3.7 Seismic Design

Section 3.7.1 describes the design parameters developed for use for the seismic analysis. Section 3.7.2 describes the seismic analysis of the two site-independent Seismic Category I structures: the Reactor Building (RXB) and Control Building (CRB). Section 3.7.3 provides the seismic analysis of subsystems. The subsystems include seismically mounted distribution systems (piping, cabling and ventilation), the bioshields, and the reactor building crane (RBC). Section 3.7.4 presents the instrumentation system for measuring the effects of an earthquake.

Appendix 3A provides the seismic analysis of the NuScale Power Module (NPM). The NPM includes the reactor vessel, containment vessel, and the associated structures, systems, and components (SSC).

The design complies with General Design Criterion 2 and 10 CFR 50, Appendix S in that SSC are designed to withstand the effects of earthquakes without loss of the capability to perform their safety functions. To ensure the design is acceptable without modification at most sites, the site independent structures are designed using the enveloping site parameters discussed in Chapter 2.0. With respect to earthquake design, two generic earthquake spectra and multiple generic soil profiles are used for the design of the site-independent Seismic Category I RXB and CRB.

The following is a brief discussion of the terms used within Section 3.7 and Section 3.8. These definitions are consistent with definitions provided in 10 CFR 50, Appendix S, Regulatory Guide (RG) 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Revision 2, Interim Staff Guidance ISG-001 (Reference 3.7.1-1), and other regulatory guidance documents.

Ground motion response spectra (GMRS) are site-specific ground motion response spectra characterized by horizontal and vertical response spectra determined as free-field motions on the ground surface or as free-field outcrop motions on the uppermost in-situ competent material using performance based procedures.

Safe shutdown earthquake (SSE) ground motion is the site-specific vibratory ground motion for which safety-related SSC are designed to remain functional. The SSE for a site is a smoothed spectra developed to envelop the GMRS. The SSE is characterized at the free ground surface. A combined license (COL) applicant may use the SSE for design of site-specific SSC.

Operating basis earthquake (OBE) ground motion is the vibratory ground motion for which those features of the nuclear power plant necessary for continued operation will remain functional. The operating basis earthquake ground motion is only associated with plant shutdown and inspection unless specifically selected by the applicant as a design input.

10 CFR 50, Appendix S provides two options for the value of the OBE. If the OBE is set to one-third or less of the SSE, the requirements associated with the OBE ground motion can be satisfied without performing explicit analysis. The OBE for the NuScale Power Plant is established as one-third of the SSE. Therefore, the OBE is not a design basis ground motion and no specific analysis is required.

Foundation input response spectra (FIRS) is the performance based site-specific seismic ground motion at the foundation level in the free field.

The GMRS, SSE, OBE and FIRS are site-specific. They are developed by the COL applicant. For the evaluation of the site-independent RXB and CRB, the certified seismic design response spectra (CSDRS) (described below) is used instead of the FIRS.

Certified Seismic Design Response Spectra are site-independent seismic design response spectra that have been developed for design of the Seismic Category I and II Structures. The NuScale CSDRS consists of two sets of spectra, identified as the CSDRS and the CSDRS-High Frequency (CSDRS-HF). The CSDRS are applied as an outcrop motion in the free-field at the foundation level of each building.

Certified Seismic Design Response Spectra (CSDRS) is a smooth broadband seismic design spectra developed to envelop the GMRS at most site and soil combinations. Development of the CSDRS is discussed in Section 3.7.1.1.1.1.

High Frequency Certified Seismic Design Response Spectra (CSDRS-HF) is a seismic design spectra developed to envelop the GMRS of most hard rock sites. The CSDRS-HF has less low frequency (below ~10 Hz) and more high frequency (above ~10 Hz) content than the CSDRS. Development of the CSDRS-HF is discussed in Section 3.7.1.1.1.2.

3.7.1 Seismic Design Parameters

3.7.1.1 Design Ground Motion

3.7.1.1.1 Design Ground Motion Response Spectra

The CSDRS is a broad spectra (similar to RG 1.60) which is intended to encompass the GMRS at most selected sites. The CSDRS is used as a design basis for Seismic Category I SSC to withstand the effects of earthquakes without loss of the capability to perform their safety functions. However, the CSDRS will not bound hard rock sites in the central and eastern United States. To improve the range of acceptable locations, site-independent Seismic Category I structures, RXB, and CRB are also evaluated using a spectra that has more content above 10 Hz than the CSDRS. This spectra is identified as the CSDRS-HF. These spectra are described in more detail below.

3.7.1.1.1.1 Certified Seismic Design Response Spectra

Response spectra were developed to envelope most sites except for the highly seismic west coast sites and the central and eastern United States hard rock sites subject to higher frequency earthquakes. The response spectra are smooth broadband geometric mean spectra that were developed based upon expert panel recommendations and comparison to available industry data providing SSEs at existing and proposed reactor sites. The vertical component was developed independently of the horizontal component, i.e., the vertical component is not a ratio of the horizontal component. The CSDRS bounds the RG 1.60 spectra anchored at 0.1g.

While similar, this spectra is not scaled from the RG 1.60 horizontal and vertical spectra. Instead, additional control points are established below 3.5 Hz and the control points above 3.5 Hz were shifted to higher frequencies. In addition, the vertical control point at 3.5 Hz was shifted to 4.5 Hz. Table 3.7.1-1 provides the horizontal and vertical control points for the CSDRS at 5 percent damping. Figure 3.7.1-1 compares the horizontal CSDRS at 5 percent damping against RG 1.60 spectra scaled to 0.1g. Figure 3.7.1-2 provides the same comparison in the vertical direction. Although not developed as a ratio, the vertical spectrum is $2/3^{rds}$ or more of the horizontal spectrum.

There are three components to the CSDRS. The two horizontal components, identified as North-South (NS) and East-West (EW) are equivalent. The three components: NS, EW and vertical (V) are mutually orthogonal. All three components are developed at 5 percent damping. The horizontal components have a peak ground acceleration (PGA) of 0.5g and the vertical component have a PGA of 0.4g.

3.7.1.1.1.2 Certified Seismic Design Response Spectra - High Frequency

In order to address the high frequency, hard rock sites, a second response spectra was developed. The CSDRS-HF was developed based on expert panel recommendations and comparison with available hard rock high frequency siting data.

Like the CSDRS, the CSDRS-HF has three mutually orthogonal components (NS, EW, and V), with the horizontal components equivalent. The vertical component was not scaled from the horizontal component. It was also developed independently. Above 2 Hz, the vertical component is $2/3^{rds}$ or more of the horizontal spectra. Above 50 Hz, the vertical component is larger than the horizontal component. Table 3.7.1-2 provides the horizontal and vertical control points for the CSDRS-HF at 5 percent damping. Figure 3.7.1-3 compares the horizontal CSDRS and CSDRS-HF at 5 percent damping. Figure 3.7.1-4 provides the same comparison for the vertical direction.

3.7.1.1.1.3 Site Applicability

The CSDRS and CSDRS-HF can be compared against the preliminary GMRS data presented in the Nuclear Regulatory Commission (NRC) Memorandum "Support Document for Screening and Prioritization Results Regarding Seismic Hazard Re-Evaluations for Operating Reactors in the Central and Eastern United States" (Reference 3.7.1-2). By inspection, it can be seen that the CSDRS and CSDRS-HF provide a reasonable envelope for site conditions. Therefore, the RXB and CRB are expected to be constructible at most sites with little or no modification.

3.7.1.1.2 Design Ground Motion Time History

Six sets of time histories (each set consists of two horizontal and one vertical time history) were developed. Five of the time history sets conform with the CSDRS and the sixth set conforms with the CSDRS-HF. Each time history set is developed in accordance with ASCE/SEI 43-05, Section 2.4 (a) through (f) (Reference 3.7.1-3). This approach aligns with the guidance provided in NRC Design Specific Review Standard 3.7.1 Subsection II.1B, Option 1, Approach 2. The CSDRS time histories are developed based upon the 1992 Landers earthquake, the 1989 Loma Prieta earthquake, the 1999 Chi-Chi earthquake, the 1999 Kocaeli earthquake, and the 1940 Imperial Valley earthquake. The CSDRS-HF time histories are based upon the 1992 Landers earthquake.

3.7.1.1.2.1 Seed Time Histories

Each seed time history is selected from actual acceleration time histories available from the Pacific Earthquake Engineering Research Center (PEER) ground motion database (Reference 3.7.1-4). The selection is based upon the intensity, duration, frequency content of the earthquake recording, and the epicenter distance from the recording station.

The acceleration recordings selected as seeds are described briefly below.

Yermo This set of time histories was recorded at the Yermo Fire Station during the 1992 Landers Earthquake, which occurred on June 28, 1992 at 04:57 am (11:57 coordinated universal time [UTC]), with an epicenter near the town of Landers, California. It was a magnitude 7.3 moment magnitude scale (MMS) earthquake. The time step is 0.02 seconds and the duration is 43.98 seconds and the maximum PGA recorded is 0.245g.

Figure 3.7.1-5a provides the unmodified Yermo acceleration, velocity, and displacement time histories and the response spectra scaled to the CSDRS in the east-west direction. Figure 3.7.1-5c and Figure 3.7.1-5e provide the same information in the north-south and vertical directions.

Capitola Recorded at station 47125 Capitola during the 1989 Loma Prieta Earthquake striking the San Francisco Bay Area of California on October 17, 1989 at 5:04 pm (October 18, 1989 at 00:04 UTC). It was a magnitude 6.9 MMS earthquake. The time step size of the recording is 0.005 seconds and the duration is 39.95 seconds. The maximum PGA recorded is 0.541g.

Figure 3.7.1-6a provides the unmodified Capitola acceleration, velocity, and displacement time histories and the response spectra scaled to the CSDRS in the east-west direction. Figure 3.7.1-6c and Figure 3.7.1-6e provide the same information in the north-south and vertical directions.

Chi-Chi Recorded at station TCU076 during the 1999 Chi-Chi Earthquake striking central Taiwan on September 21, 1999 at 1:47 am (September 20, 1999 at 17:47 UTC). This earthquake is also known as the 921 Earthquake since it occurred on September 21. It was a magnitude 7.6 MMS earthquake. The time step size of the recording is 0.005 seconds and the duration is 89.995 seconds. The maximum PGA recorded is 0.416g.

Figure 3.7.1-7a provides the unmodified Chi-Chi acceleration, velocity, and displacement time histories and the response spectra scaled to the CSDRS in the east-west direction. Figure 3.7.1-7c and Figure 3.7.1-7e provides the same information in the north-south and vertical directions.

Izmit This set of time histories was recorded at Station Izmit during the 1999 Kocaeli Earthquake which occurred on August 17, 1999 at 3:02 am (00:02 UTC) in northwestern Turkey. It was a magnitude of 7.4 MMS. The time step size of this recording is 0.005 seconds and the duration is recorded as 29.995 seconds. The maximum PGA recorded is 0.22g.

Figure 3.7.1-8a provides the unmodified Izmit acceleration, velocity, and displacement time histories and the response spectra scaled to the CSDRS in the east-west direction. Figure 3.7.1-8c and Figure 3.7.1-8e provides the same information in the north-south and vertical directions.

El Centro This set of time histories was recorded at station 117 El Centro Array #9 during the 1940 Imperial Valley Earthquake. This earthquake occurred on May 18, 1940 at 8:37 pm (May 19, 1940 at 05:35 UTC) in the Imperial Valley in southeastern Southern California. It was a magnitude 6.9 MMS earthquake. The time step size is 0.01 seconds and duration of 39.99 seconds. The maximum PGA recorded is 0.313g.

Figure 3.7.1-9a provides the unmodified El Centro acceleration, velocity, and displacement time histories and the response spectra scaled to the CSDRS in the east-west direction. Figure 3.7.1-9c and Figure 3.7.1-9e provides the same information in the north-south and vertical directions.

Lucerne These time histories were recorded at the Lucerne station during the 1992 Landers Earthquake which occurred on June 28, 1992 at 04:57 am (11:57 UTC), with an epicenter near the town of Landers, California. The 1992 Landers earthquake was a magnitude 7.3 MMS earthquake. The duration of this recording is 48.12 seconds and the time-step size is 0.005 seconds. The maximum PGA recorded is 0.818g. Although this is the same earthquake as Yermo, a different recording station was selected to better match the CSDRS-HF.

Figure 3.7.1-10a provides the unmodified Lucerne acceleration, velocity, and displacement time histories and the response spectra scaled to the CSDRS-HF in the east-west direction. Figure 3.7.1-10c and Figure 3.7.1-10e provides the same information in the north-south and vertical directions.

3.7.1.1.2.2 Generation of CSDRS and CSDRS-HF Compatible Time Histories

The numerical methodology devised by Lilhanand and Tseng (Reference 3.7.1-5) and later improved by N.A. Abrahamson (Reference 3.7.1-6) is used to generate CSDRS and CSDRS-HF compatible time histories. The methodology modifies an existing time history in the time domain so that its response spectrum closely matches a target response spectrum. The methodology, which is described in detail in the above-mentioned references, has been implemented in computer program RspMatch2009 (Reference 3.7.1-7). Validation of RSPMatch2009 is discussed in Section 3.7.5. Further improvement was incorporated in RspMatch2009 for calculation efficiency and convergence stability by using a new adjustment function, which allows the use of analytical integration and readily integrates to zero velocity and displacement without additional baseline correction. Spectrum compatible time histories were generated from the seed time histories using an iterative process with RspMatch2009. The main steps in this process are:

1) The time history is re-digitized to have 0.005 second time steps so that Nyquist frequency is 100 Hz (if necessary).

2) The time history is scaled to get the response spectrum close to the target CSDRS.

3) The scaled time history is entered into RspMatch2009 as a seed accelerogram, and the CSDRS (or CSDRS-HF) is entered as a target spectrum.

4) RspMatch2009 is used to add wavelets to the acceleration time history so that the acceleration response spectra of the modified time history matches the target spectrum. The phasing of Fourier components of the original time histories is inherently maintained.

5) The modified acceleration time history is loaded into SAP2000 to calculate acceleration response spectra using 100 frequencies per frequency decade to check for regulatory compliance.

6) The resulting response spectrum is compared to the acceptance criteria (described in Section 3.7.1.1.2.3 below).

If necessary, additional refining passes (steps 4, 5 and 6) are run.

Comparisons of the modified Yermo time histories to the CSDRS are provided in Figure 3.7.1-5b for the east-west direction, Figure 3.7.1-5d for the north-south direction, and Figure 3.7.1-5f for the vertical direction. The equivalent information is provided in Figure 3.7.1-6b, Figure 3.7.1-6d, and Figure 3.7.1-6f through Figure 3.7.1-10f for the other time histories.

3.7.1.1.2.3 Confirmation and Checking of the Modified Time Histories

Cross Correlation Coefficients of Time Histories

The cross correlation between two components of each set of modified time histories was calculated using the method described in ASCE/SEI 43-05. The cross correlation coefficients are summarized in Table 3.7.1-3. As shown in the table, no cross correlation coefficient is greater than 0.16. Thus, the time histories are statistically independent.

Time increment and Duration

The six seed time histories all have durations that exceed 20 seconds. The Nyquist frequency used for development of CSDRS and CSDRS-HF compatible time histories is 100 Hz. This results in a time increment of 0.005 seconds. The Yermo recording was in time steps of 0.02 seconds and El Centro was in time steps of 0.01 seconds. These were converted to 0.005 second time steps by linear interpolation.

Strong Motion Duration

The strong motion duration is defined as the time between 5 percent and 75 percent Arias Intensity. Arias Intensity plots for the modified Yermo time histories are provided in Figure 3.7.1-5b for the east-west direction, Figure 3.7.1-5d for the north-south direction and Figure 3.7.1-5f for the vertical direction. The equivalent information is provided in Figure 3.7.1-6b, Figure 3.7.1-6d, and Figure 3.7.1-6f through Figure 3.7.1-10a for the other time histories.

The strong motion durations are summarized in Table 3.7.1-4. All strong motion durations are greater than six seconds with exception of the NS component of the modified Izmit recording, which is 5.265 seconds.

As shown in Figure 3.7.1-11, the normalized Arias intensity time history for the NS component of the Izmit time history shows significant shaking for several seconds after 75 percent intensity is reached. The vertical black dashed lines show the time of the 5 percent (at 1.36 seconds) and 75 percent (at 6.625 seconds) Arias intensities. The vertical green dashed line indicates the 6 second duration is achieved at about 80 percent Arias intensity. Strong shaking starts before the 5 percent time and continues after the 75 percent time. Thus, the strong motion duration of this component of the Izmit time history is acceptable.

Comparison to Target Response Spectra

The response spectra of the five CSDRS compatible time history sets were generated by SAP2000 (Reference 3.7.1-8) at 600 frequencies, i.e. 200 frequencies per decade evenly distributed in the logarithmic frequency scale and the seven frequency control points used to define the CSDRS. The total number of frequencies used is 607. The response spectra of the five CSDRS compatible time histories are compared with the CSDRS to examine the degree of compatibility.

No frequency point in any of the CSDRS compatible time histories is greater than 30 percent above the CSDRS and no point is more than 10 percent below the target. In addition, there are no instances where more than 10 percent of the frequency points fall below the target response spectrum. The comparison data is tabulated in Table 3.7.1-5. Figure 3.7.1-12a, Figure 3.7.1-12b, and Figure 3.7.1-12c provide a visual comparison of the average of the five CSDRS compatible time histories to the CSDRS. As can be seen in these figures, the average is equal to, or slightly above, the CSDRS target in all three directions.

For the comparison of the Lucerne time histories to the CSDRS-HF, the quantity of frequencies generated varied by direction and decade. With the exception of the decade from 0.1 to 1 Hz, which had 85 frequency points in the vertical direction, all decades had more than 100 frequencies generated. For the CSDRS-HF, the frequency range of interest is 10 - 100 Hz. In this decade 362 frequencies were generated in the vertical direction.

No frequency point in the Lucerne time histories is more than 30 percent above the CSDRS-HF, and no point is more than 10 percent below the target. In addition, there are no instances where more than 10 percent of the frequency points fall below the CSDRS-HF spectrum. The comparison data is tabulated in Table 3.7.1-5.

Power Spectra Density

To ensure there are no gaps in the spectra, power spectra density (PSD) curves were created. PSD is a measure of the distribution of power in an accelerogram as a function of frequency. The one-sided PSD computed from an accelerogram is defined in terms of Fourier amplitudes of the time history, F(ω), by the relation:

$$PSD(\omega) = \frac{2|F(\omega)|^2}{2\pi T_{sm}} \qquad \text{Eq. 3.7-1}$$

where T_{sm} is the strong motion duration.

As can be seen in Figure 3.7.1-13a and Figure 3.7.1-13b, there are no gaps in the PSDs for any time histories.

3.7.1.1.2.4 Results

Based upon the above discussion, the modified time histories are valid representations of earthquakes that match the CSDRS and CSDRS-HF.

The five CSDRS compatible time histories sets and the CSDRS-HF compatible time histories set are used for the design of the buildings, the bioshield, the fuel storage rack, and the reactor building crane.

3.7.1.1.3 Site-Specific Design Ground Motion

Site-specific seismic analysis is performed by the COL applicant to confirm that the site-independent Seismic Category I structures may be constructed without modification, or to identify where modifications are necessary. To perform that analysis a site-specific earthquake and time histories must be created.

COL Item 3.7-1: A COL applicant that references the NuScale Power Plant design certification will describe the site-specific structures, systems, and components.

COL Item 3.7-2: A COL applicant that references the NuScale Power Plant design certification will provide site-specific time histories. In addition to the above criteria for cross correlation coefficients, time step and earthquake duration, strong motion durations, comparison to response spectra and power spectra density, the applicant will also confirm that site-specific ratios V/A and AD/V^2 (A, V, D, are peak ground acceleration, ground velocity, and ground displacement, respectively) are consistent with characteristic values for the magnitude and distance of the appropriate controlling events defining the site-specific uniform hazard response spectra.

Additional site-specific seismic analysis is performed by the COL applicant to confirm the adequacy of the seismic input motion and deterministic soil columns used in the soil structure interaction (SSI) analysis. The FIRS is the starting point for conducting an SSI analysis and for making a one-to-one comparison of the seismic design capacity of the standard design and the site-specific seismic demand for a site. The FIRS for the vertical direction is obtained with the vertical to horizontal (V/H) ratios appropriate for the site. For deeply embedded structures, the variation of V/H spectral ratios on ground motion over the depth of the facility will be considered.

In addition to the FIRS, the COL applicant will develop one or more performance-based response spectra at intermediate depths between the foundation and ground surface consistent with the Interim Staff Guidance ISG-017 (Reference 3.7.1-13). The performance-based response spectra for the vertical direction can be obtained with the appropriate V/H ratios used to develop the FIRS. The site-specific FIRS response spectra satisfy the same performance criteria as the GMRS. The GMRS are those derived from the global understanding of the site soil layers above the rock condition as determined from the site exploration activities and, therefore, are unique to a particular site.

COL Item 3.7-9: A COL applicant that references the NuScale Power Plant design certification will include an analysis of the performance-based response spectra established at the surface and intermediate depth(s) that take into account the complexities of the subsurface layer profiles of the site and provide a technical justification for the adequacy of vertical to horizontal (V/H) spectral ratios used in establishing the site-specific foundation input response spectra and the performance-based response spectra for the vertical direction.

The COL applicant may use site-specific ground motion for the design of site-specific safety-related SSC.

3.7.1.2 Percentage of Critical Damping Values

3.7.1.2.1 System and Component Damping

For analyses of Seismic Category I and Seismic Category II SSC, the damping values of RG 1.61, Revision 1, "Damping Values for Seismic Design of Nuclear Power Plants" are used. These values are presented in Table 3.7.1-6. For a discussion of damping used for the NPM subsystem, refer to Appendix 3A.

3.7.1.2.2 Structural Damping

The reinforced concrete may experience some cracking during a seismic event. Two levels of stiffness are included in the models to account for any cracking the concrete may experience. To represent cracked conditions, the stiffness of walls and diaphragms are reduced by 50 percent for flexure and shear. These effective stiffness values are provided in Table 3.7.1-7.

For static analysis using SAP2000, the in-plane (normal forces and in-plane shear) and out-of-plane plate stiffness (bending and out-of-plane shear) are changed independently by changing the stiffness modifier factors. For dynamic analysis using SASSI2010 (Reference 3.7.1-12) the plate stiffnesses are controlled by Young's modulus and the plate thickness. It is not possible to reduce the bending stiffness by 50 percent for cracked concrete while preserving the axial stiffness to 100 percent for in-plane forces by modifying Young's modulus. A compromise approach is used by reducing the thickness by a factor equal to cubic root of 0.5, or 0.7937 to reduce the bending stiffness by 50 percent for the cracked concrete condition. In this approach, the uncracked axial stiffness is reduced by a factor of 0.7937. This is summarized in Table 3.7.1-7a.

It is possible that for the SSI analyses with cracked concrete condition, all structural members might not have reached their cracked shear and moment values. Therefore, envelope forces and moments from the SSI analyses with uncracked and cracked reinforced concrete are used for the design of the structures. Both uncracked and cracked conditions are evaluated with 7 percent damping. This is SSE damping for reinforced concrete as specified in RG 1.61.

For generation of in-structure response spectra, both uncracked and cracked reinforced concrete conditions are evaluated with 4 percent damping and the results are enveloped. This is OBE damping for reinforced concrete as specified in RG 1.61.

3.7.1.2.3 Soil Damping

The dynamic properties of the soil and rock materials (i.e., the shear modulus and damping ratio) are dependent on shear strain levels induced during the shaking of an earthquake motion. The soil shear modulus decreases with the increase of soil shear strain, while the soil damping increases with the increase of soil shear strain. Soil degradation and damping functions were developed from 1993 Electric Power Research Institute data (Reference 3.7.1-9). These functions are shown in Figure 3.7.1-14 and Figure 3.7.1-15. For the half-space soil or rock, the shear wave velocities are assumed independent of the shear strain and the low-strain stiffness and strain-compatible damping of the soil layer above the half-space is used.

The numerical values of the shear modulus degradation and damping ratio curves as functions of the shear strains are tabulated in Table 3.7.1-8, Table 3.7.1-9 and Table 3.7.1-10. Because this site response analysis is not for a site-specific design, it is assumed that the soil site has a cohesionless soil and the extent of soil degradation varies with depth as shown in Table 3.7.1-8 and Table 3.7.1-9. However, for a rock site with an shear-wave velocity of 3500 fps or greater, the rock degradation shown in Table 3.7.1-10 is used regardless of depth. The maximum soil damping is limited to 15 percent.

Damping values for soils are discussed further in Section 3.7.1.3 as part of the creation of strain compatible properties for the generic soil profiles.

3.7.1.3 Supporting Media for Seismic Category I Structures

The footprints of both the RXB and the CRB are rectangular. The RXB is approximately 350 feet long and 150 feet wide and embedded 86 feet. The CRB is approximately 120 feet long, 80 feet wide, and embedded 55 feet. Additional discussion about the RXB and CRB is provided in Section 1.2.

The design of the site independent Seismic Category I structures is based upon four generic soil profiles. These soil profiles are not intended to represent the different soil profiles that may be encountered at actual sites. Rather, they were selected to represent the range of conditions (soft soil, firm soil/soft rock, rock, and hard rock) that could likely be encountered at a site.

The analysis considers five soil/earthquake combinations. The two softer profiles (soft soil and firm soil/soft rock) are evaluated in combination with the CSDRS. The rock profile is evaluated in combination with both the CSDRS and the CSDRS-HF. The hard rock profile is evaluated in combination with the CSDRS-HF.

Designing the foundation, walls, and slabs for these five combinations provides a design that should be acceptable at most sites. Each applicant will confirm that the site-independent Seismic Category I structures may be constructed without modification by performing a site-specific analysis and comparing the results as discussed in Section 3.8.4.8.

3.7.1.3.1 Generic Soil Profiles

The soil profiles used for the seismic analysis were selected from a larger pool of profiles. These profiles were initially identified as soil Type 1 through soil Type 12. This nomenclature remains, even though several of the original profiles were discarded because they produced results that were similar to, or bounded by, other profiles. The rock profiles tend to control the results. However a soft soil profile has been retained to ensure that those soil configurations are acceptable. Similarly, all profiles are evaluated with high groundwater. The design envelope created by evaluating a broad range of soil conditions is sufficient to account for sites with lower water levels. For stability analysis, assuming high groundwater is a more conservative approach.

Soft Soil Profile [Type 11]

The soil profile that represents a soft soil site has a shear wave velocity of 793.3 fps at the surface, increasing to 1200 fps at 240 foot depth where it increases to 8000 fps to represent bedrock. Soil density is 120 lb/ft^3 at the surface, increasing to 130 lb/ft^3 at the 160 foot depth and to 150 lb/ft^3 at 240 feet for the bedrock.

Initial soil properties versus depth (shear wave velocity, soil unit weight, and Poisson's ratio) are provided in Table 3.7.1-11. This soil profile is shown in Figure 3.7.1-16.

Firm Soil/Soft Rock Profile [Type 8]

The soil profile that represents a firm soil/soft rock site has a shear wave velocity of 3500 fps and a unit weight of 150 lb/ft^3. The soil column below 300 feet maintains the same parameters.

Soil properties versus depth (shear wave velocity, soil unit weight, and Poisson's ratio) are provided in Table 3.7.1-12. This soil profile is shown in Figure 3.7.1-16.

Rock Profile [Type 7]

The soil profile that represents a rock site has a shear wave velocity of 5000 fps and a density is 120 lb/ft^3 at the surface. Shear wave velocity remains a constant 5000 fps. Soil density increases to 135 lb/ft^3 at 300 feet below the surface. The soil below 300 feet is modeled with a shear wave velocity of 5000 fps and a unit weight of 135 lb/ft^3.

Soil properties versus depth (shear wave velocity, soil unit weight, and Poisson's ratio) are provided in Table 3.7.1-13. This soil profile is shown in Figure 3.7.1-16.

Hard Rock Profile [Type 9]

The soil profile that represents a hard rock site has a shear wave velocity of 8000 fps and a soil density of 150 lb/ft^3. Groundwater is not present. The soil column at 300 feet below the surface has the same parameters.

Soil properties versus depth (shear wave velocity, soil unit weight, and Poisson's ratio) are provided in Table 3.7.1-14. This soil profile is shown in Figure 3.7.1-16.

Engineered Fill

All soil profiles include 25 feet of backfill around the structures. The backfill has the same properties as the Soft Soil Profile [Type 11].

3.7.1.3.2 Strain Compatible Soil Properties

The time histories are applied as the outcrop motion at the base of the RXB foundation. The soil outcrop is shown on the right side of the layered soil sketch in Figure 3.7.1-17. The strain compatible soil properties are obtained by applying the outcrop motion at the bottom elevation of the RXB foundation. The in-layer motions for the RXB SSI analysis are also calculated by applying the outcrop motion at the bottom elevation of the RXB foundation. For the calculation of the in-layer soil response motions for the CRB soil-structure interaction analysis, the outcrop motion is applied at the bottom elevation of the CRB foundation. The strain-compatible soil properties remain the same as those obtained by applying the outcrop motion at the bottom elevation of the RXB foundation.

The thickness and shear wave velocity of a soil layer determines the maximum frequency of a seismic wave that can pass through that soil layer. The relationship between these three parameters is given by Eq. 3.7-2.

$$h \leq \frac{1}{5}\frac{V_s}{f_{pass}} \qquad \text{Eq. 3.7-2}$$

where,

f_{pass} is the maximum frequency that can pass through the soil layer,

V_S is the shear wave velocity, and

h is the layer thickness.

To ensure that high frequency motion is adequately transferred to the structure, layers of 6.25 feet thickness were used between the surface and the base of the RXB and five feet thick layers were used to the 300 foot depth.

By using these thicknesses and interpolating the original data presented in Table 3.7.1-11, Table 3.7.1-12, Table 3.7.1-13, and Table 3.7.1-14, and incorporating the soil damping and shear modulus information presented in Table 3.7.1-8, Table 3.7.1-9 and Table 3.7.1-10, initial detailed soil properties for the site response analysis were developed. The low-strain shear wave velocities for the soil types are shown in Figure 3.7.1-16. The densities are shown in Figure 3.7.1-18.

For analysis, the water table is assumed to be at the grade level. For saturated soil, a P-wave velocity, V_P, of 5000 fps is used. The exception is when it must be adjusted to limit the Poisson's ratio to 0.48. The maximum soil damping is limited to 15 percent.

The in-layer soil response acceleration time histories at a depth of 86 feet for the bottom of the RXB foundation and at 56.25 feet for the bottom of the CRB foundation are calculated using the computer program SHAKE2000, Version 9.98.0, "A Computer Program for the 1-D Analysis of Geotechnical Earthquake Engineering Problems," (Reference 3.7.1-10). Validation of Shake2000 is discussed in Section 3.7.5. The nonlinear soil behavior is approximated by the equivalent linear technique described in "SHAKE, A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites," (Reference 3.7.1-11). The SHAKE2000 program performs a one-dimensional analysis of a layered soil profile subjected to a seismic wave propagating in the vertical direction. Only one acceleration component can be applied as the excitation input in each analysis. For the soil analyses, the seismic input is applied as an outcrop motion at the bottom elevation of the RXB foundation.

The nonlinear soil properties are defined by soil shear strain dependent shear moduli and damping ratios for each layer. Using the strain dependent shear modulus degradation curves and strain-dependent damping curves, the iterative procedure implemented in SHAKE2000 calculates the strain-compatible soil properties in terms of shear moduli (or shear wave velocities) and damping ratios for all layers.

To obtain a single set of the strain-compatible soil properties of a soil profile for all three excitation components, the following steps are used:

Step 1. Perform initial SHAKE2000 analysis for the first S-wave excitation, designated as SV, using the east-west (EW) acceleration time history as the input motion. Soil property iteration is required. This step calculates the strain-compatible soil properties due to the first horizontal excitation.

Step 2. Perform initial SHAKE2000 analysis for the second S-wave excitation, designated as SH, using the north-south (NS) acceleration time history as the input motion. Soil property iteration is required. This step calculates the strain-compatible soil properties due to the second horizontal excitation.

Step 3. Average the strain-compatible properties obtained in Steps 1 and 2. This step calculates final strain-compatible soil properties applicable to the horizontal excitation components (i.e. EW and NS).

Step 4. Perform the final SHAKE2000 analyses for the SV and SH excitations using the averaged strain compatible soil properties obtained in Step 3. No iteration of soil properties is required. This step calculates the in-layer horizontal acceleration response time histories that are used as the horizontal input excitations (EW and NS) in the SSI analysis.

Step 5. Perform the final SHAKE2000 analysis for the vertical excitation, designated as PV. The soil properties in terms of the P-wave velocities, V_P, of all layers are required for the vertical excitation analysis. The P-wave velocities are calculated as described below. The same strain-compatible soil damping ratios for all layers obtained in Step 3 are used. No iteration of soil properties is required. This step produces the in-layer vertical site response time histories used in the SSI analysis.

For the calculation of site responses from the vertical excitation, the confined moduli, (or P-wave velocities) are used in Step 5 instead of using the strain-compatible shear moduli, (or S-wave velocities). The calculation of V_P is described below.

Calculate the shear wave velocity, for each layer based on its strain-compatible shear modulus G and soil density ρ as:

$$V_s = \sqrt{\frac{G}{\rho}} \qquad \text{Eq. 3.7-3}$$

where G is the shear modulus calculated in Step 3, and ρ is the soil density calculated as the unit weight, γ, divided by gravity constant, g.

Calculate the P-wave velocities, for each layer using the following formula:

$$V_p = V_s\sqrt{\frac{2(1-\nu)}{(1-2\nu)}} \qquad \text{Eq. 3.7-4}$$

where ν is the Poisson's ratio of the soil layer. The Poisson's ratio can be calculated for a pair of known V_S and V_P as follows:

$$\nu = \frac{2\left(\frac{V_s}{V_p}\right)^2 - 1}{2\left(\frac{V_s}{V_p}\right)^2 - 2} \qquad \text{Eq. 3.7-5}$$

A minimum P-wave velocity of 5000 fps is used because the soil layer is below the water table. In using the V_P of 5000 fps for a saturated soil, the Poisson's ratio should be recalculated for V_P of 5000 fps using

Eq. 3.7-5. If the Poisson's ratio exceeds 0.48, the saturated V_P is recalculated using 0.48 for the Poisson's ratio in Eq. 3.7-4. The limit of 0.48 for the Poisson's ratio is a limitation of the SSI analysis.

Step 6. Perform final SHAKE2000 analyses, as described in Steps 4 and 5, using final strain compatible properties to get in-layer motion at the bottom of the CRB basemat for inputs to the CRB SSI analysis.

For each soil type, the strain-compatible properties associated with each of the five CSDRS compatible time histories are averaged so that a single set of soil properties may be used per soil type. These average strain-compatible soil properties are presented in Table 3.7.1-15, Table 3.7.1-16, and Table 3.7.1-17. There is only one set of CSDRS-HF compatible time histories, so no averaging is performed. The strain-compatible properties for the rock profiles are presented in Table 3.7.1-18 for Soil Type 7 and Table 3.7.1-19 for Soil Type 9.

Average V_S profiles are combined into a single plot, shown in Figure 3.7.1-19, for the CSDRS compatible profiles. The CSDRS-HF compatible V_S profiles are provided in Figure 3.7.1-20.

Figure 3.7.1-21, Figure 3.7.1-22 and Figure 3.7.1-23 illustrates the strain compatible damping for the soil types used with the five CSDRS compatible time histories. Figure 3.7.1-24 combines the average damping ratios for all soil types on a single plot. Figure 3.7.1-25 shows the strain compatible damping for the CSDRS-HF for Soil Type 7 and Soil Type 9.

Wave passing frequencies calculated using Eq. 3.7-2, the averaged V_S and layer thicknesses presented in Table 3.7.1-16 through Table 3.7.1-19, are tabulated in Table 3.7.1-20.

The fundamental frequency of the soil medium between a certain soil layer and the ground surface can be calculated using the relationship that the soil depth, h, equal to a quarter of the fundamental shear wave length, λ , as follows:

$$h = \lambda / 4 \qquad \text{Eq. 3.7-6}$$

Thus, the soil frequency, f, can be calculated using the S-wave velocity, as follows:

$$f = \frac{V_s}{\lambda} = \frac{V_s}{4h} \qquad \text{Eq. 3.7-7}$$

V_S is the average value over all layers within the depth h.

The average strain-compatible soil properties of the CSDRS compatible inputs have previously been shown in Figure 3.7.1-19 for shear wave velocities and Figure 3.7.1-24 for damping ratios.

The shear wave velocities of the layers above the RXB foundation bottom elevation are averaged and used to calculate the fundamental frequencies of the soil between foundation bottom and grade by using Eq. 3.7-7.

The calculated horizontal soil frequencies are shown in Table 3.7.1-21 in a low-to-high frequency sequence. Each frequency in the table correlates with the first peak in the horizontal transfer function depicting foundation input to surface output amplification.

3.7.1.3.3 Site-Specific Soil Profile

COL Item 3.7-3: A COL applicant that references the NuScale Power Plant design certification will

- develop a site-specific strain compatible soil profile.
- confirm that the criterion for the minimum required response spectrum has been satisfied.
- determine whether the seismic site characteristics fall within the seismic design parameters such as soil layering assumptions used in the certified design, range of soil parameters, shear wave velocity values, and minimum soil bearing capacity.

3.7.1.4 References

3.7.1-1 U.S. Nuclear Regulatory Commission, "Interim Staff Guidance on Seismic Issues Associated with High Frequency Ground Motion in Design Certification and Combined License Applications," ISG-001, May 2008.

3.7.1-2 U.S. Nuclear Regulatory Commission, "Support Document for Screening and Prioritization Results Regarding Seismic Hazard Re-Evaluations for Operating Reactors in the Central and Eastern United States," Memorandum, Agencywide Documents Access and Management System (ADAMS) Accession No. ML14136A126, May 21, 2014.

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3.7.1-4 Pacific Earthquake Engineering Research Center, PEER NGA Strong Motion Database, http://peer.berkeley.edu/nga/, University of California, Berkeley, CA, 2013.

3.7.1-5 Lilhanand, K. and W.S.Tseng (F.H. Wittmann, ed.), "Generation of Synthetic Time Histories Compatible with Multiple-Damping Response Spectra," Biennial international conference on structural mechanics in reactor technology (SMiRT-9), Lausanne, Switzerland, 1987.

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3.7.1-7 RspMatch2009 [Computer Program]. (2011). Lacey, WA: GeoMotions, LLC.

3.7.1-8 SAP2000 Advanced (Version 17.1.1) [Computer Program]. (2014). Berkeley, CA: Computers and Structures, Inc.

3.7.1-9 Electric Power Research Institute, "Guidelines for Determining Design Basis Ground Motions," EPRI #102293, Palo Alto, CA, 1993.

3.7.1-10 Ordonez, G. A., SHAKE2000, Version 9.98.0, "A Computer Program for the 1-D Analysis of Geotechnical Earthquake Engineering Problems," User's Manual, April 2013.

3.7.1-11 Schnabel, P.B., J. Lysmer, and H.B. Seed, "SHAKE, A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites," EERC Report No. 72-12, University of California, Berkeley, 1972.

3.7.1-12 SASSI2010 (Version 1.0) [Computer Program]. (2012). Berkeley, CA.

3.7.1-13 U.S. Nuclear Regulatory Commission, "Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses," ISG-017, March 2010.

Table 3.7.1-1: Certified Seismic Design Response Spectra Control Points at 5 Percent Damping

Horizontal (NS and EW)		Vertical (V)	
Frequency (Hz)	**Acceleration (g)**	**Frequency (Hz)**	**Acceleration (g)**
0.1	0.024	0.1	0.016
0.25	0.15	0.25	0.1
1	0.60	1	0.40
3.5	1.15	4.5	1.06
12	1.15	16	1.06
50	0.50	50	0.40
100	0.50	100	0.40

Note:
Log-log interpolation is used between the frequencies listed in the table.

Table 3.7.1-2: Certified Seismic Design Response Spectra - High Frequency Control Points at 5 Percent Damping

Horizontal (NS and EW)		Vertical (V)	
Frequency (Hz)	**Acceleration (g)**	**Frequency (Hz)**	**Acceleration (g)**
0.1	0.01	0.1	0.01
0.2	0.05	0.3	0.04
0.3	0.08	0.5	0.09
0.5	0.12	1	0.1
1	0.16	2	0.18
1.8	0.25	3.8	0.24
3.7	0.35	4.6	0.29
5	0.43	11	0.76
8	0.9	20	1.0
20	1.5	30	1.2
25	1.6	50	1.3
30	1.5	100	0.52
50	1.0	-	-
100	0.52	-	-

Note:
Log-log interpolation is used between the frequencies listed in the table.

Table 3.7.1-3: Cross-Correlation Coefficients

Original Recording (target)	Modified Acceleration Component 1	Modified Acceleration Component 2	Cross- correlation Coefficient
Yermo (CSDRS)	NS	EW	0.0103
	EW	Vertical	0.0159
	NS	Vertical	0.0258
Capitola (CSDRS)	NS	EW	0.0277
	EW	Vertical	0.0219
	NS	Vertical	0.0862
Chi-Chi (CSDRS)	NS	EW	0.0951
	EW	Vertical	0.0231
	NS	Vertical	0.0811
Izmit (CSDRS)	NS	EW	0.0888
	EW	Vertical	0.0473
	NS	Vertical	0.0798
El Centro (CSDRS)	NS	EW	0.0071
	EW	Vertical	0.0561
	NS	Vertical	0.0490
Lucerne (CSDRS-HF)	NS	EW	0.0259
	EW	Vertical	0.1162
	NS	Vertical	0.0141

Table 3.7.1-4: Duration of Time Histories

Original Recording (Target)	Component	No. of Data Points	Time Step Size (sec)	Duration (sec)	T_{05} (sec)	T_{75} (sec)	Strong Motion Duration (T_{75} - T_{05}) (sec)
Yermo (CSDRS)	EW	8802	0.005	44.005	13.075	22.245	9.170
	NS	8802	0.005	44.005	12.945	21.140	8.195
	Vertical	8802	0.005	44.005	7.320	18.470	11.150
Capitola (CSDRS)	EW	7992	0.005	39.955	4.135	10.910	6.775
	NS	7992	0.005	39.955	3.975	10.875	6.900
	Vertical	7992	0.005	39.955	3.415	10.885	7.470
Chi-Chi (CSDRS)	EW	13854	0.005	69.265	5.965	19.540	13.575
	NS	13854	0.005	69.265	4.515	22.680	18.165
	Vertical	13854	0.005	69.265	3.295	18.995	15.700
Izmit (CSDRS)	EW	6000	0.005	29.995	2.930	11.340	8.410
	NS	6000	0.005	29.995	1.360	6.625	5.265*
	Vertical	6000	0.005	29.995	1.985	9.960	7.975
El Centro (CSDRS)	EW	8004	0.005	40.015	2.095	16.545	14.450
	NS	8004	0.005	40.015	1.575	10.895	9.320
	Vertical	8004	0.005	40.015	1.885	8.000	6.115
Lucerne (CSDRS-HF)	NS	9625	0.005	48.12	7.510	16.240	8.730
	EW	9625	0.005	48.12	7.665	16.185	8.520
	Vertical	9625	0.005	48.12	6.270	16.555	10.285

Note:
* This is acceptable as explained in Section 3.7.1.1.2.3

Table 3.7.1-5: Comparison of Response Spectra to CSDRS and CSDRS-HF

Original Recordings	Component	Frequency Decade	Number of Freq. in Response Spectrum Calculation	Max. Difference below Target (%)	Max. Difference above Target[a] (%)	Max. Number of Consecutive Points below Target
Yermo (CSDRS)	NS	three decades from 0.1 to 100 Hz	607	-3.6	+23.8	1
	EW			-5.3	+26.3	4
	Vertical			-4.9	+22.4	7
Capitola (CSDRS)	NS	three decades from 0.1 to 100 Hz	607	-8.6	+23.8	10[c]
	EW			-4.3	+23.7	5
	Vertical			-7.0	+24.1	2
Chi-Chi (CSDRS)	NS	three decades from 0.1 to 100 Hz	607	-7.4	+16.1	3
	EW			-4.6	+30.0[b]	4
	Vertical			-4.6	+27.0	2
Izmit (CSDRS)	NS	three decades from 0.1 to 100 Hz	607	-7.1	+21.0	3
	EW			-5.2	+17.5	11[d]
	Vertical			-9.3	+17.8	5
El Centro (CSDRS)	NS	three decades from 0.1 to 100 Hz	607	-6.6	+16.3	7
	EW			-5.8	+27.9	14[e]
	Vertical			-7.2	+17.2	3
Lucerne (CSDRS-HF)	NS	0.1 - 1 Hz	110	-6.51	+13.11	6
		1 - 10 Hz	215			
		10 - 100 Hz	271			
	EW	0.1 - 1 Hz	132	-6.63	+13.07	19[f]
		1 - 10 Hz	148			
		10 - 100 Hz	221			
	Vertical	0.1 - 1 Hz	85[g]	-2.26	+13.65	6
		1 - 10 Hz	229			
		10 - 100 Hz	362			

Notes:

(a) The high values are obtained in low frequency range of lower than 0.2 Hz

(b) Actually 29.96 at 0.164 Hz

(c) Found at 0.145 Hz, the maximum below target is 5.2%; beyond frequency 0.162 Hz, the maximum number of below target value is 1

(d) Found at 0.12 Hz, the maximum below target is 5.2%; beyond frequency 0.135 Hz, the maximum number of below target value is 4

(e) Found at 0.22 Hz, the maximum below target is 3.9%; beyond frequency 0.254 Hz, the maximum number of below target value is 1

(f) Found at 0.123 Hz, maximum below target is 6.8%; also found at 0.21 Hz with maximum below target 6.7%; beyond 0.23 Hz the maximum number below target is five

(g) There are less than 100 points in the 0.1 Hz to 1 Hz decade. However, for the CSDRS-HF, the frequency range of interest is 10 Hz to 100 Hz. There are 362 analyzed frequencies in that decade

Table 3.7.1-6: Generic Damping Values for Dynamic Analysis

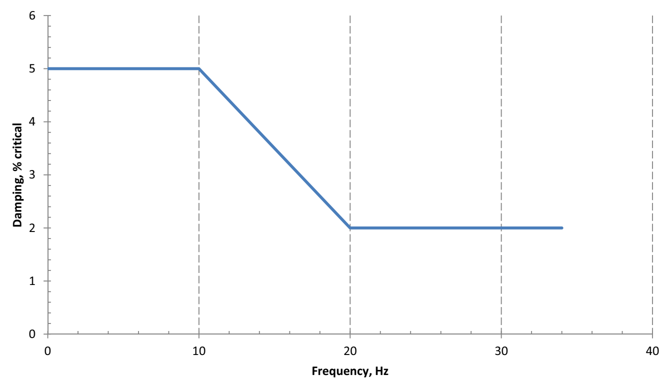
Material	SSE Damping (% of Critical Damping)	OBE Damping (% of Critical Damping)
Damping Values for Structural Material		
Reinforced Concrete	7%	4%
Reinforced Masonry	7%	4%
Prestressed Concrete	5%	3%
Welded Steel or Bolted Steel with Friction Connections	4%	3%
Bolted Steel with Bearing Connections	7%	5%

Note: For steel structures with a combination of different connection types, use the lowest specified damping value, or as an alternative, use a "weighted average" damping value based on the number of each type present in the structure.
For a discussion of damping used for the NPM subsystem, refer to the technical report TR-0916-51502, "NuScale Power Module Seismic Analysis."

Material	SSE Damping (% of Critical Damping)	OBE Damping (% of Critical Damping)
Damping Values for Piping Systems		
Piping Systems	4%	3%

Notes: As an alternative for response spectrum analyses using an envelope of the SSE or OBE response spectra at all support points (uniform support motion), frequency-dependent damping values shown in the Figure to the right may be used, subject to the following restrictions:

- Frequency-dependent damping should be used completely and consistently, if at all. (Damping values specified in Regulatory Guide 1.61 are to be used for equipment other than piping.)
- Use of the specified damping values is limited only to response spectral analyses. Acceptance of the use of the specified damping values with other types of dynamic analyses (e.g., time-history analyses or independent support motion method) requires further justification.
- When used for reconciliation or support optimization of existing designs, the effects of increased motion on existing clearances and online mounted equipment should be checked.
- Frequency-dependent damping is not appropriate for analyzing the dynamic response of piping systems using supports designed to dissipate energy by yielding.
- Frequency-dependent damping is not applicable to piping in which stress corrosion cracking has occurred, unless a case-specific evaluation is provided and reviewed and found acceptable by the NRC staff.



Material	SSE Damping (% of Critical Damping)	OBE Damping (% of Critical Damping)
Damping Values for Electrical Distribution Systems		
Cable Tray Systems		
Maximum Cable Loading	10%	7%
Empty	7%	5%
Sprayed-on Fire Retardant or other cable-restraining mechanism	7%	5%
Conduit Systems		
Maximum Cable fill	7%	5%
Empty	5%	3%

Table 3.7.1-6: Generic Damping Values for Dynamic Analysis (Continued)

Material	SSE Damping (% of Critical Damping)	OBE Damping (% of Critical Damping)
Notes: 1. Maximum cable loadings, in accordance with the plant design specification, are to be utilized in conjunction with these damping values. 2. Spare cable tray and conduit, initially empty, may be analyzed with zero cable load and these damping values. (Note: Re-analysis is expected when put into service.) 3.Restraint of the free relative movement of the cables inside a tray reduces the system damping. 4. When cable loadings of less than maximum are specified for design calculations, the applicant or licensee is expected to justify the selected damping values and obtain NRC review for acceptance on a case-by-case basis.		
Damping Values for HVAC Duct Systems		
Pocket Lock	10%	7%
Companion Angle	7%	5%
Welded	4%	3%
Damping Values for Mechanical and Electrical Components		
Motor, Fan, and Compressor Housings (protection, structural support)	3%	2%
Pressure Vessels, Heat Exchangers, and Pump and Valve Bodies (pressure boundary)	3%	2%
Welded Instrument Racks (structural support)	3%	2%
Electrical Cabinets, Panels, and Motor Control Centers (MCCs) (protection, structural support)	3%	2%
Metal Atmospheric Storage Tanks (containment, protection) - Impulsive Mode - Sloshing Mode	 3% 0.5%	 2% 0.5%

Table 3.7.1-7: Effective Stiffness of Reinforced Concrete Members

Member	Flexural Rigidity	Shear Rigidity	Axial Rigidity
Beams-nonprestressed	$0.5\ E_cI_g$	G_cA_w	-
Beams-prestressed	E_cI_g	G_cA_w	-
Columns in compression	$0.7\ E_cI_g$	G_cA_w	E_cA_g
Columns in tension	$0.5\ E_cI_g$	G_cA_w	E_sA_s
Walls and diaphragms - uncracked	E_cI_g $(f_b < f_{cr})$	G_cA_w $(V < V_c)$	E_cA_g
Walls and diaphragms - cracked	$0.5\ E_cI_g$ $(f_b > f_{cr})$	$0.5\ G_cA_w$ $(V > V_c)$	E_cA_g

Where,

A_g = Gross area of the concrete section

A_s = Gross area of the reinforcing steel

A_w = Web area

E_c = Concrete compressive modulus, from ACI-349 = $57,000(f'c)^{1/2}$

E_s = Steel modulus

f_b = Bending stress

f_{cr} = Cracking stress

G_c = Concrete shear modulus = $0.4E_c$

I_g = Gross moment of inertia

V = Wall shear

V_c = Nominal concrete shear capacity

Table 3.7.1-7a: Effective Stiffness Changes of Cracked Reinforced Concrete Finite Element Model Members

Flexural Rigidity	Shear Rigidity	Axial Rigidity
$0.5\ E_cI_g$	$0.7937G_cA_w$	$0.7937E_cA_g$

Table 3.7.1-8: Soil Shear Modulus Degradation and Strain-Dependent Soil Damping (0-120 ft)

1. Depth 0-20 ft			2. Depth 20-50 ft			3. Depth 50-120 ft		
Strain	**G/G_{max}**	**Damping (%)**	**Strain**	**G/G_{max}**	**Damping (%)**	**Strain**	**G/G_{max}**	**Damping (%)**
0.0001	1	1.5	0.0001	1	1.2	0.0001	1	1
0.0003	1	1.6	0.0003	1	1.2	0.0003	1	1
0.001	0.985	1.9	0.001	0.995	1.3	0.001	1	1.1
0.003	0.915	2.8	0.003	0.95	2	0.003	0.97	1.7
0.01	0.75	5.1	0.01	0.825	3.6	0.01	0.875	2.8
0.03	0.52	9	0.03	0.62	6.8	0.03	0.695	5.3
0.1	0.275	15.4	0.1	0.36	12.6	0.1	0.43	10.3
0.3	0.125	21.5	0.3	0.175	18.7	0.3	0.23	16.3
1	0.045	28	1	0.067	25	1	0.09	22.8

Table 3.7.1-9: Soil Shear Modulus Degradation and Strain-Dependent Soil Damping (120 ft-1000 ft)

4. Depth 120-250 ft			5. Depth 250-500 ft			6. Depth 500-1000 ft		
Strain	G/G_{max}	Damping (%)	Strain	G/G_{max}	Damping (%)	Strain	G/G_{max}	Damping (%)
0.0001	1	0.8	0.0001	1	0.8	0.0001	1	0.6
0.0003	1	0.8	0.0003	1	0.8	0.0003	1	0.6
0.001	1	0.9	0.001	1	0.8	0.001	1	0.6
0.003	0.975	1.3	0.003	0.985	1	0.003	0.99	0.8
0.01	0.905	2.2	0.01	0.93	1.8	0.01	0.95	1.3
0.03	0.755	4.3	0.03	0.805	3.4	0.03	0.86	2.4
0.1	0.495	8.8	0.1	0.56	7.3	0.1	0.65	5.5
0.3	0.28	14.3	0.3	0.335	12.5	0.3	0.41	10.2
1	0.115	21	1	0.15	19.2	1	0.2	16.7

Table 3.7.1-10: Strain-Dependent Soil Shear Moduli and Soil Damping Ratios for Gravel and Rock

7. Gravel (130+ ft)			8. Rock Average			
Strain	**G/G_{max}**	**Damping (%)**	**Strain**	**G/G_{max}**	**Strain**	**Damping (%)**
0.0001	1	3	0.0001	1	0.0001	0.4
0.0003	1	3	0.0003	1	0.001	0.8
0.001	1	3.3	0.001	0.9875	0.01	1.5
0.003	0.985	4	0.003	0.9525	0.1	3
0.01	0.82	6.5	0.01	0.9	1	4.6
0.03	0.57	10.1	0.03	0.81	-	-
0.1	0.32	16	0.1	0.725	-	-
0.3	0.14	22.5	1	0.55	-	-
1	0.05	27.5	-	-	-	-

Table 3.7.1-11: Soft Soil [Type 11] Parameters

Layer No.	Thickness (ft)	Depth (ft)	Shear Wave Velocity Vs (ft/s)	Unit Weight (pcf)	Poisson's Ratio
1	2	-2	703.3	120	0.35
2	3	-5	703.3	120	0.35
3	15	-20	703.3	120	0.35
4	20	-40	981.8	120	0.35
5	20	-60	1163.8	120	0.35
6	20	-80	1199	120	0.35
7	20	-100	1136	120	0.35
8	20	-120	1143	120	0.35
9	40	-160	1162	130	0.35
10	40	-200	1181	130	0.35
11	40	-240	1200	130	0.35
12	60	-300	8000	150	0.25
13	Halfspace	-300	8000	150	0.25

Table 3.7.1-12: Firm Soil/Soft Rock [Type 8] Parameters

Layer No.	Thickness (ft)	Depth (ft)	Shear Wave Velocity Vs (ft/s)	Unit Weight (pcf)	Poisson's Ratio
1	2	-2	3500	150	0.25
2	3	-5	3500	150	0.25
3	15	-20	3500	150	0.25
4	20	-40	3500	150	0.25
5	20	-60	3500	150	0.25
6	20	-80	3500	150	0.25
7	20	-100	3500	150	0.25
8	20	-120	3500	150	0.25
9	40	-160	3500	150	0.25
10	40	-200	3500	150	0.25
11	40	-240	3500	150	0.25
12	60	-300	3500	150	0.25
13	Halfspace	-300	3500	150	0.25

Table 3.7.1-13: Rock [Type 7] Parameters

Layer No.	Thickness (ft)	Depth (ft)	Shear Wave Velocity Vs (ft/s)	Unit Weight (pcf)	Poisson's Ratio
1	2	-2	5000	120	0.38
2	3	-5	5000	120	0.38
3	15	-20	5000	120	0.38
4	20	-40	5000	120	0.35
5	20	-60	5000	125	0.35
6	20	-80	5000	125	0.35
7	20	-100	5000	125	0.35
8	20	-120	5000	130	0.32
9	40	-160	5000	130	0.32
10	40	-200	5000	135	0.32
11	40	-240	5000	135	0.32
12	60	-300	5000	135	0.30
13	Halfspace	-300	5000	135	0.30

Table 3.7.1-14: Hard Rock [Type 9] Parameters

Layer No.	Thickness (ft)	Depth (ft)	Shear Wave Velocity Vs (ft/s)	Unit Weight (pcf)	Poisson's Ratio
1	2	-2	8000	150	0.25
2	3	-5	8000	150	0.25
3	15	-20	8000	150	0.25
4	20	-40	8000	150	0.25
5	20	-60	8000	150	0.25
6	20	-80	8000	150	0.25
7	20	-100	8000	150	0.25
8	20	-120	8000	150	0.25
9	40	-160	8000	150	0.25
10	40	-200	8000	150	0.25
11	40	-240	8000	150	0.25
12	60	-300	8000	150	0.25
13	Halfspace	-300	8000	150	0.25

Table 3.7.1-15: Average Strain-Compatible Properties for CSDRS for Rock [Type 7]

Layer No.	Depth(ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
1	6.25	6.25	0.004	120	5000	0.38	11365
2	12.5	6.25	0.006	120	4993	0.38	11349
3	18.75	6.25	0.007	120	4980	0.38	11319
4	25	6.25	0.008	120	4971	0.36	10513
5	31.25	6.25	0.009	120	4956	0.35	10317
6	37.5	6.25	0.009	120	4939	0.35	10282
7	43.75	6.25	0.01	123	4928	0.35	10258
8	50	6.25	0.01	125	4918	0.35	10237
9	56.25	6.25	0.01	125	4907	0.35	10215
10	62.5	6.25	0.011	125	4898	0.35	10197
11	68.75	6.25	0.011	125	4890	0.35	10180
12	75	6.25	0.011	125	4883	0.35	10165
13	80	5	0.011	125	4876	0.35	10151
14	85	5	0.012	125	4870	0.35	10138
15	90	5	0.012	125	4864	0.35	10125
16	95	5	0.012	125	4858	0.35	10113
17	100	5	0.012	125	4853	0.35	10102
18	105	5	0.012	130	4852	0.32	9431
19	110	5	0.012	130	4847	0.32	9422
20	115	5	0.012	130	4843	0.32	9412
21	120	5	0.013	130	4838	0.32	9403
22	125	5	0.013	130	4834	0.32	9395
23	130	5	0.013	130	4829	0.32	9386
24	135	5	0.013	130	4825	0.32	9379
25	140	5	0.013	130	4821	0.32	9371
26	145	5	0.013	130	4818	0.32	9364
27	150	5	0.013	130	4814	0.32	9357
28	155	5	0.013	130	4811	0.32	9351
29	160	5	0.013	130	4808	0.32	9345
30	165	5	0.013	135	4809	0.32	9347
31	170	5	0.013	135	4806	0.32	9342
32	175	5	0.013	135	4803	0.32	9336
33	180	5	0.013	135	4801	0.32	9331
34	185	5	0.013	135	4798	0.32	9326
35	190	5	0.013	135	4796	0.32	9322
36	195	5	0.013	135	4794	0.32	9317
37	200	5	0.013	135	4791	0.32	9312
38	205	5	0.014	135	4789	0.32	9308
39	210	5	0.014	135	4787	0.32	9304
40	215	5	0.014	135	4785	0.32	9300
41	220	5	0.014	135	4783	0.32	9296
42	225	5	0.014	135	4781	0.32	9292
43	230	5	0.014	135	4779	0.32	9288
44	235	5	0.014	135	4777	0.32	9285
45	240	5	0.014	135	4775	0.32	9282
46	245	5	0.014	135	4774	0.30	8930
47	250	5	0.014	135	4772	0.30	8927
48	255	5	0.014	135	4770	0.30	8924
49	260	5	0.014	135	4768	0.30	8920

Table 3.7.1-15: Average Strain-Compatible Properties for CSDRS for Rock [Type 7] (Continued)

Layer No.	Depth(ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
50	265	5	0.014	135	4766	0.30	8917
51	270	5	0.014	135	4765	0.30	8914
52	275	5	0.014	135	4763	0.30	8911
53	280	5	0.014	135	4762	0.30	8908
54	285	5	0.014	135	4760	0.30	8905
55	290	5	0.014	135	4759	0.30	8903
56	295	5	0.014	135	4757	0.30	8900
57	300	5	0.014	135	4756	0.30	8897
		Halfspace	0.014	135	5000	0.30	9354

Table 3.7.1-16: Average Strain-Compatible Properties for CSDRS for Soft Soil [Type 11]

Layer No.	Depth(ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
1	6.25	6.25	0.045	120	625	0.48	3187
2	12.5	6.25	0.101	120	487	0.48	2481
3	18.75	6.25	0.149	120	371	0.48	1891
4	25	6.25	0.074	120	712	0.48	3632
5	31.25	6.25	0.08	120	739	0.48	3770
6	37.5	6.25	0.092	120	702	0.48	3581
7	43.75	6.25	0.084	120	805	0.48	4106
8	50	6.25	0.082	120	867	0.48	4421
9	56.25	6.25	0.063	120	933	0.48	4759
10	62.5	6.25	0.066	120	932	0.48	4754
11	68.75	6.25	0.068	120	943	0.48	4806
12	75	6.25	0.071	120	929	0.48	4739
13	80	5	0.074	120	919	0.48	4683
14	85	5	0.083	120	832	0.48	4240
15	90	5	0.085	120	824	0.48	4200
16	95	5	0.087	120	817	0.48	4163
17	100	5	0.088	120	810	0.48	4129
18	105	5	0.089	120	812	0.48	4141
19	110	5	0.09	120	807	0.48	4112
20	115	5	0.092	120	801	0.48	4082
21	120	5	0.093	120	795	0.48	4054
22	125	5	0.066	130	917	0.48	4674
23	130	5	0.067	130	911	0.48	4645
24	135	5	0.068	130	906	0.48	4617
25	140	5	0.07	130	899	0.48	4585
26	145	5	0.072	130	893	0.48	4552
27	150	5	0.073	130	886	0.48	4517
28	155	5	0.075	130	879	0.48	4483
29	160	5	0.076	130	873	0.48	4451
30	165	5	0.075	130	890	0.48	4539
31	170	5	0.077	130	885	0.48	4511
32	175	5	0.078	130	879	0.48	4484
33	180	5	0.079	130	875	0.48	4459
34	185	5	0.08	130	870	0.48	4436
35	190	5	0.081	130	865	0.48	4413
36	195	5	0.082	130	861	0.48	4389
37	200	5	0.083	130	856	0.48	4364
38	205	5	0.082	130	874	0.48	4458
39	210	5	0.083	130	870	0.48	4435
40	215	5	0.084	130	865	0.48	4413
41	220	5	0.085	130	861	0.48	4391
42	225	5	0.086	130	857	0.48	4370
43	230	5	0.087	130	854	0.48	4352
44	235	5	0.088	130	850	0.48	4333
45	240	5	0.089	130	846	0.48	4313
46	245	5	0.008	150	7945	0.25	13762
47	250	5	0.008	150	7936	0.25	13745

Table 3.7.1-16: Average Strain-Compatible Properties for CSDRS for Soft Soil [Type 11] (Continued)

Layer No.	Depth(ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
48	255	5	0.009	150	7925	0.25	13726
49	260	5	0.009	150	7910	0.25	13700
50	265	5	0.009	150	7894	0.25	13672
51	270	5	0.01	150	7880	0.25	13649
52	275	5	0.01	150	7869	0.25	13629
53	280	5	0.01	150	7859	0.25	13611
54	285	5	0.01	150	7850	0.25	13597
55	290	5	0.01	150	7844	0.25	13586
56	295	5	0.01	150	7839	0.25	13578
57	300	5	0.01	150	7837	0.25	13573
		Halfspace	0.01	150	8000	0.25	13856

Table 3.7.1-17: Average Strain-Compatible Properties for CSDRS for Firm Soil/Soft Rock [Type 8]

Layer No.	Depth(ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
1	6.25	6.25	0.006	150	3500	0.25	6062
2	12.5	6.25	0.008	150	3482	0.25	6032
3	18.75	6.25	0.009	150	3462	0.25	5997
4	25	6.25	0.01	150	3443	0.25	5963
5	31.25	6.25	0.011	150	3429	0.25	5939
6	37.5	6.25	0.011	150	3417	0.25	5919
7	43.75	6.25	0.012	150	3405	0.25	5898
8	50	6.25	0.012	150	3394	0.25	5879
9	56.25	6.25	0.013	150	3385	0.25	5863
10	62.5	6.25	0.013	150	3377	0.25	5849
11	68.75	6.25	0.013	150	3369	0.25	5836
12	75	6.25	0.013	150	3363	0.25	5825
13	80	5	0.013	150	3358	0.25	5816
14	85	5	0.014	150	3353	0.25	5808
15	90	5	0.014	150	3349	0.25	5801
16	95	5	0.014	150	3345	0.25	5794
17	100	5	0.014	150	3342	0.25	5788
18	105	5	0.014	150	3338	0.25	5782
19	110	5	0.014	150	3335	0.25	5776
20	115	5	0.014	150	3332	0.25	5771
21	120	5	0.015	150	3329	0.25	5766
22	125	5	0.015	150	3327	0.25	5762
23	130	5	0.015	150	3324	0.25	5757
24	135	5	0.015	150	3321	0.25	5751
25	140	5	0.015	150	3317	0.25	5746
26	145	5	0.015	150	3314	0.25	5740
27	150	5	0.015	150	3311	0.25	5734
28	155	5	0.015	150	3307	0.25	5729
29	160	5	0.015	150	3304	0.25	5723
30	165	5	0.016	150	3301	0.25	5718
31	170	5	0.016	150	3298	0.25	5711
32	175	5	0.016	150	3294	0.25	5706
33	180	5	0.016	150	3291	0.25	5700
34	185	5	0.017	150	3288	0.25	5694
35	190	5	0.017	150	3285	0.25	5689
36	195	5	0.017	150	3282	0.25	5684
37	200	5	0.017	150	3279	0.25	5679
38	205	5	0.017	150	3276	0.25	5675
39	210	5	0.017	150	3274	0.25	5671
40	215	5	0.017	150	3272	0.25	5666
41	220	5	0.017	150	3269	0.25	5662
42	225	5	0.017	150	3267	0.25	5658
43	230	5	0.018	150	3265	0.25	5655
44	235	5	0.018	150	3263	0.25	5651
45	240	5	0.018	150	3261	0.25	5648
46	245	5	0.018	150	3259	0.25	5645
47	250	5	0.018	150	3257	0.25	5642

Table 3.7.1-17: Average Strain-Compatible Properties for CSDRS for Firm Soil/Soft Rock [Type 8] (Continued)

Layer No.	Depth(ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
48	255	5	0.018	150	3256	0.25	5639
49	260	5	0.018	150	3254	0.25	5636
50	265	5	0.018	150	3253	0.25	5634
51	270	5	0.018	150	3251	0.25	5631
52	275	5	0.018	150	3249	0.25	5628
53	280	5	0.018	150	3248	0.25	5626
54	285	5	0.018	150	3246	0.25	5623
55	290	5	0.018	150	3245	0.25	5620
56	295	5	0.018	150	3243	0.25	5617
57	300	5	0.018	150	3241	0.25	5614
		Halfspace	0.018	150	3500	0.25	6062

Table 3.7.1-18: Strain-Compatible Properties for CSDRS-HF for Rock [Type 7]

Layer No.	Depth (ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
1	6.25	6.25	0.005	120	5000	0.380	11365.2
2	12.5	6.25	0.007	120	4991.6	0.380	11346
3	18.75	6.25	0.007	120	4978.8	0.380	11317.1
4	25	6.25	0.008	120	4971	0.356	10512.5
5	31.25	6.25	0.009	120	4959.6	0.350	10324.3
6	37.5	6.25	0.009	120	4946.9	0.350	10297.7
7	43.75	6.25	0.009	125	4938.9	0.350	10281
8	50	6.25	0.009	125	4932.9	0.350	10268.6
9	56.25	6.25	0.009	125	4927.4	0.350	10257.2
10	62.5	6.25	0.01	125	4922.1	0.350	10246.3
11	68.75	6.25	0.01	125	4918.5	0.350	10238.6
12	75	6.25	0.01	125	4915.8	0.350	10233
13	80	5	0.01	125	4912.3	0.350	10225.7
14	85	5	0.01	125	4909.1	0.350	10219.2
15	90	5	0.01	125	4906.5	0.350	10213.7
16	95	5	0.01	125	4904.3	0.350	10209.2
17	100	5	0.01	125	4902	0.350	10204.3
18	105	5	0.01	130	4902.8	0.320	9529.3
19	110	5	0.01	130	4900.7	0.320	9525.2
20	115	5	0.01	130	4899	0.320	9521.9
21	120	5	0.01	130	4897.7	0.320	9519.4
22	125	5	0.01	130	4896.8	0.320	9517.7
23	130	5	0.01	130	4896.3	0.320	9516.7
24	135	5	0.01	130	4896.2	0.320	9516.5
25	140	5	0.011	130	4895.2	0.320	9514.5
26	145	5	0.011	130	4894.5	0.320	9513.2
27	150	5	0.011	130	4894.4	0.320	9513
28	155	5	0.011	130	4894.7	0.320	9513.7
29	160	5	0.01	130	4895.5	0.320	9515.2
30	165	5	0.01	135	4898.5	0.320	9520.9
31	170	5	0.01	135	4898.2	0.320	9520.5
32	175	5	0.01	135	4897.7	0.320	9519.5
33	180	5	0.011	135	4896.8	0.320	9517.7
34	185	5	0.011	135	4896	0.320	9516
35	190	5	0.011	135	4894.8	0.320	9513.8
36	195	5	0.011	135	4892.4	0.320	9509.2
37	200	5	0.011	135	4889.4	0.320	9503.2
38	205	5	0.011	135	4886.5	0.320	9497.7
39	210	5	0.011	135	4884	0.320	9492.8
40	215	5	0.011	135	4881.3	0.320	9487.5
41	220	5	0.011	135	4878.9	0.320	9482.9
42	225	5	0.011	135	4876.7	0.320	9478.7
43	230	5	0.011	135	4874.3	0.320	9473.9
44	235	5	0.011	135	4872.1	0.320	9469.7
45	240	5	0.011	135	4870.2	0.320	9466
46	245	5	0.011	135	4868.9	0.300	9108.8
47	250	5	0.011	135	4867.9	0.300	9107.1
48	255	5	0.011	135	4867.4	0.300	9106.1
49	260	5	0.011	135	4867.2	0.300	9105.6

Table 3.7.1-18: Strain-Compatible Properties for CSDRS-HF for Rock [Type 7] (Continued)

Layer No.	Depth (ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
50	265	5	0.011	135	4866.4	0.300	9104.2
51	270	5	0.011	135	4866	0.300	9103.5
52	275	5	0.011	135	4865.9	0.300	9103.2
53	280	5	0.011	135	4865.8	0.300	9103
54	285	5	0.011	135	4865.3	0.300	9102.2
55	290	5	0.011	135	4864.1	0.300	9099.8
56	295	5	0.011	135	4863	0.300	9097.8
57	300	5	0.011	135	4862.2	0.300	9096.3
		Halfspace	0.011	135	5000	0.300	9354.2

Table 3.7.1-19: Strain-Compatible Properties for CSDRS-HF for Hard Rock [Type 9]

Layer No.	Depth (ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
1	6.25	6.25	0.003	150	8000	0.250	13856.4
2	12.5	6.25	0.005	150	8000	0.250	13856.4
3	18.75	6.25	0.006	150	8000	0.250	13856.4
4	25	6.25	0.006	150	7992.2	0.250	13842.9
5	31.25	6.25	0.007	150	7982	0.250	13825.3
6	37.5	6.25	0.007	150	7974.1	0.250	13811.6
7	43.75	6.25	0.007	150	7967.8	0.250	13800.6
8	50	6.25	0.007	150	7962.7	0.250	13791.7
9	56.25	6.25	0.008	150	7958.5	0.250	13784.5
10	62.5	6.25	0.008	150	7955.2	0.250	13778.8
11	68.75	6.25	0.008	150	7952.6	0.250	13774.2
12	75	6.25	0.008	150	7949	0.250	13768
13	80	5	0.008	150	7946	0.250	13762.9
14	85	5	0.008	150	7944.1	0.250	13759.5
15	90	5	0.008	150	7940.8	0.250	13753.8
16	95	5	0.009	150	7936.5	0.250	13746.5
17	100	5	0.009	150	7932.9	0.250	13740.2
18	105	5	0.009	150	7929.9	0.250	13734.9
19	110	5	0.009	150	7927.4	0.250	13730.6
20	115	5	0.009	150	7925.4	0.250	13727.1
21	120	5	0.009	150	7923.1	0.250	13723.2
22	125	5	0.009	150	7920.1	0.250	13717.9
23	130	5	0.009	150	7917.3	0.250	13713.2
24	135	5	0.009	150	7914.8	0.250	13708.9
25	140	5	0.009	150	7912.6	0.250	13705
26	145	5	0.009	150	7910.6	0.250	13701.6
27	150	5	0.009	150	7908.8	0.250	13698.5
28	155	5	0.009	150	7906	0.250	13693.6
29	160	5	0.009	150	7903.4	0.250	13689.1
30	165	5	0.009	150	7901.1	0.250	13685.1
31	170	5	0.009	150	7899.1	0.250	13681.6
32	175	5	0.009	150	7897.3	0.250	13678.5
33	180	5	0.009	150	7895.8	0.250	13675.9
34	185	5	0.009	150	7894.5	0.250	13673.6
35	190	5	0.009	150	7893.4	0.250	13671.8
36	195	5	0.009	150	7892.6	0.250	13670.4
37	200	5	0.009	150	7892	0.250	13669.4
38	205	5	0.009	150	7891.7	0.250	13668.8
39	210	5	0.009	150	7891.6	0.250	13668.6
40	215	5	0.009	150	7891.6	0.250	13668.7
41	220	5	0.009	150	7891.9	0.250	13669.1
42	225	5	0.009	150	7890.9	0.250	13667.4
43	230	5	0.009	150	7890.1	0.250	13666.1
44	235	5	0.009	150	7889.6	0.250	13665.3
45	240	5	0.009	150	7889.5	0.250	13665
46	245	5	0.009	150	7889.7	0.250	13665.3
47	250	5	0.009	150	7890.1	0.250	13666
48	255	5	0.009	150	7890.7	0.250	13667
49	260	5	0.009	150	7890.6	0.250	13666.9

Table 3.7.1-19: Strain-Compatible Properties for CSDRS-HF for Hard Rock [Type 9] (Continued)

Layer No.	Depth (ft)	Layer Thickness (ft)	Damping Ratio	Unit Weight (pcf)	Vs (fps)	Poisson's Ratio	Vp (fps)
50	265	5	0.009	150	7890.3	0.250	13666.4
51	270	5	0.009	150	7890.1	0.250	13666.1
52	275	5	0.009	150	7890	0.250	13665.9
53	280	5	0.009	150	7889.4	0.250	13664.9
54	285	5	0.009	150	7888.9	0.250	13664
55	290	5	0.009	150	7888.1	0.250	13662.6
56	295	5	0.009	150	7887.2	0.250	13661.1
57	300	5	0.009	150	7886.5	0.250	13659.8
		Halfspace	0.009	150	8000	0.250	13856.4

Table 3.7.1-20: Wave Passing Frequencies

Soil Type	Soil Type Description	CSDRS Compatible Inputs (Hz)	CSDRS-HF Compatible Input (Hz)
11	Soft soil	12	-
8	Firm soil/soft rock	108	-
7	Rock	157	157
9	Hard rock	-	254

Table 3.7.1-21: Shear Wave Fundamental Frequencies of Soil Columns above RXB Foundation Bottom Elevation

Soil Type	Soil Type Description	CSDRS Compatible Soil Frequency (Hz)	CSDRS-HF Compatible Soil Frequency (Hz)
11	Soft soil	2.27	-
8	Firm soil/soft rock	10.03	-
7	Rock	14.50	14.55
9	Hard rock	-	23.43

