REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**253-8300**
SRP Section:	**03.07.01 – Seismic Design Parameters**
Application Section:	**3.7.1**
Date of RAI Issue:	**10/19/2015**

Question No. 03.07.01-5

10 CFR 50 Appendix S requires that the horizontal component of the Safe Shutdown Earthquake Ground Motion in the free field at the foundation level of the structures must be an appropriate response spectrum with a peak ground acceleration of at least 0.1g. DCD Section 3.7.1.1.1, Design Ground Motion Response Spectra, and Appendix 3.7A.2.3, Strain-Compatible Free-Field Seismic Response Motions, state that Figures 3.7A-12 and 3.7A-13 in Appendix 3.7A show that the horizontal components of the CSDRS in the free-field at the foundation level ($CSDRS_{ff}$) of all APR1400 Seismic Category I structures satisfy the Appendix S 0.1g requirement. These two figures show the envelop of the $CSDRS_{ff}$ for all nine generic soil profiles for the Nuclear Island (NI) structures, the emergency diesel generator building (EDGB), and the diesel fuel oil tank (DFOT), compared to the design time history response spectra at the ground surface, and the CSDRS scaled to 0.1g PGA. For the standard design of APR1400, the nine soil profiles S1 through S9 represent a wide range of potential sites, with fundamental site frequencies in the range from 1.27 Hz to 12.01 Hz, as shown in Table 5-21 of APR1400-E-S-NR-14001-P, Rev. 0. In order for the staff to assess whether the CSDRS in the free field at the foundation level of the NI, EDGB, and DFOT structures meets the Appendix S 0.1g requirement, the applicant is requested to provide the following additional information:

a) **Plots comparing the $CSDRS_{ff}$ for each soil profile**

   i) Since each of the nine soil profiles can potentially be a valid COL site, these generic soil profiles should be assessed separately when comparing to the Appendix S 0.1g requirement. The use of the envelope, as shown in Figures 3.7A-12 and 3.7A-23, is not sufficient to show that all soil cases satisfy Appendix S. The staff notes that individual $CSDRS_{ff}$ are available in APR1400-E-S-NR-14001-P, Rev. 0; however, this technical report is not incorporated by reference (IBR) in the DCD, and the figures in the report do not show a direct comparison to an appropriate response spectrum with a peak ground acceleration of at least 0.1g. Therefore, the applicant is requested to supplement Figures 3.7A-12 and 3.7A-13, to show that each of the 9 $CSDRS_{ff}$ for the NI, EDGB, and DFOT structures satisfies the Appendix S 0.1g requirement.

[NOTE: In supplementing Figures 3.7A-12 and 3.7A-13, figures should be provided separately for each building; otherwise the figures would be too crowded. In addition, the curves should be rendered with different line styles/weights, in addition to different colors, to accommodate black-and-white copying.]

ii) The CSDRS are defined in DCD Section 3.7.1.1.1 as linearly interpolated on a log-log scale between the control points. The CSDRS scaled to 0.1g in Figures 3.7A-12, 3.7A-13, and 3.7A-14 are not correct because they are interpolated on a log-linear scale. Therefore, the CSDRS scaled to 0.1g should be corrected in Figures 3.7A-12 through 3.7A-14 of the DCD.

iii) Some of the labels in Figures 3.7A-12 and 3.7A-13 do not appear to be in the correct order. For example, labels for EDGB and DFOT appear to be switched in Figure 3.7A-12, and the labels for NI, EDGB, and DFOT seemingly should be EDGB, DFOT, and NI, respectively, in Figure 3.7A-13 (based on comparison to Figures 5-25 through 5-31 in APR1400-E-S-NR-14001-P, Rev. 0). In this report, Figure 5-26 appears to be exactly the same as Figure 5-25. The applicant is requested to correct these incorrect labels and figures in the DCD and report.

[NOTE: Given the mistakes cited above, all other figures and tables in the DCD and technical reports referenced in the DCD should be checked for accuracy, and any required revisions should be submitted to the staff as soon as possible, to facilitate an efficient staff review.]

b) Differences in $CSDRS_{ff}$ for Soil Profiles S6 and S7

Figures 5-25 and 5-26 of APR1400-E-S-NR-14001-P, Rev. 0 show that the $CSDRS_{ff}$ in the horizontal directions for soil profiles S6 and S7 appear to be significantly different from the other soil cases for the NI structure. Figure 5-27 shows that the $CSDRS_{ff}$ in the vertical direction for these two soil cases are also different but not as significant. The variation in the strain-compatible soil profiles among the 9 layered soil profiles are gradual, as shown in Figures 5-14 through 5-22, and as shown by the approximately linear behavior of the soil fundamental frequency on a log scale in Figure 5-24. The transfer functions shown in Figure 5-23 also indicate that amplification effect occurs at various frequency points below 50 Hz for all soil cases. It is not obvious to the staff why only $CSDRS_{ff}$ for S6 and S7 show the large dips as shown in Figures 5-25 and 5-26 and why other soil profiles for the NI structure (and all soil cases for EDGB and DFOT) do not show any dips at their fundamental frequencies. The applicant is requested to explain in detail (1) the method to calculate the $CSDRS_{ff}$ and (2) why soil cases S6 and S7 for the NI behave differently from the remaining soil cases, and if the results presented in the technical report are not accurate, to include the corrected results for all soil cases, for all 3 structures.

Response – (Rev. 3)

a) Figures 3.7A-12, 3.7A-13, and 3.7A-14 in DCD Tier 2 and Figures 5-25 through 5-31 in APR1400-E-S-NR-14001-P/NP, Rev.0, "Seismic Design Bases" will be revised as indicated in the attachment associated with this response. The revised figures are presented on a log-log scale. Labels on the revised figures, along with those which have not been changed in the DCD and technical reports, have been reviewed and confirmed to be correct. DCD Tier 2, Section 3.7.6 cites ARP1400-E-S-NR-14001-P/NP, Rev.0, "Seismic Design Bases" as Reference 9.

b) The $CSDRS_{ff}$ is generated from outcrop motions using generic soil profiles and the SHAKE91 program. The outcrop motions are calculated at the foundation elevation of each building. The procedure described in the NEI white paper Section 3.1.3, "Consistent Site-Response/Soil-Structure Interaction Analysis and Evaluation," (June 12, 2009) was followed to produce the results.

The relatively large dips in the response spectra at the foundation base elevation for the S6 and S7 soil cases for the NI are due to the specific site layering configurations and site properties of the S6 and S7 profiles. These dips are consistent with the lower amplitude in the site response transfer functions from the half-space to the foundation base level of the NI for S6 and S7 profiles. The lower transfer function amplitudes at the NI foundation base level are reflected in the $CSDRS_{ff}$ for S6 and S7 profiles at all frequency range as well as from 3 Hz to 20 Hz.

The transfer functions from the half-space to the outcropping layer at the foundation level of the NI structures, and DFOT/EDGB, using generic soil profiles and the SHAKE91 program, are indicated in Figures 1 through 16. And the transfer functions for S2, S6 and S7 profiles from the ground surface to the outcropping layer at the foundation base level of each of these structures are indicated in Figures 17 through 22. These comparisons for S6 and S7 indicate that dips in the response spectra for S6 and S7 profiles at the foundation base level are consistent with the transfer functions from the ground surface to the foundation base level.

The input parameters for calculating transfer functions using the SHAKE91 program are the thickness of the soil layer, damping ratio, unit weight density, and shear wave velocity. However, the discontinuity of the shear wave velocity is expected to affect the transfer functions among the various input parameters.

To demonstrate this expectation, the transfer functions and response spectra at upper and lower layers of the interfaces which have discontinuity of shear wave velocity are computed using generic soil profiles as shown in Figures 23 through 26. Figures 23 and 25 represent the transfer functions and response spectra at layers numbers 40 and 41 of the S1 profile, as presented in DCD Tier 2, Table 3.7A-1. As indicated in Figures 23 and 25, transfer functions and response spectra at layer numbers 40 and 41 are quite different from each other, even though soil layer numbers 40 and 41 have similar input parameters, for thickness, unit weight density, and damping ratio, which are representative of the sand soil type. Despite all other parameters being similar, the shear wave velocities of layer numbers 40 and 41 are not similar.

Similarly, Figures 24 and 26 represent the transfer functions and response spectra at layer numbers 20 and 21 of the S2 profile, as presented in DCD Tier 2, Table 3.7A-2. Soil layer numbers 20 and 21 have similar input parameters for the sand soil type, except for the shear wave velocities.

Thus, the large dips in the transfer functions and response spectra for the S6 and S7 profiles are reasonable because the interface which has a discontinuous shear wave velocity is located between the FIRS elevations of the NI structure and the DFOT/EDGB for the S6 and S7 profiles.

The soil profiles are provided on the enclosed CD (9 text files in CD)

A. Generic Soil Profile for S1

B. Generic Soil Profile for S2

C. Generic Soil Profile for S3

D. Generic Soil Profile for S4

E. Generic Soil Profile for S6

F. Generic Soil Profile for S7

G. Generic Soil Profile for S8

H. Generic Soil Profile for S9

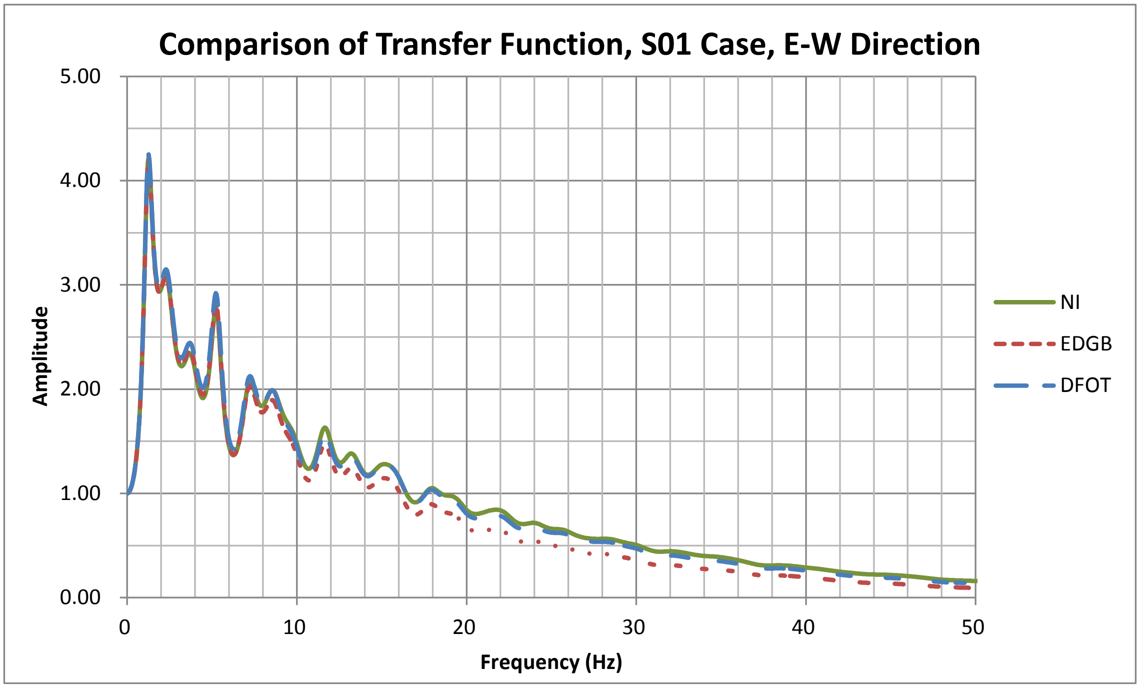

Figure 1: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S01 Case, E-W Direction

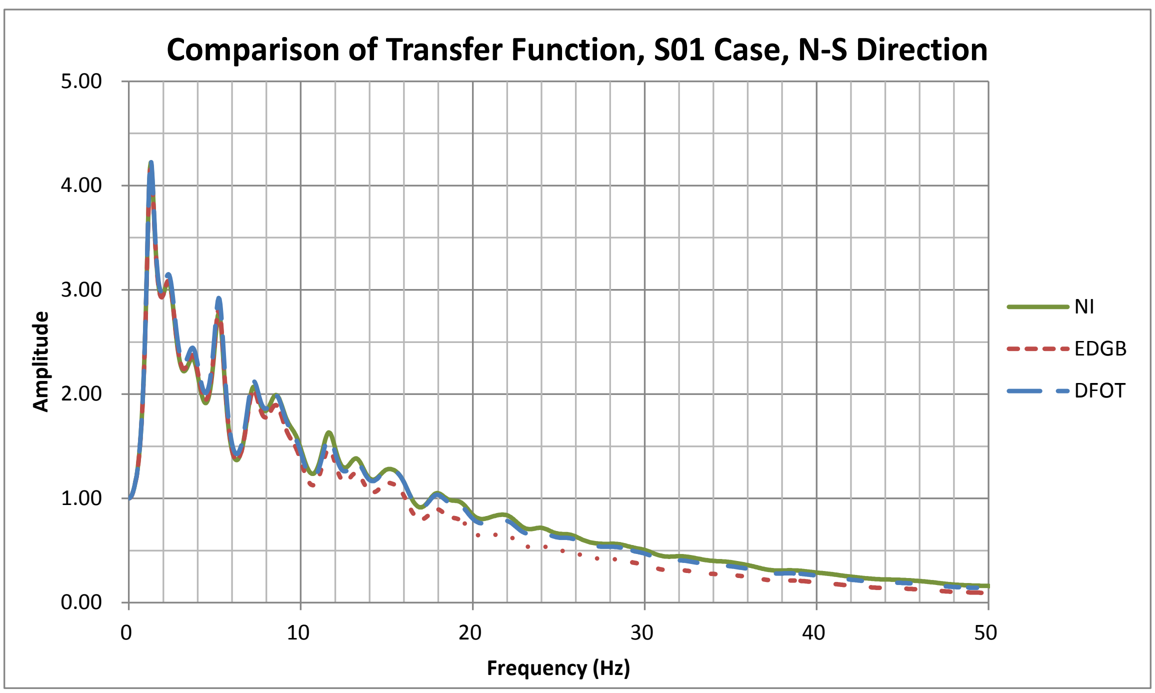

Figure 2: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S01 Case, N-S Direction

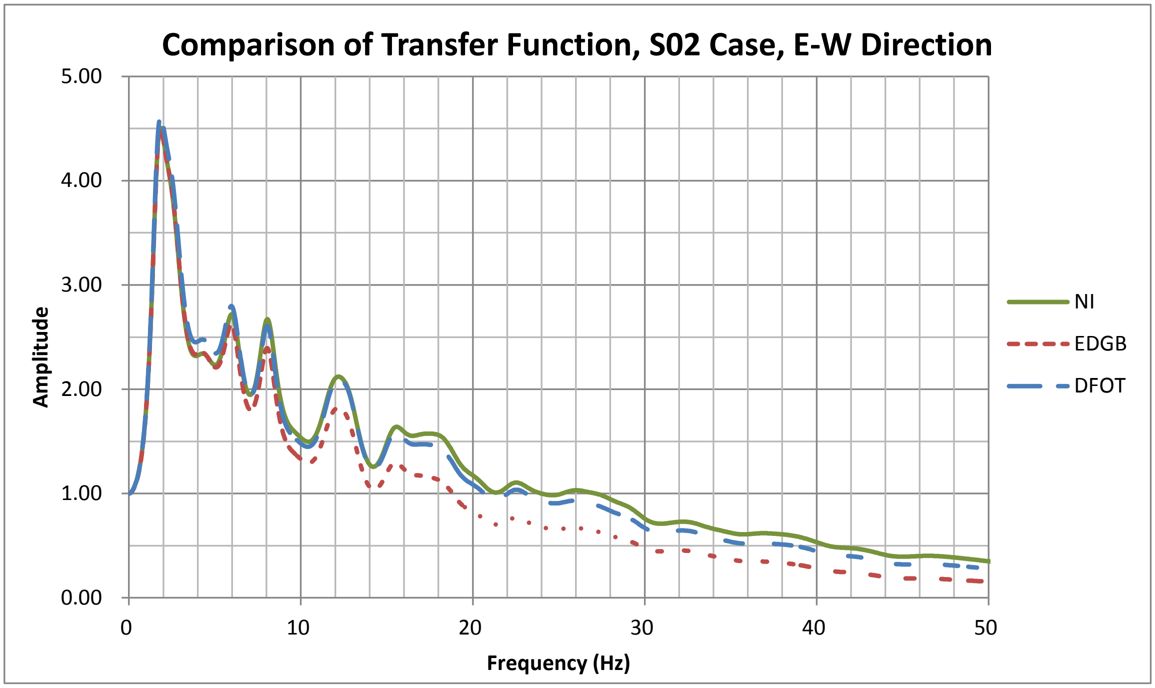

Figure 3: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S02 Case, E-W Direction

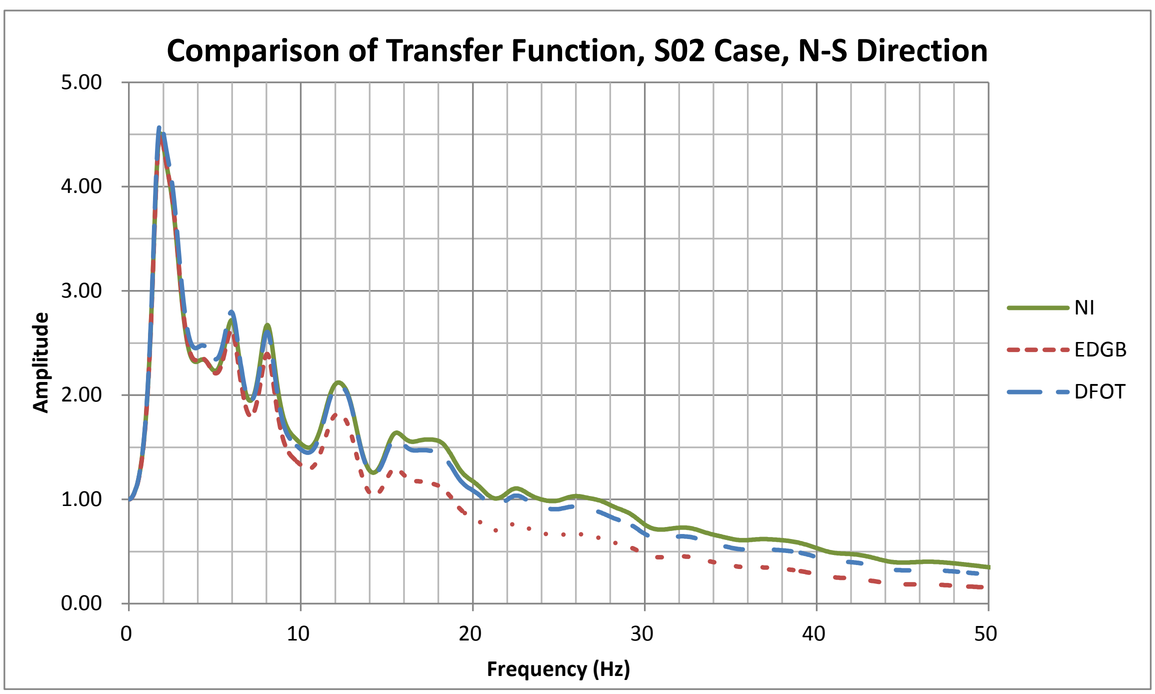

Figure 4: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S02 Case, N-S Direction

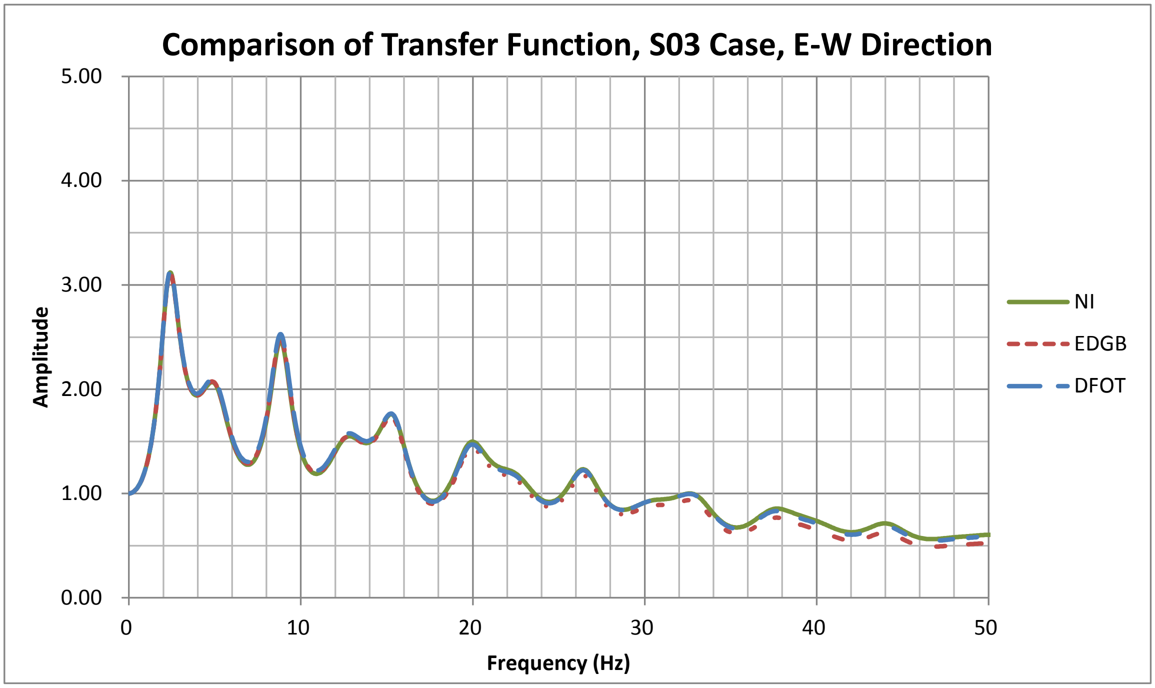

Figure 5: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S03 Case, E-W Direction

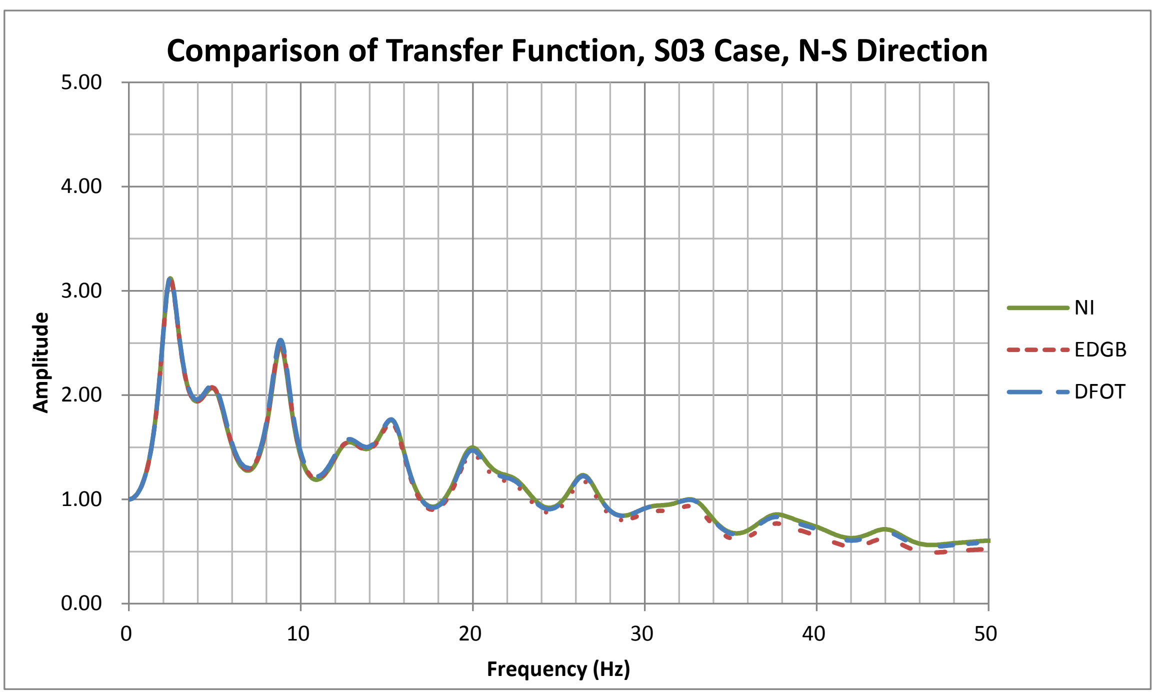

Figure 6: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S03 Case, N-S Direction

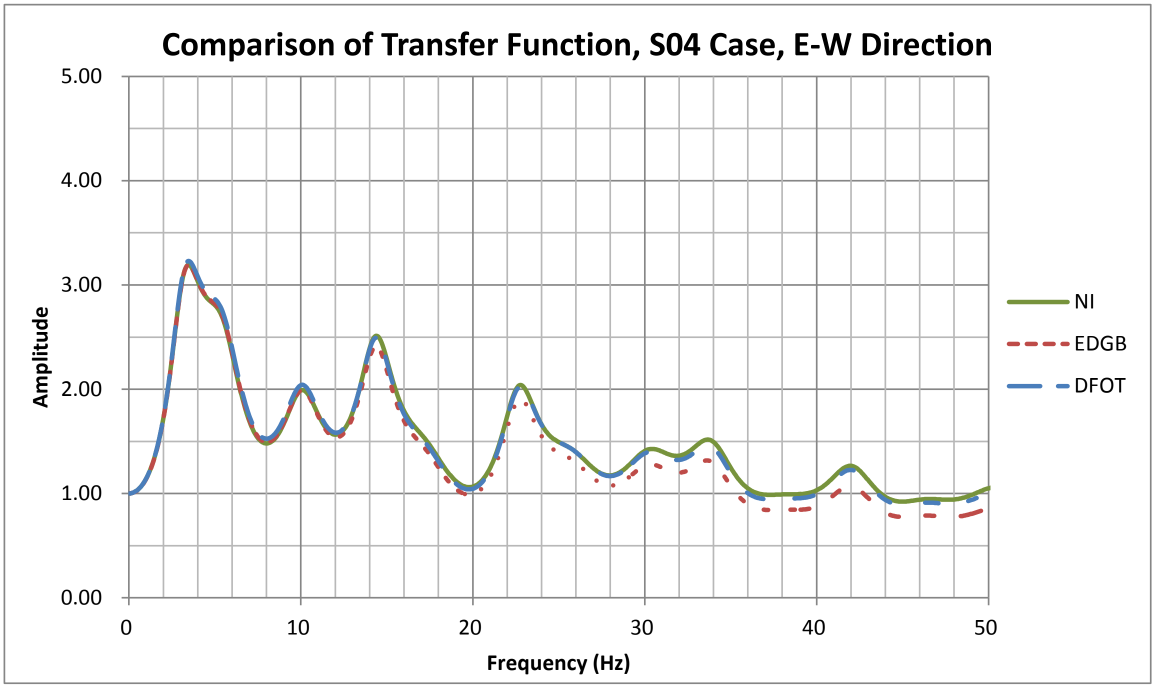

Figure 7: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S04 Case, E-W Direction

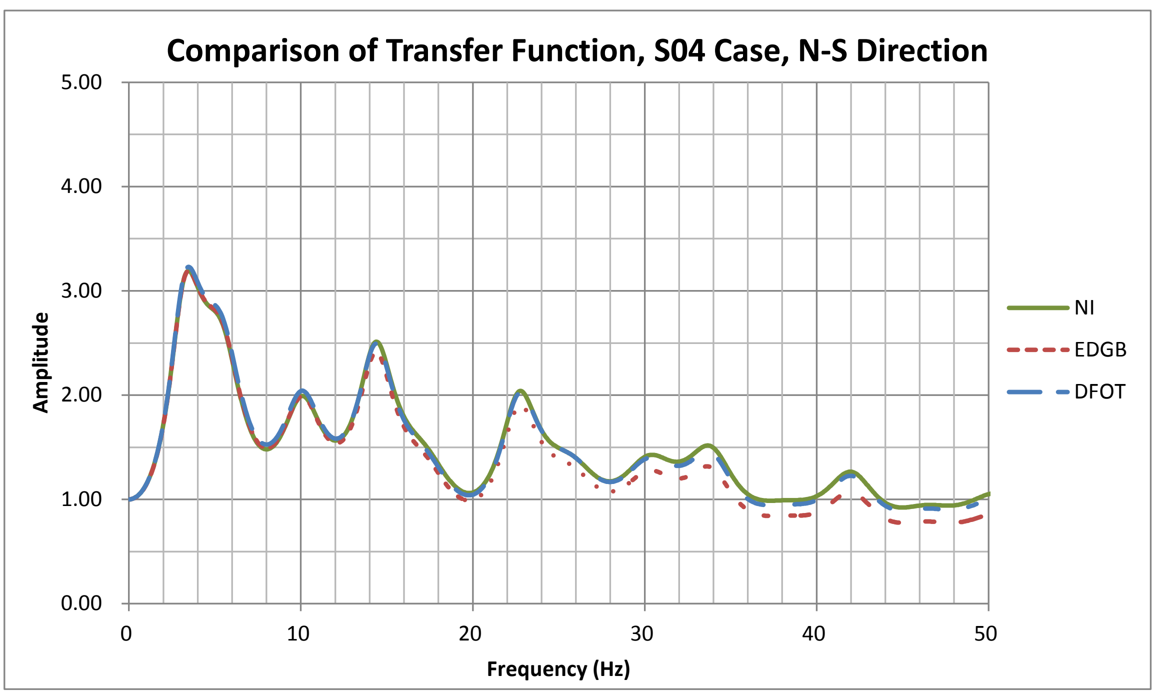

Figure 8: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S04 Case, N-S Direction

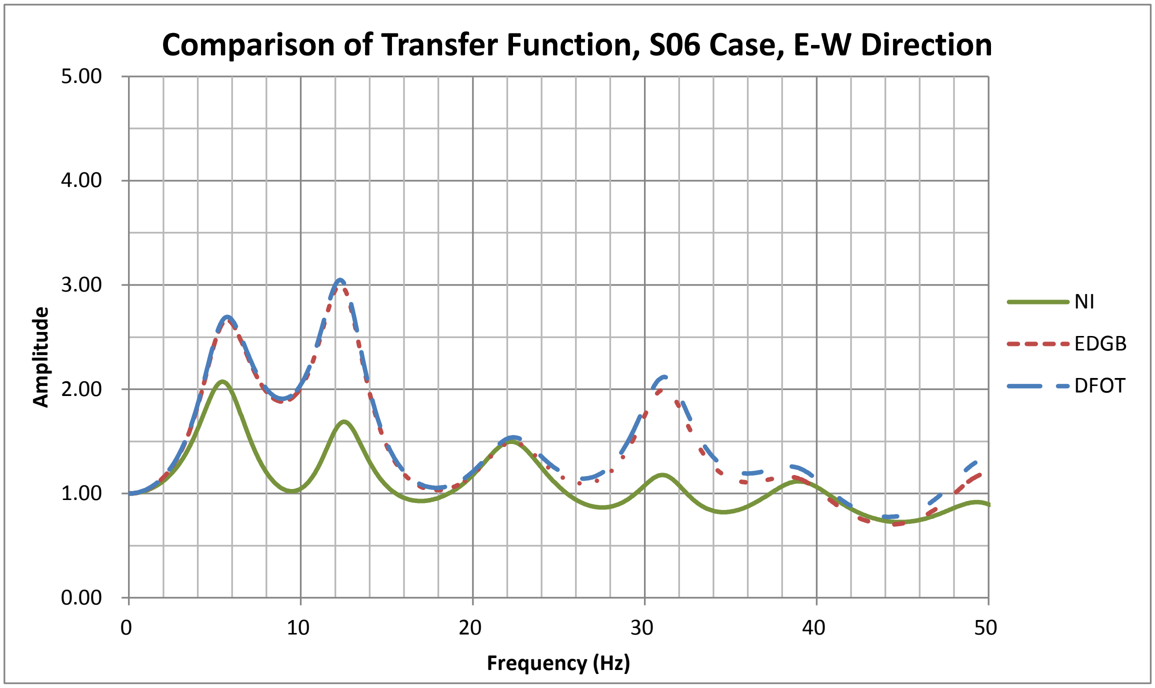

Figure 9: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S06 Case, E-W Direction

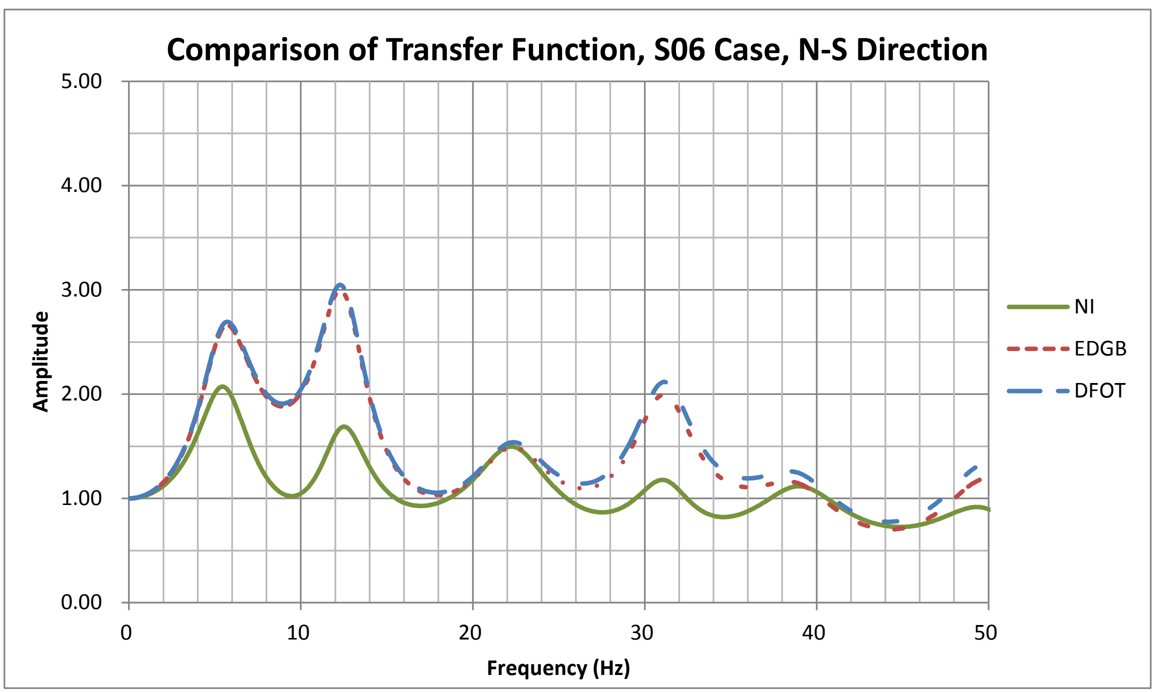

Figure 10: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S06 Case, N-S Direction

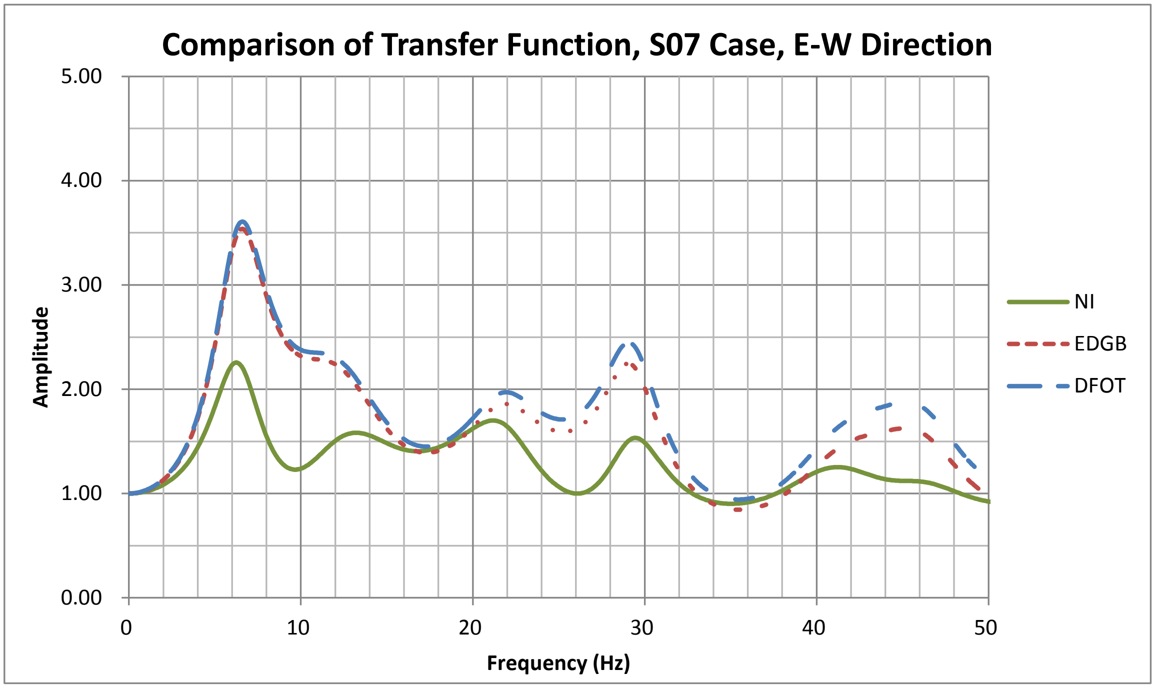

Figure 11: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S07 Case, E-W Direction

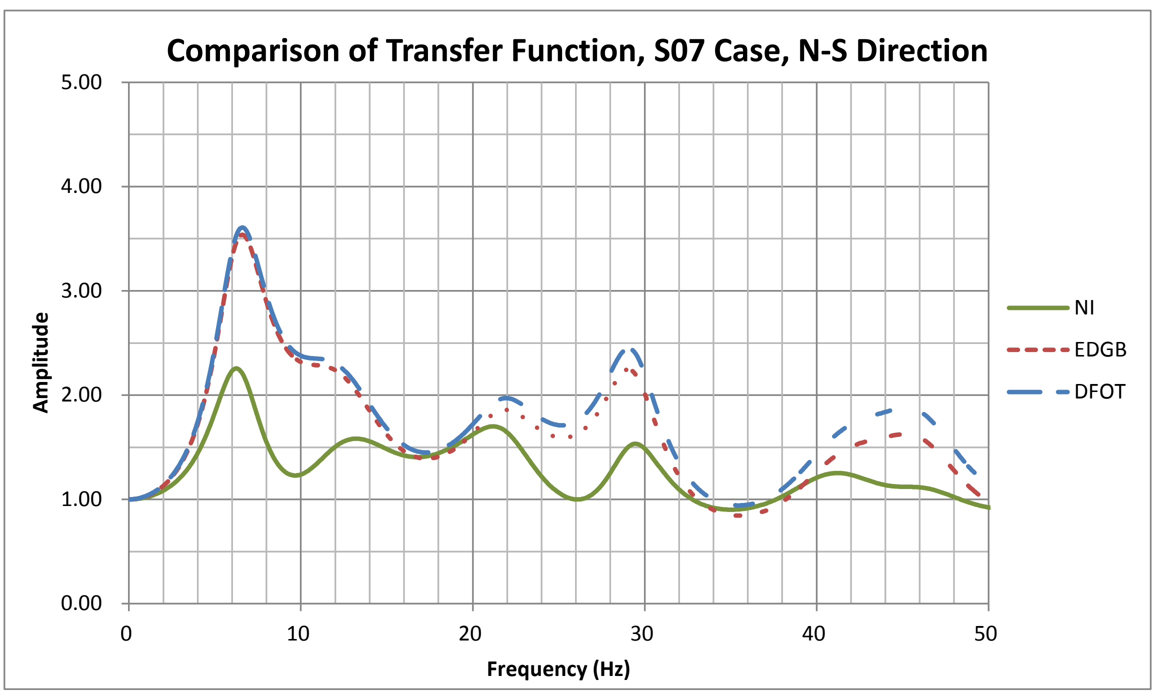

Figure 12: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S07 Case, N-S Direction

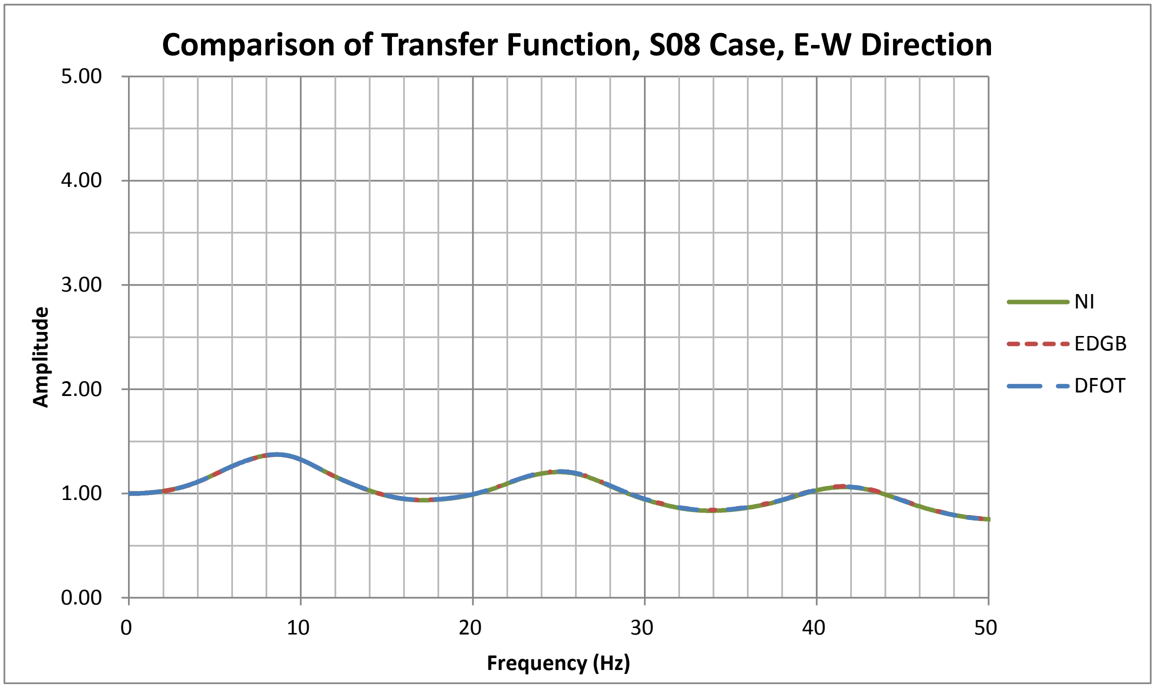

Figure 13: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S08 Case, E-W Direction

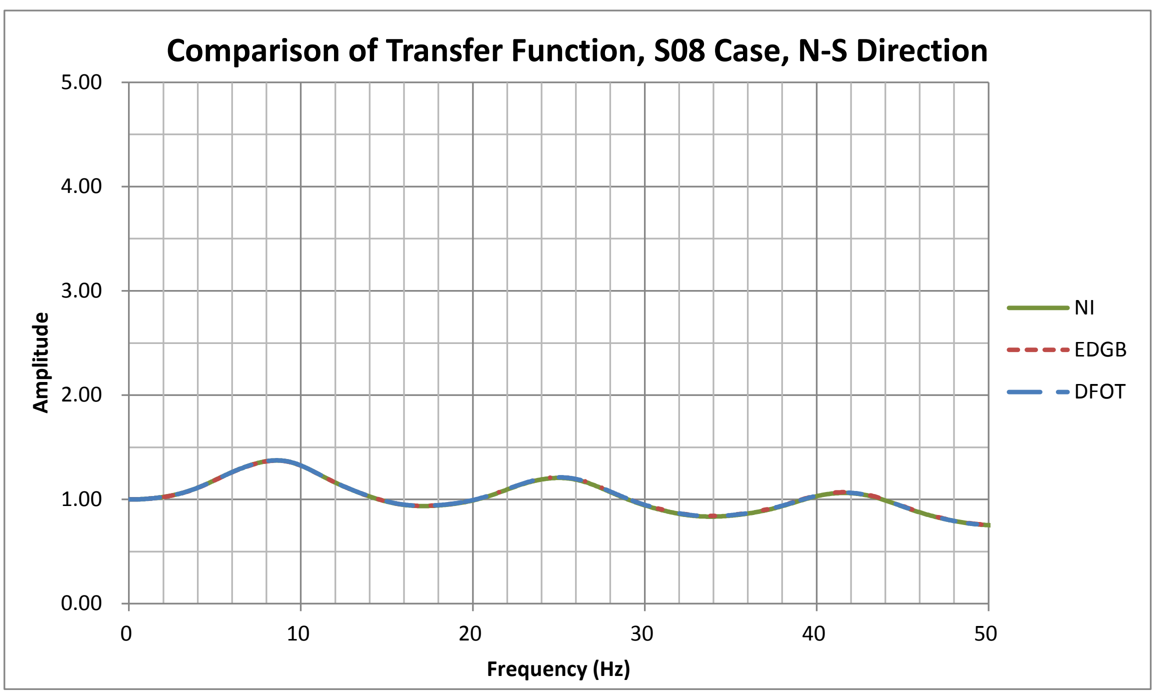

Figure 14: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S08 Case, N-S Direction

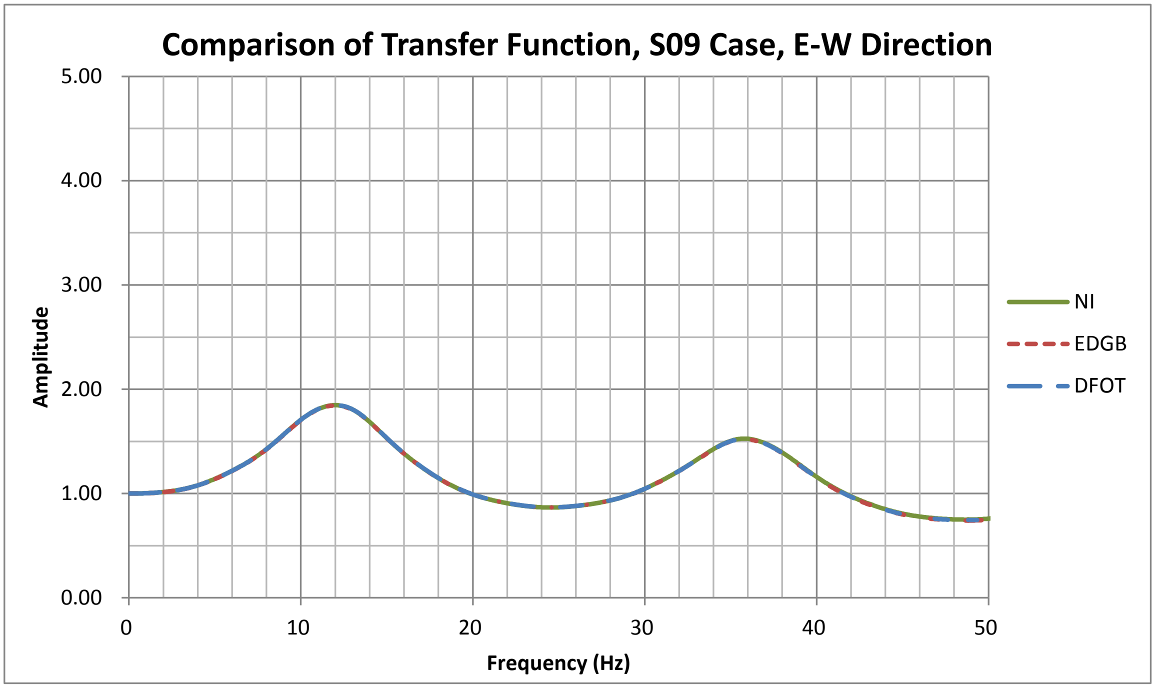

Figure 15: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S09 Case, E-W Direction

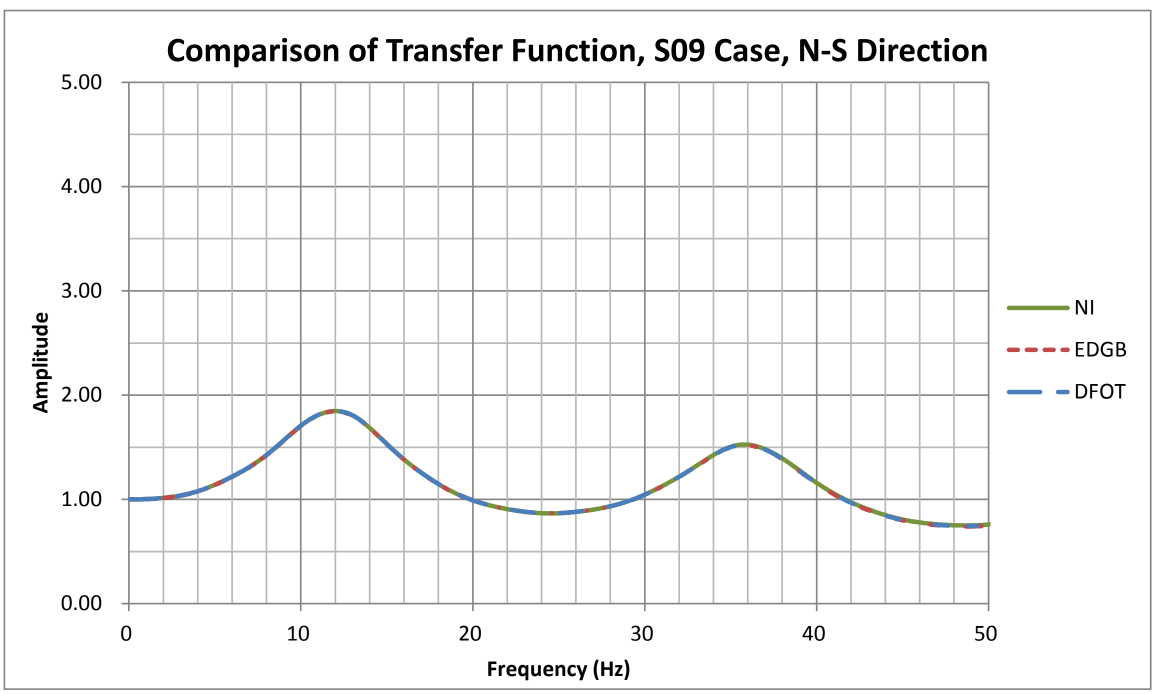

Figure 16: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S09 Case, N-S Direction

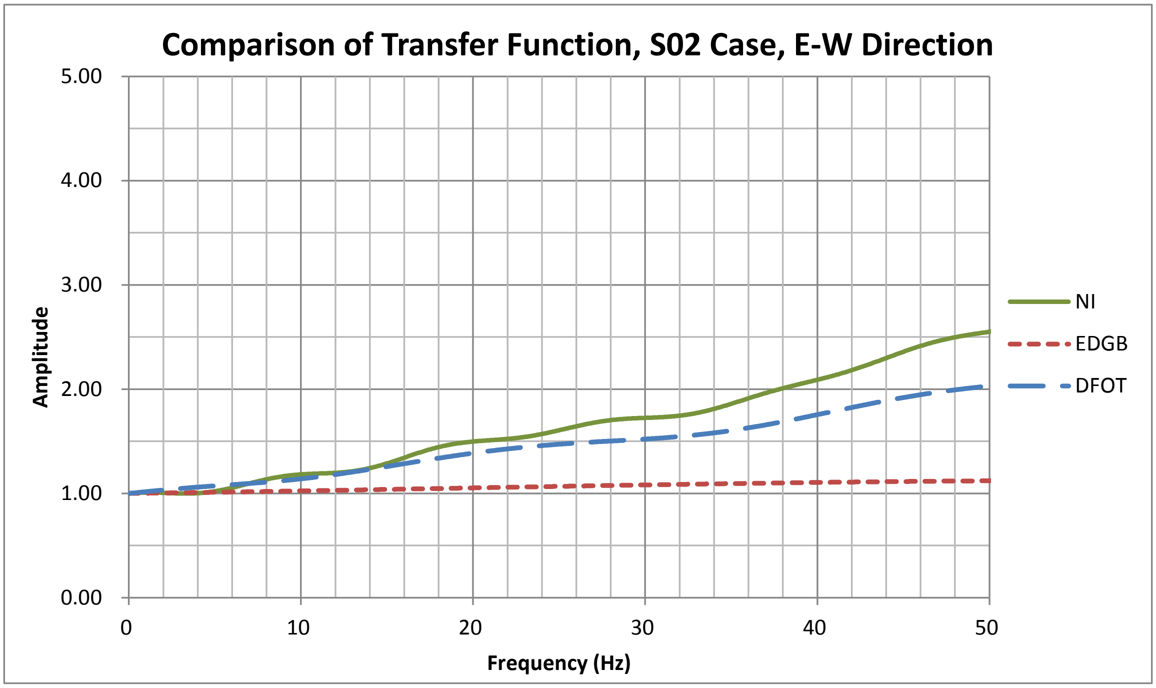

Figure 17: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S02 Case, E-W Direction

