RAI 03.07.01-27, Supplement 1, Revision 1

QUESTION:

Follow-up Question to RAI 03.07.01-19 (STP-NRC-100093)

1. 10CFR50, Appendix S requires that evaluation for SSE must take into account soil-structure interaction (SSI) effects and the expected duration of vibratory motion. In the response to the first paragraph of RAI 03.07.01-19, the applicant has presented its approach for developing the input motion for the SSI analysis and design of the DGFOSV that takes into account the impact of the nearby heavy RB and RSW Pump House structures. The applicant also stated that *"Conservatively, a 3-dimensional SAP2000 response spectrum analysis was used to obtain the safe-shutdown earthquake (SSE) design forces due to structure inertia. The seismic induced dynamic soil pressure on DGFOSV walls were computed using the method of ASCE 4-98, Subsection 3.5.3.2"* The response, however, does not provide details as to how the SSI analysis of the DGFOSV are performed and how the input motion developed are subsequently specified in the SSI analysis of DGFOSV to develop the structural response and in-structure response spectra for any equipment and subsystems within DGFOSV. From the response it appears that the applicant has not included explicitly DGFOSV structural model in the SASSI model of the RB and RSW Pump House structures to properly evaluate the SSSI effect on the DGFOSV. In order for the staff to determine if the evaluation of DGFOSV for SSE has appropriately accounted SSI effects, the applicant is requested to provide in the FSAR the following information:

   (a) Describe in detail the method used for the SSI analysis of DGFOSV including the procedures for treatment of strain dependent backfill material properties in the model, input motion used and how it is specified in the analysis, variation of soil properties, and the computer programs used for SSI analysis.

   (b) Describe in detail how SAP2000 analysis of DGFOSV was performed including, how foundation soil/backfill material was represented, how many modes were extracted, what modal damping values were used, how the input motion was specified, and what type of boundary conditions were used.

   (c) Demonstrate that the DGFOSV foundation response spectra and dynamic soil pressure (on DGFOSV basement walls using ASCE 4-98 criteria) used in the design of DGFOSV will envelop the results of structure to structure (SSSI) interaction analysis which explicitly models DGFOSV structure in the SSI model of RB and the RSW Pump House structure.

   (d) Describe in detail if there is any Category I tunnel structure for transporting Diesel Fuel Oil between DGFOSV and the Diesel Generator located in other buildings including its layout and configuration and seismic analysis and design method.

2. In the response to Item 2 of RAI 03.07.01-19, the applicant has stated that the P-wave damping ratios are assigned the same values as those calculated for the S-wave damping ratios because of the **upcoming** recommendations of ASCE 4-09 standards. It is further stated that this recommendation is based on the recent observation of earthquake data and the realization that the waves generated due to SSI effects are mainly surface and shear waves. It is noted that the NRC has not endorsed ASCE 4-09 for estimating the P-wave damping. In general, the P-wave damping is primarily associated with the site response rather than SSI effects. Because the Pwave energy for the most part will travel in water within the saturated soil media at relatively high propagation speed and is not affected by shear strains of degraded soil, the P-wave damping will be small. As such, the applicant is requested to provide quantitative assessment by performing sensitivity analysis that shows that seismic responses of Category I structures are not adversely affected to a lower P-wave damping.

REVISED SUPPLEMENTAL RESPONSE:

The original supplement 1 response to this RAI was submitted with STPNOC letter U7-C-STP-NRC-100274, dated December 21, 2010. This revision provides the following based on discussions with the NRC on February 2^{nd} and 3rd, 2011.

1. Clarify that the seismic soil pressures in Figures 3H.6-226 to 3H.6-231 are incremental seismic soil pressures.
2. Clarify that all walls of the diesel generator fuel oil storage vaults are designed for incremental seismic soil pressures shown in Figures 3H.6-226 to 3H.6-231.
3. Clarify how the diesel generator fuel oil tank was modeled in the soil-structure interaction analyses of the diesel generator fuel oil storage vaults.

The revisions are indicated by revision bars in the margin.

The response to Part 2 of this RAI was submitted with STPNOC letter U7-C-STP-NRC-100208 dated September 15, 2010. The response to Part 1(d) is provided in the Supplement 2, Revision 1 response to this RAI which is being submitted concurrently with this response. This supplemental response provides the response to Parts 1(a) through 1(c).

1a) Soil-Structure Interaction (SSI) Analysis of Diesel Generator Fuel Oil Storage Vaults (DGFOSV)

The DGFOSV are reinforced concrete structures, located below grade with an access room above grade. The DGFSOV house fuel oil tanks and transfer pumps. The locations of the DGFOSV and nearby structures are shown in Figure 3H.6-221 (see Enclosure 1).

The following two types of SSI analyses are performed for DGFOSV:

- 3D SSI analyses of DGFOSV alone for calculating in-structure response spectra and design accelerations/forces of the structure. These analyses were performed considering both full and empty fuel oil tanks.
- 2D structure-soil-structure interaction (SSSI) analysis of DGFOSV and adjacent structures to obtain seismic soil pressures.

3D SSI Analysis

The SSI analyses of the 3D model of DGFOSV are performed using SASSI2000 computer program (using subtraction method).

Structural Model:

The structural part of the model consists of shell elements to model the exterior walls, and the roof slabs and 3D solid elements to model the basemat and the mud mat. Structure self weight and other applicable weights of equipment, live load, piping, metal decking, missile barrier cover are included in the structural model. The fuel tank is modeled with the fuel and tank weight lumped at the center of gravity of the tank and the tank lumped weight rigidly connected to the base mat at tank saddle locations as shown in Figure 03.07.01-27.28. The fuel tank procurement specification will require that the fuel tank with fuel in it should have predominant frequencies greater than 33 Hz in horizontal and vertical directions. The fuel tank portion of the model has been assigned a damping value of 0.5%. For the other parts of the structure two damping values are used; 7% damping and 4% damping. The results from the 7% structural damping are used for design of the DGFOSV. The results from the 4% damping are used for generation of in-structure response spectra. Both full and empty fuel oil tank conditions are considered in the analysis. Figure 3H.6-222 (see Enclosure 1) shows the typical 3D structural model of the DGFOSV for various SSI analyses. The following provides the details of the SSI model and method of analysis.

Strain Dependent Soil Properties Used in SSI Analyses:

The strain dependent soil properties used in the model are in accordance with the properties provided in COLA Part 2, Tier 2 Table 3H.6-1 for the in-situ soil and Table 3H.6-2 for the backfill soil, with the exception that for soil layers below the ground water table, the Poisson's ratio is capped at 0.495 for determining the compression wave velocity. The thickness of soil layers is adjusted to provide a vertical direction passing frequency of at least 33 Hz (based on one fifth of shear wave length criterion).

Analysis Cases, Passing Frequency and Cutoff Frequency for the SSI Analyses:

- The following cases are analyzed for both 4% and 7% structural damping values:

  For full fuel oil tank case:

  - Lower Bound (LB) in-situ soil
  - Mean in-situ Soil
  - Upper Bound (UB) in-situ soil
  - LB backfill over LB in-situ soil
  - Mean backfill over mean in-situ soil
  - UB backfill over UB backfill
  - UB in-situ soil with soil separation
  - UB in-situ soil with cracked concrete

  For Empty fuel oil tank case:

  - UB in-situ soil with empty fuel tank

  Note: For soil separation, cracked concrete and empty fuel oil tank cases, the UB in-situ soil is used because the UB in-situ soil case in general governed.

- A cut-off frequency of 35 Hz was used for all SSI analyses for transfer function calculation.
- Vertical direction passing frequencies (based on one fifth of shear wave length criterion and considering lower bound in-situ soil) are equal to or greater than 33 Hz.
- Horizontal direction passing frequencies are equal to or greater than 33 Hz, except at following locations:

  - For LB in-situ soil, the passing frequency for the top 4 ft soil layer is 30.3 Hz.
  - At the foundation toe, the passing frequencies for in-situ soil are 20 Hz for LB, 25.8 Hz for mean, 31.6 Hz for UB; and for backfill are 23.1 Hz for LB, 28.3 Hz for mean and 34.7 Hz for UB.

To evaluate the effect of 20 Hz passing frequency for LB in-situ case, the foundation toe was divided into two elements, thus increasing the passing frequency to 40 Hz. This refined model with LB in-situ soil properties was analyzed and 5% damped spectra from this model were compared with the spectra from the original model with passing frequency of 20 Hz. The spectra comparison plots are shown in Figures 03.07.01-27.1 through 03.07.01-27.24. The comparison shows that:

- In the X direction, there is insignificant difference between the response spectra from the two models
- In the Y direction, the response spectra from the two models matched well except at frequency of about 3.8 Hz where the refined model produced higher spectra.

However, spectra from both the models are enveloped by the spectra for UB in-situ soil case

- In the vertical direction, the spectra from the two models matched well (insignificant difference)

Based on the above evaluation it is concluded that the horizontal direction passing frequencies are acceptable.

Input Motion:

As described in COLA Part 2, Tier 2 Section 3H.6.7, the input motion considers the impact of the nearby Reactor Building (RB) and UHS/RSW Pump House. From the procedure described in this COLA section it was determined that the 0.3g Regulatory Guide 1.60 spectra envelop all other spectra derived from the SSI analyses to take into account the impact of nearby large structures. Therefore, in this SSI analysis, acceleration time histories consistent with 0.3g Regulatory Guide 1.60 spectra are used as input at the grade elevation.

Response Combination, Enveloping and Spectra Peak Widening:

For all analysis cases, the responses due to two horizontal directions and vertical direction input motions are combined using square-root sum of squares (SRSS) method. Then, the responses from all analysis cases and all locations considered for spectra generation are enveloped to determine one set of un-widened horizontal and vertical response spectra. Finally, per Regulatory Guide 1.122, the enveloped un-widened response spectra are peak widened by plus-minus 15% on the frequency scale to obtain the final response spectra for DGFOSV. The resulting enveloping response spectra for DGFOSV are shown in Figures 3H.6-223 and 3H.6-224 (see Enclosure 1).

2D SSSI Analysis

Two 2D SSSI models are developed and analyzed to evaluate the effects of nearby structures on the three DGFOSV and to calculate the seismic soil pressures on the structures.

The first SSSI model is for a section cut in the North-South direction, consisting of UHS/RSW Pump house, RSW Piping Tunnel, DGFOSV 1B, DGFOSV 1C and RB. The details of this SSSI analysis have been provided in the response to RAI 03.07.02-24, Supplement 1, submitted with STPNOC letter U7-C-STP-NRC-100253 dated November 29, 2010.

The second SSSI model is for a section cut in the East-West direction consisting of diesel generator fuel oil tunnel (DGFOT), DGFOSV 1A and the Crane Foundation Retaining Wall. The model for this SSSI analysis is shown in Figure 3H.6-225 (see Enclosure 1). The model details of the SSSI analysis is provided below.

Structural Models:

DGFOSV Model:

East-West direction of 2D DGFOSV model is idealized by a stick model of beam elements. Axial, flexural, and shear deformation effects are included in beam element stiffness. The fuel oil tank is also modeled using beam elements and its mass is lumped at its CG. The basemat and the mud mat are modeled using four node plain strain elements. The model properties (stiffness and mass) for the 2D plane analysis correspond to per unit depth (one foot dimension in the out-of-plane direction) of the DGFOSV.

DGFOT Model:

Four node plane strain elements are used to model the exterior walls, base slab, the top slab and the mud mat. Applicable weights are included at appropriate locations in the model. The structural model properties (stiffness and mass) for the 2D plane strain model correspond to per unit depth (one foot dimension in out-of-plane direction).

Crane Wall:

The Crane Wall is modeled using beam elements with nodes located 17 ft away from the DGFOSV east wall (clear distance between the DGFOSV 1A exterior wall face and the west face of the Crane Wall). Beam section properties (stiffness and mass) for the 2D plane strain model correspond to per unit depth (one foot dimension in out-of-plane direction).

The SSSI analysis of the 2D model of DGFOSV with other structures, which affects the DGFOSV in the East-West direction, is performed using SASSI2000 computer program, using subtraction method. The following provides the details of the SSSI analysis.

Strain Dependent Soil Properties Used in SSSI Model:

The strain dependent soil properties used in the model are in accordance with the properties provided in COLA Part 2, Tier 2 Table 3H.6-1 for the in-situ soil, and Table 3H.6-2 for the backfill soil, with the exception that for soil layers below the ground water table, the Poisson's ratio is capped at 0.495 for determining the compression wave velocity. The thickness of soil layers is adjusted to provide a vertical direction passing frequency of at least 33 Hz (based on one fifth of shear wave length criterion).

To evaluate the effects of the soil variation, five soil cases are considered:

- UB in-situ soil with UB backfill between the structures.
- LB in-situ soil with LB backfill between the structures.
- Mean in-situ soil with Mean backfill between the structures.
- Mean in-situ soil with LB backfill between the structures.

- Mean in-situ soil with UB backfill between the structures.

Passing Frequency and Cut-off Frequency for SSSI Model:

- Cut-off frequency of 33 Hz is used in the analysis.
- Vertical direction passing frequencies are equal to or greater than 33.5 Hz.
- Horizontal direction passing frequencies are equal to or greater than 30.48 Hz.

Input Motion:

STP 3&4 site specific SSE motion, as described in COLA Part 2, Tier 2 Subsection 3H.6.5.1.1.2, is applied at the grade elevation, in the East-West direction.

Comparison of DGFOSV Foundation Spectra from 3D SSI analysis and 2D SSSI Analysis:

Figures 03.07.01-27.25, 03.07.01-27.26 and 03.07.01-27.27 show the comparisons between the DGFOSV foundation level 5% damped response spectra obtained from the 3D SSI analysis (enveloped for all soil cases and used for the design of the DGFOSV) and the 5% damped foundation spectra obtained from 2D SSSI analyses. The comparisons show that the design spectra obtained from the 3D SSI analyses envelop the spectra obtained from the 2D SSSI analyses. Note that the input motion for the 3D SSI analysis corresponds to 0.3g Regulatory Guide 1.60 spectra, and the input motion for 2D SSSI analysis is the site specific SSE.

1b. The SAP2000 response spectrum analysis described in response to RAI 03.07.01-19, submitted with letter U7-C-STP-NRC-100093, dated April 29, 2010, is no longer used. The revised SSI analyses are described in Part 1a above. All in-structure response spectra and maximum accelerations for DGFOSV are based on this revised SSI analysis. The design of DGFOSV has also been revised and the seismic loads are conservatively determined using equivalent static method. The details for this equivalent static method will be provided in the response to RAI 03.08.04-30, Revision 1, which is currently scheduled to be submitted by March 15, 2011.

1c. The comparison of the DGFOSV foundation response spectra from 3D SSI analysis and 2D SSSI analysis is provided in Part 1a above.

The structural analysis and design of the DGFOSV have been revised to consider incremental seismic soil pressures from the SSSI analysis described in part 1a above. Figures 3H.6-226 through 3H.6-231 show a comparison of the incremental seismic soil pressures obtained from SSSI and the ASCE 4-98 methodology and the incremental seismic soil pressure used in the design of all DGFOSV walls. The revised design results for the DGFOSV will be provided in the response to RAI 03.08.04-30, Revision 1, which is currently scheduled to be submitted by March 15, 2011.

COLA Part 2, Tier 2, Section 3H.6 will be revised as shown in Enclosure 1.

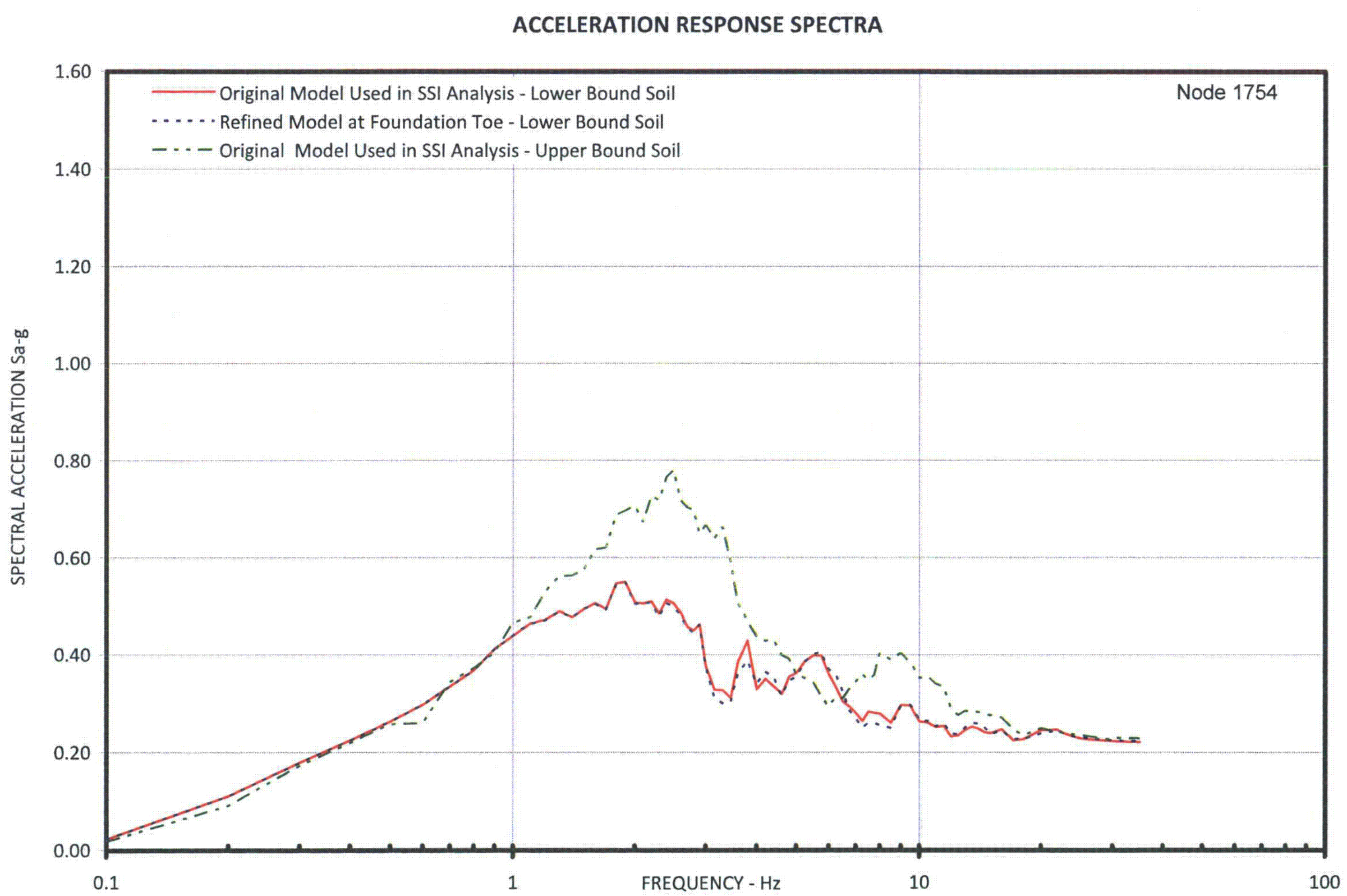

Figure 03.07.01-27.1 - 5% Damped Spectral Comparison in X Direction at Top of Foundation (Center), El. -3.0 ft

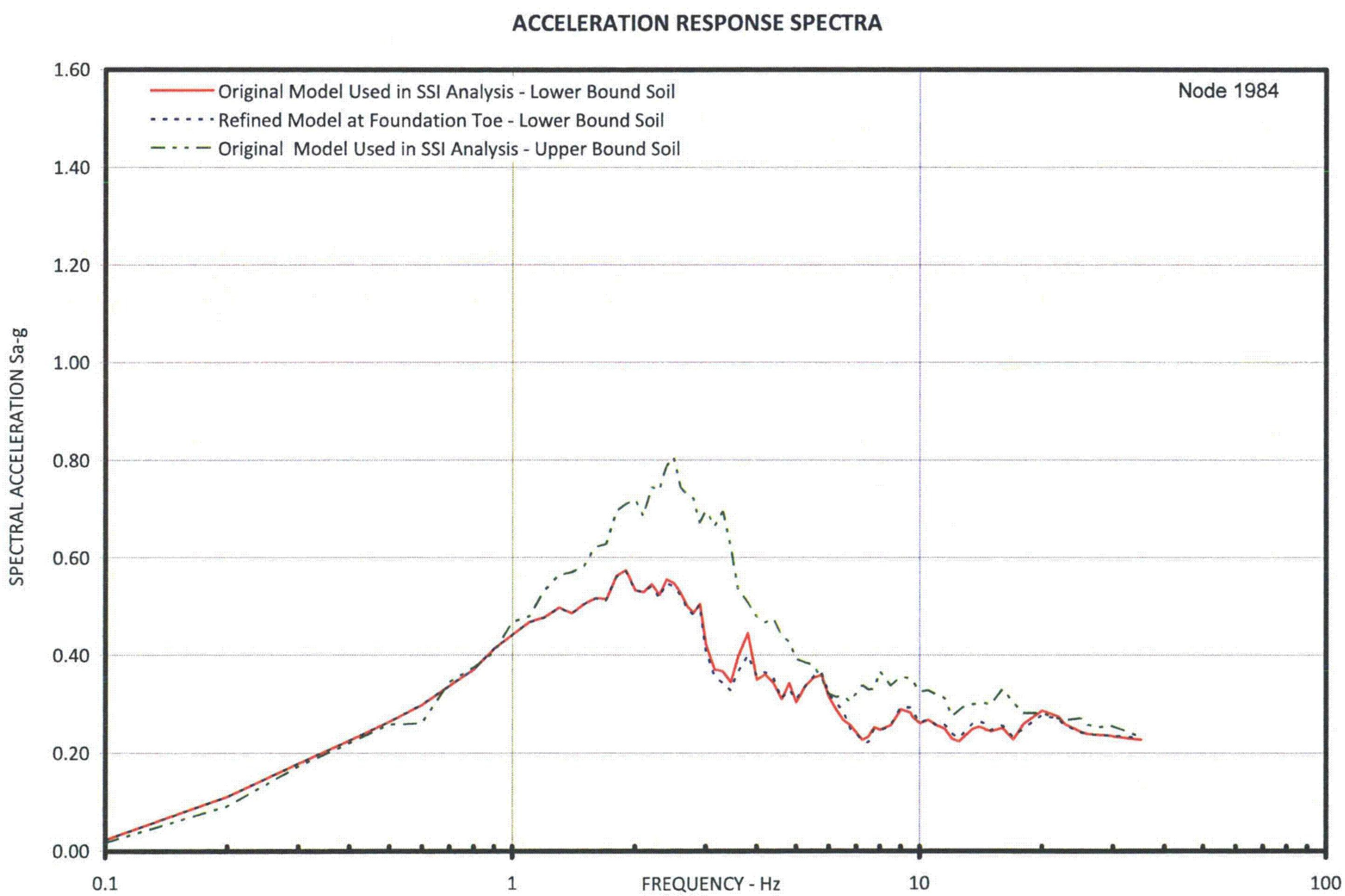

Figure 03.07.01-27.2 - 5% Damped Spectral Comparison in X Direction at C.G. of Oil Tank

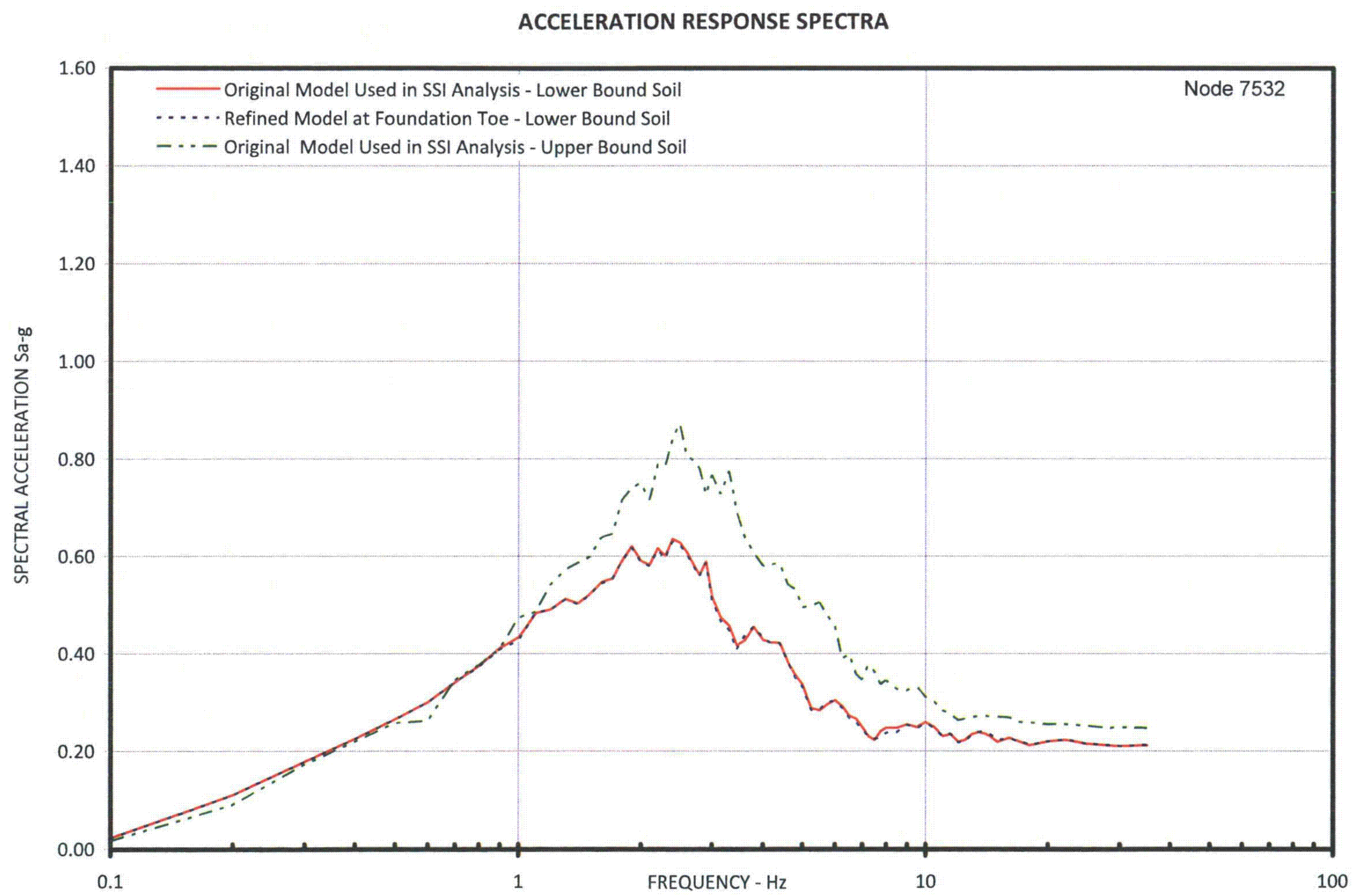

Figure 03.07.01-27.3 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Corner away from access room), El. 30.0 ft

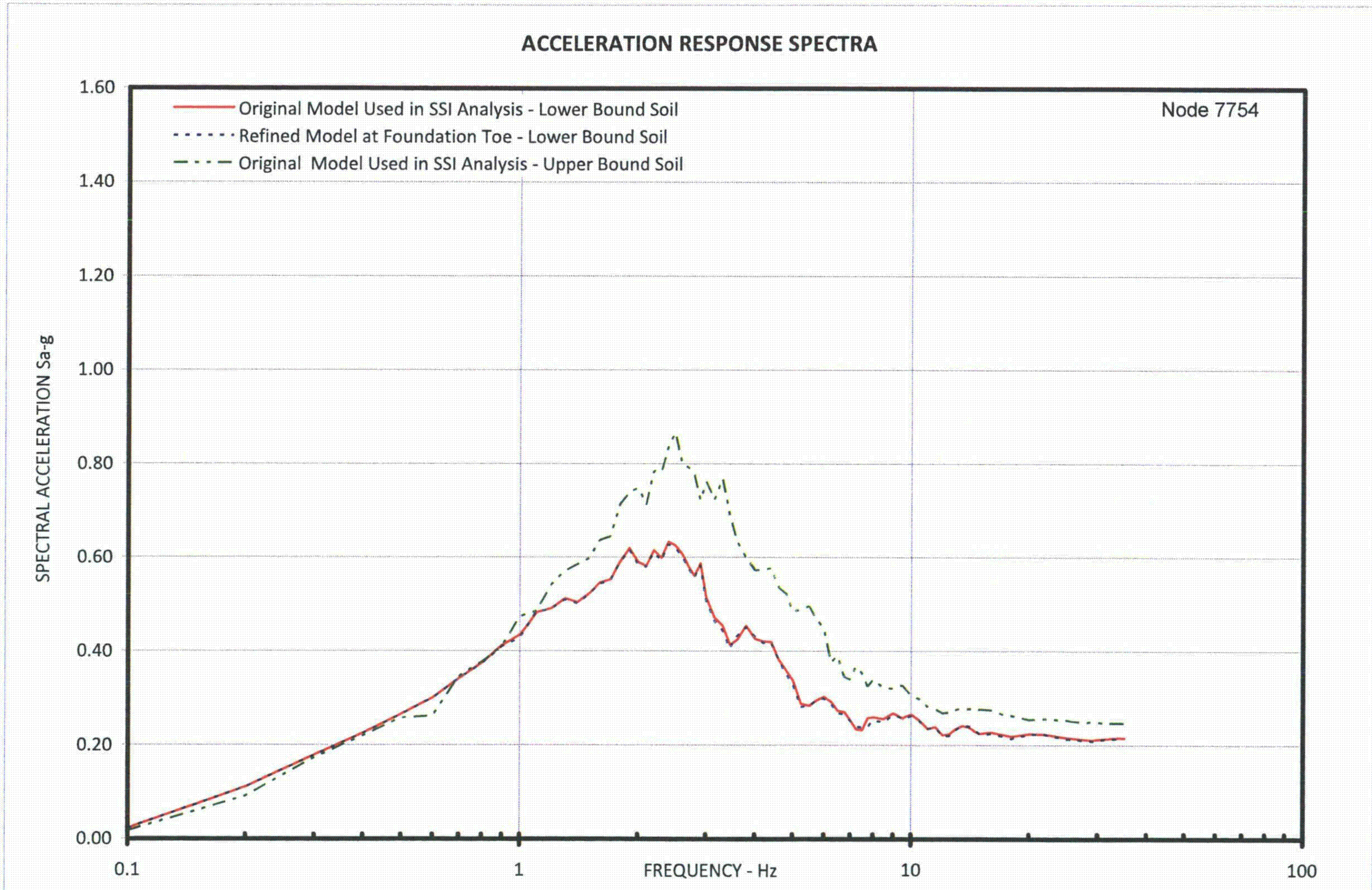

Figure 03.07.01-27.4 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Center), El. 30.0 ft

