DTE Electric Company
Fermi 3 – ESBWR

SSSI Sensitivity Studies of CB and FWSC with Engineered Backfill Summary Report

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Executive Summary

This report presents the summary of two Fermi 3 Structure-Soil-Structure Interaction (SSSI) analyses: (1) SSSI effect between the Reactor Building/Fuel Building (RB/FB) and Control Building (CB) and (2) SSSI effect between the CB and Fire Water Service Complex (FWSC). Both SSSI analyses are performed for models which include engineered backfill above the top of the Bass Islands Group bedrock. The purpose of these analyses is to determine the SSSI effects of the RB/FB and FWSC on the seismic responses of the CB. These SSSI 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 of the CB obtained from these analyses, which include (i) the SSSI effects between the RB/FB and CB and (ii) the SSSI effect between the CB and FWSC, are bounded by the corresponding responses presented in ESBWR Design Control Document (Reference 4) with substantial margin. Only exceptions are a small exceedance of the lateral soil pressure in a small area just above the top of the basemat of the CB and in the bottom half of the basemat. The adequacy of the wall designs for these exceedances in the lateral soil pressures is being evaluated and the results will be presented to the NRC by September 30, 2013.

1.0 Introduction

The scope of this report is to present the summary of two Fermi 3 Structure-Soil-Structure Interaction (SSSI) analyses: (1) SSSI effect between the Reactor Building/Fuel Building (RB/FB) and Control Building (CB) and (2) SSSI effect between the CB and Fire Water Service Complex (FWSC). Both SSSI analyses are performed for models which include engineered backfill above the top of the Bass Islands Group bedrock. The purpose of these analyses is to determine the SSSI effects of the RB/FB and FWSC on the seismic responses of the CB. These SSSI 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 in structure responses of the CB obtained from these analyses, which include the SSSI effects (i) between the RB/FB and CB and the SSSI effect between the CB and FWSC, are bounded by the corresponding responses presented in ESBWR Design Control Document (Reference 4) with substantial margin,

2.0 SSSI Effect between RB/FB and CB

As stated in ESBWR DCD Section 3A.8-11 (Reference 4), the RB/FB effects on the CB are more significant than the CB effects on the RB/FB because the size of the RB/FB is much larger than the CB. To evaluate the RB/FB effects on the CB, the SSSI analysis is performed by the following two steps:

Step 1: Perform the RB/FB Soil-Structure-Interaction (SSI) analysis to obtain the ground motion response at the center of the CB basemat location in the free-field.

Step 2: Perform the CB SSI analysis using the ground motion response at the center of the CB basemat location in the free-field (input motion) obtained in Step 1.

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 (RB/FB and CB) 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.
- 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-engineered backfill profile properties consider the impact of acceleration time histories based upon the CEUS SSC model (obtained from Reference 7).
- 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 excavated volume for the RB/FB and CB models are from the bottom of the buildings basemat up to grade (top of the engineered backfill). Excavated volume is modeled using 8-node solid elements. To meet SASSI2010 computer code (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.
- To keep the number of interaction nodes in the SASSI2010 LB model within the SASSI2010 computer code capacity (within about 20,000 interaction nodes), the LB model layer thicknesses and the mesh dimensions in the excavated volume are kept the same as those for the UB model. The LB model is adequate for frequencies up to about 19 Hz. In evaluating the SSSI effect on soil pressures on the CB due to the RB/FB, the low passing frequency of the LB model does not affect the results because soil pressure is mainly due to low frequency response.
- For RB/FB, the in-column acceleration time histories represent the SSI Foundation Input Response Spectra (FIRS) for the respective rock-engineered backfill profiles (UB and LB) and are applied at the elevation of the bottom of RB/FB's basemat. These time histories include the impact of the CEUS SSC model (obtained from Reference 7). 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.

2.1 SSI Analysis of RB/FB to Obtain Motion at CB Basemat Elevation

SSI analysis of RB/FB has been performed to obtain the ground motion response at the center of the bottom of the CB basemat location in the free-field (Step 1, Section 2.0). Details of the structural model, soil-rock properties and input motion used in the RB/FB

SSI analysis are provided in References 10 and 13. The analysis is performed for UB and LB subsurface profiles.

The acceleration time histories in the two horizontal directions (X- and Y-directions) and in the vertical direction (Z-direction) at the center of the bottom of CB basemat (Elevation – 10.4 m) due to the three components of input in the RB/FB SSI model are calculated using the SASSI2010 computer code. The time histories in the X-direction, Y-direction, and Z-direction, including the effect of three directions of excitations are calculated using the algebraic summation of the co-direction accelerations at each time step. These acceleration time histories are used in the SSI analysis of the CB (in Step 2, Section 2.0). 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).

2.2 SSI Analysis of CB

2.2.1 Structure Model

Figure 2-1 presents a 3D view of the CB structural model. The structural model is same as the CB structural model in Reference 10, which was 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 plate elements. The interior of the CB is modeled by lumped mass beam elements. The shell elements have an aspect ratio not greater than 2.7 and their dimensions satisfy the requirement of a minimum passing frequency of 50 Hz in each direction for the UB. 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 9)).

2.2.2 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 for the UB. 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 2-1 and 2-2 provide the UB and LB rock-engineered backfill 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 computer code 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.

2.2.3 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.

2.2.4 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) at the bottom of the basemat (at Elevation -10.40 m) are obtained per Section 2.1. The horizontal direction acceleration time histories are specified as vertically propagating shear waves and the vertical direction acceleration time history is specified as a vertically propagating compression wave.

2.3 Analyses Response Results and Comparisons with DCD Responses

Transfer Functions

Transfer functions were calculated at the key locations of CB, in Reference 10. 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

The calculated and interpolated transfer function plots provided in Reference 10 are shown in Figures 2-2 through 2-13 of this report. The plots of the transfer functions show they are smooth and reasonable.

Floor Response Spectra (FRS)

Five percent (5%) damping FRS is calculated at the key locations of the CB. Figures 2-14 through 2-19 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 (which account for the SSSI effect between RB/FB and CB) by a considerable margin.

Maximum Absolute Accelerations

The enveloped maximum absolute vertical accelerations (envelop of UB and LB rock-engineered backfill profile cases) and their comparisons with the corresponding DCD values are presented in Table 2-3. In CB stick, the maximum ratio with the DCD is 40% and for oscillators the maximum ratio with DCD is 62% (Oscillator Node 9003).

Maximum Beam Forces and Moments

The enveloping beam forces and moments (envelop of UB and LB rock-engineered backfill profile cases) and their comparisons with the corresponding DCD values are presented in Table 2-4. The maximum ratio with DCD is about 65%.

Maximum Lateral Soil Pressures on Walls

The variation of lateral soil pressures on walls are shown in Figures 2-20 through 2-23.

The lateral soil pressures on the walls obtained from the SSSI 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 pressures from SSSI analyses exceed the DCD pressure by about 10%) and in the bottom half of the basemat. The adequacy of the wall designs for these exceedances in the lateral soil pressures is being evaluated and the results will be presented to the NRC by September 30, 2013.

3.0 SSSI Effect between CB and FWSC

SSSI is performed for CB with the FWSC. The SSSI model is composed of the coupled CB and FWSC structures and coupled through soil-rock profile using SASSI2010 computer code. The input motions for the coupled SSSI model are the FIRS at the bottom of the CB basemat elevation. The following provides general descriptions of the coupled CB and FWSC models, seismic input motions, and specific information regarding method of analysis:

- The SSSI models are prepared to be analyzed using SASSI2010 computer code (Reference 5).
- The SSSI model (coupled CB-FWSC) consists of two parts: (1) structural portion and (2) rock-engineered backfill (i.e., engineered backfill and the underlying bedrock) profile portion.
- The structural portions of the model are based on the verified ESBWR seismic model information provided in Reference 6.
- 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-engineered backfill profile properties consider the impact of acceleration time histories based upon the CEUS SSC model (obtained from Reference 7).
- 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 excavated volume for the CB part of the model is from the bottom of the building's basemat (Elevation -10.4 m) to grade (Elevation 4.5 m). The excavated volume for the FWSC part of the model is from the bottom of the fill concrete under the FWSC basemat (Elevation -6.96 m) to grade (Elevation 4.5 m). The excavated volumes are modeled using 8-node solid elements. To meet SASSI2010 computer code (Reference 8) requirements, the maximum horizontal and vertical mesh dimensions in the excavated volumes 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.
- To keep the number of interaction nodes in the SASSI2010 LB model within the SASSI2010 computer code capability (within about 20,000 interaction nodes), the LB model layer thicknesses and the mesh dimensions in the excavated volume are kept the same as those for the UB model. The LB model is adequate for frequencies up to about 19 Hz. In evaluating the SSSI effect on soil pressures on the CB due to the FWSC, the low passing frequency of the LB model does not affect the results because soil pressure is mainly due to low frequency response.
- The in-column acceleration time histories representing 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 CB basemat. These time histories include the impact of the CEUS SSC model (obtained from Reference 7). 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 SSSI analyses are performed using modified subtraction method (MSM).
- The SSSI 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).

3.1 SSSI Analysis of CB and FWSC

3.1.1 Structure Model

Figure 3-1 presents a 3D view of the CB and FWSC structural model. For clarity, the fill concrete under the basemat of the FWSC is not shown in Figure 3-1. The structural models of the individual CB and FWSC are obtained from Reference 6.

The structural model of the CB consists of thin plate elements and 3D lumped mass beam (stick) elements. The basemat and the exterior walls of the CB up to the grade elevation are modeled with thin shell elements. The interior of the CB are modeled by 3D lumped mass beam elements. The shell elements have an aspect ratio not greater than 2.05. For calculating the lateral soil pressure on the exterior walls of the CB, 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 OBE damping of 4% for the reinforced concrete elements.

The structural model of the FWSC consists of thin plate elements, 3D lumped mass beam (stick) elements and 3D eight node solid elements. The basemat is modeled by thin plates. The two Firewater Storage Tanks (FWS) and a Fire Pump Enclosure (FPE) are modeled by 3D lumped mass beam elements. The fill concrete under the basemat is modeled by 3D eight node solid elements. The maximum aspect ratio of the plate elements is 1.2.

3.1.2 Site-Specific Rock-Engineered Backfill Model

Two rock-engineered backfill profiles are considered in the CB-FWSC 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 SSSI 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 3-1 and 3-2 provide the UB and LB rock-engineered backfill properties, respectively, used in the model. Based on the mesh dimensions in the excavated volume and the layer thicknesses in the model, the minimum passing frequency for the UB rock-engineered backfill case is 50.7 Hz (using the 20% shear wave length criteria as recommended in SASSI2010 computer code User's Manual).

3.1.3 SSSI Method of Analysis

The SSSI analyses are performed using SASSI2010 computer code (Reference 5). Modified Subtraction Method (MSM) is used for the analyses. The selection of the interaction nodes is based on the conclusions of the CB Benchmark Summary Report (Reference 12) and FWSC Benchmark Summary Report (Reference 11). In addition to the nodes at the side and bottom boundaries of the excavated rock-engineered backfill volumes of the two structures, nodes at the top surface (Elevation 4.5 m) and at Elevation -2.0 m in the excavated volume are added as interaction nodes. Separate analyses are performed for each of the two horizontal directions and the vertical direction.

3.1.4 Seismic Input Motion

The seismic input motions corresponding to UB and LB rock-engineered backfill profiles in the two horizontal directions (X- and Y-directions) and the vertical direction (Z-direction) are FIRS in-column motions at the bottom of the CB basemat (at Elevation -10.4 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.

3.2 Analyses Response Results and Comparisons with DCD Responses

Transfer Functions

Transfer functions are calculated at the key locations of the 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 3-2 through 3-13 show both calculated and interpolated transfer functions. These transfer functions are generally smooth. There are some spikes specially in the interpolated transfer functions for the LB case at high frequencies close to 50 Hz (see Figures 3-9, 3-10, 3-12, and 3-13). Occasionally, these spikes occur in the interpolated transfer functions due to the interpolation scheme built into the SASSI2010 computer code. These peaks in the interpolated transfer functions do not have any effect on the acceleration response spectra, the element forces/moments and the soil pressures, because of the insignificant energy in the input motion at frequencies close to 50 Hz. This is evident from the response spectra plots that do not have sharp peaks or show unreasonable behavior at those frequencies.

Floor Response Spectra (FRS) at CB Key Nodes

Five percent (5%) damping FRS are calculated at the key locations of the CB. Figures 3-14 through 3-19 show the comparisons of FRS calculated from the SSSI 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 in CB

The enveloped maximum absolute vertical accelerations (envelop of the UB and LB rock-engineered backfill profile cases) and their comparisons with the corresponding DCD values are presented in Table 3-3. In general, the ratios between the calculated values to the corresponding DCD values are less than about 50%. The maximum ratio is about 61%, for oscillator 9003.

Maximum Beam Forces and Moments in CB

The enveloping beam forces and moments (envelop of the UB and LB rock-engineered backfill profile cases) and their comparisons with the corresponding DCD values are presented in Table 3-4. The maximum ratio with DCD is about 60%.

Maximum Lateral Soil Pressures on Walls

The variation of lateral soil pressures on CB exterior walls are shown in Figures 3-20 through 3-23.

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 exceeds the DCD pressure by about 10%) and in the bottom half of the basemat . The adequacy of the wall designs for these exceedances in the lateral soil pressures is being evaluated and the results will be presented to the NRC by September 30, 2013.

4.0 Conclusion

The scope of this report is to present the summary of two Fermi 3 structure-Soil-Structure Interaction (SSSI) analyses: (1) SSSI effect between the Reactor Building/Fuel Building (RB/FB) and Control Building (CB) and (2) SSSI effect between the CB and Fire Water Service Complex (FWSC). Both SSSI analyses are performed for models which include engineered backfill above the top of the Bass Islands Group bedrock. The purpose of these analyses is to determine the SSSI effects of the RB/FB and FWSC on the seismic responses of the CB. These SSSI 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 of the CB obtained from these analyses, which include (i) the SSSI effects between the RB/FB and CB and (ii) the SSSI effect between the CB and FWSC, are bounded by the corresponding responses presented in ESBWR Design Control Document (Reference 4), with substantial margin. Only exceptions are a small exceedance of the lateral soil pressure in a small area just above the top of the basemat of the CB and in the bottom half of the basemat. The adequacy of the wall designs for these exceedances in the lateral soil pressures is being evaluated and the results will be presented to the NRC by September 30, 2013.

5.0 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. NRC Regulatory Guide 1.61, Rev 1, “Damping Values for Seismic Design of Nuclear Power Plants”.
10. S&L Report SL-011956, Revision 0, “SSI Analysis of Reactor Building and Control Building with Engineered Backfill Summary Report”.
11. S&L Report Sl-011863, Revision 0, “Modified Subtraction Method (MSM) Fire Water Service Complex Benchmark Summary Report”.
12. S&L Report SL-011874, Revision 0, “Modified Subtraction Method (MSM) Control Building Benchmark Summary Report”.
13. S&L Calculation 2013-03375, Revision 1, “Fermi 3 ESBWR – SSI Analysis with Engineered Backfill (UB and LB) of Reactor Building/Fuel Building MSM”.