Figure 3.7.1-1: NuScale Horizontal CSDRS at 5 Percent Damping

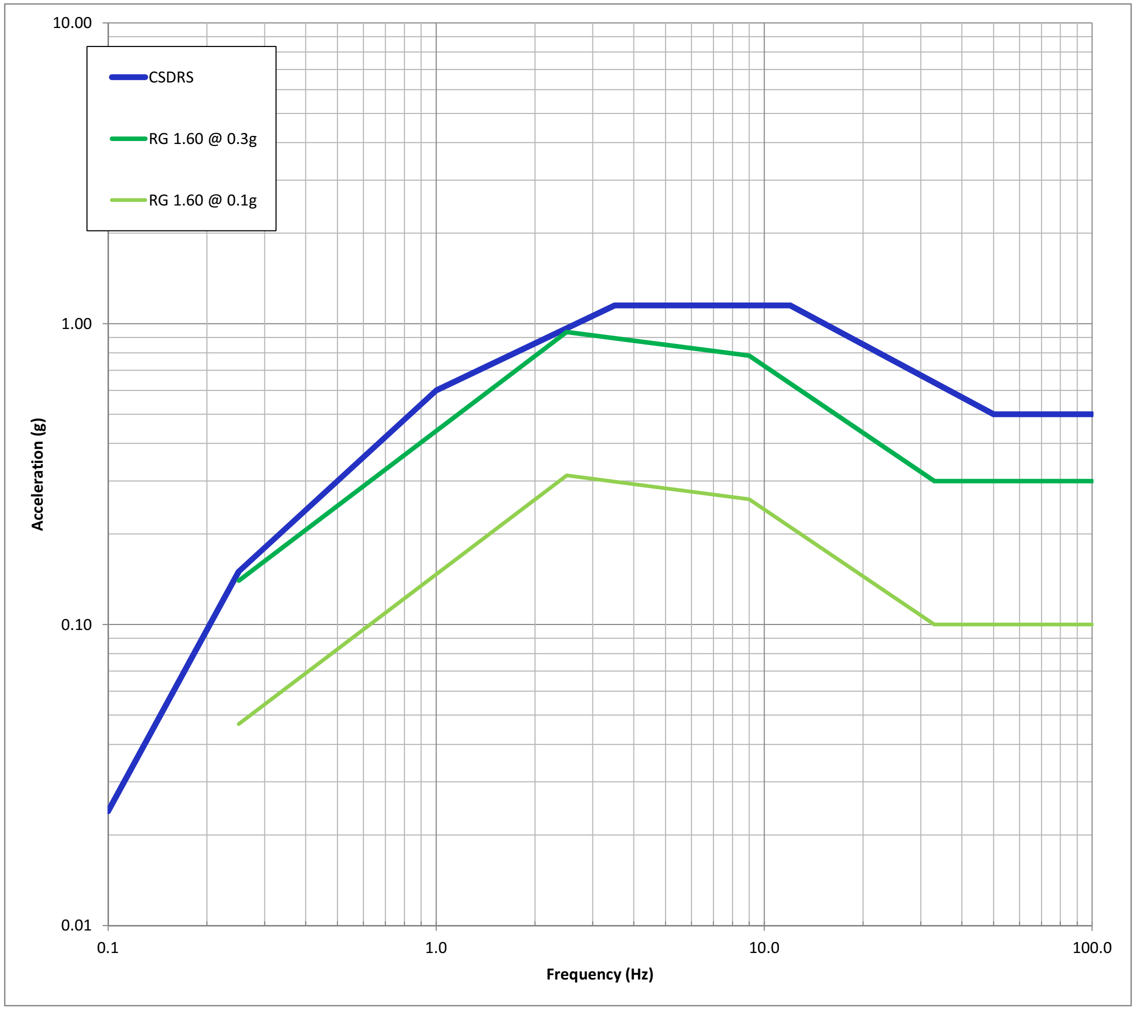


Figure 3.7.1-2: NuScale Vertical CSDRS at 5 Percent Damping

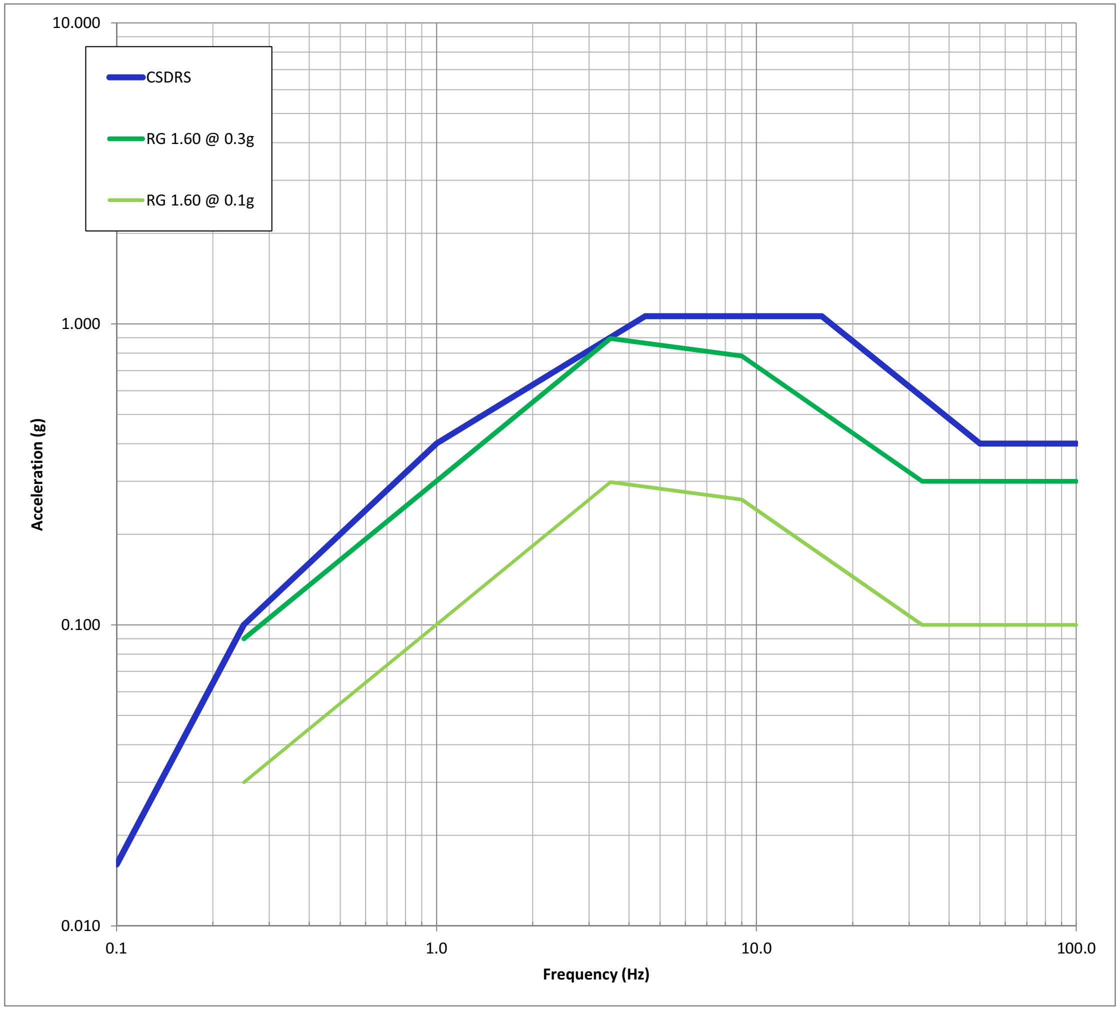
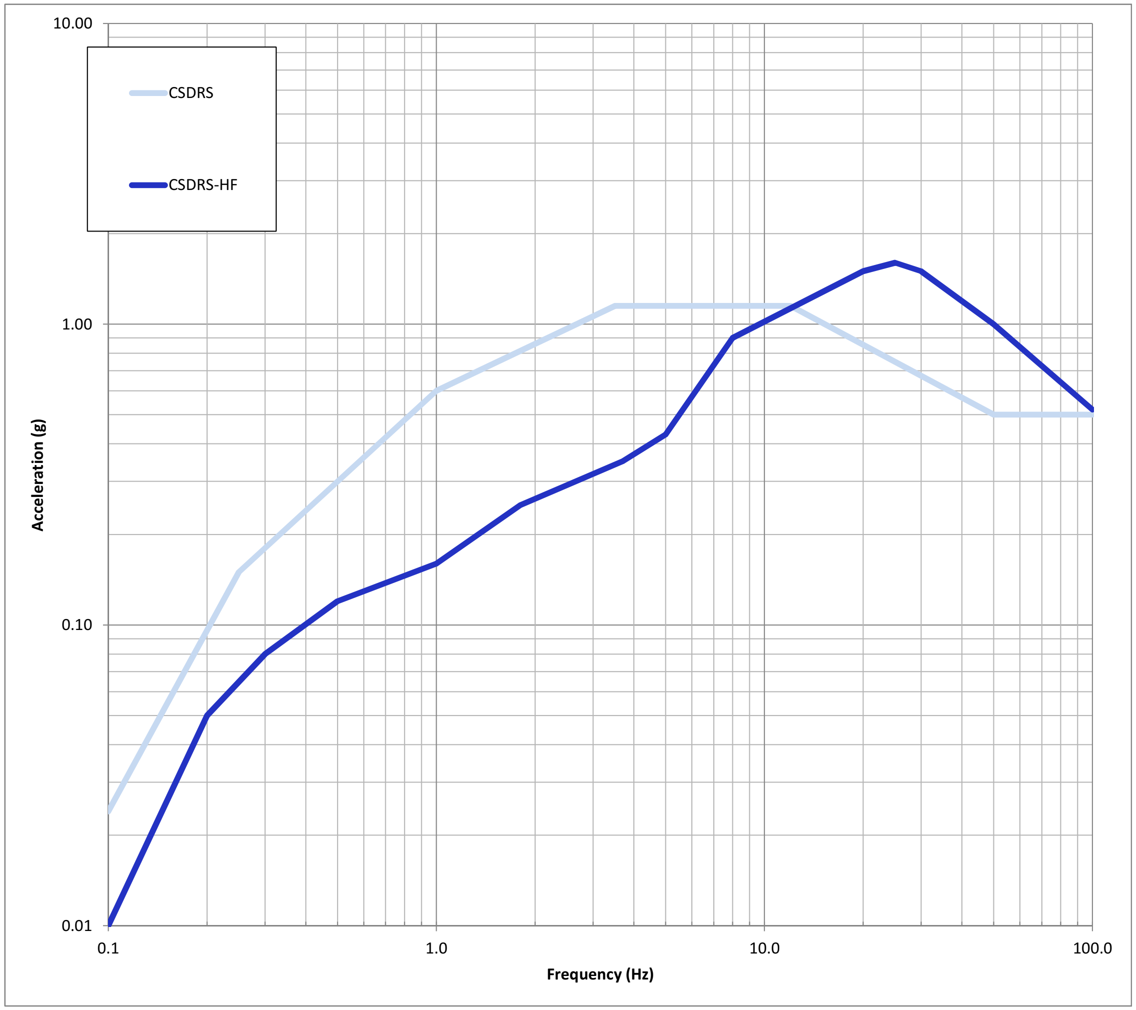
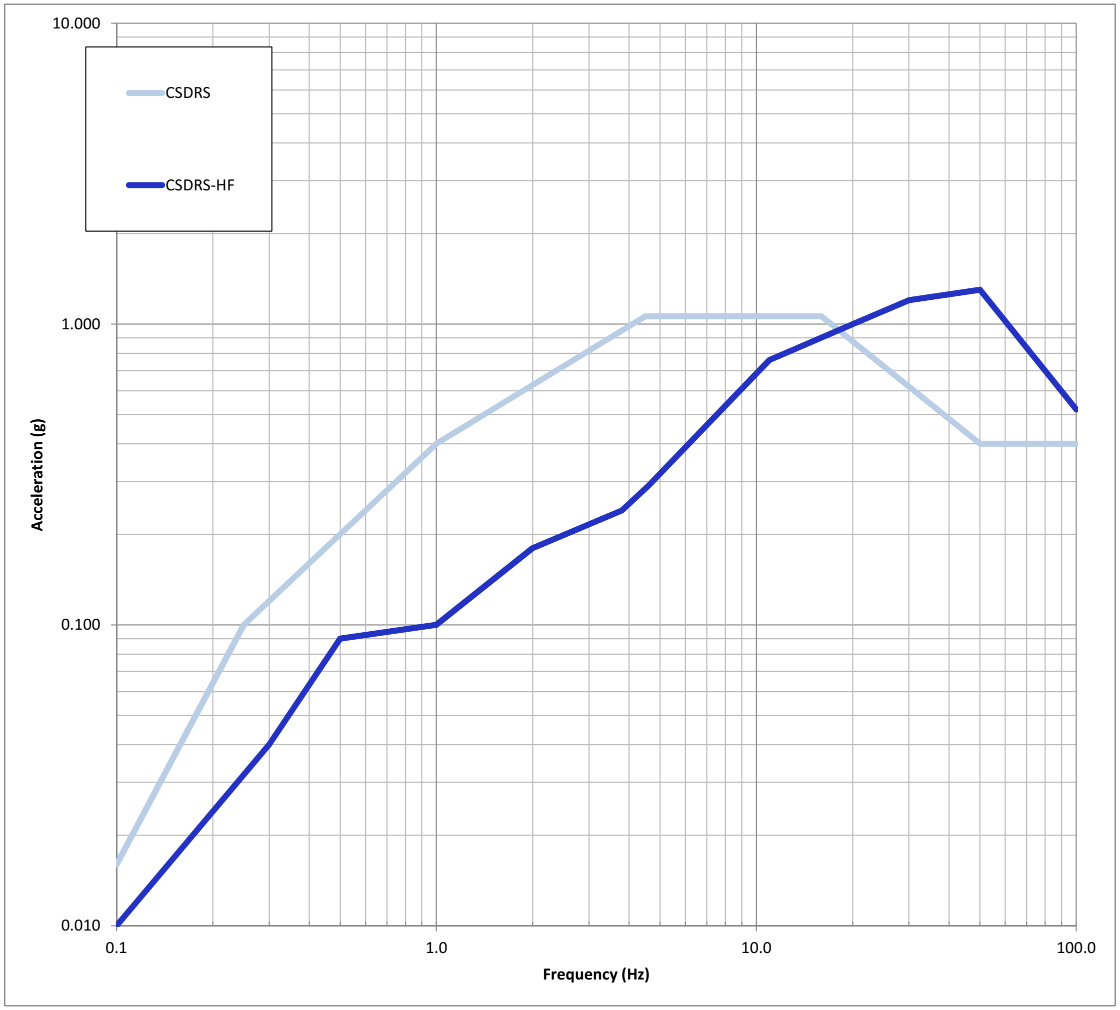


Figure 3.7.1-3: NuScale Horizontal CSDRS-HF at 5 Percent Damping



Note: CSDRS-HF is evaluated for the RXB and the CRB only

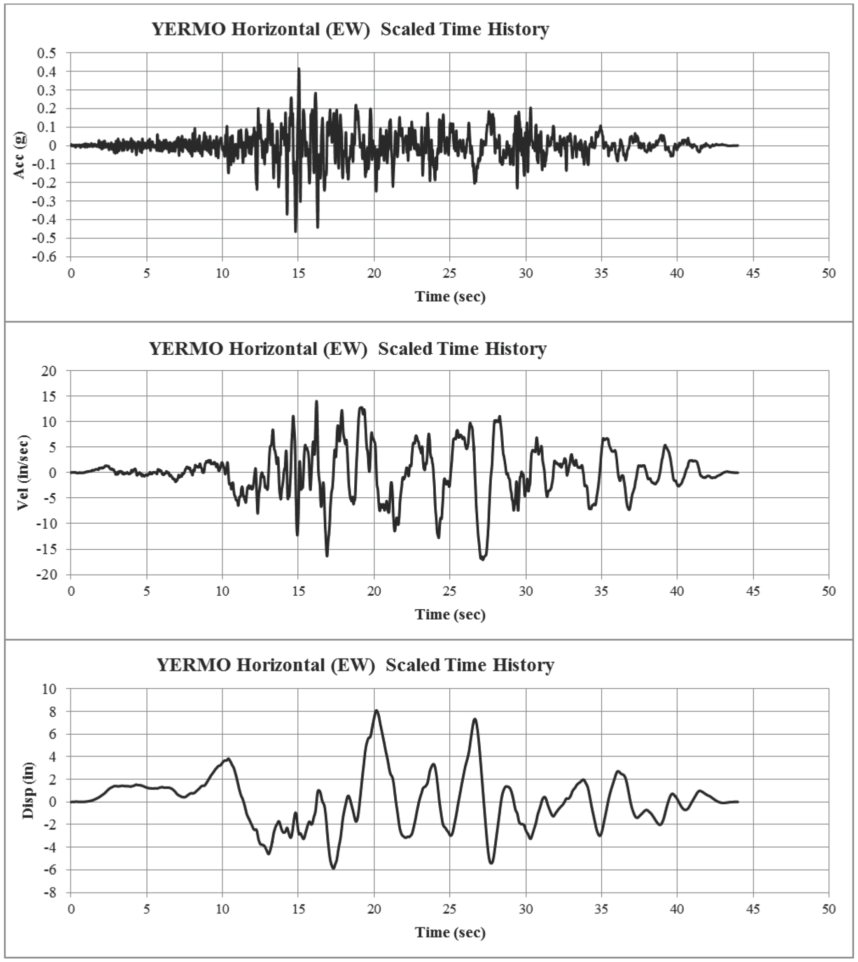
Figure 3.7.1-4: NuScale Vertical CSDRS-HF at 5 Percent Damping



Note: CSDRS-HF is evaluated for the RXB and the CRB only

Figure 3.7.1-5a: Original Time Histories for Yermo East-West

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

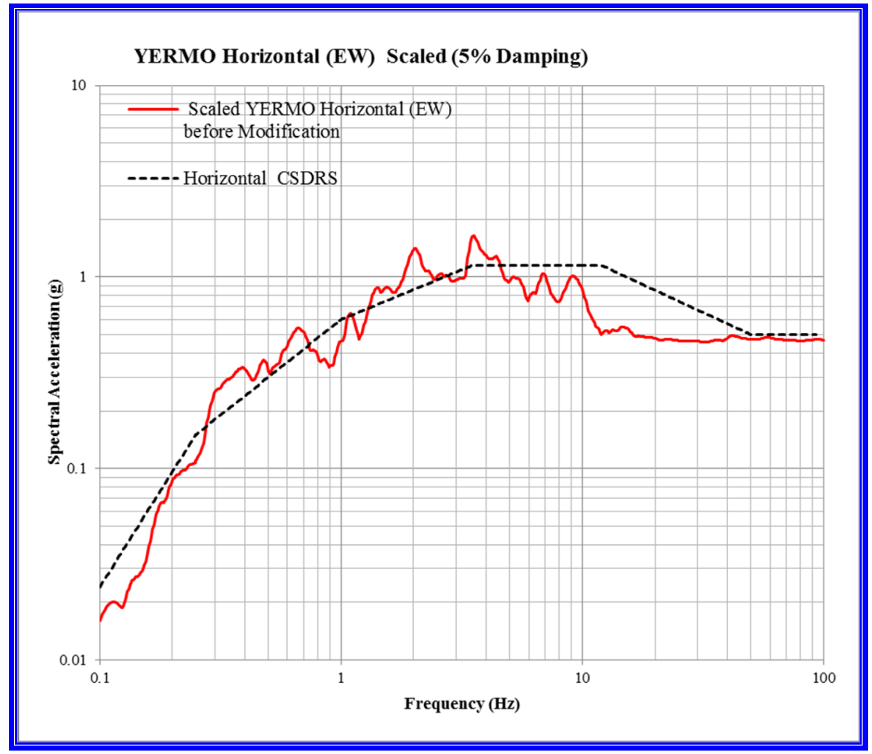
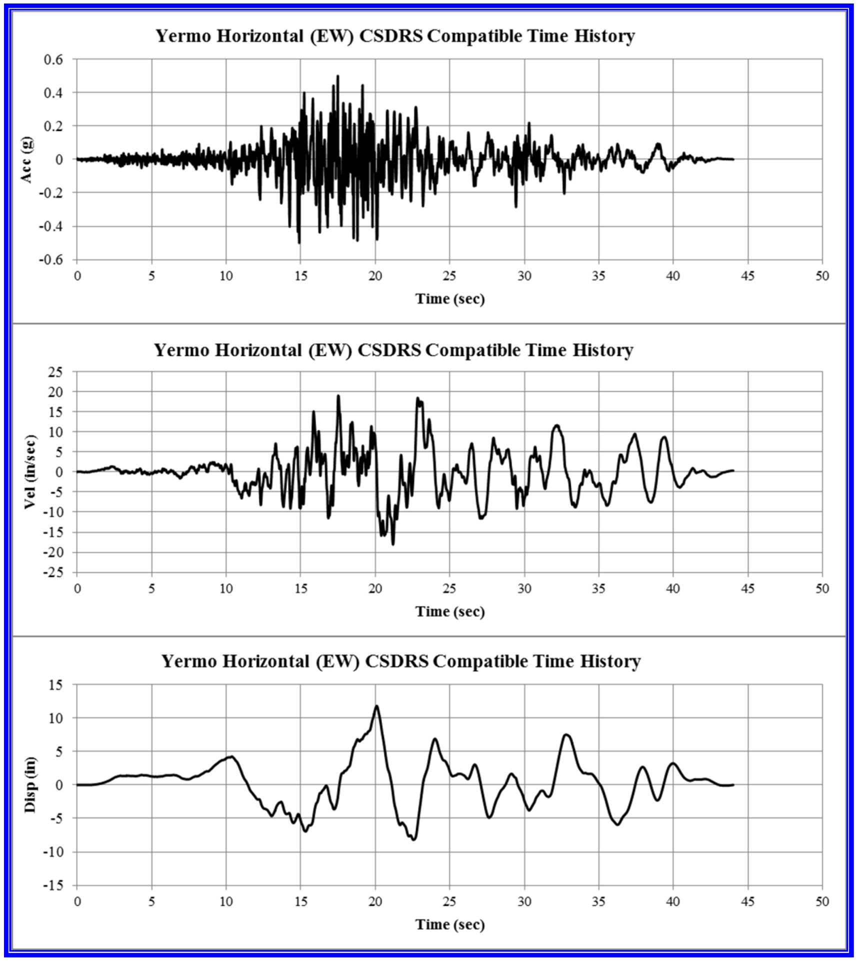
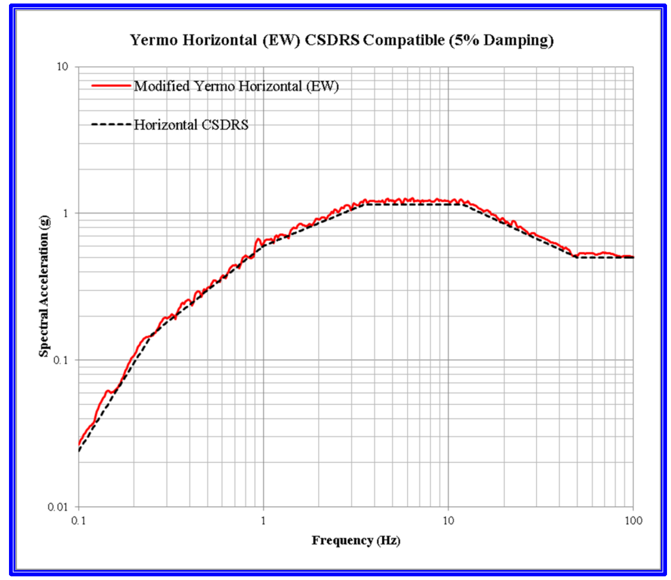


Figure 3.7.1-5b: CSDRS Compatible Time Histories for Yermo East-West

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

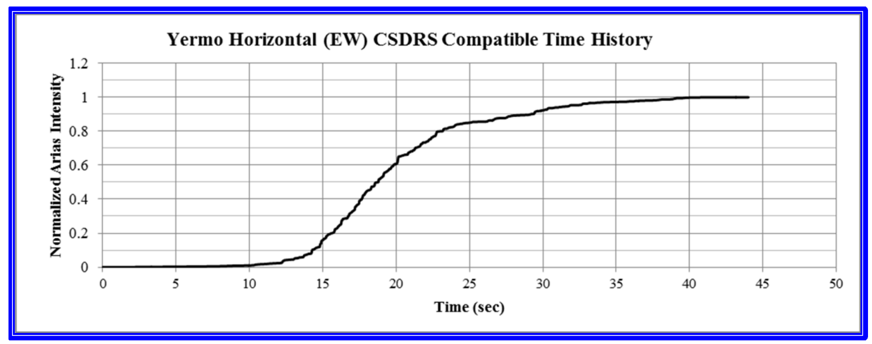
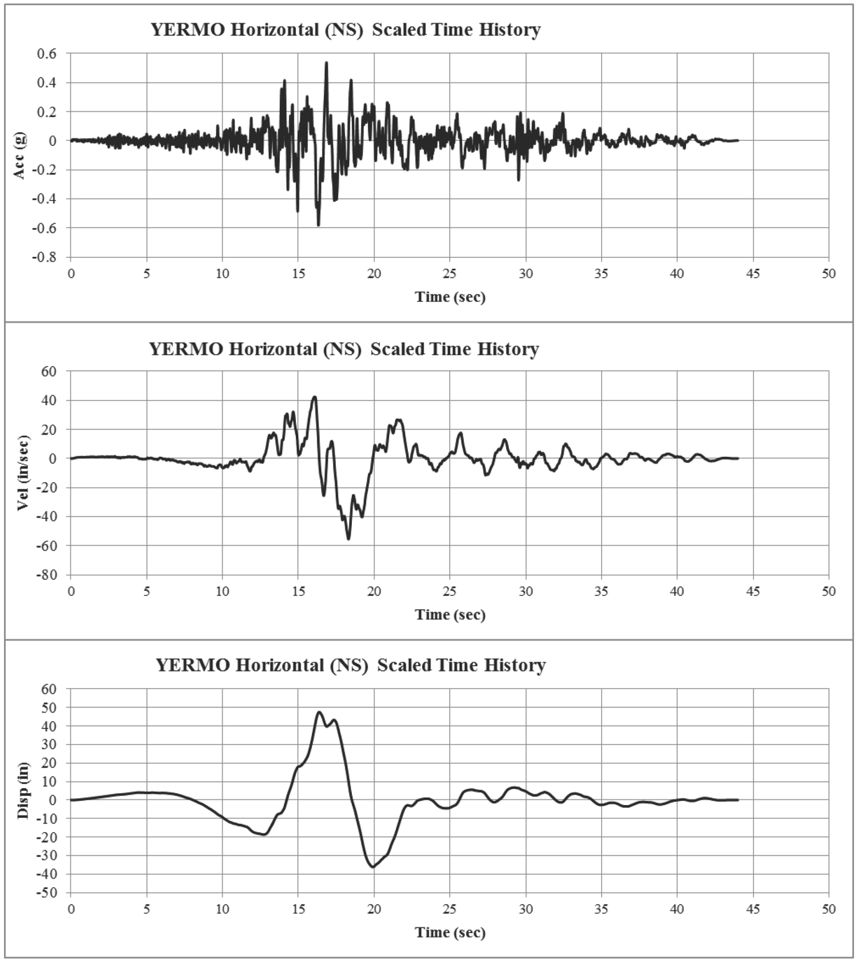


Figure 3.7.1-5c: Original Time Histories for Yermo North-South

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

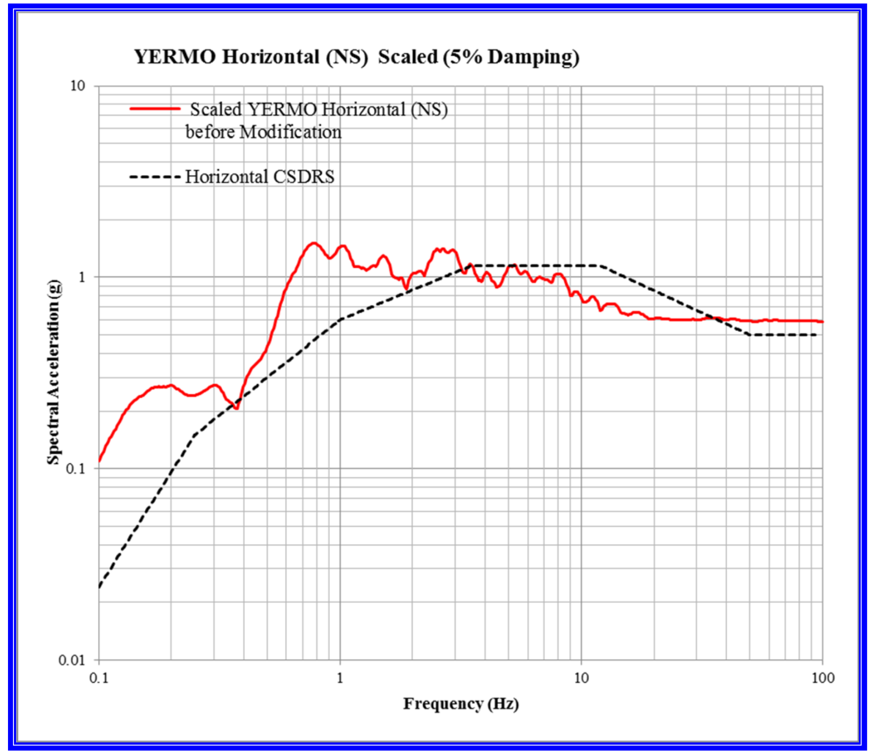
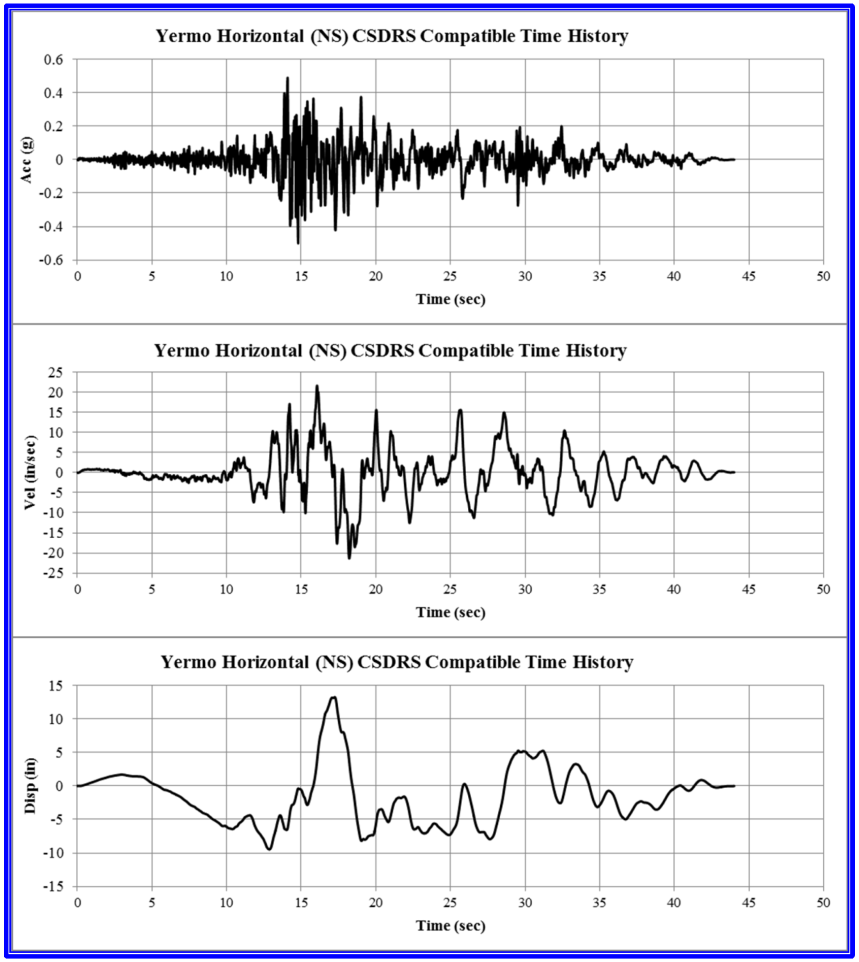
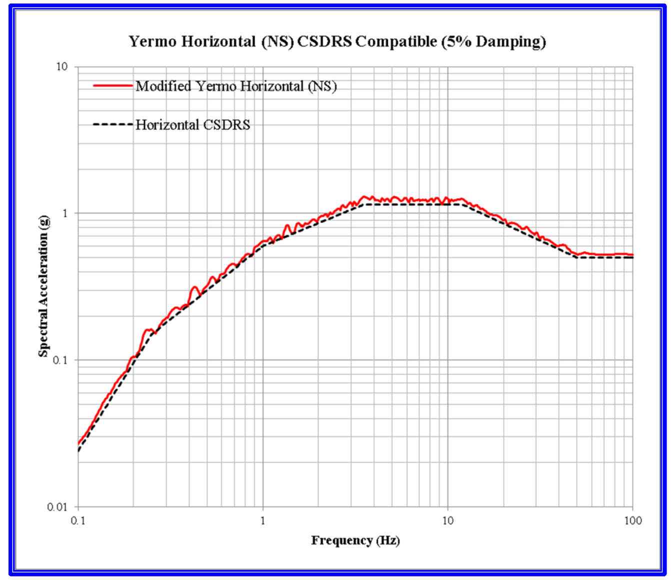


Figure 3.7.1-5d: CSDRS Compatible Time Histories for Yermo North-South

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

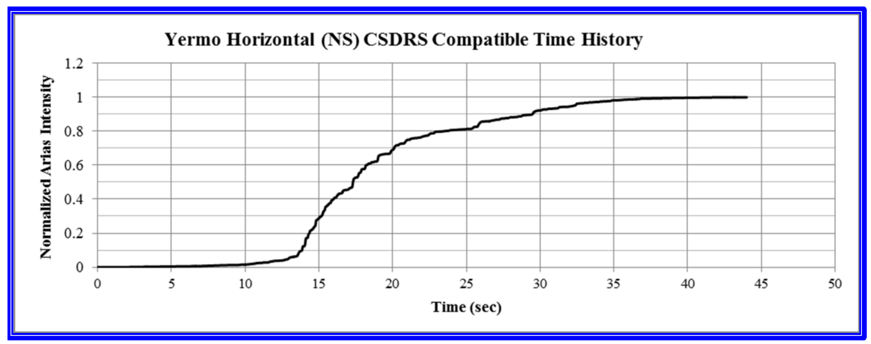
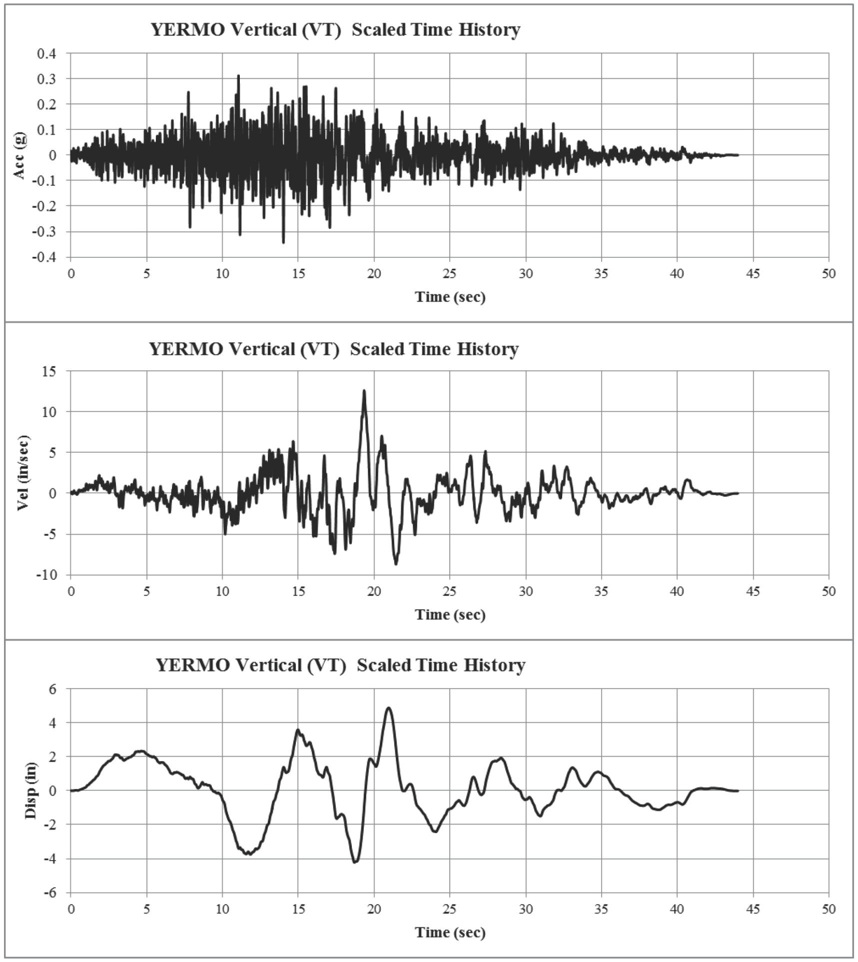


Figure 3.7.1-5e: Original Time Histories for Yermo Vertical

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

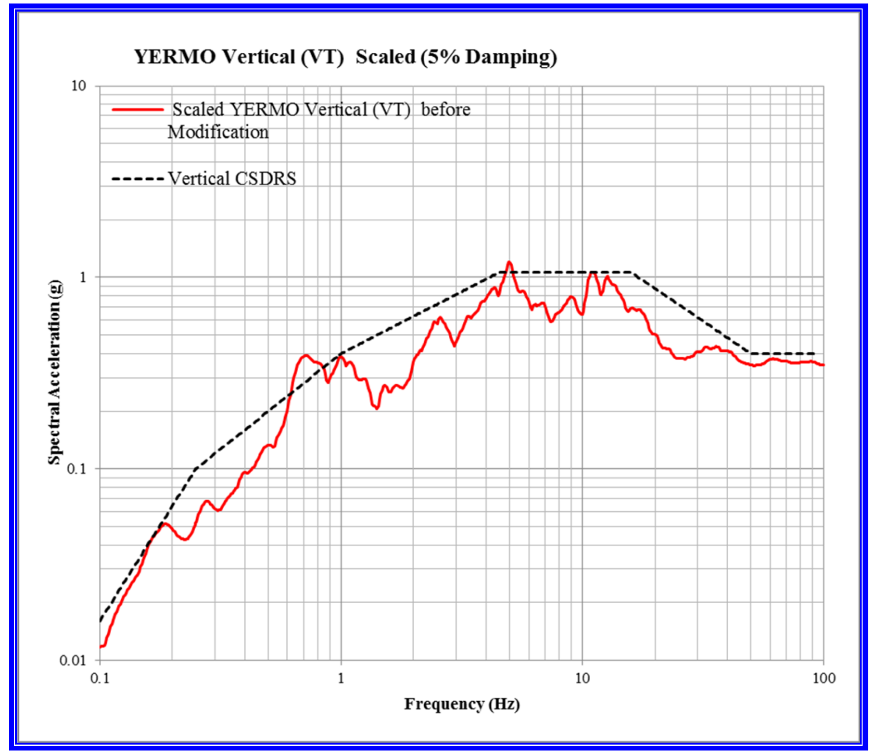
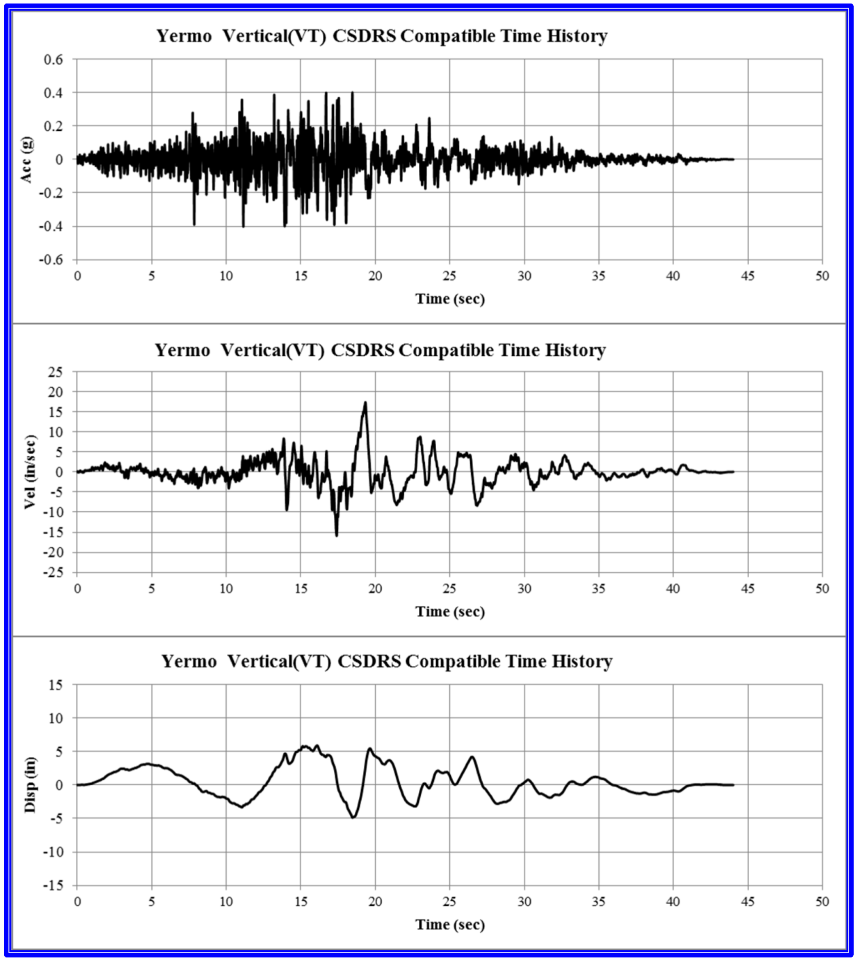
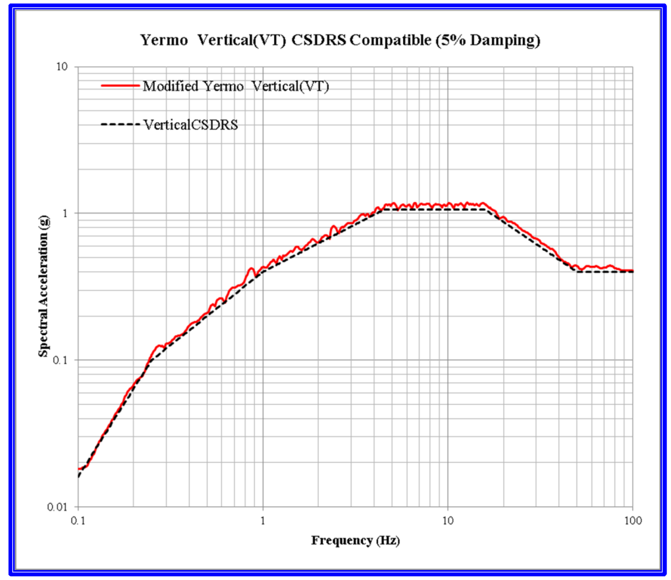


Figure 3.7.1-5f: CSDRS Compatible Time Histories for Yermo Vertical

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

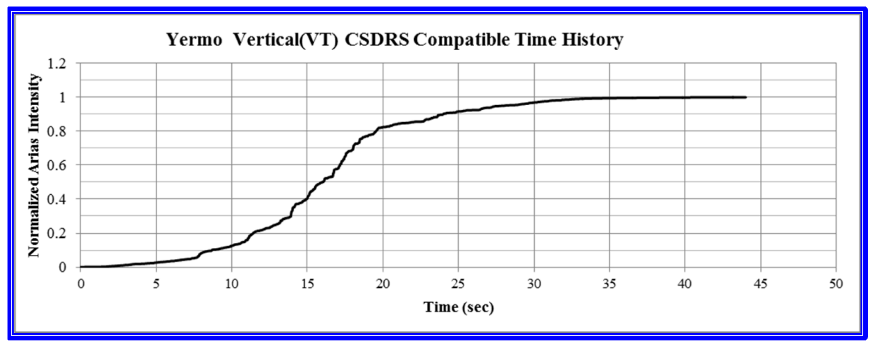
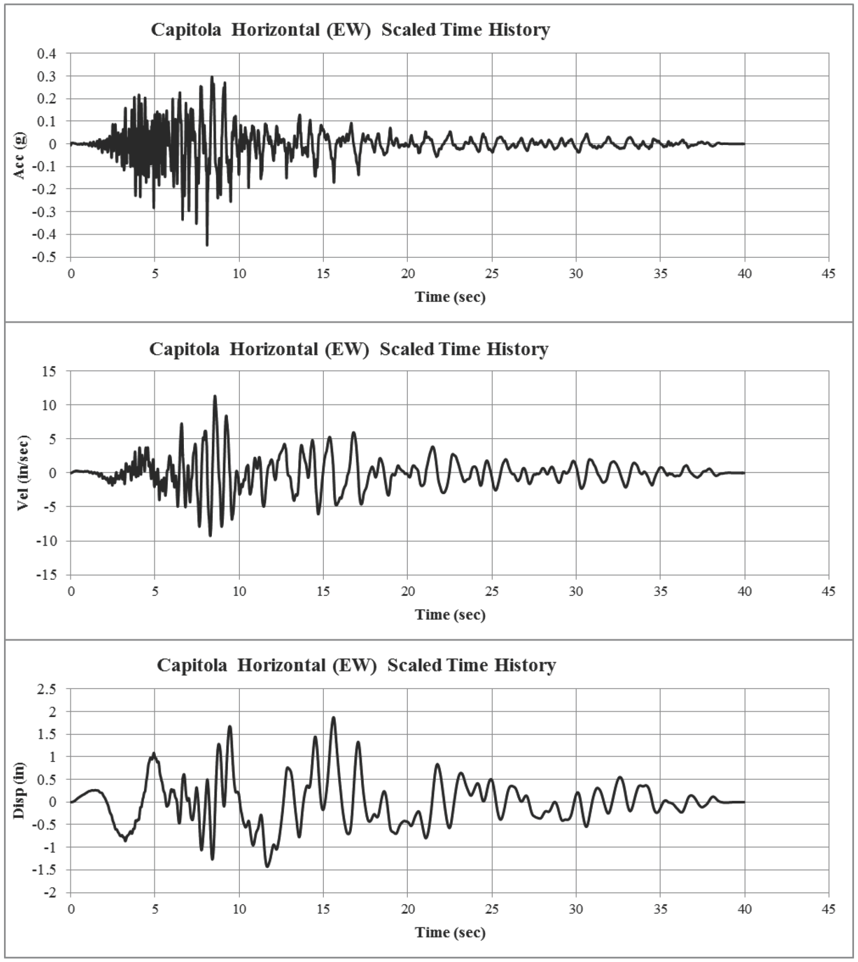


Figure 3.7.1-6a: Original Time Histories for Capitola East-West

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

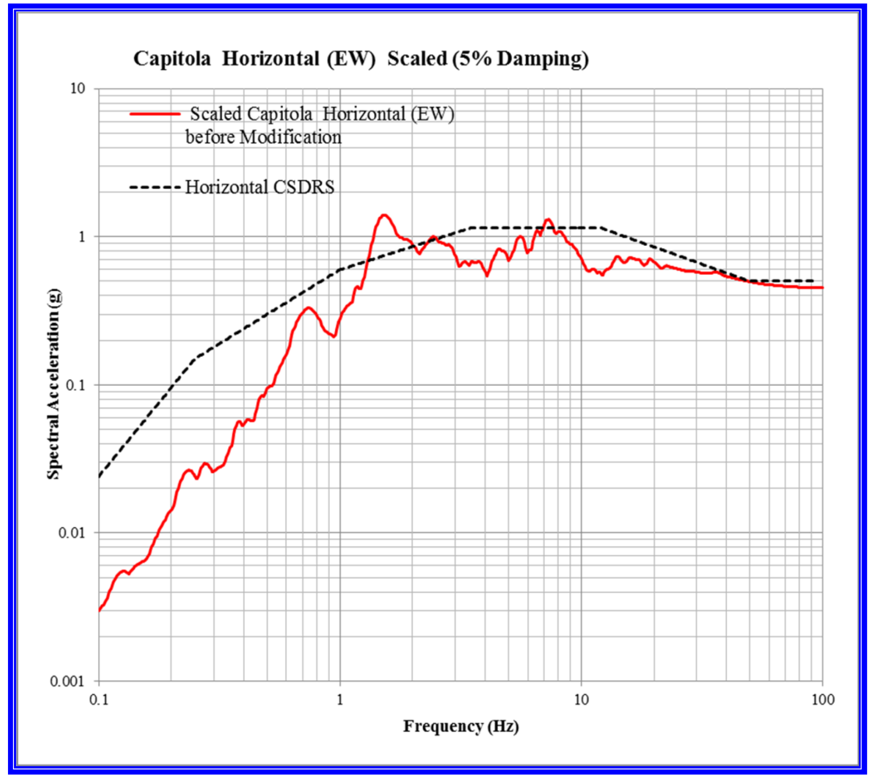
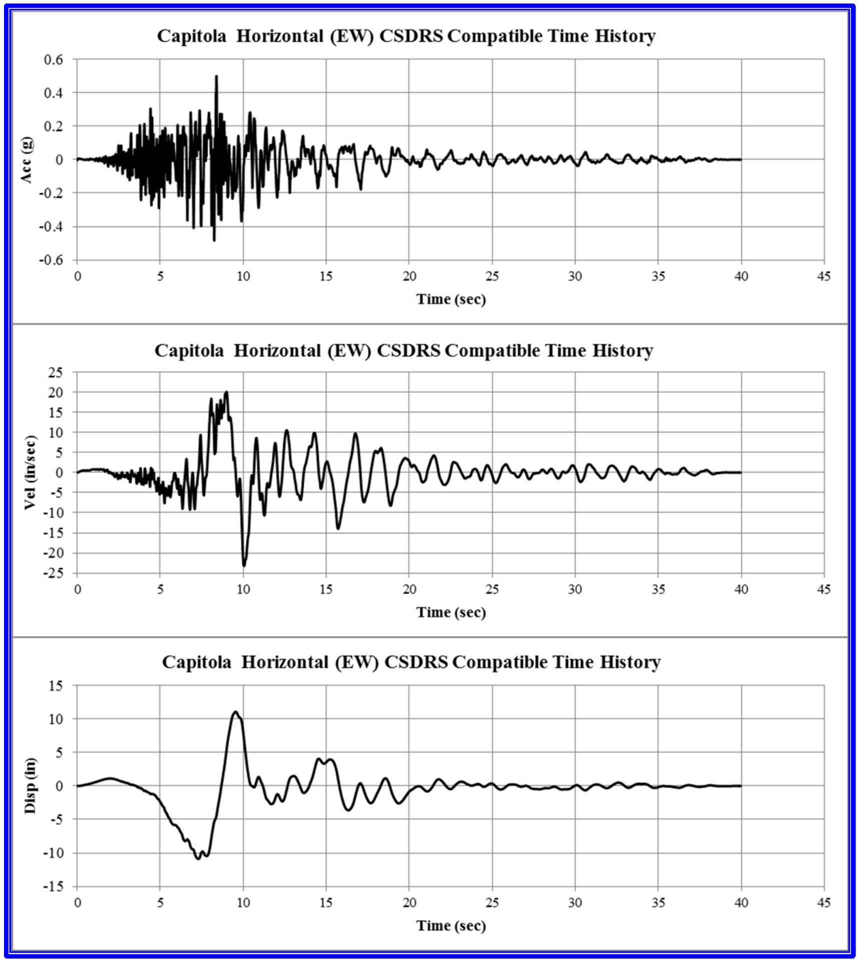
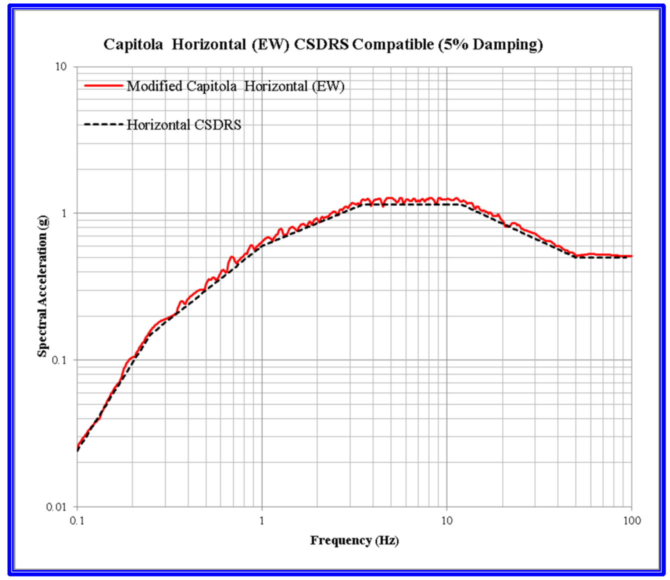


Figure 3.7.1-6b: CSDRS Compatible Time Histories for Capitola East-West

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

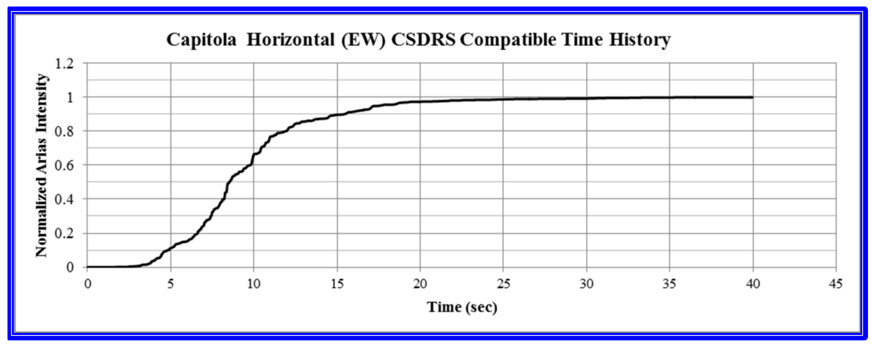
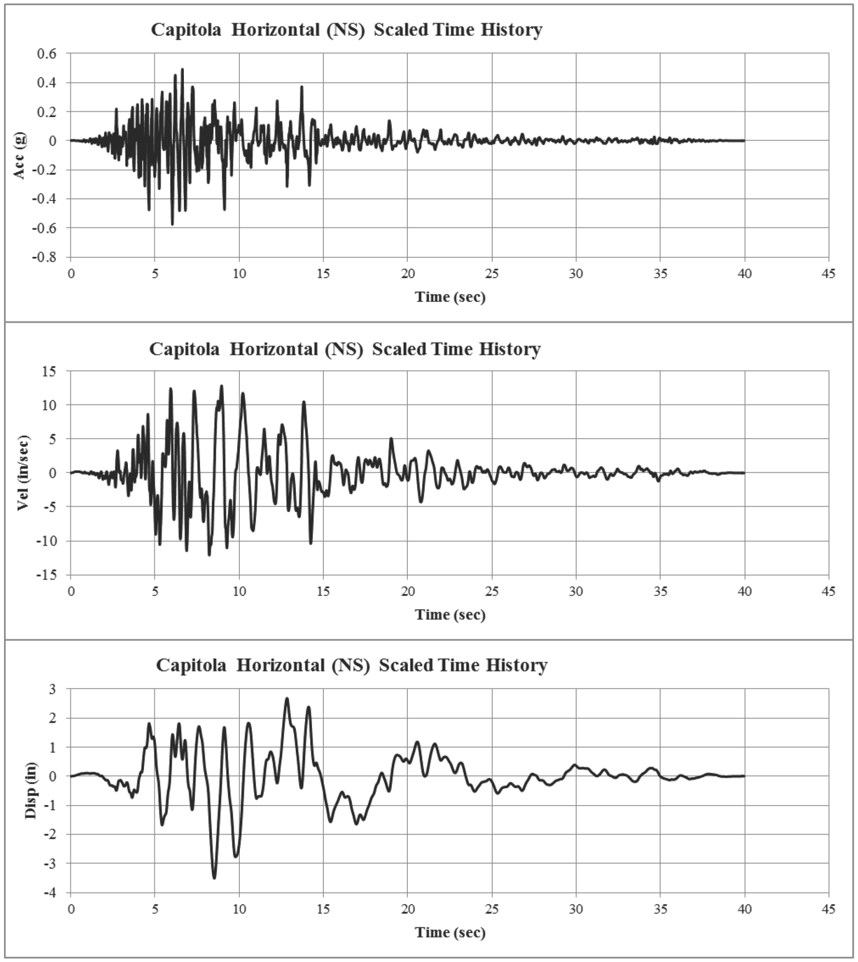


Figure 3.7.1-6c: Original Time Histories for Capitola North-South

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

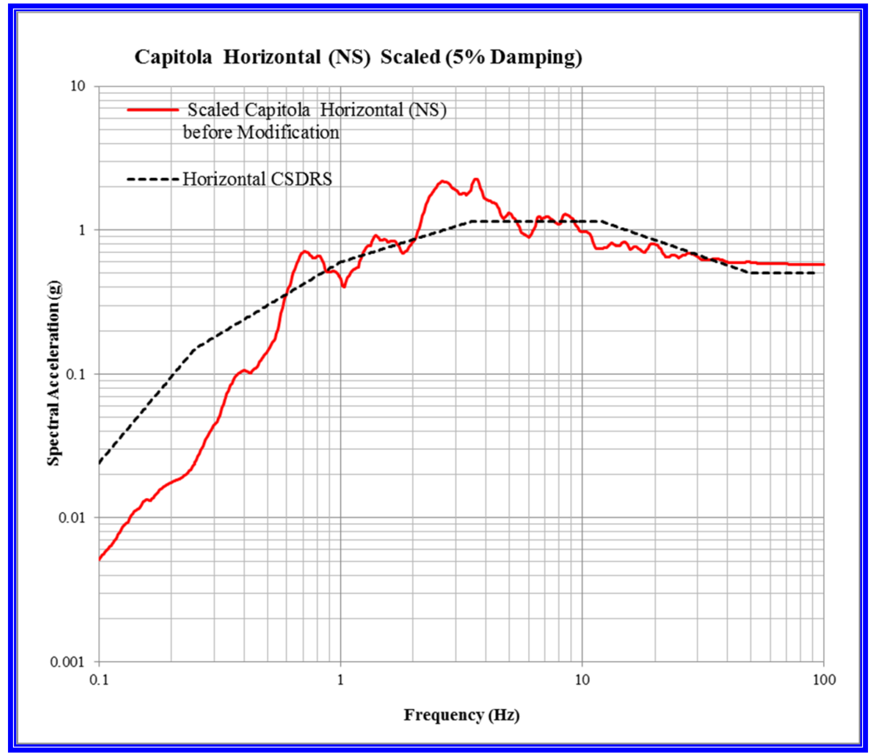
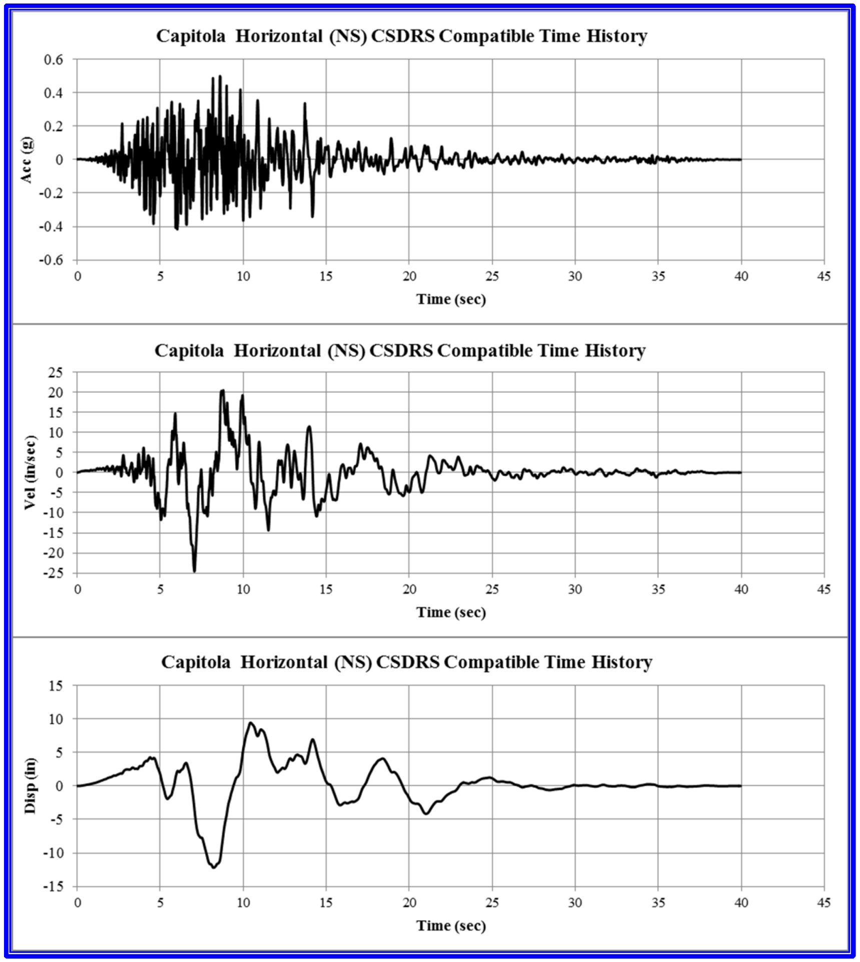
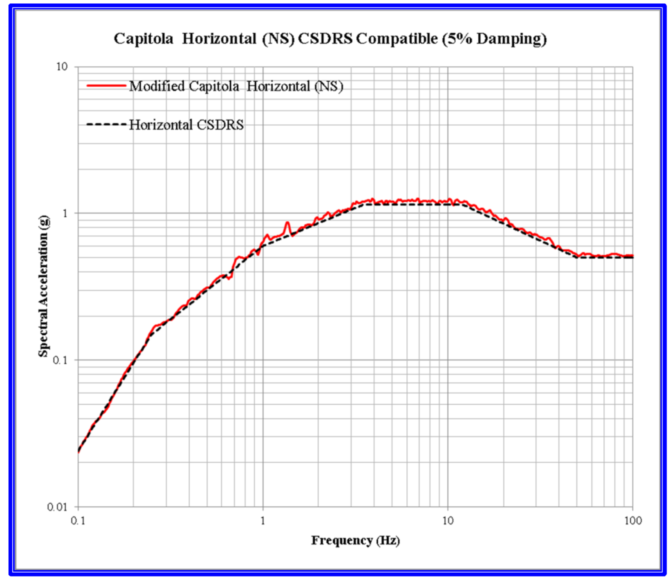


Figure 3.7.1-6d: CSDRS Compatible Time Histories for Capitola North-South

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

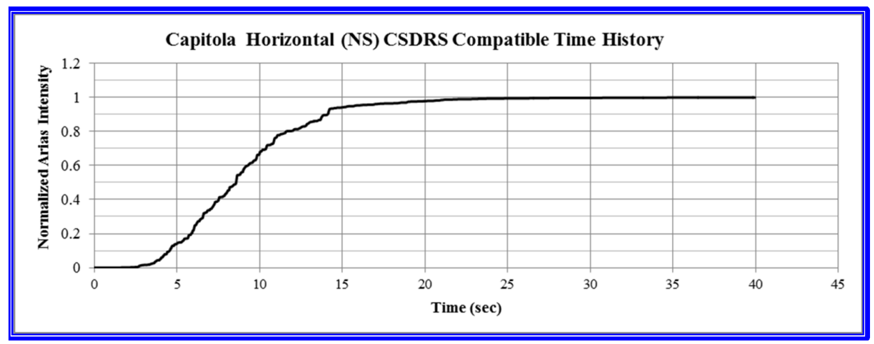
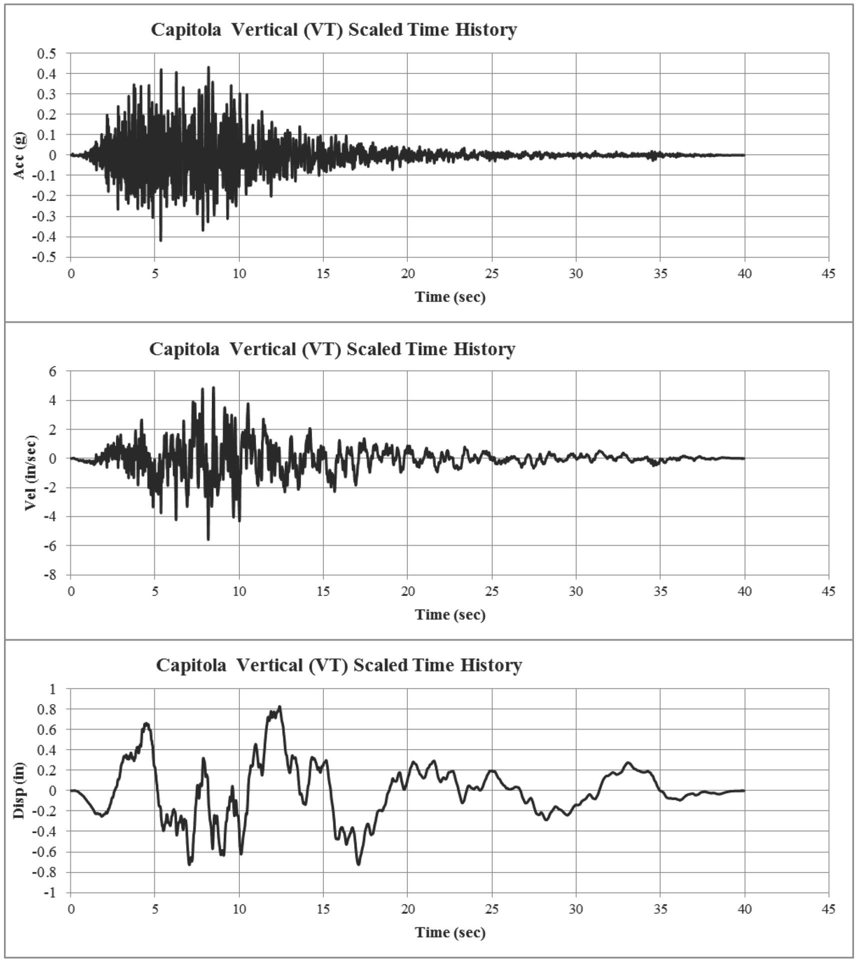


Figure 3.7.1-6e: Original Time Histories for Capitola Vertical

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

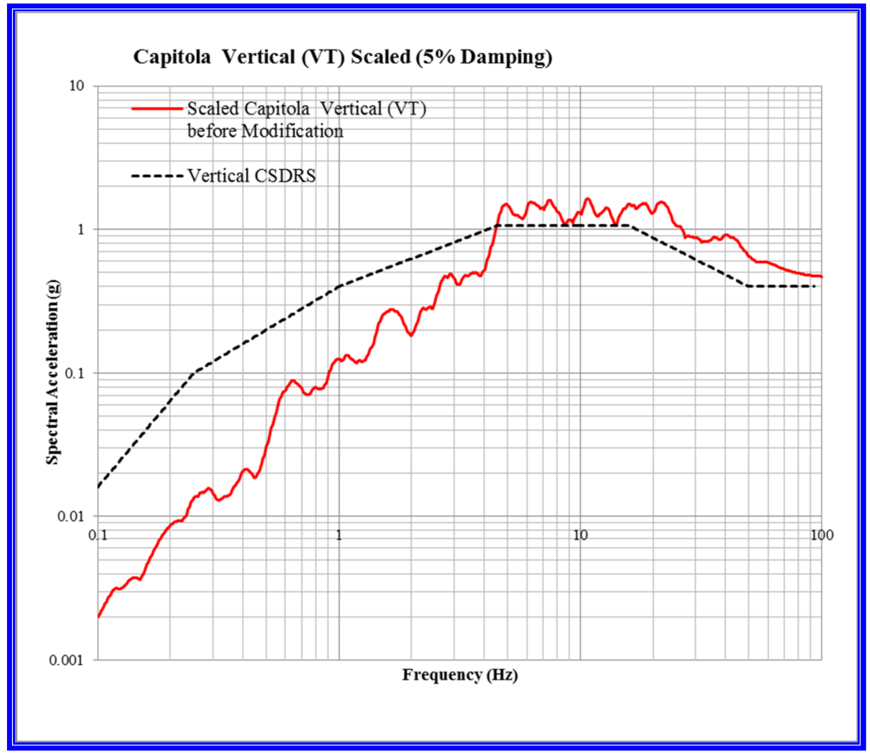
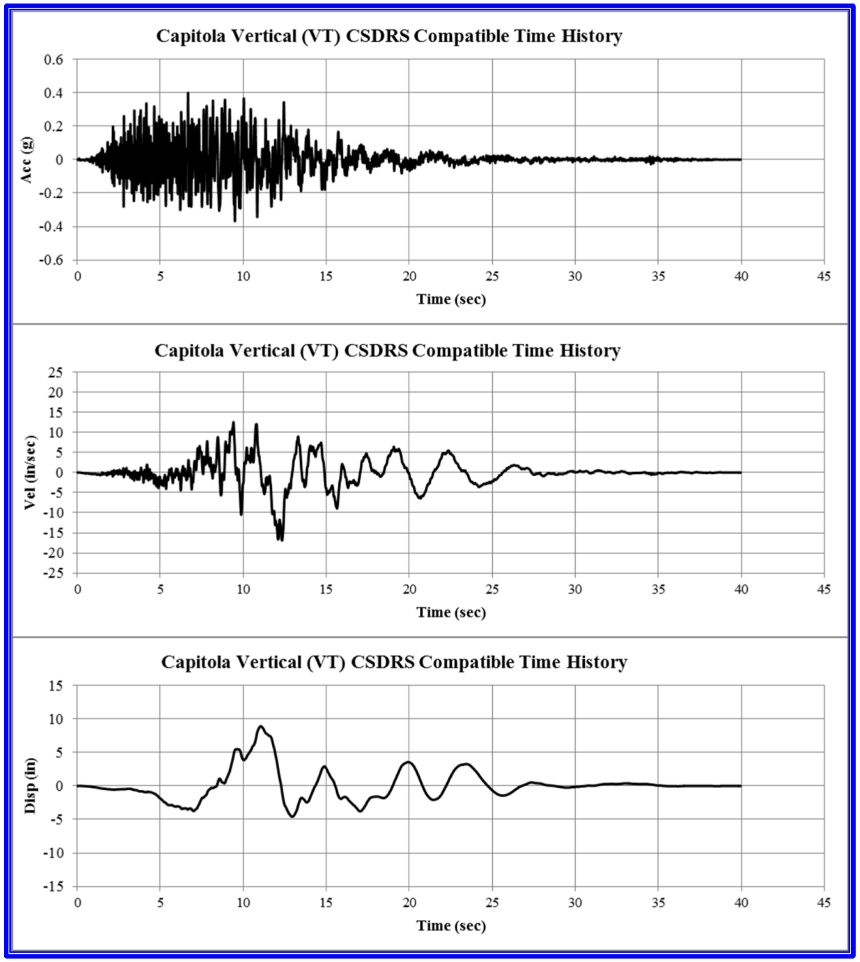
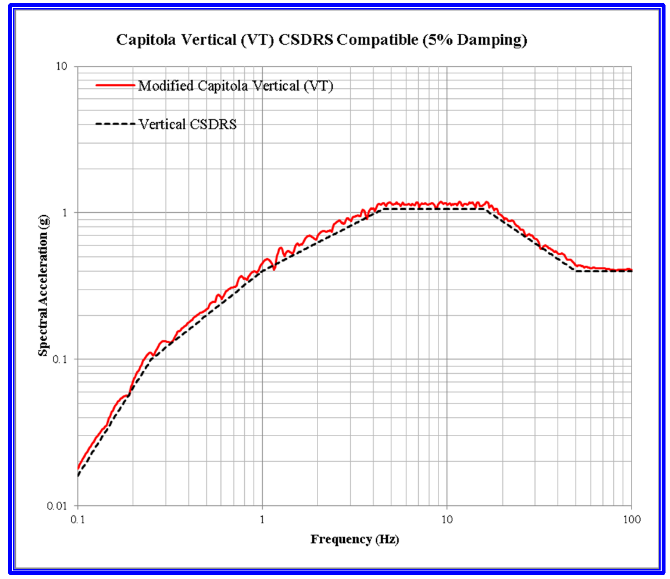


Figure 3.7.1-6f: CSDRS Compatible Time Histories for Capitola Vertical

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

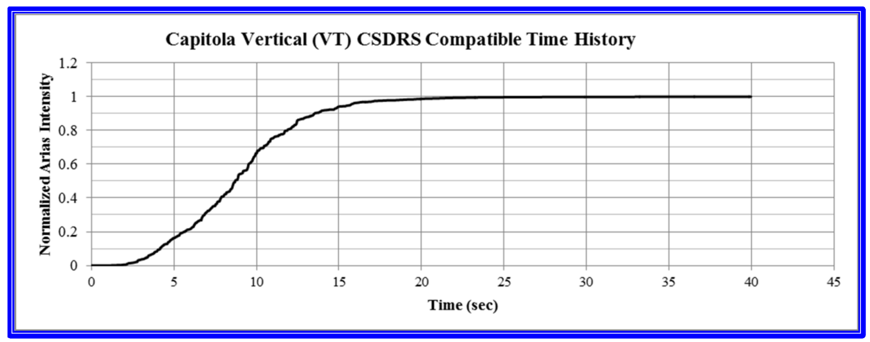
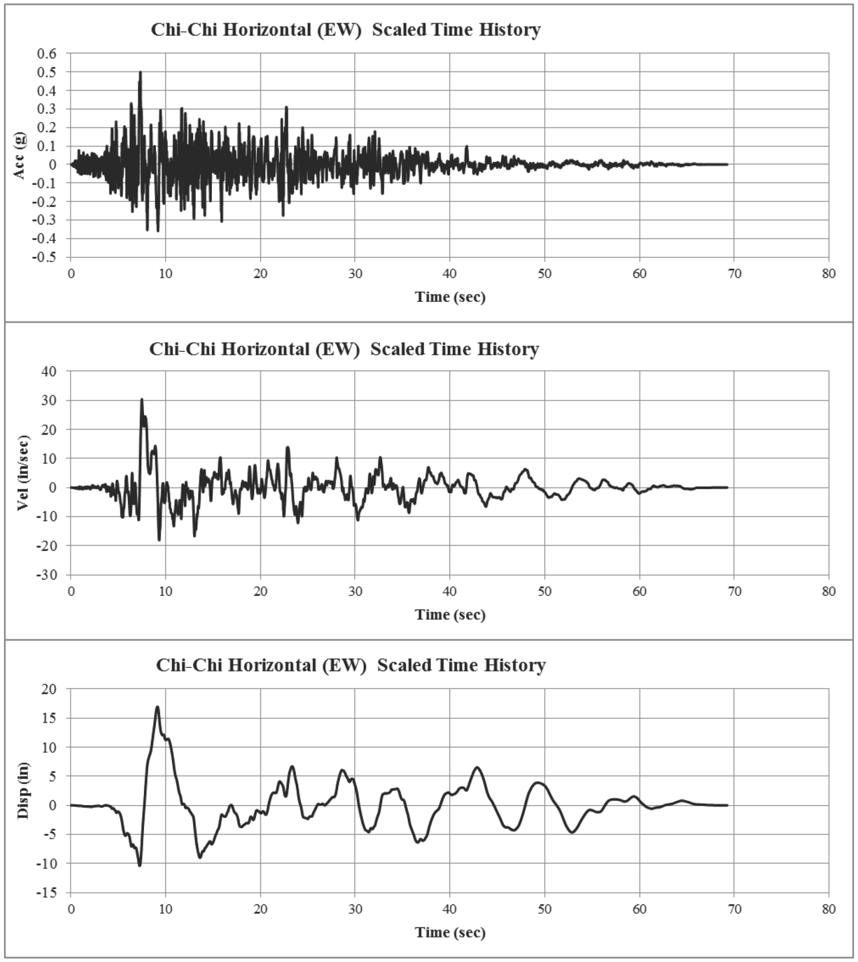


Figure 3.7.1-7a: Original Time Histories for Chi-Chi East-West

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

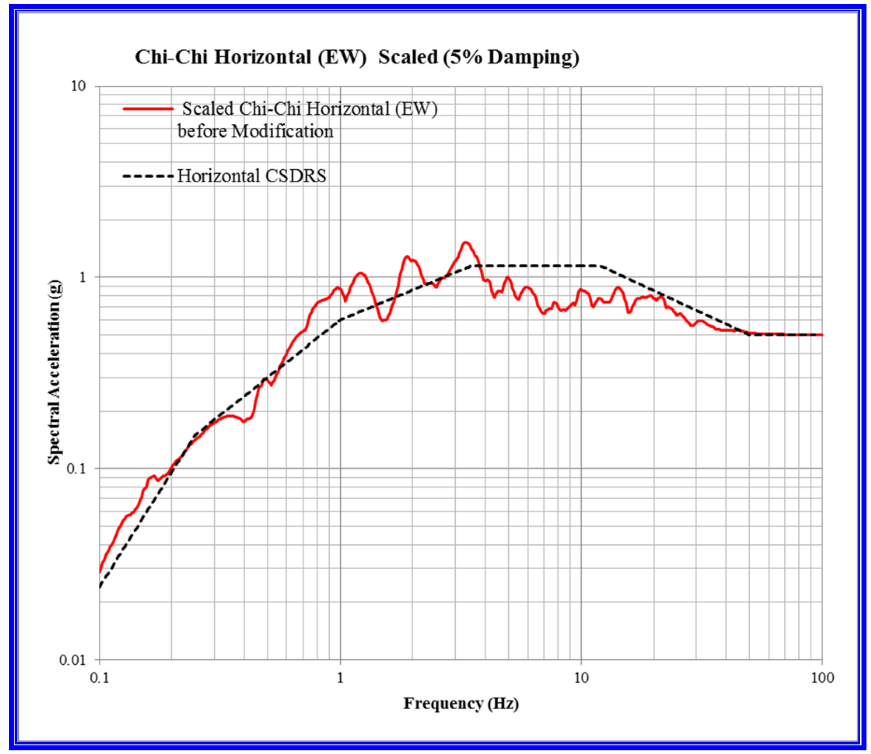
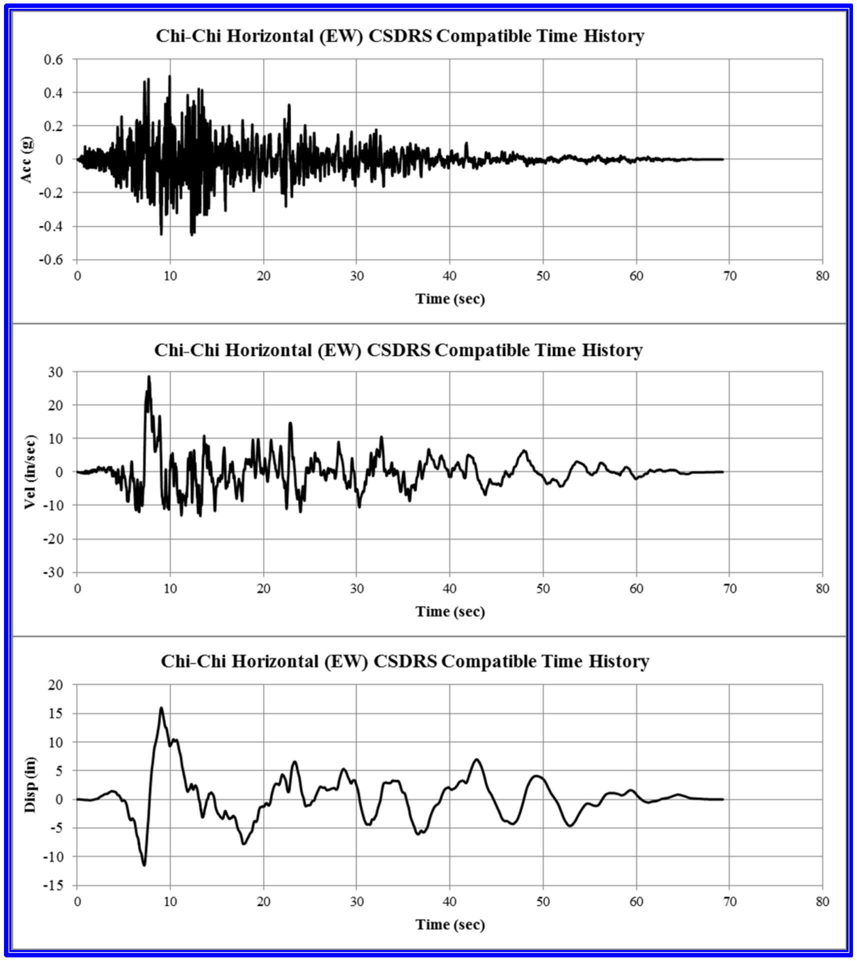
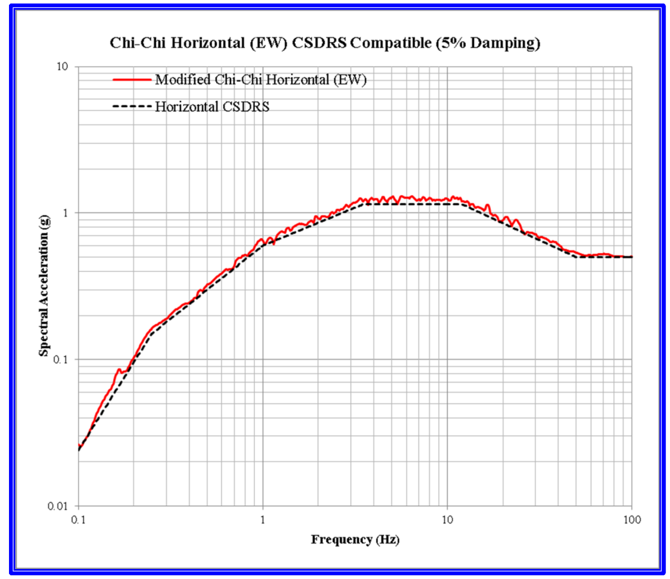