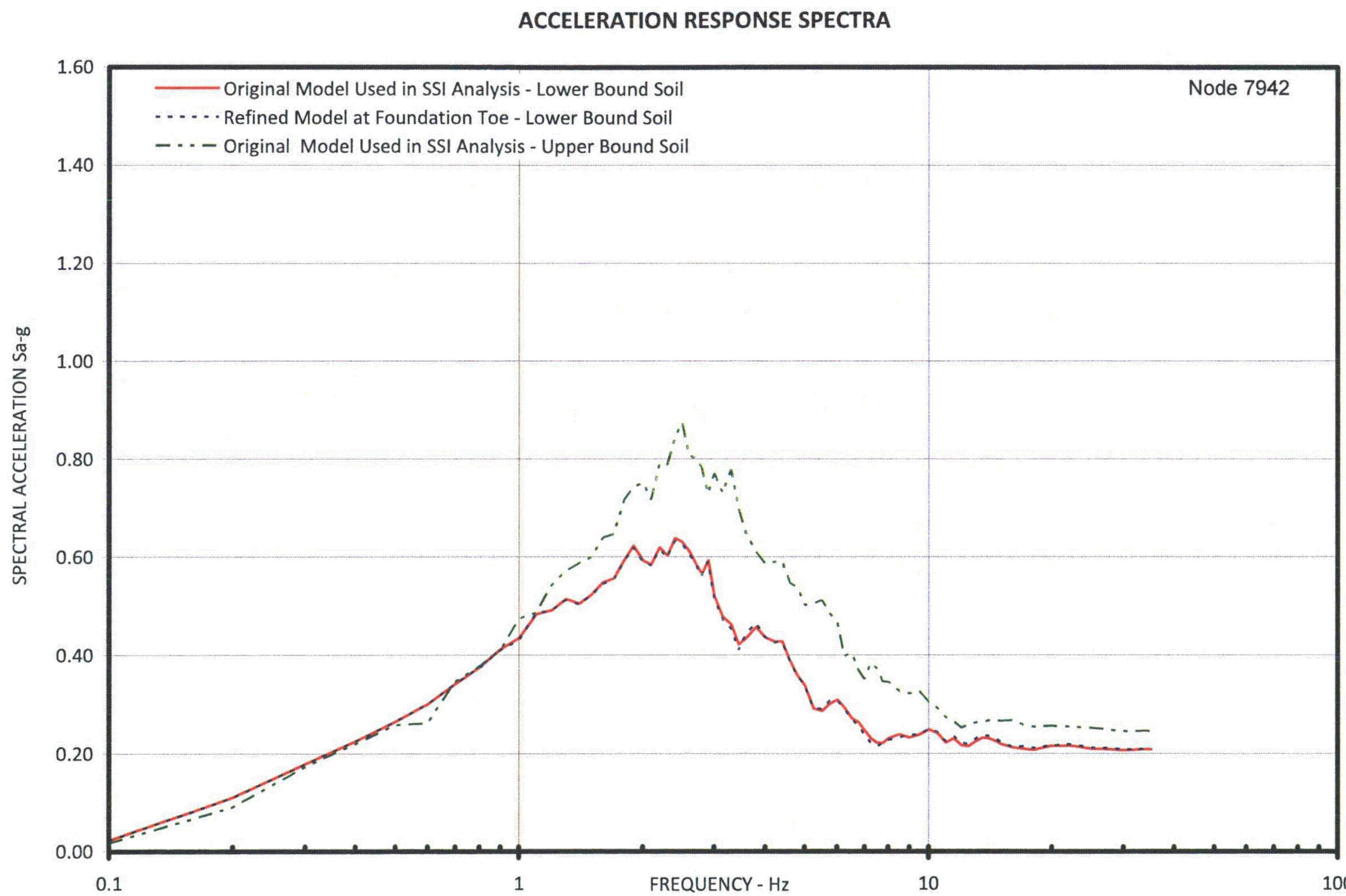

Figure 03.07.01-27.5 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Corner near access room), El. 30.0 ft

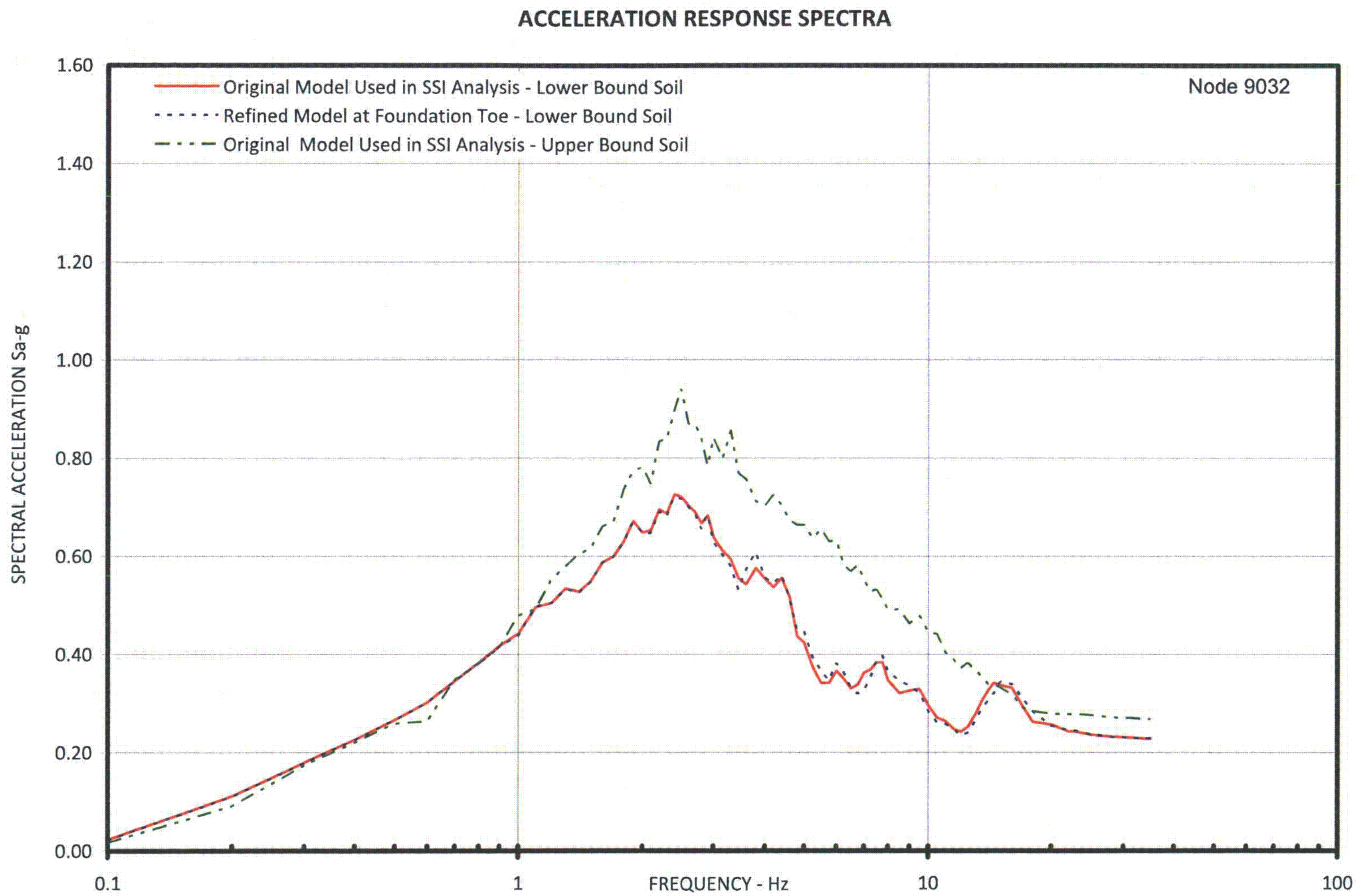

Figure 03.07.01-27.6 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Corner), El. 50.0 ft

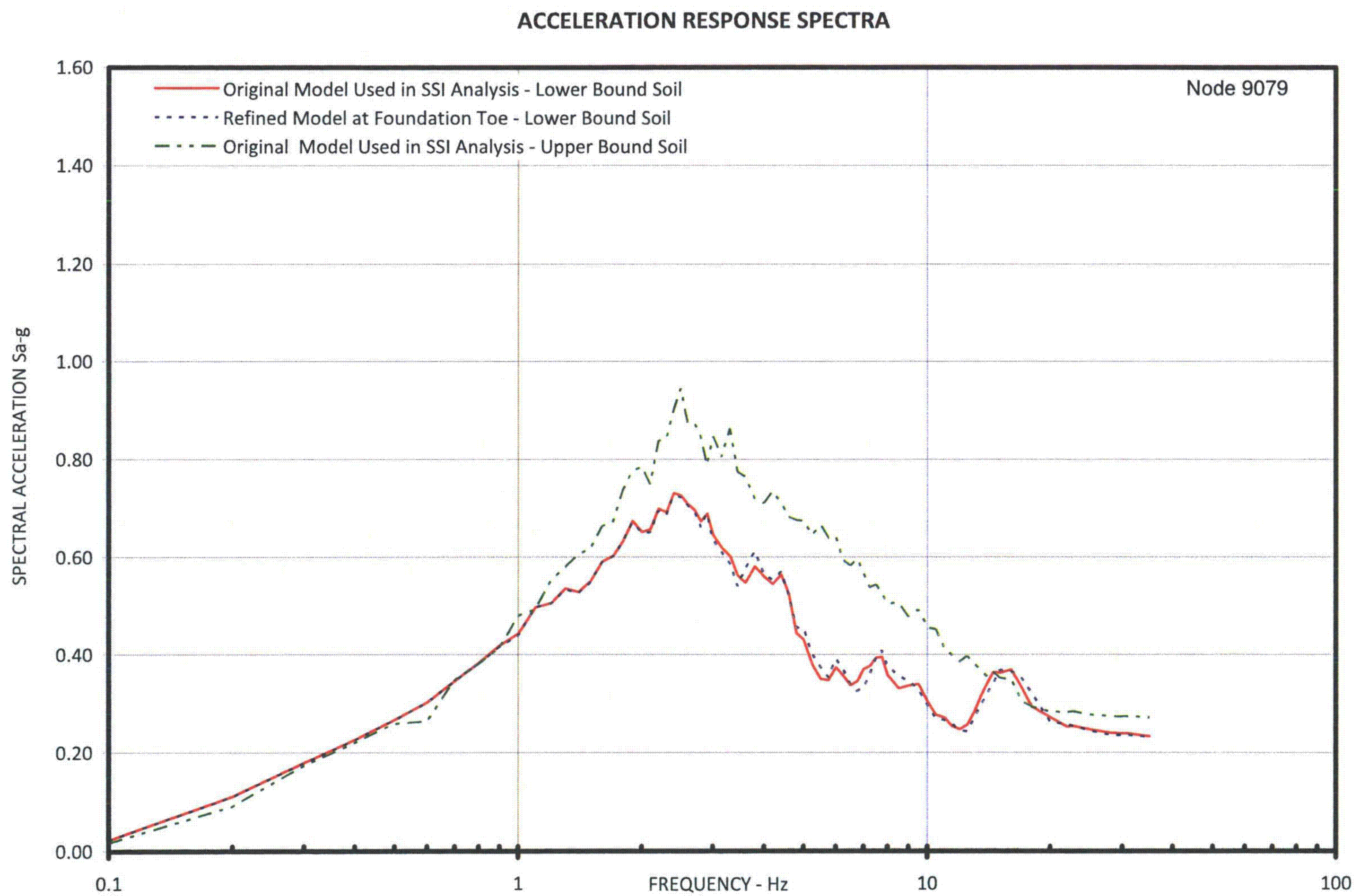

Figure 03.07.01-27.7 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Center), El. 50.0 ft

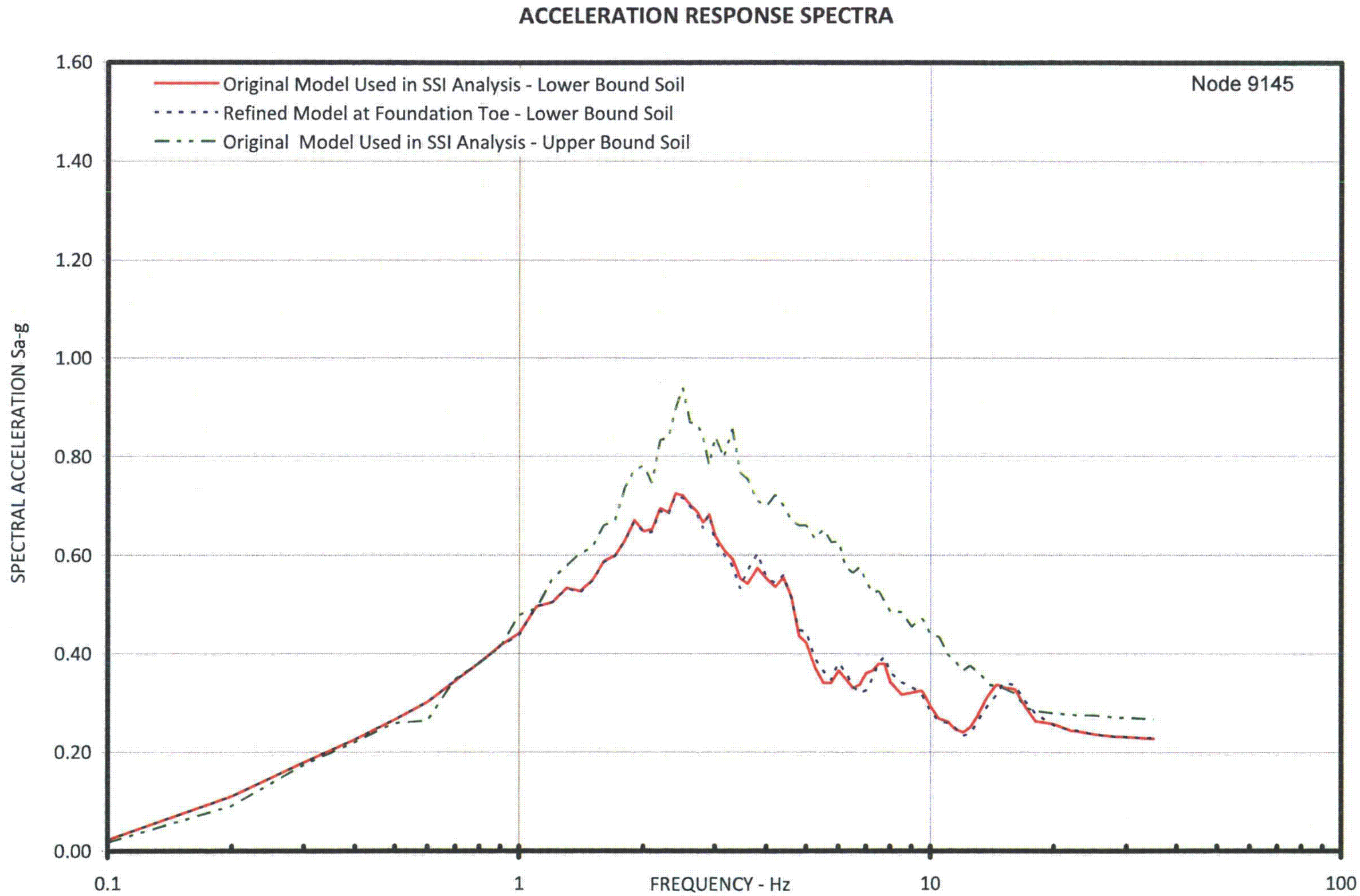

Figure 03.07.01-27.8 - 5% Damped Spectral Comparison in X Direction at Top of Roof Slab (Building corner), El. 50.0 ft

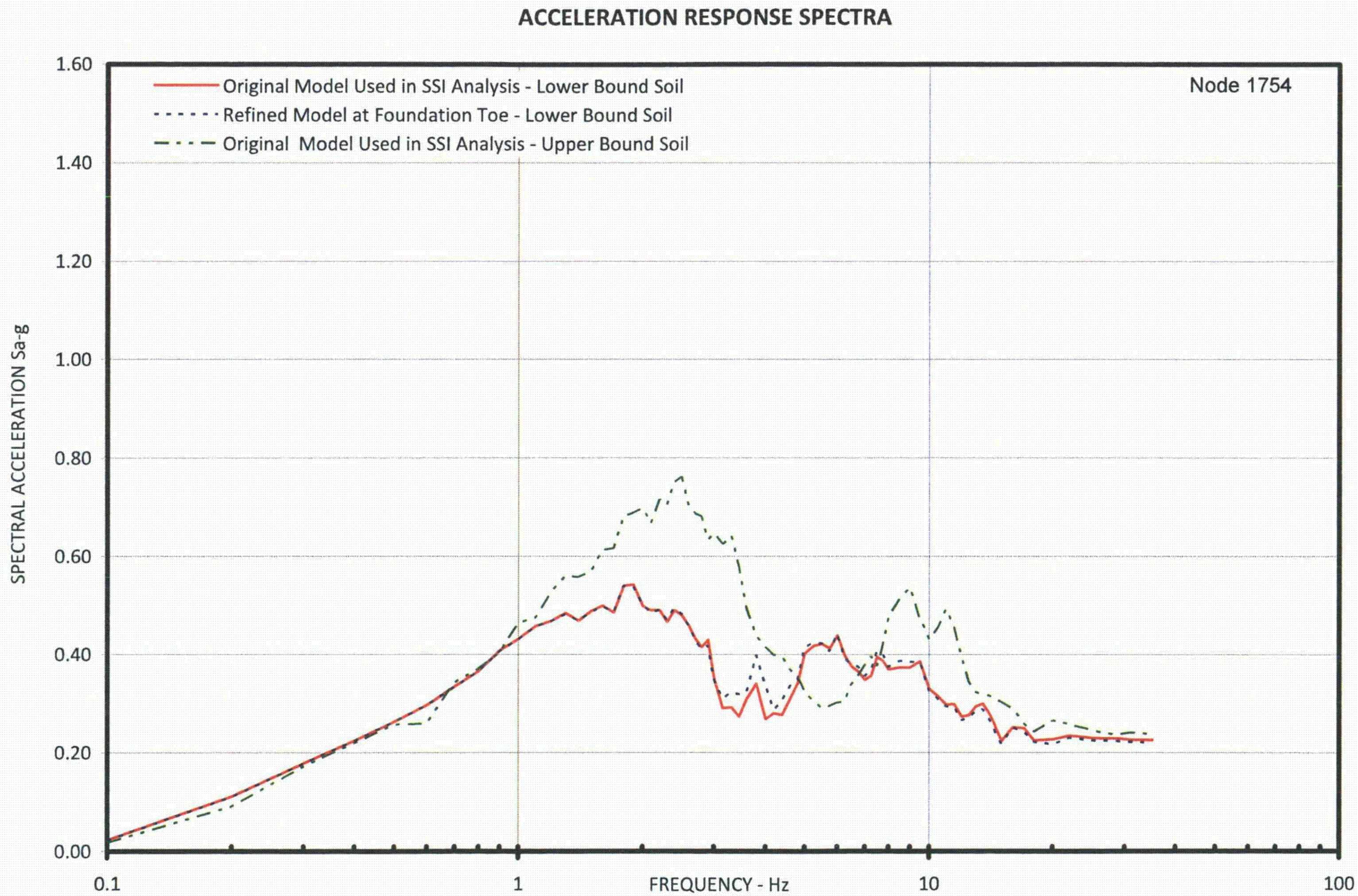

Figure 03.07.01-27.9 - 5% Damped Spectral Comparison in Y Direction at Top of Foundation (Center), El. -3.0 ft

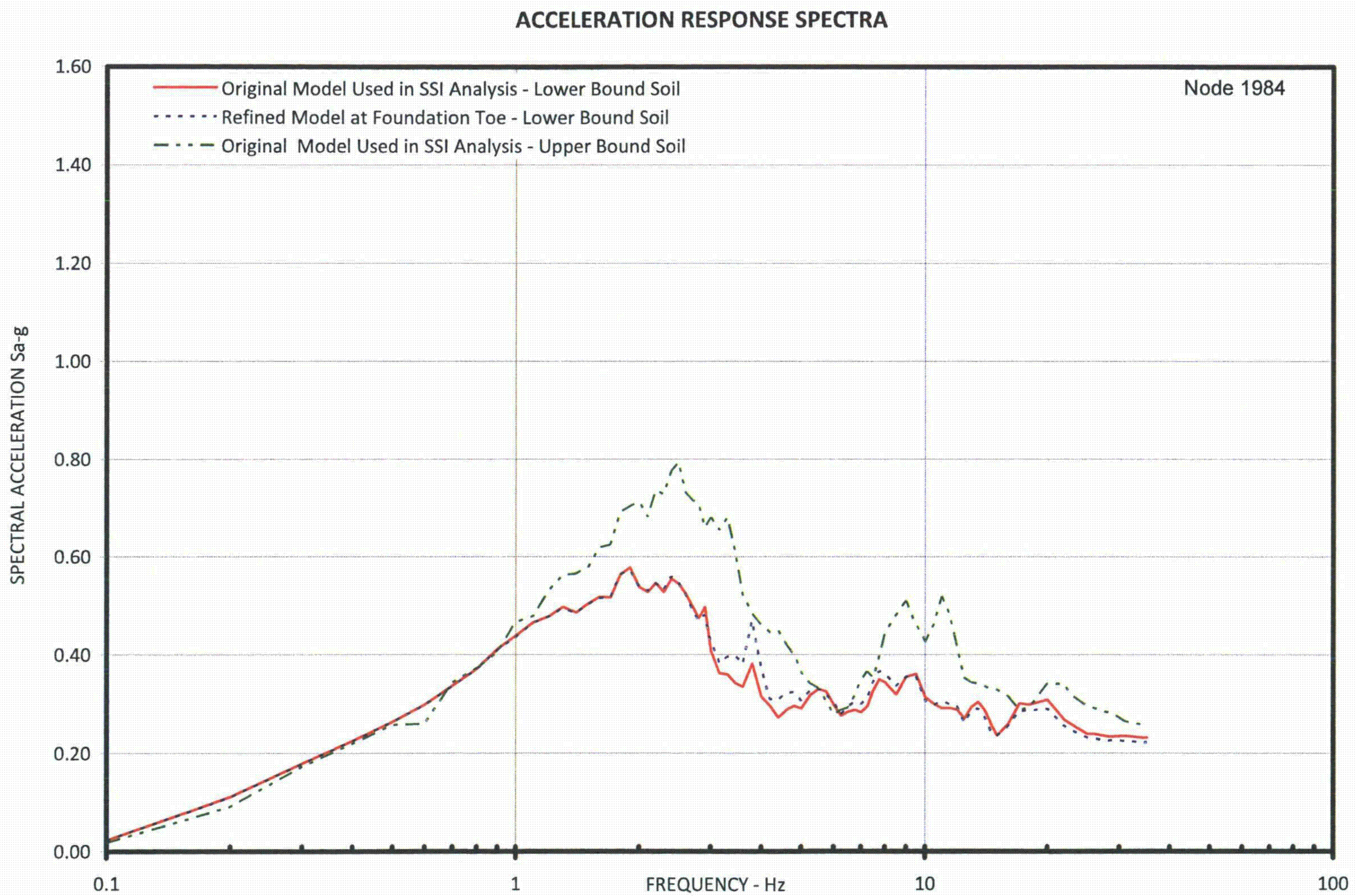

Figure 03.07.01-27.10 - 5% Damped Spectral Comparison in Y Direction at C.G. of Oil Tank

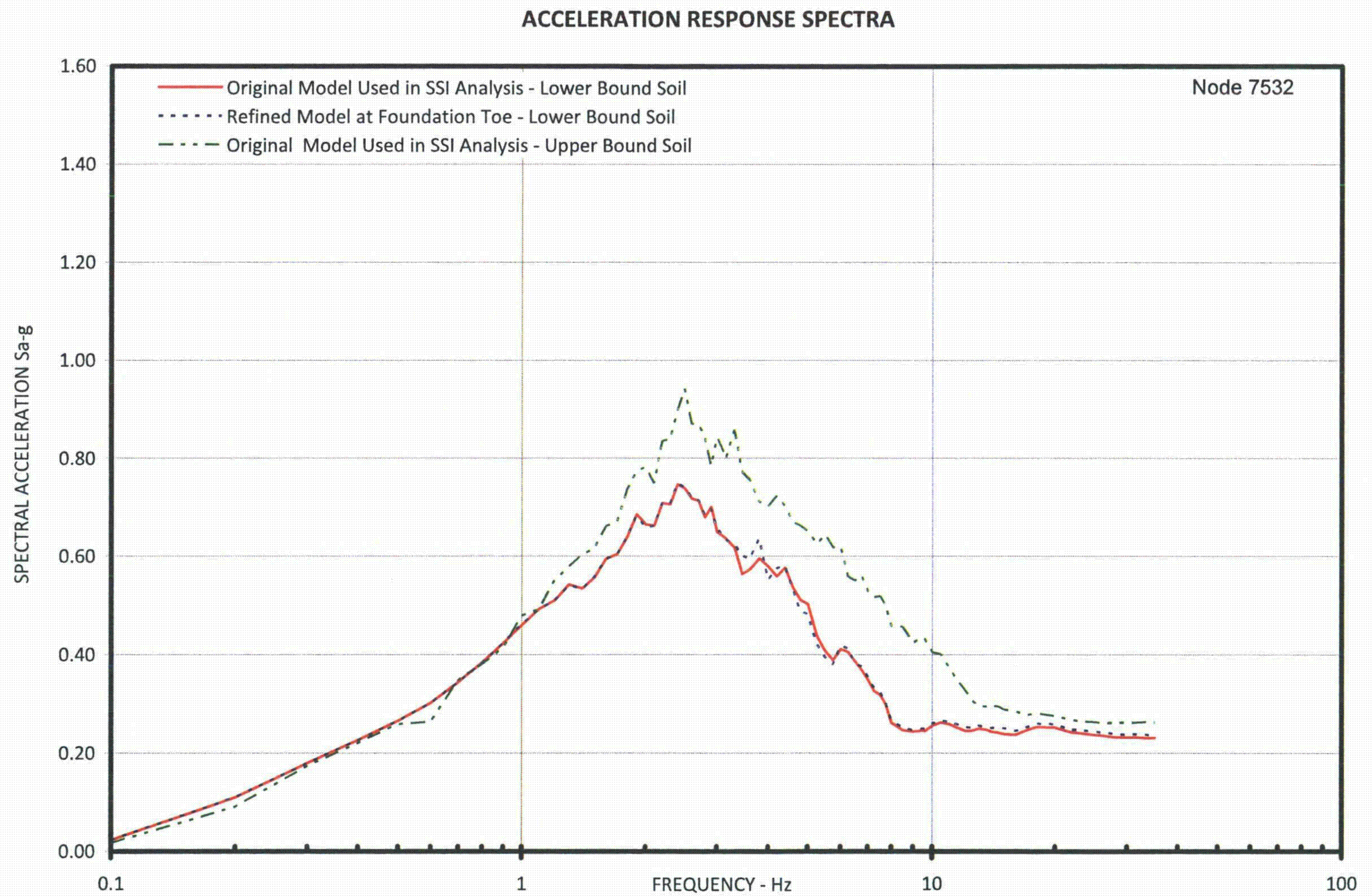

Figure 03.07.01-27.11 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Corner away from access room), El. 30.0 ft

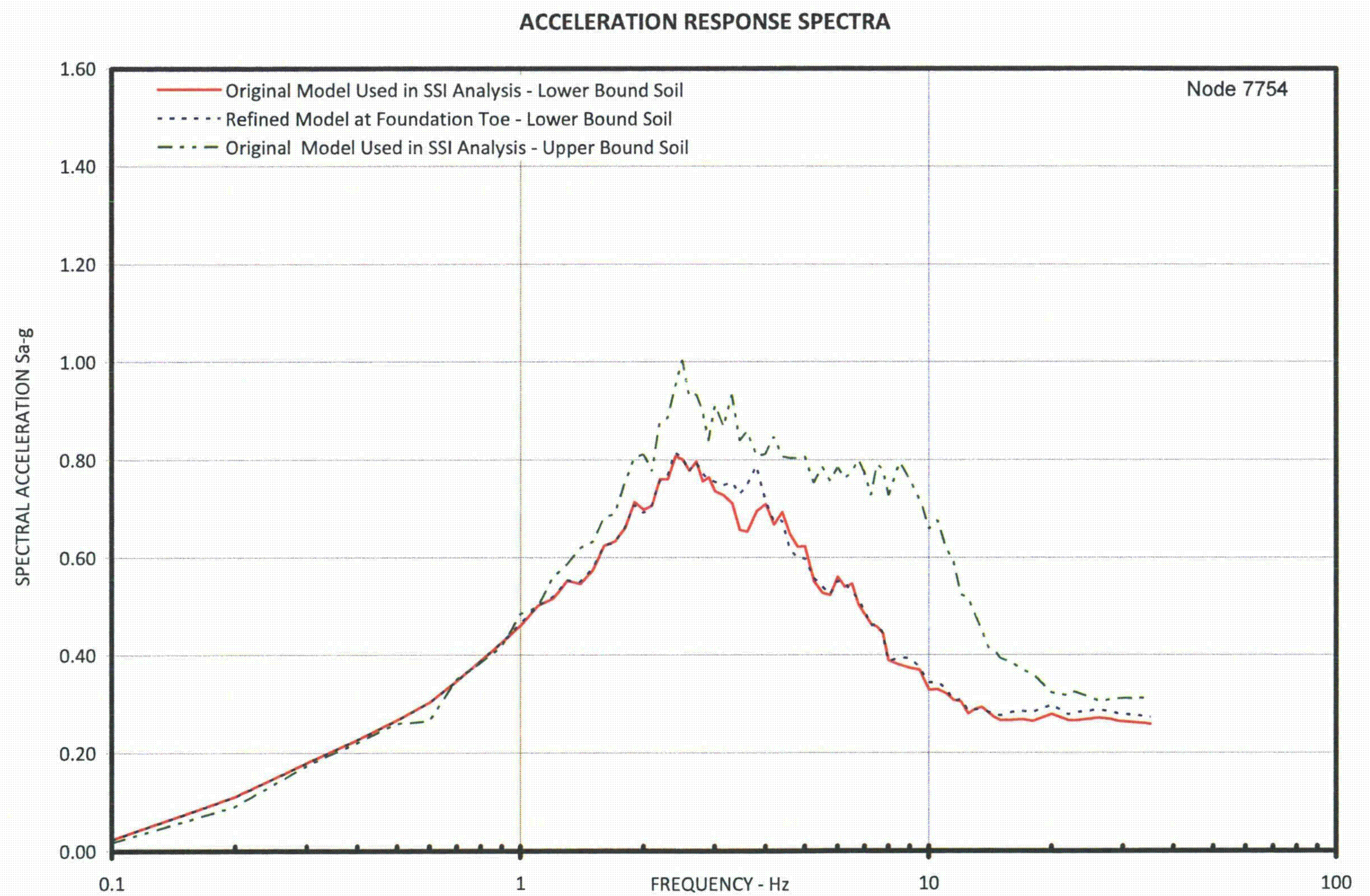

Figure 03.07.01-27.12 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Center), El. 30.0 ft