Table 2-1: Upper Bound (UB) rock-engineered backfill profile for SASSI analysis of the CB (SSSI effect of RB/FB)

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 2-2: Lower Bound (LB) rock-engineered backfill profile for SASSI analysis of the CB (SSSI effect of RB/FB)

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 2-3: CB maximum vertical accelerations for envelope of UB and LB rock-engineered backfill profiles (SSSI effect of RB/FB)

(a) Maximum seismic accelerations

Elev. (m)	DCD Node No. (For Ref.)	CB3 Node No.	Stick Model	Z-dir. (g)
13.80	6	500	CB	0.37
9.06	5	480	CB	0.34
4.65	4	460	CB	0.29
-2.00	3	430	CB	0.22
-7.40	2	410	CB	0.19
-10.40	1	400	CB	0.19
13.80	9001	901	Oscillator	1.03
	9002	902	Oscillator	0.76
	9003	903	Oscillator	0.88
9.06	9101	911	Oscillator	1.04
	9102	912	Oscillator	0.64
	9103	913	Oscillator	0.84
4.65	9201	921	Oscillator	0.52
	9202	922	Oscillator	0.67
-2.00	9301	931	Oscillator	0.60

(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.)	CB3 Node No.	Stick Model	Z-dir.
13.80	6	500	CB	37%
9.06	5	480	CB	40%
4.65	4	460	CB	39%
-2.00	3	430	CB	39%
-7.40	2	410	CB	37%
-10.40	1	400	CB	37%
13.80	9001	901	Oscillator	47%
	9002	902	Oscillator	56%
	9003	903	Oscillator	62%
9.06	9101	911	Oscillator	52%
	9102	912	Oscillator	51%
	9103	913	Oscillator	59%
4.65	9201	921	Oscillator	40%
	9202	922	Oscillator	47%
-2.00	9301	931	Oscillator	43%

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

Table 2-4: CB seismic forces and moments for envelope of UB and LB rock-engineered backfill profiles (SSSI effect of RB/FB)

(a) Seismic forces and moments

Elev. (m)	DCD (for Ref.)		CB3			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			38.6	31.0	
		6	1	9	481	9.8	11.1	70.3	64.6	7.3
9.06	5		1	8	483			95.3	81.1	
		5	1	7	461	17.8	19.7	169.6	163.4	14.6
4.65	4		3	3	463			97.1	58.4	
		4	3	3	431	37.2	37.0	279.9	247.6	12.8
-2.00	3		3	2	433			205.2	215.8	
-7.40	2	3	3	2	411	58.9	64.7	435.9	458.0	13.8

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.)		CB3			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			24%	25%	
		6	1	9	481	30%	38%	28%	33%	10%
9.06	5		1	8	483			26%	29%	
		5	1	7	461	33%	36%	30%	37%	11%
4.65	4		3	3	463			13%	11%	
		4	3	3	431	49%	46%	25%	25%	7%
-2.00	3		3	2	433			17%	21%	
-7.40	2	3	3	2	411	47%	65%	28%	30%	6%

Table 2-5: Wall lateral soil pressures for envelope of UB and LB rock-engineered backfill profiles and comparison to DCD values

Floor Level (m)	C1 and C5 Wall Soil Pressure (MPa)		CA and CD Wall Soil Pressure (MPa)		Envelope (MPa)		DCD Design Wall Soil Pressure (MPa)	
	CB3 (LB)	CB3 (UB)	CB3 (LB)	CB3 (UB)	C1 and C5 Wall	CA and CD Wall	C1 and C5 Wall	CA and CD Wall
4.65								
Slab								
3.95 -2.00	0.04	0.06	0.04	0.06	0.06	0.06	0.22	0.22
Slab								
-2.50 -7.40	0.07	0.08	0.08	0.08	0.08	0.08	0.18	0.18
Basemat								

Table 3-1: Upper Bound (UB) rock-engineered backfill profile for SSSI analysis of theCB-FWSC

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 3-2: Lower Bound (LB) rock-engineered backfill profile for SSSI analysis of the CB-FWSC

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 3-3: CB maximum vertical accelerations for envelope of UB and LB rock-enineered backfill profiles (SSSI effect of CB-FWSC)

(a) Maximum seismic accelerations

Elev. (m)	DCD node	SASSI node	Stick Model	Z-dir. (g)
13.8	6	500	CB	0.34
9.06	5	480	CB	0.32
4.65	4	460	CB	0.29
-2	3	430	CB	0.20
-7.4	2	410	CB	0.20
-10.4	1	400	CB	0.20
13.8	9001	901	Oscillator	0.99
	9002	902	Oscillator	0.70
	9003	903	Oscillator	0.87
9.06	9101	911	Oscillator	0.92
	9102	912	Oscillator	0.67
	9103	913	Oscillator	0.83
4.65	9201	921	Oscillator	0.51
	9202	922	Oscillator	0.63
-2	9301	931	Oscillator	0.64

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

Elev. (m)	DCD node	SASSI node	Stick Model	Z-dir. (g)
13.8	6	500	CB	34%
9.06	5	480	CB	37%
4.65	4	460	CB	39%
-2	3	430	CB	36%
-7.4	2	410	CB	39%
-10.4	1	400	CB	39%
13.8	9001	901	Oscillator	45%
	9002	902	Oscillator	52%
	9003	903	Oscillator	61%
9.06	9101	911	Oscillator	46%
	9102	912	Oscillator	53%
	9103	913	Oscillator	58%
4.65	9201	921	Oscillator	39%
	9202	922	Oscillator	44%
-2	9301	931	Oscillator	46%

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

Table 3-4: CB Seismic forces and moments for envelope of UB and LB rock-engineered backfill profiles (SSSI effect of CB-FWSC)

(a) Seismic forces and moments

Elev. (m)	DCD (for Ref.)		CB4			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			40.1	31.1	
		6	1	9	481	10.6	13.6	71.3	73.7	20.0
9.06	5		1	8	483			94.9	90.0	
		5	1	7	461	19.6	24.9	174.6	192.0	40.1
4.65	4		3	3	463			90.9	47.5	
		4	3	3	431	34.9	34.5	278.7	264.1	79.8
-2.00	3		3	2	433			193.3	190.1	
-7.40	2	3	3	2	411	54.1	48.6	411.1	400.3	148.1

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

Elev. (m)	DCD (for Ref.)		CB4			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			25%	25%	
		6	1	9	481	32%	47%	29%	37%	27%
9.06	5		1	8	483			26%	33%	
		5	1	7	461	37%	45%	30%	43%	31%
4.65	4		3	3	463			13%	9%	
		4	3	3	431	46%	43%	25%	27%	45%
-2.00	3		3	2	433			16%	18%	
-7.40	2	3	3	2	411	43%	49%	26%	26%	60%

Table 3-5: Wall lateral soil pressures for envelope of UB and LB rock-engineered backfill profiles and comparison to DCD values (SSSI effect of CB-FWSC)

Floor Level (m)	C1 and C5 Wall Soil Pressure (MPa)		CA and CD Wall Soil Pressure (MPa)		Envelope (MPa)		DCD Design Wall Soil Pressure (MPa)	
	CB4 (LB)	CB4 (UB)	CB4 (LB)	CB4 (UB)	C1 and C5 Wall	CA and CD Wall	C1 and C5 Wall	CA and CD Wall
4.65								
Slab								
3.95 -2.00	0.04	0.05	0.04	0.06	0.05	0.06	0.22	0.22
Slab								
-2.50 -7.40	0.07	0.08	0.08	0.08	0.08	0.08	0.18	0.18
Basemat								

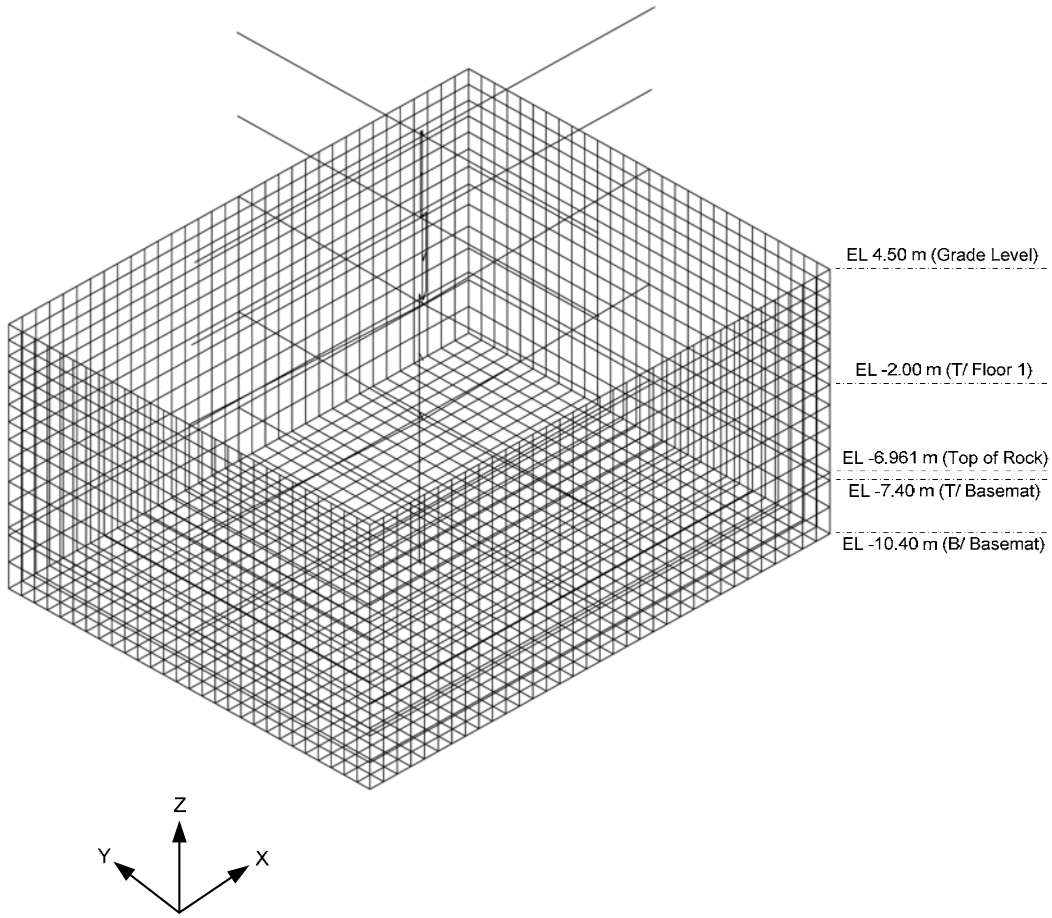


Figure 2-1: 3D view of the CB (SSSI effect of RB/FB)

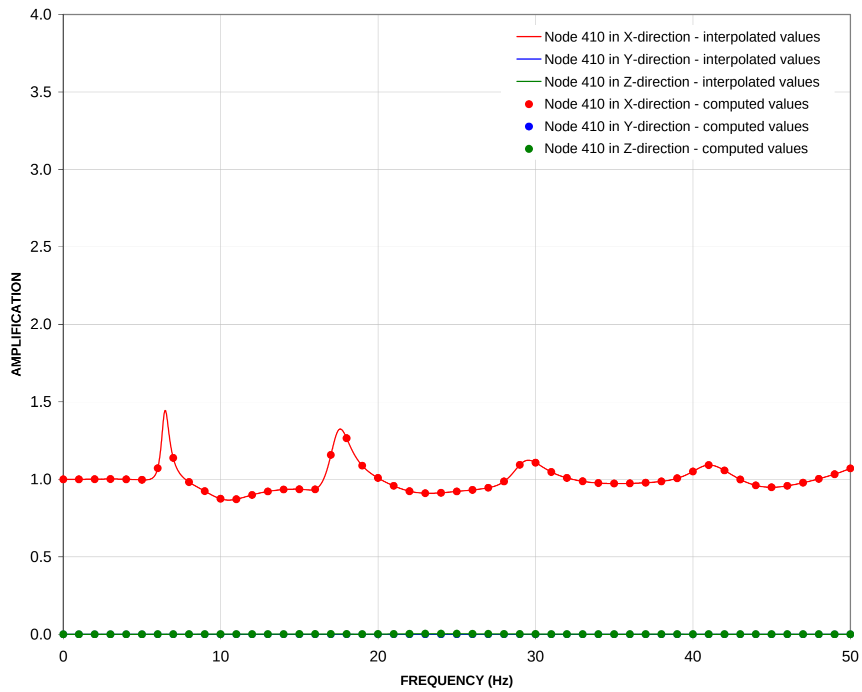


Figure 2-2: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, Node 410, X direction input motion (Considering SSSI effect of RB/FB)

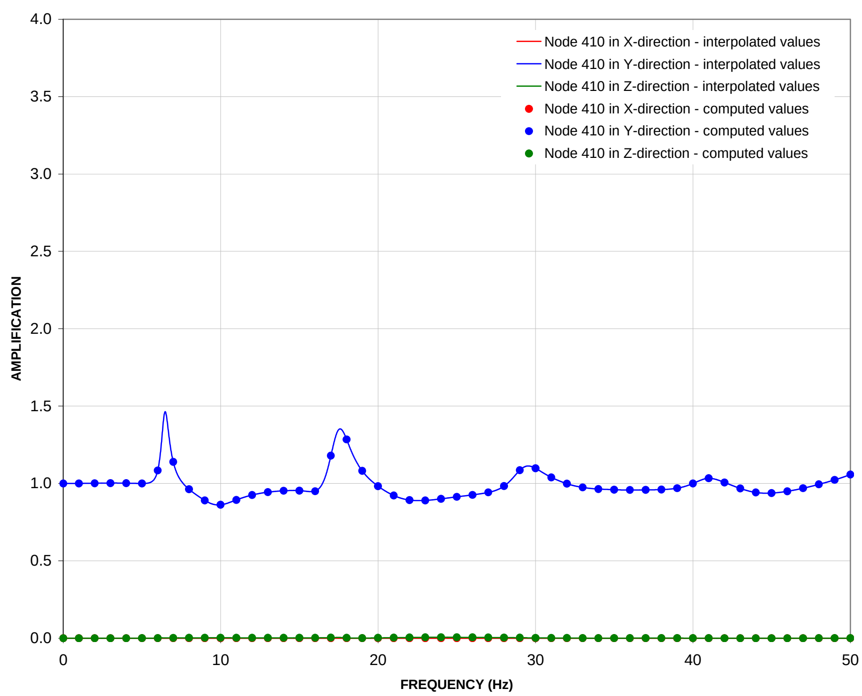


Figure 2-3: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, Node 410, Y direction input motion (Considering SSSI effect of RB/FB)

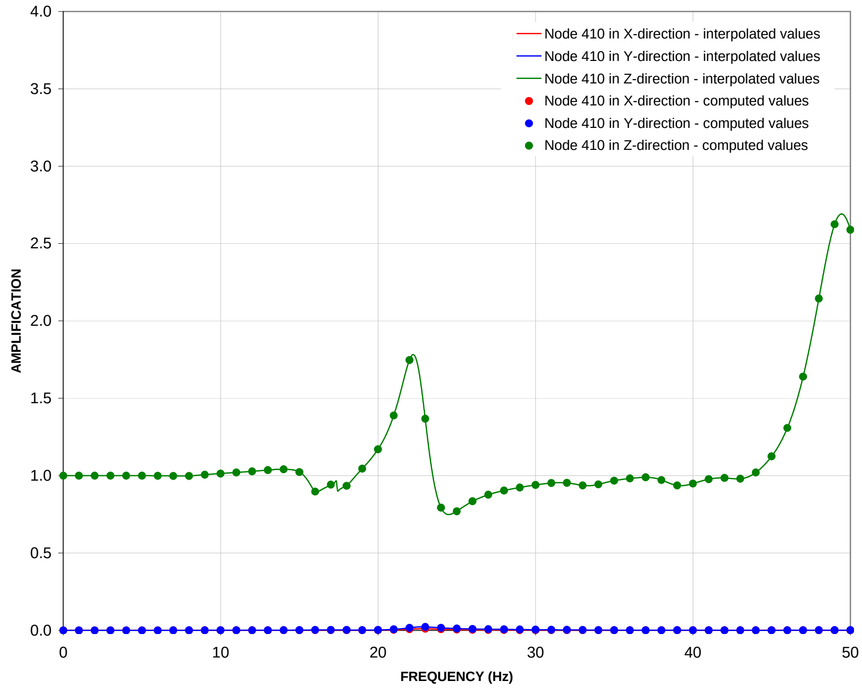


Figure 2-4: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, Node 410, Z direction input motion (Considering SSSI effect of RB/FB)

