectra (FRS)

Five percent (5%) damping FRS are calculated at the key locations of the RB/FB. Figures 3.5-37 through 3.5-54 show the comparisons of FRS calculated from the SSI analyses and the corresponding enveloped FRS provided in DCD. The comparisons show that DCD FRS bound the corresponding calculated FRS spectra by a considerable margin.

Maximum Absolute Accelerations

The enveloped maximum absolute vertical accelerations (envelop of the UB and LB rock profile cases) and their comparisons with the corresponding DCD values are presented in Tables 3.5-1 through 3.5-6. In general, the ratios between the calculated values to the corresponding DCD values are less than about 45%. The maximum ratio is about 61%, for oscillator 9072 (Table 3.5-5).

Maximum Beam Forces and Moments

The enveloping beam forces and moments (envelop of the UB and LB rock profile cases) and their comparisons with the corresponding DCD values are presented in Tables 3.5-7 through 3.5-12. The maximum ratio with DCD is about 74% (Table 3.5-12).

Maximum Lateral Soil Pressures on Walls

The variation of lateral soil pressures on walls are shown in Figures 3.5-55 through 3.5-58.

Lateral soil pressures shown in Figures 3.5-55 through 3.5-58 exceed the lateral soil pressures shown in Figures 3A.8.8-1and 3A.8.8-2 in DCD (from El. -15.5 m to El. -5.50 m). The adequacy of the wall designs for the lateral soil pressures are evaluated in Report SL-012018, "Evaluation of Reactor Building/Fuel Building and Control Building Dynamic Bearing Capacity, Foundation Stability, and Wall Seismic Soil Pressures Summary Report".

4.0 Control Building (CB)

4.1 Structure Model

Figure 4.1-1 presents a 3D view of the CB structural model. The structural model of the CB is obtained from Reference 6. The length (north-south direction) and the width (east-west direction) of the building are 30.3 m and 23.8 m, respectively. The structural model consists of thin plate elements and 3D lumped mass beam (stick) elements. The basemat and the exterior walls up to the grade elevation are modeled with thin shell elements. The interior of the CB is modeled by lumped mass beam elements. The shell elements have an aspect ratio not greater than 1:2.7 and their dimensions satisfy the requirement of a minimum passing frequency of 50 Hz in each direction. For calculating the lateral soil pressure on the exterior walls, the embedded portions of the exterior walls have double nodes connected by 3D rigid springs. One end of each spring is connected to the wall node and the other to the adjacent engineered backfill/rock layer. The pairs of the double nodes at the same elevation have the same location coordinates.

The damping values of the structural elements in CB (obtained from Reference 6) were changed to an OBE damping value of 4% (for reinforced concrete per Regulatory Guide 1.61 (Reference 10)).

4.2 Site-Specific Rock-Engineered Backfill Model

Two rock-engineered backfill profiles are considered in the CB model; upper bound (UB) and lower bound (LB). The properties for the UB and LB rock-engineered backfill profiles are obtained from Reference 7. The layer thicknesses for each profile are adjusted as needed to match the SSI structural model geometry, and maintaining a minimum shear wave passing frequency of 50 Hz. In case the adjusted layering covers two or more layers provided in Reference 7, the shear wave and compression wave velocities of the adjusted layer are determined using the equivalent wave travel time procedure and the unit weights and damping ratios are determined using thickness weighted average procedure. Tables 4.2-1 and 4.2-2 provide the UB and LB rock properties, respectively, used in the model.

The excavation volume is from the bottom of the basemat (Elevation -10.40 m) to the top of the engineered backfill (Elevation 4.5 m). The excavated volume is modeled using 8-node solid elements. To meet SASSI2010 requirements, the maximum horizontal and vertical mesh dimensions in the excavated volume are limited to less than 20% of the UB subsurface material shear wave length at frequency of 50 Hz.

4.3 SSI Method of Analysis

The SSI analysis is performed using SASSI2010 computer code (Reference 5). Direct Method (DM) is used for the analysis. All nodes in the excavated volume are interaction nodes. Separate analyses are performed for each of the two horizontal directions and the vertical direction.

4.4 Seismic Input Motion

The seismic input motions corresponding to UB and LB rock profiles and in two horizontal directions (X- and Y-directions) and the vertical direction (Z-direction) are FIRS in-column motions at the bottom of the basemat (at Elevation -10.40 m). These time histories are from Reference 7 and include the impact of the CEUS SSC Model. The horizontal direction time histories are specified as vertically propagating shear waves and the vertical direction time history is specified as a vertically propagating compression wave.

4.5 Analyses Response Results and Comparisons with DCD Responses

Transfer Functions

Transfer functions are calculated at the key locations of CB. The key locations are the locations where the DCD provides enveloped floor response spectra (FRS). The key locations are:

- CB Top of Foundation
- CB Roof

Figures 4.5-1 through 4.5-12 show both calculated and interpolated transfer functions. All transfer functions are smooth and reasonable.

Floor Response Spectra (FRS)

Five percent (5%) damping FRS are calculated at the key locations of the CB. Figures 4.5-13 through 4.5-18 show the comparisons of FRS calculated from the SSI analyses and the corresponding enveloped FRS provided in DCD. The comparisons show that DCD FRS bound the corresponding calculated FRS spectra by a considerable margin.

Maximum Absolute Accelerations

The enveloped maximum absolute vertical accelerations (envelop of UB and LB rock profile cases) and their comparisons with the corresponding DCD values are presented in Table 4.5-1. In CB stick, the maximum ratio with the DCD is 39% and for oscillators the maximum ratio with DCD is 61% (Oscillator Node 9003).

Maximum Beam Forces and Moments

The enveloping beam forces and moments (envelop of UB and LB rock profile cases) and their comparisons with the corresponding DCD values are presented in Table 4.5-2. The maximum ratio with DCD is about 63%.

Maximum Lateral Soil Pressures on Walls

The variation of lateral soil pressures on walls are shown in Figures 4.5-19 through 4.5-22.

The lateral soil pressures on the walls obtained from the SSI analyses are in general enveloped by the lateral pressures shown in Figures 3A.8.8-3 and 3A.8.8-4 of DCD, by a large margin. Only exceptions are a small area just above the top of the base mat (where the soil pressure from SSI analyses exceed the DCD pressure by about 8%); and in the bottom half of the basemat. The adequacy of the wall designs for the lateral soil pressures are evaluated in Report SL-012018, "Evaluation of Reactor Building/Fuel Building and Control Building Dynamic Bearing Capacity, Foundation Stability, and Wall Seismic Soil Pressures Summary Report".

5.0 Conclusion

This report presents the summary of Fermi 3 Soil-Structure Interaction (SSI) analyses performed for the Reactor Building/Fuel Building (RB/FB) and Control Building (CB), with engineered backfill above the top of the Bass Islands Group bedrock. These SSI analyses address the related questions in (i) NRC Letter No. 77 (Reference 1), regarding the impact of the Central and Eastern United States (CEUS) Seismic Source Characterization (SSC) model for Fermi 3 Site; (ii) NRC RAI letter No. 79 (Reference 2), regarding previously submitted SSI analyses; and (iii) the April 2012 Audit Summary for the Fermi 3 Combined License Application Seismic Analysis (Reference 3).

The results from these analyses demonstrate that the in structure responses obtained from these analyses are bounded by the corresponding responses presented in ESBWR Design Control Document (Reference 4), with substantial margin. The lateral soil pressures have been calculated and the adequacy of the wall designs for the lateral soil pressures are evaluated in Report SL-012018, "Evaluation of Reactor Building/Fuel Building and Control Building Dynamic Bearing Capacity, Foundation Stability, and Wall Seismic Soil Pressures Summary Report".

6.0 References

1. Letter from Jerry Hale (USNRC) to Jack M. Davis (Detroit Edison), "Request for Additional Information Letter No. 77 Related to Chapter 1.05 for the Fermi 3 Combined License Application," dated May 17, 2012.

2. Letter from Tekia Govan (USNRC) to Peter W. Smith (Detroit Edison), "Request for Additional Information Letter No. 79 Related to Chapters 03.07.02 and 13.03 for the Fermi 3 Combined License Application," dated August 7, 2012.

3. Letter from Tekia Govan (USNRC) to Peter W. Smith (Detroit Edison), "Audit Summary April 2012 for the Fermi 3 Combined License Application Seismic Analysis," dated July 27, 2012.

4. ESBWR Design Control Document, Tier 2, Revision 9, December 2010.

5. SASSI2010, S&L Program No. 03.7.316-1.0-250USER-M01 Type 2 Status O.

6. DTE Electric Company Letter No. 2012-MEP-F3COLA-0083, "Transmittal of Verified ESBWR Seismic Model Information," 12/10/2012; Document no: SZGESR312052a2_SER-DTF-010_A.geh proprietary information class II (internal); Document Title: SER-DTF-010 Appendix A RB/FB Complex SASSI House Data for Model native File; Transmittal Letter: GEDT-KH2-2012-0057-R1, dated 12/10/12.

7. DTE Electric Company Letter No. 2013-MEP-F3COLA-0021, "Soil Profile and Acceleration Time Histories Based Upon the Central and Eastern United States Seismic Source Characterization Model," February 14, 2013.

8. SASSI2010 Version 1.0 User's Manual, "A System for Analysis of Soil-Structure Interaction," Farhang Ostadan and Nan Deng, May 2012.

9. DTE Electric Company Letter No. 2013-MEP-F3COLA-0002, dated January 3, 2013, Attachment 1, "GEH Letter GEDT-KH2-2013-0002," Jan 3 2013; Transmittal of TODI LC1-3-A25-TDI-5008 revision 0.

10. NRC Regulatory Guide 1.61, Rev 1, "Damping Values for Seismic Design of Nuclear Power Plants".

11. DTE Electric Company, Fermi 3 – ESBWR, "Modified Subtraction Method (MSM) Reactor Building/Fuel Building Benchmark Summary Report," SL-011814, Rev. 0, May 2, 2013.

Table 3.2- 1: Upper Bound (UB) rock-engineered backfill properties for SASSI analysis of the RB/FB

Layer No.	Thickness (m)	Top Elevation (m)	Unit Weight (tonnef/m)	S-Wave Velocity (m/s)	P-Wave Velocity (m/s)	Damping Ratio (%)	S-Wave Passing Frequency (Hz)	P-Wave Passing Frequency (Hz)
1	0.88	4.50	2.34	228.60	427.67	2.26	51.95	97.20
2	0.88	3.62	2.34	228.60	427.67	3.63	51.95	97.20
3	0.89	2.74	2.34	228.60	427.67	4.73	51.37	96.11
4	0.91	1.85	2.34	233.06	435.96	4.87	51.22	95.82
5	0.94	0.94	2.34	244.80	665.96	5.14	52.08	141.69
6	1.00	0.00	2.34	258.08	1316.01	5.50	51.62	263.20
7	1.00	-1.00	2.34	270.91	1377.74	4.91	54.18	275.55
8	1.10	-2.00	2.34	288.34	1459.99	3.94	52.43	265.45
9	1.10	-3.10	2.34	311.88	1459.99	3.89	56.71	265.45
10	1.10	-4.20	2.34	313.78	1459.99	3.99	57.05	265.45
11	1.10	-5.30	2.34	332.51	1459.99	3.87	60.46	265.45
12	2.00	-6.40	2.38	909.98	2952.97	1.40	91.00	295.30
13	2.00	-8.40	2.40	2448.75	4861.51	0.50	244.87	486.15
14	1.10	-10.40	2.40	2505.46	4973.86	0.50	455.54	904.34
15	2.00	-11.50	2.40	2508.33	4979.58	0.50	250.83	497.96
16	2.00	-13.50	2.40	2516.12	4995.12	0.50	251.61	499.51
17	0.63	-15.50	2.40	2496.01	4955.40	0.50	792.38	1573.14
18	2.96	-16.13	2.40	2485.34	4933.98	0.50	167.93	333.38
19	3.38	-19.09	2.40	2460.96	4885.66	0.50	145.62	289.09
20	3.66	-22.47	2.40	2449.07	4861.73	0.50	133.83	265.67
21	3.69	-26.13	2.40	2463.70	4890.93	0.50	133.53	265.09
22	3.20	-29.82	2.40	1707.18	3649.96	0.71	106.70	228.12
23	3.20	-33.02	2.40	1430.85	3250.89	0.85	89.43	203.18
24	3.20	-36.22	2.40	1276.20	3004.93	0.95	79.76	187.81
25	3.20	-39.42	2.40	1284.71	3025.44	0.95	80.29	189.09
26	3.20	-42.62	2.40	1289.61	3037.23	0.95	80.60	189.83
27	3.20	-45.82	2.40	1271.69	2994.97	0.95	79.48	187.19
28	3.20	-49.02	2.40	1265.22	2979.73	0.95	79.08	186.23
29	3.20	-52.22	2.40	1319.79	3108.00	0.95	82.49	194.25
30	3.20	-55.42	2.40	1331.98	3136.64	0.95	83.25	196.04
31	3.20	-58.62	2.40	1531.62	3606.83	0.95	95.73	225.43
32	3.20	-61.82	2.40	1581.91	3725.28	0.95	98.87	232.83
33	3.20	-65.02	2.40	1599.47	3766.40	0.95	99.97	235.40
34	3.20	-68.22	2.40	1603.25	3775.24	0.95	100.20	235.95
35	3.67	-71.42	2.40	1979.00	4173.35	0.46	107.85	227.43
36	6.16	-75.09	2.40	3532.33	6608.32	0.37	114.69	214.56
37	6.40	-81.25	2.40	3521.05	6587.02	0.37	110.03	205.84
38	6.40	-87.65	2.40	3549.09	6639.68	0.37	110.91	207.49
39	6.19	-94.05	2.40	3481.12	6512.44	0.37	112.48	210.42
40	6.86	-100.24	2.56	3343.05	6047.91	0.37	97.46	176.32
41	6.86	-107.10	2.56	3343.05	6047.91	0.37	97.46	176.32
42	6.89	-113.96	2.56	3351.58	6063.38	0.37	97.29	176.01
43	6.89	-120.85	2.56	3351.58	6063.38	0.37	97.29	176.01
44	7.50	-127.74	2.70	3401.87	6255.34	0.10	90.72	166.81
45	7.50	-135.24	2.70	3401.87	6255.34	0.10	90.72	166.81
46	7.50	-142.74	2.70	3401.87	6255.34	0.10	90.72	166.81
47	7.50	-150.24	2.70	3401.87	6255.34	0.10	90.72	166.81
-	halfspace	-157.74	2.70	3401.87	6255.34	0.10	-	-

Table 3.2- 2: Lower Bound (LB) rock-engineered backfill properties for SASSI analysis of the RB/FB

Layer No.	Thickness (m)	Top Elevation (m)	Unit Weight (tonnef/m)	S-Wave Velocity (m/s)	P-Wave Velocity (m/s)	Damping Ratio (%)	S-Wave Passing Frequency (Hz)	P-Wave Passing Frequency (Hz)
1	0.88	4.50	1.90	103.94	194.46	6.22	23.62	44.20
2	0.88	3.62	1.90	111.25	208.14	10.26	25.28	47.30
3	0.89	2.74	1.90	96.32	180.36	12.78	21.64	40.53
4	0.91	1.85	1.90	94.19	176.43	13.28	20.70	38.78
5	0.94	0.94	1.90	95.97	261.36	13.59	20.42	55.61
6	1.00	0.00	1.90	92.61	472.21	13.83	18.52	94.44
7	1.00	-1.00	1.90	97.70	497.92	13.29	19.54	99.58
8	1.10	-2.00	1.90	110.95	565.09	12.35	20.17	102.74
9	1.10	-3.10	1.90	118.19	602.96	12.24	21.49	109.63
10	1.10	-4.20	1.90	123.32	628.54	12.12	22.42	114.28
11	1.10	-5.30	1.90	130.61	665.83	11.85	23.75	121.06
12	2.00	-6.40	2.26	397.32	1584.41	4.51	39.73	158.44
13	2.00	-8.40	2.40	1632.57	3241.00	1.77	163.26	324.10
14	1.10	-10.40	2.40	1670.30	3315.90	1.77	303.69	602.89
15	2.00	-11.50	2.40	1672.19	3319.72	1.77	167.22	331.97
16	2.00	-13.50	2.40	1677.25	3329.95	1.77	167.73	333.00
17	0.63	-15.50	2.40	1664.21	3303.60	1.77	528.32	1048.76
18	2.96	-16.13	2.40	1656.89	3289.32	1.77	111.95	222.25
19	3.38	-19.09	2.40	1640.74	3257.11	1.77	97.09	192.73
20	3.66	-22.47	2.40	1632.51	3241.15	1.77	89.21	177.11
21	3.69	-26.13	2.40	1642.57	3260.62	1.77	89.03	176.73
22	3.20	-29.82	2.40	1138.12	2433.30	2.43	71.13	152.08
23	3.20	-33.02	2.40	951.19	2161.34	2.77	59.45	135.08
24	3.20	-36.22	2.40	847.04	1994.46	3.03	52.94	124.65
25	3.20	-39.42	2.40	849.75	2000.85	3.03	53.11	125.05
26	3.20	-42.62	2.40	851.31	2004.51	3.03	53.21	125.28
27	3.20	-45.82	2.40	845.72	1991.30	3.03	52.86	124.46
28	3.20	-49.02	2.40	843.69	1986.49	3.03	52.73	124.16
29	3.20	-52.22	2.40	831.07	1956.81	3.03	51.94	122.30
30	3.20	-55.42	2.40	828.45	1950.62	3.03	51.78	121.91
31	3.20	-58.62	2.40	958.73	2257.64	3.03	59.92	141.10
32	3.20	-61.82	2.40	991.82	2335.61	3.03	61.99	145.98
33	3.20	-65.02	2.40	996.59	2347.03	3.03	62.29	146.69
34	3.20	-68.22	2.40	997.61	2349.47	3.03	62.35	146.84
35	3.67	-71.42	2.40	1300.91	2747.45	1.56	70.89	149.72
36	6.16	-75.09	2.40	2354.88	4405.55	1.28	76.46	143.04
37	6.40	-81.25	2.40	2347.26	4391.35	1.28	73.35	137.23
38	6.40	-87.65	2.40	2366.16	4426.45	1.28	73.94	138.33
39	6.19	-94.05	2.40	2320.75	4341.62	1.28	74.98	140.28
40	6.86	-100.24	2.56	2228.70	4031.94	1.28	64.98	117.55
41	6.86	-107.10	2.56	2228.70	4031.94	1.28	64.98	117.55
42	6.89	-113.96	2.56	2234.49	4042.25	1.28	64.86	117.34
43	6.89	-120.85	2.56	2234.49	4042.25	1.28	64.86	117.34
44	7.50	-127.74	2.70	2268.02	4170.23	0.10	60.48	111.21
45	7.50	-135.24	2.70	2268.02	4170.23	0.10	60.48	111.21
46	7.50	-142.74	2.70	2268.02	4170.23	0.10	60.48	111.21
47	7.50	-150.24	2.70	2268.02	4170.23	0.10	60.48	111.21
-	halfspace	-157.74	2.70	2268.02	4170.23	0.10	-	-

Table 3.5- 1: RB/FB enveloping (UB and LB) maximum vertical accelerations

Elevation (m)	DCD Node No.	Stick Model	SASSI maximum vertical acceleration (g)	DCD maximum vertical acceleration (g)	Maximum vertical acceleration ratio (SASSI / DCD)
52.40	110	RB/FB	0.42	1.27	32.95%
34.00	109	RB/FB	0.34	0.83	40.86%
27.00	108	RB/FB	0.31	0.73	42.34%
22.50	107	RB/FB	0.27	0.73	37.65%
17.50	106	RB/FB	0.24	0.73	33.43%
13.57	105	RB/FB	0.25	0.74	33.96%
9.06	104	RB/FB	0.26	0.73	35.19%
4.65	103	RB/FB	0.25	0.78	31.81%
-1.00	102	RB/FB	0.23	0.76	29.72%
-6.40	101	RB/FB	0.22	0.68	31.89%
-11.50	2	RB/FB	0.20	0.63	31.07%
-15.50	1	RB/FB	0.20	0.51	38.49%

Table 3.5- 2: RB/FB enveloping (UB and LB) maximum vertical acceleration: RCCV

Elevation (m)	DCD Node No.	Stick Model	SASSI maximum vertical acceleration (g)	DCD maximum vertical acceleration (g)	Maximum vertical acceleration ratio (SASSI / DCD)
34.00	209	RCCV	0.34	0.90	37.59%
27.00	208	RCCV	0.33	0.88	37.23%
17.50	206	RCCV	0.26	0.73	35.85%
13.57	205	RCCV	0.25	0.78	31.53%
9.06	204	RCCV	0.23	0.65	34.73%
4.65	203	RCCV	0.21	0.70	30.22%
-1.00	202	RCCV	0.20	0.59	33.34%
-6.40	201	RCCV	0.19	0.59	32.13%

Table 3.5- 3: RB/FB enveloping (UB and LB) maximum vertical acceleration: Vent Wall /Pedestal

Elevation (m)	DCD Node No.	Stick Model	SASSI maximum vertical acceleration (g)	DCD maximum vertical acceleration (g)	Maximum vertical acceleration ratio (SASSI / DCD)
17.50	701	VW	0.27	1.10	24.64%
14.50	702	VW	0.27	1.04	26.05%
11.50	703	VW	0.27	0.92	29.07%
8.50	704	VW	0.28	0.77	35.90%
7.4625	705	VW	0.28	0.70	39.81%
4.65	706, 303	Pedestal	0.26	0.67	38.50%
2.4165	377	Pedestal	0.23	0.64	36.57%
-1.00	302	Pedestal	0.20	0.59	33.52%
-2.753	376	Pedestal	0.19	0.51	37.99%
-6.40	301	Pedestal	0.19	0.50	37.89%

Table 3.5- 4: RB/FB enveloping (UB and LB) maximum vertical acceleration: RSW

Elevation (m)	DCD Node No.	Stick Model	SASSI maximum vertical acceleration (g)	DCD maximum vertical acceleration (g)	Maximum vertical acceleration ratio (SASSI / DCD)
24.18	707	RSW	0.35	0.97	35.83%
20.20	708	RSW	0.34	0.94	36.55%
15.775	709	RSW	0.33	0.84	38.97%
11.35	710	RSW	0.30	0.76	39.87%
7.4625	711	RSW	0.28	0.70	39.83%
4.65	712	RSW	0.26	0.67	38.49%
2.4615	713	RSW	0.23	0.64	36.59%
1.96	714	RSW	0.23	0.64	36.64%
-0.80	715	RSW	0.24	0.65	36.29%

Table 3.5- 5: RB/FB enveloping (UB and LB) maximum vertical acceleration: RB/FB slab oscillators (Elevations 17.50 m to 52.40 m)

Elevation (m)	DCD Node No.	Stick Model	SASSI maximum vertical acceleration (g)	DCD maximum vertical acceleration (g)	Maximum vertical acceleration ratio (SASSI / DCD)
52.40	9101	Oscillator	0.45	1.20	37.12%
	9102	Oscillator	0.73	1.82	39.98%
	9103	Oscillator	1.46	3.14	46.57%
	9104	Oscillator	1.15	2.45	46.99%
	9105	Oscillator	0.80	2.32	34.57%
	9106	Oscillator	1.37	2.99	45.71%
	9107	Oscillator	1.03	2.80	36.85%
	9108	Oscillator	0.72	2.61	27.60%
34.00	9091	Oscillator	0.50	1.29	38.49%
	9092	Oscillator	0.42	1.08	39.08%
27.00	9081	Oscillator	0.46	1.16	39.27%
	9082	Oscillator	0.43	0.99	43.25%
	9083	Oscillator	0.39	1.09	36.04%
	9084	Oscillator	0.43	1.32	32.65%
	9085	Oscillator	0.37	0.97	37.68%
22.50	9071	Oscillator	0.63	1.60	39.08%
	9072	Oscillator	0.80	1.31	61.20%
	9073	Oscillator	0.93	2.03	45.72%
	9074	Oscillator	0.59	1.31	44.70%
	9075	Oscillator	0.50	1.16	43.04%
17.50	9061	Oscillator	0.75	1.79	41.99%
	9062	Oscillator	0.86	1.49	58.01%
	9063	Oscillator	0.36	0.82	43.97%
	9064	Oscillator	0.83	1.84	45.01%
	9065	Oscillator	0.40	1.42	28.17%

Table 3.5- 6: RB/FB enveloping (UB and LB) maximum vertical acceleration: RB/FB slab oscillators (Elevations -6.40 m to 13.57 m)

Elevation (m)	DCD Node No.	Stick Model	SASSI maximum vertical acceleration (g)	DCD maximum vertical acceleration (g)	Maximum vertical acceleration ratio (SASSI / DCD)
13.57	9051	Oscillator	0.34	0.81	42.53%
	9052	Oscillator	0.42	1.46	29.01%
9.06	9041	Oscillator	0.30	0.88	34.37%
	9042	Oscillator	0.47	1.42	33.09%
4.65	9031	Oscillator	0.68	1.17	57.72%
	9032	Oscillator	0.36	0.97	36.98%
	9033	Oscillator	0.50	1.02	48.98%
	9034	Oscillator	0.64	1.51	42.31%
	9035	Oscillator	0.38	1.38	27.57%
-1.00	9021	Oscillator	0.51	1.12	45.60%
	9022	Oscillator	0.72	1.45	49.55%
	9023	Oscillator	0.42	1.01	41.57%
	9024	Oscillator	0.42	0.89	46.66%
	9025	Oscillator	0.45	1.34	33.70%
	9026	Oscillator	0.57	1.57	36.33%
	9027	Oscillator	0.28	0.88	31.68%
-6.40	9011	Oscillator	0.42	0.92	45.24%
	9012	Oscillator	0.47	0.92	50.55%
	9013	Oscillator	0.54	1.35	39.79%