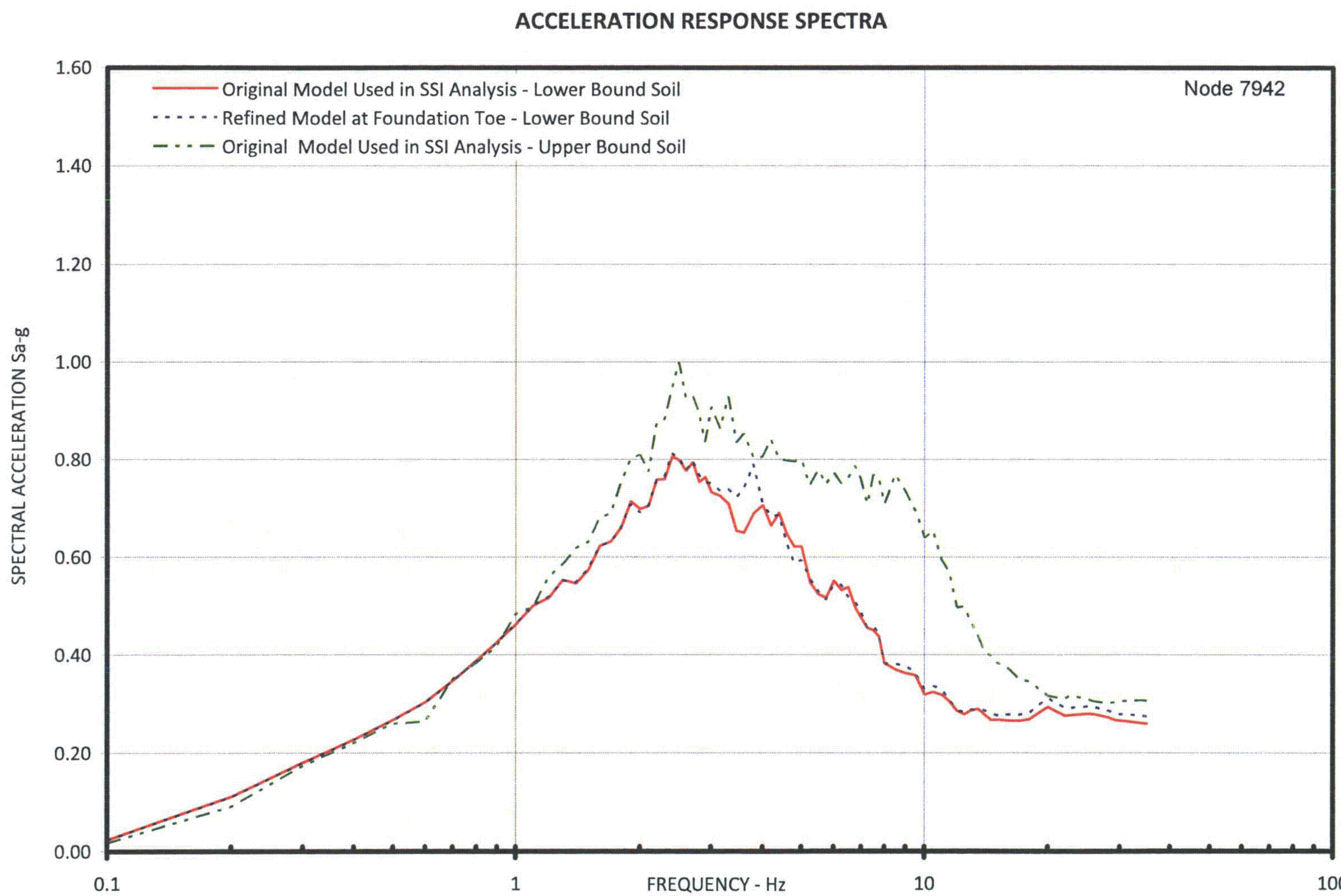

Figure 03.07.01-27.13 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Corner near access room), El. 30.0 ft

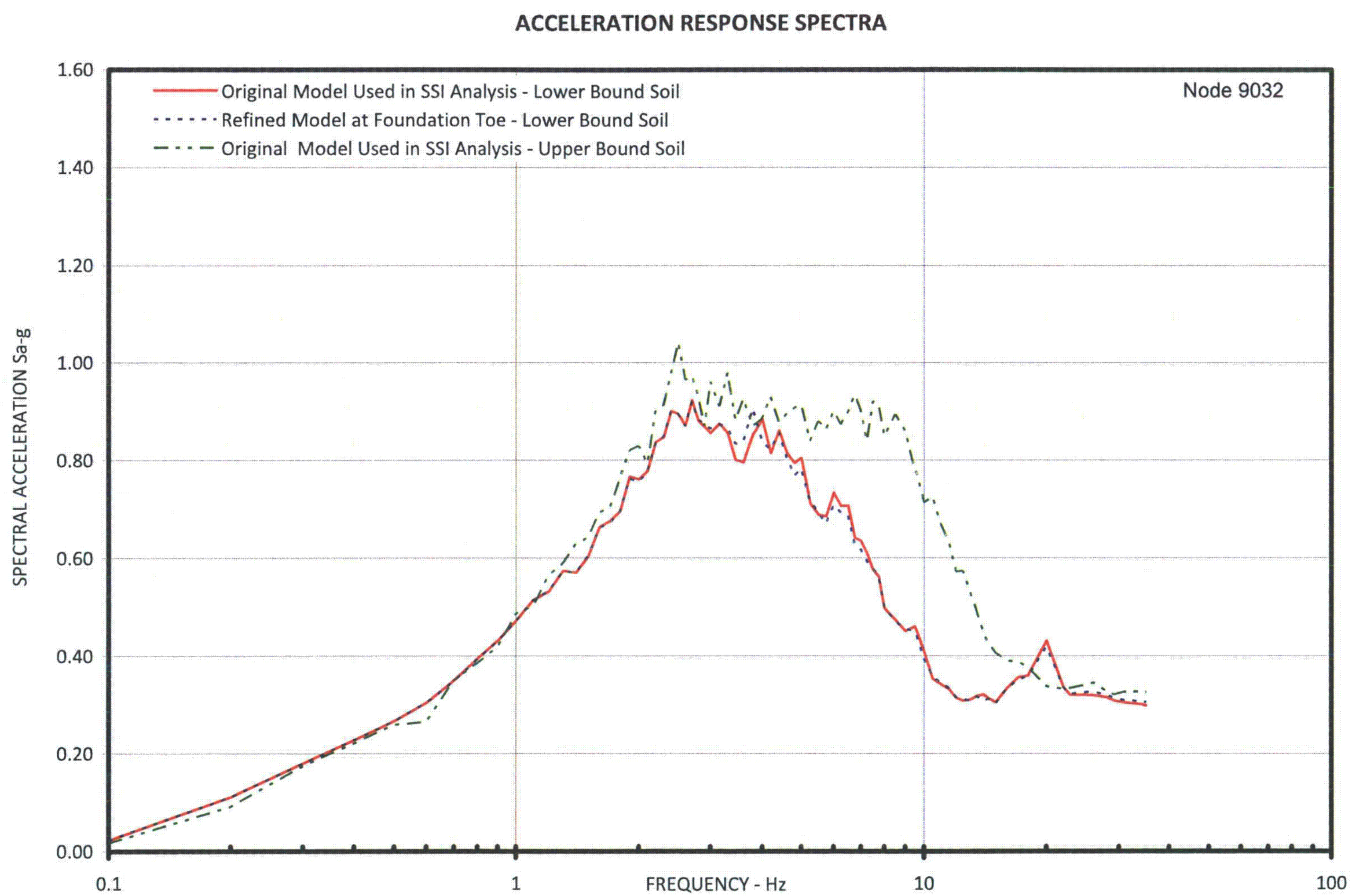

Figure 03.07.01-27.14 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Corner), El. 50.0 ft

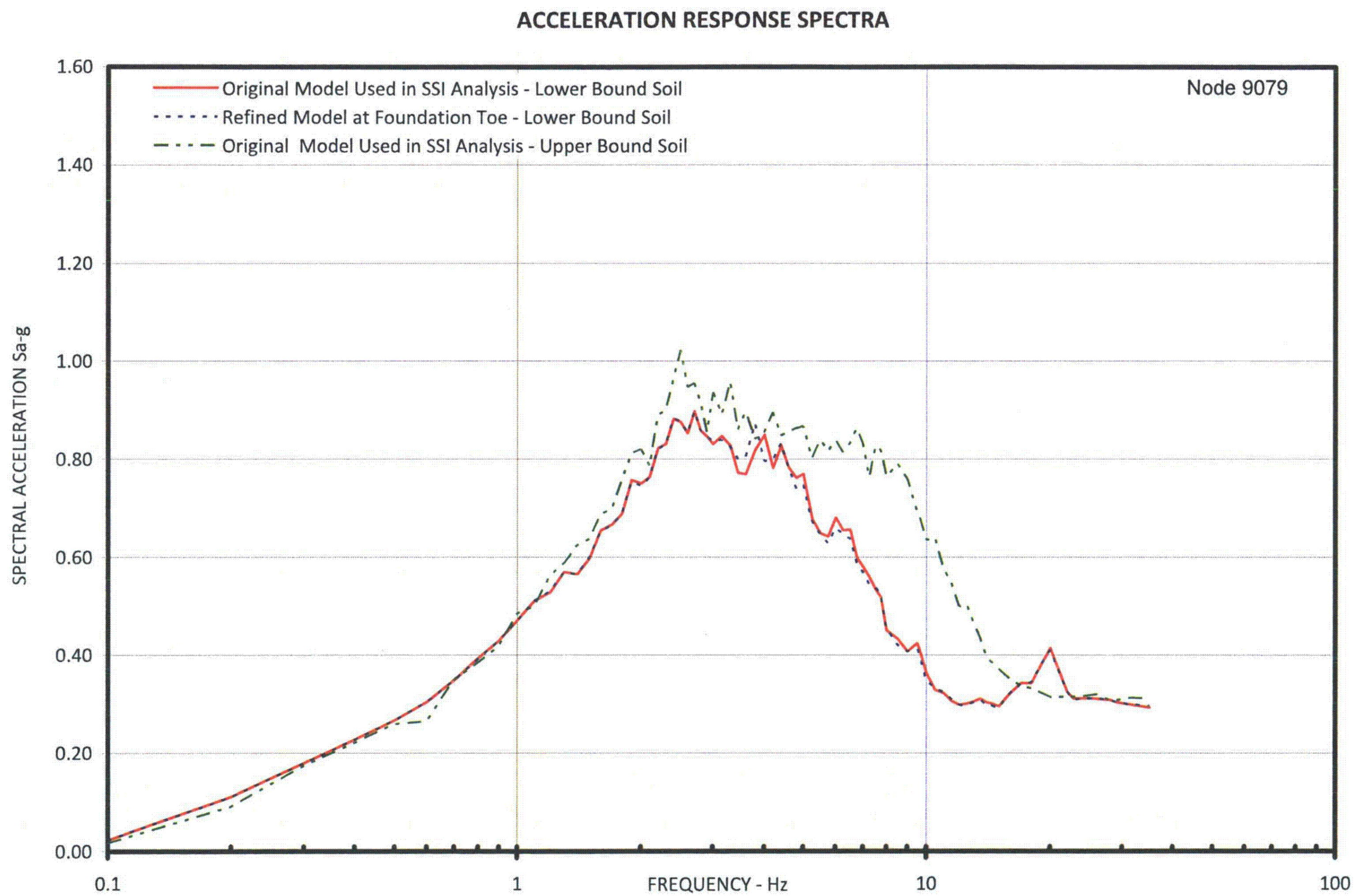

Figure 03.07.01-27.15 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Center), El. 50.0 ft

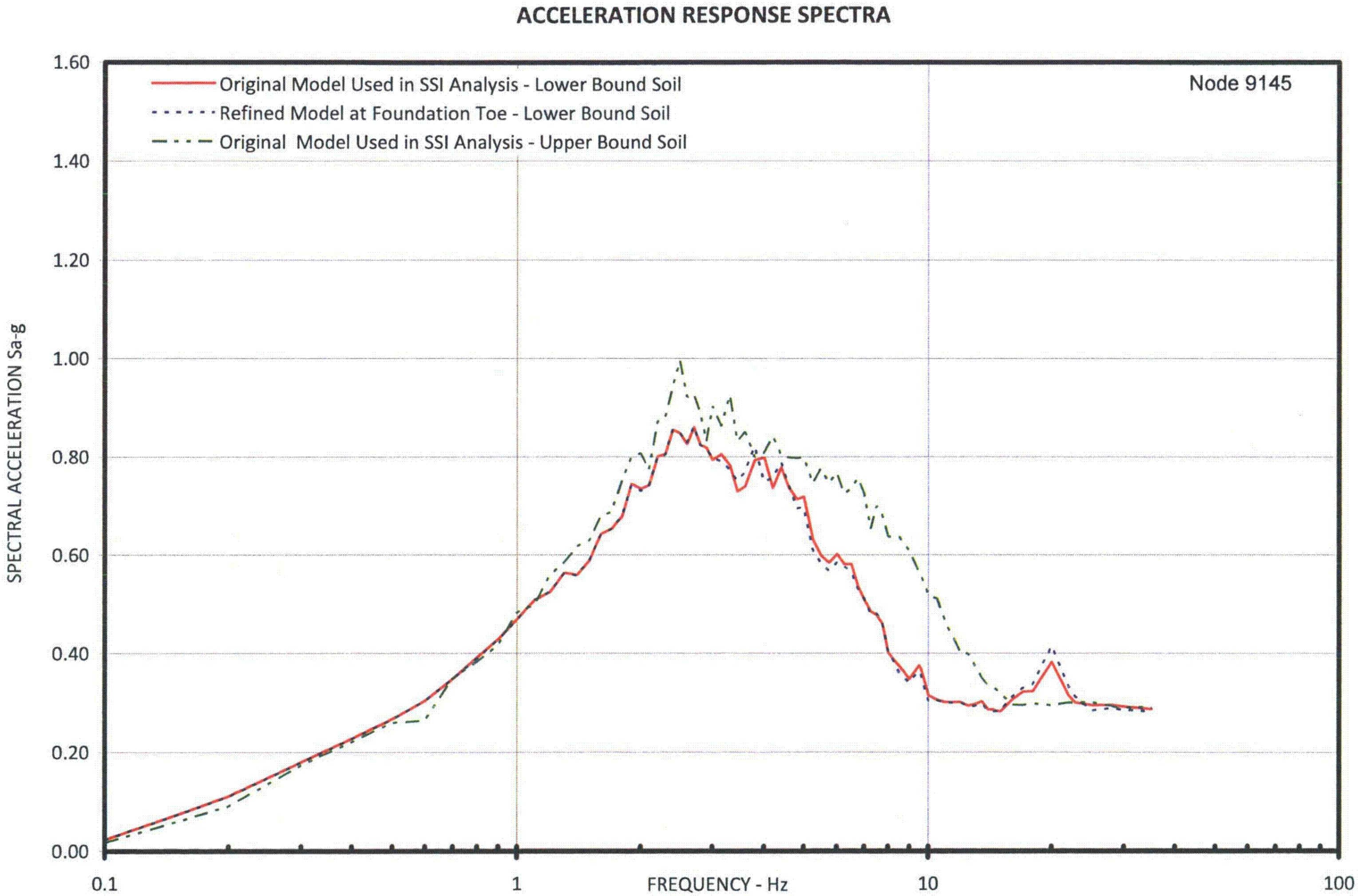

Figure 03.07.01-27.16 - 5% Damped Spectral Comparison in Y Direction at Top of Roof Slab (Building corner), El. 50.0 ft

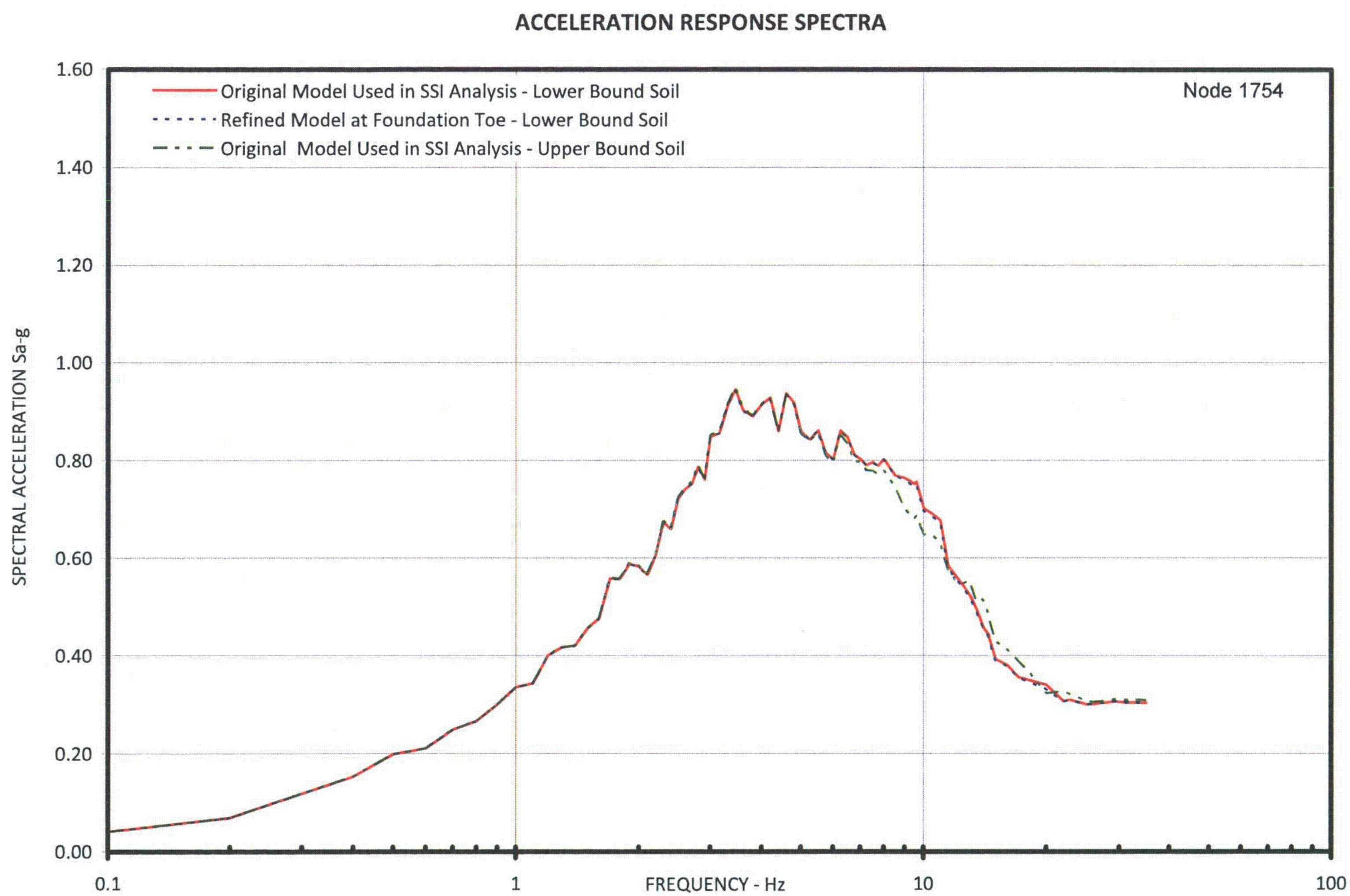

Figure 03.07.01-27.17 - 5% Damped Spectral Comparison in Vertical Direction at Top of Foundation (Center), El. -3.0 ft

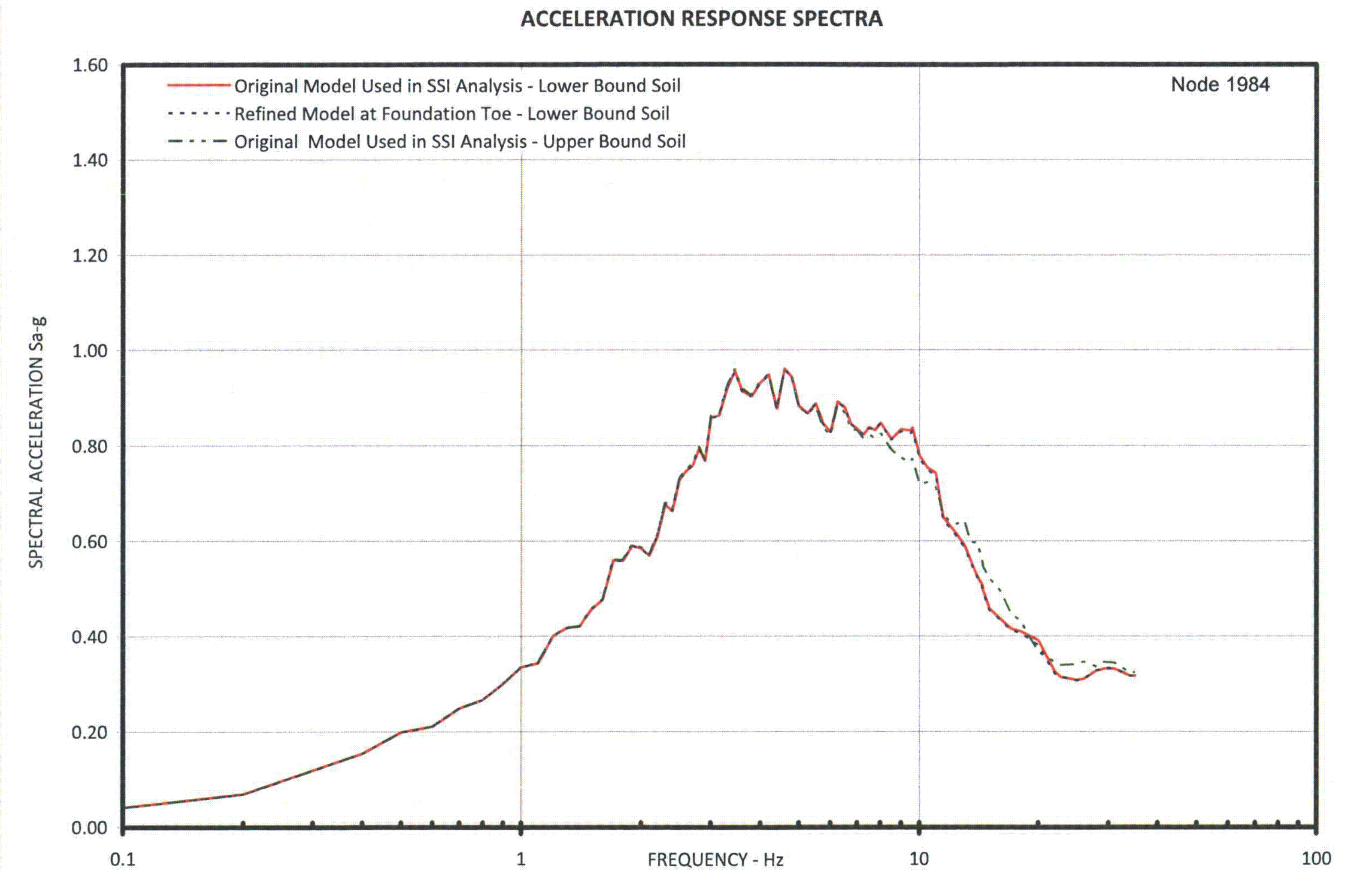

Figure 03.07.01-27.18 - 5% Damped Spectral Comparison in Vertical Direction at C.G. of Oil Tank

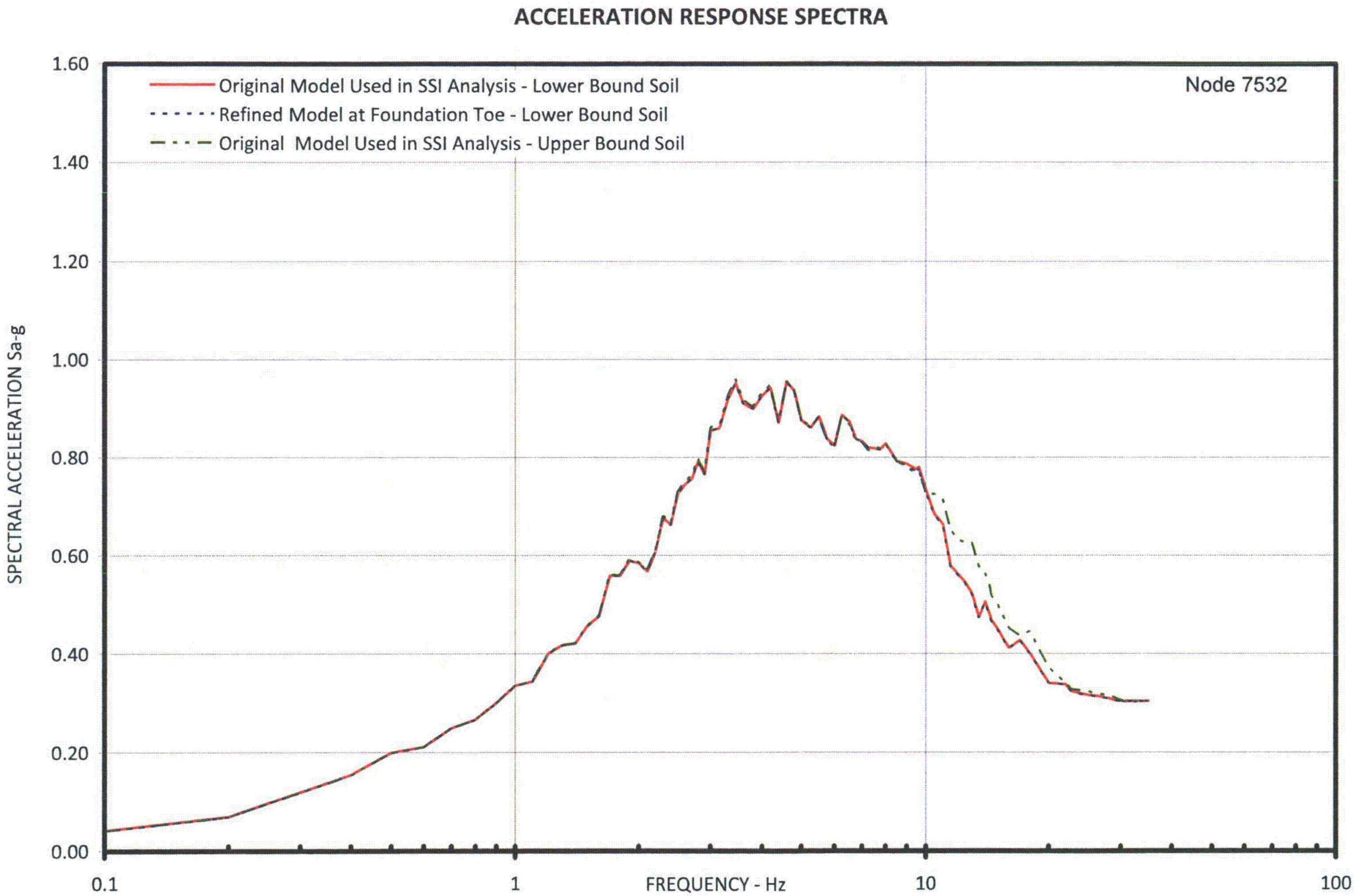

Figure 03.07.01-27.19 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Corner away from access room), El. 30.0 ft

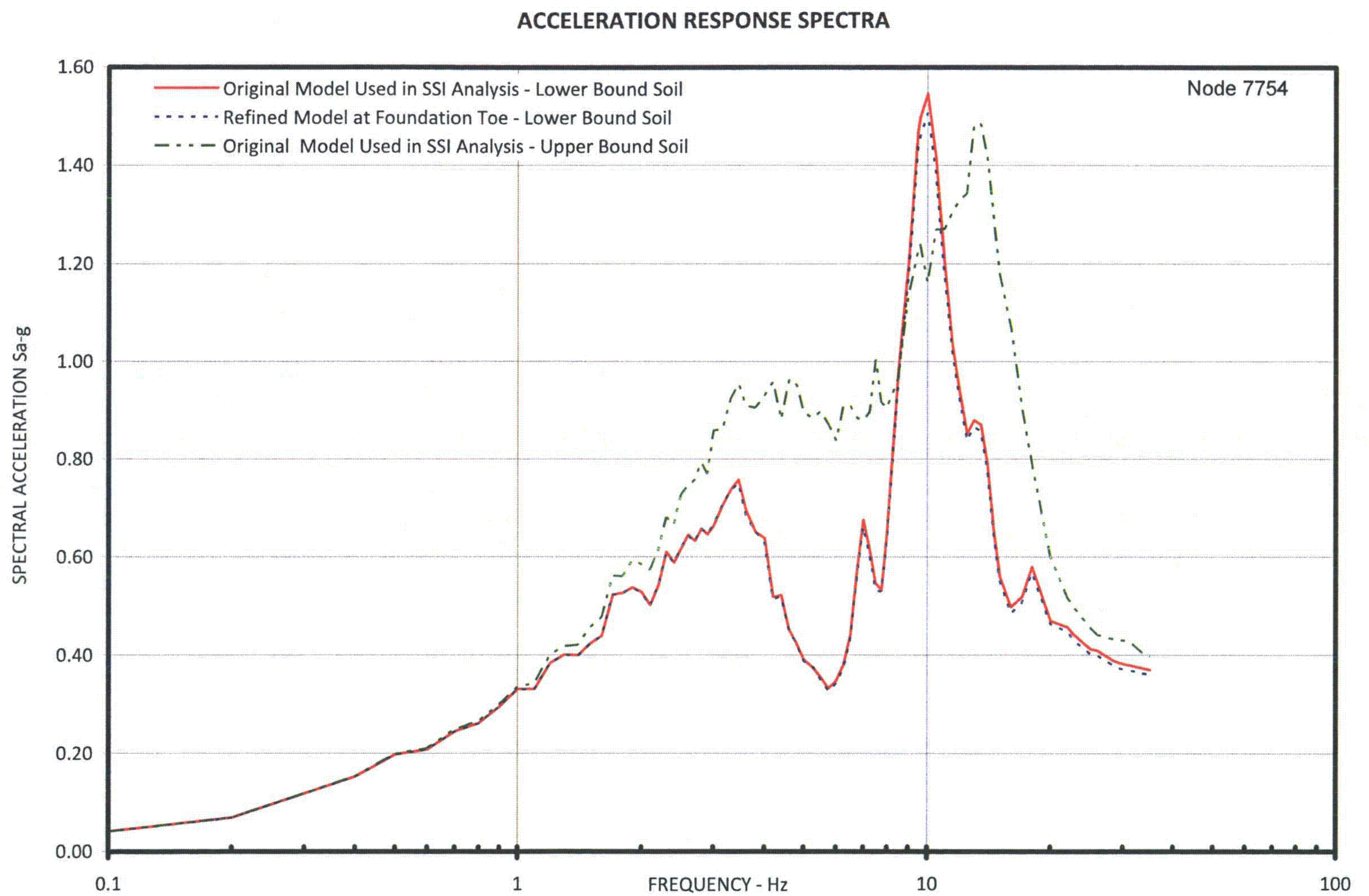

Figure 03.07.01-27.20 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Center), El. 30.0 ft