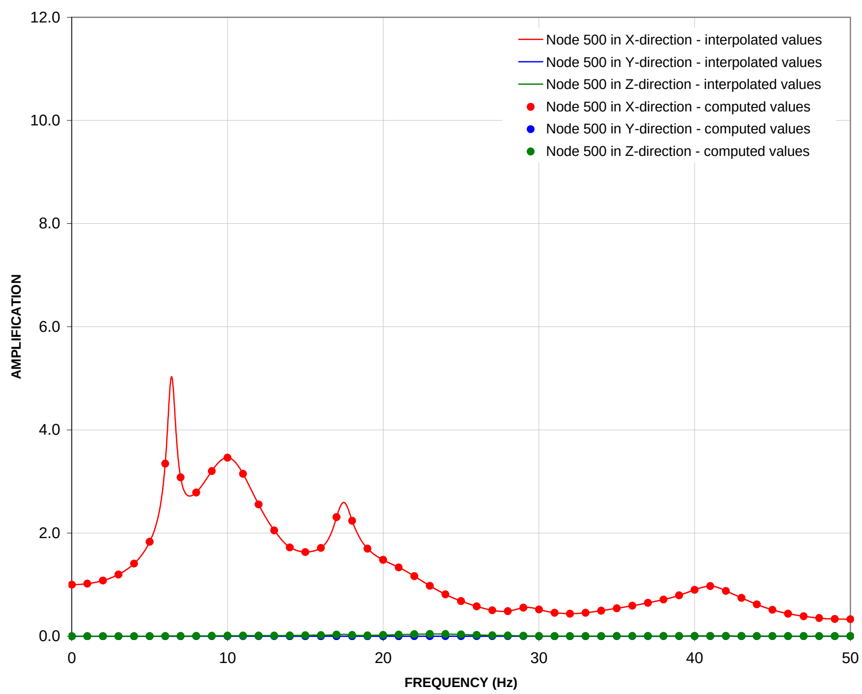


Figure 2-5: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, Node 500, X direction input motion (Considering SSSI effect of RB/FB)

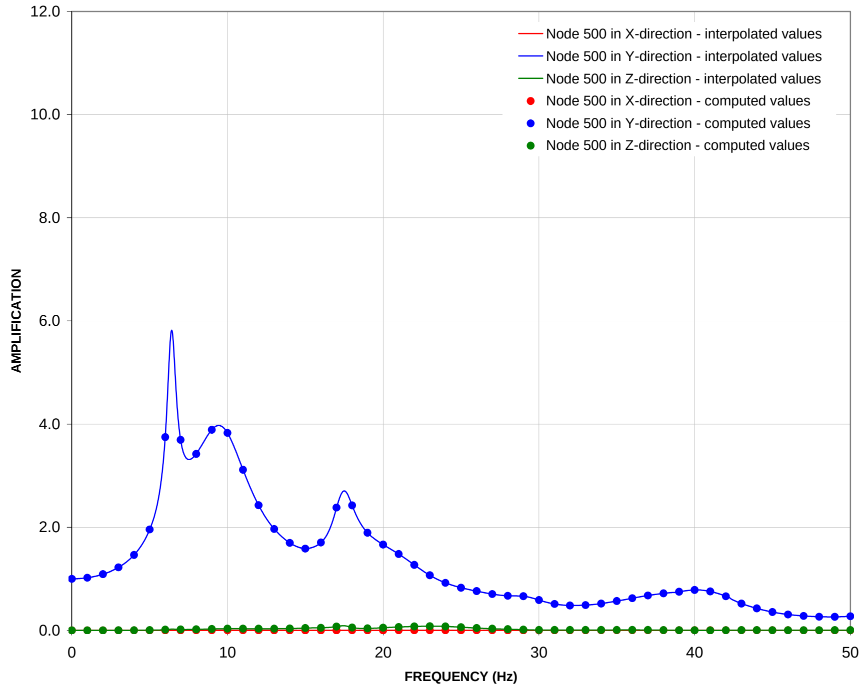


Figure 2-6: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, Node 500, Y direction input motion (Considering SSSI effect of RB/FB)

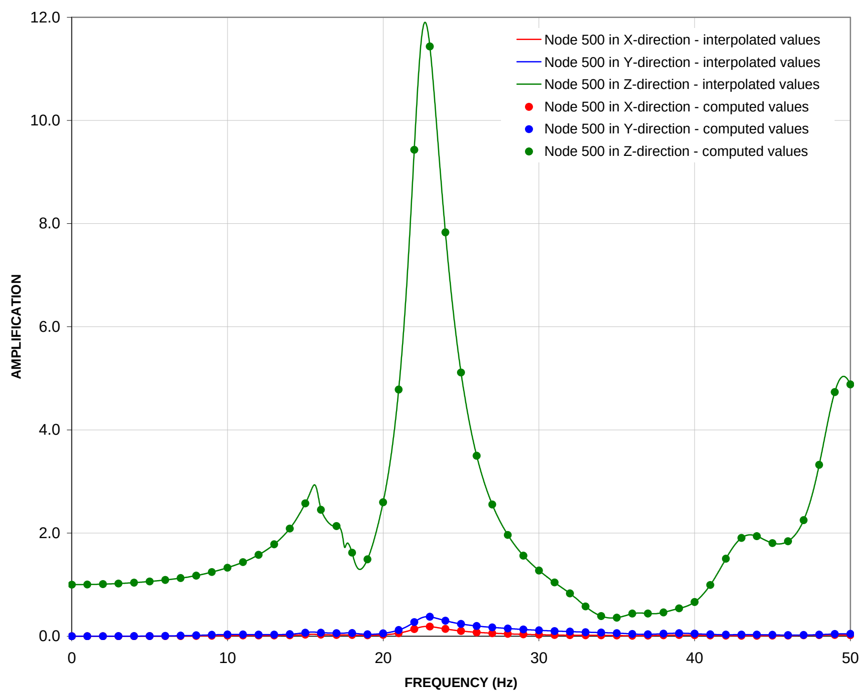


Figure 2-7: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, Node 500, Z direction input motion (Considering SSSI effect of RB/FB)

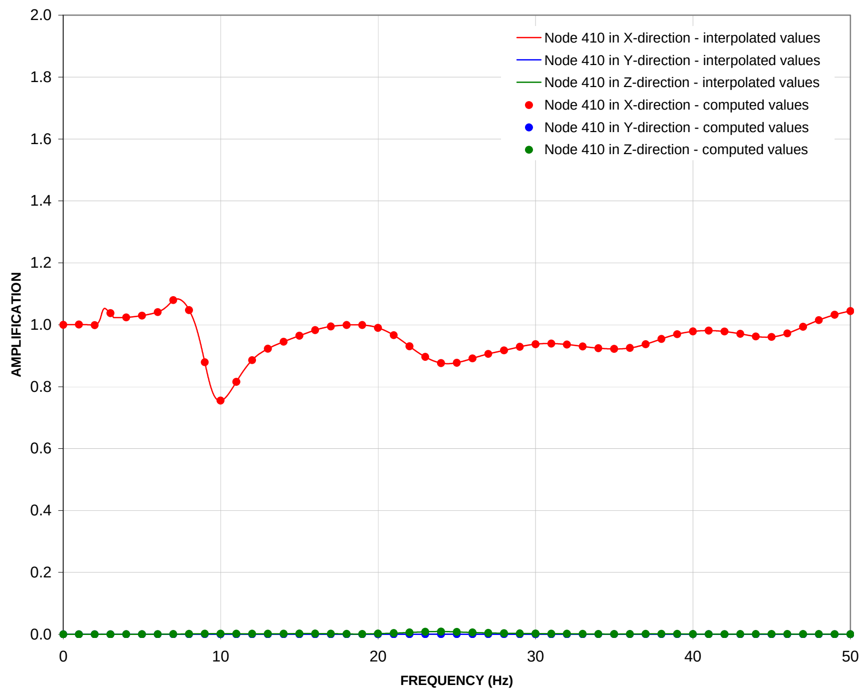


Figure 2-8: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, Node 410 X direction input motion (Considering SSSI effect of RB/FB)

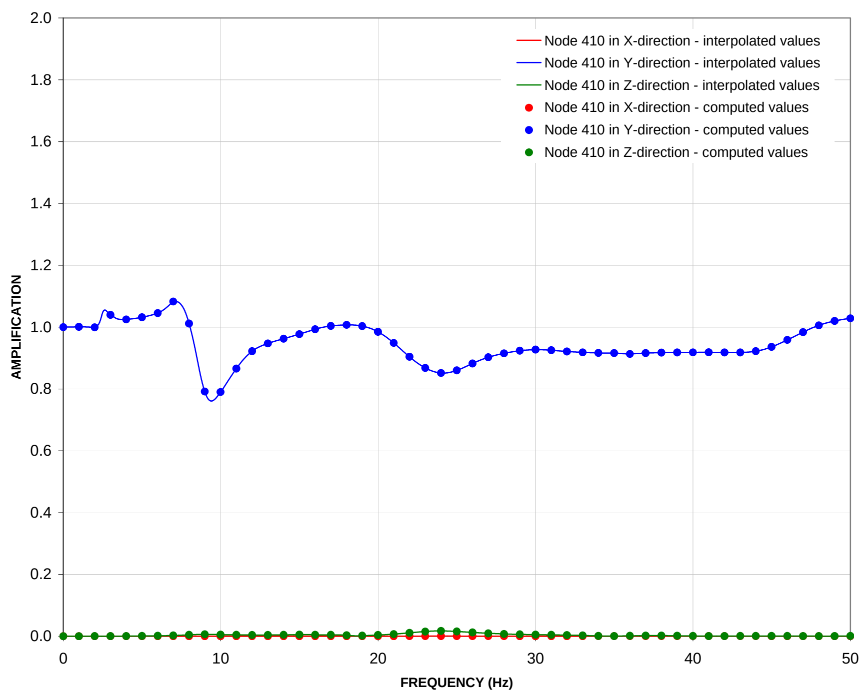


Figure 2-9: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, Node 410 Y direction input motion (Considering SSSI effect of RB/FB)

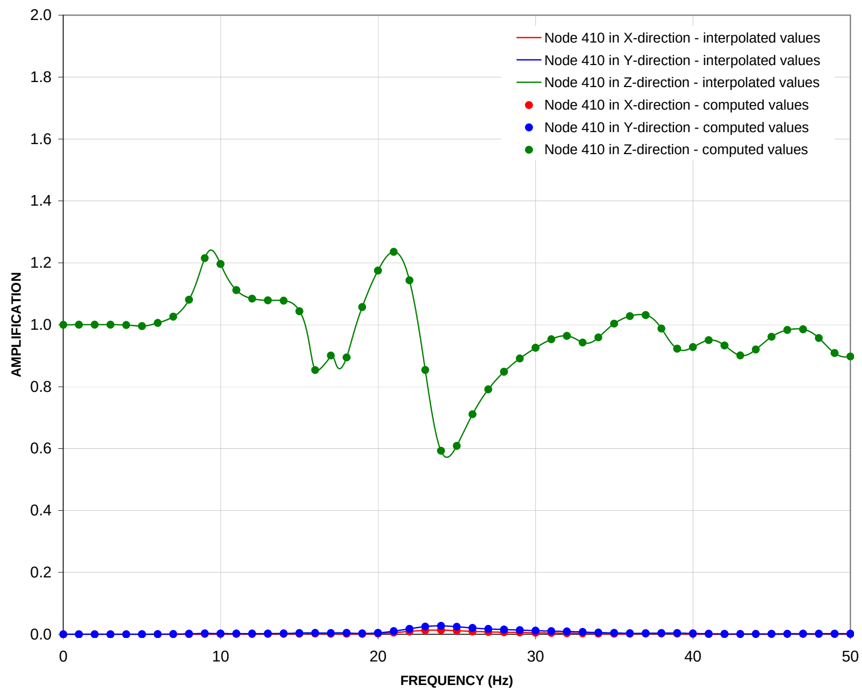


Figure 2-10: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, Node 410 Z direction input motion (Considering SSSI effect of RB/FB)

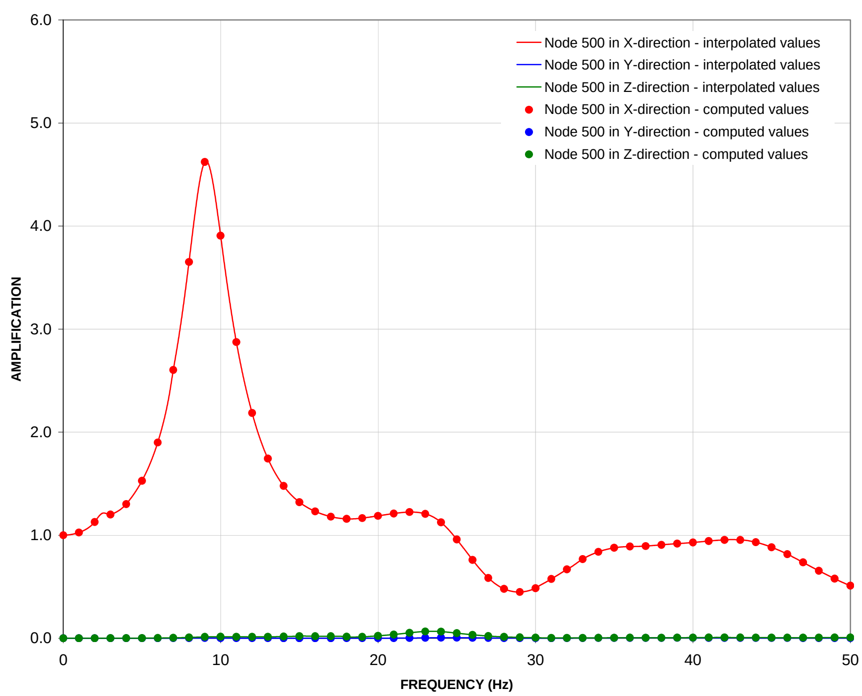


Figure 2-11: Transfer functions - CB roof (EL 13.8 m), LB subsurface profile, Node 500, X direction input motion (Considering SSSI effect of RB/FB)

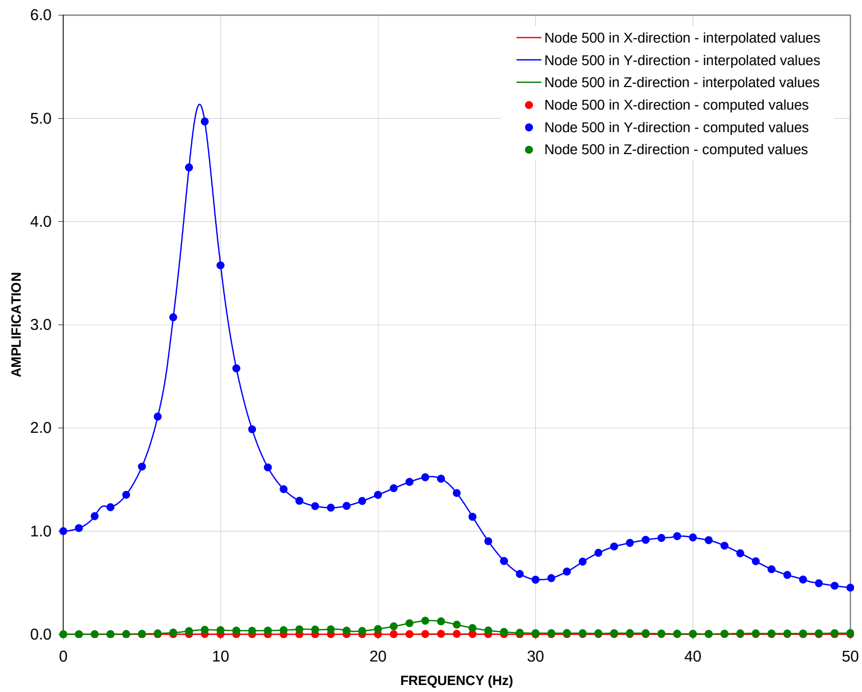


Figure 2-12: Transfer functions - CB roof (EL 13.8 m), LB subsurface profile, Node 500, Y direction input motion (Considering SSSI effect of RB/FB)