Table 3.5- 7: RB/FB maximum enveloping (UB and LB) seismic forces and moments: RB/FB
(a) Maximum enveloping seismic forces and moments

Elev. (m)	Element No.	DCD Node No.	Shear force (MN)		Bending moment (MN-m)		Torsion (MN-m)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
52.4	1110	110 109	80.1	91.0	930.2 2007.9	925.0 2346.8	559.5
34.0	1109	109 108	95.1	91.2	2604.2 3259.8	3203.4 3731.7	1101.4
27.0	1108	108 107	224.8	212.0	3386.5 4443.6	4438.7 5194.3	2049.5
22.5	1107	107 106	251.0	237.9	4692.0 5704.4	5560.5 6550.4	3781.4
17.5	1106	106 105	272.4	277.9	6210.7 7181.2	6862.9 7699.5	3205.6
13.57	1105	105 104	290.5	292.2	7484.5 8650.2	7866.7 9045.1	3338.0
9.06	1104	104 103	312.5	312.9	8809.2 10143.4	9171.7 10363.7	3688.1
4.65	1103	103 102	352.6	258.8	6308.6 8126.2	5722.8 6883.8	4336.7
-1.00	1102	102 101	339.5	248.1	7451.7 9014.9	6565.1 7454.5	4048.2
-6.40	1101	101 2	223.7	165.0	6538.5 7604.6	5938.1 6219.1	3453.9

Table 3.5- 7: RB/FB maximum enveloping (UB and LB) seismic forces and moments: RB/FB (continued)

(b) Comparison of maximum enveloping seismic forces and moments to DCD

Elev. (m)	Element No.	DCD Node No.	Shear force ratio (SASSI / DCD)		Bending moment ratio (SASSI / DCD)		Torsion ratio (SASSI / DCD)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
52.4	1110	110 109	53%	58%	57% 47%	51% 53%	41%
34.0	1109	109 108	50%	60%	47% 50%	58% 59%	46%
27.0	1108	108 107	53%	53%	44% 50%	62% 60%	61%
22.5	1107	107 106	52%	51%	47% 50%	60% 58%	62%
17.5	1106	106 105	51%	50%	50% 52%	58% 56%	63%
13.57	1105	105 104	51%	49%	52% 52%	55% 54%	64%
9.06	1104	104 103	51%	48%	52% 52%	53% 53%	62%
4.65	1103	103 102	42%	30%	33% 35%	28% 28%	38%
-1.00	1102	102 101	39%	26%	31% 33%	26% 25%	35%
-6.40	1101	101 2	24%	16%	23% 24%	20% 18%	30%

Table 3.5- 8: RB/FB maximum enveloping (UB and LB) seismic forces and moments: RCCV
(a) Maximum enveloping seismic forces and moments

Elev. (m)	Element No.	DCD Node No.	Shear force (MN)		Bending moment (MN-m)		Torsion (MN-m)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
34.0	1209	209 208	76.0	100.5	78.9 540.9	204.8 870.6	16.5
27.0	1208	208 206	89.1	119.1	644.6 1351.9	1277.6 2386.7	1179.8
17.5	1206	206 205	119.3	125.0	1415.8 1872.5	2590.4 3061.2	1268.2
13.57	1205	205 204	132.3	137.5	1939.0 2529.0	3164.5 3743.6	1396.9
9.06	1204	204 203	148.0	150.0	2631.8 3273.1	3870.5 4473.7	1620.1
4.65	1203	203 202	74.3	74.3	3393.1 3802.5	4546.7 4947.3	1183.1
-1.00	1202	202 201	87.9	80.9	3917.7 4362.7	5084.6 5461.2	1027.2
-6.40	1201	201 2	60.8	45.6	4453.5 4670.8	5531.5 5624.8	579.6

Table 3.5- 8: RB/FB maximum enveloping (UB and LB) seismic forces and moments: RCCV (continued)

(b) Comparison of maximum enveloping seismic forces and moments to DCD

Elev. (m)	Element No.	DCD Node No.	Shear force ratio (SASSI / DCD)		Bending moment ratio (SASSI / DCD)		Torsion ratio (SASSI / DCD)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
34.0	1209	209 208	55%	55%	40% 51%	35% 58%	46%
27.0	1208	208 206	54%	48%	38% 46%	50% 55%	65%
17.5	1206	206 205	52%	43%	43% 45%	55% 53%	64%
13.57	1205	205 204	50%	42%	45% 47%	53% 52%	64%
9.06	1204	204 203	49%	41%	47% 48%	51% 50%	62%
4.65	1203	203 202	33%	26%	49% 48%	50% 47%	41%
-1.00	1202	202 201	32%	24%	49% 46%	47% 44%	35%
-6.40	1201	201 2	23%	15%	47% 43%	44% 40%	30%

Table 3.5- 9: RB/FB maximum enveloping (UB and LB) seismic forces and moments: Pedestal

(a) Maximum enveloping seismic forces and moments

Elev. (m)	Element No.	DCD Node No.	Shear force (MN)		Bending moment (MN-m)		Torsion (MN-m)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
4.65	1303	303 377	14.4	14.1	191.7 220.5	249.7 273.1	58.4
2.4165	1377	377 302	21.4	20.7	271.7 323.5	337.0 391.6	70.9
-1.00	1302	302 376	26.3	21.7	332.2 335.2	395.7 370.3	51.3
-2.75	1376	376 301	26.5	21.7	335.2 417.4	395.8 461.2	51.3
-6.40	1301	301 2	25.1	18.0	392.1 493.8	460.0 487.1	34.9

(b) Comparison of maximum enveloping seismic forces and moments to DCD

Elev. (m)	Element No.	DCD Node No.	Shear force ratio (SASSI / DCD)		Bending moment ratio (SASSI / DCD)		Torsion ratio (SASSI / DCD)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
4.65	1303	303 377	44%	31%	33% 37%	40% 41%	41%
2.4165	1377	377 302	45%	31%	37% 42%	41% 42%	41%
-1.00	1302	302 376	40%	27%	40% 36%	41% 35%	35%
-2.75	1376	376 301	40%	27%	36% 37%	38% 35%	35%
-6.40	1301	301 2	24%	15%	34% 30%	34% 25%	30%

Table 3.5- 10: RB/FB maximum enveloping (UB and LB) seismic forces and moments: Vent Wall

(a) Maximum enveloping seismic forces and moments

Elev. (m)	Element No.	DCD Node No.	Shear force (MN)		Bending moment (MN-m)		Torsion (MN-m)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
17.50	701	701 702	7.9	10.6	24.8 30.3	22.5 29.4	19.7
14.50	702	702 703	8.6	10.4	32.0 41.1	32.8 57.5	20.6
11.50	703	703 704	9.8	11.2	41.8 62.1	58.1 90.6	21.3
8.50	704	704 705	11.1	12.2	63.4 75.0	91.5 102.0	21.7
7.4625	705	705 706	5.9	6.6	68.9 79.4	97.9 114.4	10.8

(b) Comparison of maximum enveloping seismic forces and moments to DCD

Elev. (m)	Element No.	DCD Node No.	Shear force ratio (SASSI / DCD)		Bending moment ratio (SASSI / DCD)		Torsion ratio (SASSI / DCD)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
17.50	701	701 702	23%	29%	32% 27%	26% 22%	17%
14.50	702	702 703	24%	26%	27% 18%	22% 22%	17%
11.50	703	703 704	27%	27%	18% 18%	22% 23%	18%
8.50	704	704 705	29%	27%	19% 20%	23% 23%	18%
7.4625	705	705 706	14%	16%	19% 17%	22% 22%	11%

Table 3.5- 11: RB/FB maximum enveloping (UB and LB) seismic forces and moments: RSW
(a) Maximum enveloping seismic forces and moments

Elev. (m)	Element No	DCD Node No	Shear Force (MN)		Bending Moment (MN-m)		Torsion (MN-m)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
24.18	707	707 708	1.3	1.0	0.8 5.8	0.8 4.4	0.2
20.2	708	708 709	6.3	3.8	8.9 33.5	6.7 20.3	0.5
15.775	709	709 710	7.0	4.5	35.1 65.3	21.2 41.0	0.7
11.35	710	710 711	7.3	5.5	65.6 93.6	41.2 62.1	0.7
7.4625	711	711 712	15.1	17.0	67.4 95.2	91.6 132.1	11.5
4.65	712	713 714	6.3	6.1	40.4 50.9	52.7 62.8	12.5
2.4165	713	713 714	0.5	0.5	1.2 1.0	1.1 0.9	0.1
1.96	714	714 715	0.3	0.3	1.0 0.2	0.8 0.2	0.03

Table 3.5- 11: RB/FB maximum enveloping (UB and LB) seismic forces and moments: RSW (continued)

(b) Comparison of maximum enveloping seismic forces and moments to DCD

Elev. (m)	Element No.	DCD Node No.	Shear force ratio (SASSI / DCD)		Bending moment ratio (SASSI / DCD)		Torsion ratio (SASSI / DCD)
			X-Dir	Y-Dir	X-Dir	Y-Dir	
24.18	707	707 708	42%	36%	39% 44%	46% 36%	38%
20.2	708	708 709	43%	31%	48% 42%	40% 30%	36%
15.775	709	709 710	40%	31%	43% 41%	30% 31%	36%
11.35	710	710 711	37%	33%	41% 40%	30% 31%	29%
7.4625	711	711 712	37%	48%	34% 33%	50% 53%	49%
4.65	712	713 714	44%	31%	32% 38%	40% 42%	41%
2.4165	713	713 714	31%	38%	33% 35%	34% 33%	30%
1.96	714	714 715	33%	39%	35% 44%	34% 44%	30%

Table 3.5- 12: RB/FB maximum enveloping (UB and LB) seismic forces and moments: RPV
(a) Maximum enveloping seismic forces and moments

Elev. (m)	Element No.	DCD Node No.	Axial (MN)	Shear force (MN)		Bending moment (MN-m)	
				X-Dir	Y-Dir	X-Dir	Y-Dir
Shroud Bottom	844	845	3.8	5.0	2.5	11.3	5.7
		846	3.8			15.8	7.3
RPV Support	871	815	8.3	12.4	9.5	63.7	48.4
		711	8.3			65.5	54.3

(b) Comparison of maximum enveloping seismic forces and moments to DCD

Elev. (m)	Element No.	DCD Node No.	Axial (SASSI/DCD)	Shear force ratio (SASSI / DCD)		Bending moment ratio (SASSI / DCD)	
				X-Dir	Y-Dir	X-Dir	Y-Dir
Shroud Bottom	844	845	45%	70%	35%	70%	40%
		846	45%			74%	42%
RPV Support	871	815	33%	67%	53%	44%	36%
		711	33%			46%	40%

Table 4.2- 1: Upper bound rock-engineered backfill properties for the SASSI analysis of the CB

Layer	Thickness (m)	Unit Weight (tonf/m3)	S-wave Velocity (m/s)	P-wave Velocity (m/s)	S-wave Damp. Ratio (%)	P-wave Damp. Ratio (%)	Elev. at Top of Layer (m)	S-wave Passing Freq. (Hz)	P-wave Passing Freq. (Hz)
1	0.890	2.339	228.60	427.67	2.27	2.27	4.500	51.4	96.1
2	0.890	2.339	228.60	427.67	3.65	3.65	3.610	51.4	96.1
3	0.890	2.339	228.60	427.67	4.73	4.73	2.720	51.4	96.1
4	0.900	2.339	233.13	436.09	4.87	4.87	1.830	51.8	96.9
5	0.950	2.339	245.00	674.06	5.14	5.14	0.930	51.6	141.9
6	0.980	2.339	258.14	1316.33	5.50	5.50	-0.020	52.7	268.6
7	1.000	2.339	270.75	1376.95	4.92	4.92	-1.000	54.1	275.4
8	1.140	2.339	288.73	1459.99	3.94	3.94	-2.000	50.7	256.1
9	1.230	2.339	312.12	1459.99	3.89	3.89	-3.140	50.8	237.4
10	1.240	2.339	314.25	1459.99	4.02	4.02	-4.370	50.7	235.5
11	1.351	2.339	341.19	1459.99	3.78	3.78	-5.610	50.5	216.1
12	0.439	2.403	2429.87	4824.15	0.50	0.50	-6.961	1107.0	2197.8
13	1.500	2.403	2429.87	4824.15	0.50	0.50	-7.400	324.0	643.2
14	1.500	2.403	2454.83	4873.53	0.50	0.50	-8.900	327.3	649.8
15	2.565	2.403	2505.45	4973.83	0.50	0.50	-10.400	195.4	387.8
16	2.530	2.403	2516.12	4995.12	0.50	0.50	-12.965	198.9	394.9
17	0.640	2.403	2496.01	4955.40	0.50	0.50	-15.495	780.0	1548.6
18	2.957	2.403	2485.34	4933.98	0.50	0.50	-16.135	168.1	333.7
19	3.383	2.403	2460.96	4885.66	0.50	0.50	-19.092	145.5	288.8
20	3.658	2.403	2449.07	4861.73	0.50	0.50	-22.475	133.9	265.8
21	3.688	2.403	2463.70	4890.93	0.50	0.50	-26.133	133.6	265.2
22	2.286	2.403	1707.18	3649.96	0.71	0.71	-29.821	149.4	319.3
23	2.286	2.403	1707.18	3649.96	0.71	0.71	-32.107	149.4	319.3
24	3.094	2.403	1276.20	3004.93	0.95	0.95	-34.393	82.5	194.2
25	3.094	2.403	1276.20	3004.93	0.95	0.95	-37.487	82.5	194.2
26	3.048	2.403	1289.61	3037.23	0.95	0.95	-40.581	84.6	199.3
27	3.048	2.403	1289.61	3037.23	0.95	0.95	-43.629	84.6	199.3
28	3.048	2.403	1265.22	2979.73	0.95	0.95	-46.677	83.0	195.5
29	3.048	2.403	1265.22	2979.73	0.95	0.95	-49.725	83.0	195.5
30	3.200	2.403	1331.98	3136.64	0.95	0.95	-52.773	83.2	196.0
31	3.200	2.403	1331.98	3136.64	0.95	0.95	-55.973	83.2	196.0
32	3.200	2.403	1581.91	3725.28	0.95	0.95	-59.173	98.9	232.8
33	3.200	2.403	1581.91	3725.28	0.95	0.95	-62.373	98.9	232.8
34	3.216	2.403	1603.25	3775.24	0.95	0.95	-65.573	99.7	234.8
35	3.216	2.403	1603.25	3775.24	0.95	0.95	-68.789	99.7	234.8
36	3.078	2.403	2072.03	4259.39	0.37	0.37	-72.005	134.6	276.8
37	6.157	2.403	3532.33	6608.32	0.37	0.37	-75.083	114.7	214.7
38	6.401	2.403	3521.05	6587.02	0.37	0.37	-81.240	110.0	205.8
39	6.401	2.403	3549.09	6639.68	0.37	0.37	-87.641	110.9	207.5
40	6.187	2.403	3481.12	6512.44	0.37	0.37	-94.042	112.5	210.5
41	6.858	2.563	3343.05	6047.91	0.37	0.37	-100.229	97.5	176.4
42	6.858	2.563	3343.05	6047.91	0.37	0.37	-107.087	97.5	176.4
43	6.888	2.563	3351.58	6063.38	0.37	0.37	-113.945	97.3	176.1
44	6.888	2.563	3351.58	6063.38	0.37	0.37	-120.833	97.3	176.1
Half Space		2.707	3401.87	6255.34	0.10	0.10			

Table 4.2- 2: Lower bound rock-engineered backfill properties for the SASSI analysis of the CB

Layer	Thickness (m)	Unit Weight (tonf/m3)	S-wave Velocity (m/s)	P-wave Velocity (m/s)	S-wave Damp. Ratio (%)	P-wave Damp. Ratio (%)	Elev. at Top of Layer (m)	S-wave Passing Freq. (Hz)	P-wave Passing Freq. (Hz)
1	0.890	1.906	103.98	194.54	6.25	6.25	4.500	23.4	43.7
2	0.890	1.906	111.02	207.70	10.29	10.29	3.610	24.9	46.7
3	0.890	1.906	96.32	180.36	12.78	12.78	2.720	21.6	40.5
4	0.900	1.906	94.16	176.37	13.28	13.28	1.830	20.9	39.2
5	0.950	1.906	96.05	264.54	13.59	13.59	0.930	20.2	55.7
6	0.980	1.906	92.53	471.79	13.83	13.83	-0.020	18.9	96.3
7	1.000	1.906	97.59	497.32	13.30	13.30	-1.000	19.5	99.5
8	1.140	1.906	111.07	565.72	12.35	12.35	-2.000	19.5	99.2
9	1.230	1.906	118.26	603.33	12.24	12.24	-3.140	19.2	98.1
10	1.240	1.906	124.81	635.96	12.09	12.09	-4.370	20.1	102.6
11	1.351	1.906	132.42	675.32	11.75	11.75	-5.610	19.6	100.0
12	0.439	2.403	1620.01	3216.10	1.77	1.77	-6.961	738.0	1465.2
13	1.500	2.403	1620.01	3216.10	1.77	1.77	-7.400	216.0	428.8
14	1.500	2.403	1636.62	3249.02	1.77	1.77	-8.900	218.2	433.2
15	2.565	2.403	1670.30	3315.89	1.77	1.77	-10.400	130.2	258.5
16	2.530	2.403	1677.31	3330.08	1.77	1.77	-12.965	132.6	263.2
17	0.640	2.403	1664.21	3303.60	1.77	1.77	-15.495	520.1	1032.4
18	2.957	2.403	1656.89	3289.32	1.77	1.77	-16.135	112.1	222.5
19	3.383	2.403	1640.74	3257.11	1.77	1.77	-19.092	97.0	192.6
20	3.658	2.403	1632.51	3241.15	1.77	1.77	-22.475	89.3	177.2
21	3.688	2.403	1642.57	3260.62	1.77	1.77	-26.133	89.1	176.8
22	2.286	2.403	1138.12	2433.30	2.43	2.43	-29.821	99.6	212.9
23	2.286	2.403	1138.12	2433.30	2.43	2.43	-32.107	99.6	212.9
24	3.094	2.403	847.04	1994.46	3.03	3.03	-34.393	54.8	128.9
25	3.094	2.403	847.04	1994.46	3.03	3.03	-37.487	54.8	128.9
26	3.048	2.403	851.31	2004.51	3.03	3.03	-40.581	55.9	131.5
27	3.048	2.403	851.31	2004.51	3.03	3.03	-43.629	55.9	131.5
28	3.048	2.403	843.69	1986.49	3.03	3.03	-46.677	55.4	130.3
29	3.048	2.403	843.69	1986.49	3.03	3.03	-49.725	55.4	130.3
30	3.200	2.403	828.45	1950.62	3.03	3.03	-52.773	51.8	121.9
31	3.200	2.403	828.45	1950.62	3.03	3.03	-55.973	51.8	121.9
32	3.200	2.403	991.82	2335.61	3.03	3.03	-59.173	62.0	146.0
33	3.200	2.403	991.82	2335.61	3.03	3.03	-62.373	62.0	146.0
34	3.216	2.403	997.61	2349.47	3.03	3.03	-65.573	62.0	146.1
35	3.216	2.403	997.61	2349.47	3.03	3.03	-68.789	62.0	146.1
36	3.078	2.403	1381.35	2839.59	1.28	1.28	-72.005	89.8	184.5
37	6.157	2.403	2354.88	4405.55	1.28	1.28	-75.083	76.5	143.1
38	6.401	2.403	2347.26	4391.35	1.28	1.28	-81.240	73.3	137.2
39	6.401	2.403	2366.16	4426.45	1.28	1.28	-87.641	73.9	138.3
40	6.187	2.403	2320.75	4341.62	1.28	1.28	-94.042	75.0	140.3
41	6.858	2.563	2228.70	4031.94	1.28	1.28	-100.229	65.0	117.6
42	6.858	2.563	2228.70	4031.94	1.28	1.28	-107.087	65.0	117.6
43	6.888	2.563	2234.49	4042.25	1.28	1.28	-113.945	64.9	117.4
44	6.888	2.563	2234.49	4042.25	1.28	1.28	-120.833	64.9	117.4
Half Space		2.707	2268.02	4170.23	0.10	0.10			

Table 4.5- 1: CB maximum vertical seismic accelerations for envelope of UB and LB soil conditions

(a) Maximum vertical seismic accelerations

Elev. (m)	DCD Node No. (For Ref.)	CB Node No.	Stick Model	Z-dir. (g)
13.80	6	500	CB	0.34
9.06	5	480	CB	0.32
4.65	4	460	CB	0.29
-2.00	3	430	CB	0.20
-7.40	2	410	CB	0.19
-10.40	1	400	CB	0.19
13.80	9001	901	Oscillator	1.05
	9002	902	Oscillator	0.75
	9003	903	Oscillator	0.87
9.06	9101	911	Oscillator	0.93
	9102	912	Oscillator	0.64
	9103	913	Oscillator	0.84
4.65	9201	921	Oscillator	0.49
	9202	922	Oscillator	0.63
-2.00	9301	931	Oscillator	0.59

Table 4.5- 1: CB maximum vertical seismic accelerations for envelope of UB and LB soil conditions (continued)

(b) Comparison of maximum vertical seismic accelerations to DCD values
Ratio defined as CB values (a) / DCD values[1]

Elev. (m)	DCD Node No. (For Ref.)	CB Node No.	Stick Model	Z-dir.
13.80	6	500	CB	34%
9.06	5	480	CB	37%
4.65	4	460	CB	39%
-2.00	3	430	CB	35%
-7.40	2	410	CB	37%
-10.40	1	400	CB	37%
13.80	9001	901	Oscillator	48%
	9002	902	Oscillator	56%
	9003	903	Oscillator	61%
9.06	9101	911	Oscillator	47%
	9102	912	Oscillator	51%
	9103	913	Oscillator	59%
4.65	9201	921	Oscillator	37%
	9202	922	Oscillator	44%
-2.00	9301	931	Oscillator	43%

Note: (1) DCD values are in Table 3A.9-3g of DCD.

Table 4.5- 2: CB seismic forces and moments for envelope of UB and LB soil conditions
(a) Seismic forces and moments

Elev. (m)	DCD (for Ref.)		CB			Shear		Moment		Torsion (MN-m)
	Node No.	Elm. No.	Beam Elm. Group No.	Beam Elm. No.	Node No.	X-Dir (MN)	Y-Dir (MN)	X-Dir (MN-m)	Y-Dir (MN-m)	
13.80	6		1	10	503			40.5	34.3	
		6	1	9	481	10.7	10.9	73.1	63.7	8.1
9.06	5		1	8	483			99.1	80.1	
		5	1	7	461	19.1	20.1	179.2	163.2	15.2
4.65	4		3	3	463			102.8	61.4	
		4	3	3	431	34.2	34.6	277.8	233.8	13.7
-2.00	3		3	2	433			225.1	218.8	
-7.40	2	3	3	2	411	53.9	62.2	405.7	453.6	14.8

Note: The torsional moments shown in this table are the geometric torsional moments and do not include the accidental torsional moment due to 5% accidental eccentricity.