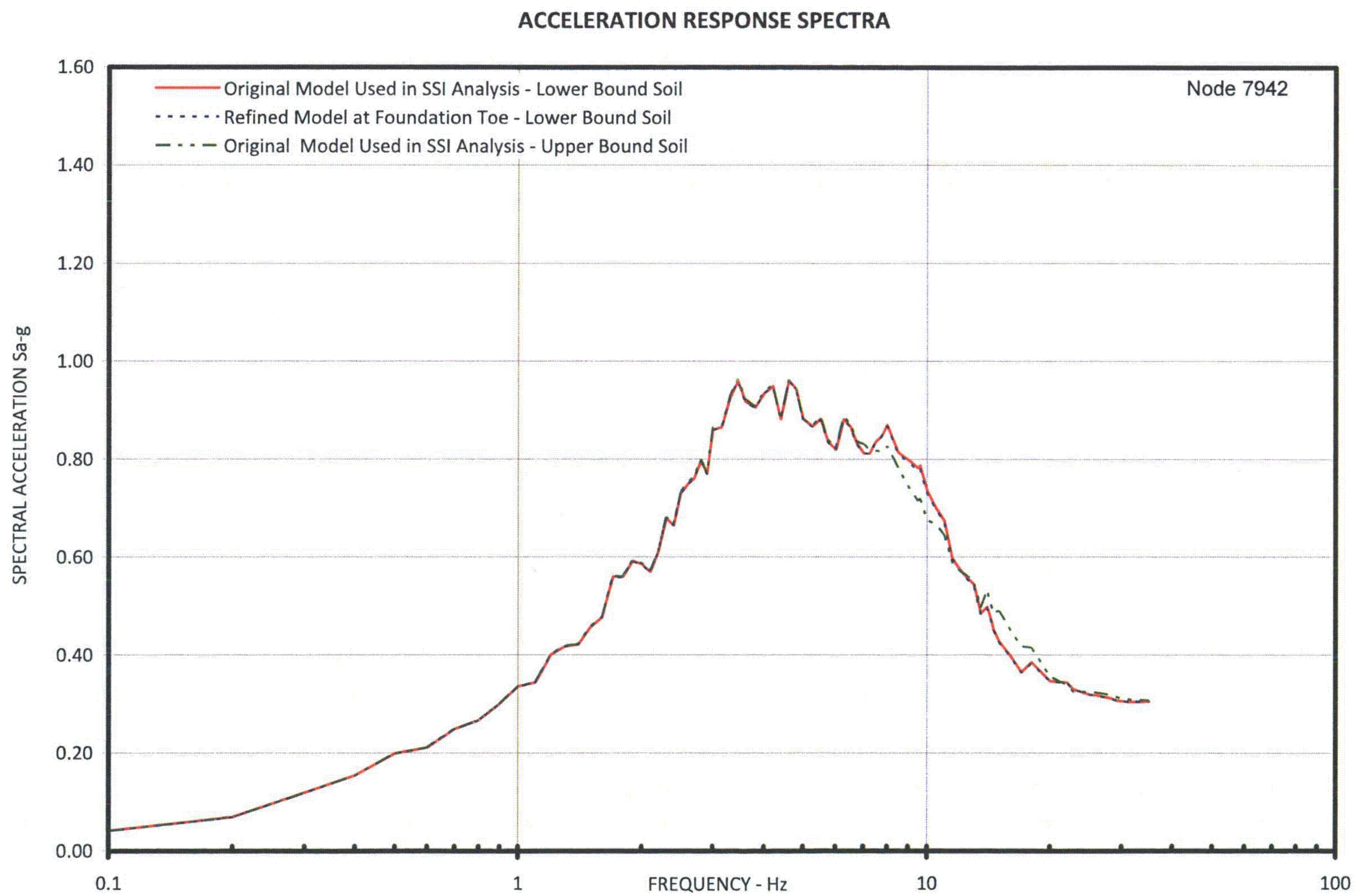

Figure 03.07.01-27.21 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Corner near access room), El. 30.0 ft

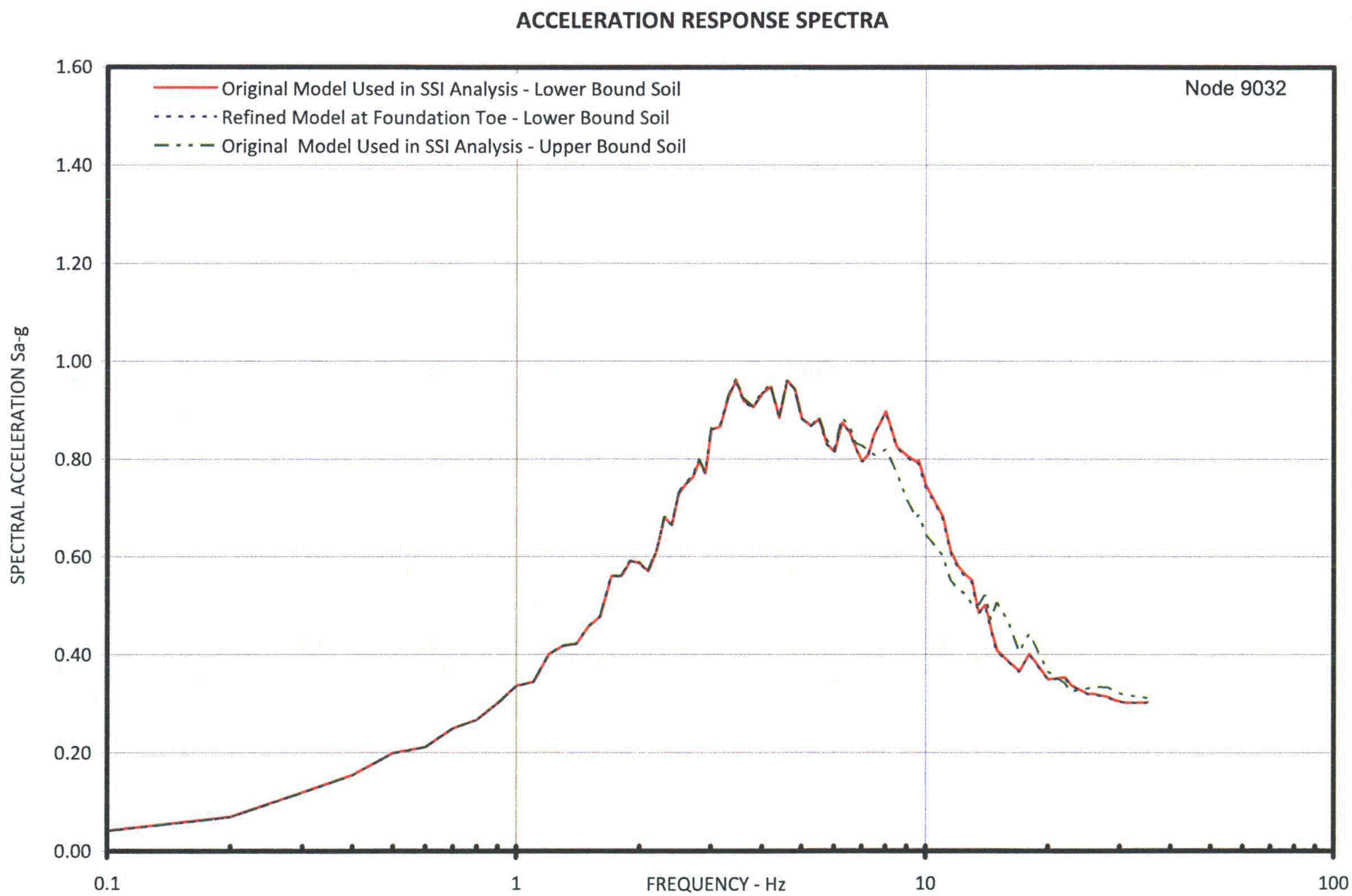

Figure 03.07.01-27.22 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Corner), El. 50.0 ft

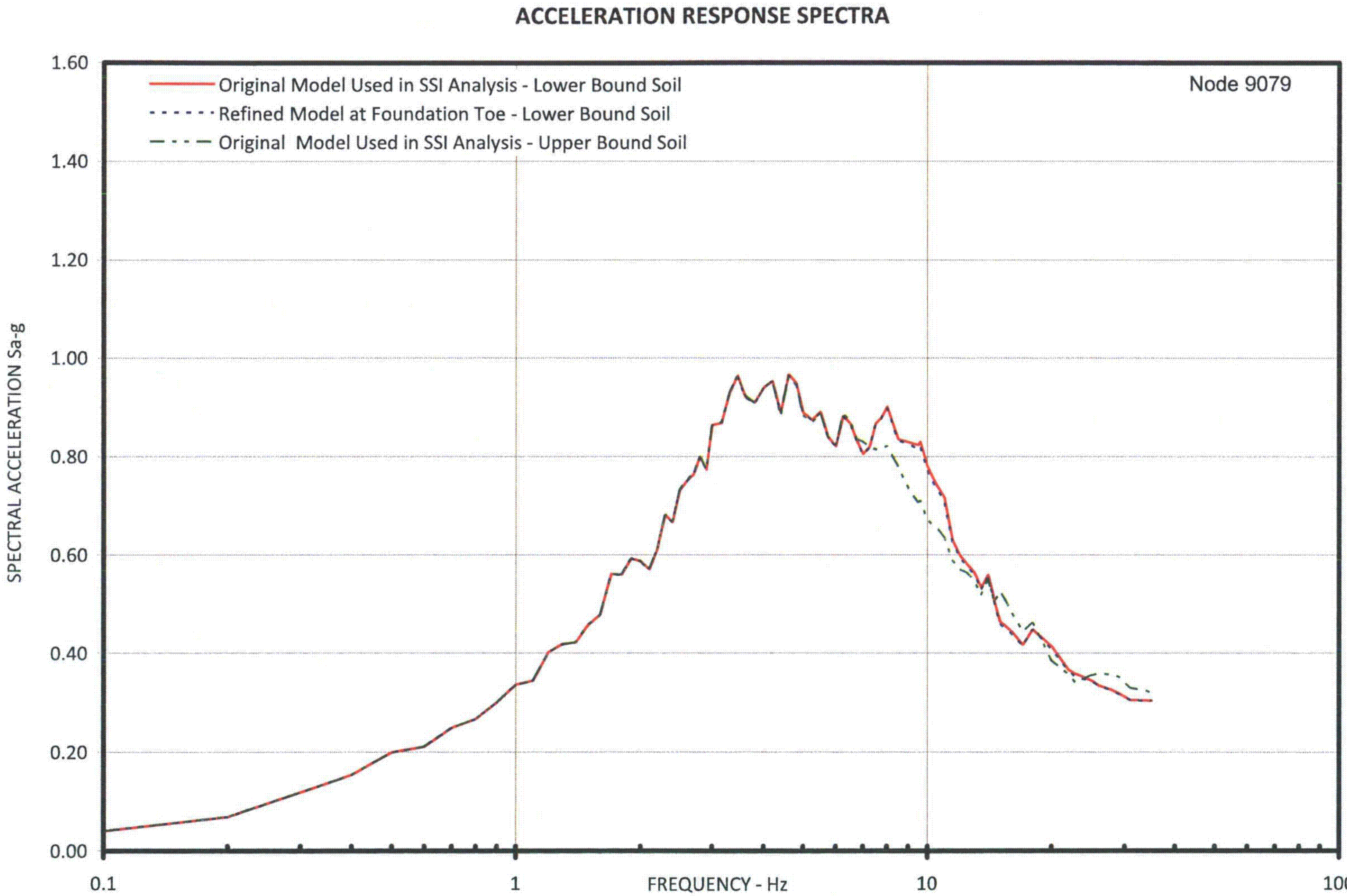

Figure 03.07.01-27.23 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Center), El. 50.0 ft

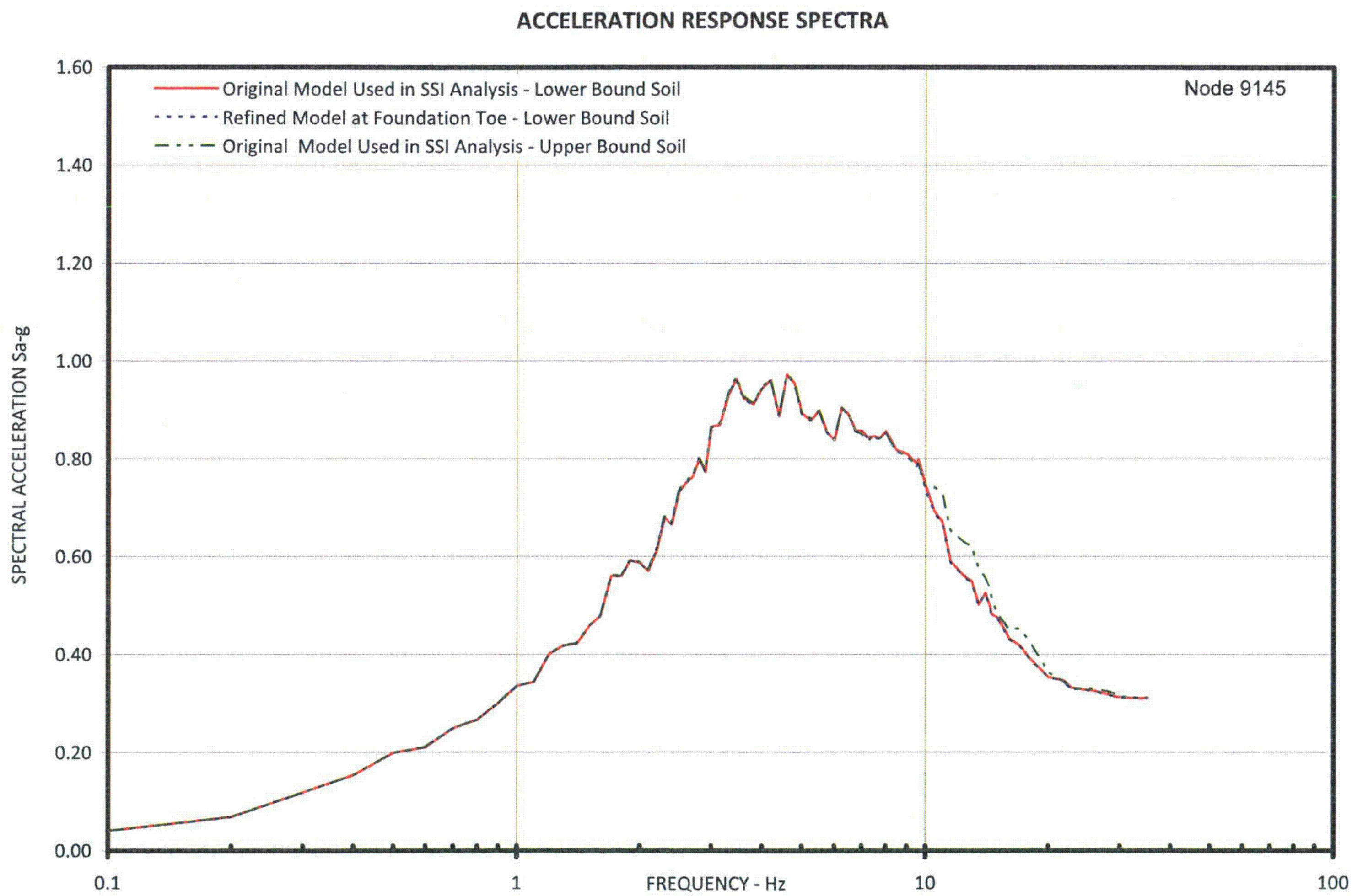

Figure 03.07.01-27.24 - 5% Damped Spectral Comparison in Vertical Direction at Top of Roof Slab (Building corner), El. 50.0 ft

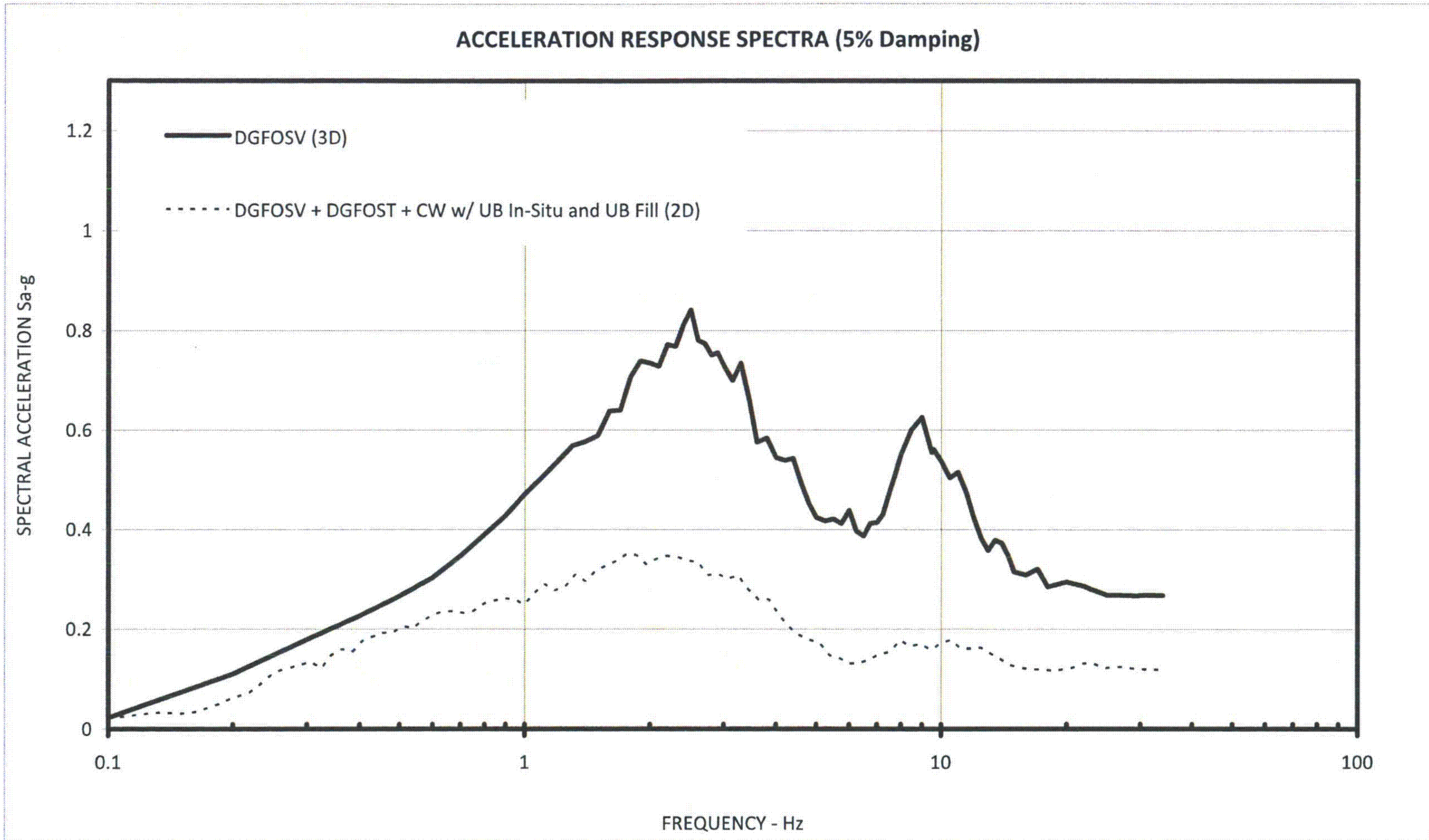

Figure 03.07.01-27.25: Comparison of Horizontal Response Spectra at DGFOSV 1A Basemat Top

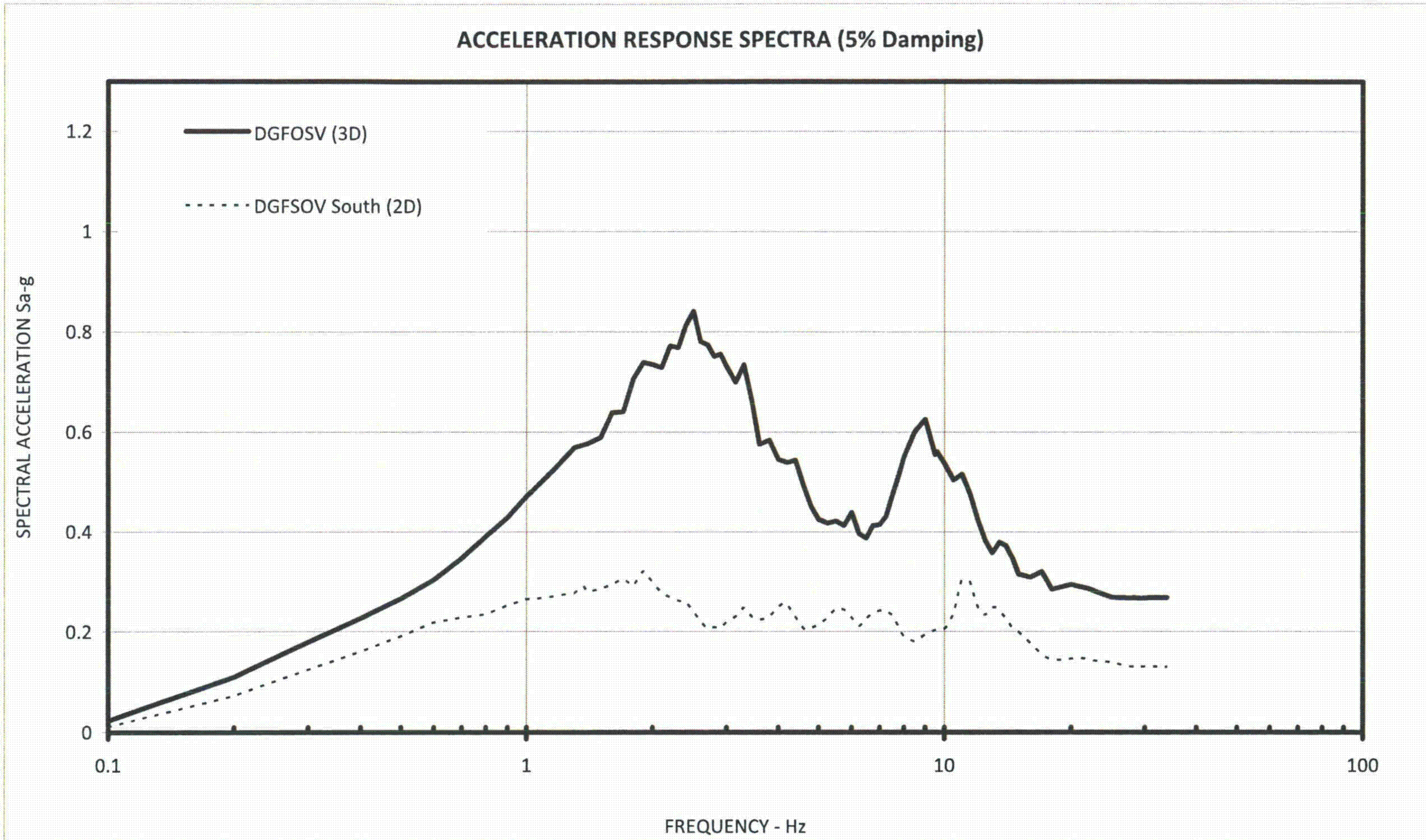

Figure 03.07.01-27.26: Comparison of Horizontal Response Spectra at DGFOSV 1C Basemat Top

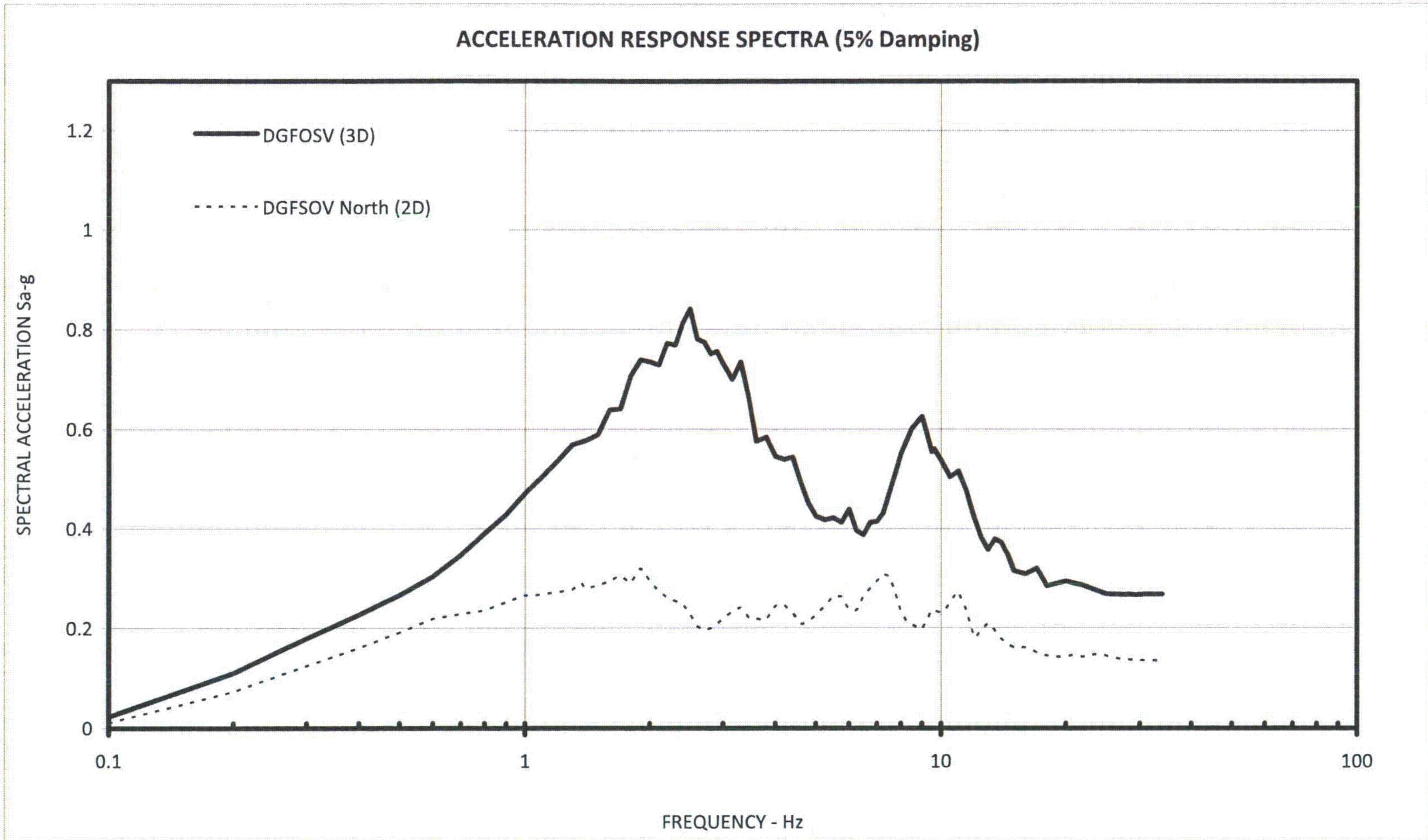

Figure 03.07.01-27.27: Comparison of Horizontal Response Spectra at DGFOSV 1B Basemat Top

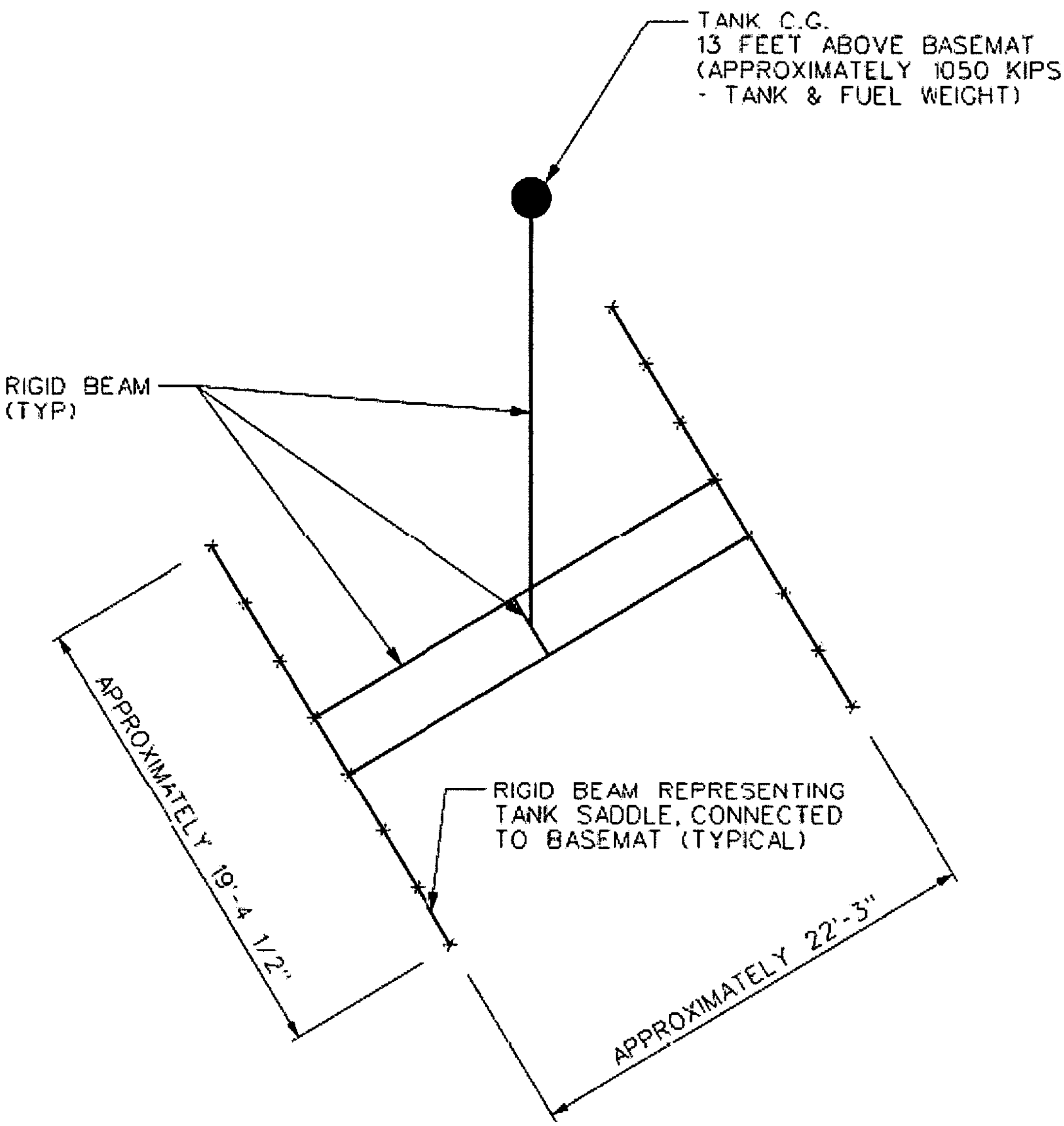

Figure 03.07.01-27.28: Diesel Generator Fuel Oil Tank Model

RAI 03.07.01-27
Enclosure 1

Revisions to COLA Section 3H.6

3H.6.7 Diesel Generator Fuel Oil Storage Vaults (DGFOSV)

The Diesel Generator Fuel Oil Storage Vaults (DGFOSV) are reinforced concrete structures, located below grade with an access room above grade. The DGFOSV house fuel oil tanks and transfer pumps. The DGFOSV are buried in the structural back-fill. The embedment depth to the bottom of the 2 ft thick mudmat is approximately 45 ft, the maximum height from the bottom of the mudmat is approximately 61 ft, and the basemat dimensions are approximately 81.5 ft by 48 ft. Properties of the backfill are described in Section 3H.6.5.2.4. ~~A 3-dimensional SAP2000 response spectrum analysis was used to obtain the SSE design forces due to structure inertia. The seismic induced dynamic soil pressures on DGFOSV walls and roof were computed using the method of ASCE 4-98, Subsection 3.5.3.2.~~

Two DGFOSV are located about ~~50~~53feet away from the south face of the Reactor Building (RB), which is a heavy multistory structure. The third DGFOSV is located approximately ~~38~~40 feet away from the north face of the Reactor Service Water (RSW) Pump House. Figure 3H.6-221 shows the DGFOSV locations relative to other structures. Considering the soil profile at the STP Units 3 & 4 site, the induced acceleration at the foundation level of the DGFOSV during a safe-shutdown earthquake (SSE) event may be amplified due to their close proximity to the RB (for the two) or the RSW Pump House (for the third). To establish the input motion for the soil-structure interaction (SSI) analysis of the DGFOSV, considering the impact of the nearby heavy RB (for the two) and RSW Pump House (for the third) structures, an analysis as described below was performed.