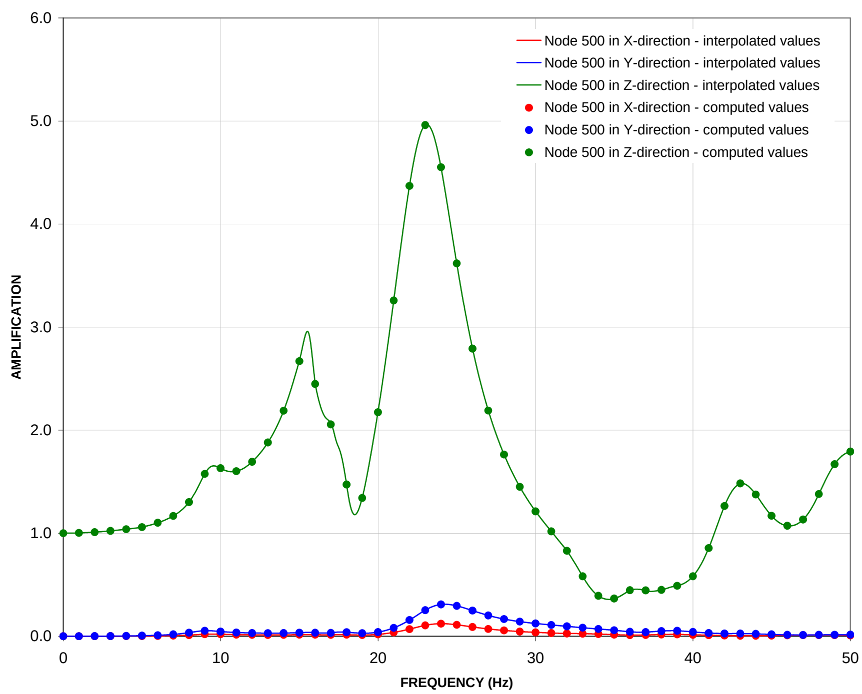


Figure 2-13: Transfer functions - CB roof (EL 13.8 m), LB subsurface profile, Node 500, Z direction input motion (Considering SSSI effect of RB/FB)

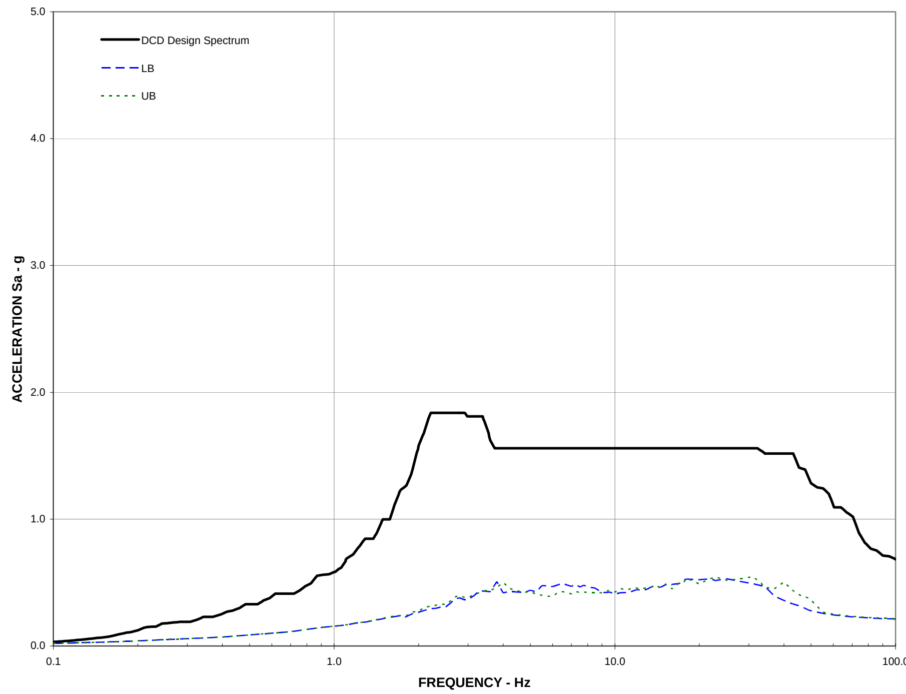


Figure 2-14: Comparison of floor response spectra – 5% damping, CB basemat (El -7.4 m), Node 410, X direction (Considering SSSI effect of RB/FB)

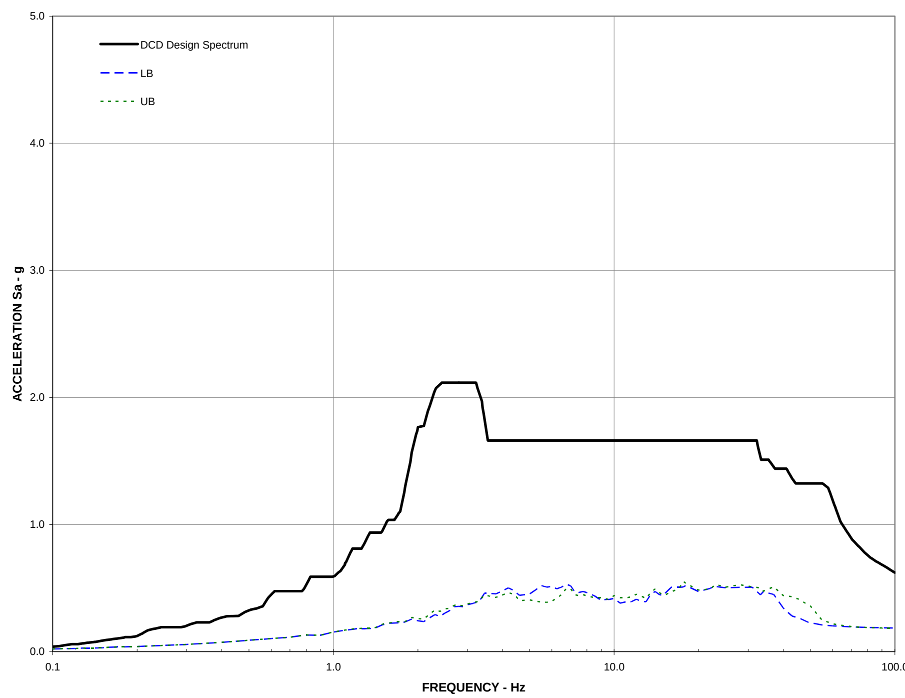


Figure 2-15: Comparison of floor response spectra – 5% damping, CB basemat (El -7.4 m), Node 410, Y direction (Considering SSSI effect of RB/FB)

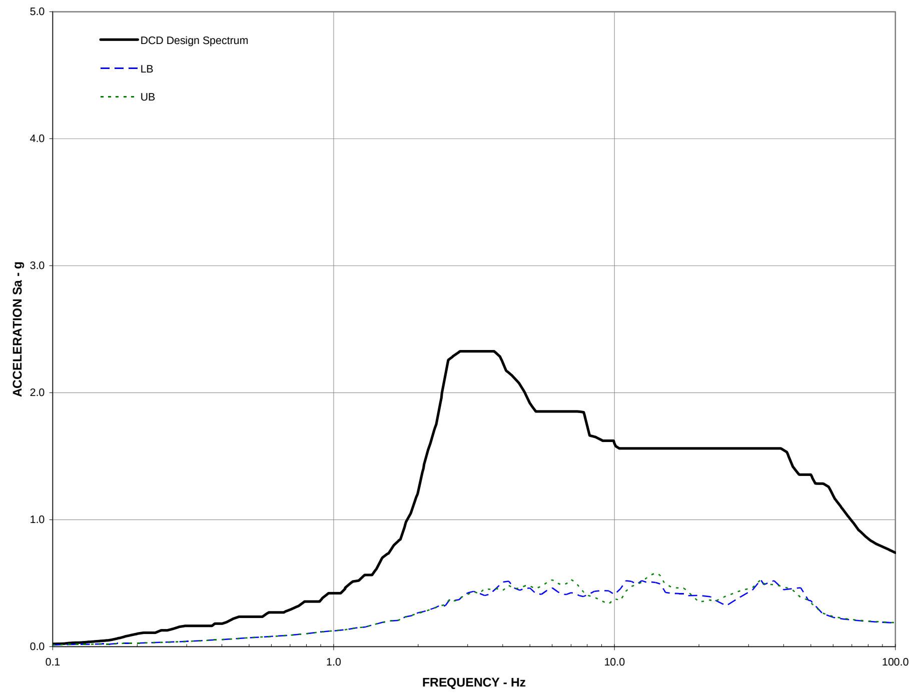


Figure 2-16: Comparison of floor response spectra – 5% damping, CB basemat (El -7.4 m), Node 410, Z direction (Considering SSSI effect of RB/FB)

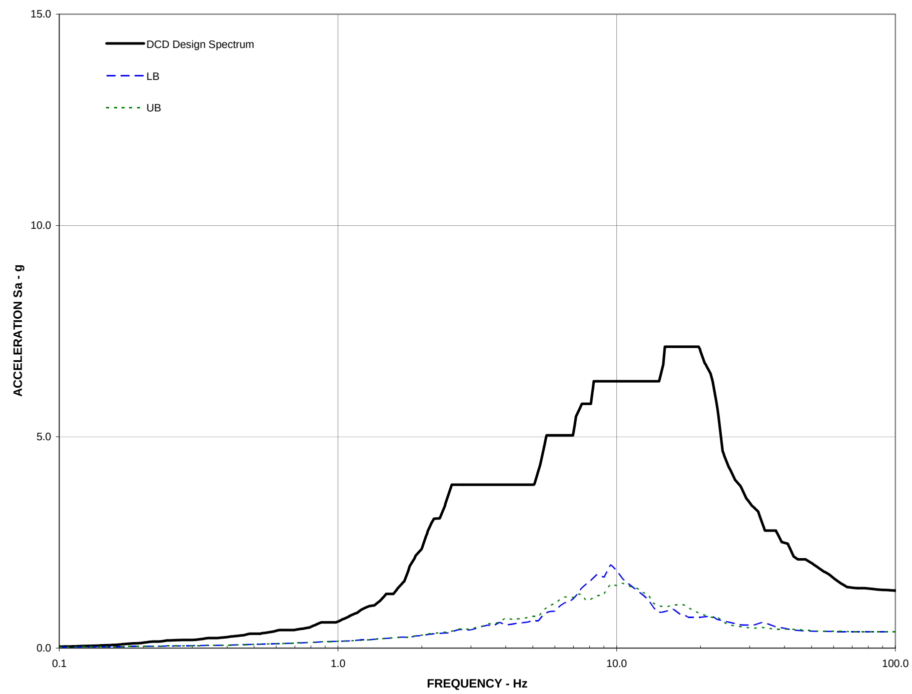


Figure 2-17: Comparison of floor response spectra – 5% damping, CB roof (El 13.8 m), Node 500, X direction (Considering SSSI effect of RB/FB)

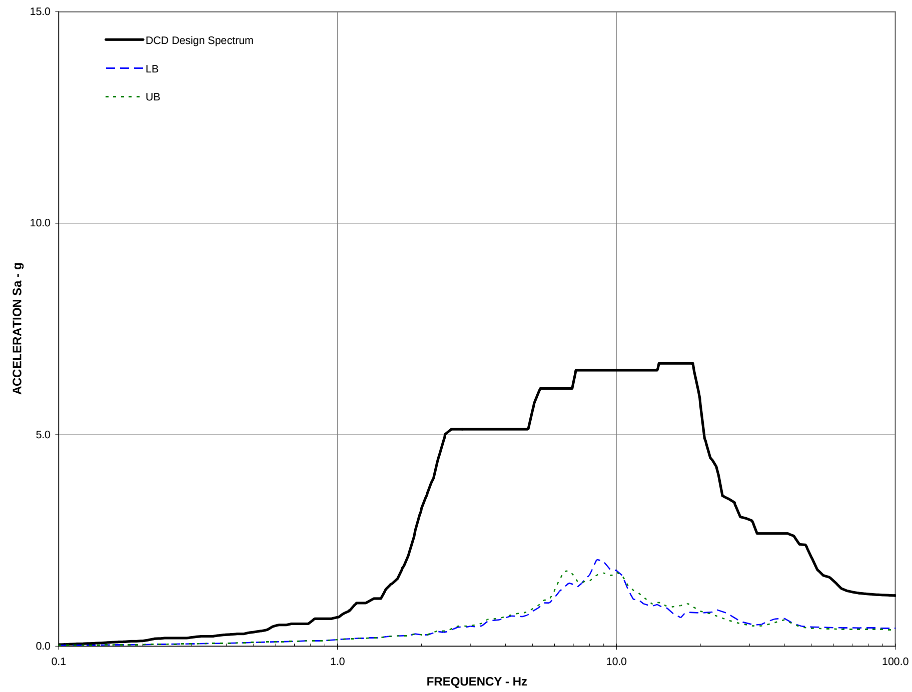


Figure 2-18: Comparison of floor response spectra – 5% damping, CB roof (El 13.8 m), Node 500, Y direction (Considering SSSI effect of RB/FB)