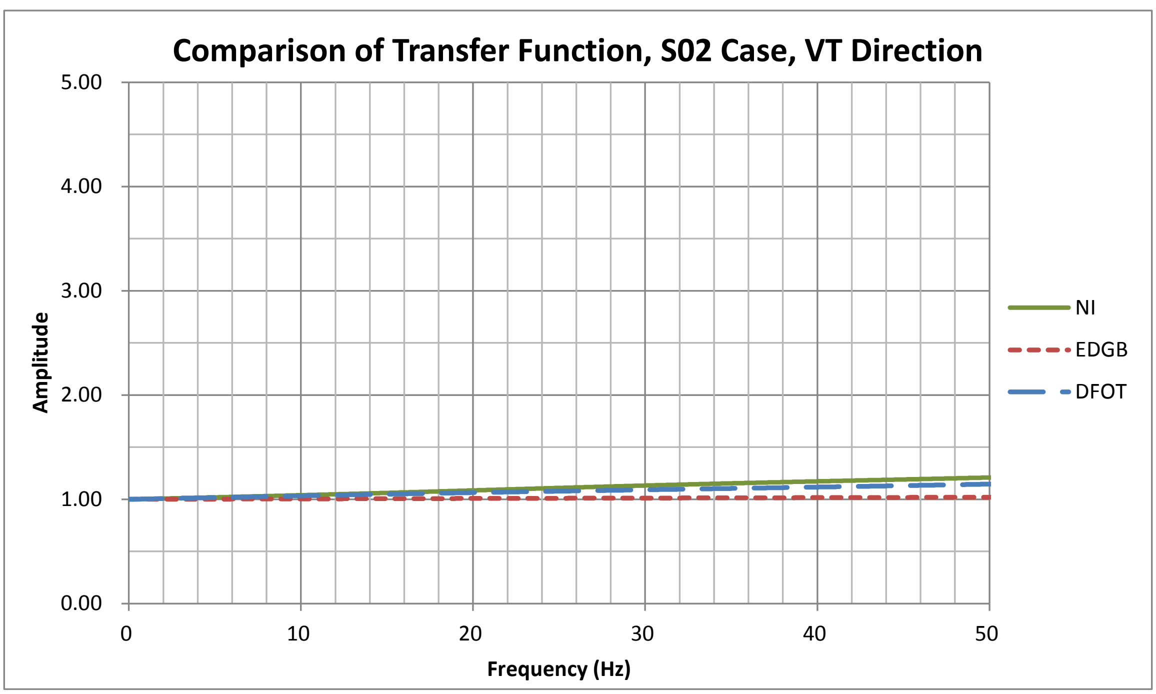

Figure 18: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S02 Case, Vertical Direction

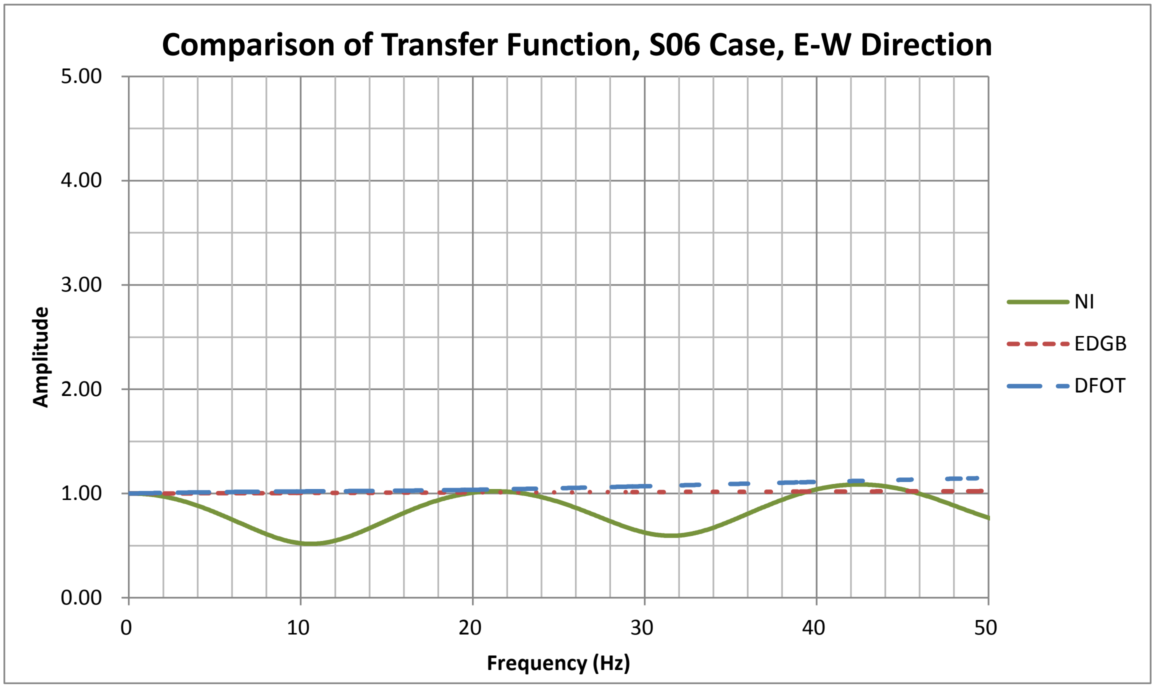

Figure 19: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S06 Case, E-W Direction

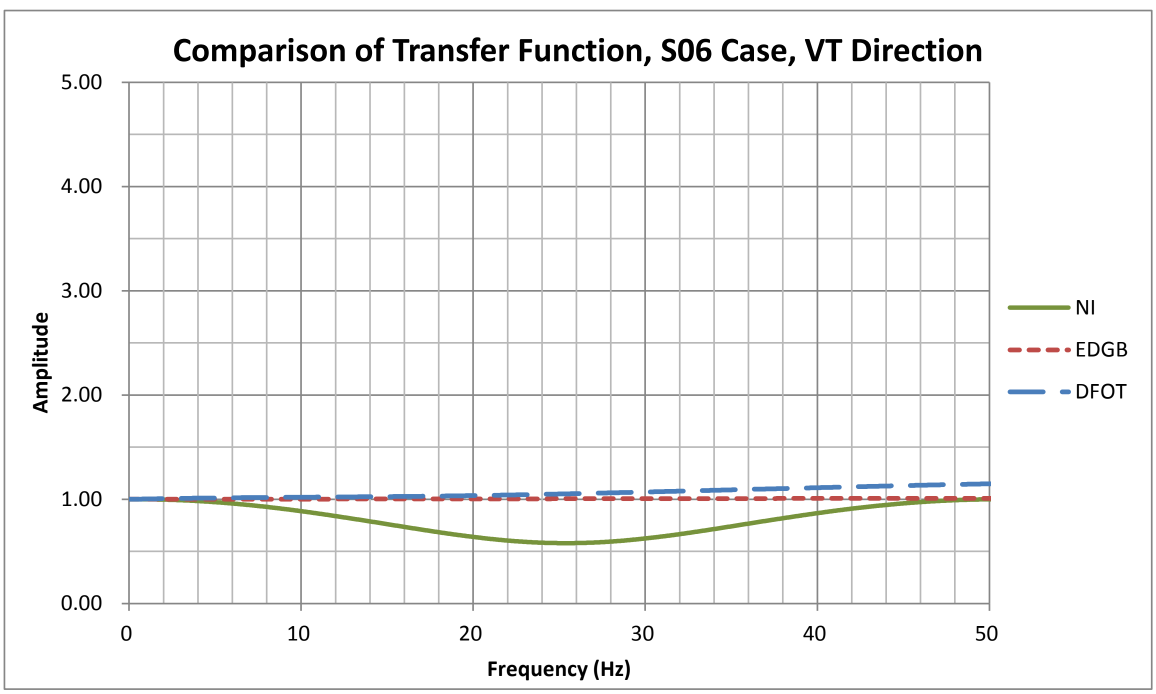

Figure 20: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S06 Case, Vertical Direction

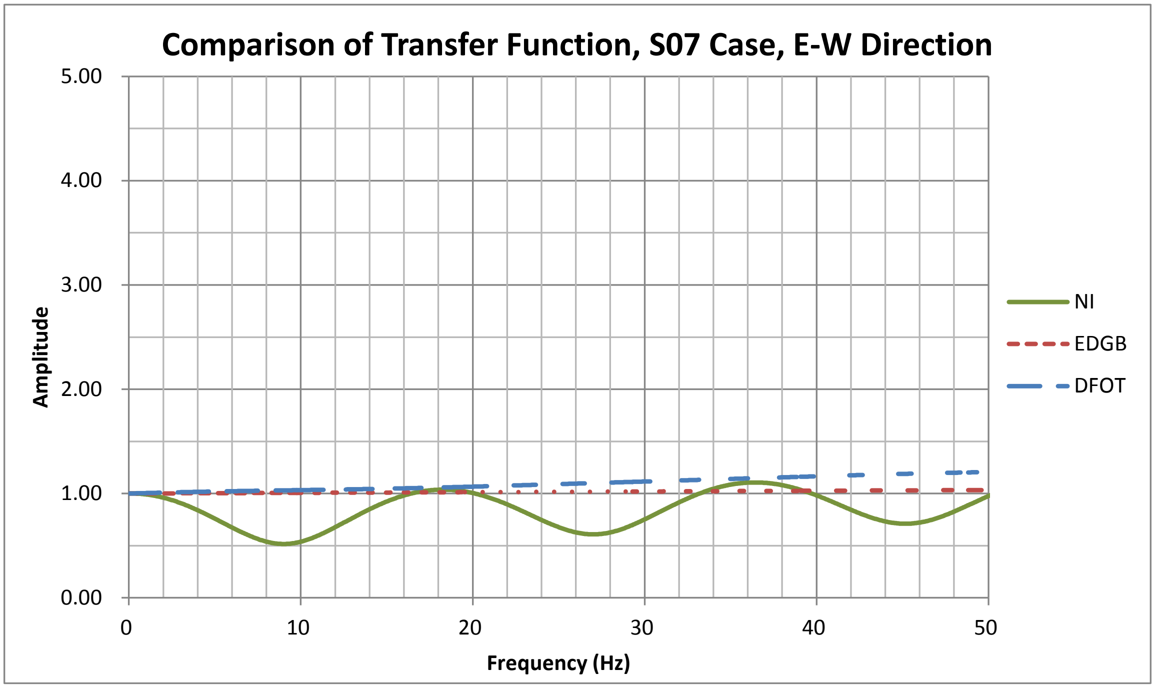

Figure 21: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S07 Case, E-W Direction

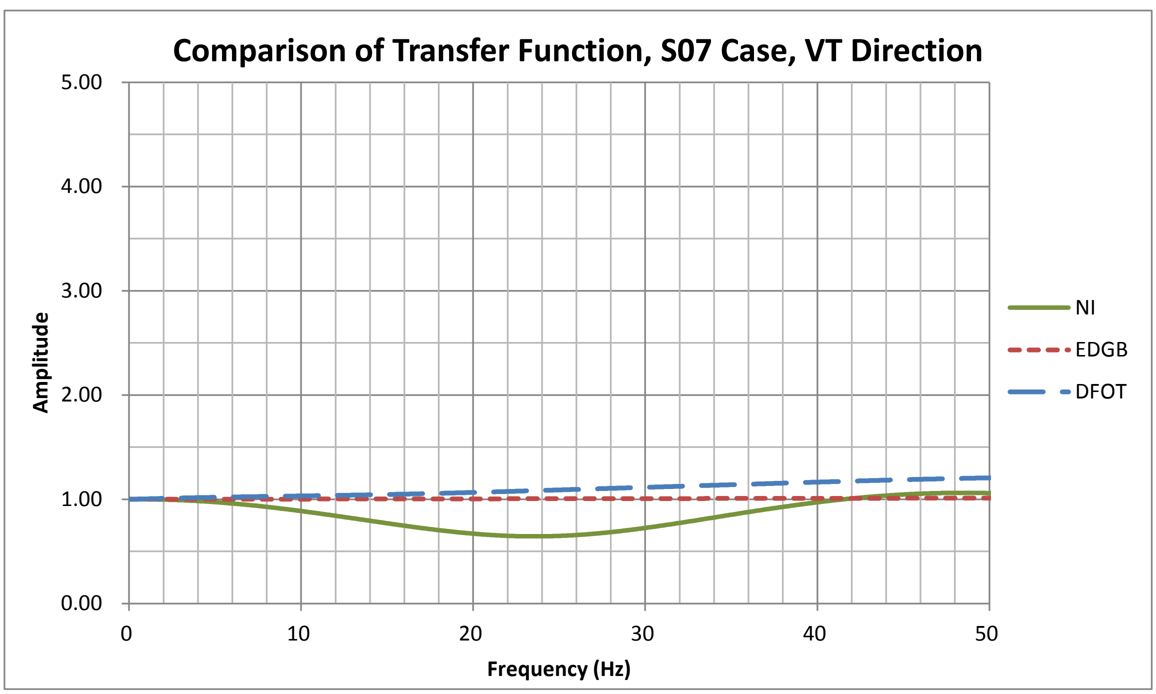

Figure 22: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S07 Case, Vertical Direction

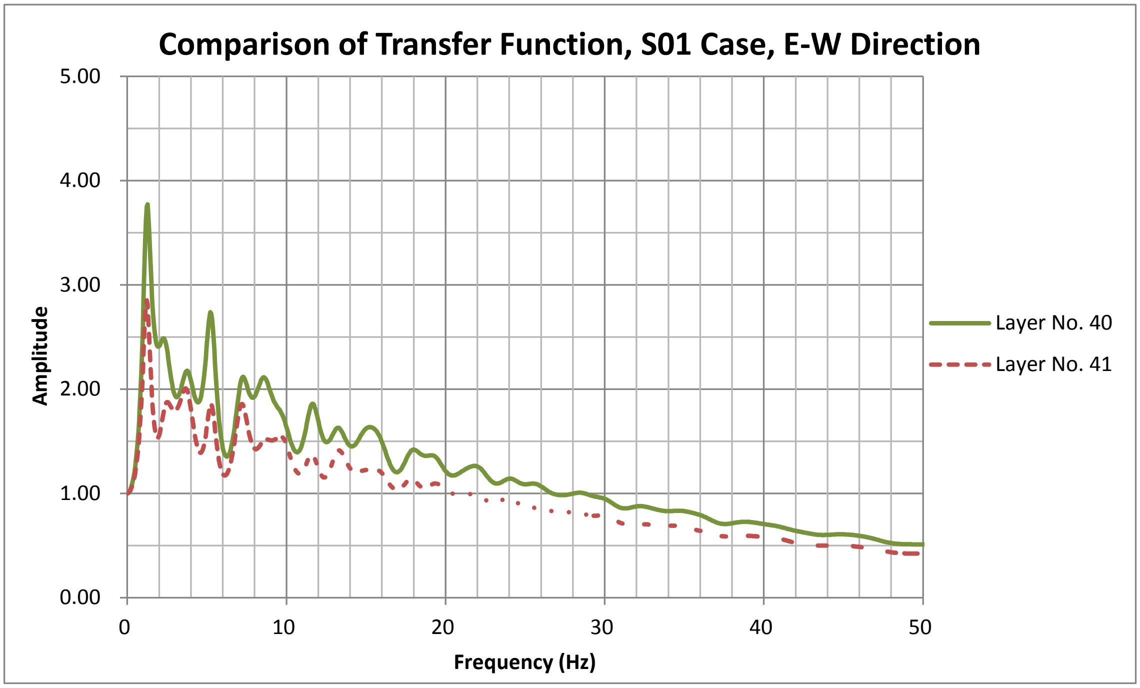

Figure 23: Comparison of Transfer Function for 40th and 41th Layer, S01 Case, E-W Direction

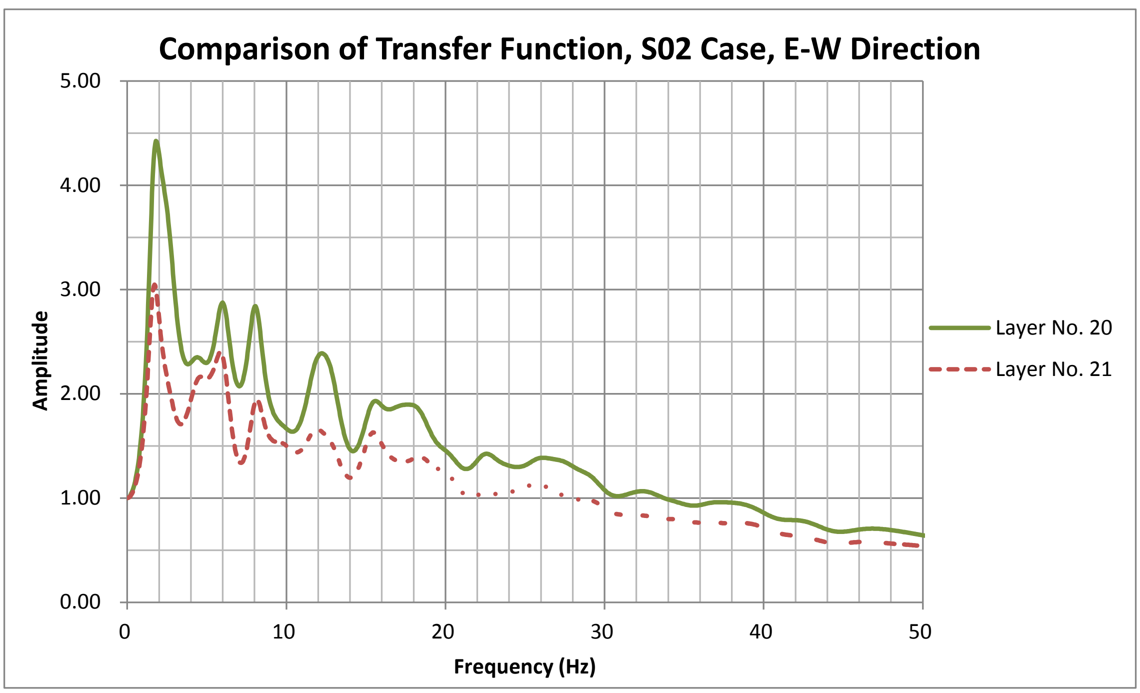

Figure 24: Comparison of Transfer Function for 20th and 21th Layer, S02 Case, E-W Direction

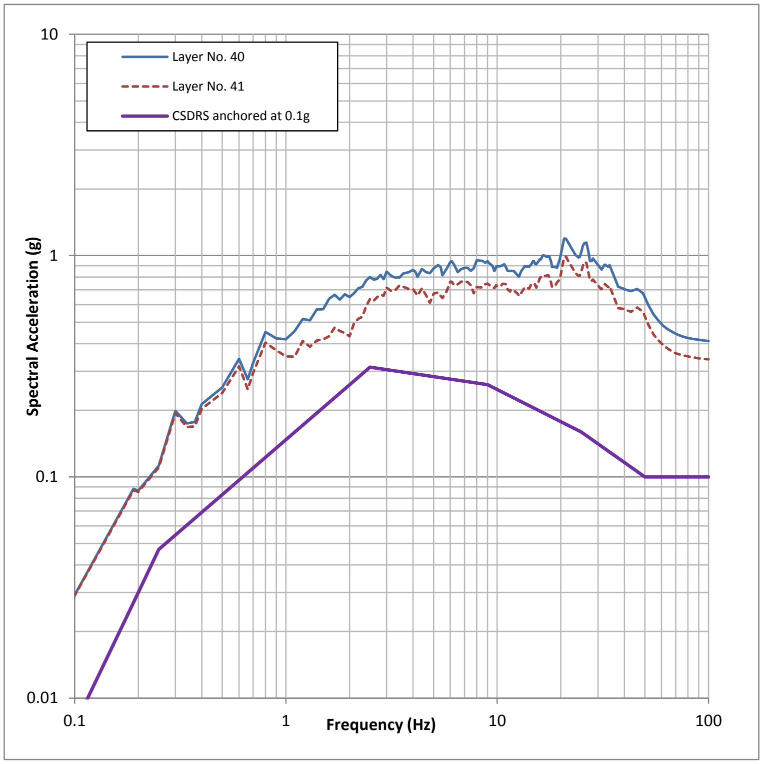

Figure 25: Comparison of Response Spectra for 40th and 41th Layer, S01 Case, E-W Direction

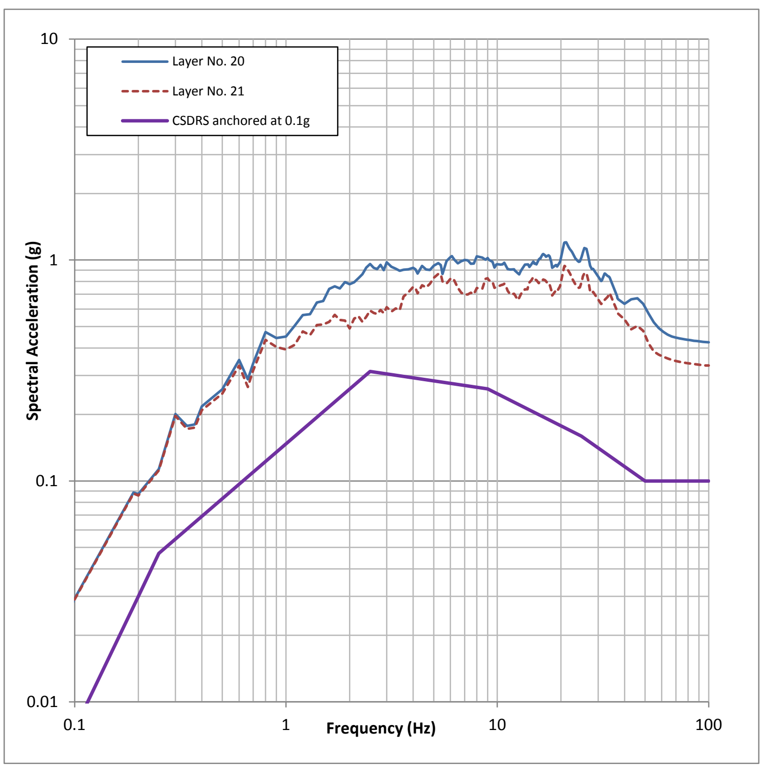

Figure 26: Comparison of Response Spectra for 20th and 21th Layer, S02 Case, E-W Direction

Impact on DCD

DCD Tier 2 Section 3.7.1.1.1 and Figures 3.7A-12 through 3.7A-14 will be revised, as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

Technical report APR1400-E-S-NR-14001-P/NP, Rev. 0, Section 5.3, Appendix A, and Figures 5-25 through 5-31 will be revised, as indicated in the attachment associated with this response.

3.7.1.1 Design Ground Motion

The design response spectra of the site-independent SSE are now referred to as the certified seismic design response spectra (CSDRS). The CSDRS and design time histories compatible with CSDRS are described in the following subsections.

3.7.1.1.1 Design Ground Motion Response Spectra

The peak ground acceleration (PGA) of the CSDRS has been established as 0.3g for the APR1400 design for both the horizontal and vertical directions.

The horizontal and vertical CSDRS for the APR1400 are based on the NRC Regulatory Guide (RG) 1.60 (Reference 3) response spectra, enriched in the high frequency range in the following manner.

a. The spectral amplitudes of the horizontal and vertical response spectra at control frequencies 9 Hz and below are equal to those of the NRC RG 1.60 response spectra.

b. The control frequency at which the PGA is reached is changed from 33 Hz to 50 Hz for both the horizontal and vertical spectra.

c. A control frequency at 25 Hz is added. The spectral amplitudes at 25 Hz are set to the NRC RG 1.60 response spectra at 25 Hz scaled by a factor of 1.30 for both the horizontal and vertical spectra.

d. Linearly vary the modified spectra, on a log-log-scale, between the control frequencies 9 Hz, 25 Hz, and 50 Hz.

The digitized values of the resulting APR1400 horizontal and vertical CSDRS for 2, 3, 4, 5, 7, and 10 percent damping values are provided in Table 3.7-1. The APR1400 horizontal and vertical CSDRS are presented in Figures 3.7-1 and 3.7-2, respectively.

The CSDRS are applied at the finished grade in the free-field as an additional requirement from 10 CFR Part 50, Appendix S. ~~Figures 3.7A-12 and 3.7A-13~~ in Appendix 3.7A show

Figures 3.7A-12 (1 of 3 and 2 of 3), 3.7A-13 (1 of 3 and 2 of 3), and 3.7A-14 (1 of 3 and 2 of 3) that the horizontal components of CSDRS in the free-field at the foundation level of the APR1400 standard plant seismic Category I structures satisfy the PGA of at least 0.1g. The vertical component of CSDRS in the free-field at the foundation level of the APR1400 standard plant seismic Category I structures is presented in ~~Figure 3.7A-14~~ Figures 3.7A-12 (3 of 3), 3.7A-13 (3 of 3), and 3.7A-14 (3 of 3) in Appendix 3.7A. The site response motions in Figure 3.7A-12 through 3.7A-14 correspond to outcrop motion in the free-field.

The site-specific seismic design can be developed for other seismic Category I and II SSCs, which are not included in the APR1400 standard plant design, at the combined license (COL) stage using the site-specific SSE derived from the ground motion response spectra (GMRS) in accordance with NRC RG 1.208 (Reference 4). In this case, the COL applicant is to determine the site-specific SSE and OBE that are applied to the seismic design of the site-specific seismic Category I and II SSCs and to the basis for the plant shutdown and is to verify the appropriateness of the site-specific SSE and OBE (COL 3.7(1)).

The COL applicant is to confirm that the horizontal components of the site-specific SSE ground motion in the free-field at the foundation level of the structures that are not included in the APR1400 standard plant design satisfy a PGA of at least 0.1g (COL 3.7(2)).

3.7.1.1.2 Design Ground Motion Time History

The three design acceleration time histories composed of two horizontal (H1 and H2) and one vertical components (VT), which envelop the CSDRS, are applied in both soil-structure interaction analyses and fixed-base analyses of seismic Category I structures. The initial seed motions that were modified to create the design time histories are actual seed-recorded Northridge earthquake time histories.

The design time histories are generated with an increment of time size of 0.005 second to provide a Nyquist frequency of 100 Hz. Figures 3.7-3, 3.7-4, and 3.7-5 show the acceleration, velocity, and displacement time histories for H1, H2, and VT components for each time step, respectively. The design time histories, H1, H2, and VT, are applied in the east-west (E-W) direction, north-south (N-S) direction, and vertical direction, respectively. The absolute values of correlation coefficients for each pair of the design time histories are as follows:

Correlation coefficient for H1 and H2 = 0.032

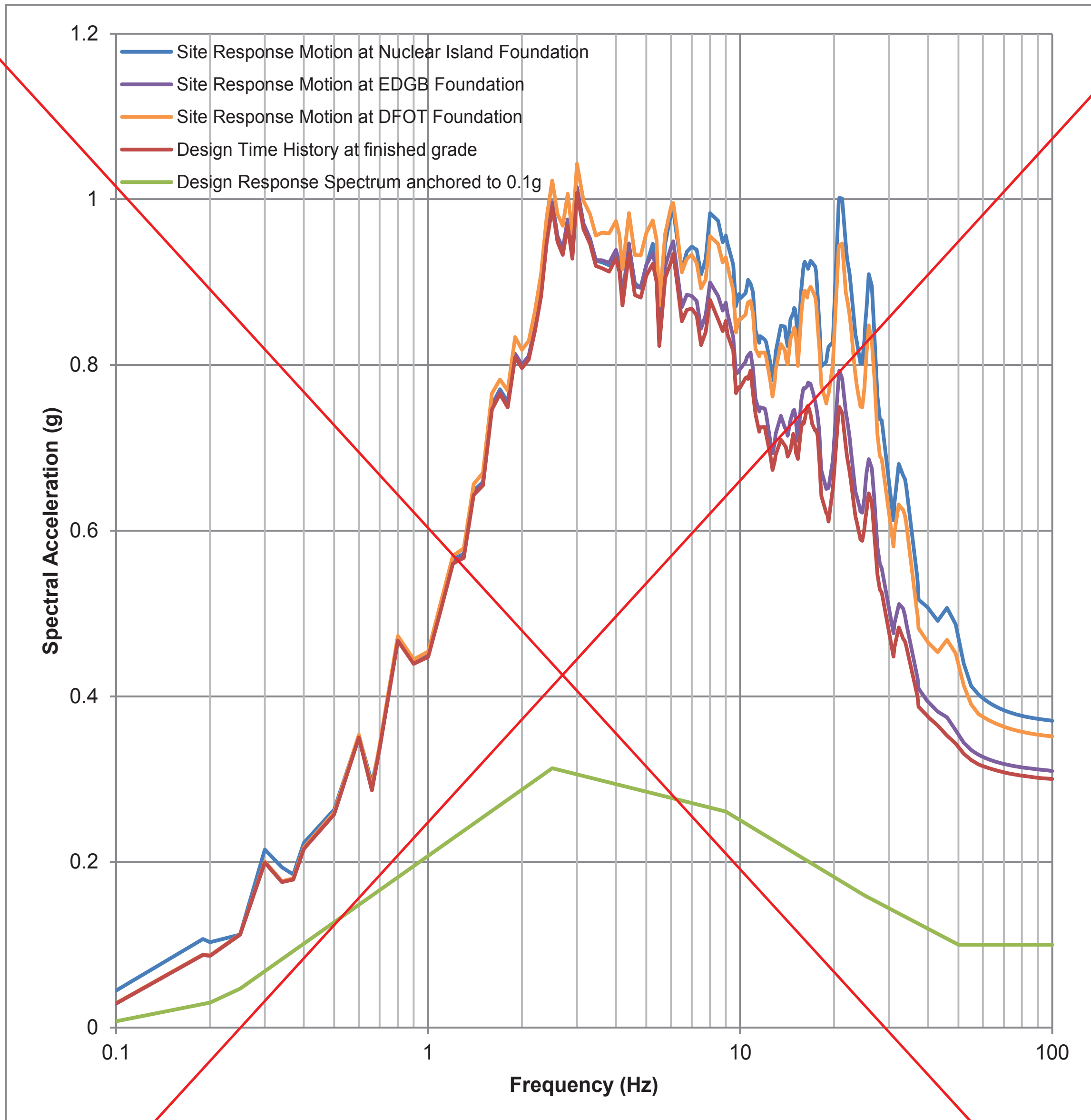

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Seismic Category I Structures, E-W Motion, 5% damping

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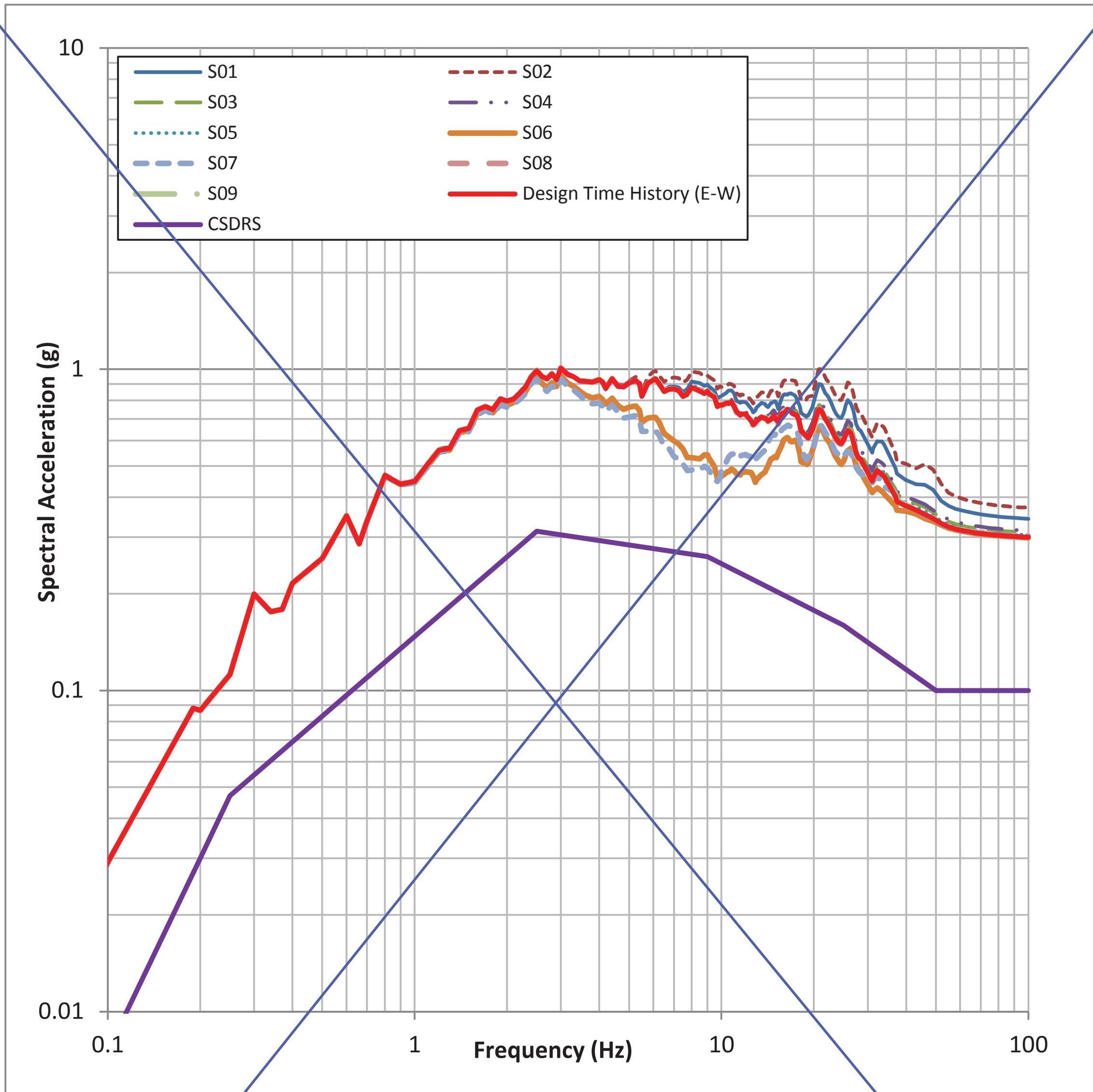

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Nuclear Island Structure, E-W Motion, 5% damping
(1 of 3)

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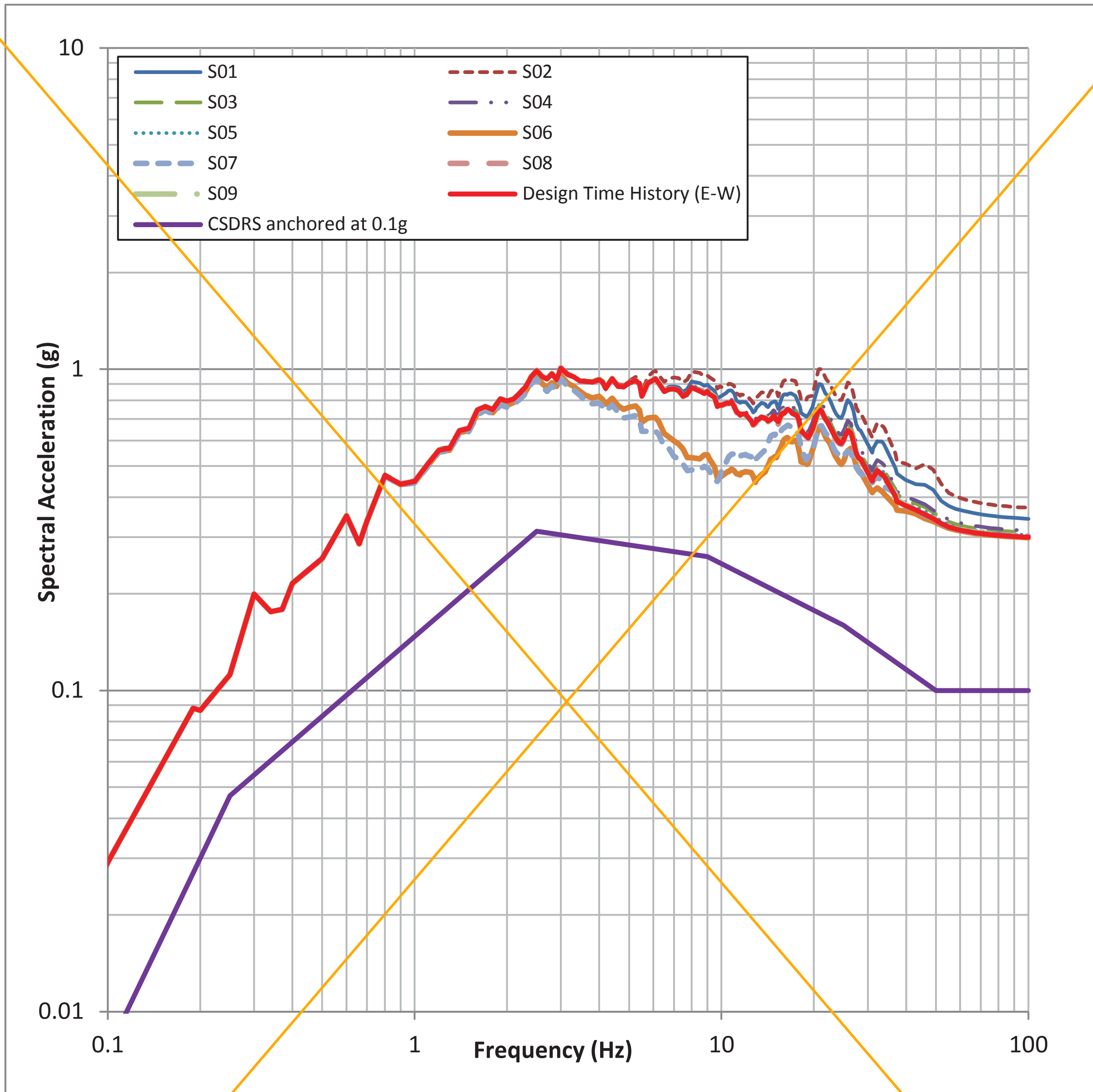

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Nuclear Island Structure, Outcrop E-W Motion, 5% damping

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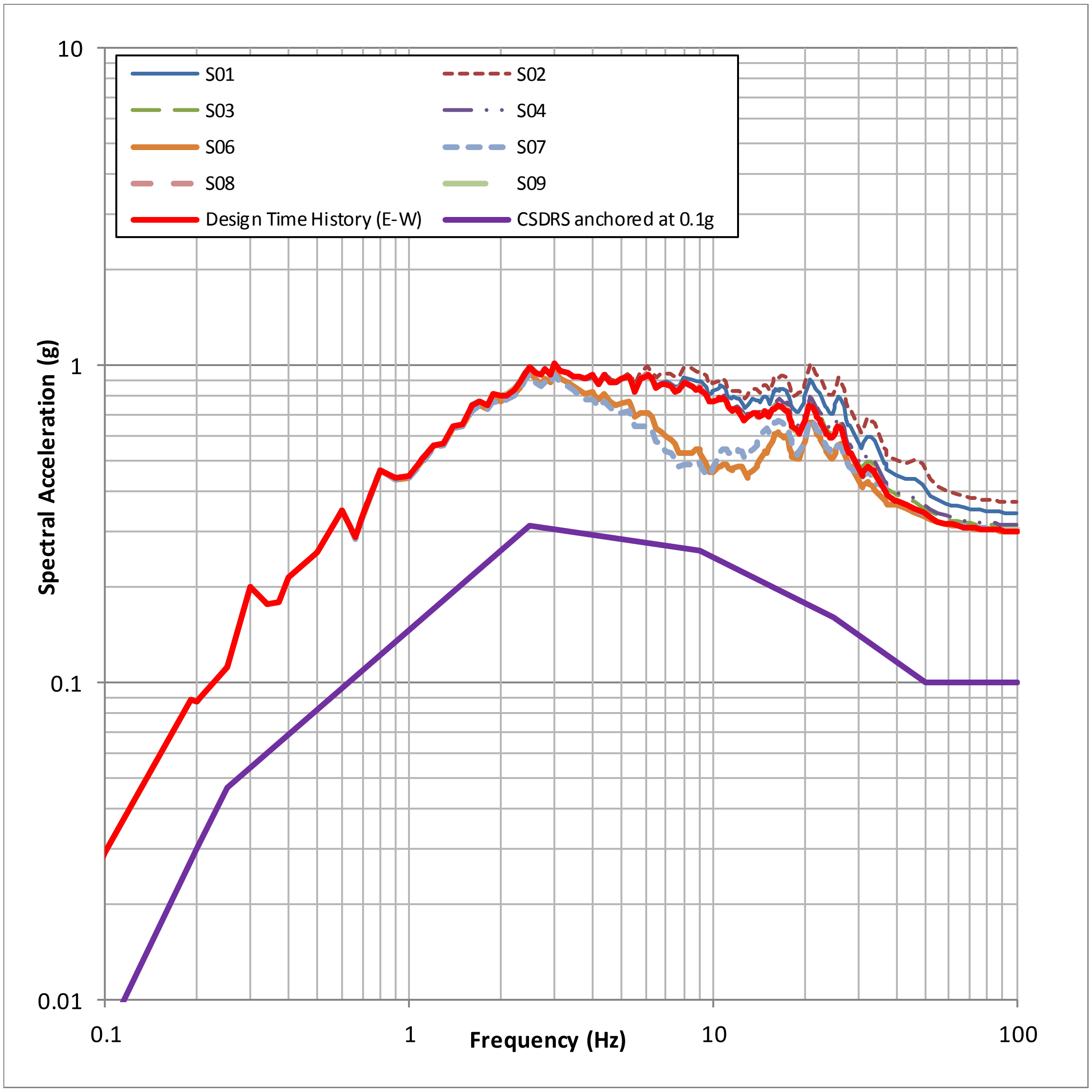

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Nuclear Island Structure, E-W Motion, 5% damping
(1 of 3)

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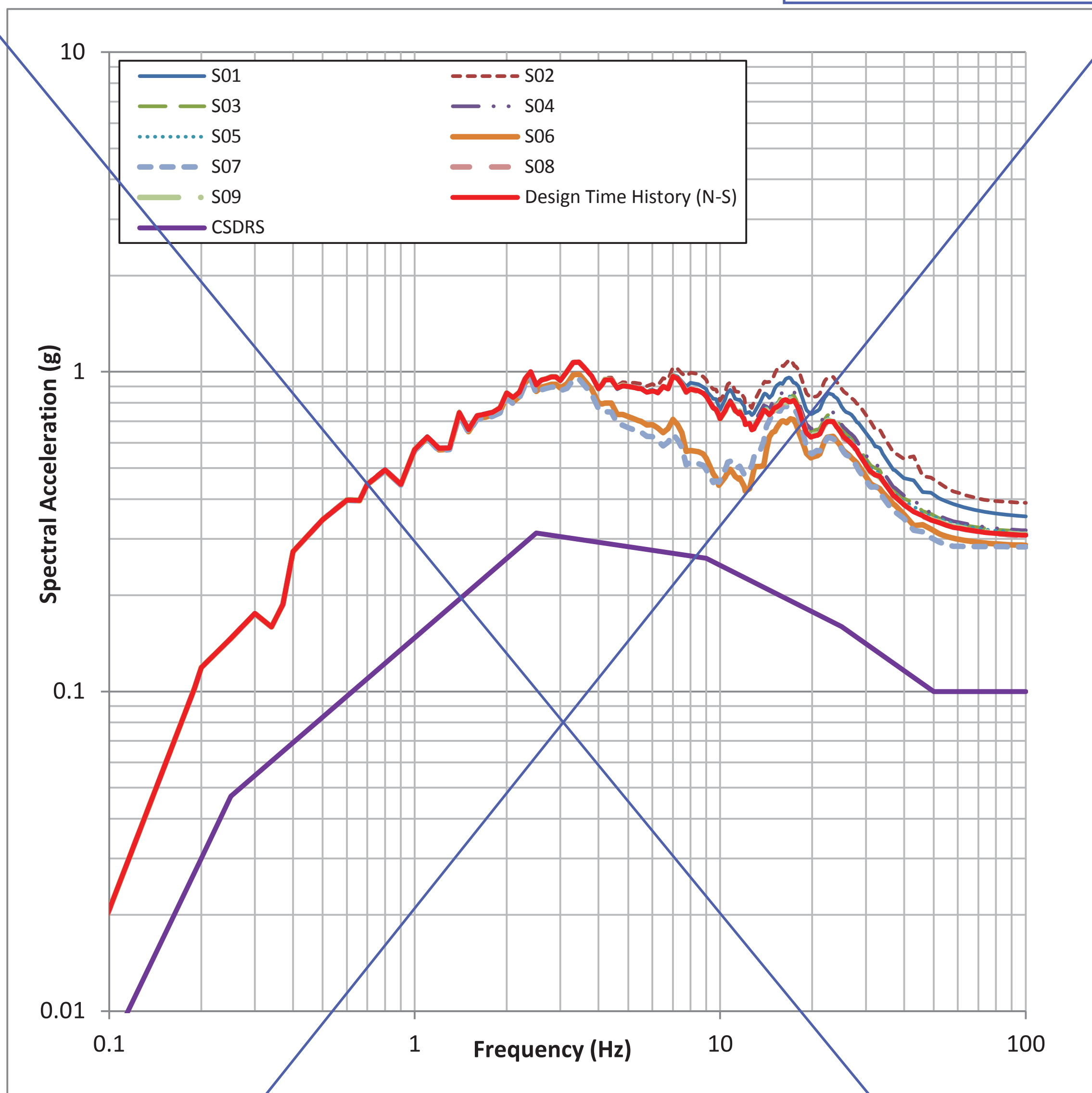

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Nuclear Island Structure, N-S Motion, 5% damping (2 of 3)

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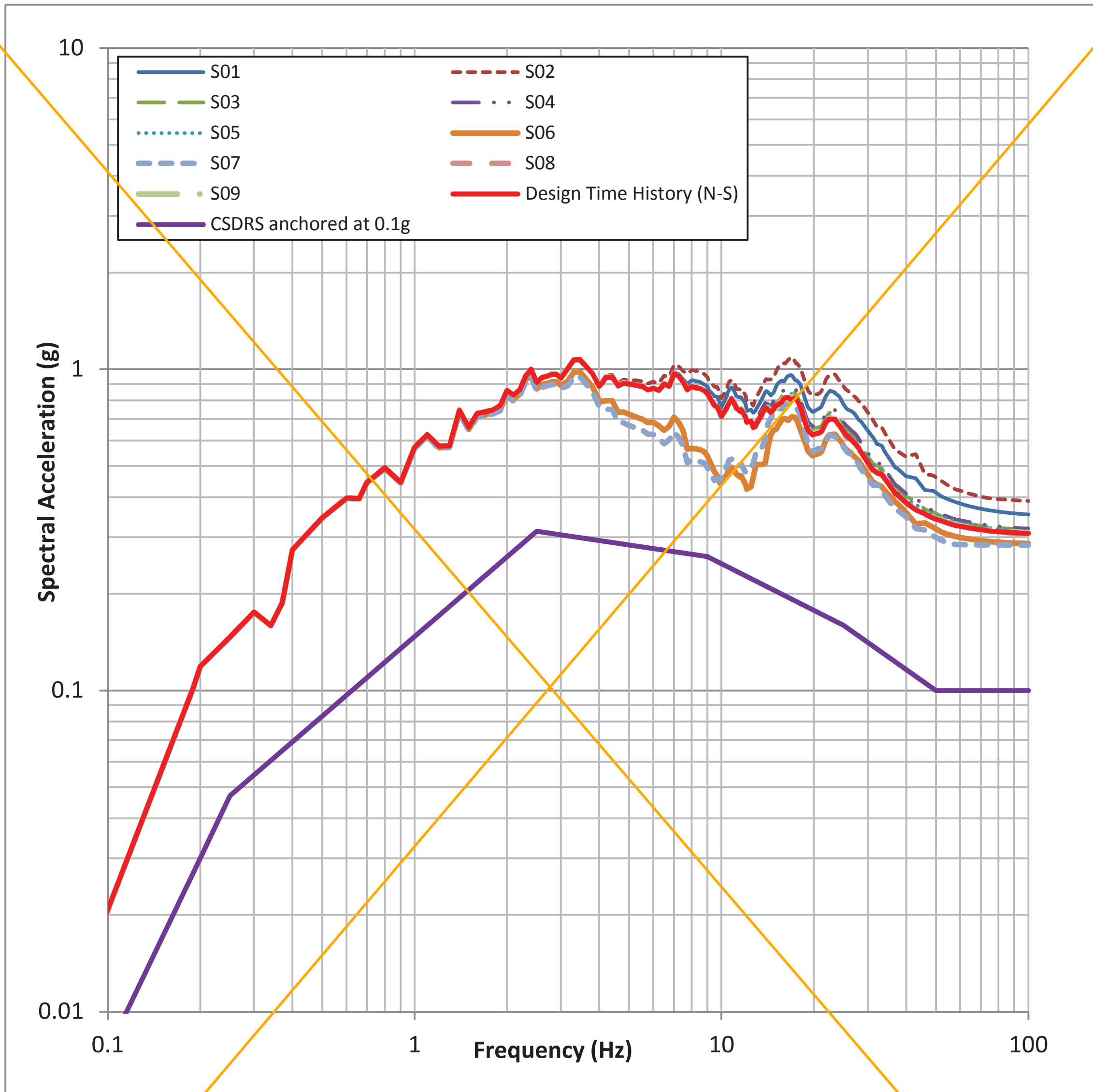

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Nuclear Island Structure, Outcrop N-S Motion, 5% damping

(2 of 3)