Five interaction nodes at the ground surface and five at the depth corresponding to the bottom elevation of the DGFOSV foundations are added to the three dimensional SSI SASSI2000 model of the RB for obtaining free field responses for the two DGFOSV close to the RB. These five nodes correspond to the four corners and the center of the DGFOSV. This RB SSI model is analyzed for the STP site-specific SSE. For each of these two DGFOSV, first an average of the spectra at five nodes at the surface and foundation each is calculated and then envelope of the two average spectra is calculated. A similar SSI analysis is performed for the third DGFOSV close to the RSW Pump House. Since the diesel oil tank is a standard plant equipment, the input motion for the SSI analysis should also consider the 0.3g Regulatory Guide 1.60 response spectra. ~~Finally~~Therefore, the envelope of the envelope average spectra for the three DGFOSV and the 0.3g Regulatory Guide 1.60 response spectr~~um~~a ~~is~~are used as the input response spectra for the SSI analysis of the DGFOSV. The 0.3g Regulatory Guide 1.60 response spectra were found to be the bounding spectra. The DGFOSV and the equipment and components inside the vault are designed using the results of the SSI analysis.

The comparison of response spectra (the minimum required 0.1g Regulatory Guide 1.60 spectra, the FIRS, and the deconvolved SHAKE outcrop spectra for the site-specific SSE specified at the ground surface) at the foundation level of the DGFOSV is presented in Figures 3H.6-11d through 3H.6-11L. As can be seen from these figures, the deconvolved SHAKE outcrop spectra envelop the minimum required spectra and FIRS for the three sets of soil properties.

The following two types of soil-structure interaction (SSI) analyses are performed for DGFOSV:

- 3D SSI analyses of DGFOSV alone for calculating in-structure response spectra and design accelerations/forces of the structure. These analyses were performed considering both full and empty fuel oil tanks.
- 2D structure-soil-structure interaction (SSSI) analysis of DGFOSV and adjacent structures to obtain seismic soil pressures.

3D SSI Analysis

The SSI analyses of the 3D model of DGFOSV are performed using SASSI2000 computer program (using subtraction method).

Structural Model:

The structural part of the model consists of shell elements to model the exterior walls, and the roof slabs and 3D solid elements to model the basemat and the mud mat. Structure self weight and other applicable weights of equipment, live load, piping, metal decking, missile barrier cover are included in the structural model. The fuel tank is modeled with the fuel and tank weight lumped at the center of gravity of the tank and the tank lumped weight rigidly connected to the base mat at tank saddle locations. The fuel tank procurement specification will require that the fuel tank with fuel in it should have predominant frequencies greater than 33 Hz in horizontal and vertical directions. The fuel tank portion of the model has been assigned a damping value of 0.5%. For the other parts of the structure two damping values are used; 7% damping and 4% damping. The results from the 7% structural damping are used for design of the DGFOSV. The results from the 4% damping are used for generation of in-structure response spectra. Both full and empty fuel oil tank conditions are considered in the analysis.
Figure 3H.6-222 shows the typical 3D structural model of the DGFOSV for various SSI analyses. The following provides the details of the SSI model and method of analysis.

Strain Dependent Soil Properties Used in SSI Analyses:

The strain dependent soil properties used in the model are in accordance with the properties provided in Table 3H.6-1 for the in-situ soil and Table 3H.6-2 for the backfill soil, with the exception that for soil layers below the ground water table, the Poisson's ratio is capped at 0.495 for determining the compression wave velocity. The thickness of soil layers are adjusted to provide a vertical direction passing frequency of at least 33 Hz (based on one fifth of shear wave length criterion).

Analysis Cases, Passing Frequency and Cutoff Frequency for the SSI Analyses:

- The following cases are analyzed for both 4% and 7% structural damping cases:

  For full fuel oil tank case:

  - Lower Bound (LB) in-situ soil
  - Mean in-situ Soil
  - Upper Bound (UB) in-situ soil

- LB backfill over LB in-situ soil
- Mean backfill over mean in-situ soil
- UB backfill over UB backfill
- UB in-situ soil with soil separation
- UB in-situ soil with cracked concrete

For Empty fuel oil tank case:

- UB in-situ soil with empty fuel tank

Note: For soil separation, cracked concrete and empty fuel oil tank cases, the UB in-situ soil is used because the UB in-situ soil case in general governed.

- A cut-off frequency of 35 Hz was used for all SSI analyses for transfer function calculation.
- Vertical direction passing frequencies (based on one fifth of shear wave length criterion and considering lower bound in-situ soil) are equal to or greater than 33 Hz.
- Horizontal direction passing frequencies are equal to or greater than 33 Hz, except at following locations:

  - For LB in-situ soil, the passing frequency for the top 4 ft soil layer is 30.3 Hz.
  - At the foundation toe, the passing frequencies for in-situ soil are 20 Hz for LB, 25.8 Hz for mean, 31.6 Hz for UB; and for backfill are 23.1 Hz for LB, 28.3 Hz for mean and 34.7 Hz for UB.

To evaluate the effect of 20 Hz passing frequency for LB in-situ case, the foundation toe was divided into two elements, thus increasing the passing frequency to 40 Hz. This refined model with LB in-situ soil properties was analyzed and 5% damped spectra from this model were compared with the spectra from the original model with passing frequency of 20 Hz. The comparison shows that:

- In the X direction, there is insignificant difference between the response spectra from the two models
- In the Y direction, the response spectra from the two models matched well except at frequency of about 3.8 Hz where the refined model produced higher spectra. However, spectra from both the models are enveloped by the spectra for UB in-situ soil case
- In the vertical direction, the spectra from the two models matched well (insignificant difference)

Based on the above evaluation it is concluded that the horizontal direction passing frequencies are acceptable.

<u>Input Motion:</u>

In the SSI analysis, acceleration time histories, consistent with 0.3g Regulatory Guide 1.60, are used as input at the grade elevation. The response spectra from these time histories envelop the amplified response spectra at the DGFOSV locations considering the effect of nearby heavy RB and UHS/RSW Pump House structures.

Response Combination, Enveloping and Spectra Peak Widening:

For all analysis cases, the responses due to two horizontal directions and vertical direction input motions are combined using square-root sum of squares (SRSS) method. Then, the responses from all analysis cases and all locations considered for spectra generation are enveloped to determine one set of un-widened horizontal and vertical response spectra. Finally, per Regulatory Guide 1.122, the enveloped un-widened response spectra are peak widened by plus-minus 15% on the frequency scale to obtain the final response spectra for DGFOSV. The resulting enveloping response spectra for DGFOSV are shown in Figures 3H.6-223 and 3H.6-224.

2D SSSI Analysis

Two 2D SSSI models are developed and analyzed to evaluate the effects of nearby structures on the three DGFOSV and to calculate the seismic soil pressures on the structures.

The first SSSI model is for a section cut in the North-South direction, consisting of UHS/RSW Pump house, RSW Piping Tunnel, DGFOSV 1B, DGFOSV 1C and RB. The details of this SSSI analysis are provided in Section 3H.6.5.3.

The second SSSI model is for a section cut in the East-West direction consisting of diesel generator fuel oil tunnel (DGFOT), DGFOSV 1A and the Crane Foundation Retaining Wall. The model for this SSSI analysis is shown in Figure 3H.6-225 and the details of the model are provided below.

Structural Models:

DGFOSV Model:

East-West direction of 2D DGFOSV model is idealized by a stick model of beam elements. Axial, flexural, and shear deformation effects are included in beam element stiffness. The fuel oil tank is also modeled using beam elements and its mass is lumped at its CG. The basemat and the mud mat are modeled using four node plain strain elements. The model properties (stiffness and mass) for the 2D plane analysis correspond to per unit depth (one foot dimension in the out-of-plane direction) of the DGFOSV.

DGFOT Model:

Four node plane strain elements are used to model the exterior walls, base slab, the top slab and the mud mat. Applicable weights are included at appropriate locations in the model. The structural model properties (stiffness and mass), for the 2D plane strain model correspond to per unit depth (one foot dimension in out-of-plane direction).

Crane Wall:

The Crane Wall is modeled using beam elements with nodes located 17 ft away from the

DGFOSV east wall (clear distance between the DGFOSV 1A exterior wall face and the west face of the Crane Wall). Beam section properties (stiffness and mass), for the 2D plane strain model correspond to per unit depth (one foot dimension in out-of-plane direction).

The SSSI analysis of the 2D model of DGFOSV with other structures, which affects the DGFOSV in the East-West direction is performed using SASSI2000 computer program using subtraction method. The following provides the details of this SSSI analysis.

Strain Dependent Soil Properties Used in SSSI Model:

The strain dependent soil properties used in the model are in accordance with the properties provided in Table 3H.6-1 for the in-situ soil, and Table 3H.6-2 for the backfill soil, with the exception that for soil layers below the ground water table, the Poisson's ratio is capped at 0.495 for determining the compression wave velocity. The thickness of soil layers are adjusted to provide a vertical direction passing frequency of at least 33 Hz (based on one fifth of shear wave length criterion).

To evaluate the effects of the soil variation, five soil cases are considered:

- UB in-situ soil with UB backfill between the structures.
- LB in-situ soil with LB backfill between the structures.
- Mean in-situ soil with Mean backfill between the structures.
- Mean in-situ soil with LB backfill between the structures.
- Mean in-situ soil with UB backfill between the structures.

Passing Frequency and Cut-off Frequency for SSSI Model:

- Cut-off frequency of 33 Hz is used in the analysis.
- Vertical direction passing frequencies are equal to or greater than 33.5 Hz.
- Horizontal direction passing frequencies are equal to or greater than 30.48 Hz.

Input Motion:

STP 3&4 site specific SSE motion, as described in Subsection 3H.6.5.1.1.2, is applied at the grade elevation, in the East-West direction.

The applicable codes, standards, and specifications from Section 3H.6.4 are used for analysis and design of the DGFOSV.

The DGFOSV are designed to the applicable loads and load combinations specified in Section 3H.6.4.

The incremental seismic soil pressures used in design are shown in Figures 3H.6-226 through 3H.6-231.

The settlement information on the DGFOSV is included in Section 2.5S.4.10.

The forces and moments at critical locations in the DGFOSV along with the provided longitudinal and transverse reinforcement are included in Table 3H.6-11 in conjunction with Figures 3H.6-140 through 3H.6-208.

The calculated factors of safety against sliding, overturning, and flotation for the DGFOSV are included in Table 3H.6-12.

The tornado missile impact evaluation results for the DGFOSV are included in Table 3H.6-13.

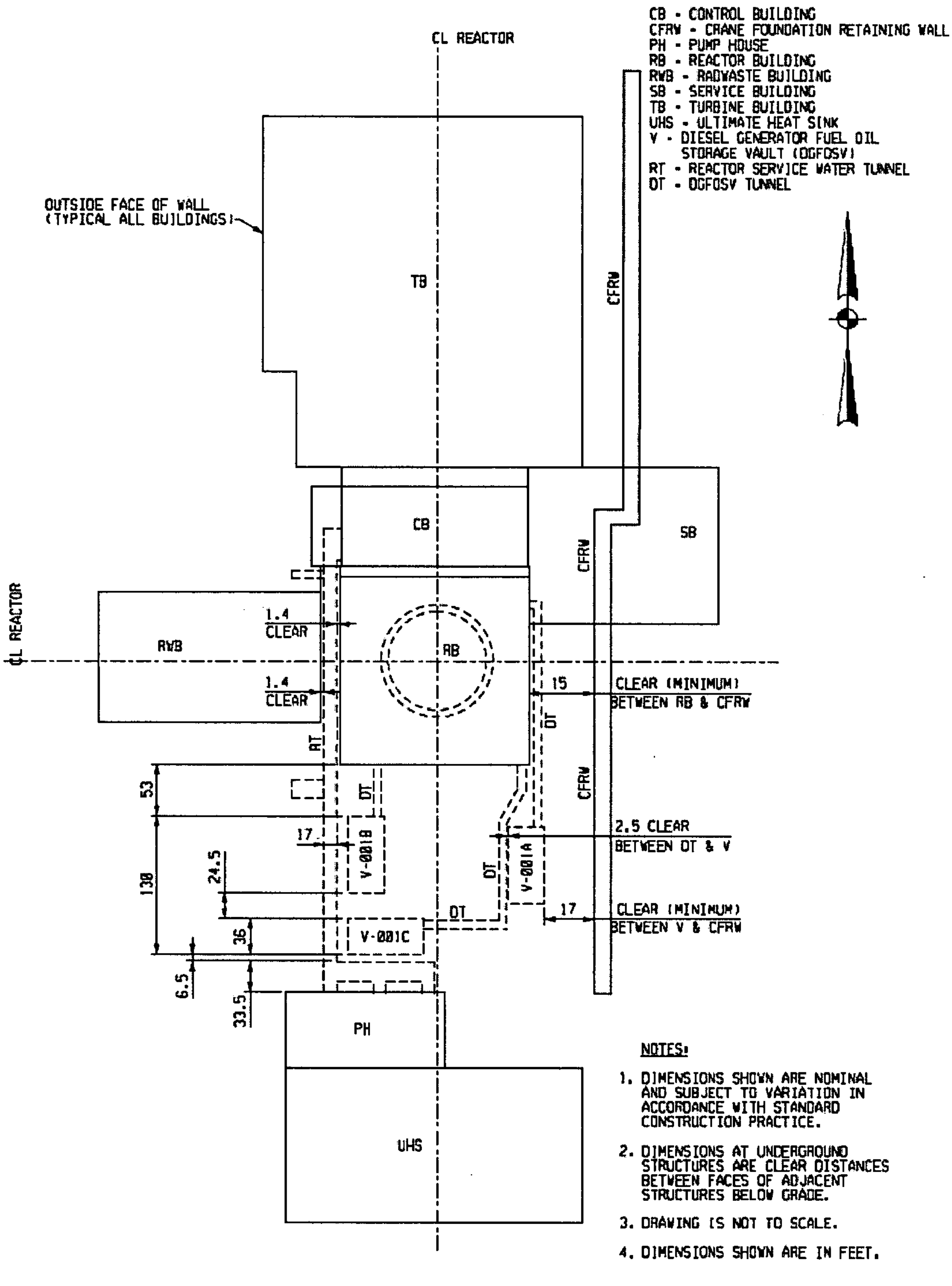

Figure 3H.6-221: Partial Site Plan

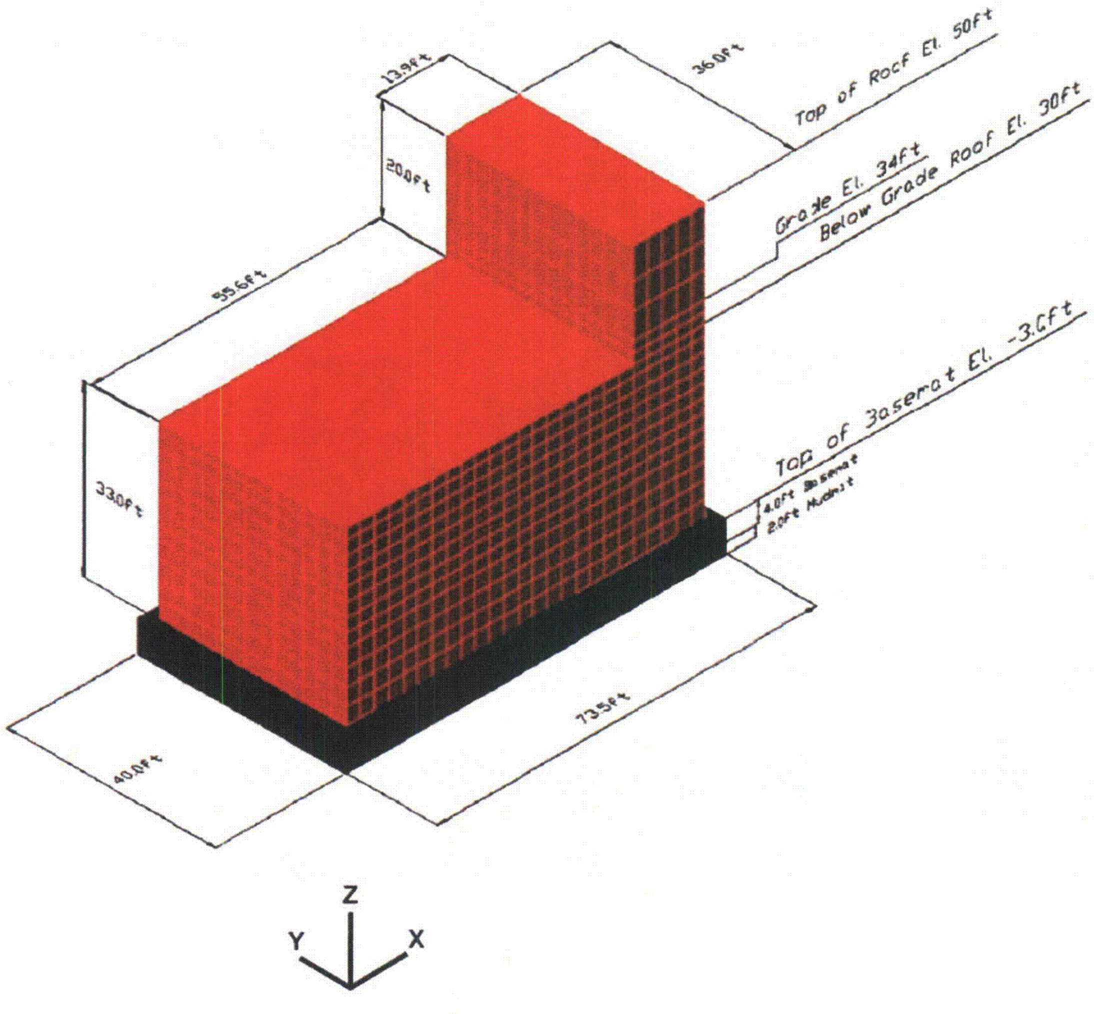

Figure 3H.6-222: 3D Model of DGFOSV for SSI Analysis

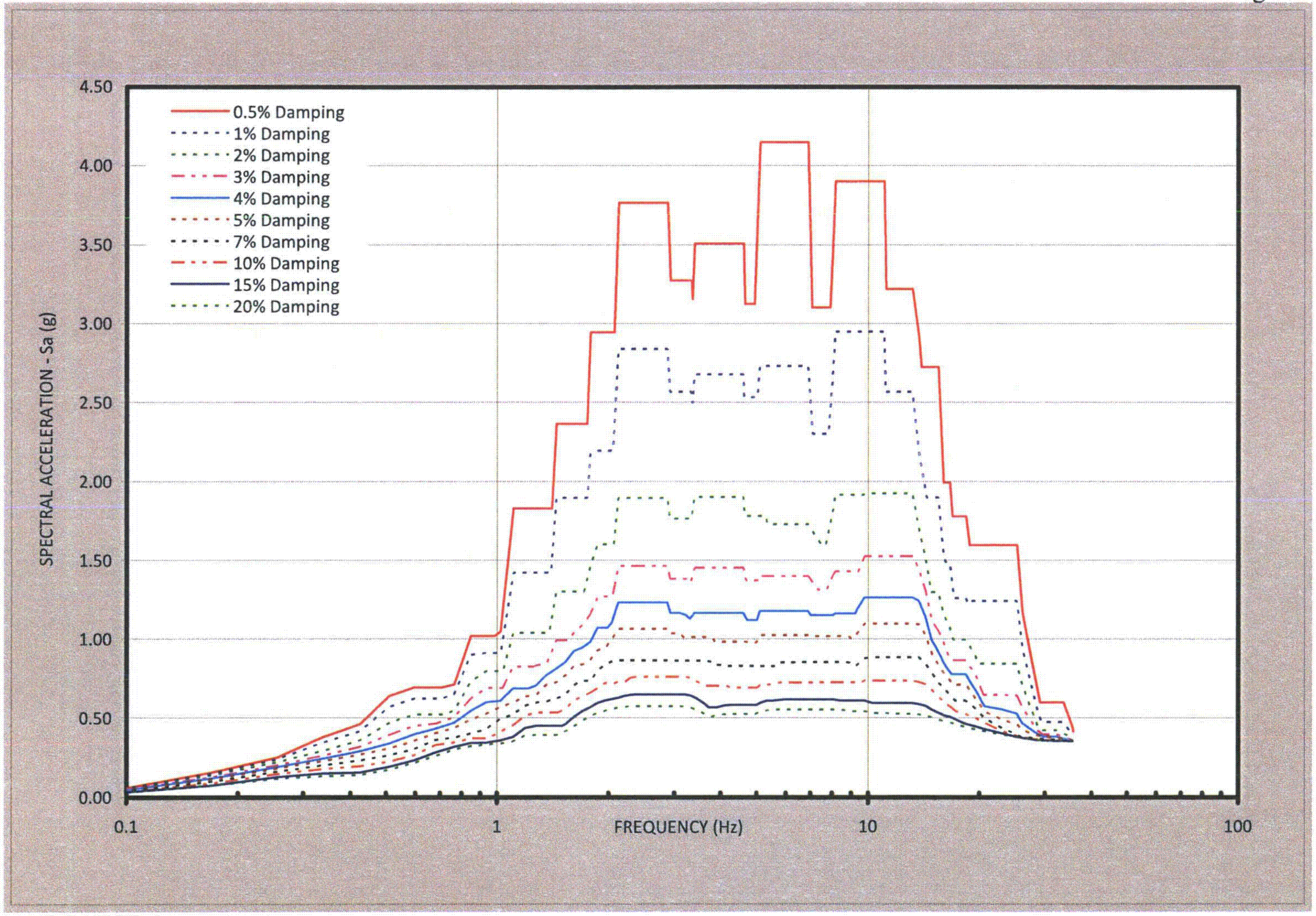

Figure 3H.6-223: Enveloped Broadened Horizontal Direction Response Spectra for DGFOSV

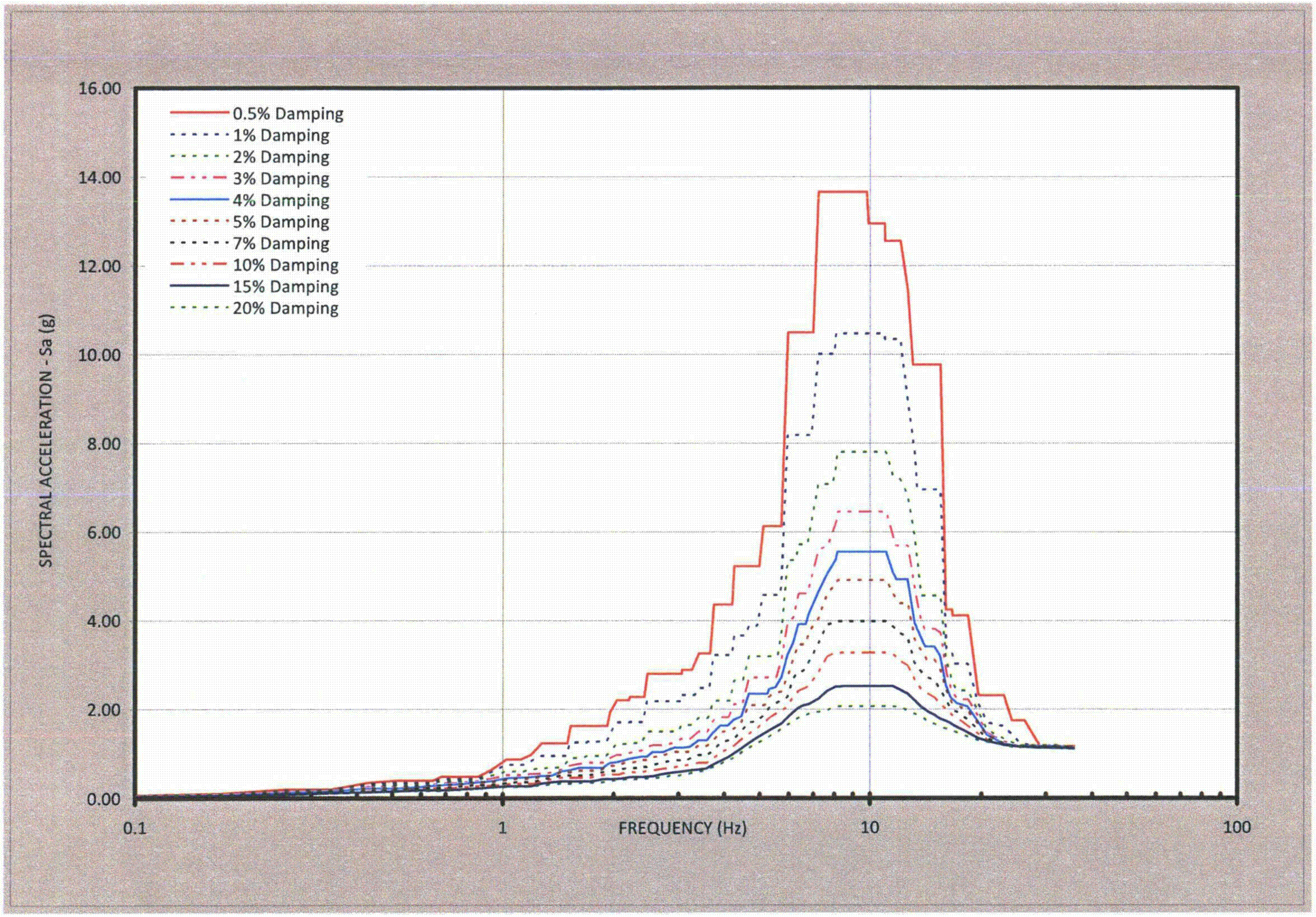

Figure 3H.6-224: Enveloped Broadened Vertical Direction Response Spectra for DGFOSV

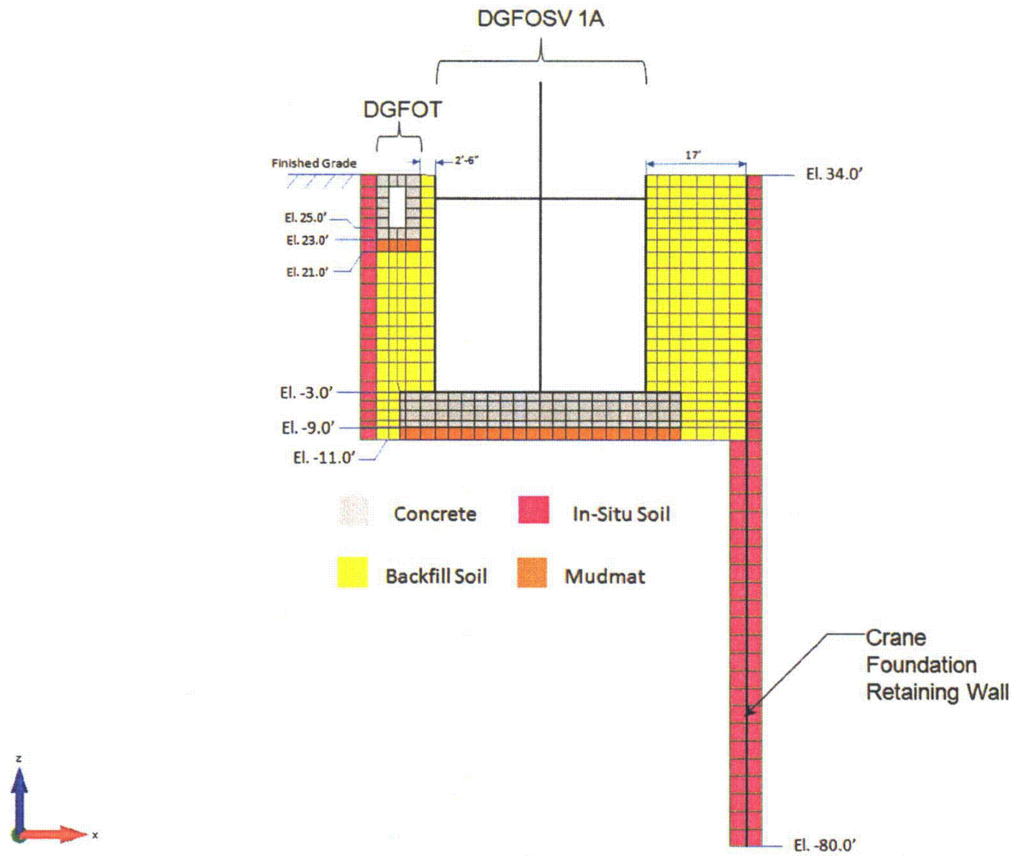

Figure 3H.6-225: 2D SSSI Model of DGFOT, DGFOSV and Crane Foundation Retaining Wall