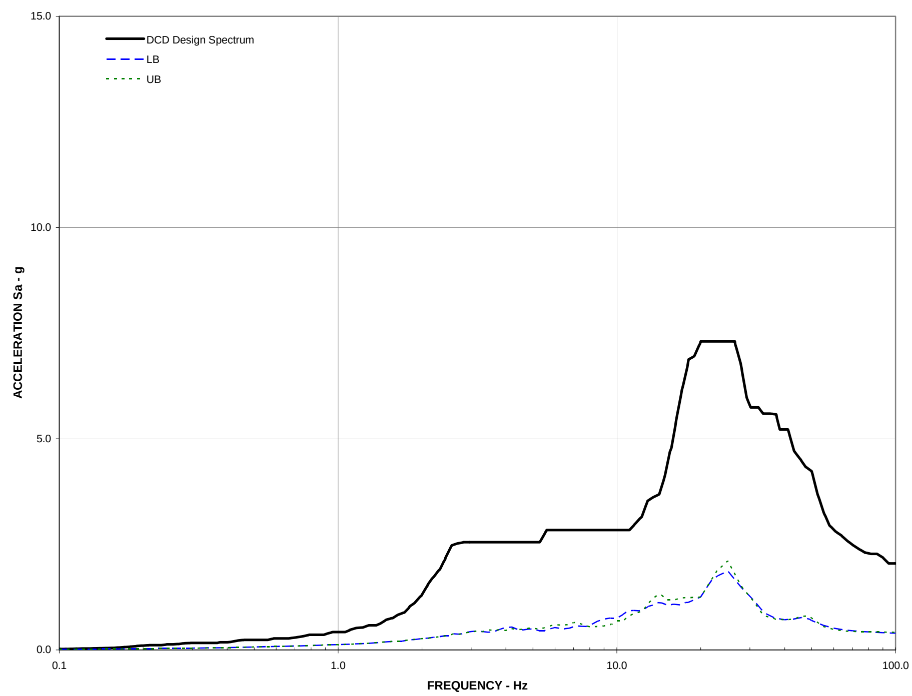
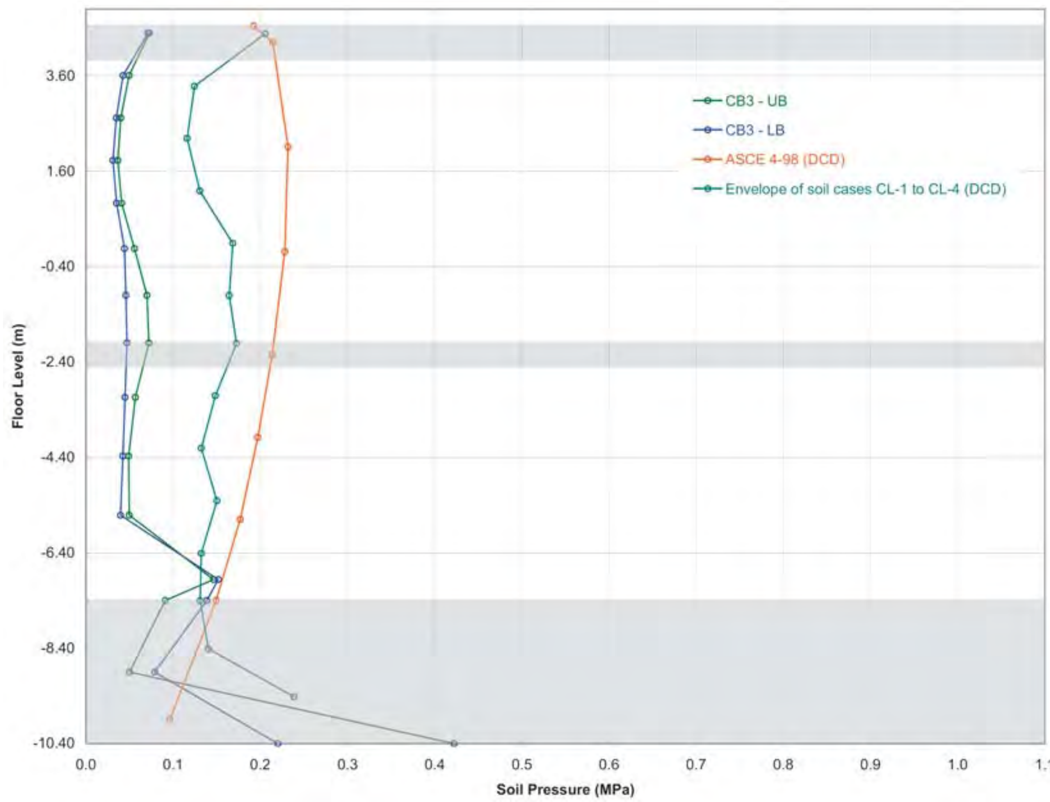


Figure 2-19: Comparison of floor response spectra – 5% damping, CB roof (El 13.8 m), Node 500, Z direction (Considering SSSI effect of RB/FB)



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

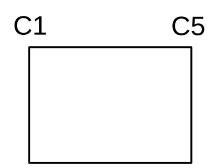
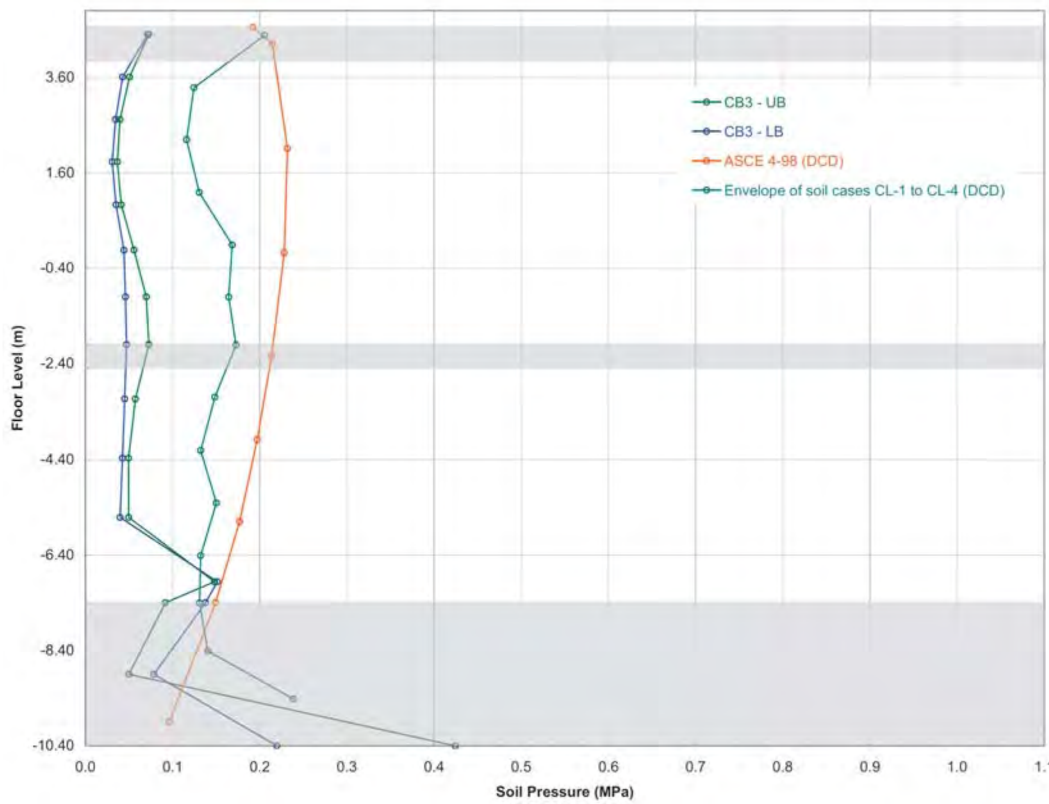


Figure 2-20: Lateral soil pressure for CB north wall (C1)
(Considering SSSI effect of RB/FB)



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

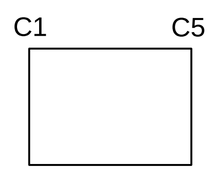
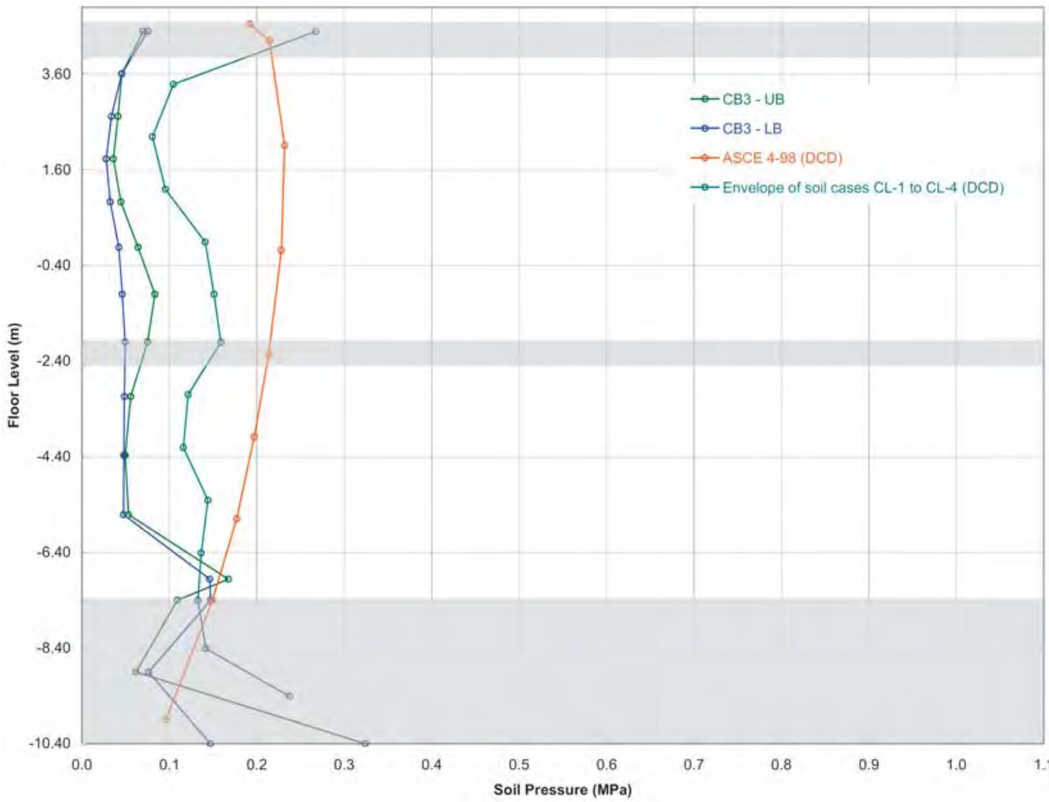


Figure 2-21: Lateral soil pressure for CB south wall (C5)
(Considering SSSI effect of RB/FB)



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

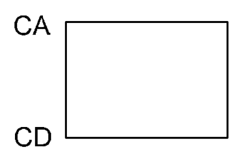
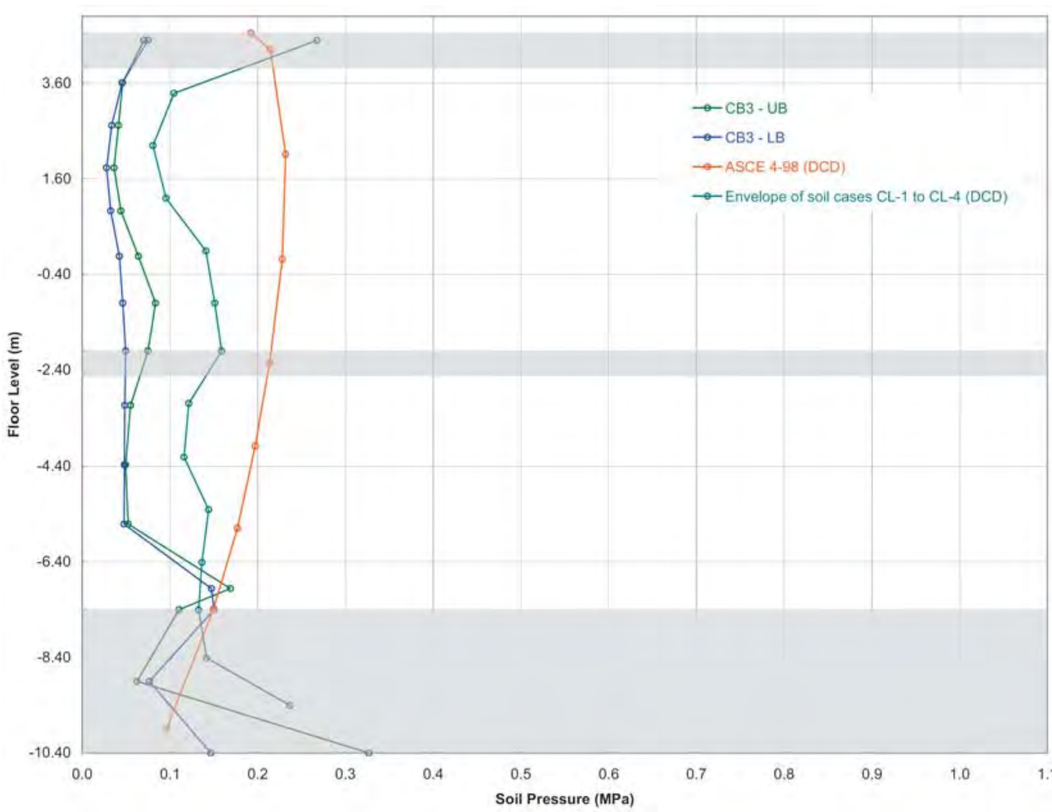


Figure 2-22: Lateral soil pressure for CB east wall (CA)
(Considering SSSI effect of RB/FB)



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

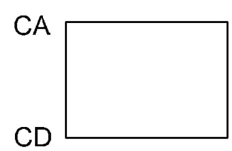


Figure 2-23: Lateral soil pressure for CB west wall (CD)
(Considering SSSI effect of RB/FB)

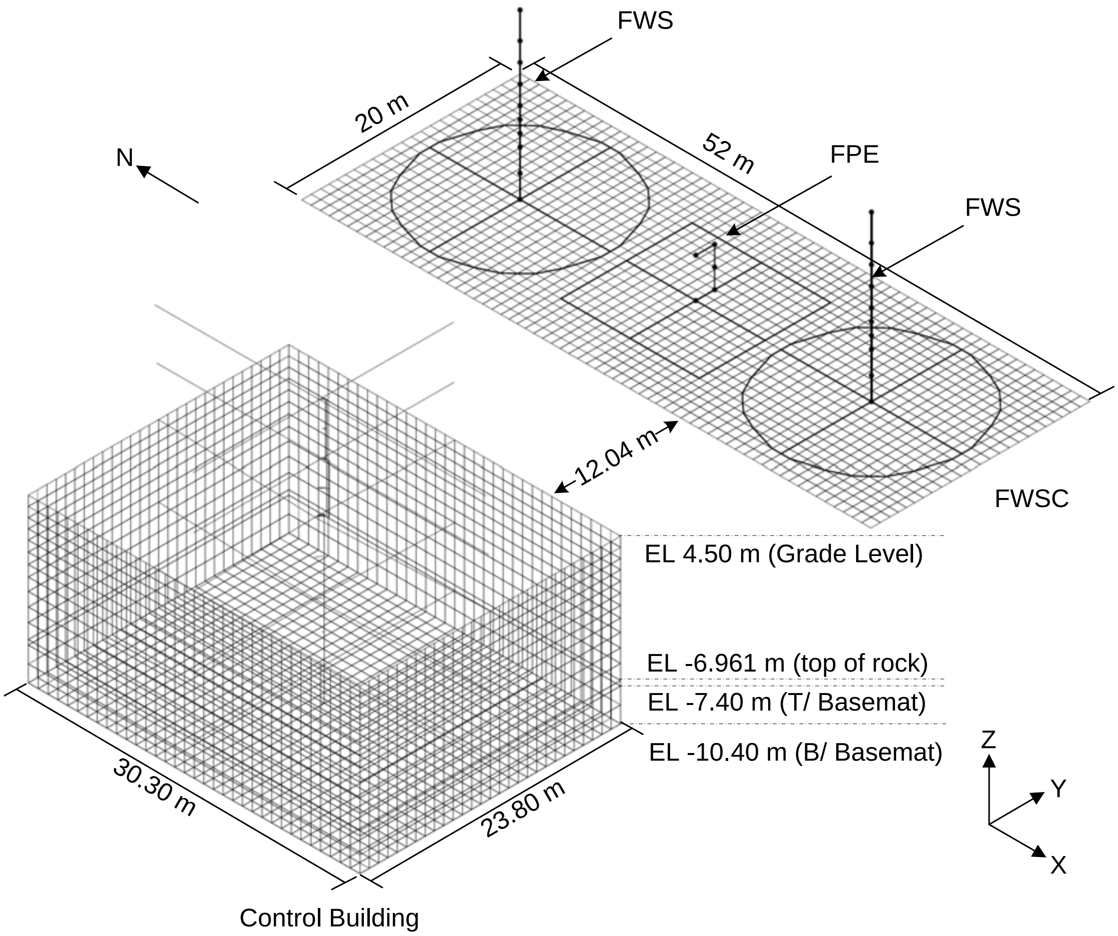


Figure 3-1: 3D view of the CB – FWSC

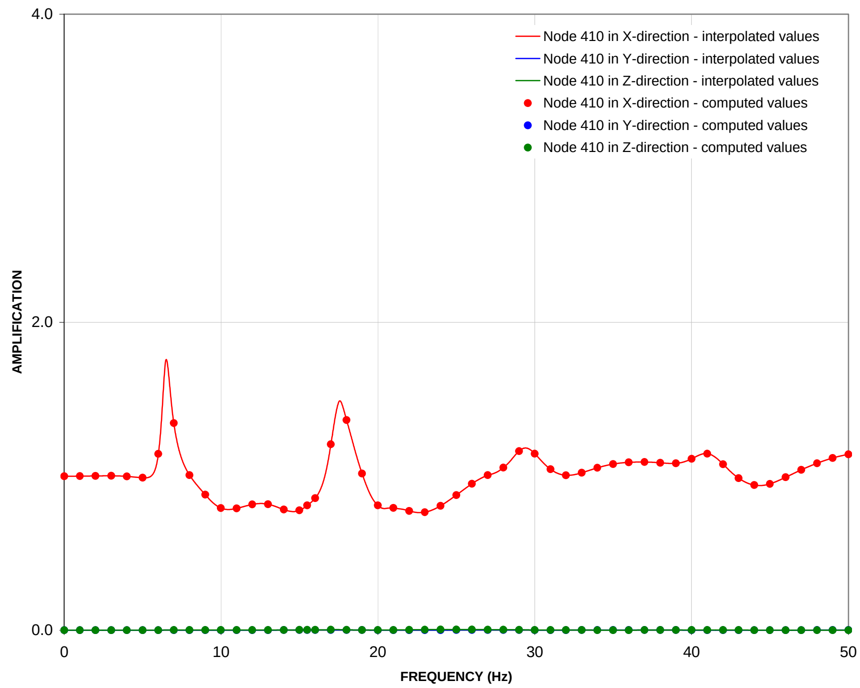


Figure 3-2: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, Node 410 X direction input motion (Considering SSSI effect of FWSC)