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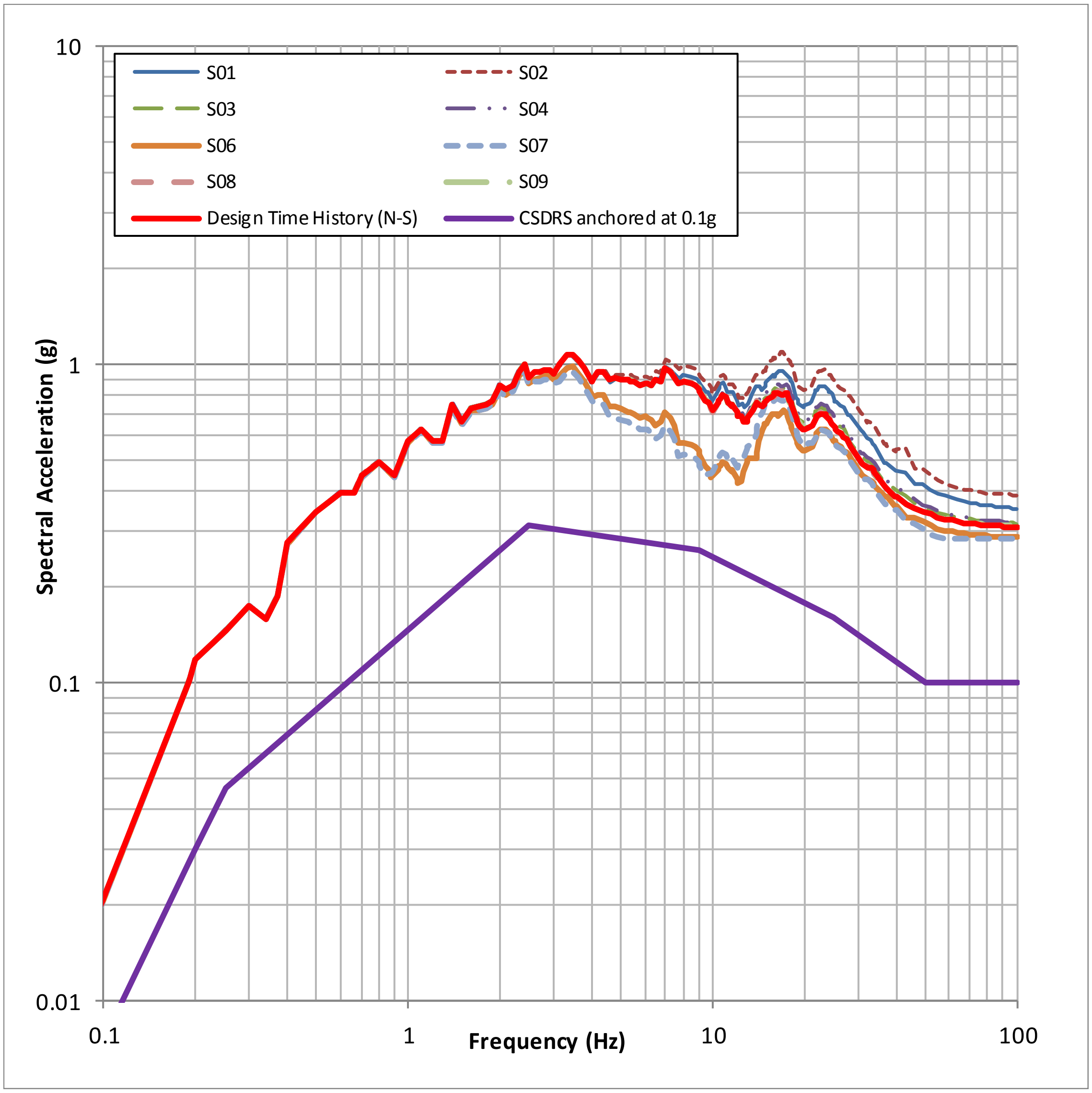

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Nuclear Island Structure, N-S Motion, 5% damping
(2 of 3)

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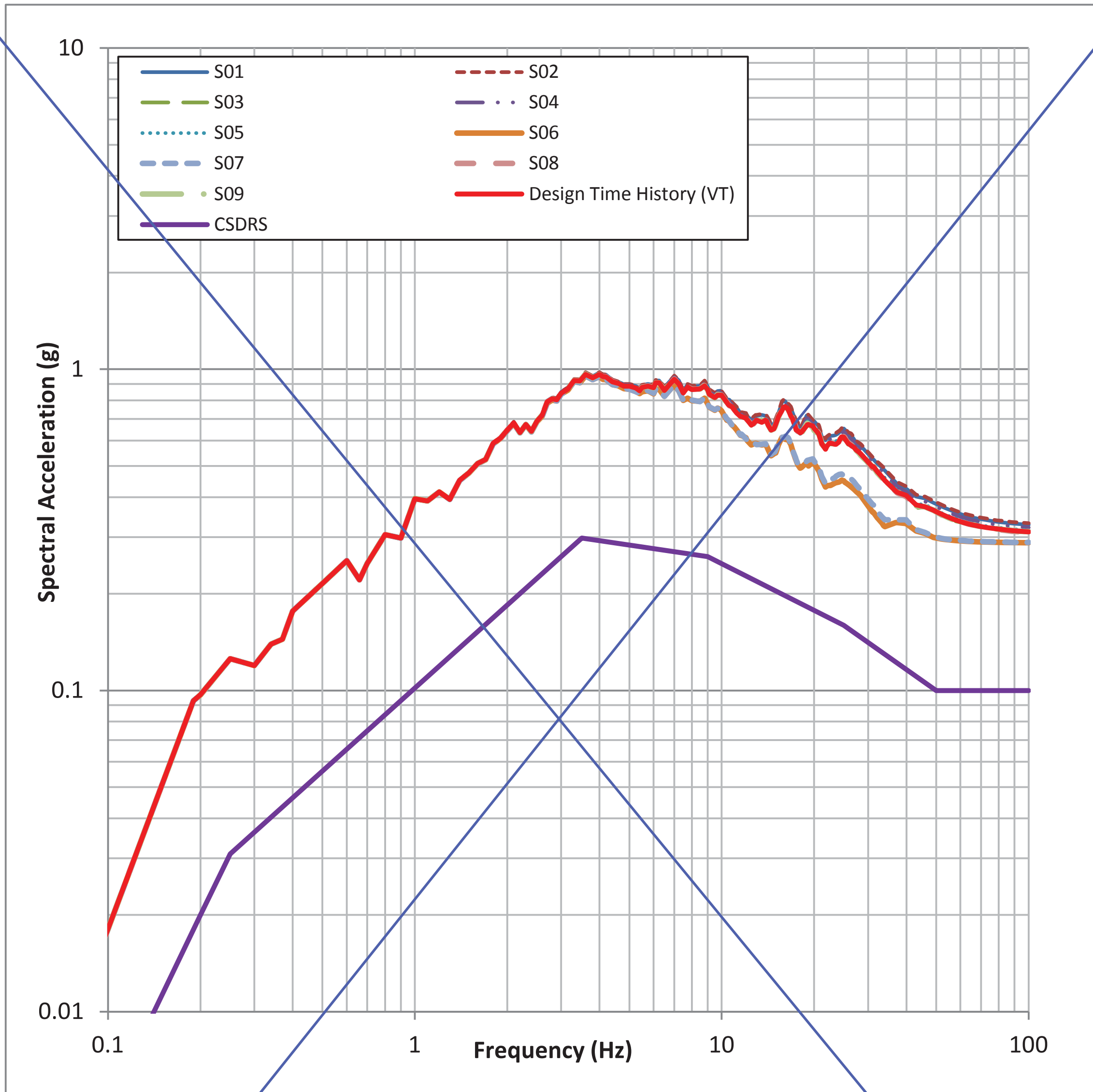

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Nuclear Island Structure, Vertical Motion, 5% damping

(3 of 3)

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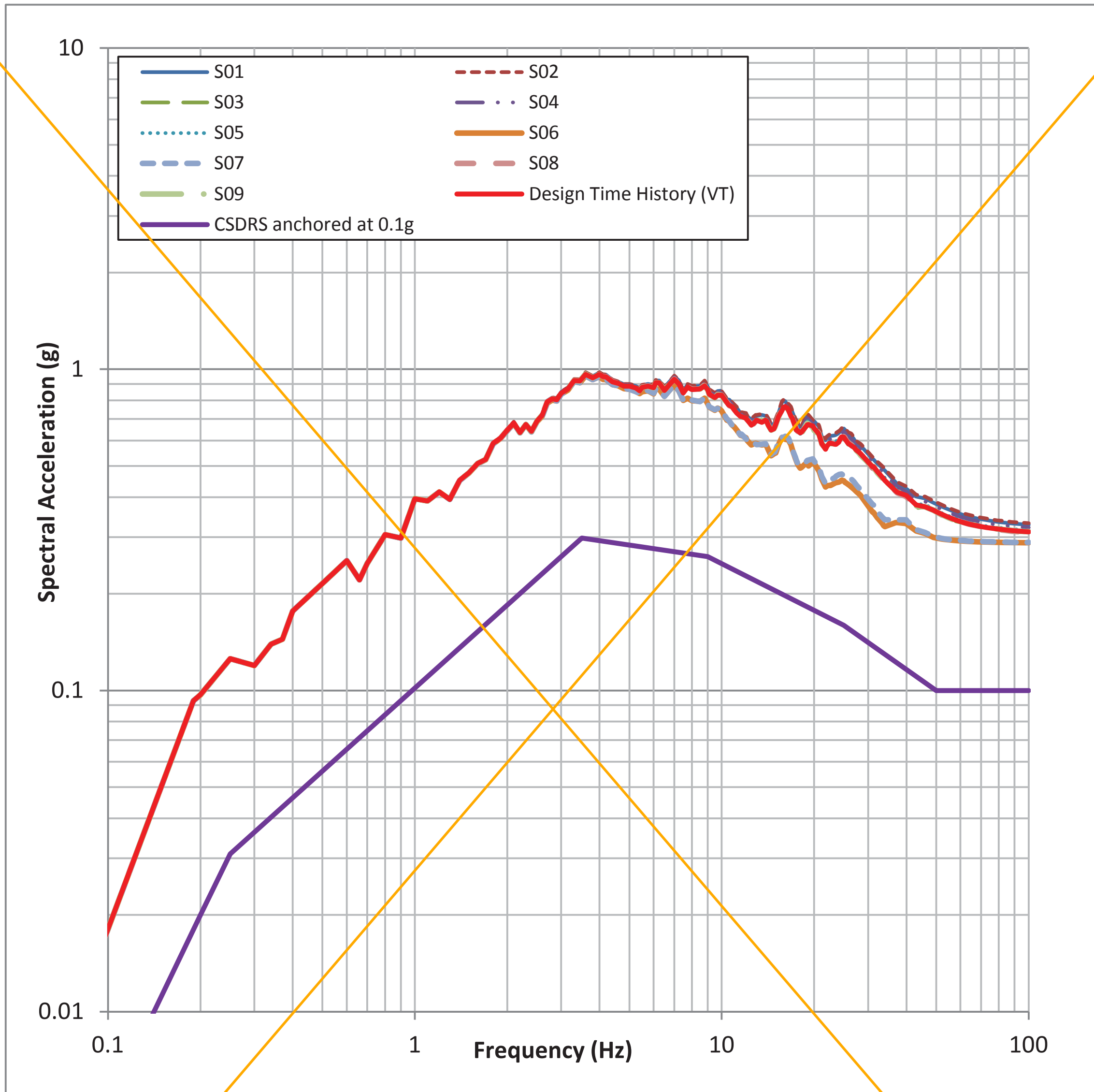

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Nuclear Island Structure, Vertical Motion, 5% damping

Outcrop

(3 of 3)

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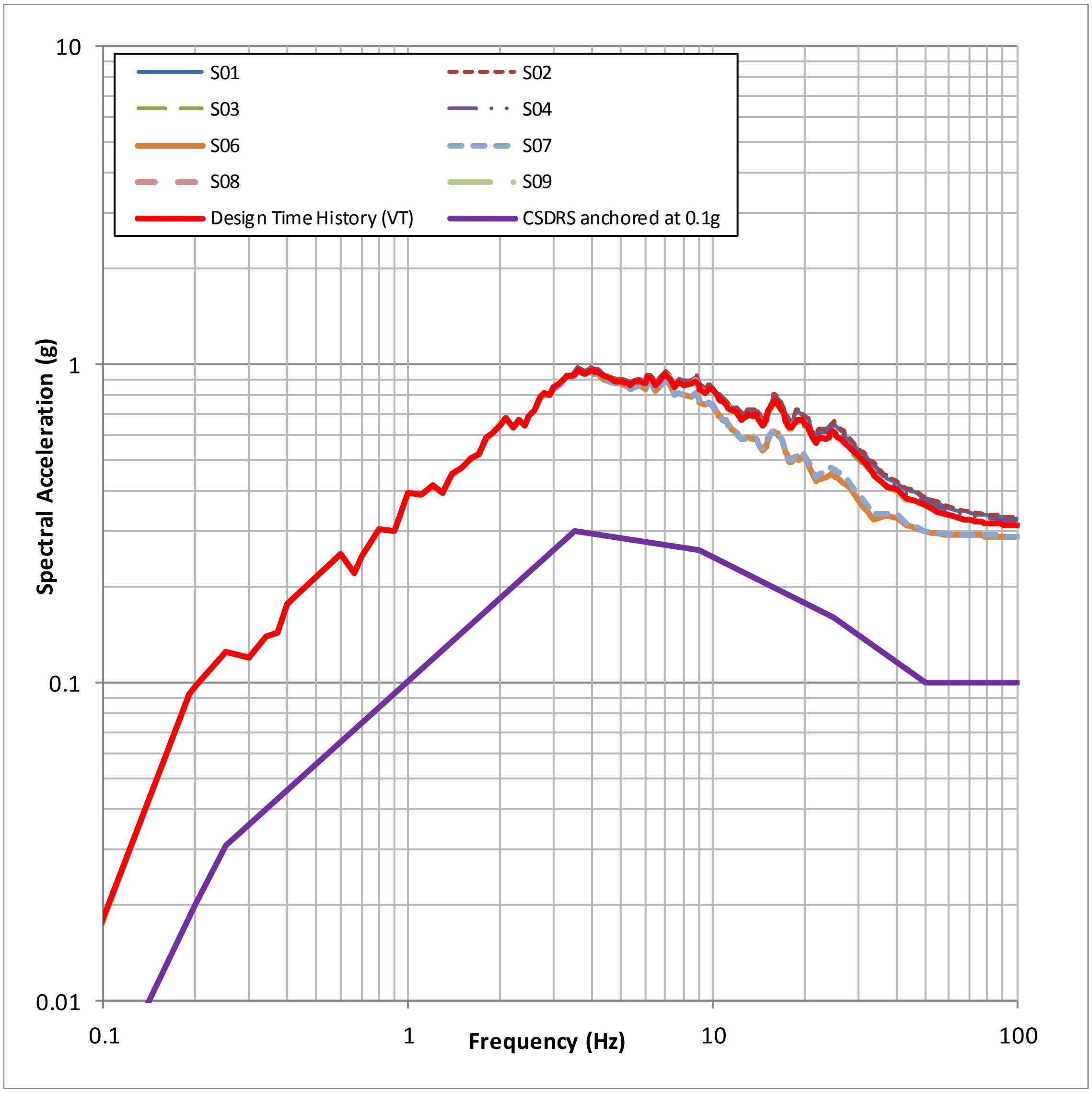

Figure 3.7A-12 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Nuclear Island Structure, Vertical Motion, 5% damping

(3 of 3)

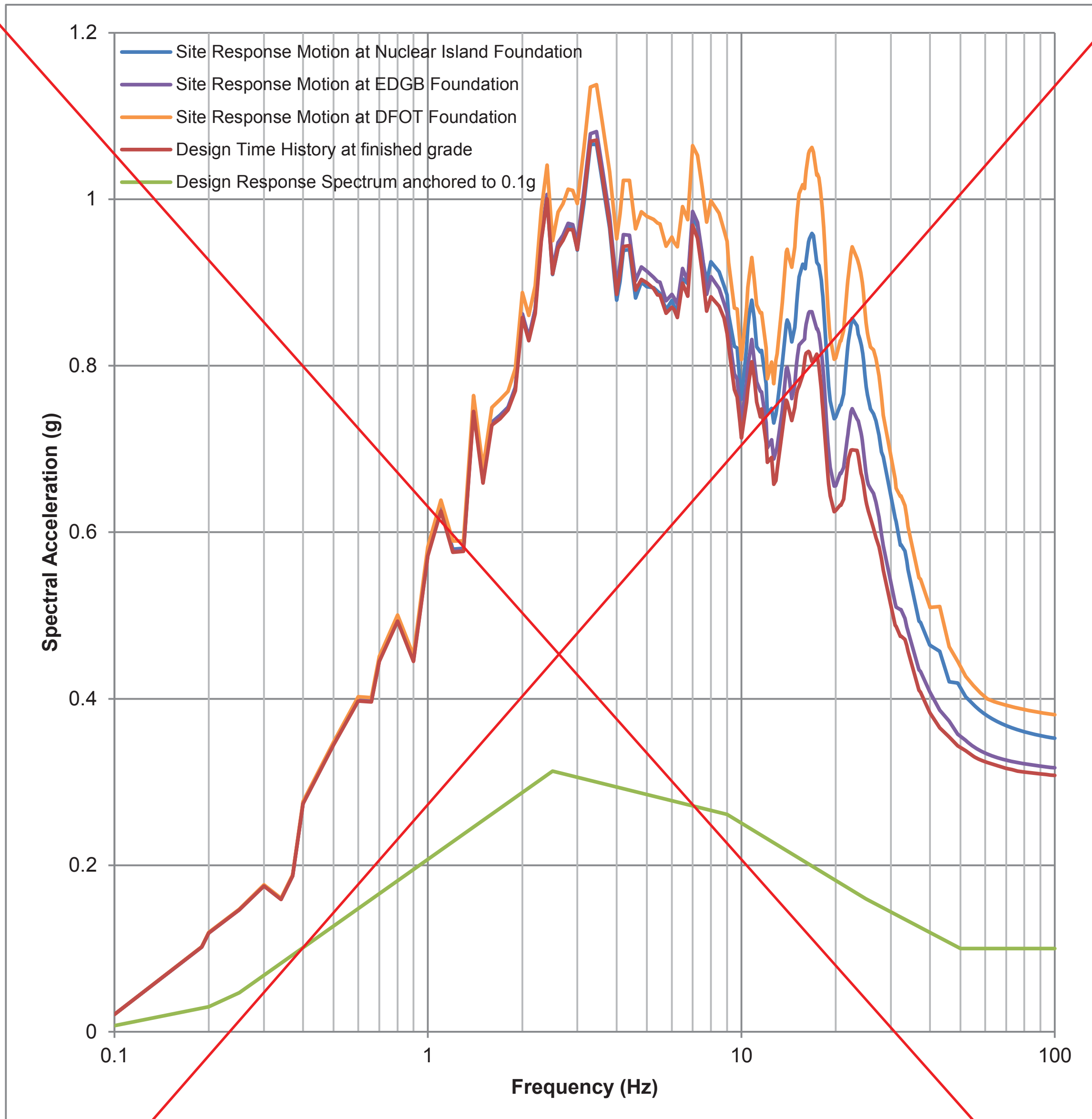

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Seismic Category I Structures, N-S Motion, 5% damping

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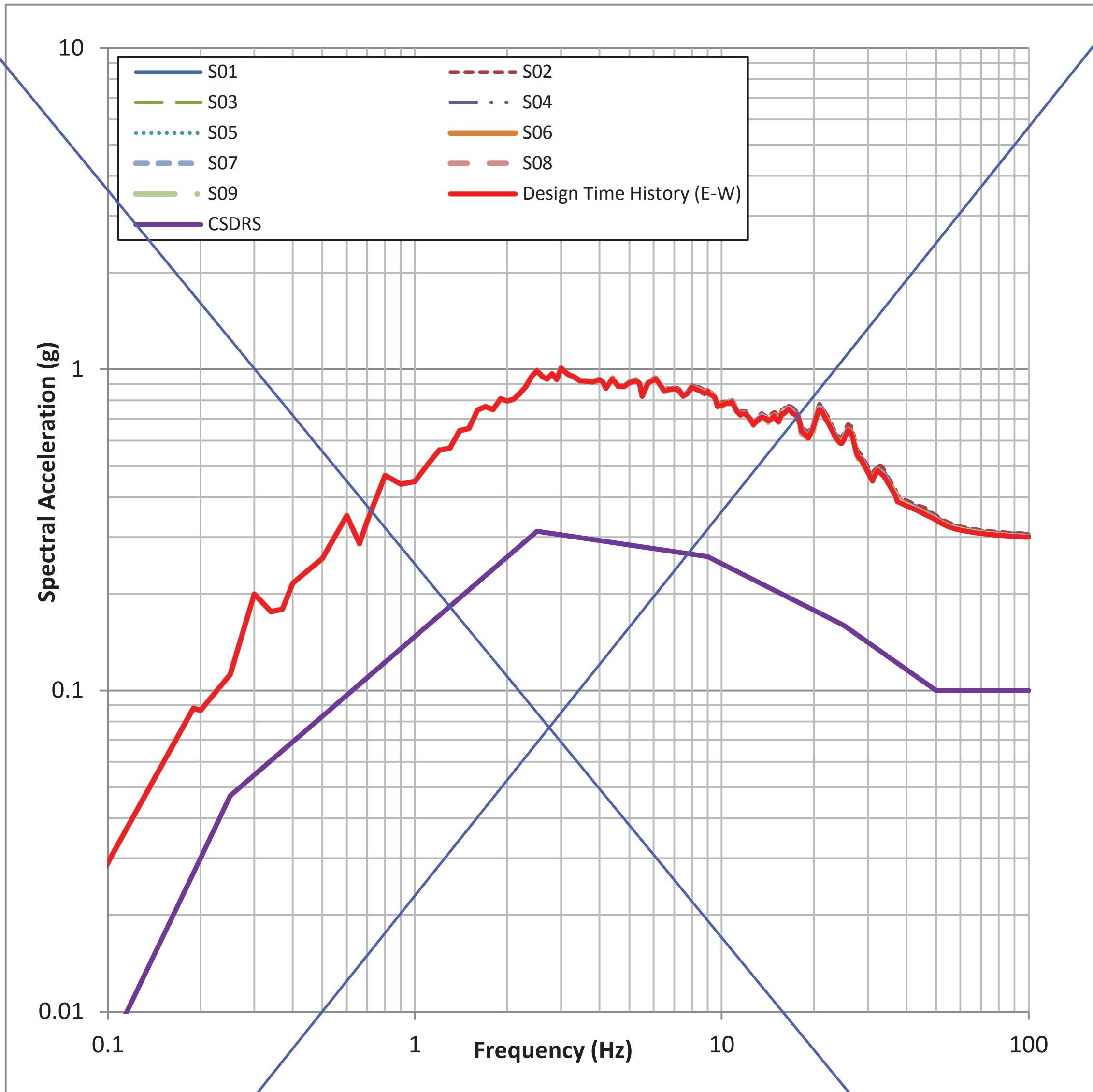

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Emergency Diesel Generator Building, E-W Motion, 5% damping

(1 of 3)

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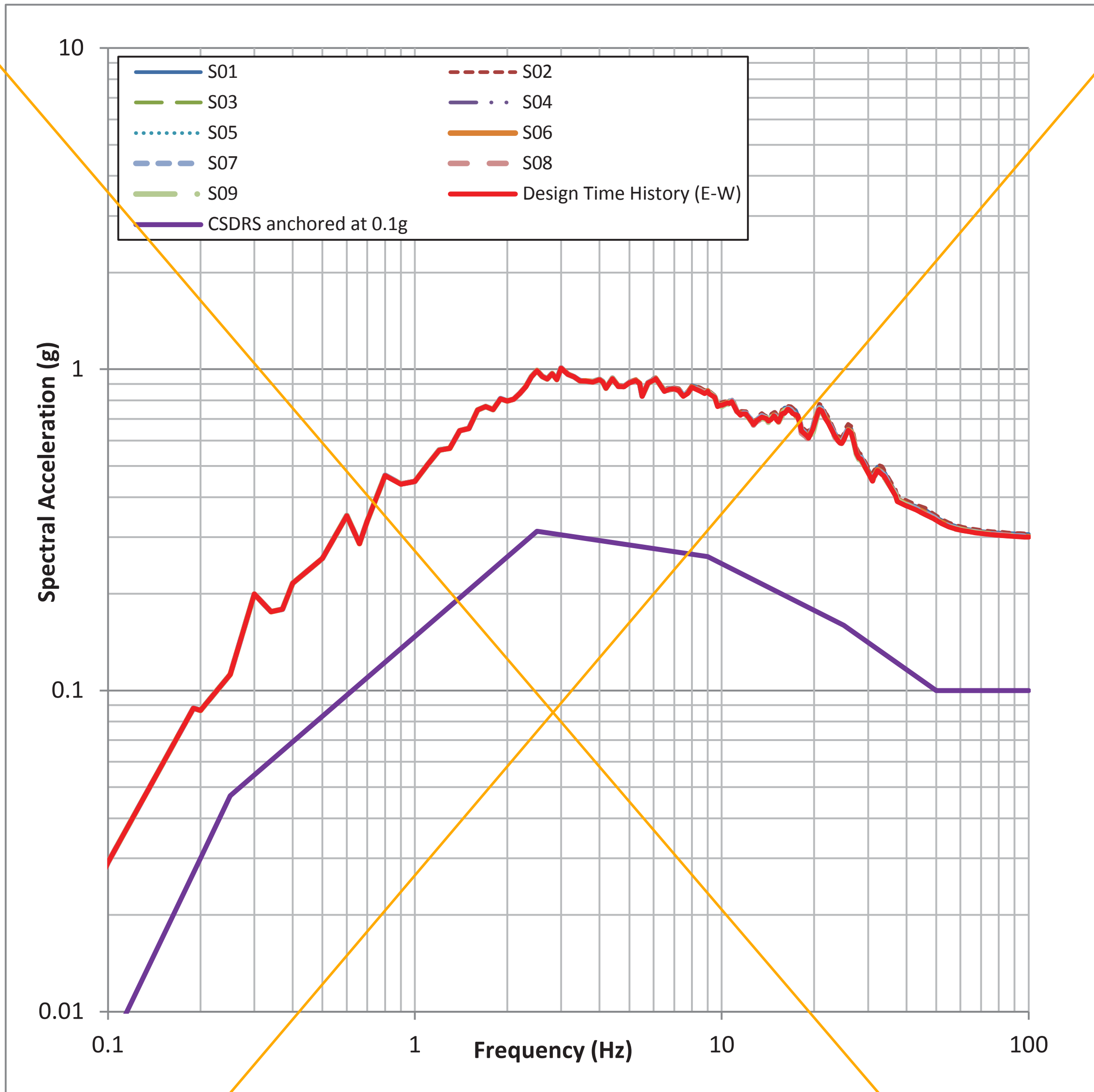

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Emergency Diesel Generator Building, E-W Motion, 5% damping
Outcrop
(1 of 3)

RAI 253-8300 - Question 03.07.01-5_Rev.3

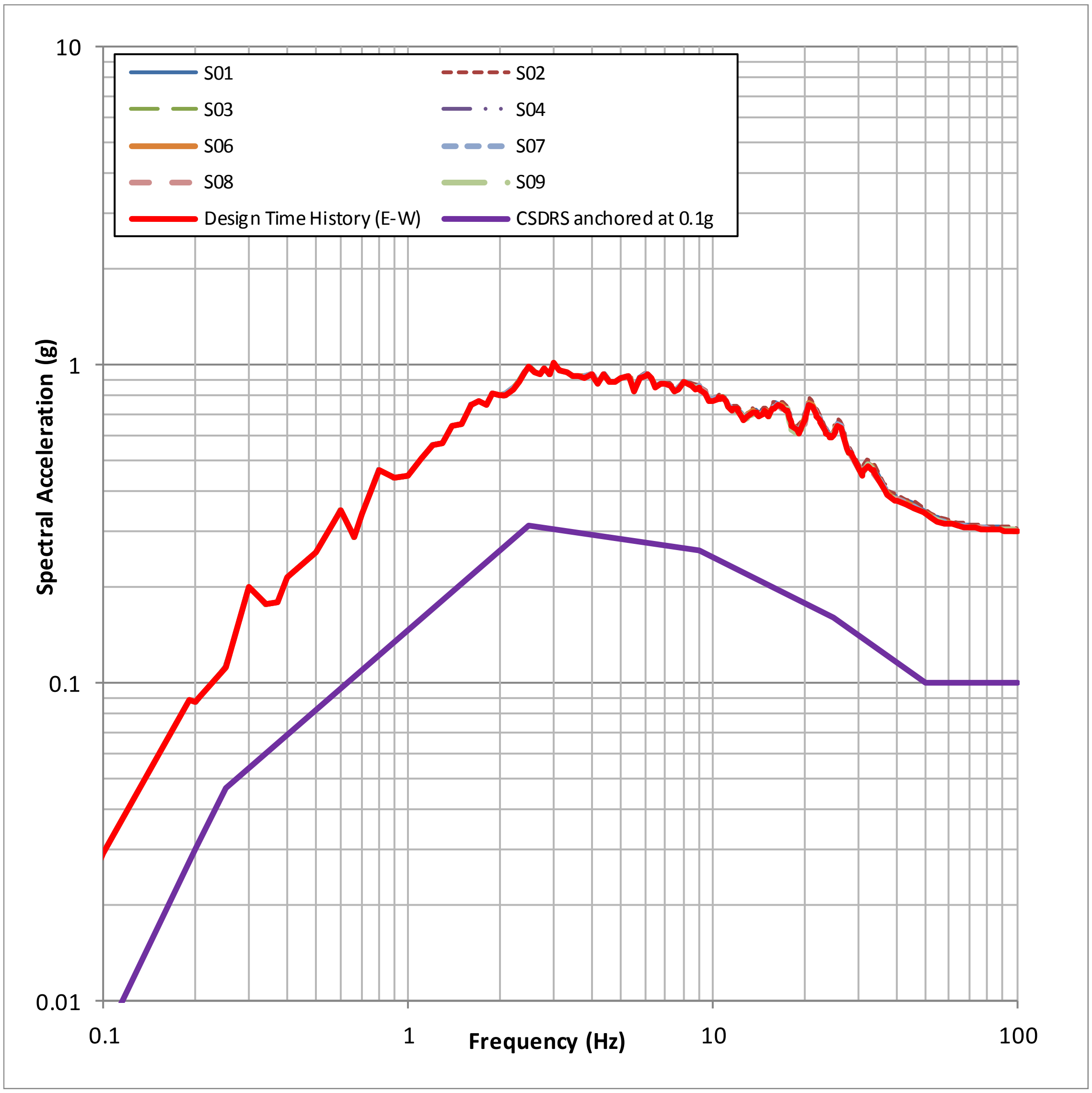

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Emergency Diesel Generator Building, E-W Motion, 5% damping
(1 of 3)

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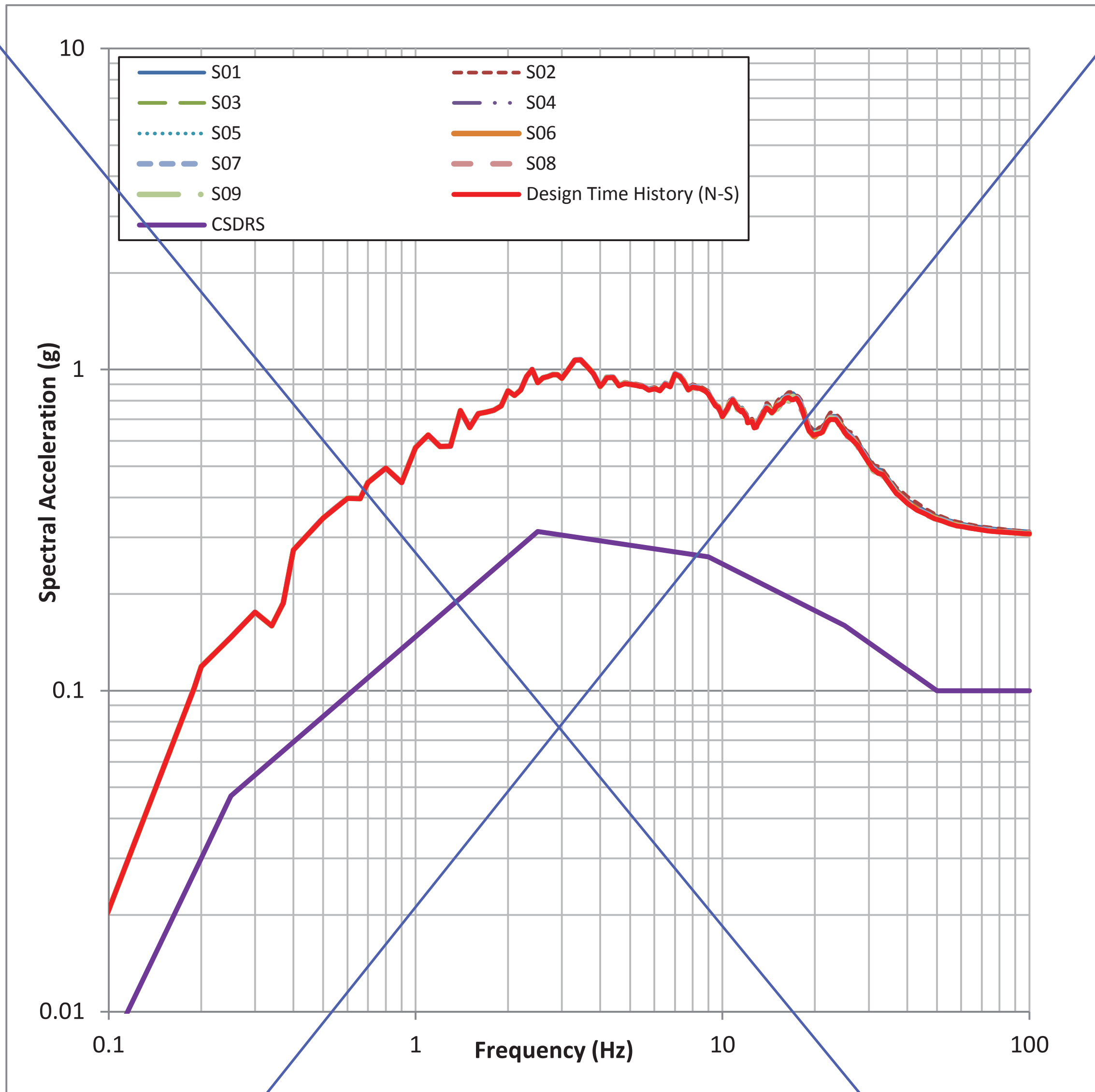

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Emergency Diesel Generator Building, N-S Motion, 5% damping
(2 of 3)

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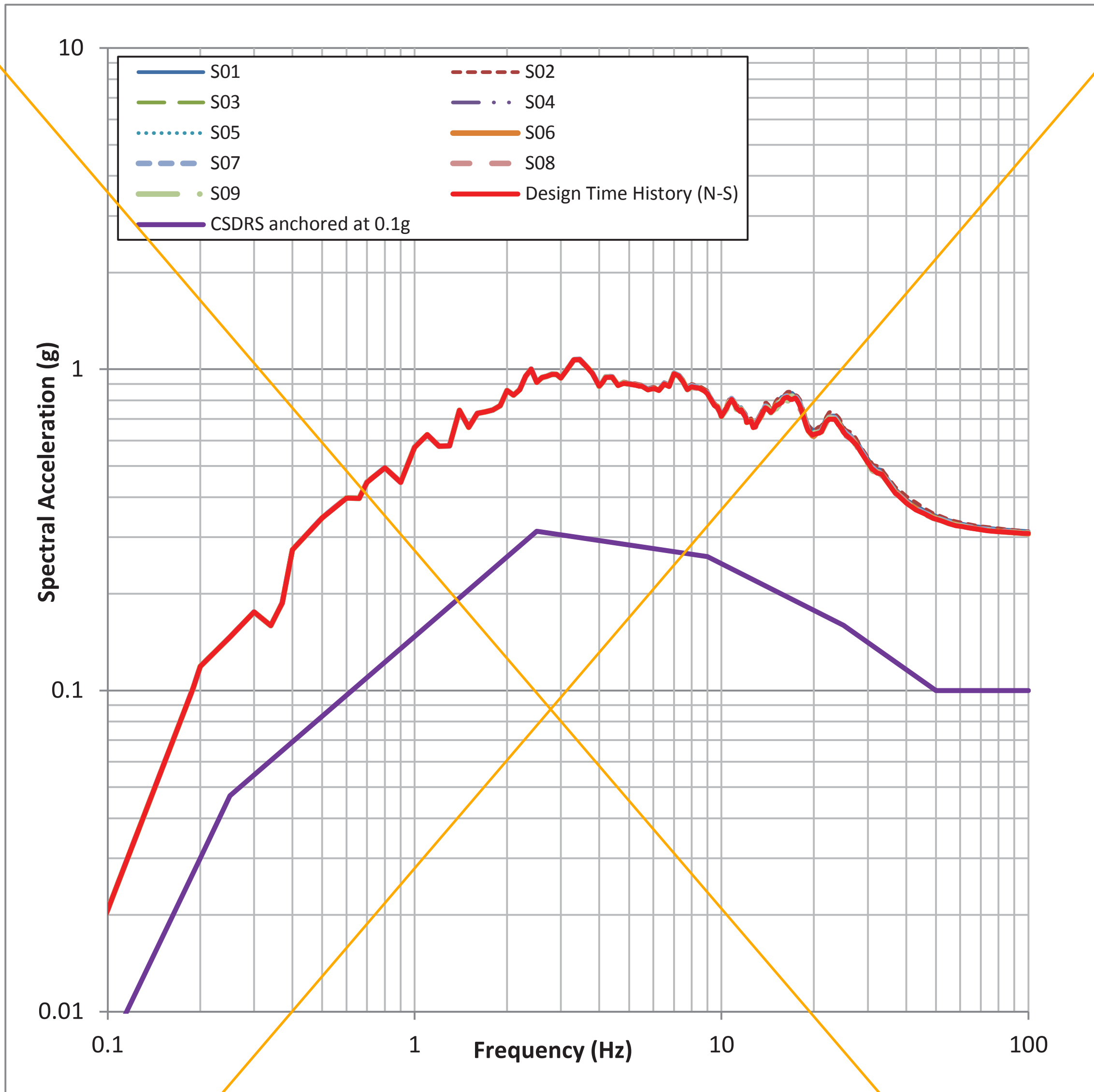

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Emergency Diesel Generator Building, N-S Motion, 5% damping

Outcrop

(2 of 3)

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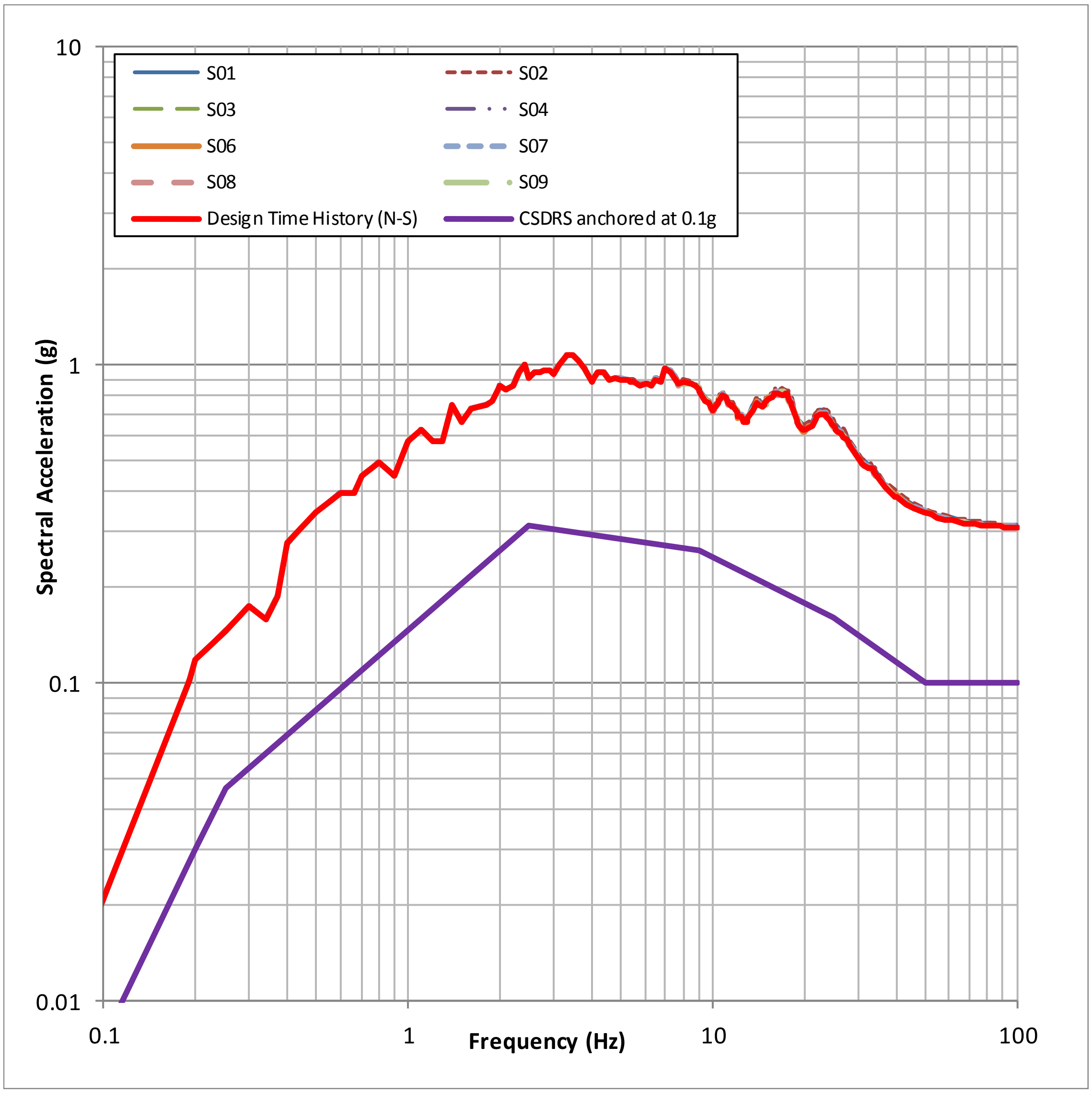

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Emergency Diesel Generator Building, N-S Motion, 5% damping

(2 of 3)

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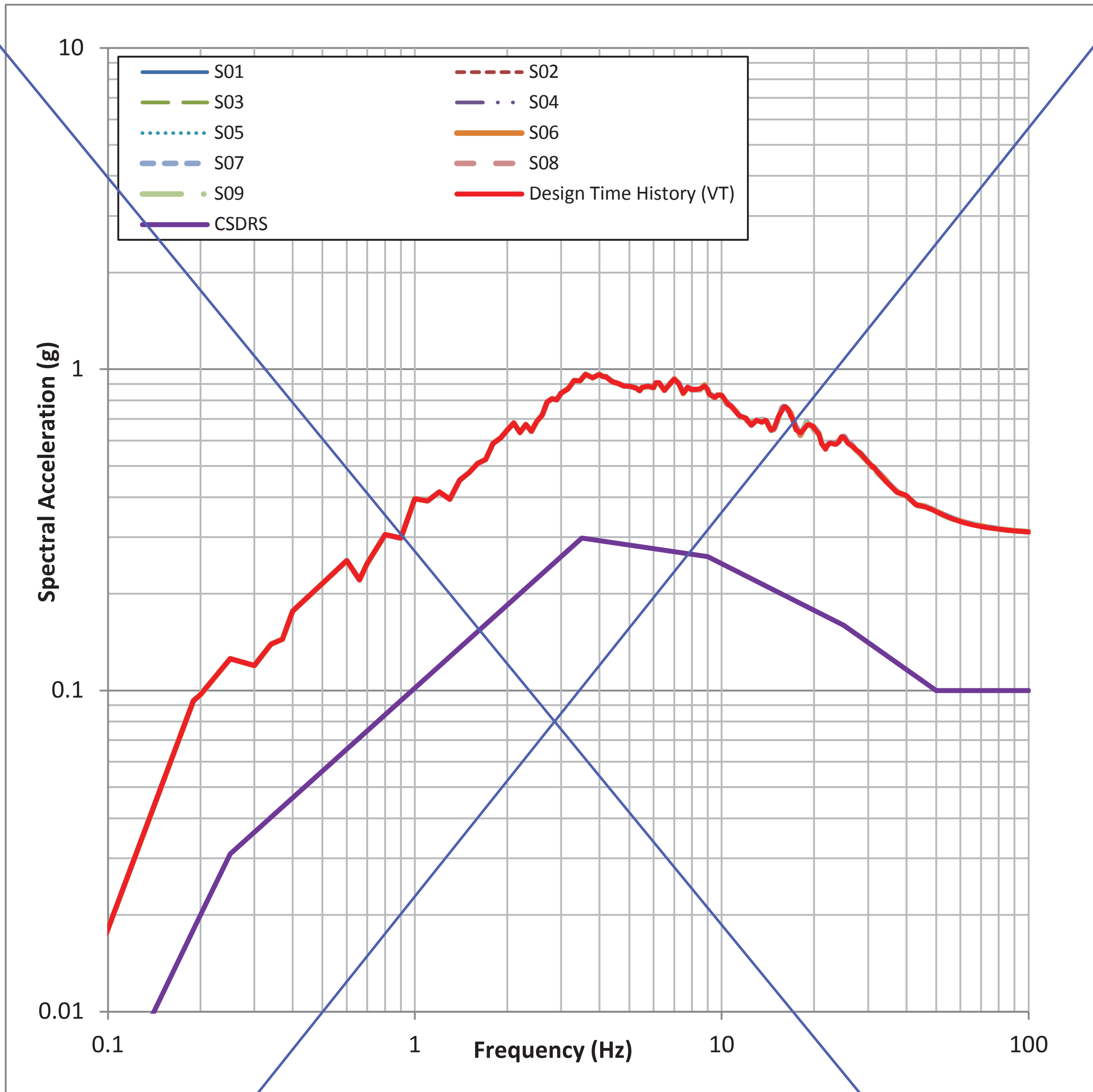

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Emergency Diesel Generator Building, Vertical Motion, 5% damping
(3 of 3)

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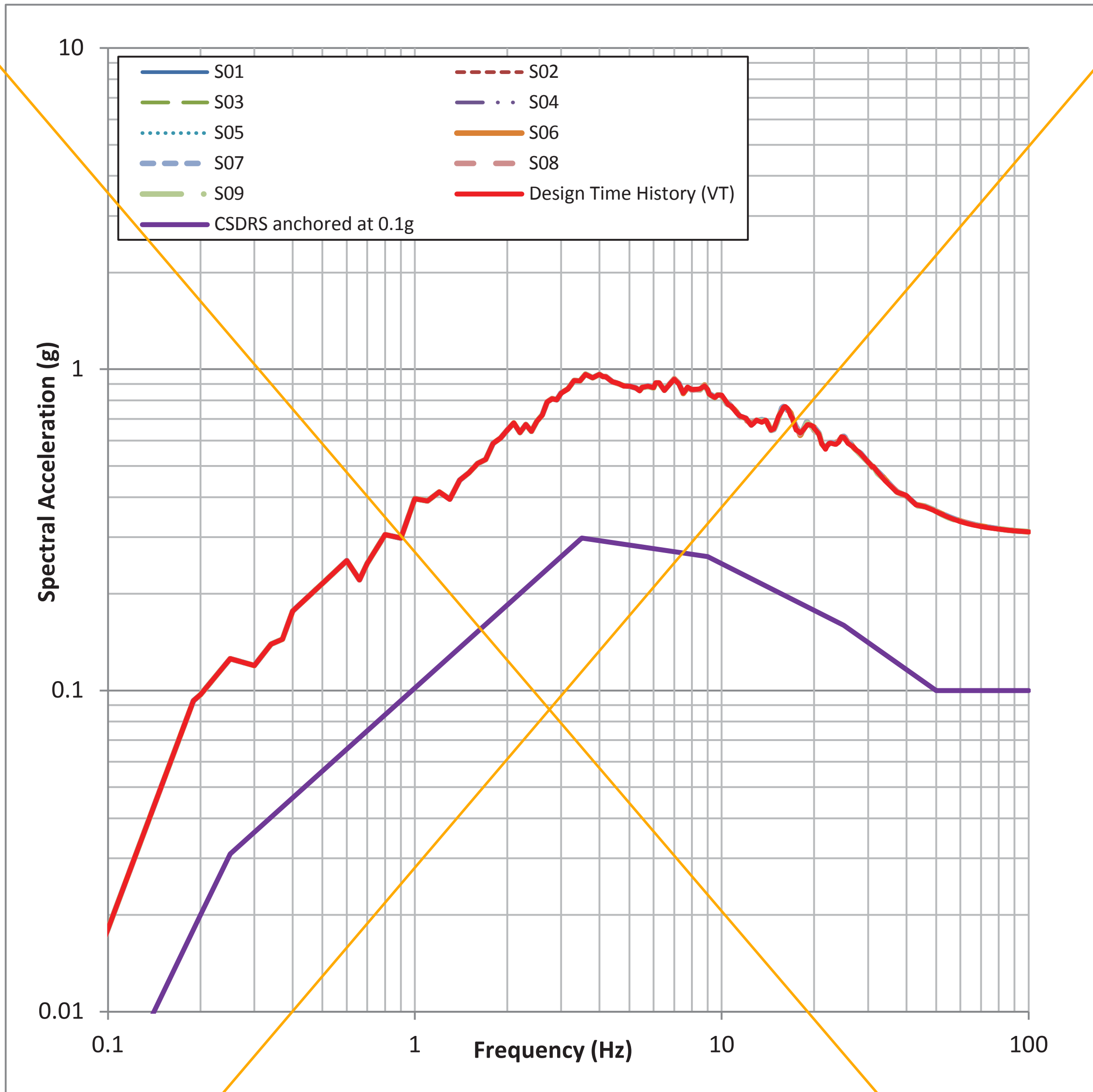

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Emergency Diesel Generator Building, Outcrop Vertical Motion, 5% damping

(3 of 3)

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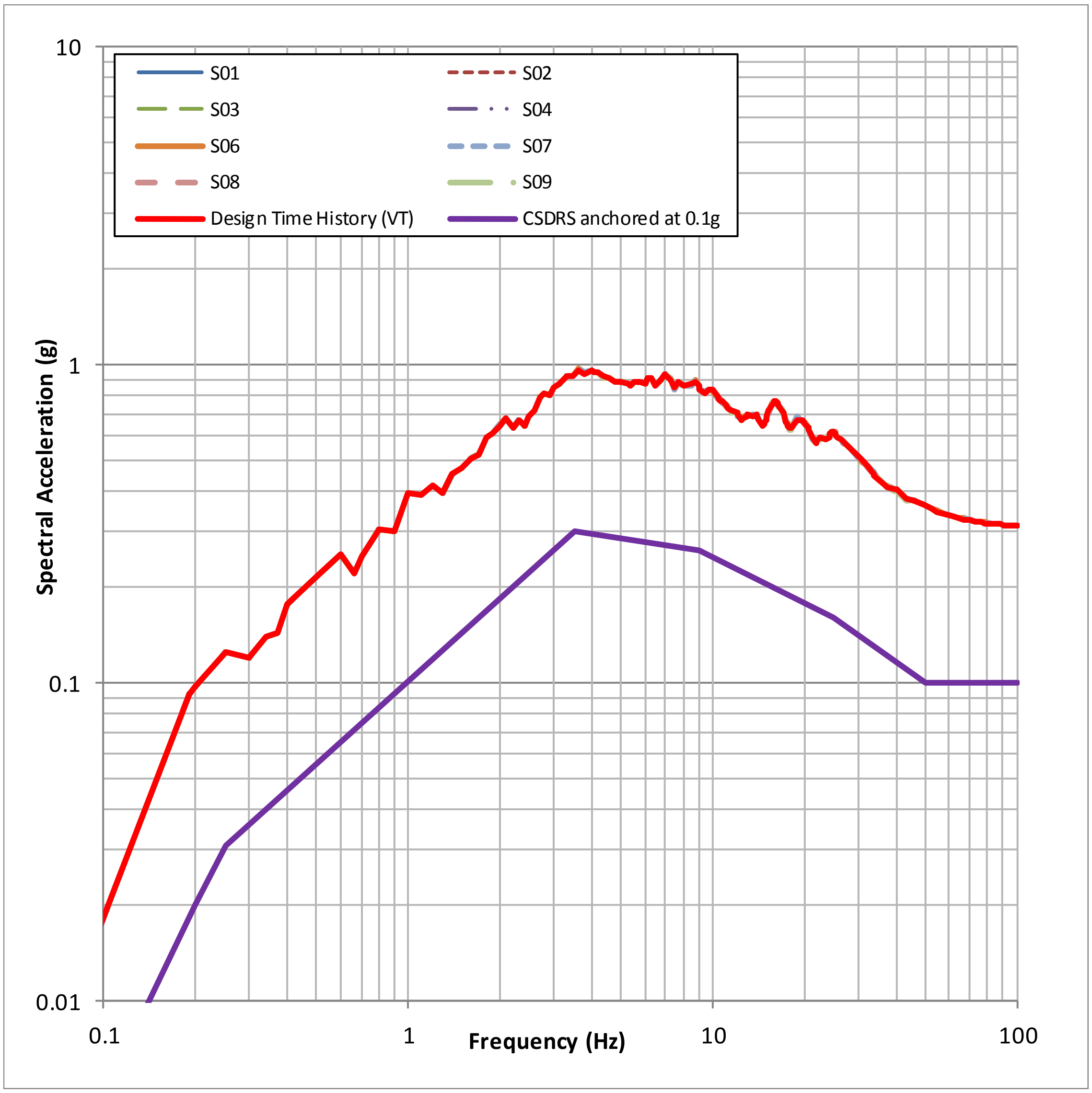