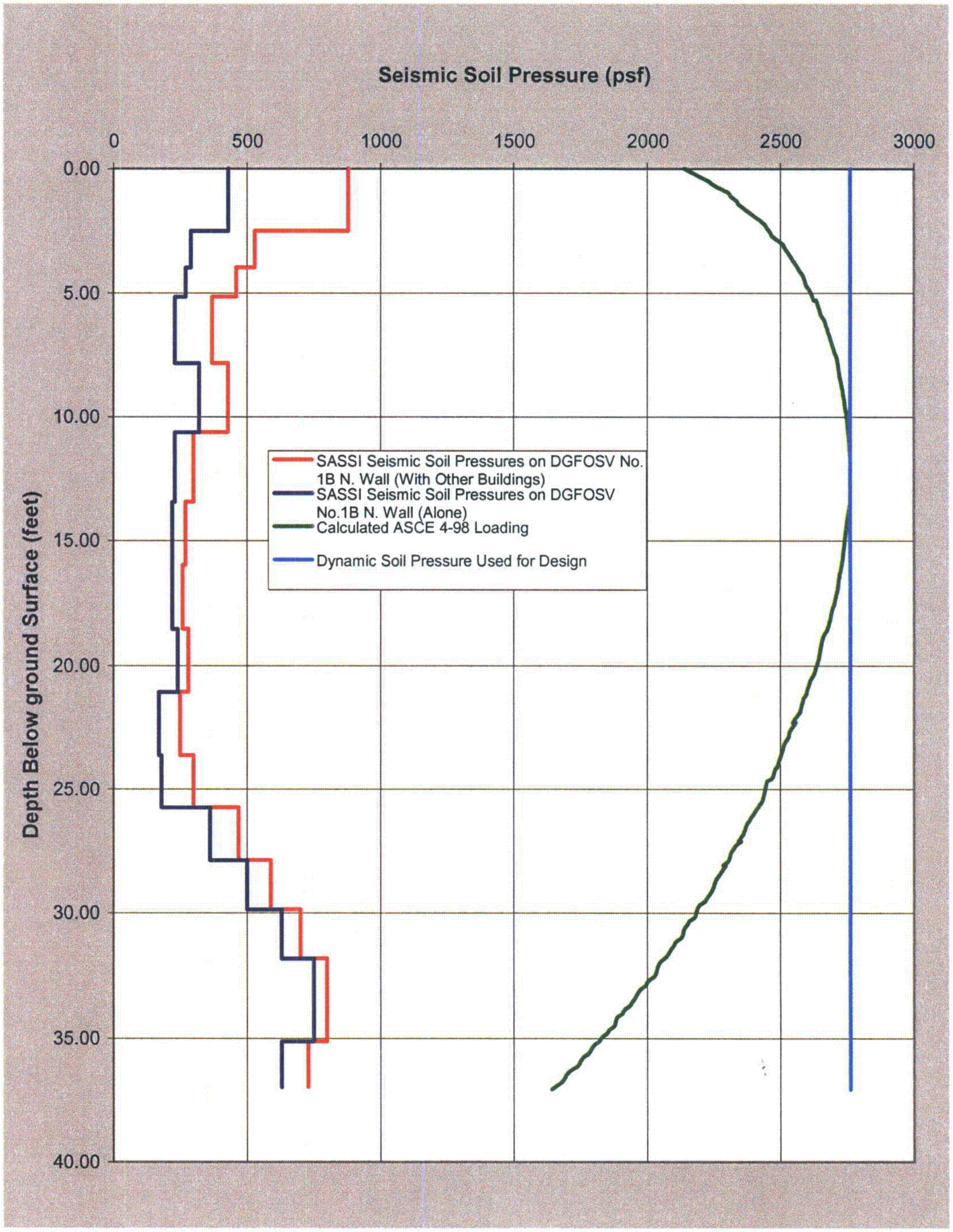

Figure 3H.6-226: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1B North Wall

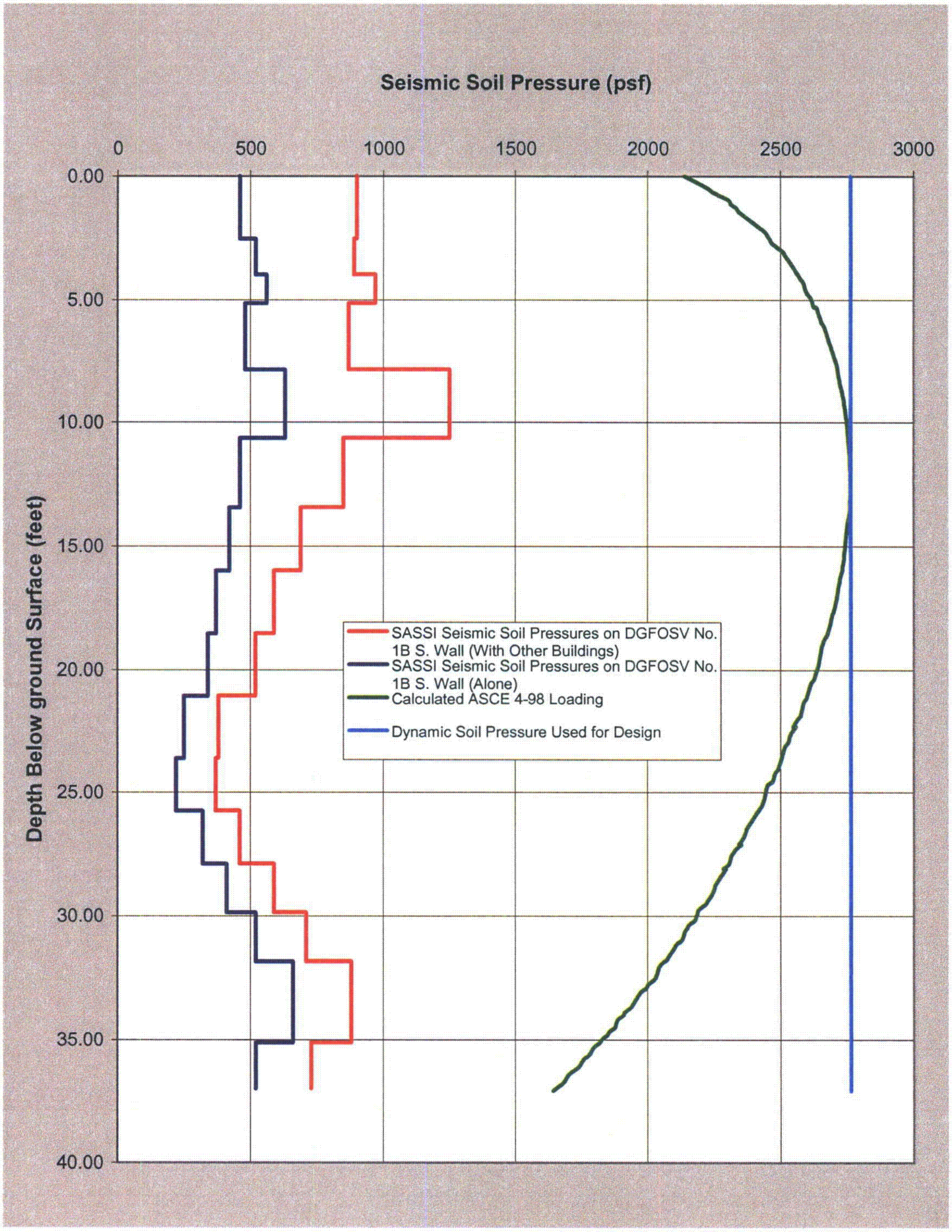

Figure 3H.6-227: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1B South Wall

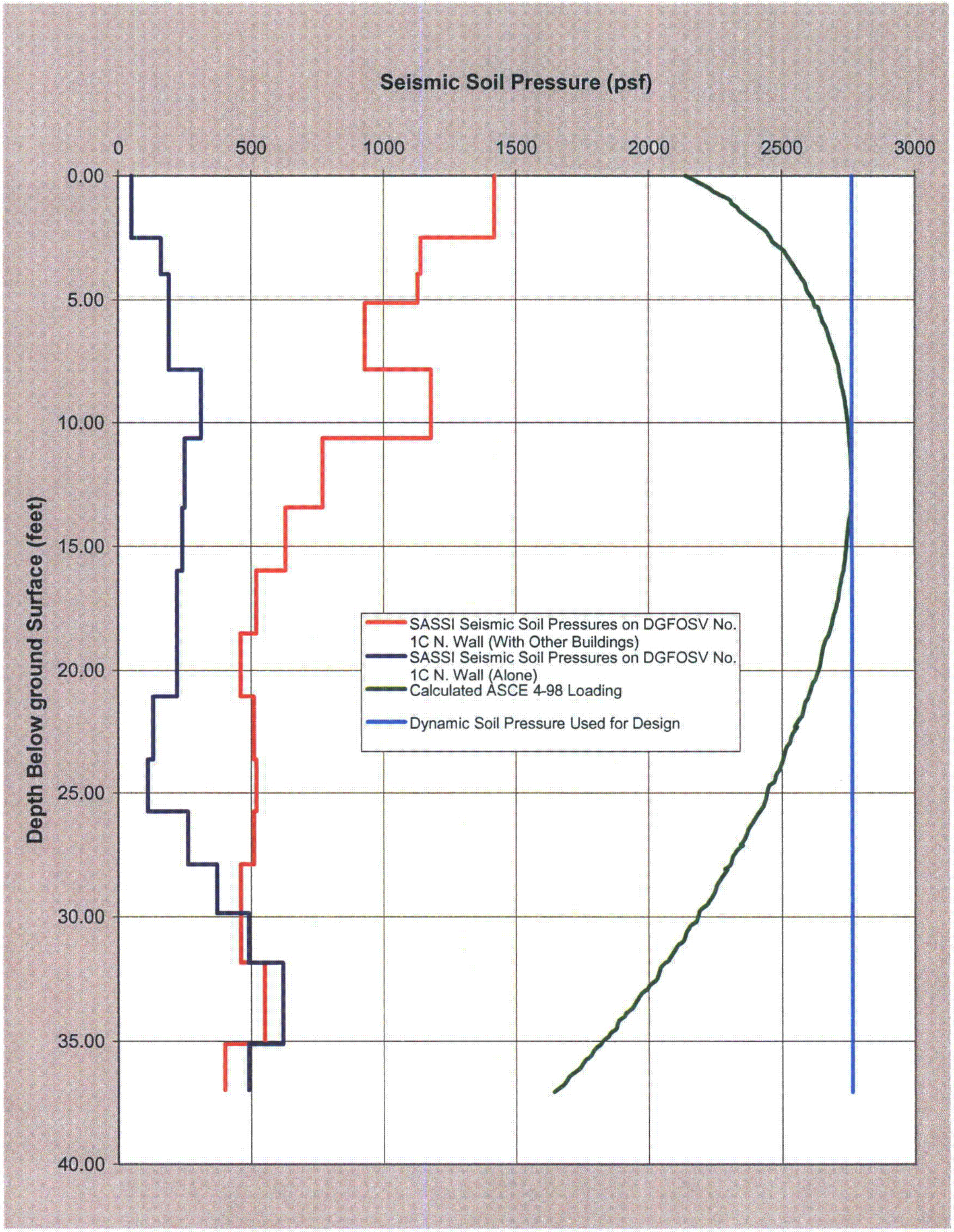

Figure 3H.6-228: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1C North Wall

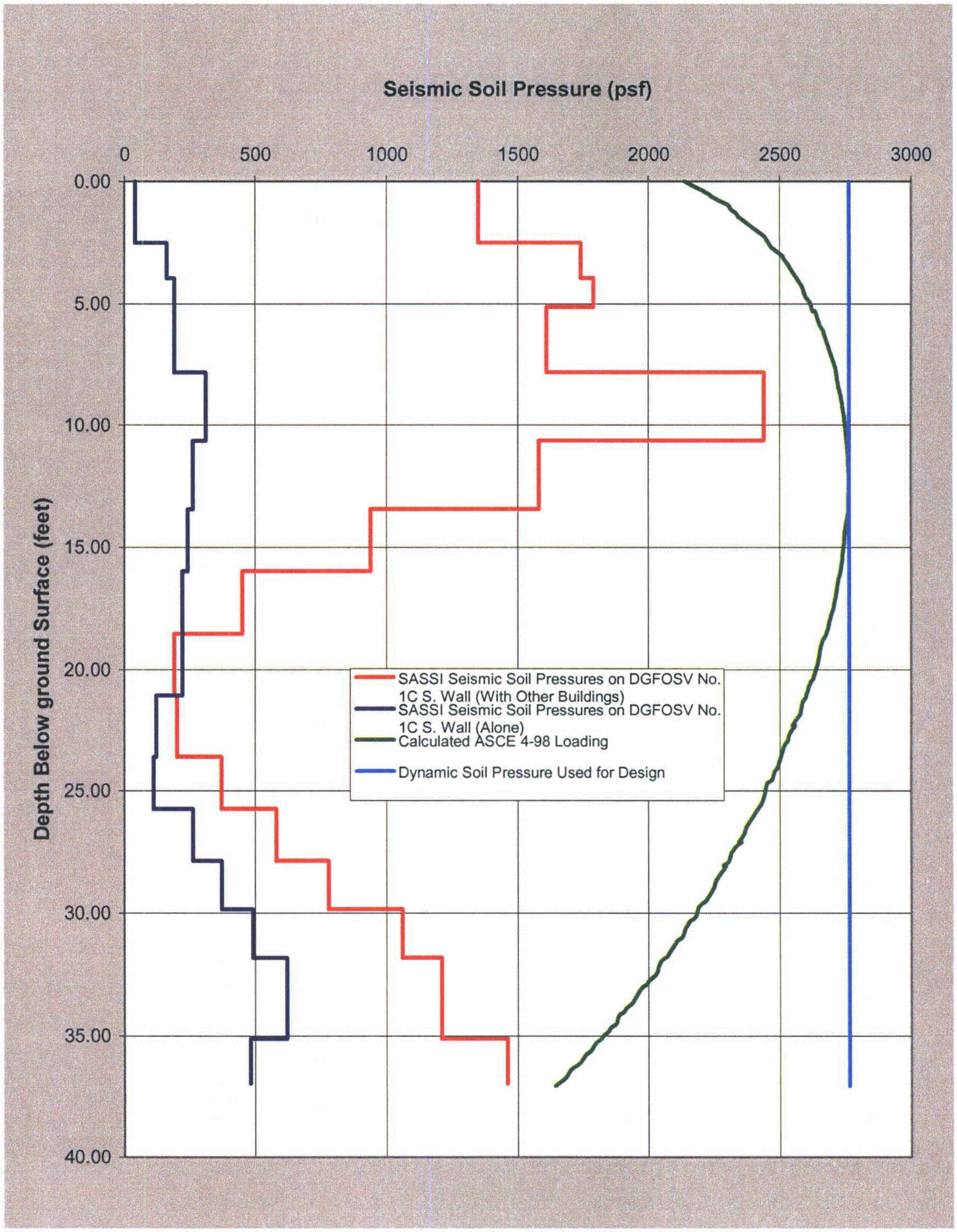

Figure 3H.6-229: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1C South Wall

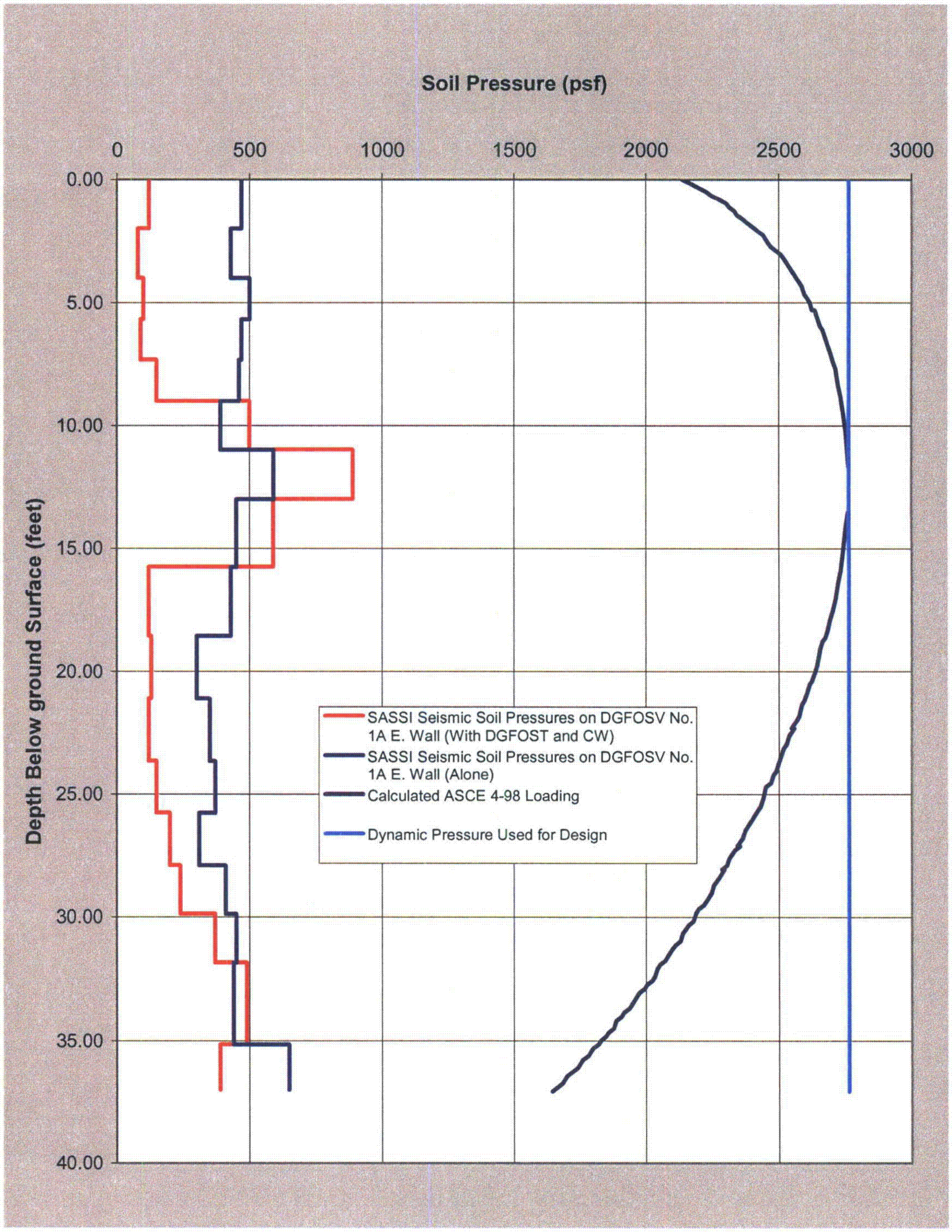

Figure 3H.6-230: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1A East Wall

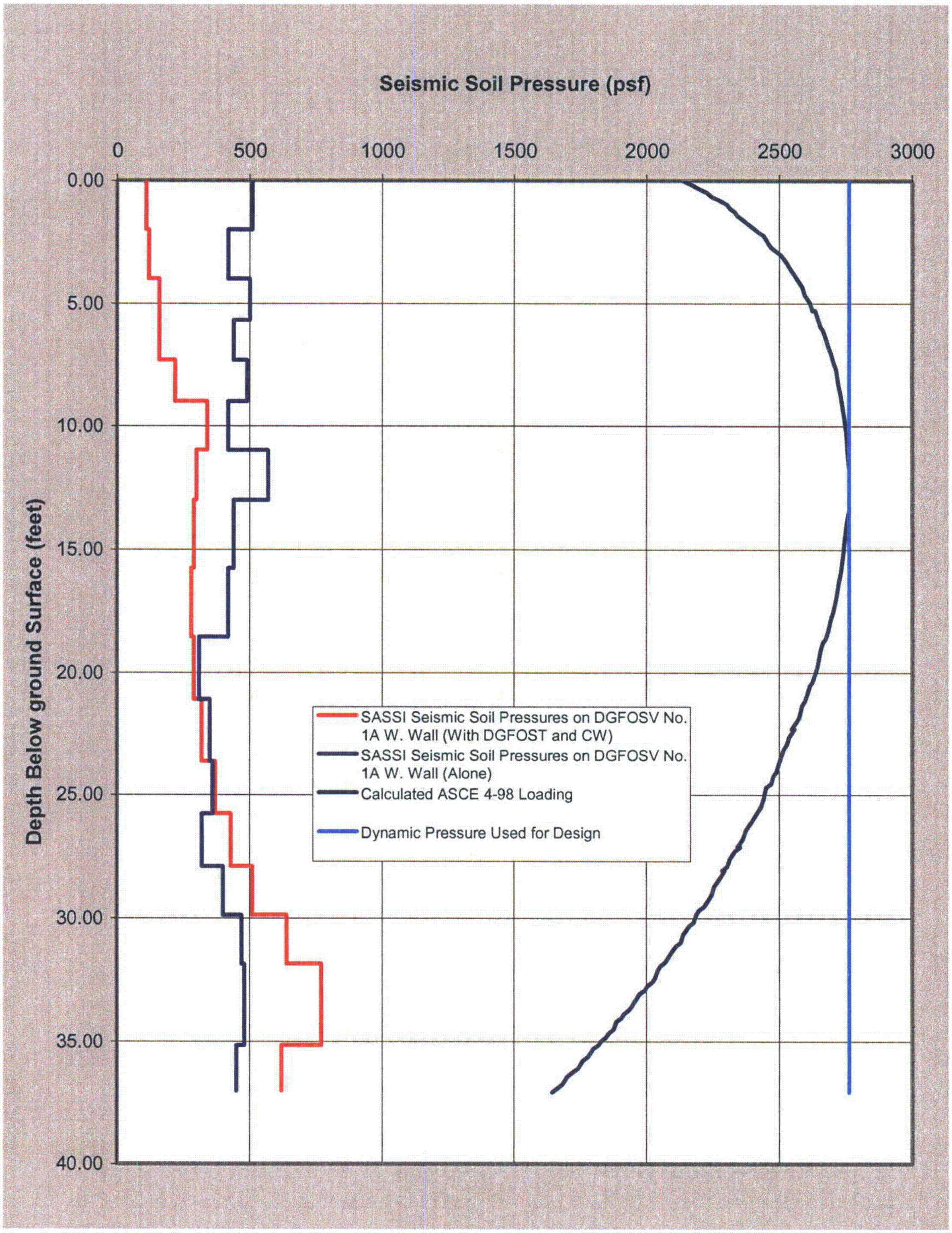

Figure 3H.6-231: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures on Diesel Generator Fuel Oil Storage Vault No. 1A West Wall

RAI 03.07.01-27, Supplement 2, Revision 1

QUESTION:

Follow-up Question to RAI 03.07.01-19 (STP-NRC-100093)

1. 10CFR50, Appendix S requires that evaluation for SSE must take into account soil-structure interaction (SSI) effects and the expected duration of vibratory motion. In the response to the first paragraph of RAI 03.07.01-19, the applicant has presented its approach for developing the input motion for the SSI analysis and design of the DGFOSV that takes into account the impact of the nearby heavy RB and RSW Pump House structures. The applicant also stated that *"Conservatively, a 3-dimensional SAP2000 response spectrum analysis was used to obtain the safe-shutdown earthquake (SSE) design forces due to structure inertia. The seismic induced dynamic soil pressure on DGFOSV walls were computed using the method of ASCE 4-98, Subsection 3.5.3.2"* The response, however, does not provide details as to how the SSI analysis of the DGFOSV are performed and how the input motion developed are subsequently specified in the SSI analysis of DGFOSV to develop the structural response and in-structure response spectra for any equipment and subsystems within DGFOSV. From the response it appears that the applicant has not included explicitly DGFOSV structural model in the SASSI model of the RB and RSW Pump House structures to properly evaluate the SSSI effect on the DGFOSV. In order for the staff to determine if the evaluation of DGFOSV for SSE has appropriately accounted SSI effects, the applicant is requested to provide in the FSAR the following information:

   (a) Describe in detail the method used for the SSI analysis of DGFOSV including the procedures for treatment of strain dependent backfill material properties in the model, input motion used and how it is specified in the analysis, variation of soil properties, and the computer programs used for SSI analysis.

   (b) Describe in detail how SAP2000 analysis of DGFOSV was performed including, how foundation soil/backfill material was represented, how many modes were extracted, what modal damping values were used, how the input motion was specified, and what type of boundary conditions were used.

   (c) Demonstrate that the DGFOSV foundation response spectra and dynamic soil pressure (on DGFOSV basement walls using ASCE 4-98 criteria) used in the design of DGFOSV will envelop the results of structure to structure (SSSI) interaction analysis which explicitly models DGFOSV structure in the SSI model of RB and the RSW Pump House structure.

   (d) Describe in detail if there is any Category I tunnel structure for transporting Diesel Fuel Oil between DGFOSV and the Diesel Generator located in other buildings including its layout and configuration and seismic analysis and design method.

2. In the response to Item 2 of RAI 03.07.01-19, the applicant has stated that the P-wave damping ratios are assigned the same values as those calculated for the S-wave damping ratios because of the **upcoming** recommendations of ASCE 4-09 standards. It is further stated that this recommendation is based on the recent observation of earthquake data and the realization that the waves generated due to SSI effects are mainly surface and shear waves. It is noted that the NRC has not endorsed ASCE 4-09 for estimating the P-wave damping. In general, the P-wave damping is primarily associated with the site response rather than SSI effects. Because the Pwave energy for the most part will travel in water within the saturated soil media at relatively high propagation speed and is not affected by shear strains of degraded soil, the P-wave damping will be small. As such, the applicant is requested to provide quantitative assessment by performing sensitivity analysis that shows that seismic responses of Category I structures are not adversely affected to a lower P-wave damping.

REVISED SUPPLEMENTAL RESPONSE:

The original supplement 2 response to this RAI was submitted with STPNOC letter U7-C-STP-NRC-110008, dated January 17, 2011. This revision provides the following based on discussions with the NRC on February 2nd and 3rd, 2011.

1. Clarify that the seismic soil pressures in Figures 3H.7-5 through 3H.7-8 are incremental seismic soil pressures.
2. Clarify how the induced seismic forces at the diesel generator fuel oil tunnel bends are combined with other seismic loads including seismic soil pressures.

The revisions are indicated by revision bars in the margin.

The response to Part 2 of this RAI was submitted with STPNOC letter U7-C-STP-NRC-100208 dated September 15, 2010. The response to Parts 1(a) through 1(c) is provided in the Supplement 1, Revision 1 response to this RAI which is being submitted concurrently with this response. This supplemental response provides the response to Part 1(d).

1(d). The layout of the Diesel Generator Fuel Oil Tunnels (DGFOTs) is as shown in COLA Part 2, Tier 2 Figure 3H.6-221 provided in response to Part 1(a) of this RAI. There are three (3) reinforced concrete DGFOTs approximately 50 ft, 200 ft, and 220 ft long for each unit. Each DGFOT is connected at one end to the Reactor Building (RB) and at the other end to a Diesel Generator Fuel Oil Storage Vault (DGFOSV). There is a seismic gap between each of the tunnels and the adjoining RB or DGFOSV. For magnitude of the required and provided seismic gaps at interface of DGFOTs and the adjoining RB and DGFOSVs, see the Supplement 1, Revision 1 response to RAI 03.08.04-31 which was submitted with NINA letter U7-C-NINA-NRC-110008 dated January 31, 2011.

Each DGFOT has two access regions which extend above grade; one access region is located where the tunnel interfaces with the DGFOSV and another where the tunnel interfaces with the RB. The top of the DGFOT is located at grade. The DGFOT No. 1B, which is the shortest tunnel, running approximately 50 ft between the RB and DGFOSV No. 1B, has a wall thickness of 2'-0" on both sides. The interior below grade dimensions of this tunnel are approximately 7 ft high by 3.5 ft wide. The other two longer DGFOTs (approximately 200 ft and 220 ft long) have a wall thickness of 2'-0" on one side and 2'-6" on the other side to allow for placement of embedded conduits. The interior below grade dimensions of these tunnels are approximately 7 ft high by 3 ft wide. Any fuel leak from the fuel oil lines or water infiltration within the tunnels will be collected in a sump and removed by pumps. The tunnels slope away from the DGFOSV and the RB towards the sump located at the center of the tunnel runs. The access regions provide access to the below grade portions of the DGFOTs during maintenance and inspection. The overall above grade dimensions of the access regions are approximately 7.5 ft wide by 7.5 ft long and 15 ft high.

The details of DGFOT design will be provided in the response to Part 10 of RAI 03.08.04-30, Revision 1 which is scheduled to be submitted by March 15, 2011. The following provides details of seismic analysis for DGFOTs.

Seismic Analysis for Generation of In-structure Response Spectra:

The DGFOTs are long reinforced concrete tunnels with above grade access regions at the two ends of each tunnel. The widened envelop spectra of the resulting in-structure response spectra from the following two seismic analyses are used as the final in-structure response spectra for these tunnels and their access regions.

- Two dimensional (2D) soil-structure-interaction (SSI) analysis of a typical cross section of the DGFOT
- Three dimensional (3D) fixed base seismic analysis of the DGFOT No. 1B (approximately 50 ft long) including its access regions at the two ends of the tunnel.

The details of the above two seismic analyses are provided below.

A. 2D SSI Analysis of a Typical Cross section of DGFOT

SASSI2000 computer code is used for the SSI analysis, using the direct method. Figure 3H.7-20 shows the structural part of the 2D plane-strain model of the DGFOT with 2 ft thick mud mat under the base mat. The top of the tunnel is at the grade elevation. The specifics of the 2D SSI model are as follows:

- The structural properties (i.e. mass and stiffness) for the 2D model correspond to per unit depth (1 ft dimension in out-of-plane direction) of the tunnel.

- Layered soil is modeled up to 74 ft depth (more than two times the horizontal cross section dimension of the tunnel plus its embedment depth) with halfspace below it.

- Sixteen cases of strain dependent soil properties representing the in-situ lower bound, mean and upper bound; lower bound backfill over in-situ lower bound, mean backfill over in-situ mean and upper bound backfill over in-situ upper bound; cracked concrete wall with in-situ upper bound soil, soil separation with in-situ upper bound soil; ABWR DCD/Tier 2 generic soil profiles UB1D, VP3D, VP4D, VP5D, VP7D, R , R with soil separation and R with cracked wall.

- Concrete and mud mat damping are assigned 4% for all cases (conservatively 4% damping is also used for cracked concrete cases).

- Groundwater is considered at 8 ft depth for site-specific soil and backfill cases and 2 ft depth for DCD cases. In site-specific and backfill cases, the groundwater effect is included by using minimum P-wave velocity of 5000 ft/sec with Poisson's ratio capped at 0.495. In DCD cases, the groundwater effect is included by using minimum P-wave velocity of 4800 ft/sec with Poisson's ratio capped at 0.495 (per Section 3A.3.3 of DCD, the compression wave velocity of water is 1463 m/sec, i.e. 4800 ft/sec).

- The models are capable of passing frequencies up to at least 33 Hz, in both the vertical and horizontal directions.

- For all SSI cases analyzed, a cut-off frequency of 35 Hz is used for transfer function calculations.

- Acceleration time histories consistent with Regulatory Guide 1.60 response spectra anchored at 0.3g peak ground acceleration are used as input at the grade elevation.

- Since the tunnels run along both East-West and North-South directions, the horizontal input motions from both East-West and North-South time histories are considered. East-West input motion is applied to the tunnel sections running North-South and North-South input motion is applied to the tunnel sections running East-West. The input motions consistent with RG 1.60 response spectra anchored at 0.3g peak ground acceleration envelop both the site-specific input motions and the amplified site-specific motions considering the impact of nearby heavy RB and Ultimate Heat Sink (UHS)/Reactor Service Water (RSW) Pump House.

- In-structure response spectra are generated at the top of floor slab (middle of span), at the top of the roof slab (middle of span) and at the mid-height of two walls of the tunnel cross-section.

- The responses from the horizontal and vertical directions are combined using the square-root-of-sum-of-square (SRSS) method.

- The responses from all SSI analyses cases are enveloped.

- The in-structure response spectra at the top of the floor slab (middle of span), at the roof of slab (middle of span) and at the mid-height of two walls of the tunnel cross-section are enveloped to conservatively provide the in-structure response spectra for the entire 2D cross-section of the tunnel.