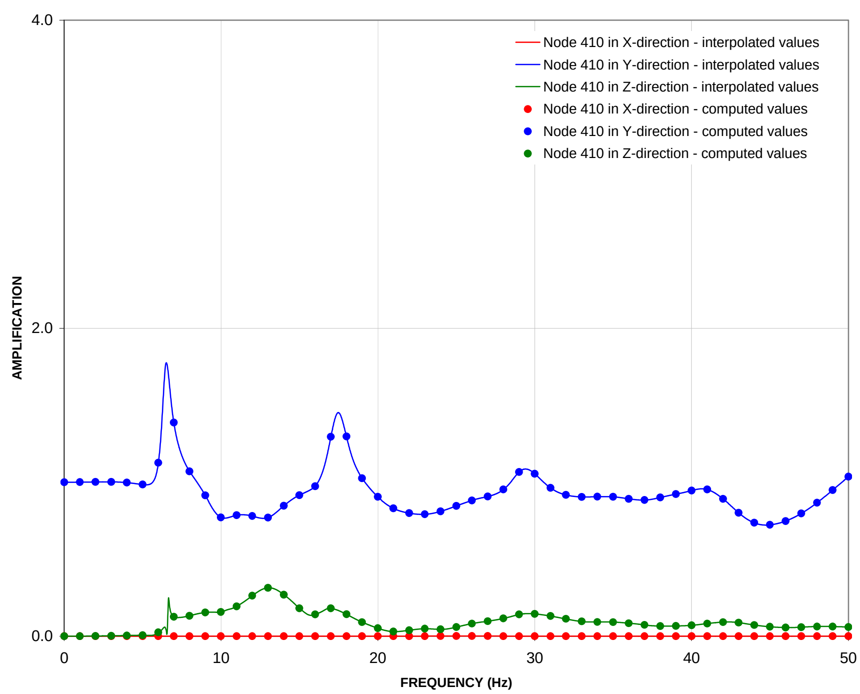


Figure 3-3: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, Node 410 Y direction input motion (Considering SSSI effect of FWSC)

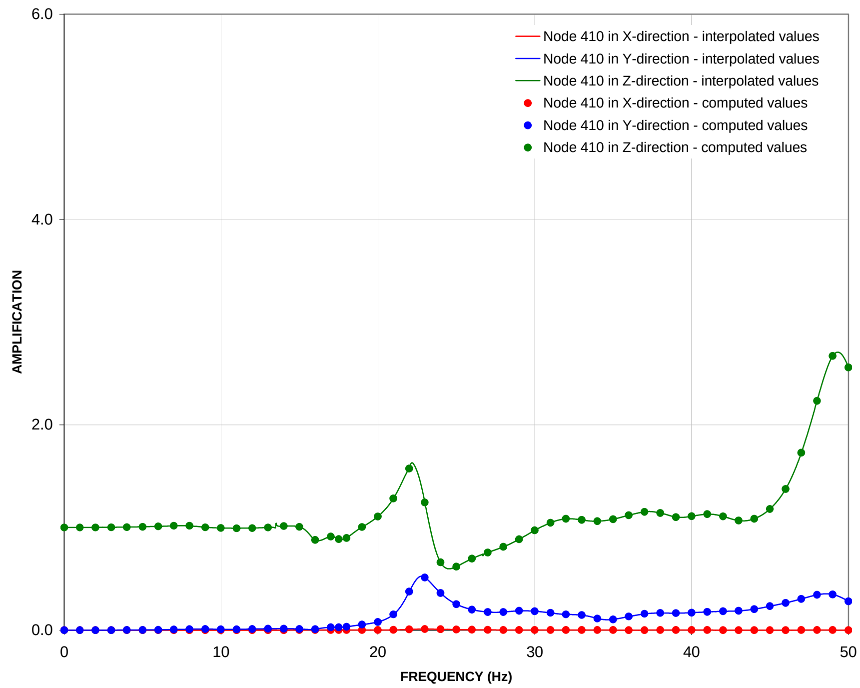


Figure 3-4: Transfer functions - CB foundation (EL -7.4 m), UB subsurface profile, Node 410 Z direction input motion (Considering SSSI effect of FWSC)

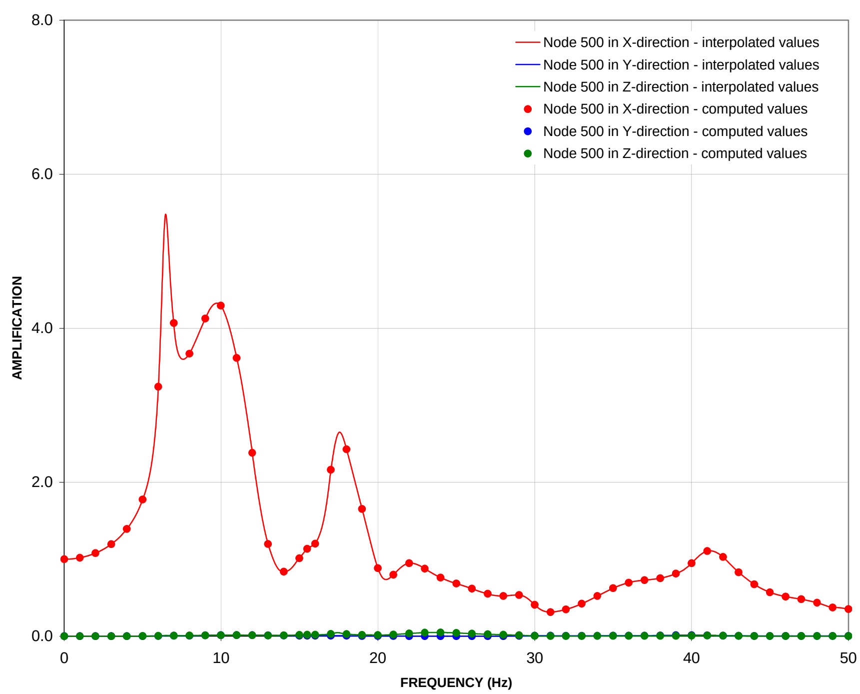


Figure 3-5: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, Node 500 X direction input motion (Considering SSSI effect of FWSC)

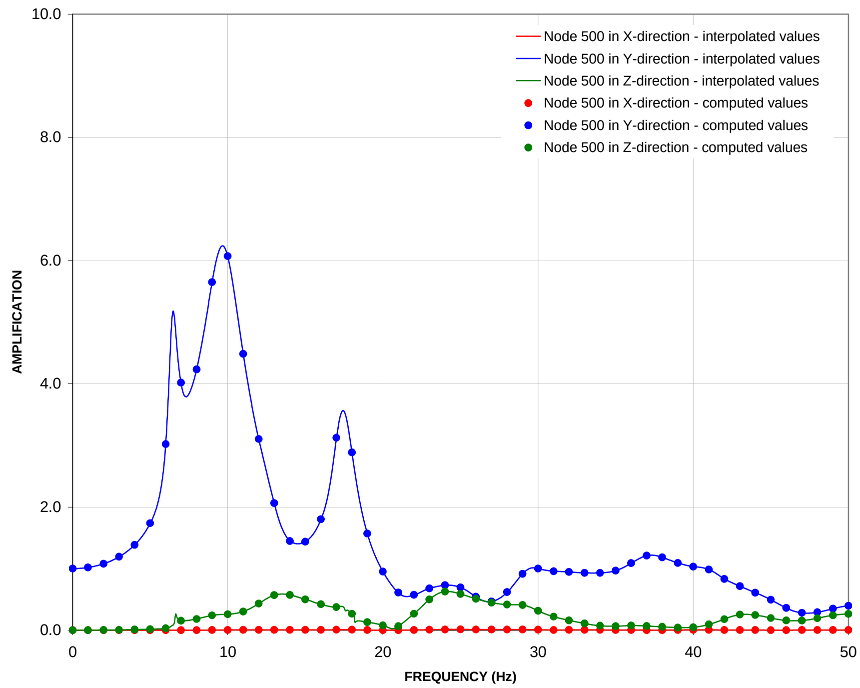


Figure 3-6: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, Node 500 Y direction input motion (Considering SSSI effect of FWSC)

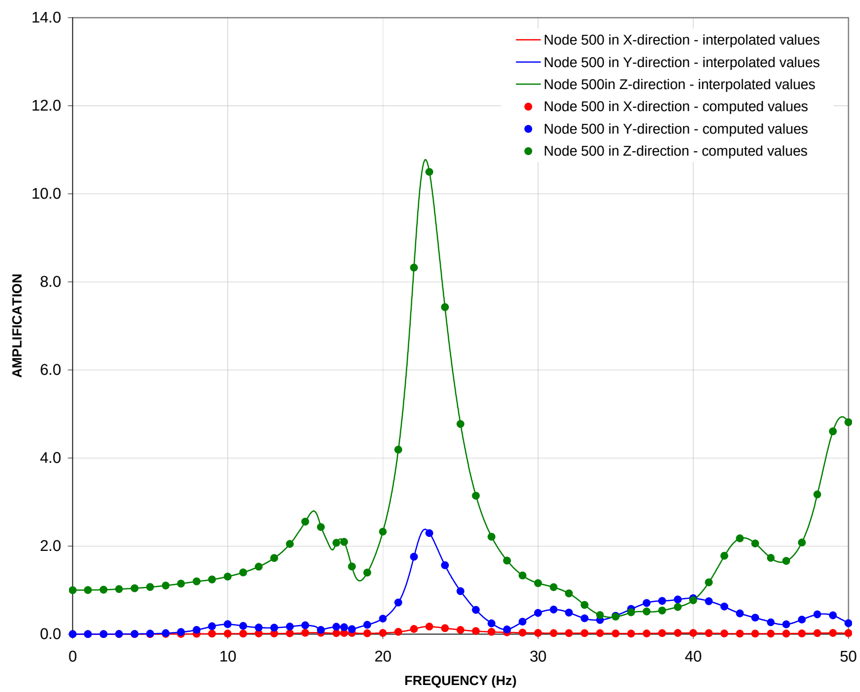


Figure 3-7: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, Node 500 Z direction input motion (Considering SSSI effect of FWSC)

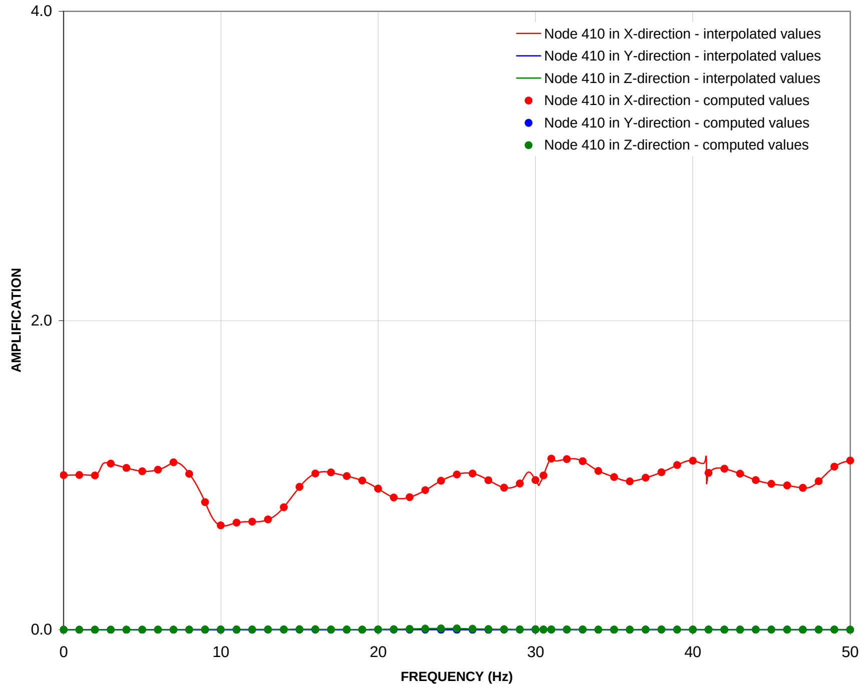


Figure 3-8: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, Node 410 X direction input motion (Considering SSSI effect of FWSC)

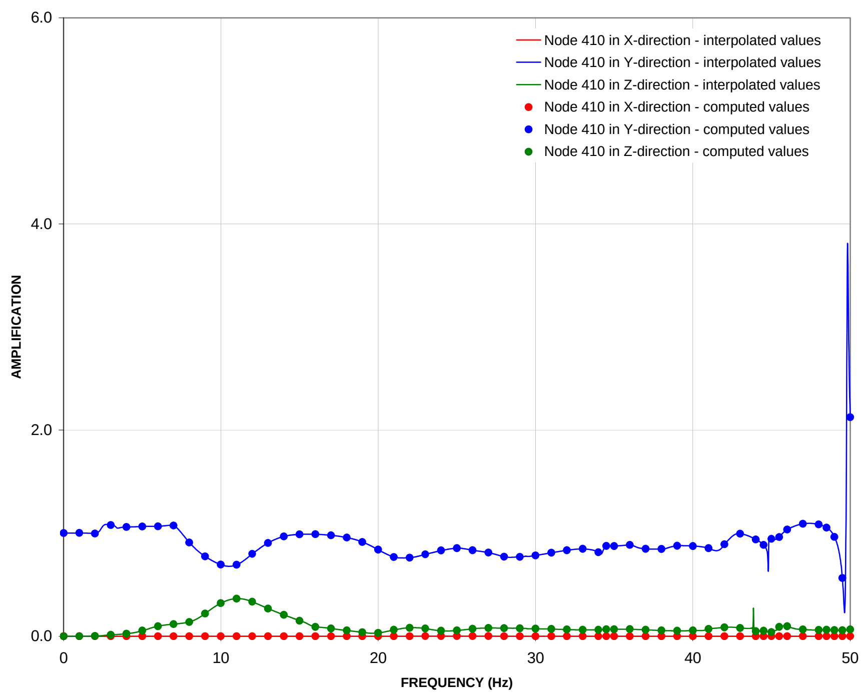


Figure 3-9: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, Node 410 Y direction input motion (Considering SSSI effect of FWSC)