Figure 3.7A-13 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Emergency Diesel Generator Building, Vertical Motion, 5% damping

(3 of 3)

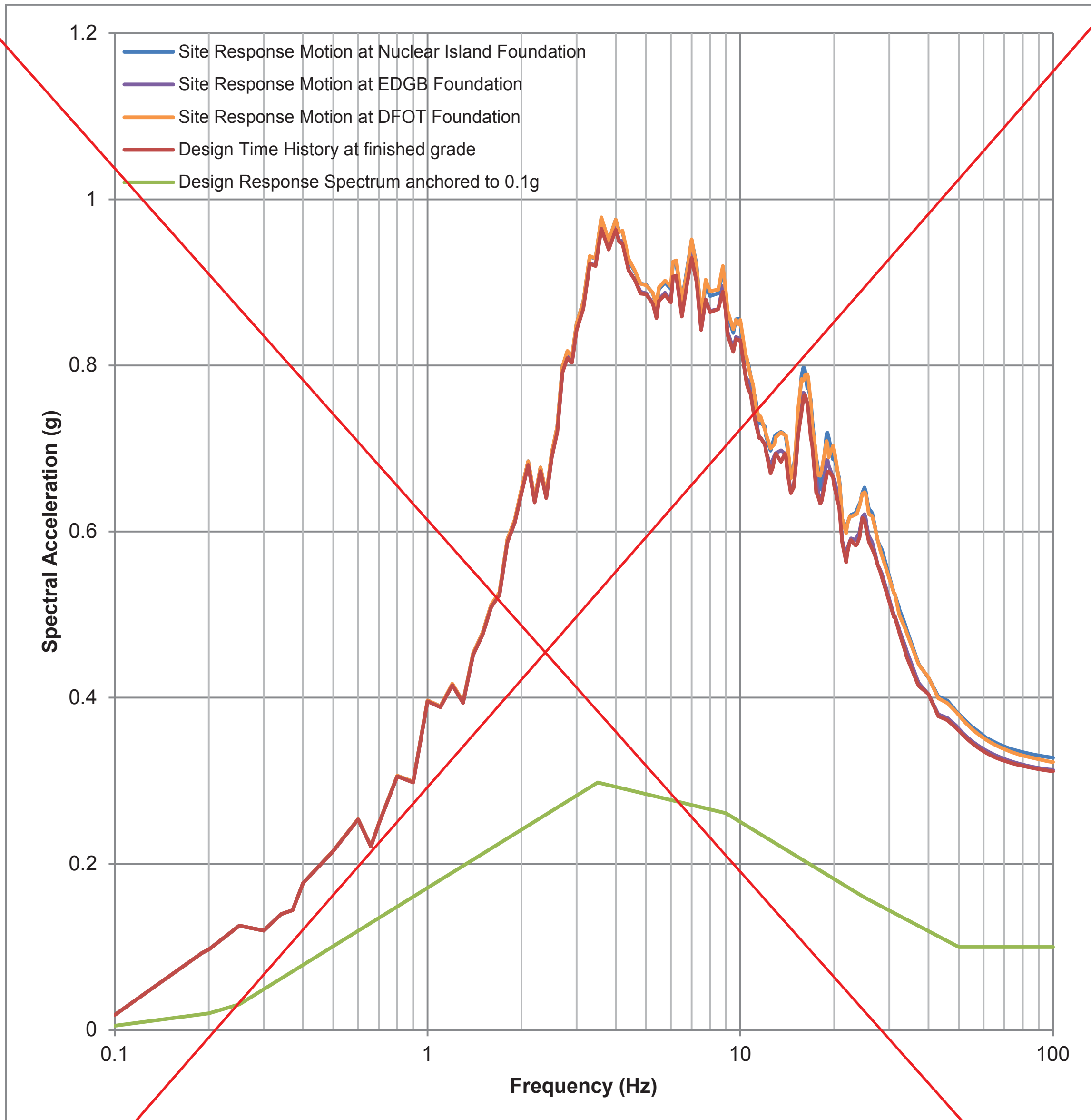

Figure 3.7A-14 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Seismic Category I Structure, Vertical Motion, 5% damping

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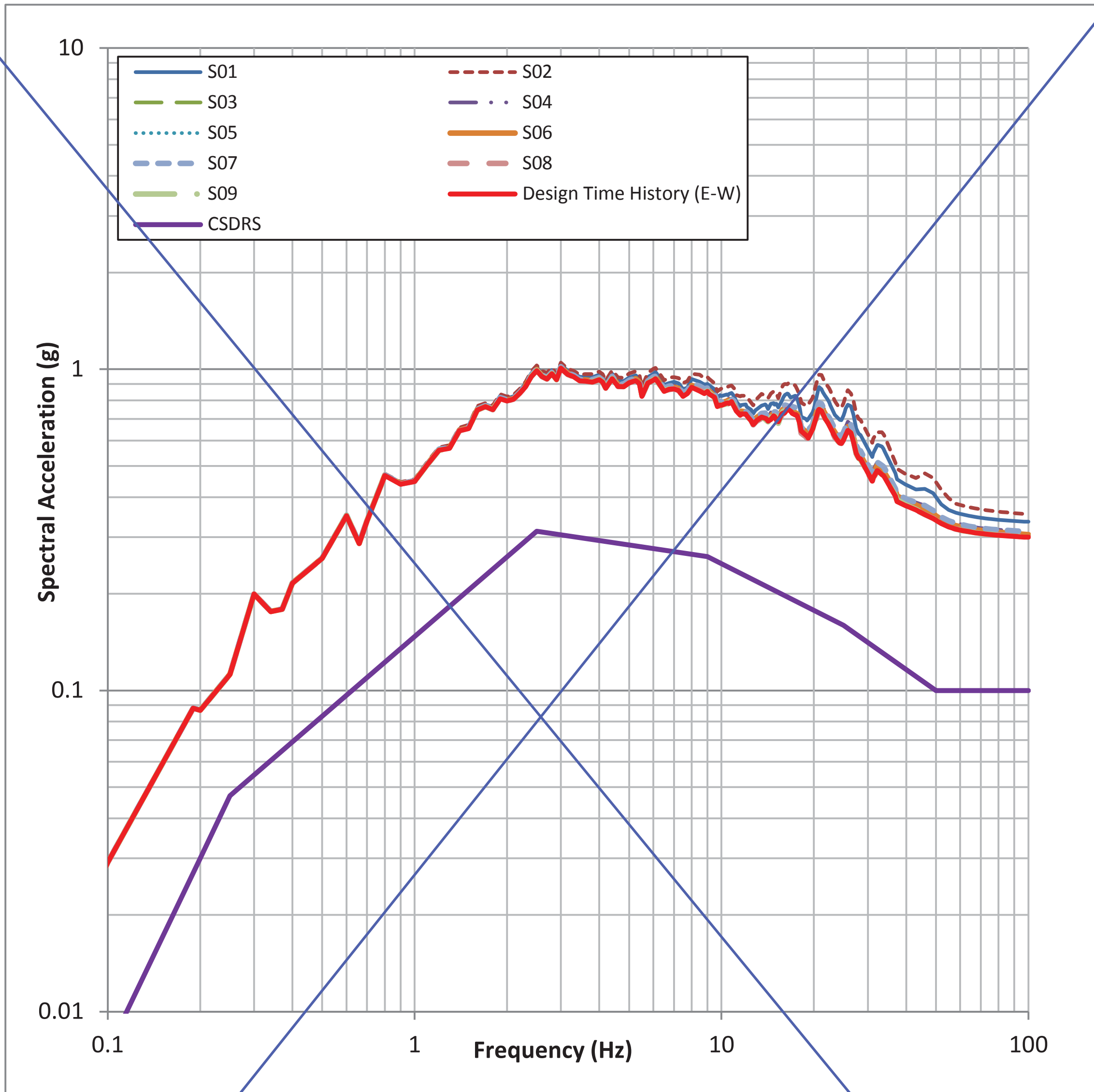

Figure 3.7A-14Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, E-W Motion, 5% damping

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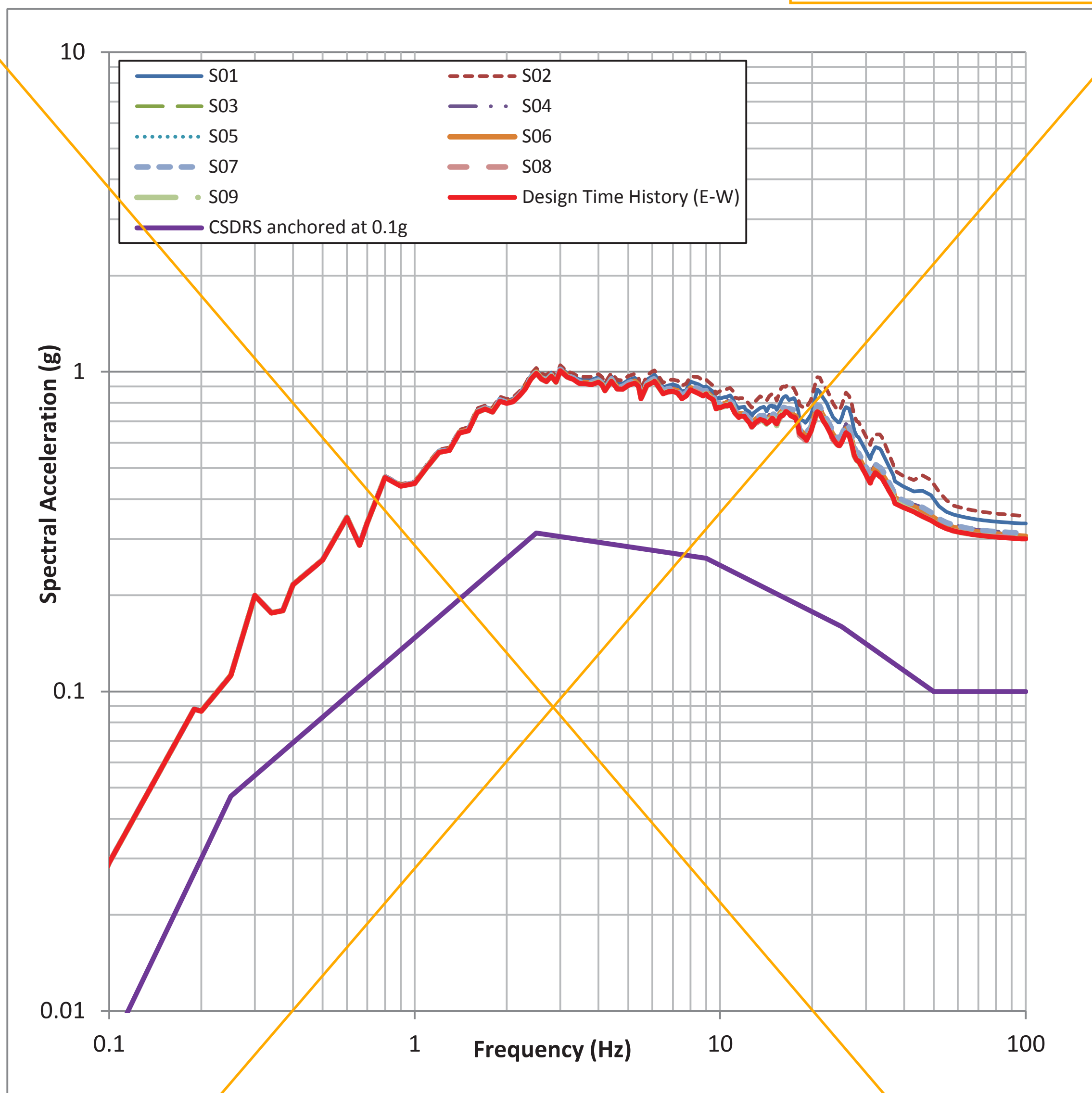

Figure 3.7A-14Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, E-W Motion, Outcrop 5% damping

(1 of 3)

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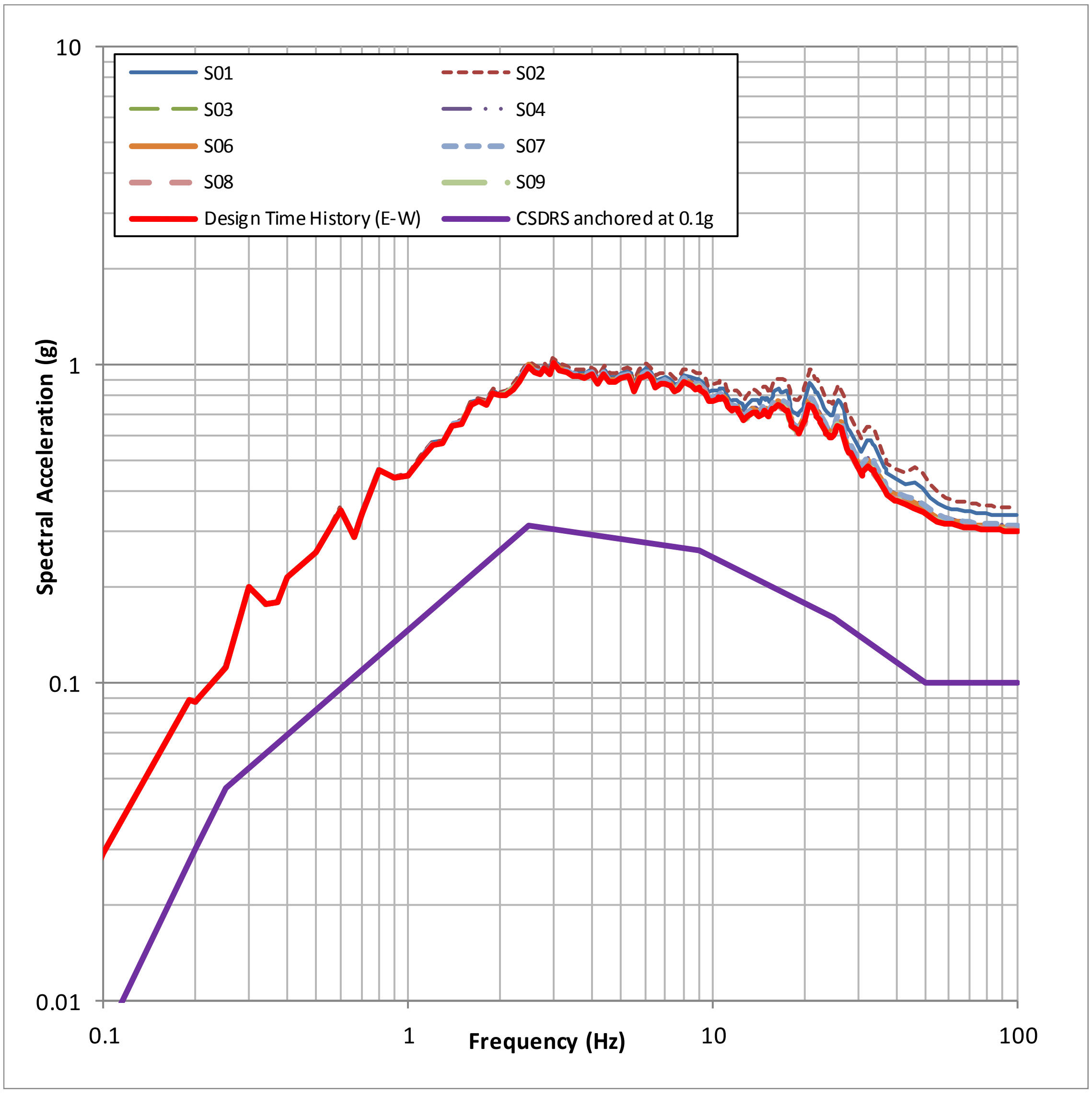

Figure 3.7A-14 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, E-W Motion, 5% damping
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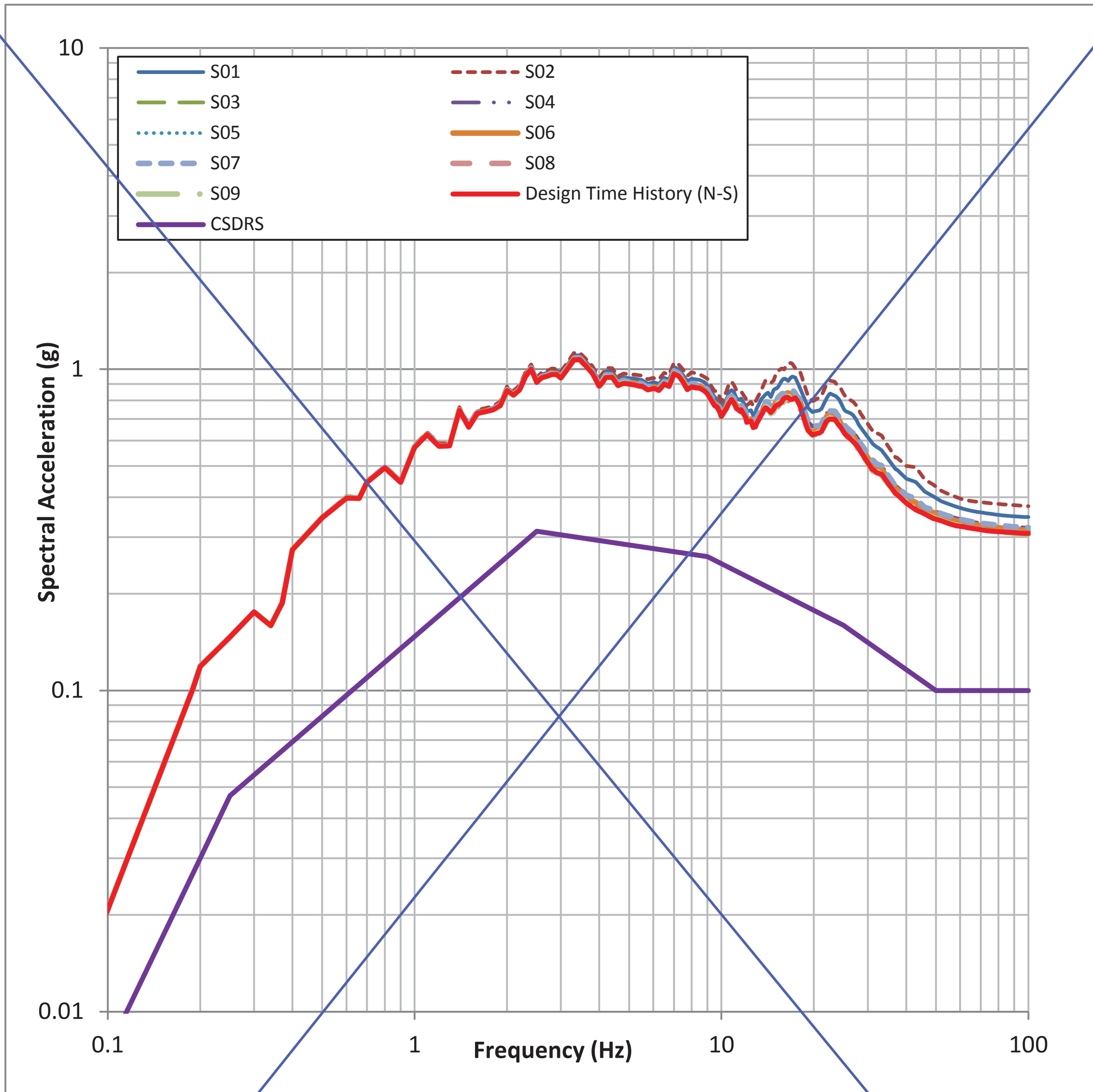

Figure 3.7A-14 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, N-S Motion, 5% damping
(2 of 3)

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RAI 253-8300 - Question 03.07.01-5_Rev.2

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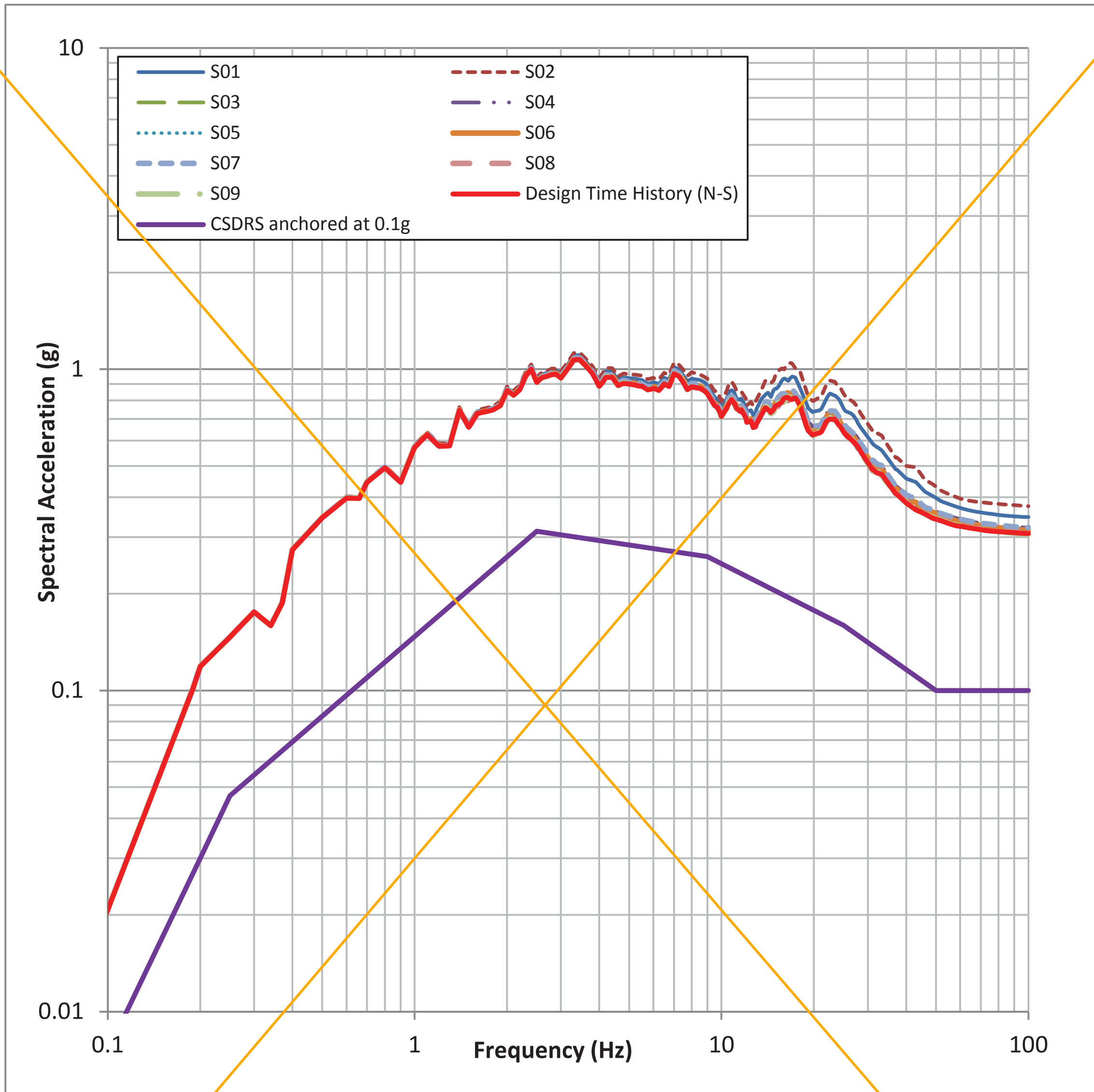

Figure 3.7A-14 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, N-S Motion, 5% damping

Outcrop

(2 of 3)

RAI 253-8300 - Question 03.07.01-5_Rev.3

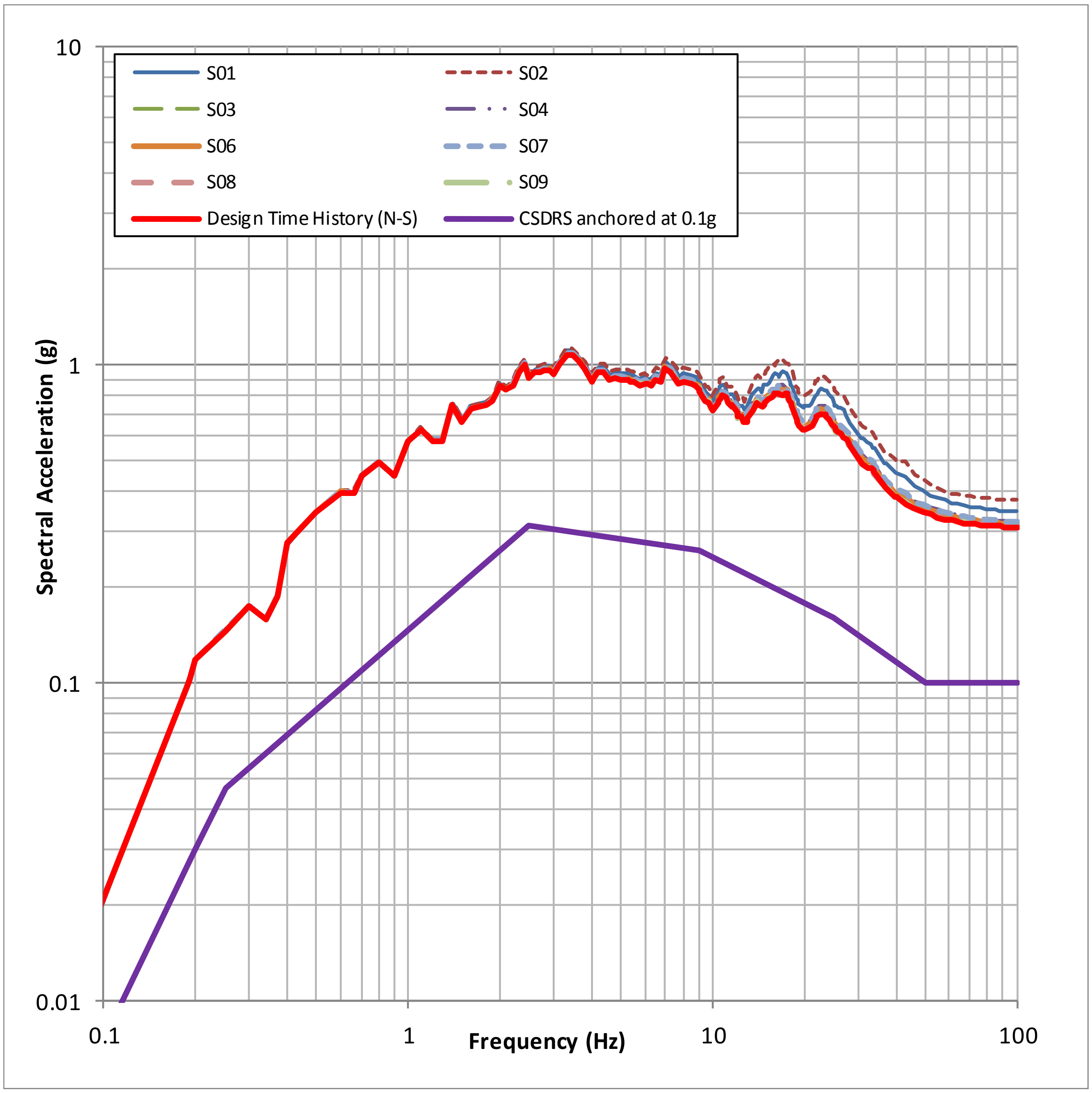

Figure 3.7A-14 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, N-S Motion, 5% damping

(2 of 3)

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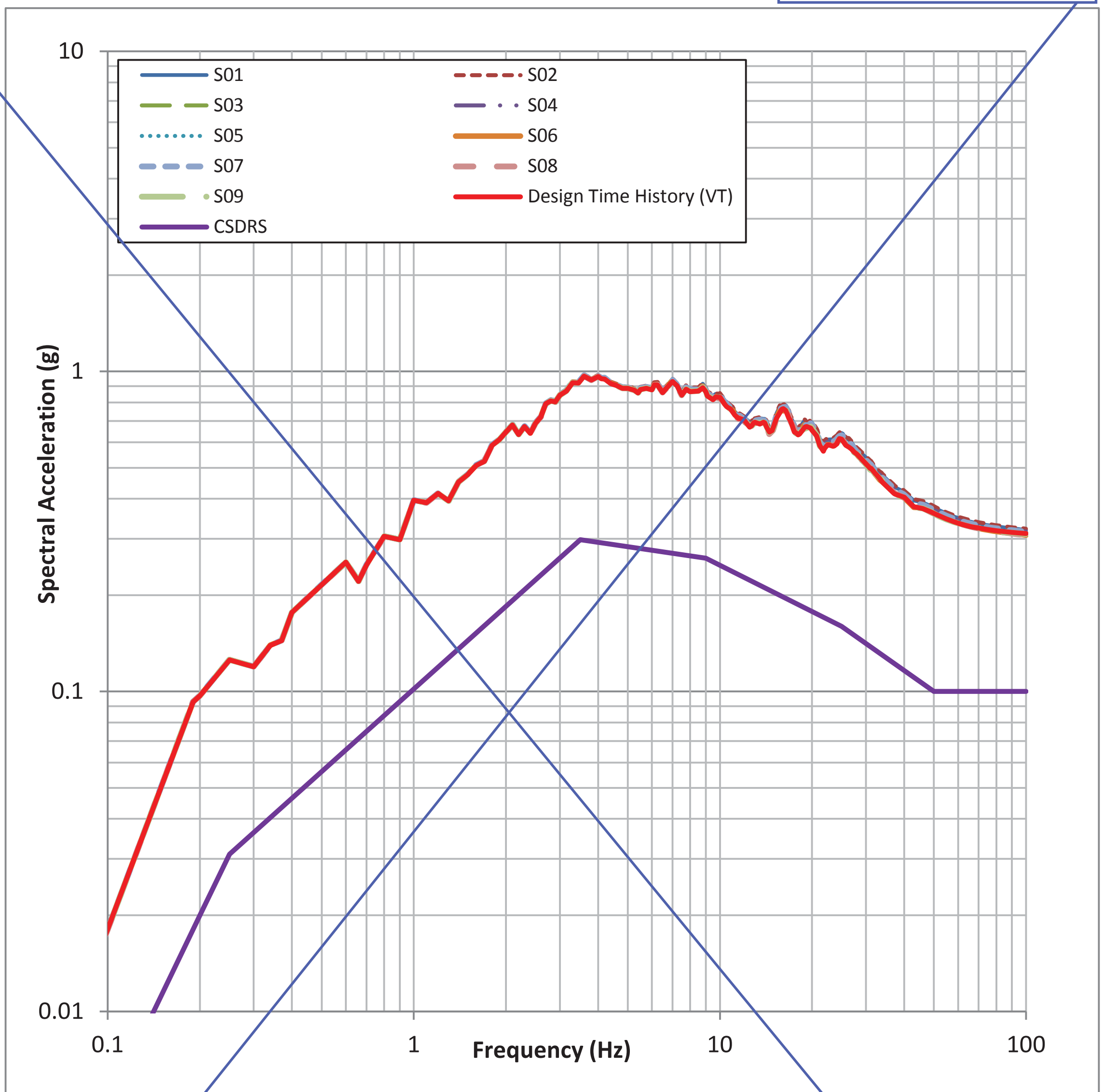

Figure 3.7A-14 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, Vertical Motion, 5% damping
(3 of 3)

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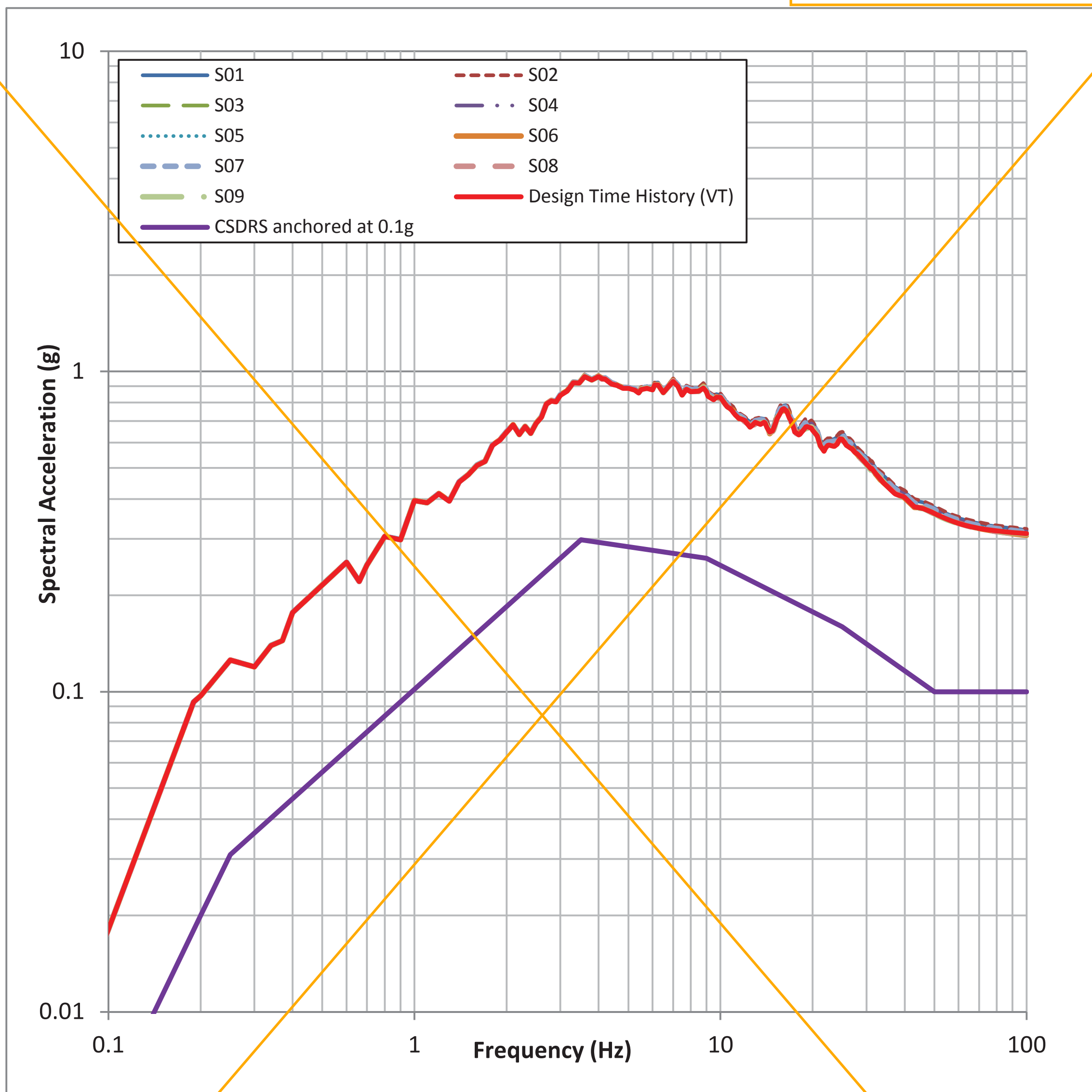

Figure 3.7A-14 Comparison of Design Time History Compatible with CSDRS with Site Response Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, Vertical Motion, 5% damping

Outcrop

(3 of 3)

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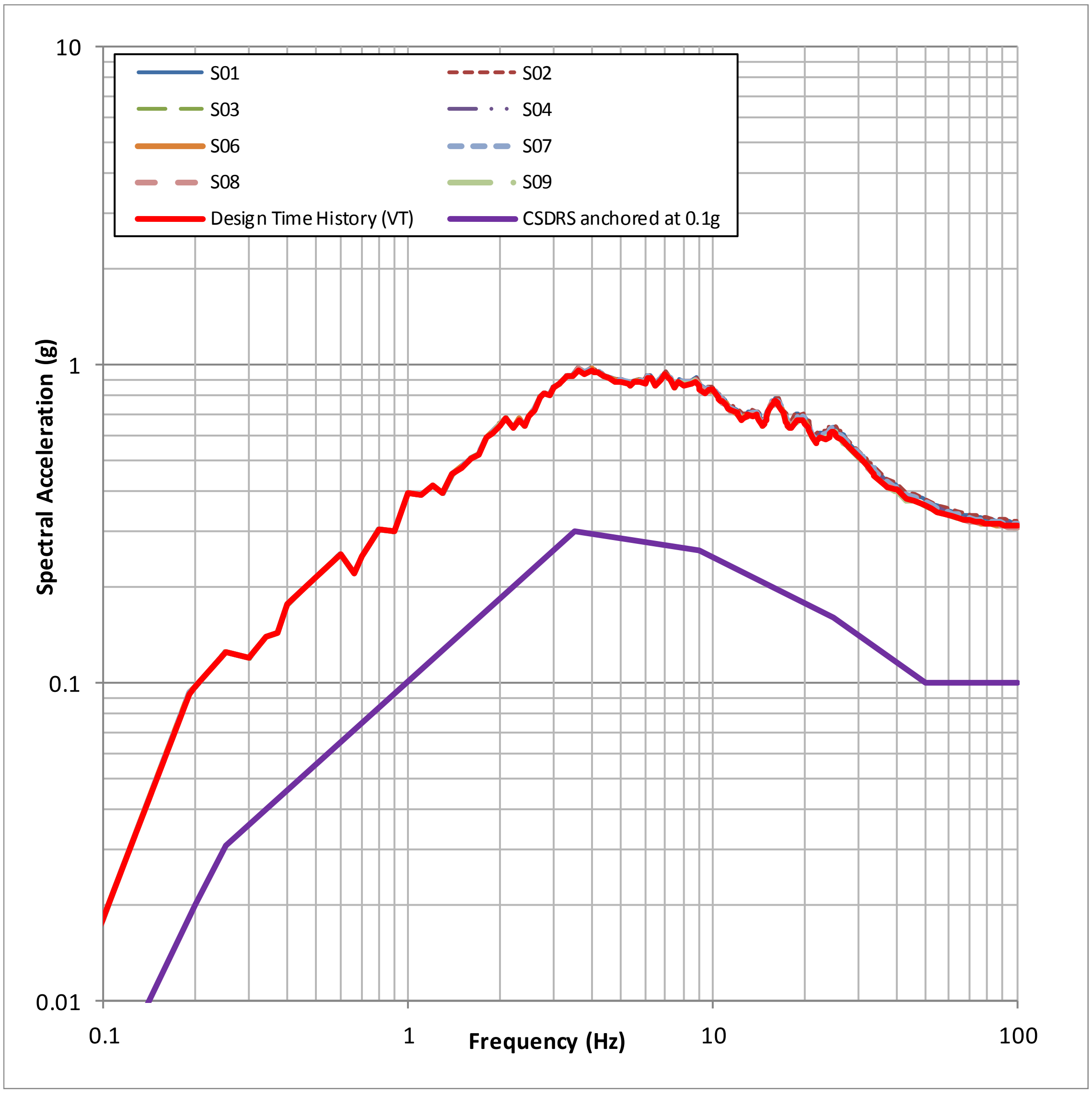

Figure 3.7A-14 Comparison of Design Time History Compatible with CSDRS with Site Response Outcrop Motion at Foundation Base Elevation of Diesel Fuel Oil Tank, Vertical Motion, 5% damping

(3 of 3)

Figures 5-14 to 5-22 are the equivalent-linear properties used in the SSI analysis of the seismic category I structures.

Using the averaged shear-strain-compatible shear wave velocity profiles as tabulated in Tables 5-12 through 5-20, the free-field site response amplification (transfer) function computed for the horizontal ground surface motion relative to the horizontal motion at depth at the top of half-space for each of the nine generic site profiles S1 through S9 are plotted in Figure 5-23. The fundamental horizontal site frequencies for S1 through S9 as shown in Figure 5-23 are tabulated in Table 5-21 and plotted in Figure 5-24. As indicated in Table 5-21 and Figure 5-15, the fundamental horizontal site frequencies for S1 through S9 cover a wide frequency range from 1.27 to 12 Hz. These site frequencies form approximately a log linear site-frequency-versus-site-profile-case straight line. Hence, the generic site profiles S1 through S9 considered for design of the APR1400 standard plant cover a wide range of site frequencies from soft soil to hard rock sites.

The dynamic properties for the free-field generic site profiles S1 through S9 given in Tables 5-12 through 5-20 are the properties used for developing the free-field soil/rock models for the SSI analysis of the APR1400 standard plant structures.

5.3 Strain-Compatible Response Motion at Foundation Level

The 10 CFR Part 50 Appendix S specifies a minimum safety requirement that the design basis ground motion for a horizontal component in the free-field at the foundation level of seismic category I structures must use an appropriate DRS with a peak ground acceleration value of at least 0.1g. Figures 5-25 through 5-31 show the response spectra of the strain-compatible time histories of free-field outcrop motions computed at the foundation level of the APR1400 nuclear island (NI) structures, emergency diesel generator building (EDGB), and diesel fuel oil tank room (DFOT), respectively. These figures indicate that the above minimum safety requirement is satisfied.

The transfer functions computed from the half-space to the outcropping layer at the foundation level of NI, EDGB, and DFOT for S1 through S4 and S6 through S9 soil profiles using SHAKEcomputer program are described in Appendix A.

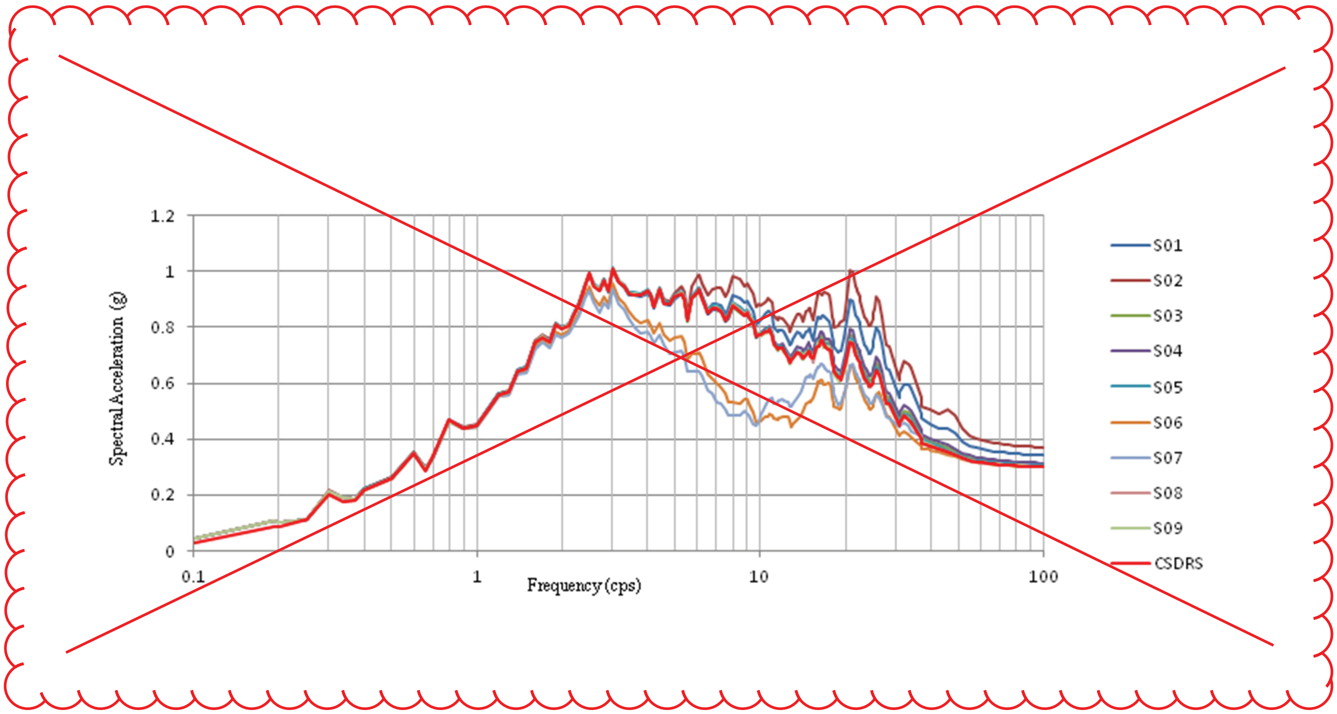

Figure 5-25 Strain-Compatible Response Spectra at Foundation Level of NI Structures (E-W)

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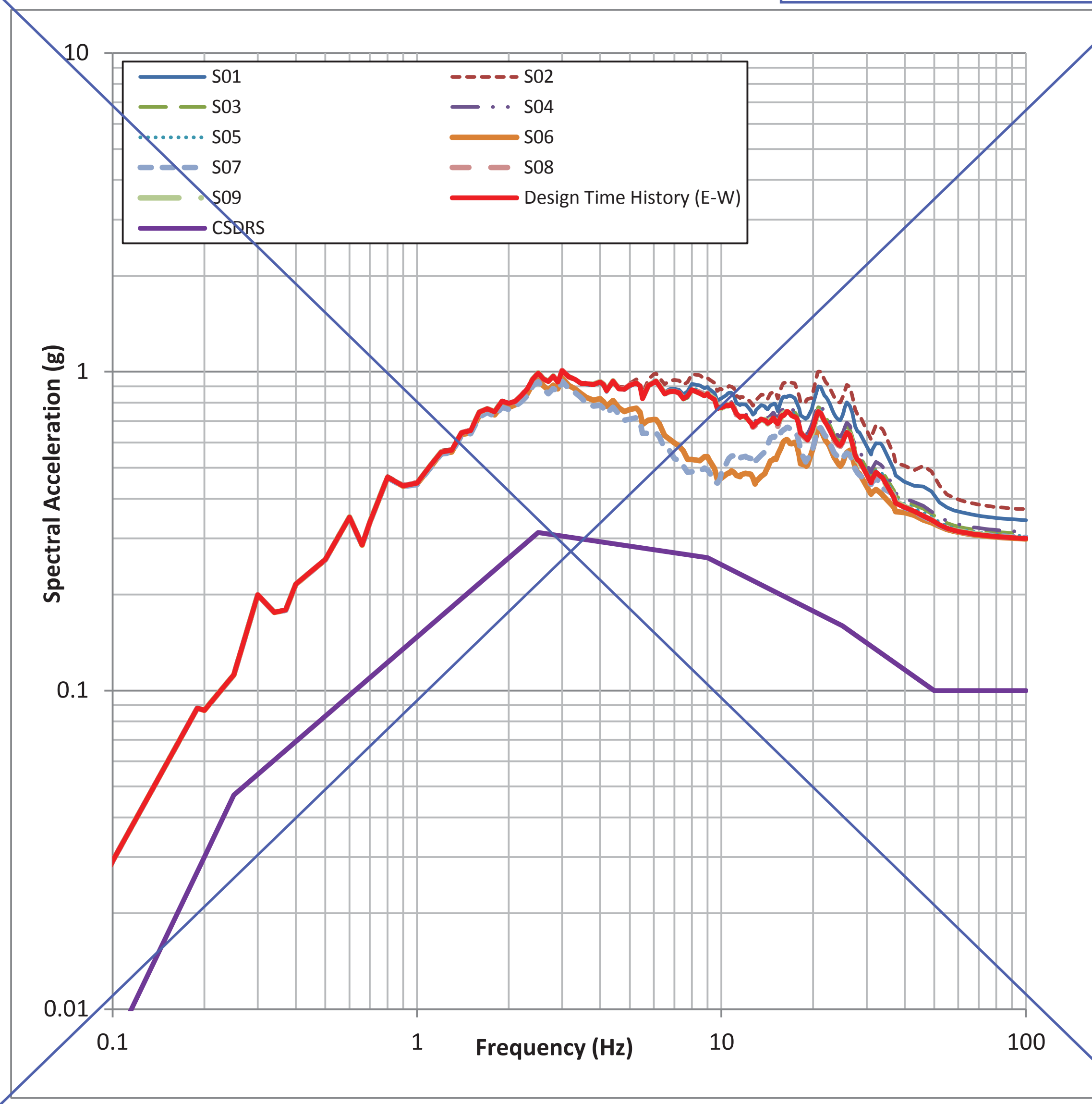

Figure 5-25 Strain-Compatible Response Spectra at Foundation Level of NI Structures (E-W)

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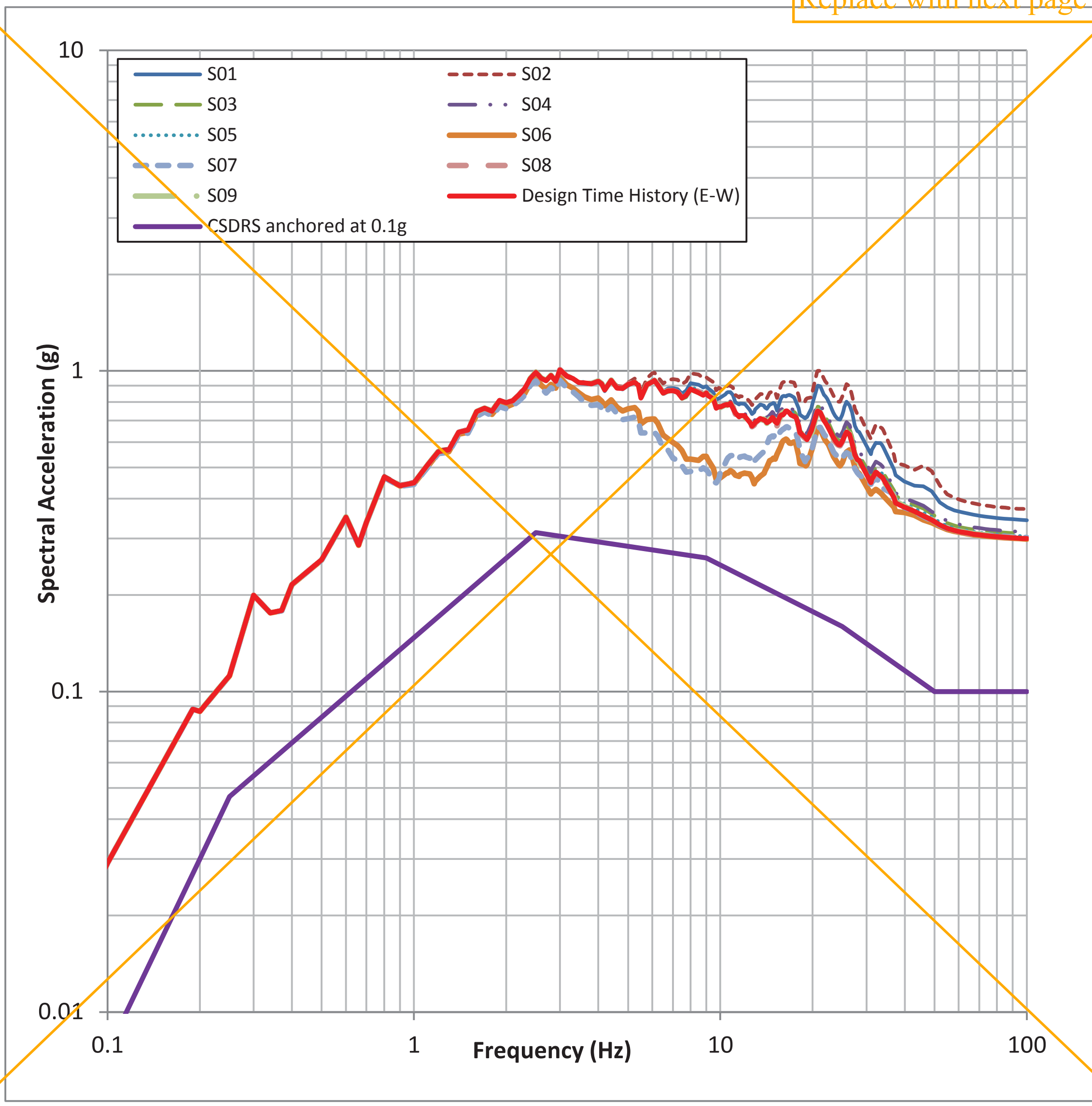