In response to an action item from the NRC's audit performed during the week of October 18, 2010, the following additional information is also included:

> The foundation input response spectra (FIRS) for the DGFOT were calculated and were compared to the outcrop spectra at the foundation level of the DGFOT. The outcrop spectra were calculated from a deconvolution analysis performed in the SHAKE program with the site-specific SSE motion applied at the free field ground surface. Figures 3H.7-22 through 3H.7-30 show the comparison of the outcrop response spectra and the FIRS, in the two horizontal directions and the vertical direction for the lower bound, mean and upper bound in-situ soil properties. These figures show that the FIRS are enveloped by the foundation outcrop spectra in all cases. The figures also show that the response spectra at the SHAKE outcrop of DGFOT foundation level also envelop a broad band spectrum anchored at 0.1g. This is the minimum requirement as stated in SRP 3.7.1 and Appendix S to 10 CFR 50. The broadband spectrum used in this comparison is conservatively defined as the Regulatory Guide 1.60 spectrum anchored at 0.1g.

B. 3D Fixed Base Analysis of DGFOT No. 1B Including its Two Access Regions

A 3D fixed base seismic (basemat fixed) analysis of DGFOT No. 1B running between the RB and DGFOSV No. 1B is performed. The following provides the details of this fixed base analysis:

- SAP2000 computer code is used to perform the seismic analysis.

- Modal time history method of analysis is used.

- Shell elements are used for modeling the reinforced concrete tunnel section and the access regions at the two ends of the tunnel.

- 4% damping is used for the shell elements.
- Acceleration time histories (two horizontal directions and a vertical direction) consistent with Regulatory Guide 1.60 response spectra anchored at 0.3g peak ground acceleration are used as input motions.
- Nodal acceleration time history responses obtained from the SAP2000 analysis are processed using the RSG computer code to calculate in-structure response spectra at selected nodes. The nodes selected for the in-structure response spectra generation are; four nodes on top of each access regions (middle of four walls) and three nodes at the top of tunnel (middle of the tunnel).
- The maximum co-directional responses from each of the three directions of excitations are combined using the SRSS method.
- The in-structure response spectra at the selected nodes are enveloped to conservatively provide the in-structure response spectra from fixed base analysis, for the entire tunnel and the access regions.

The corresponding in-structure response spectra obtained from the 2D SSI analysis and in-structure response spectra obtained from the 3D fixed base analysis described in parts A and B above are enveloped and peak widened by ± 30%. The 30% peak widening is used to cover any frequency shift due to the foundation soil flexibility, which is not included in the fixed base seismic analysis. The final widened in-structure response spectra for the horizontal and vertical directions of the DGFOTs and their access regions are provided in Figures 3H.7-31 and 3H.7-32, respectively. The spectra in Figures 3H.7-31 and 3H.7-32 provide the in-structure response spectra for the entire SGFOTs and their access towers at the two ends.

Structure-Soil-Structure Interaction (SSSI) Analysis to Obtain Seismic Soil Pressures:

Two 2D section cuts are taken for site-specific SSSI analyses; one East-West section cut through DGFOT No. 1C, DGFOSV No. 1A and the Crane Foundation Retaining Wall (CFRW) and one East-West section cut through the RB, DGFOT No. 1A and the CFRW. These SSSI analyses are used to obtain seismic soil pressures on the walls of DGFOT considering the effect of nearby structures.

The SSSI model and analyses details for the section cut through DGFOT No. 1C, DGFOSV No. 1A and the CFRW have been provided in the response to Part 1(a) of this RAI which is being submitted concurrently with this response.

The structural part of the SSSI model for the section cut through the RB, DGFOT No. 1A and the CFRW is shown in Figure 3H.7-21. The methodology for the SSSI model including strain dependent soil properties; soil cases analyzed; and method of analyses are the same as those for the section cut through DGFOT No. 1C, DGFOSV No. 1A and the CFRW described in the response to Part 1(a) of this RAI. This SSSI model is capable of passing frequencies up to at least 33 Hz in both the vertical and horizontal directions and the analysis uses a cut-off frequency of 33 Hz for calculation of transfer functions.

Figures 3H.7-5 through 3H.7-8 show a comparison of the incremental SSI, SSSI, ASCE 4-98 seismic soil pressures and the enveloping incremental seismic soil pressures used for the design of the DGFOT walls.

The design of the DGFOTs also accounts for the axial tensile strain and the seismic induced forces at the tunnel bends due to SSE wave propagation. To determine the required reinforcement, the induced forces at the tunnel bends are considered to act simultaneously with all other applicable loads (including dynamic soil pressures) in the seismic load combinations. For more information on this subject, see the response to Part 10 of RAI 03.08.04-30, Revision 1 which is scheduled to be submitted by March 15, 2011.

COLA Part 2, Tier 2, Section 3H will be revised as shown in Enclosure 4 of the response to RAI 03.08.04-30, Revision 1 which is scheduled to be submitted by March 15, 2011.

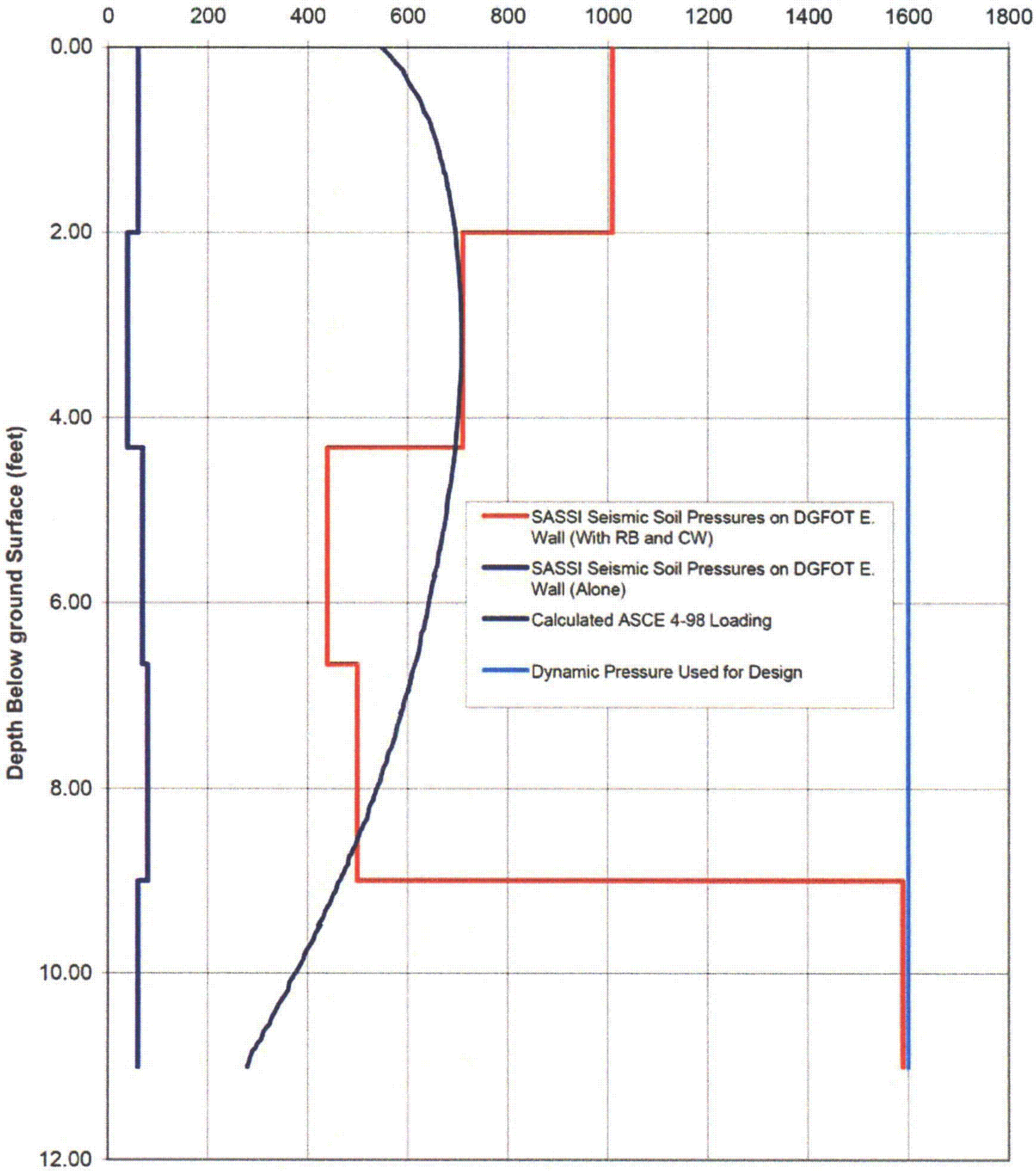

Figure 3H.7-5: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures (psf) on Fuel Oil Tunnel East Wall with Reactor Building and Crane Wall

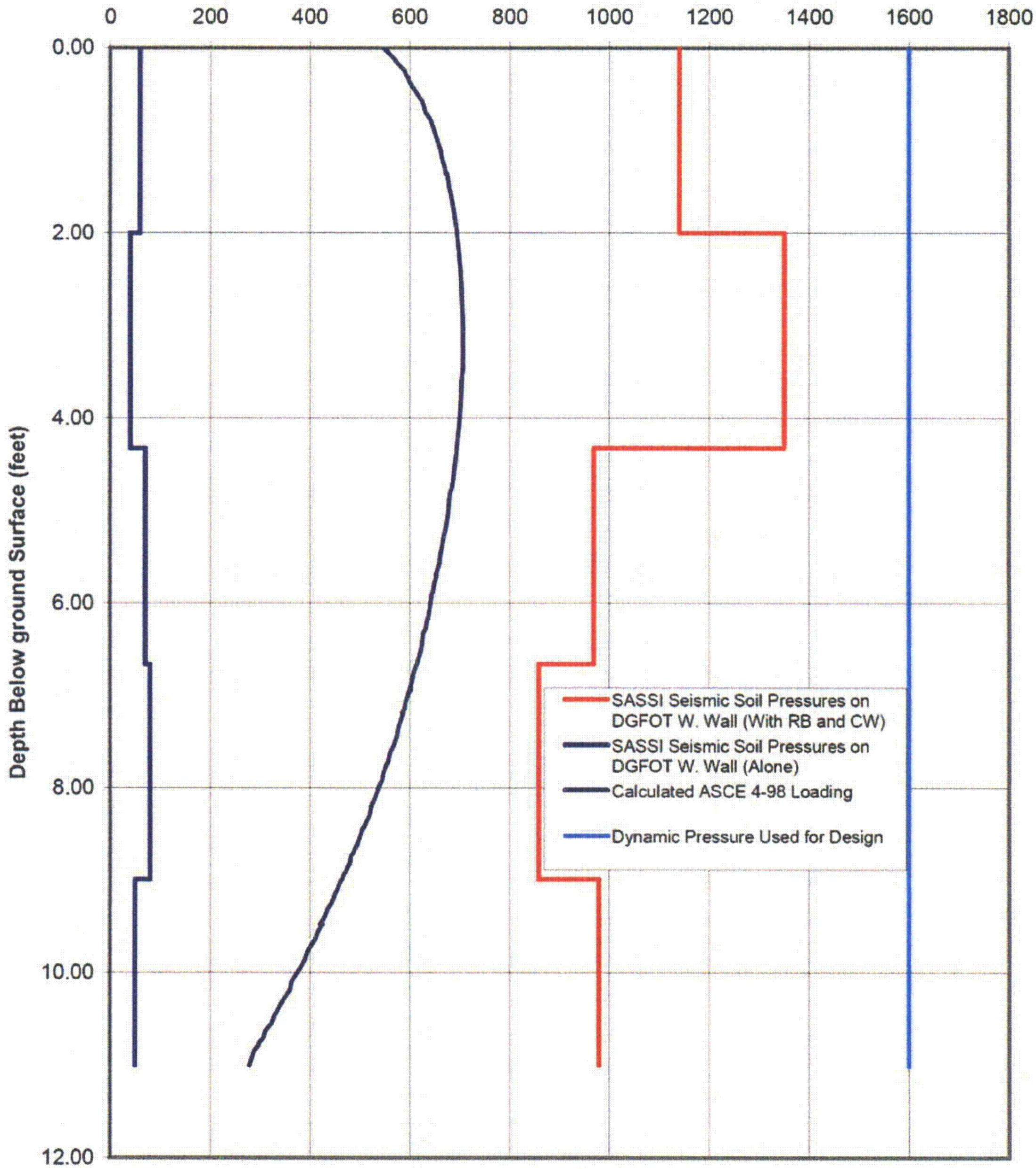

Figure 3H.7-6: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures (psf) on Fuel Oil Tunnel West Wall with Reactor Building and Crane Wall

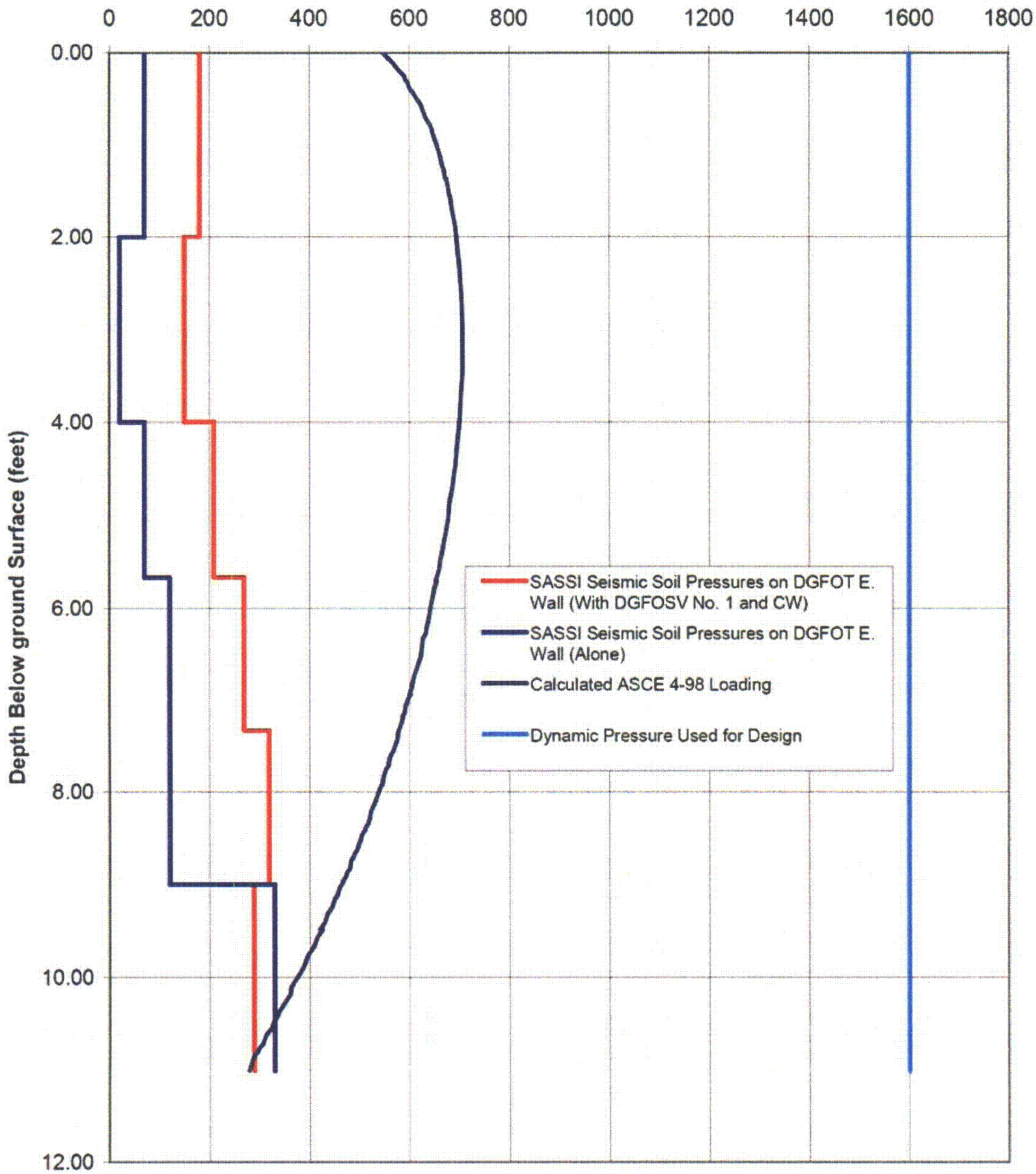

Figure 3H.7-7: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures (psf) on Fuel Oil Tunnel East Wall with Diesel Generator Fuel Oil Storage Vault and Crane Wall

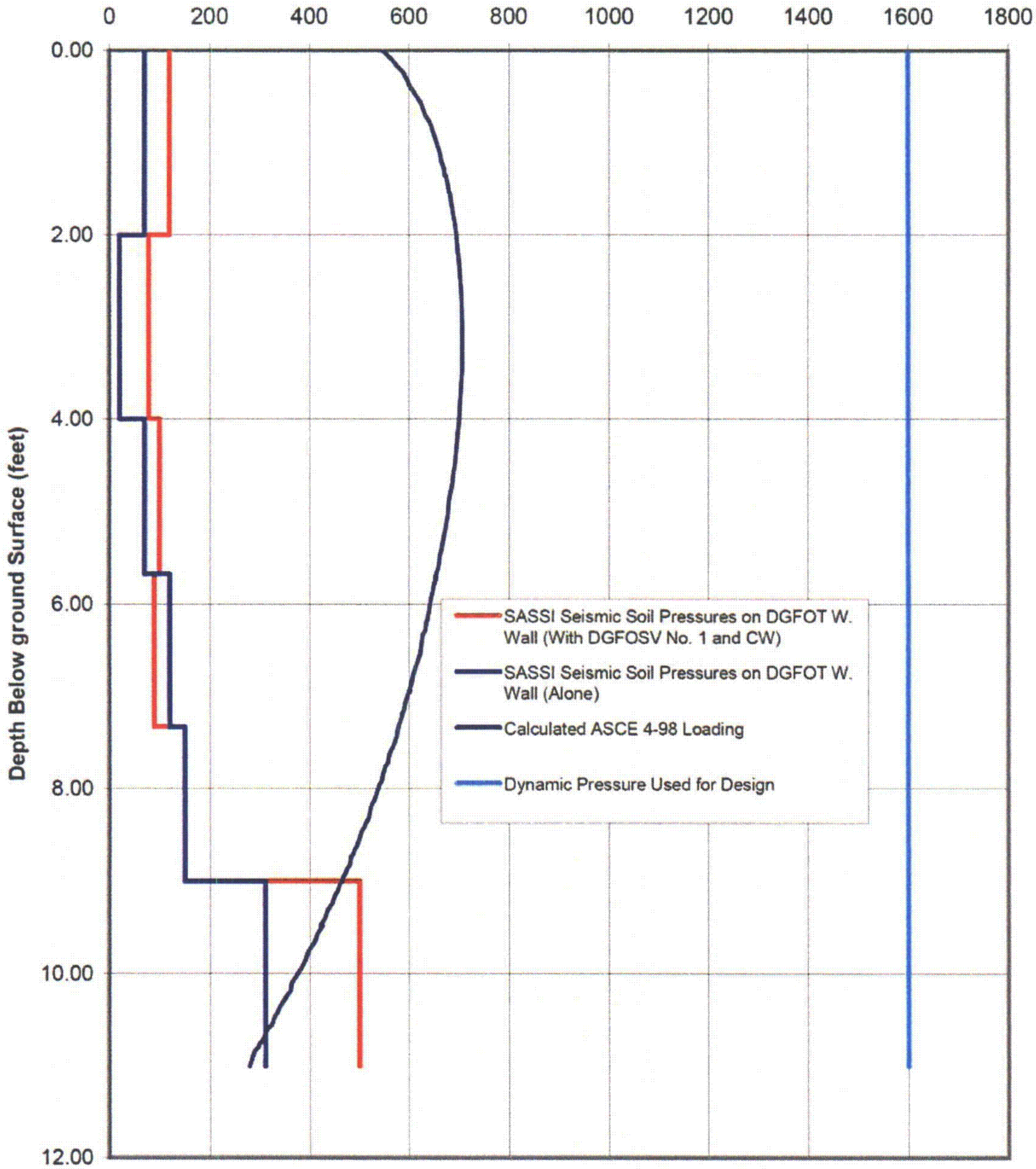

Figure 3H.7-8: SSI, SSSI, ASCE 4-98 and Design Lateral Seismic Soil Pressures (psf) on Fuel Oil Tunnel West Wall with Diesel Generator Fuel Oil Storage Vault and Crane Wall

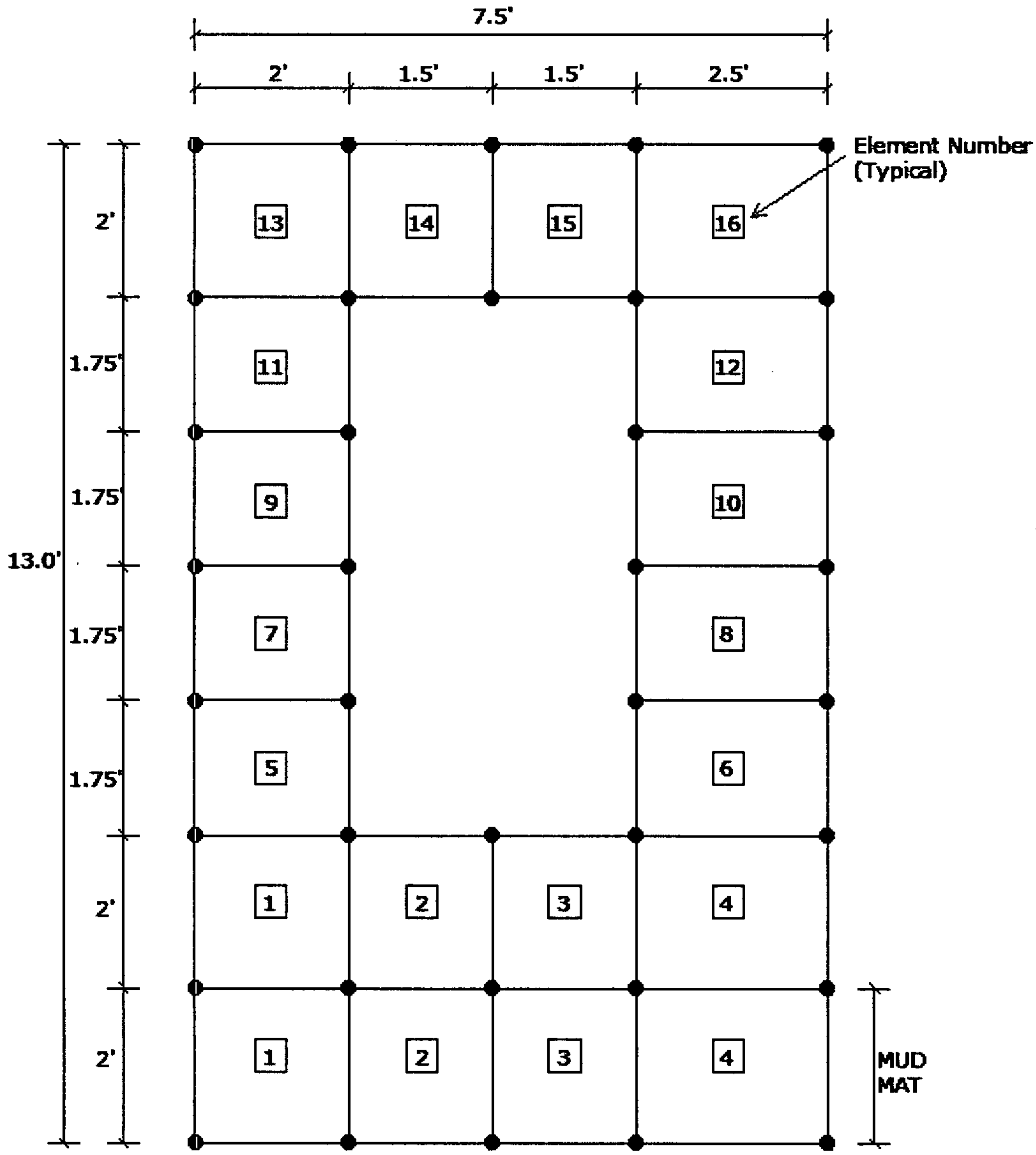

Figure 3H.7-20: 2D Model for SSI Analysis of a Typical Cross section of DGFOT

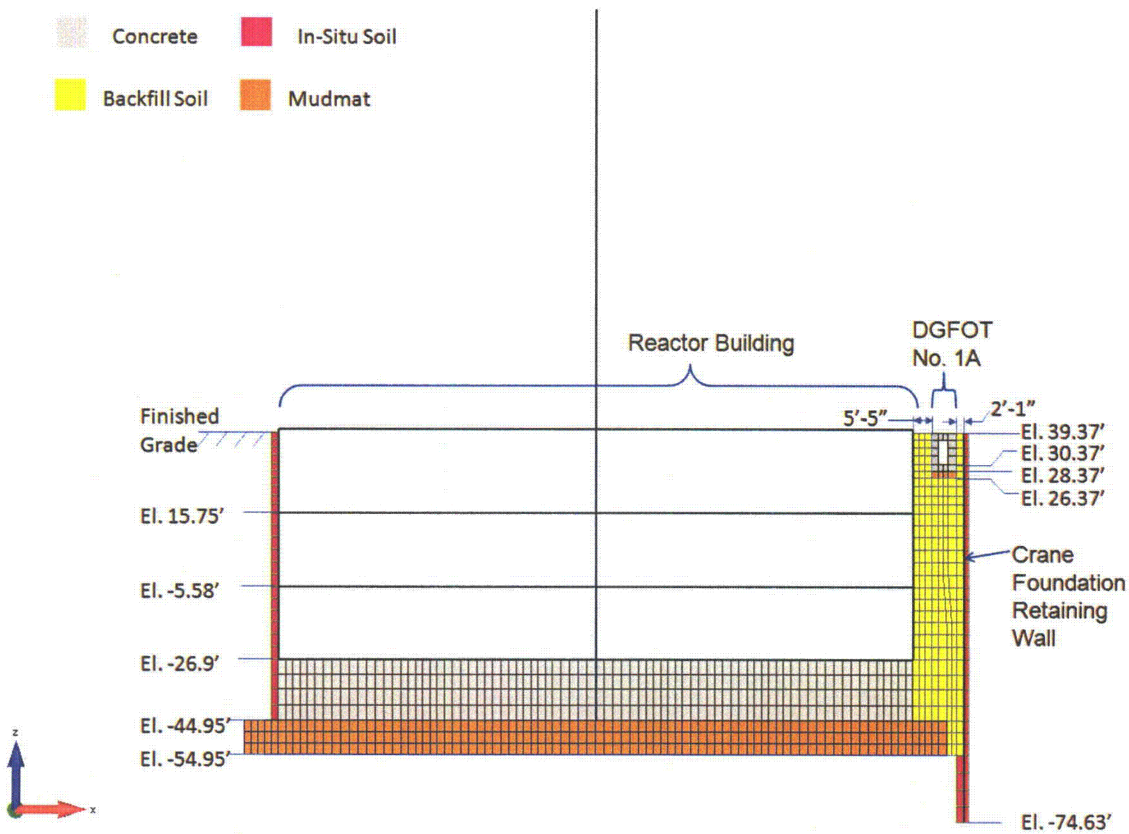

Figure 3H.7-21: 2D SSSI Model of RB, DGFOT and Crane Foundation Retaining Wall

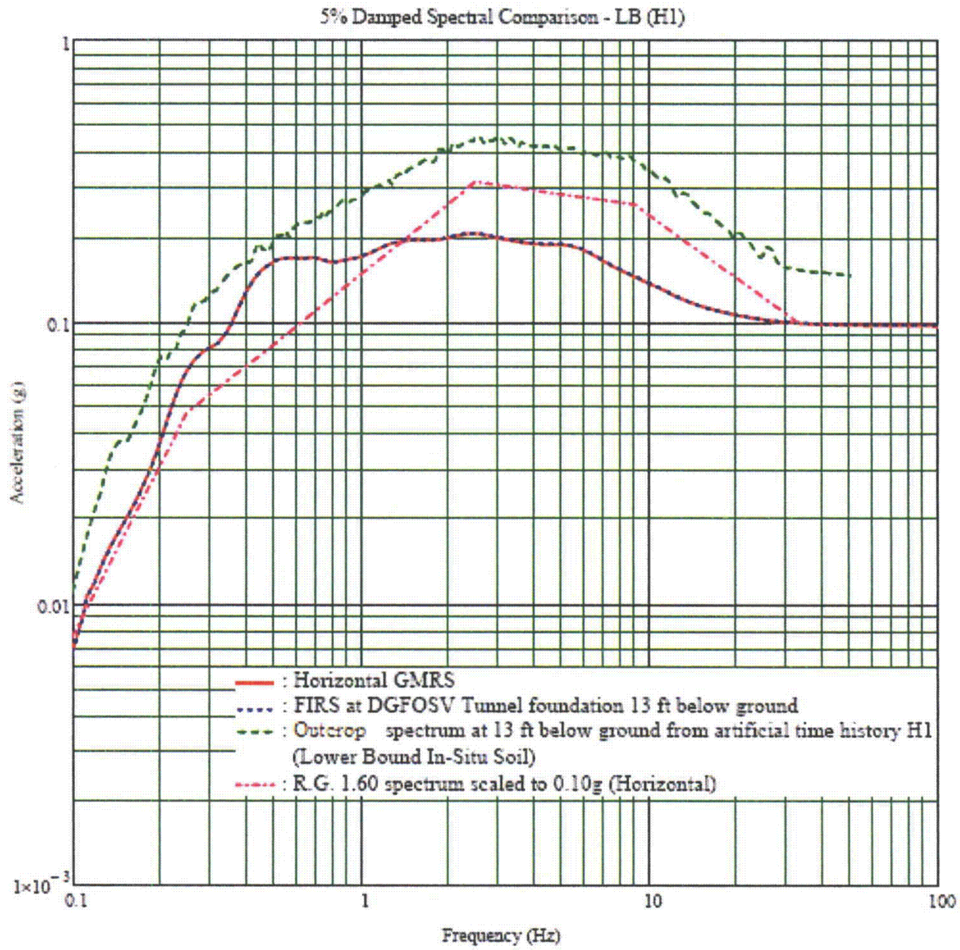

Figure 3H.7-22: Comparison of Spectra at Foundation of DGFOT – Lower Bound Soil Properties, Horizontal X Direction