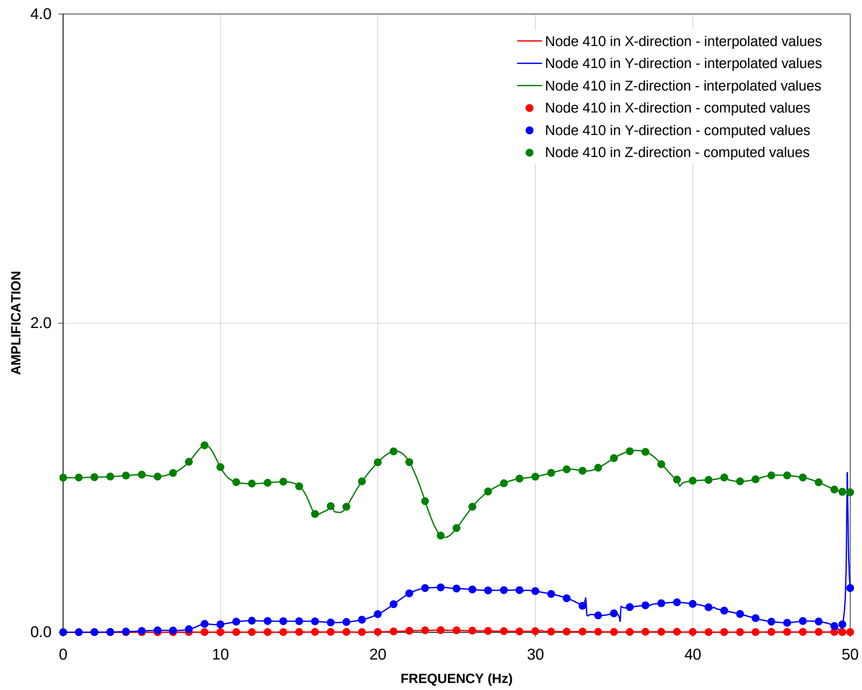


Figure 3-10: Transfer functions - CB foundation (EL -7.4 m), LB subsurface profile, Node 410 Z direction input motion (Considering SSSI effect of FWSC)

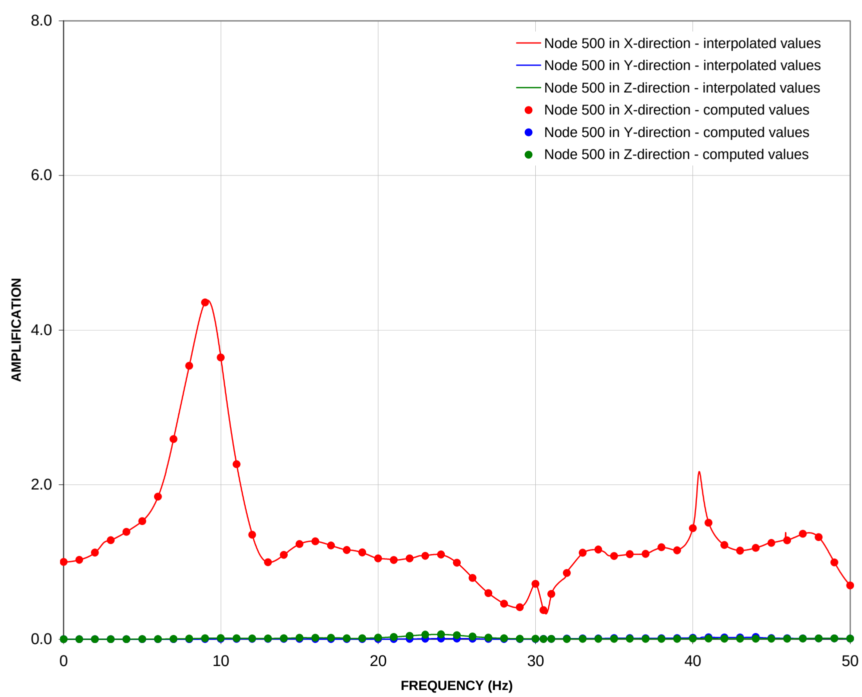


Figure 3-11: Transfer functions - CB roof (EL 13.8 m), LB subsurface profile, Node 500 X direction input motion (Considering SSSI effect of FWSC)

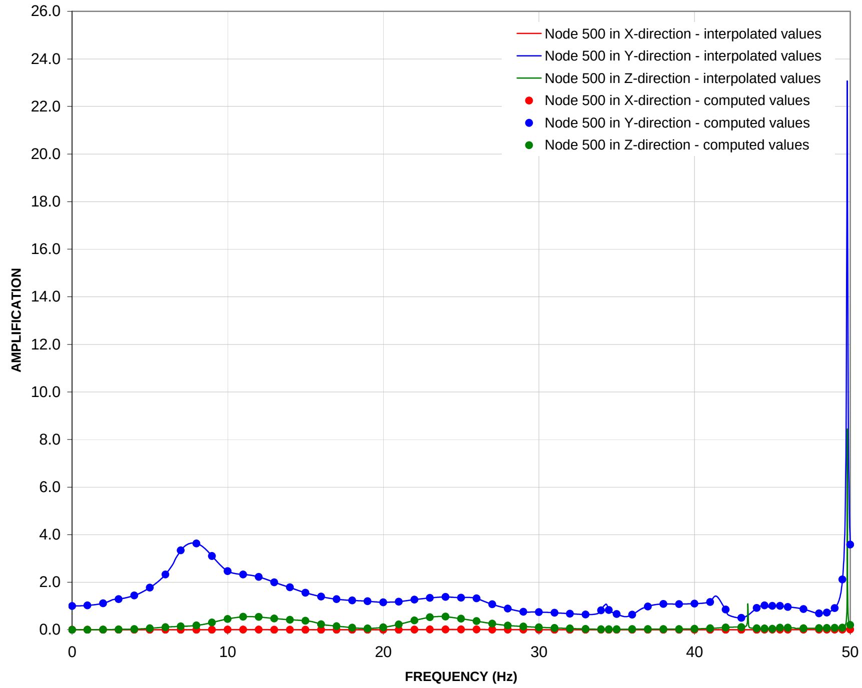


Figure 3-12: Transfer functions - CB roof (EL 13.8 m), LB subsurface profile, Node 500 Y direction input motion (Considering SSSI effect of FWSC)

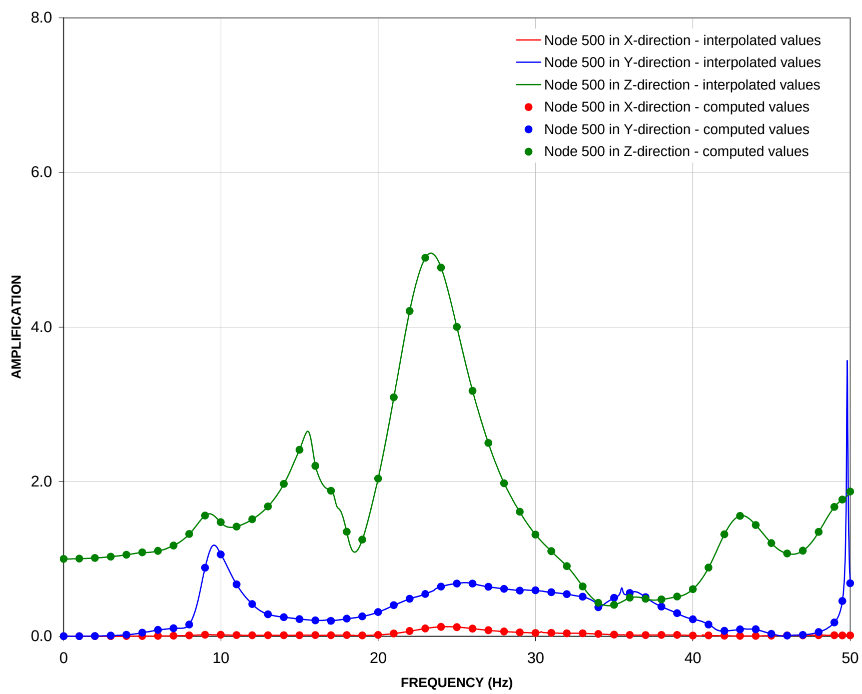


Figure 3-13: Transfer functions - CB roof (EL 13.8 m), UB subsurface profile, Node 500 Z direction input motion (Considering SSSI effect of FWSC)

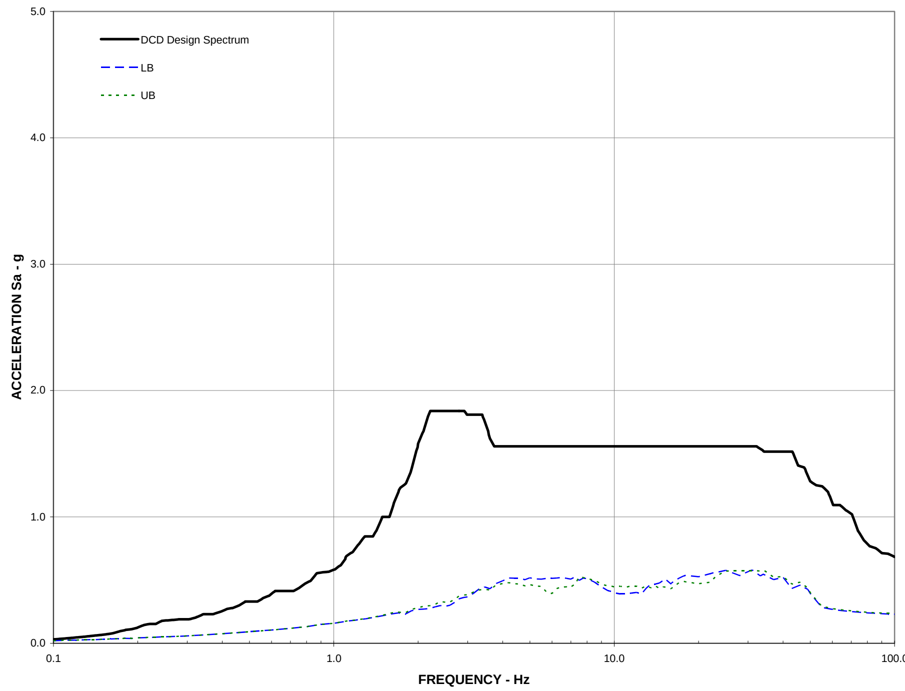


Figure 3-14: Comparison of floor response spectra – 5% damping, CB basemat (El -7.4 m), Node 410, X direction (Considering SSSI effect of FWSC)

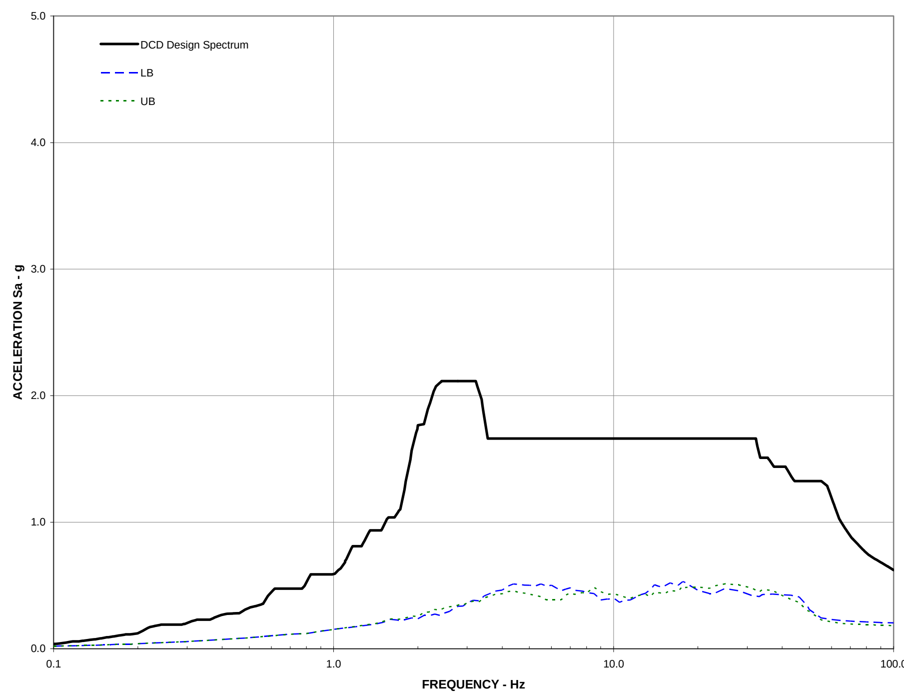


Figure 3-15: Comparison of floor response spectra – 5% damping, CB basemat (El -7.4 m), Node 410, Y direction (Considering SSSI effect of FWSC)

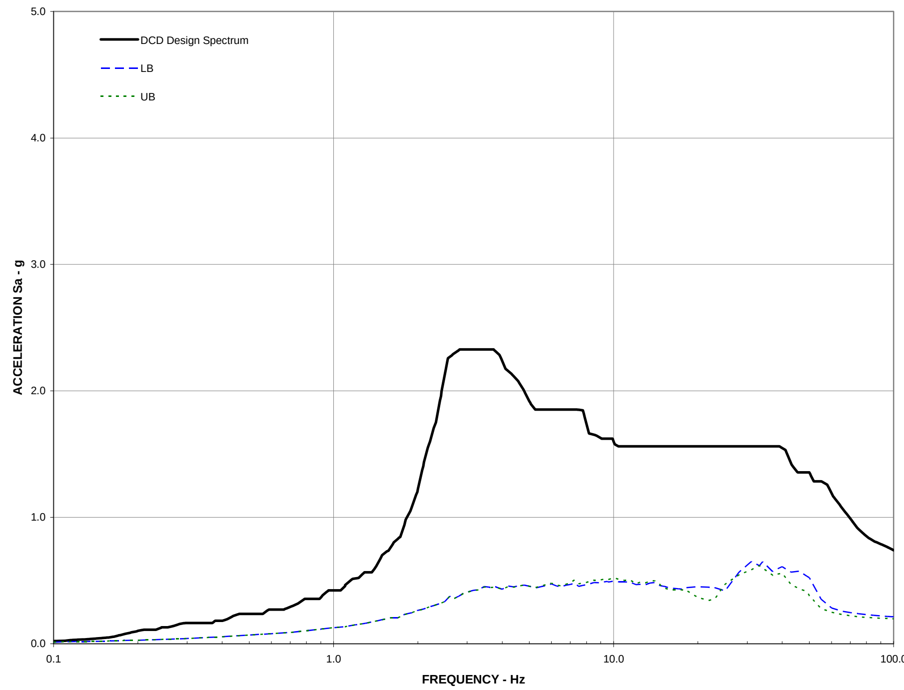


Figure 3-16: Comparison of floor response spectra – 5% damping, CB basemat (El -7.4 m), Node 410, Z direction (Considering SSSI effect of FWSC)

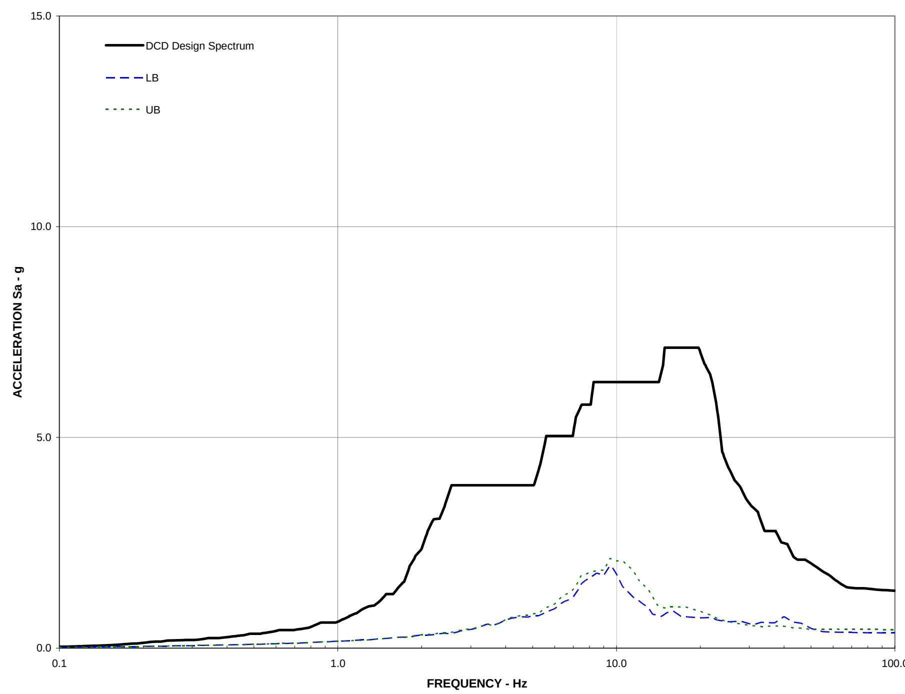


Figure 3-17: Comparison of floor response spectra – 5% damping, CB roof (El 13.8 m), Node 500, X direction (Considering SSSI effect of FWSC)