(b) Comparison of seismic forces and moments to DCD values
Ratio defined as CB values (a) / DCD values

Elev. (m)	DCD (for Ref.)		CB			Shear		Moment		Torsion
	Node No.	Elm. No.	Beam Elm. Group No.	Beam Elm. No.	Node No.	X-Dir	Y-Dir	X-Dir	Y-Dir	
13.80	6		1	10	503			25%	28%	
		6	1	9	481	32%	37%	29%	32%	11%
9.06	5		1	8	483			28%	29%	
		5	1	7	461	36%	37%	31%	37%	12%
4.65	4		3	3	463			14%	11%	
		4	3	3	431	45%	43%	24%	24%	8%
-2.00	3		3	2	433			18%	21%	
-7.40	2	3	3	2	411	43%	63%	26%	30%	6%

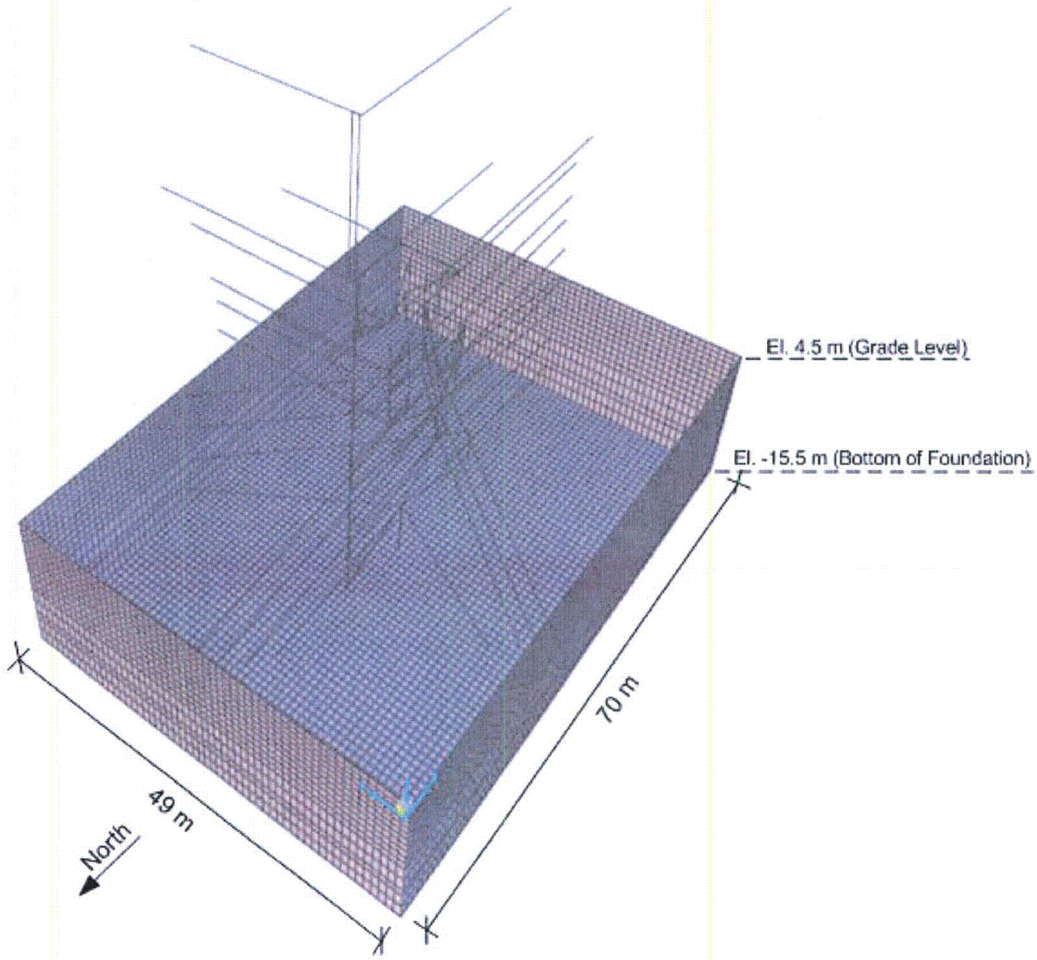


Figure 3.1- 1: 3D view of the RB/FB model

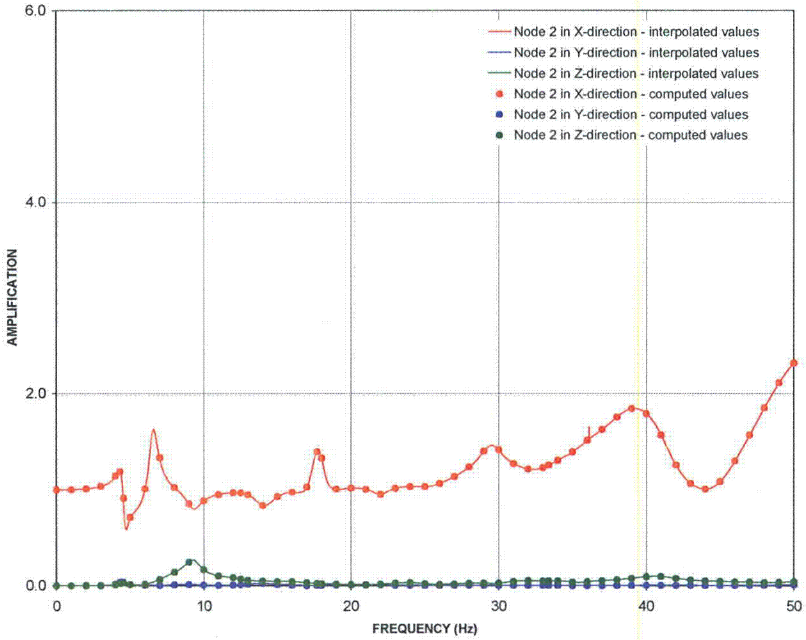


Figure 3.5- 1: Transfer functions - RB/FB Basemat, UB subsurface profile, node 2, X direction input motion

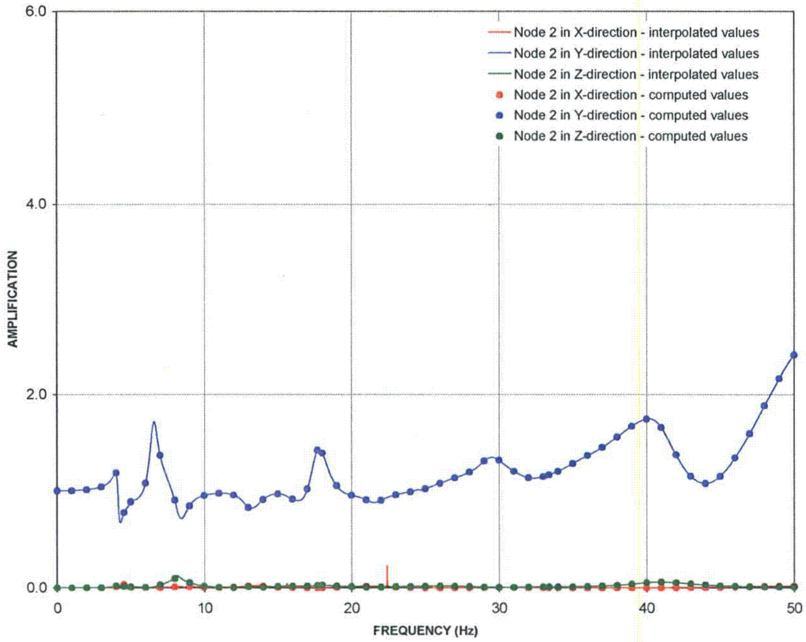


Figure 3.5- 2: Transfer functions - RB/FB Basemat, UB subsurface profile, node 2, Y direction input motion

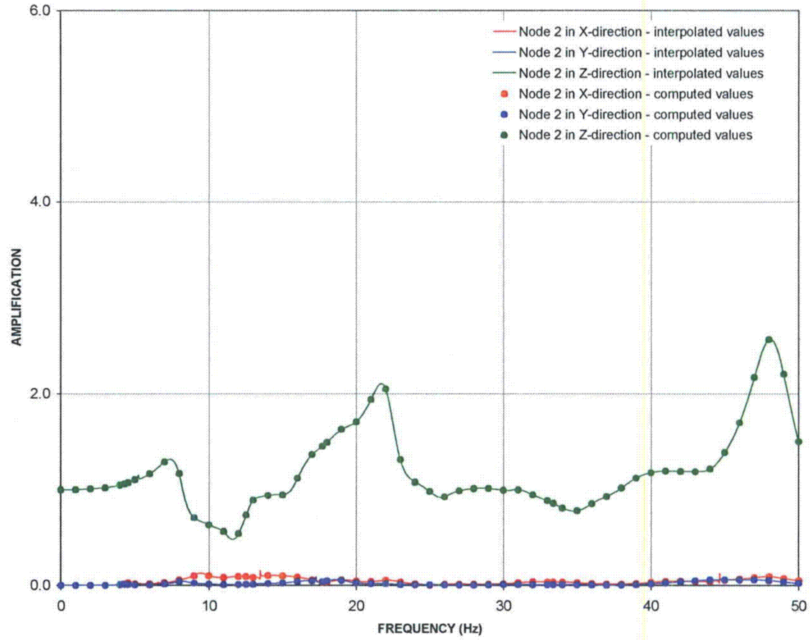


Figure 3.5- 3: Transfer functions - RB/FB Basemat, UB subsurface profile, node 2, Z direction input motion

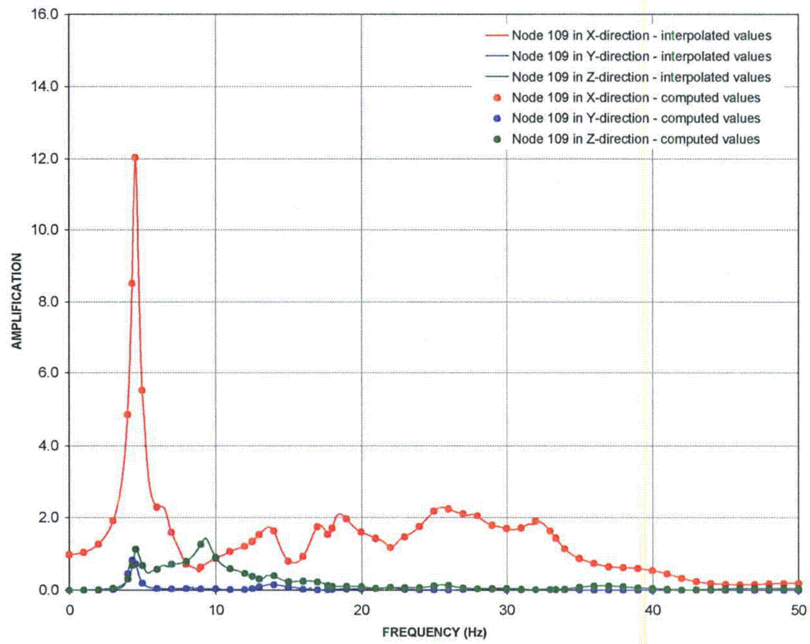


Figure 3.5- 4: Transfer functions - RB/FB Refueling Floor, UB subsurface profile, node 109, X direction input motion

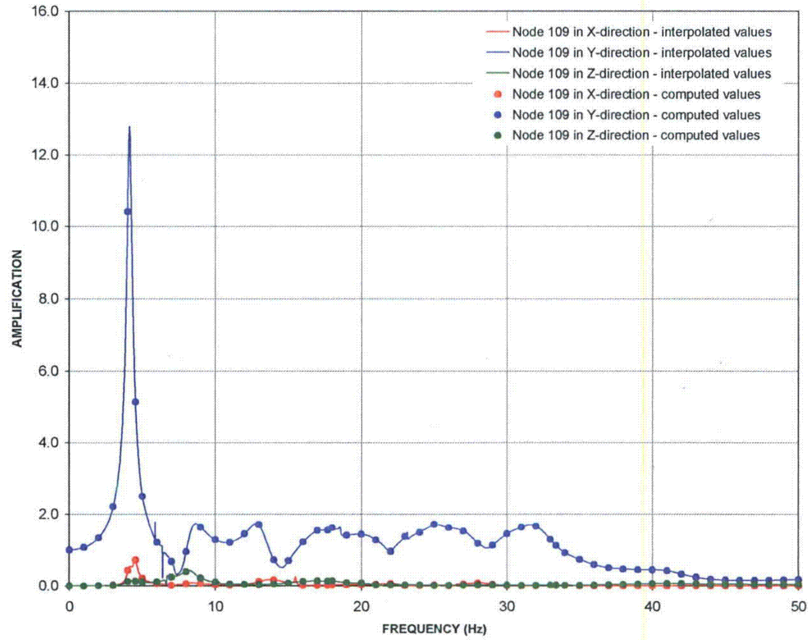


Figure 3.5- 5: Transfer functions - RB/FB Refueling Floor, UB subsurface profile, node 109, Y direction input motion

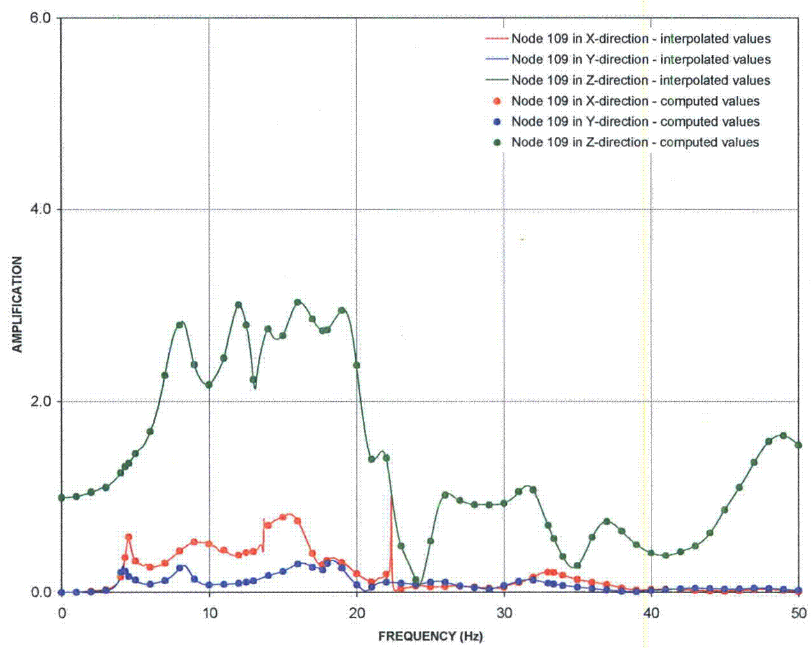


Figure 3.5- 6: Transfer functions - RB/FB Refueling Floor, UB subsurface profile, node 109, Z direction input motion

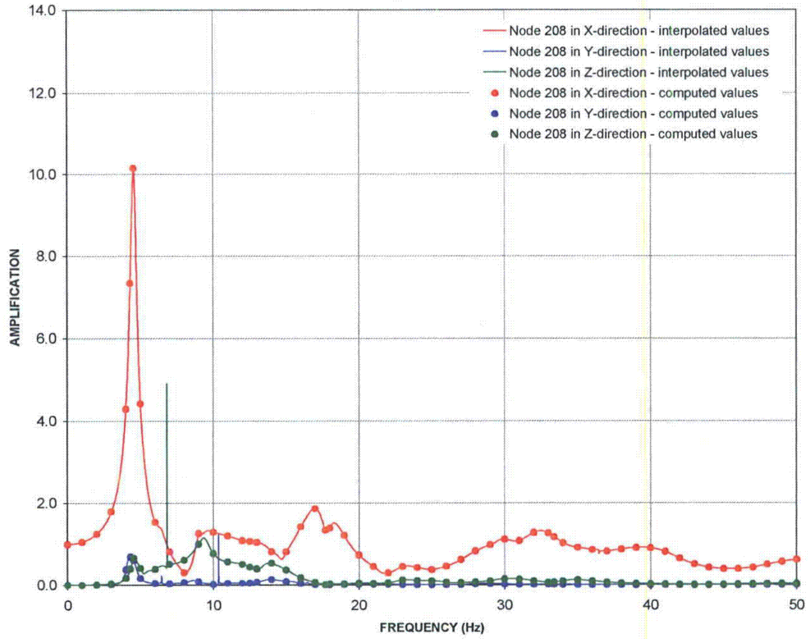


Figure 3.5- 7: Transfer functions - RCCV Top Slab, UB subsurface profile, node 208, X direction input motion

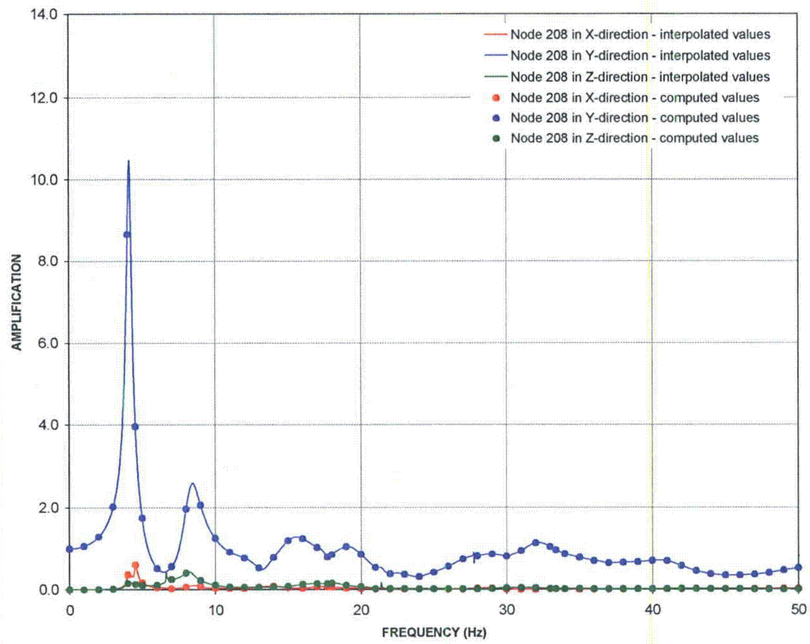


Figure 3.5- 8: Transfer functions - RCCV Top Slab, UB subsurface profile, node 208, Y direction input motion

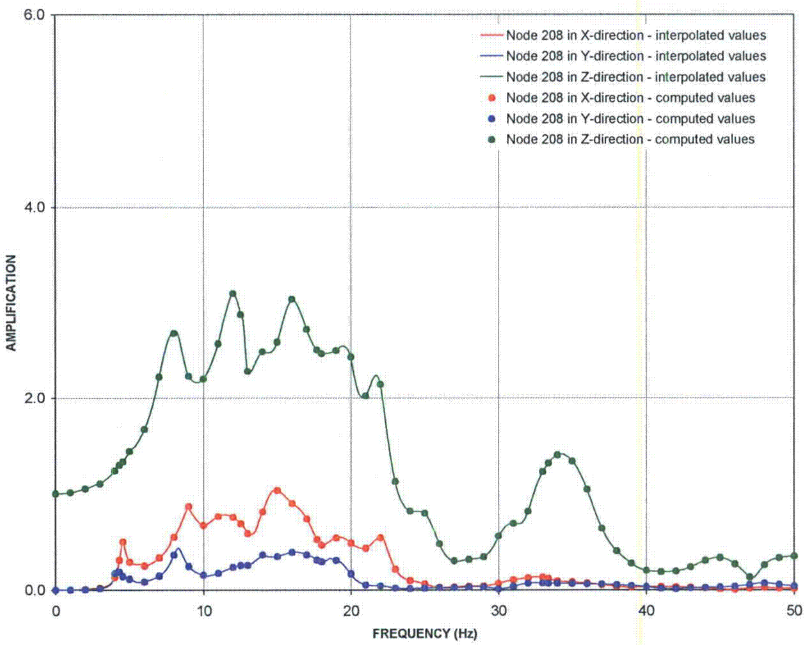


Figure 3.5- 9: Transfer functions - RCCV Top Slab, UB subsurface profile, node 208, Z direction input motion

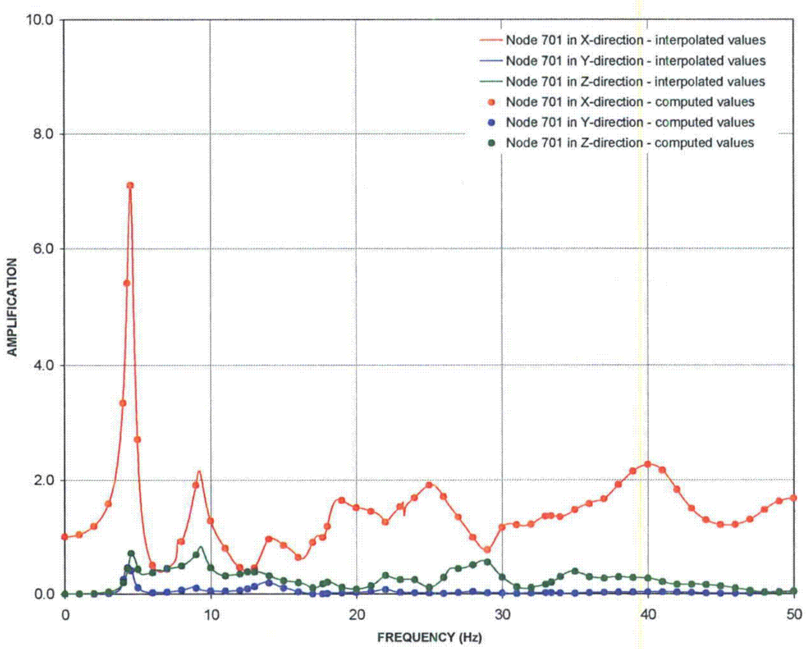


Figure 3.5- 10: Transfer functions - Vent Wall Top, UB subsurface profile, node 701, X direction input motion

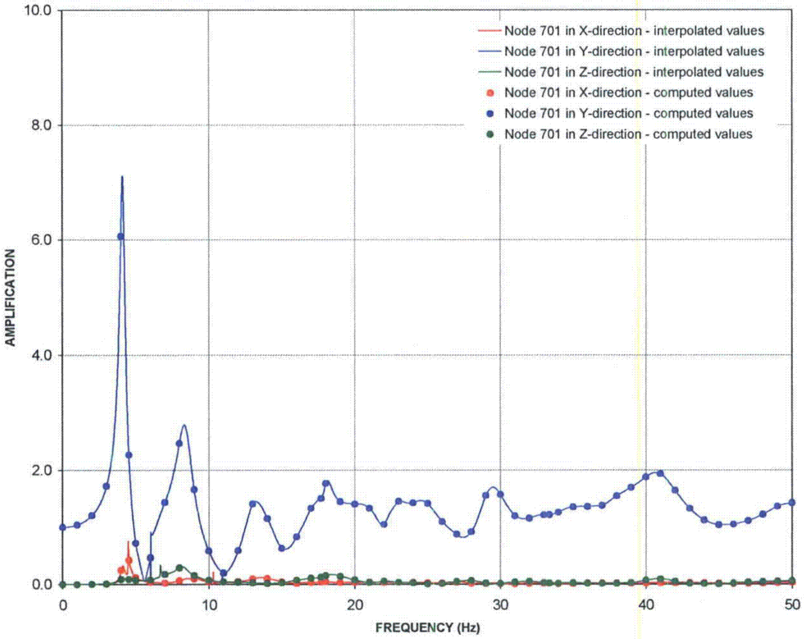


Figure 3.5- 11: Transfer functions - Vent Wall Top, UB subsurface profile, node 701, Y direction input motion

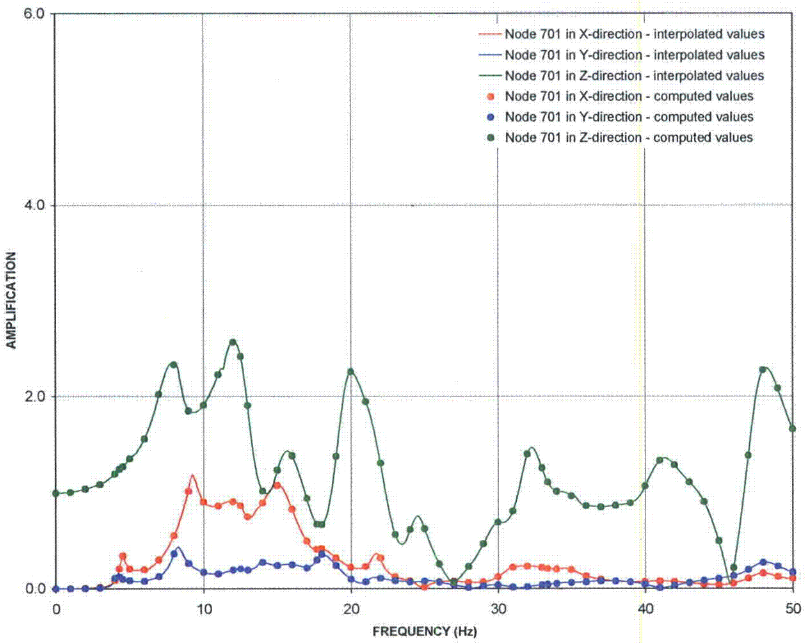


Figure 3.5- 12: Transfer functions - Vent Wall Top, UB subsurface profile, node 701, Z direction input motion

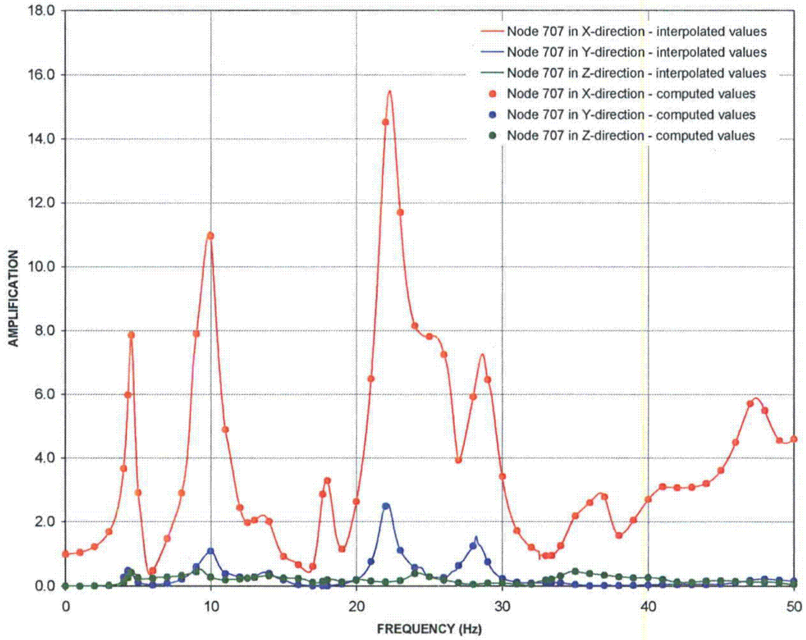


Figure 3.5- 13: Transfer functions - RSW Top, UB subsurface profile, node 707, X direction input motion

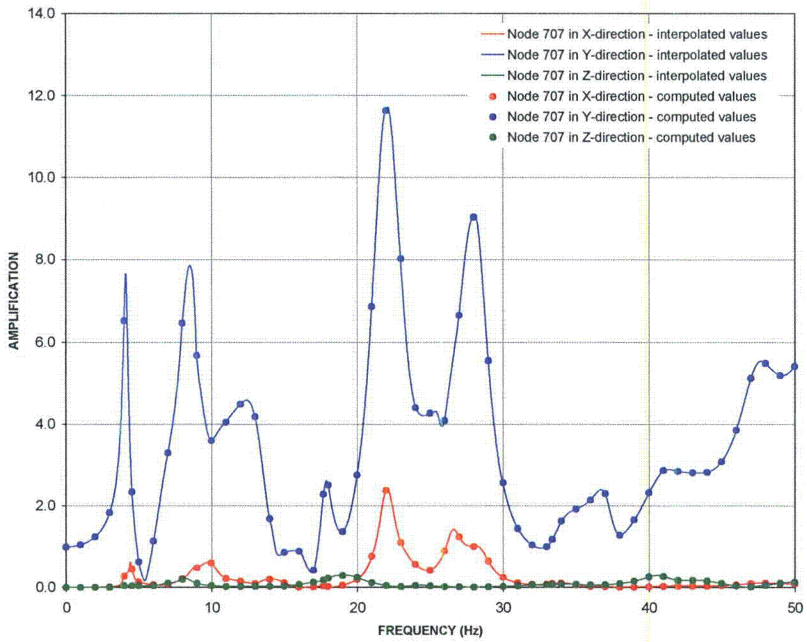


Figure 3.5- 14: Transfer functions - RSW Top, UB subsurface profile, node 707, Y direction input motion