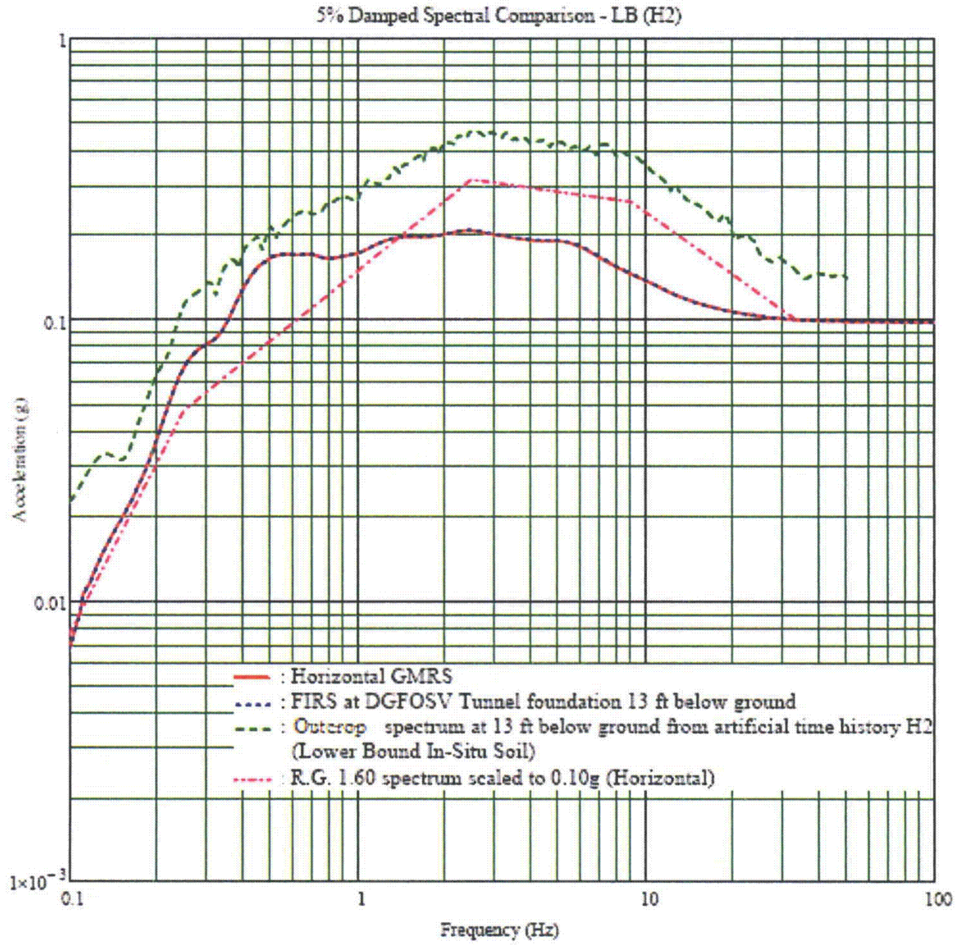

Figure 3H.7-23: Comparison of Spectra at Foundation of DGFOT – Lower Bound Soil Properties, Horizontal Y Direction

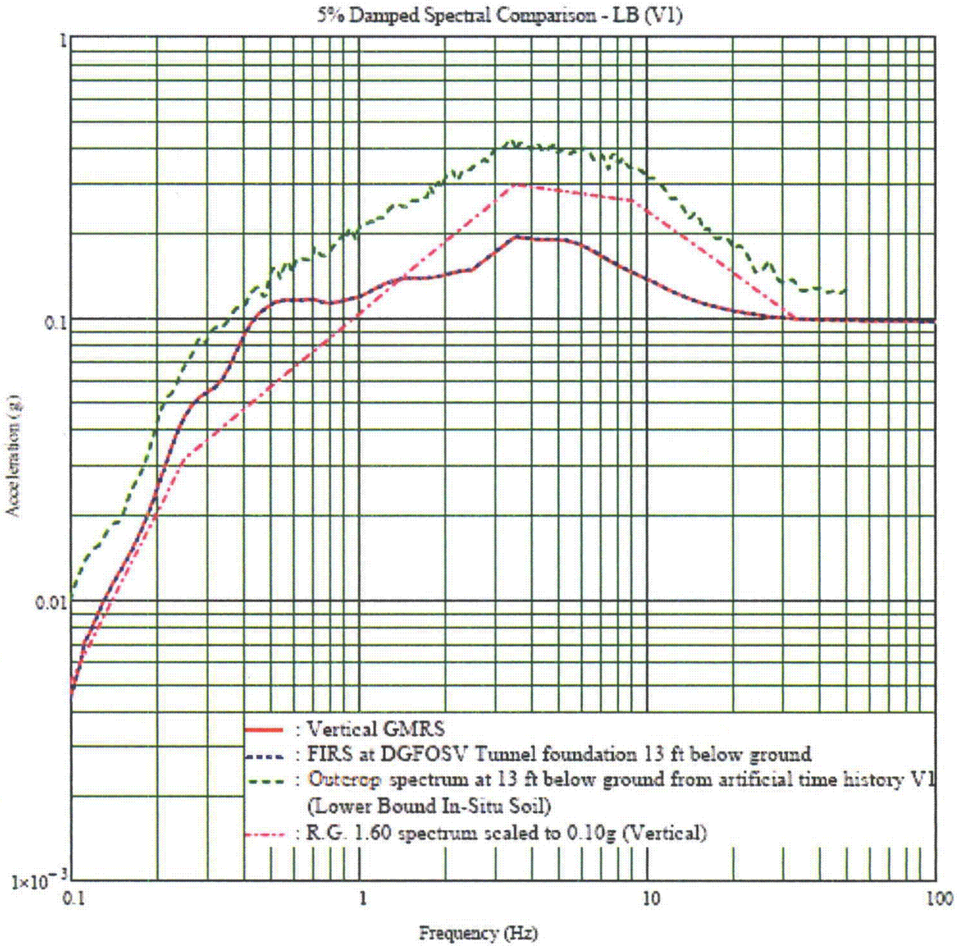

Figure 3H.7-24: Comparison of Spectra at Foundation of DGFOT – Lower Bound Soil Properties, Vertical Direction

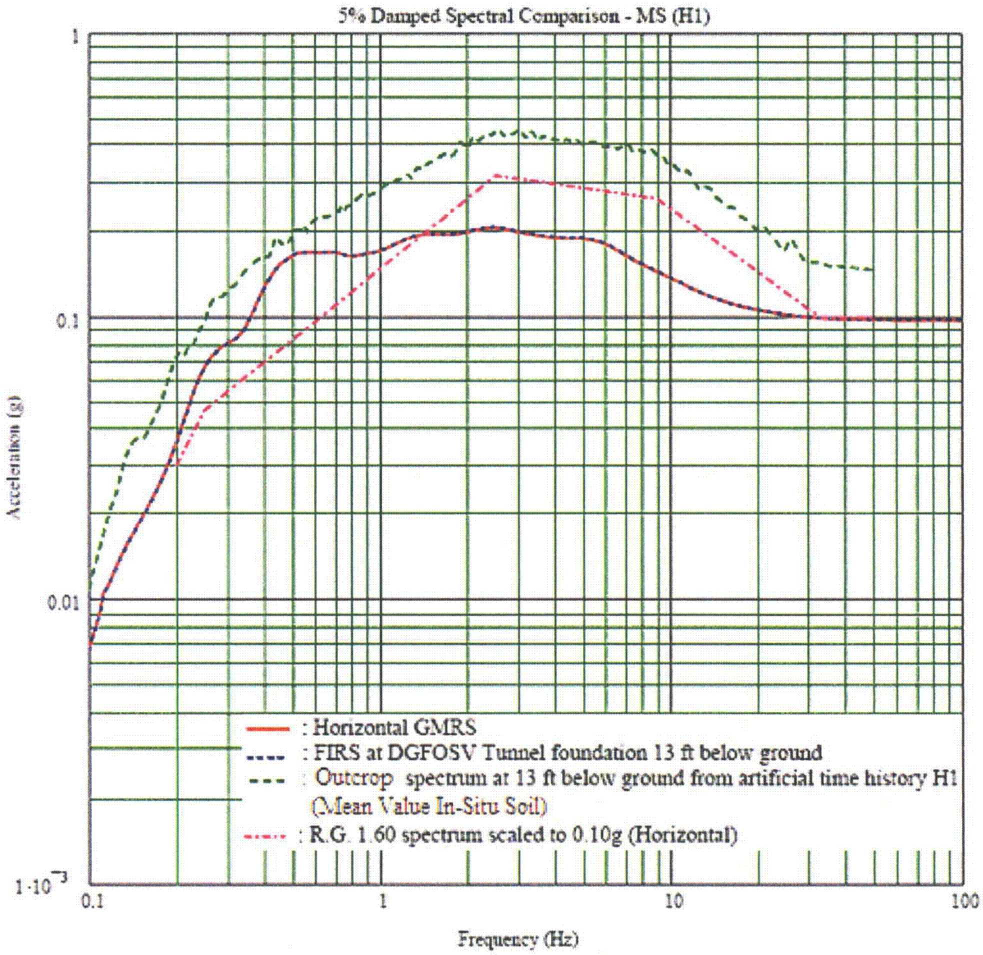

Figure 3H.7-25: Comparison of Spectra at Foundation of DGFOT – Mean Soil Properties, Horizontal X Direction

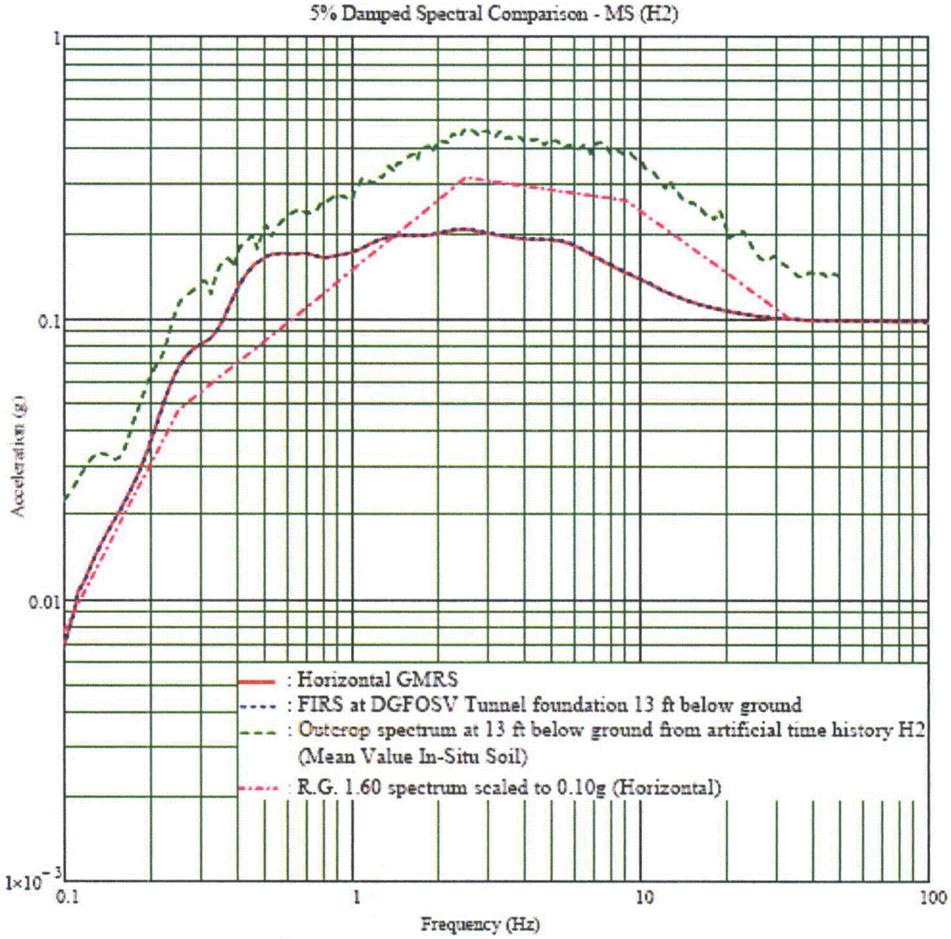

Figure 3H.7-26: Comparison of Spectra at Foundation of DGFOT – Mean Soil Properties, Horizontal Y Direction

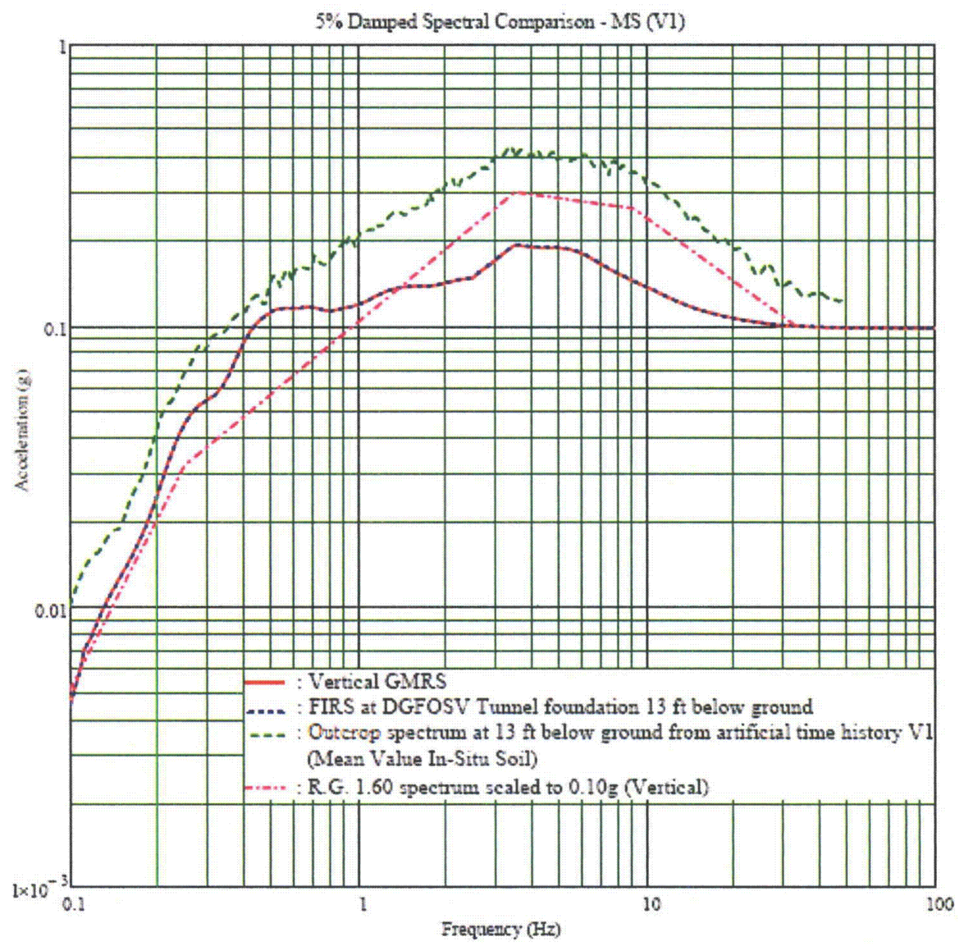

Figure 3H.7-27: Comparison of Spectra at Foundation of DGFOT – Mean Soil Properties, Vertical Direction

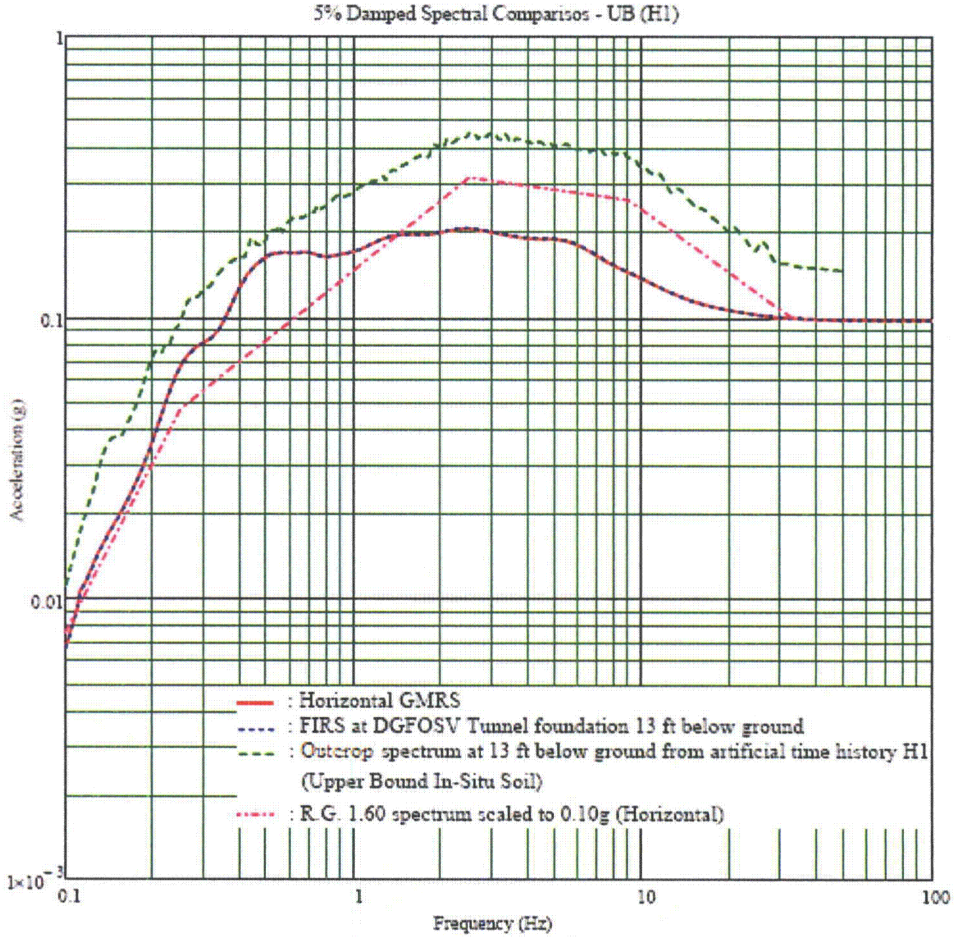

Figure 3H.7-28: Comparison of Spectra at Foundation of DGFOT – Upper Bound Soil Properties, Horizontal X Direction

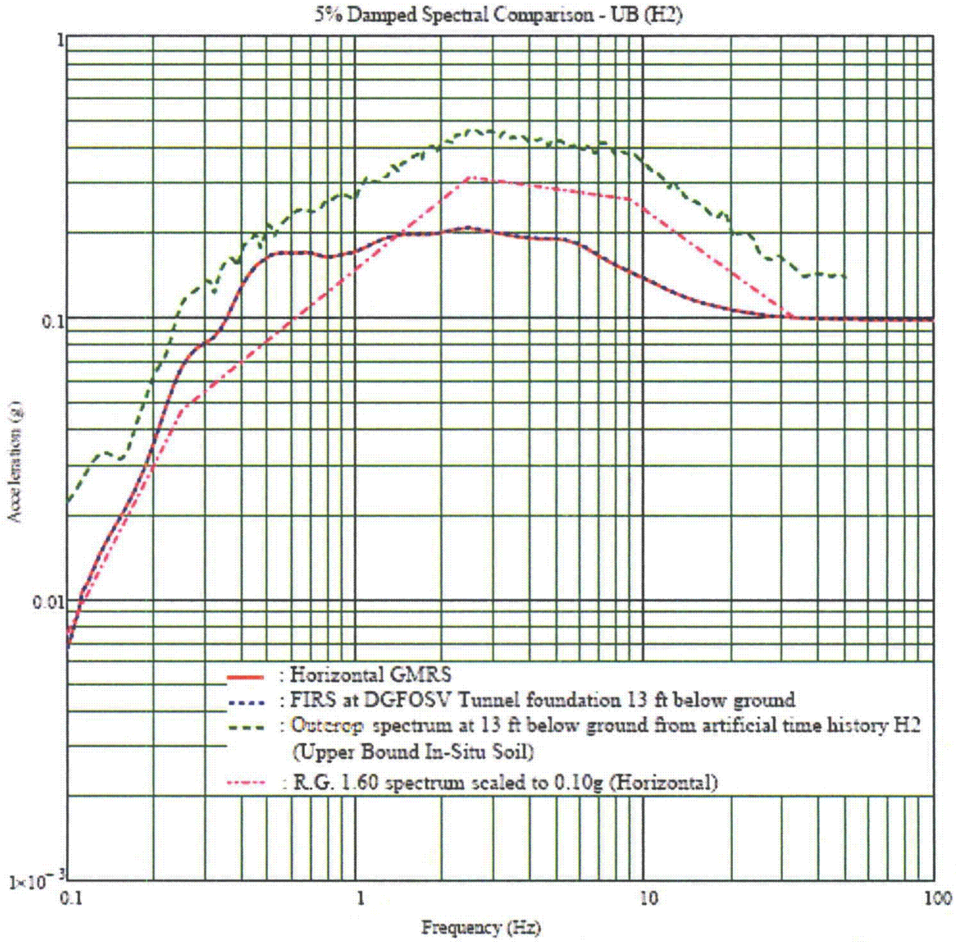

Figure 3H.7-29: Comparison of Spectra at Foundation of DGFOT – Upper Bound Soil Properties, Horizontal Y Direction

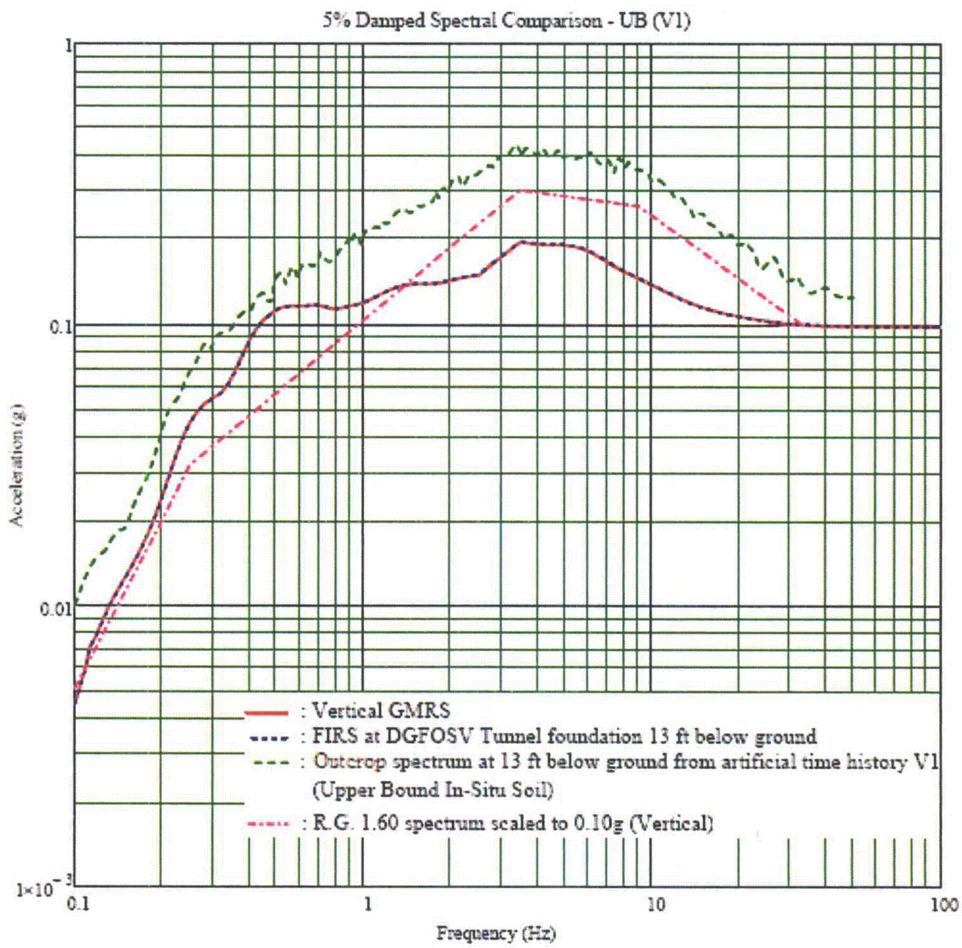

Figure 3H.7-30: Comparison of Spectra at Foundation of DGFOT – Upper Bound Soil Properties, Vertical Direction

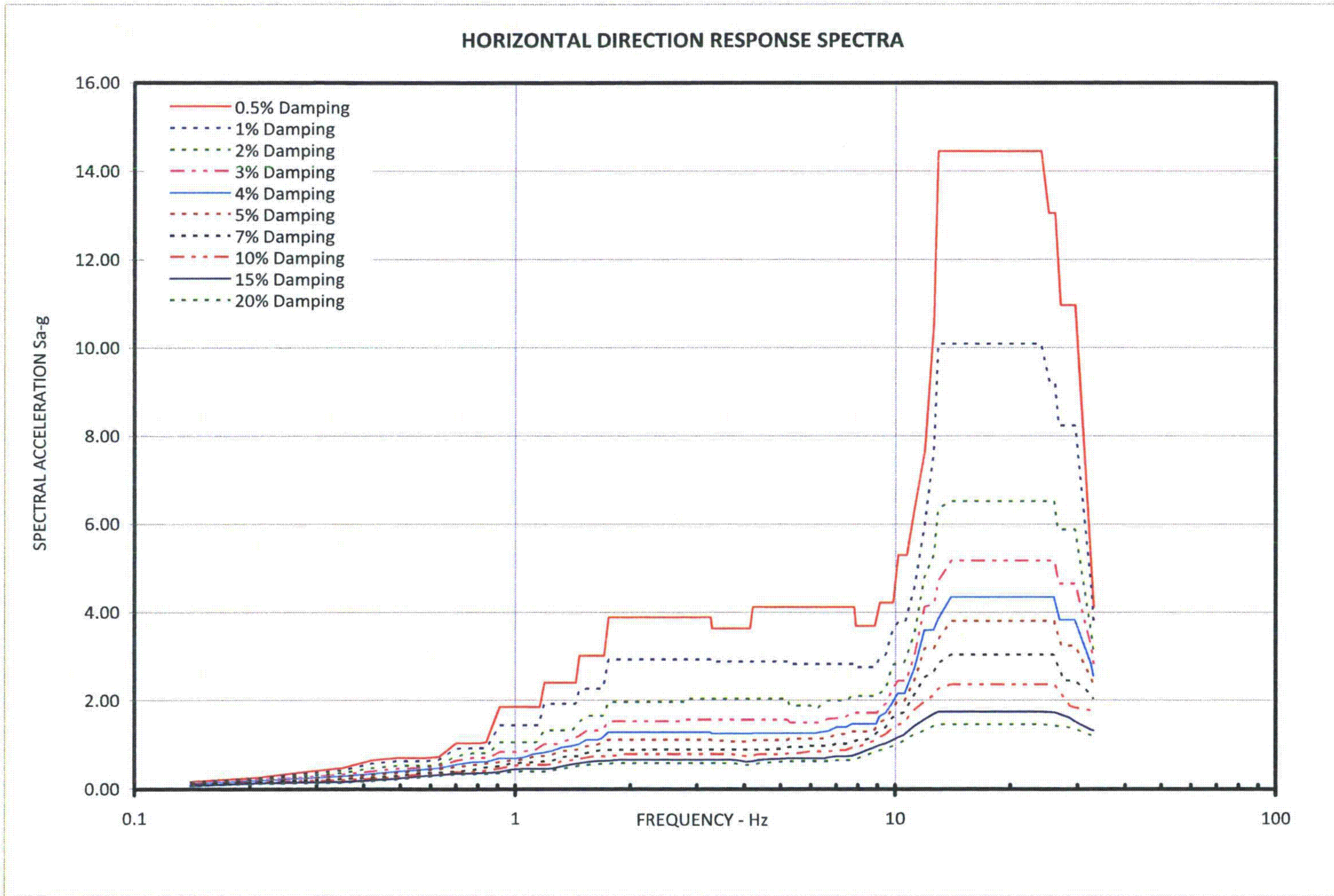

Figure 3H.7-31: Enveloped, Broadened Horizontal Response Spectra for DGFOTs

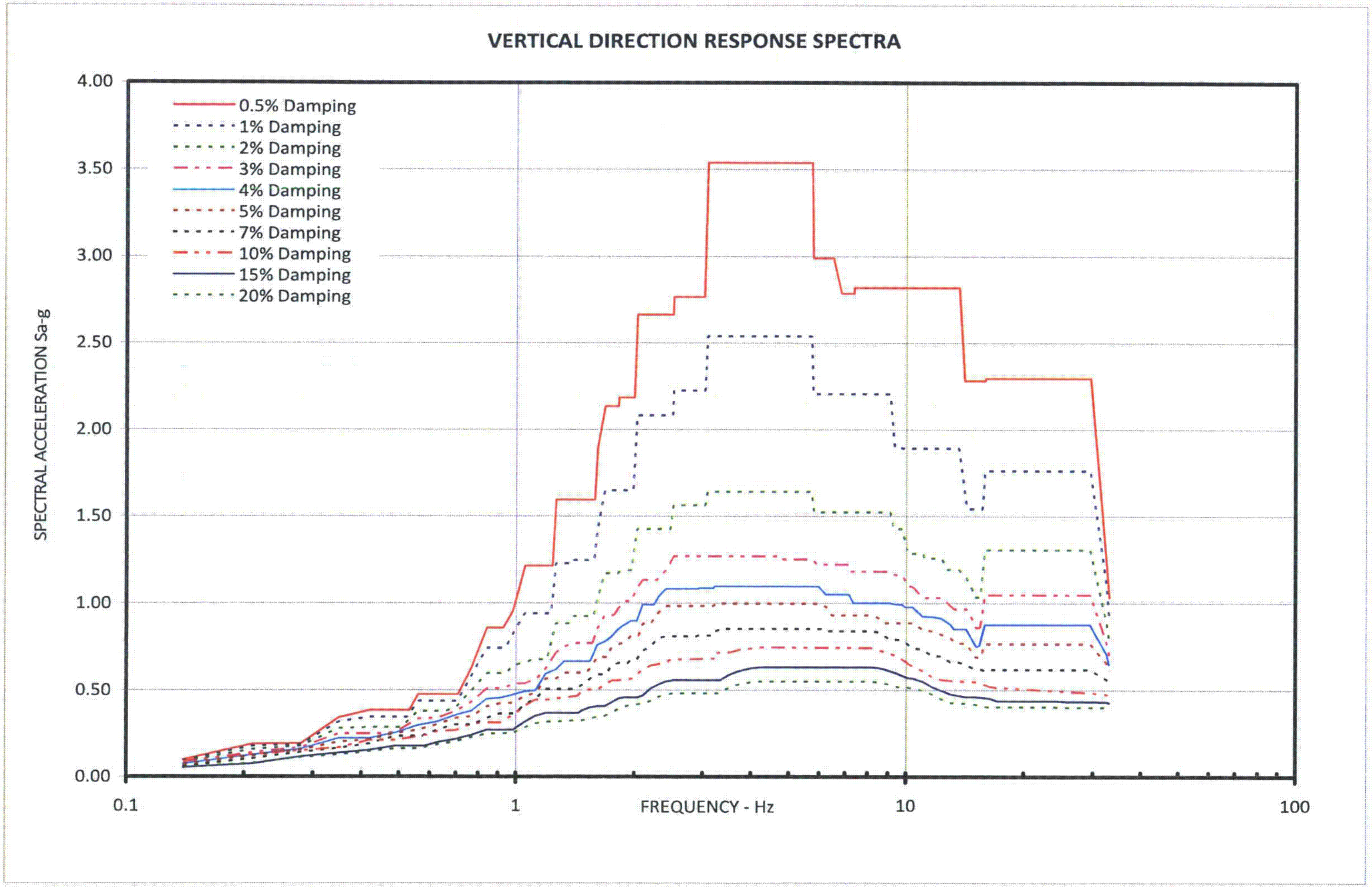

Figure 3H.7-32: Enveloped, Broadened Vertical Response Spectra for DGFOTs