Figure 5-25 Strain-Compatible Response Spectra at Foundation Level of NI Structures (E-W)

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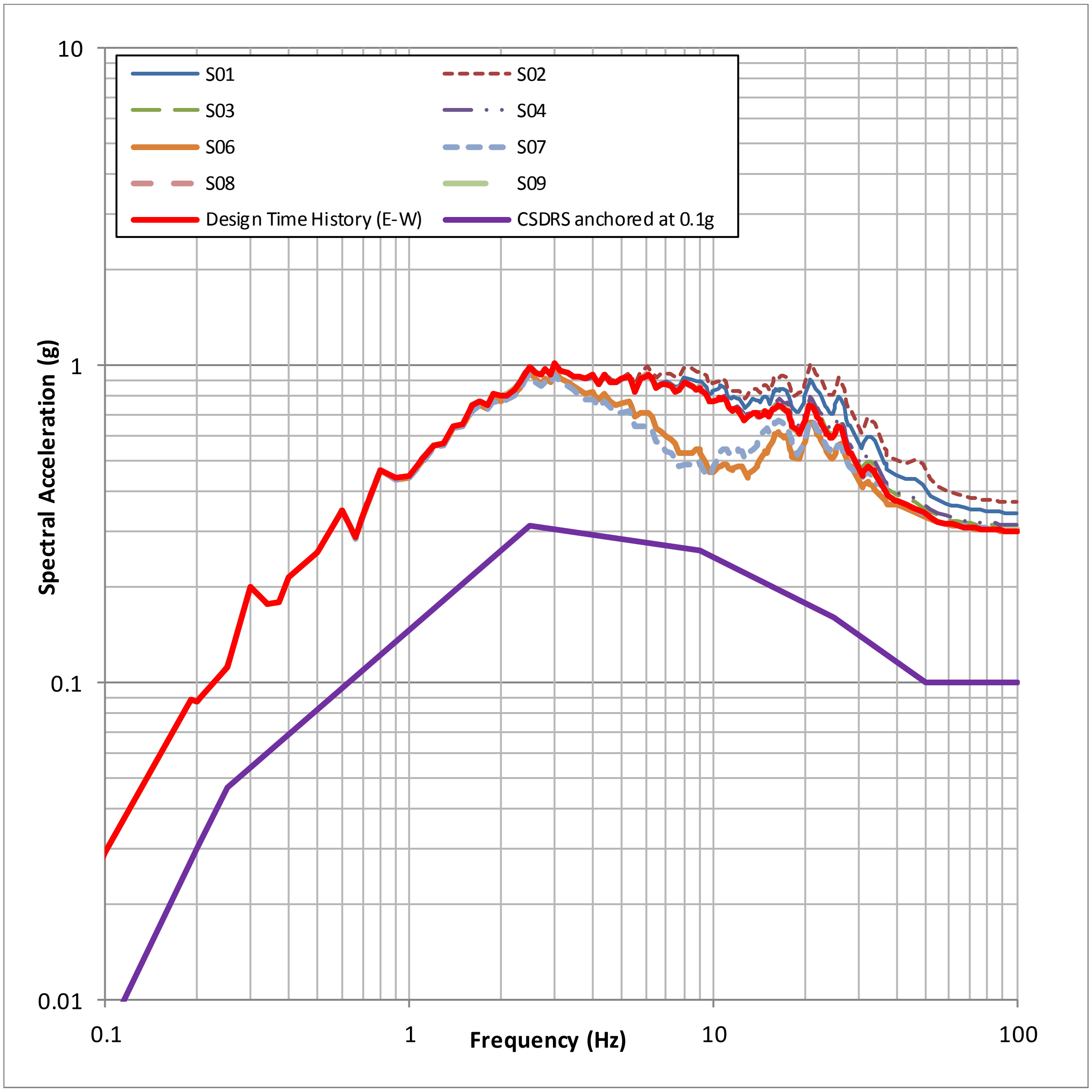

Figure 5-25 Strain-Compatible Response Spectra at Foundation Level of NI Structures (E-W)

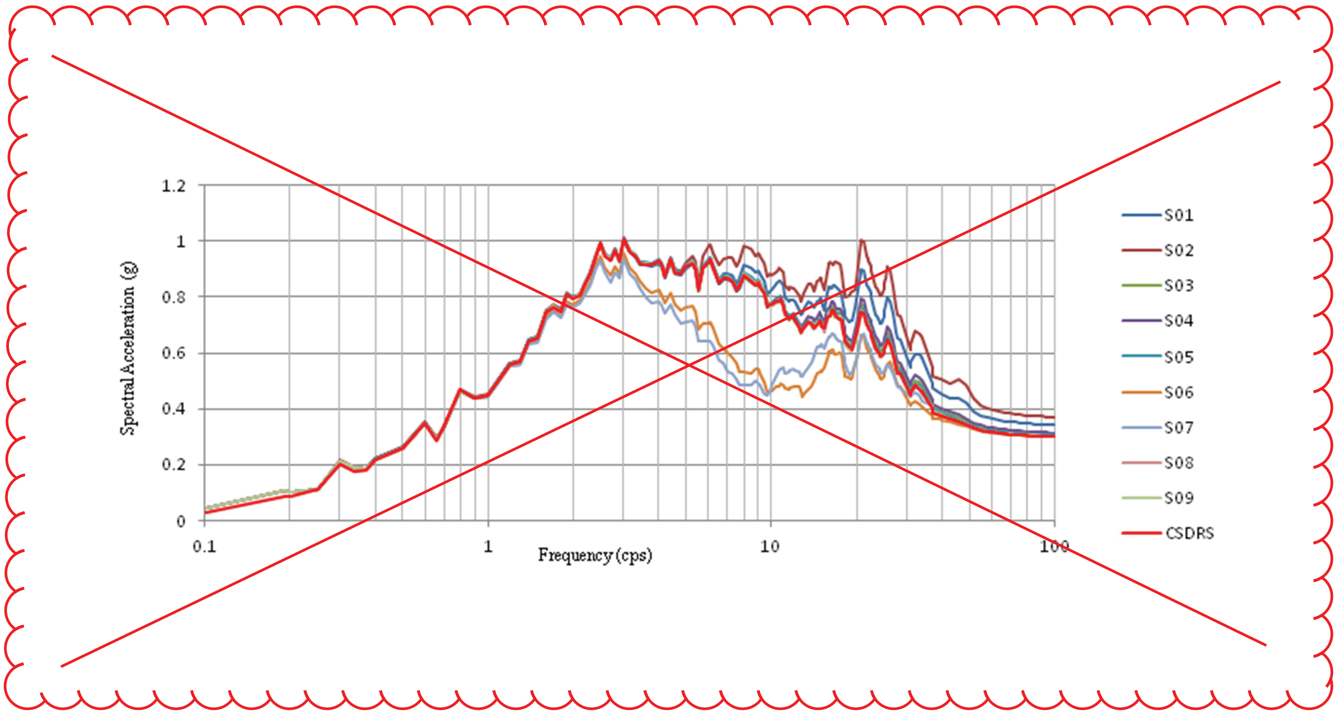

Figure 5-26 Strain-Compatible Response Spectra at Foundation Level of NI Structures (N-S)

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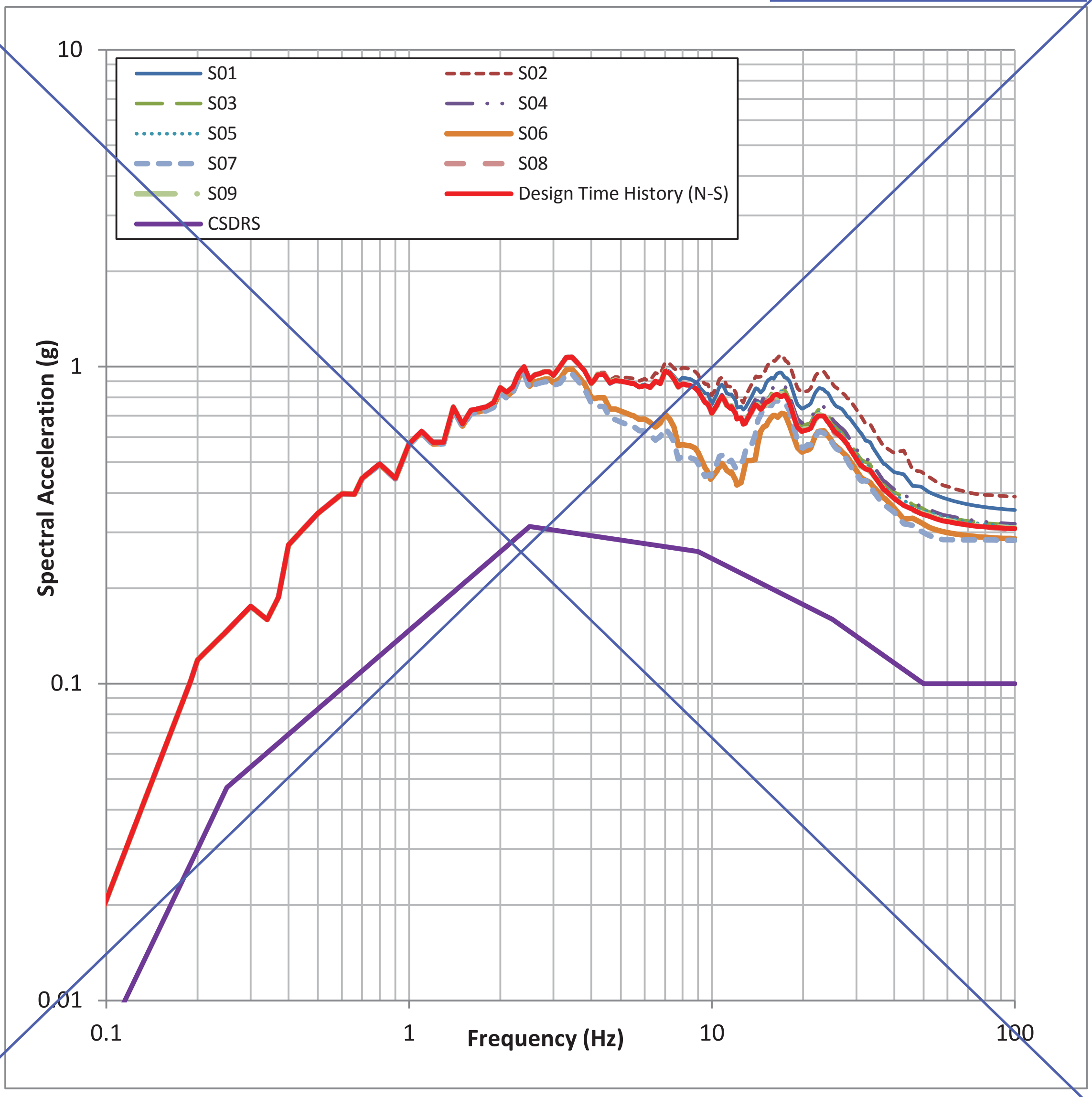

Figure 5-26 Strain-Compatible Response Spectra at Foundation Level of NI Structures (N-S)

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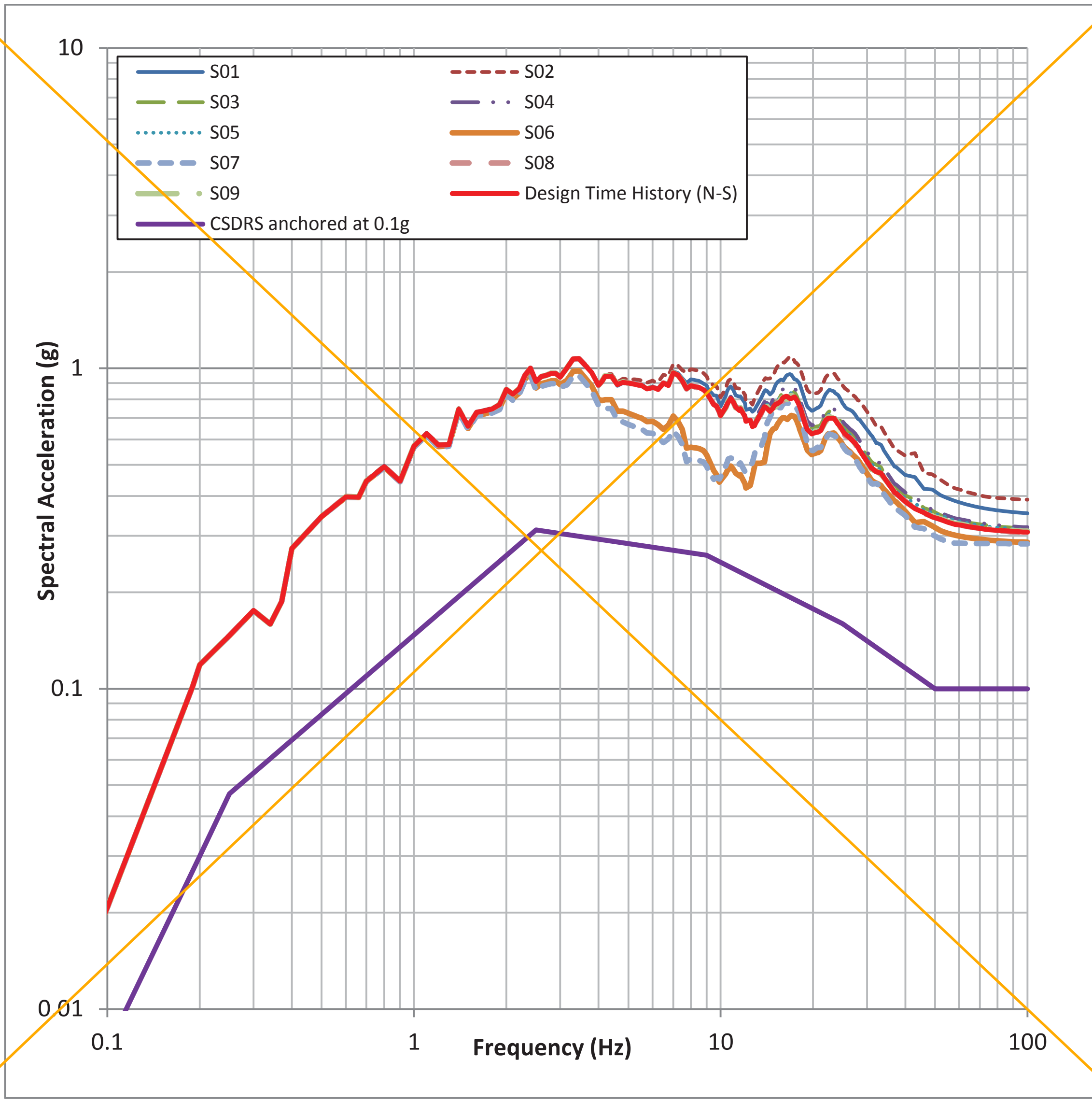

Figure 5-26 Strain-Compatible Response Spectra at Foundation Level of NI Structures (N-S)

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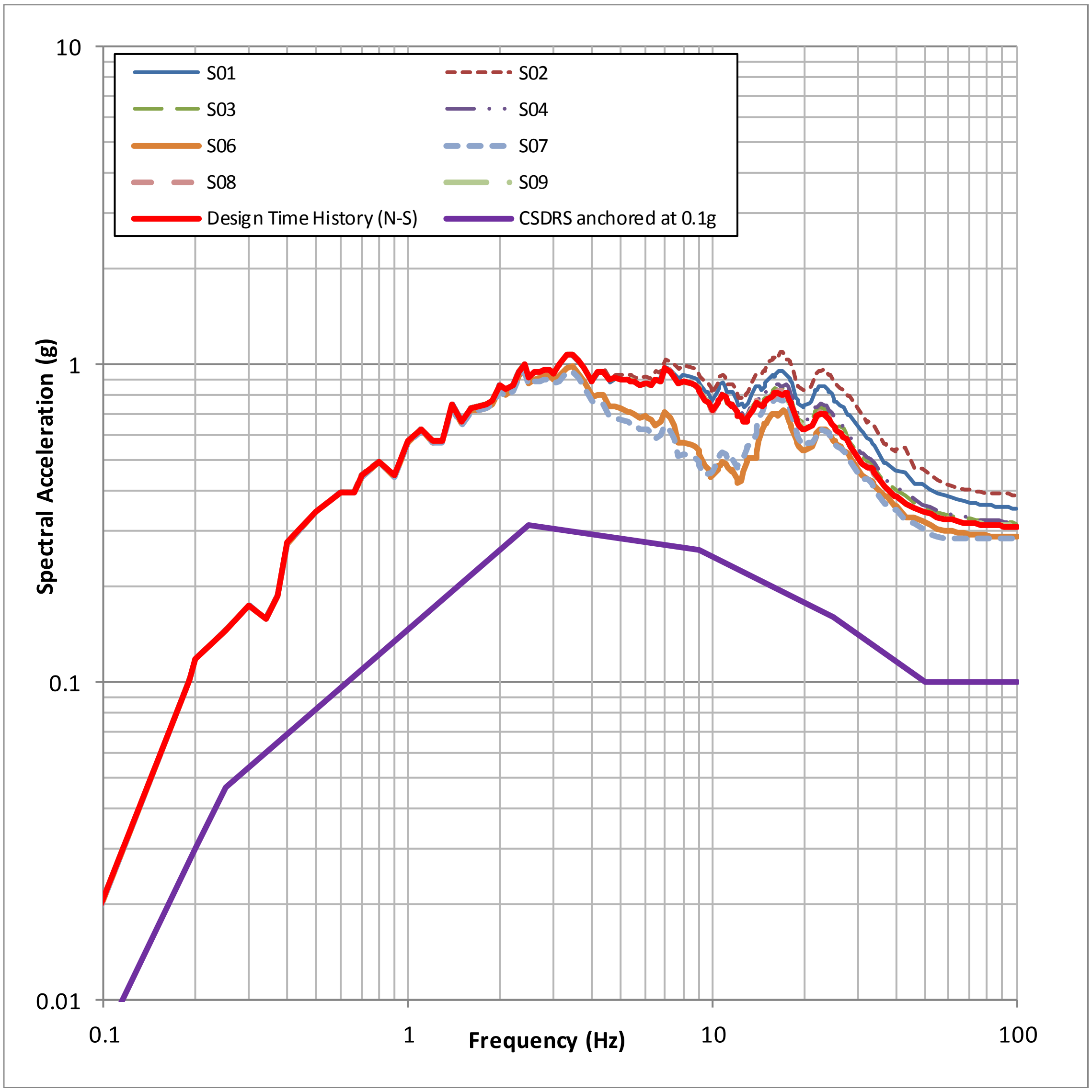

Figure 5-26 Strain-Compatible Response Spectra at Foundation Level of NI Structures (N-S)

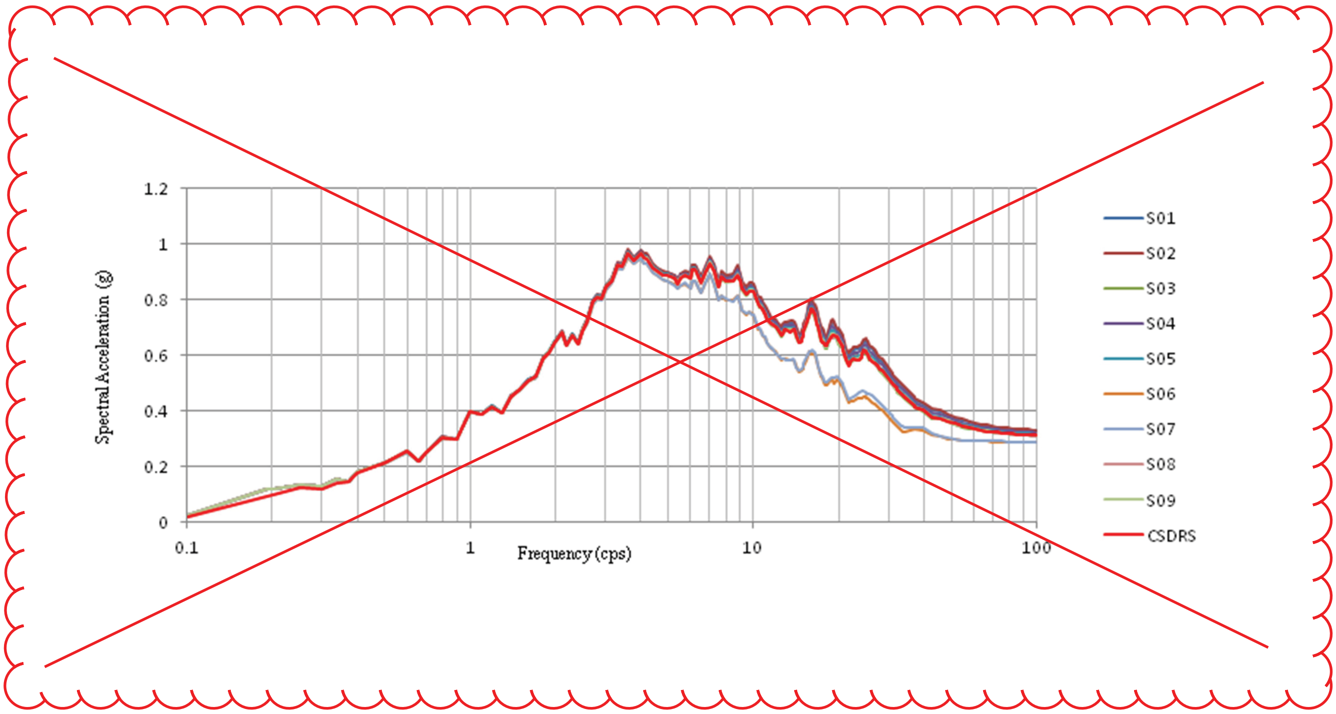

Figure 5-27 Strain-Compatible Response Spectra at Foundation Level of NI Structures (Vertical)

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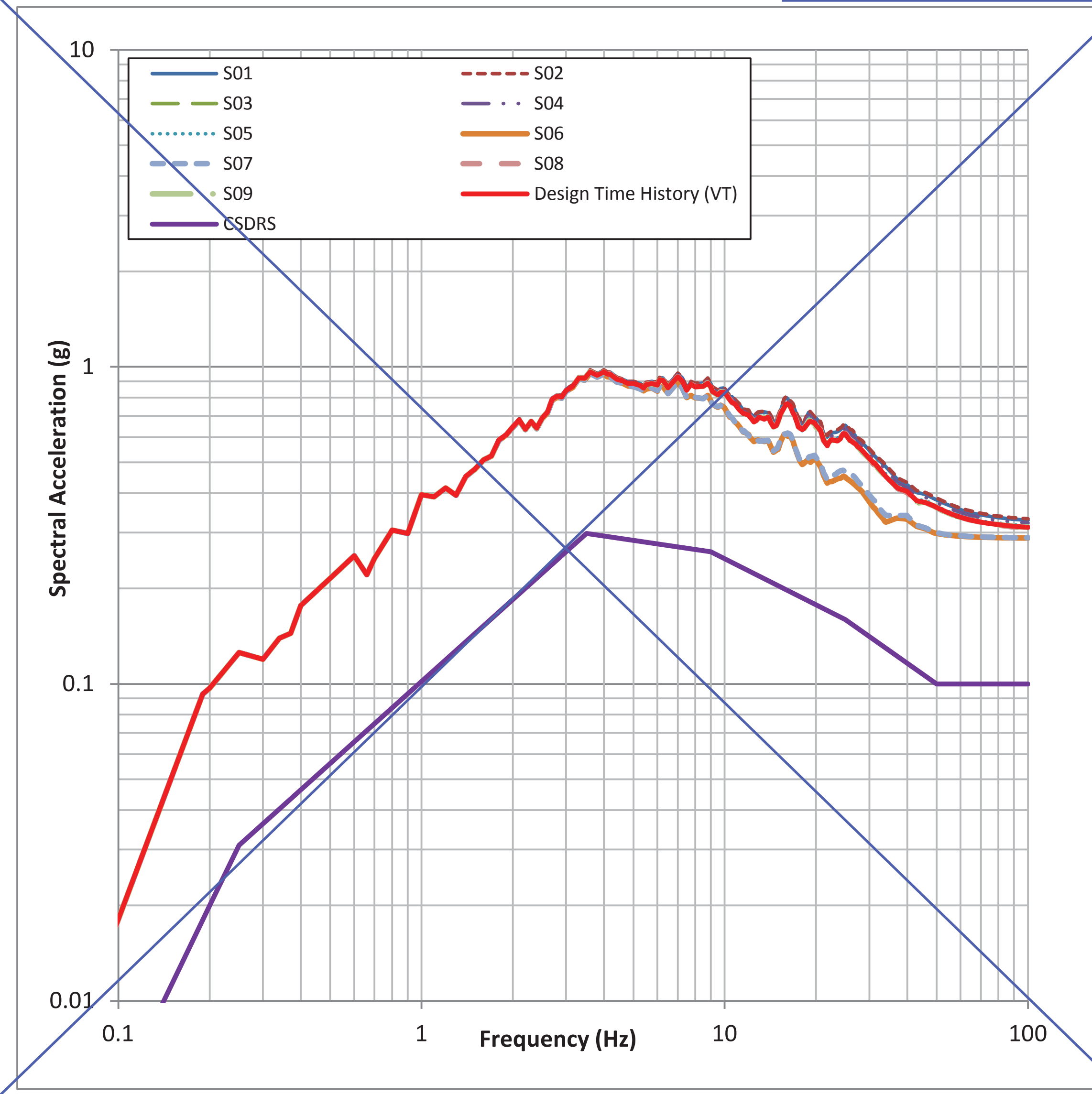

Figure 5-27 Strain-Compatible Response Spectra at Foundation Level of NI Structures (Vertical)

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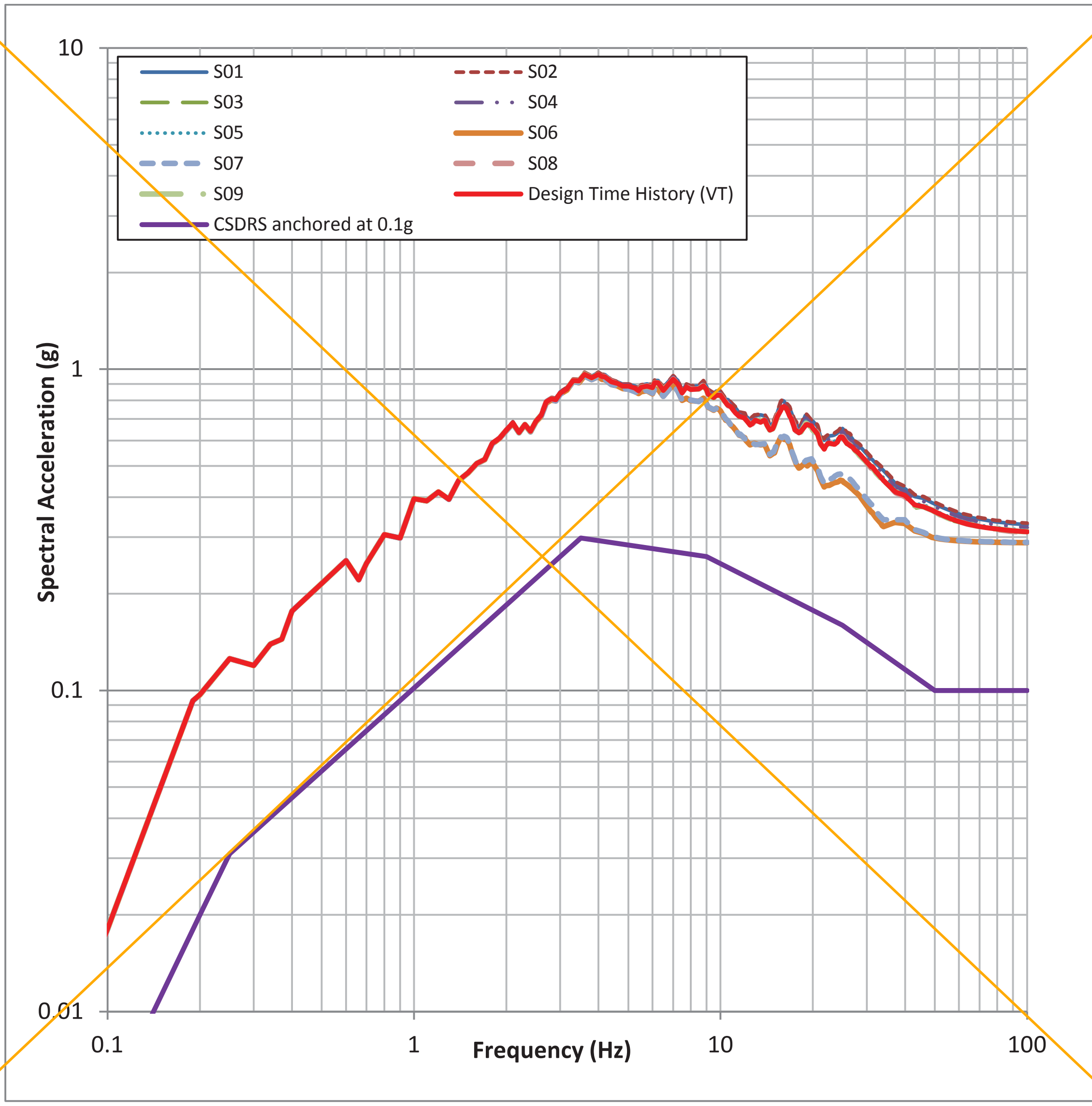

Figure 5-27 Strain-Compatible Response Spectra at Foundation Level of NI Structures (Vertical)

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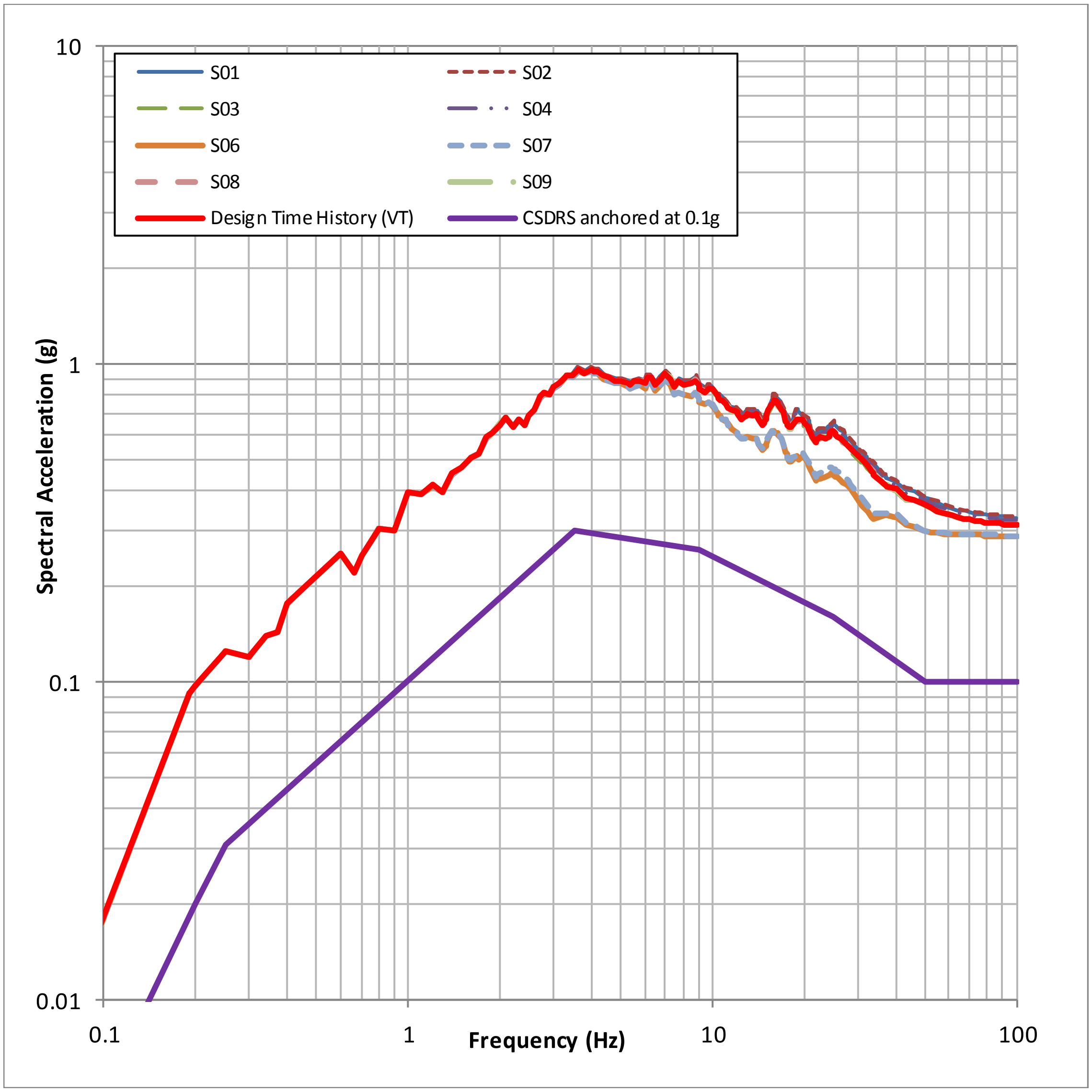

Figure 5-27 Strain-Compatible Response Spectra at Foundation Level of NI Structures (Vertical)

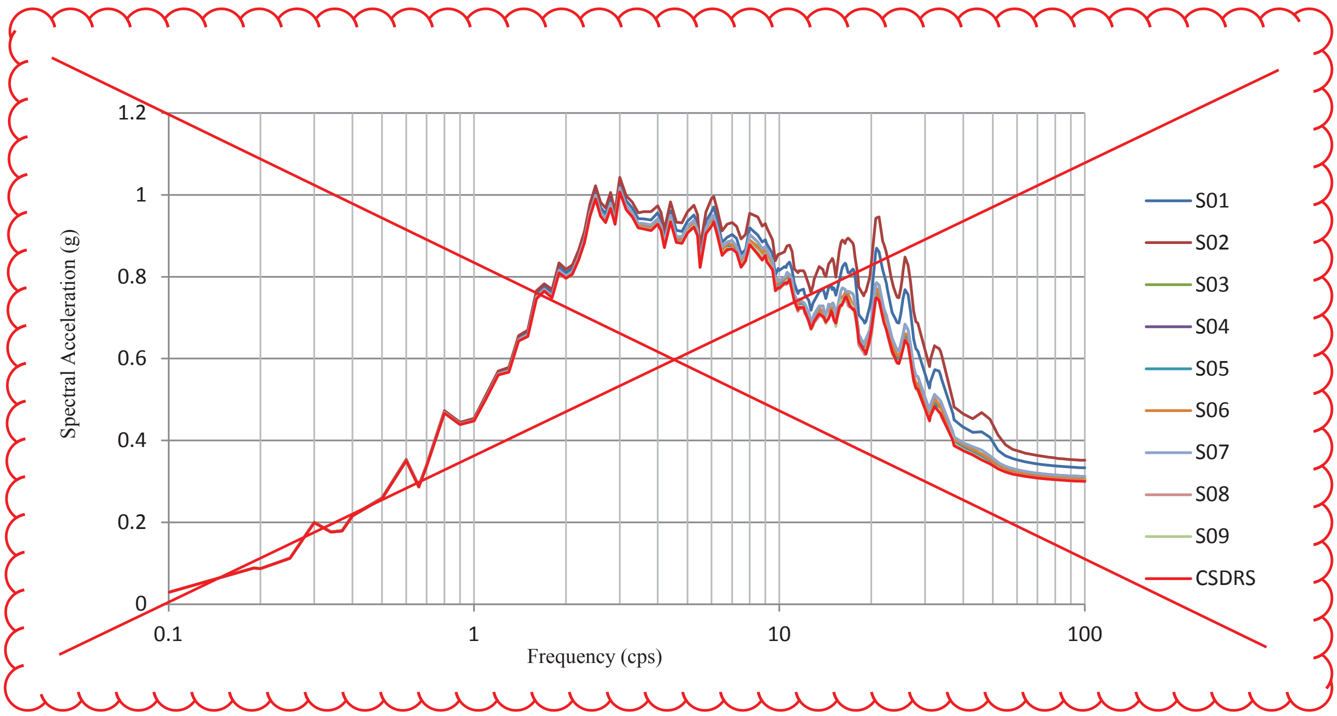

Figure 5-28 Strain-Compatible Response Spectra at Foundation Level of EDGB (E-W)

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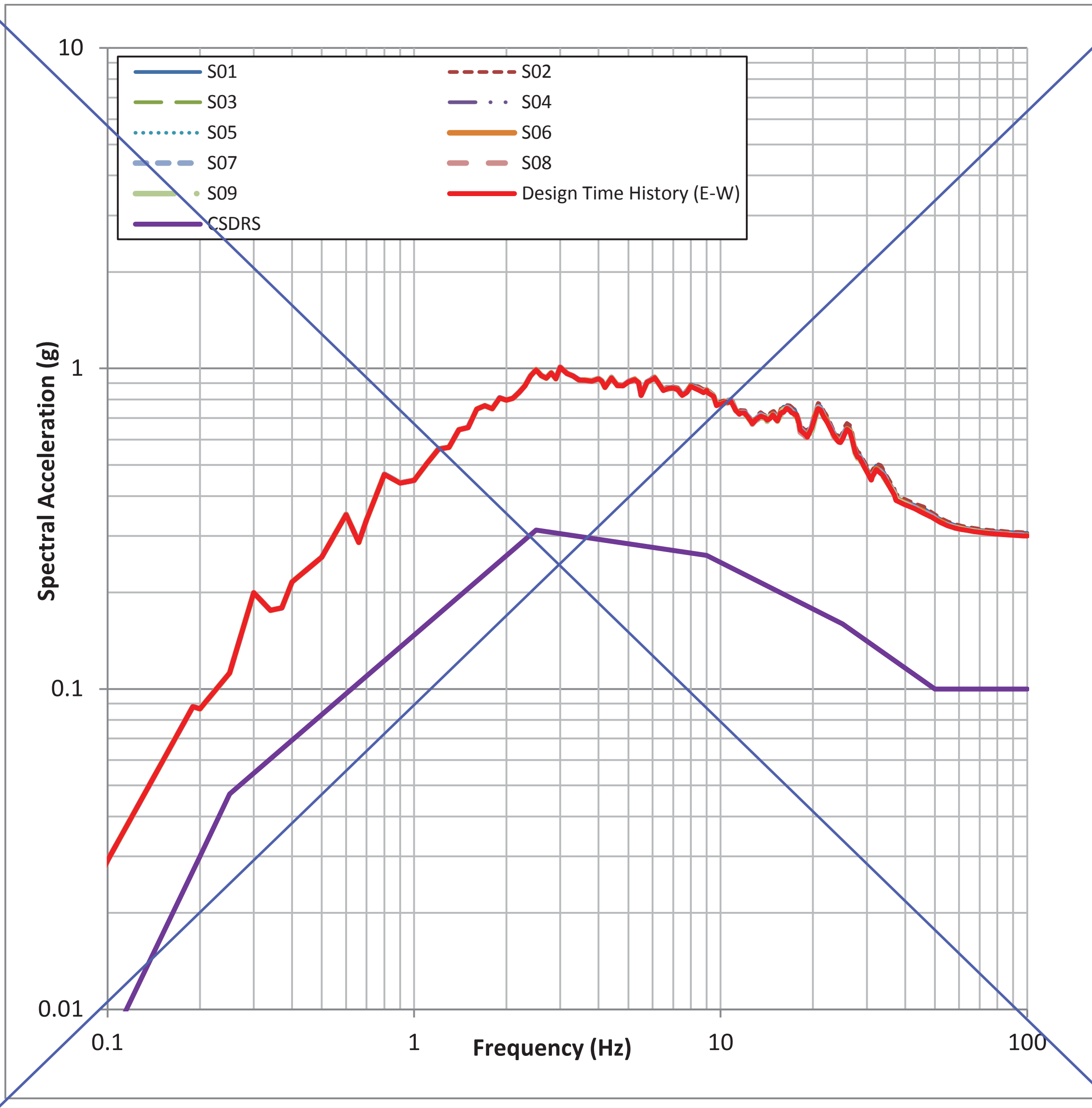

Figure 5-28 Strain-Compatible Response Spectra at Foundation Level of EDGB (E-W)

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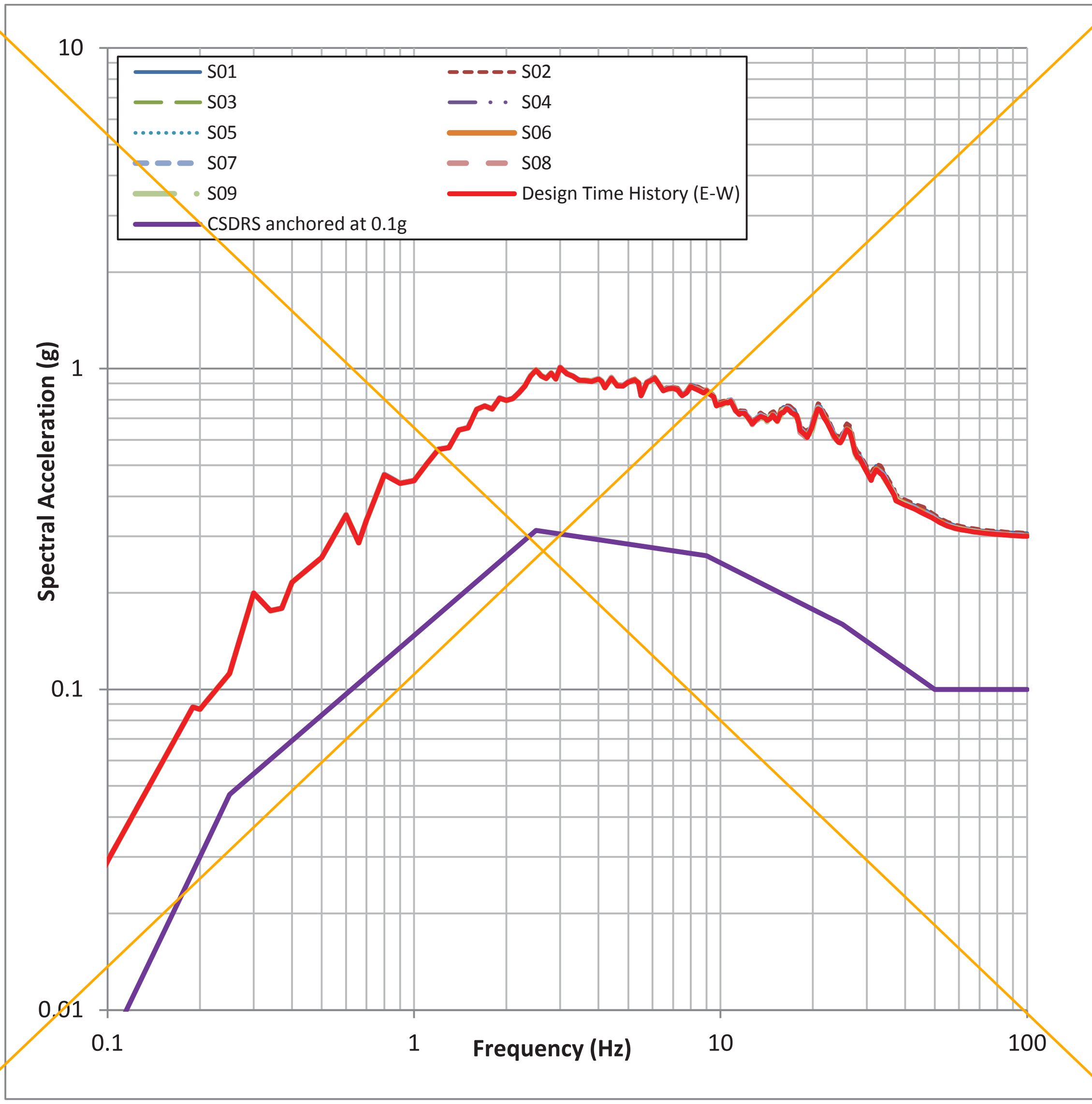

Figure 5-28 Strain-Compatible Response Spectra at Foundation Level of EDGB (E-W)

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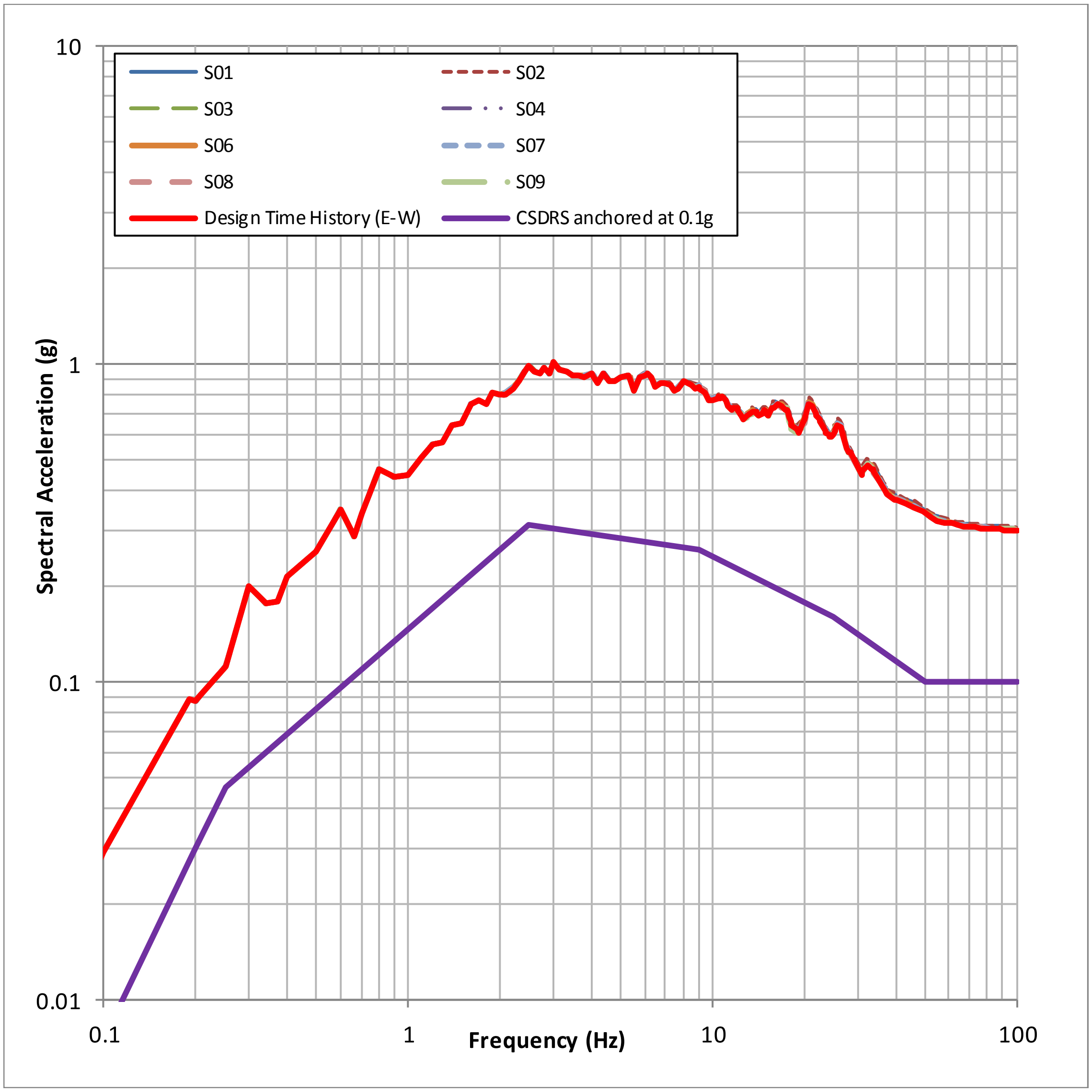

Figure 5-28 Strain-Compatible Response Spectra at Foundation Level of EDGB (E-W)

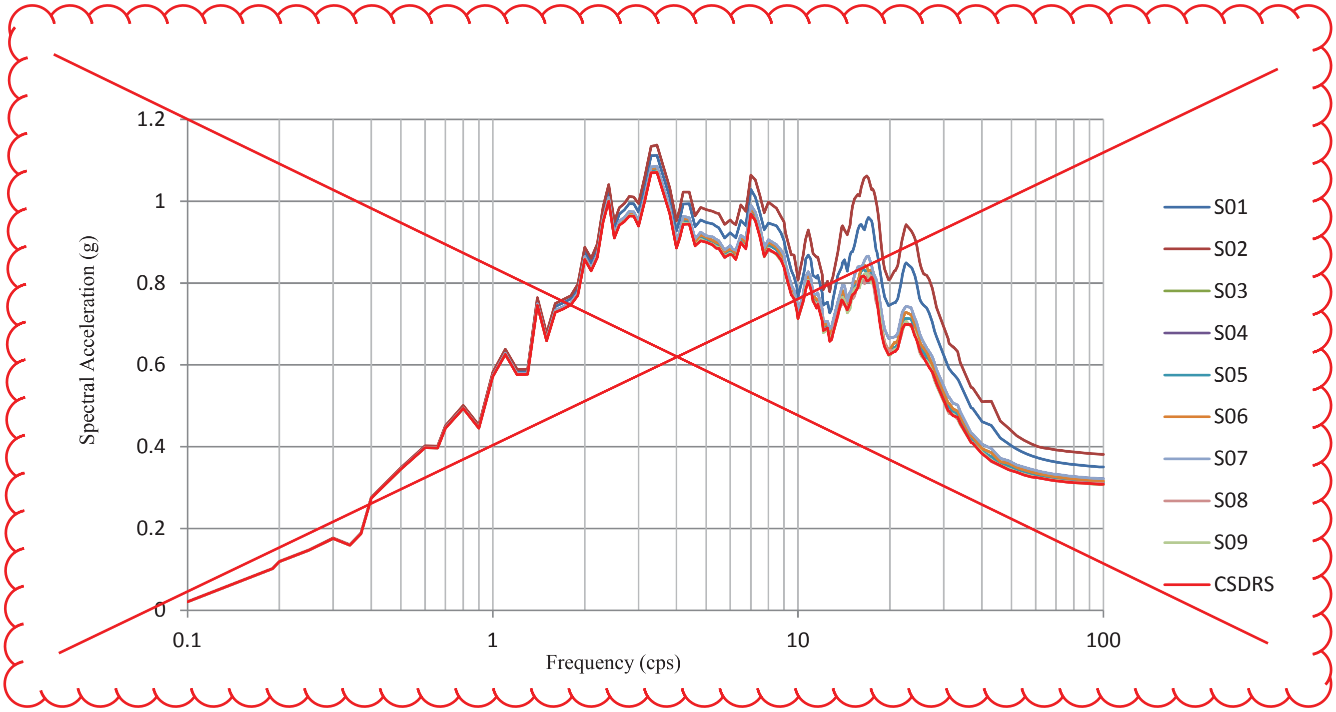

Figure 5-29 Strain-Compatible Response Spectra at Foundation Level of EDGB (N-S)