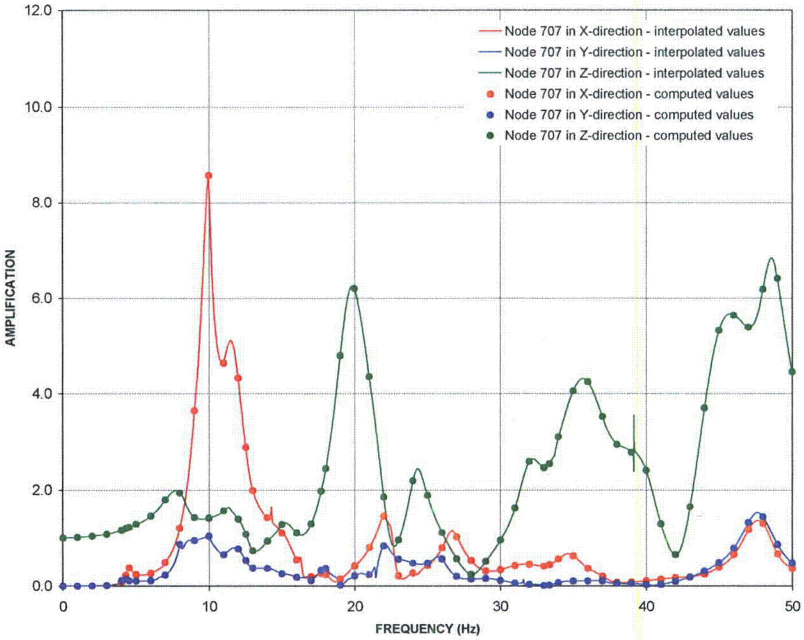


Figure 3.5- 15: Transfer functions - RSW Top, UB subsurface profile, node 707, Z direction input motion

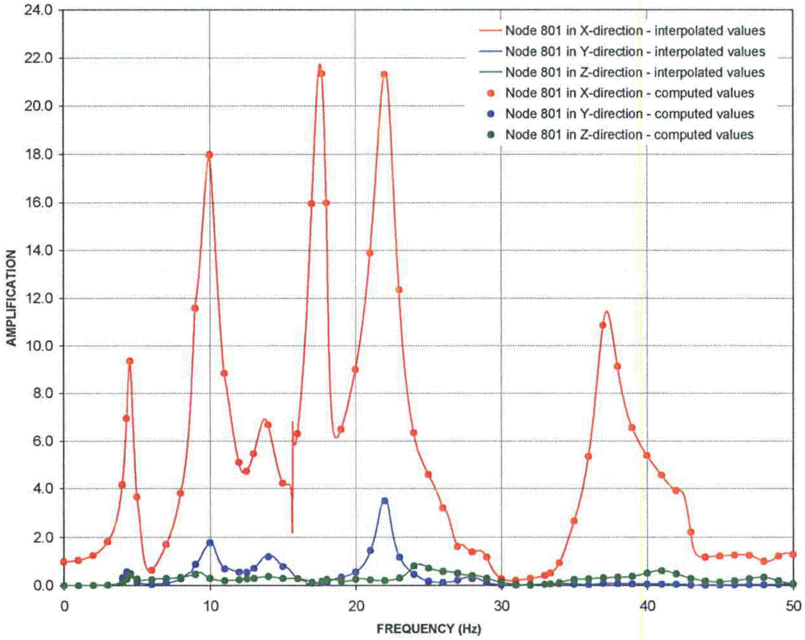


Figure 3.5- 16: Transfer functions - RPV Top, UB subsurface profile, node 801, X direction input motion

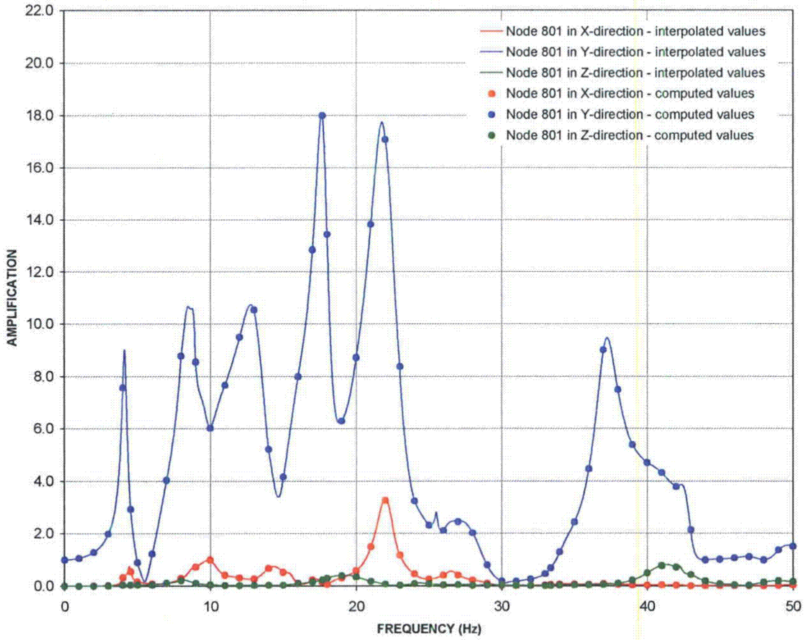


Figure 3.5- 17: Transfer functions - RPV Top, UB subsurface profile, node 801, Y direction input motion

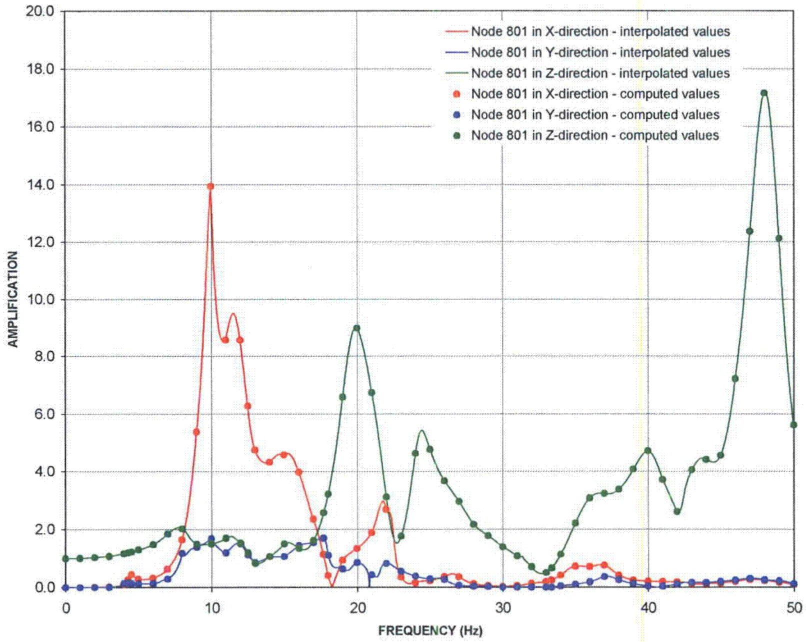


Figure 3.5- 18: Transfer functions - RPV Top, UB subsurface profile, node 801, Z direction input motion

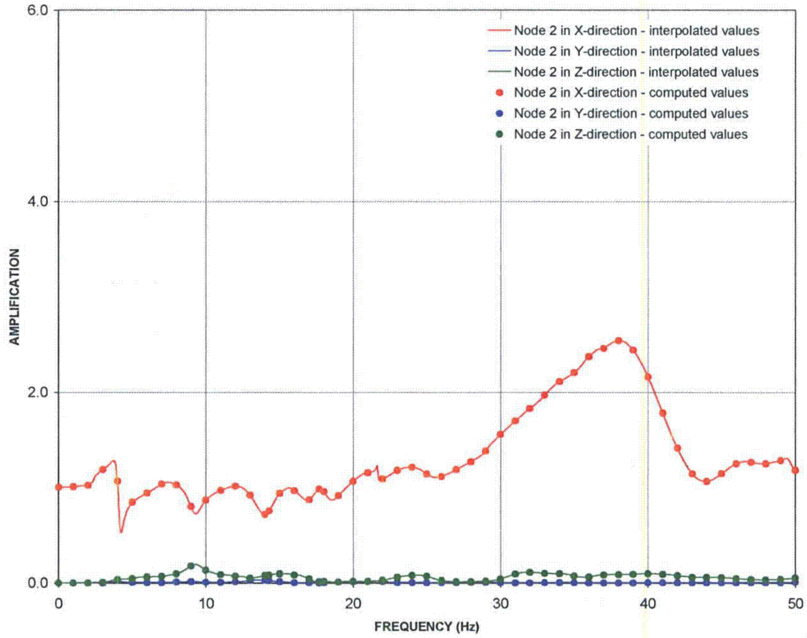


Figure 3.5- 19: Transfer functions - RB/FB Basemat, LB subsurface profile, node 2, X direction input motion

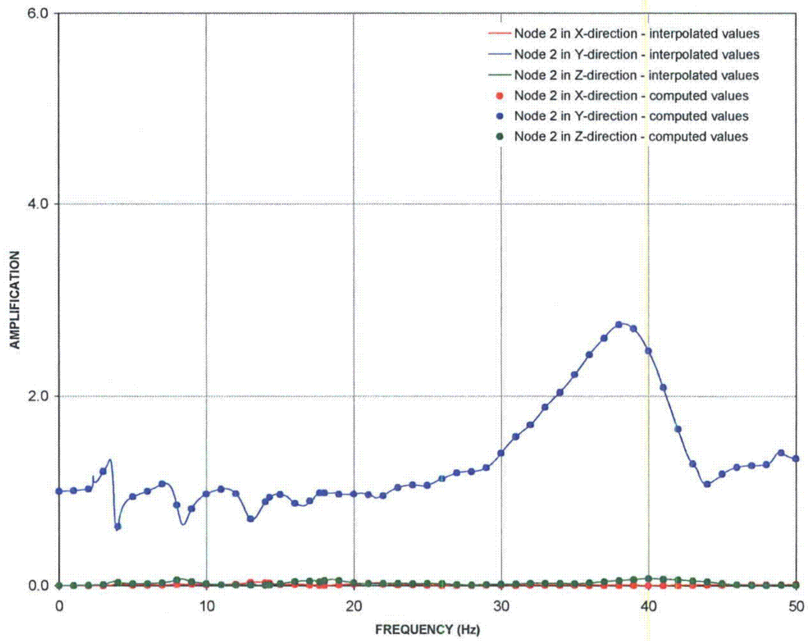


Figure 3.5- 20: Transfer functions - RB/FB Basemat, LB subsurface profile, node 2, Y direction input motion

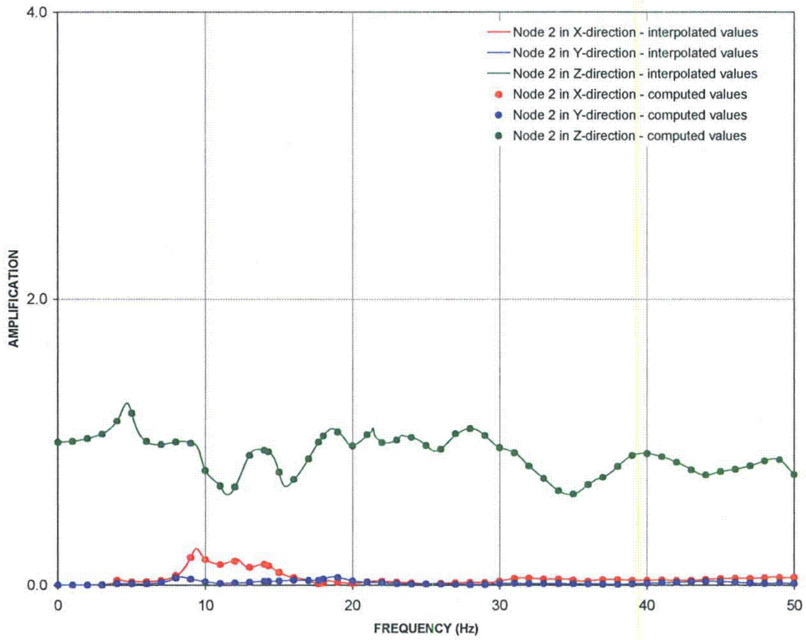


Figure 3.5- 21: Transfer functions - RB/FB Basemat, LB subsurface profile, node 2, Z direction input motion

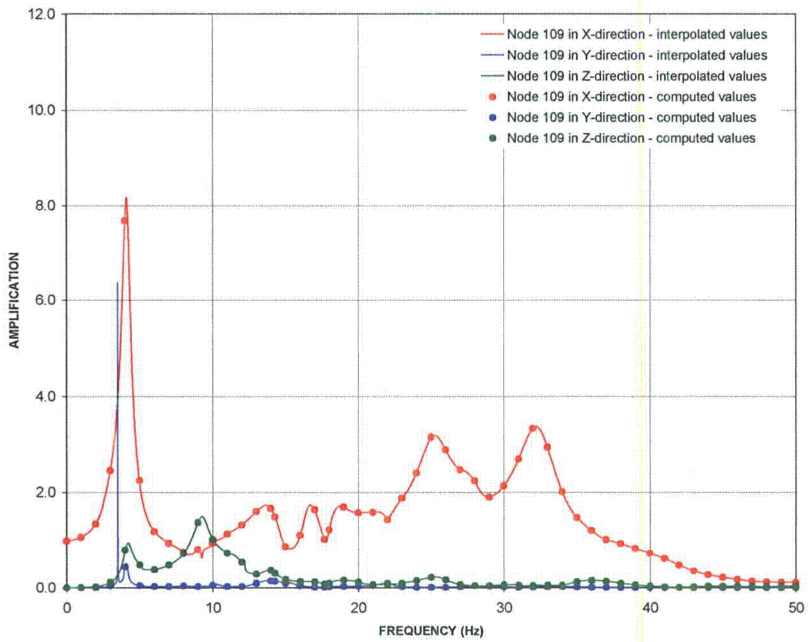


Figure 3.5- 22: Transfer functions - RB/FB Refueling Floor, LB subsurface profile, node 109, X direction input motion

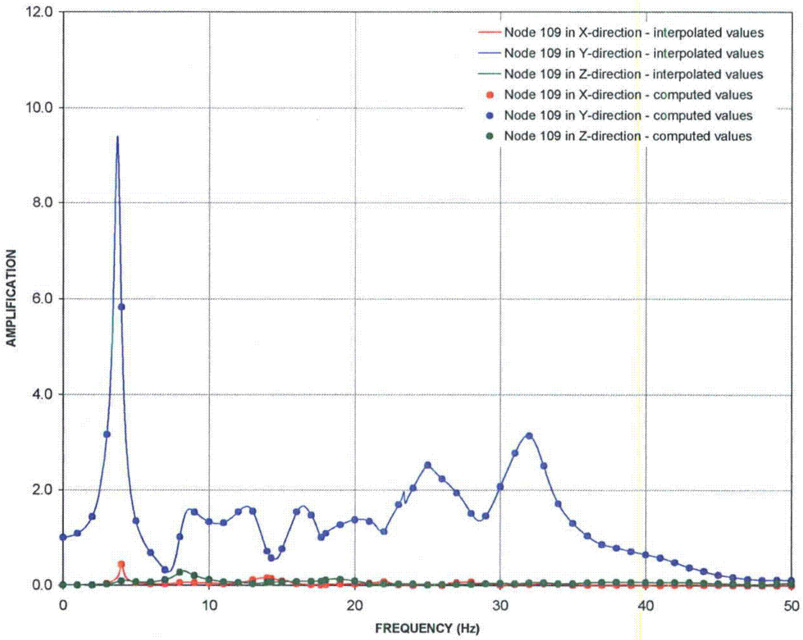


Figure 3.5- 23: Transfer functions - RB/FB Refueling Floor, LB subsurface profile, node 109, Y direction input motion

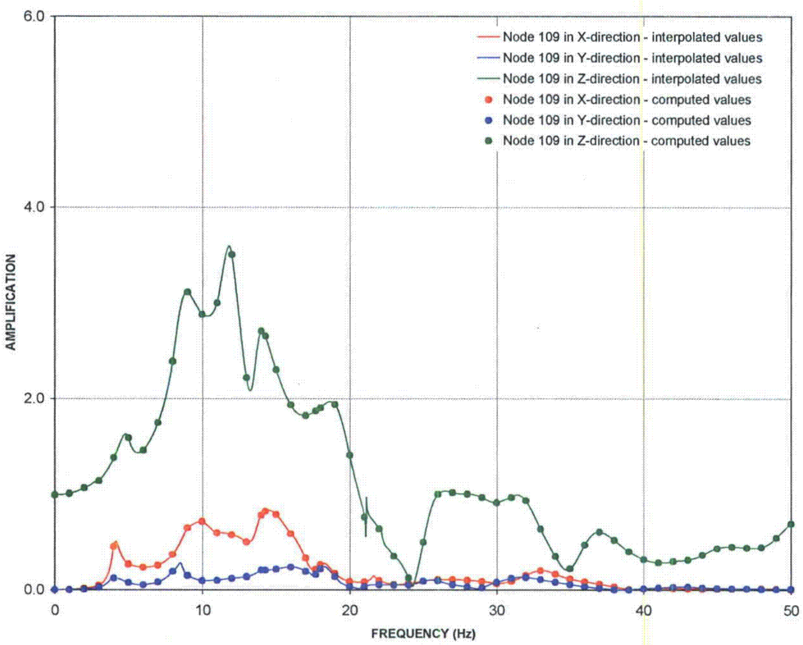


Figure 3.5- 24: Transfer functions - RB/FB Refueling Floor, LB subsurface profile, node 109, Z direction input motion

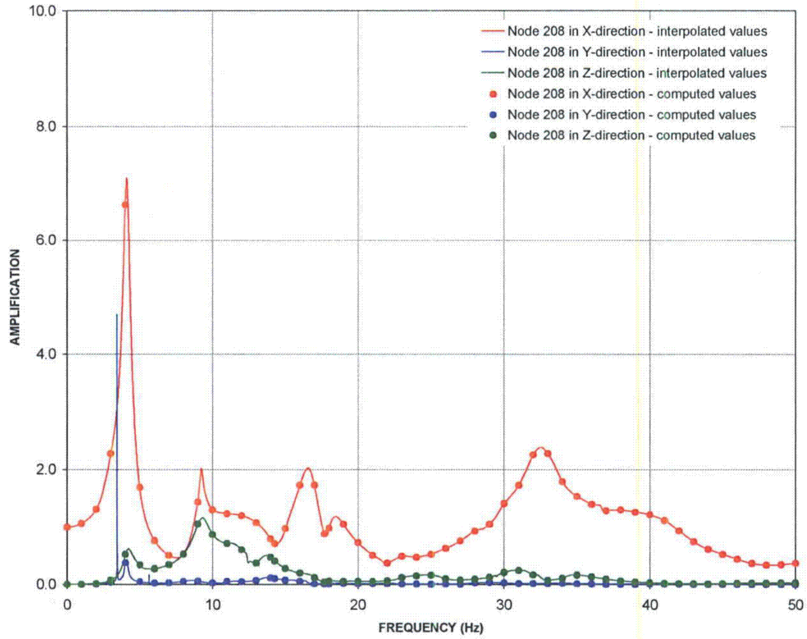


Figure 3.5- 25: Transfer functions - RCCV Top Slab, LB subsurface profile, node 208, X direction input motion

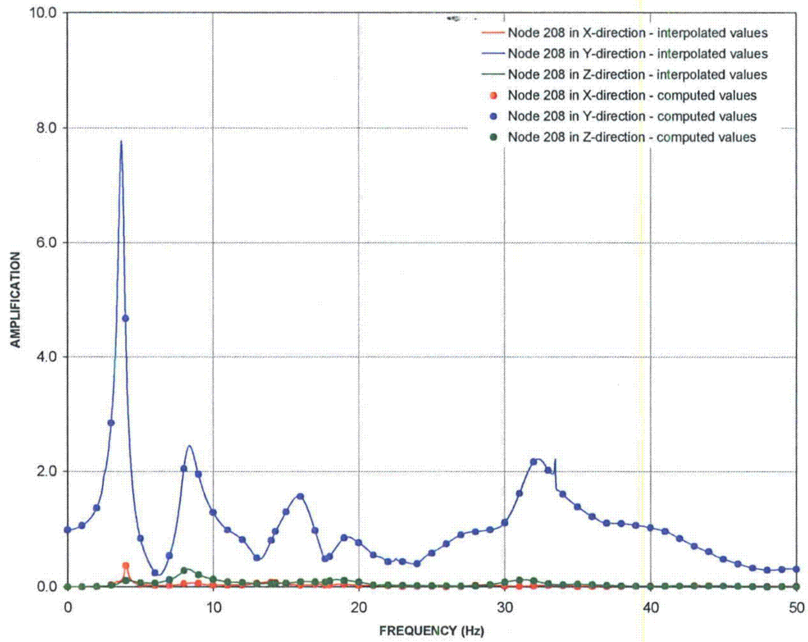


Figure 3.5- 26: Transfer functions - RCCV Top Slab, LB subsurface profile, node 208, Y direction input motion

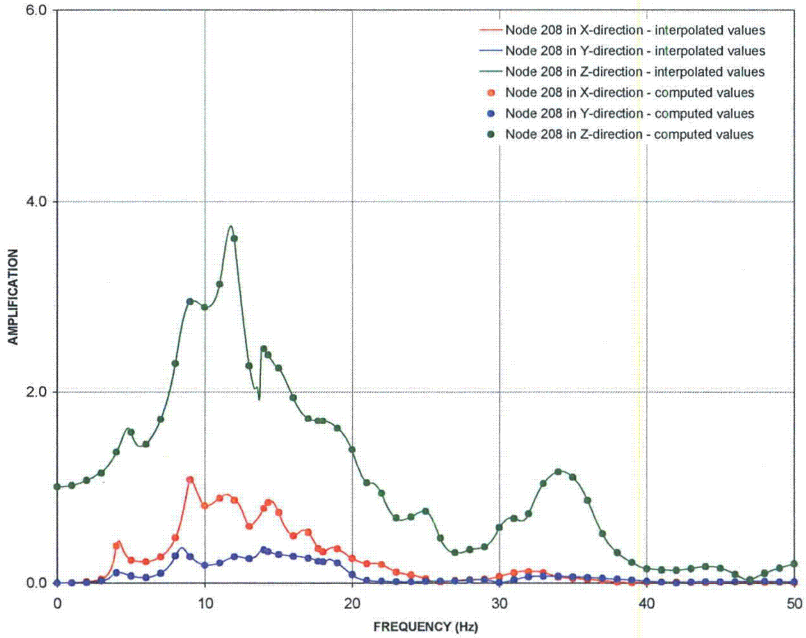


Figure 3.5- 27: Transfer functions - RCCV Top Slab, LB subsurface profile, node 208, Z direction input motion

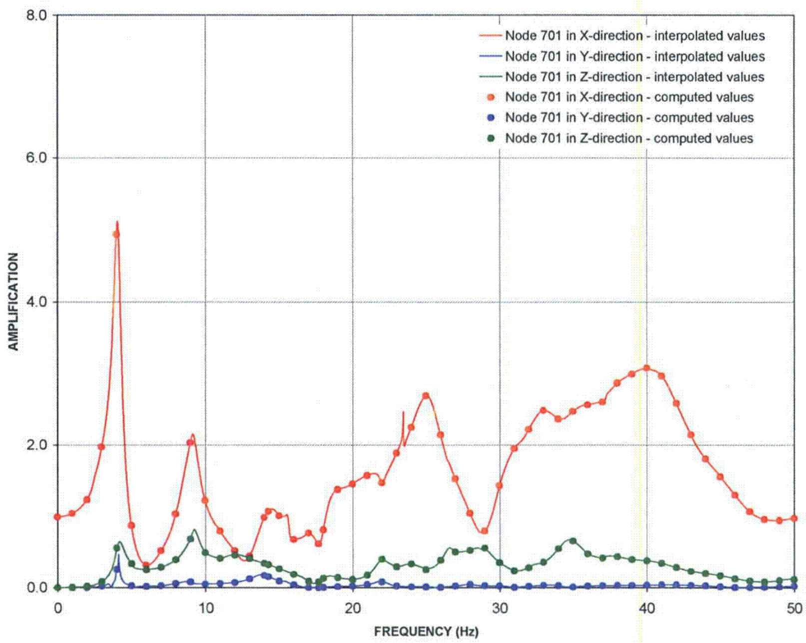


Figure 3.5- 28: Transfer functions - Vent Wall Top, LB subsurface profile, node 701, X direction input motion