Figure 3.7.1-7b: CSDRS Compatible Time Histories for Chi-Chi East-West

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

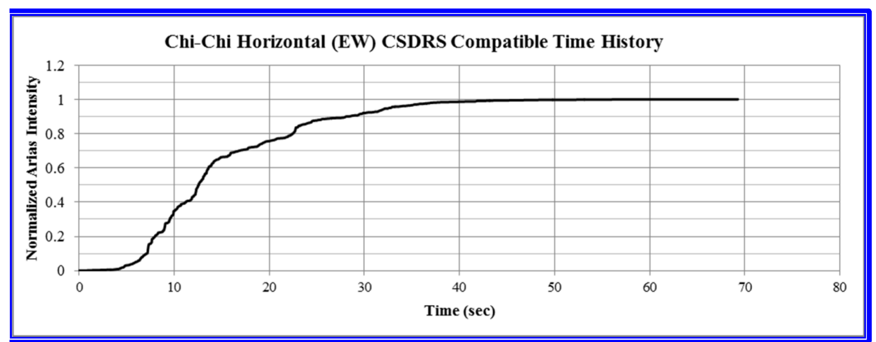
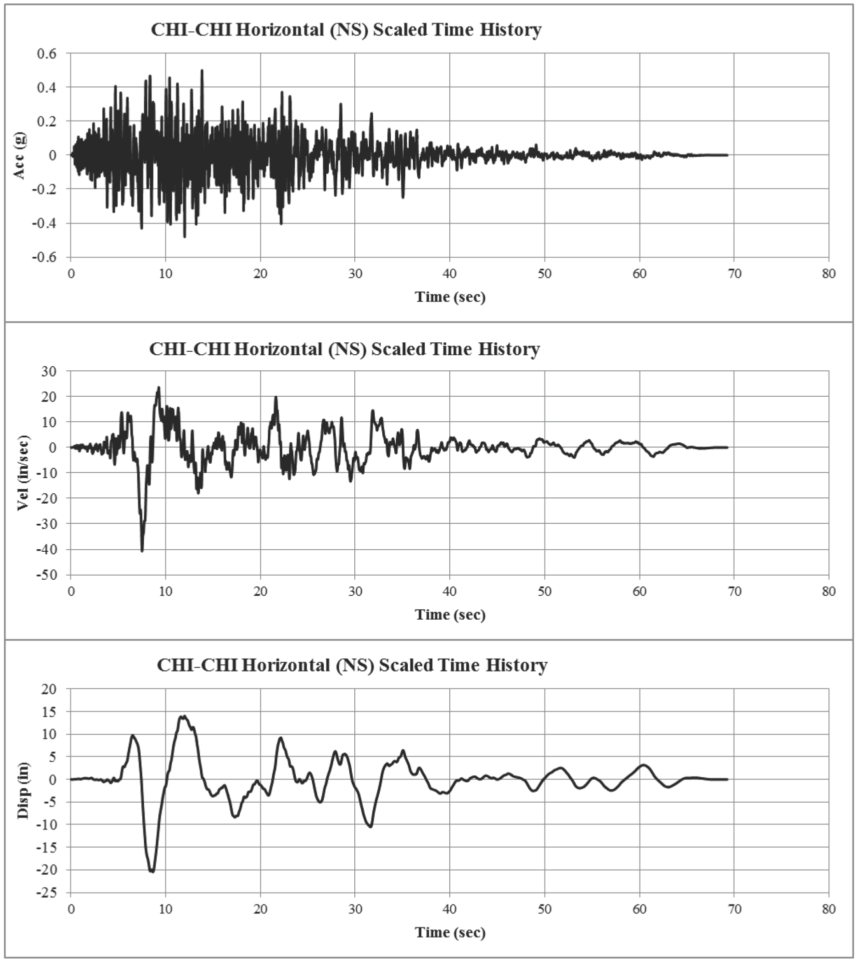


Figure 3.7.1-7c: Original Time Histories for Chi-Chi North-South

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

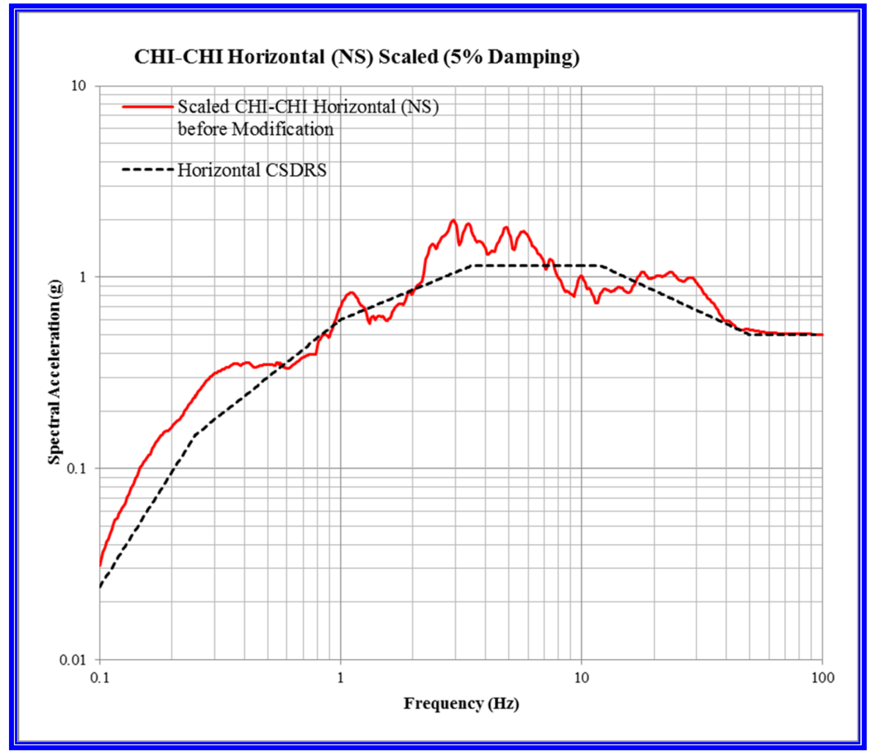
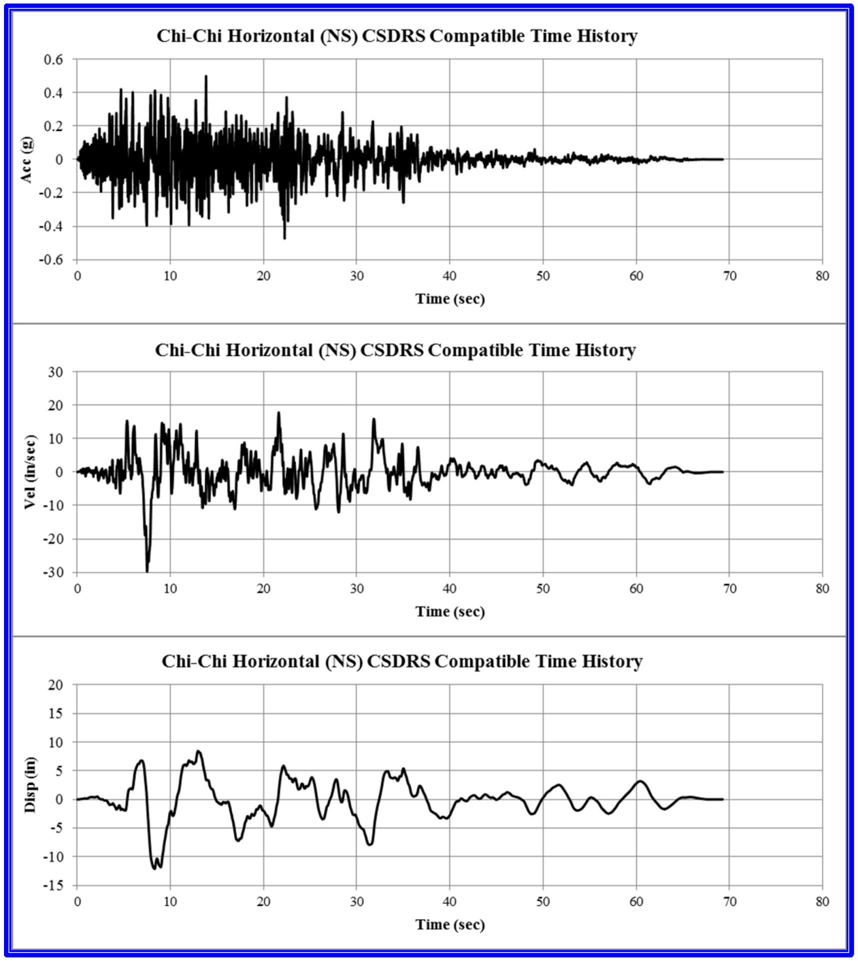
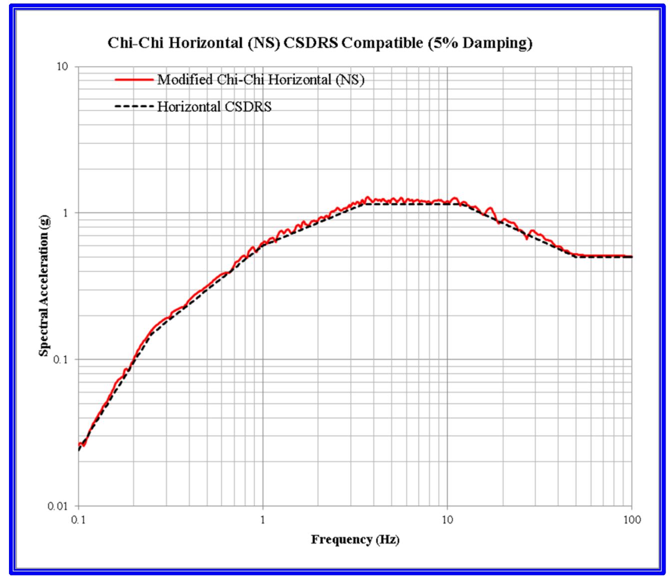


Figure 3.7.1-7d: CSDRS Compatible Time Histories for Chi-Chi North-South

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

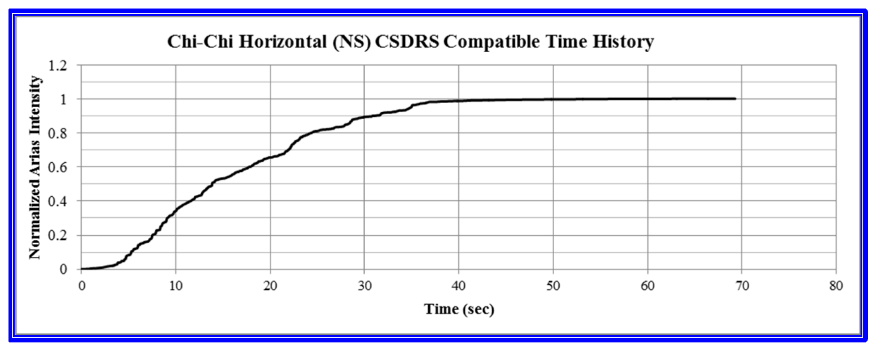
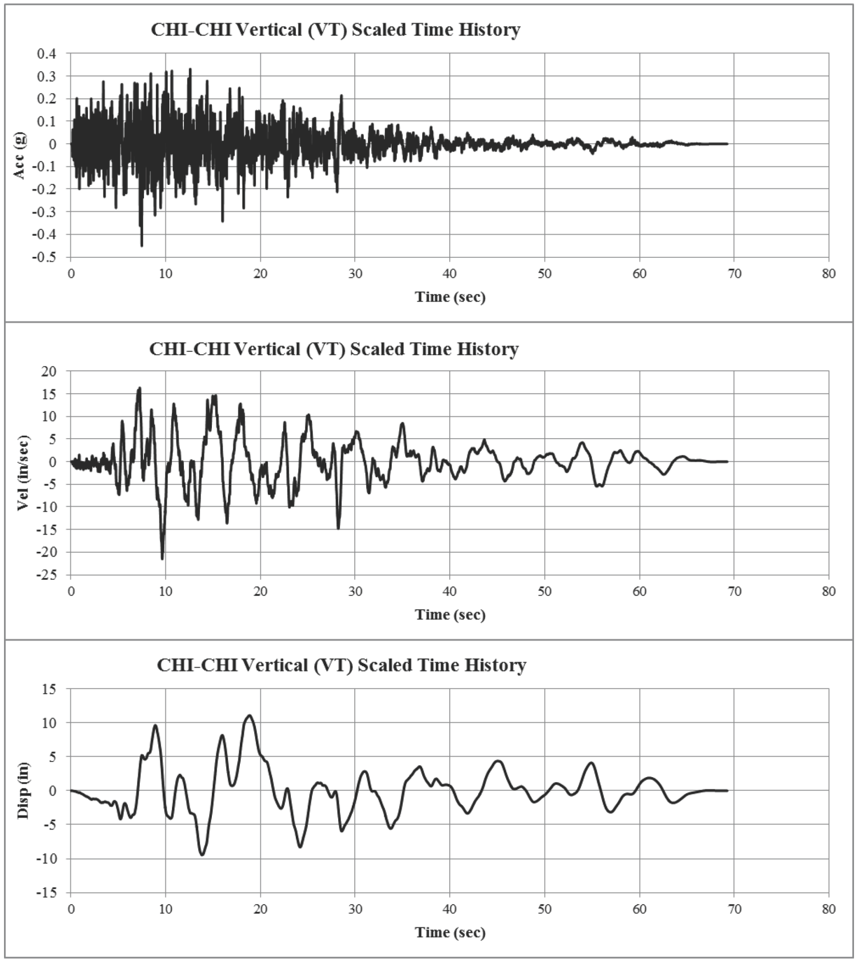


Figure 3.7.1-7e: Original Time Histories for Chi-Chi Vertical

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

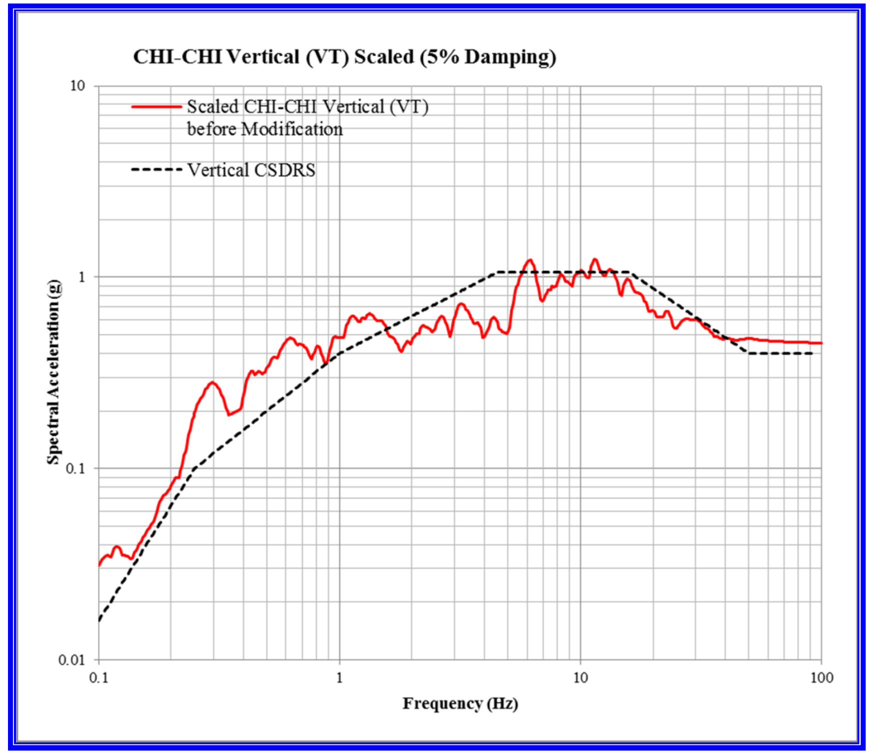
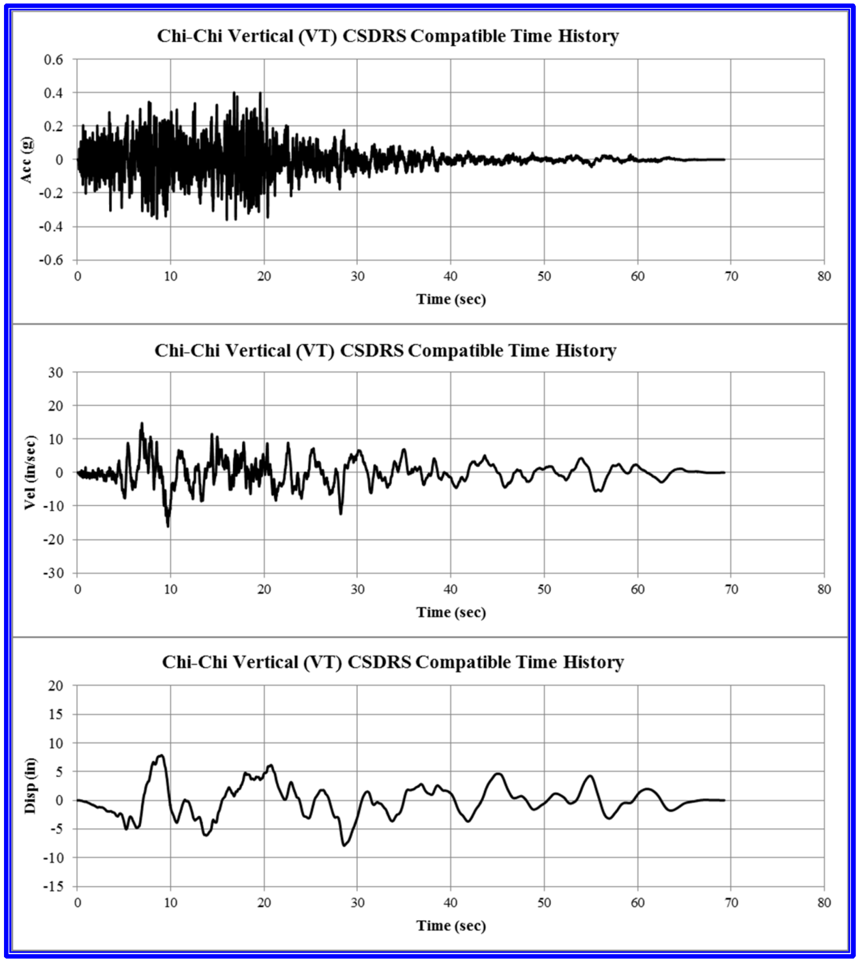
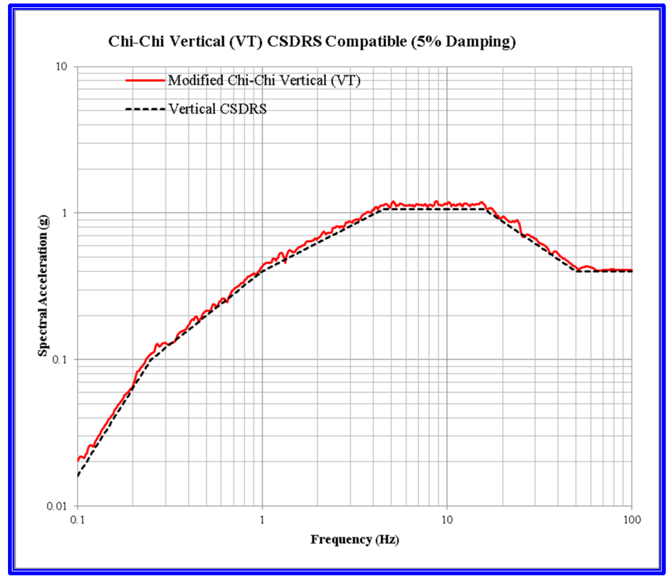


Figure 3.7.1-7f: CSDRS Compatible Time Histories for Chi-Chi Vertical

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

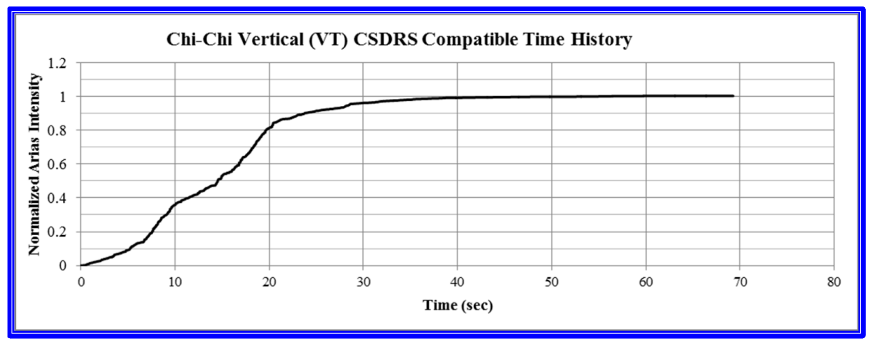
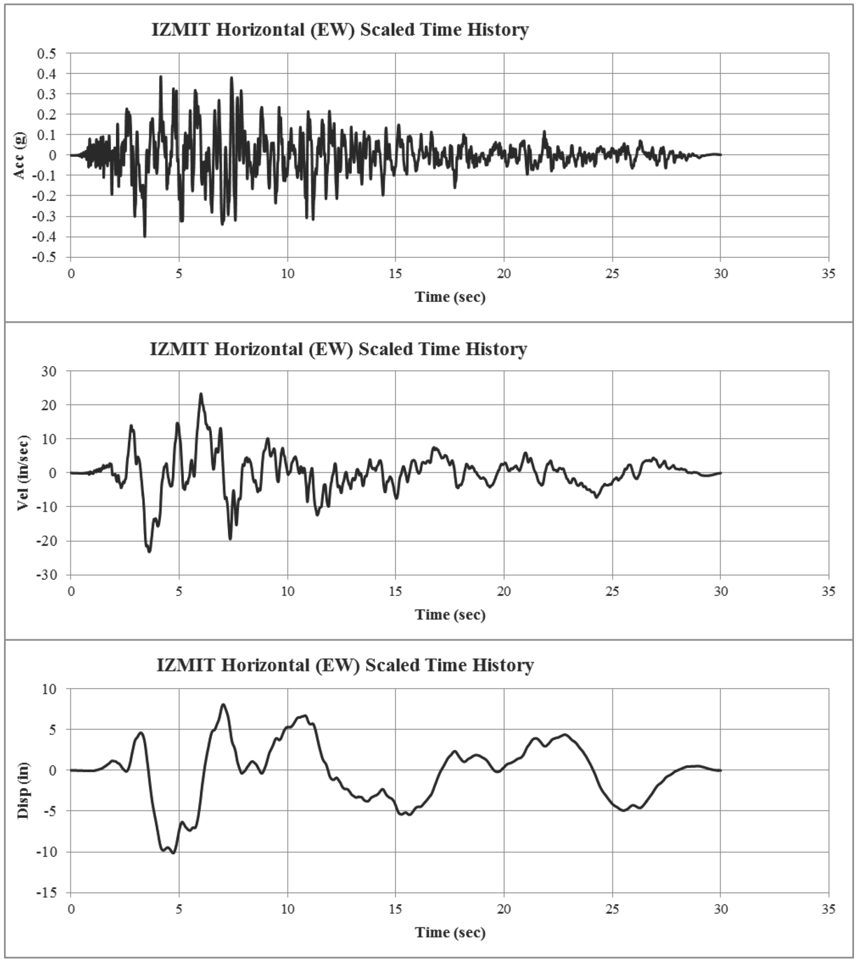


Figure 3.7.1-8a: Original Time Histories for Izmit East-West

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

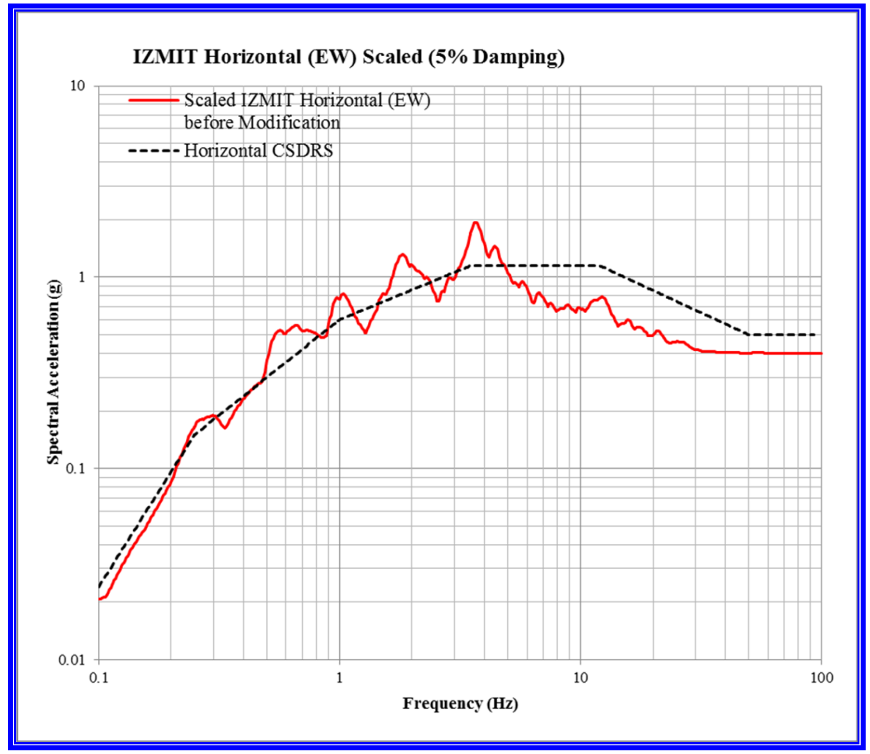
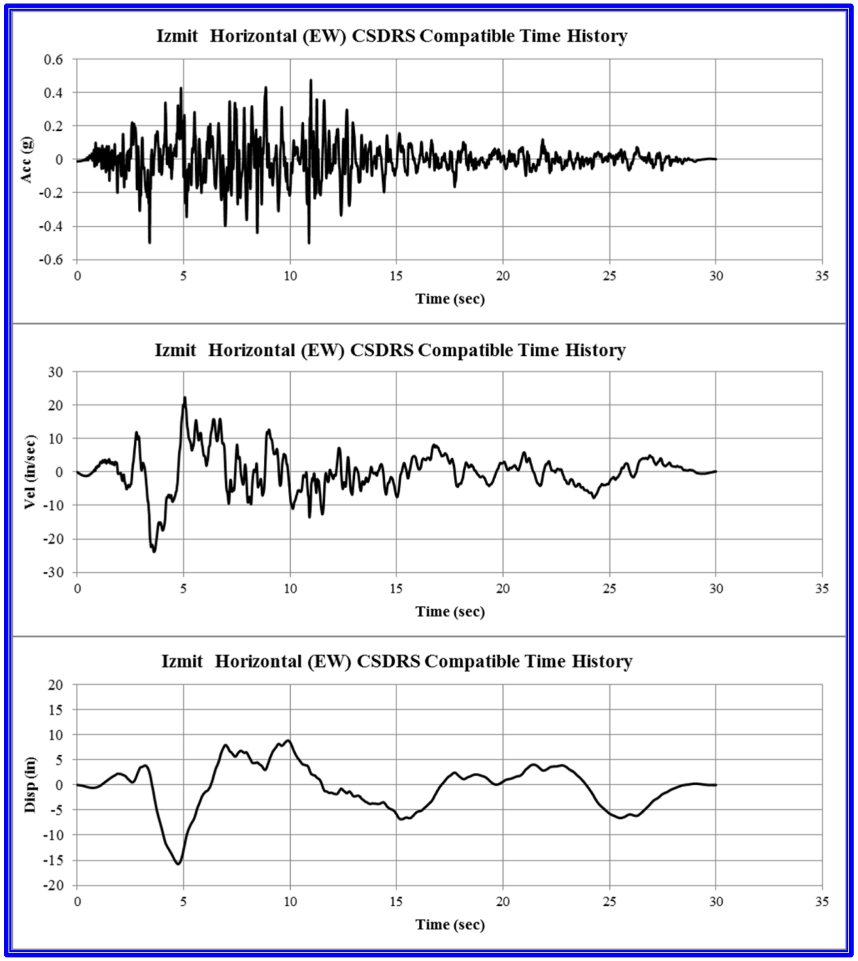
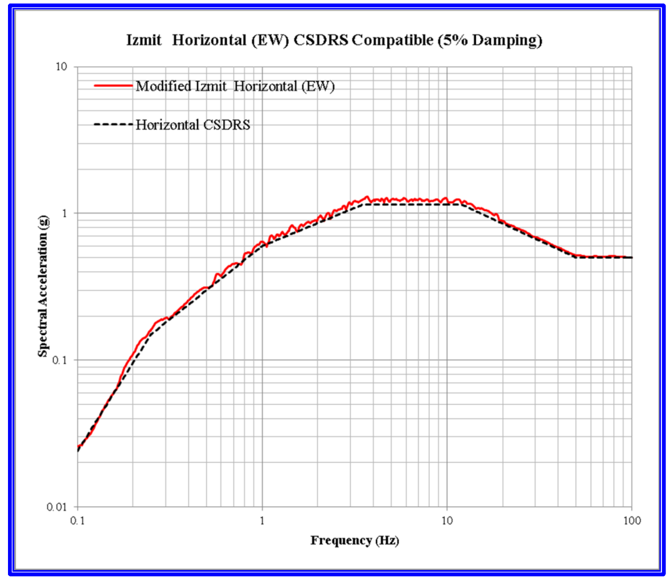


Figure 3.7.1-8b: CSDRS Compatible Time Histories for Izmit East-West

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

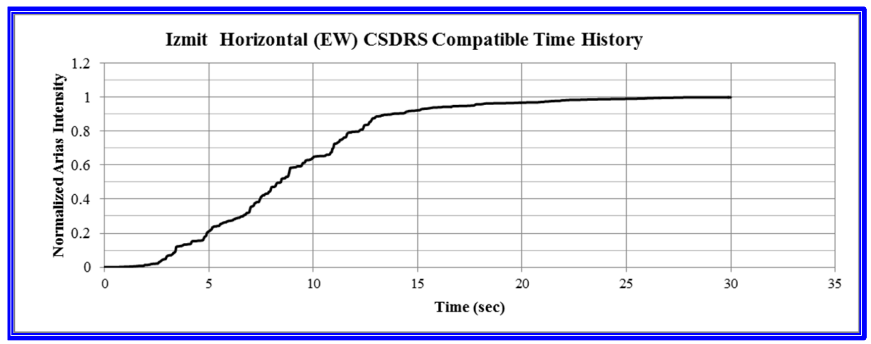
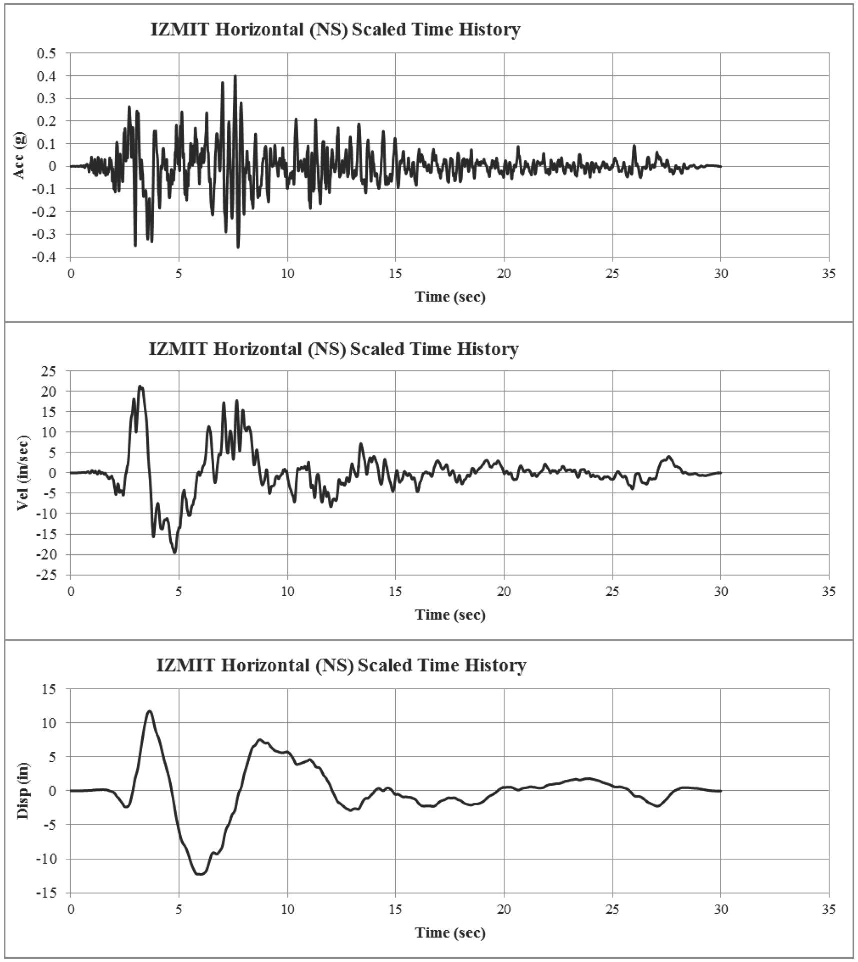


Figure 3.7.1-8c: Original Time Histories for Izmit North-South

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

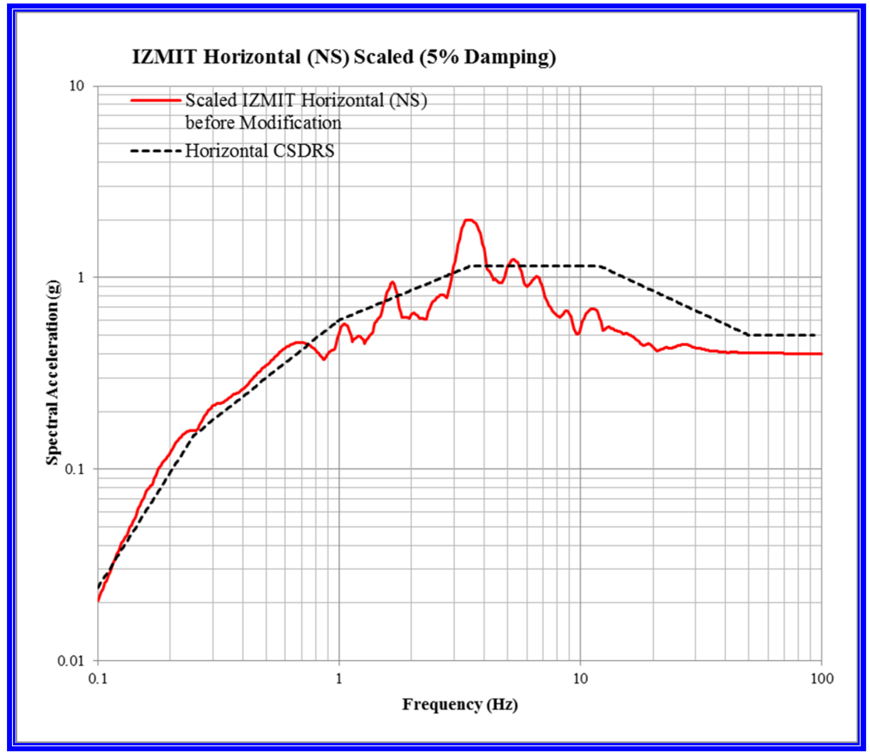
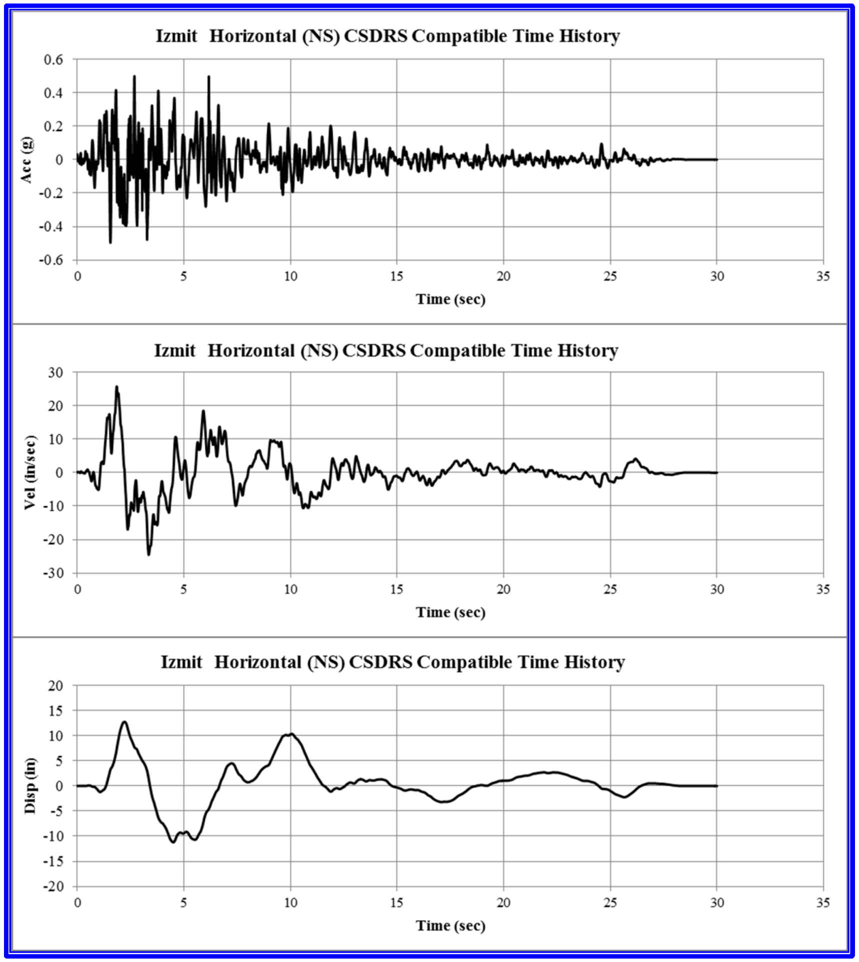
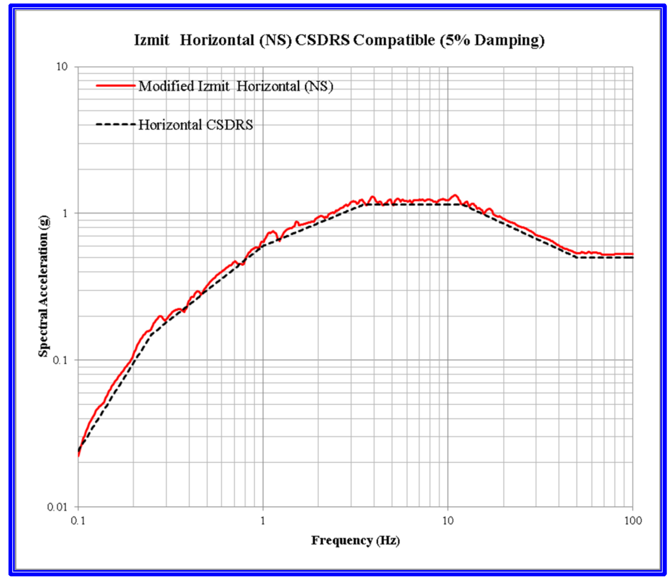


Figure 3.7.1-8d: CSDRS Compatible Time Histories for Izmit North-South

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

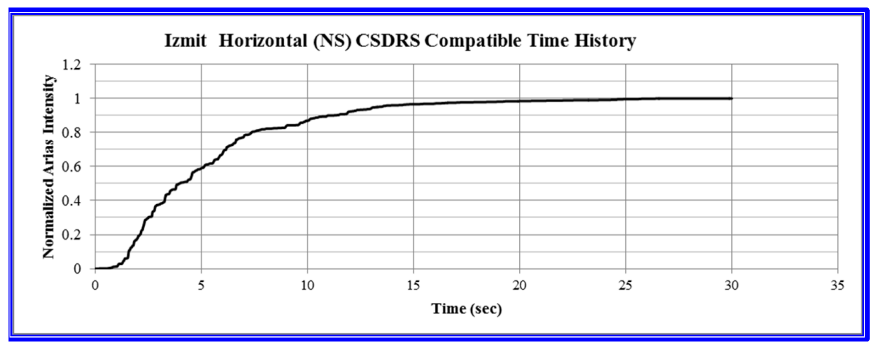
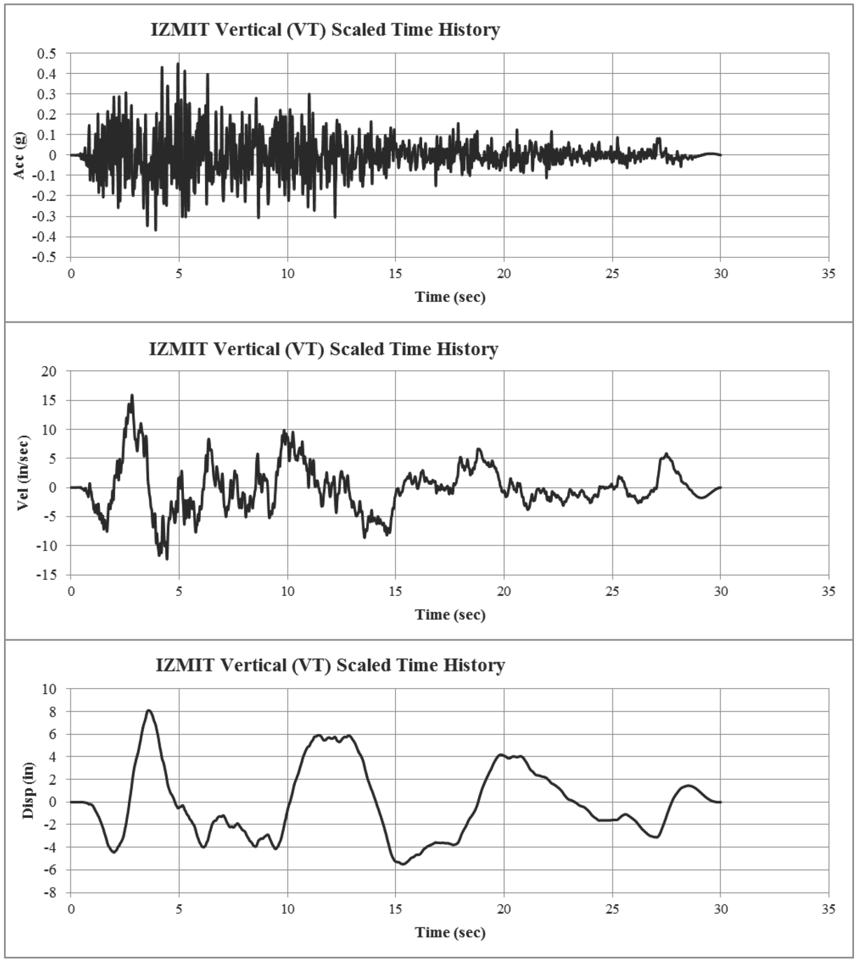


Figure 3.7.1-8e: Original Time Histories for Izmit Vertical

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

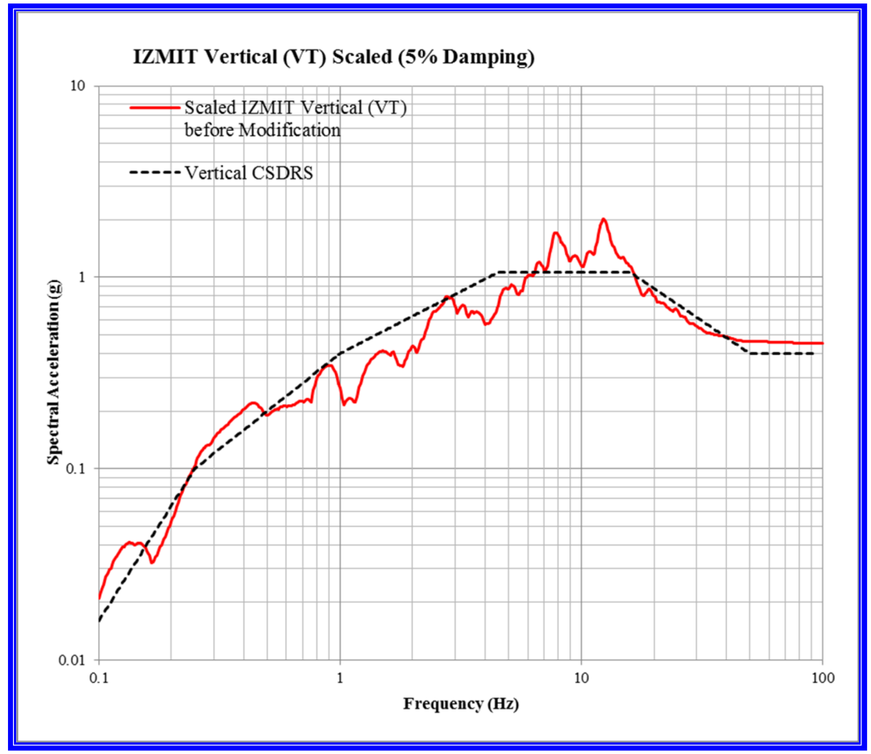
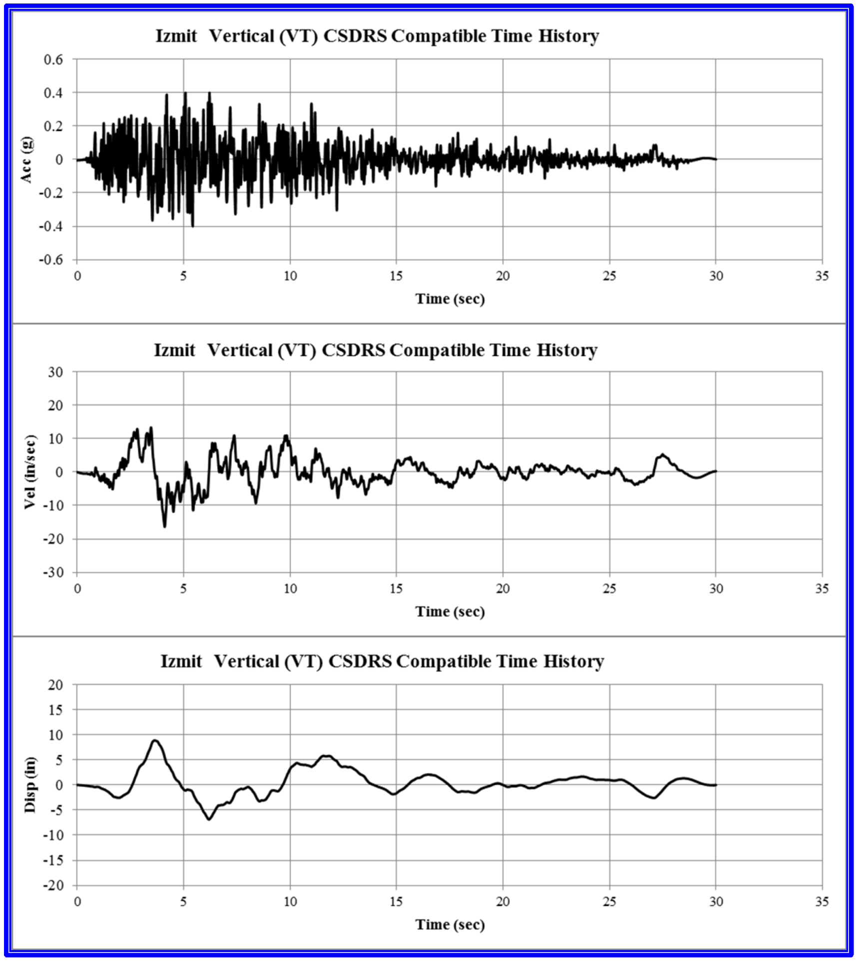
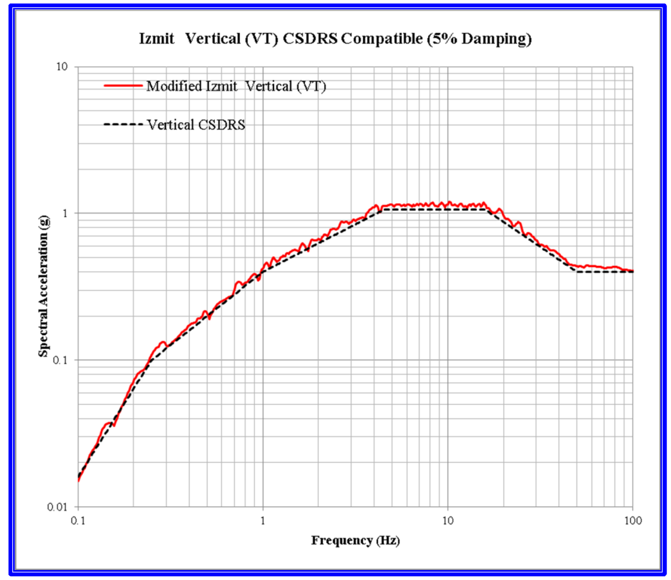


Figure 3.7.1-8f: CSDRS Compatible Time Histories for Izmit Vertical

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

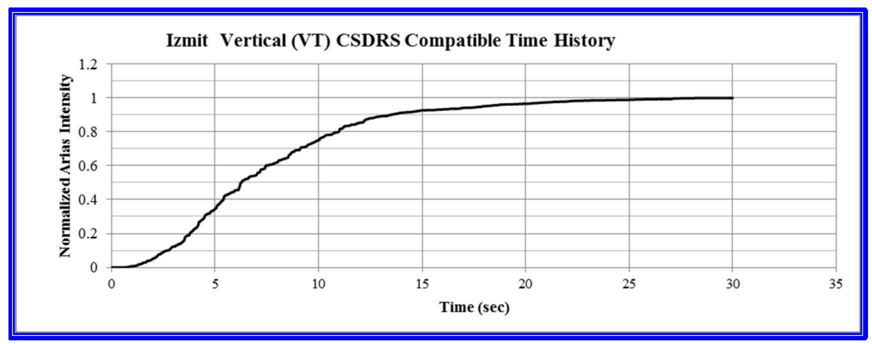
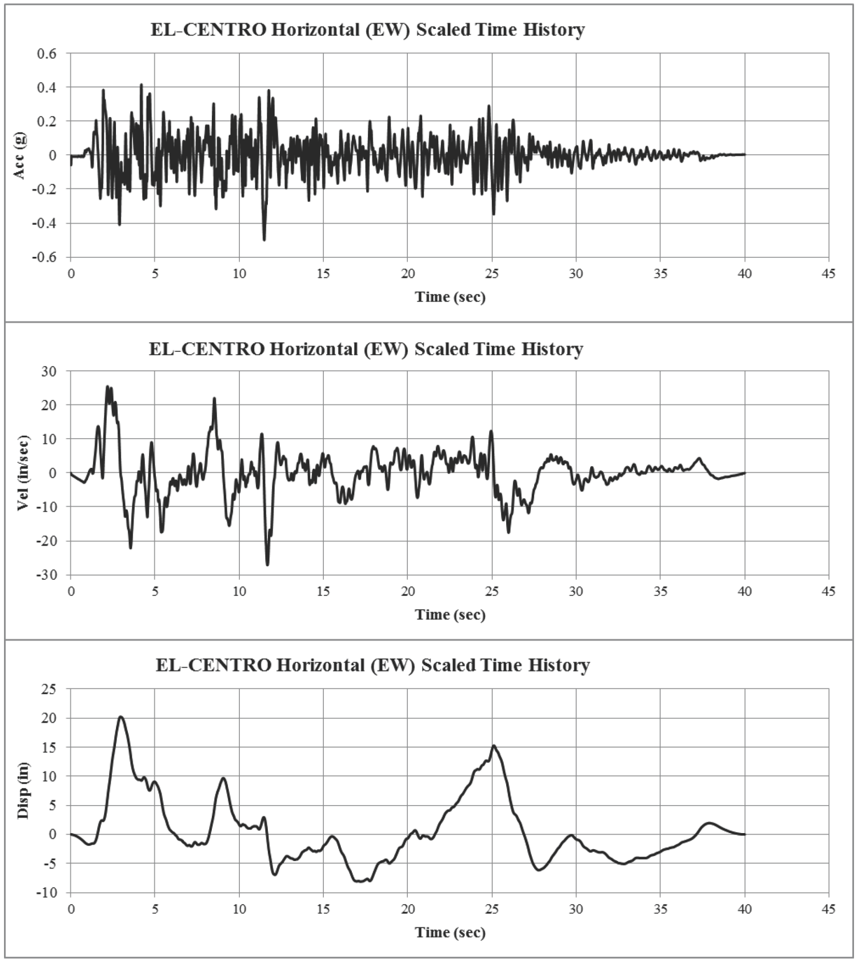


Figure 3.7.1-9a: Original Time Histories for El Centro East-West

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

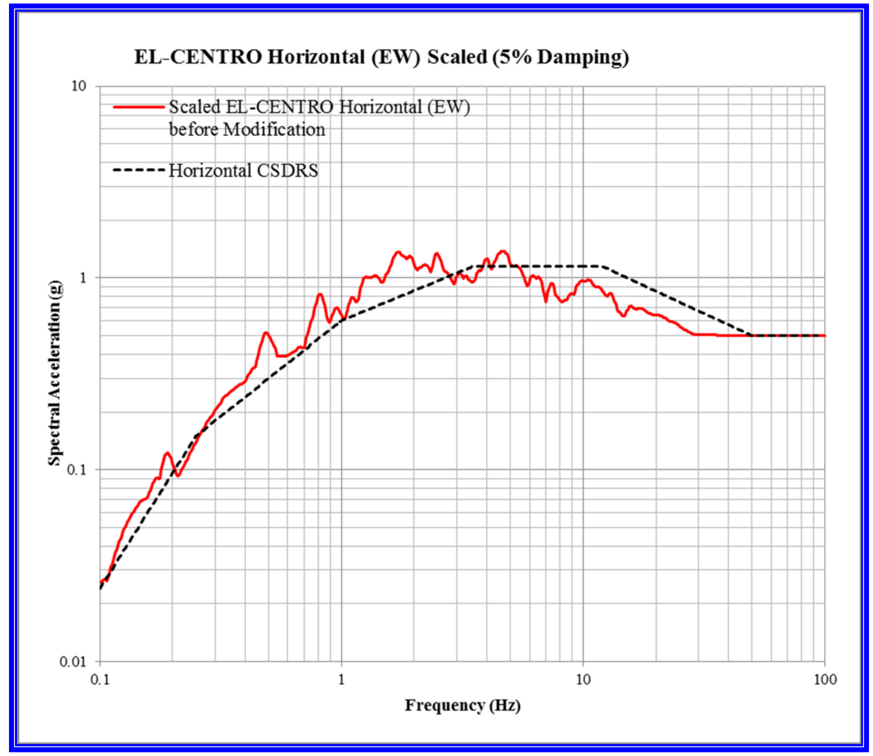
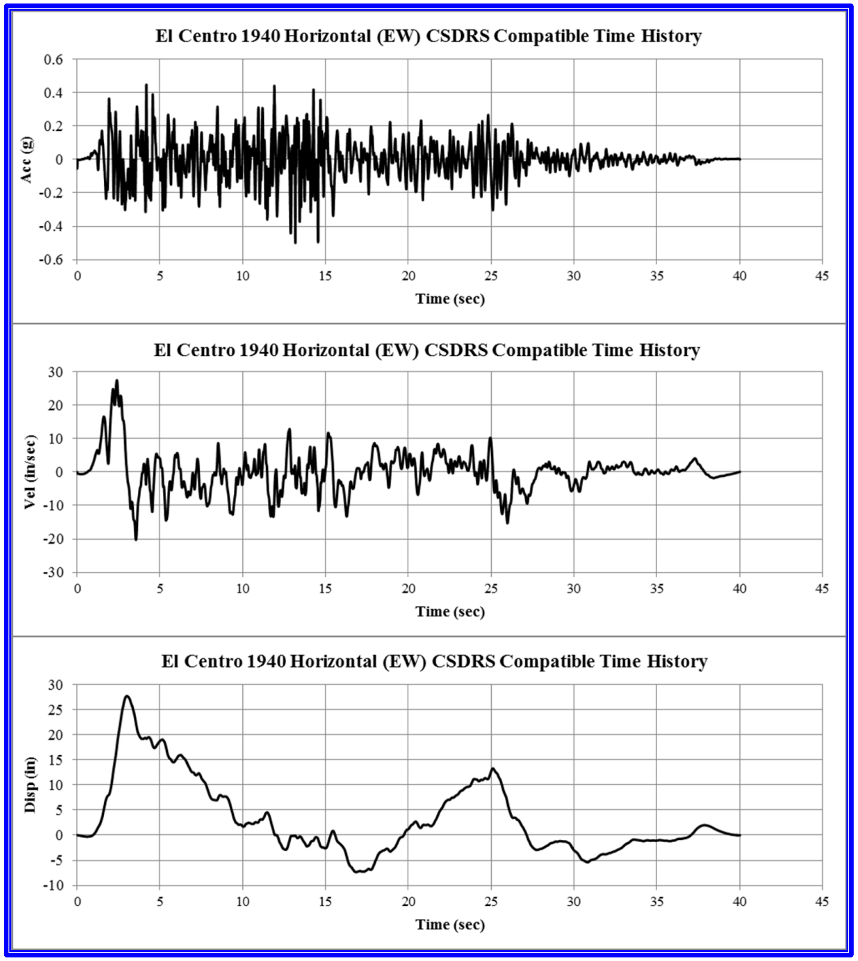
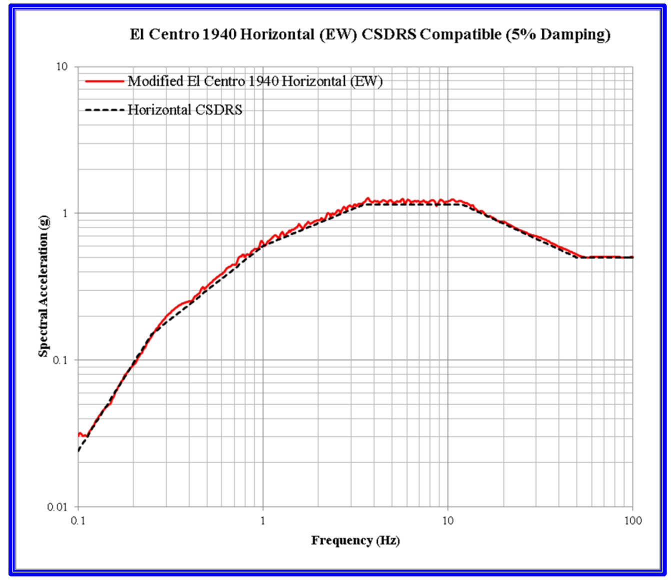


Figure 3.7.1-9b: CSDRS Compatible Time Histories for El Centro East-West

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

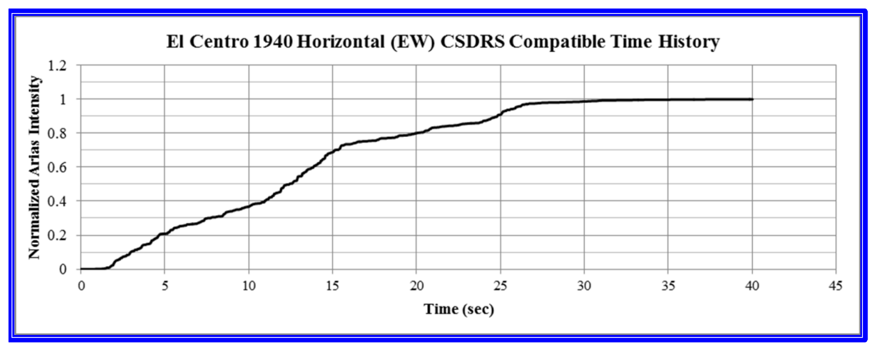
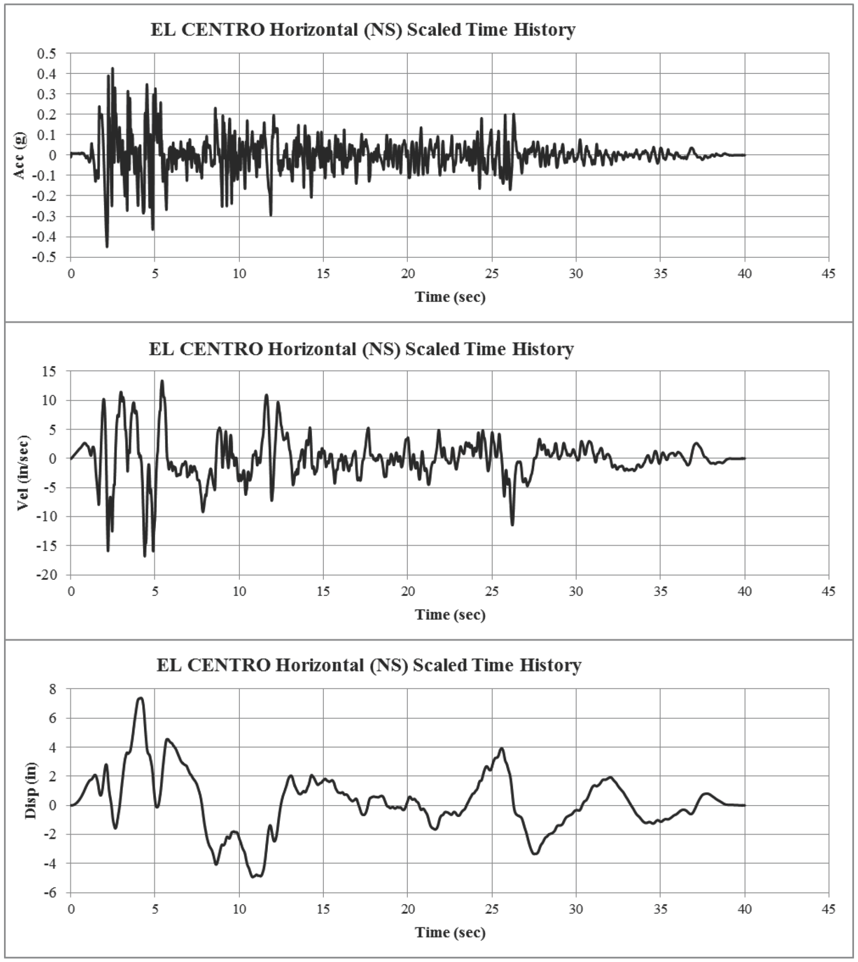


Figure 3.7.1-9c: Original Time Histories for El Centro North South

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

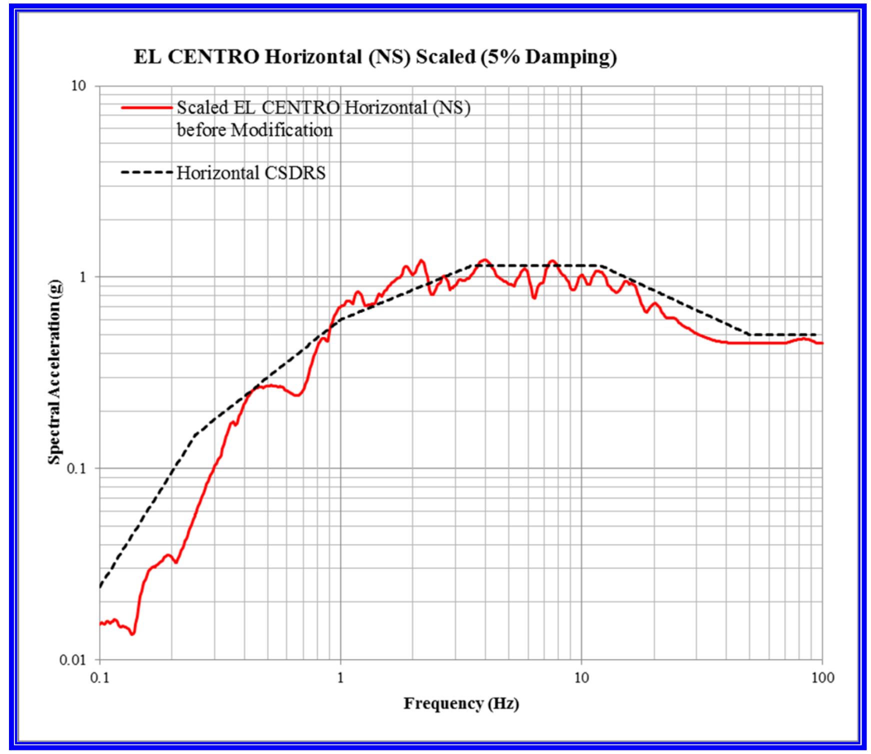
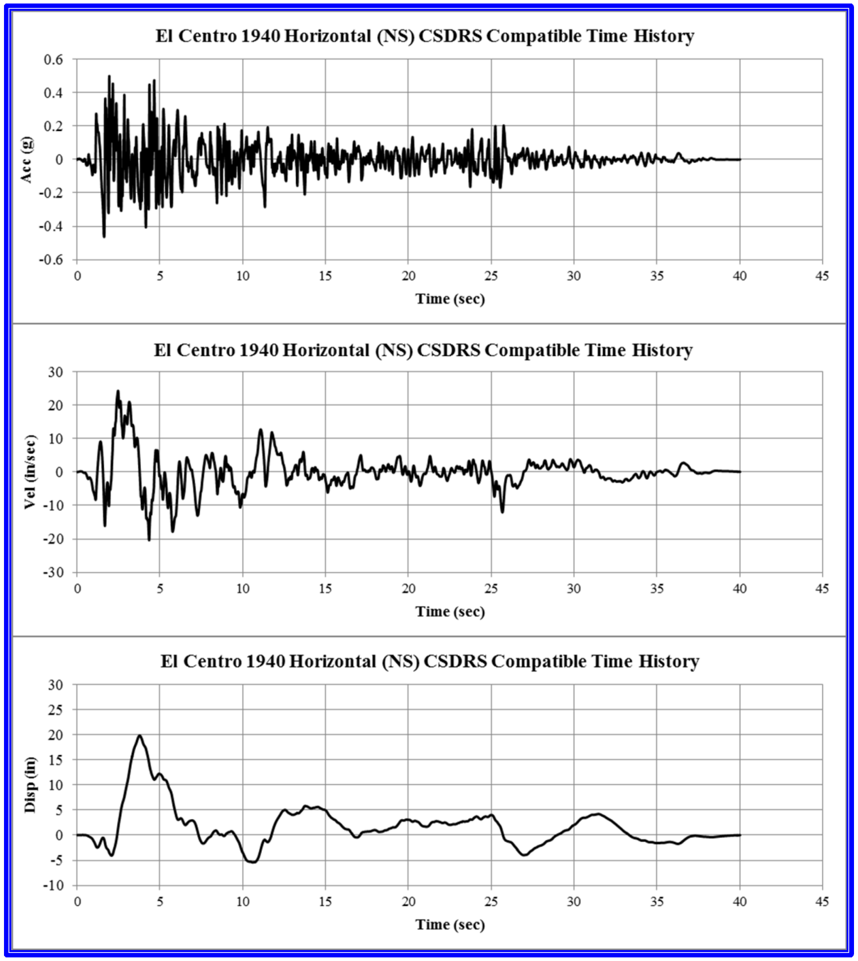
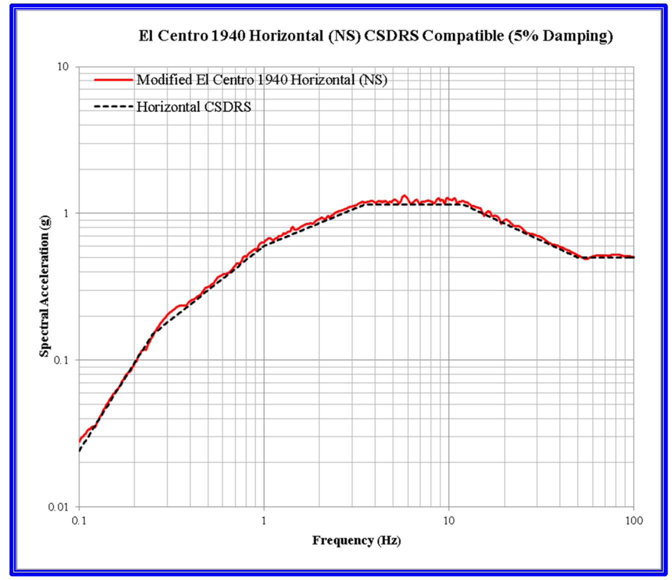


Figure 3.7.1-9d: CSDRS Compatible Time Histories for El Centro North-South

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

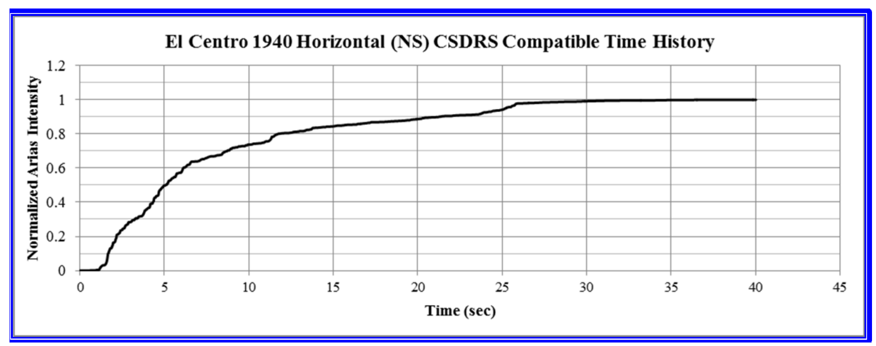
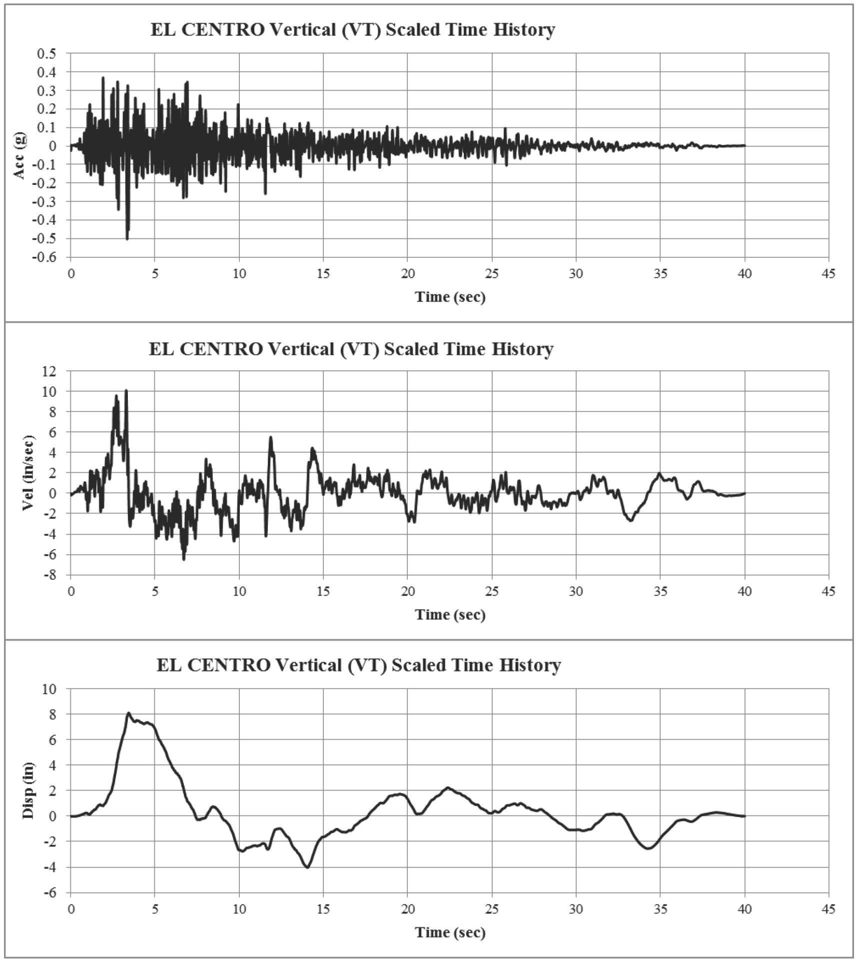


Figure 3.7.1-9e: Original Time Histories for El Centro Vertical

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

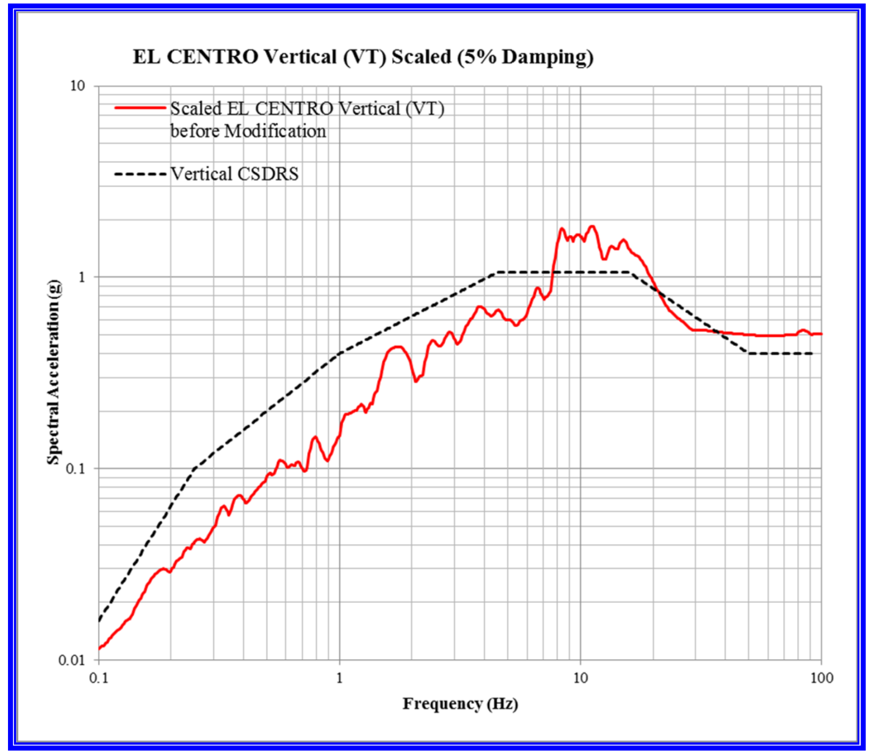
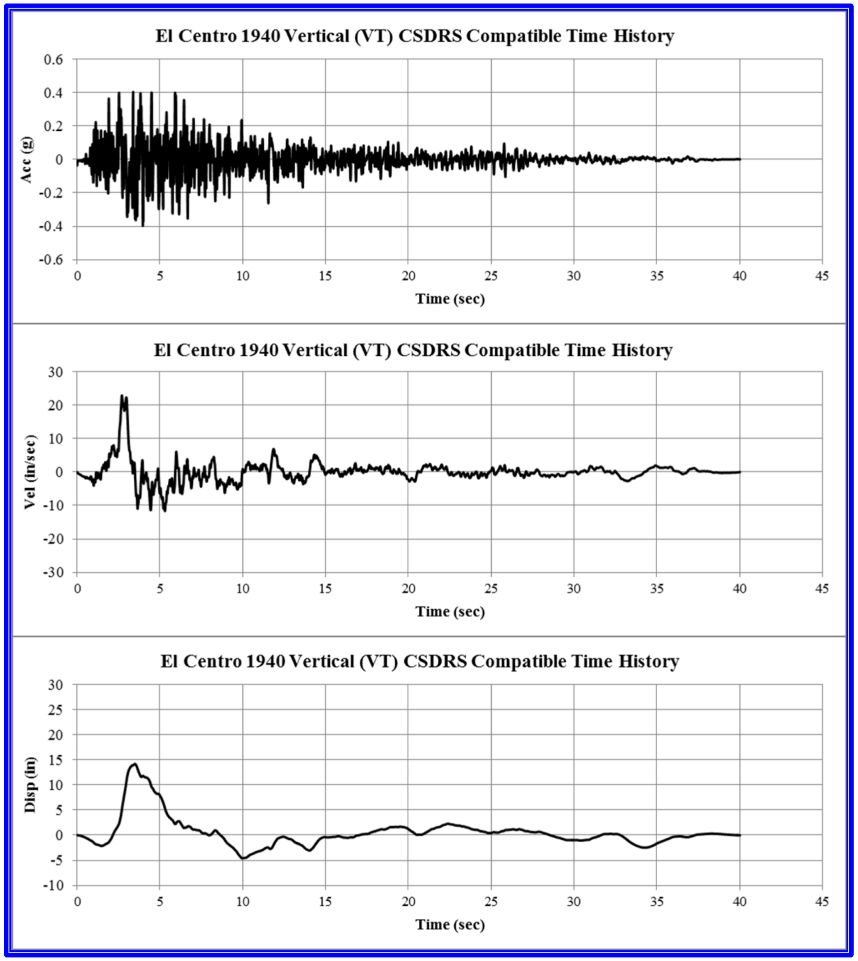
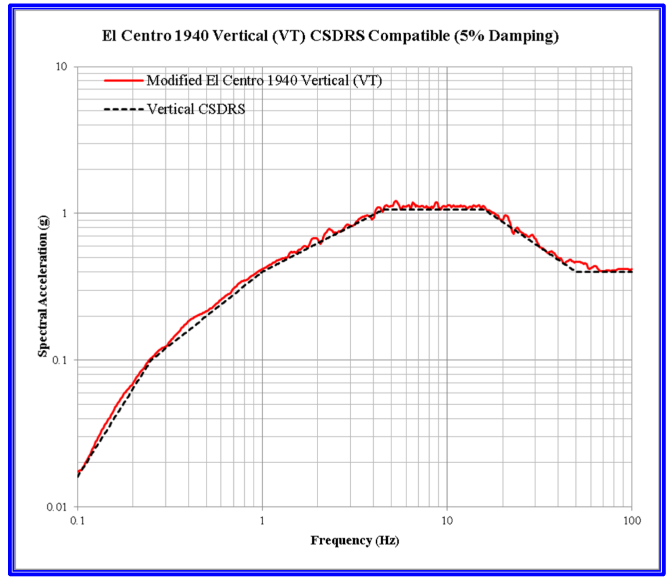


Figure 3.7.1-9f: CSDRS Compatible Time Histories for El Centro Vertical

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

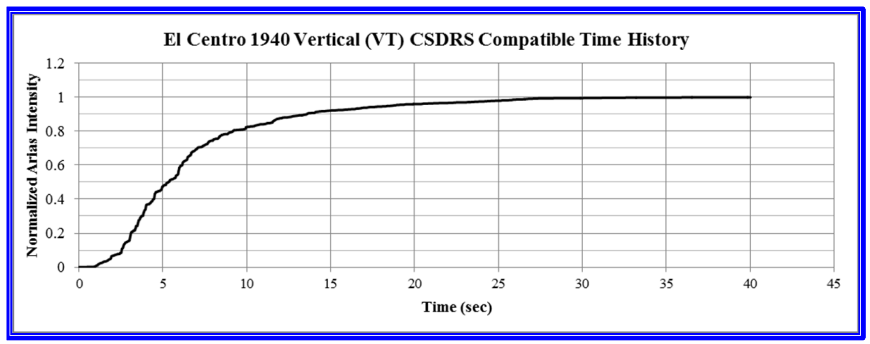
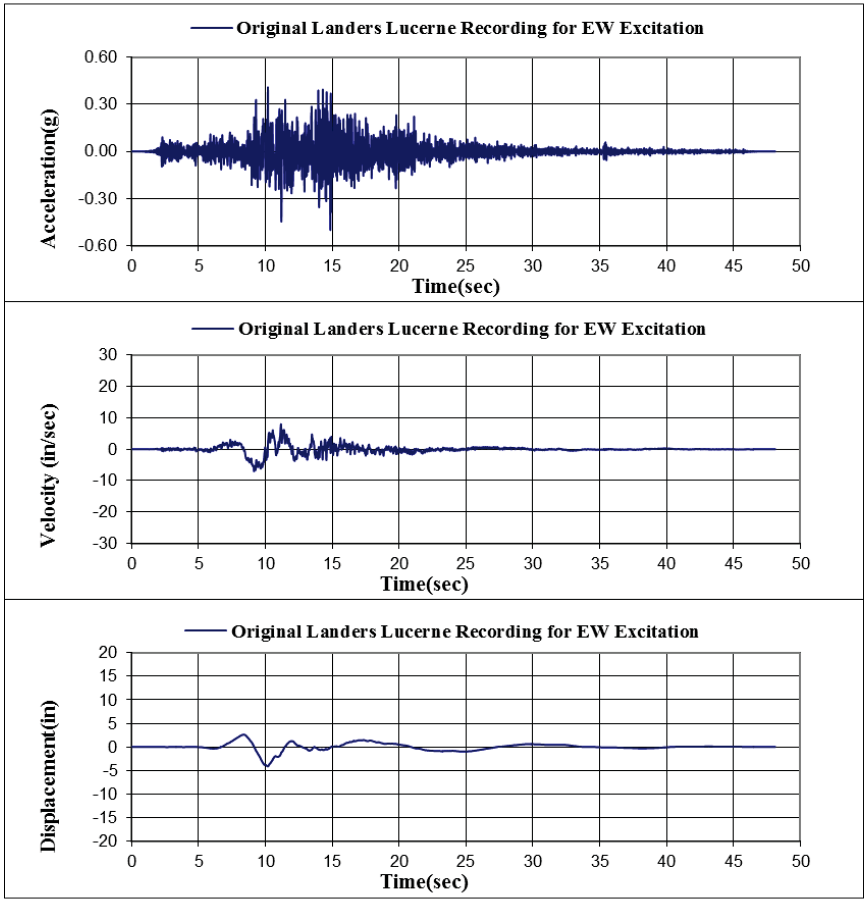