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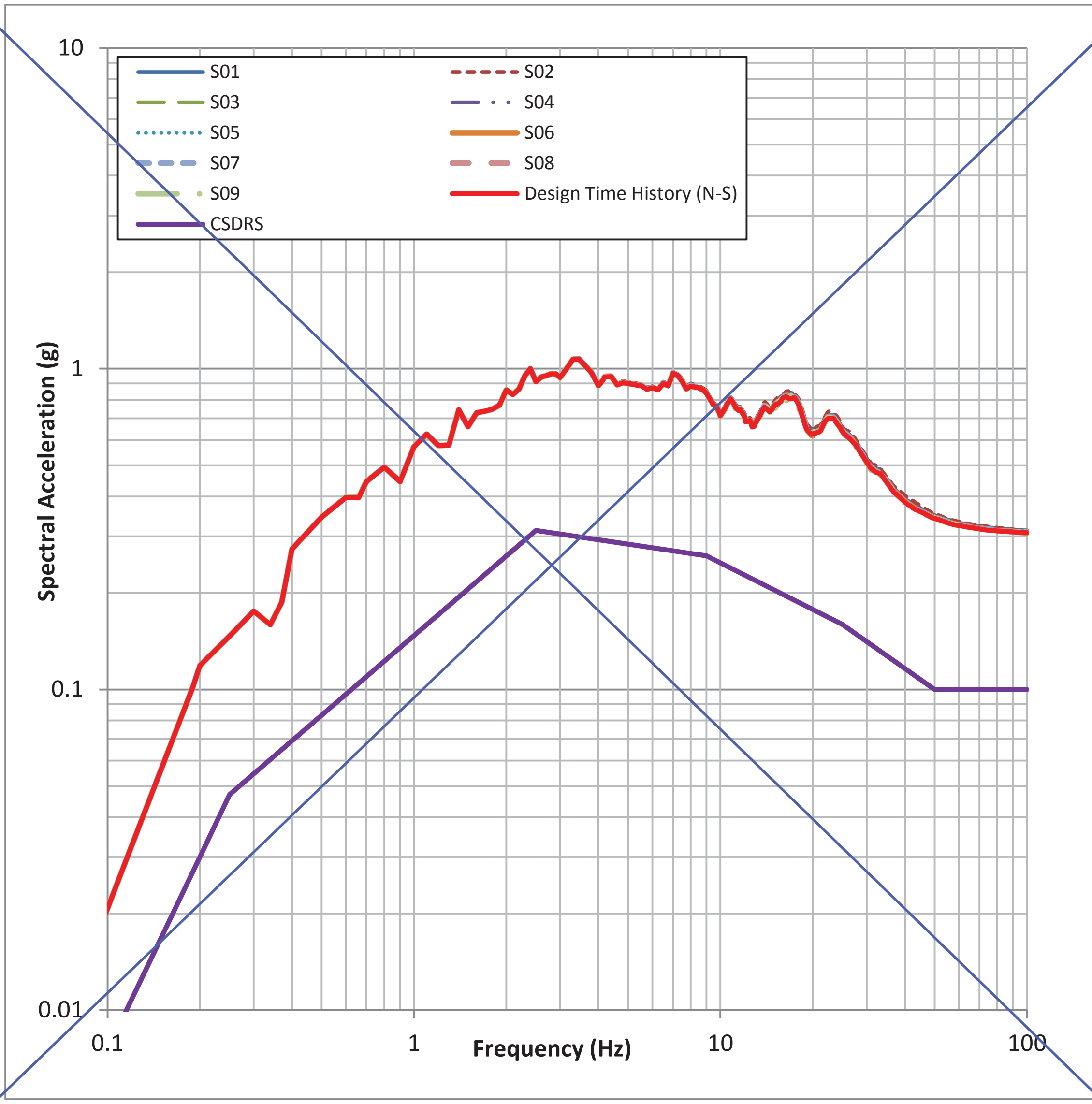

Figure 5-29 Strain-Compatible Response Spectra at Foundation Level of EDGB (N-S)

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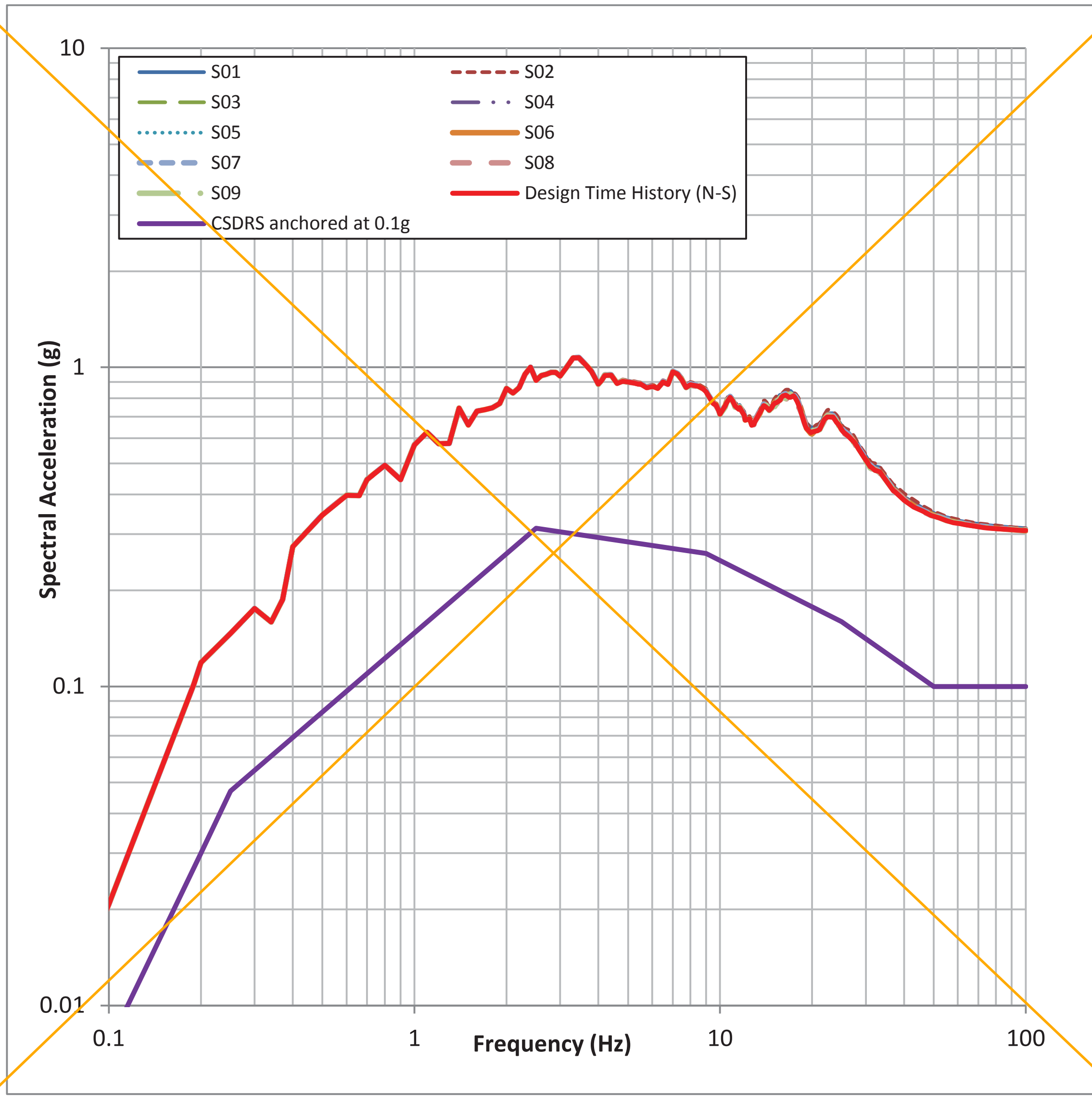

Figure 5-29 Strain-Compatible Response Spectra at Foundation Level of EDGB (N-S)

RAI 253-8300 - Question 03.07.01-5_Rev.3

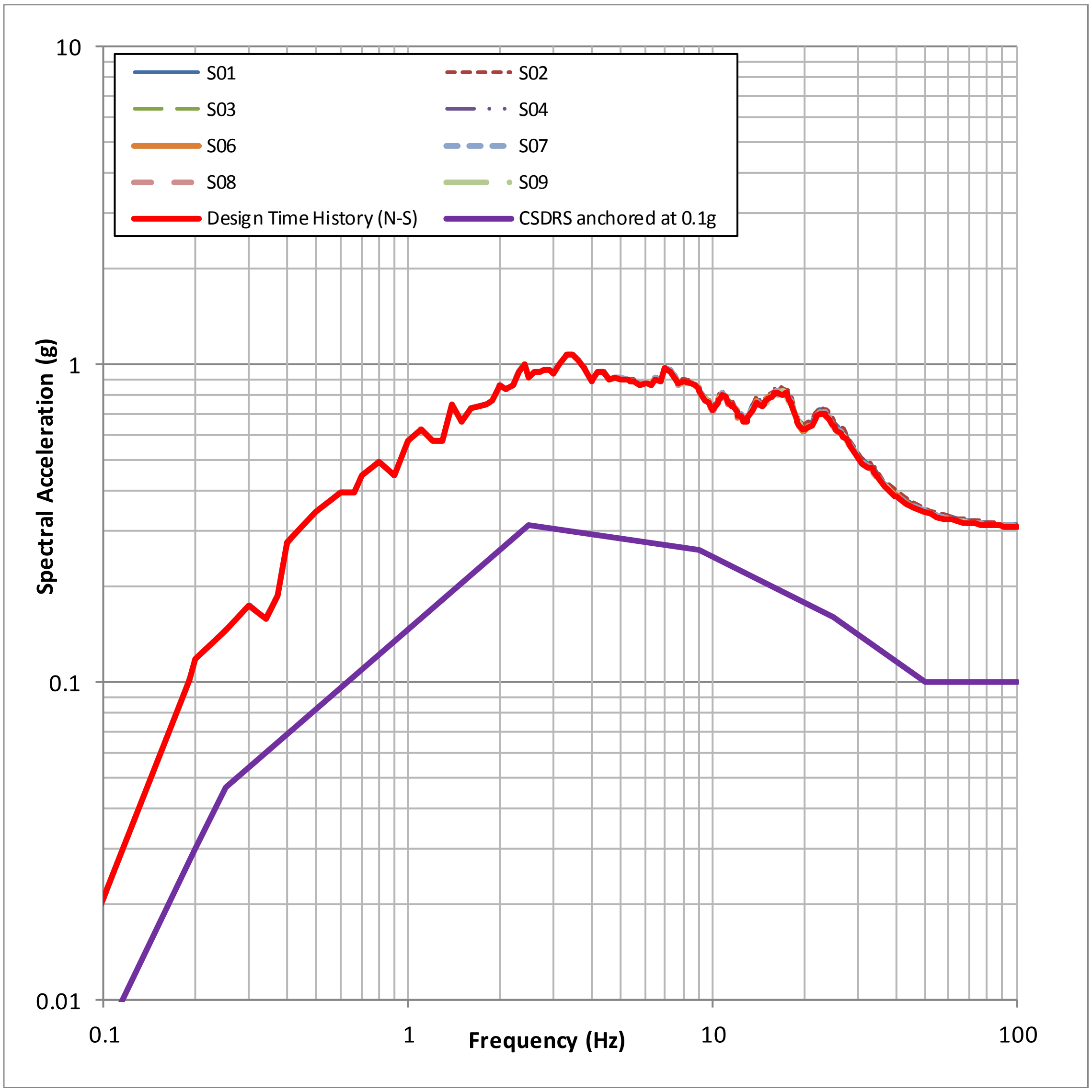

Figure 5-29 Strain-Compatible Response Spectra at Foundation Level of EDGB (N-S)

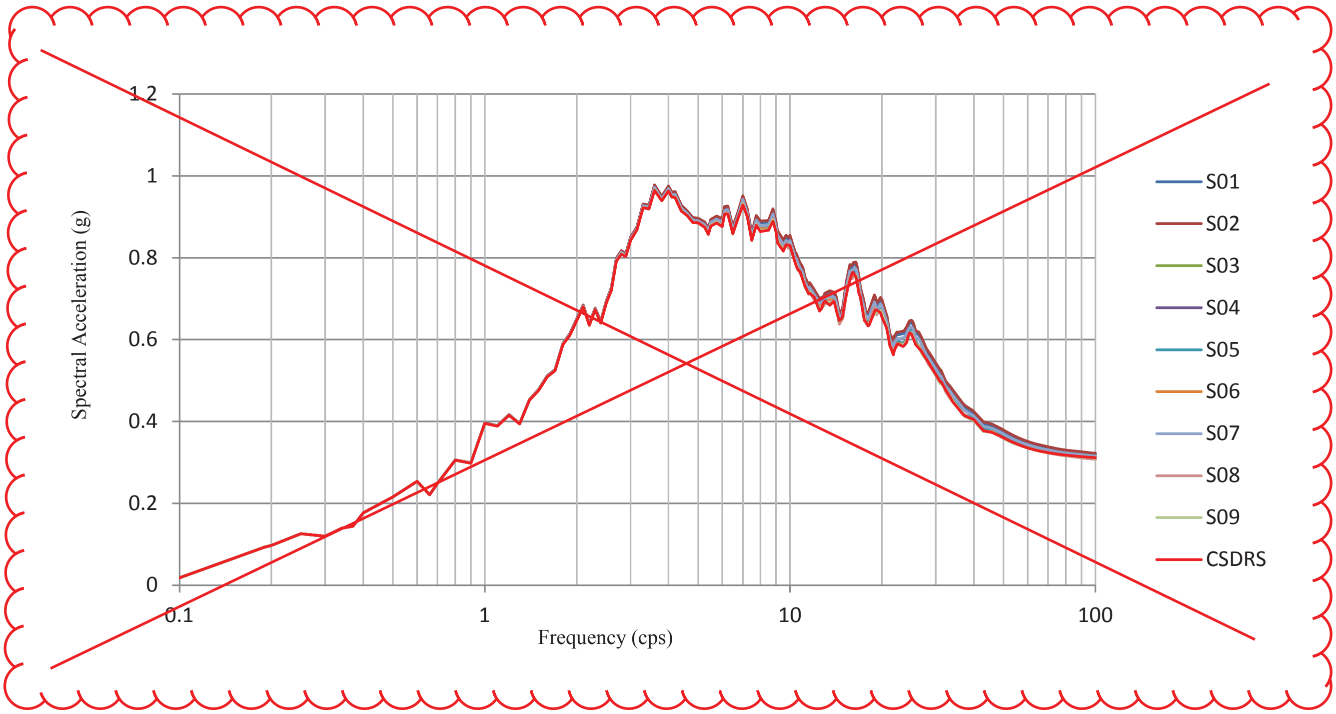

Figure 5-30 Strain-Compatible Response Spectra at Foundation Level of EDGB (Vertical)

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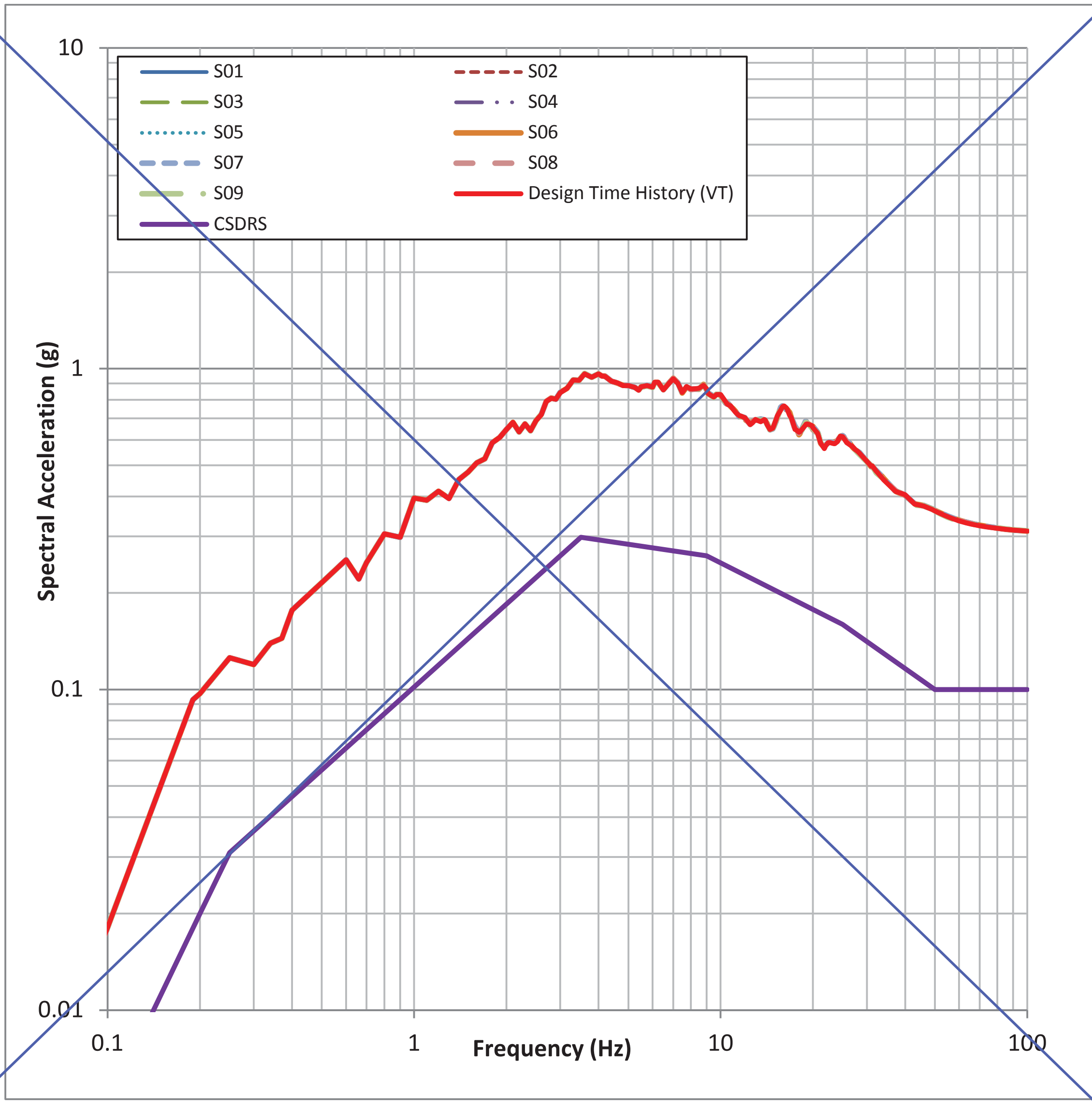

Figure 5-30 Strain-Compatible Response Spectra at Foundation Level of EDGB (Vertical)

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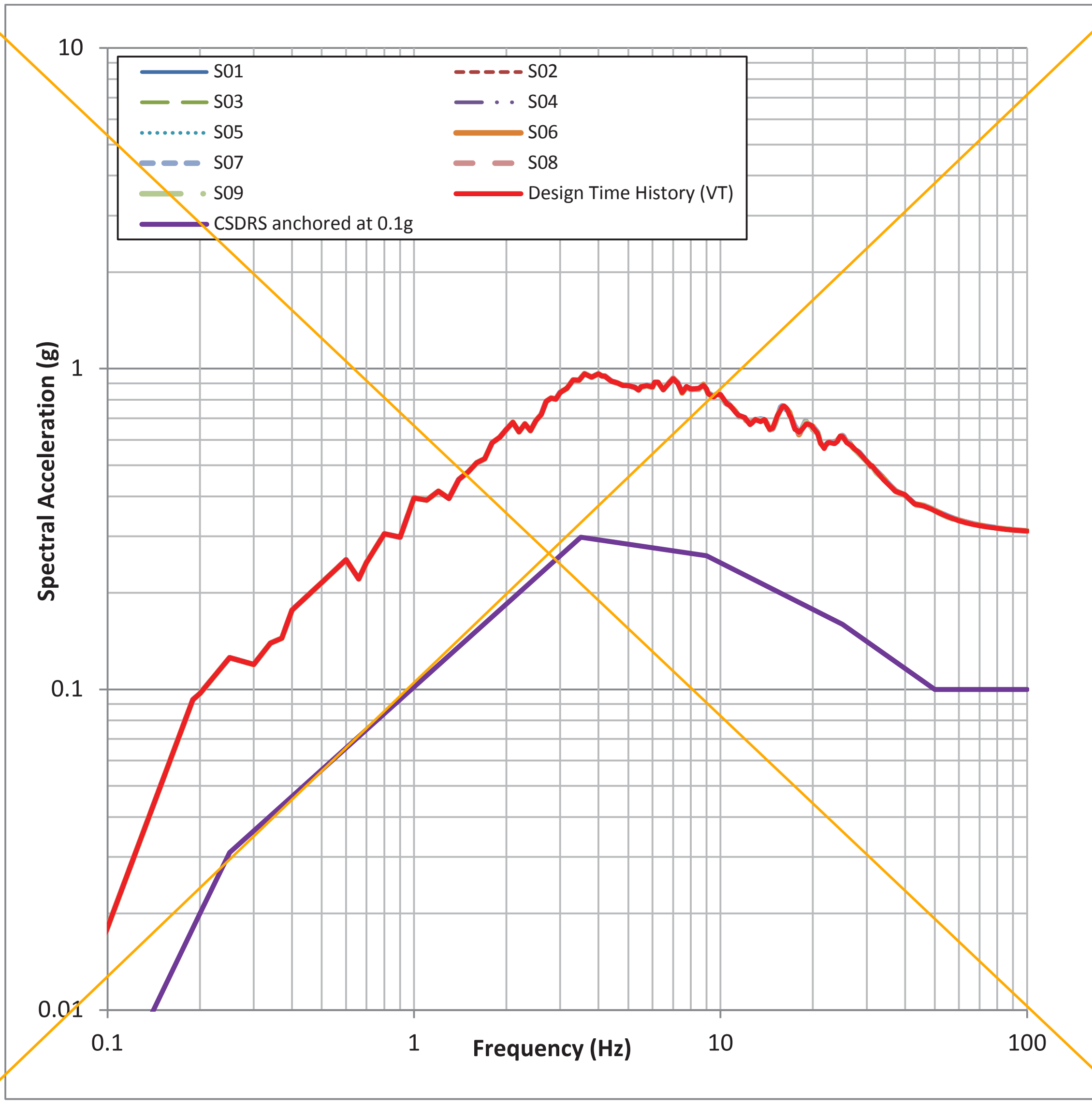

Figure 5-30 Strain-Compatible Response Spectra at Foundation Level of EDGB (Vertical)

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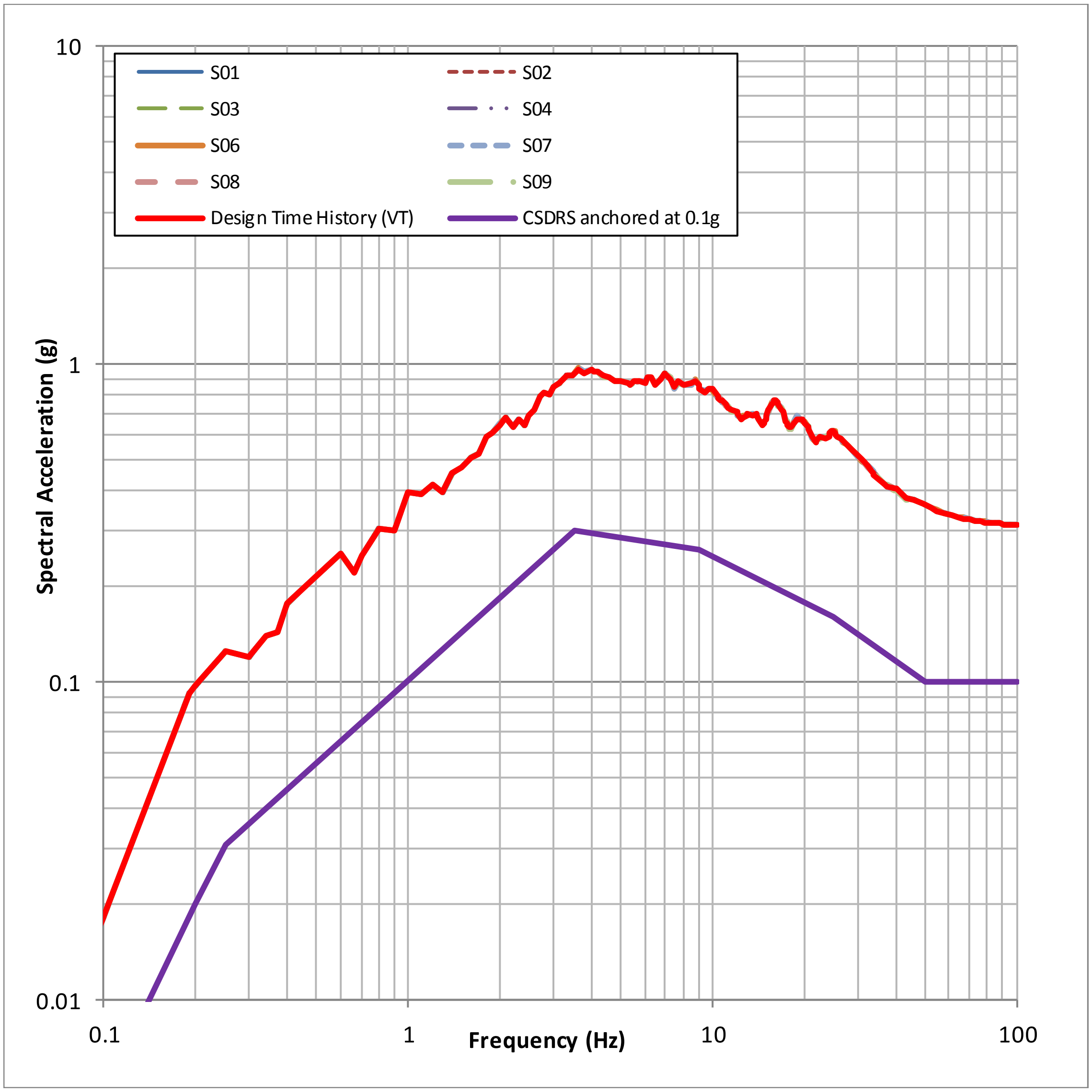

Figure 5-30 Strain-Compatible Response Spectra at Foundation Level of EDGB (Vertical)

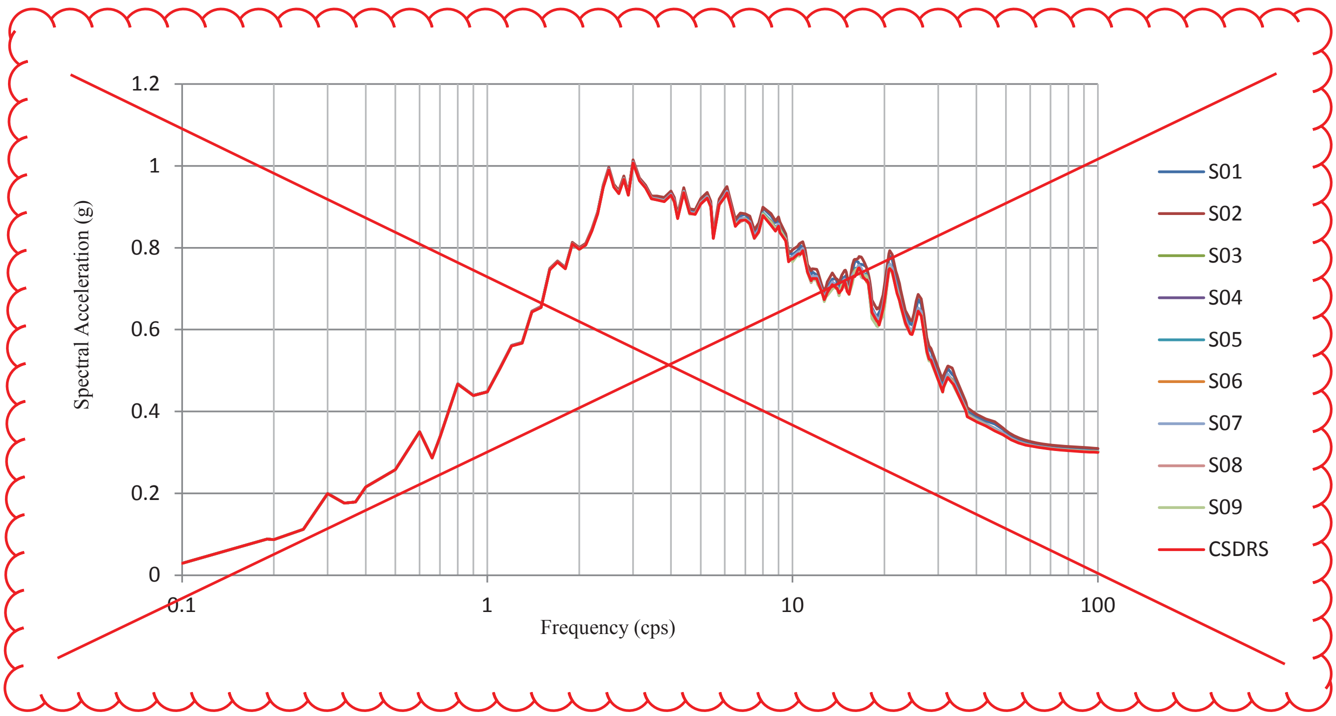

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(E-W) (1 of 3)

Replace with next page

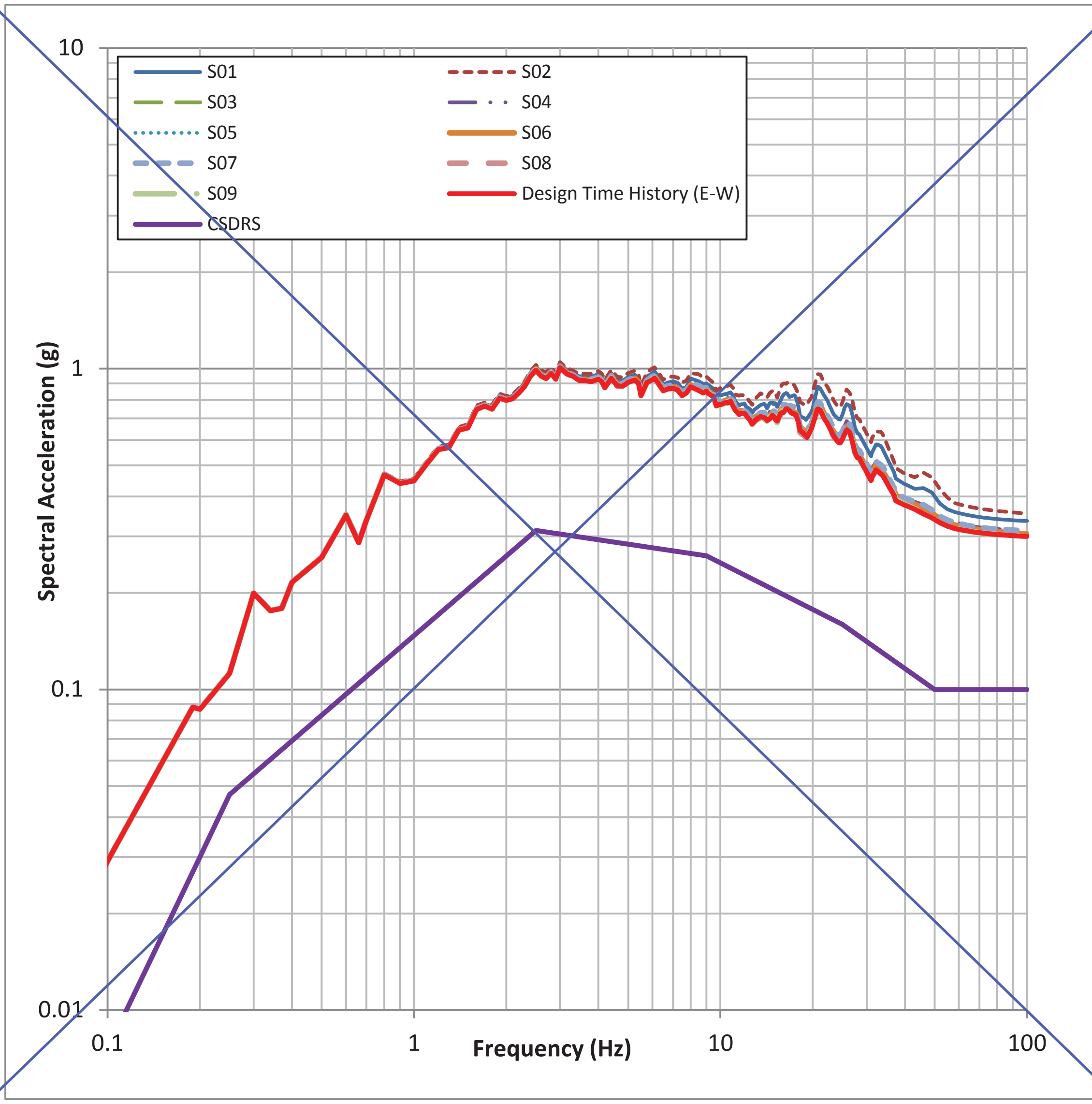

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(E-W) (1 of 3)

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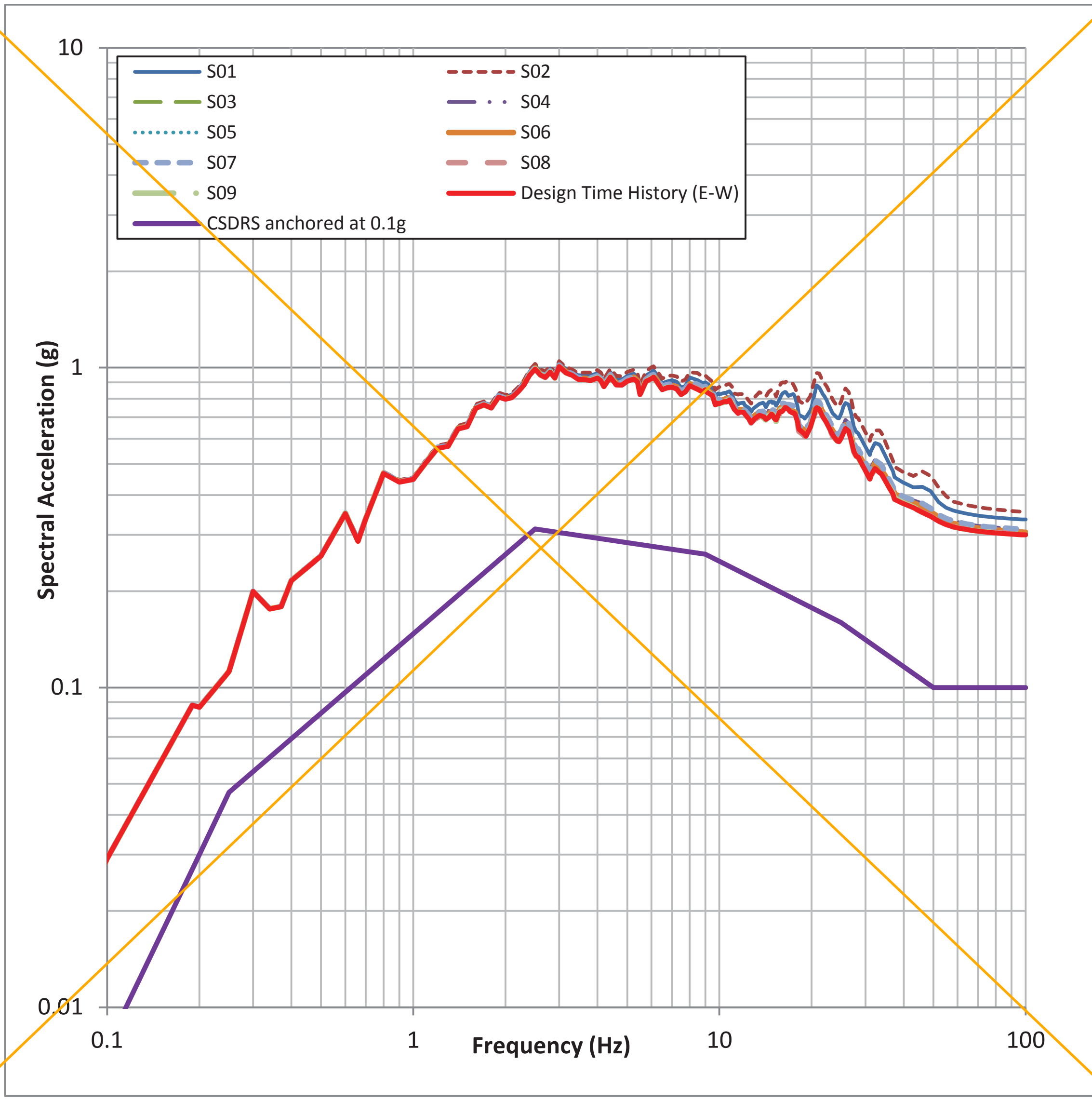

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(E-W) (1 of 3)

RAI 253-8300 - Question 03.07.01-5_Rev.3

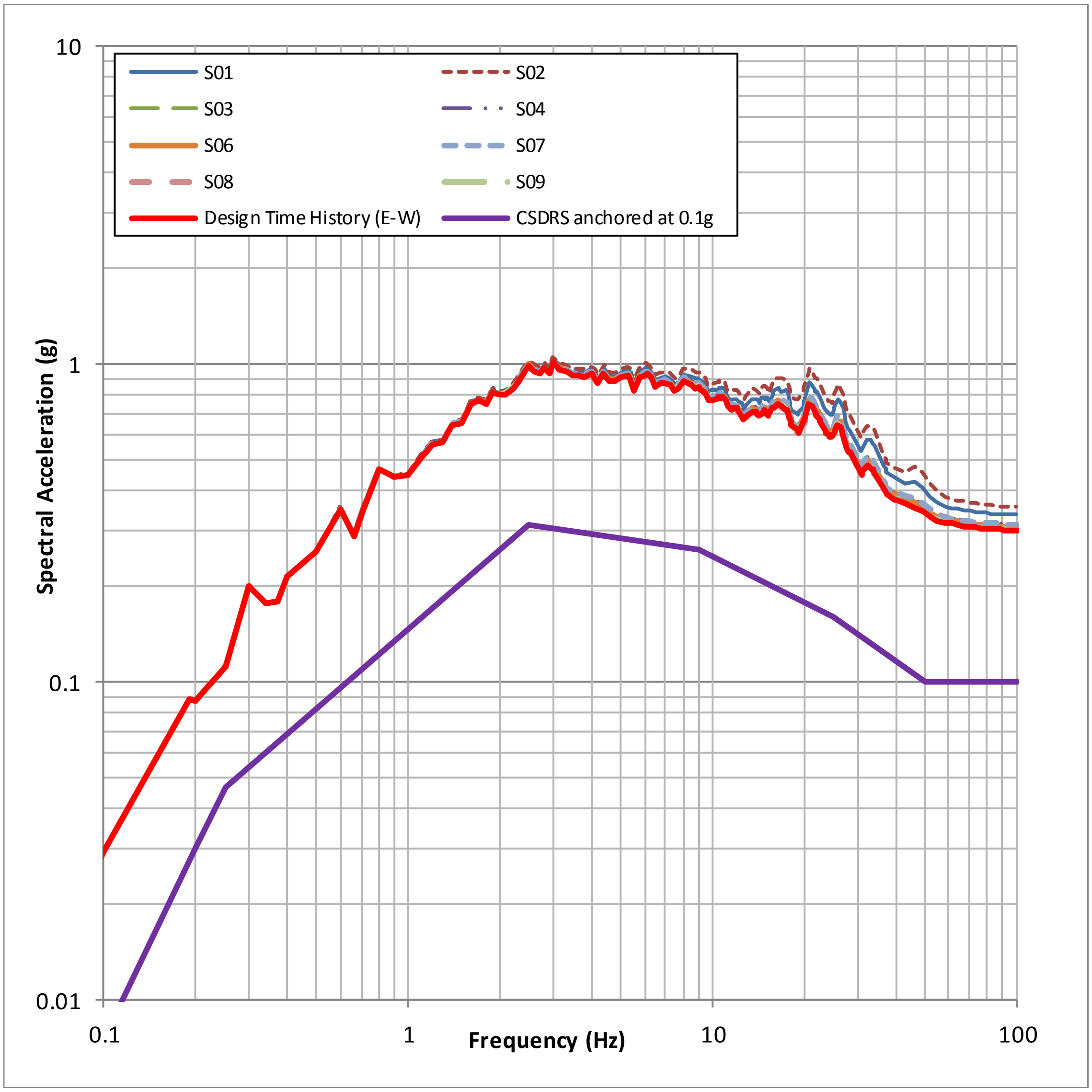

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(E-W) (1 of 3)

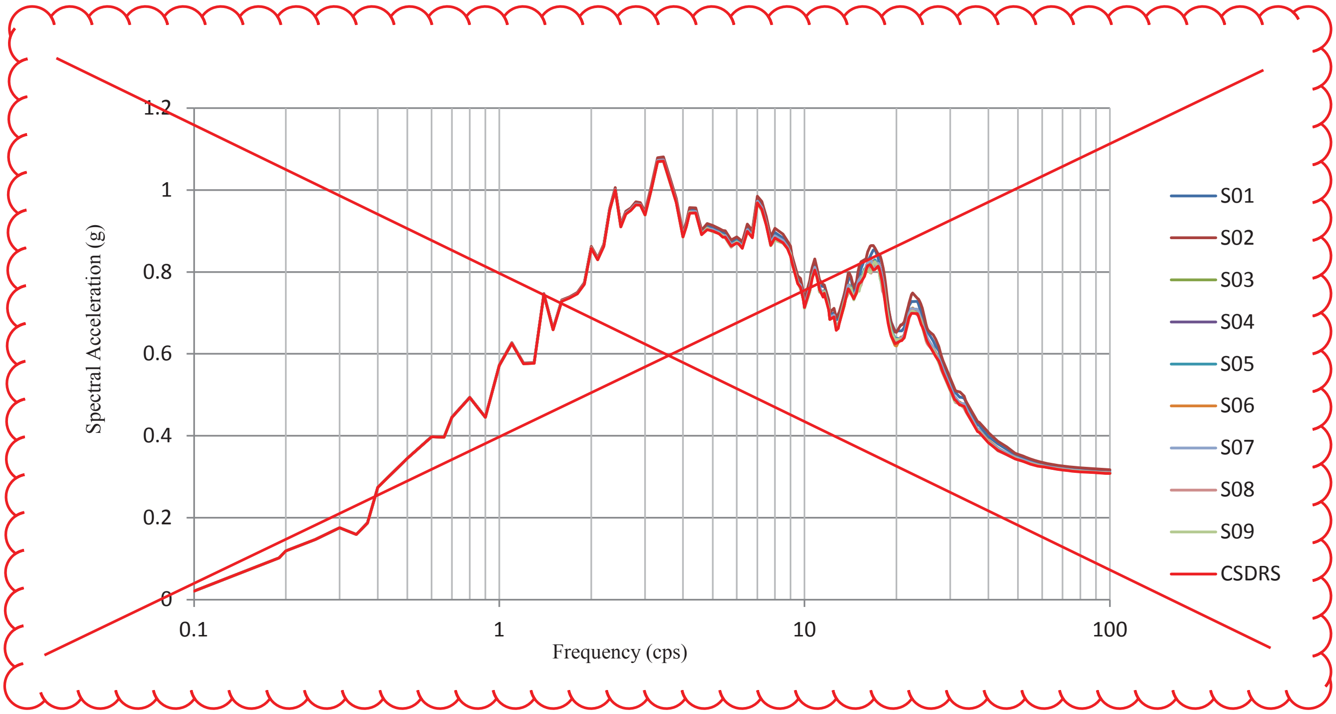

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(N-S) (2 of 3)

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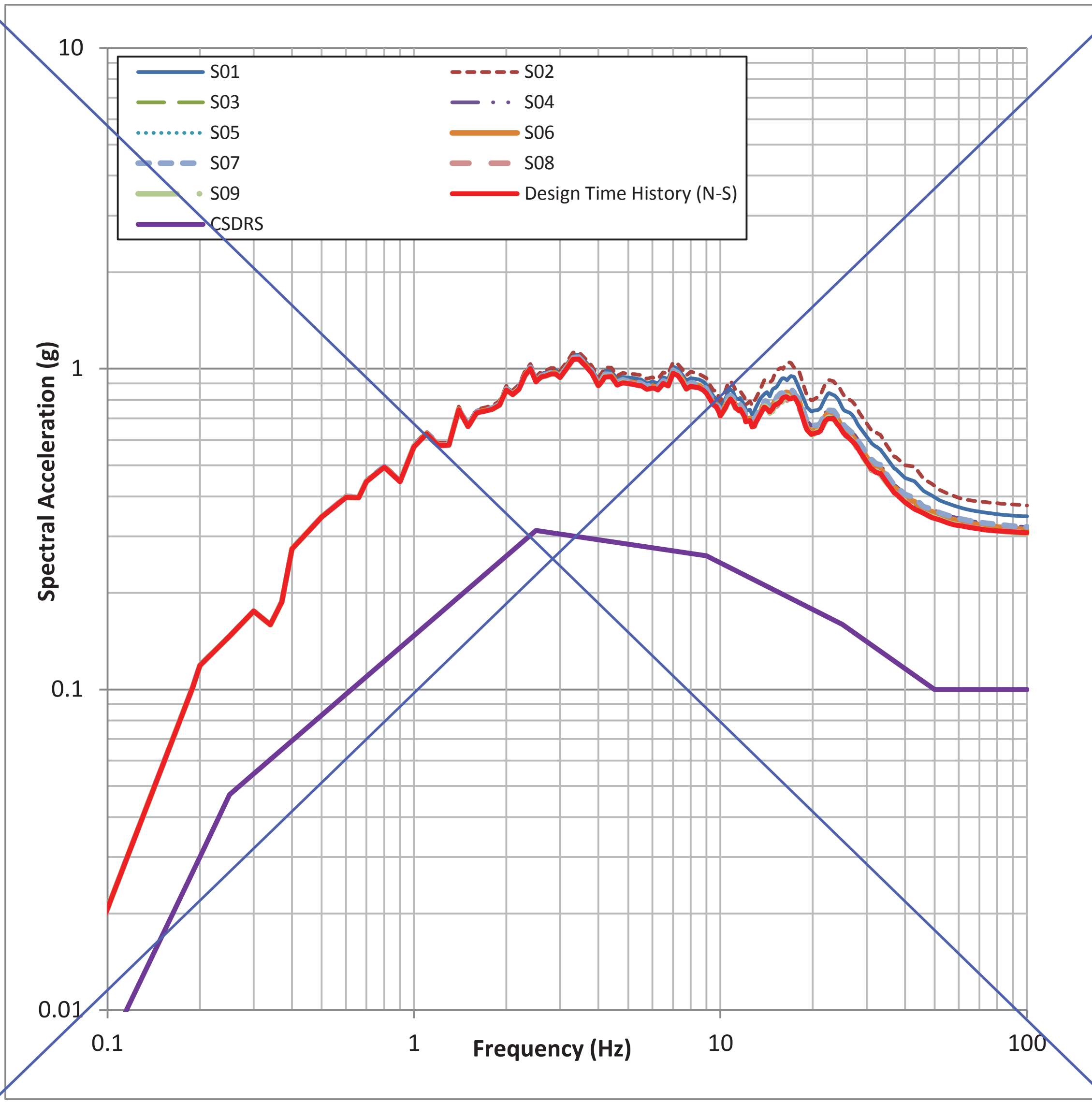

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(N-S) (2 of 3)

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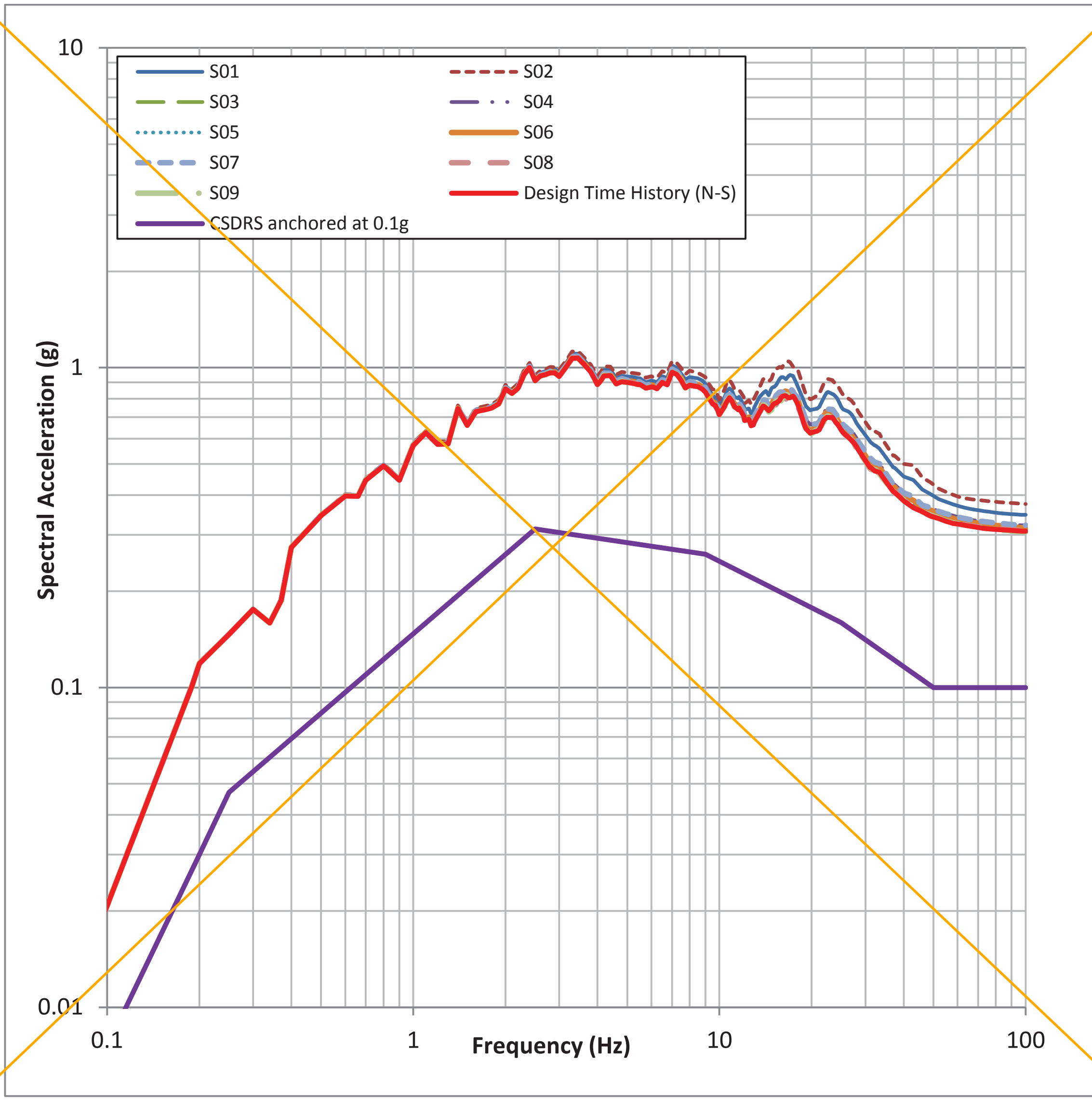