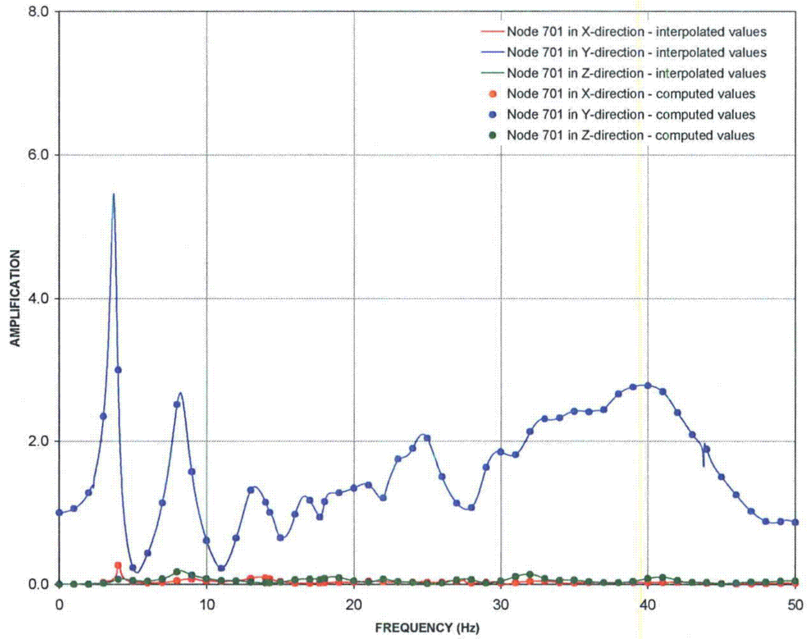


Figure 3.5- 29: Transfer functions - Vent Wall Top, LB subsurface profile, node 701, Y direction input motion

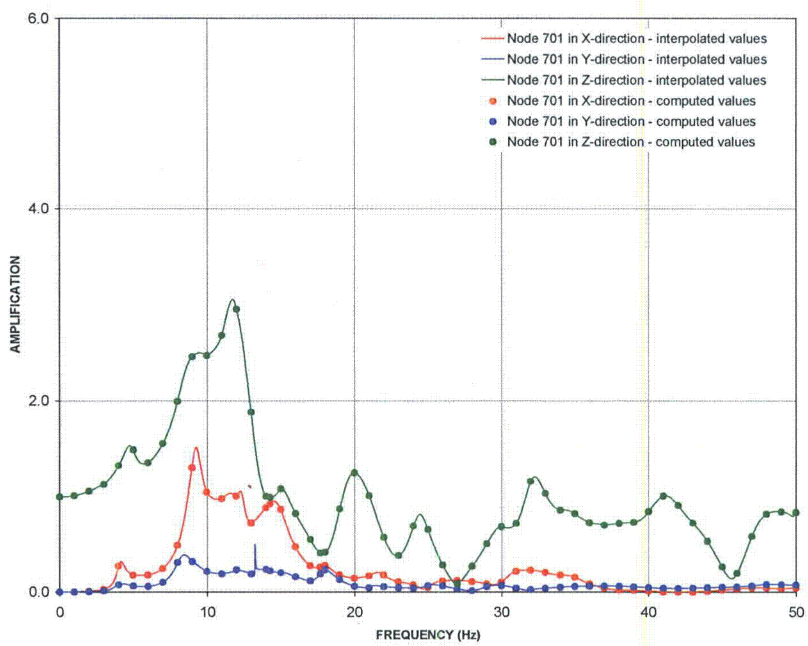


Figure 3.5- 30: Transfer functions - Vent Wall Top, LB subsurface profile, node 701, Z direction input motion

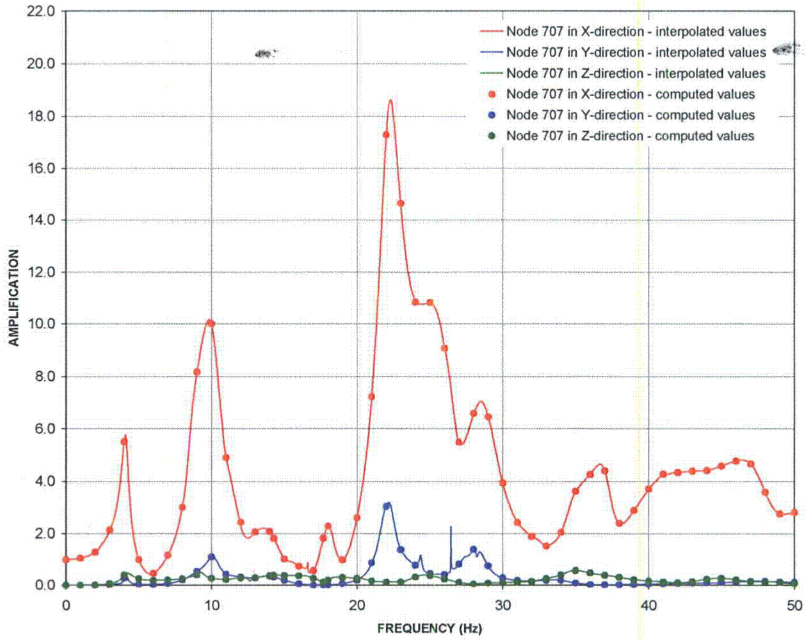


Figure 3.5- 31: Transfer functions - RSW Top, LB subsurface profile, node 707, X direction input motion

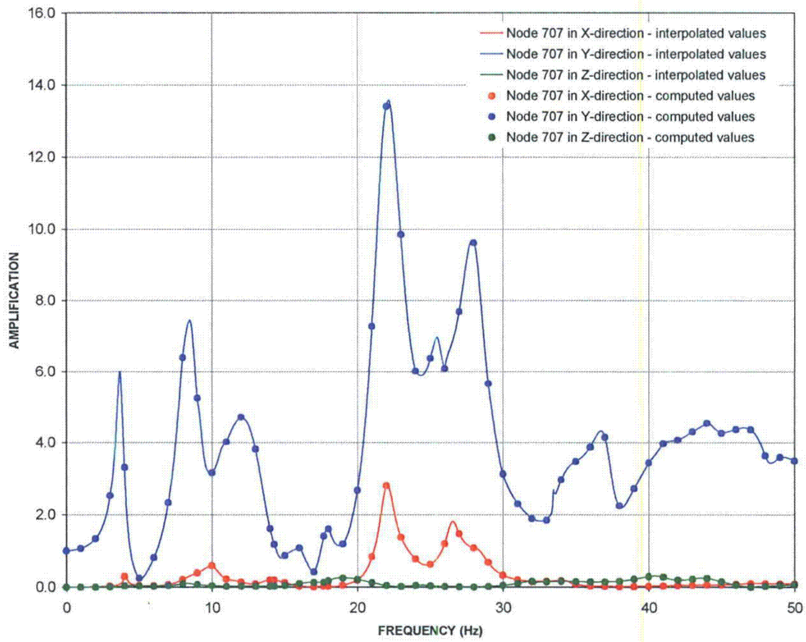


Figure 3.5- 32: Transfer functions - RSW Top, LB subsurface profile, node 707, Y direction input motion

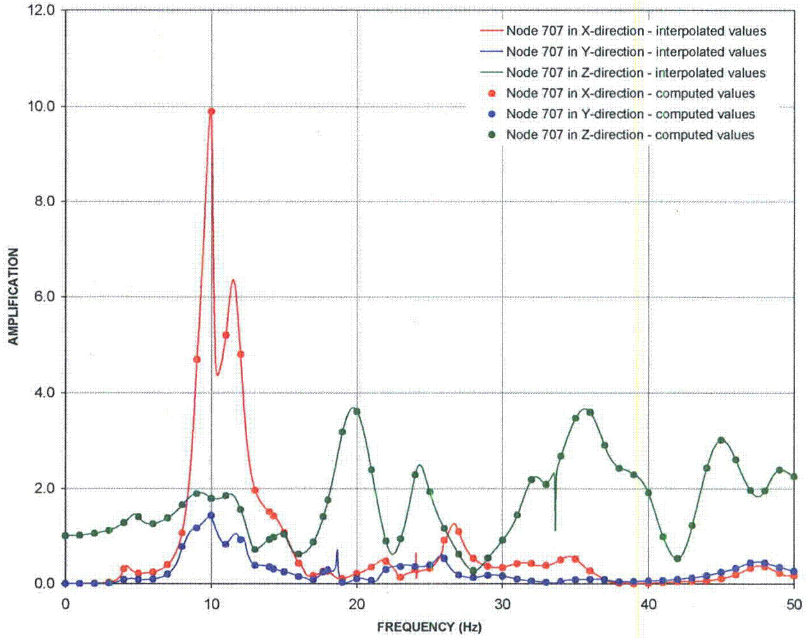


Figure 3.5- 33: Transfer functions - RSW Top, LB subsurface profile, node 707, Z direction input motion

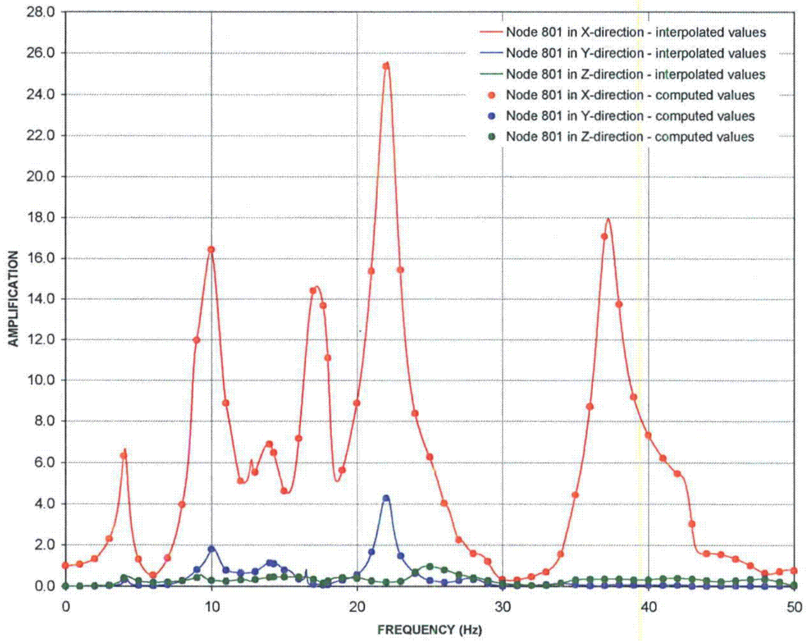


Figure 3.5- 34: Transfer functions - RPV Top, LB subsurface profile, node 801, X direction input motion

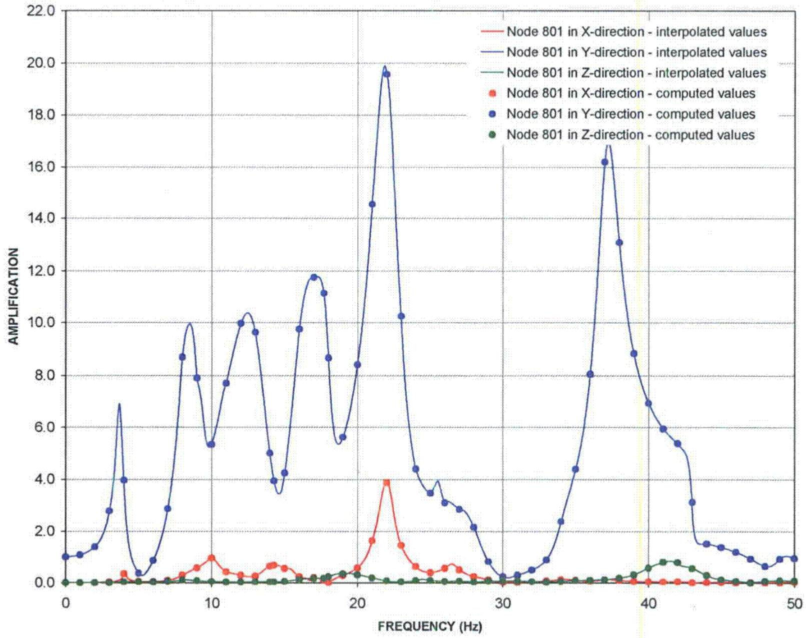


Figure 3.5- 35: Transfer functions - RPV Top, LB subsurface profile, node 801, Y direction input motion

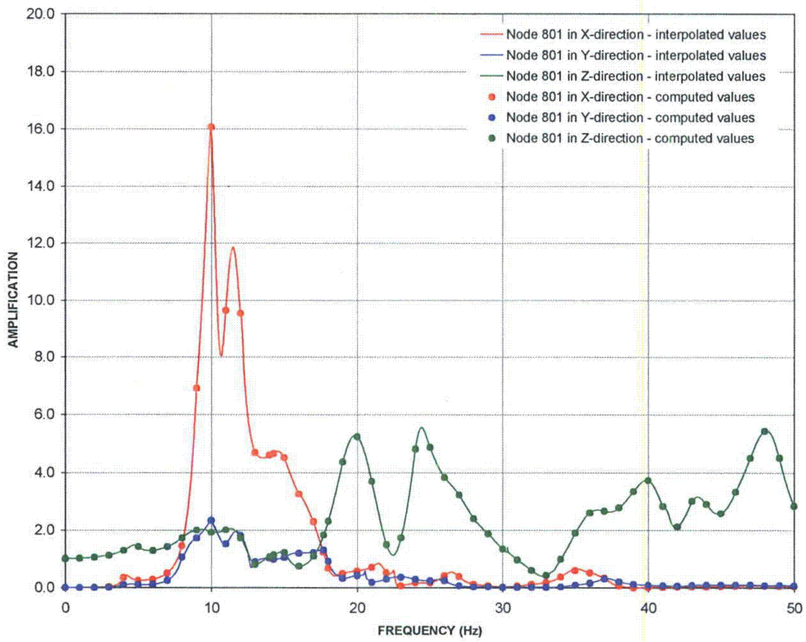


Figure 3.5- 36: Transfer functions - RPV Top, LB subsurface profile, node 801, Z direction input motion

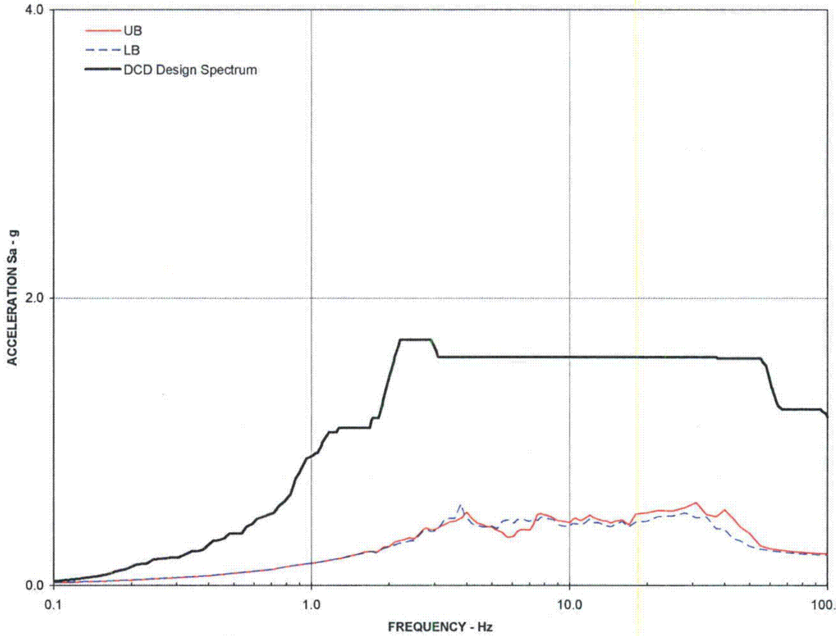


Figure 3.5- 37: Comparison of response spectra – 5% damping RB/FB Basemat, node 2, X direction

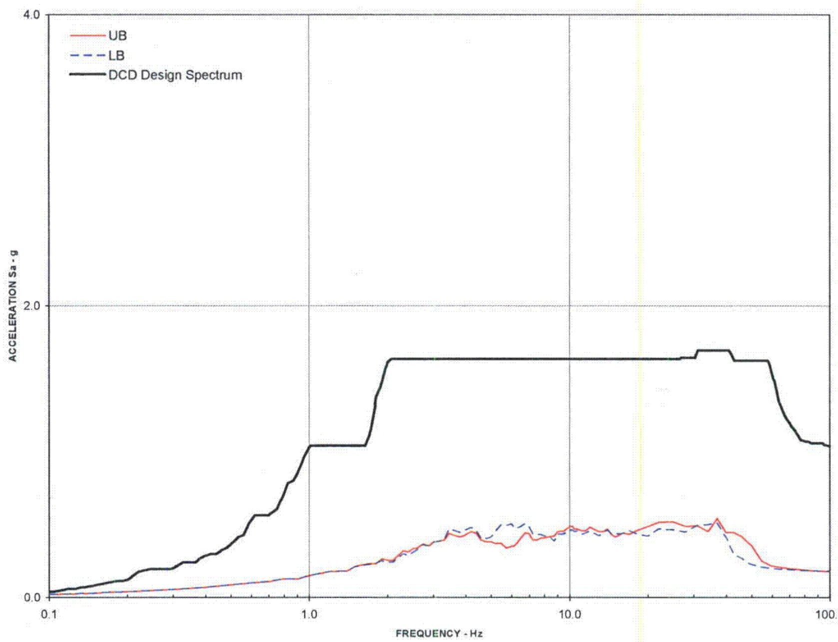


Figure 3.5- 38: Comparison of response spectra – 5% damping RB/FB Basemat, node 2, Y direction

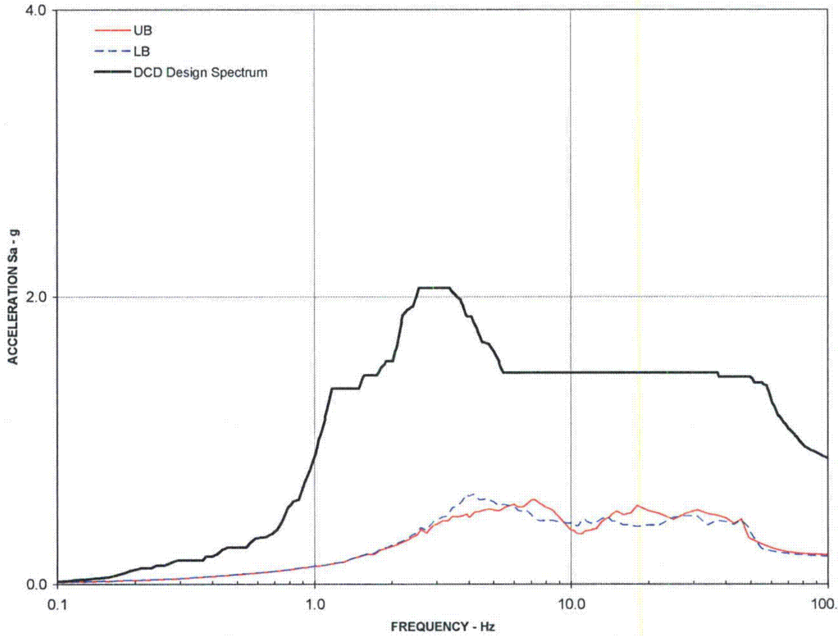


Figure 3.5- 39: Comparison of response spectra – 5% damping RB/FB Basemat, node 2, Z direction

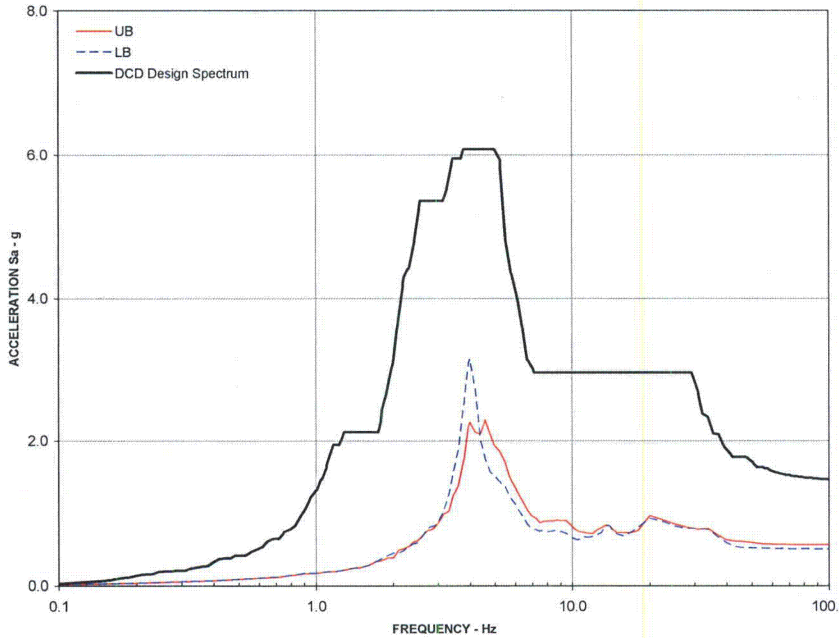


Figure 3.5- 40: Comparison of response spectra – 5% damping RB/FB Refueling Floor, node 109, X direction

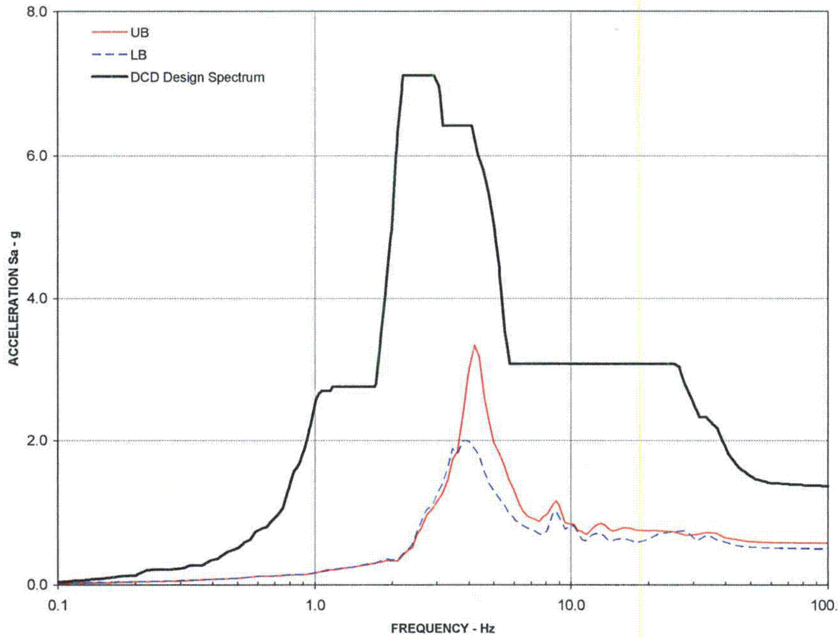


Figure 3.5- 41: Comparison of response spectra – 5% damping RB/FB Refueling Floor, node 109, Y direction

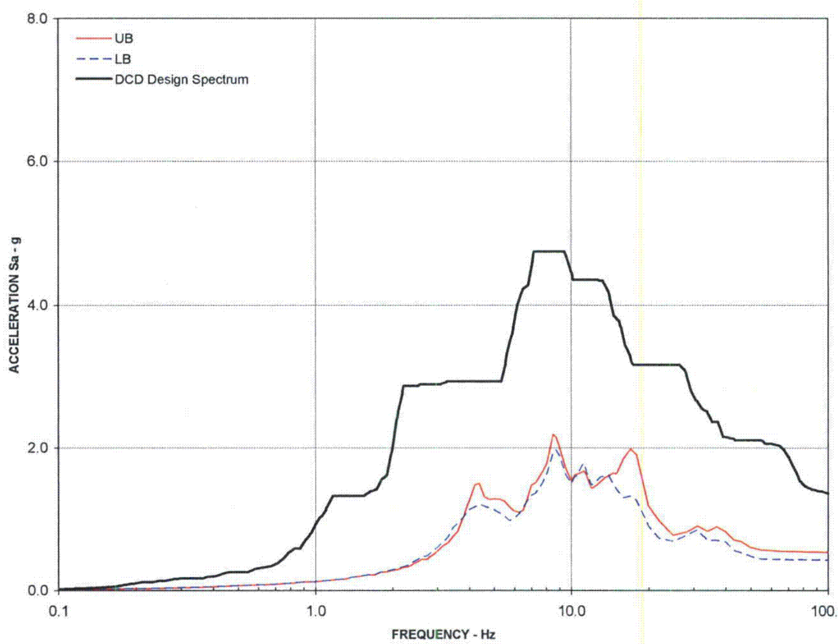


Figure 3.5- 42: Comparison of response spectra – 5% damping RB/FB Refueling Floor, node 109, Z direction

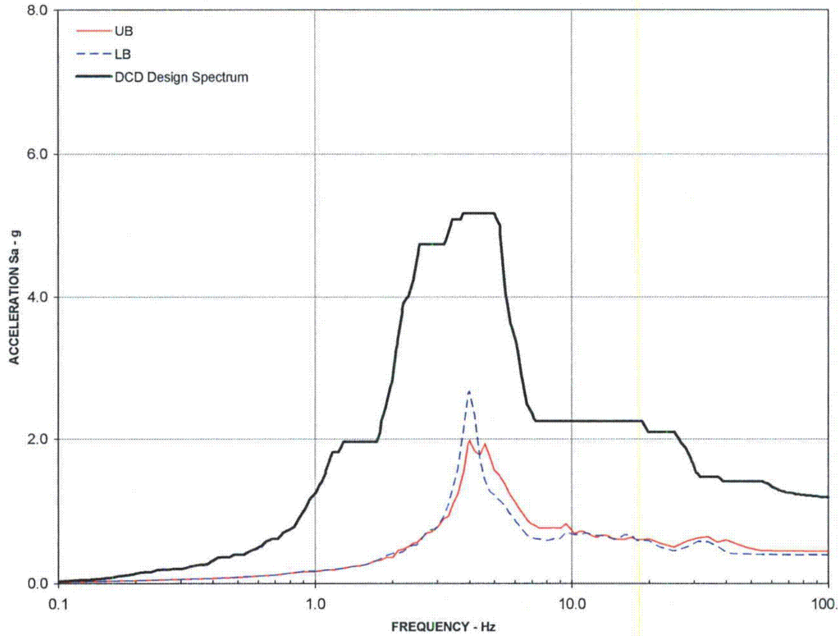


Figure 3.5- 43: Comparison of response spectra – 5% damping RCCV Top Slab, node 208, X direction