Figure 3.7.1-10a: Original Time Histories for Lucerne East-West

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

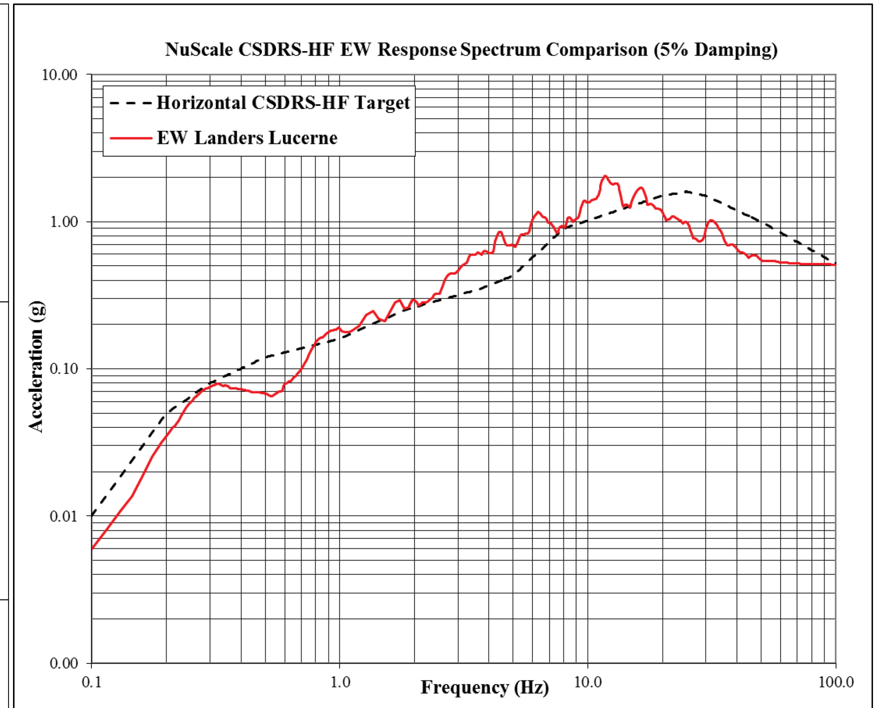
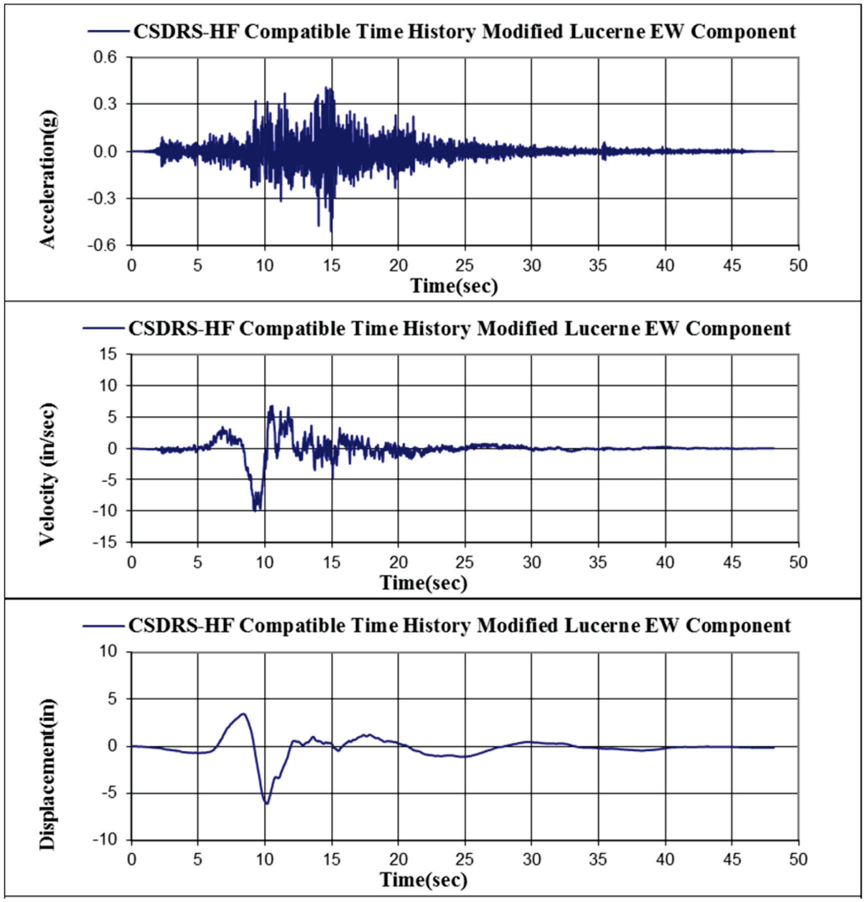
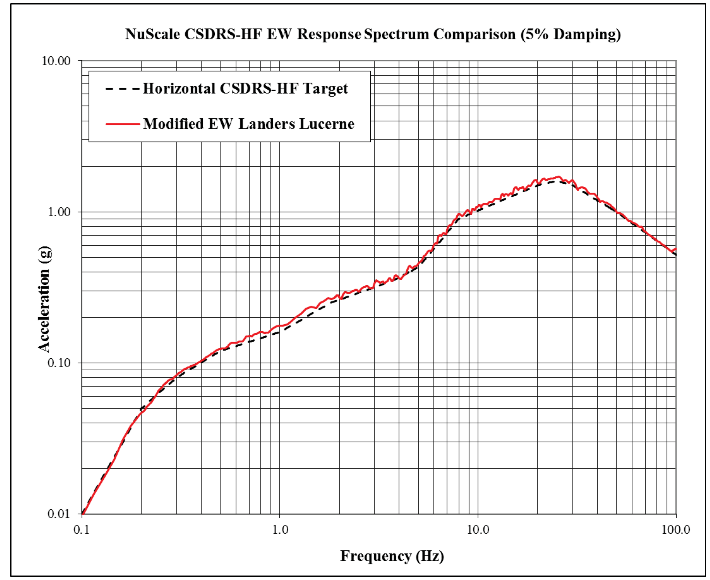


Figure 3.7.1-10b: CSDRS-HF Compatible Time Histories for Lucerne East-West

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

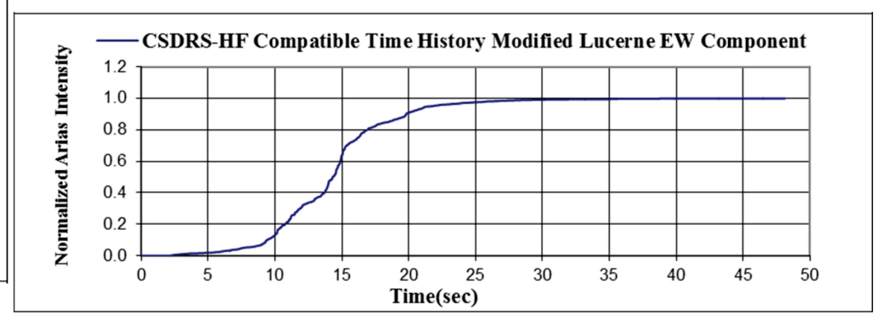
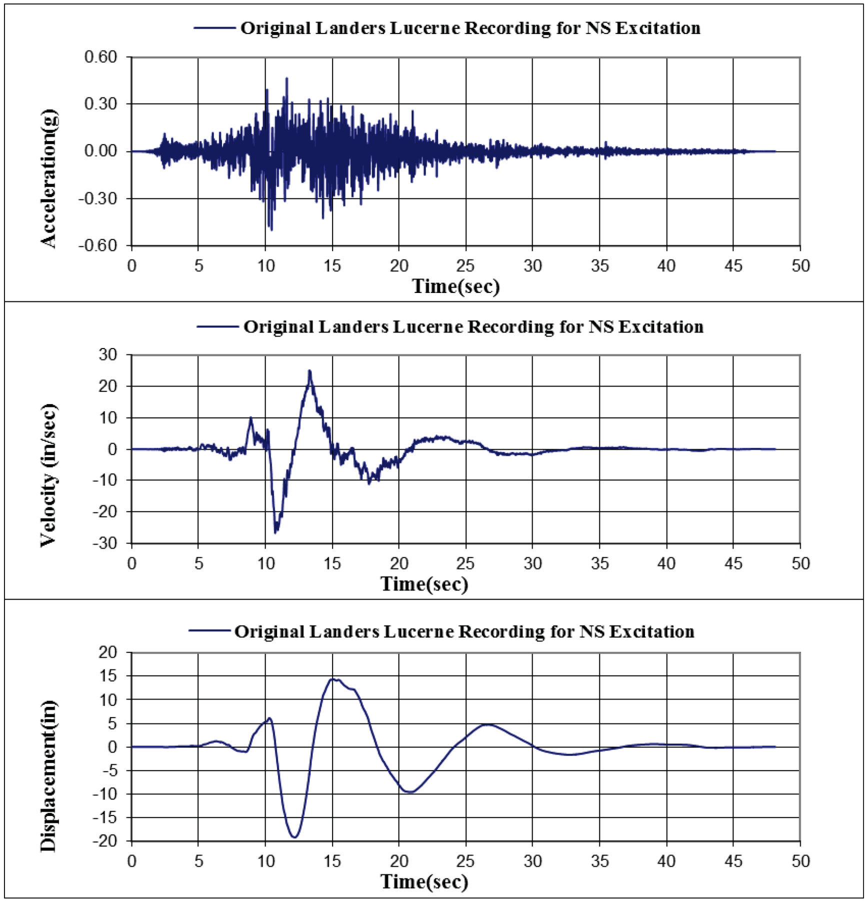


Figure 3.7.1-10c: Original Time Histories for Lucerne North-South

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

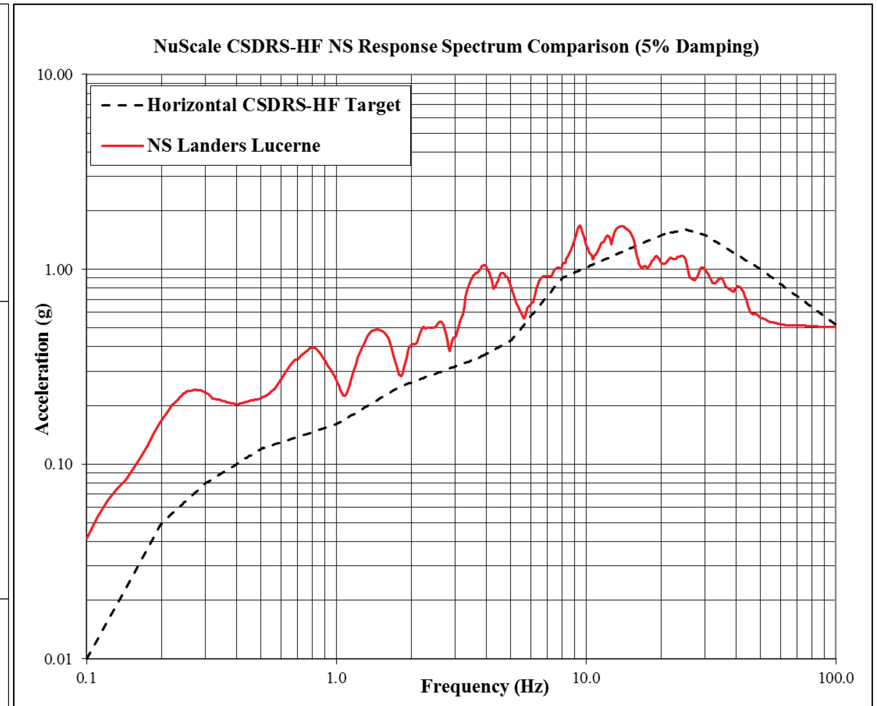
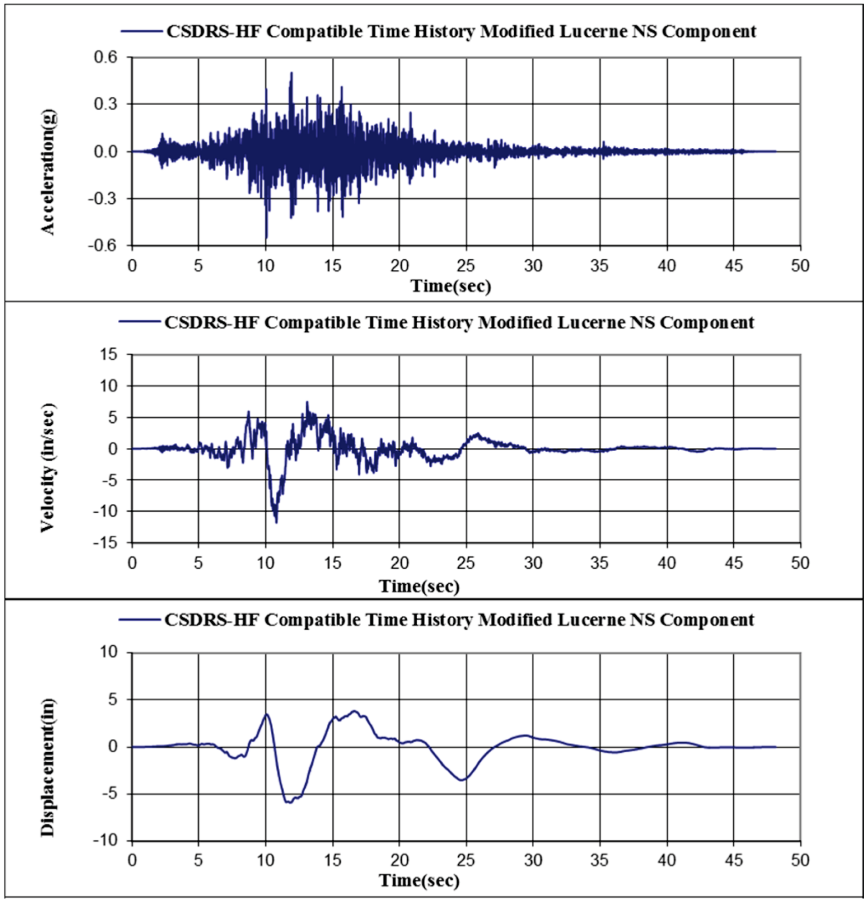
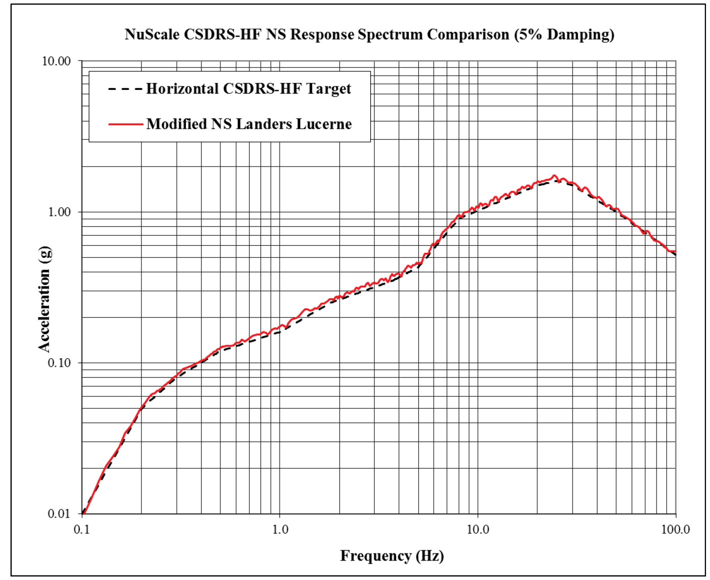


Figure 3.7.1-10d: CSDRS-HF Compatible Time Histories for Lucerne North-South

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

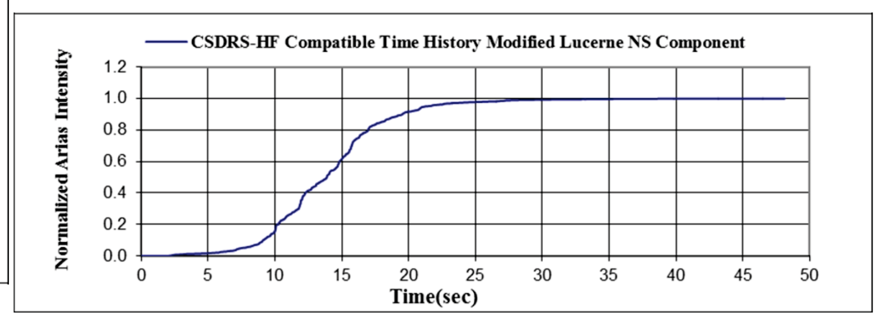
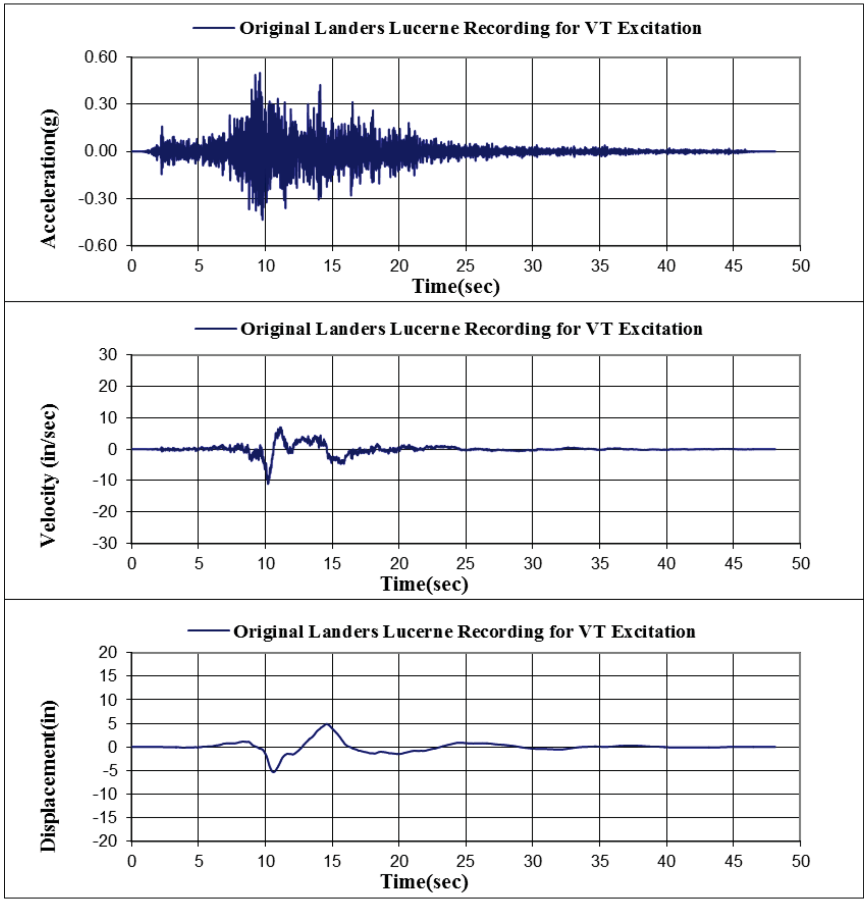


Figure 3.7.1-10e: Original Time Histories for Lucerne Vertical

Acceleration, Velocity, and Displacement Time Histories



Response Spectrum Scaled to CSDRS

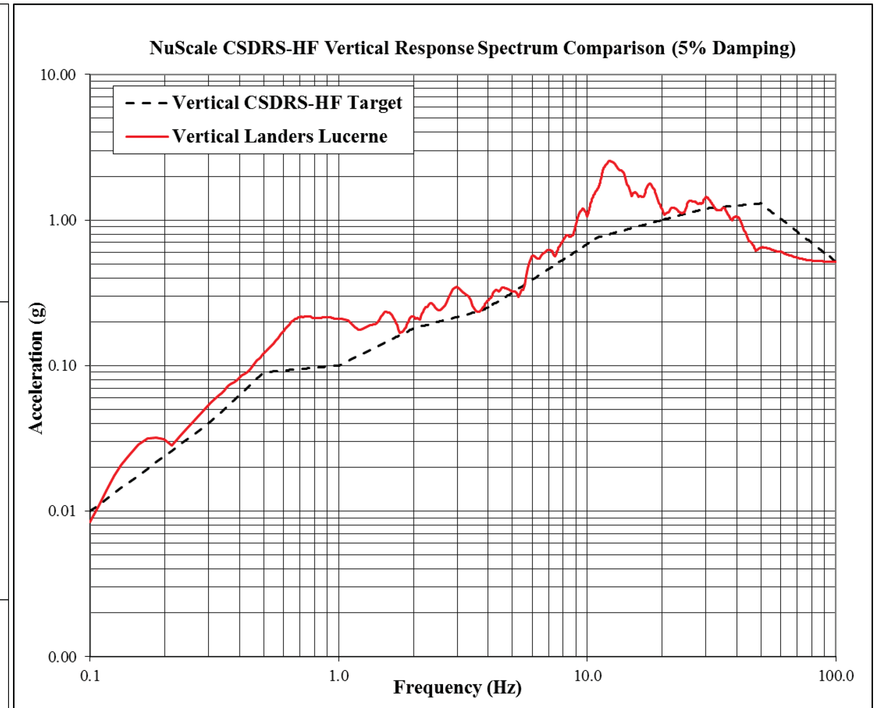
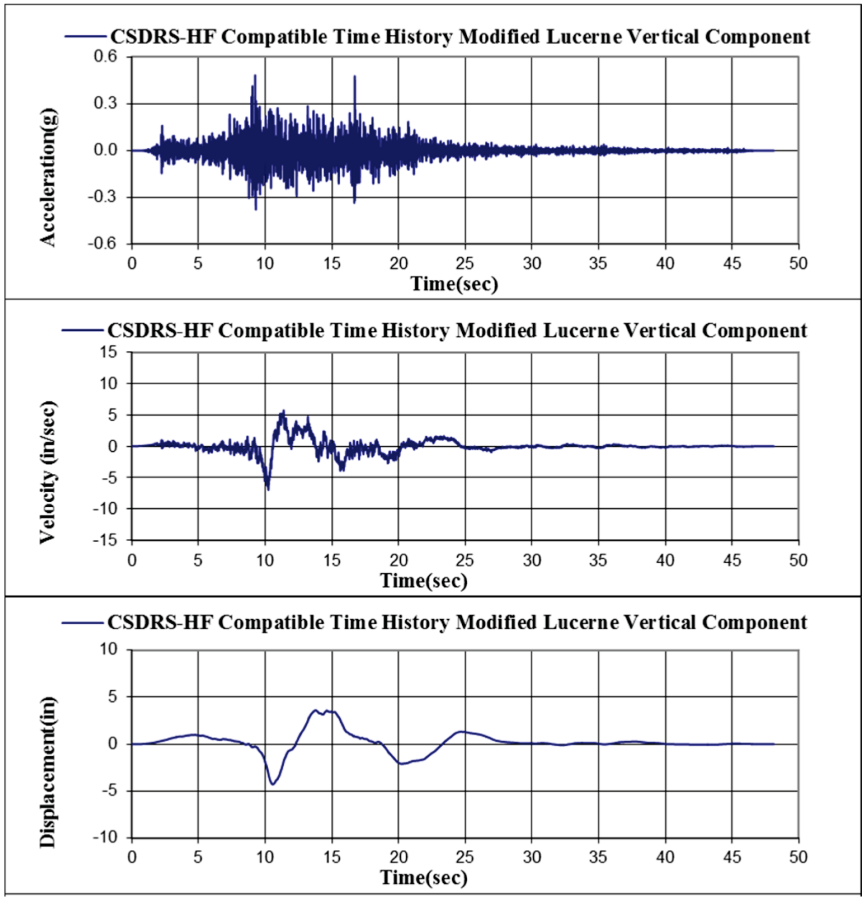
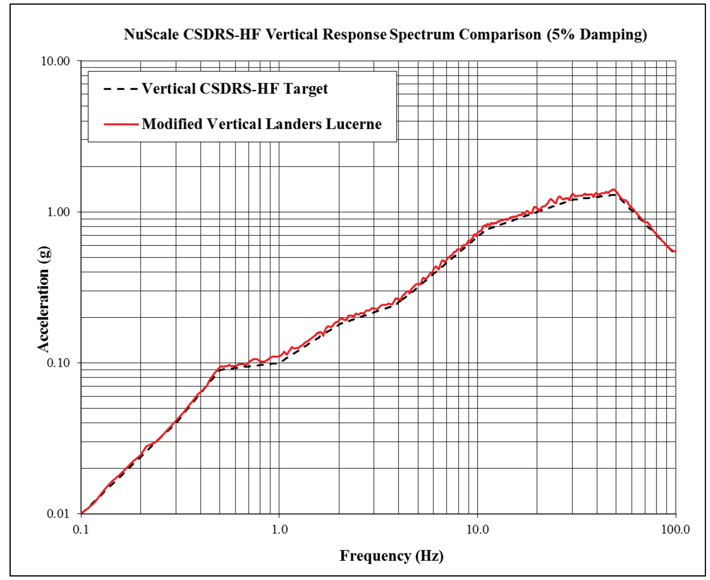


Figure 3.7.1-10f: CSDRS-HF Compatible Time Histories for Lucerne Vertical

Acceleration, Velocity, and Displacement Time Histories



Modified Response Spectrum Compared to CSDRS



Arias Intensity

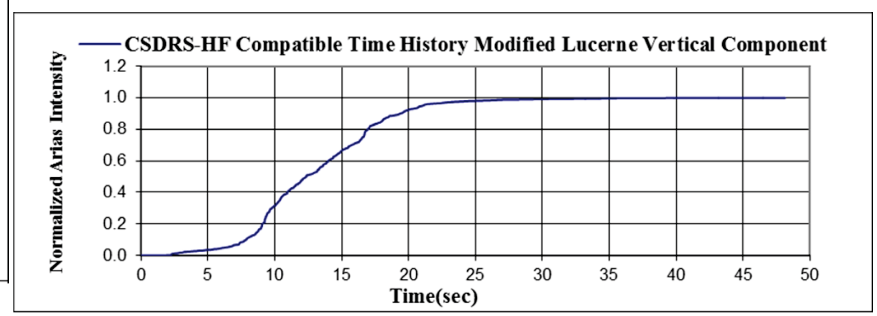


Figure 3.7.1-11: Normalized Arias Intensity Curve of North-South Component of Izmit Time History

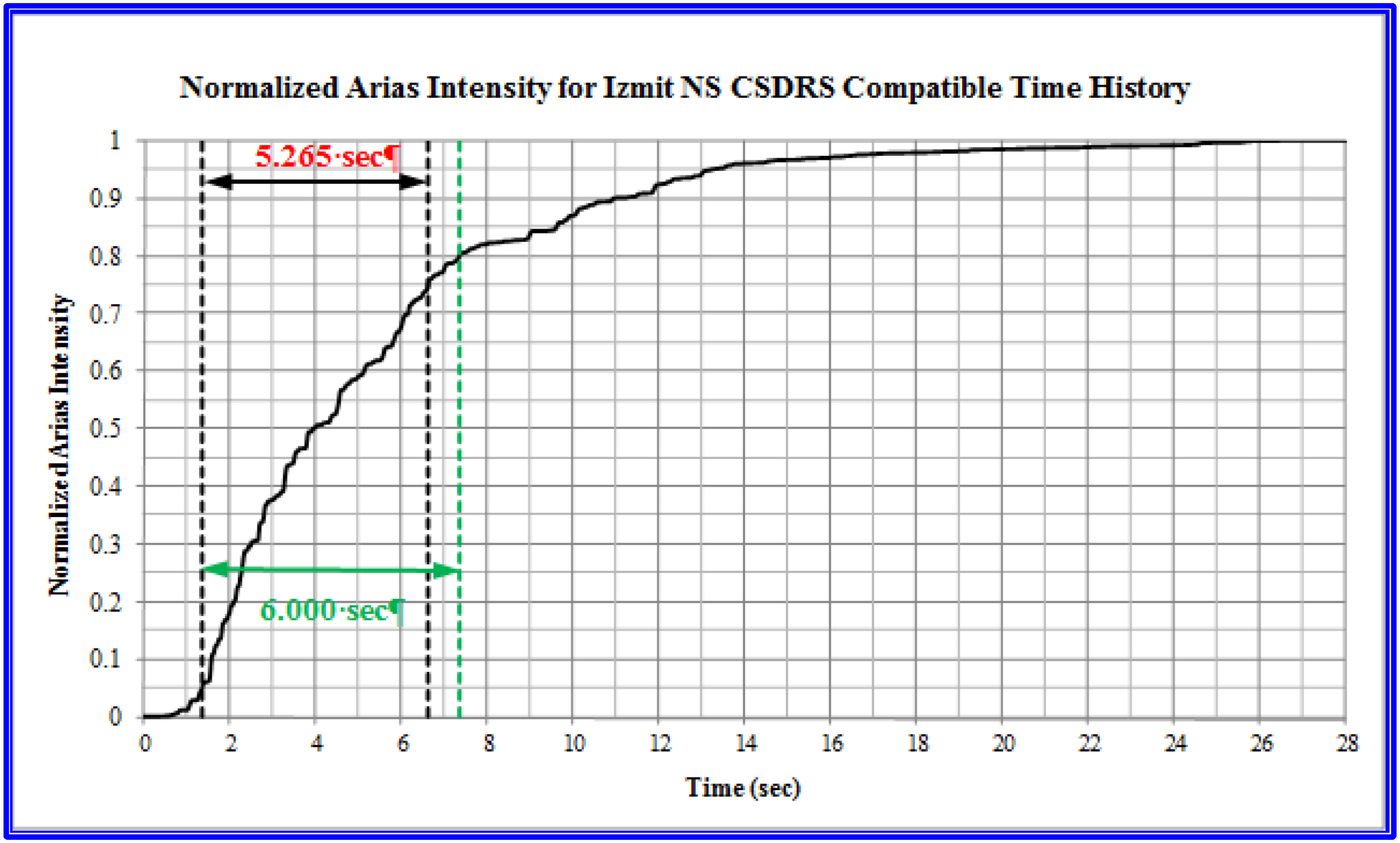


Figure 3.7.1-12a: Average Response Spectra East-West

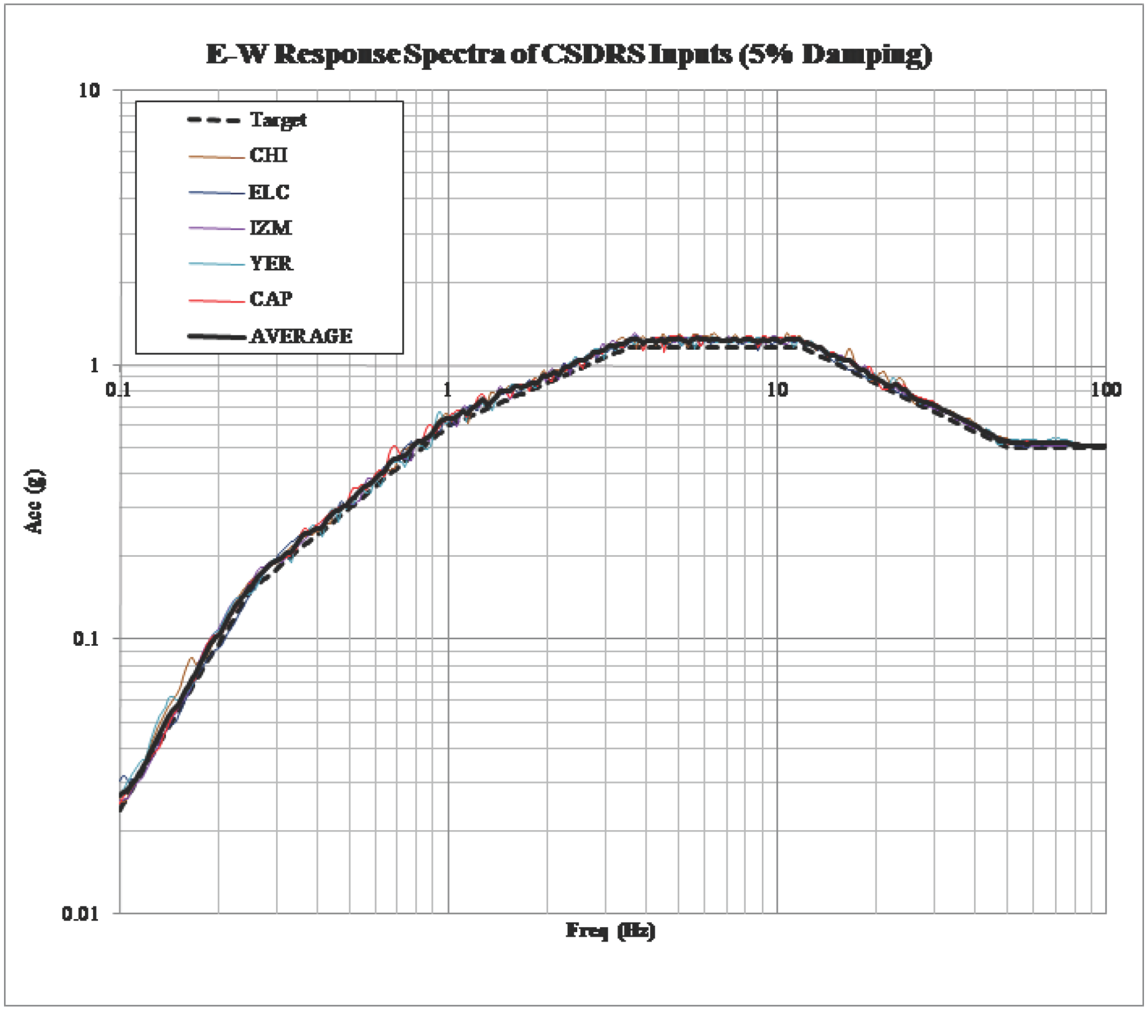


Figure 3.7.1-12b: Average Response Spectra North-South

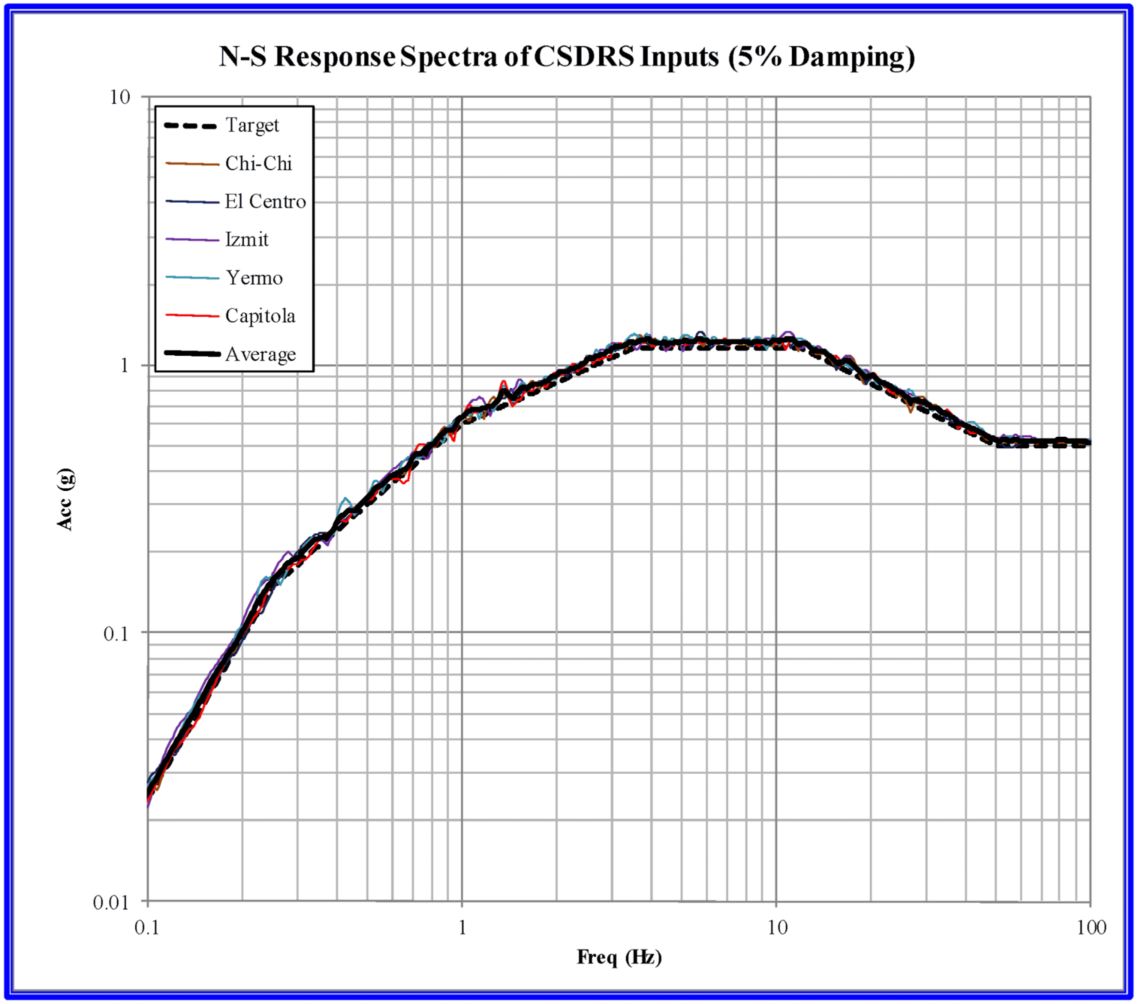


Figure 3.7.1-12c: Average Response Spectra Vertical

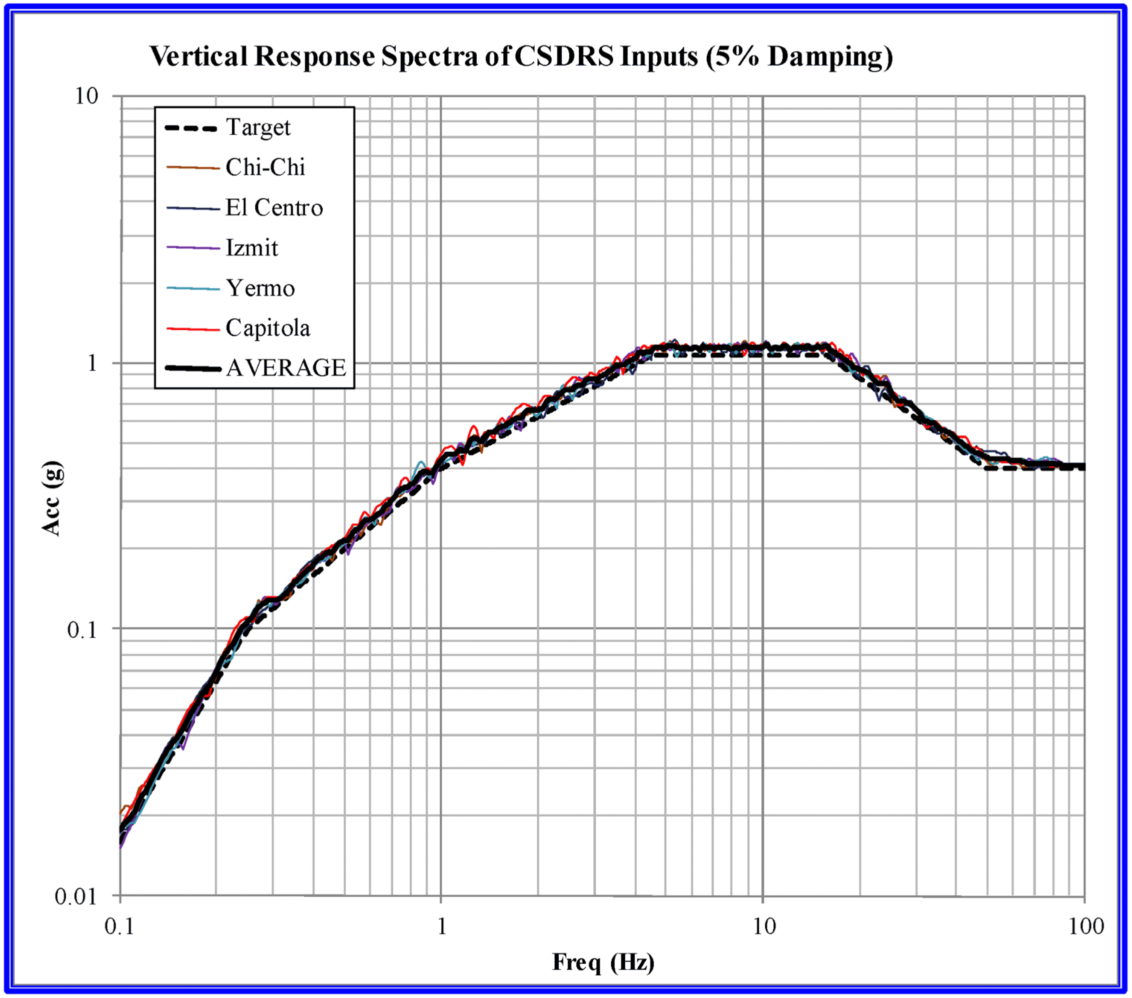


Figure 3.7.1-13a: Power Spectral Density Curves CSDRS Compatible Time Histories

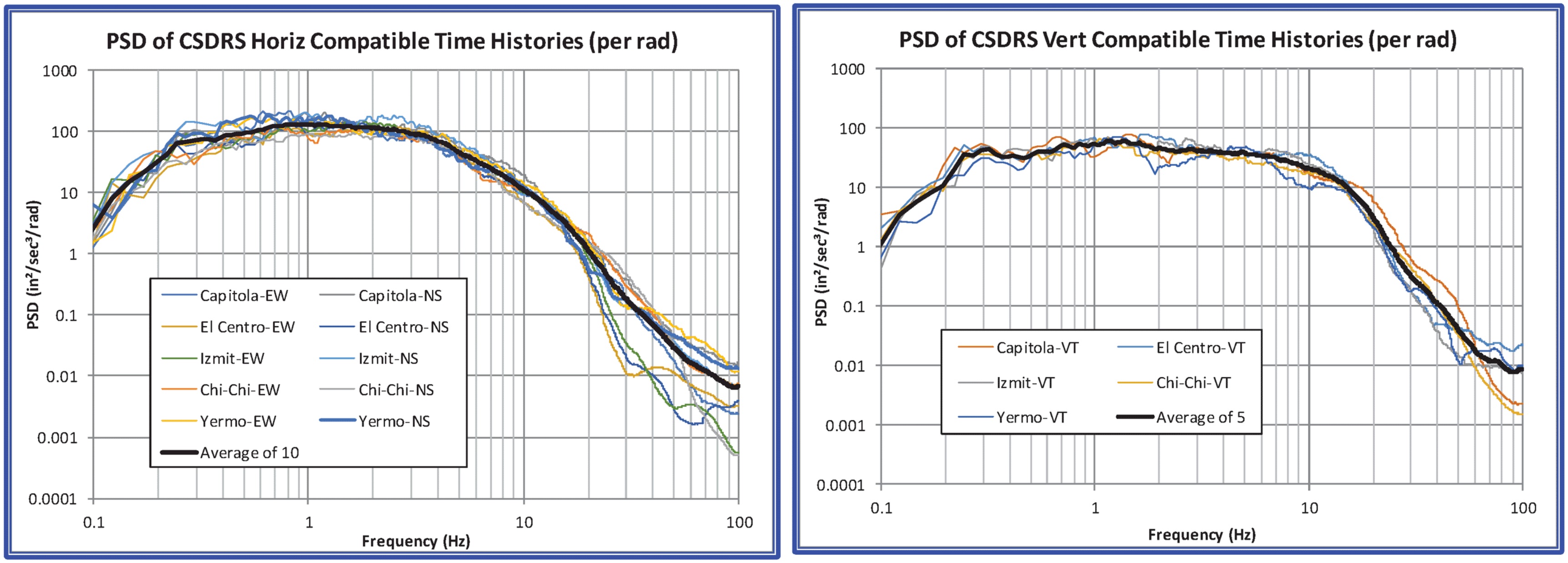


Figure 3.7.1-13b: Power Spectral Density Curves CSDRS-HF Compatible Time Histories

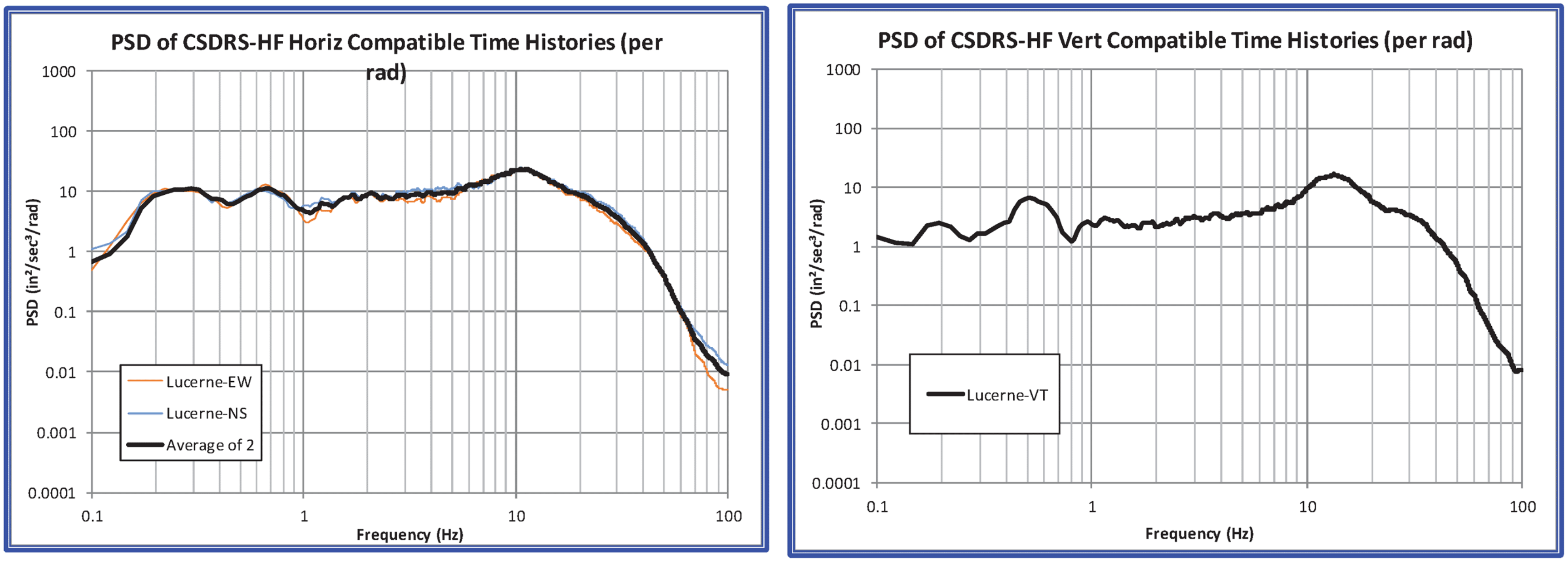


Figure 3.7.1-14: Soil Shear Modulus Degradation Curves

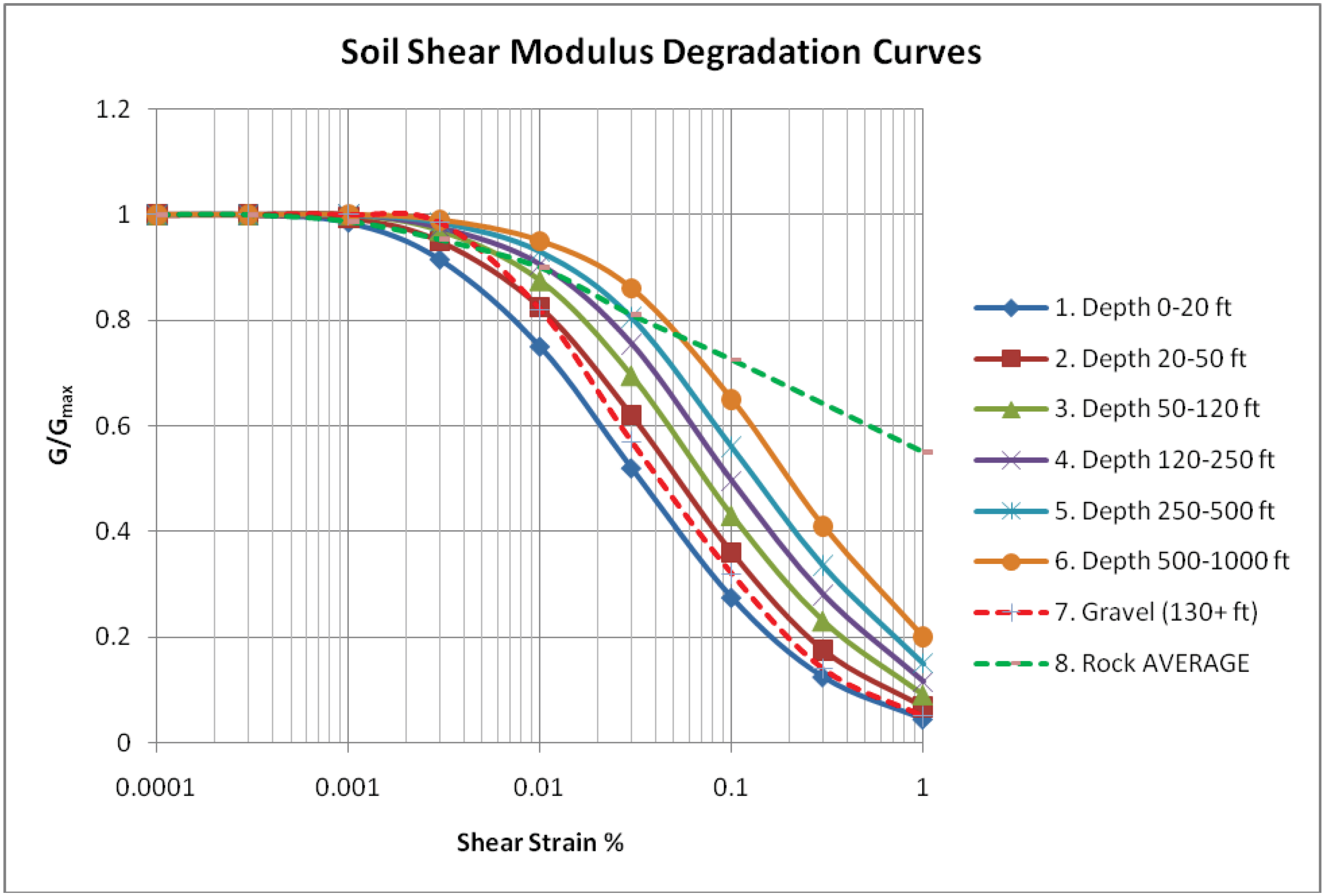


Figure 3.7.1-15: Strain Dependent Soil Damping Curves

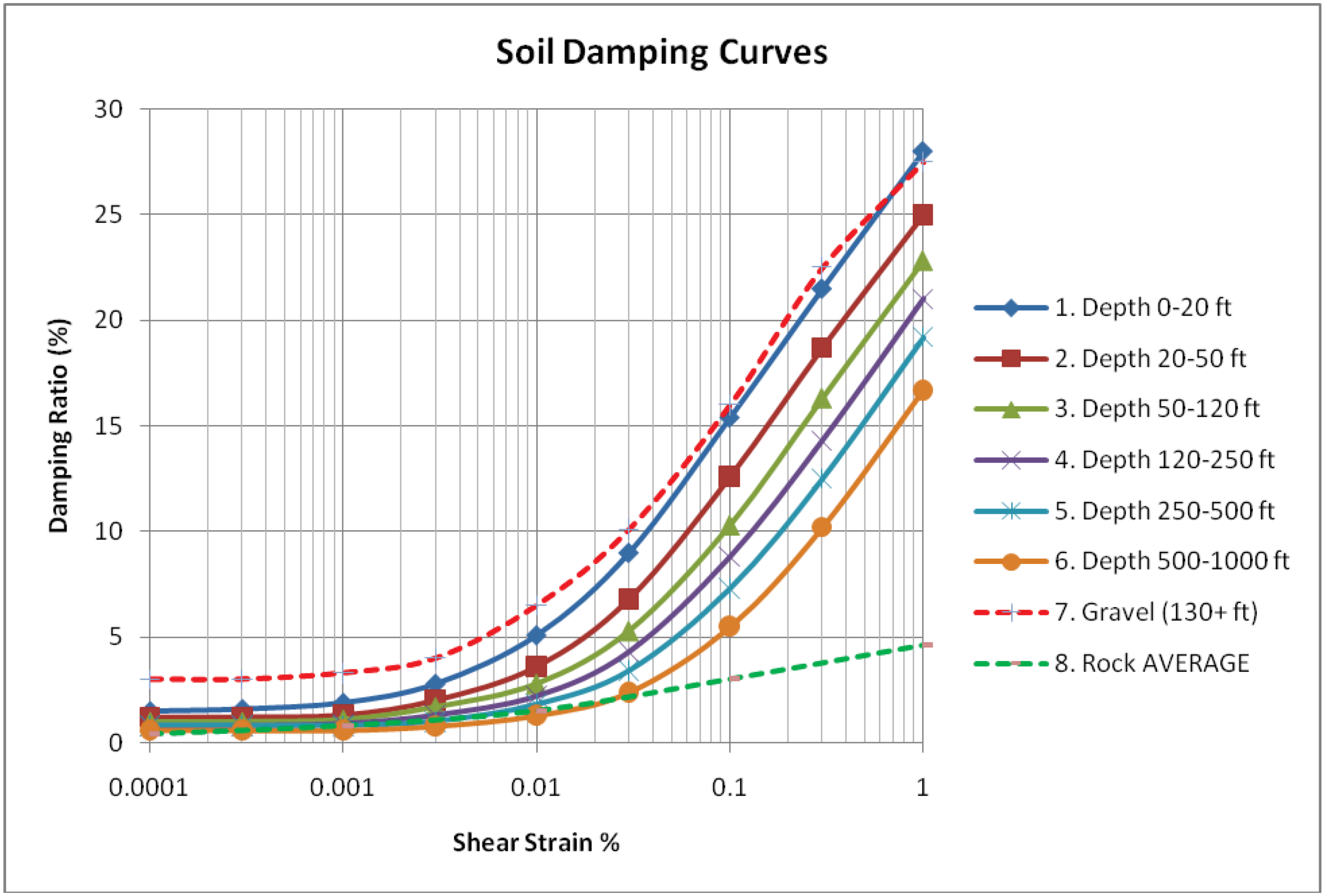


Figure 3.7.1-16: Shear Wave Velocities for All Soil Types

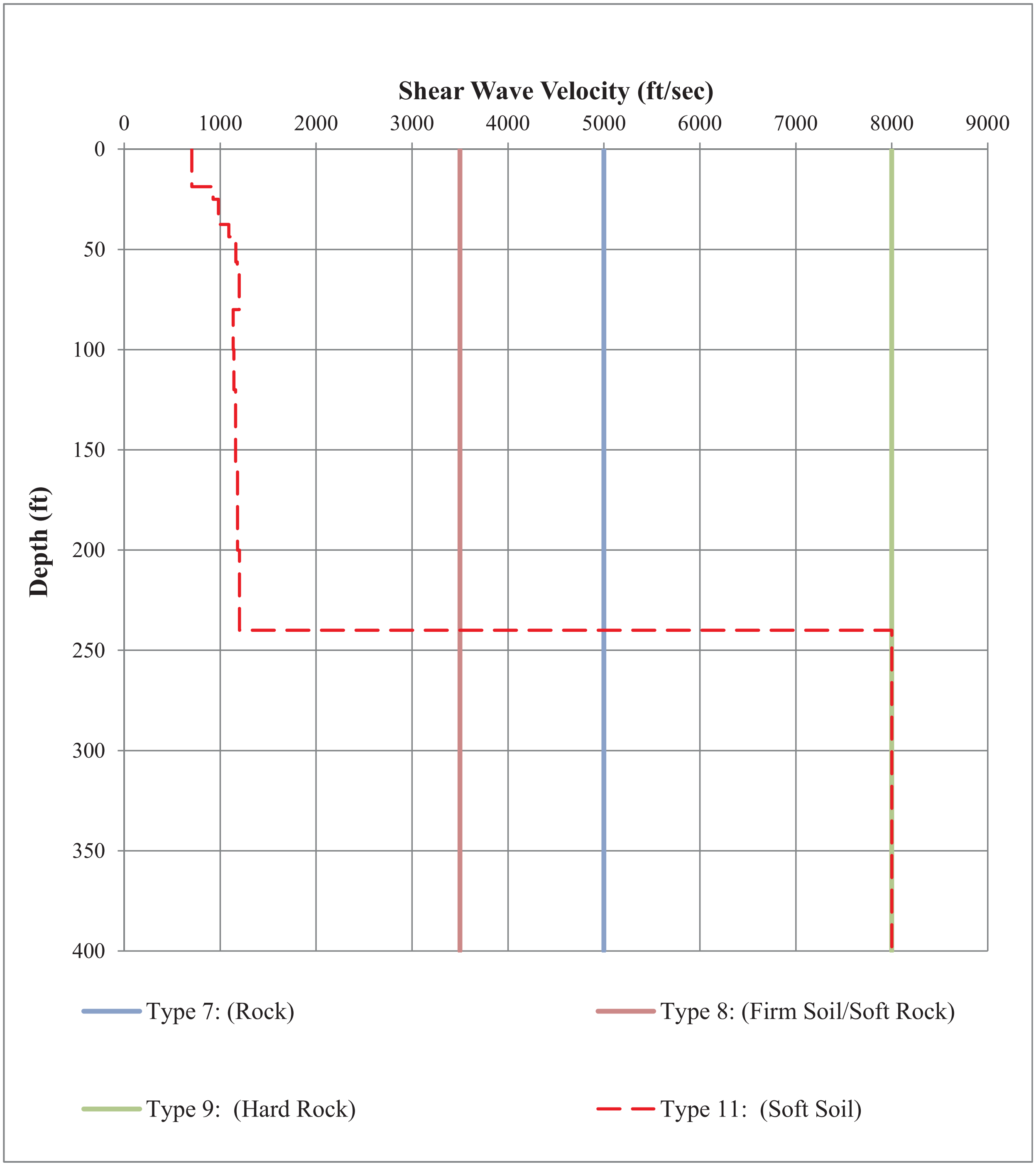


Figure 3.7.1-17: Layered Soil Model Used for NuScale Power Plant

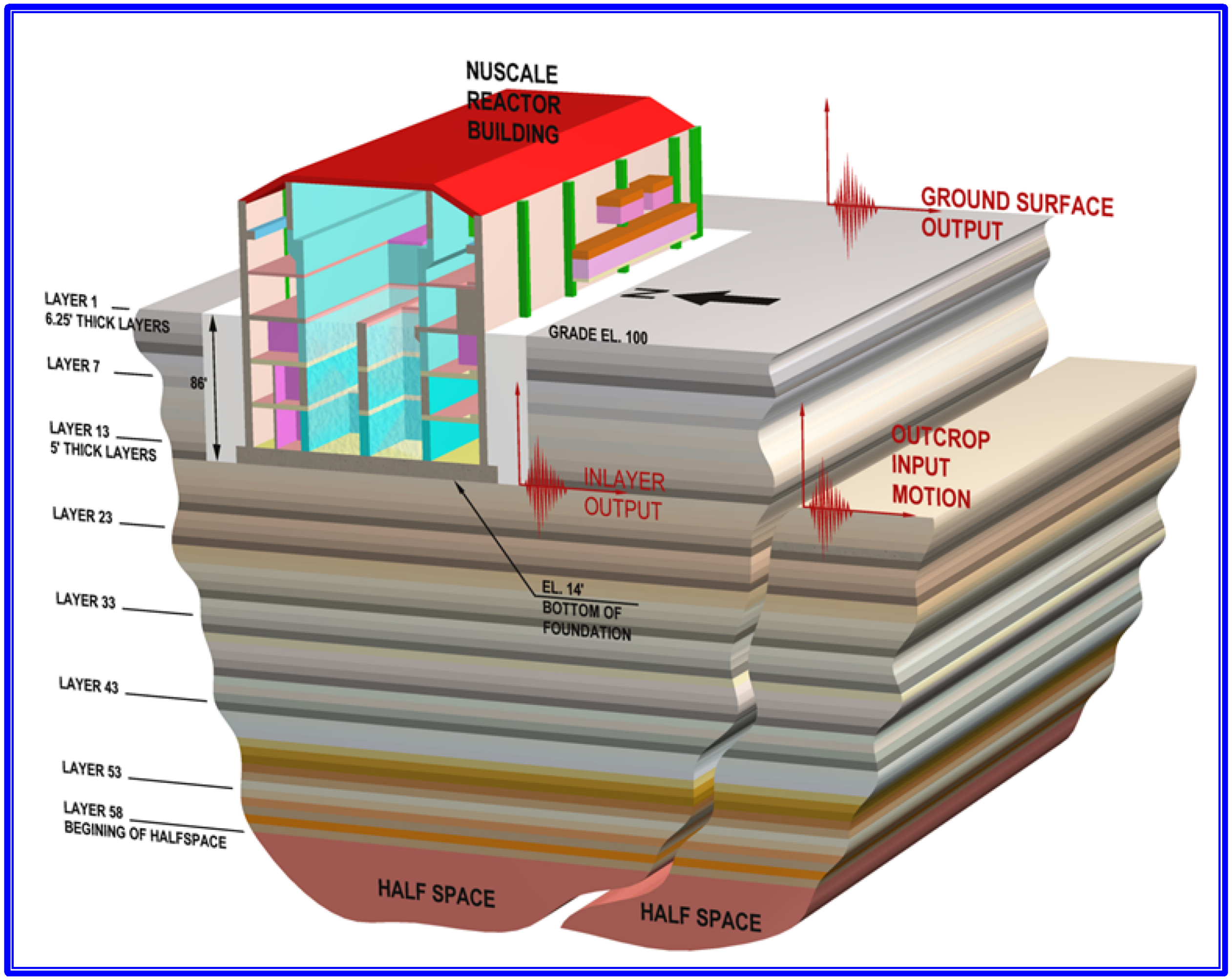


Figure 3.7.1-18: Density for All Soil Types

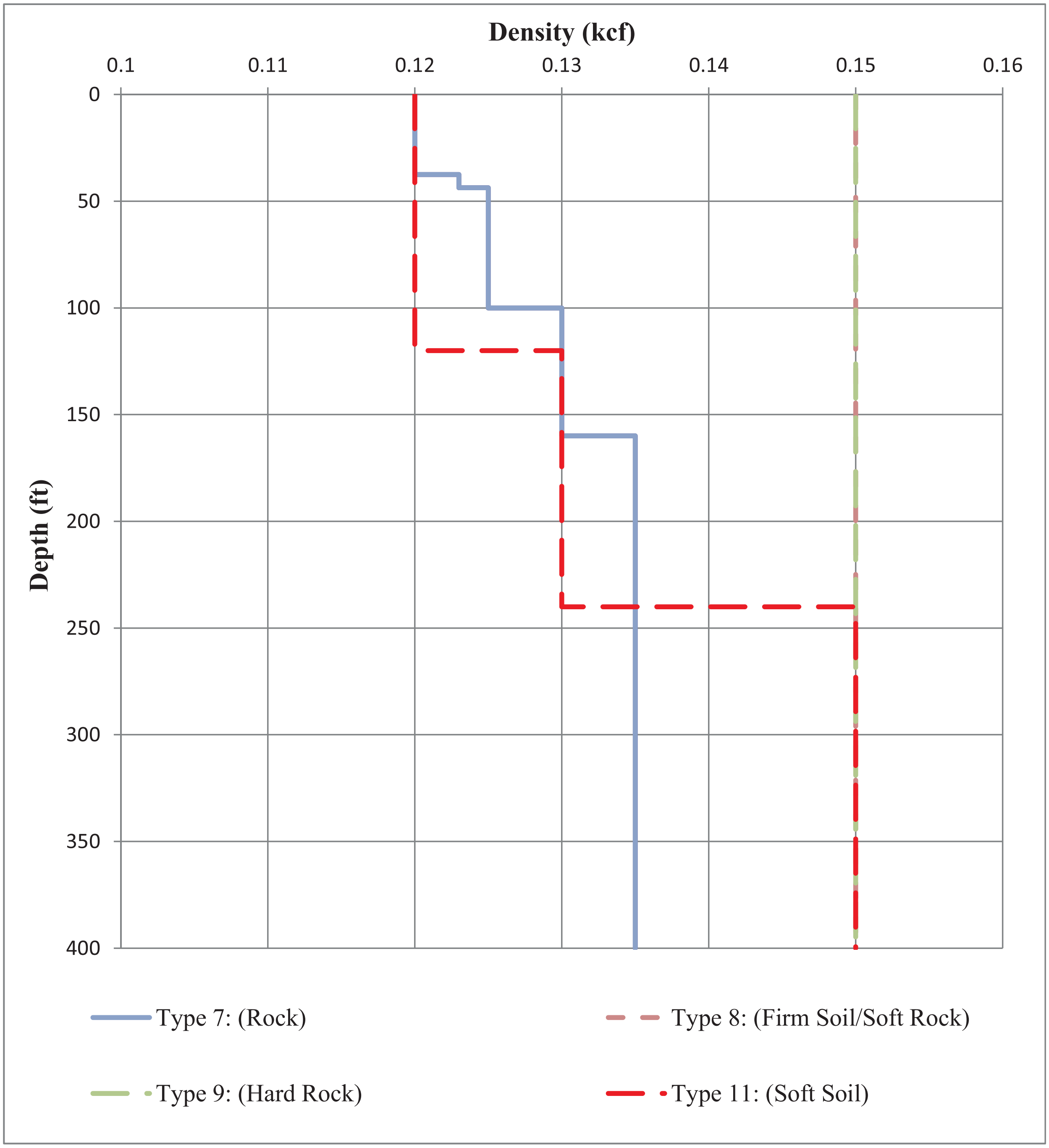


Figure 3.7.1-19: Average Strain Compatible V_S Profiles for CSDRS Compatible Inputs

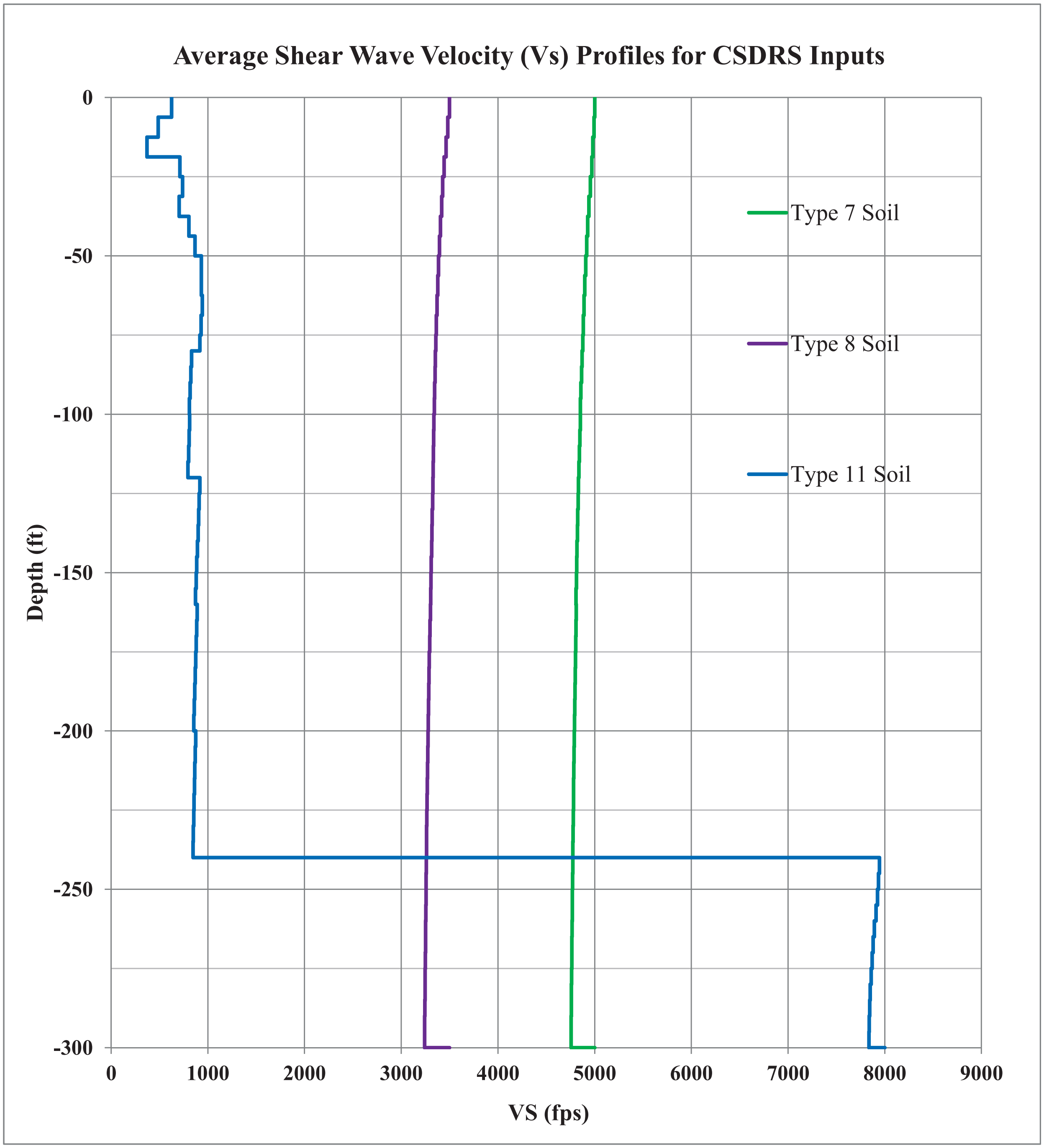


Figure 3.7.1-20: Strain Compatible V_s Profiles for CSDRS-HF Compatible Input

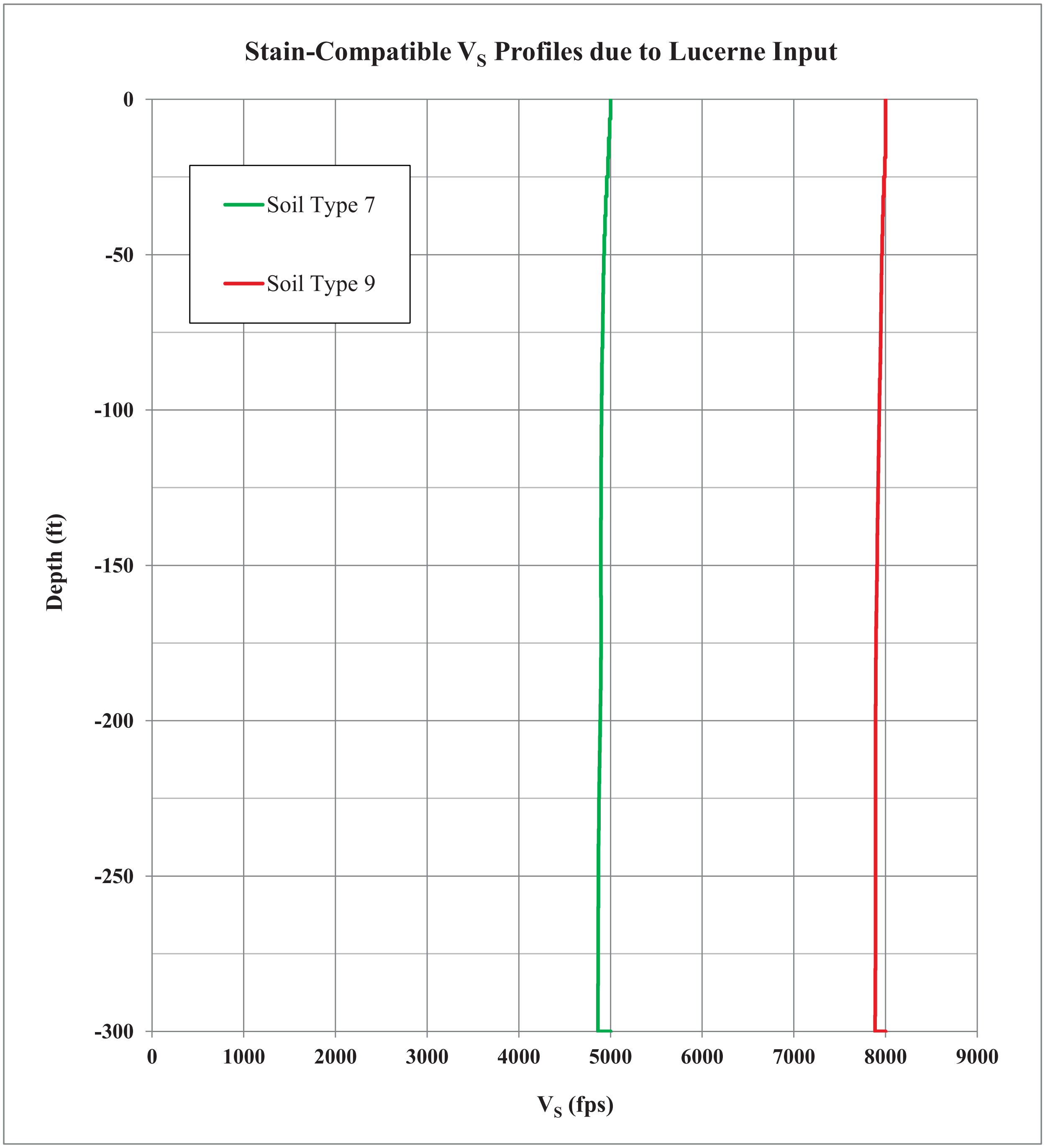


Figure 3.7.1-21: Strain Compatible Damping for Soil Type 7 for CSDRS Compatible Inputs

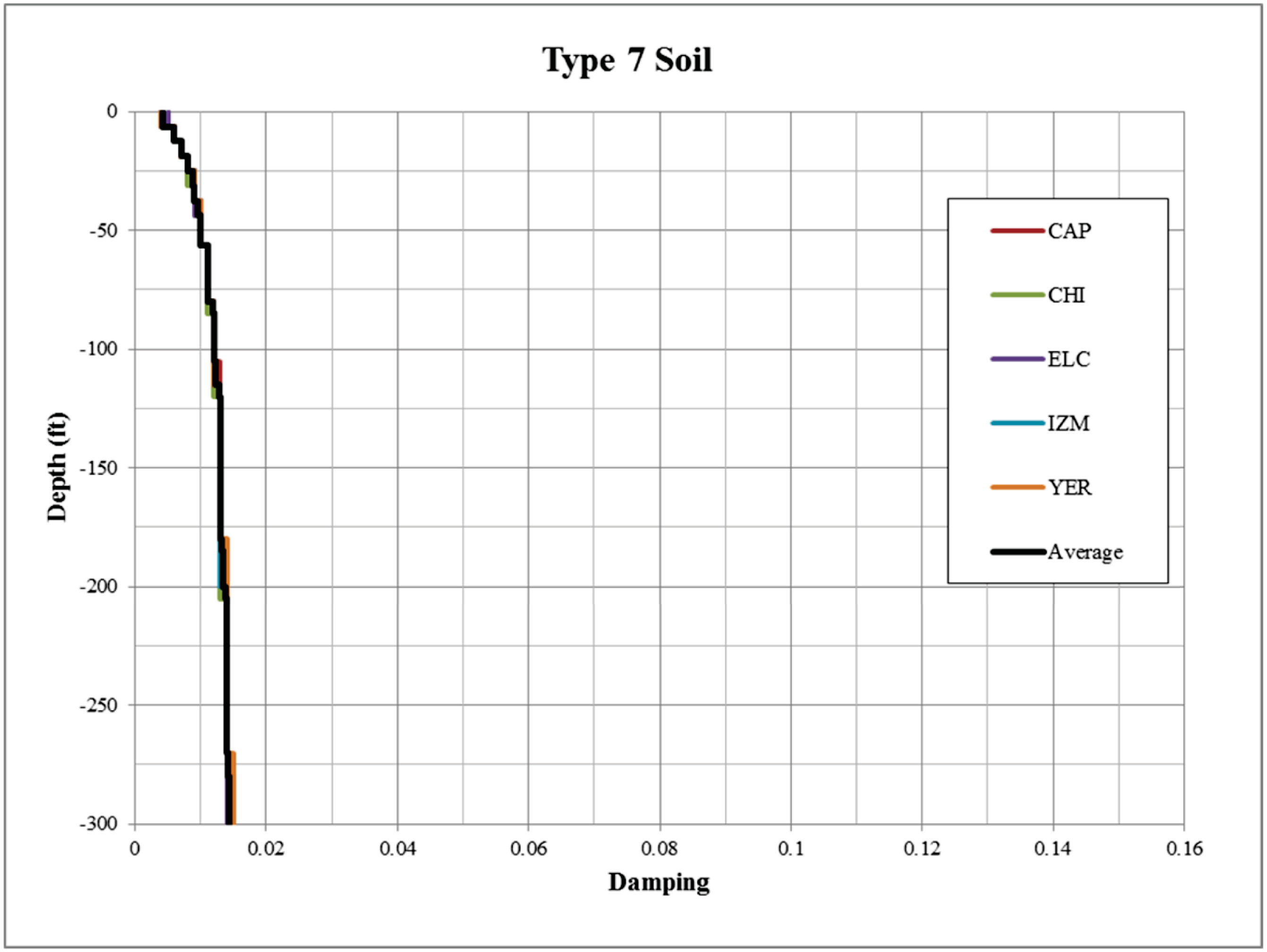


Figure 3.7.1-22: Strain Compatible Damping for Soil Type 8 for CSDRS Compatible Inputs