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(N-S) (2 of 3)

RAI 253-8300 - Question 03.07.01-5_Rev.3

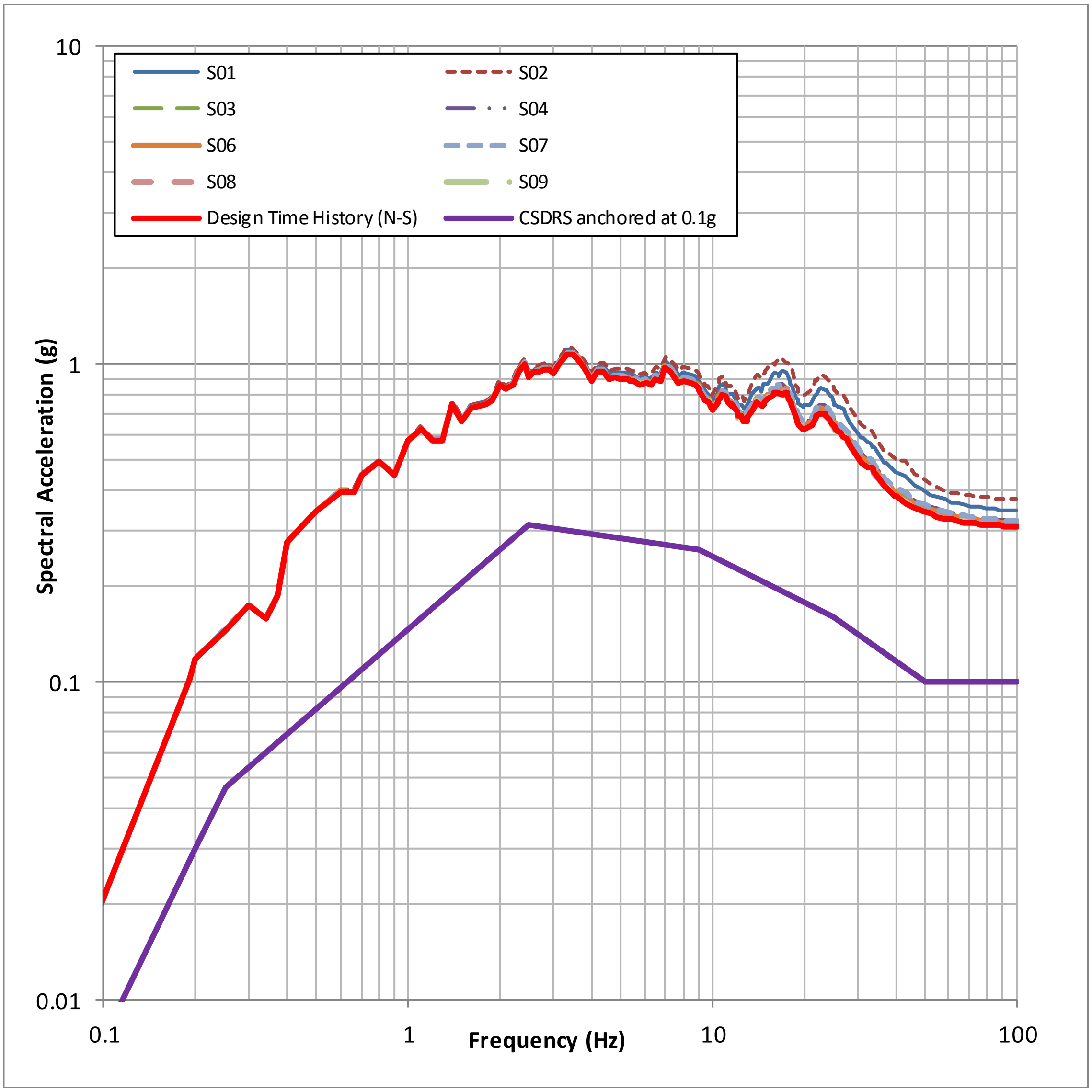

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(N-S) (2 of 3)

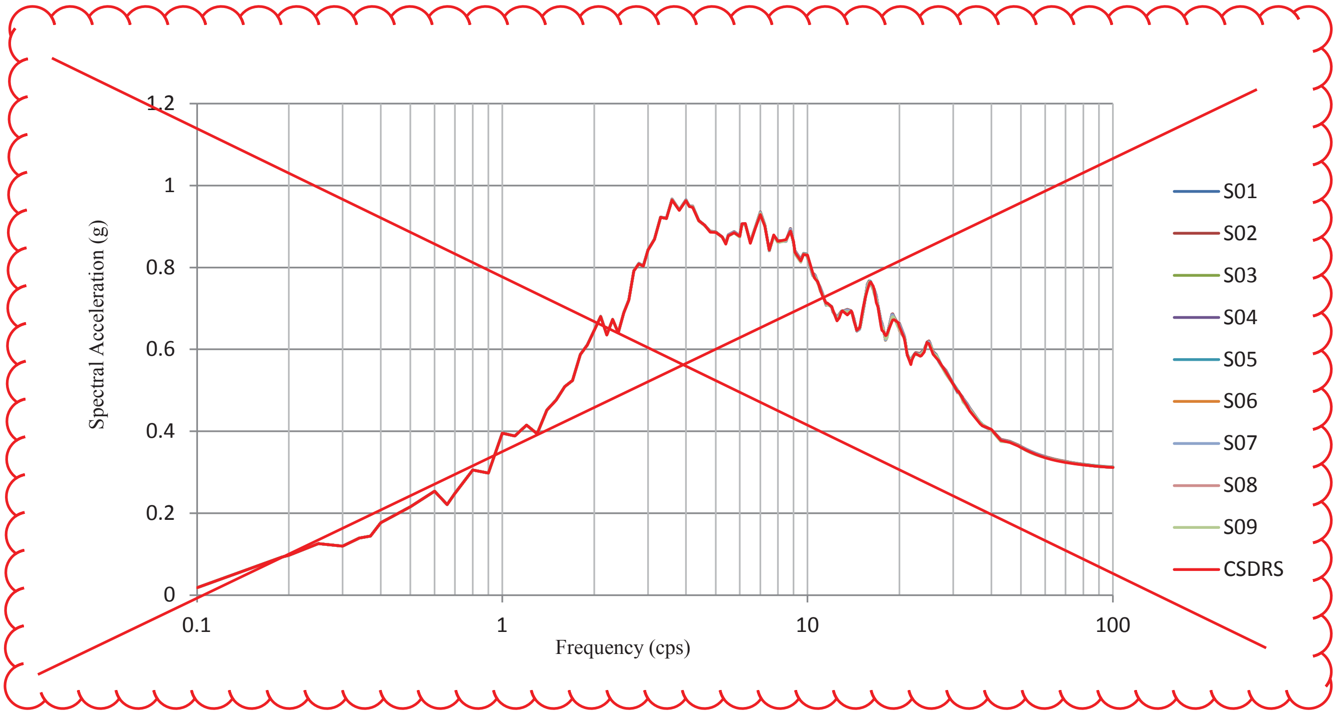

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(Vertical) (3 of 3)

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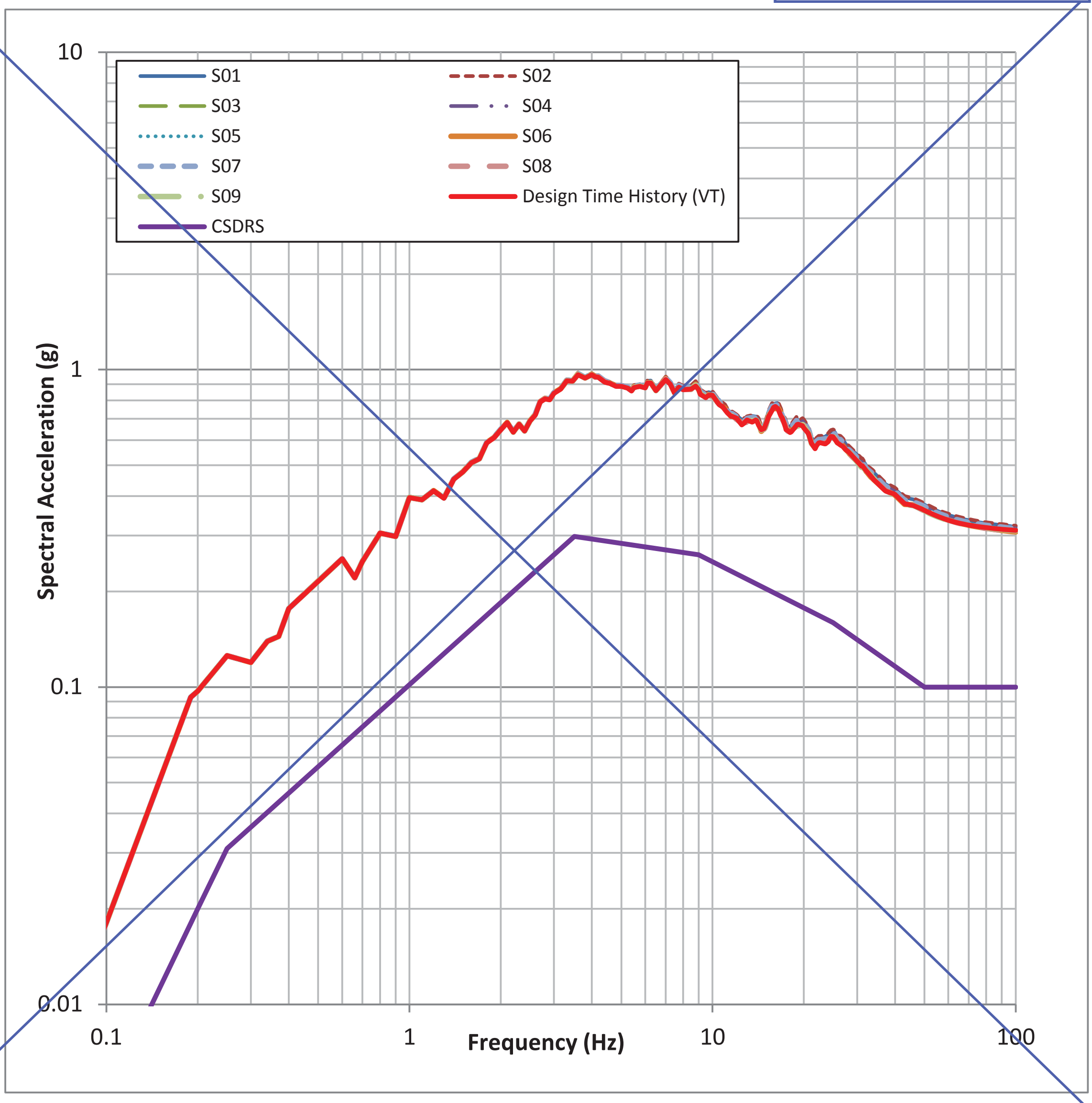

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(Vertical) (3 of 3)

Replace with next page

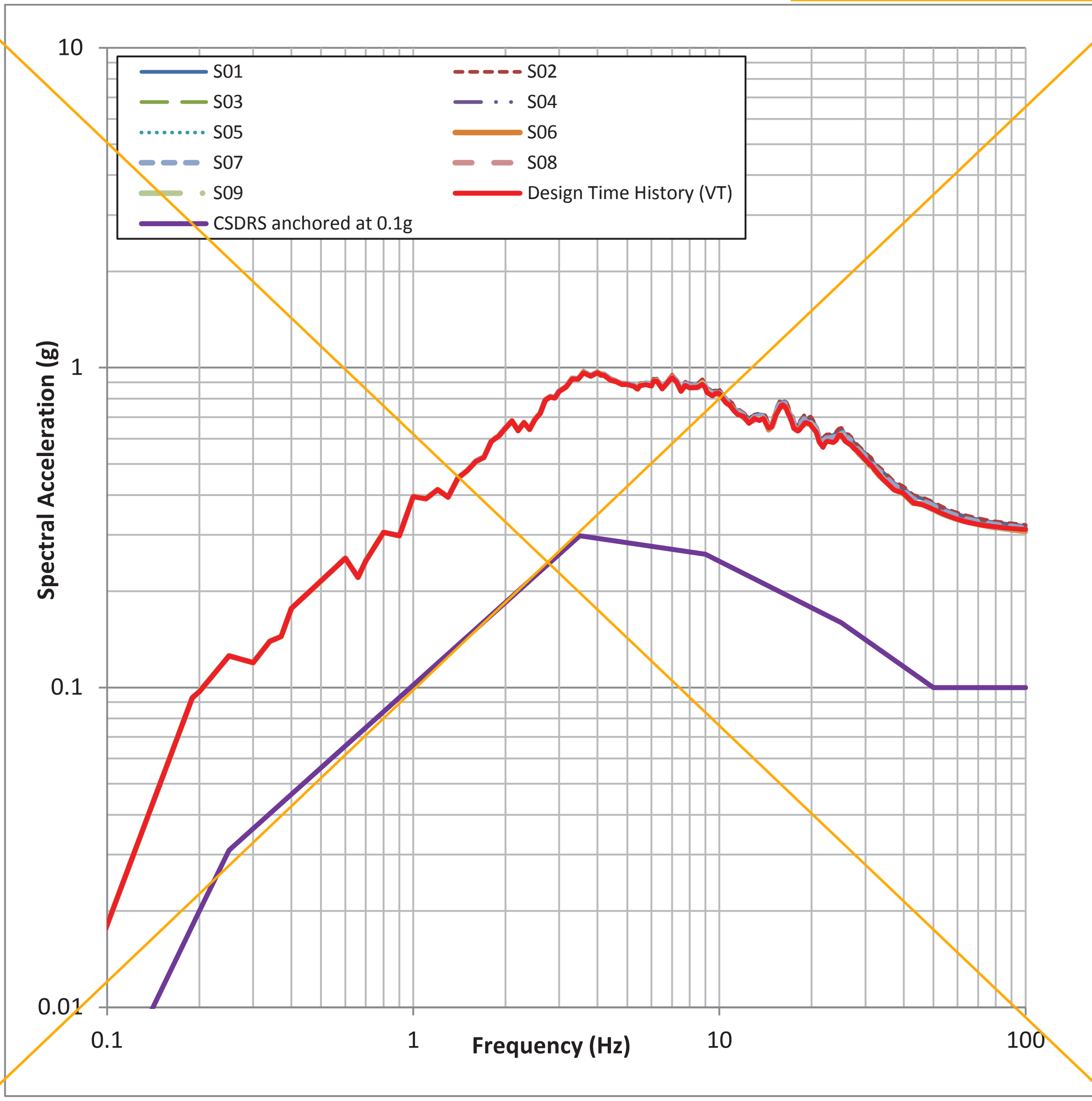

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(Vertical) (3 of 3)

RAI 253-8300 - Question 03.07.01-5_Rev.3

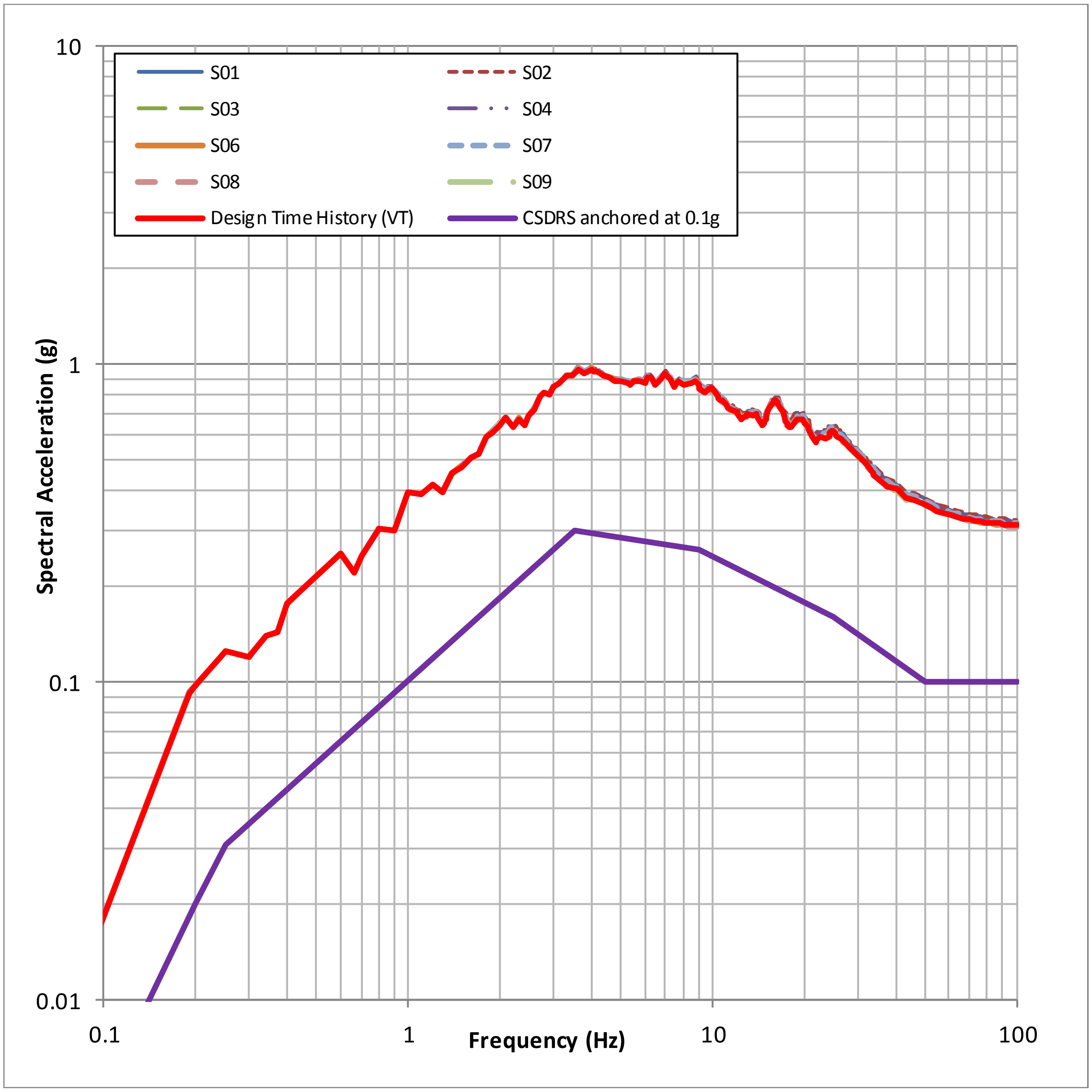

Figure 5-31 Strain-Compatible Response Spectra at Foundation Level of DFOT Room(Vertical) (3 of 3)

APPENDIX A

TRANSFER FUCNTIONS COMPUTED USING SHAKE COMPUTER PROGRAM

The relatively large dips in the response spectra at the foundation base elevation for the S6 and S7 soil cases for the NI as shown in Figure 5-25 through 5-27 are due to the specific site layering configurations and site properties of the S6 and S7 profiles. These dips are consistent with the lower amplitude in the site response transfer functions from the half-space to the foundation base level of the NI for S6 and S7 profiles. The lower transfer function amplitudes at the NI foundation base level are reflected in the strain-compatible response spectra at foundation level of NI for S6 and S7 profiles at all frequency range as well as from 3 Hz to 20 Hz.

16

The transfer functions from the half-space to the outcropping layer at the foundation level of the NI structures, and DFOT/EDGB, using generic soil profiles and the SHAKE computer program, are indicated in Figures A-1 through A-~~18~~. And the transfer functions for S2, ~~S5,~~ S6 and S7 profiles from the ground surface to the outcropping layer at the foundation base level of each of these structures are indicated in Figures A-~~19~~ through A-~~26~~. These comparisons for S6 and S7 indicate that dips in the response spectra for S6 and S7 profiles at the foundation base level are consistent with the transfer functions from the ground surface to the foundation base level.

17 22 23 25 23

The transfer functions and response spectra at upper and lower layers of the interfaces which have discontinuity of shear wave velocity are computed using generic soil profiles as shown in Figures A-~~27~~ through A-~~32~~. Figures A-~~27~~ and A-~~30~~ represent the transfer functions and response spectra at layer numbers 40 and 41 of the S1 profile, as presented in Table 5-3. As indicated in Figures A-~~27~~ and A-~~30~~, transfer functions and response spectra at layer numbers 40 and 41 are quite different from each other, even though soil layer numbers 40 and 41 have similar input parameters, for thickness, unit weight density, and damping ratio, which are representative of the sand soil type. Despite all other parameters being similar, the shear wave velocities of layer numbers 40 and 41 are not similar.

26 25 23

24 26

Similarly, Figures A-~~28~~ and A-~~31~~ represent the transfer functions and response spectra at layer numbers 20 and 21 of the S2 profile, as presented in Table 5-4. Soil layer numbers 20 and 21 have similar input parameters for the sand soil type, except for the shear wave velocities. ~~Figures A-29 and A-32 represent the transfer functions and response spectra at soil layer numbers 20 and 21 of the S5 profile, as presented in Table 5-7. The soil layer numbers 20 and 21 of the S5 profile are of the rock soil type, and those layers have similar input parameters, except for the shear wave velocities.~~

Thus, the large dips in the transfer functions and response spectra for the S6 and S7 profiles are reasonable because the interface which has a discontinuous shear wave velocity is located between the FIRS elevations of the NI structure and the DFOT/EDGB for the S6 and S7 profiles.

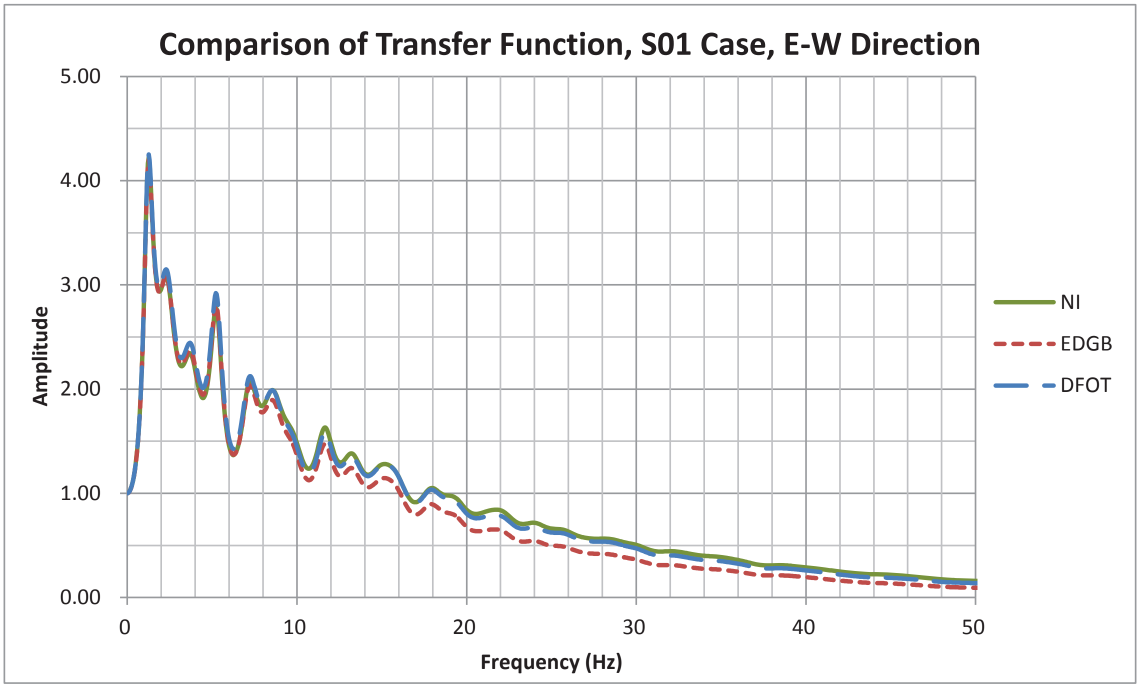

Figure A-1: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S01 Case, E-W Direction

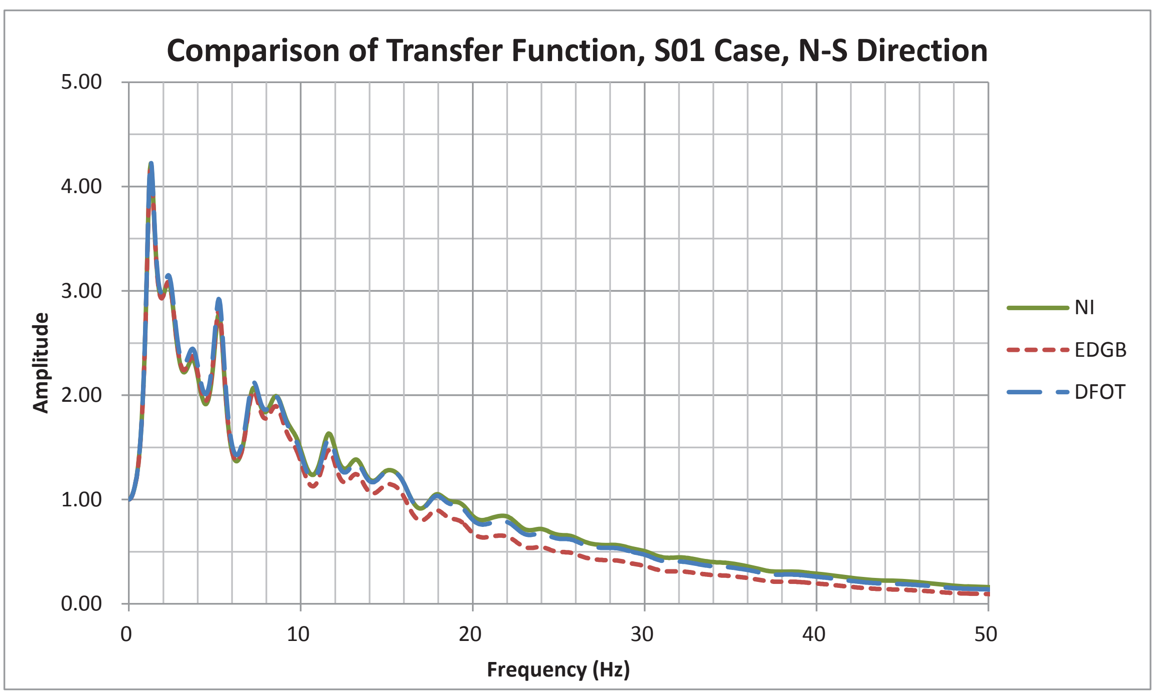

Figure A-2: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S01 Case, N-S Direction

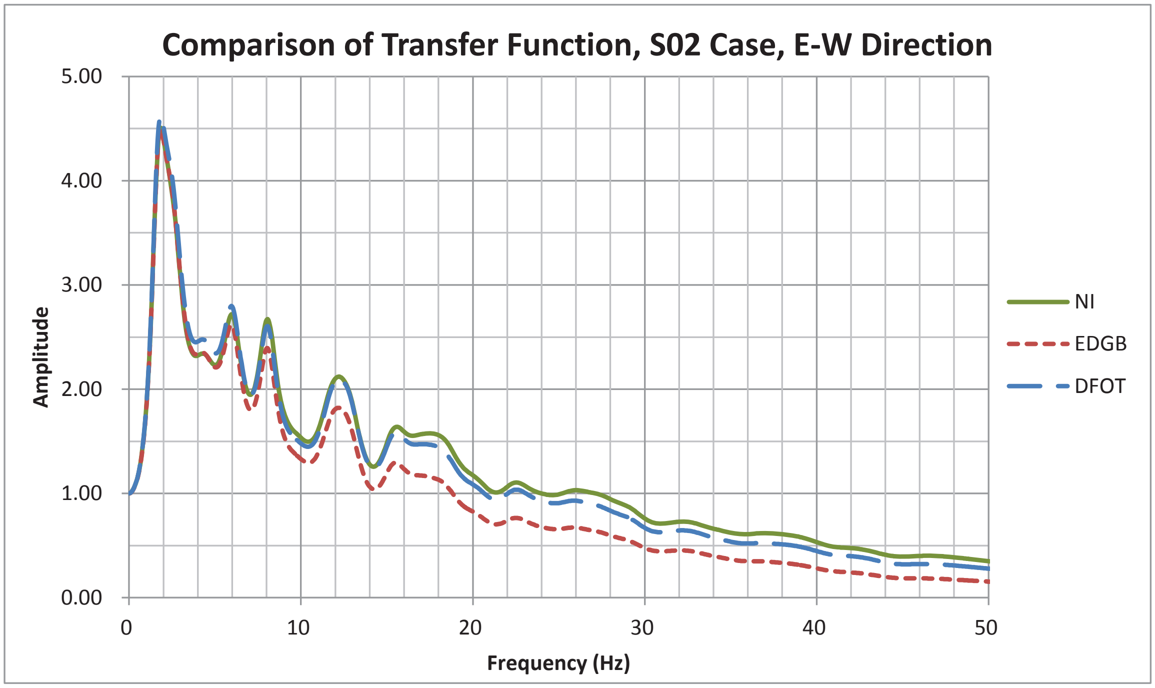

Figure A-3: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S02 Case, E-W Direction

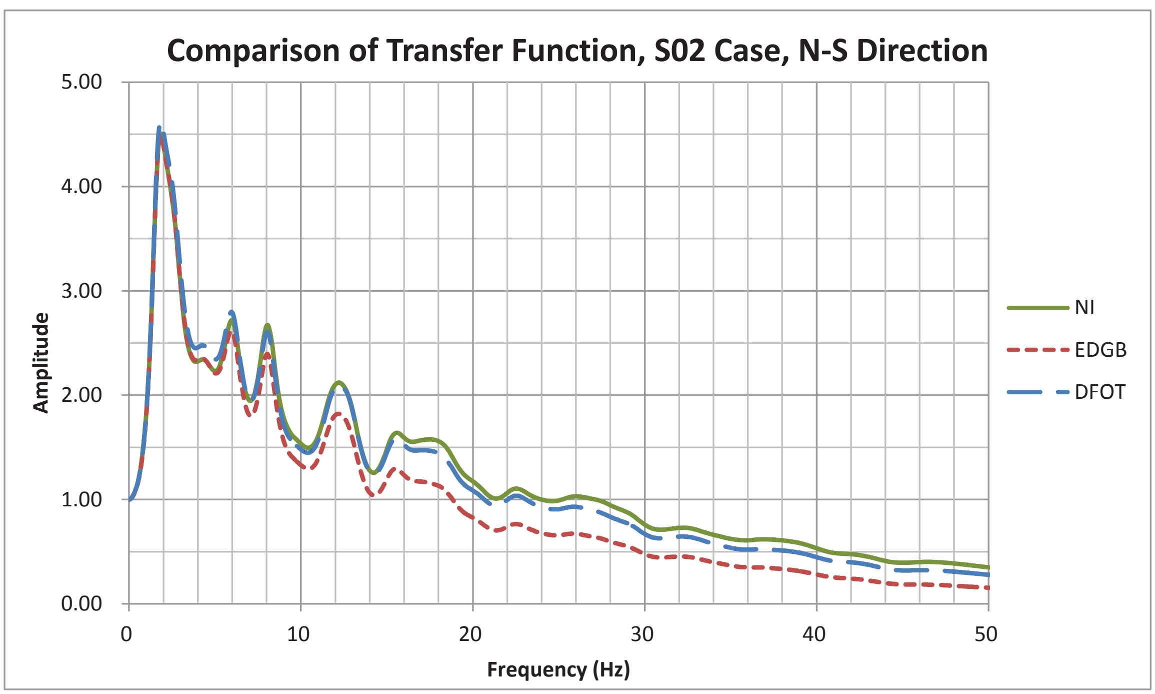

Figure A-4: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S02 Case, N-S Direction

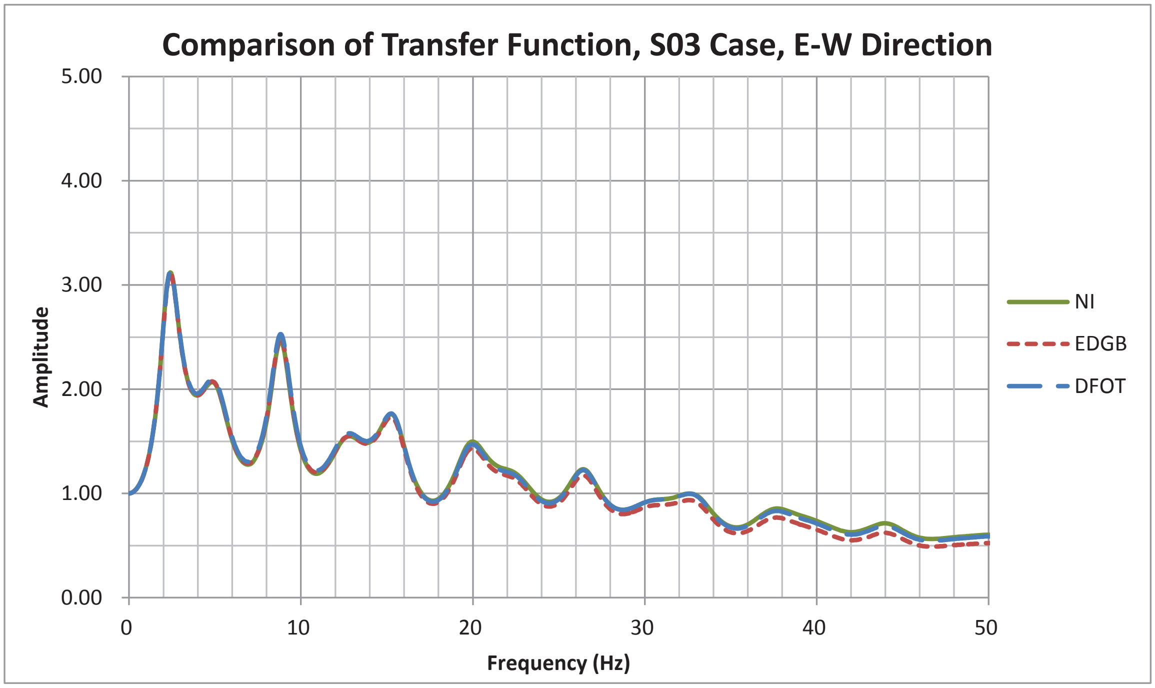

Figure A-5: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S03 Case, E-W Direction

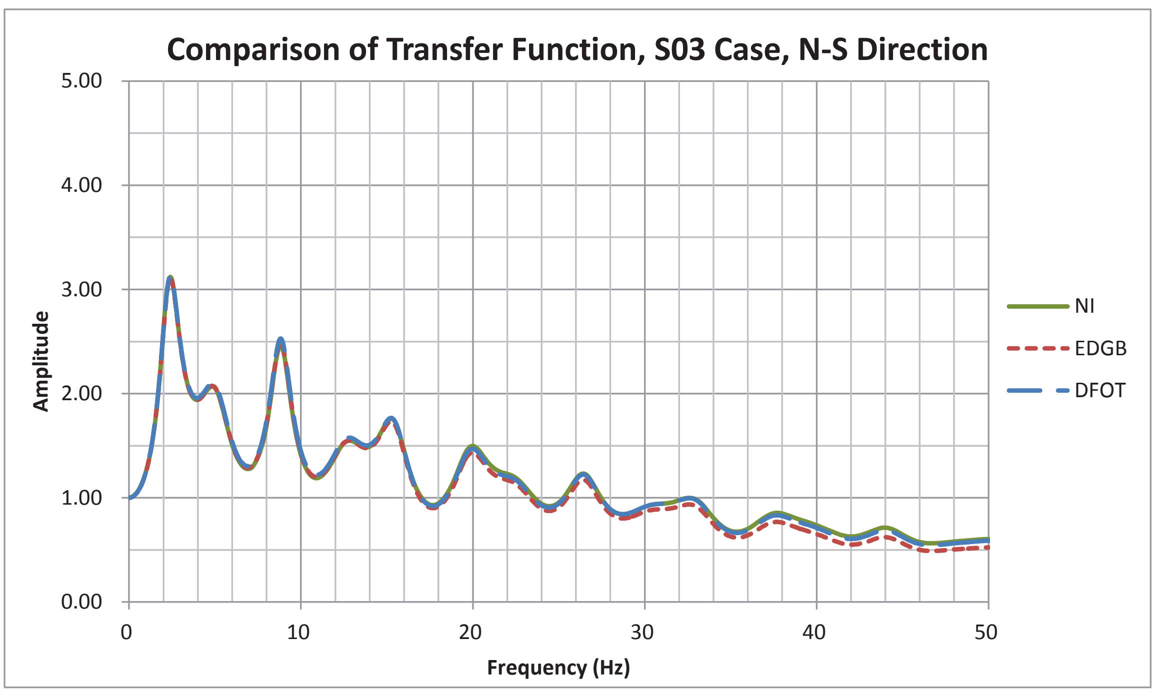

Figure A-6: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S03 Case, N-S Direction

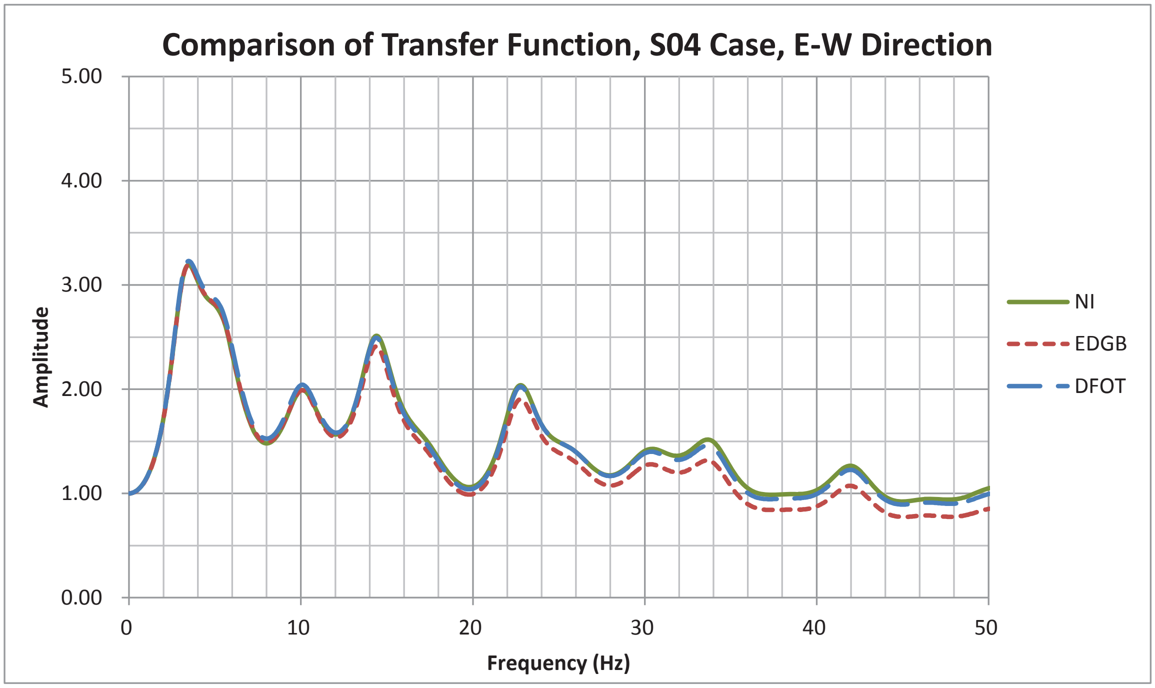

Figure A-7: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S04 Case, E-W Direction

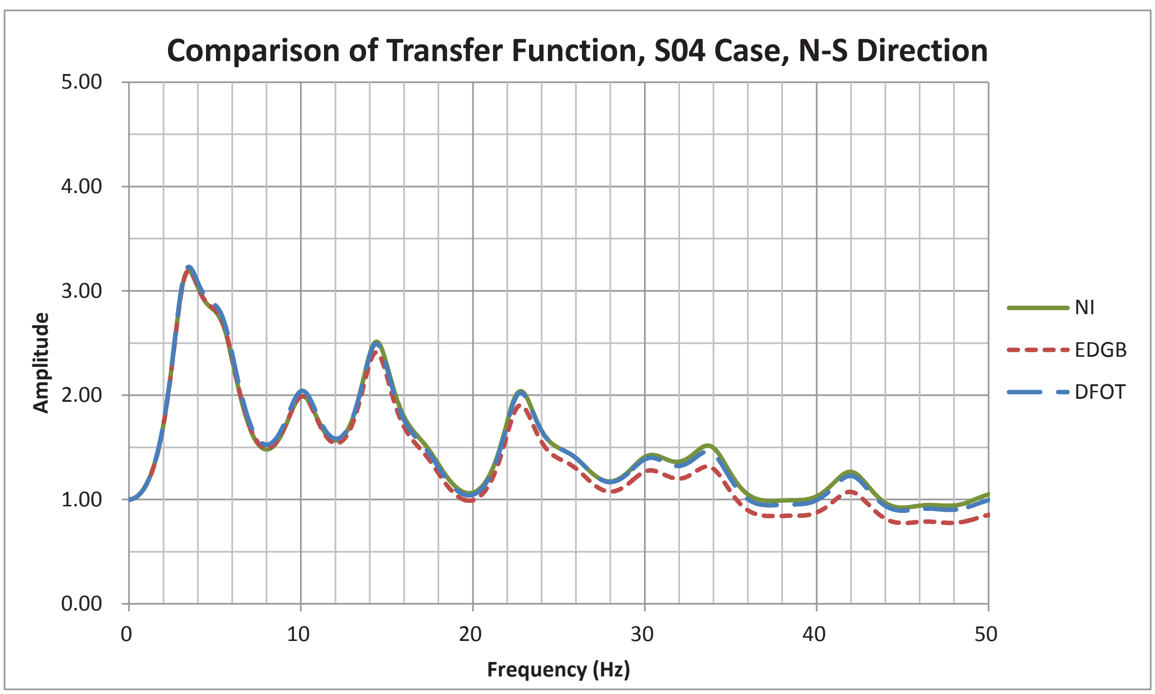

Figure A-8: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S04 Case, N-S Direction

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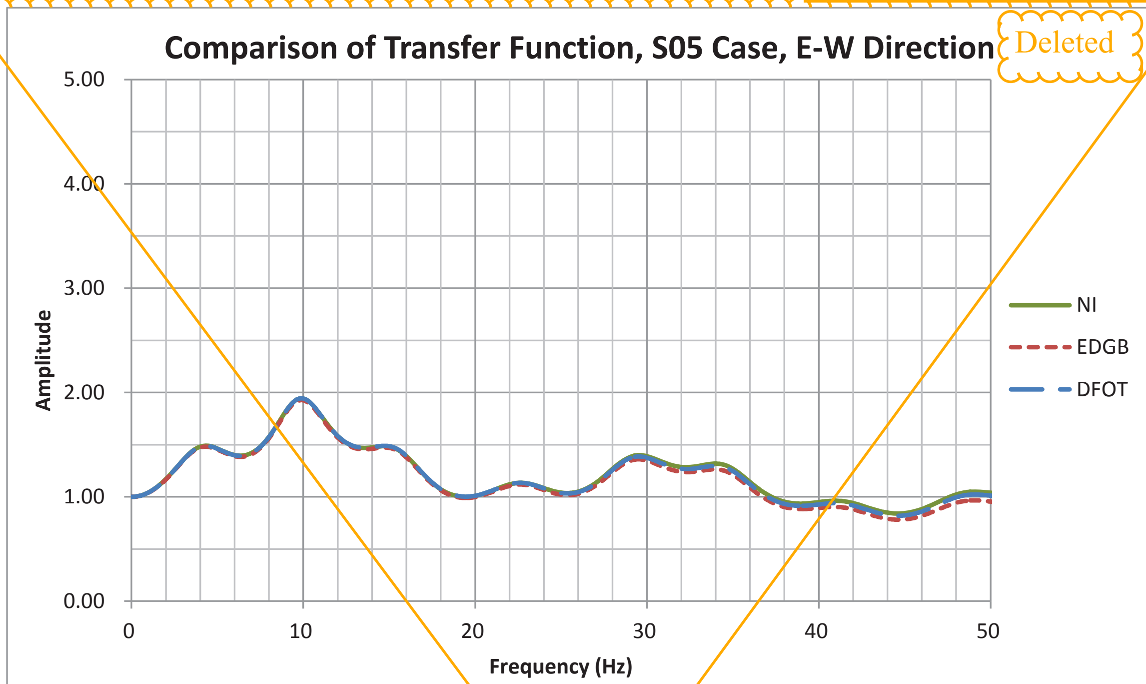

Figure A-9: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S05 Case, E-W Direction

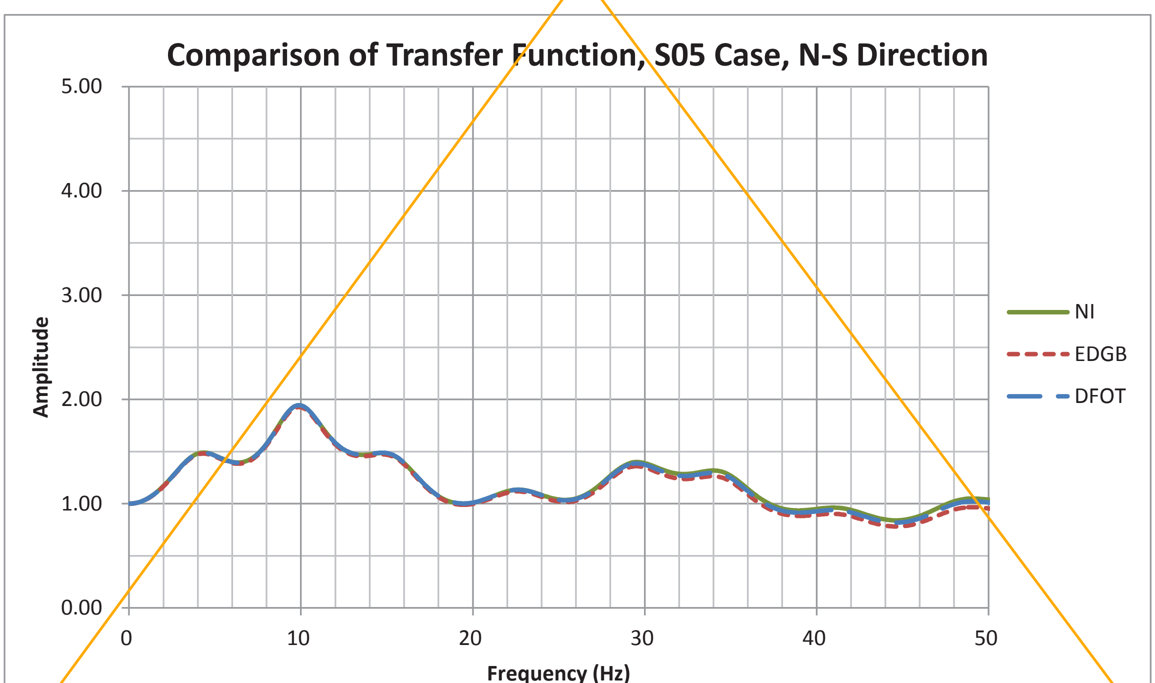

Figure A-10: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S05 Case, N-S Direction

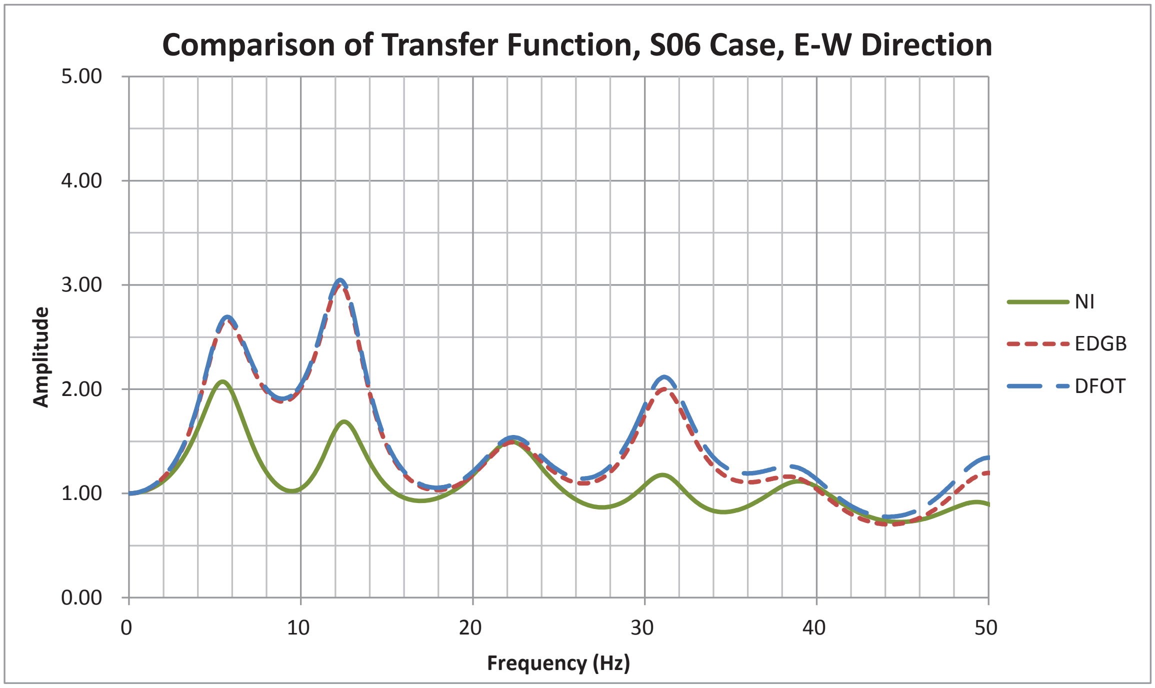

Figure A-~~11~~ 9: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S06 Case, E-W Direction