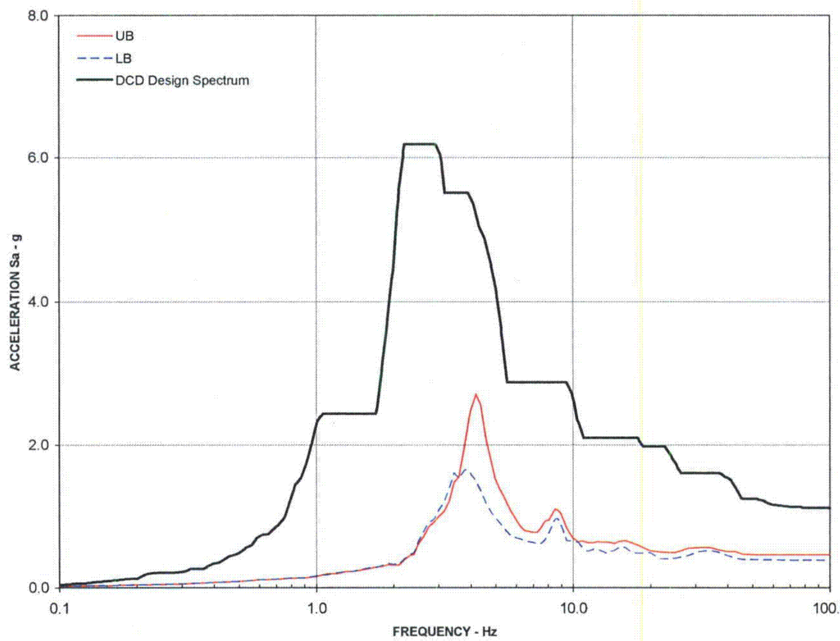


Figure 3.5- 44: Comparison of response spectra – 5% damping RCCV Top Slab, node 208, Y direction

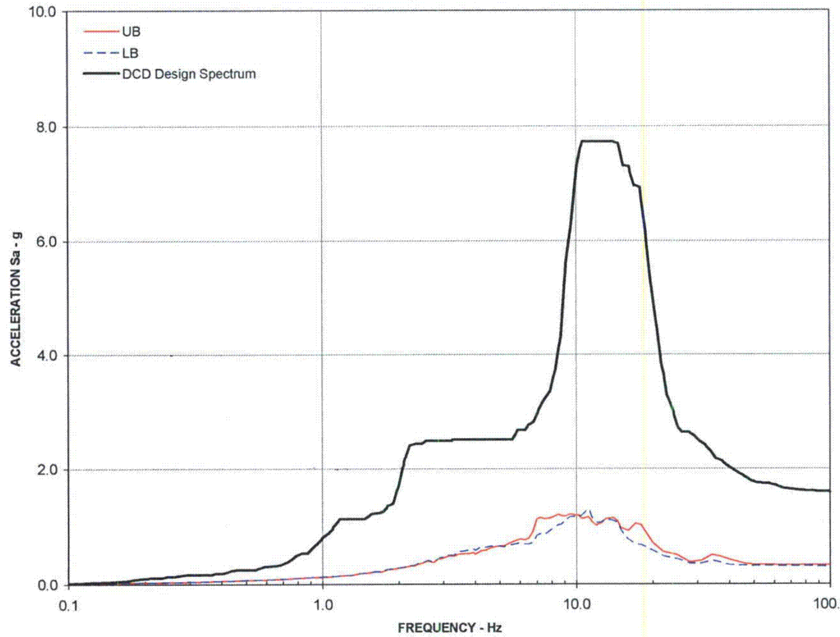


Figure 3.5- 45: Comparison of response spectra – 5% damping RCCV Top Slab, node 208, Z direction

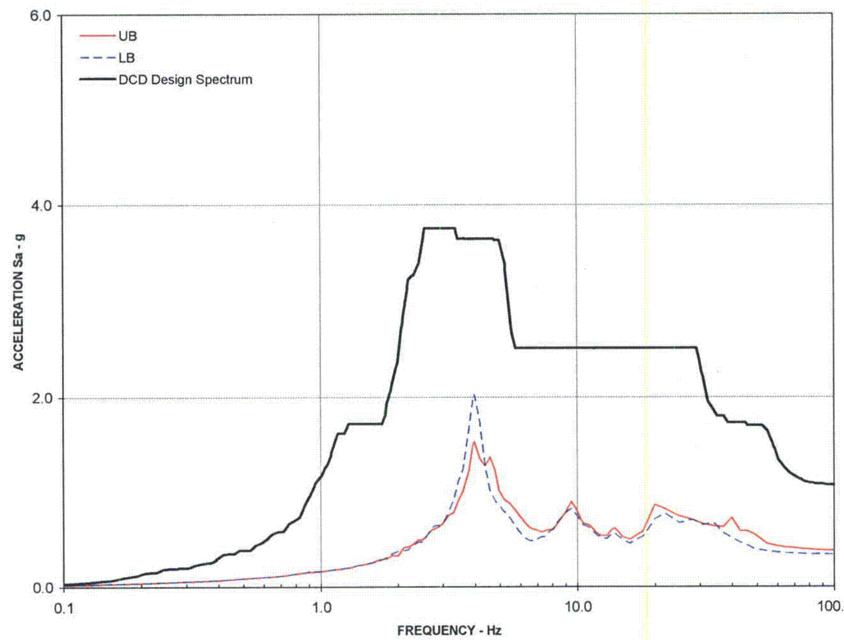


Figure 3.5- 46: Comparison of response spectra – 5% damping Vent Wall Top, node 701, X direction

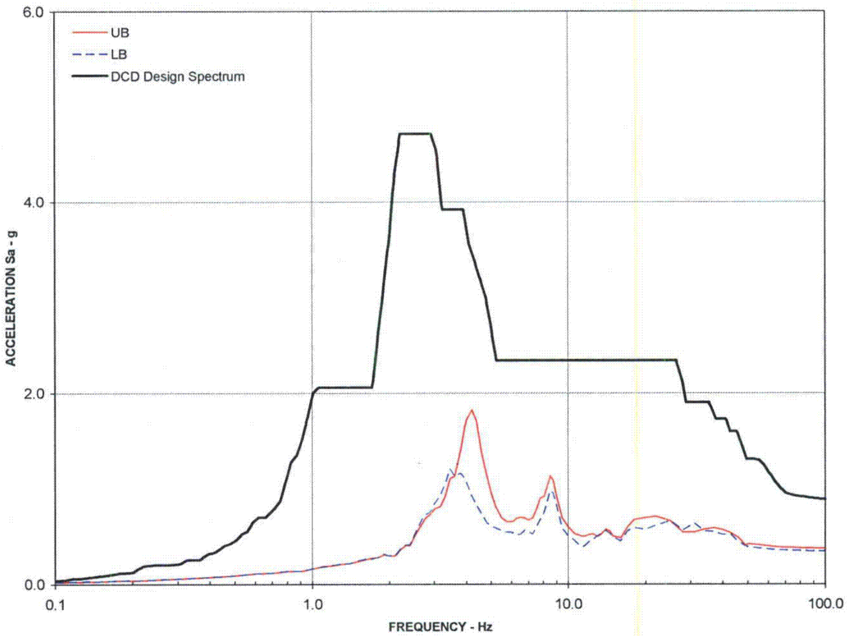


Figure 3.5- 47: Comparison of response spectra – 5% damping Vent Wall Top, node 701, Y direction

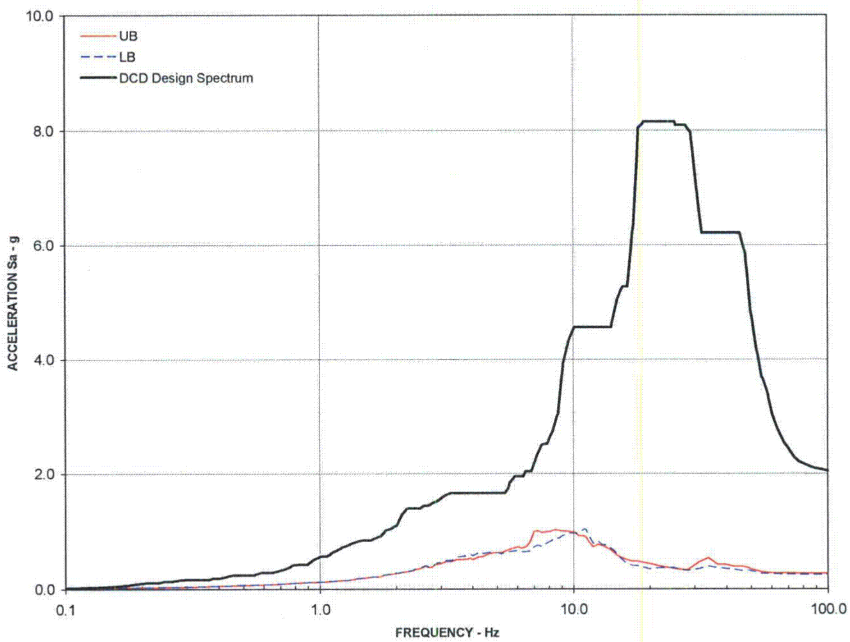


Figure 3.5- 48: Comparison of response spectra – 5% damping Vent Wall Top, node 701, Z direction

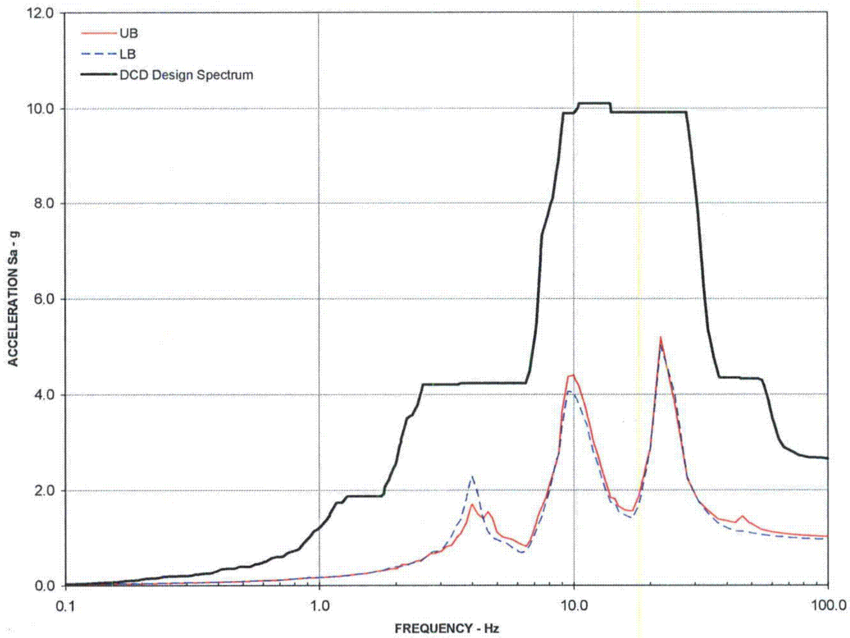


Figure 3.5- 49: Comparison of response spectra – 5% damping RSW Top, node 707, X direction

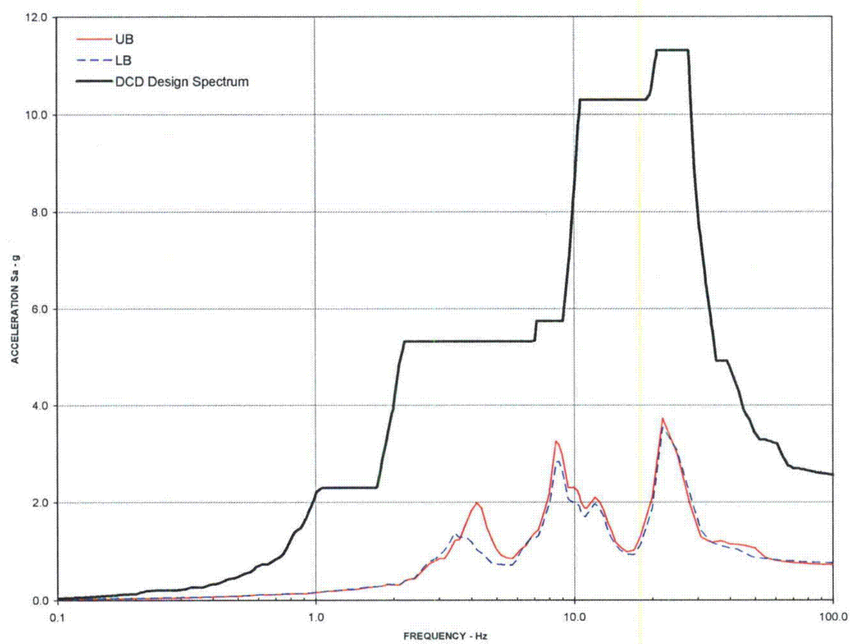


Figure 3.5- 50: Comparison of response spectra – 5% damping RSW Top, node 707, Y direction

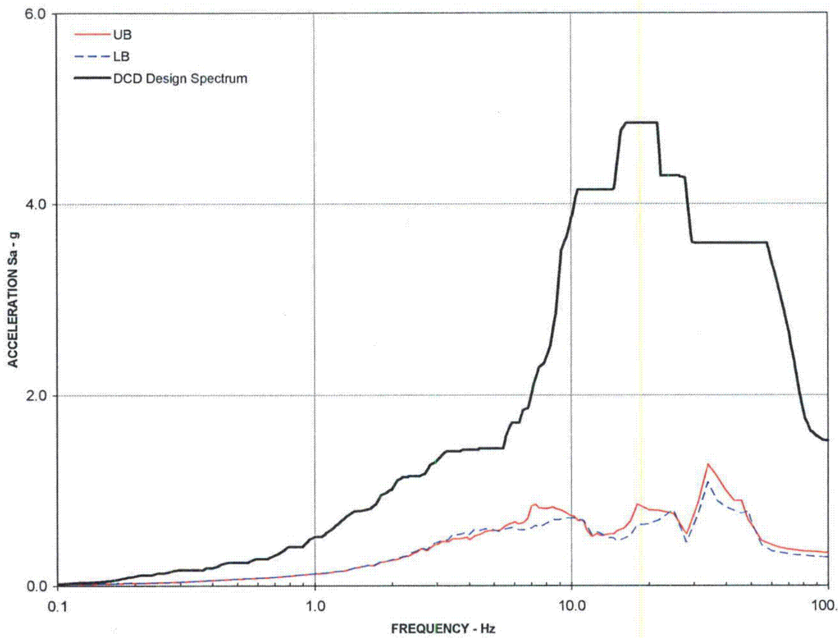


Figure 3.5- 51: Comparison of response spectra – 5% damping RSW Top, node 707, Z direction

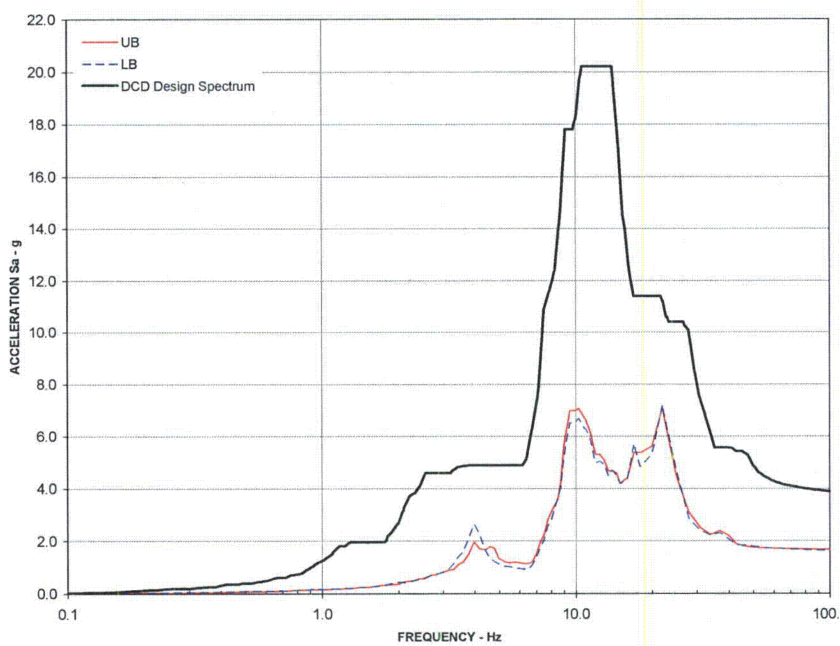


Figure 3.5- 52: Comparison of response spectra – 5% damping RPV Top, node 801, X direction

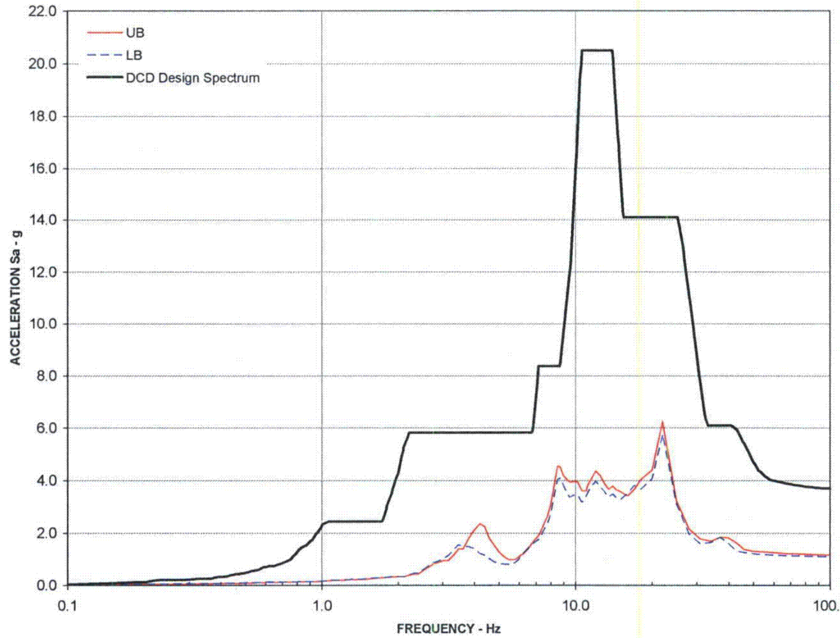


Figure 3.5- 53: Comparison of response spectra – 5% damping RPV Top, node 801, Y direction

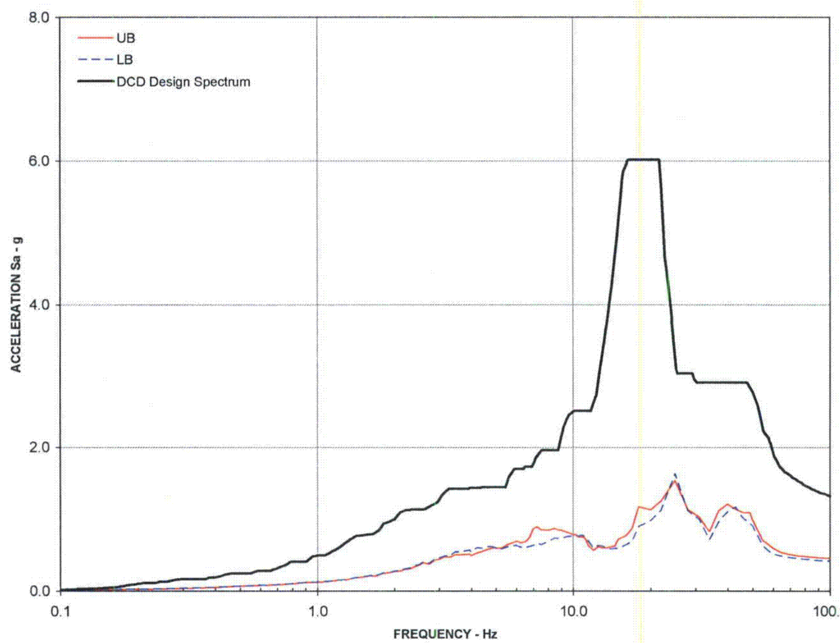
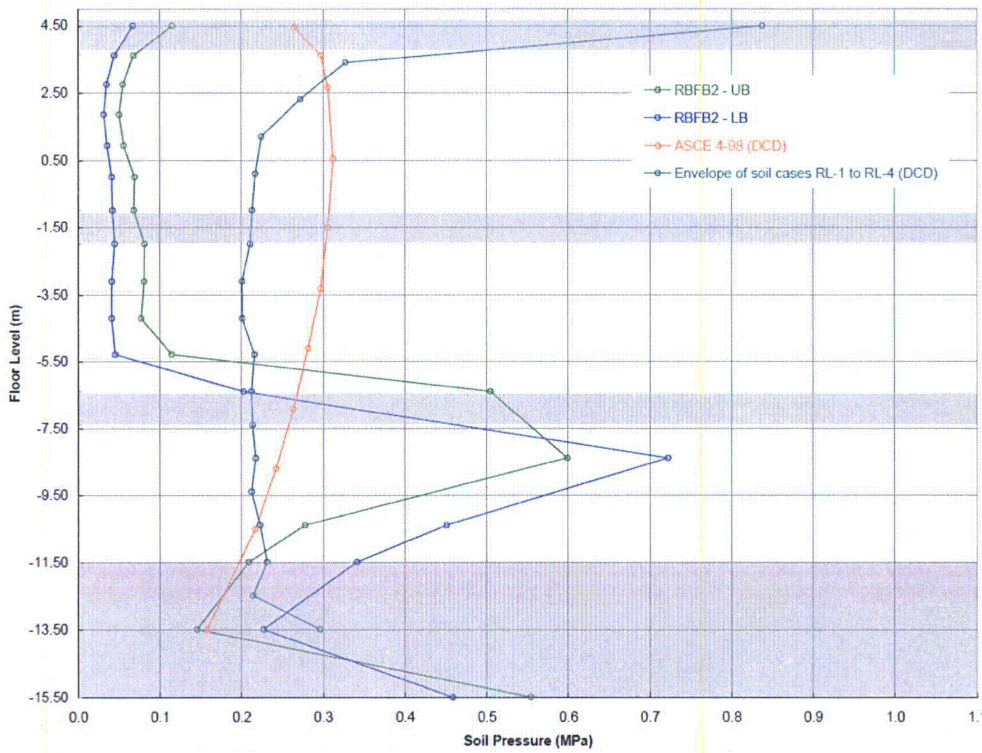


Figure 3.5- 54: Comparison of response spectra – 5% damping RPV Top, node 801, Z direction



Note: The shaded areas show the thickness of foundation mat and floor slabs.

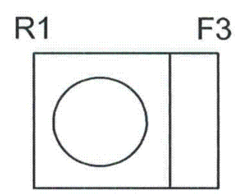
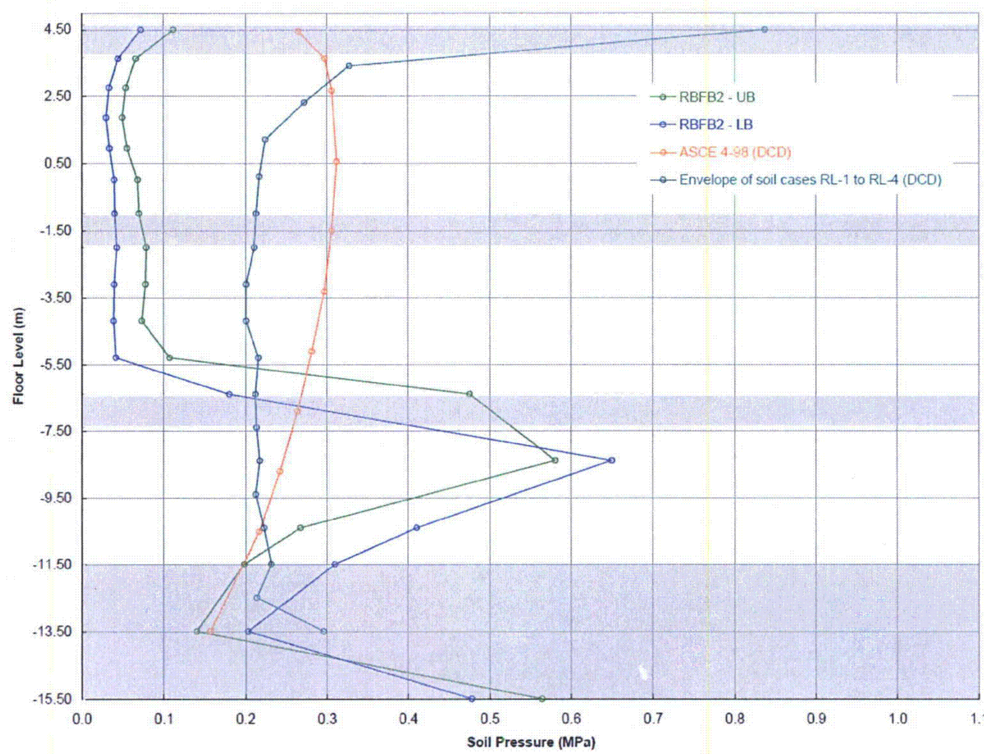


Figure 3.5- 55: Lateral soil pressure for RB/FB north wall (R1)



Note: The shaded areas show the thickness of foundation mat and floor slabs.