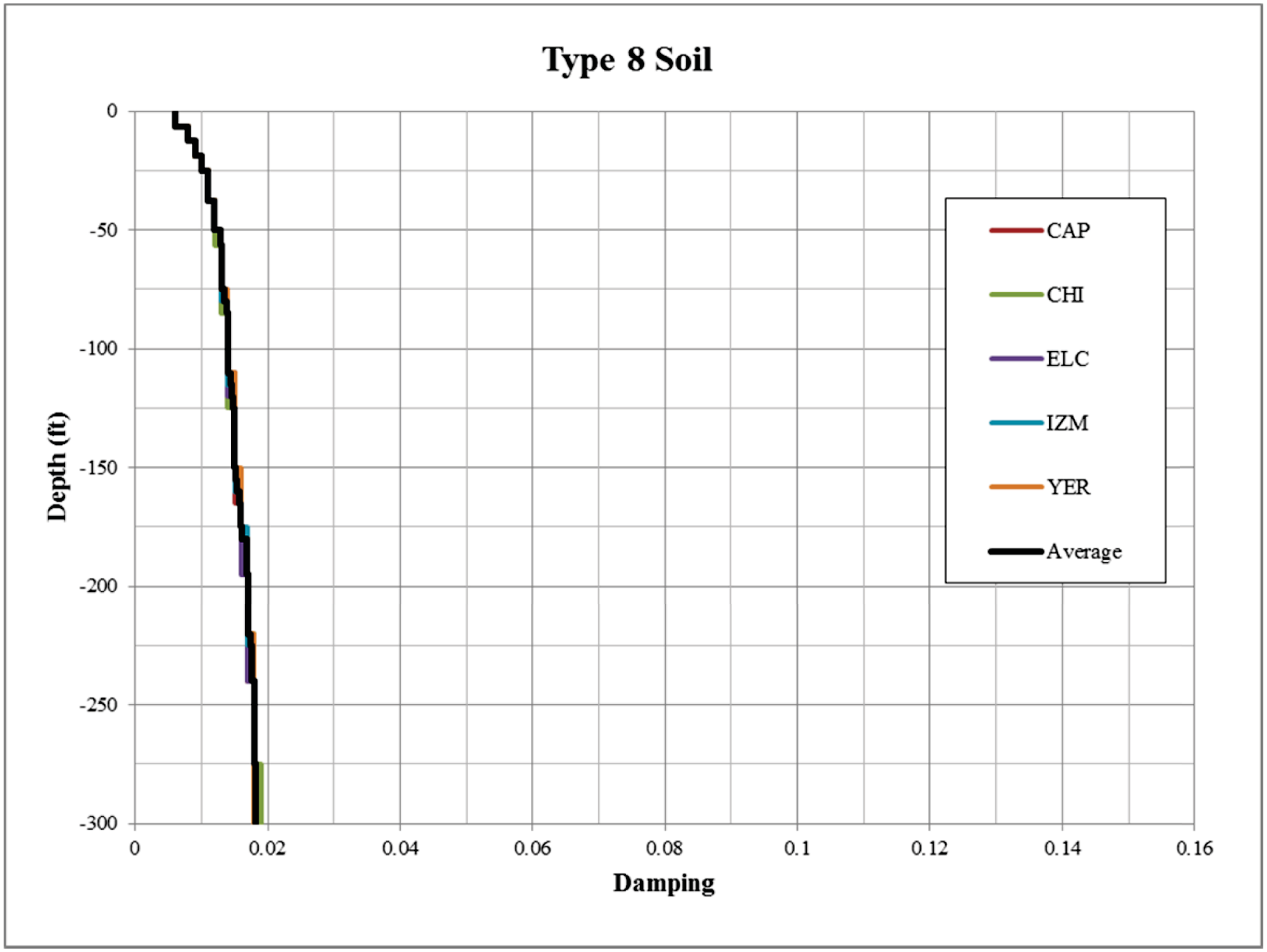


Figure 3.7.1-23: Strain Compatible Damping for Soil Type 11 for CSDRS Compatible Inputs

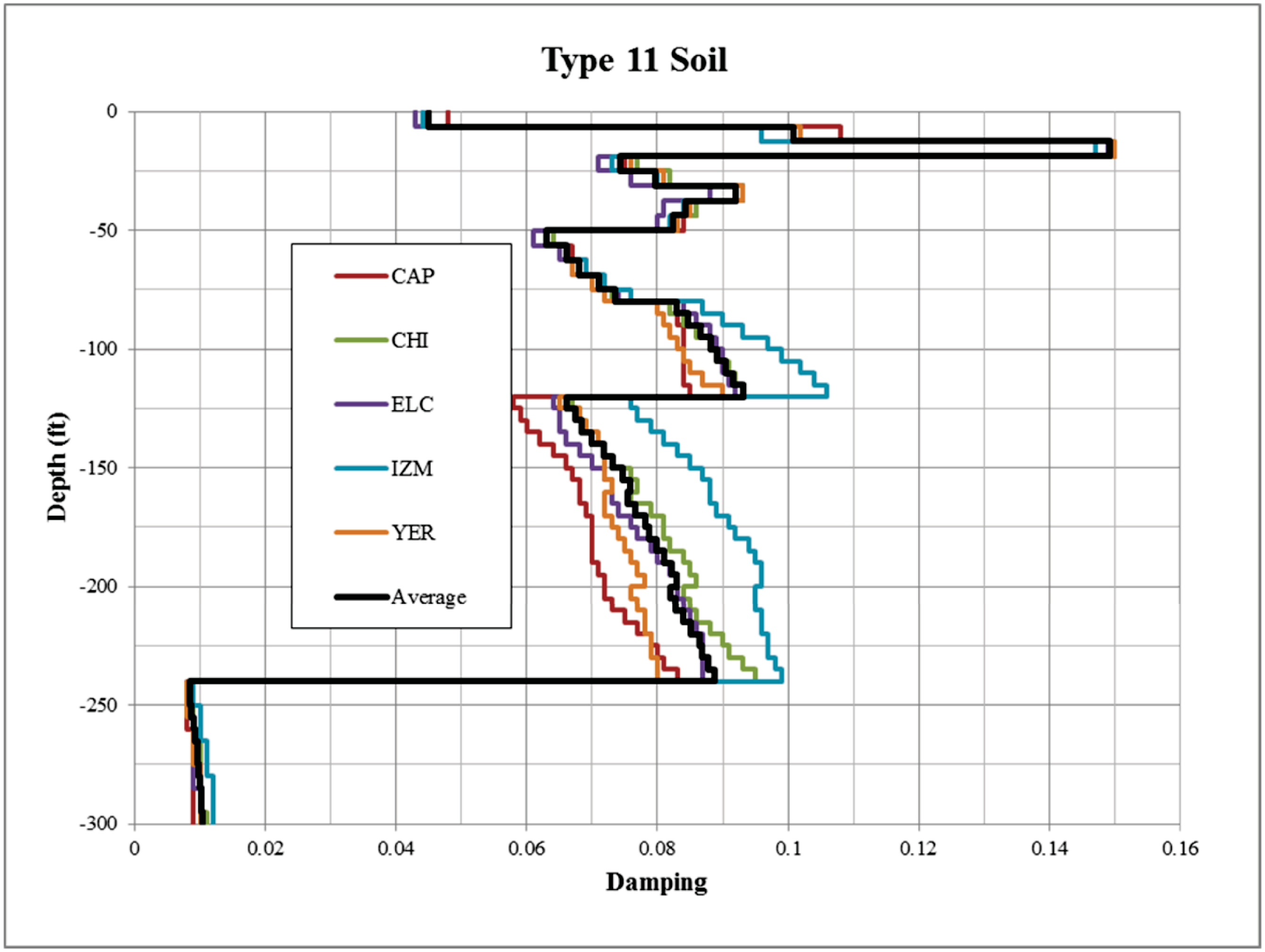


Figure 3.7.1-24: Comparison of Average Strain Compatible Damping for CSDRS Compatible Inputs

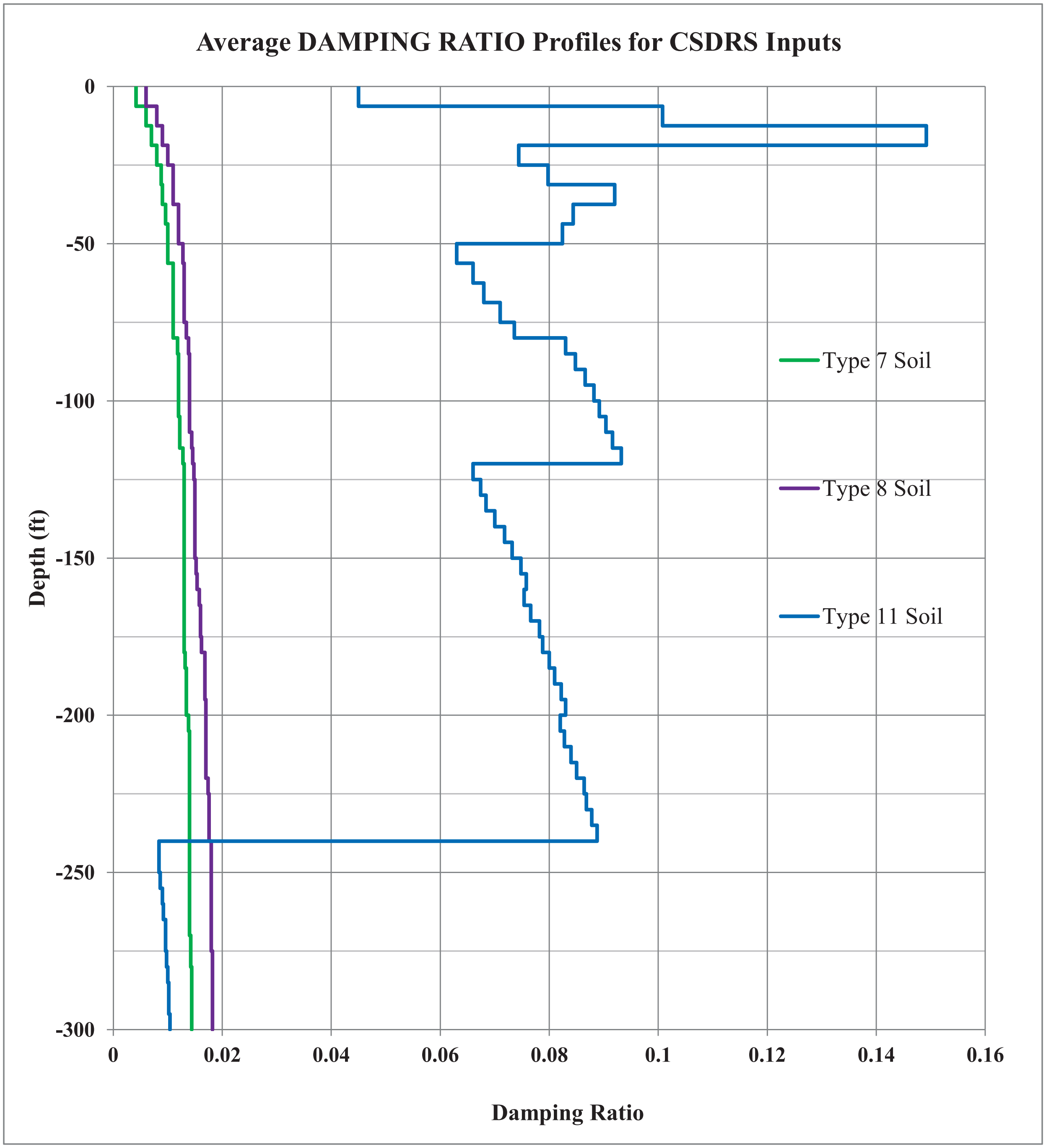
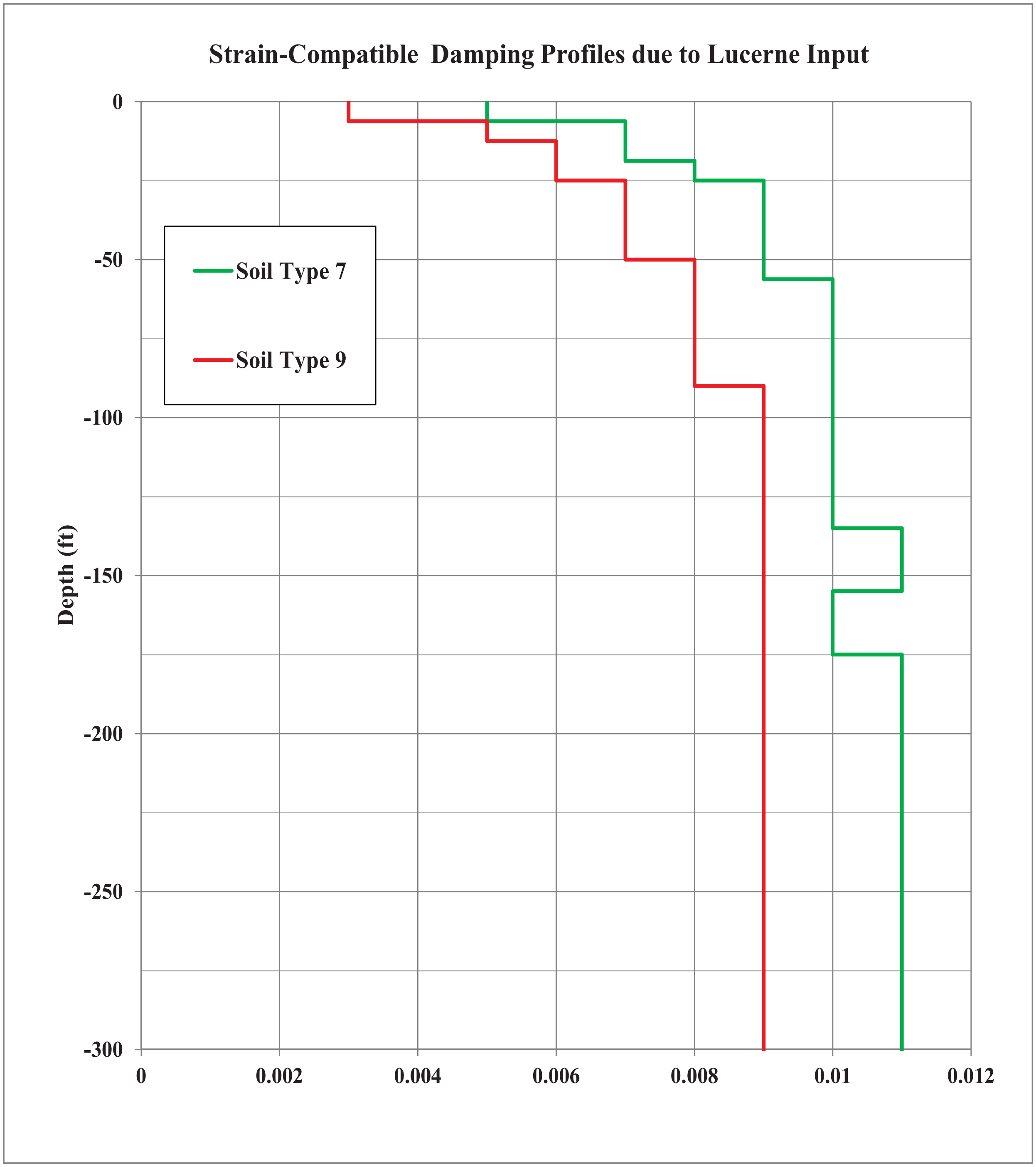


Figure 3.7.1-25: Comparison of Strain Compatible Damping for CSDRS-HF Compatible Input



3.7.2 Seismic System Analysis

There are only two site independent Seismic Category I structures, the RXB and the CRB. The RXB is designed for up to twelve installed NPMs. The structural analysis is performed with all twelve modules in place. Section 3.7.2.9.1 provides discussion about the effect on the structure if a seismic event were to occur during operation with less than the full complement of twelve NPMs.

Due to its proximity to the RXB, the Radioactive Waste Building (RWB) is categorized as Seismic Category II. The RWB is also classified as RW-IIa (high hazard) in accordance with Regulatory Guide (RG) 1.143, "Design Guidance For Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants," Rev. 2. The RWB is designed using the same methodology as the Seismic Category I structures. The interaction of the Seismic Category II RWB with the Seismic Category I RXB is discussed in Section 3.7.2.8.

The RXB, CRB, and RWB are shown together in Figure 3.7.2-1 and in a cutaway view in Figure 3.7.2-2. The origin of the global coordinate system of the finite element models is located at the centerline of the bottom of the RXB foundation at the west end of the building. This location is shown in Figure 3.7.2-3 and Figure 3.7.2-4. The X axis is in the east-west direction with east positive. The Y axis is north-south with north positive, and the Z axis is vertical with up positive.

Site specific seismic analysis is discussed in Section 3.7.2.16.

3.7.2.1 Seismic Analysis Methods

The seismic analysis of Seismic Category I SSC use linear equivalent static analysis, linear dynamic analysis, complex frequency response methods or nonlinear analysis and are designed to withstand the effects of the SSE and remain functional in accordance with Regulatory Guide 1.29. The two site independent Seismic Category I structures, the RXB and the CRB, are primarily analyzed using the time history method, and supplemented with additional analyses as described in the following sections.

3.7.2.1.1 Computer Programs

The RXB and CRB are analyzed using three commercially available computer programs: SAP2000 (Reference 3.7.2-1), SASSI2010 (Reference 3.7.2-2) and ANSYS (Reference 3.7.2-3). Each of these three programs is described briefly below. Validation of software is discussed in Section 3.7.5. A summary of the analysis cases is provided in Table 3.7.2-35.

3.7.2.1.1.1 SAP2000

The RXB and CRB finite element models are developed using SAP2000. These models are the master models. The finite element models used with ANSYS and SASSI2010 are created from the SAP2000 models. The structural analyses are performed using SAP2000 as described in Section 3.8.4.

3.7.2.1.1.2 ANSYS

A finite element structural analysis model of the RXB was developed using ANSYS to determine the hydrodynamic pressures on the reactor pool walls and foundation from a Fluid-Structure Interaction analysis. This was necessary since neither the SAP2000 nor SASSI2010 computer programs have an explicit fluid element formulation to accurately calculate the hydrodynamic effects due to all three directional components of earthquake input motions. The ANSYS model of the RXB is based on the SAP2000 model. The use of ANSYS to develop correction factors is described in Section 3.7.2.1.3.4. The addition of the water mass that is modeled with fluid finite elements is meshed accordingly to match the existing meshing of the RXB and NPM finite elements.

3.7.2.1.1.3 SASSI2010

For the seismic analyses, the finite element models of the RXB and CRB developed using the SAP2000 computer program are converted to SASSI2010 models with identical input data of the geometry, material properties, element connectivities, and boundary conditions. The SASSI2010 models are used to perform soil structure interaction (SSI) analysis. In addition to individual models for the RXB and CRB, a large-scale finite element model was constructed that includes both buildings and the Seismic Category II RWB. This model is referred to as the triple building model and is used to examine structure-soil-structure interactions (SSSI). SASSI2010 can handle models in excess of 100,000 nodes with approximately 20,000 interaction nodes. SASSI2010 analyzes the finite element models using the Complex Frequency Response Analysis Method. To perform the analysis, the time history of input ground motion is transformed to the frequency domain by fast Fourier transform. The seismic responses calculated in the frequency domain are then transformed back to the time domain by inverse fast Fourier transform.

Model Dimensions

In the vertical direction, the finite element model of each building extends to the bottom of the foundation. In performing the analyses, soil layers to 300 feet below grade level are included. Below 300 feet, the parameters (shear wave velocity, density and poisson's ratio) of the four generic soil profiles described in Section 3.7.1.3.1 remain constant. Therefore the variable depth method of SASSI2010 is used to add soil layers in order to simulate a semi-infinite halfspace at the bottom of the soil layer base.

In the horizontal direction, the finite element model of each building is extended out 25 feet around the entire perimeter of the building, to model the backfill soil. Beyond the 25 foot backfill soil region, SASSI2010 extends the parameters of the in-situ or free-field soil (i.e., Soil Type 7, 8, 9 or 11) as a semi-infinite elastic half space.

Free-field soil is included in the triple building model. This model has an overall length of 2005.5 feet, a width of 768.5 feet and a depth of 360 feet. For dynamic analysis of the triple building model using SASSI2010, the free field boundaries extends to elastic halfspace implicitly. This is accomplished by SASSI2010 itself. For static analyses, the SAP2000 models explicitly adds the free field soil beyond the backfill soil boundaries. The triple building model is used to determine the static response of the three buildings including the effects of differential displacements. The vertical depth is deeper than the SSI model. At this depth, the vertical displacement become insignificant due to soil stiffness. The horizontal boundaries are also extended a sufficient distance to have insignificant change in the static response of the buildings.

Cut-off Frequency

For the analysis of Soil Types 7, 8 and 11 with the CSDRS the cut-off frequency was established at 52 Hz. This is higher than the wave passing frequency of the soft soil profile (Soil Type 11) but less than the passing frequency of the other two soils (see Table 3.7.1-20). The low wave passing frequency of the soft soil is not a concern. Although high frequency content is not transmitted into or through the building for Soil Type 11, it is transmitted by the Soil Type 7 and Soil Type 8 profiles and by the Soil Type 7 and Soil Type 9 profiles evaluated with the CSDRS-HF. The buildings and associated SSC are designed to remain operable following any of these earthquake/soil combinations, therefore high frequency content is addressed in the design of the site independent Seismic Category I structures by the use of soil profiles that are stiffer than Soil Type 11.

For the analysis with the rock profiles (Soil Type 7 and 9) and the CSDRS-HF, the cut-off frequency was established at 72 Hz. The CSDRS-HF at a cut-off frequency of 72 Hz is less than the peak ground acceleration frequency, which occurs at 100 Hz. Using a 72 Hz cut off frequency is acceptable because it is above the frequency where maximum acceleration occurs (25 Hz horizontal and 50 Hz vertical).

The building models have element sizes that are similar to the 6.25 feet layers that were used to determine the wave passage frequency of the soil. There are instances where development of the model required individual elements to have a dimension as large as 12 feet in the RXB and as large as 20 feet in the CRB. However, the typical element size is approximately 6 feet. Therefore the wave passage frequencies of both buildings is above the cut-off frequencies used for the analysis.

In the CRB model, the elements with large dimensions or aspect ratios are nonstructural areas or membrane elements used for the purpose of applying wind loads to the steel beams and columns of the steel frame structure above elevation 120 ft. The 20 ft elements are located on the north and south walls whereas the 12 ft elements are located on the east and west walls above elevation 120 ft. Similar surface area loads are applied to the CRB roof to evenly distribute applied loads. The loads are applied as surface pressure on these areas and then transferred to the structural elements through the shared nodes. These coarse elements are not present in the seismic analyses and will not, therefore, affect the seismic demand results. In the RXB model, there are 24 elements with approximate dimensions of 12 ft x 6 ft at the pool floor. These are transition solid elements beginning in the top layer of solid elements used to model the basemat. The mesh transitions into the uniform soil mesh, matching the soil interaction nodes at the base elevation of the basemat, with an average element size of approximately 6.25 ft. The single layer of coarse basemat transition elements have minimal or no effect on the seismic analysis results.

Modeling Approach

Analysis Methods

There are several modeling approaches that can be used for modeling the excavated soil in the SSI analysis: the direct method (DM), the subtraction method (SM), the modified subtraction method (MSM), and the extended subtraction method (ESM). Each method has different computational demands. A brief discussion of the different methods follows:

The direct method partitions the soil structure system between the building and the excavated soils. It requires only the free-field motions and the free-field soil impedances to compute the seismic excitations on the foundation of structure. The soils to be excavated are retained with the foundation. Therefore, interaction between the structure and the foundation is calculated at all excavated soil nodes. In the analysis, the DM treats all translational degrees of freedoms of the excavated soil as SSI interaction nodes. This corresponds to a theoretically exact SSI model for the excavated soil dynamics. DM analysis is computationally intensive and cannot be used with the large detailed models created for the NuScale buildings.

To reduce computational time, a simplified method, called the subtraction method, was developed. The SM assumes only the nodes at the interface of the excavated soil volume and surrounding free field soils act as interaction nodes. In mathematical implementation, only those specified interaction nodes are described by equations of motion. The seismic load component and free-field soil impedance are neglected for the non-interaction nodes within the excavated soil volume. Therefore, the excavated soil motion can produce spurious vibration modes. This simplification results in anomalies in the transfer functions, usually seen as spurious spikes for soft free-field soils at relatively high frequency ranges. The SM approach for the excavated soil can be visualized as the five planes that represent the sides and bottom of the "box" that models the excavated volume.

The modified subtraction method includes the nodes at the ground surface of the excavated soil as interaction nodes. The MSM approach for the excavated soil can be visualized as the six planes that represent the sides, bottom, and top of the "box" that models the excavated volume. The inclusion of the ground surface nodes as interaction nodes provides significantly improved boundary conditions and improves the excavated soil response accuracy.

Within SASSI2010, a further enhancement of the MSM is available; this methodology is called the extended subtraction method. In the ESM, intermediate planes may be defined within the excavated volume. The addition of intermediate planes reduces the amount of interpolation that must be performed within the excavated volume, and further improves the accuracy of the excavated soil response. As additional planes are added, the ESM approaches the DM in both accuracy and computational time. The NuScale buildings are evaluated with an ESM model.

<u>Ensuring Accurate Results</u>

Both the MSM and ESM reduce the potential for the spurious results produced by the subtraction method. The use of intermediate planes in the ESM method make it even less likely than the MSM to produce inaccurate results. When they occur, these errors can be seen in the transfer functions. However, due to the size and complexity of these models, it is not practical to review transfer functions at all the nodes in the models. Therefore, errors are found by questioning unexpected results. Transfer functions at several key locations were investigated. Spurious spikes were found in a few transfer functions, which are due to the built-in interpolation functions in the software. However, the corresponding seismic input at those frequencies were insignificant, therefore, the corresponding in-structure response spectra (ISRS) do not have any spurious peaks. Based on the ISRS examinations and nonexistence of any spurious peaks in the ISRS, it is concluded that the spurious spikes have no effect on the ISRS or the RXB design.

The design process for the site-independent RXB and CRB is to consider multiple soil types, two building stiffnesses (for cracked and uncracked concrete), and multiple time histories. This large data set makes it more likely to notice an anomaly, since it is unlikely to occur in all the different combinations used as input.

For the CSDRS, the results from five time histories were averaged for each soil type to produce a single set of results for that soil type. These results are then combined and the maximums are used (i.e., the results are enveloped). For the determination of forces, moments, and shears, the results from the CSDRS-HF analysis are also included and, thus, bounded by the design. Averaging reduces the potential for a spurious peak to drive an overly conservative design. Bounding the two stiffnesses and various soil combinations ensures that a spurious low point will not result in an inadequate design.

Two other aspects of the design process also ensure the acceptability of the structures.

- Standardized design of walls. The thicknesses and internal steel reinforcement of the primary walls are generally consistent throughout each building. Areas where forces are lower are not optimized for the local load.
- Site-independent design. A site-specific analysis is performed to confirm that the design is adequate for that specific location. A different SSE and soil column will not produce anomalies at the same locations. A spurious low point will not result in a change to the standardized design.

Benchmarking

For the analysis of the Seismic Category I RXB and CRB with the extended subtraction method, a single intermediate plane was used. This approach is designated as 7P, to reflect the four sides of the excavated volume, and the top, bottom, and middle horizontal planes. Benchmarking of the 7P approach was performed by comparing the results to the DM and to a nine plane model.

7P vs Direct Method Comparison

Comparisons between the DM and 7P ESM have been performed for the CRB and RXB. ISRS and transfer functions have been generated from both methods and compared.

The ISRS calculated by the CRB 7P model are very close to those calculated by the DM model. There are some increases found in several ISRS. A direct comparison with the DCA ISRS cannot be provided due to differences in the structural damping values used in the CRB ISRS generation model (4 percent structural damping) and the CRB design model (7 percent structural damping).

However, the ISRS generated at 7 percent structural damping for 7P and DM produced results that are within 15 percent of each other. Most corresponding values from each model are the same.

The transfer function shapes calculated by the CRB 7P model are nearly identical to those calculated by DM, with the exception of a few peak values. No spurious peaks are found in the transfer functions.

Additionally, forces, moments, and displacements in the CRB exterior walls from both methods are compared. These results are within 10 percent of each other. See Table 3.7.2-46 and Table 3.7.2-44.

To use the direct method for the SASSI SSI analysis of the full RXB model, the number of required interaction nodes (28,830) exceeds the SASSI2010 program limit of 20,000. Therefore, a half model was used to obtain the results by the DM.

The ISRS calculated by the RXB 7P model are also within 15 percent of those calculated by the DM model. Similar to the CRB, the transfer function shapes show excellent agreement between 7P and DM, except at a few peak values. At some limited locations in the model, large differences are observed at specific frequencies which do not affect the results.

No spurious peaks are introduced in most of the RXB transfer functions. Spurious spikes are seen in some transfer functions for both 7P and DM, but do not affect the RXB ISRS. Oftentimes, adding a frequency point or shifting the frequency close to a spike location eliminates the spurious spike.

Soil pressures, forces, moments, and displacements at key locations in the RXB are also compared between the two methods. These comparisons show that the 7P and DM differ, at most, 20 percent from each other. The 20 percent difference in response is between the soil pressure in the north RXB wall at the EL 307.5" soil layer. However, the larger response comes from the 7P model, and is, thus, bounding. See Table 3.7.2-48, Table 3.7.2-45, and Table 3.7.2-47.

<u>7P vs 9P Comparison</u>

In the 9P model, additional planes are added above and below the center plane, halving the vertical distance used for interpolation of results. This benchmarking was performed to confirm that the results of the 7P and 9P model were similar and further confirms that the ESM approaches the DM in accuracy.

The comparison of 7P to 9P is accomplished by looking at the in-structure response spectra (ISRS) at three locations in the reactor building:

- The northeast corner on top of the basemat as shown in Figure 3.7.2-5.
- The NPM1 East bay wall at the lug support as shown in Figure 3.7.2-6.
- The center of the roof slab as shown in Figure 3.7.2-7.

In addition, bending moments at the center of the roof are compared to investigate if the moment responses calculated by the analysis using the 7P interaction nodes are close to those from the analysis using the 9P interaction nodes. These comparisons are performed with the CSDRS and all five CSDRS-compatible time histories for Soil Type 11 (soft soil) and Soil Type 7 (rock) using cracked concrete and 4 percent damping.

The 7P versus 9P ISRS comparisons for the Capitola time histories are provided in Figure 3.7.2-8, Figure 3.7.2-9, and Figure 3.7.2-10. The corresponding results for the other time histories are similar. As can be seen in these figures, there is very close correlation between the 7P and 9P models, with the larger variation occurring in the soft soil. This level of agreement justifies using a 7P versus a 9P model and, because the results are similar, demonstrates the acceptability of using the extended subtraction method as an alternative to the direct method.

While the results are similar, they are not exact. This difference is not a concern because of the methodology used in developing accelerations and forces in the structures. Each building is evaluated with several soil types and two stiffnesses. In addition, for the CSDRS, five separate time histories are evaluated, and the results are averaged.

COL Item 3.7-15: A COL applicant that references the NuScale Power Plant design certification will determine the appropriate site-specific number of interaction planes for soil structure interaction.

Cracked Model Stiffness

For SASSI2010 analyses, the plate stiffnesses are only controlled by two input parameters. The two parameters are the Young's modulus and the plate thickness. It is not possible to reduce the bending stiffness by 50 percent for cracked concrete while preserving the axial stiffness at 100 percent for in-plane forces by modifying Young's modulus. A compromise approach is used by reducing the thickness by a factor equal to cubic root of 0.5, or 0.7937 to reduce the bending stiffness in half for the cracked concrete condition. In this approach, the uncracked axial stiffness is reduced by a factor of 0.7937.

Soil Separation

A study was performed to investigate the effects of a gap forming between the RXB and the backfill soil during an earthquake.

The RXB was analyzed for Soil Type 7 with cracked concrete properties and 7 percent concrete material damping. Soil Type 7 was chosen because that is the case that produced the highest ISRS and forces and moments at the majority of the locations. Cracked concrete properties were chosen to be consistent with the use of 7 percent damping for the concrete material.

To model the soil separation, the Young's modulus of the backfill elements down to a depth of 25’ (the top four layers of backfill elements) was decreased by a factor of 100.

Soil separation has minimal effect on the response of the structure. The following responses and transfer functions calculated without soil separation are compared with those calculated with soil separation:

- **Forces at RXM Lug Supports**

  The comparison indicates that the lug support reactions with soil separation are lower than those without soil separation. See Table 3.7.2-39.

- **ISRS and TFs at Selected Locations**

  The comparison of the spectral acceleration transfer functions (TF) at selected locations indicates a few spurious spikes in the high frequency ranges that have no effect on the corresponding ISRS. See Figure 3.7.2-130 through Figure 3.7.2-135.

- **Soil Pressures on Walls**

  The comparisons show that there are increases in the average pressures. However, there is no increase in the maximum forces and moments in the walls.

- **Maximum Shears and Moments in Exterior Walls and Two Pilasters**

  The maximum out of plane (OOP) shear remains about the same. The maximum OOP moment decreases about 10 percent due to soil separation. See Table 3.7.2-40.

  The total vertical base reaction remains essentially unchanged. See Table 3.7.2-42.

The ISRS, displacements, and demand forces and moments due to soil separation effects investigated above are within the design capacities. Therefore, the effect of backfill soil separation is covered by the available design margin and has no effect on the overall RXB design.

A soil-separation study was also done for the CRB. To account for the effect of partial soil separation in the analysis model for the study, the Young's moduli of the backfill soil solid elements down to 1/3 of the embedment, which is approximately equal to the total thickness of the top three layers of backfill soil (18.75′), were factored by 1/100. Conclusions similar to those of the RXB were reached, i.e., the spectral acceleration transfer functions and ISRS at critical locations between the two models virtually overlay one another, increases in forces due to soil separation are within design margins of the building components, leaving the building design unaltered. See Figure 3.7.2-136 through Figure 3.7.2-141 and Table 3.7.2-41 and Table 3.7.2-43. The soil separation study did result in minor modifications to two vertical ISRS in the CRB - at elevation 63'-3" and 76'-6". The final floor response spectra is shown in Figure 3.7.2-118a and Figure 3.7.2-119a, respectively.

Based on the results of these studies, it is concluded that modeling the structures as fully embedded is an acceptable design approach. This will be confirmed through a site-specific evaluation as described in COL Item 3.7-11.

COL Item 3.7-11: A COL applicant that references the NuScale Power Plant design certification will perform a site-specific analysis that assesses the effects of soil separation. The COL applicant will confirm that the in-structure response spectra in the soil separation cases are bounded by the in-structure response spectra shown in FSAR Figure 3.7.2-107 through Figure 3.7.2-122.

Effect of Non-Vertically Propagating Seismic Waves

A sensitivity study was performed to determine the effect of non-vertically propagating shear waves. This study, first, establishes a procedure for evaluating a structure that experiences non-vertically propagating seismic waves, and second, analyzes the RXB DCA model with non-vertically propagating seismic waves.

The intent of the SSI analysis study with non-vertically propagating (that is, inclined) waves is to compare the SSI results with those of the design-basis case, which uses conventional, vertically propagating shear (SV and SH) and P-waves for the seismic input. A body wave (either SV- or P-wave) propagating at an inclined angle will include both horizontal and vertical motions in the free field, whereas an inclined SH-wave generates only horizontal motion in the free field.

For the sensitivity study, Soil Type 7 was selected for the free-field soil properties because it is a nearly uniform soil profile with a high shear wave velocity, Vs, of 5,000 ft/sec. Using a uniform and stiff soil for this study will give conservative results because, for non-uniform and soft soil profiles, the angle of incidence decreases as the wave propagates toward the surface, due to Snell's law and, thus, the effect of non-vertically propagating waves will be much less.

Analyses were performed and results compared for the following angles of incidence, α, where α is measured from the vertical axis (see Figure 3.7.2-149):

$\alpha = 0°$ or apparent wave velocity = ∞, that is, the vertically propagating wave case

$\alpha = 17°$ or apparent wave velocity $\approx$ 5,000 / sin(17°) = 17,100 ft/sec (5.2 km/sec)

$\alpha = 30°$ or apparent wave velocity $\approx$ 5,000 / sin(30°) = 10,000 ft/sec (3.0 km/sec).

For the non-vertically propagating wave cases, the control point must be at the surface. If the control point were at the foundation level, there would be a shift in the soil column frequency of inclined waves. But because the in-layer motion at the foundation level is determined for $\alpha = 0°$, there would be a mismatch in the soil column frequency between the in-layer motion and the non-vertically propagating wave. This would result in incorrect responses being generated. Therefore, the control point is taken at the surface.

Free Field Acceleration Response Spectra

When combining the horizontal responses due to inclined SV-waves with the horizontal responses due to inclined P-waves, it is implied that the corresponding coupling responses in the free-field at the foundation level are also combined. This combination of the free-field responses at the foundation level due to inclined waves results in response spectra at the foundation level which are much higher than the design-basis, foundation CSDRS and, thus, violate the design basis of the plant.

In the comparison of acceleration response spectra (ARS) in the free field, the $\alpha = 0°$ (vertically propagating) curve represents the CSDRS case. The results from this case show the effect of the coupling terms due to non-vertically propagating waves. These results show that, even though the horizontal input motion at the surface is the same for all angles of incidence of inclined SV waves (Figure 3.7.2-150) the motion at the foundation depth exceeds those of the CSDRS (or FIRS) even without including the coupling terms from inclined waves. For example, see Figure 3.7.2-151. Figure 3.7.2-150 shows the X-response ARS at the surface due to SV-waves for $\alpha = 0°$, 17°, and 30°. Note that these curves are identical because the control point is at the ground surface. The CSDRS at the rock outcrop (dashed line) is shown for reference only. All three ARS at the surface due to SV-waves for $\alpha = 0°$, 17°, and 30° are identical. Once coupling terms from inclined waves are considered, the motion at the foundation depth far exceeds those of the CSDRS responses. For example, see Figure 3.7.2-152. Therefore, the coupling terms from inclined waves should not be included in the response calculation in order to properly maintain the as-defined design-basis seismic inputs, the CSDRS and CSDRS-HF.

Note that in the legends of the figures, “X/SV” means the X-response due to SV-wave input and “X/P” means the X-response due to P-wave input. Also, when a response is referred to as “CSDRS,” it means the “response due to the CSDRS-compatible input time history.”

ISRS Results

The SSI effects due to the RXB being subjected to non-vertically propagating waves are also studied. Comparisons of ISRS results for all angles of incidence with the broadened design ISRS show that there are exceedances at a few locations at narrow frequency bandwidths. These exceedances are due to the fact that the free-field within (in-layer) motions for inclined waves at depth exceed the corresponding motions from the CSDRS with vertically propagating waves, resulting in an effective SSI input motion that is higher than the CSDRS input motion. For a sample of results, see Figure 3.7.2-153 through Figure 3.7.2-155. In addition, if the complete set of time histories were used, the ISRS would smooth out and flatten.

Finally, it is concluded that combining the coupling responses due to non-vertically propagating waves can lead to overly conservative results. The combination of the free-field responses at the foundation level due to inclined waves results in a design response spectrum which is much higher than the CSDRS.

COL Item 3.7-13: A COL applicant that references the NuScale Power Plant design certification will perform a site-specific analysis that assesses the effects of non-vertically propagating seismic waves on the free-field ground motions and seismic responses of Seismic Category I structures, systems, and components.

3.7.2.1.2 Effect of an Empty Dry Dock

A study was performed to determine the effect of an empty dry dock on the response of the RXB. Three separate SASSI models were created for this purpose. The first was the RXB modeled with nominal NPM stiffnesses. The second was an RXB model with NPM stiffnesses multiplied by 1.3, resulting in an approximate +15 percent NPM frequency change in dominant modes. The third model included NPM stiffnesses divided by 1.3, resulting in an approximate -15 percent NPM frequency change in dominant modes. The following parameters were also used in the study:

- One set of CSDRS-compatible seismic inputs: Capitola.
- One soil type: Soil Type 7.
- One concrete condition: cracked.
- Two structural concrete damping ratios: 4 percent for ISRS generation and lug support reaction calculation and 7 percent structural damping for force and moment calculation.

The maximum forces and moments in the four RXB exterior walls and in the four walls around the dry dock, the lug support reactions at the 12 NPMs, and forces and moments in one pilaster in the north wall at column line RX-4, were calculated for the empty dry dock condition and compared with the corresponding design capacities based on the full dry dock condition. See Table 3.7.2-59 and Table 3.7.2-60 for a sample of results.

Comparisons between floor ISRS and ISRS at the Reactor Building crane wheels were also made. These plots can be found in Figure 3.7.2-172 through Figure 3.7.2-175.

Based on the comparison of the seismic demands and design capacities, the empty dry dock condition is bounded by the RXB design, which is based on the full dry dock condition. In addition, all ISRS from the empty dry dock condition are either bounded by or are within 10 percent of the full dry dock condition.

COL Item 3.7-14: A COL applicant that references the NuScale Power Plant design certification will demonstrate that the site-specific seismic demand is bounded by the FSAR capacity for an empty dry dock condition.

3.7.2.1.3 Finite Element Models

Meshing of the area elements was done automatically using SAP2000 by defining a maximum element size in each direction. The aspect ratios were also kept as low as possible (closer to square shape), and internal sharp angles were avoided.

Meshing for both the RXB and CRB models were refined further, and it is shown that further refinement does not affect the structural response. The mesh refinement was done by dividing each side of the area elements into two, breaking each element to four elements. The structural responses compared include both local and global responses of the structure. The comparison shows that effects of further mesh refinement on the structural response is negligible. In addition to the modal analysis, to compare the natural frequencies and mass participation ratios, static analysis cases due to 1g loading in the x, y or z directions were used to make different comparisons. Soil elements' height were determined based on 1/5th of the wave length.

Minor changes in the natural frequencies and their mass participation ratios indicate that other dynamic characteristics of the building models would not change by mesh refinement. To show that mesh refinement does not have a major impact on ISRS, comparisons were made of the ISRS based on the CSDRS-compatible Capitola ground motion and the CSDRS-HF-compatible Lucerne ground motion at a few key locations. The comparisons were between the same RXB and CRB stand-alone SAP2000 model and refined mesh building models used for the other compared structural responses. Results show that mesh refinement has an insignificant effect on the ISRS. The triple building model has the same mesh as the stand-alone model. Also, as it was mentioned, the SSSI effects are not expected to change with mesh refinement, therefore, no mesh sensitivity analysis was done for the triple building model.

3.7.2.1.3.1 Reactor Building

The RXB houses safety-related equipment and facilities pertinent to the operation and support of the NPMs and provides anchorages and support for various SSC. The RXB is a reinforced concrete structure that is deeply embedded in soil, and supported on a 10 foot thick foundation basemat. The RXB has an outside length (excluding pilasters) of 346.0 feet in the East-West direction, a width (excluding pilasters) of 150.5 feet in the North-South direction. The dimensions between the centerlines of the outer walls are 341' 0" by 145' 6". There are five pilasters along both the north and south walls and three pilasters on the east and west walls. These pilasters are 5.0 feet wide and extend 5.0 feet out from the wall. In addition, there are four corner pilasters. These pilasters are 12.5 feet wide and extend 2.5 feet out from the wall. The overall height is approximately 167 feet from the top of roof to the bottom of basemat. The embedment of the RXB is 86 feet. The baseline plant top of concrete (TOC) for the RXB is at Elevation (EL.) 100'-0". Although the actual site surface will be approximately 6 inches below the baseline elevation, and sloped away from the safety-related structures, "grade" is also considered to be at EL. 100'-0".

Section 1.2.2.1 contains additional discussion of the RXB and Figure 1.2-10 through Figure 1.2-20 provide elevation and section views of the building.

The predominant feature of the RXB is the ultimate heat sink (UHS) pool. This pool includes the spent fuel pool, refueling area pool, and the reactor pool. The dry dock is also assumed to be full of water and part of the UHS for the seismic analysis. This large pool occupies the center of the building and runs 80 percent of the length of the building. Although the pool and bay walls extend to the bioshields at EL. 126', the nominal top of the pool is at EL. 100'-0." The normal reactor pool water depth is maintained at 69 feet, which results in a water surface at EL. 94'-0". The reactor pool has bays to house up to twelve NPMs.

Both the NPMs and the water in the pool contribute a large amount of weight to the global mass of the RXB and thus impact the dynamic characteristics of the building.

The typical thickness for the main structural interior and exterior concrete walls is 5 feet, the primary floor slabs are 3 feet thick with reinforced concrete T-beams (2 feet by 2 feet). The basemat foundation thickness is 10 feet. The foundation TOC elevation is 24'-0". The foundation for the reactor pool area and spent fuel pool area is raised and has an elevation of 25'-0” at the top of the liner. The refueling area (southwestern pool region only) foundation is lowered and has an elevation of 19'-0" at the top of the liner. Several buttress elements and stiffener walls are located around the exterior or interior perimeter of the structure. The RXB roof has slopes on two sides with a flat segment in the middle; the roof slab thickness is 4 feet and the top of roof elevation is 181'-0".

A 3D view of the RXB is shown in Figure 3.7.2-11. Interior section views are shown in Figure 3.7.2-12, Figure 3.7.2-13, and Figure 3.7.2-14. These figures are for illustration purposes and do not reflect the actual soil strata. The embedded portion of the RXB is modeled with 25 foot thick backfill soil from grade to the bottom of the foundation.

Reactor Building SASSI2010 Model

Figure 3.7.2-15 shows the 3D view of the embedded SASSI2010 RXB finite element model. This figure includes the RXB itself, the backfill soil, and the excavated soil finite element mesh. The finite elements of the embedded portion of the RXB are masked by those of the excavated soil, which is shown in blue. Some of the beam elements can be seen in red. Figure 3.7.2-16 shows the SASSI2010 model from the same view point without hidden lines. The figure clearly shows the RXB is embedded in soil.

Figure 3.7.2-17 shows the backfill soil modeled by solid elements. For the SASSI2010 analysis, the properties of the backfill soil are assumed those of Soil Type 11. Figure 3.7.2-18 show the SASSI2010 finite element mesh of the RXB model, where the ground surface is indicated by a gray horizontal plane. In this figure, the rigid soil springs connecting the RXB and backfill soil model with the excavated soil model are seen as dots.

Figure 3.7.2-19 shows the excavated soil model without the hidden lines. The length, width, and height dimensions of the excavated soil are identical to those of the backfill soil shown in Figure 3.7.2-17. Figure 3.7.2-20 shows the north half of the SASSI2010 model without the hidden lines. The floors, beam elements modeling the pilasters in walls, and the six NPMs in the north side of the RXB and a portion of the reactor building crane can be seen modeled by beam elements in red. Figure 3.7.2-21 shows all beam elements in the SASSI2010 model.

The free field soil is defined such that the RXB with backfill soil can fit exactly to the 'pit' in the excavated soil halfspace. The connectivity between the RXB with backfill soil and the excavated free field soil is achieved by connecting the skin nodes of the excavated soil model with the nodes on the embedded skin of the RXB with backfill model using rigid soil springs. The skin nodes of the excavated soil model and the skin nodes of the RXB with backfill model have identical coordinates, and they are in one-to-one correspondence matching pairs.

The rigid springs have a zero length and have a stiffness value large enough to simulate rigid connection. The large stiffness used is arbitrarily chosen to be ten billion lbs per inch, or 10^{10} lbs/inch, in the three global directions. A sensitivity analysis was performed by increasing the stiffness of the RXB rigid springs by an order of magnitude, to 10^{11} lb/in, and comparing results obtained from the base case, rigid spring stiffness of 10^{10} lb/in. For this study, the RXB model with cracked concrete properties, 7 percent concrete damping, Soil Type 7, and the Capitola input motion, was used. Comparisons of transfer functions and ISRS show that increasing the rigid spring stiffness has no discernible effect on the transfer functions and ISRS.

The model dimensions, the quantities of elements and masses, and structural damping ratios used for the SASSI2010 model are summarized in Table 3.7.2-1.

The NPMs and the Reactor Building crane (RBC) are included in the RXB model as beam models. These two subsystems are discussed in the following sections.

The reactor building basemat is designed using a combination of different models. First, the structural responses from the building models are extracted. Then they are applied to separate basemat models to determine structural design forces and moments for the basemat. Table 3.7.2-49 and Table 3.7.2-50 show which models are used, what results are extracted, and how these results are used to design the basemat.

3.7.2.1.3.2 NuScale Power Modules

Up to twelve NPMs will be inside the RXB. The modules are partially immersed in the reactor pool. The NPMs are not permanently bolted or welded to the pool floor or walls. Instead they are geometrically supported and constrained at four locations. The geometrical constraints are designed to keep each NPM in its location before, during, and after a seismic event.

The base support is a steel skirt that rests outside a permanently installed ring plate attached at the bottom of the reactor pool. The other three geometrical supports are steel lug restraints located on the walls of each bay at approximately the midpoint of the module (~EL. 75’). The NPM has lugs that align with a slot in the restraint. Each restraint prevents movement in the direction parallel to the wall and allows the NPM to move freely in the upward direction. In other words, the lug and restraint provides only horizontal restraint in the in-plane direction for the supporting wall.

The lug and lug restraint combination is shown in Figure 3.7.2-22. Figure 3.7.2-23 shows the top view of a restrained NPM. The placement of the twelve NPMs in the model of the RXB is shown in Figure 3.7.2-24. An enlarged view of the NPM pool region is shown in Figure 3.7.2-25.

Figure 3.7.2-26 shows a view of the RXB model with twelve NPMs within the support walls. The lug restraints can be seen near the mid-height of the NPMs in the figure. Figure 3.7.2-27 shows a single NPM. In this figure, the lug restraint can be seen at the upper part of the NPM and the support skirt can be seen at the base of the NPM.

NuScale Power Module Model Included in the Reactor Building SASSI2010 Model

Within the SASSI2010 building model, the NPM is represented by a beam model as shown in Figure 3.7.2-28. The beam model was developed to have similar dynamic characteristics as a 3-D ANSYS model of a single dry NPM. To validate the NPM beam model, a modal analysis was performed in order to tune the simplified beam model to match the simplified 3-D model response. The frequencies for the most significant modes are shown in Table 6-21 of

TR-0916-51502 and demonstrate dynamic compatibility with the 3-D model by matching mode frequencies with significant mass participation, thereby assuring adequate force transfer through the building dynamic response. The simplified beam model captures the overall dynamic behavior of the 3-D NPM model required for the building response analyses used in the SASSI2010 and SAP2000 models. The skirt support at the base of the containment restricts horizontal and vertical movements. Eight rigid beams arranged like the legs of a spider are modeled to connect the NPM model containment skirt to nodes in the building model located at the interface of the skirt and pool floor. Table 3.7.2-36 and Table 3.7.2-37 outline the NPM beam model to RXB model interface boundary conditions for the SASSI2010 and ANSYS models, respectively.

Detailed NuScale Power Module Model Included in the Reactor Building SASSI2010 Model

The RXB-NPM interface and NPM specific analyses replace the simplified beam model with a more detailed NPM beam model. This more detailed beam model, described in Section 6.4 of TR-0916-51502, is generated by adding mass and spring elements to create a fluid structure interaction response that is equivalent to a 3D model of an NPM and pool bay, and is shown in Figure 6-14 of the technical report. The development and validation of the detailed beam model are described in Section 6.5 of TR-0916-51502. The reactor building model that uses the detailed NPM beam models is structurally similar to the SASSI2010 model previously described. Because fluid mass has been added to the detailed NPM beam model, a more enhanced methodology for modeling hydrodynamic mass in the pool area was used. This is described in Section 3.1.3 of TR-0916-51502. The NPM beam models are replaced with the detailed beam models for selected SSI analyses to evaluate the RXB-NPM interactions. The RXB analysis produces local acceleration time histories that are used as input to the NPM seismic analysis as described in Section 8.0 of TR-0916-51502. The seismic analysis of the NPM is discussed in Appendix 3A.

At the interface between the NPM and the RXB, the design loads for the skirt supports are defined as the envelope of the SASSI2010 building model and the 3-D model discussed in Appendix 3A and Appendix 3B.2.7. The lug supports are designed for a generic capacity in a detailed submodel and checked against the reaction forces from the SASSI2010 building model and 3-D model. This is described in more detail in Appendix 3B.2.7.

The RXB SAP2000 model, SASSI2010 model, and detailed NPM model described in TR-0916-51502 are the design basis analysis models to be used for COL Item validation.

3.7.2.1.3.3 Reactor Building Crane

The RBC is a bridge crane used to transport modules between the operating locations and the refueling and disassembly area and the drydock. The RBC travels on rails on the top of the reactor pool walls at EL. 145'-6". When not in use, the RBC is parked over the refueling pool with the trolley at the north end near the dry dock gate. In this position, the RBC is not above either the SFP or the NPMs. The RBC is described in Section 9.1.5.

Reactor Building Crane Model Included in the Reactor Building SASSI2010 Model

Figure 3.7.2-29 shows the beam and spring model used to represent the RBC. For the analysis of the RXB, the RBC is unloaded (i.e., no suspended NPM) and located in the middle of the reactor pool area as shown in Figure 3.7.2-24. The RXB analysis produces in-structure response spectra (ISRS) that are used as input to the RBC seismic analysis.

3.7.2.1.3.4 Ultimate Heat Sink Pool

The UHS pool contributes a large amount of weight to the global mass of the RXB. This fluid impacts the dynamic characteristics of the building. Figure 3.7.2-30 provides a visualization of the hydrodynamic structural system (building and UHS pools). Figure 3.7.2-31 provides a similar view, but eliminates the structure and shows only the pool water. In the RXB SAP2000 model, the hydrodynamic load generated due to the pool water mass during a seismic event is addressed by assigning lumped masses on the pool walls and foundation nodes that are in contact with the pool water.

These lumped nodal masses are multiplied by the nodal accelerations during the dynamic analyses and introduce equivalent dynamic pressures on the walls and foundation as impulsive pressures. All of the pool water mass is assigned as lumped nodal masses in the two horizontal and vertical directions separately. Neither the SAP2000 nor SASSI2010 computer programs have an explicit fluid element formulation to accurately calculate the hydrodynamic effects due to all three directional components of earthquake input motions. To develop a correction factor, a fluid structure interaction (FSI) model was created in ANSYS and used to develop fluid loads. These results were compared to the SASSI2010 dynamic results and a correction factor established.

ANSYS Model

In the ANSYS model, the foundation was modeled with two layers of 3D SOLID185 finite elements. In the pool region, the foundation is raised by 1 foot to support the twelve NPMs. Therefore, a layer of 1 foot solid elements was added in the pool water region. This foundation modeling using the solid elements provides an accurate geometrical height for the pool water level and the support locations of the NPMs on the bay and pool walls. As in the SAP2000 model, the NPMs are vertically unrestrained and rest on the pool foundation. All the building exterior and interior walls are modeled using SHELL181 elements. The wall horizontal distance is defined at the neutral surface from the global coordinate system origin. All slabs are modeled using SHELL181 elements. The slab height or vertical distance is defined at the neutral surface from the global coordinate system origin. The exterior and interior roofs are modeled using the SHELL181 elements. The roof height or vertical distance is defined at the neutral surface from the global coordinate system origin.

In order to capture the interaction of pool water with the NPMs and analyze hydrodynamic effects, the Containment Vessel (CNV) of each NPM is modeled with SHELL181 elements as a cylindrical shell with the proper outer diameter. The Reactor Pressure Vessel inside the CNV is modeled with BEAM188 elements. This model matches the dynamic characteristics (e.g., natural frequency) of the NPM beam model. The bottom nodes of the CNV and the pool foundation surfaces are modeled by CONTA173 and TARGE170 elements to allow potential uplifting of the NPM. The CONTA173 element is used to represent contact and sliding between 3-D "target" surfaces (TARGE170) and a deformable surface, defined by this element. This element has three degrees of freedom at each node: translations in the nodal x, y, and z directions. This element is located on the surfaces of 3-D solid or shell elements without mid-side nodes (SHELL181) and has the same geometric characteristics as the shell element face with which it is connected.

The concrete T-beams underneath the slabs and concrete pilasters are modeled with BEAM188 elements. All water mass regions are modeled by FLUID80 fluid finite elements. This fluid element is defined by eight nodes having three degrees of freedom at each node: translation in the nodal x, y, and z directions. This element is used to model fluids contained within vessels having no net flow rate and is well suited for calculating hydrostatic pressures and fluid/solid interactions. The bottom nodes of the foundation are represented by COMBIN14 spring elements. The bottom of the foundation basemat of the RXB ANSYS model has three COMBIN14 spring elements attached to each node with stiffness values of $1x10^8$ lbf/in, $1x10^8$ lbf/in, and $1x10^8$ lbf/in in the E-W, N-S, and vertical directions, respectively.

The ANSYS model used for this evaluation is shown in Figure 3.7.2-32, Figure 3.7.2-33, and Figure 3.7.2-34. For the ANSYS model, the “z” ordinate is at the top of the pool water, in order to define the location of the free water surface in the fluid-structure interaction analysis, instead of at the base of the foundation, which is used for the building analyses in SAP2000 and SASSI2010.

The locations of the RXB pool walls are modeled at the neutral planes and the pool walls are 5 foot thick. Therefore, in modeling the fluid as three dimensional fluid elements, the fluid mass will be greater than it actually is due to 2.5 foot less wall thickness because of the locations of the neutral planes. Thus, the fluid mass density is reduced to compensate for the extra water mass created inside the pool area in the ANSYS FSI analysis model. The extra fluid volume is estimated to be ~ 24.4 percent. This is the reduction factor applied to the water mass density in the dynamic analysis. In the SAP2000 model, the location of the RXB pool walls at the neutral planes has no effect when the pool water is modeled as lumped masses, since the lumped masses are calculated separately.

Fixed-base boundary conditions are used by connecting the nodes at the bottom of the base to boundary condition nodes with three orthogonal 0.1 inch-long COMBIN14 spring elements in the X, Y, Z directions. These boundary condition nodes are fixed in translation in the direction of the attached spring element and are free in the other degrees of freedom. For example, boundary condition nodes i, j, k attached to spring elements along X, Y, Z directions, respectively, are fixed in translation, X,Y, Z, respectively. The input to the ANSYS analysis is the CSDRS-compatible Capitola time history.

ANSYS Results

The ANSYS model was used to run X, Y, and Z input motion time histories separately and evaluate the results. The results are split based on sections created from the eastern wall (X1 to X3) and northern wall (Y1 to Y5), as shown in Figure 3.7.2-35. The maximum accelerations using the ANSYS model due to the three separate input time history motions and the combined resultant obtained using square root-of-the-sum of the squares (SRSS) methodology accelerations are plotted in Figure 3.7.2-36 and Figure 3.7.2-37.

The average ANSYS hydrodynamic pressure is calculated in the following fashion:

- Calculate the SRSS hydrodynamic pressure due to three separate input motions
- Find the height difference between elevations (element height)
- Create trapezoidal pressure areas from this height by the difference in pressures, i.e.:

$$A = h \times \frac{P_{above} + P_{below}}{2} \quad \text{Eq. 3.7-8}$$

- The average pressure is the sum of pressures over heights, i.e.:

$$P_{hd} = \frac{\Sigma A}{\Sigma h} \quad \text{Eq. 3.7-9}$$

The SRSS hydrodynamic pressure results for all wall sections are plotted in Figure 3.7.2-38 and Figure 3.7.2-39, and the average values are provided in Table 3.7.2-2.

SASSI2010 Results

The RXB SASSI2010 model is an embedded model. For this study it was run with soil types 7, 8 and 11 and separate X, Y, and Z input motion time histories in order to obtain the pool wall segment (X1 to X3 and Y1 to Y5) and foundation acceleration results. The CSDRS-compatible Capitola time history was applied to the model with uncracked concrete conditions.

For each segment, the absolute acceleration results from the three input motion time histories were combined using SRSS and are shown in Figure 3.7.2-40 through Figure 3.7.2-45 for the X and Y segments with soil types 7, 8 and 11.

Equivalent wall pressures are determined from the nodal wall accelerations, the tributary area surrounding the nodes, and the lumped water mass values assigned to the nodes. The average SASSI2010 equivalent hydrostatic pressure was calculated in the following fashion:

- Using SAP2000, extract a list of nodes where water weight is applied to the model, w_w.
- Using SASSI2010, extract a list of accelerations at these nodes, a_{SASSI}.
- Obtain the force at a single node by:

$$f_n = ma = \frac{w_w}{g} \times a_{SASSI} \qquad \text{Eq. 3.7-10}$$

- Divide each nodal force by tributary area to obtain nodal pressures:

$$P_n = \frac{f_n}{TribArea} \qquad \text{Eq. 3.7-11}$$

- Calculate the average static pressure of slices made of elevation and wall section by finding the average of the nodal pressures contained in that slice
- Find the height difference between elevations
- Create trapezoidal areas from this height by the difference in pressures, i.e.,

$$A = h \times \frac{P_{above} + P_{below}}{2} \qquad \text{Eq. 3.7-12}$$

- The average pressure is the sum of pressures over heights, i.e.

$$P_{static} = \frac{\Sigma A}{\Sigma h} \qquad \text{Eq. 3.7-13}$$

Average vertical pressure (Z) on the pool floor was obtained from the nodal pressure values on all pool bottom nodes for the X, Y, and Z direction CSDRS Capitola input motions. The average pressure values on the pool floor in the Z direction due to X, Y, and Z input motions were combined via SRSS to obtain the total vertical (Z) pressure reported in Table 3.7.2-2. Average equivalent static pressure from SASSI2010 for each soil type and each wall segment are presented in Table 3.7.2-3. The table also includes a weighted wall average based on the lengths of the walls.

Equivalent Static Pressure Estimation

The SASSI2010 (corrected) equivalent static pressure due to hydrodynamic effects is calculated as follows:

$$P_{addl} = P_{hd} \times \frac{a_{SASSI}}{a_{ANSYS}} \qquad \text{Eq. 3.7-14}$$

Where:

- P_{addl} = equivalent static pressure,
- P_{hd} = hydrodynamic pressure from ANSYS,
- a_{SASSI} = acceleration from SASSI2010 using either soil type 7, 8, or 11; and
- a_{ANSYS} = acceleration from ANSYS.

The FSI analysis uses synthetic ground motions based on Capitola seed time histories. Based on the overall building base shear comparison in Table 3.8.5-3, these runs using soil types 7, 8, and 11, and the CSDRS spectrum are more controlling than the soil type 9, CSDRS-HF spectrum case. Therefore, the factors used to convert ANSYS FSI hydrodynamic pressures to equivalent static pressures for soil types 7, 8, and 11 adequately envelope soil type 9.

Once the factors between SASSI2010 and ANSYS acceleration are obtained, the additional equivalent hydrostatic pressure for SASSI2010 can be computed. Table 3.7.2-4 through Table 3.7.2-6 present the average values for each segment and soil type, and includes a weighted value for each wall.

Table 3.7.2-7 compares this equivalent static pressure with the original static pressures obtained from SASSI2010.

Development of Correction Factor

The maximum static wall pressure differences between the ANSYS and SASSI2010 models are summarized in Table 3.7.2-8. The SASSI2010 analysis with lumped water masses does not represent fluid-structure-interaction behavior, and, therefore, underestimates the hydrodynamic pressures on the RXB walls. In order to account for this, an ANSYS FSI analysis, in which the water elements were explicitly modeled, was performed. Based on these results, it was determined that an additional 4.2 psi needed to be included in the SAP2000 RXB model. This added pressure accounts for the missing 3D effects of fluid-impulsive pressure on the pool walls and foundation.

The pressure at the bottom of the pool due to gravity loading of the water is approximately 30 psi (62.4 lb/ft^3 * 69 ft depth *1/144 ft^2/in^2). Consequently, the average pressure on the wall is half this amount, or 15 psi. The pressure of 4.20 psi is 28 percent of the average pressure (4.20 psi/15 psi = 0.28). Therefore, a 1.28g vertical static loading was added to the SAP2000 model to ensure this additional pressure is accounted for in the design. See Figure 3.7.2-129. Increasing the downward acceleration by a factor of 1.28 corrects for the underestimated fluid pressure, due to mass lumping, in the SSI model. Analyses have been performed that confirm that the 1.28 x gravity load bounds a 4.2 psi pressure profile.

The total hydrodynamic load consists of the lumped-mass hydrodynamic load from the SASSI2010 analysis (which underestimates the hydrodynamic load) and the fluid-structure-interaction correction load from the ANSYS analysis. The effects of the lumped-mass-based hydrodynamic pressures on the pool walls and floor are included in the determination of forces on the walls and floor from the SSI analysis. These hydrodynamic effects from SASSI2010 are included in the E_{ss} term of the governing load combination (see FSAR Section 3.8.4.3.16 for the definition of E_{ss}). The "missing" hydrodynamic load is added to the hydrostatic load to determine the total fluid pressure on the RXB walls and foundation.

COL Item 3.7-12: A COL applicant that references the NuScale Power Plant design certification will perform an analysis that uses site-specific soil and time histories to confirm the adequacy of the fluid-structure interaction correction factor.

3.7.2.1.3.5 Control Building

A general discussion of the CRB and the major features and components is provided in Section 1.2.2.2. Architectural drawings, including plan and section views are provided in Figure 1.2-21 through Figure 1.2-27.

The CRB is located approximately 34 feet to the east of the RXB and its primary function is to house the Main Control Room and the Technical Support Center.

The CRB is a reinforced concrete building with an upper steel structure supporting the roof. The reinforced concrete portion of the building is Seismic Category I. The SSC on the top floor have no safety-related or risk-significant functions. The walls and roof above this floor are provided for weather protection/climate control. This part of the structure is not required to be Seismic Category I. However, to ensure it will not fail and affect the Seismic Category I portion of the building, or the Seismic Category I RXB, the steel portion of the building is classified and analyzed as a Seismic Category II structure.

The CRB is 81' 0" wide (excluding pilasters) in the East-West direction and 119' 8" wide (excluding pilasters) in the North-South direction. The dimensions between the centerlines of the outer walls are 78' 0" by 116' 8". There are two pilasters along both the east and west walls and a single pilaster on the north and south walls. These pilasters are 3.0 feet wide and extend 3.0 feet out from the wall. In addition, there are four corner pilasters. These pilasters are 7.5 feet wide and extend 1.5 feet out from the wall. The Control Building is centered on a below grade basemat with dimensions of 91' 0" by 129' 8". The building has a total height of 96'-2" from the top of the steel roof to the bottom of the basemat foundation. The embedded portion of the CRB is approximately 55 ft below grade, and the CRB extends approximately 41'-2" above grade. The steel super structure exists from EL. 120'-0" to EL. 141'-2" and consists of a vertical and horizontal steel bracing system.

The typical thicknesses for the exterior and interior structural concrete walls are 3 feet and 2 feet, respectively. The primary floor slabs are 3 ft thick and other minor slabs are 2 feet thick. Embedded immediately below the 3 foot thick slabs are reinforced concrete T-beams which are 3 feet wide and 2 feet deep. The basemat foundation thickness is 5 feet and the foundation TOC is at EL. 50' 0". The tunnel connecting the CRB and RXB is located from EL. 100'-0" down to the bottom of foundation near Grid Line D. The tunnel has two levels; the upper tunnel floor is for access to the RXB at approximately EL. 76'-6" and the lower tunnel floor at EL. 50'-0" is a utilities tunnel for the RXB. The tunnel exterior walls and top slab are 3 ft thick.

The CRB 3D model is shown in Figure 3.7.2-46 without soil. Figure 3.7.2-47, Figure 3.7.2-48 and Figure 3.7.2-49 show various section cuts of the CRB 3D model with soil. These figures are for illustration purposes and do not reflect the actual soil strata. The embedded portion of the CRB is surrounded by backfill soil from grade to the bottom level of the foundation.

Control Building SASSI2010 Model

The SAP2000 CRB model is shown in Figure 3.7.2-50 without the backfill soil. The beam elements in the CRB model are shown in Figure 3.7.2-51. The CRB model with the backfill soil, which is modeled using solid elements, is shown in Figure 3.7.2-52 with 25 foot wide backfill soil.

Figure 3.7.2-53 shows the 3D view of the SASSI2010 CRB finite element model converted from the SAP2000 model. This figure includes the CRB and the backfill soil.

Figure 3.7.2-54 shows the excavated soil model for the CRB model without the hidden lines. The length, width, and height dimensions of the excavated soil are identical to the boundaries of the backfill soil model shown in Figure 3.7.2-55. In the SASSI2010 analysis, the properties of the backfill soil are assumed those of Soil Type 11.

Figure 3.7.2-56 shows the SASSI2010 solid elements modeling the concrete basemat. Figure 3.7.2-57 show the shell and beam elements of the CRB SASSI2010 model. Figure 3.7.2-58 shows all beam elements in the SASSI2010 model, which are identical to those shown in Figure 3.7.2-51.

The CRB and backfill soil is modeled surrounded by the free-field soil. The connectivity between the CRB with backfill and the free-field is achieved by connecting the skin nodes of the embedded model of the CRB and backfill soil with the skin nodes of the free-field soil model using soil springs. The skin nodes of the excavated soil model, and the skin nodes of the CRB and backfill model have identical coordinates and are in matching pairs.

The springs have a zero length and have a large stiffness value to simulate rigid connection. The large stiffness used is arbitrarily chosen as 10^{10} lbs/inch, in the three global directions. This high stiffness value does not cause numerical instability and keeps the displacements of two connected nodes to be the same.

The model dimensions, the quantities of elements and masses, and structural damping ratios used for the SASSI2010 model are summarized in Table 3.7.2-9.

The control building basemat is designed using a combination of different models. First, the structural responses from the building models are extracted. Then they are applied to a separate basemat model to determine structural design forces and moments for the basemat. Table 3.7.2-51 and Table 3.7.2-52 show which models were used, what results are extracted, and how these results are used to design the basemat.

3.7.2.1.3.6 Comparison of SAP2000 and SASSI2010 Models

The SASSI2010 model data were obtained by converting the data of the SAP2000 models. To verify that the SAP2000 model has been converted accurately into the SASSI2010 model, the total weights of the two models and the fixed base modal frequencies of the two models are compared.

The model frequencies and mode shapes of the fixed base SAP2000 model were calculated by a modal frequency analysis. The SASSI2010 analysis does not perform modal analysis. However, the major vibration frequencies of a certain location can be obtained to be those of the major amplitudes in the acceleration response transfer functions of the location.

In the calculation of the structural frequencies for comparison, the structure is assumed to be surface founded in both the SAP2000 and SASSI2010 analyses. In the SASSI2010 analysis, the backfill soil was also assumed to be seated on top of a rigid halfspace with the structure. For both the SAP2000 and SASSI2010 fixed-base analyses, the backfill soil is included as solid elements surrounding the buildings. The backfill soil is free around the perimeter and fixed at the bottom. The backfill soil is measured 25 ft outward from the exterior walls and extends from the bottom of the RWB, the RXB, and the CRB basemats to the ground surface. Properties of the Soil Type 11 are used to model the backfill soil. Soil Type 11 is chosen because it has an average shear wave velocity of 768 ft/sec for the upper 85 ft of soil, which is close to a typical backfill soil shear velocity of 800 ft/sec. Each layer of soil depth is assigned a different set of material properties, which include Young's modulus, Poisson's ratio, and damping coefficient.

Table 3.7.2-10 provides modal frequency comparisons at several locations in the RXB. Table 3.7.2-11 provides similar information for the CRB. These comparisons are made for critical locations where maximum displacements are expected to occur. These critical locations are listed in Table 3.7.2-11. Note that SASSI2010 does not perform modal analysis; therefore, frequencies corresponding to peaks of transfer functions at the critical locations are compared with the SAP2000 modal analysis. For example, at the center of the roof in the CRB model, SASSI output is compared with the 72nd mode whose modal frequency matches the frequency at the peak of transfer function.

As can be seen from the tables, the SAP2000 modal frequencies are close to the corresponding SASSI2010 frequencies estimated from the transfer function peaks with a maximum difference of about 6 percent. This implies that the mass and stiffness of the structures in the SAP2000 have been closely duplicated in the SASSI2010 model. However, the effect of backfill soil is more accurately captured in the SASSI2010 transfer functions than in the modal analysis of SAP2000, because the SASSI2010 transfer functions include the effects of structural damping while the SAP2000 modal frequencies are independent of the structural damping.

Note that the RXB SAP2000 frequency values in Table 3.7.2-10 differ slightly from those in Table 3.7.2-14 and Table 3.7.2-15. This is because after the models were shown to be structurally equivalent there were minor enhancements made as a part of the analyses. This is true for the CRB SAP2000 frequency values presented in Table 3.7.2-11, Table 3.7.2-16, and Table 3.7.2-17. The values in Table 3.7.2-10 and Table 3.7.2-11 should only be used for SASSI to SAP2000 comparison purposes.

3.7.2.1.3.7 Triple Building Model

The standalone SAP2000 RXB and CRB models (discussed above) were combined with a SAP2000 model of the RWB to make a single CRB-RXB-RWB SAP2000 model. The combined, or triple, building model is shown in Figure 3.7.2-59 which includes the three buildings with the backfill. Figure 3.7.2-60, Figure 3.7.2-61 and Figure 3.7.2-62 show isometric views of the three buildings without the backfill soil elements from three viewpoints. The backfill soil, which is modeled using solid elements, is shown in Figure 3.7.2-63. All beam elements in the combined model are shown in Figure 3.7.2-64. The spring or link elements are shown in Figure 3.7.2-65. The elevation view showing separation between the three buildings is shown in Figure 3.7.2-66.

SASSI2010 Triple Building Model

Figure 3.7.2-67 shows an isometric view of the SASSI2010 triple building model. This model includes the three buildings, backfill soil, and the excavated soil.

Figure 3.7.2-68 shows the north half of the triple building model. The interiors of the three buildings and six NPMs, which are modeled using beam elements can be seen in red.

Figure 3.7.2-69 and Figure 3.7.2-70 show two views of the South side of the buildings. The tunnel between the CRB and the RXB can be seen in these views. Figure 3.7.2-71 is a view of the north side of the triple building model.

Figure 3.7.2-72 shows the beam elements of the triple building model. This figure is similar to the beam element plot of the combined SAP2000 model in Figure 3.7.2-64.

Figure 3.7.2-73 shows the excavated soil solid elements and Figure 3.7.2-74 shows the backfill soil solid elements of the triple building model.

Figure 3.7.2-75 shows the rigid soil springs between the embedded skin nodes of the structures and backfill soil and the excavated soils. Note that each dot is actually a spring connecting two coincident nodes, one is on the skin of the excavated soil model and the other is on the skin of the structure and backfill model.

Figure 3.7.2-76 shows the interaction nodes for the soil impedance calculation. These include the following nodes:

- nodes on the exterior surface (four sides, top and bottom) of the excavated soil
- nodes in the horizontal planes located at the middle elevation of the excavated soil of each building
- nodes in the vertical plane between the excavated soils of the RWB and RXB
- nodes in the vertical plane between the excavated soils of the RXB and CRB

The model dimensions, the quantities of elements and masses, and structural damping ratios used for the SASSI2010 triple building model are summarized in Table 3.7.2-12. Key dimensions and weights of the three buildings are provided in Table 3.7.2-13.

3.7.2.2 Natural Frequencies and Responses

The Seismic Category I structures are represented by deeply embedded 3D finite element models. Because the SASSI2010 computer program uses a complex frequency response analysis method, the natural frequencies, participation factors, mode shapes, modal masses, and percentage of cumulative mass ratios are not generated by the SASSI2010 analysis. However, this information is available from the SAP2000 models, the natural frequencies and modal mass ratios have been tabulated. The SAP2000 model assumes a fixed base boundary condition.

Table 3.7.2-14 and Table 3.7.2-15 provides frequencies and modal mass ratios for the cracked and uncracked RXB models and Table 3.7.2-16 and Table 3.7.2-17 provide the equivalent information for the CRB. For each excitation direction (two horizontal and one vertical), all modes with frequencies less than the zero period acceleration frequency of the input spectrum are adequately represented in the model. A preliminary modal analysis has been performed to establish that a sufficient number of discrete mass degrees of freedom have been included in the dynamic model to predict a sufficient number of modes.

Figure 3.7.2-77 through Figure 3.7.2-85 show mode shapes for the first significant frequency in each direction in each of the four models (cracked and uncracked RXB and cracked and uncracked CRB). These preliminary modal analyses produce mode shapes that are reasonably smooth.

3.7.2.3 Procedures Used for Analytical Modeling

The general approach for the analysis of the structures is:

1) create a building model with major equipment in SAP2000

   a) develop the NPM model

   b) develop the RBC model

   c) develop hydrodynamic loads in ANSYS to adjust the SAP2000 RXB model

2) convert the SAP2000 model to a SASSI2010 model and validate the SASSI2010 model

3) perform multiple "runs" of SASSI2010 using the different combinations of the CSDRS and CSDRS-HF (discussed in Section 3.7.1.1), soil profiles (discussed in Section 3.7.1.2), cracked and uncracked concrete stiffness, and material damping values (discussed in Section 3.7.1.3).

4) combine the results to create bounding values for design

3.7.2.4 Soil-Structure Interaction

Soil-Structure Interaction (SSI) analysis is performed with SASSI2010. The CSDRS, CSDRS-HF and associated time histories sets are developed in Section 3.7.1.1. The soil types are developed in Section 3.7.1.3. As discussed in Section 3.7.1.3, these soil profiles represent a range of conditions from soft soil to hard rock and are used to develop building designs that are acceptable at most sites with little or no additional modification.

In addition to the data converted from the SAP2000 model, the SASSI2010 model requires the model of the excavated soil. Thus, the excavated soil properties, the excavated soil finite elements, the interaction nodes, and the rigid springs connecting the RXB model and the excavated free-field soil are added to form the complete SASSI2010 model.

The SASSI2010 modules used in this SSI analysis are:

1) HOUSE - defines the finite element model of the soil-structure system

2) SITE - forms and solves the transmitting boundary problem; it also performs the site response analysis

3) POINT3 - solves for the point loads applied at layer interface

4) ANALYS - calculates the transfer functions

5) COMBIN - combines the transfer functions calculated by several ANALYS runs

6) MOTION - calculates accelerations or relative displacements at selected locations

7) STRESS- stresses, forces, and moments in elements modeling structural members

The first five modules calculate the transfer function values at selected frequencies. The STRESS and MOTION modules perform interpolation to obtain the transfer functions at all frequencies. Then they calculate the seismic responses by convolving the input acceleration time history with the interpolated transfer functions.

For computation efficiency, SASSI2010 calculates transfer functions only at selected frequencies, which are specified in the SITE module data, and then the full transfer functions are obtained by interpolation in the MOTION and STRESS modules for response calculation.

The frequencies used for transfer function calculation by the ANALYS module for each soil types are tabulated in Table 3.7.2-18 for the standalone RXB model and Table 3.7.2-19 for the RXB with triple building model. Table 3.7.2-20 and Table 3.7.2-21 provide the frequencies used with the CRB.

The SASSI2010 analysis is performed in the frequency domain using the method of Fast Fourier Transform (FFT). The frequency step size, df, is equal to the reciprocal of the time duration as depicted in the following equation:

$$df = \frac{1}{dt \times N} = \frac{1}{duration}(Hz) \qquad \text{Eq. 3.7-15}$$

where,

dt = time step size in seconds,

N = is the number of time history data points used for the FFT.

This N value has to be any power of 2 and greater than or equal to the actual number of data points of the excitation time history.

In the SASSI2010 analyses, the numbers of the actual input acceleration time history may vary. However, the number of N used in the FFT is

$N = 2^{14} = 16384$, which is greater than the numbers of all acceleration data points.

The time step of the time histories is always 0.005 sec. Thus, the frequency step size, df, is:

$$df = \frac{1}{0.005 \times 16384} = \frac{1}{81.92} = 0.012207\ Hz \qquad \text{Eq. 3.7-16}$$

In Table 3.7.2-18 through Table 3.7.2-21 each frequency is defined by a number of frequency steps. The selection of frequencies using the numbers of frequency steps is specified in the data for the SITE module. The corresponding actual frequencies in Hz are calculated by n × df, where n is the number of frequency steps.

The flow of SASSI2010 data files created by the various modules and their flow among the modules is presented in Figure 3.7.2-89, which was abridged from SASSI2010 User's Manual.

The analysis steps are:

- Analyze the embedded structure for the East-West (X) direction shaking. The horizontal in-layer motion is applied in the East-West (X) direction at the foundation elevation as a vertically propagating vertical shear (SV) wave.
- Analyze the embedded structure for the north-south (Y) direction shaking. The horizontal in-layer motion is applied in the North-South (Y) direction at the foundation elevation as a vertically propagating horizontal shear (SH) wave.
- Analyze the structure for the vertical (Z) shaking. The vertical in-layer motion is applied at the foundation elevation as a vertically propagating pressure (P) wave.

In the analysis using the SASSI2010 STRESS and MOTION modules, individual cases must be run for each combination of parameters. A total of 612 STRESS and MOTION cases can be produced based on:

540 analysis cases with the CSDRS

- five CSDRS compatible seismic inputs: Yermo, Capitola, Chi-Chi, Izmit, and El Centro
- three directions: EW, NS and vertical
- three soil profile types: Soil Types 7, 8, and 11
- two concrete conditions: cracked and uncracked
- three building models: RXB, CRB and Triple Building
- two damping values: 7 percent and 4 percent

72 cases with the CSDRS-HF

- one CSDRS-HF compatible seismic input: Lucerne
- three directions: EW, NS and vertical
- two soil profile types: Soil Types 7 and 9
- two concrete conditions: cracked and uncracked
- three building models: RXB, CRB and Triple Building
- two damping values: 7 percent and 4 percent

3.7.2.4.1 Methodology for Combining Results

The results from the multiple STRESS/MOTION analyses are combined to produce a single set to be used in structural design and evaluation. This process is described in the following steps and shown in Table 3.7.2-22.