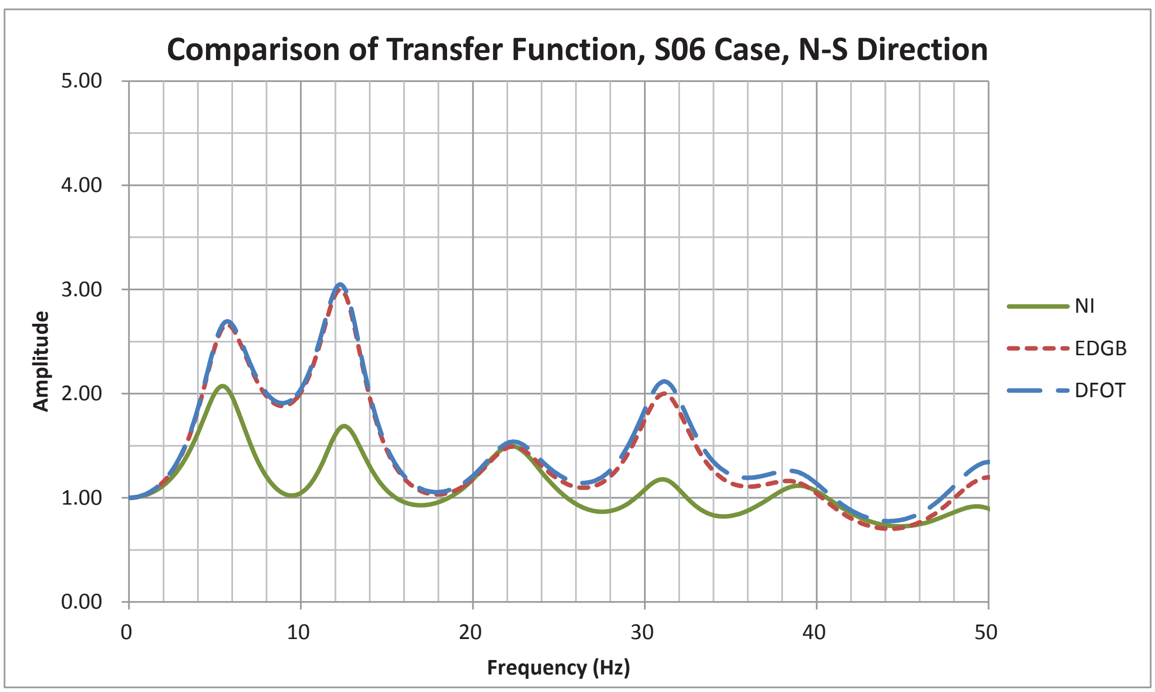

Figure A-~~12~~ 10: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S06 Case, N-S Direction

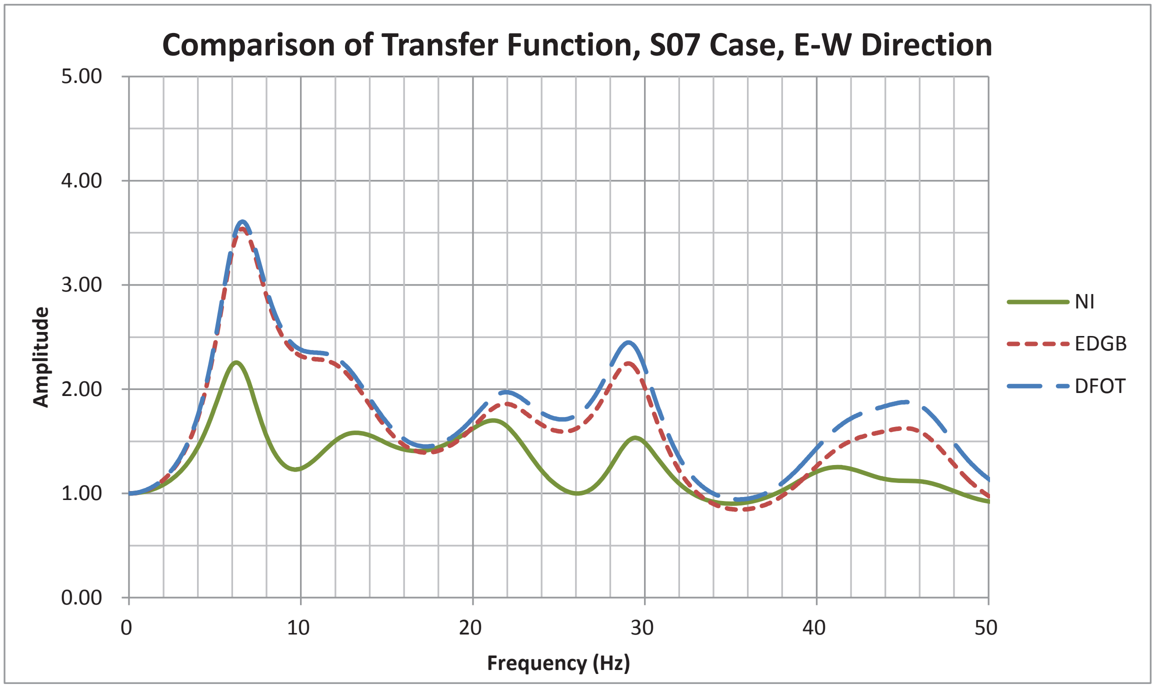

Figure A-~~13~~ 11: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S07 Case, E-W Direction

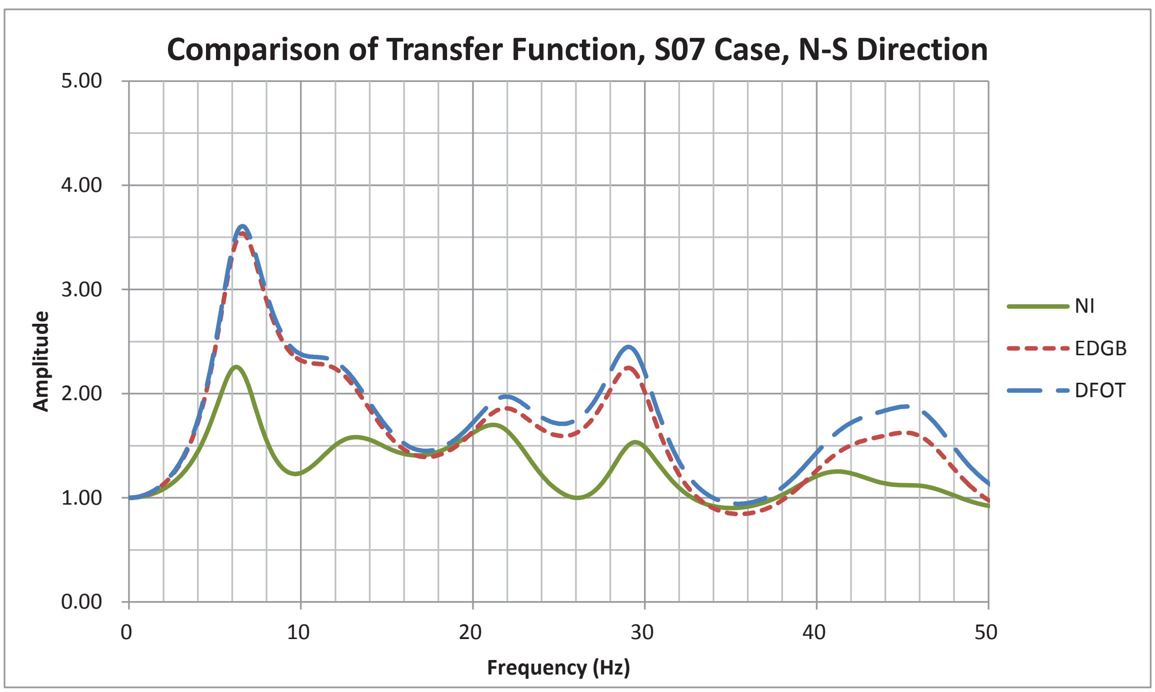

Figure A-~~14~~ 12: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S07 Case, N-S Direction

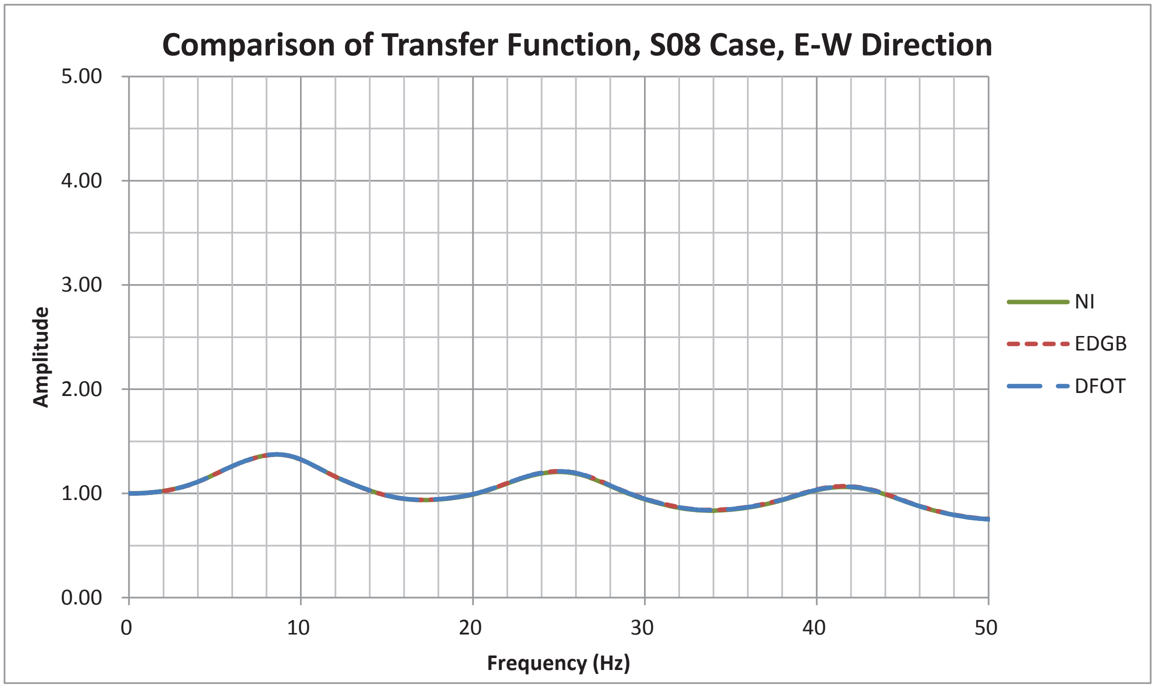

Figure A-~~15~~: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S08 Case, E-W Direction

13

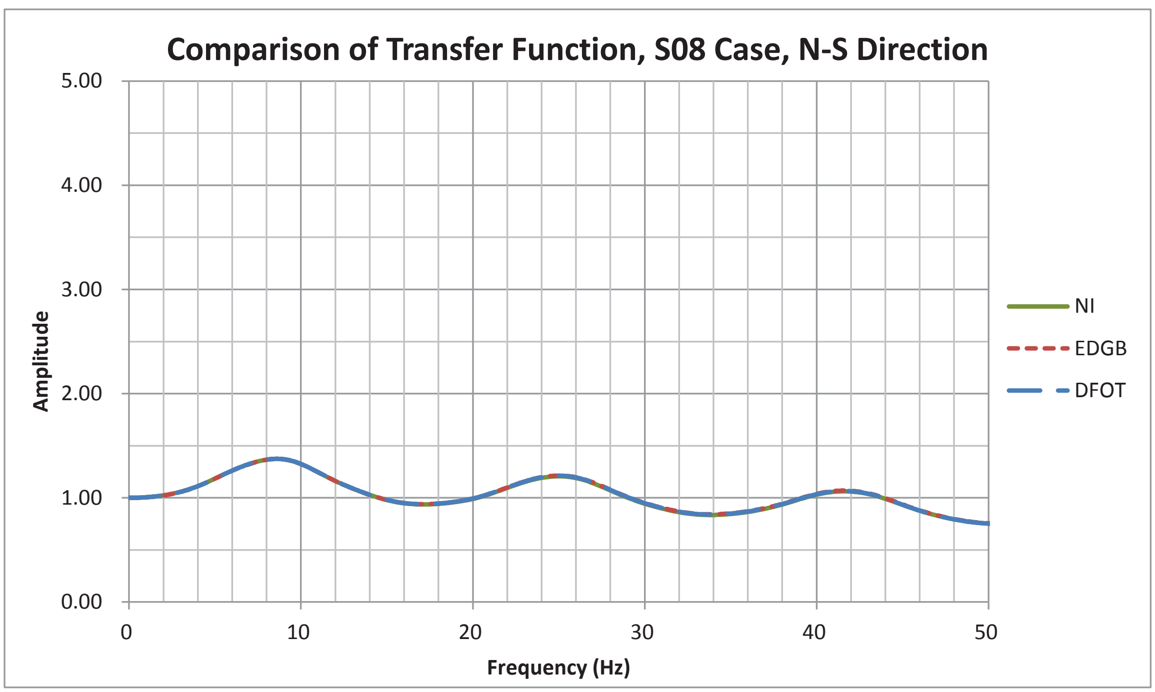

Figure A-~~16~~: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S08 Case, N-S Direction

14

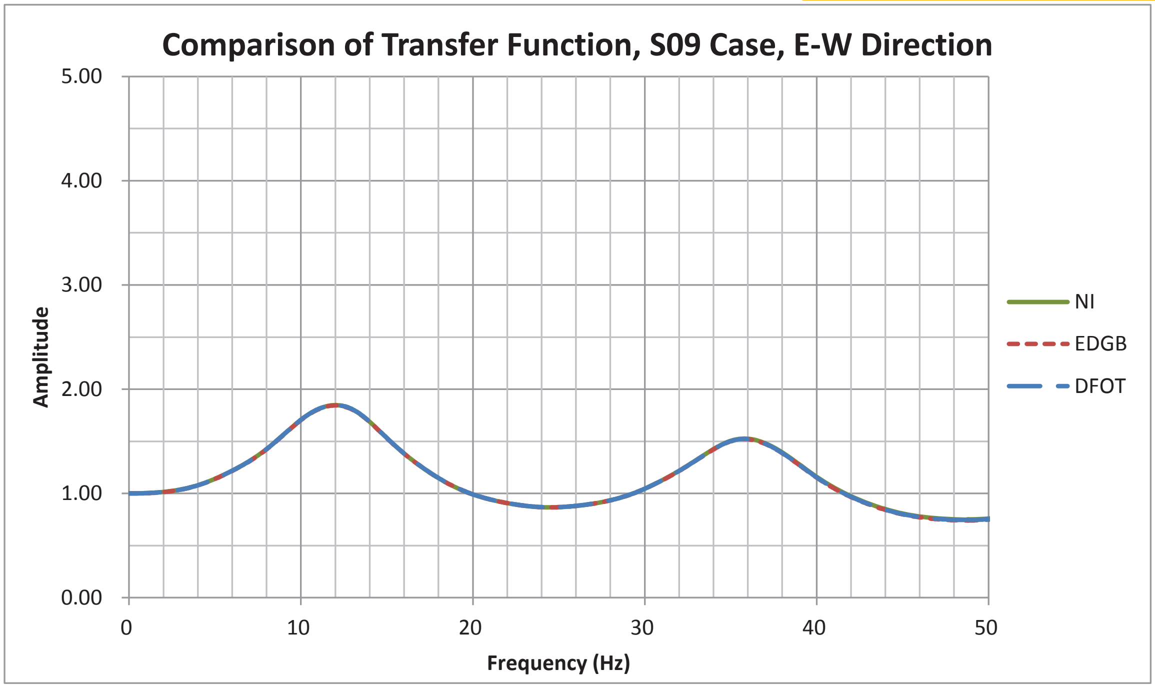

Figure A-~~17~~ 15: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S09 Case, E-W Direction

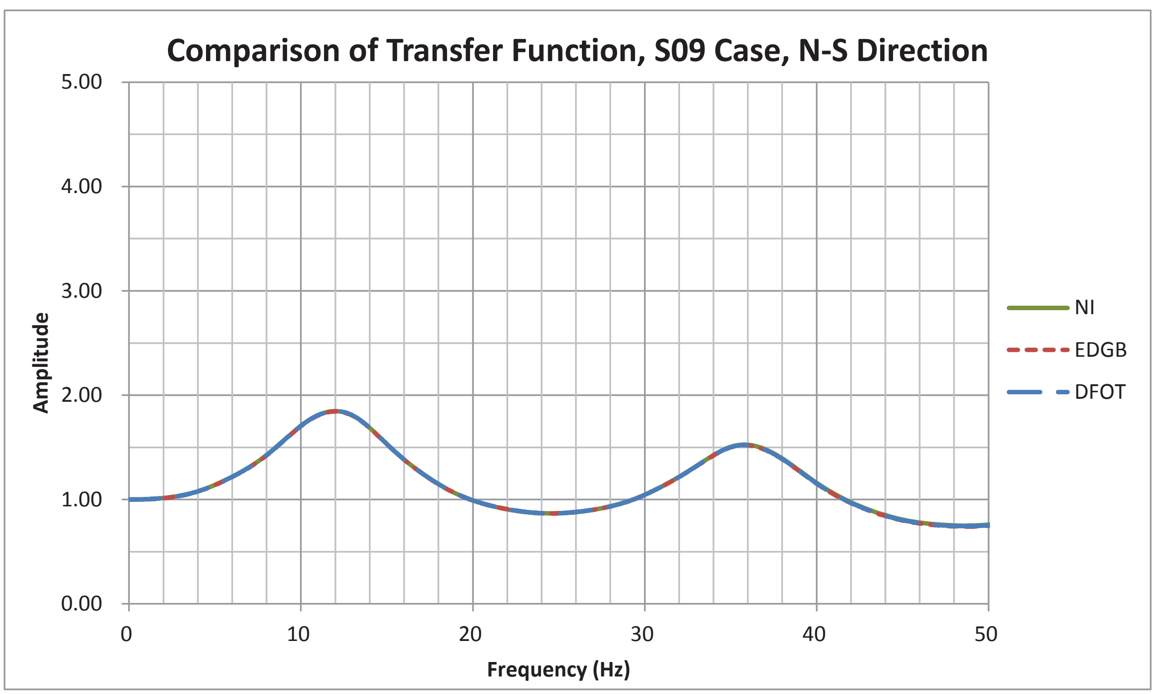

Figure A-~~18~~ 16: Comparison of Transfer Function from Half-space Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S09 Case, N-S Direction

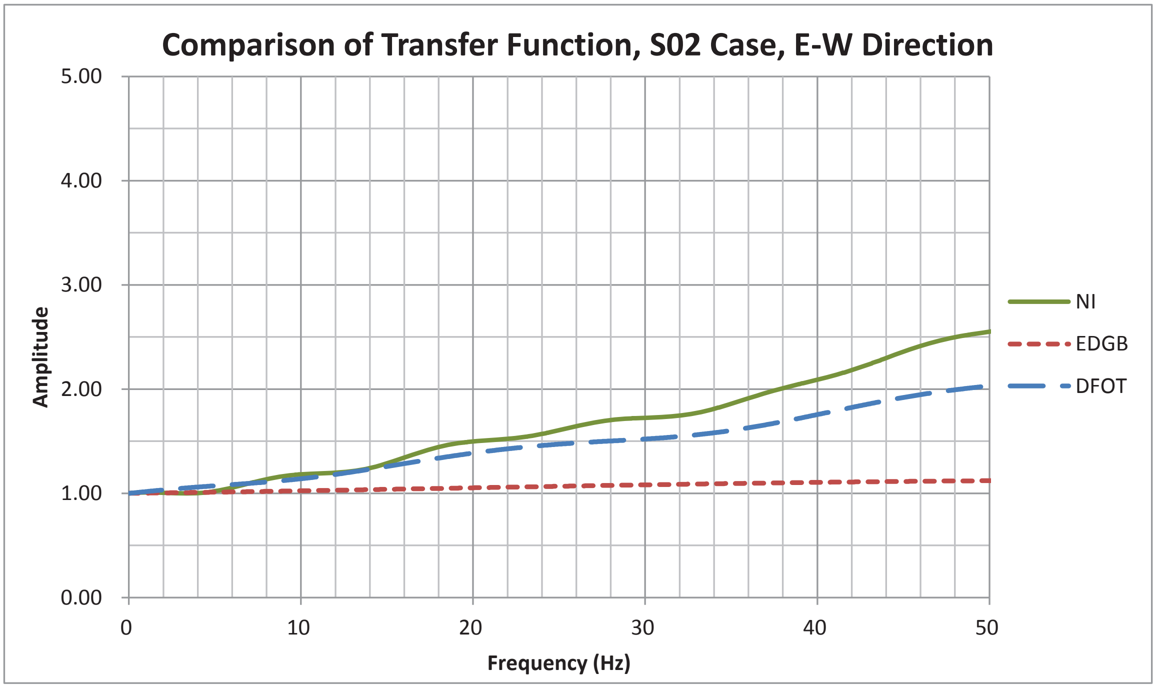

Figure A-~~19~~ 17: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S02 Case, E-W Direction

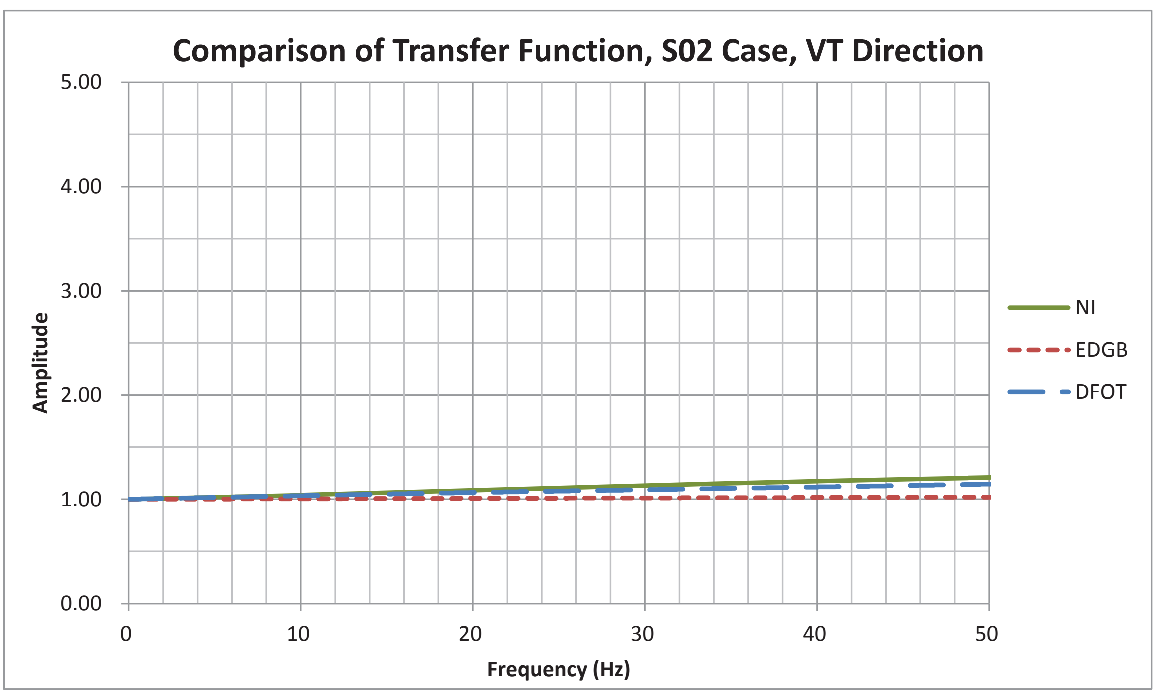

Figure A-~~20~~ 18: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S02 Case, Vertical Direction

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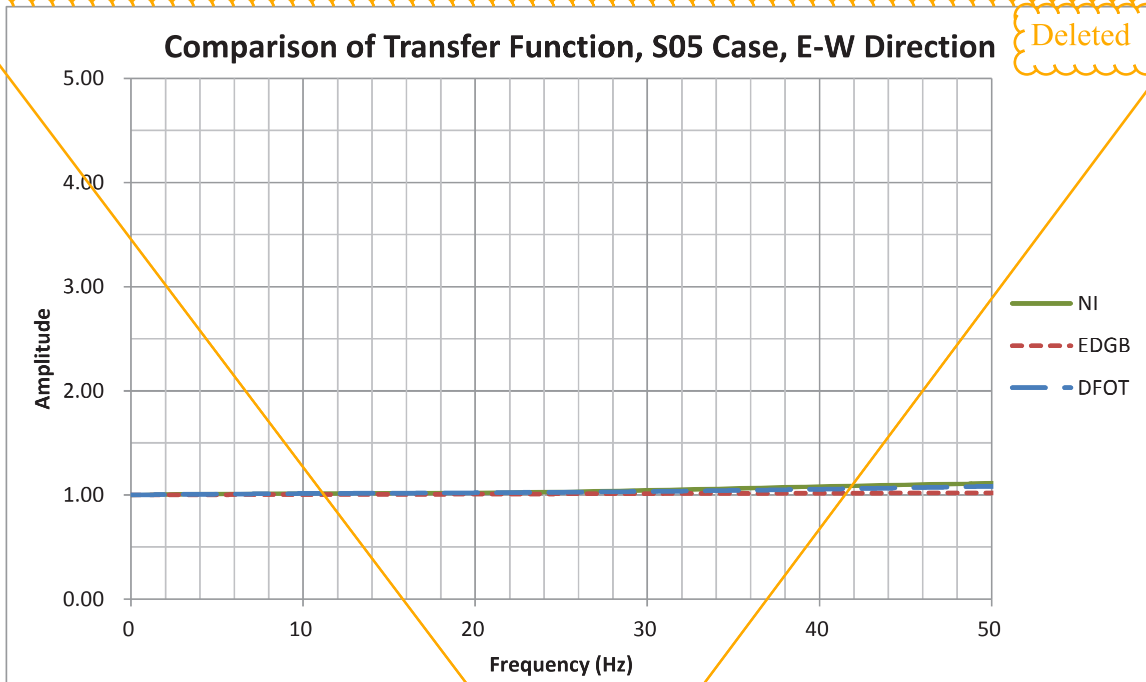

Figure A-21: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S05 Case, E-W Direction

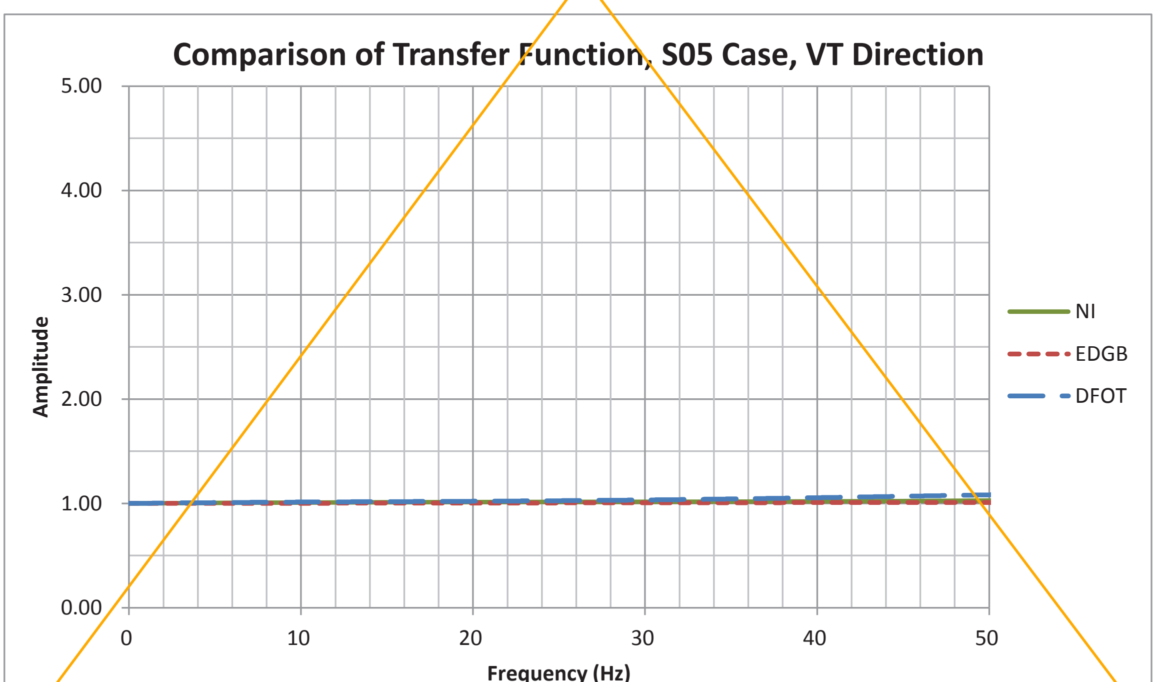

Figure A-22: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S05 Case, Vertical Direction

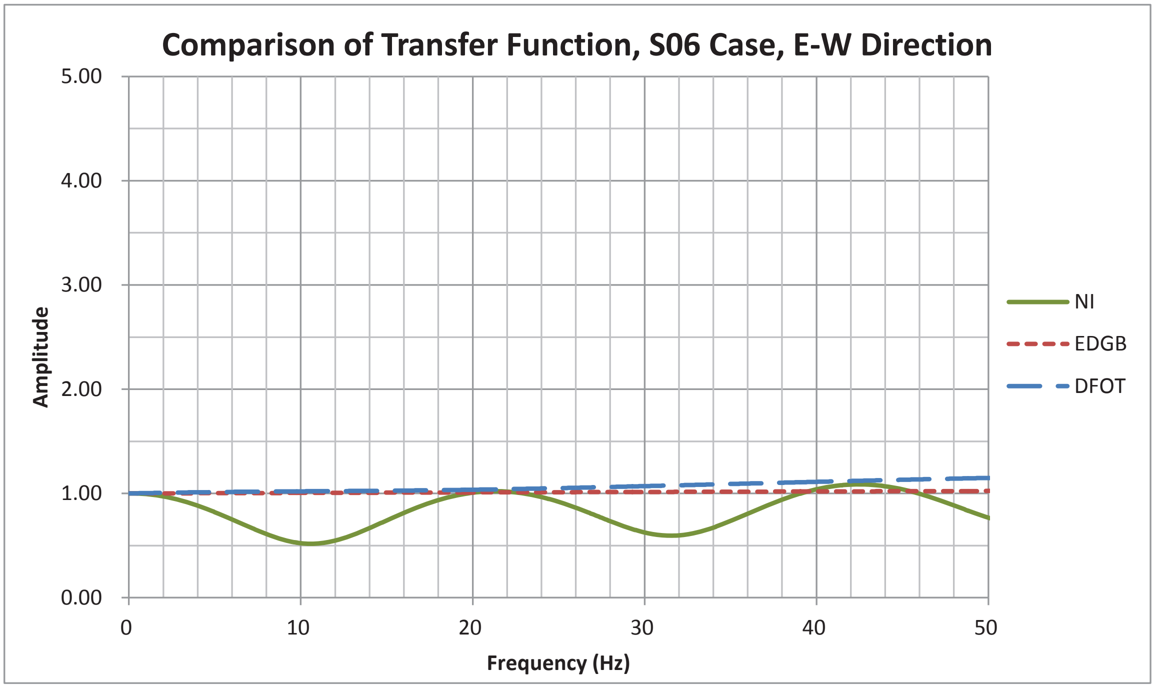

Figure A-23: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S06 Case, E-W Direction

19

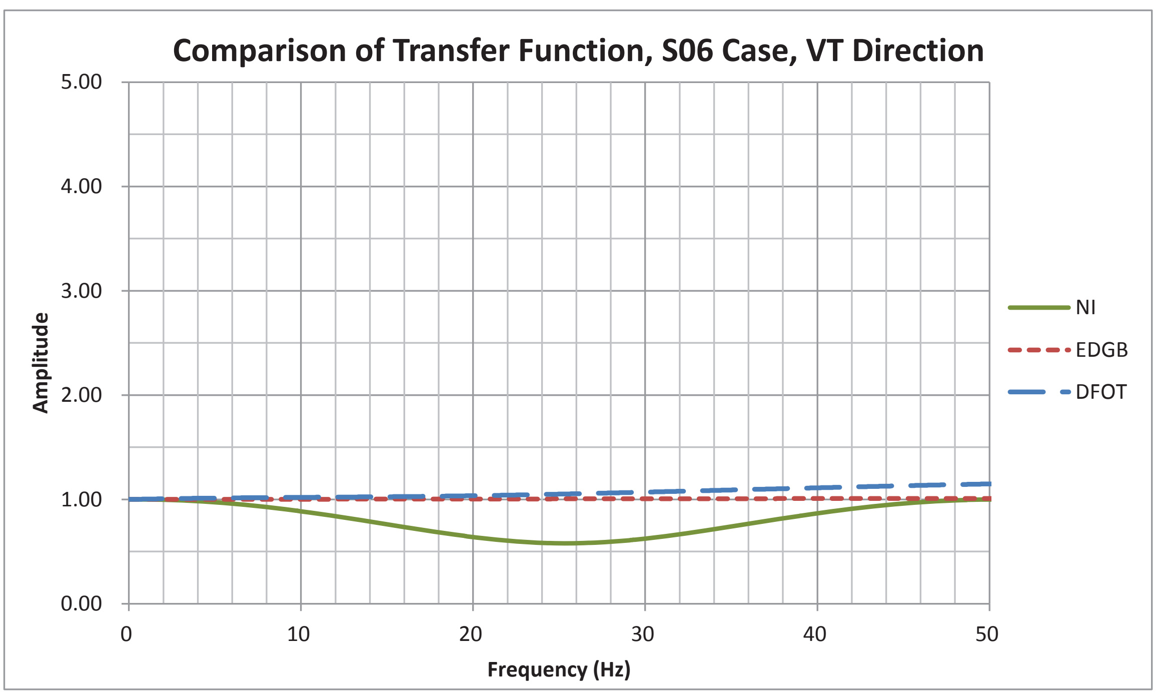

Figure A-24: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S06 Case, Vertical Direction

20

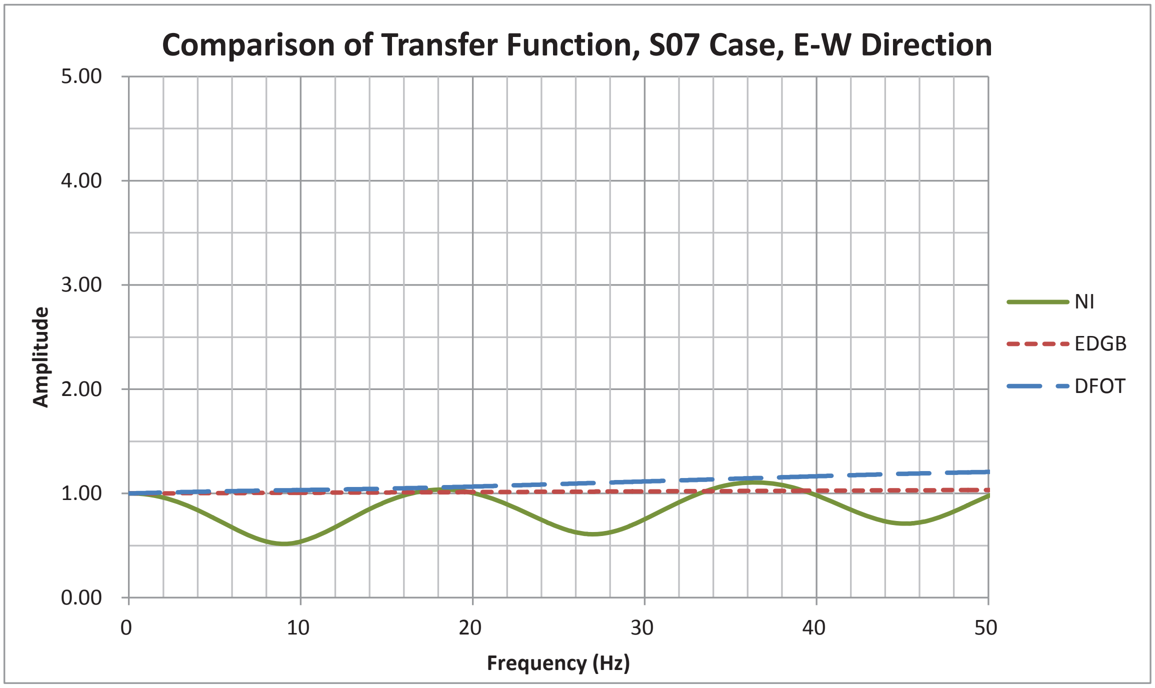

Figure A-25: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S07 Case, E-W Direction
21

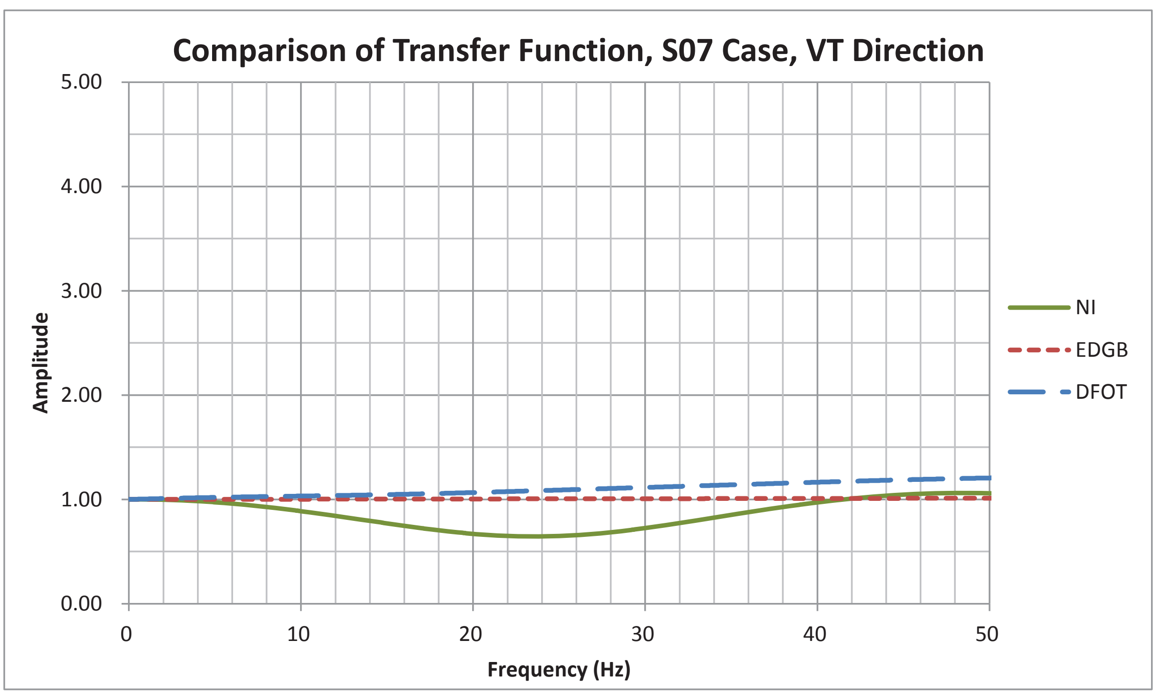

Figure A-26: Comparison of Transfer Function from Surface Level to Outcropping Layer at the Foundation Level for NI, EDGB and DFOT, S07 Case, Vertical Direction
22

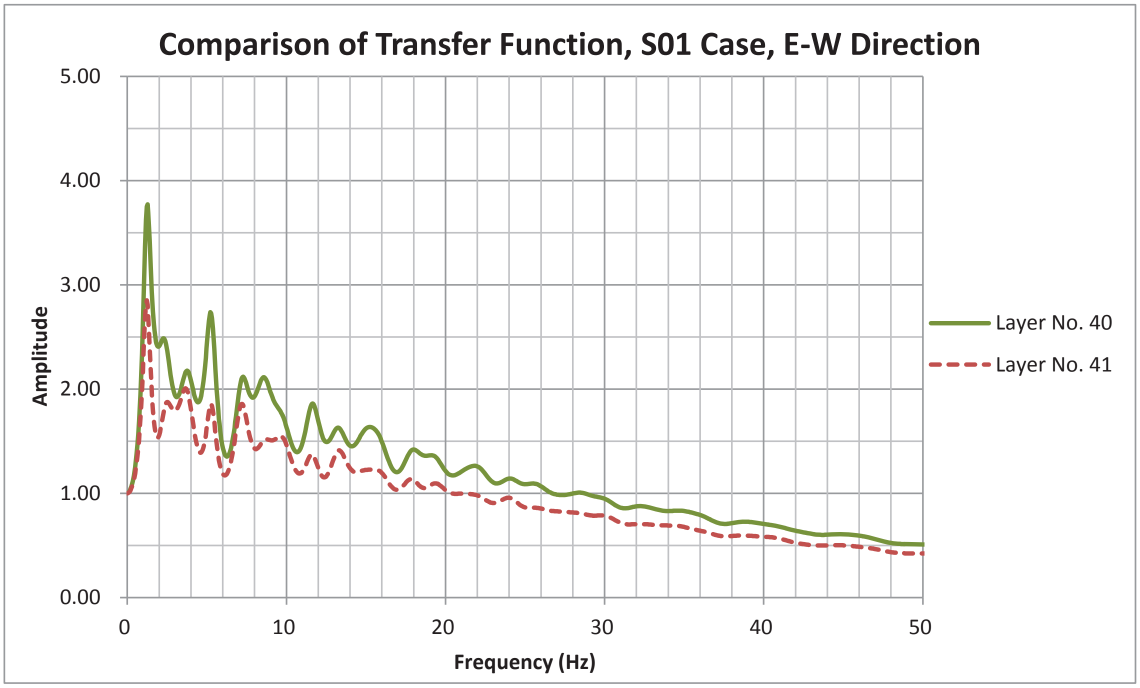

Figure A-~~27~~ 23: Comparison of Transfer Function for 40th and 41th Layer, S01 Case, E-W Direction

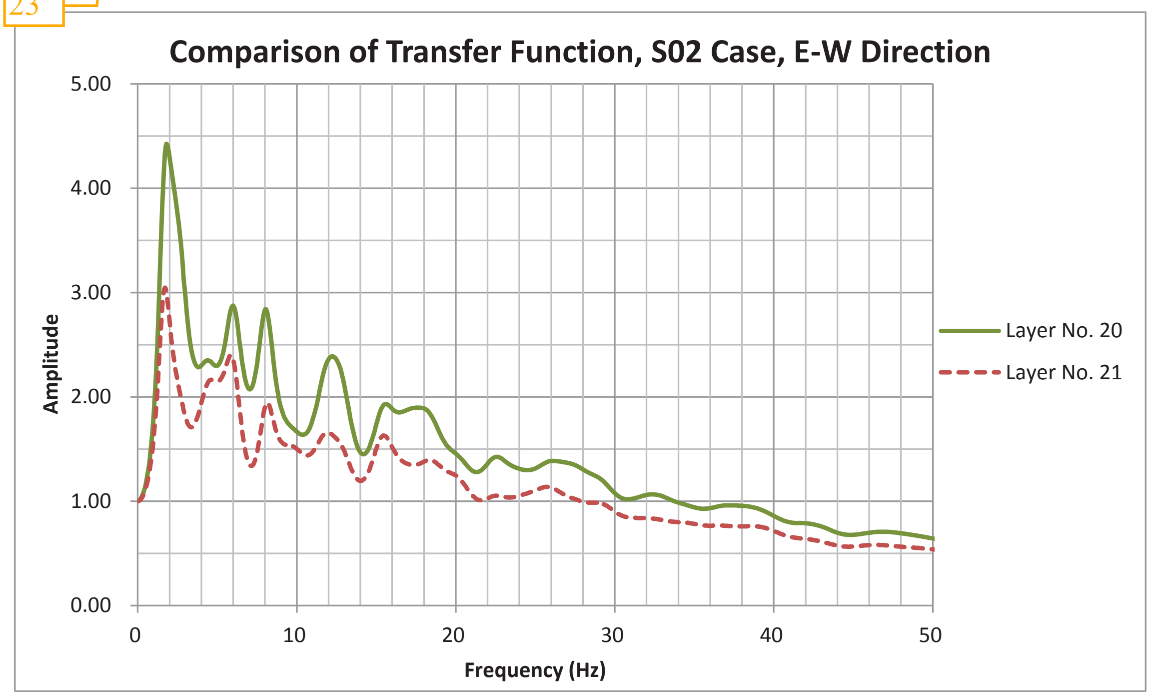

Figure A-~~28~~ 24: Comparison of Transfer Function for 20th and 21th Layer, S02 Case, E-W Direction

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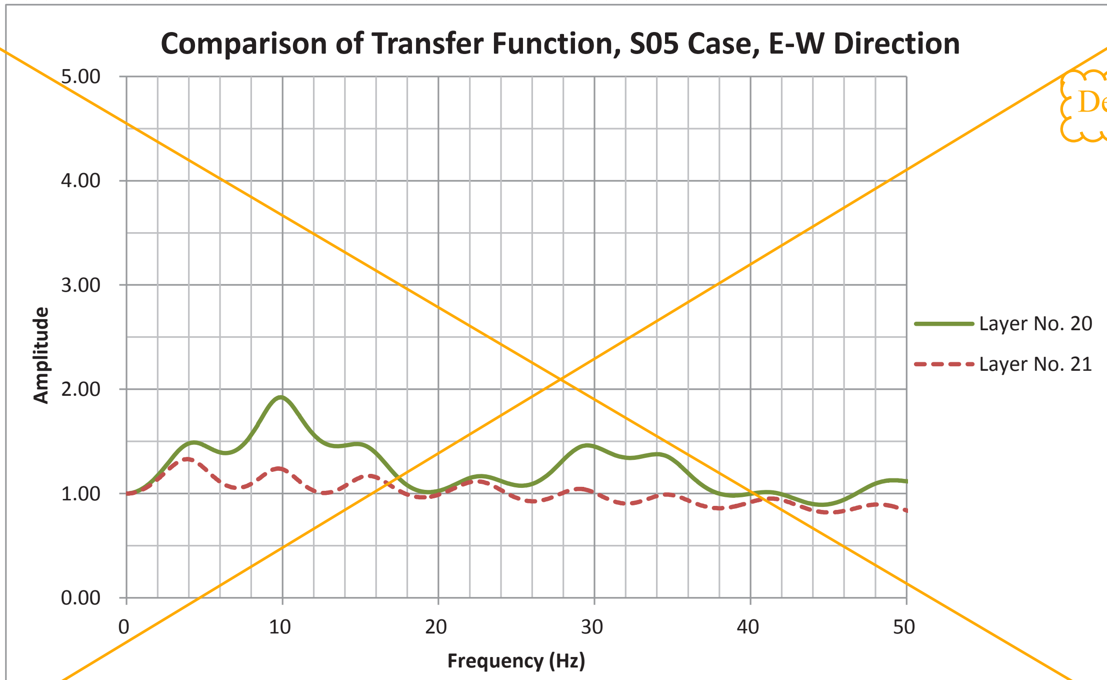

~~Figure A-29: Comparison of Transfer Function for 20th and 21th Layer, S05 Case, E-W Direction~~

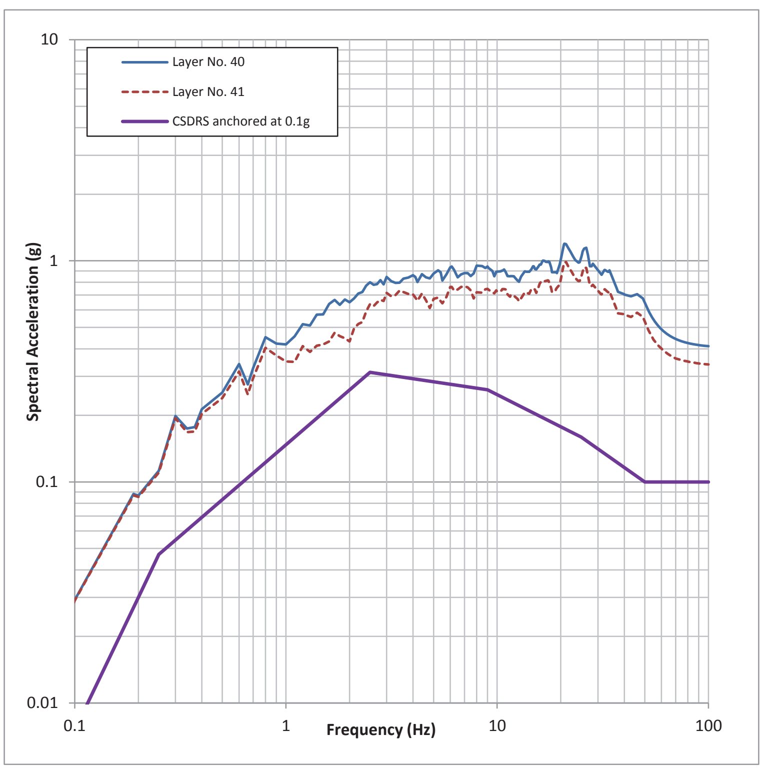

Figure A-~~30~~ 25: Comparison of Response Spectra for 40th and 41th Layer, S01 Case, E-W Direction

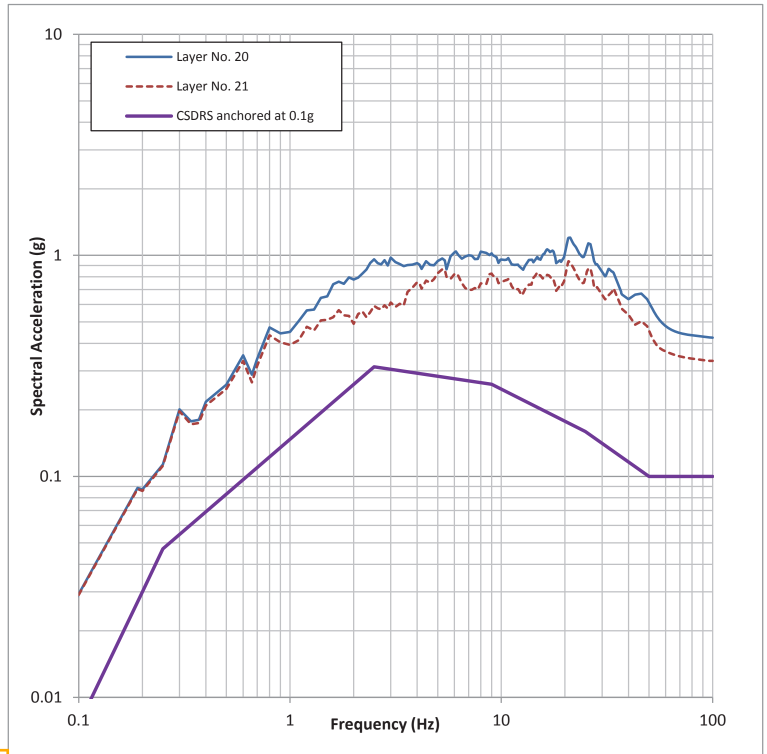

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Figure A-31: Comparison of Response Spectra for 20th and 21th Layer, S02 Case, E-W Direction

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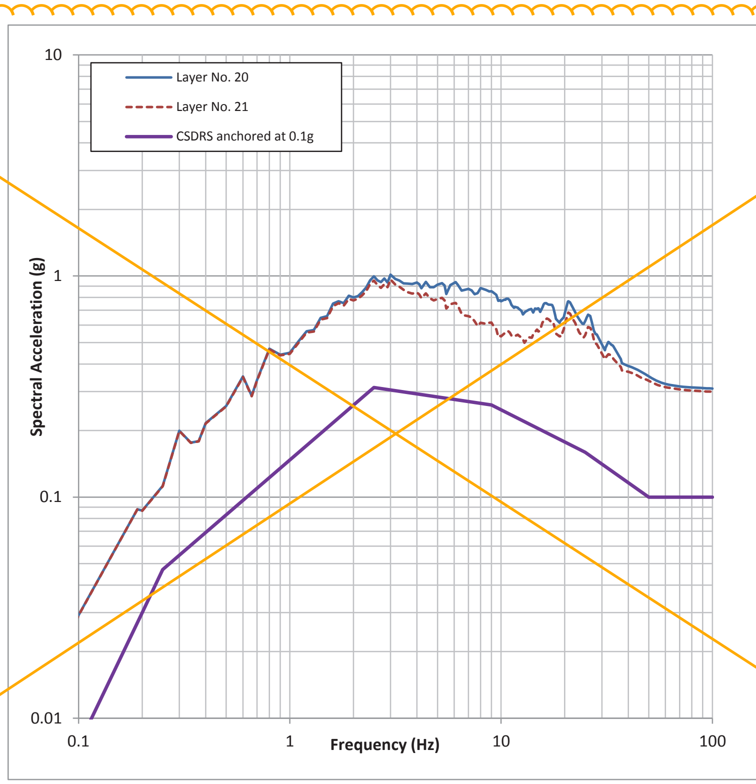

~~Figure A-32: Comparison of Response Spectra for 20th and 21th Layer, S05 Case, E-W Direction~~