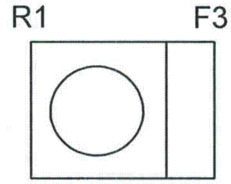
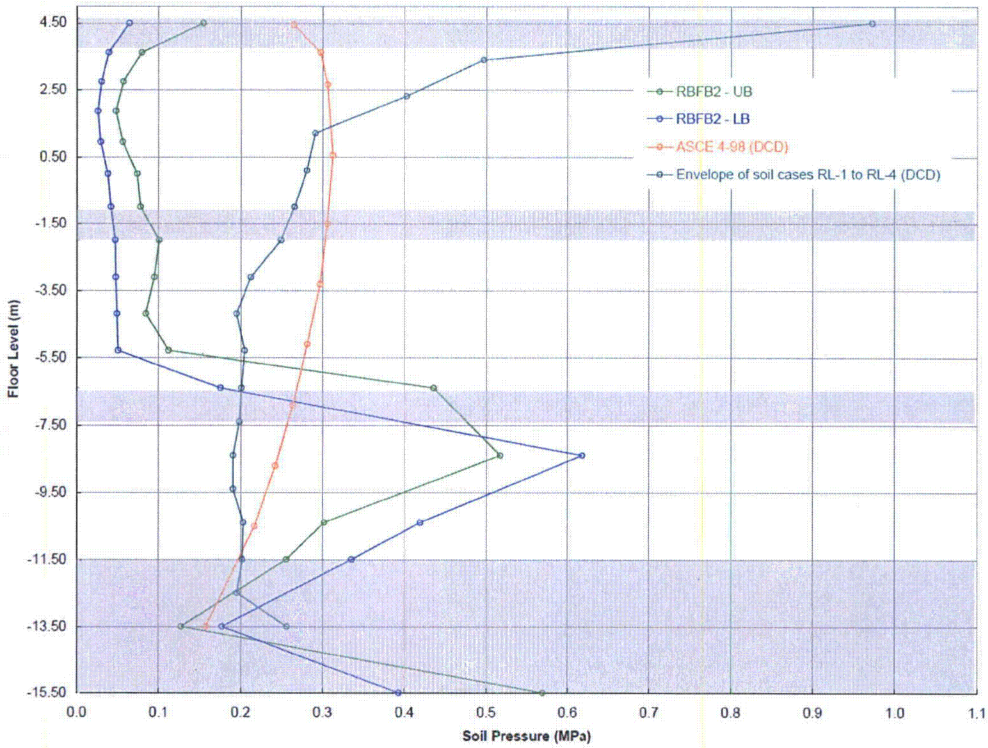


Figure 3.5- 56: Lateral soil pressure for RB/FB south wall (F3)



Note: The shaded areas show the thickness of foundation mat and floor slabs.

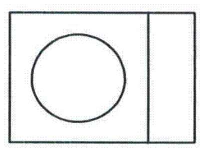
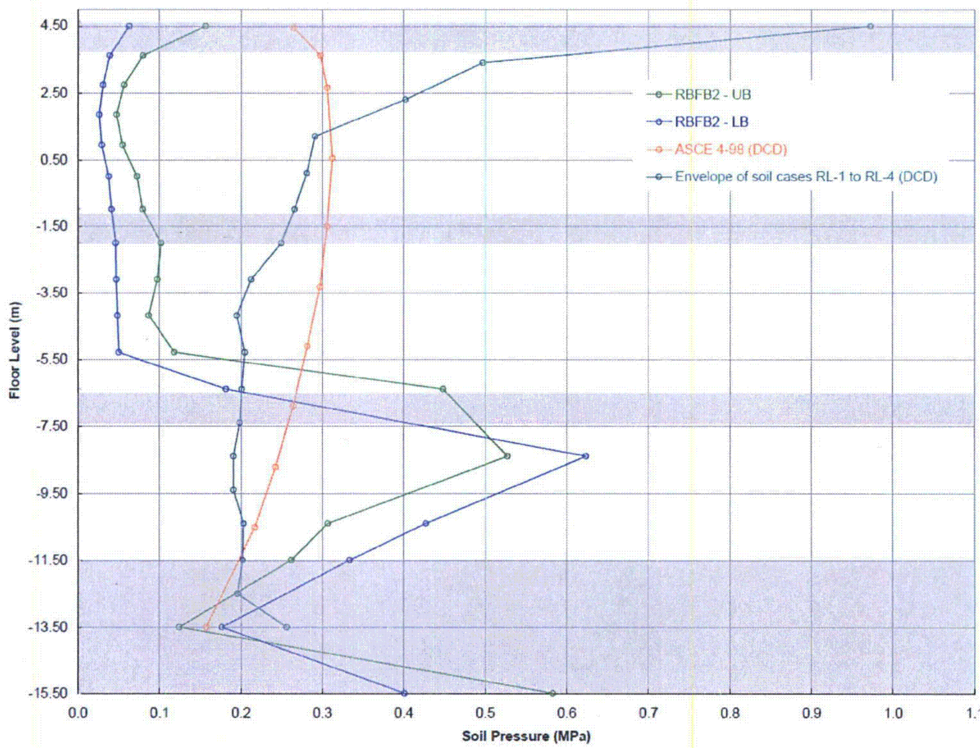


Figure 3.5- 57: Lateral soil pressure for RB/FB east wall (RA)



Note: The shaded areas show the thickness of foundation mat and floor slabs.

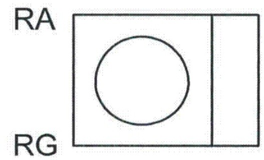


Figure 3.5- 58: Lateral soil pressure for RB/FB west wall (RG)

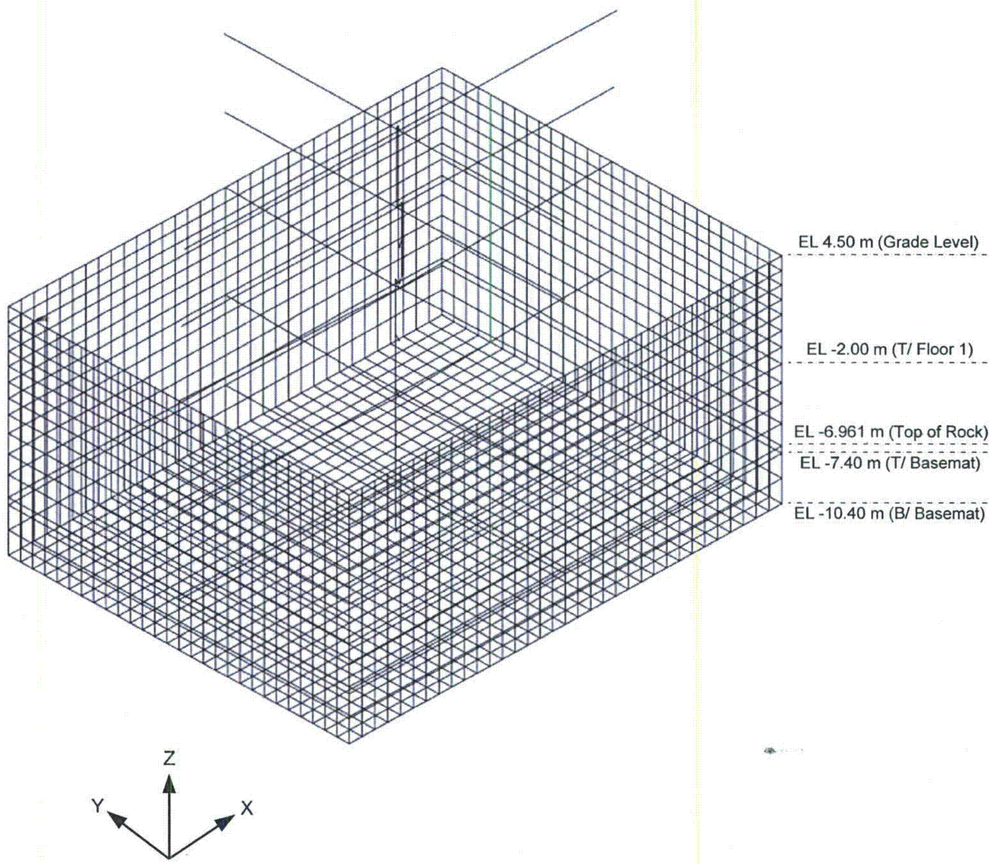


Figure 4.1- 1: 3D view of the Control Building model

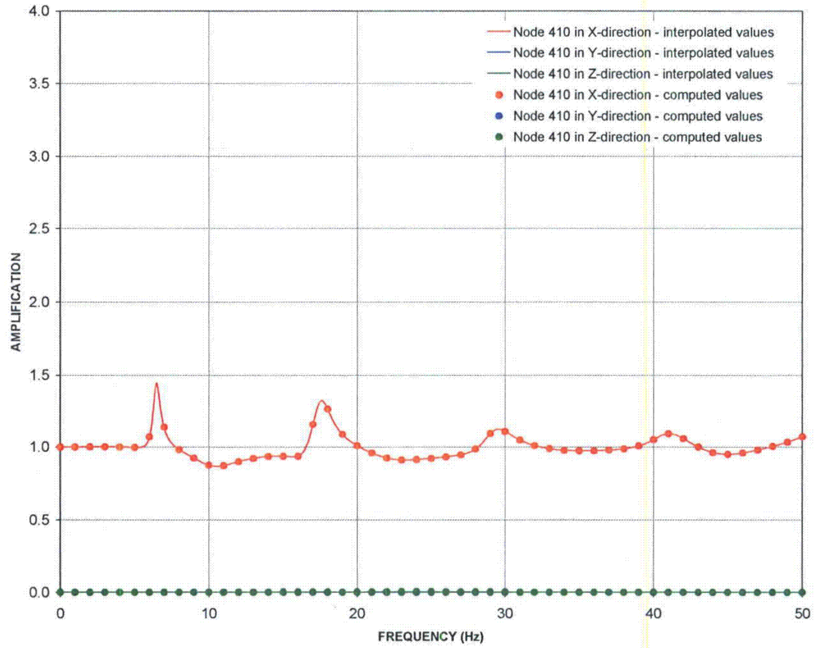


Figure 4.5- 1: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, node 410, X direction input motion

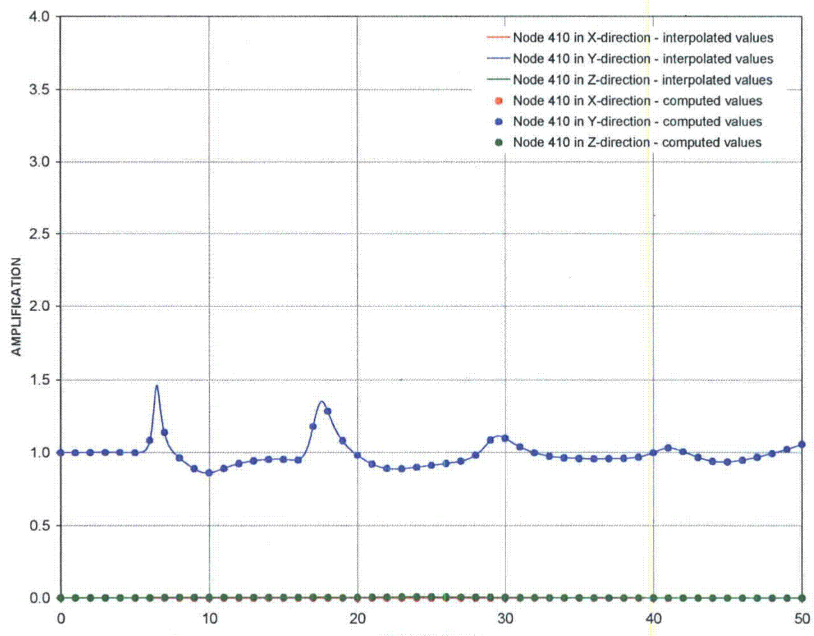


Figure 4.5- 2: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, node 410, Y direction input motion

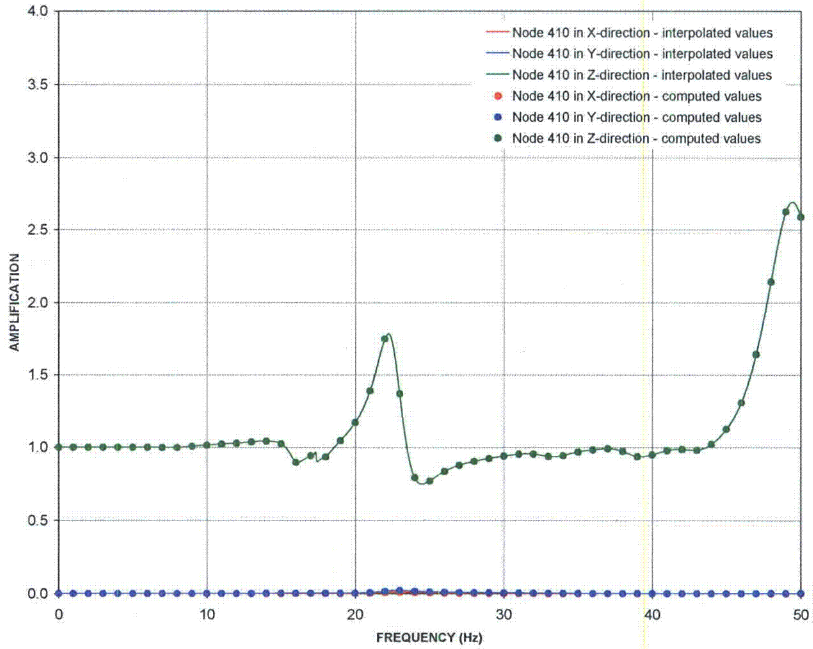


Figure 4.5- 3: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, node 410, Z direction input motion

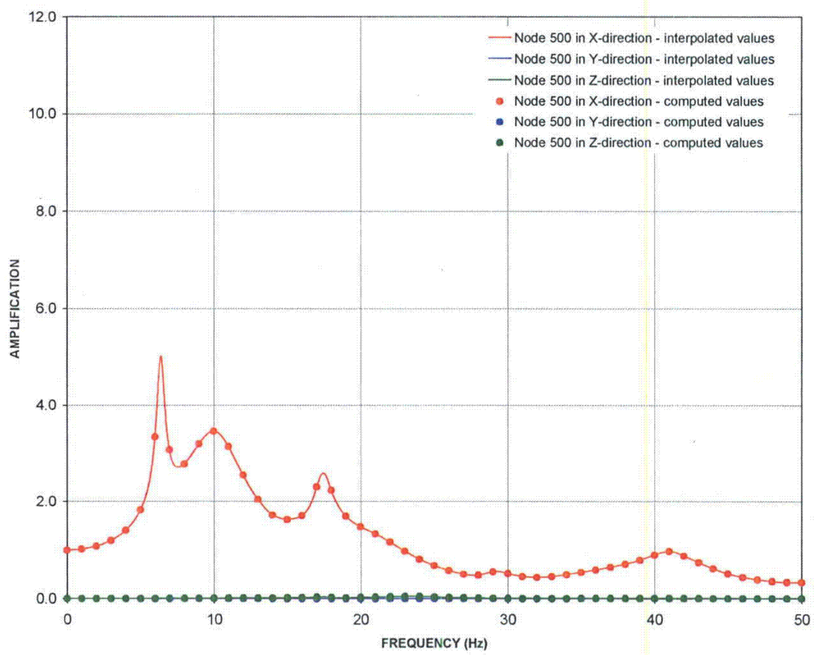


Figure 4.5- 4: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, node 500, X direction input motion

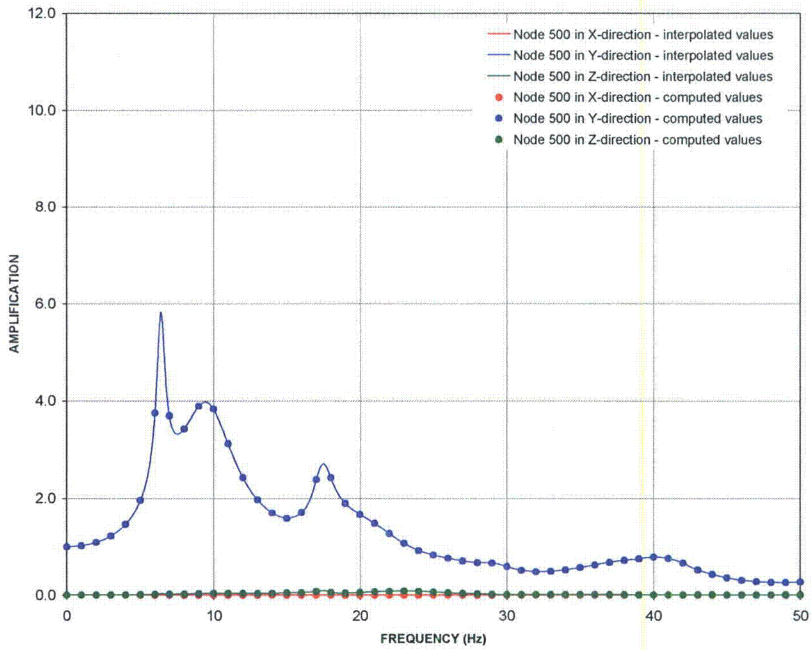


Figure 4.5- 5: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, node 500, Y direction input motion

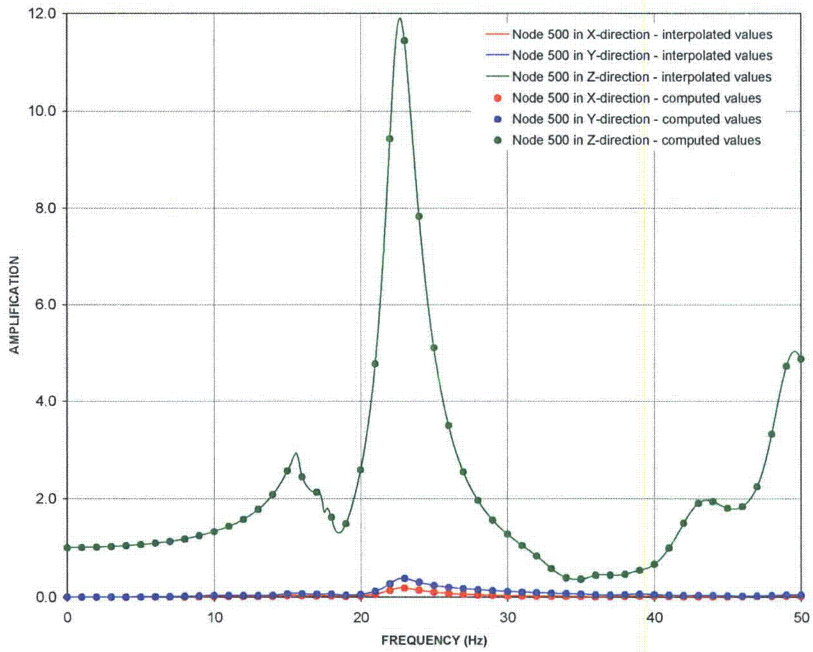


Figure 4.5- 6: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, node 500, Z direction input motion

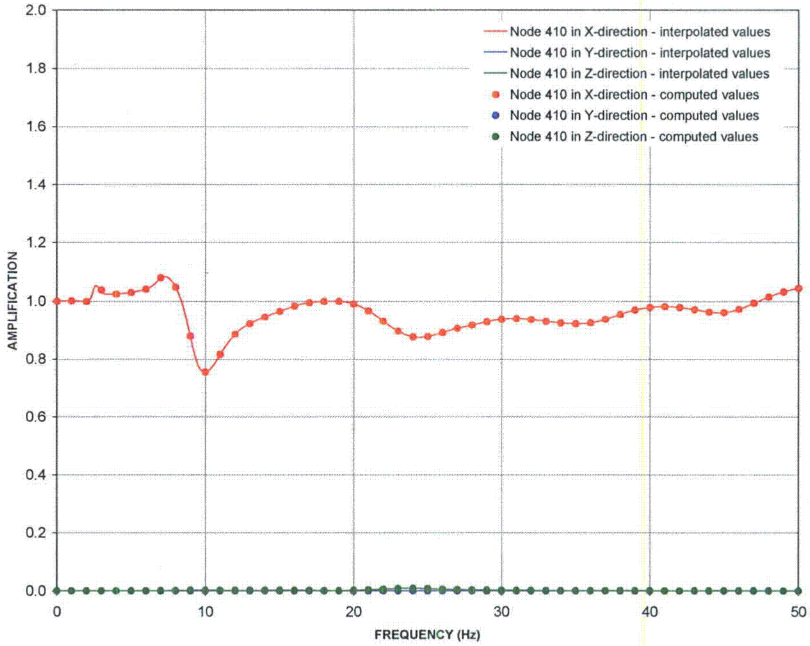


Figure 4.5- 7: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, node 410, X direction input motion

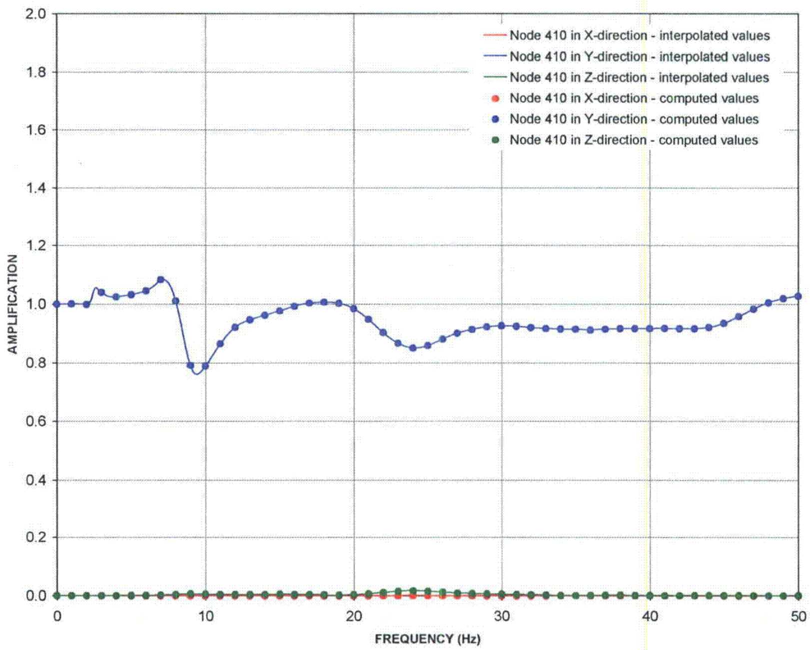


Figure 4.5- 8: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, node 410, Y direction input motion

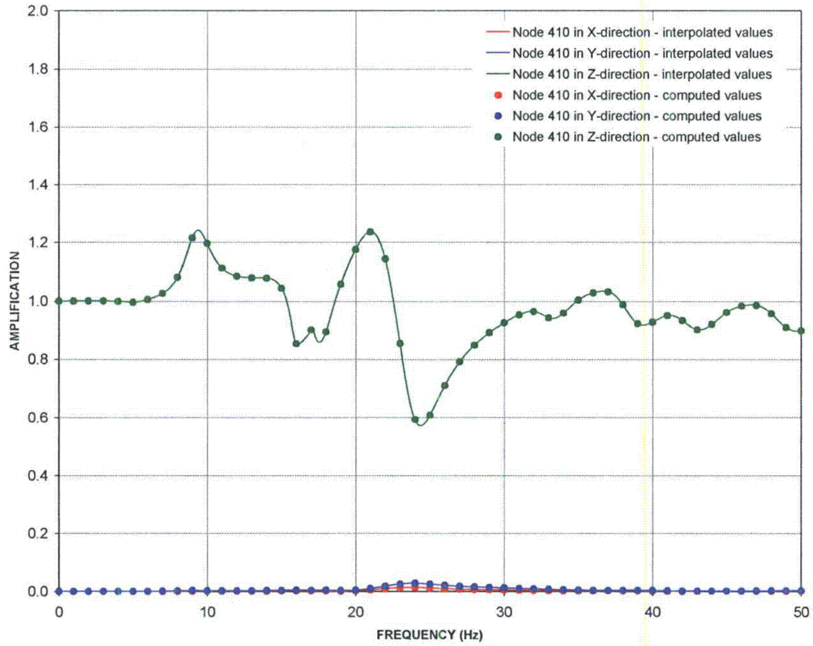


Figure 4.5- 9: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, node 410, Z direction input motion

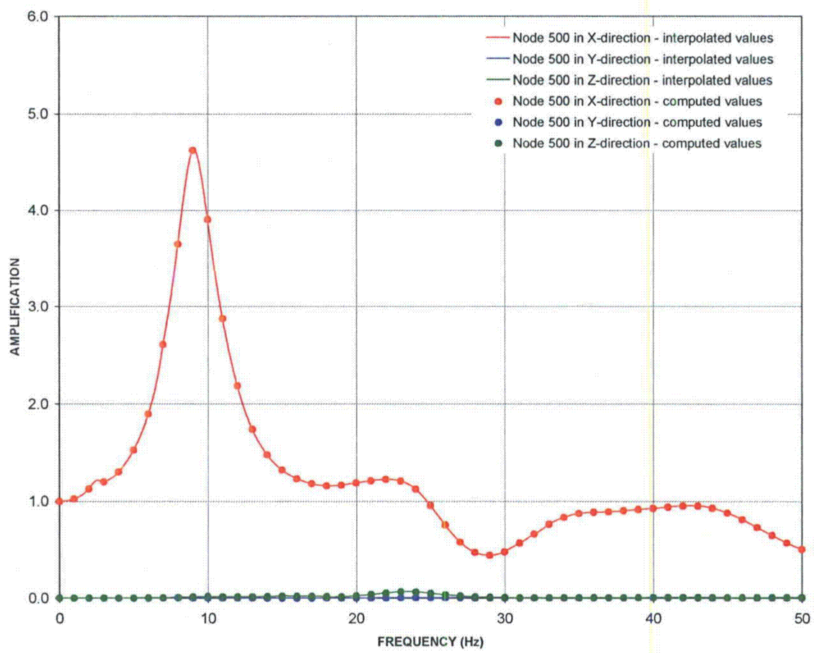


Figure 4.5- 10: Transfer functions - CB roof (EL 13.8 m), LB subsurface profile, node 500, X direction input motion