Step1: SRSS Combination of Responses due to Three Components of Each Seismic Input

The three sets of responses for each structural member, due to the three acceleration components (i.e. X-, Y-, and Z-components) of each building/soil/time history/cracking/damping case are combined by the SRSS method.

Step 2: Averaging of Responses due to Five CSDRS Time histories

For each soil type and building, the SRSS results from the five CSDRS compatible time histories obtained in step 1 are averaged to obtain a single set of responses for the four combinations of cracked and uncracked with 4 percent and 7 percent damping. Since there is only one set of the CSDRS-HF compatible input, no averaging is necessary for the CSDRS-HF responses.

Step 3: Enveloping Average Responses for Soil Types and Concrete Conditions

After the SRSS and averaging processes described in Steps 1 and 2 are performed, there are 10 sets of results for each building (cracked and uncracked for each soil/CSDRS combination) for each damping value. These results are enveloped for each building (RXB, CRB, and Triple).

Step 4: Enveloping the results from the Standalone and Triple Building Model

Steps 1 through 3 are repeated for each building and the triple building model. The 10 responses from the individual model and the 10 equivalent response from the triple building model are enveloped to obtain the final set for use in the building design.

3.7.2.4.2 Maximum Forces and Moments in Shell Elements

The floors and walls are modeled using the SASSI2010 Thick Shell (SHL17) Element. The concrete walls and floor slabs are modeled at their centerline (neutral plane) locations and the force and moment are calculated at the centerlines of the walls and slabs. The following force and moment components of a shell element are determined:

- Membrane Forces S_{xx}, S_{yy}
- In-Plane Shear S_{xy}
- Out-of Plane Moment ($M_{xx} + M_{xy}$) and ($M_{yy} + M_{xy}$)
- Out-of Plane Shear V_{xz}, V_{yz}

The element force and moments are computed with respect to local element coordinates in five locations, four corner nodes (I, J, K and L) and the element center of gravity (CG) shown in Figure 3.7.2-90. This figure shows the location of the infinitesimal element where the positive component of forces and moments are computed.

The positive local z-axis is oriented outward from the page based on the right hand rule. The points where stresses are computed are numbered 1 through 5. Points 1 through 4 are located approximately 80 percent from the element CG to the corner nodes. Point 5 is located at the element CG as shown in Figure 3.7.2-90. The positive definitions for each force and moment component are shown in Figure 3.7.2-91.

These forces and moments are then combined as described in Section 3.7.2.4.1. Steps 2 and 3 of this process are illustrated in Table 3.7.2-23 for an example shell element.

3.7.2.4.3 Maximum Forces and Moments in Beam Elements

The structural members, columns, pilasters, and T- beams are modeled using the SASSI2010 beam elements at their centerline (neutral axis) locations and the forces and moments are calculated at both ends of member, Nodes (I, J). The computed forces and moments are referenced to the local beam axes of the beam element as shown in Figure 3.7.2-92. The force and moment components are defined below:

- Force P1 in the local beam axis 1
- Force P2 in the local beam axis 2
- Force P3 in the local beam axis 3
- Moment M1 about the local beam axis 1
- Moment M2 about the local beam axis 2
- Moment M3 about the local beam axis 3

These forces and moments are then combined as described in Section 3.7.2.4.1. Steps 2 and 3 of this process are illustrated in Table 3.7.2-24 for an example beam element.

3.7.2.4.4 Maximum Stresses in Solid Elements

The foundation (basemat slab) and backfill soil are modeled by the SASSI2010 solid elements. The stresses in a solid element are computed at the centroid of the solid element and are referred to in the global axes. These stress components are shown in Figure 3.7.2-93 using an infinitesimal cube at the centroid of a solid element:

- Normal stress σ_{xx} in the global X-direction normal to the Y-Z plane
- Normal stress σ_{yy} in the global Y-direction normal to the Z-X plane
- Normal stress σ_{zz} in the global Z-direction normal to the X-Y plane

- Shear stress T_{xy} in the global Y-direction parallel to the Y-Z plane
- Shear stress T_{xz} in the global Z-direction parallel to the Y-Z plane
- Shear stress T_{yz} in the global Z-direction parallel to the Z-X plane

These stresses are then combined as described in Section 3.7.2.4.1. Steps 2 and 3 of this process are illustrated in Table 3.7.2-25 for an example solid element.

3.7.2.4.5 Relative Displacements at Selected Locations

Multiple locations on both the RXB and CRB have been selected for presentation of relative displacement. The node numbers and their global coordinates of the selected locations are shown in Table 3.7.2-26 for the RXB and Table 3.7.2-27 for the CRB. These locations can be seen in Figure 3.7.2-94 for the RXB and in Figure 3.7.2-95 for the CRB.

The relative displacement results from the different cases are post-processed using the steps described in Section 3.7.2.4.1.

The relative displacements calculated for the selected locations in both the standalone models and the triple building model are presented in Table 3.7.2-28 and Table 3.7.2-29. The displacements are in the global directions.

3.7.2.4.6 Design Approach

The initial structural analysis of the RXB was performed with the entire suite of analysis cases as described above. The CRB analysis did not include all the triple building model cases. For the triple building model, Soil Type 7 was evaluated with the CSDRS and Soil Type 9 was evaluated with the CSDRS-HF. These cases are selected because they represent controlling conditions. In general, Soil Type 7 with the CSDRS is controlling for both the RXB and the CRB.

The analysis cases used to determine the seismic demand for Seismic Category I SSC can be labeled using nine identification codes:

1) RXB Standalone Structural Response

2) RXB Triple Building Structural Response

3) RXB Stand-Alone ISRS

4) RXB Triple Building ISRS

5) NPM ISRS

6) CRB Stand-Alone ISRS

7) CRB Stand-Alone Structural Response

8) CRB Triple Building Structural Response

9) CRB Triple Building ISRS

Each code represents a different combination of the 540 CSDRS cases and the 72 CSDRS-HF cases listed in Section 3.7.2.4. Table 3.7.2-33 provides the tabulated seismic parameter combinations for the eight identification codes to identify: seed input time history, soil type, direction, building model, concrete condition, and damping. Table 3.7.2-34 provides a list of the Seismic Category I SSC and the associated identification codes for the analysis used to calculate the seismic demands.

The methodology for combining the results of these seismic analysis cases is described in Section 3.7.2.4.1.

3.7.2.5 Development of In-Structure Floor Response Spectra

Development of ISRS follows the guidance in RG 1.122, "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components" Rev. 1. The SASSI2010 MOTION module is used to produce accelerations for ISRS development. A 4 percent structural damping is used for both cracked and uncracked concrete.

3.7.2.5.1 Averaging and Combining Analysis Cases

Step 1. At each selected nodal location, the three co-directional ISRS from a single soil, time history, and stiffness are combined using SRSS.

Step 2. Step 1 is repeated for each of the cases that were analyzed.

Step 3. The ISRS from the five CSDRS time histories is averaged for each soil type and stiffness. For the CSDRS-HF no averaging is necessary since there is only one CSDRS-HF compatible input.

Step 4. For each selected area, all of the ISRS (this usually includes more than one node) are combined and the envelope obtained for each of the three directions.

Step 5. Each envelope response spectra is broadened by ±15 percent.

Step 6. Steps 1 through 5 are repeated to generate ISRS at damping ratios of 2, 3, 4, 5, 7, and 10 percent.

This process is shown for a single node in Figure 3.7.2-99 through Figure 3.7.2-103. The first three figures show the development of the average ISRS for the three soil cases (7, 8, and 9) and two stiffnesses (cracked and uncracked). Figure 3.7.2-102 shows the combination of averages and the development of the ISRS envelope. The upper three plots show this process for the CSDRS compatible time histories and soil cases and the bottom three plots show the process for the ISRS from the CSDRS-HF compatible time histories and soil cases. Figure 3.7.2-103 shows the development of the broadened spectra at various damping values. The upper three plots show the envelop ISRS for each direction and the different damping ratios. In these plots the broadening of the 2 percent damping results is shown. The bottom three plots provide the broadened results for all damping ratios.

3.7.2.5.2 Comparison of In-Structure Response Spectra between Single and Triple Building Models

The structure-soil-structure interaction of the triple model has an effect on the ISRS of the RXB. Other than the ISRS at top of basemat, the ISRS of the standalone model are higher than those of the triple building model. The reduction in the ISRS of the triple building model is attributed to the extra damping effect provided by the close presence of the RWB and the CRB on the sides of the RXB.

This can be seen in Figure 3.7.2-104, Figure 3.7.2-105 and Figure 3.7.2-106.

Because neither the standalone nor triple building model produce bounding results at all locations, ISRS enveloping the two models are used for design of structures, systems, and components in the RXB and CRB.

3.7.2.5.3 Reactor Building In-Structure Response Spectra

For convenience in design of components and supports that need to be Seismic Category I or Seismic Category II, ISRS at multiple nodes at each floor are combined to develop a single ISRS for each floor. The ISRS corresponding to each main floor of the RXB identified below are provided in the listed figures. Although ISRS are provided at the NPM base (floor at EL. 25' 0"), time histories were used as input for the evaluation of the NPMs as described in Appendix 3A. The governing ISRS envelop the ISRS taken from node locations on the corners of the buildings to capture the torsional and rocking components. See Table 3.7.2-53 for a list of nodes enveloped at each floor to produce the floor ISRS. Figure 3.7.2-142 through Figure 3.7.2-148 show the locations of the nodes selected for floor ISRS generation.

Floor	Figure
24’-0”	Figure 3.7.2-107
25’-0”	Figure 3.7.2-108
50’-0”	Figure 3.7.2-109
75’-0”	Figure 3.7.2-110
100’-0”	Figure 3.7.2-111
126’-0”	Figure 3.7.2-112
181’-0”	Figure 3.7.2-113

3.7.2.5.4 Reactor Building Crane In-Structure Response Spectra

The seismic analysis of the RBC uses ISRS for input. The ISRS are generated at four selected individual crane wheel locations. These locations are on the reactor pool wall at the crane rail slab at El. 145'-6", see Table 3.7.2-56. The enveloping ISRS for these four locations are provided in Figure 3.7.2-114. In addition to these four nodes, a fifth node located on the crane rail slab is used to generate the ISRS in the vertical direction. This node is used because when soil separation effects are considered, the vertical direction is not bounded by the enveloped ISRS of the other four nodes. The seismic analysis of the RBC is completed per ASME NOG-1 (Reference 3.7.2-4).

3.7.2.5.5 Not Used

3.7.2.5.6 NuScale Power Module Skirt, Lug Supports, and Reactor Flange Tool Base In-Structure Response Spectra

At the CNV skirts of NPM1 and NPM6, response spectra are generated for the time histories at nodes directly beneath each corresponding NPM. The SASSI coordinates of these ISRS locations are listed in Table 3.7.2-54.

This results in skirt response spectra for each module, based on the six seismic cases provided (Soil Type 7, Capitola time history, cracked and uncracked concrete, and three NPM stiffness cases) each with three components (X,Y, and Z). Six resulting ISRS (two modules x one skirt support x three directions) for the nominal stiffness cases for NPM1 and NPM6 CNV skirts are shown in Figure 3.7.2-156 and Figure 3.7.2-157. These ISRS are an envelope of the cracked and uncracked concrete conditions.

At the CNV lugs of NPM1 and NPM6, response spectra are generated for the time histories at the nodes listed in Table 3.7.2-55. The spectra for the nominal stiffness cases are then enveloped at each of the lugs on NPM1 and NPM6, resulting in 18 total enveloping spectra (two modules x three lugs x three directions). These spectra are shown in Figure 3.7.2-158 through Figure 3.7.2-163. These ISRS are an envelope of the cracked and uncracked concrete conditions.

Response spectra are generated for time histories at four reactor flange tool (RFT) base locations. The coordinates of these ISRS locations are listed in Table 3.7.2-58. For each case, there are 12 (3 directions x 4 locations) ISRS generated. For the two analysis cases (cracked and uncracked concrete), the total number of ISRS is 24 (12 x 2 cases). The plots of the ISRS for the nominal stiffness cases are presented in Figure 3.7.2-164 through Figure 3.7.2-171.

3.7.2.5.7 Control Building In-Structure Response Spectra

The ISRS corresponding to each main floor of the CRB identified below are provided in the listed figures. The governing ISRS envelop the ISRS taken from node locations on the corners of the buildings to capture the torsional and rocking components. Coordinates selected for floor ISRS generation in the CRB are listed in Table 3.7.2-57.

Floor	Figure
50′-0″	Figure 3.7.2-117a and Figure 3.7.2-117b
63′-3″	Figure 3.7.2-118a and Figure 3.7.2-118b
76′-6″	Figure 3.7.2-119a and Figure 3.7.2-119b
100′-0″	Figure 3.7.2-120a and Figure 3.7.2-120b

Floor	Figure
120’-0”	Figure 3.7.2-121a and Figure 3.7.2-121b
140’-0”	Figure 3.7.2-122a and Figure 3.7.2-122b

3.7.2.6 Three Components of Earthquake Motion

The three components of earthquake motion are developed as separate time histories as discussed in Section 3.7.1.1. These time history motions are applied to the building models as input to the SASSI2010 analysis. For the desired output (ISRS, forces and moments, displacements, etc.) the responses for the structure are combined using square root of the sum of the squares in conformance with RG 1.92, “Combining Modal Responses and Spatial Components in Seismic Response Analysis” Rev. 3.

3.7.2.7 Combination of Modal Responses

Modal combination is not utilized for the analysis of the RXB or CRB. These structures are evaluated using SASSI2010 finite element models. SASSI2010 utilizes time history analysis in the frequency domain in which the equations of motion are solved for the soil and structural elements.

3.7.2.8 Interaction of Non-Seismic Category I Structures with Seismic Category I Structures

A failure of a nearby structure could adversely affect the Seismic Category I RXB and Seismic Category I portions of the CRB. These nearby structures are assessed (or analyzed if necessary) as described below to ensure that there is no credible potential for adverse interactions. Figure 1.2-4 provides a site plan showing the standard plant layout. The non-Seismic Category I structures that are adjacent to the Seismic Category I RXB and CRB are:

- RWB (Seismic Category II), adjacent to RXB
- CRB above elevation 120' (Seismic Category II), above Seismic Category I CRB and adjacent to RXB
- CRB areas below elevation 120' as noted in Section 1.2.2.2
- [[North and South Turbine Generator Buildings (Seismic Category III), adjacent to RXB]]
- [[Central Utilities Building (Seismic Category III), adjacent to CRB]]
- [[Annex Building (Seismic Category III) adjacent to RXB]]

The Seismic Category II portion of the CRB was analyzed along with the Seismic Category I portion of the structure. The codes, standards, specifications, loads and loading combinations, design and analysis procedures, and structural acceptance criteria for the Seismic Category I portion of the CRB also applies to the Seismic Category II portion of the CRB to the extent required to comply with DSRS 3.7.2 - Section II - Acceptance Criteria 8 (a), (b), or (c).

The RWB is approximately 25 feet away from the RXB. The RWB is a robust concrete structure; therefore, this building can affect the Seismic Category I RXB.

The RWB is designed using the provisions of RG 1.143, Rev. 2. Therefore, the seismic input is one-half of the CSDRS (and CSDRS-HF). However, because of the proximity of the RWB to the RXB, there is a potential seismic 2 over 1 interaction of the RWB structure with the RXB. In order to ensure that there are no unacceptable interactions, the exterior and interior walls, the slab at grade (EL. 100'-0") and the foundation basemat of the RWB are designed for the CSDRS and CSDRS-HF rather than the ½ SSE load specified in RG 1.143, Rev. 2. This analysis confirms that the RWB will not collapse from a CSDRS or CSDRS-HF earthquake and adversely affect the Seismic Category I RXB.

The contribution of the RWB to the RXB wall pressure have been included in the analysis of the RXB wall pressure.

COL Item 3.7-4: A COL applicant that references the NuScale Power Plant design certification will confirm that nearby structures exposed to a site-specific safe shutdown earthquake will not collapse and adversely affect the Reactor Building or Seismic Category I portion of the Control Building.

3.7.2.9 Effects of Parameter Variations on Floor Response Spectra

Uncertainties in seismic modeling, due to variation in input parameters such soil column and earthquake spectrum and structural properties such as material strength, cracking, mass properties, and specific locations of structures, systems, and components are accounted for in three ways:

- **A Conservative Design Approach**

  The NuScale design considers ground motions that bound most sites, and performs multiple SASSI2010 analysis using different combinations of soil profiles and cracked and uncracked properties. Bounding results are used in the design.

- **ISRS Broadening**

  The bounding ISRS are broadened as specified in the RG 1.122, Rev. 1. The envelope ISRS is broadened 15 percent on a linear frequency scale.

- **Site-Specific Analysis**

  A site-specific analysis is performed to show that the design provides sufficient capacity to resist the site-specific demand.

3.7.2.9.1 Effects of Operation with less than Twelve NuScale Power Modules

The RXB is designed and constructed to hold twelve NPMs, each in its own bay within the Reactor Pool, but can be operated with fewer than the full complement of twelve. To account for this variation in a significant design parameter, a study was performed to investigate the effect of a reduced number of NPMs within the building, to confirm adequacy of the design under less than full loading conditions. The study evaluated a case with seven NPMs, six on the south side of the pool, and a single NPM in the bay on northeast corner of the reactor pool. This configuration is shown in Figure 3.7.2-98. Figure 3.7.2-25 shows the full complement of NPMs, and Figure 3.7.2-24 shows the entire ultimate heat sink, which includes the reactor pool, refueling pool, spent fuel pool and dry dock area. These pools are all hydro-dynamically connected. This layout was selected because it allows several important aspects to be investigated simultaneously.

- The pool load is eccentric. The south side of the reactor pool is heavier due to the presence of the NPMs.
- NPM Bay 1 is empty. This bay and in particular, the west wall, will experience different hydrodynamic water pressure compared with bay walls with an NPM on both sides of the wall since there is no NPM on either side of the wall. The west wall of NPM Bay 1 and NPM Bay 12 experience the highest forces of the bay walls. This has been attributed to the Refueling Pool water volume, which is much greater than the volume in the bays.
- The forces experienced on an internal NPM bay wall when there is only an NPM on one side is investigated by locating a module in NPM Bay 6.

The study used the CSDRS compatible Capitola time histories with Soil Type 7 and the CSDRS-HF compatible Lucerne time histories with Soil Type 9. Global effects on the building are examined by comparing the ISRS at the foundation and the roof. The enveloping ISRS for these two locations are provided in Figure 3.7.2-107 and Figure 3.7.2-113 respectively. Local effects are examined by comparing the forces on the NPM at the lug restraints and the skirt and on the bay walls.

3.7.2.9.1.1 Comparison at the Foundation

Figure 3.7.2-123 provides the ISRS for a node at the northwest corner of the RXB at the top of the basemat (EL. 24' 0"). The upper three plots on this figure compare the results of the 12 and 7 NPM cases with the CSDRS in the three directions, and the bottom three plots provide the same comparison for the CSDRS-HF. Figure 3.7.2-124 provides the same comparisons for a node at the midpoint of the north wall and Figure 3.7.2-125 provides the comparison at the northeast corner of the top of basemat. The ISRS are observed to virtually overlay each other, comparable in shape and frequency and peak of response in all cases.

3.7.2.9.1.2 Comparison at the Roof

Figure 3.7.2-126 provides the ISRS for a node at the northwest corner of the roof of the RXB at (EL. 181' 0"). The upper three figures compare the results of the 12 and 7 NPM cases with the CSDRS in the three directions, and the bottom three figures provide the same comparison for the CSDRS-HF. Figure 3.7.2-127 provides the same comparisons for a node at the midpoint of the north wall and Figure 3.7.2-128 provides the comparison at the northeast corner of the top of basemat.

The ISRS at the roof vary slightly between the two cases. However, the peaks occur at the same frequency and the difference in magnitude between the two cases is small. This variation in spectra is similar to that seen between cracked and uncracked conditions and between results from the five different CSDRS compatible time histories. Therefore the results at the roof are considered equivalent.

3.7.2.9.1.3 Comparison at the NPM Restraints

Each NPM is supported within its bay by a skirt at the base of the containment, resting in a ring anchored to the basemat, and by three higher lateral supports, one at the pool wall and one each at the side wing walls, which provide resistance to motion in the horizontal plane of the supporting wall. The maximum forces (at any restraint) for each case are provided in Table 3.7.2-30 for the comparison using Soil Type 7 and the CSDRS and in Table 3.7.2-31 for the comparison using Soil Type 9 and the CSDRS. The values in the tables are from the study and do not represent the actual forces used for the design.

As can be seen in the tables, the maximum forces vary slightly (less than 5 percent) at each location, however neither case (12 NPM or 7 NPM) is controlling either for the CSDRS or for the CSDRS-HF. Like the results at the roof, this variation is within the range produced by the different cases that are included in the full analysis.

3.7.2.9.1.4 Comparison at the NPM Bay Walls

In addition to the restraints, the wing walls and the pool walls are subjected to forces during the seismic event. Table 3.7.2-32 provides a summary comparison of the forces and moments in the three walls associated with NPM Bay 1, which is empty for the 7 NPM case and Bay 6 which contains an NPM in the 7 NPM case. Only the results for the Soil Type 7 and the CSDRS are presented. Soil Type 9 and the CSDRS-HF produced similar but smaller results. The results are provided for two elevations: the base of the wall and the NPM lug restraint. The tables are laid out with the data for the North pool wall shifted to the right.

The west wing wall, which experiences the highest force with twelve NPM sees the greatest increase due to the removal of the NPM from the Bay. This increase occurs primarily in the bending moment and out of plane shear. There was very little change in in-plane stress. The moments increased by approximately 20 percent.

The Bay 1/2 wing wall, which has empty bays on either side, had increases of similar magnitude to the west wing wall, but since the initial moments were smaller, the percentage change is larger. The Bay 5/6 wing wall (which has a module only on one side in the NPM case) saw increases of about half the magnitude of the Bay 1/2 wing wall. The east wall, which is a pool wall not a wing wall, saw virtually no increase.

The NPM Bay 1 pool experience the largest forces with all twelve modules in place. Again, this is attributed to the large water volume in the refueling pool to the west of the bay. With the removal of the module for the 7 NPM case. The bending moments increased by 30 to 40 percent. This increase is attributed to the larger water volume. The Bay 6 pool wall was essentially unaffected. Bay 6 contains a module in the 7 NPM case.

3.7.2.9.1.5 Conclusion of the Study

The 7 NPM case did not produce a tangible change in the reaction of the building as a whole (Section 3.7.2.9.1.1 and Section 3.7.2.9.1.2). The 6 NPM case, which would cause a slightly more asymmetric load, is expected to produce similar results. The mass of the overall structure is relatively unaffected by the mass difference between a NPM and the water. Therefore the quantity of modules installed in the building is expected to have no effect on the building.

Similarly, the absence of modules did not significantly affect the forces that are transmitted to an installed NPM (Section 3.7.2.9.1.3). Therefore removing individual modules for refueling does not impact the installed and operating modules.

The walls of bays without an installed module do see an increase in the forces, principally in bending moment. These increases are on the order of 40 percent. However, the wing walls are all designed the same. As such, they are designed for the highest loaded wall, which is the west wing wall. The increases seen in the west wing wall when an NPM is not present in Bay 1 do not exceed the capacity of the wall. In addition, the increase is less significant because there is no module supported by the wall.

The pool wall in an empty bay also sees an increase of about 40 percent. Again, the highest forces occur at the west end of the pool. The forces at the pool wall in Bay 1 when it is empty are similar to those in the reactor pool area. Since the entire pool wall is a consistent design, these forces are also acceptable.

The difference in results between operation with twelve NPMs and operation with fewer NPMs in place is small and within the capacity of the building design. Site-specific configurations, outside of the scope of the presented 12 NPM and 7 NPM cases, require additional analysis to be performed by the COL applicant.

COL Item 3.7-10: A COL applicant that references the NuScale Power Plant design certification will perform a site-specific configuration analysis that includes the Reactor Building with applicable configuration layout of the desired NuScale Power Modules. The COL applicant will confirm the following are bounded by the corresponding design certified seismic demands:

1) The in-structure response spectra of the standard design at the foundation and roof. See FSAR Figure 3.7.2-107 and Figure 3.7.2-108 for foundation in-structure response spectra and Figure 3.7.2-113 for roof in-structure response spectra.
2) The maximum forces in the NuScale Power Module lug restraints and skirts. See Table 3B-28.
3) The site-specific in-structure response spectra for the NuScale Power Module at the skirt support will be shown to be bounded by the in-structure response spectra in Figure 3.7.2-156 and Figure 3.7.2-157. The site-specific in-structure response spectra for the NuScale Power Module at the lug restraints will be

shown to be bounded by the in-structure response spectra in Figure 3.7.2-158 through Figure 3.7.2-163.

4) The maximum forces and moments in the west wing wall and pool wall. See Table 3B-23a and Table 3B-23b.

5) Not used.

6) The site-specific in-structure response spectra shown immediately below will be shown to be bounded by their corresponding certified in-structure response spectra:

   - Reactor Building north exterior wall at EL 75′-0″: bounded by in-structure response spectra in Figure 3.7.2-110
   - Reactor Building west exterior wall at EL 126′-0″: bounded by in-structure response spectra in Figure 3.7.2-112
   - Reactor Building crane wheels at EL 145′-6″: bounded by in-structure response spectra in Figure 3.7.2-114
   - Control Building east wall at EL 76′-6″: bounded by in-structure response spectra in Figure 3.7.2-119a and Figure 3.7.2-119b
   - Control Building south wall at EL 120′-0″: bounded by in-structure response spectra in Figure 3.7.2-121a and Figure 3.7.2-121b

If not, the standard design will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands.

3.7.2.9.2 Foundation Uplift

Foundation uplift did not occur in either deeply embedded structure. The evaluation is provided in Section 3.8.5.

3.7.2.10 Use of Constant Vertical Static Factors

Constant vertical static factors are not used in the design of the Seismic Category I and II structures. Vertical seismic loads are generated from the SASSI2010 analysis.

3.7.2.11 Method Used to Account for Torsional Effects

Inertial torsional effects are inherently considered in the seismic analysis using a 3D finite element model with backfill soil. The potential for accidental torsion is considered insignificant due to physical geometry of the structures which are deeply embedded with most mass at the foundation. Within the RXB the two largest masses are the pool and the NPMs.

The element demand forces and moments obtained from SASSI2010 due to east-west and north-south CSDRS (and CSDRS-HF) inputs have been increased by 5 percent to account for accidental torsion. The total demand forces and moments are obtained using SRSS, as shown below.

$$\sqrt{(\alpha \cdot A_{NS})^2 + (\alpha \cdot A_{EW})^2 + (A_{VT})^2} \qquad \text{Eq. 3.7-17}$$

where,

A_{NS} maximum element forces due to the SSE in the North-South direction

A_{EW} maximum element forces due to the SSE in the East-West direction

A_{VT} maximum element forces due to the SSE in the vertical direction

α factor to account for accidental torsion effect in NS or EW (1.05)

3.7.2.12 Comparison of Responses

The response spectrum method is not used in the evaluation of the site independent Seismic Category I and II structures. The SASSI2010 analysis is a time history analysis method. Therefore, a direct comparison is not applicable.

3.7.2.13 Methods for Seismic Analysis of Dams

The design does not include nor require the presence of a dam.

3.7.2.14 Determination of Dynamic Stability of Seismic Category I Structures

Section 3.8.5 provides discussion regarding bearing pressure, lateral wall pressure, overturning, sliding, and flotation.

3.7.2.15 Analysis Procedure for Damping

Section 3.7.1.2 describes the damping ratios used for seismic analysis of the RXB and CRB. As stated in Section 3.7.1.2.1, for analyses of Seismic Category I SSC, the damping values of RG 1.61, Revision 1 are used. These values are presented in Table 3.7.1-6. For the soil and rock materials, the damping ratio is obtained based on strain-compatible soil properties generated for each soil profile. Soil material damping ratios are shown on Table 3.7.1-15 through Table 3.7.1-19 for each soil type considered. Soil damping ratio is limited to 15 percent.

The implementation of these damping values in the dynamic analyses of the NuScale RXB and CRB does not follow guidance from DSRS Section 3.7.2.II.13. Instead, damping procedures that are more suitable with the type of analysis performed are followed. For transient analysis with ANSYS, Rayleigh material damping is used. For soil-structure interaction analysis with SASSI2010, hysteretic material damping is used. Both Rayleigh and hysteretic damping provide responses equivalent to the composite modal damping approach. Only major components, such as the NPM and the RBC, are included in the dynamic models. For other systems and components, their mass is applied to the model and ISRS are calculated at the corresponding damping level in Table 3.7.1-6.

3.7.2.16 Site Specific Seismic Analysis

Site-specific seismic analysis is performed by the COL applicant to confirm that the site-independent Seismic Category I structures may be constructed without modification, or to identify where modifications are necessary. This comparison is performed in Section 3.8.4.8. The site specific analysis is performed using the site specific SSE developed in Section 3.7.1.1.3 (COL Item 3.7-1) and the site specific soil profile developed in Section 3.7.1.3.3 (COL Item 3.7-3). Appendix 3B critical sections include RXB and CRB exterior walls that are subject to earth pressures. Therefore, by comparing seismic demand in these walls per COL Item 3.7-5, site-specific versus lateral certified standard soil pressures are also compared.

COL Item 3.7-5: A COL applicant that references the NuScale Power Plant design certification will perform a soil-structure interaction analysis of the Reactor Building and the Control Building using the NuScale SASSI2010 models for those structures. The COL applicant will confirm that the site-specific seismic demands of the standard design for critical structures, systems, and components in Appendix 3B are bounded by the corresponding design certified seismic demands and, if not, the standard design for critical structures, systems, and components will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands. Seismic demands investigated shall include forces, moments, deformations, in-structure response spectra, and seismic stability of the structures.

COL Item 3.7-6: A COL applicant that references the NuScale Power Plant design certification will perform a structure-soil-structure interaction analysis that includes the Reactor Building, the Control Building, the Radioactive Waste Building and both Turbine Generator Buildings. The COL applicant will confirm that the site-specific seismic demands of the standard design structures, systems, and components are bounded by the corresponding design certified seismic demands and, if not, the standard design structures, systems, and components will be shown to have appropriate margin or should be appropriately modified to accommodate the site-specific demands.

3.7.2.17 References

3.7.2-1 SAP2000 Advanced (Version 17.1.1) [Computer Program]. (2015). Walnut Creek, California: Computers and Structures, Inc.

3.7.2-2 SASSI2010 (Version 1.0) [Computer Program]. (2012). Berkeley, CA.

3.7.2-3 ANSYS (Release 16.0) [Computer Program]. (2015). Canonsburg, PA: ANSYS Incorporated.

3.7.2-4 American Society of Mechanical Engineers, *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)*, ASME NOG-1, 2004, New York, NY.

Table 3.7.2-1: Summary of Reactor Building SASSI2010 Model

Model Portions	Description	
Overall model dimensions	391' long (East-West), 195.5' wide (North-South), 165' high, embedded 86' deep	(n/a)
General	Number of lumped masses†	30,568
	Concrete structural damping for calculation of acceleration responses for ISRS generation (percent)	4
	Concrete structural damping for calculation of member forces and moments for structural design (percent)	7
RXB (including Backfill Soil)	Total number of nodes	30,762
	Backfill soil solid elements	9,236
	Foundation mat solid elements	2,839
	Beam elements	6,453
	Plate elements	18,818
	Spring elements modeling NPM support stiffness	1,114
	Fraction of quadrilateral and triangular elements (%)	2.45
	Typical element size (ft)	6
	Maximum element size (ft)	12
	Typical aspect ratio	1.29
	Maximum aspect ratio*	11.9
Connection between RXB and excavated soil	7P interaction nodes for extended subtraction method	7,950
	Rigid springs connecting RXB and excavated free-field soil	4,470
Excavated soil	Excavated soil nodes	28,830
	Excavated soil solid elements	25,620

Notes: † All masses are assigned as assembled joint lumped masses at each node.
*The aspect ratio of 11.9 is for a small number of non-structural, surface elements.

Table 3.7.2-2: Average Hydrodynamic Pressure from ANSYS

Section	Pressure (psi)
X Wall	
X1	11.852
X2	10.437
X3	11.504
Y Wall	
Y1	12.836
Y2	10.376
Y3	10.434
Y4	10.015
Y5	11.085
Foundation	
Z	12.884

Table 3.7.2-3: Equivalent Average Static Pressure from SASSI2010

Segment	Soil Type 7 (psi)	Soil Type 8 (psi)	Soil Type 11 (psi)
X1	2.331	1.841	0.99
X2	14.511	11.178	6.774
X3	2.152	1.707	0.926
Weighted X Wall	**7.726**	**5.978**	**3.558**
Y1	4.163	3.528	1.588
Y2	4.294	3.782	2.041
Y3	8.174	7.326	3.946
Y4	5.24	4.583	2.35
Y5	5.691	5.231	2.303
Weighted Y Wall	**5.48**	**4.844**	**2.492**
Z Foundation	**8.742**	**8.2**	**6.85**

Note: Weighted wall pressures are based on the weighted average of the lengths of each wall segment. Refer to Figure 3.7.2-35 for wall section length values.

Table 3.7.2-4: Summary of Average Pressures and Equivalent Static Pressure for SASSI2010 Soil Type 7

Segment	ANSYS	a_{SASSI}/a_{ANSYS}	SASSI2010
	Average Hydrodynamic Pressure, P_{hd} (psi)	Average Factors	Equivalent Static Pressure, P_{hd} x a_{SASSI}/a_{ANSYS} (psi)
X1	11.852	0.92	
X2	10.437	1.04	
X3	11.504	0.92	
Weighted X Wall	**11.124**	**0.97**	**10.816**
Y1	12.836	0.97	
Y2	10.376	0.94	
Y3	10.434	0.87	
Y4	10.015	0.91	
Y5	11.085	0.90	
Weighted Y Wall	**10.492**	**0.92**	**9.608**
Z Foundation	**12.884**	**1.00**	**12.945**

Note: Weighted wall pressures and a_{SASSI}/a_{ANSYS} factors are based on the weighted average of the lengths of each wall segment. Refer to Figure 3.7.2-35 for wall section length values.

Table 3.7.2-5: Summary of Average Pressures and Equivalent Static Pressure for SASSI2010 Soil Type 8

Segment	ANSYS	a_{SASSI}/a_{ANSYS}	SASSI2010
	Average Hydrodynamic Pressure, P_{hd} (psi)	Average Factors	Equivalent Static Pressure, $P_{hd} \times a_{SASSI}/a_{ANSYS}$ (psi)
X1	11.852	0.73	
X2	10.437	0.79	
X3	11.504	0.73	
Weighted X Wall	**11.124**	**0.76**	**8.406**
Y1	12.836	**0.82**	
Y2	10.376	**0.83**	
Y3	10.434	**0.78**	
Y4	10.015	**0.8**	
Y5	11.085	**0.82**	
Weighted Y Wall	**10.492**	**0.81**	**8.481**
Z Foundation	**12.884**	**0.94**	**12.122**

Note: Weighted wall pressures and a_{SASSI}/a_{ANSYS} factors are based on the weighted average of the lengths of each wall segment. Refer to Figure 3.7.2-35 for wall section length values.

Table 3.7.2-6: Summary of Average Pressures and Equivalent Static Pressure for SASSI2010 Soil Type 11

Segment	ANSYS	a_{SASSI}/a_{ANSYS}	SASSI2010
	Average Hydrodynamic Pressure, P_{hd} (psi)	Average Factors	Equivalent Static Pressure, $P_{hd} \times a_{SASSI}/a_{ANSYS}$ (psi)
X1	11.852	0.4	
X2	10.437	0.48	
X3	11.504	0.4	
Weighted X Wall	**11.124**	**0.44**	**4.843**
Y1	12.836	0.38	
Y2	10.376	0.46	
Y3	10.434	0.43	
Y4	10.015	0.42	
Y5	11.085	0.37	
Weighted Y Wall	**10.492**	**0.42**	**4.452**
Z Foundation	**12.884**	**0.79**	**10.223**

Note: Weighted wall pressures and a_{SASSI}/a_{ANSYS} factors are based on the weighted average of the lengths of each wall segment. Refer to Figure 3.7.2-35 for wall section length values.

Table 3.7.2-7: Comparison of Pressures

Segment	SASSI2010 Equivalent Static Pressure from ANSYS Hydrodynamic Analysis (psi) (See Tables 3.7.2-4, 3.7.2-5 and 3.7.2-6)	SASSI2010 Original Static Pressures from Hydro Lumped Masses (psi) (See Table 3.7.2-3)	Difference (psi)	% Difference
Soil Type 7				
Weighted X Wall	10.816	7.726	3.09	29%
Weighted Y Wall	9.608	5.48	4.129	43%
Z Foundation	12.945	8.742	4.203	32%
Soil Type 8				
Weighted X Wall	8.406	5.978	2.428	29%
Weighted Y Wall	8.481	4.844	3.637	43%
Z Foundation	12.122	8.2	3.921	32%
Soil Type 11				
Weighted X Wall	4.843	3.558	1.286	27%
Weighted Y Wall	4.452	2.492	1.96	44%
Z Foundation	10.223	6.85	3.373	33%

Table 3.7.2-8: Final Surface Pressure Adjustment in SAP2000 Model Due to FSI Effects

Segment	Soil Type 7 Difference	Soil Type 8 Difference	Soil Type 11 Difference	Maximum Difference per Section	Envelope Pressure to be Added to SAP2000 Model
	(psi)	(psi)	(psi)	(psi)	(psi)
Weighted X Wall	3.090	2.428	1.286	3.090	**4.20**
Weighted Y Wall	4.129	3.637	1.960	4.129	
Z Foundation	4.203	3.921	3.373	4.203	

Table 3.7.2-9: Summary of Control Building SASSI2010 Model

Model Portions	Description	Total Number Used
Overall dimensions	78′-0″ long (East-West), 116′-8″ wide (North-South), 96' 9" High embedded 56′-3″	(n/a)
All	Total unconstrained degrees of freedom	76,410
	Lumped masses†	8,415
	Concrete structural damping for calculation of acceleration responses for ISRS generation (percent)	4
	Concrete structural damping for calculation of member forces and moments for structural design (percent)	7
CRB (including backfill soil)	CRB and backfill soil nodes	8,415
	Backfill soil solid elements	3,555
	Foundation mat solid elements	411
	Beam elements	1,393
	Plate elements	4,069
	Fraction of quadrilateral and triangular elements (percent)	1.14
	Typical element size (ft)	6
	Maximum element size (ft)	20
	Typical aspect ratio	1.24
	Maximum aspect ratio	6.61
Connection between CRB and excavated soil	Interaction nodes (7P) for extended subtraction method	3,390
	Number of impedance degrees-of-freedom	10,170
	Rigid Springs connecting CRB and excavated soil	1,869
Excavated soil	Excavated soil nodes	8,640
	Excavated soil solid elements	7,254

Notes: † All masses are assigned as assembled joint lumped masses at each node.

Table 3.7.2-10: Summary of Reactor Building Fixed-Base Modal Frequency Comparison

Node No.	Location Description	Modal Direction	SAP2000		SASSI2010 Frequency (Hz)	Difference (%)
			Mode No.	Frequency (Hz)		
23850	Top East corner of 5' E-W pool wall	N-S	1	3.08	2.95	**-4.2**
30204	Center of roof	N-S	2	3.26	3.06	**-6.1**
		Vertical	3	3.33	3.37	**1.2**
17199	NPM 1 West support	N-S	2	3.26	3.05	**-6.4**
		N-S	17	5.61	5.31	**-5.3**
20502	CRDM†	N-S	2	3.26	3.05	**-6.4**
		N-S	17	5.61	5.34	**-4.8**
		N-S	138	13.5	13.1	**-3.0**
30616	Northeast top corner of roof	N-S	2	3.26	3.06	**-6.1**
		E-W	16	5.50	5.33	**-3.1**

Notes: †Used for frequency comparison between SAP2000 and SASSI2010.

Table 3.7.2-11: Summary of Control Building Fixed-Base Model Frequency Comparison

Node No.	Location Description	Modal Direction	SAP2000		SASSI2010	Difference (%)
			Mode No.	Freq (Hz)	Freq. (Hz)	
39757	Roof center	Z (Vert)	72	6.35	6.35	**0.00**
39866	East side mid-span at roof	X (E-W)	106	11.37	11.50	**1.14**
39783	North side mid-span at roof	Y (N-S)	114	14.81	14.38	**-2.90**
39860	North-East corner at roof level	Z (Vert)	122	19.90	19.81	**-0.45**
39860	North-East corner at roof level	Z (Vert)	128	27.90	28.83	**3.33**
38297	Middle of third floor slab	Z (Vert)	102	10.30	10.24	**-0.58**
38297	Middle of third floor slab	Z (Vert)	122	19.90	20.32	**2.11**

Table 3.7.2-12: Summary of Triple Building SASSI2010 Model

Model Portions	Description	Total Number Used
Overall model dimensions	725.5′ long (East-West), 218.5′ wide (North-South), 167′ high, model embedment: RXB = 86′, RWB = 34′, CRB = 55′.	(n/a)
General	Lumped masses†	46,762
	Total weight (lbs)	1,101,956,194
	Concrete structural damping for calculation of acceleration responses for ISRS generation (percent)	4
	Concrete structural damping for calculation of member forces and moments for structural design (percent)	7
Triple building model (including backfill soil)	Total number of nodes	47,034
	Backfill soil solid elements	13,716
	Foundation mat solid elements	4,339
	Beam elements	9,352
	Plate elements	31,455
	Spring elements modeling NPM support stiffness	1,114
	Interface springs between RWB and RXB	156
	Interface springs between RXB and CRB	279
Connection between model and excavated soil	7P interaction nodes for extended subtraction method	14,456
	Rigid springs connecting three buildings and excavated free-field soil	6,580
Excavated soil	Excavated soil nodes	44,071
	Excavated soil solid elements	40,336

Notes: † All masses are assigned as assembled joint lumped masses at each node.

Table 3.7.2-13: Dimensions and Weights of the Three Buildings

Building	Radioactive Waste Building	Reactor Building	Control Building
Structural dimensions	184.0′(EW) × 168.5′(NS) × 83′(Vertical)	346.0′(EW) × 150.5′(NS) × 167′(Vertical)	81.0′(EW) × 119.67′(NS) × 95′(Vertical)
Locations proximity to RXB	25′ to the West of RXB between centerlines of walls	(n/a)	34′ to the East of RXB between centerlines of walls
Structural weight (kips)	96,460	515,500†	45,000
Embedment depth	34′	86′	55′

† Pool water weight not included

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
1	3.89	0.26	0.002	0.000	0.000
2	3.83	0.26	0.002	0.002	0.000
3	0.52	1.93	0.002	0.012	0.000
4	0.43	2.33	0.004	0.012	0.000
5	0.35	2.87	0.004	0.540	0.000
6	0.31	3.23	0.004	0.540	0.021
7	0.30	3.32	0.004	0.540	0.023
8	0.28	3.58	0.004	0.540	0.023
9	0.25	4.07	0.004	0.540	0.025
10	0.24	4.18	0.004	0.540	0.025
11	0.23	4.26	0.011	0.540	0.026
12	0.23	4.30	0.011	0.540	0.026
13	0.22	4.50	0.017	0.550	0.026
14	0.21	4.66	0.140	0.550	0.026
15	0.21	4.78	0.170	0.550	0.026
16	0.21	4.78	0.180	0.550	0.026
17	0.21	4.80	0.180	0.550	0.026
18	0.20	4.90	0.190	0.550	0.026
19	0.20	5.02	0.200	0.550	0.026
20	0.19	5.17	0.210	0.600	0.026
21	0.19	5.25	0.390	0.600	0.027
22	0.18	5.44	0.520	0.600	0.031
23	0.18	5.66	0.520	0.610	0.031
24	0.18	5.70	0.530	0.610	0.045
25	0.17	5.74	0.530	0.610	0.058
26	0.17	5.81	0.530	0.610	0.059
27	0.17	5.88	0.590	0.610	0.059
28	0.17	5.99	0.600	0.610	0.061
29	0.17	6.03	0.630	0.610	0.061
30	0.16	6.09	0.630	0.610	0.061
31	0.16	6.10	0.630	0.610	0.061
32	0.16	6.11	0.630	0.610	0.062
33	0.16	6.12	0.630	0.610	0.062
34	0.16	6.12	0.630	0.610	0.062
35	0.16	6.13	0.630	0.610	0.062
36	0.16	6.14	0.630	0.610	0.062
37	0.16	6.15	0.630	0.610	0.062
38	0.16	6.17	0.630	0.620	0.062
39	0.16	6.20	0.640	0.620	0.062
40	0.16	6.22	0.640	0.620	0.062
41	0.16	6.28	0.640	0.640	0.062
42	0.16	6.42	0.640	0.640	0.062
43	0.15	6.49	0.640	0.650	0.062
44	0.15	6.49	0.640	0.650	0.062
45	0.15	6.50	0.640	0.650	0.062
46	0.15	6.51	0.640	0.650	0.062
47	0.15	6.52	0.640	0.650	0.062

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
48	0.15	6.53	0.640	0.650	0.062
49	0.15	6.55	0.640	0.650	0.062
50	0.15	6.59	0.640	0.660	0.062
51	0.15	6.60	0.640	0.680	0.063
52	0.15	6.63	0.640	0.680	0.063
53	0.15	6.64	0.640	0.680	0.063
54	0.15	6.70	0.650	0.680	0.063
55	0.15	6.70	0.650	0.680	0.065
56	0.15	6.73	0.650	0.680	0.065
57	0.15	6.81	0.650	0.680	0.066
58	0.15	6.82	0.650	0.680	0.074
59	0.15	6.88	0.650	0.680	0.075
60	0.14	6.92	0.650	0.680	0.083
61	0.14	6.95	0.650	0.680	0.084
62	0.14	7.00	0.650	0.680	0.084
63	0.14	7.04	0.650	0.680	0.120
64	0.14	7.09	0.660	0.680	0.120
65	0.14	7.12	0.660	0.680	0.130
66	0.14	7.13	0.660	0.680	0.140
67	0.14	7.16	0.660	0.690	0.160
68	0.14	7.17	0.660	0.690	0.190
69	0.14	7.20	0.660	0.690	0.190
70	0.14	7.21	0.660	0.690	0.190
71	0.14	7.22	0.660	0.700	0.190
72	0.14	7.28	0.660	0.700	0.190
73	0.14	7.31	0.660	0.700	0.190
74	0.14	7.34	0.670	0.700	0.190
75	0.14	7.37	0.670	0.700	0.190
76	0.14	7.39	0.670	0.700	0.190
77	0.13	7.42	0.670	0.700	0.200
78	0.13	7.43	0.670	0.710	0.200
79	0.13	7.48	0.670	0.710	0.200
80	0.13	7.51	0.670	0.710	0.210
81	0.13	7.53	0.680	0.710	0.210
82	0.13	7.58	0.680	0.710	0.210
83	0.13	7.60	0.690	0.710	0.210
84	0.13	7.63	0.690	0.710	0.210
85	0.13	7.67	0.690	0.710	0.210
86	0.13	7.71	0.690	0.710	0.210
87	0.13	7.77	0.690	0.710	0.210
88	0.13	7.78	0.690	0.710	0.210
89	0.13	7.82	0.690	0.720	0.220
90	0.13	7.85	0.690	0.720	0.220
91	0.13	7.86	0.690	0.720	0.220
92	0.13	7.86	0.690	0.720	0.220
93	0.13	7.92	0.690	0.720	0.220
94	0.13	7.96	0.690	0.720	0.220
95	0.13	7.99	0.700	0.720	0.220
96	0.12	8.03	0.700	0.720	0.220

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
97	0.12	8.06	0.700	0.720	0.220
98	0.12	8.10	0.700	0.720	0.220
99	0.12	8.12	0.700	0.720	0.220
100	0.12	8.16	0.700	0.720	0.220
101	0.12	8.21	0.700	0.720	0.220
102	0.12	8.23	0.700	0.720	0.220
103	0.12	8.23	0.700	0.720	0.220
104	0.12	8.24	0.700	0.720	0.220
105	0.12	8.25	0.700	0.720	0.220
106	0.12	8.26	0.700	0.720	0.220
107	0.12	8.26	0.700	0.720	0.220
108	0.12	8.28	0.700	0.720	0.220
109	0.12	8.29	0.700	0.720	0.220
110	0.12	8.31	0.700	0.720	0.220
111	0.12	8.31	0.700	0.720	0.220
112	0.12	8.33	0.700	0.720	0.220
113	0.12	8.34	0.700	0.720	0.220
114	0.12	8.35	0.700	0.720	0.220
115	0.12	8.37	0.700	0.720	0.220
116	0.12	8.42	0.700	0.720	0.220
117	0.12	8.44	0.710	0.720	0.220
118	0.12	8.45	0.710	0.720	0.220
119	0.12	8.51	0.710	0.720	0.220
120	0.12	8.59	0.710	0.720	0.230
121	0.12	8.63	0.710	0.720	0.230
122	0.12	8.63	0.710	0.720	0.230
123	0.12	8.68	0.710	0.720	0.230
124	0.12	8.68	0.710	0.730	0.230
125	0.12	8.69	0.710	0.730	0.230
126	0.11	8.72	0.710	0.730	0.230
127	0.11	8.72	0.710	0.730	0.230
128	0.11	8.79	0.710	0.730	0.230
129	0.11	8.83	0.710	0.730	0.230
130	0.11	8.86	0.710	0.730	0.230
131	0.11	8.88	0.710	0.730	0.230
132	0.11	8.92	0.710	0.730	0.230
133	0.11	8.93	0.710	0.730	0.230
134	0.11	8.93	0.710	0.730	0.230
135	0.11	8.97	0.720	0.730	0.240
136	0.11	9.04	0.720	0.730	0.240
137	0.11	9.06	0.720	0.730	0.240
138	0.11	9.07	0.720	0.730	0.240
139	0.11	9.07	0.720	0.730	0.240
140	0.11	9.08	0.720	0.730	0.240
141	0.11	9.09	0.720	0.730	0.240
142	0.11	9.12	0.720	0.730	0.240
143	0.11	9.15	0.720	0.730	0.240
144	0.11	9.18	0.720	0.730	0.240
145	0.11	9.18	0.720	0.730	0.240

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
146	0.11	9.22	0.720	0.730	0.240
147	0.11	9.23	0.720	0.730	0.240
148	0.11	9.25	0.720	0.730	0.240
149	0.11	9.26	0.720	0.730	0.240
150	0.11	9.31	0.720	0.730	0.240
151	0.11	9.31	0.720	0.740	0.250
152	0.11	9.33	0.730	0.740	0.250
153	0.11	9.39	0.730	0.740	0.250
154	0.11	9.42	0.730	0.740	0.250
155	0.11	9.45	0.730	0.740	0.250
156	0.11	9.45	0.730	0.740	0.250
157	0.11	9.50	0.730	0.740	0.250
158	0.10	9.53	0.730	0.740	0.250
159	0.10	9.55	0.730	0.740	0.250
160	0.10	9.56	0.730	0.740	0.250
161	0.10	9.63	0.730	0.740	0.250
162	0.10	9.64	0.730	0.740	0.250
163	0.10	9.68	0.730	0.740	0.250
164	0.10	9.73	0.730	0.740	0.250
165	0.10	9.76	0.730	0.740	0.250
166	0.10	9.78	0.730	0.740	0.250
167	0.10	9.78	0.730	0.740	0.250
168	0.10	9.81	0.730	0.740	0.250
169	0.10	9.83	0.730	0.740	0.250
170	0.10	9.85	0.730	0.750	0.250
171	0.10	9.88	0.730	0.750	0.250
172	0.10	9.91	0.730	0.750	0.250
173	0.10	9.91	0.730	0.750	0.250
174	0.10	9.97	0.730	0.750	0.250
175	0.10	9.99	0.730	0.750	0.250
176	0.10	10.00	0.730	0.750	0.250
177	0.10	10.03	0.730	0.750	0.250
178	0.10	10.05	0.730	0.750	0.250
179	0.10	10.06	0.730	0.750	0.250
180	0.10	10.09	0.730	0.750	0.250
181	0.10	10.13	0.730	0.750	0.250
182	0.10	10.14	0.730	0.750	0.250
183	0.10	10.18	0.730	0.750	0.250
184	0.10	10.19	0.730	0.750	0.250
185	0.10	10.20	0.730	0.750	0.250
186	0.10	10.22	0.730	0.750	0.250
187	0.10	10.25	0.730	0.750	0.250
188	0.10	10.28	0.730	0.750	0.260
189	0.10	10.31	0.730	0.750	0.260
190	0.10	10.32	0.740	0.760	0.260
191	0.10	10.34	0.740	0.760	0.260
192	0.10	10.35	0.740	0.760	0.260
193	0.10	10.40	0.740	0.760	0.260
194	0.10	10.41	0.740	0.760	0.260

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
195	0.10	10.43	0.740	0.760	0.260
196	0.10	10.44	0.740	0.760	0.270
197	0.10	10.46	0.740	0.760	0.300
198	0.10	10.51	0.740	0.760	0.300
199	0.09	10.55	0.740	0.760	0.300
200	0.09	10.63	0.740	0.760	0.300
201	0.09	10.65	0.740	0.760	0.300
202	0.09	10.67	0.740	0.760	0.310
203	0.09	10.69	0.740	0.760	0.310
204	0.09	10.72	0.740	0.760	0.310
205	0.09	10.72	0.740	0.760	0.310
206	0.09	10.75	0.740	0.760	0.310
207	0.09	10.77	0.740	0.760	0.310
208	0.09	10.78	0.740	0.760	0.310
209	0.09	10.81	0.740	0.760	0.320
210	0.09	10.81	0.750	0.760	0.320
211	0.09	10.85	0.750	0.760	0.320
212	0.09	10.86	0.750	0.760	0.320
213	0.09	10.87	0.750	0.760	0.320
214	0.09	10.87	0.750	0.760	0.330
215	0.09	10.89	0.750	0.760	0.330
216	0.09	10.92	0.750	0.760	0.330
217	0.09	10.95	0.750	0.770	0.330
218	0.09	10.96	0.750	0.770	0.330
219	0.09	10.97	0.750	0.770	0.340
220	0.09	10.99	0.750	0.770	0.340
221	0.09	11.00	0.750	0.770	0.340
222	0.09	11.04	0.750	0.770	0.340
223	0.09	11.04	0.750	0.770	0.350
224	0.09	11.06	0.750	0.770	0.350
225	0.09	11.09	0.750	0.770	0.350
226	0.09	11.10	0.750	0.770	0.350
227	0.09	11.14	0.750	0.770	0.350
228	0.09	11.16	0.750	0.770	0.350
229	0.09	11.18	0.750	0.770	0.350
230	0.09	11.19	0.750	0.770	0.350
231	0.09	11.22	0.750	0.770	0.350
232	0.09	11.24	0.750	0.770	0.350
233	0.09	11.27	0.750	0.770	0.360
234	0.09	11.28	0.750	0.770	0.360
235	0.09	11.33	0.750	0.770	0.370
236	0.09	11.34	0.750	0.780	0.370
237	0.09	11.37	0.750	0.780	0.370
238	0.09	11.40	0.750	0.780	0.370
239	0.09	11.42	0.750	0.780	0.370
240	0.09	11.44	0.760	0.780	0.380
241	0.09	11.49	0.760	0.780	0.380
242	0.09	11.50	0.760	0.780	0.380
243	0.09	11.54	0.760	0.780	0.380

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
244	0.09	11.58	0.760	0.780	0.380
245	0.09	11.61	0.760	0.780	0.380
246	0.09	11.62	0.760	0.780	0.380
247	0.09	11.67	0.760	0.780	0.380
248	0.09	11.67	0.760	0.780	0.380
249	0.09	11.72	0.760	0.780	0.380
250	0.09	11.74	0.760	0.780	0.380
251	0.08	11.77	0.760	0.780	0.390
252	0.08	11.82	0.760	0.780	0.390
253	0.08	11.85	0.760	0.780	0.390
254	0.08	11.88	0.760	0.780	0.390
255	0.08	11.92	0.760	0.780	0.390
256	0.08	11.96	0.760	0.780	0.390
257	0.08	11.98	0.770	0.780	0.390
258	0.08	12.01	0.770	0.780	0.390
259	0.08	12.04	0.770	0.780	0.390
260	0.08	12.07	0.770	0.780	0.390
261	0.08	12.11	0.770	0.780	0.390
262	0.08	12.18	0.770	0.780	0.390
263	0.08	12.21	0.770	0.780	0.390
264	0.08	12.23	0.770	0.780	0.400
265	0.08	12.27	0.770	0.780	0.400
266	0.08	12.30	0.770	0.780	0.400
267	0.08	12.35	0.780	0.780	0.400
268	0.08	12.37	0.780	0.780	0.400
269	0.08	12.41	0.780	0.790	0.400
270	0.08	12.46	0.780	0.790	0.400
271	0.08	12.49	0.780	0.790	0.400
272	0.08	12.55	0.780	0.790	0.400
273	0.08	12.56	0.780	0.790	0.400
274	0.08	12.58	0.780	0.790	0.400
275	0.08	12.65	0.780	0.790	0.400
276	0.08	12.69	0.780	0.790	0.400
277	0.08	12.76	0.780	0.790	0.400
278	0.08	12.80	0.780	0.790	0.400
279	0.08	12.85	0.780	0.800	0.410
280	0.08	12.89	0.780	0.800	0.410
281	0.08	12.93	0.780	0.800	0.420
282	0.08	12.99	0.780	0.800	0.430
283	0.08	13.00	0.790	0.800	0.440
284	0.08	13.04	0.790	0.800	0.440
285	0.08	13.07	0.800	0.800	0.440
286	0.08	13.14	0.800	0.800	0.450
287	0.08	13.15	0.800	0.800	0.460
288	0.08	13.20	0.800	0.800	0.460
289	0.08	13.30	0.800	0.800	0.460
290	0.07	13.34	0.800	0.800	0.470
291	0.07	13.42	0.800	0.800	0.480
292	0.07	13.45	0.800	0.800	0.510

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
293	0.07	13.51	0.800	0.800	0.510
294	0.07	13.52	0.800	0.800	0.540
295	0.07	13.60	0.800	0.800	0.540
296	0.07	13.63	0.800	0.800	0.540
297	0.07	13.71	0.800	0.800	0.550
298	0.07	13.74	0.800	0.800	0.550
299	0.07	13.82	0.800	0.800	0.550
300	0.07	13.90	0.800	0.800	0.550
301	0.07	13.91	0.800	0.800	0.550
302	0.07	13.98	0.800	0.800	0.560
303	0.07	14.08	0.800	0.800	0.570
304	0.07	14.12	0.800	0.810	0.580
305	0.07	14.18	0.800	0.810	0.580
306	0.07	14.25	0.800	0.810	0.580
307	0.07	14.30	0.800	0.810	0.580
308	0.07	14.35	0.800	0.810	0.580
309	0.07	14.41	0.800	0.810	0.590
310	0.07	14.49	0.800	0.810	0.590
311	0.07	14.53	0.800	0.810	0.590
312	0.07	14.61	0.800	0.810	0.590
313	0.07	14.67	0.800	0.820	0.590
314	0.07	14.73	0.800	0.820	0.600
315	0.07	14.82	0.800	0.820	0.600
316	0.07	14.86	0.800	0.820	0.600
317	0.07	14.90	0.810	0.820	0.610
318	0.07	14.98	0.810	0.820	0.610
319	0.07	15.06	0.810	0.820	0.610
320	0.07	15.11	0.810	0.820	0.610
321	0.07	15.21	0.810	0.820	0.610
322	0.07	15.27	0.810	0.820	0.610
323	0.07	15.36	0.810	0.820	0.610
324	0.06	15.46	0.810	0.820	0.610
325	0.06	15.51	0.810	0.820	0.610
326	0.06	15.55	0.810	0.820	0.610
327	0.06	15.66	0.810	0.820	0.610
328	0.06	15.73	0.810	0.820	0.610
329	0.06	15.79	0.810	0.820	0.610
330	0.06	15.93	0.810	0.830	0.620
331	0.06	15.96	0.810	0.830	0.620
332	0.06	16.02	0.810	0.830	0.620
333	0.06	16.17	0.810	0.830	0.620
334	0.06	16.25	0.820	0.830	0.620
335	0.06	16.29	0.820	0.830	0.620
336	0.06	16.45	0.820	0.830	0.620
337	0.06	16.47	0.820	0.830	0.620
338	0.06	16.58	0.820	0.830	0.630
339	0.06	16.71	0.820	0.830	0.630
340	0.06	16.74	0.820	0.830	0.630
341	0.06	16.82	0.820	0.830	0.630

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
342	0.06	16.97	0.820	0.830	0.630
343	0.06	17.06	0.820	0.830	0.630
344	0.06	17.12	0.820	0.830	0.630
345	0.06	17.27	0.820	0.840	0.630
346	0.06	17.34	0.820	0.840	0.630
347	0.06	17.37	0.830	0.840	0.630
348	0.06	17.53	0.830	0.840	0.630
349	0.06	17.63	0.830	0.840	0.630
350	0.06	17.72	0.830	0.840	0.640
351	0.06	17.92	0.830	0.840	0.640
352	0.06	17.96	0.830	0.840	0.640
353	0.06	18.06	0.830	0.840	0.640
354	0.05	18.21	0.830	0.840	0.640
355	0.05	18.28	0.830	0.840	0.640
356	0.05	18.43	0.830	0.840	0.640
357	0.05	18.58	0.830	0.840	0.640
358	0.05	18.65	0.830	0.840	0.640
359	0.05	18.73	0.830	0.840	0.650
360	0.05	18.97	0.830	0.840	0.650
361	0.05	19.00	0.830	0.840	0.650
362	0.05	19.15	0.830	0.840	0.660
363	0.05	19.28	0.830	0.850	0.660
364	0.05	19.38	0.840	0.850	0.670
365	0.05	19.46	0.840	0.850	0.670
366	0.05	19.61	0.840	0.850	0.670
367	0.05	19.75	0.840	0.850	0.670
368	0.05	19.89	0.840	0.850	0.680
369	0.05	20.10	0.840	0.850	0.680
370	0.05	20.19	0.840	0.850	0.680
371	0.05	20.27	0.840	0.850	0.680
372	0.05	20.66	0.840	0.850	0.680
373	0.05	20.67	0.840	0.850	0.680
374	0.05	20.77	0.840	0.850	0.690
375	0.05	21.03	0.840	0.850	0.690
376	0.05	21.11	0.840	0.850	0.690
377	0.05	21.16	0.840	0.850	0.690
378	0.05	21.52	0.840	0.850	0.700
379	0.05	21.65	0.840	0.850	0.700
380	0.05	21.74	0.850	0.850	0.700
381	0.05	22.07	0.850	0.850	0.700
382	0.05	22.12	0.850	0.860	0.700
383	0.05	22.13	0.850	0.860	0.710
384	0.04	22.46	0.850	0.860	0.710
385	0.04	22.47	0.850	0.860	0.710
386	0.04	22.62	0.850	0.860	0.710
387	0.04	23.06	0.850	0.860	0.710
388	0.04	23.14	0.850	0.860	0.710
389	0.04	23.28	0.850	0.860	0.710
390	0.04	23.69	0.850	0.860	0.710

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
391	0.04	23.78	0.850	0.860	0.720
392	0.04	23.89	0.860	0.860	0.720
393	0.04	24.29	0.860	0.860	0.720
394	0.04	24.40	0.860	0.860	0.720
395	0.04	24.49	0.860	0.860	0.720
396	0.04	25.03	0.860	0.860	0.720
397	0.04	25.15	0.860	0.860	0.720
398	0.04	25.20	0.860	0.860	0.720
399	0.04	25.71	0.860	0.860	0.720
400	0.04	25.78	0.860	0.870	0.720
401	0.04	25.87	0.860	0.870	0.730
402	0.04	26.34	0.860	0.870	0.730
403	0.04	26.37	0.870	0.870	0.730
404	0.04	26.67	0.870	0.870	0.730
405	0.04	27.29	0.870	0.870	0.730
406	0.04	27.38	0.870	0.870	0.730
407	0.04	27.57	0.870	0.870	0.730
408	0.04	28.12	0.870	0.870	0.730
409	0.04	28.14	0.870	0.870	0.730
410	0.04	28.31	0.870	0.870	0.730
411	0.03	29.05	0.870	0.870	0.740
412	0.03	29.13	0.870	0.870	0.740
413	0.03	29.22	0.870	0.870	0.740
414	0.03	30.05	0.870	0.870	0.740
415	0.03	30.07	0.870	0.870	0.740
416	0.03	30.22	0.870	0.870	0.740
417	0.03	31.08	0.870	0.870	0.740
418	0.03	31.15	0.870	0.870	0.750
419	0.03	31.37	0.870	0.880	0.750
420	0.03	32.21	0.880	0.880	0.750
421	0.03	32.22	0.880	0.880	0.750
422	0.03	32.45	0.880	0.880	0.750
423	0.03	33.36	0.880	0.880	0.750
424	0.03	33.49	0.880	0.880	0.750
425	0.03	33.61	0.880	0.880	0.750
426	0.03	34.65	0.880	0.880	0.750
427	0.03	34.78	0.880	0.880	0.760
428	0.03	34.86	0.880	0.880	0.760
429	0.03	36.11	0.880	0.880	0.760
430	0.03	36.33	0.880	0.880	0.760
431	0.03	36.54	0.880	0.880	0.760
432	0.03	37.69	0.880	0.880	0.760
433	0.03	37.77	0.890	0.880	0.760
434	0.03	38.06	0.890	0.890	0.760
435	0.03	39.42	0.890	0.890	0.760
436	0.03	39.56	0.890	0.890	0.760
437	0.03	39.79	0.890	0.890	0.770
438	0.02	41.06	0.890	0.890	0.770
439	0.02	41.38	0.890	0.890	0.770

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
440	0.02	41.51	0.890	0.890	0.770
441	0.02	43.20	0.890	0.890	0.770
442	0.02	43.23	0.890	0.890	0.770
443	0.02	43.60	0.890	0.890	0.780
444	0.02	45.44	0.890	0.890	0.780
445	0.02	45.48	0.900	0.900	0.780
446	0.02	45.99	0.900	0.900	0.780
447	0.02	47.86	0.900	0.900	0.780
448	0.02	48.35	0.900	0.900	0.790
449	0.02	48.53	0.900	0.900	0.790
450	0.02	50.80	0.900	0.900	0.790
451	0.02	50.96	0.900	0.900	0.790
452	0.02	51.25	0.900	0.900	0.790
453	0.02	53.97	0.900	0.910	0.790
454	0.02	54.17	0.900	0.910	0.790
455	0.02	54.75	0.900	0.910	0.800
456	0.02	57.18	0.900	0.910	0.800
457	0.02	57.39	0.900	0.910	0.800
458	0.02	58.08	0.910	0.910	0.810
459	0.02	61.80	0.910	0.910	0.810
460	0.02	61.98	0.910	0.910	0.810
461	0.02	62.17	0.910	0.910	0.820
462	0.02	66.39	0.910	0.910	0.820
463	0.01	66.69	0.910	0.910	0.820
464	0.01	66.95	0.910	0.910	0.830
465	0.01	72.43	0.910	0.910	0.830
466	0.01	72.85	0.910	0.920	0.830
467	0.01	73.53	0.910	0.920	0.830
468	0.01	78.62	0.910	0.920	0.840
469	0.01	79.10	0.910	0.920	0.840
470	0.01	80.26	0.910	0.920	0.840
471	0.01	87.27	0.910	0.920	0.850
472	0.01	87.96	0.920	0.920	0.850
473	0.01	88.16	0.920	0.920	0.850
474	0.01	96.45	0.930	0.920	0.850
475	0.01	96.91	0.930	0.930	0.860
476	0.01	97.52	0.930	0.930	0.870
477	0.01	107.52	0.930	0.940	0.870
478	0.01	108.80	0.930	0.940	0.890
479	0.01	109.35	0.940	0.940	0.890
480	0.01	123.25	0.950	0.940	0.900
481	0.01	123.62	0.950	0.940	0.920
482	0.01	125.80	0.950	0.950	0.920
483	0.01	139.93	0.950	0.950	0.940
484	0.01	144.16	0.960	0.950	0.940
485	0.01	144.50	0.960	0.960	0.940
486	0.01	165.83	0.960	0.970	0.940
487	0.01	167.00	0.960	0.980	0.950
488	0.01	170.54	0.980	0.980	0.950

Table 3.7.2-14: Frequencies and Modal Mass Ratios for the Reactor Building Cracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
489	0.01	197.77	0.990	0.980	0.950
490	0.01	199.07	0.990	0.990	0.950
491	0.00	220.56	0.990	0.990	0.950
492	0.00	265.28	0.990	0.990	0.970
493	0.00	266.17	0.990	0.990	0.970
494	0.00	267.98	0.990	0.990	0.980
495	0.00	382.57	0.990	1.000	0.980
496	0.00	384.04	1.000	1.000	0.980
497	0.00	416.17	1.000	1.000	0.980
498	0.00	611.76	1.000	1.000	1.000
499	0.00	723.42	1.000	1.000	1.000
500	0.00	749.18	1.000	1.000	1.000

Notes:
The first significant frequency in each direction is highlighted.