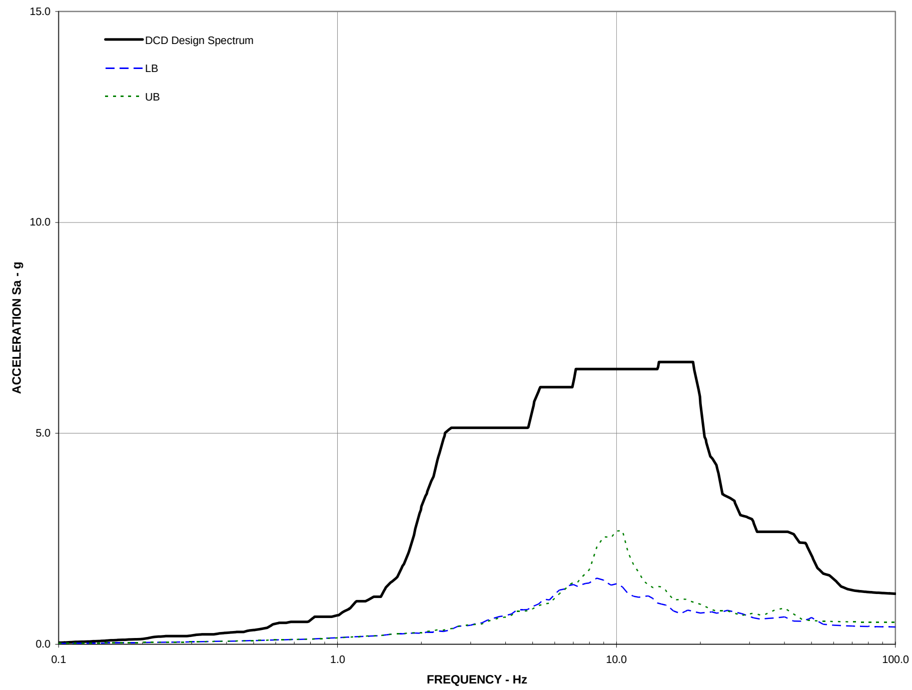


Figure 3-18: Comparison of floor response spectra – 5% damping, CB roof (El 13.8 m), Node 500, Y direction (Considering SSSI effect of FWSC)

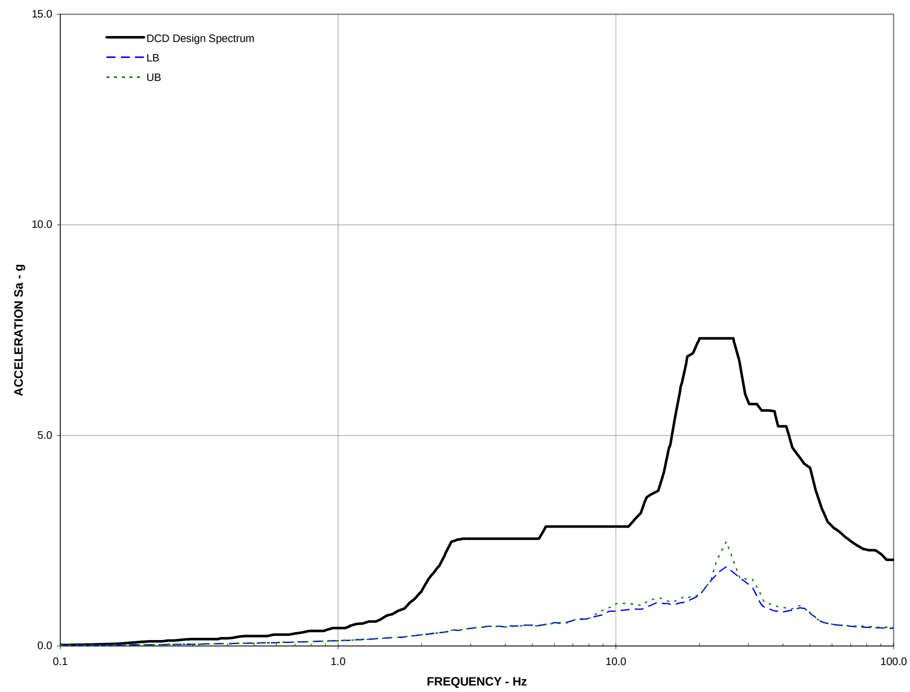
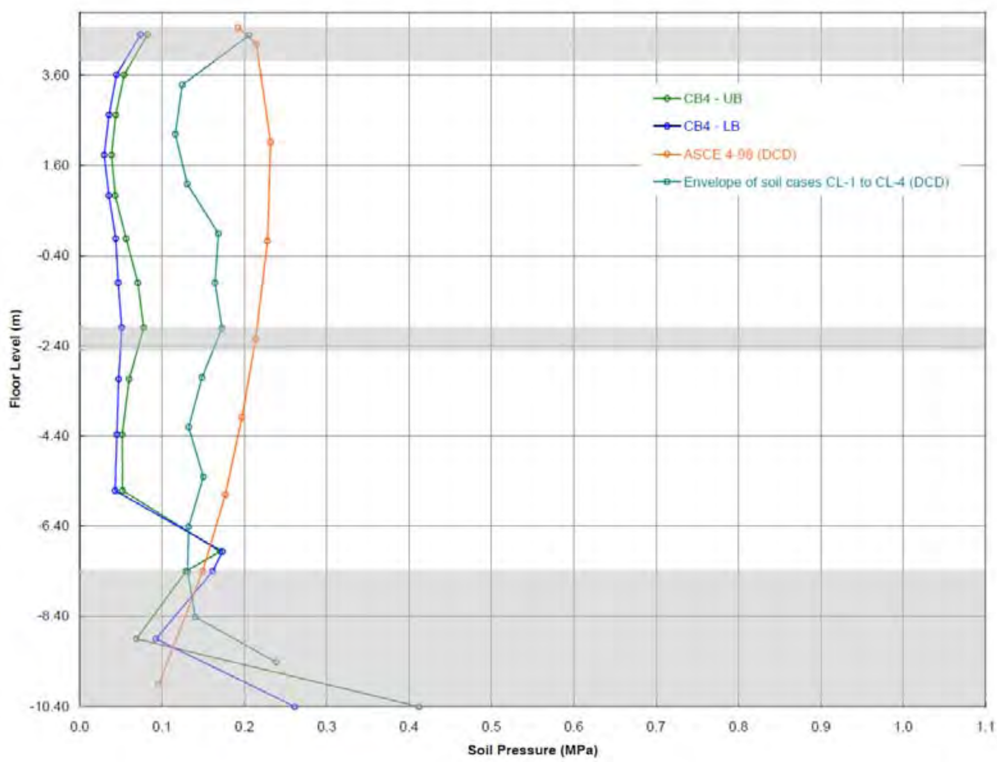


Figure 3-19: Comparison of floor response spectra – 5% damping, CB roof (El 13.8 m), Node 500, Z direction (Considering SSSI effect of FWSC)



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

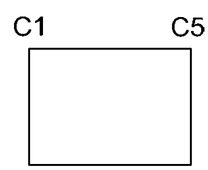
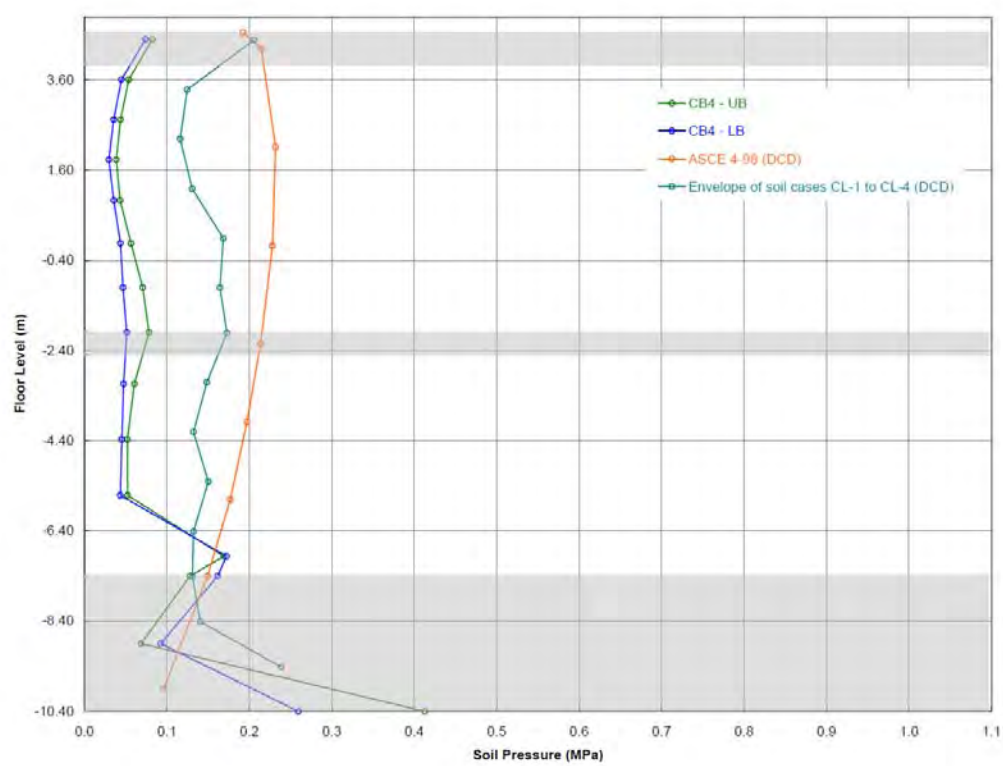


Figure 3-20: Lateral soil pressure for CB north wall (C1) (Considering SSSI effect of FWSC)



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

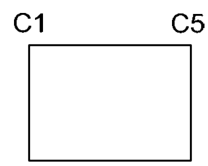
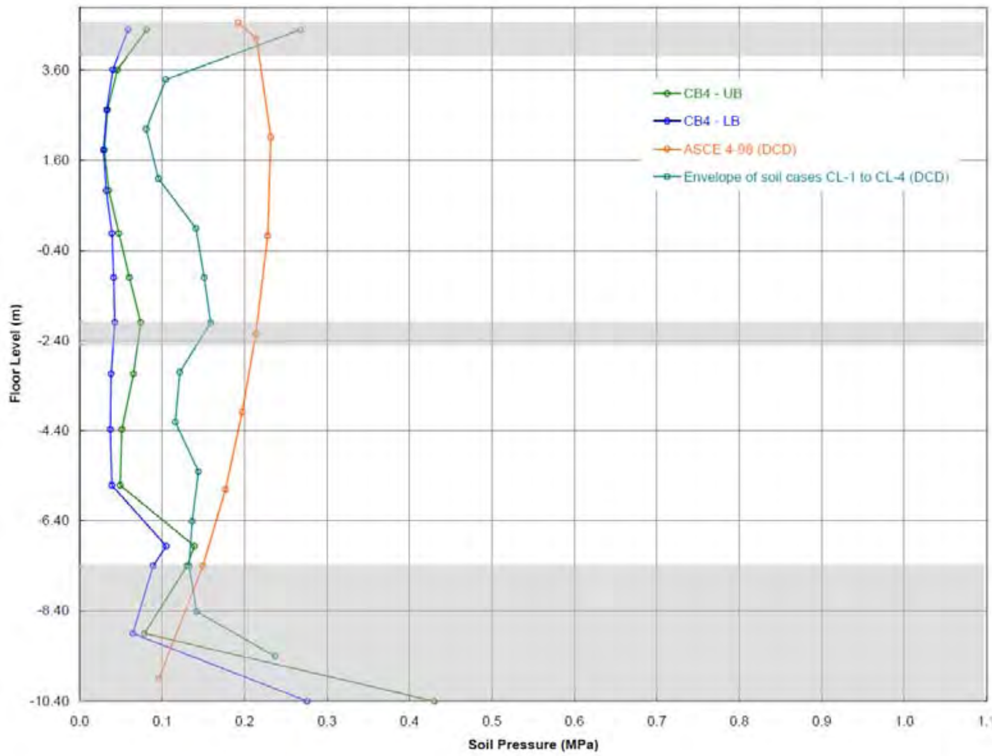


Figure 3-21: Lateral soil pressure for CB south wall (C5)
(Considering SSSI effect of FWSC)



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

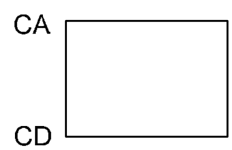
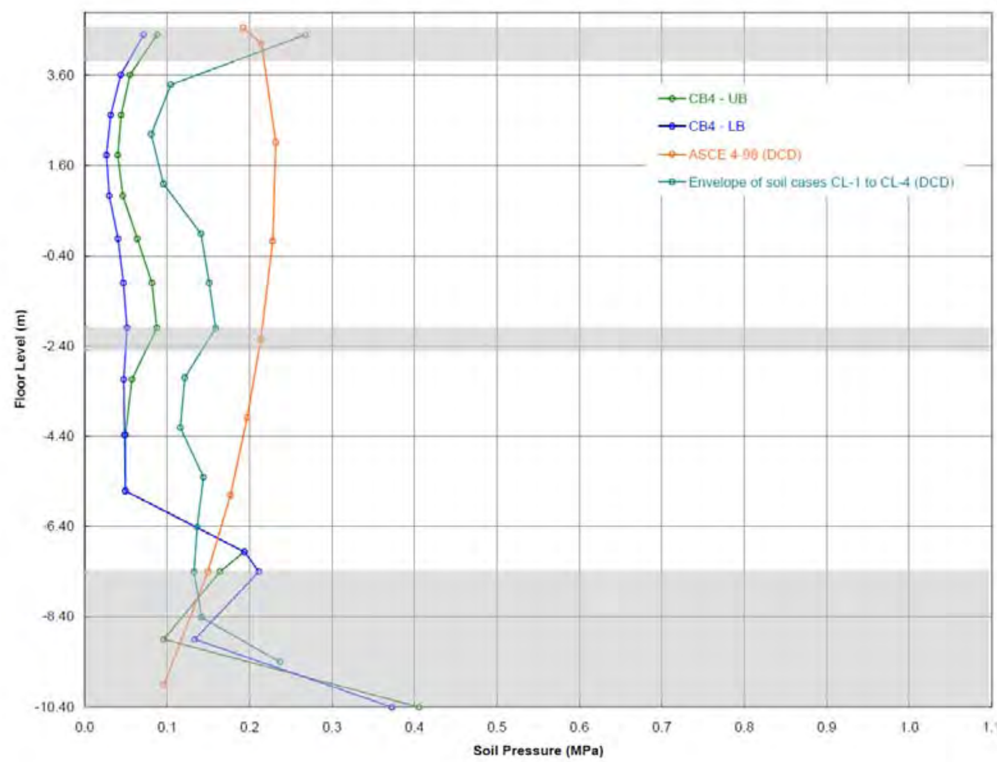


Figure 3-22: Lateral soil pressure for CB east wall (CA) (Considering SSSI effect of FWSC)



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

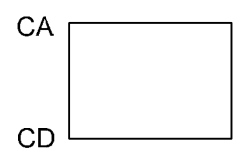


Figure 3-23: Lateral soil pressure for CB west wall (CD)
(Considering SSSI effect of FWSC)