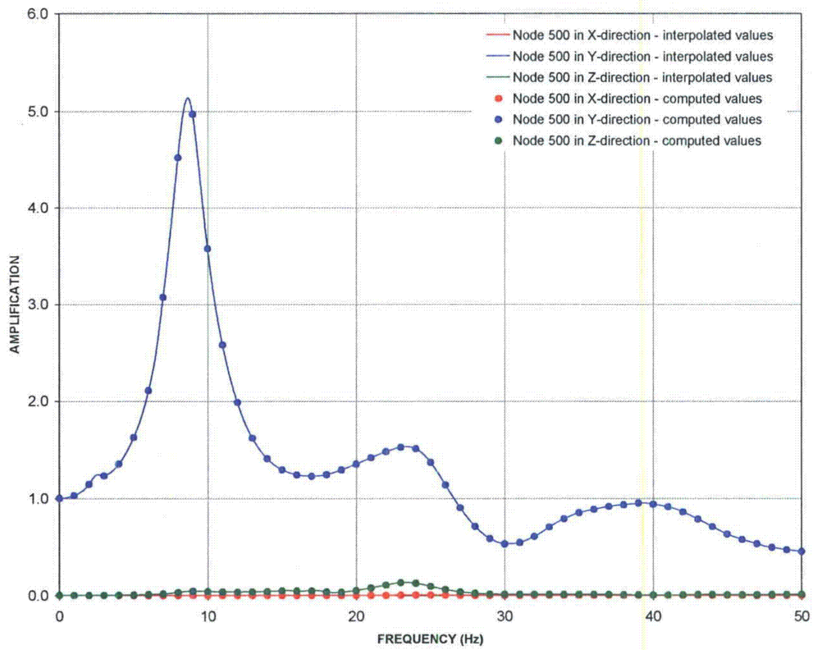


Figure 4.5- 11: Transfer functions - CB roof (EL 13.8 m), LB subsurface profile, node 500, Y direction input motion

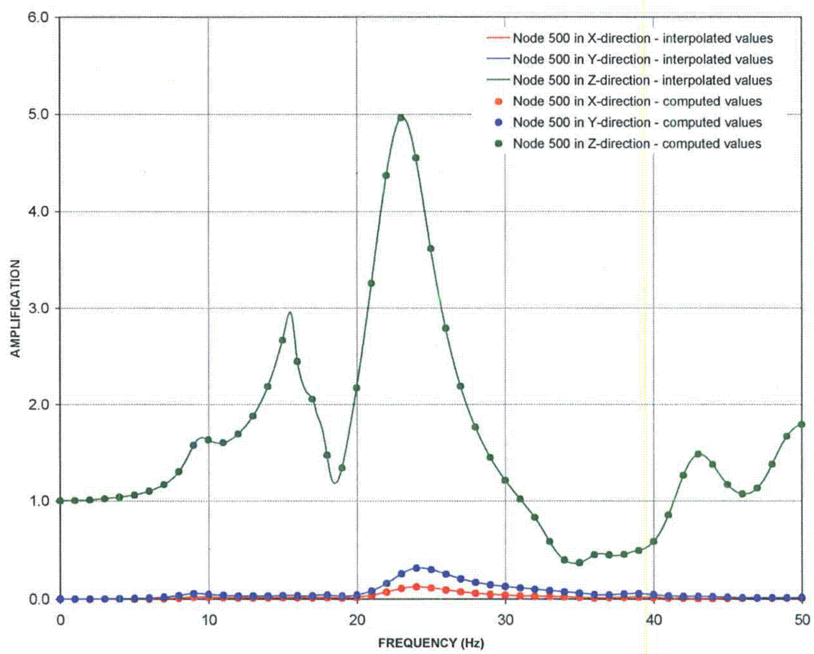


Figure 4.5- 12: Transfer functions - CB roof (EL 13.8 m), LB subsurface profile, node 500, Z direction input motion

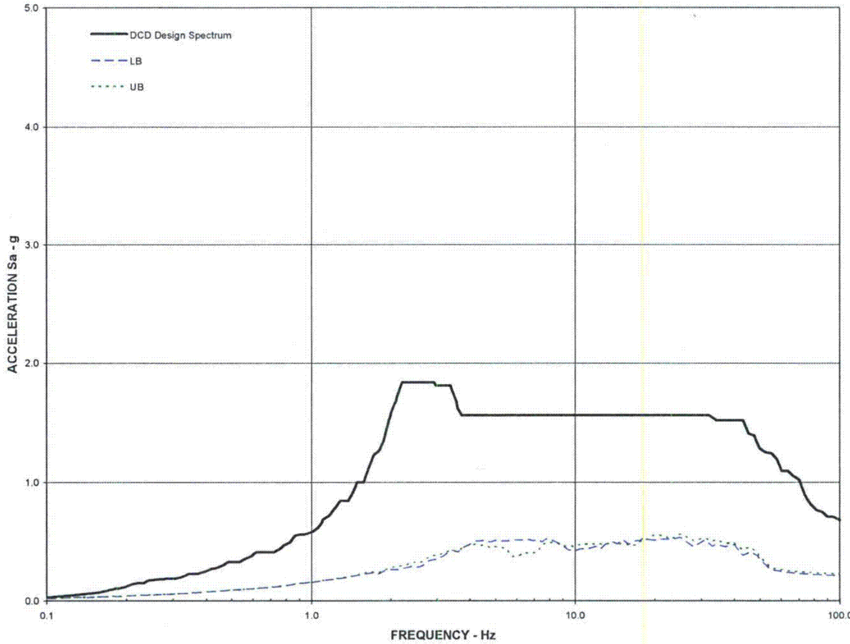


Figure 4.5- 13: Comparison of floor response spectra – 5% damping CB foundation (EL -7.4 m), node 410, X direction

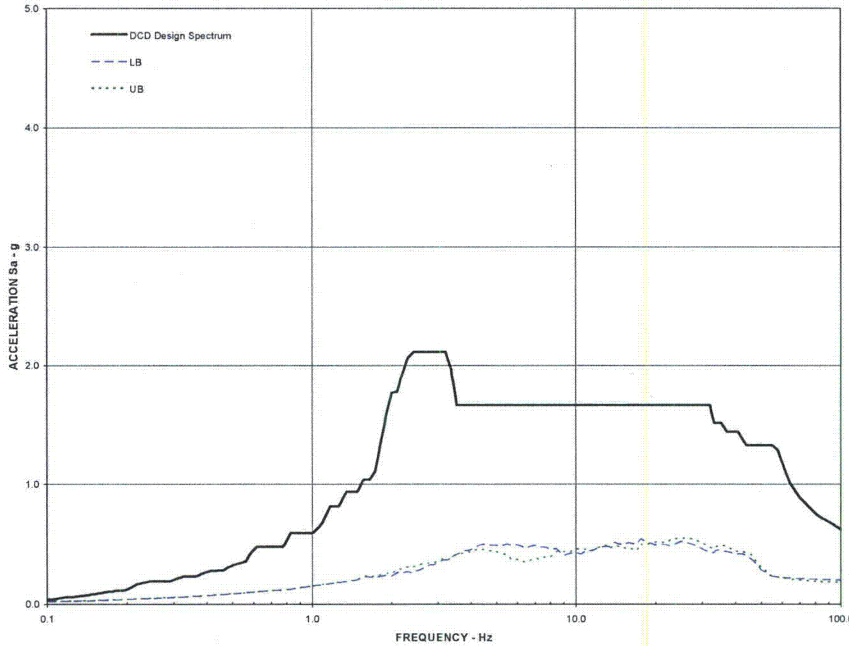


Figure 4.5- 14: Comparison of floor response spectra – 5% damping CB foundation (EL -7.4 m), node 410, Y direction

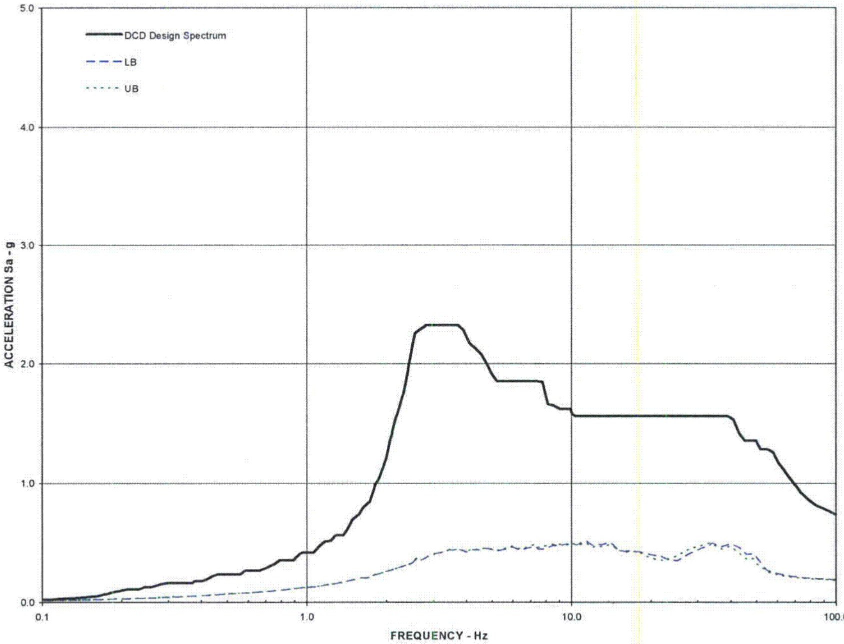


Figure 4.5- 15: Comparison of floor response spectra – 5% damping CB foundation (EL -7.4 m), node 410, Z direction

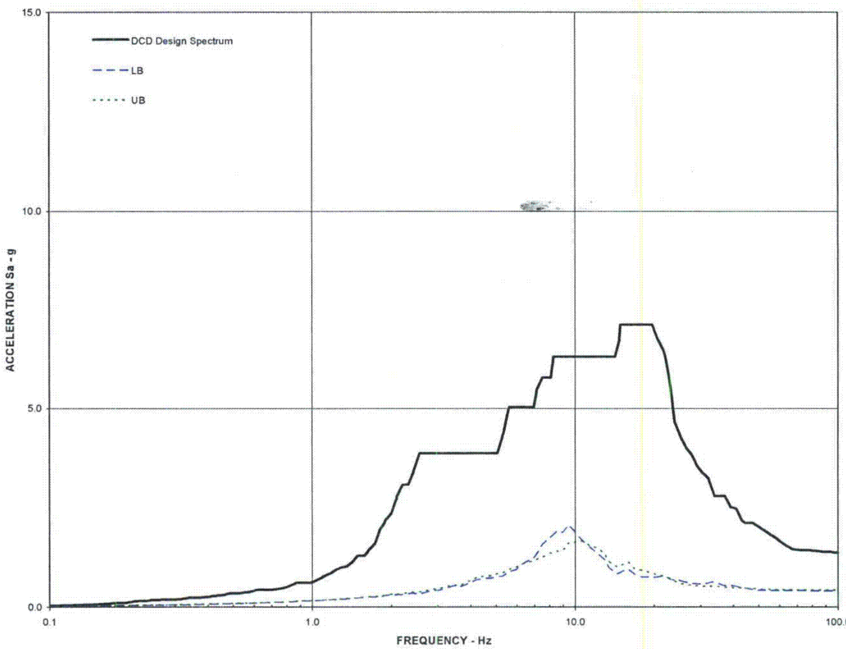


Figure 4.5- 16: Comparison of floor response spectra – 5% damping CB roof (EL 13.8 m), node 500, X direction

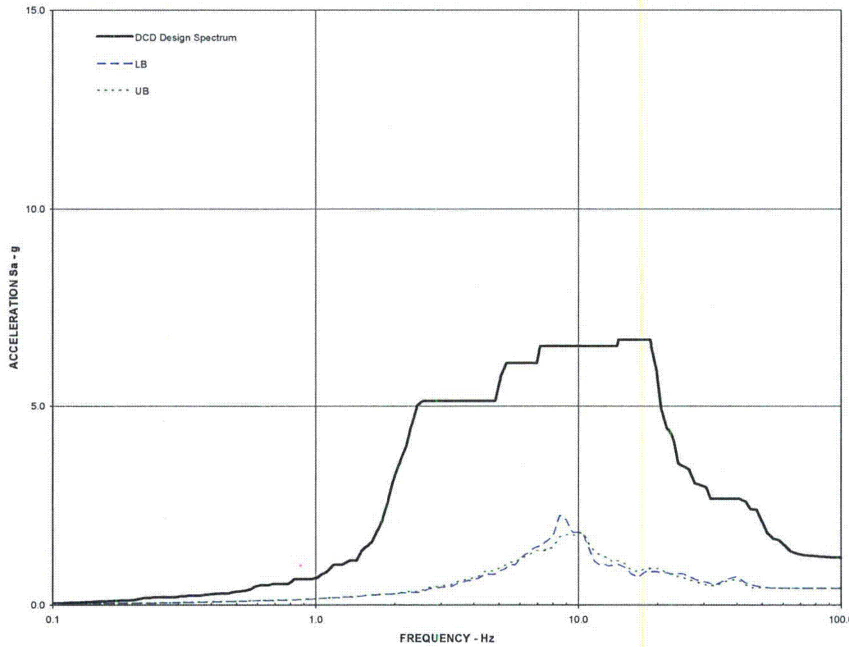


Figure 4.5- 17: Comparison of floor response spectra – 5% damping CB roof (EL 13.8 m), node 500, Y direction

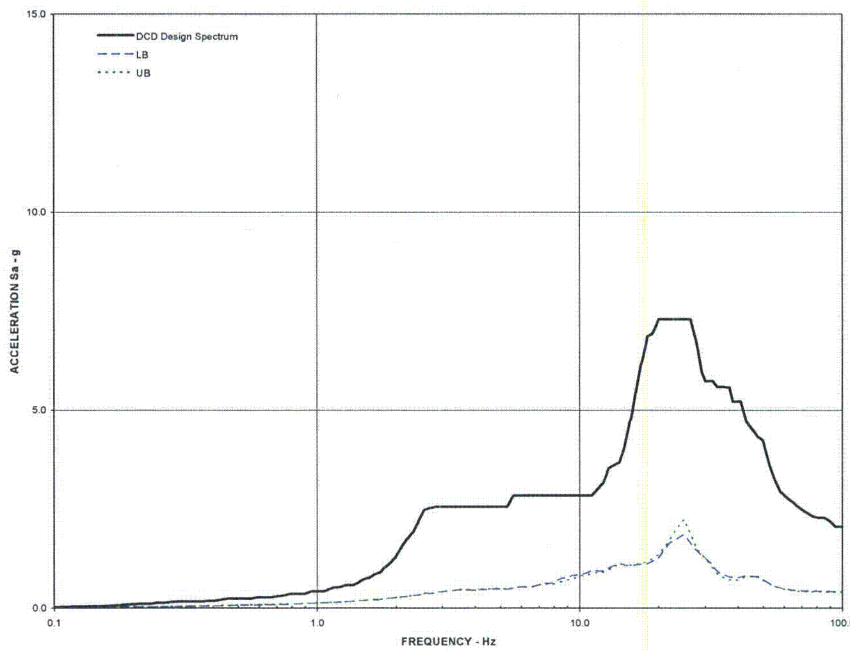
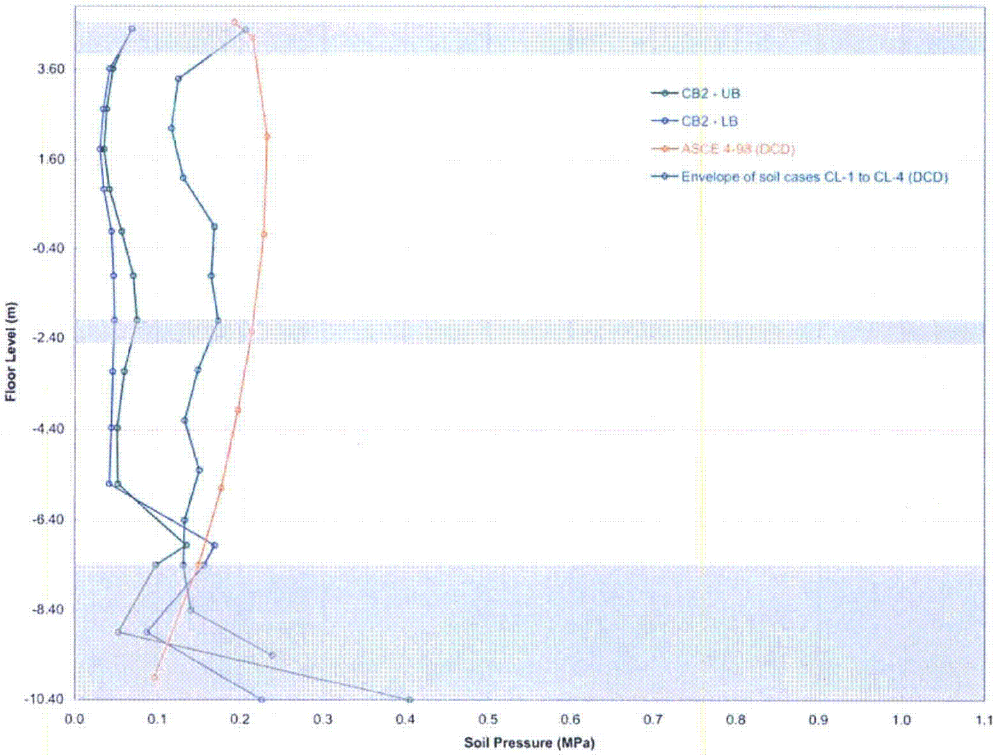


Figure 4.5- 18: Comparison of floor response spectra – 5% damping CB roof (EL 13.8 m), node 500, Z direction



Note: The shaded areas show the thickness of the foundation mat and floor slabs.

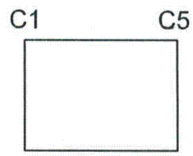
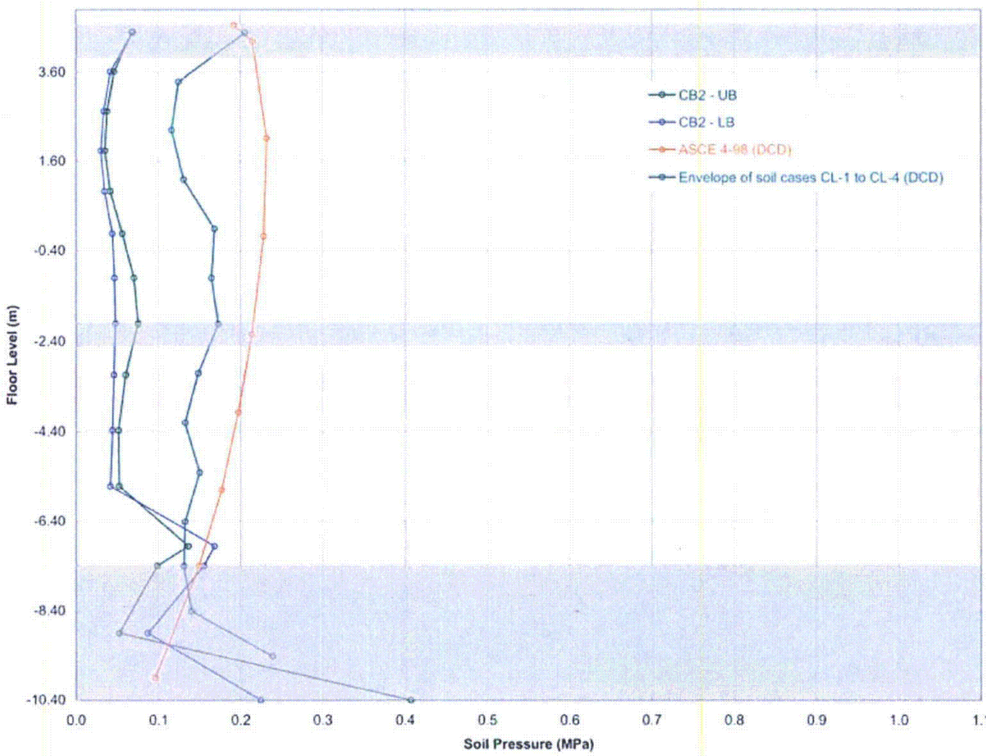


Figure 4.5- 19: Lateral soil pressure for CB north wall (C1)



Note: The shaded areas show the thickness of the foundation mat and floor slabs.

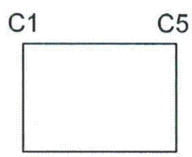
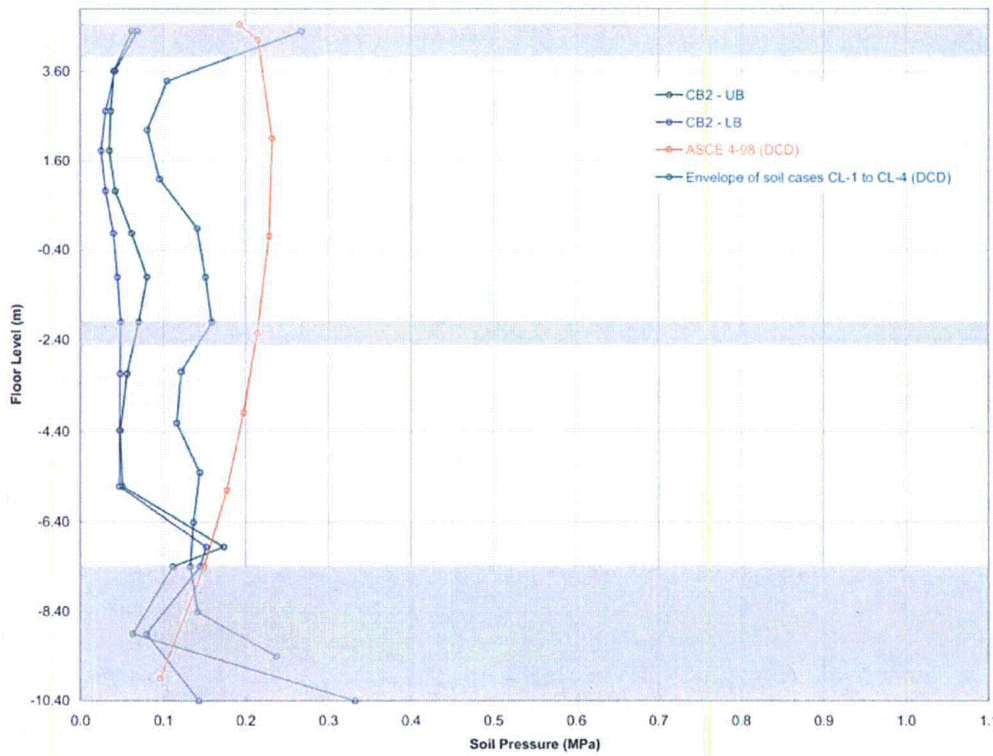


Figure 4.5- 20: Lateral soil pressure for CB south wall (C5)



Note: The shaded areas show the thickness of the foundation mat and floor slabs.

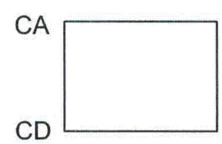
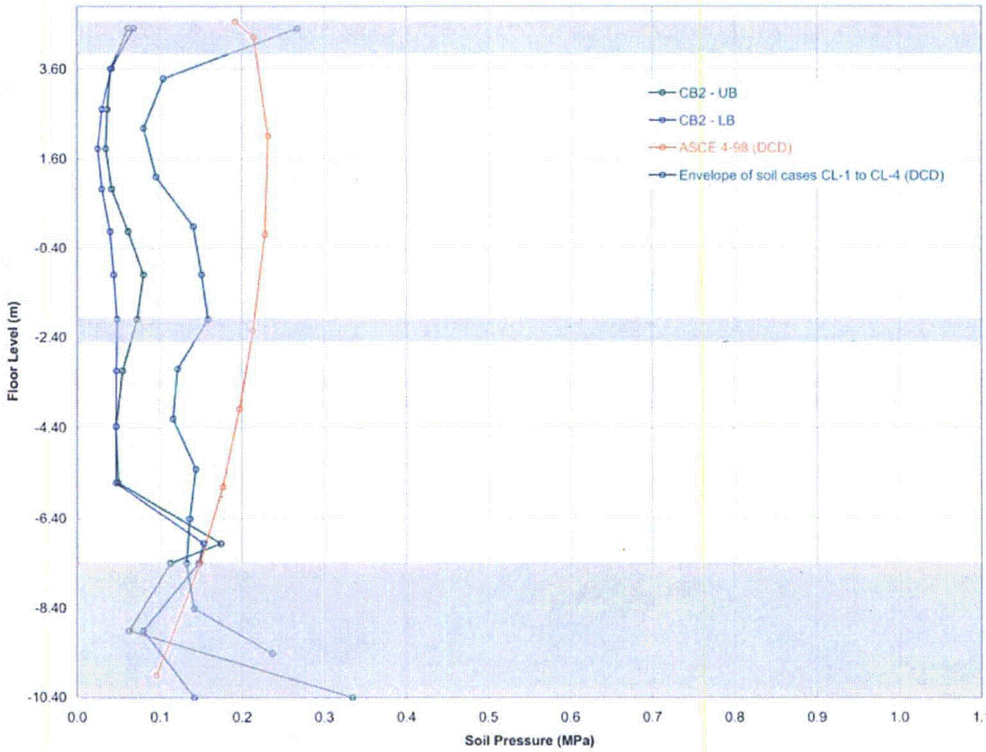


Figure 4.5- 21: Lateral soil pressure for CB east wall (CA)



Note: The shaded areas show the thickness of the foundation mat and floor slabs.

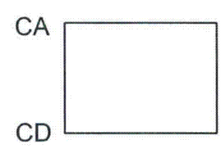


Figure 4.5- 22: Lateral soil pressure for CB west wall (CD)