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
1	3.89	0.26	0.002	0.000	0.000
2	3.83	0.26	0.002	0.002	0.000
3	0.43	2.34	0.004	0.002	0.000
4	0.39	2.55	0.004	0.019	0.000
5	0.34	2.97	0.004	0.540	0.000
6	0.30	3.29	0.004	0.540	0.005
7	0.23	4.29	0.007	0.540	0.005
8	0.23	4.37	0.009	0.540	0.020
9	0.22	4.53	0.017	0.560	0.020
10	0.22	4.59	0.029	0.560	0.026
11	0.21	4.69	0.130	0.560	0.027
12	0.21	4.80	0.160	0.560	0.027
13	0.20	4.93	0.160	0.560	0.027
14	0.20	5.05	0.160	0.560	0.027
15	0.19	5.25	0.370	0.560	0.028
16	0.19	5.39	0.370	0.590	0.028
17	0.18	5.46	0.510	0.600	0.032
18	0.18	5.64	0.510	0.600	0.038
19	0.18	5.68	0.510	0.600	0.038
20	0.17	5.72	0.510	0.610	0.053
21	0.17	5.76	0.510	0.610	0.061
22	0.17	5.82	0.510	0.610	0.061
23	0.17	5.91	0.600	0.610	0.062
24	0.17	6.03	0.610	0.610	0.063
25	0.16	6.06	0.620	0.610	0.063
26	0.16	6.14	0.620	0.610	0.064
27	0.16	6.25	0.620	0.610	0.064
28	0.16	6.30	0.620	0.620	0.064
29	0.16	6.34	0.620	0.620	0.064
30	0.16	6.38	0.620	0.630	0.064
31	0.16	6.42	0.630	0.630	0.064
32	0.16	6.45	0.630	0.630	0.064
33	0.15	6.46	0.630	0.630	0.064
34	0.15	6.47	0.630	0.630	0.064
35	0.15	6.48	0.630	0.630	0.064
36	0.15	6.50	0.630	0.630	0.064
37	0.15	6.50	0.630	0.630	0.064
38	0.15	6.52	0.630	0.630	0.064
39	0.15	6.52	0.630	0.630	0.064
40	0.15	6.52	0.630	0.630	0.064
41	0.15	6.54	0.630	0.630	0.064
42	0.15	6.55	0.630	0.630	0.064
43	0.15	6.58	0.630	0.630	0.064
44	0.15	6.59	0.630	0.640	0.064
45	0.15	6.68	0.630	0.640	0.064
46	0.15	6.71	0.630	0.660	0.064
47	0.15	6.72	0.630	0.680	0.065

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
48	0.15	6.80	0.630	0.680	0.070
49	0.15	6.85	0.630	0.680	0.070
50	0.15	6.88	0.630	0.680	0.070
51	0.15	6.90	0.660	0.680	0.073
52	0.14	7.00	0.660	0.680	0.120
53	0.14	7.09	0.660	0.680	0.120
54	0.14	7.14	0.670	0.680	0.130
55	0.14	7.15	0.670	0.680	0.130
56	0.14	7.16	0.670	0.680	0.170
57	0.14	7.22	0.670	0.690	0.180
58	0.14	7.24	0.670	0.690	0.190
59	0.14	7.28	0.680	0.690	0.200
60	0.14	7.33	0.680	0.690	0.200
61	0.14	7.33	0.680	0.690	0.200
62	0.14	7.35	0.680	0.700	0.200
63	0.14	7.38	0.690	0.700	0.200
64	0.13	7.41	0.690	0.700	0.200
65	0.13	7.43	0.690	0.700	0.200
66	0.13	7.45	0.690	0.700	0.210
67	0.13	7.48	0.700	0.700	0.210
68	0.13	7.49	0.700	0.700	0.210
69	0.13	7.49	0.700	0.700	0.210
70	0.13	7.56	0.700	0.700	0.210
71	0.13	7.58	0.700	0.700	0.210
72	0.13	7.59	0.700	0.700	0.210
73	0.13	7.60	0.700	0.700	0.210
74	0.13	7.64	0.700	0.710	0.210
75	0.13	7.66	0.700	0.710	0.220
76	0.13	7.68	0.700	0.710	0.220
77	0.13	7.71	0.700	0.710	0.220
78	0.13	7.72	0.700	0.710	0.220
79	0.13	7.77	0.700	0.710	0.220
80	0.13	7.80	0.700	0.710	0.220
81	0.13	7.84	0.700	0.710	0.220
82	0.13	7.86	0.700	0.710	0.220
83	0.13	7.89	0.700	0.710	0.220
84	0.13	7.91	0.700	0.710	0.220
85	0.13	7.93	0.700	0.710	0.220
86	0.12	8.01	0.700	0.710	0.220
87	0.12	8.04	0.700	0.710	0.220
88	0.12	8.09	0.700	0.720	0.220
89	0.12	8.10	0.700	0.720	0.220
90	0.12	8.11	0.710	0.720	0.220
91	0.12	8.13	0.710	0.720	0.220
92	0.12	8.17	0.710	0.720	0.220
93	0.12	8.21	0.710	0.720	0.220
94	0.12	8.27	0.710	0.720	0.220
95	0.12	8.29	0.710	0.720	0.220
96	0.12	8.32	0.710	0.720	0.220

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
97	0.12	8.35	0.710	0.720	0.220
98	0.12	8.39	0.710	0.720	0.220
99	0.12	8.45	0.710	0.720	0.220
100	0.12	8.50	0.710	0.720	0.220
101	0.12	8.54	0.710	0.730	0.220
102	0.12	8.56	0.710	0.730	0.220
103	0.12	8.63	0.710	0.730	0.220
104	0.12	8.64	0.710	0.730	0.220
105	0.12	8.65	0.710	0.730	0.220
106	0.12	8.68	0.710	0.730	0.220
107	0.12	8.69	0.710	0.730	0.220
108	0.11	8.74	0.710	0.730	0.220
109	0.11	8.83	0.710	0.730	0.220
110	0.11	8.90	0.710	0.730	0.220
111	0.11	8.94	0.710	0.730	0.220
112	0.11	9.05	0.710	0.730	0.220
113	0.11	9.07	0.710	0.730	0.220
114	0.11	9.08	0.710	0.730	0.220
115	0.11	9.10	0.710	0.730	0.220
116	0.11	9.12	0.710	0.730	0.220
117	0.11	9.14	0.710	0.730	0.220
118	0.11	9.16	0.710	0.730	0.220
119	0.11	9.19	0.710	0.730	0.220
120	0.11	9.20	0.710	0.730	0.220
121	0.11	9.24	0.710	0.740	0.220
122	0.11	9.26	0.710	0.740	0.220
123	0.11	9.31	0.710	0.740	0.220
124	0.11	9.31	0.720	0.740	0.220
125	0.11	9.34	0.720	0.740	0.220
126	0.11	9.35	0.730	0.740	0.230
127	0.11	9.40	0.730	0.740	0.230
128	0.11	9.42	0.730	0.740	0.230
129	0.11	9.44	0.730	0.740	0.230
130	0.11	9.44	0.730	0.740	0.230
131	0.11	9.46	0.730	0.740	0.230
132	0.11	9.50	0.730	0.740	0.230
133	0.11	9.52	0.730	0.740	0.230
134	0.10	9.53	0.730	0.740	0.230
135	0.10	9.53	0.730	0.740	0.230
136	0.10	9.55	0.730	0.740	0.230
137	0.10	9.56	0.730	0.740	0.230
138	0.10	9.58	0.730	0.740	0.230
139	0.10	9.59	0.730	0.740	0.230
140	0.10	9.66	0.730	0.740	0.230
141	0.10	9.67	0.730	0.740	0.230
142	0.10	9.75	0.730	0.740	0.230
143	0.10	9.76	0.730	0.740	0.230
144	0.10	9.77	0.730	0.740	0.230
145	0.10	9.80	0.730	0.740	0.230

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
146	0.10	9.81	0.730	0.740	0.230
147	0.10	9.84	0.730	0.740	0.230
148	0.10	9.86	0.730	0.740	0.230
149	0.10	9.87	0.730	0.740	0.230
150	0.10	9.90	0.730	0.740	0.230
151	0.10	9.92	0.730	0.740	0.230
152	0.10	9.98	0.730	0.740	0.230
153	0.10	9.99	0.730	0.740	0.230
154	0.10	10.01	0.730	0.740	0.230
155	0.10	10.05	0.730	0.740	0.230
156	0.10	10.07	0.730	0.740	0.230
157	0.10	10.09	0.730	0.740	0.230
158	0.10	10.12	0.730	0.740	0.240
159	0.10	10.14	0.730	0.740	0.240
160	0.10	10.17	0.730	0.750	0.240
161	0.10	10.19	0.730	0.750	0.240
162	0.10	10.21	0.730	0.750	0.240
163	0.10	10.22	0.730	0.750	0.240
164	0.10	10.24	0.730	0.750	0.240
165	0.10	10.29	0.730	0.750	0.240
166	0.10	10.29	0.730	0.750	0.240
167	0.10	10.31	0.730	0.750	0.240
168	0.10	10.33	0.730	0.750	0.240
169	0.10	10.37	0.730	0.750	0.240
170	0.10	10.42	0.730	0.750	0.240
171	0.10	10.43	0.730	0.750	0.240
172	0.10	10.46	0.730	0.750	0.240
173	0.10	10.47	0.730	0.750	0.250
174	0.10	10.50	0.730	0.750	0.260
175	0.09	10.53	0.730	0.750	0.260
176	0.09	10.59	0.730	0.750	0.260
177	0.09	10.63	0.730	0.760	0.260
178	0.09	10.68	0.730	0.760	0.260
179	0.09	10.71	0.730	0.760	0.260
180	0.09	10.73	0.730	0.760	0.260
181	0.09	10.73	0.730	0.760	0.260
182	0.09	10.78	0.730	0.760	0.290
183	0.09	10.79	0.730	0.760	0.290
184	0.09	10.80	0.730	0.760	0.290
185	0.09	10.81	0.730	0.760	0.300
186	0.09	10.81	0.730	0.760	0.310
187	0.09	10.84	0.730	0.760	0.310
188	0.09	10.85	0.740	0.760	0.310
189	0.09	10.88	0.740	0.760	0.310
190	0.09	10.90	0.740	0.760	0.310
191	0.09	10.91	0.740	0.760	0.310
192	0.09	10.92	0.740	0.760	0.320
193	0.09	10.94	0.740	0.760	0.320
194	0.09	10.98	0.740	0.760	0.320

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
195	0.09	11.00	0.740	0.760	0.320
196	0.09	11.00	0.740	0.760	0.330
197	0.09	11.02	0.740	0.760	0.330
198	0.09	11.05	0.740	0.760	0.330
199	0.09	11.07	0.740	0.760	0.330
200	0.09	11.07	0.740	0.760	0.330
201	0.09	11.09	0.740	0.760	0.330
202	0.09	11.11	0.740	0.760	0.330
203	0.09	11.12	0.740	0.760	0.330
204	0.09	11.15	0.740	0.760	0.340
205	0.09	11.18	0.740	0.760	0.340
206	0.09	11.19	0.740	0.760	0.340
207	0.09	11.21	0.740	0.760	0.340
208	0.09	11.23	0.740	0.760	0.340
209	0.09	11.25	0.740	0.760	0.340
210	0.09	11.27	0.740	0.760	0.340
211	0.09	11.28	0.740	0.760	0.340
212	0.09	11.30	0.740	0.760	0.340
213	0.09	11.34	0.740	0.760	0.340
214	0.09	11.35	0.740	0.770	0.340
215	0.09	11.38	0.740	0.770	0.350
216	0.09	11.41	0.740	0.770	0.350
217	0.09	11.41	0.740	0.770	0.350
218	0.09	11.45	0.750	0.770	0.350
219	0.09	11.47	0.750	0.770	0.350
220	0.09	11.49	0.750	0.770	0.350
221	0.09	11.53	0.750	0.770	0.360
222	0.09	11.54	0.750	0.770	0.360
223	0.09	11.55	0.750	0.770	0.370
224	0.09	11.59	0.750	0.770	0.370
225	0.09	11.61	0.750	0.770	0.370
226	0.09	11.64	0.750	0.770	0.370
227	0.09	11.66	0.750	0.770	0.370
228	0.09	11.68	0.750	0.770	0.370
229	0.09	11.70	0.760	0.770	0.370
230	0.09	11.72	0.760	0.770	0.370
231	0.09	11.75	0.760	0.770	0.370
232	0.09	11.76	0.760	0.770	0.370
233	0.08	11.82	0.760	0.770	0.370
234	0.08	11.84	0.760	0.770	0.370
235	0.08	11.86	0.760	0.770	0.370
236	0.08	11.89	0.760	0.770	0.370
237	0.08	11.92	0.760	0.770	0.380
238	0.08	11.94	0.760	0.770	0.380
239	0.08	11.97	0.760	0.770	0.380
240	0.08	12.01	0.760	0.770	0.380
241	0.08	12.03	0.760	0.770	0.380
242	0.08	12.06	0.760	0.770	0.380
243	0.08	12.09	0.760	0.780	0.380

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
244	0.08	12.09	0.770	0.780	0.380
245	0.08	12.17	0.770	0.780	0.380
246	0.08	12.21	0.770	0.780	0.380
247	0.08	12.22	0.770	0.780	0.380
248	0.08	12.26	0.770	0.780	0.380
249	0.08	12.32	0.770	0.780	0.380
250	0.08	12.33	0.770	0.780	0.380
251	0.08	12.35	0.770	0.780	0.380
252	0.08	12.38	0.780	0.780	0.380
253	0.08	12.42	0.780	0.780	0.380
254	0.08	12.48	0.780	0.780	0.380
255	0.08	12.49	0.780	0.780	0.380
256	0.08	12.52	0.780	0.790	0.390
257	0.08	12.55	0.780	0.790	0.390
258	0.08	12.59	0.780	0.790	0.390
259	0.08	12.61	0.780	0.790	0.390
260	0.08	12.69	0.780	0.790	0.390
261	0.08	12.72	0.780	0.790	0.390
262	0.08	12.76	0.780	0.790	0.390
263	0.08	12.79	0.780	0.790	0.390
264	0.08	12.85	0.780	0.790	0.390
265	0.08	12.86	0.780	0.790	0.390
266	0.08	12.91	0.780	0.790	0.400
267	0.08	12.97	0.780	0.790	0.400
268	0.08	13.00	0.780	0.790	0.400
269	0.08	13.05	0.790	0.790	0.400
270	0.08	13.07	0.790	0.790	0.400
271	0.08	13.12	0.790	0.800	0.400
272	0.08	13.15	0.800	0.800	0.400
273	0.08	13.18	0.800	0.800	0.400
274	0.08	13.24	0.800	0.800	0.410
275	0.08	13.31	0.800	0.800	0.430
276	0.07	13.35	0.800	0.800	0.490
277	0.07	13.36	0.800	0.800	0.490
278	0.07	13.43	0.800	0.800	0.520
279	0.07	13.47	0.800	0.800	0.540
280	0.07	13.49	0.800	0.800	0.540
281	0.07	13.54	0.800	0.800	0.560
282	0.07	13.61	0.800	0.800	0.560
283	0.07	13.68	0.800	0.800	0.560
284	0.07	13.74	0.800	0.800	0.560
285	0.07	13.76	0.800	0.800	0.560
286	0.07	13.82	0.800	0.800	0.570
287	0.07	13.86	0.800	0.800	0.570
288	0.07	13.91	0.800	0.800	0.570
289	0.07	13.94	0.800	0.800	0.570
290	0.07	14.05	0.800	0.800	0.570
291	0.07	14.08	0.800	0.800	0.580
292	0.07	14.11	0.800	0.800	0.580

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
293	0.07	14.16	0.800	0.800	0.590
294	0.07	14.26	0.800	0.800	0.590
295	0.07	14.29	0.800	0.800	0.590
296	0.07	14.36	0.800	0.800	0.590
297	0.07	14.42	0.800	0.800	0.600
298	0.07	14.44	0.800	0.800	0.600
299	0.07	14.51	0.800	0.810	0.600
300	0.07	14.57	0.800	0.810	0.600
301	0.07	14.60	0.800	0.810	0.600
302	0.07	14.67	0.800	0.810	0.600
303	0.07	14.75	0.800	0.810	0.600
304	0.07	14.84	0.800	0.810	0.600
305	0.07	14.90	0.800	0.810	0.610
306	0.07	14.98	0.800	0.810	0.610
307	0.07	15.01	0.800	0.810	0.610
308	0.07	15.06	0.800	0.810	0.610
309	0.07	15.15	0.800	0.810	0.610
310	0.07	15.22	0.810	0.810	0.610
311	0.07	15.28	0.810	0.820	0.610
312	0.07	15.34	0.810	0.820	0.610
313	0.06	15.43	0.810	0.820	0.610
314	0.06	15.46	0.810	0.820	0.620
315	0.06	15.55	0.810	0.820	0.620
316	0.06	15.61	0.810	0.820	0.620
317	0.06	15.66	0.810	0.820	0.620
318	0.06	15.78	0.810	0.820	0.620
319	0.06	15.80	0.810	0.820	0.620
320	0.06	15.91	0.810	0.820	0.620
321	0.06	16.01	0.810	0.820	0.620
322	0.06	16.05	0.810	0.820	0.620
323	0.06	16.13	0.810	0.820	0.630
324	0.06	16.24	0.810	0.820	0.630
325	0.06	16.27	0.820	0.820	0.630
326	0.06	16.37	0.820	0.820	0.630
327	0.06	16.44	0.820	0.830	0.630
328	0.06	16.48	0.820	0.830	0.630
329	0.06	16.59	0.820	0.830	0.640
330	0.06	16.73	0.820	0.830	0.640
331	0.06	16.78	0.820	0.830	0.640
332	0.06	16.88	0.820	0.830	0.640
333	0.06	17.01	0.820	0.830	0.640
334	0.06	17.03	0.820	0.830	0.640
335	0.06	17.16	0.820	0.830	0.640
336	0.06	17.28	0.820	0.830	0.640
337	0.06	17.31	0.820	0.830	0.650
338	0.06	17.39	0.820	0.830	0.650
339	0.06	17.55	0.820	0.830	0.650
340	0.06	17.59	0.830	0.830	0.650
341	0.06	17.68	0.830	0.840	0.650

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
342	0.06	17.82	0.830	0.840	0.650
343	0.06	17.94	0.830	0.840	0.650
344	0.06	18.05	0.830	0.840	0.650
345	0.06	18.15	0.830	0.840	0.650
346	0.05	18.19	0.830	0.840	0.650
347	0.05	18.27	0.830	0.840	0.650
348	0.05	18.49	0.830	0.840	0.660
349	0.05	18.52	0.830	0.840	0.660
350	0.05	18.69	0.830	0.840	0.660
351	0.05	18.79	0.830	0.840	0.660
352	0.05	18.88	0.830	0.840	0.660
353	0.05	19.05	0.830	0.840	0.660
354	0.05	19.18	0.830	0.840	0.670
355	0.05	19.22	0.830	0.840	0.670
356	0.05	19.26	0.840	0.840	0.670
357	0.05	19.51	0.840	0.840	0.670
358	0.05	19.54	0.840	0.840	0.670
359	0.05	19.69	0.840	0.840	0.680
360	0.05	19.85	0.840	0.850	0.680
361	0.05	19.89	0.840	0.850	0.680
362	0.05	20.10	0.840	0.850	0.680
363	0.05	20.28	0.840	0.850	0.680
364	0.05	20.43	0.840	0.850	0.680
365	0.05	20.50	0.840	0.850	0.690
366	0.05	20.77	0.840	0.850	0.690
367	0.05	20.83	0.840	0.850	0.690
368	0.05	20.92	0.840	0.850	0.690
369	0.05	21.20	0.840	0.850	0.690
370	0.05	21.25	0.840	0.850	0.690
371	0.05	21.35	0.840	0.850	0.690
372	0.05	21.66	0.840	0.850	0.690
373	0.05	21.73	0.850	0.850	0.690
374	0.05	21.78	0.850	0.850	0.690
375	0.05	22.16	0.850	0.850	0.690
376	0.04	22.25	0.850	0.850	0.700
377	0.04	22.29	0.850	0.850	0.700
378	0.04	22.58	0.850	0.850	0.700
379	0.04	22.59	0.850	0.860	0.700
380	0.04	22.84	0.850	0.860	0.700
381	0.04	23.07	0.850	0.860	0.700
382	0.04	23.21	0.850	0.860	0.700
383	0.04	23.30	0.850	0.860	0.710
384	0.04	23.69	0.850	0.860	0.710
385	0.04	23.81	0.850	0.860	0.710
386	0.04	23.92	0.850	0.860	0.710
387	0.04	24.35	0.850	0.860	0.710
388	0.04	24.41	0.850	0.860	0.710
389	0.04	24.50	0.850	0.860	0.720
390	0.04	24.88	0.850	0.860	0.720

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
391	0.04	25.00	0.860	0.860	0.720
392	0.04	25.05	0.860	0.860	0.720
393	0.04	25.67	0.860	0.860	0.720
394	0.04	25.78	0.860	0.860	0.720
395	0.04	25.82	0.860	0.860	0.730
396	0.04	26.18	0.860	0.870	0.730
397	0.04	26.26	0.860	0.870	0.730
398	0.04	26.44	0.860	0.870	0.730
399	0.04	27.03	0.860	0.870	0.730
400	0.04	27.14	0.860	0.870	0.730
401	0.04	27.24	0.860	0.870	0.730
402	0.04	27.89	0.870	0.870	0.730
403	0.04	27.96	0.870	0.870	0.730
404	0.04	28.04	0.870	0.870	0.730
405	0.03	28.73	0.870	0.870	0.730
406	0.03	28.80	0.870	0.870	0.730
407	0.03	28.98	0.870	0.870	0.740
408	0.03	29.56	0.870	0.870	0.740
409	0.03	29.65	0.870	0.870	0.740
410	0.03	29.88	0.870	0.870	0.740
411	0.03	30.52	0.870	0.870	0.740
412	0.03	30.60	0.870	0.870	0.740
413	0.03	30.75	0.870	0.870	0.740
414	0.03	31.54	0.870	0.870	0.740
415	0.03	31.79	0.870	0.870	0.740
416	0.03	31.91	0.870	0.880	0.750
417	0.03	32.69	0.870	0.880	0.750
418	0.03	32.73	0.880	0.880	0.750
419	0.03	32.97	0.880	0.880	0.750
420	0.03	33.79	0.880	0.880	0.750
421	0.03	34.01	0.880	0.880	0.750
422	0.03	34.06	0.880	0.880	0.750
423	0.03	35.00	0.880	0.880	0.760
424	0.03	35.26	0.880	0.880	0.760
425	0.03	35.38	0.880	0.880	0.760
426	0.03	36.33	0.880	0.880	0.760
427	0.03	36.58	0.880	0.880	0.760
428	0.03	36.77	0.880	0.880	0.760
429	0.03	38.00	0.880	0.890	0.760
430	0.03	38.09	0.890	0.890	0.760
431	0.03	38.34	0.890	0.890	0.760
432	0.03	39.48	0.890	0.890	0.760
433	0.03	39.60	0.890	0.890	0.770
434	0.03	39.87	0.890	0.890	0.770
435	0.02	41.54	0.890	0.890	0.770
436	0.02	41.61	0.890	0.890	0.770
437	0.02	41.99	0.890	0.890	0.770
438	0.02	43.16	0.890	0.890	0.770
439	0.02	43.34	0.890	0.890	0.770

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
440	0.02	43.77	0.890	0.890	0.780
441	0.02	45.27	0.900	0.890	0.780
442	0.02	45.69	0.900	0.890	0.780
443	0.02	45.95	0.900	0.890	0.780
444	0.02	47.97	0.900	0.890	0.780
445	0.02	48.14	0.900	0.890	0.790
446	0.02	48.43	0.900	0.900	0.790
447	0.02	50.31	0.900	0.900	0.790
448	0.02	50.51	0.900	0.900	0.790
449	0.02	51.10	0.900	0.900	0.790
450	0.02	53.26	0.900	0.910	0.790
451	0.02	53.64	0.900	0.910	0.790
452	0.02	54.16	0.900	0.910	0.800
453	0.02	56.71	0.900	0.910	0.800
454	0.02	56.85	0.900	0.910	0.800
455	0.02	57.56	0.900	0.910	0.810
456	0.02	60.07	0.900	0.910	0.810
457	0.02	60.96	0.910	0.910	0.810
458	0.02	61.36	0.910	0.910	0.820
459	0.02	64.46	0.910	0.910	0.820
460	0.02	65.14	0.910	0.910	0.820
461	0.02	65.32	0.910	0.910	0.820
462	0.01	69.93	0.910	0.910	0.830
463	0.01	70.14	0.910	0.910	0.830
464	0.01	70.69	0.910	0.910	0.830
465	0.01	76.15	0.910	0.910	0.840
466	0.01	76.63	0.910	0.910	0.840
467	0.01	76.80	0.910	0.920	0.840
468	0.01	83.24	0.910	0.920	0.850
469	0.01	84.12	0.920	0.920	0.850
470	0.01	84.52	0.920	0.920	0.850
471	0.01	91.57	0.920	0.920	0.860
472	0.01	92.09	0.930	0.920	0.860
473	0.01	92.40	0.930	0.930	0.860
474	0.01	100.35	0.930	0.930	0.860
475	0.01	101.02	0.930	0.940	0.860
476	0.01	102.74	0.930	0.940	0.870
477	0.01	112.94	0.940	0.940	0.880
478	0.01	113.22	0.950	0.940	0.880
479	0.01	113.55	0.950	0.940	0.900
480	0.01	127.67	0.950	0.940	0.930
481	0.01	129.77	0.950	0.940	0.930
482	0.01	131.58	0.950	0.950	0.930
483	0.01	146.75	0.950	0.950	0.940
484	0.01	150.13	0.950	0.970	0.940
485	0.01	150.93	0.970	0.970	0.940
486	0.01	174.14	0.970	0.990	0.940
487	0.01	175.71	0.990	0.990	0.940
488	0.01	178.38	0.990	0.990	0.950

Table 3.7.2-15: Frequencies and Modal Mass Ratios for the Reactor Building Uncracked Model (Continued)

StepNum	Period	Freq	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
489	0.00	205.64	0.990	0.990	0.950
490	0.00	209.21	0.990	0.990	0.950
491	0.00	236.43	0.990	0.990	0.960
492	0.00	275.59	0.990	0.990	0.980
493	0.00	278.74	1.000	0.990	0.980
494	0.00	282.50	1.000	1.000	0.980
495	0.00	392.69	1.000	1.000	0.980
496	0.00	392.99	1.000	1.000	0.980
497	0.00	462.51	1.000	1.000	0.990
498	0.00	631.34	1.000	1.000	1.000
499	0.00	762.20	1.000	1.000	1.000
500	0.00	788.20	1.000	1.000	1.000

Notes:
The first significant frequency in each direction is highlighted.

Table 3.7.2-16: Frequencies and Modal Mass Ratios for the Control Building Cracked Model

Step Num	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
1	0.49	2.02	0.001	0.000	0.000
2	0.45	2.20	0.002	0.000	0.000
3	0.41	2.41	0.002	0.000	0.000
4	0.41	2.43	0.002	0.000	0.000
5	0.41	2.43	0.002	0.000	0.000
6	0.40	2.49	0.002	0.000	0.000
7	0.40	2.51	0.002	0.000	0.000
8	0.40	2.52	0.002	0.000	0.000
9	0.39	2.56	0.002	0.000	0.000
10	0.36	2.76	0.002	0.000	0.000
11	0.36	2.79	0.002	0.000	0.000
12	0.35	2.82	0.002	0.000	0.000
13	0.35	2.85	0.003	0.000	0.000
14	0.32	3.16	0.003	0.000	0.000
15	0.31	3.24	0.003	0.000	0.000
16	0.30	3.29	0.003	0.000	0.000
17	0.30	3.29	0.003	0.000	0.000
18	0.30	3.31	0.003	0.000	0.000
19	0.30	3.32	0.003	0.000	0.000
20	0.30	3.32	0.003	0.000	0.000
21	0.27	3.70	0.003	0.000	0.000
22	0.26	3.79	0.003	0.000	0.000
23	0.25	3.93	0.003	0.001	0.000
24	0.25	3.93	0.003	0.001	0.000
25	0.25	3.96	0.003	0.002	0.000
26	0.25	3.99	0.003	0.003	0.000
27	0.25	4.00	0.003	0.003	0.000
28	0.25	4.03	0.003	0.003	0.000
29	0.25	4.05	0.003	0.003	0.000
30	0.24	4.22	0.003	0.003	0.000
31	0.23	4.40	0.003	0.003	0.000
32	0.23	4.43	0.003	0.003	0.000
33	0.22	4.47	0.003	0.003	0.000
34	0.22	4.49	0.003	0.003	0.000
35	0.22	4.55	0.003	0.004	0.000
36	0.22	4.60	0.017	0.009	0.000
37	0.21	4.72	0.017	0.009	0.000
38	0.21	4.74	0.017	0.009	0.001
39	0.21	4.76	0.017	0.009	0.001
40	0.21	4.77	0.220	0.022	0.001
41	0.21	4.77	0.220	0.022	0.001
42	0.21	4.80	0.220	0.022	0.001
43	0.21	4.82	0.220	0.022	0.002
44	0.21	4.86	0.220	0.022	0.002
45	0.20	4.95	0.220	0.022	0.002
46	0.20	4.96	0.220	0.022	0.002
47	0.20	4.97	0.220	0.022	0.002

Table 3.7.2-16: Frequencies and Modal Mass Ratios for the Control Building Cracked Model (Continued)

Step Num	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
48	0.20	4.98	0.220	0.022	0.002
49	0.20	5.01	0.220	0.230	0.002
50	0.20	5.05	0.220	0.230	0.002
51	0.20	5.06	0.220	0.230	0.002
52	0.20	5.07	0.220	0.230	0.002
53	0.20	5.08	0.220	0.230	0.002
54	0.20	5.10	0.220	0.230	0.002
55	0.20	5.10	0.220	0.230	0.002
56	0.20	5.11	0.220	0.230	0.002
57	0.20	5.12	0.220	0.230	0.002
58	0.19	5.16	0.220	0.230	0.002
59	0.19	5.17	0.220	0.230	0.002
60	0.19	5.17	0.220	0.230	0.002
61	0.19	5.19	0.220	0.230	0.002
62	0.19	5.19	0.220	0.230	0.002
63	0.19	5.25	0.230	0.250	0.002
64	0.19	5.27	0.230	0.250	0.002
65	0.19	5.32	0.230	0.250	0.002
66	0.19	5.38	0.230	0.250	0.002
67	0.18	5.43	0.230	0.250	0.002
68	0.18	5.45	0.230	0.250	0.002
69	0.18	5.46	0.230	0.250	0.002
70	0.18	5.57	0.230	0.250	0.002
71	0.18	5.58	0.230	0.250	0.002
72	0.18	5.60	0.230	0.250	0.002
73	0.18	5.63	0.230	0.250	0.002
74	0.18	5.69	0.230	0.250	0.002
75	0.17	5.72	0.230	0.250	0.002
76	0.17	5.77	0.230	0.250	0.002
77	0.17	5.78	0.230	0.250	0.002
78	0.17	5.80	0.230	0.250	0.002
79	0.17	5.83	0.230	0.250	0.002
80	0.17	5.90	0.230	0.250	0.002
81	0.17	5.94	0.350	0.250	0.003
82	0.17	6.00	0.350	0.250	0.003
83	0.17	6.03	0.350	0.320	0.003
84	0.16	6.17	0.360	0.360	0.012
85	0.16	6.19	0.360	0.360	0.014
86	0.16	6.23	0.360	0.360	0.014
87	0.16	6.30	0.360	0.360	0.014
88	0.16	6.30	0.360	0.360	0.015
89	0.16	6.32	0.360	0.360	0.015
90	0.16	6.35	0.360	0.360	0.092
91	0.16	6.36	0.360	0.360	0.092
92	0.15	6.48	0.360	0.360	0.092
93	0.15	6.50	0.360	0.360	0.092
94	0.15	6.53	0.360	0.360	0.092
95	0.15	6.61	0.360	0.360	0.092
96	0.15	6.68	0.360	0.360	0.092

Table 3.7.2-16: Frequencies and Modal Mass Ratios for the Control Building Cracked Model (Continued)

Step Num	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
97	0.15	6.70	0.360	0.360	0.092
98	0.15	6.73	0.360	0.360	0.092
99	0.15	6.77	0.360	0.360	0.092
100	0.15	6.79	0.360	0.360	0.093
101	0.15	6.88	0.440	0.360	0.095
102	0.14	6.90	0.440	0.360	0.095
103	0.14	6.95	0.450	0.400	0.096
104	0.14	7.05	0.450	0.400	0.097
105	0.14	7.06	0.450	0.400	0.097
106	0.14	7.09	0.450	0.400	0.099
107	0.14	7.16	0.450	0.420	0.099
108	0.14	7.25	0.470	0.440	0.110
109	0.14	7.35	0.470	0.440	0.110
110	0.14	7.39	0.530	0.440	0.110
111	0.13	7.48	0.530	0.520	0.120
112	0.13	7.57	0.540	0.530	0.130
113	0.13	7.58	0.540	0.530	0.130
114	0.13	7.68	0.540	0.540	0.210
115	0.13	7.77	0.550	0.540	0.220
116	0.13	7.79	0.550	0.540	0.230
117	0.13	7.85	0.550	0.540	0.230
118	0.13	7.99	0.560	0.540	0.240
119	0.12	8.05	0.560	0.560	0.240
120	0.12	8.10	0.580	0.560	0.240
121	0.12	8.27	0.590	0.560	0.250
122	0.12	8.30	0.600	0.570	0.260
123	0.12	8.38	0.600	0.590	0.260
124	0.12	8.40	0.640	0.600	0.280
125	0.12	8.56	0.640	0.600	0.280
126	0.12	8.64	0.640	0.610	0.280
127	0.12	8.69	0.640	0.650	0.280
128	0.11	8.82	0.650	0.650	0.280
129	0.11	8.91	0.650	0.650	0.280
130	0.11	9.09	0.660	0.650	0.290
131	0.11	9.13	0.660	0.650	0.290
132	0.11	9.29	0.660	0.650	0.290
133	0.11	9.41	0.660	0.650	0.300
134	0.10	9.58	0.660	0.670	0.300
135	0.10	9.70	0.660	0.670	0.300
136	0.10	9.83	0.660	0.670	0.300
137	0.10	9.86	0.660	0.670	0.310
138	0.10	10.06	0.660	0.700	0.310
139	0.10	10.18	0.670	0.700	0.310
140	0.10	10.51	0.670	0.710	0.310
141	0.09	10.56	0.670	0.710	0.320
142	0.09	10.62	0.680	0.720	0.320
143	0.09	10.95	0.680	0.730	0.330
144	0.09	11.11	0.680	0.730	0.330
145	0.09	11.29	0.680	0.730	0.330

Table 3.7.2-16: Frequencies and Modal Mass Ratios for the Control Building Cracked Model (Continued)

Step Num	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
146	0.09	11.38	0.680	0.730	0.360
147	0.09	11.58	0.680	0.740	0.360
148	0.09	11.75	0.700	0.740	0.360
149	0.08	11.91	0.700	0.740	0.380
150	0.08	12.11	0.700	0.750	0.380
151	0.08	12.27	0.710	0.750	0.380
152	0.08	12.49	0.720	0.750	0.390
153	0.08	12.89	0.730	0.750	0.390
154	0.08	13.10	0.730	0.750	0.390
155	0.08	13.20	0.730	0.750	0.400
156	0.07	13.71	0.740	0.760	0.400
157	0.07	13.86	0.740	0.760	0.400
158	0.07	14.16	0.740	0.760	0.400
159	0.07	14.76	0.740	0.780	0.400
160	0.07	14.89	0.760	0.780	0.400
161	0.07	15.13	0.760	0.780	0.430
162	0.06	15.68	0.760	0.790	0.430
163	0.06	15.85	0.770	0.790	0.430
164	0.06	16.13	0.770	0.790	0.470
165	0.06	17.08	0.780	0.800	0.470
166	0.06	17.19	0.790	0.800	0.470
167	0.06	17.62	0.790	0.810	0.480
168	0.05	18.45	0.790	0.820	0.480
169	0.05	18.60	0.800	0.820	0.480
170	0.05	19.27	0.800	0.820	0.540
171	0.05	20.12	0.820	0.830	0.540
172	0.05	20.31	0.820	0.830	0.540
173	0.05	20.91	0.820	0.830	0.580
174	0.04	22.66	0.840	0.830	0.580
175	0.04	22.86	0.840	0.850	0.580
176	0.04	23.21	0.840	0.850	0.600
177	0.04	25.28	0.860	0.850	0.600
178	0.04	25.43	0.860	0.860	0.600
179	0.04	26.66	0.860	0.860	0.640
180	0.04	28.48	0.860	0.880	0.640
181	0.03	28.66	0.880	0.880	0.640
182	0.03	29.40	0.880	0.880	0.720
183	0.03	33.01	0.880	0.890	0.720
184	0.03	33.20	0.890	0.890	0.720
185	0.03	34.20	0.890	0.890	0.760
186	0.03	40.00	0.890	0.900	0.760
187	0.02	40.36	0.900	0.900	0.760
188	0.02	41.18	0.900	0.900	0.780
189	0.02	49.72	0.910	0.900	0.780
190	0.02	49.88	0.910	0.910	0.780
191	0.02	53.00	0.910	0.910	0.810
192	0.01	66.95	0.920	0.910	0.810
193	0.01	67.52	0.920	0.920	0.810
194	0.01	70.93	0.920	0.920	0.860

Table 3.7.2-16: Frequencies and Modal Mass Ratios for the Control Building Cracked Model (Continued)

Step Num	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
195	0.01	101.00	0.920	0.920	0.860
196	0.01	101.85	0.930	0.930	0.860
197	0.01	104.54	0.930	0.930	0.910
198	0.00	222.23	0.930	0.930	0.950
199	0.00	240.06	0.960	0.930	0.950
200	0.00	242.83	0.960	0.960	0.950

Notes:
The first significant frequency in each direction is highlighted.

Table 3.7.2-17: Frequencies and Modal Mass Ratios for the Control Building Uncracked Model

StepNum	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
1	0.49	2.02	0.001	0.000	0.000
2	0.45	2.20	0.002	0.000	0.000
3	0.41	2.41	0.002	0.000	0.000
4	0.41	2.43	0.002	0.000	0.000
5	0.41	2.43	0.002	0.000	0.000
6	0.40	2.49	0.002	0.000	0.000
7	0.40	2.51	0.002	0.000	0.000
8	0.40	2.52	0.002	0.000	0.000
9	0.39	2.56	0.002	0.000	0.000
10	0.36	2.76	0.002	0.000	0.000
11	0.36	2.79	0.002	0.000	0.000
12	0.35	2.82	0.002	0.000	0.000
13	0.35	2.85	0.003	0.000	0.000
14	0.32	3.16	0.003	0.000	0.000
15	0.31	3.24	0.003	0.000	0.000
16	0.30	3.29	0.003	0.000	0.000
17	0.30	3.29	0.003	0.000	0.000
18	0.30	3.31	0.003	0.000	0.000
19	0.30	3.32	0.003	0.000	0.000
20	0.30	3.32	0.003	0.000	0.000
21	0.27	3.70	0.003	0.000	0.000
22	0.26	3.79	0.003	0.000	0.000
23	0.25	3.93	0.003	0.001	0.000
24	0.25	3.93	0.003	0.001	0.000
25	0.25	3.96	0.003	0.002	0.000
26	0.25	3.99	0.003	0.003	0.000
27	0.25	4.00	0.003	0.003	0.000
28	0.25	4.03	0.003	0.003	0.000
29	0.25	4.05	0.003	0.003	0.000
30	0.24	4.22	0.003	0.003	0.000
31	0.23	4.40	0.003	0.003	0.000
32	0.23	4.43	0.003	0.003	0.000
33	0.22	4.47	0.003	0.003	0.000
34	0.22	4.49	0.003	0.003	0.000
35	0.22	4.55	0.003	0.004	0.000
36	0.22	4.61	0.018	0.009	0.000
37	0.21	4.72	0.018	0.009	0.000
38	0.21	4.74	0.018	0.009	0.001
39	0.21	4.76	0.018	0.009	0.001
40	0.21	4.77	0.018	0.009	0.001
41	0.21	4.78	0.210	0.023	0.001
42	0.21	4.80	0.210	0.024	0.001
43	0.21	4.82	0.210	0.024	0.002
44	0.21	4.86	0.210	0.024	0.002
45	0.20	4.95	0.210	0.024	0.002
46	0.20	4.96	0.210	0.024	0.002
47	0.20	4.97	0.210	0.024	0.002

Table 3.7.2-17: Frequencies and Modal Mass Ratios for the Control Building Uncracked Model (Continued)

StepNum	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
48	0.20	4.98	0.210	0.024	0.002
49	0.20	5.02	0.220	0.220	0.002
50	0.20	5.05	0.220	0.220	0.002
51	0.20	5.06	0.220	0.220	0.002
52	0.20	5.07	0.220	0.220	0.002
53	0.20	5.08	0.220	0.220	0.002
54	0.20	5.10	0.220	0.220	0.002
55	0.20	5.10	0.220	0.220	0.002
56	0.20	5.11	0.220	0.220	0.002
57	0.20	5.12	0.220	0.220	0.002
58	0.19	5.16	0.220	0.220	0.002
59	0.19	5.17	0.220	0.220	0.002
60	0.19	5.17	0.220	0.220	0.002
61	0.19	5.19	0.220	0.220	0.002
62	0.19	5.26	0.220	0.220	0.002
63	0.19	5.27	0.230	0.240	0.002
64	0.19	5.27	0.230	0.240	0.002
65	0.19	5.32	0.230	0.240	0.002
66	0.19	5.38	0.230	0.240	0.002
67	0.18	5.43	0.230	0.240	0.002
68	0.18	5.45	0.230	0.240	0.002
69	0.18	5.46	0.230	0.240	0.002
70	0.18	5.57	0.230	0.240	0.002
71	0.18	5.58	0.230	0.240	0.002
72	0.18	5.60	0.230	0.240	0.002
73	0.18	5.63	0.230	0.240	0.002
74	0.18	5.69	0.230	0.240	0.002
75	0.17	5.72	0.230	0.240	0.002
76	0.17	5.77	0.230	0.240	0.002
77	0.17	5.78	0.230	0.240	0.002
78	0.17	5.80	0.230	0.240	0.002
79	0.17	5.83	0.230	0.240	0.002
80	0.17	5.90	0.230	0.240	0.002
81	0.17	5.96	0.340	0.240	0.003
82	0.17	6.00	0.340	0.240	0.003
83	0.17	6.06	0.340	0.310	0.003
84	0.16	6.19	0.350	0.340	0.013
85	0.16	6.20	0.350	0.340	0.015
86	0.16	6.23	0.350	0.340	0.015
87	0.16	6.30	0.350	0.340	0.015
88	0.16	6.30	0.350	0.340	0.015
89	0.16	6.32	0.350	0.340	0.015
90	0.16	6.36	0.350	0.340	0.015
91	0.16	6.37	0.350	0.350	0.092
92	0.15	6.46	0.350	0.350	0.092
93	0.15	6.50	0.350	0.350	0.092
94	0.15	6.53	0.350	0.350	0.092
95	0.15	6.61	0.350	0.350	0.092

Table 3.7.2-17: Frequencies and Modal Mass Ratios for the Control Building Uncracked Model (Continued)

StepNum	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
96	0.15	6.68	0.350	0.350	0.092
97	0.15	6.70	0.350	0.350	0.092
98	0.15	6.73	0.350	0.350	0.092
99	0.15	6.77	0.350	0.350	0.092
100	0.15	6.79	0.350	0.350	0.092
101	0.15	6.85	0.350	0.350	0.092
102	0.14	6.93	0.430	0.350	0.095
103	0.14	6.96	0.440	0.350	0.095
104	0.14	7.00	0.440	0.390	0.095
105	0.14	7.09	0.440	0.390	0.096
106	0.14	7.13	0.440	0.390	0.097
107	0.14	7.18	0.440	0.410	0.098
108	0.14	7.27	0.450	0.420	0.110
109	0.14	7.31	0.450	0.420	0.110
110	0.13	7.41	0.530	0.420	0.110
111	0.13	7.48	0.530	0.420	0.110
112	0.13	7.51	0.530	0.500	0.120
113	0.13	7.60	0.530	0.520	0.120
114	0.13	7.70	0.540	0.520	0.210
115	0.13	7.80	0.540	0.520	0.230
116	0.13	7.81	0.540	0.520	0.240
117	0.13	7.86	0.540	0.520	0.240
118	0.13	8.00	0.550	0.520	0.240
119	0.12	8.06	0.550	0.530	0.240
120	0.12	8.08	0.560	0.550	0.250
121	0.12	8.20	0.570	0.550	0.250
122	0.12	8.31	0.580	0.550	0.260
123	0.12	8.42	0.590	0.580	0.270
124	0.12	8.45	0.630	0.580	0.280
125	0.12	8.54	0.630	0.590	0.280
126	0.12	8.65	0.630	0.590	0.280
127	0.11	8.72	0.630	0.640	0.280
128	0.11	8.82	0.640	0.640	0.280
129	0.11	8.89	0.650	0.640	0.280
130	0.11	9.09	0.650	0.640	0.280
131	0.11	9.23	0.660	0.640	0.280
132	0.11	9.30	0.660	0.640	0.290
133	0.10	9.57	0.660	0.650	0.290
134	0.10	9.59	0.660	0.650	0.290
135	0.10	9.73	0.660	0.670	0.290
136	0.10	9.76	0.660	0.670	0.290
137	0.10	9.89	0.660	0.670	0.290
138	0.10	10.09	0.660	0.700	0.290
139	0.10	10.30	0.670	0.700	0.290
140	0.10	10.40	0.670	0.700	0.290
141	0.09	10.56	0.670	0.710	0.290
142	0.09	10.62	0.680	0.710	0.290
143	0.09	10.95	0.680	0.720	0.290

Table 3.7.2-17: Frequencies and Modal Mass Ratios for the Control Building Uncracked Model (Continued)

StepNum	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
144	0.09	11.06	0.680	0.720	0.310
145	0.09	11.21	0.680	0.730	0.310
146	0.09	11.36	0.680	0.730	0.340
147	0.09	11.60	0.680	0.740	0.340
148	0.08	11.77	0.690	0.740	0.340
149	0.08	11.94	0.690	0.740	0.370
150	0.08	12.11	0.690	0.740	0.380
151	0.08	12.23	0.710	0.750	0.380
152	0.08	12.39	0.710	0.750	0.390
153	0.08	12.87	0.730	0.750	0.390
154	0.08	13.10	0.730	0.750	0.400
155	0.08	13.16	0.730	0.750	0.400
156	0.07	13.68	0.730	0.750	0.400
157	0.07	13.88	0.740	0.760	0.400
158	0.07	14.12	0.740	0.760	0.410
159	0.07	14.68	0.740	0.770	0.410
160	0.07	14.95	0.750	0.770	0.410
161	0.07	15.20	0.750	0.770	0.420
162	0.06	15.68	0.750	0.790	0.420
163	0.06	15.89	0.770	0.790	0.420
164	0.06	16.16	0.770	0.790	0.460
165	0.06	16.81	0.770	0.800	0.460
166	0.06	17.15	0.780	0.800	0.460
167	0.06	17.71	0.780	0.800	0.480
168	0.05	18.44	0.790	0.810	0.480
169	0.05	18.60	0.800	0.820	0.480
170	0.05	19.41	0.800	0.820	0.490
171	0.05	20.09	0.820	0.820	0.490
172	0.05	20.38	0.820	0.830	0.490
173	0.05	21.26	0.820	0.830	0.550
174	0.04	22.75	0.840	0.830	0.550
175	0.04	22.82	0.840	0.850	0.560
176	0.04	23.06	0.840	0.850	0.610
177	0.04	25.07	0.850	0.860	0.610
178	0.04	25.29	0.860	0.860	0.610
179	0.04	26.13	0.860	0.860	0.660
180	0.03	28.76	0.870	0.870	0.660
181	0.03	28.99	0.870	0.880	0.660
182	0.03	29.52	0.870	0.880	0.710
183	0.03	32.69	0.880	0.890	0.710
184	0.03	33.33	0.890	0.890	0.720
185	0.03	34.00	0.890	0.890	0.760
186	0.03	39.88	0.890	0.890	0.760
187	0.02	40.20	0.900	0.900	0.760
188	0.02	40.63	0.900	0.900	0.780
189	0.02	49.56	0.910	0.900	0.780
190	0.02	50.60	0.910	0.910	0.780
191	0.02	53.01	0.910	0.910	0.810

Table 3.7.2-17: Frequencies and Modal Mass Ratios for the Control Building Uncracked Model (Continued)

StepNum	Period	Frequency	SumUX	SumUY	SumUZ
Unitless	Sec	Cyc/sec	Unitless	Unitless	Unitless
192	0.01	67.15	0.910	0.910	0.810
193	0.01	68.09	0.920	0.920	0.810
194	0.01	70.11	0.920	0.920	0.860
195	0.01	101.04	0.920	0.920	0.860
196	0.01	102.30	0.930	0.930	0.870
197	0.01	104.37	0.930	0.930	0.910
198	0.00	220.95	0.930	0.930	0.950
199	0.00	243.88	0.960	0.930	0.950
200	0.00	246.64	0.960	0.960	0.950

Notes:
The first significant frequency in each direction is highlighted.

Table 3.7.2-18: Frequencies Used in Transfer Function Calculation for Standalone Reactor Building Model

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
1	1	0.01221	1	0.01221	1	0.01221	1	0.01221	1	0.01221
2	41	0.5005	41	0.5005	41	0.5005	41	0.5005	41	0.5005
3	82	1.001	82	1.001	82	1.001	82	1.001	82	1.001
4	123	1.501	123	1.501	123	1.501	123	1.501	125	1.526
5	164	2.002	164	2.002	164	2.002	164	2.002	164	2.002
6	186	2.271	205	2.502	205	2.502	205	2.502	205	2.502
7	205	2.502	246	3.003	246	3.003	246	3.003	246	3.003
8	246	3.003	258	3.149	258	3.149	258	3.149	258	3.149
9	258	3.149	281	3.43	281	3.43	281	3.43	281	3.43
10	281	3.43	287	3.503	287	3.503	287	3.503	287	3.503
11	287	3.503	328	4.004	328	4.004	328	4.004	328	4.004
12	328	4.004	369	4.504	369	4.504	369	4.504	369	4.504
13	369	4.504	410	5.005	410	5.005	410	5.005	410	5.005
14	410	5.005	451	5.505	451	5.505	451	5.505	451	5.505
15	451	5.505	493	6.018	493	6.018	493	6.018	493	6.018
16	493	6.018	533	6.506	533	6.506	533	6.506	533	6.506
17	533	6.506	574	7.007	574	7.007	574	7.007	574	7.007
18	574	7.007	615	7.507	615	7.507	615	7.507	615	7.507
19	615	7.507	656	8.008	656	8.008	656	8.008	656	8.008
20	656	8.008	697	8.508	697	8.508	697	8.508	697	8.508
21	697	8.508	738	9.009	738	9.009	738	9.009	738	9.009
22	738	9.009	779	9.509	779	9.509	779	9.509	779	9.509
23	779	9.509	800	9.766	820	10.01	820	10.01	820	10.01
24	820	10.01	810	9.888	861	10.51	861	10.51	861	10.51
25	861	10.51	820	10.01	902	11.01	902	11.01	902	11.01
26	902	11.01	830	10.13	943	11.51	943	11.51	943	11.51
27	943	11.51	840	10.25	984	12.01	984	12.01	984	12.01
28	984	12.01	861	10.51	1024	12.5	1024	12.5	1024	12.5

Table 3.7.2-18: Frequencies Used in Transfer Function Calculation for Standalone Reactor Building Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
29	1024	12.5	902	11.01	1065	13	1065	13	1065	13
30	1065	13	943	11.51	1106	13.5	1106	13.5	1106	13.5
31	1106	13.5	984	12.01	1147	14	1147	14	1147	14
32	1147	14	1024	12.5	1188	14.5	1188	14.5	1188	14.5
33	1188	14.5	1065	13	1229	15	1229	15	1229	15
34	1229	15	1106	13.5	1270	15.5	1270	15.5	1270	15.5
35	1270	15.5	1147	14	1311	16	1311	16	1311	16
36	1311	16	1188	14.5	1393	17	1393	17	1393	17
37	1393	17	1229	15	1475	18.01	1475	18.01	1475	18.01
38	1475	18.01	1270	15.5	1557	19.01	1557	19.01	1557	19.01
39	1557	19.01	1311	16	1639	20.01	1639	20.01	1639	20.01
40	1639	20.01	1353	16.52	1721	21.01	1721	21.01	1721	21.01
41	1721	21.01	1373	16.76	1803	22.01	1803	22.01	1803	22.01
42	1803	22.01	1393	17	1885	23.01	1885	23.01	1885	23.01
43	1885	23.01	1413	17.25	1917	23.4	1917	23.4	1917	23.4
44	1917	23.4	1433	17.49	1967	24.01	1967	24.01	1967	24.01
45	1967	24.01	1475	18.01	2048	25	2048	25	2048	25
46	2048	25	1557	19.01	2130	26	2130	26	2130	26
47	2130	26	1639	20.01	2212	27	2212	27	2212	27
48	2171	26.5	1721	21.01	2294	28	2294	28	2294	28
49	2212	27	1803	22.01	2376	29	2376	29	2376	29
50	2294	28	1885	23.01	2458	30	2458	30	2458	30
51	2349	28.67	1917	23.4	2540	31.01	2540	31.01	2540	31.01
52	2403	29.33	1967	24.01	2622	32.01	2622	32.01	2622	32.01
53	2458	30	2048	25	2704	33.01	2704	33.01	2704	33.01
54	2513	30.68	2130	26	2786	34.01	2786	34.01	2786	34.01
55	2567	31.34	2212	27	2950	36.01	2950	36.01	2950	36.01
56	2622	32.01	2294	28	3113	38	3113	38	3113	38
57	2704	33.01	2376	29	3277	40	3277	40	3277	40
58	2786	34.01	2458	30	3326	40.6	3326	40.6	3326	40.6

Table 3.7.2-18: Frequencies Used in Transfer Function Calculation for Standalone Reactor Building Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
59	2867	35	2540	31.01	3441	42	3441	42	3441	42
60	2950	36.01	2622	32.01	3605	44.01	3605	44.01	3605	44.01
61	3031	37	2704	33.01	3769	46.01	3769	46.01	3769	46.01
62	3113	38	2786	34.01	3933	48.01	3933	48.01	3933	48.01
63	3196	39.01	2950	36.01	4096	50	4096	50	4096	50
64	3277	40	3113	38	4260	52	4260	52	4260	52
65	3332	40.67	3277	40	-	-	4424	54	4424	54
66	3386	41.33	3326	40.6	-	-	4588	56.01	4588	56.01
67	3441	42	3441	42	-	-	4752	58.01	4752	58.01
68	3523	43.01	3605	44.01	-	-	4916	60.01	4916	60.01
69	3605	44.01	3769	46.01	-	-	5080	62.01	5080	62.01
70	3687	45.01	3933	48.01	-	-	5243	64	5243	64
71	3769	46.01	4096	50	-	-	5407	66	5407	66
72	3851	47.01	4260	52	-	-	5571	68.01	5571	68.01
73	3933	48.01	-	-	-	-	5735	70.01	5735	70.01
74	4014	49	-	-	-	-	5899	72.01	5899	72.01
75	4055	49.5	-	-	-	-	-	-	-	-
76	4096	50	-	-	-	-	-	-	-	-
77	4137	50.5	-	-	-	-	-	-	-	-
78	4178	51	-	-	-	-	-	-	-	-
79	4260	52	-	-	-	-	-	-	-	-

Table 3.7.2-19: Frequencies Used in Transfer Function Calculation for RXB from Triple Building Model

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
1	1	0.01221	1	0.01221	1	0.01221	1	0.01221	1	0.01221
2	41	0.5005	41	0.5005	41	0.5005	41	0.5005	41	0.5005
3	82	1.001	82	1.001	82	1.001	82	1.001	82	1.001
4	123	1.501	123	1.501	123	1.501	123	1.501	125	1.526
5	164	2.002	164	2.002	164	2.002	164	2.002	164	2.002
6	186	2.271	205	2.502	205	2.502	205	2.502	205	2.502
7	205	2.502	246	3.003	246	3.003	246	3.003	246	3.003
8	246	3.003	258	3.149	258	3.149	258	3.149	258	3.149
9	258	3.149	281	3.43	281	3.43	281	3.43	281	3.43
10	281	3.43	287	3.503	287	3.503	287	3.503	287	3.503
11	287	3.503	328	4.004	328	4.004	328	4.004	328	4.004
12	328	4.004	369	4.504	369	4.504	369	4.504	369	4.504
13	369	4.504	410	5.005	410	5.005	410	5.005	410	5.005
14	410	5.005	451	5.505	451	5.505	451	5.505	451	5.505
15	451	5.505	493	6.018	493	6.018	493	6.018	493	6.018
16	493	6.018	533	6.506	533	6.506	533	6.506	533	6.506
17	533	6.506	574	7.007	574	7.007	574	7.007	574	7.007
18	574	7.007	615	7.507	615	7.507	615	7.507	615	7.507
19	615	7.507	656	8.008	656	8.008	656	8.008	656	8.008
20	656	8.008	697	8.508	697	8.508	697	8.508	697	8.508
21	697	8.508	738	9.009	738	9.009	738	9.009	738	9.009
22	738	9.009	779	9.509	779	9.509	779	9.509	779	9.509
23	779	9.509	820	10.01	820	10.01	820	10.01	820	10.01
24	820	10.01	861	10.51	861	10.51	861	10.51	861	10.51
25	861	10.51	902	11.01	902	11.01	902	11.01	902	11.01
26	902	11.01	943	11.51	943	11.51	943	11.51	943	11.51
27	943	11.51	984	12.01	984	12.01	984	12.01	984	12.01
28	984	12.01	1024	12.5	1024	12.5	1024	12.5	1024	12.5
29	1024	12.5	1065	13	1065	13	1065	13	1065	13

Table 3.7.2-19: Frequencies Used in Transfer Function Calculation for RXB from Triple Building Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
30	1065	13	1106	13.5	1106	13.5	1106	13.5	1106	13.5
31	1106	13.5	1147	14	1147	14	1147	14	1147	14
32	1147	14	1188	14.5	1188	14.5	1188	14.5	1188	14.5
33	1188	14.5	1229	15	1229	15	1229	15	1229	15
34	1229	15	1270	15.5	1270	15.5	1270	15.5	1270	15.5
35	1270	15.5	1311	16	1311	16	1311	16	1311	16
36	1311	16	1393	17	1393	17	1393	17	1393	17
37	1393	17	1475	18.01	1475	18.01	1475	18.01	1475	18.01
38	1475	18.01	1557	19.01	1557	19.01	1557	19.01	1557	19.01
39	1557	19.01	1639	20.01	1639	20.01	1639	20.01	1639	20.01
40	1639	20.01	1721	21.01	1721	21.01	1721	21.01	1721	21.01
41	1721	21.01	1803	22.01	1803	22.01	1803	22.01	1803	22.01
42	1803	22.01	1885	23.01	1885	23.01	1885	23.01	1885	23.01
43	1885	23.01	1917	23.4	1917	23.4	1917	23.4	1917	23.4
44	1917	23.4	1967	24.01	1967	24.01	1967	24.01	1967	24.01
45	1967	24.01	2048	25	2048	25	2048	25	2048	25
46	2048	25	2130	26	2130	26	2130	26	2130	26
47	2130	26	2212	27	2212	27	2212	27	2212	27
48	2212	27	2294	28	2294	28	2294	28	2294	28
49	2294	28	2376	29	2376	29	2376	29	2376	29
50	2376	29	2458	30	2458	30	2458	30	2458	30
51	2458	30	2540	31.01	2540	31.01	2540	31.01	2540	31.01
52	2540	31.01	2622	32.01	2622	32.01	2622	32.01	2622	32.01
53	2622	32.01	2704	33.01	2704	33.01	2704	33.01	2704	33.01
54	2704	33.01	2786	34.01	2786	34.01	2786	34.01	2786	34.01
55	2786	34.01	2950	36.01	2950	36.01	2950	36.01	2950	36.01
56	2950	36.01	3113	38	3113	38	3113	38	3113	38
57	3113	38	3277	40	3277	40	3277	40	3277	40
58	3277	40	3326	40.6	3326	40.6	3326	40.6	3326	40.6
59	3326	40.6	3441	42	3441	42	3441	42	3441	42

Table 3.7.2-19: Frequencies Used in Transfer Function Calculation for RXB from Triple Building Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
60	3441	42	3605	44.01	3605	44.01	3605	44.01	3605	44.01
61	3605	44.01	3769	46.01	3769	46.01	3769	46.01	3769	46.01
62	3769	46.01	3933	48.01	3933	48.01	3933	48.01	3933	48.01
63	3851	47.01	4096	50	4096	50	4096	50	4096	50
64	3933	48.01	4260	52	4260	52	4260	52	4260	52
65	4014	49	-	-	4424	54	4424	54	4424	54
66	4096	50	-	-	4588	56.01	4588	56.01	4588	56.01
67	4178	51	-	-	4752	58.01	4752	58.01	4752	58.01
68	4260	52	-	-	4916	60.01	4916	60.01	4916	60.01
69	-	-	-	-	5080	62.01	5080	62.01	5080	62.01
70	-	-	-	-	5243	64	5243	64	5243	64
71	-	-	-	-	5407	66	5407	66	5407	66
72	-	-	-	-	5571	68.01	5571	68.01	5571	68.01
73	-	-	-	-	5735	70.01	5735	70.01	5735	70.01
74	-	-	-	-	5899	72.01	5899	72.01	5899	72.01

Note: The cutoff frequency for Soil Type 7 with the CSDRS is established at 52 Hz. For the RXB from the Triple Building Model, additional frequencies were added to ensure all of the seismic input motion was captured and to ensure there were no peaks in the transfer functions.

Table 3.7.2-20: Frequencies Used in Transfer Function Calculation for Standalone CRB Model

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
1	1	0.01221	1	0.01221	1	0.01221	1	0.01221	1	0.01221
2	41	0.5005	41	0.5005	41	0.5005	41	0.5005	41	0.5005
3	82	1.001	82	1.001	82	1.001	82	1.001	82	1.001
4	123	1.501	123	1.501	123	1.501	123	1.501	125	1.526
5	164	2.002	164	2.002	164	2.002	164	2.002	164	2.002
6	205	2.502	205	2.502	205	2.502	205	2.502	205	2.502
7	246	3.003	246	3.003	246	3.003	246	3.003	246	3.003
8	258	3.149	258	3.149	258	3.149	258	3.149	258	3.149
9	281	3.43	281	3.43	281	3.43	281	3.43	281	3.43
10	287	3.503	287	3.503	287	3.503	287	3.503	287	3.503
11	328	4.004	328	4.004	328	4.004	328	4.004	328	4.004
12	369	4.504	369	4.504	369	4.504	369	4.504	369	4.504
13	410	5.005	410	5.005	410	5.005	410	5.005	410	5.005
14	451	5.505	451	5.505	451	5.505	451	5.505	451	5.505
15	493	6.018	493	6.018	493	6.018	493	6.018	493	6.018
16	533	6.506	533	6.506	533	6.506	533	6.506	533	6.506
17	574	7.007	574	7.007	574	7.007	574	7.007	574	7.007
18	615	7.507	615	7.507	615	7.507	615	7.507	615	7.507
19	656	8.008	656	8.008	656	8.008	656	8.008	656	8.008
20	697	8.508	697	8.508	697	8.508	697	8.508	697	8.508
21	738	9.009	738	9.009	738	9.009	738	9.009	738	9.009
22	779	9.509	779	9.509	779	9.509	779	9.509	779	9.509
23	820	10.01	820	10.01	820	10.01	820	10.01	820	10.01
24	861	10.51	861	10.51	861	10.51	861	10.51	861	10.51
25	902	11.01	902	11.01	902	11.01	902	11.01	902	11.01
26	943	11.51	943	11.51	943	11.51	943	11.51	943	11.51
27	984	12.01	984	12.01	984	12.01	984	12.01	984	12.01
28	1024	12.5	1024	12.5	1024	12.5	1024	12.5	1024	12.5

Table 3.7.2-20: Frequencies Used in Transfer Function Calculation for Standalone CRB Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
29	1065	13	1065	13	1065	13	1065	13	1065	13
30	1106	13.5	1106	13.5	1106	13.5	1106	13.5	1106	13.5
31	1115	13.61	1115	13.61	1115	13.61	1115	13.61	1115	13.61
32	1147	14	1147	14	1147	14	1147	14	1147	14
33	1188	14.5	1188	14.5	1188	14.5	1188	14.5	1188	14.5
34	1229	15	1229	15	1229	15	1229	15	1229	15
35	1253	15.3	1253	15.3	1253	15.3	1253	15.3	1253	15.3
36	1270	15.5	1270	15.5	1270	15.5	1270	15.5	1270	15.5
37	1311	16	1311	16	1311	16	1311	16	1311	16
38	1352	16.5	1393	17	1393	17	1393	17	1393	17
39	1393	17	1475	18.01	1475	18.01	1475	18.01	1475	18.01
40	1475	18.01	1557	19.01	1557	19.01	1557	19.01	1557	19.01
41	1557	19.01	1639	20.01	1639	20.01	1639	20.01	1639	20.01
42	1639	20.01	1721	21.01	1721	21.01	1721	21.01	1721	21.01
43	1659	20.25	1803	22.01	1803	22.01	1803	22.01	1803	22.01
44	1693	20.67	1819	22.2	1819	22.2	1819	22.2	1819	22.2
45	1748	21.34	1885	23.01	1885	23.01	1885	23.01	1885	23.01
46	1803	22.01	1917	23.4	1917	23.4	1917	23.4	1917	23.4
47	1819	22.2	1967	24.01	1967	24.01	1967	24.01	1967	24.01
48	1885	23.01	2048	25	2048	25	2048	25	2048	25
49	1917	23.4	2130	26	2130	26	2130	26	2130	26
50	1967	24.01	2163	26.4	2163	26.4	2163	26.4	2163	26.4
51	2048	25	2212	27	2212	27	2212	27	2212	27
52	2089	25.5	2294	28	2294	28	2294	28	2294	28
53	2130	26	2376	29	2376	29	2376	29	2376	29
54	2163	26.4	2458	30	2458	30	2458	30	2458	30
55	2196	26.81	2540	31.01	2540	31.01	2540	31.01	2540	31.01
56	2212	27	2622	32.01	2622	32.01	2622	32.01	2622	32.01
57	2294	28	2704	33.01	2704	33.01	2704	33.01	2704	33.01
58	2376	29	2786	34.01	2786	34.01	2786	34.01	2786	34.01

Table 3.7.2-20: Frequencies Used in Transfer Function Calculation for Standalone CRB Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
59	2458	30	2950	36.01	2950	36.01	2950	36.01	2950	36.01
60	2512	30.66	3113	38	3113	38	3113	38	3113	38
61	2567	31.34	3277	40	3277	40	3277	40	3277	40
62	2622	32.01	3326	40.6	3326	40.6	3326	40.6	3326	40.6
63	2663	32.51	3441	42	3441	42	3441	42	3441	42
64	2704	33.01	3605	44.01	3605	44.01	3605	44.01	3605	44.01
65	2786	34.01	3769	46.01	3769	46.01	3769	46.01	3769	46.01
66	2868	35.01	3793	46.3	3793	46.3	3793	46.3	3793	46.3
67	2925	35.71	3933	48.01	3933	48.01	3933	48.01	3933	48.01
68	2950	36.01	4096	50	4096	50	4096	50	4096	50
69	2990	36.5	4260	52	4260	52	4260	52	4260	52
70	3031	37	-	-	-	-	4424	54	4424	54
71	3113	38	-	-	-	-	4588	56.01	4588	56.01
72	3138	38.31	-	-	-	-	4752	58.01	4752	58.01
73	3170	38.7	-	-	-	-	4916	60.01	4916	60.01
74	3195	39	-	-	-	-	5080	62.01	5080	62.01
75	3277	40	-	-	-	-	5243	64	5243	64
76	3326	40.6	-	-	-	-	5407	66	5407	66
77	3338	40.75	-	-	-	-	5571	68.01	5571	68.01
78	3359	41	-	-	-	-	5735	70.01	5735	70.01
79	3441	42	-	-	-	-	5899	72.01	5899	72.01
80	3523	43.01	-	-	-	-	-	-	-	-
81	3541	43.23	-	-	-	-	-	-	-	-
82	3605	44.01	-	-	-	-	-	-	-	-
83	3687	45.01	-	-	-	-	-	-	-	-
84	3769	46.01	-	-	-	-	-	-	-	-
85	3793	46.3	-	-	-	-	-	-	-	-
86	3851	47.01	-	-	-	-	-	-	-	-
87	3892	47.51	-	-	-	-	-	-	-	-
88	3956	48.29	-	-	-	-	-	-	-	-

Table 3.7.2-20: Frequencies Used in Transfer Function Calculation for Standalone CRB Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Fre-quency Steps	Frequency (Hz)	No. of Fre-quency Steps	Frequency (Hz)	No. of Fre-quency Steps	Frequency (Hz)	No. of Fre-quency Steps	Frequency (Hz)	No. of Fre-quency Steps	Frequency (Hz)
89	4015	49.01	-	-	-	-	-	-	-	-
90	4096	50	-	-	-	-	-	-	-	-
91	4178	51	-	-	-	-	-	-	-	-
92	4219	51.5	-	-	-	-	-	-	-	-
93	4240	51.76	-	-	-	-	-	-	-	-

Table 3.7.2-21: Frequencies Used in Transfer Function Calculation for CRB with Triple Building CRB Model

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
1	-	-	-	-	1	0.01221	-	-	1	0.01221
2	-	-	-	-	41	0.5005	-	-	41	0.5005
3	-	-	-	-	82	1.001	-	-	82	1.001
4	-	-	-	-	123	1.501	-	-	123	1.501
5	-	-	-	-	164	2.002	-	-	164	2.002
6	-	-	-	-	205	2.502	-	-	205	2.502
7	-	-	-	-	246	3.003	-	-	246	3.003
8	-	-	-	-	258	3.149	-	-	258	3.149
9	-	-	-	-	281	3.43	-	-	281	3.43
10	-	-	-	-	287	3.503	-	-	287	3.503
11	-	-	-	-	328	4.004	-	-	328	4.004
12	-	-	-	-	369	4.504	-	-	369	4.504
13	-	-	-	-	410	5.005	-	-	410	5.005
14	-	-	-	-	451	5.505	-	-	451	5.505
15	-	-	-	-	493	6.018	-	-	493	6.018
16	-	-	-	-	533	6.506	-	-	533	6.506
17	-	-	-	-	574	7.007	-	-	574	7.007
18	-	-	-	-	615	7.507	-	-	615	7.507
19	-	-	-	-	656	8.008	-	-	656	8.008
20	-	-	-	-	697	8.508	-	-	697	8.508
21	-	-	-	-	738	9.009	-	-	738	9.009
22	-	-	-	-	779	9.509	-	-	779	9.509
23	-	-	-	-	820	10.01	-	-	820	10.01
24	-	-	-	-	861	10.51	-	-	861	10.51
25	-	-	-	-	902	11.01	-	-	902	11.01
26	-	-	-	-	943	11.51	-	-	943	11.51
27	-	-	-	-	984	12.01	-	-	984	12.01
28	-	-	-	-	1024	12.5	-	-	1024	12.5
29	-	-	-	-	1065	13	-	-	1065	13

Table 3.7.2-21: Frequencies Used in Transfer Function Calculation for CRB with Triple Building CRB Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
30	-	-	-	-	1106	13.5	-	-	1106	13.5
31	-	-	-	-	1147	14	-	-	1147	14
32	-	-	-	-	1188	14.5	-	-	1188	14.5
33	-	-	-	-	1229	15	-	-	1229	15
34	-	-	-	-	1270	15.5	-	-	1270	15.5
35	-	-	-	-	1311	16	-	-	1311	16
36	-	-	-	-	1393	17	-	-	1393	17
37	-	-	-	-	1475	18.01	-	-	1475	18.01
38	-	-	-	-	1557	19.01	-	-	1557	19.01
39	-	-	-	-	1639	20.01	-	-	1639	20.01
40	-	-	-	-	1721	21.01	-	-	1721	21.01
41	-	-	-	-	1803	22.01	-	-	1803	22.01
42	-	-	-	-	1885	23.01	-	-	1885	23.01
43	-	-	-	-	1917	23.4	-	-	1917	23.4
44	-	-	-	-	1967	24.01	-	-	1967	24.01
45	-	-	-	-	2048	25	-	-	2048	25
46	-	-	-	-	2130	26	-	-	2130	26
47	-	-	-	-	2212	27	-	-	2212	27
48	-	-	-	-	2294	28	-	-	2294	28
49	-	-	-	-	2376	29	-	-	2376	29
50	-	-	-	-	2458	30	-	-	2458	30
51	-	-	-	-	2540	31.01	-	-	2540	31.01
52	-	-	-	-	2622	32.01	-	-	2622	32.01
53	-	-	-	-	2704	33.01	-	-	2704	33.01
54	-	-	-	-	2786	34.01	-	-	2786	34.01
55	-	-	-	-	2950	36.01	-	-	2950	36.01
56	-	-	-	-	3113	38	-	-	3113	38
57	-	-	-	-	3277	40	-	-	3277	40
58	-	-	-	-	3326	40.6	-	-	3326	40.6
59	-	-	-	-	3441	42	-	-	3441	42

Table 3.7.2-21: Frequencies Used in Transfer Function Calculation for CRB with Triple Building CRB Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
60	-	-	-	-	3605	44.01	-	-	3605	44.01
61	-	-	-	-	3769	46.01	-	-	3769	46.01
62	-	-	-	-	3933	48.01	-	-	3933	48.01
63	-	-	-	-	4096	50	-	-	4096	50
64	-	-	-	-	4260	52	-	-	4260	52
65	-	-	-	-	-	-	-	-	-	-
66	-	-	-	-	-	-	-	-	-	-
67	-	-	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-
69	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-
71	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-
73	-	-	-	-	-	-	-	-	-	-
74	-	-	-	-	-	-	-	-	-	-
75	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	-	-	-	-
77	-	-	-	-	-	-	-	-	-	-
78	-	-	-	-	-	-	-	-	-	-
79	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-
81	-	-	-	-	-	-	-	-	-	-
82	-	-	-	-	-	-	-	-	-	-
83	-	-	-	-	-	-	-	-	-	-
84	-	-	-	-	-	-	-	-	-	-
85	-	-	-	-	-	-	-	-	-	-
86	-	-	-	-	-	-	-	-	-	-
87	-	-	-	-	-	-	-	-	-	-
88	-	-	-	-	-	-	-	-	-	-
89	-	-	-	-	-	-	-	-	-	-

Table 3.7.2-21: Frequencies Used in Transfer Function Calculation for CRB with Triple Building CRB Model (Continued)

No.	For CSDRS Inputs						For CSDRS-HF Inputs			
	Soil Type 11		Soil Type 8		Soil Type 7		Soil Type 7		Soil Type 9	
	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)	No. of Frequency Steps	Frequency (Hz)
90	-	-	-	-	-	-	-	-	-	-
91	-	-	-	-	-	-	-	-	-	-
92	-	-	-	-	-	-	-	-	-	-
93	-	-	-	-	-	-	-	-	-	-

Note: Soil Types 8 and 11 with the CSDRS and Soil Type 7 with the CSDRS-HF are not considered for the design because, in general, the controlling case for the CRB is the Soil Type 7 with CSDRS. The frequencies in this table are used to study the structural response of the CRB where high frequencies are expected to be non-damaging and have been limited to 52 Hz.

Table 3.7.2-22: Methodology for Combining SASSI2010 Results

Model	Soil	Earthquake	Cracked or Uncracked	7% or 4% Damping (only 7% shown)	Direction	Step 1	Step 2	Step 3	Step 4
Single Building	S7	Capitola - CSDRS	Cracked	7%	X	SRSS	Averaged	Enveloped (largest value selected)	Enveloped (largest value selected)
					Y				
					Z				
		Yermo - CSDRS	Cracked	7%	X	SRSS			
					Y				
					Z				
		Chi-Chi - CSDRS	Cracked	7%	X	SRSS			
					Y				
					Z				
		Izmit - CSDRS	Cracked	7%	X	SRSS			
					Y				
					Z				
		El Centro - CSDRS	Cracked	7%	X	SRSS			
					Y				
					Z				
		Capitola - CSDRS	Uncracked	7%	X	SRSS	Averaged		
					Y				
					Z				
		Yermo - CSDRS	Uncracked	7%	X	SRSS			
					Y				
					Z				
		Chi-Chi - CSDRS	Uncracked	7%	X	SRSS			
					Y				
					Z				
		Izmit - CSDRS	Uncracked	7%	X	SRSS			
					Y				
					Z				
		El Centro - CSDRS	Uncracked	7%	X	SRSS			
					Y				
					Z				

Table 3.7.2-22: Methodology for Combining SASSI2010 Results (Continued)

Model	Soil	Earthquake	Cracked or Uncracked	7% or 4% Damping (only 7% shown)	Direction	Step 1	Step 2	Step 3	Step 4
Single Building (cont)	S8	All 5 CSDRS combined	Cracked	7%	not shown	SRSS	Averaged	Enveloped (largest value selected) (cont)	Enveloped (largest value selected)
		All 5 CSDRS combined	Uncracked	7%	not shown	SRSS	Averaged		
	S11	All 5 CSDRS combined	Cracked	7%	not shown	SRSS	Averaged		
		All 5 CSDRS combined	Uncracked	7%	not shown	SRSS	Averaged		
	S7	Lucerne - CSDRS-HF	Cracked	7%	not shown	SRSS	used		
		Lucerne - CSDRS-HF	Uncracked	7%	not shown	SRSS	used		
	S9	Lucerne - CSDRS-HF	Cracked	7%	not shown	SRSS	used		
		Lucerne - CSDRS-HF	Uncracked	7%	not shown	SRSS	used		
Triple Building	S7	All 5 CSDRS combined	Cracked	7%	not shown	SRSS	Averaged	Enveloped (largest value selected)	
		All 5 CSDRS combined	Uncracked	7%	not shown	SRSS	Averaged		
	S8	All 5 CSDRS combined	Cracked	7%	not shown	SRSS	Averaged		
		All 5 CSDRS combined	Uncracked	7%	not shown	SRSS	Averaged		
	S11	All 5 CSDRS combined	Cracked	7%	not shown	SRSS	Averaged		
		All 5 CSDRS combined	Uncracked	7%	not shown	SRSS	Averaged		
	S7	Lucerne - CSDRS-HF	Cracked	7%	not shown	SRSS	used		
		Lucerne - CSDRS-HF	Uncracked	7%	not shown	SRSS	used		
	S9	Lucerne - CSDRS-HF	Cracked	7%	not shown	SRSS	used		
		Lucerne - CSDRS-HF	Uncracked	7%	not shown	SRSS	used		

Table 3.7.2-23: Example Averaging and Bounding Forces and Moments in a Shell Element

Building and Case	Soil Type	Input Motion	In-Plane Stresses (lb/in)			Bending Moments (lb-in/in)			Out-of-Plane Shears (lb/in)	
			Sxx	Syy	Sxy	Mxx	Myy	Mxy	Vxz	Vyz
RXB Cracked	S7	Capitola	25,421	24,239	20,666	24,666	17,188	3,979	881	747
		Chi-Chi	23,653	22,477	19,184	24,611	17,410	3,853	790	849
		El Centro	24,691	23,430	20,006	22,885	15,594	3,566	811	858
		Izmit	26,884	25,619	21,419	23,358	15,845	3,497	823	821
		Yermo	22,994	21,972	18,646	21,495	15,975	3,353	763	843
		Average	24,728	23,547	19,984	23,403	16,402	3,649	814	824
	S8	Capitola	24,782	23,600	20,178	26,490	16,545	3,555	901	731
		Chi-Chi	22,071	20,875	17,906	24,413	13,283	3,436	818	775
		El Centro	23,146	22,304	18,994	23,355	12,474	3,441	856	727
		Izmit	26,041	24,789	20,691	23,497	14,153	3,345	802	772
		Yermo	22,934	21,914	18,625	22,603	12,926	2,999	776	734
		Average	23,795	22,697	19,279	24,072	13,876	3,355	831	748
	S11	Capitola	8,587	8,414	6,972	12,072	5,971	1,728	388	343
		Chi-Chi	8,235	8,106		13,719	6,216	1,955	369	375
		El Centro	9,489	9,238	7,738	12,812	6,086	1,835	460	363
		Izmit	6,670	6,636	5,451	12,794	6,448	1,745	368	339
		Yermo	7,881	7,782	6,358	13,947	5,789	1,774	380	404
		Average	8,172	8,035	6,630	13,069	6,102	1,807	393	365
	S7 CSDRS-HF	Lucerne	8,694	8,374	6,894	17,538	10,849	3,648	353	894
	S9 CSDRS-HF	Lucerne	8,767	8,730	6,846	23,012	17,662	4,826	395	**946**
RXB Uncracked	S7	Capitola	27,961	25,991	20,376	40,772	28,157	7,583	930	744
		Chi-Chi	25,188	23,329	18,679	38,097	29,340	7,306	830	747
		El Centro	28,908	26,302	21,504	39,216	28,501	7,204	930	741
		Izmit	27,180	25,254	19,888	47,202	31,774	8,570	861	871
		Yermo	27,303	25,502	20,046	37,651	27,259	6,979	916	816
		Average	**27,308**	**25,276**	**20,099**	**40,587**	**29,006**	7,528	**893**	784
	S8	Capitola	25,901	23,859	18,997	38,805	25,367	6,770	876	604
		Chi-Chi	24,636	22,760	18,353	37,201	23,020	6,394	831	641
		El Centro	26,958	24,649	20,101	36,271	23,788	6,465	885	637
		Izmit	25,295	23,569	18,621	43,224	27,382	7,557	859	794
		Yermo	25,237	23,536	18,514	36,187	22,310	5,678	874	658
		Average	25,605	23,675	18,917	38,338	24,373	6,573	865	667
	S11	Capitola	9,044	8,675	6,644	20,112	10,450	3,809	395	331
		Chi-Chi	8,336	8,071	6,088	22,968	11,203	4,078	365	360
		El Centro	10,219	9,697	7,563	19,933	10,826	3,801	462	321
		Izmit	7,364	7,155	5,410	22,307	10,848	3,817	402	331
		Yermo	8,367	8,104	6,124	23,039	10,891	4,036	389	370
		Average	8,666	8,340	6,366	21,672	10,844	3,908	403	342
	S7 CSDRS-HF	Lucerne	8,335	8,068	6,189	34,133	18,836	6,076	350	944
	S9 CSDRS-HF	Lucerne	9,466	9,442	6,944	34,549	27,556	**8,661**	422	930
Envelope			**27,308**	**25,276**	**20,099**	**40,587**	**29,006**	**8,661**	**893**	**946**

Notes: Light shaded values are the average for the soil type, dark shaded values are the enveloping values

Table 3.7.2-24: Example Averaging and Bounding Forces and Moments in a Beam Element

Concrete Condition	Soil Type	Input Motion	I-, J-Node	Force (lb)			Moment (lb-in)		
				P1	P2	P3	M1	M2	M3
RXB Cracked	S7	Capitola	I	637,407	193,697	1,181,917	412,354	53,506,728	26,831,360
			J	637,407	193,697	1,181,917	412,354	39,727,921	22,090,779
		Chi-Chi	I	605,835	203,933	1,113,766	382,457	54,639,195	27,127,127
			J	605,835	203,933	1,113,766	382,457	36,331,216	21,467,599
		El Centro	I	595,258	182,415	1,158,737	431,611	58,002,098	30,048,007
			J	595,258	182,415	1,158,737	431,611	39,075,733	21,080,785
		Izmit	I	597,170	174,524	1,257,765	417,618	53,111,937	27,758,354
			J	597,170	174,524	1,257,765	417,618	42,184,573	22,792,687
		Yermo	I	631,705	186,292	1,106,687	413,987	49,080,244	29,286,079
			J	631,705	186,292	1,106,687	413,987	34,417,183	22,402,406
		Average	I	**613,475**	**188,172**	**1,163,774**	**411,605**	**53,668,040**	28,210,185
			J	**613,475**	**188,172**	**1,163,774**	**411,605**	38,347,325	21,966,851
	S8	Capitola	I	562,000	184,238	1,153,557	388,632	52,020,060	22,785,266
			J	562,000	184,238	1,153,557	388,632	38,622,388	18,772,060
		Chi-Chi	I	550,112	158,114	1,043,581	342,481	50,562,492	23,853,645
			J	550,112	158,114	1,043,581	342,481	32,709,311	18,696,986
		El Centro	I	505,340	143,621	1,121,451	373,514	53,758,459	27,056,749
			J	505,340	143,621	1,121,451	373,514	38,768,764	19,742,069
		Izmit	I	560,288	158,502	1,222,493	339,117	52,485,355	24,937,075
			J	560,288	158,502	1,222,493	339,117	41,808,530	20,666,742
		Yermo	I	582,658	158,353	1,068,467	337,027	49,703,132	24,338,879
			J	582,658	158,353	1,068,467	337,027	33,650,974	19,472,160
		Average	I	552,079	160,566	1,121,910	356,154	51,705,900	24,594,323
			J	552,079	160,566	1,121,910	356,154	37,111,993	19,470,003
	S11	Capitola	I	257,270	59,307	403,576	255,352	16,552,991	10,615,267
			J	257,270	59,307	403,576	255,352	14,930,671	8,535,264
		Chi-Chi	I	293,223	65,835	396,276	258,744	15,463,742	13,052,968
			J	293,223	65,835	396,276	258,744	14,721,401	10,180,712
		El Centro	I	292,358	60,765	431,509	246,559	19,029,981	10,351,437
			J	292,358	60,765	431,509	246,559	17,819,488	9,204,187
		Izmit	I	278,958	57,754	309,371	241,028	15,319,816	10,759,694
			J	278,958	57,754	309,371	241,028	14,880,940	9,034,444
		Yermo	I	294,250	55,669	362,607	252,580	15,388,736	10,383,976
			J	294,250	55,669	362,607	252,580	14,356,934	9,274,927
		Average	I	283,212	59,866	380,668	250,852	16,351,053	11,032,668
			J	283,212	59,866	380,668	250,852	15,341,887	9,245,907
	S7 CSDRS-HF	Lucerne	I	373,561	121,764	403,694	254,608	18,623,356	**31,318,146**
			J	373,561	121,764	403,694	254,608	12,734,847	25,545,983
	S9 CSDRS-HF	Lucerne	I	479,816	181,405	399,931	406,410	19,654,656	30,147,657
			J	479,816	181,405	399,931	406,410	14,669,735	27,624,580

Table 3.7.2-24: Example Averaging and Bounding Forces and Moments in a Beam Element (Continued)

Concrete Condition	Soil Type	Input Motion	I-, J-Node	Force (lb)			Moment (lb-in)		
				P1	P2	P3	M1	M2	M3
RXB Uncracked	S7	Capitola	I	503177	136714	990325	240334	47728301	22957648
			J	503177	136714	990325	240334	26903246	17075218
		Chi-Chi	I	477980	144613	906650	223207	48052732	20748716
			J	477980	144613	906650	223207	23619734	16522109
		El Centro	I	482232	136389	1021567	273547	57345486	23206848
			J	482232	136389	1021567	273547	29210868	16971605
		Izmit	I	488239	154495	970733	254468	48779104	20410280
			J	488239	154495	970733	254468	24999686	16097664
		Yermo	I	521693	134568	987745	262223	49063036	23885512
			J	521693	134568	987745	262223	25767281	17313973
		Average	I	494664	141356	975404	250756	50193732	22241801
			J	494664	141356	975404	250756	26100163	16796114
	S8	Capitola	I	449167	119045	915208	258787	46752452	19562338
			J	449167	119045	915208	258787	25502740	14671997
		Chi-Chi	I	445700	113581	892656	246846	47978456	17524636
			J	445700	113581	892656	246846	22826407	14177852
		El Centro	I	421962	110157	957442	294160	53817100	19393758
			J	421962	110157	957442	294160	27211140	14659895
		Izmit	I	455339	137083	900209	286474	46130782	19409752
			J	455339	137083	900209	286474	23489015	15119757
		Yermo	I	470027	109893	912937	269061	46073035	18891382
			J	470027	109893	912937	269061	23830826	14820340
		Average	I	448439	117952	915690	271066	48150365	18956373
			J	448439	117952	915690	271066	24572026	14689968
	S11	Capitola	I	215592	50087	318730	164136	14406850	8422293
			J	215592	50087	318730	164136	10106866	6773966
		Chi-Chi	I	242159	50422	294886	170618	13034136	9648666
			J	242159	50422	294886	170618	9521196	8272594
		El Centro	I	227958	47277	349567	159867	16996507	9398820
			J	227958	47277	349567	159867	12087318	7778459
		Izmit	I	222365	45830	250395	162442	13142626	7669092
			J	222365	45830	250395	162442	10335833	6696791
		Yermo	I	244552	48332	289408	178821	12854863	8362527
			J	244552	48332	289408	178821	10097128	7089083
		Average	I	230525	48390	300597	167177	14086997	8700280
			J	230525	48390	300597	167177	10429668	7322179
	S7 CSDRS-HF	Lucerne	I	310218	104076	301263	194939	16932305	28534100
			J	310218	104076	301263	194939	10259199	23333607
	S9 CSDRS-HF	Lucerne	I	430396	132238	339826	323484	19230911	31145227
			J	430396	132238	339826	323484	12075167	25131998
Envelope				**613,475**	**188,172**	**1,163,774**	**411,605**	**53,668,040**	**31,318,146**

Notes: Light shaded values are the average for the soil type, dark shaded values are the enveloping values.

Table 3.7.2-25: Example Averaging and Bounding Forces and Moments in a Solid Element

Concrete Condition	Soil Type	Input Motion	Stresses (psi)					
			σxx	σyy	σzz	τxy	τxz	τyz
RXB Cracked	S7	Capitola	151.89	117.72	111.93	57.93	148.2	42.82
		Chi-Chi	139.7	103.53	98.61	48.48	132.82	35.69
		El Centro	136.36	115.11	96.95	48.25	124.59	36.59
		Izmit	139.27	105.45	96.91	52.86	124.92	37.26
		Yermo	127.98	92.61	91.21	46.78	123.53	32.38
		Average	139.04	106.88	99.12	50.86	130.81	36.95
	S8	Capitola	144.52	137.42	100.82	51.52	138.02	39.08
		Chi-Chi	150.01	126.88	96.78	50.42	138.2	34.5
		El Centro	122.91	137.04	90.02	52.17	121.06	37.91
		Izmit	131.94	126.31	92.25	53.17	127.45	34.96
		Yermo	127.14	113.48	88.05	46.2	122.59	33.46
		Average	135.3	128.23	93.58	50.7	129.46	35.98
	S11	Capitola	120.32	86.85	48.2	29.38	76.46	22.48
		Chi-Chi	138.15	75.82	53.68	33.79	87.89	20.99
		El Centro	115.82	96.59	46.43	28.89	69	26.1
		Izmit	124.24	94.06	48.29	28.11	71.64	25.08
		Yermo	138.08	80.44	51.6	32.79	80.89	22.01
		Average	127.32	86.75	49.64	30.59	77.18	23.33
	S7 CSDRS-HF	Lucerne	55.39	41.68	37.57	22.59	49.75	13.66
	S9 CSDRS-HF	Lucerne	51.4	37.8	45.77	21.5	58.76	15.18
RXB Uncracked	S7	Capitola	156.84	125.5	113.26	63.01	151.34	46.98
		Chi-Chi	144.77	97.27	98.16	56.78	133.43	37.04
		El Centro	144.54	124.65	102.88	58.84	133	42.59
		Izmit	140.04	107.16	96.99	56.94	128.34	38.28
		Yermo	132.62	105.14	94.12	56.73	126.99	35.78
		Average	**143.76**	111.94	**101.08**	**58.46**	**134.62**	**40.13**
	S8	Capitola	152.55	150.27	103.51	56.43	141.34	45.02
		Chi-Chi	156.08	124.2	96.03	52.77	139.33	35.31
		El Centro	133.57	148.3	94.51	58.21	127.04	41.82
		Izmit	136.46	134.01	96.63	56.46	133.54	36.67
		Yermo	134.56	118.09	88.32	51.9	125.16	34.69
		Average	142.64	**134.97**	95.8	55.15	133.28	38.7
	S11	Capitola	120.85	88.68	48.01	29.38	75.18	24.14
		Chi-Chi	138.67	79.98	53.4	34.41	87.46	22.83
		El Centro	115.57	95.82	47.13	28.61	69.18	27.64
		Izmit	124.48	94.2	48.55	29.44	71.85	26.79
		Yermo	139.81	85.42	50.77	34.37	80.19	23.7
		Average	127.87	88.82	49.57	31.24	76.77	25.02
	S7 CSDRS-HF	**Lucerne**	54.05	49.28	39.97	25.12	49.11	17.17
	S9 CSDRS-HF	**Lucerne**	52.39	45.17	50.3	25.07	63.72	18.5
Envelope			**143.76**	**134.97**	**101.08**	**58.46**	**134.62**	**40.13**

Note: Light shaded values are the average for the soil type, dark shaded values are the enveloping values.

Table 3.7.2-26: Selected Reactor Building Locations for Relative Displacement

Location ID (Figure 3.7.2 -94)	X-Coord (inch)	Y-Coord (inch)	Z-Coord (inch)	Location Description
10952	0	-873	420	El. 50’-0”, southwest corner at Gridline 1 & E
10974	0	873	420	El. 50’-0”, northwest corner at Gridline 1 & A
11136	420	-453	420	El. 50’-0”, southwest corner of Pool Wall at Gridline 2 & D
11148	420	453	420	El. 50’-0”, northwest corner of Pool Wall at Gridline 2 & B
12073	3672	-453	420	El. 50’-0”, southeast corner of Pool Wall at Gridline 6 & D
12085	3672	453	420	El. 50’-0”, northeast corner of Pool Wall at Gridline 6 & B
12220	4092	-873	420	El. 50’-0”, southeast corner at Gridline 7 & E
12242	4092	873	420	El. 50’-0”, northeast corner at Gridline 7 & A
16925	0	-873	720	El. 75’-0”, southwest corner at Gridline 1 & E
16947	0	873	720	El. 75’-0”, northwest corner at Gridline 1 & A
17109	420	-453	720	El. 75’-0”, southwest corner of Pool Wall at Gridline 2 & D
17121	420	453	720	El. 75’-0”, northwest corner of Pool Wall at Gridline 2 & B
18019	3672	-453	720	El. 75’-0”, southeast corner of Pool Wall at Gridline 6 & D
18031	3672	453	720	El. 75’-0”, northeast corner of Pool Wall at Gridline 6 & B
18165	4092	-873	720	El. 75’-0”, southeast corner at Gridline 7 & E
18187	4092	873	720	El. 75’-0”, northeast corner at Gridline 7 & A
22810	0	-873	1020	El. 100’-0”, southwest corner at Gridline 1 & E
22832	0	873	1020	El. 100’-0”, northwest corner at Gridline 1 & A
22994	420	-453	1020	El. 100’-0”, southwest corner of Pool Wall at Gridline 2 & D
23006	420	453	1020	El. 100’-0”, northwest corner of Pool Wall at Gridline 2 & B
23907	3672	-453	1020	El. 100’-0”, southeast corner of Pool Wall at Gridline 6 & D
23919	3672	453	1020	El. 100’-0”, northeast corner of Pool Wall at Gridline 6 & B
24054	4092	-873	1020	El. 100’-0”, southeast corner at Gridline 7 & E
24076	4092	873	1020	El. 100’-0”, northeast corner at Gridline 7 & A
25487	0	-873	1320	El. 125’-0”, southwest corner at Gridline 1 & E
25509	0	873	1320	El. 125’-0”, northwest corner at Gridline 1 & A
25568	420	-453	1320	El. 125’-0”, southwest corner of Pool Wall at Gridline 2 & D
25569	420	453	1320	El. 125’-0”, northwest corner of Pool Wall at Gridline 2 & B
26333	3672	-453	1320	El. 125’-0”, southeast corner of Pool Wall at Gridline 6 & D
26345	3672	453	1320	El. 125’-0”, northeast corner of Pool Wall at Gridline 6 & B
26449	4092	-873	1320	El. 125’-0”, southeast corner at Gridline 7 & E
26471	4092	873	1320	El. 125’-0”, northeast corner at Gridline 7 & A
27467	0	-873	1548	Southwest corner at Gridline 1 & E at El. 145’-6”
27489	0	873	1548	Northwest corner at Gridline 1 & A at El. 145’-6”
27663	2019.5	-453	1548	Center of north crane slab at El. 145’-6”
27664	2019.5	453	1548	Center of south crane slab at El. 145’-6”
27900	4092	-873	1548	Southeast corner at Gridline 7 & E at El. 145’-6”
27922	4092	873	1548	Northeast corner at Gridline 7 & A at El. 145’-6”
29076	0	-873	1824	Southwest corner at Gridline 1 & E at El. 163’-0”
29098	0	873	1824	Northwest corner at Gridline 1 & A at El. 163’-0”
29343	4092	-873	1824	Southeast corner at Gridline 7 & E at El. 163’-0”
29365	4092	873	1824	Northeast corner at Gridline 7 & A at El. 163’-0”
946	2019.5	0	0	Reference node near the center of basemat bottom

Table 3.7.2-27: Selected Control Building Locations for Relative Displacement Calculation

Location ID (Figure 3.7.2 -95)	X-Coord (inch)	Y-Coord (inch)	Z-Coord (inch)	Location Description
32322	4500	-700	405	At top of basemat on the south-west corner (Gridlines 1 & E)
32345	4500	700	405	At top of basemat on the north-west corner (Gridlines 1 & A)
32526	4968	-8	405	At top of basemat on the mid-point of basemat and Gridline 2
34297	4500	-700	570	El. 63′-3″, on the south-west corner of the Gridlines 1 and E
34311	4500	125	570	El. 63′-3″, on the Gridlines of 1 and B.3
34408	4751.33	-270	570	El. 63′-3″, on the Gridlines 1.7 and D
35463	4200	-155	720	El. 76′-6″, on the north-west corner of tunnel at Gridline C
35614	4500	-700	720	El. 76′-6″, south-west corner of CRB
35627	4500	58.5	720	El. 76′-6″, on the Gridline 1 and south of Gridline B.3
35637	4500	700	720	El. 76′-6″, on the north-west corner (Gridlines 1 & A)
35787	4809.67	58.5	720	El. 76′-6″, mid-point of 3 foot slab
35902	5010	-700	720	El. 76′-6″, on the Gridline E at the south stairwell
35925	5010	700	720	El. 76′-6″, on the Gridline A at the north stairwell
36009	5154	58.5	720	El. 76′-6″, Gridline 3 at the mid-point of the slab
36158	5436	58.5	720	El. 76′-6″, east wall at the mid-point of the slab
37970	4200	-155	1020	Tunnel at El. 100′-00, Gridline C and north-west tunnel corner
38144	4500	700	1020	El. 100′-00″, north-west corner (Gridlines 1 & A)
38294	4809.67	58.5	1020	El. 100′-00″, mid-point of 3 foot slab
38409	5010	-700	1020	El. 100′-00″, on the Gridline E at the south stairwell
38432	5010	700	1020	El. 100′-00″, on the Gridline A at the north stairwell
38652	5436	-700	1020	At top of backfill at El. 100′-00″, south-east corner at Gridlines 4 & E
38665	5436	58.5	1020	El. 100′-00″, east wall at the mid-point of the slab
39083	4500	-631	1260	El. 120′-00″, south-west corner at Gridlines 1 and E
39105	4500	700	1260	El. 120′-00″, north-west corner at Gridlines 1 & A
39215	4809.67	58.5	1260	El. 120′-00″, mid-point of 3 foot slab
39254	4918	-421	1260	El. 120′-00″, at point south of Gridline D and west of Gridline 2
39368	5106	700	1260	El. 120′-00″, on the Gridline A at the north stairwell
39490	5436	58.5	1260	El. 120′-00″, east wall at the mid-point of the slab
39705	4500	-700	1518	At roof top El. 140′-00″, south-west corner
39710	4500	-8	1518	At roof top El. 140′-00″, mid-point of roof at Grid 1
39715	4500	700	1518	At roof top El. 140′-00″, north-west corner
39778	4936	-8	1518	At roof top El. 140′-00″, mid-point of roof
39860	5436	-700	1518	At roof top El. 140′-00″, south-east corner
39866	5436	-8	1518	At roof top El. 140′-00″, mid-point of roof at Grid 4
39872	5436	700	1518	At roof top El. 140′-00″, north-east corner
31890	4968	-8	345	Reference node near the bottom center of basemat bottom

Table 3.7.2-28: Relative Displacement at Selected Locations on Reactor Building

Location ID (Figure 3.7.2-94)	RXB Model			Triple Model			Envelope		
	Displ-X (inch)	Displ-Y (inch)	Displ-Z (inch)	Displ-X (inch)	Displ-Y (inch)	Displ-Z (inch)	Displ-X (inch)	Displ-Y (inch)	Displ-Z (inch)
10952	0.07	0.18	0.31	0.07	0.18	0.31	0.07	0.18	0.31
10974	0.07	0.18	0.32	0.06	0.18	0.31	0.07	0.18	0.32
11136	0.06	0.17	0.19	0.06	0.16	0.18	0.06	0.17	0.19
11148	0.06	0.17	0.19	0.06	0.17	0.18	0.06	0.17	0.19
12073	0.07	0.19	0.2	0.07	0.18	0.19	0.07	0.19	0.2
12085	0.07	0.19	0.2	0.07	0.18	0.2	0.07	0.19	0.2
12220	0.07	0.21	0.32	0.07	0.19	0.31	0.07	0.21	0.32
12242	0.07	0.21	0.32	0.06	0.2	0.32	0.07	0.21	0.32
16925	0.11	0.3	0.33	0.11	0.29	0.33	0.11	0.3	0.33
16947	0.11	0.3	0.33	0.11	0.3	0.32	0.11	0.3	0.33
17109	0.11	0.29	0.19	0.11	0.29	0.19	0.11	0.29	0.19
17121	0.11	0.28	0.19	0.1	0.28	0.18	0.11	0.28	0.19
18019	0.12	0.31	0.21	0.12	0.31	0.2	0.12	0.31	0.21
18031	0.12	0.31	0.21	0.12	0.31	0.2	0.12	0.31	0.21
18165	0.12	0.32	0.33	0.12	0.31	0.33	0.12	0.32	0.33
18187	0.11	0.32	0.33	0.12	0.31	0.33	0.12	0.32	0.33
22810	0.16	0.44	0.34	0.15	0.43	0.34	0.16	0.44	0.34
22832	0.15	0.43	0.34	0.15	0.43	0.34	0.15	0.43	0.34
22994	0.16	0.41	0.19	0.15	0.41	0.19	0.16	0.41	0.19
23006	0.15	0.4	0.19	0.15	0.41	0.18	0.15	0.41	0.19
23907	0.17	0.44	0.21	0.18	0.43	0.2	0.18	0.44	0.21
23919	0.17	0.44	0.21	0.18	0.43	0.21	0.18	0.44	0.21
24054	0.17	0.44	0.34	0.17	0.43	0.34	0.17	0.44	0.34
24076	0.17	0.44	0.34	0.17	0.43	0.35	0.17	0.44	0.35
25487	0.21	0.64	0.35	0.2	0.62	0.35	0.21	0.64	0.35
25509	0.21	0.65	0.35	0.2	0.63	0.35	0.21	0.65	0.35
25568	0.2	0.79	0.19	0.2	0.76	0.18	0.2	0.79	0.19
25569	0.2	0.82	0.19	0.19	0.78	0.18	0.2	0.82	0.19
26333	0.22	0.57	0.21	0.23	0.57	0.2	0.23	0.57	0.21
26345	0.22	0.57	0.21	0.23	0.57	0.2	0.23	0.57	0.21
26449	0.23	0.56	0.35	0.22	0.55	0.35	0.23	0.56	0.35
26471	0.23	0.56	0.35	0.22	0.55	0.36	0.23	0.56	0.36
27467	0.25	0.78	0.35	0.24	0.76	0.36	0.25	0.78	0.36
27489	0.25	0.8	0.36	0.24	0.77	0.35	0.25	0.8	0.36
27663	0.22	1.43	0.09	0.22	1.32	0.09	0.22	1.43	0.09
27664	0.22	1.42	0.09	0.21	1.31	0.09	0.22	1.42	0.09
27900	0.27	0.65	0.36	0.26	0.64	0.35	0.27	0.65	0.36
27922	0.28	0.65	0.35	0.26	0.65	0.36	0.28	0.65	0.36
29076	0.32	0.94	0.36	0.3	0.92	0.36	0.32	0.94	0.36
29098	0.32	0.94	0.36	0.3	0.91	0.35	0.32	0.94	0.36
29343	0.33	0.77	0.36	0.31	0.77	0.35	0.33	0.77	0.36
29365	0.34	0.77	0.36	0.31	0.77	0.36	0.34	0.77	0.36

Table 3.7.2-29: Relative Displacement at Selected Locations on Control Building

Location ID (Figure 3.7.2-95)	CRB Model			Triple Model			Envelope		
	Displ-X (inch)	Displ-Y (inch)	Displ-Z (inch)	Displ-X (inch)	Displ-Y (inch)	Displ-Z (inch)	Displ-X (inch)	Displ-Y (inch)	Displ-Z (inch)
32322	0.03	0.02	0.21	0.05	0.03	0.07	0.05	0.03	0.21
32345	0.03	0.02	0.22	0.05	0.03	0.08	0.05	0.03	0.22
32526	0.02	0.01	0	0	0	0	0.02	0.01	0
34297	0.1	0.07	0.21	0.07	0.07	0.09	0.1	0.07	0.21
34311	0.09	0.07	0.15	0.09	0.06	0.04	0.09	0.07	0.15
34408	0.09	0.06	0.08	0.06	0.06	0.02	0.09	0.06	0.08
35463	0.16	0.17	0.26	0.11	0.22	0.11	0.16	0.22	0.26
35614	0.16	0.11	0.21	0.11	0.1	0.1	0.16	0.11	0.21
35627	0.15	0.11	0.15	0.12	0.1	0.05	0.15	0.11	0.15
35637	0.16	0.11	0.23	0.11	0.1	0.11	0.16	0.11	0.23
35787	0.15	0.11	0.05	0.11	0.09	0.03	0.15	0.11	0.05
35902	0.16	0.11	0.15	0.1	0.12	0.06	0.16	0.12	0.15
35925	0.16	0.11	0.15	0.1	0.1	0.06	0.16	0.11	0.15
36009	0.14	0.11	0.05	0.1	0.08	0.02	0.14	0.11	0.05
36158	0.15	0.11	0.14	0.11	0.09	0.06	0.15	0.11	0.14
37970	0.28	0.26	0.26	0.18	0.26	0.12	0.28	0.26	0.26
38144	0.28	0.2	0.23	0.19	0.16	0.13	0.28	0.2	0.23
38294	0.28	0.2	0.14	0.2	0.17	0.2	0.28	0.2	0.2
38409	0.27	0.2	0.15	0.17	0.17	0.07	0.27	0.2	0.15
38432	0.28	0.2	0.16	0.18	0.17	0.07	0.28	0.2	0.16
38652	0.27	0.19	0.22	0.17	0.15	0.12	0.27	0.19	0.22
38665	0.29	0.19	0.14	0.19	0.15	0.08	0.29	0.19	0.14
39083	0.35	0.25	0.2	0.23	0.21	0.1	0.35	0.25	0.2
39105	0.36	0.25	0.23	0.25	0.2	0.13	0.36	0.25	0.23
39215	0.36	0.25	0.17	0.28	0.21	0.23	0.36	0.25	0.23
39254	0.36	0.25	0.09	0.24	0.21	0.1	0.36	0.25	0.1
39368	0.36	0.25	0.16	0.25	0.22	0.09	0.36	0.25	0.16
39490	0.36	0.24	0.14	0.28	0.19	0.08	0.36	0.24	0.14
39705	0.44	0.31	0.21	0.3	0.36	0.13	0.44	0.36	0.21
39710	0.52	0.31	0.15	0.73	0.34	0.08	0.73	0.34	0.15
39715	0.45	0.31	0.23	0.34	0.34	0.14	0.45	0.34	0.23
39778	0.52	0.32	0.42	0.73	0.48	0.51	0.73	0.48	0.51
39860	0.44	0.31	0.22	0.29	0.34	0.14	0.44	0.34	0.22
39866	0.52	0.31	0.14	0.73	0.31	0.09	0.73	0.31	0.14
39872	0.45	0.31	0.22	0.33	0.3	0.14	0.45	0.31	0.22

Table 3.7.2-30: Comparison of Maximum Lug and Skirt Reactions using Soil Type 7 (CSDRS)

Input Case	East Wing Wall ($x10^3$ kip)	Pool Wall ($x10^3$ kip)	West Wing Wall ($x10^3$ kip)	NPM Skirt E-W Reaction ($x10^3$ kip)	NPM Skirt N-S Reaction ($x10^3$ kip)
12 NPMs	1.8	2.3	2.0	0.8	0.9
7 NPMs	1.8	2.3	1.9	0.8	0.9

Note: Highlighted values are the larger of the two cases

Table 3.7.2-31: Comparison of Maximum Lug and Skirt Reactions using Soil Type 9 (CSDRS-HF)

Input Case	East Wing Wall ($x10^3$ kip)	Pool Wall ($x10^3$ kip)	West Wing Wall ($x10^3$ kip)	NPM Skirt E-W Reaction ($x10^3$ kip)	NPM Skirt N-S Reaction ($x10^3$ kip)
12 NPMs	1.8	2.2	1.9	0.6	0.9
7 NPMs	1.8	2.1	2.0	0.7	0.9

Note: Highlighted values are the larger of the two cases

Table 3.7.2-32: Max Forces and Moments at wall locations using Soil Type 7, CSDRS Input

Bay 1 West Wing Wall	Model	In-Plane Stress (kip/ft)			Bending Moments (kip-ft/ft)			Out of Plane Shear (kip/ft)	
		Sxx	Syy	Sxy	Mxx	Myy	Mxy	Vxz	Vyz
Base	12 NPM	421	82	132	415	101	172	59	21
	7 NPM	418	83	130	494	120	213	67	25
Lug	12 NPM	438	175	113	197	665	93	49	72
	7 NPM	425	195	119	211	761	87	51	88

Bay 1 Pool Wall	Model	In-Plane Stress (kip/ft)			Bending Moments (kip-ft/ft)			Out of Plane Shear (kip/ft)	
		Sxx	Syy	Sxy	Mxx	Myy	Mxy	Vxz	Vyz
Base	12 NPM	110	31	173	98	23	11	18	7
	7 NPM	105	29	166	96	23	13	18	7
Lug	12 NPM	100	117	115	130	153	59	139	42
	7 NPM	95	121	139	139	215	76	166	52

Bay 1 / 2 Wing Wall	Model	In-Plane Stress (kip/ft)			Bending Moments (kip-ft/ft)			Out of Plane Shear (kip/ft)	
		Sxx	Syy	Sxy	Mxx	Myy	Mxy	Vxz	Vyz
Base	12 NPM	231	244	123	99	86	45	15	21
	7 NPM	227	242	117	117	111	65	15	26
Lug	12 NPM	196	215	70	87	176	58	18	23
	7 NPM	193	191	64	98	241	56	26	34

Note: Shaded entries are maximum forces either for the wing walls, or for the pool walls.

Bay 5/6 Wing Wall	Model	In-Plane Stress (kip/ft)			Bending Moments (kip-ft/ft)			Out of Plane Shear (kip/ft)	
		Sxx	Syy	Sxy	Mxx	Myy	Mxy	Vxz	Vyz
Base	12 NPM	134	139	93	96	87	48	15	21
	7 NPM	132	135	88	105	98	58	15	25
Lug	12 NPM	103	118	56	91	180	76	17	25
	7 NPM	102	113	47	95	189	83	18	29

Bay 6 Pool Wall	Model	In-Plane Stress (kip/ft)			Bending Moments (kip-ft/ft)			Out of Plane Shear (kip/ft)	
		Sxx	Syy	Sxy	Mxx	Myy	Mxy	Vxz	Vyz
Base	12 NPM	294	80	162	80	20	14	20	7
	7 NPM	288	78	156	79	20	14	20	7
Lug	12 NPM	179	95	147	96	65	25	63	18
	7 NPM	180	92	144	95	60	27	55	18

Bay 6 East Wall	Model	In-Plane Stress (kip/ft)			Bending Moments (kip-ft/ft)			Out of Plane Shear (kip/ft)	
		Sxx	Syy	Sxy	Mxx	Myy	Mxy	Vxz	Vyz
Base	12 NPM	401	68	210	129	35	39	26	8
	7 NPM	398	67	209	127	34	37	26	8
Lug	12 NPM	253	110	211	118	85	50	55	13
	7 NPM	253	108	211	117	81	50	54	13

Note: Shaded entries are maximum forces either for the wing walls, or for the pool walls.

Table 3.7.2-33: Definition of Seismic Analysis Identification Codes

Identification Code	CSDRS Input					CSDRS Soil Type			CSDRS-HF Input	CSDRS-HF Soil Type		Damping		Concrete Condition		Building Model		
	Yermo	Capitola	Chi-Chi	Izmit	El Centro	7	8	11	Lucerne	7	9	OBE 4%	SSE 7%	Cracked	Uncracked	RXB	CRB	Triple
1	X	X	X	X	X	X	X	X	X	X	X	-	X	X	X	X	-	-
2	X	X	X	X	X	X	X	X	X	X	X	-	X	X	X	-	-	X
3	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	X	-	-
4	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	-	-	X
5	-	X	-	-	-	X	-	-	-	-	-	X	-	X	X	X	-	-
6	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	-	X	-
7	X	X	X	X	X	X	X	X	X	X	X	-	X	X	X	-	X	-
8	X	X	X	X	X	X	-	-	X	-	X	-	X	X	X	-	-	X

Note: All seismic analysis codes include runs in the three primary directions (i.e. east-west, north-south, and vertical).

Table 3.7.2-34: SSC Seismic Analysis Identification Code Assignments

SSC	Description	Identification Code
CNTS	containment system	5
SGS	steam generator system	5
RXC	reactor core	5
CRDS	control rod drive system	5
CRA	control rod assembly	5
NSA	neutron source assembly	5
RCS	reactor coolant system	5
CVCS	chemical and volume control system	5
ECCS	emergency core cooling system	5
DHRS	decay heat removal system	5
CRHS	control room habitability system	6
CRVS	normal control room HVAC system	6
RFT	Reactor Flange Tool	5
FHE	fuel handling equipment	3
SFSS	spent fuel storage system	3
RPCS	reactor pool cooling system	3, 4
UHS	ultimate heat sink	3, 4
CES	containment evacuation system	5
MSS	main steam system	5
FWS	feedwater system	5
EDSS	highly reliable DC power system	3[1], 4[1], 6[2]
MPS	module protection system	3[1], 4[1], 6[2]
NMS	neutron monitoring system	3, 4
SDIS	safety display and indication system	6
ICIS	in-core instrumentation system	5
PPS	plant protection system	3[1], 4[1], 6[2]
RMS	radiation monitoring system	3[1], 4[1], 6[2]
RXB	Reactor Building	1, 2
RXB	Reactor Building - NPM Lug and Skirt Supports	5
RBC	Reactor Building crane	3
RBCM	Reactor Building Components - Pool Liner	1, 2
RBCM	Reactor Building Components - Bioshield	3
CRB	Control Building	7, 8
SMS	seismic monitoring system	3[1], 4[1], 6[2]

[1]Design for SSC located in the Reactor Building

[2]Design for SSC located in the Control Building

Table 3.7.2-35: Analysis Model Summary

No.	Analysis Model	Concrete Condition	Computer Program	SSI and SSSI Soil Types Considered	SSI and SSSI Time History Inputs Used	Purpose	Building Response	FSAR Explanation and Figures	FSAR Results
1	RXB stand-alone bldg	Uncracked & cracked	SAP2000	N/A	N/A	Static analysis	Member forces	Sections: 3.7.2.1.1.1, 3.7.2.1.2.1, 3.8.4.1.1, 3.8.4.3, 3.8.4.4.1, 3.8.5.4.1.2; Figures: 3.7.2-4, 3.8.4-15 through -20	Tables: 3B-2 through -25; Figures 3B-7 through -47
2	RXB stand-alone bldg	Uncracked & cracked	SASSI2010	7, 8 & 11 (with CSDRS Input); 7 & 9 (with CSDRS-HF Input)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic SSI analysis using 7% material damping	Member forces	Sections: 3.7.2.1.1.3, 3.7.2.1.2.1, 3.7.2.1.2.4, 3.7.2.4, 3.7.2.11, 3.7.5.1.4, 3.8.4.3, 3.8.5.4.1.2; Figures 3.7.2-15 through -21 & -35 (SASSI Input); Table 3.7.2-8 (SASSI Input)	Tables: 3B-2 through -25; Figures 3B-7 through -47
3	RXB stand-alone bldg	Uncracked & cracked	SASSI2010	7, 8 & 11 (with CSDRS Input); 7 & 9 (with CSDRS-HF Input)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic ISRS generation using 4% material damping	ISRS	Sections: 3.7.2.1.1.3, 3.7.2.1.2.1, 3.7.2.1.2.4, 3.7.2.4, 3.7.2.5, 3.7.2.5.3, 3.7.2.9, 3.7.5.1.4, 3.8.4.3; Figures 3.7.2-15 through -21 & -35 (SASSI Input); Table 3.7.2-8 (SASSI Input)	Figures: 3.7.2-99 through -103
4	RXB stand-alone bldg	Uncracked	ANSYS	Wall accelerations are based on soil types 7, 8, and 11 w CSDRS Input.	CSDRS: Capitola	Slosh heights in reactor pool and determine fluid-structure interaction effects of the RXB Pool	Accelerati-ons, fluid pressures	Sections: 3.7.2.1.1.2, 3.7.2.1.2.4, 3.7.5.1.4, 3.8.4.3; Figures: 3.7.2-32 through -35, 3.8.5-8 through -14	Table 3.7.2-8; Figures 3.7.2-36 through -39
5	RXB stand-alone bldg - 7 NPM	Cracked	SASSI2010	7 (CSDRS) & 9 (CSDRS-HF)	CSDRS: Capitola CSDRS-HF: Lucerne	Seismic ISRS generation using 4% material damping & 7 NuScale Power Modules (NPMs) - study for comparision purposes only.	ISRS	Sections: 3.7.2.9.1, 3.8.4.3, 3.8.4.3.22.3; Figure 3.7.2-98	Figures: 3.7.2-107, -113, and 3.7.2-123 through -128

Table 3.7.2-35: Analysis Model Summary (Continued)

No.	Analysis Model	Concrete Condition	Computer Program	SSI and SSSI Soil Types Considered	SSI and SSSI Time History Inputs Used	Purpose	Building Response	FSAR Explanation and Figures	FSAR Results
6	RXB base mat - partial model	Uncracked	SAP2000	RXB soil pressures applied envelope the RXB stand-alone and triple building SAP and SASSI models.	RXB soil pressures applied envelope the RXB stand-alone and triple building SAP and SASSI models.	Static analysis of RXB base mat. Uses both stand-alone and combined models.	Member forces	Sections: 3.8.4.3, 3.8.5.4.1.2; Figures 3.8.5-1 & -2	Figures: 3.8.5-4 and 3.8.5-5
7	RXB base mat - partial model	Uncracked	SAP2000	RXB soil pressures applied envelope the RXB stand-alone and triple building SAP and SASSI models.	RXB soil pressures applied envelope the RXB stand-alone and triple building SAP and SASSI models.	Seismic analysis of RXB base mat. Uses both stand-alone and combined models.	Member forces	Sections: 3.8.4.3, 3.8.5.4.1.2, 3.8.5.5.4, & 3.8.5.6.3; Figures 3.8.5-1 thru -7.	Section 3.8.5.1
8	CRB base mat - partial model	Uncracked	SAP2000	CRB soil pressures applied envelope the CRB stand-alone and triple building SAP and SASSI models.	CRB soil pressures applied envelope the CRB stand-alone and triple building SAP and SASSI models.	Seismic analysis of CRB base mat. Uses both stand-alone and combined models.	Member forces	Sections: 3.8.5.4.1.3, 3.8.5.5.4, 3.8.5.6.3; Figure 3.8.5-3a	Sections: 3.8.5.1 & 3B.3.3.1; Figures: 3B-75 & -76; Tables: 3B-34 through -41
9	RXB lug restraint -partial model	Cracked	SAP2000	N/A	N/A	Design of the NPM lug supports	Member forces	Sections: 3.7.2.1.2.2, 3.8.2.1.3, 3.8.2.4.2, 3.8.4.3; Figures: 3.7.2-22, -23, -26, -27, -28, & 3.8.2-3	Tables: 3B-26 & 27; Figures: 3B-51 through -64
10	CRB stand-alone bldg	Uncracked and cracked	SAP2000	N/A	N/A	Static analysis	Member forces	Sections: 3.7.2.1.1.1, 3.7.2.1.2.5, 3.8.4.1.2, 3.8.4.3, 3.8.4.4.2; Figures: 3.7.2-50 through -52, 3.8.4-21 through - 26, 3.8.5-40	Tables: 3B-28 through - 49; Figures 3B-65 through - 85
11	CRB stand-alone bldg	Uncracked and cracked	SASSI2010	7, 8 & 11 (with CSDRS Input); 7 & 9 (with CSDRS-HF Input)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic SSI analysis using 7% material damping	Member forces	Sections: 3.7.2.1.1.3, 3.7.2.1.2.5, 3.7.2.4, 3.7.2.11, 3.8.4.3; Figures: 3.7.2-53 through -58, 3.8.5-34 & -35	Tables: 3B-28 through - 49; Figures 3B-65 through - 85

Table 3.7.2-35: Analysis Model Summary (Continued)

No.	Analysis Model	Concrete Condition	Computer Program	SSI and SSSI Soil Types Considered	SSI and SSSI Time History Inputs Used	Purpose	Building Response	FSAR Explanation and Figures	FSAR Results
12	CRB stand-alone bldg	Uncracked and cracked	SASSI2010	7, 8 & 11 (with CSDRS Input); 7 & 9 (with CSDRS-HF Input)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic ISRS generation using 4% material damping	ISRS	Sections: 3.7.2.1.1.3, 3.7.2.1.2.5, 3.7.2.4, 3.7.2.5, 3.7.2.5.6, 3.7.2.9, 3.8.4.3; Figures: 3.7.2-53 through -58, 3.8.5-34 & -35	See envelope of cracked and uncraked condition - Figures: 3.7.2-117a through -122b.
13	RXB-CRB-RWB multiple bldg	Uncracked and cracked	SAP2000	N/A	N/A	Static analysis	Member forces	Sections: 3.7.2.1.2.7, 3.8.4.3; Figures: 3.7.2-59 through -66	Tables: 3B-2 through -25, 3B-28 through -51; Figures: 3B-7 through -47 and 3B-65 through -85
14	RXB-CRB-RWB multiple bldg (RXB)	Uncracked and cracked	SASSI2010	7, 8 & 11 (with CSDRS Input); 7 & 9 (with CSDRS-HF Input)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic SSI analysis using 7% material damping	RXB member forces	Sections: 3.7.2.1.1.3, 3.7.2.1.2.7, 3.7.2.4, 3.7.2.11, 3.8.4.3; Figures: 3.7.2-67 through -75	Tables: 3B-2 through -25, 3B-28 through -51; Figures: 3B-7 through -47 and 3B-65 through -85
15	RXB-CRB-RWB multiple bldg (CRB)	Uncracked and cracked	SASSI2010	7 (CSDRS) & 9 (CSDRS-HF)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic SSI analysis using 7% material damping	CRB member forces	Sections: 3.7.2.1.1.3, 3.7.2.1.2.7, 3.7.2.4, 3.7.2.11, 3.8.4.3; Figures: 3.7.2-67 through -75	Tables: 3B-2 through -25, 3B-28 through -51; Figures: 3B-7 through -47 and 3B-65 through -85
16	RXB-CRB-RWB multiple bldg (RXB)	Uncracked and cracked	SASSI2010	7, 8 & 11 (with CSDRS Input); 7 & 9 (with CSDRS-HF Input)	CSDRS: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Seismic ISRS generation using 4% material damping	RXB ISRS	Sections: 3.7.2.1.1.3, 3.7.2.1.2.7, 3.7.2.4, 3.7.2.5, 3.7.2.9, 3.8.4.3	Figures: 3.7.2-104 through -106
17	Envelope of ISRS for RXB	Envelope of cracked & uncracked	SASSI2010	See above	See above	Seismic ISRS generation using 4% material damping	ISRS	Sections: 3.7.2.5.3, 3.7.2.9	Figures: 3.7.2-107 through -113
18	Envelope of ISRS for CRB	Envelope of cracked & uncracked	SASSI2010	See above	See above	Seismic ISRS generation using 4% material damping	ISRS	Sections:3.7.2.5.6, 3.7.2.9	Figures: 3.7.2-117a through -122b
19	RXB linear stability - stand-alone building	Cracked & uncracked	N/A	N/A	N/A	Evaluate flotation, sliding, and overturning	Factor of safety	Sections: 3.8.4.3, 3.8.5, 3.8.5.4.1.2, 3.8.5.5, 3.8.5.6.1	Table 3.8.5-5

Table 3.7.2-35: Analysis Model Summary (Continued)

No.	Analysis Model	Concrete Condition	Computer Program	SSI and SSSI Soil Types Considered	SSI and SSSI Time History Inputs Used	Purpose	Building Response	FSAR Explanation and Figures	FSAR Results
20	RXB nonlinear stability - stand-alone model (however, input seismic base reactions envelope both the RXB Stand-Alone and Triple Bldg SASSI Models)	Cracked & uncracked	ANSYS	7, 8 & 11 (with CSDRS Input); 9 (with CSDRS-HF Input)	CSDRS Averaged Reactions from: Capitola, Chi-Chi, El Centro, Izmit, Yermo. CSDRS-HF: Lucerne	Evaluate flotation, sliding, and overturning	Displace-ment	Sections: 3.8.4.3, 3.8.5, 3.8.5.4.1.2, 3.8.5.6.1; Table 3.8.5-6	Figures: 3.8.5-53 through -76; Table 3.8.5-12
21	CRB linear stability - stand-alone building	Cracked & uncracked	N/A	N/A	N/A	Evaluate flotation, sliding, and overturning	Factor of safety	Sections: 3.8.4.3, 3.8.5, 3.8.5.4.1.3, 3.8.5.5	Not presented
22	CRB nonlinear stability - stand-alone model	Cracked & uncracked	ANSYS	7 & 11 (with CSDRS Input)	CSDRS: Capitola	Evaluate flotation, sliding, and overturning	Displace-ment	Sections: 3.8.4.3, 3.8.5, 3.8.5.4.1.4, 3.8.5.6.2; Figures: 3.8.5-26 & -27, 3.8.5-48	Table 3.8.5-13; Figures: 3.8.5-49 & -50; Sections: 3.8.5.6.2.2 & 3.8.5.6.2.3
23	RXB-CRB-RWB multiple bldg - settlement	Cracked & uncracked	SAP2000	N/A	N/A	Evaluate settlement for RXB and CRB	Settlement	Sections: 3.8.4.3; Figures: 3.8.5-41	Table 3.8.5-8
24	NuScale Power Module (NPM's 1 and 6)	Cracked & uncracked	ANSYS	7 (with CSDRS Input)	CSDRS: Capitola	Determine reaction forces for NPM, ISRS and time histories for NPM components.	Reactions, forces, moments, ISRS, time histories	Sections: 3.7.2.1.2.2, 3.7.3; Appendix 3A; Table 3.9-8; TR-0916-51502 Sections 3.1.5 & 5.0	TR-0916-51502 Tables 8-1 through 8-9; Figures B-1 through B-33
25	RXB fuel storage racks	N/A	ANSYS	Analysis based on RXB ISRS	Analysis based on RXB ISRS	Structural analysis of the RXB fuel storage racks	Member stresses	Sections: 3.7.3, 3.8.4.3.1.7, 9.1; TR-0816-49833	See COL Item 9.1-8
26	Reactor Building crane (RBC)	N/A	ANSYS	Analysis based on RXB ISRS	Analysis based on RXB ISRS	Structural analysis of RBC	Member forces	Section 9.1.5	Not presented

Table 3.7.2-35: Analysis Model Summary (Continued)

No.	Analysis Model	Concrete Condition	Computer Program	SSI and SSSI Soil Types Considered	SSI and SSSI Time History Inputs Used	Purpose	Building Response	FSAR Explanation and Figures	FSAR Results
27	RXB bioshield - partial model	Cracked & uncracked	SAP2000	Analysis based on RXB ISRS	Analysis based on RXB ISRS	Structural analysis of bioshield	Member forces	Sections: 3.7.3, 3.7.3.3.1; Figures: 3.7.2-176a through 3.7.2-176d, 3.7.3-1 through 3.7.3-4; Tables 3.7.3-8 through -14	Table 3.7.3-14
28	Reactor Flange Tool Refueling Configuration	Cracked & uncracked	ANSYS	Soil Type 7 (with CSDRS Input)	CSDRS: Capitola	Determine core plate time histories and ISRS, as well as reactions for structural components	Reaction forces, moments, ISRS, time histories	Sections: 3.8.4.1.15, 3.8.4.3.1.12, 3.8.4.4.2, 3.8.4.5 Figures: 3.8.4.34, 3.8.4.35, 3.8.4.36	Tables: 3.8.4-21, 3.8.4-22, 3.8.4-23; TR-0916-51502 Tables 8-8 and 8-9; Figures B-34 through B-39

Table 3.7.2-36: SASSI2010 3D Equivalent Stick Model

		Interface Boundary Conditions					
Location	**Support**	**X (East-West)**	**Y (North - South)**	**Z (Vertical)**	**RX**	**RY**	**RZ**
Top of NPM	CNV pool wall lug	Restrained	Free	Free	Free	Free	Free
	CNV west side lug	Free	Restrained	Free	Free	Free	Free
	CNV east side lug	Free	Restrained	Free	Free	Free	Free
Base of NPM skirt support (2 node link elements)	End of rigid beam 1	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 2	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 3	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 4	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 5	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 6	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 7	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 8	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free

Table 3.7.2-37: ANSYS 3D Finite Element Beam Model

		Interface Boundary Conditions					
Location	**Support**	**X (East-West)**	**Y (North - South)**	**Z (Vertical)**	**RX**	**RY**	**RZ**
Top of NPM	CNV pool wall lug	Spring with high stiffness	Free	Free	Free	Free	Free
	CNV west side lug	Free	Spring with high stiffness	Free	Free	Free	Free
	CNV east side lug	Free	Spring with high stiffness	Free	Free	Free	Free
Base of NPM skirt support (2 node link element)	End of rigid beam 1	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 2	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 3	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 4	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 5	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 6	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 7	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
	End of rigid beam 8	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free
NPM base-to - base of NPM skirt support	Spider center(1)	Spring with high stiffness	Spring with high stiffness	Spring with high stiffness	Free	Free	Free

Note (1): Two nodes are included at this location (nodes 101 and 600 in TR-0916-51502). Only translation is transferred between these two nodes; that is, the NPM is free to twist.

Table 3.7.2-38: Not Used

Table 3.7.2-39: Comparison of Lug Reactions due to Capitola Input for Model A and Model B

Input Model	East Wing Wall N-S Lug Reaction (lbf)	Pool Wall E-W Lug Reaction (lbf)	West Wing Wall N-S Lug Reaction (lbf)	CNV Skirt E-W Reaction (lbf)	CNV Skirt N-S Reaction (lbf)
Model A (No Soil Separation)	1,681,105	2,193,854	1,872,121	723,757	809,450
Model B (with Soil Separation)	1,306,025	1,871,725	1,325,447	683,689	739,499
% Difference†	-22.3%	-14.7%	-29.2%	-5.5%	-8.6%

†% Difference = (Model B - Model A) / (Model A) × 100

Table 3.7.2-40: Comparison of Maximum Out-of-Plane Shears and Moments due to Capitola Input in RXB Exterior Walls

Row No.	Z-Coordinate (in)	Model A (No Soil Separation)				Model B (With Soil Separation)			
		Vxz (kip/ft)	Vyz (kip/ft)	Mxx+Mxy (kip-ft/ft)	Myy+Mxy (kip-ft/ft)	Vxz (kip/ft)	Vyz (kip/ft)	Mxx+Mxy (kip-ft/ft)	Myy+Mxy (kip-ft/ft)
1	**1132.5**	91	91	229	220	85	84	207	203
2	**1057.5**	95	95	413	411	89	87	373	370
3	**982.6**	67	68	215	225	67	68	165	169
4	**907.5**	54	53	332	332	65	66	373	373
5	**832.5**	75	75	221	221	96	97	231	240
6	**760.1**	96	97	202	166	86	88	170	190
7	**682.5**	69	66	226	209	88	89	284	286
8	**607.5**	53	53	168	148	63	64	184	179
9	**532.5**	49	49	168	158	60	61	217	234
10	**457.5**	45	45	131	135	56	56	155	171
Maximum		**96**	**97**	**413**	**411**	**96**	**97**	**373**	**373**
Capacities		**212†**		**1298‡**		**212†**		**1298**	

†Minimum OOP shear capacity: 56 kip/ft from concrete and 146 kips/ft from stirrups.

Table 3.7.2-41: Comparison of Maximum Out-of-Plane Shear Forces and Moments in CRB Exterior Walls due to Capitola Input

Row No.	Elevation (ft)	Maximum Seismic Demands in Each Row (No Soil Separation)				Maximum Seismic Demands in Each Row (With Soil Separation)			
		Vxz	Vyz	Mxx+Mxy	Myy+Mxy	Vxz	Vyz	Mxx+Mxy	Myy+Mxy
		(kip/ft)	(kip/ft)	(kip-ft/ft)	(kip-ft/ft)	(kip/ft)	(kip/ft)	(kip-ft/ft)	(kip-ft/ft)
For the Three Rows of Wall Shell Elements above Grade									
1	**101.7**	12	7	61	21	12	7	59	22
2	**95.0**	12	4	25	17	12	6	33	25
3	**88.3**	14	14	45	21	14	18	47	30
Maximum Seismic Demands (above Grade)		**14**	**14**	**61**	**21**	**14**	**18**	**59**	**30**
Capacities		**37 (=37+0†)**	**37 (=37+0†)**	**378**	**378**	**37**	**37**	**378**	**378**
For the 8 Rows of Wall Shell Elements below Grade									
4	**81.9**	20	14	35	38	27	18	46	37
5	**75.6**	12	5	37	26	15	6	50	30
6	**69.4**	11	6	36	27	13	9	34	28
7	**63.1**	11	15	35	24	10	16	29	29
8	**56.9**	12	11	33	20	10	10	28	18
9	**50.6**	12	4	31	28	10	4	26	26
10	**43.8**	11	5	25	29	10	5	22	27
11	**36.9**	6	13	17	28	6	13	15	26
Maximum Seismic Demands (below Grade)		**20**	**15**	**37**	**38**	**27**	**18**	**50**	**37**
Capacities		**84 (=37+47†)**	**84 (=37+47†)**	**378**	**378**	**84**	**84**	**378**	**378**

† Total OOP Shear Capacity = Concrete Shear Capacity + Stirrup Shear Capacity.

Table 3.7.2-42: Total Vertical Seismic RXB Base Reactions due to Capitola Input

Concrete Case	Soil Type	Seismic Input	Maximum Total Vertical Reaction (kips)		% Difference‡
			Model A (No Separation)	Model B (Soil Separation)	
Cracked 7% Damping	7	Capitola	222,932	222,537	**-0.2%**

‡ % = (Model B - Model A) / (Model A) ×100

Table 3.7.2-43: Total Vertical Seismic CRB Base Reactions

Concrete Case	Soil Type	Seismic Input	Maximum Total Vertical Reaction (kips)		% Diff‡
			Model A (No Separation)	Model B (Soil Separation)	
Cracked 7% Damping	7	Capitola	22,228	22,787	**+3%**

‡ % = (Model B-Model A)/ (Model A)*100%

Table 3.7.2-44: Relative Displacement at Critical Locations of Standalone CRB Model

Node No.	Relative Displacements (inch)					
	7P			DM		
	X-Disp	Y-Disp	Z-Disp	X-Disp	Y-Disp	Z-Disp
32322	0.01	0.01	0.03	0.01	0.01	0.02
34297	0.03	0.03	0.03	0.03	0.03	0.03
35463	0.03	0.03	0.01	0.03	0.03	0.01
36158	0.04	0.06	0.02	0.04	0.06	0.02
37970	0.05	0.04	0.02	0.05	0.03	0.02
38665	0.10	0.09	0.02	0.10	0.10	0.02
39083	0.11	0.11	0.04	0.11	0.12	0.04
39490	0.15	0.11	0.02	0.16	0.12	0.02
39705	0.16	0.17	0.05	0.16	0.18	0.05
39778	0.42	0.20	0.42	0.45	0.21	0.42
Maximum†	**0.42**	**0.20**	**0.42**	**0.45**	**0.21**	**0.42**

†Maximum displacements are found at Node 39778 at the center of the roof.

Table 3.7.2-45: Comparison of Maximum Forces and Moments in the North Pool Wall near the North Lug Support of RXM1 between 7P and DM

Force or Moment Compared	Description	Maximum Values		
		7P	DM	Difference (%)†
Sxx (kip/ft)	In-Plane Force in the EW Direction	182	186	**-2.3%**
Syy (kip/ft)	In-Plane Force in the Vertical Direction	164	172	**-4.9%**
Sxy (kip/ft)	In-Plane Shear Force	211	221	**-4.6%**
Mxx (kip-ft/ft)‡	Bending about the Vertical Axis	326	347	**-6.1%**
Myy (kip-ft/ft)‡	Bending about EW Axis	372	393	**-5.2%**
Vxz (kip/ft)	Out-of-Plane Shear in the Vertical Section	214	228	**-6.1%**
Vyz (kip/ft)	Out-of-Plane Shear in the Horizontal (EW) Section	92	97	**-4.4%**

† % = (7P-DM)/DM*100. A negative % indicates that the 7P value is less than the DM value

‡ The twisting moment Mxy was added to Mxx and Myy.

Table 3.7.2-46: Comparison of Maximum Seismic Out-of-Plane Shear Forces and Moments in CRB Exterior Walls

Elevation No.	Elevation Centroid Z (in)	Maximums in Each Elevation (7P)				Maximums in Each Elevation (DM)			
		Vxz (kip/ft)	Vyz (kip/ft)	Mxx+Mxy (kip-ft/ft)	Myy+Mxy (kip-ft/ft)	Vxz (kip/ft)	Vyz (kip/ft)	Mxx+Mxy (kip-ft/ft)	Myy+Mxy (kip-ft/ft)
For the Three Rows of Wall Shell Elements above Grade									
1	**1220**	12	7	61	21	11	7	61	23
2	**1140**	12	4	25	16	12	4	27	18
3	**1060**	14	15	45	23	15	16	44	24
Maximum Seismic Demands (above Grade)		**14**	**15**	**61**	**23**	**15**	**16**	**61**	**24**
Capacities		**37**		**378**		**37**		**378**	
Wall Shell Elements below Grade									
4	**982.5**	21	14	36	38	22	15	39	37
5	**907.5**	13	6	37	27	14	6	39	27
6	**832.5**	12	6	37	26	12	6	37	28
7	**757.5**	12	15	36	25	12	15	36	26
8	**682.5**	12	12	35	20	12	13	35	21
9	**607.5**	13	4	34	28	13	5	34	28
10	**525.0**	11	5	27	29	11	6	28	28
11	**442.5**	6	14	17	28	5	13	19	27
Maximum Seismic Demands (below Grade)		**21**	**15**	**37**	**38**	**22**	**15**	**39**	**37**
Capacities		**84**†		**378**		**84**†		**378**	

† Total OOP Shear Capacity = Concrete Shear Capacity + Stirrup Shear Capacity.

Table 3.7.2-47: Comparison of RXB Relative Displacements between 7P and DM

Node No.	Coordinate			7P			DM		
	X (inch)	Y (inch)	Z (inch)	X-DIS (inch)	Y-DIS (inch)	Z-DIS (inch)	X-DIS (inch)	Y-DIS (inch)	Z-DIS (inch)
10974	0	873	420	0.06	0.11	0.19	0.06	0.10	0.15
11148	420	453	420	0.05	0.10	0.08	0.05	0.09	0.07
12085	3672	453	420	0.06	0.12	0.10	0.06	0.11	0.10
12242	4092	873	420	0.06	0.13	0.20	0.06	0.11	0.17
16947	0	873	720	0.11	0.24	0.25	0.10	0.22	0.22
17121	420	453	720	0.10	0.20	0.09	0.10	0.18	0.08
18031	3672	453	720	0.12	0.24	0.13	0.12	0.22	0.13
18187	4092	873	720	0.11	0.23	0.24	0.11	0.21	0.22
22832	0	873	1020	0.16	0.45	0.32	0.16	0.44	0.29
23006	420	453	1020	0.15	0.35	0.10	0.15	0.34	0.09
23919	3672	453	1020	0.17	0.39	0.15	0.17	0.37	0.15
24076	4092	873	1020	0.18	0.37	0.29	0.18	0.35	0.27
25509	0	873	1320	0.21	0.76	0.36	0.21	0.74	0.34
25569	420	453	1320	0.20	0.95	0.10	0.20	0.94	0.08
26345	3672	453	1320	0.23	0.58	0.16	0.23	0.56	0.15
26471	4092	873	1320	0.25	0.54	0.33	0.25	0.51	0.31
27489	0	873	1548	0.26	0.95	0.37	0.26	0.93	0.35
27664	2019.5	453	1548	0.22	1.61	0.05	0.22	1.64	0.05
27922	4092	873	1548	0.30	0.66	0.35	0.30	0.63	0.33
29098	0	873	1824	0.34	1.13	0.38	0.34	1.11	0.36
29365	4092	873	1824	0.37	0.80	0.36	0.38	0.77	0.34

Table 3.7.2-48: North RXB Wall Soil Pressure Comparison

Soil Layer Centroidal Z (inch)	7P	DM
	Soil Pressure (ksf)	Soil Pressure (ksf)
907.5	**2.4**	**2.6**
832.5	**3.9**	**3.9**
757.5	**8.0**	**8.1**
682.5	**6.8**	**6.8**
607.5	**5.3**	**5.7**
532.5	**5.3**	**5.2**
457.5	**4.3**	**4.7**
382.5	**4.5**	**4.4**
307.5	**3.6**	**3.0**

Table 3.7.2-49: Building Models Used for RXB Basemat Design

<table>
<tr><th>Software</th><th>Bldgs. Included in the Model</th><th>Basemat Modeled As</th><th>Bldg. Model Results Used</th></tr>
<tr><td rowspan="2">SASSI</td><td>Standalone (RXB)
FSAR Table 3.7.2-1</td><td>2 Layers of Solid Elements</td><td rowspan="2">Envelope of Soil Bearing Pressure from Seismic Loads of both Models</td></tr>
<tr><td>Triple Bldg. (RXB, CRB, and RWB)
FSAR Table 3.7.2-12</td><td>2 Layers of Solid Elements</td></tr>
<tr><td rowspan="2">SAP2000</td><td>Standalone (RXB)
FSAR Table 3.8.4-6</td><td>2 Layers of Solid Elements</td><td rowspan="2">Envelope of Soil Bearing Pressure from Static Loads of both Models</td></tr>
<tr><td>Triple Bldg. (RXB, CRB, and RWB)
FSAR Section 3.7.2.1.2.7</td><td>2 Layers of Solid Elements</td></tr>
</table>

Table 3.7.2-50: Basemat Model Used for RXB Basemat Design

Software	Bldgs. Included in the Model	Basemat Modeled As	Results Used
SAP2000	Standalone (RXB) FSAR Figure 3.8.5-1	1 Layer of Shell Elements	Enveloping Soil Bearing Pressure from Static and Seismic Loads Applied as Pressures on the Basemat Model

Table 3.7.2-51: Building Models Used for CRB Basemat Design

<table>
<tr><th>Software</th><th>Bldgs. Included in the Model</th><th>Basemat Modeled As</th><th>Bldg. Model Results Used</th></tr>
<tr><td rowspan="2">SASSI</td><td>Standalone (CRB)
FSAR Table 3.7.2-9</td><td>1 Layer of Solid Elements</td><td rowspan="2">1) Enveloping foundation forces and moments are obtained by post-processing the forces and moments in the bottom of the shell elements of the exterior walls joining the basemat as the forces and moments for the perimeter area of the basemat.

2) Envelop the centroidal vertical stresses (σ_{zz}) in the foundation solid elements of the entire basemat.</td></tr>
<tr><td>Triple Bldg. (RXB, CRB, and RWB)
FSAR Table 3.7.2-12</td><td>1 Layer of Solid Elements</td></tr>
<tr><td rowspan="2">SAP2000</td><td>Standalone (CRB)
FSAR Table 3.8.4-8</td><td>1 Layer of Solid Elements</td><td rowspan="2">1) Enveloping foundation forces and moments are obtained by post-processing the forces and moments in the bottom of the shell element walls joining the basemat.

2) Enveloping foundation static forces and moments are obtained by post-processing the foundation solid element nodal forces of the entire basemat.</td></tr>
<tr><td>Triple Bldg. (RXB, CRB, and RWB)
FSAR Section 3.7.2.1.2.7</td><td>1 Layer of Solid Elements</td></tr>
</table>

Table 3.7.2-52: Basemat Model Used for CRB Basemat Design

Software	Bldgs. Included in the Model	Basemat Modeled As	Results Used
SAP2000	Standalone (CRB) FSAR Figure 3B-74	1 Layer of Shell Elements	1) Total (static + seismic) enveloping centroidal vertical stresses (σ_{zz}) obtained from the building model are applied as upward pressure to the isolated basemat shell model in the foundation solid elements of the entire basemat. This provides forces and moments in the interior region of the foundation. 2) For elements in the perimeter region, the (static + seismic) enveloping wall forces and moments are used as foundation forces and moments. 3) For the elements in the tunnel: a) the total (static + seismic) wall forces and moments are used as foundation seismic forces and moments. b) In addition, total (static + seismic) enveloping centroidal vertical stresses (σ_{zz}) obtained from the building model are applied as upward uniformly distributed loads on tunnel dimension by hand calculation. c) Total demand forces and moments are obtained as (3a+3b).

Table 3.7.2-53: Floor Elevation and Nodes for Floor ISRS Generation

Floor No.	TOC Elevation	Note	Standalone RXB Node	Triple Model Node	Coordinates (inch)		
					X	Y	Z
1	EL 24'-0"	Top of Basemat	3996	3652	0	873	120
			4741	4325	1872	873	120
			5642	5142	4092	873	120
2	EL. 25′-0″	Pool Floor (NPM Base)	6041	5525	2019.5	305.5	132
			6093	5577	2314.5	305.5	132
			6145	5629	2609.5	305.5	132
			6197	5681	2904.5	305.5	132
			6249	5733	3199.5	305.5	132
			6301	5785	3509.5	305.5	132
			6065	5549	2167	177	132
			6013	5497	1872	177	132
			6069	5553	2167	453	132
			6017	5501	1872	453	132
			6325	5809	3672	177	132
			6273	5757	3347	177	132
			6329	5813	3672	453	132
			6277	5761	3347	453	132
			6317	5801	3672	-453	132
			6265	5749	3347	-453	132
			6321	5808	3672	-177	132
			6269	5753	3347	-177	132
			6057	5541	2167	-453	132
			6005	5489	1872	-453	132
			6061	5545	2167	-177	132
			6009	5493	1872	-177	132
3	EL. 50′-0″		10974	9955	0	873	420
			11050	10022	216	0	420
			11054	10026	216	279	420
			11234	10185	824	705	420
			11542	10451	1872	453	420
			11675	10566	2314.6	621	420
			11995	10844	3347	621	420
			12174	11002	3924	88.5	420
			12178	11006	3924	360	420
			12242	11067	4092	873	420
4	EL. 75′-0″		16925	14941	0	-873	720
			16947	14963	0	873	720
			17207	15193	824	705	720
			17630	15556	2314.5	621	720
			17942	15826	3347	621	720
			18031	15903	3672	453	720
			18123	15986	3924	360	720

Table 3.7.2-53: Floor Elevation and Nodes for Floor ISRS Generation (Continued)

Floor No.	TOC Elevation	Note	Standalone RXB Node	Triple Model Node	Coordinates (inch)		
					X	Y	Z
5	EL. 100′-0″	Grade Floor	22810	19886	0	-837	1020
			22821	19897	0	0	1020
			22832	19908	0	837	1020
			22905	19972	216	-228	1020
			23092	20138	824	705	1020
			23517	20503	2314.5	621	1020
			23829	20773	3347	621	1020
			24008	20931	3924	88.5	1020
			24012	20935	3924	360	1020
			23386	20390	1872	453	1020
			23915	20847	3672	177	1020
			23919	20851	3672	453	1020
6	EL. 126′-0″		25487	22328	0	-873	1320
			25509	22350	0	873	1320
			25625	22466	824	705	1320
			25826	22667	1872	453	1320
			25831	22672	1872	873	1320
			25952	22793	2314.5	621	1320
			26258	23099	3347	621	1320
			26345	23186	3672	453	1320
			26419	23260	3924	88.5	1320
			26423	23264	3924	360	1320
			26471	23312	4092	873	1320
Roof	EL. 181′-0″	Top of Roof	29953	26794	0	-537	1980
			29960	26801	0	0	1980
			29967	26808	0	537	1980
			30110	26951	824	0	1980
			30350	27191	2019.5	0	1980
			30357	27198	2019.5	537	1980
			30515	27356	2830.75	0	1980
			30748	27589	4092	-537	1980
			30755	27596	4092	0	1980
			30762	27603	4092	537	1980

Table 3.7.2-54: SASSI Containment Vessel Skirt Coordinates

	X (in.)	Y (in.)	Z (in.)
RXM 1	2019.5	305.5	132
RXM 6	3509.5	305.5	132

Table 3.7.2-55: SASSI Containment Vessel Lug Coordinates

		X (in.)	Y (in.)	Z (in.)
RXM 1	West Lug	1915.88	305.5	673.73
	North Lug	2019.5	409.12	673.73
	East Lug	2123.12	305.5	673.73
RXM 6	West Lug	3405.88	305.5	673.73
	North Lug	3509.5	409.12	673.73
	East Lug	3613.12	305.5	673.73

Table 3.7.2-56: Selected Crane Wheel Locations and a Crane Rail Slab Node for In-Structure Response Spectra Presentation

Location No.	Coordinates (inches)			Location Description
	X (E-W)	Y (N-S)	Z (VT)	
1	2215	-453	1548	SW Crane Wheel
2	2215	453	1548	NW Crane Wheel
3	3067.25	-453	1548	SE Crane Wheel
4	3067.25	453	1548	NE Crane Wheel
5	420.0	453	1548	Crane Rail Slab at Grid Line RX-2 at El. 145'-6"

Table 3.7.2-57: Coordinates of Standalone and Triple Building Models for Control Building Floor In-Structure Response Spectra Generation

Count No.	Standalone CRB Model			Triple Building Model		
	X (in.)	Y (in.)	Z (in.)	X (in.)	Y (in.)	Z (in.)
1	4500	-700	405	4470	-705	405
2	4500	-8	405	4470	-8	405
3	4500	700	405	4470	705	405
4	4968	-8	405	4938	-8	405
5	5154	58.5	405	5124	58.5	405
6	5436	-700	405	5406	-705	405
7	5436	-8	405	5406	-8	405
8	5436	700	405	5406	705	405
9	4500	-270	570	4470	-270	570
10	4500	700	570	4470	705	570
11	4693	-491.5	570	4663	-491.5	570
12	4751.33	-270	570	4721.33	-270	570
13	4751.33	-8	570	4721.33	-8	570
14	5436	-700	570	5406	-705	570
15	4389	-270	720	4359	-270	720
16	4500	-8	720	4470	-8	720
17	4500	700	720	4470	705	720
18	4693	-491.5	720	4663	-491.5	720
19	4809.67	-8	720	4779.67	-8	720
20	4809.67	58.5	720	4779.67	58.5	720
21	4809.67	353.5	720	4779.67	353.5	720
22	5436	-700	720	5406	-705	720
23	4389	-270	1020	4359	-270	1020
24	4500	-8	1020	4470	-8	1020
25	4500	58.5	1020	4470	58.5	1020
26	4500	700	1020	4470	705	1020
27	4693	-491.5	1020	4663	-491.5	1020
28	4809.67	-8	1020	4779.67	-8	1020
29	4809.67	58.5	1020	4779.67	58.5	1020
30	4809.67	284	1020	4779.67	284	1020
31	5304	-324.5	1020	5274	-324.5	1020
32	5304	-8	1020	5274	-8	1020
33	5304	284	1020	5274	284	1020
34	5436	-700	1020	5406	-705	1020
35	4500	700	1260	4470	700	1260
36	4693	-491.5	1260	4663	-491.5	1260
37	4809.67	-8	1260	4779.67	-8	1260
38	4809.67	58.5	1260	4779.67	58.5	1260
39	4809.67	423	1260	4779.67	423	1260
40	5436	-700	1260	5406	-700	1260
41	4500	700	1518	4470	700	1518
42	5436	-700	1518	5406	-700	1518

Table 3.7.2-58: Coordinates of Selected Reactor Flange Tool Nodes

Joint No.	X (in.)	Y (in.)	Z (in.)
6328	1191	-228	132.1
6329	1255	-88.5	132.1
6330	1383	-88.5	132.1
6331	1447	-228	132.1

Table 3.7.2-59: Comparison of Empty Dry Dock Condition Lug Reactions with Final Safety Analysis Report Results (Capitola Input and Nominal NuScale Power Module Stiffness)

Dry Dock Condition	West Wing Wall N-S Lug Reaction (kips)	Pool Wall E-W Lug Reaction (kips)	East Wing Wall N-S Lug Reaction (kips)
Full	1,333	1,392	1,377
Empty	1,319	1,273	1,277

Table 3.7.2-60: Comparison of Maximum Empty Dry Dock Condition Forces in NuScale Power Module Skirt Supports with Final Safety Analysis Report Results (Capitola Input and Nominal NuScale Power Module Stiffness)

Dry Dock Condition	CNV Skirt E-W Reaction (kips)	CNV Skirt N-S Reaction (kips)	CNV Skirt Vertical Reaction (kips)
Full	524	455	1,625
Empty	539	452	1,645

Figure 3.7.2-1: Control Building, Reactor Building, and Radioactive Waste Building in Soil (Looking Northeast)

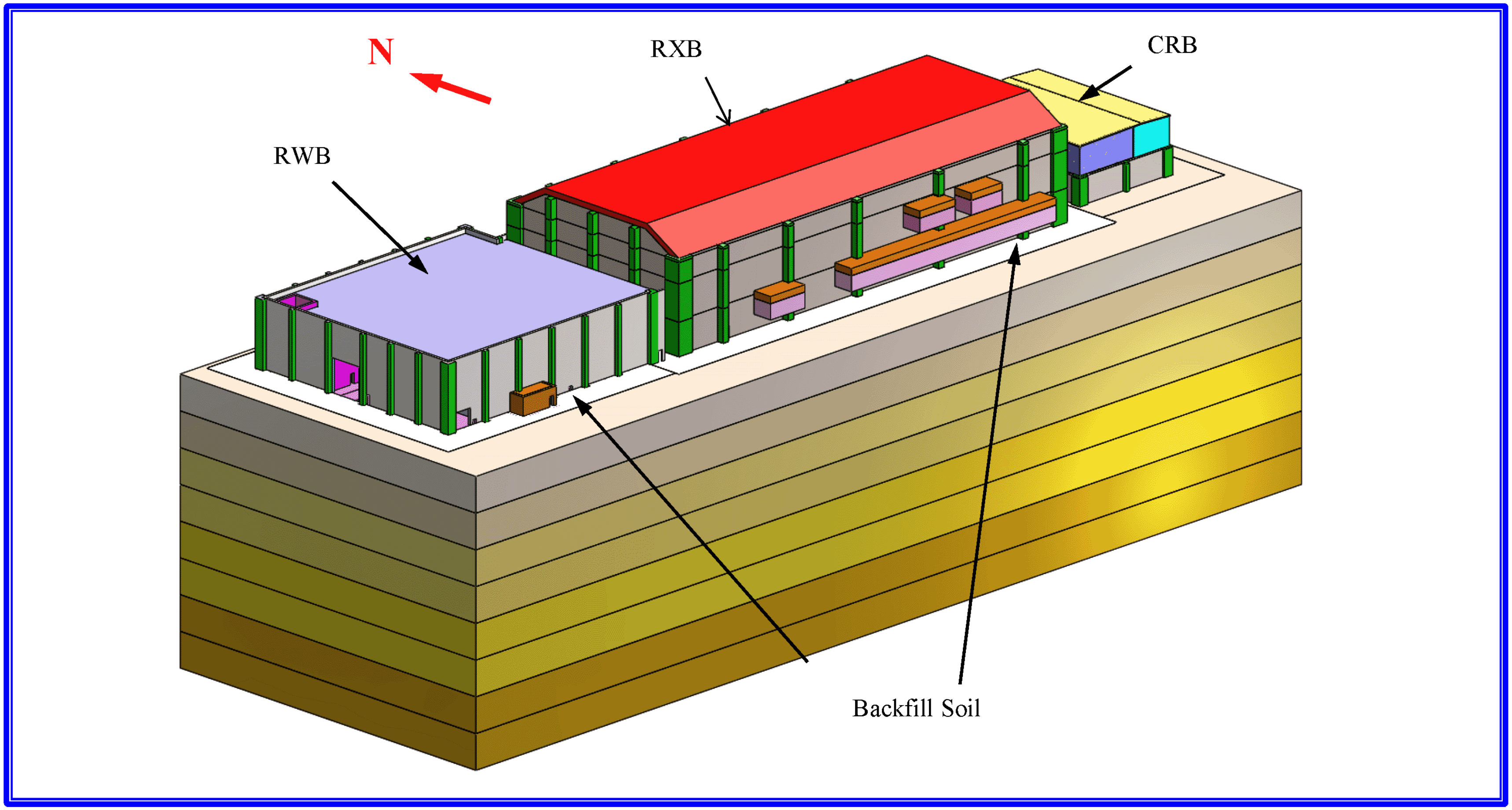


Figure 3.7.2-2: Section View of Control Building, Reactor Building, and Radioactive Waste Building in Soil (Looking Northeast)

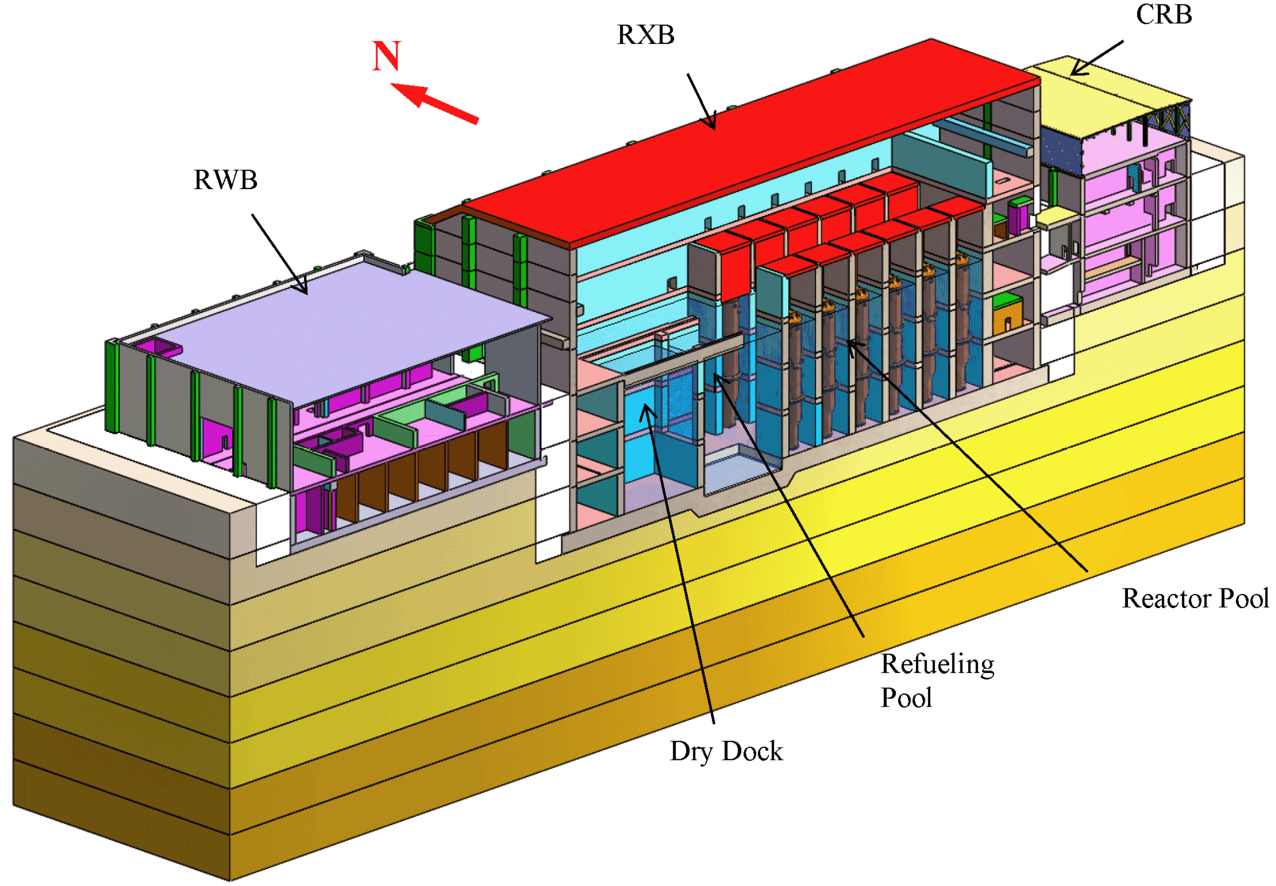


Figure 3.7.2-3: Global Origin of Building Models

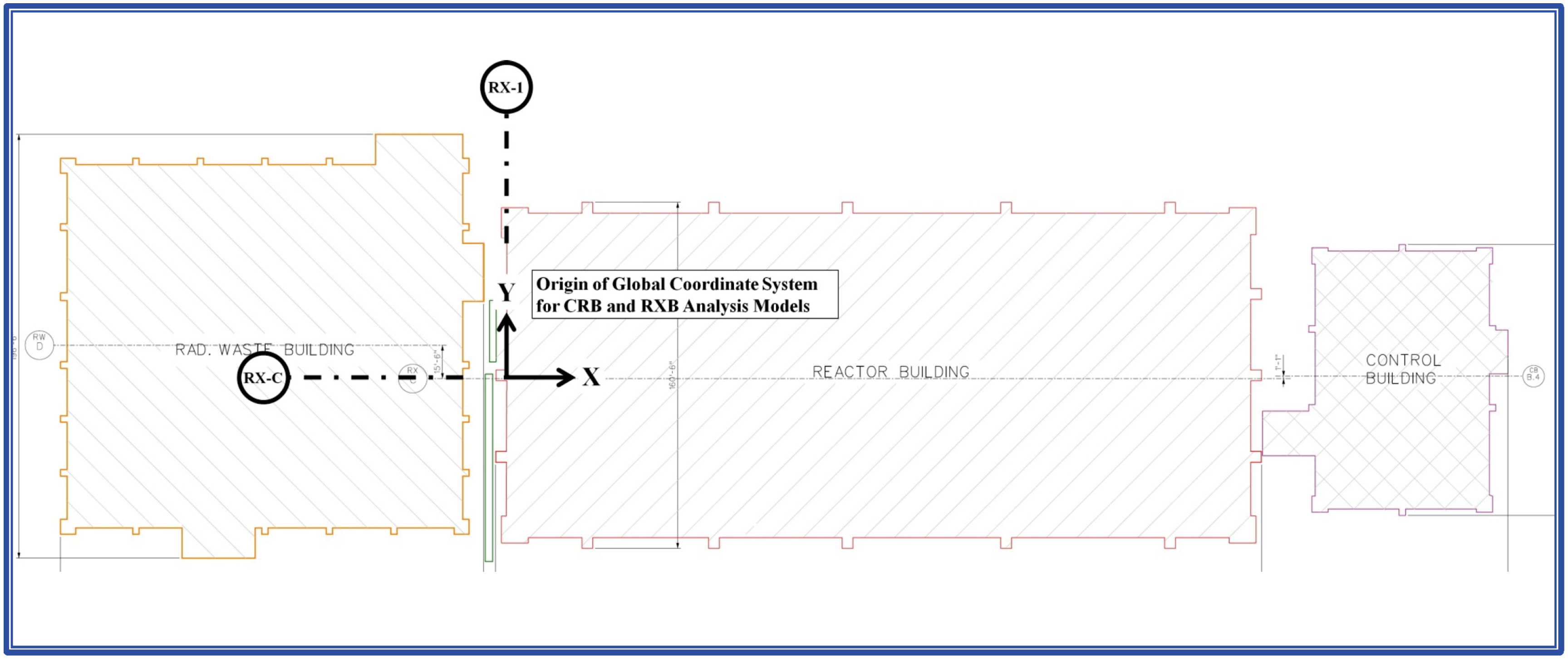


Figure 3.7.2-4: Reactor Building Model Showing Global X, Y, and Z Axes at Origin

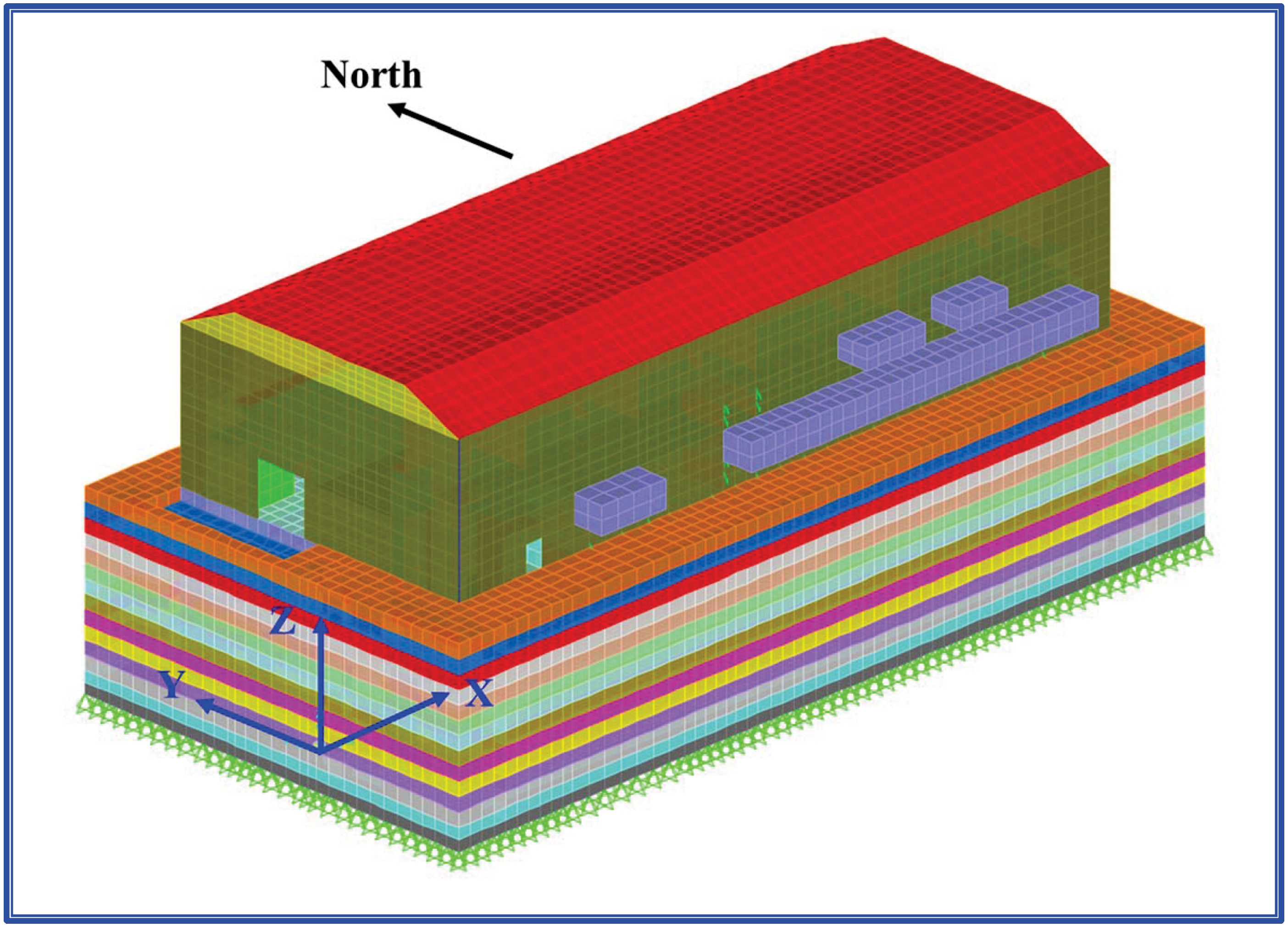


Figure 3.7.2-5: Location at Northeast Corner on Top of Basemat used for 7P versus 9P Comparison

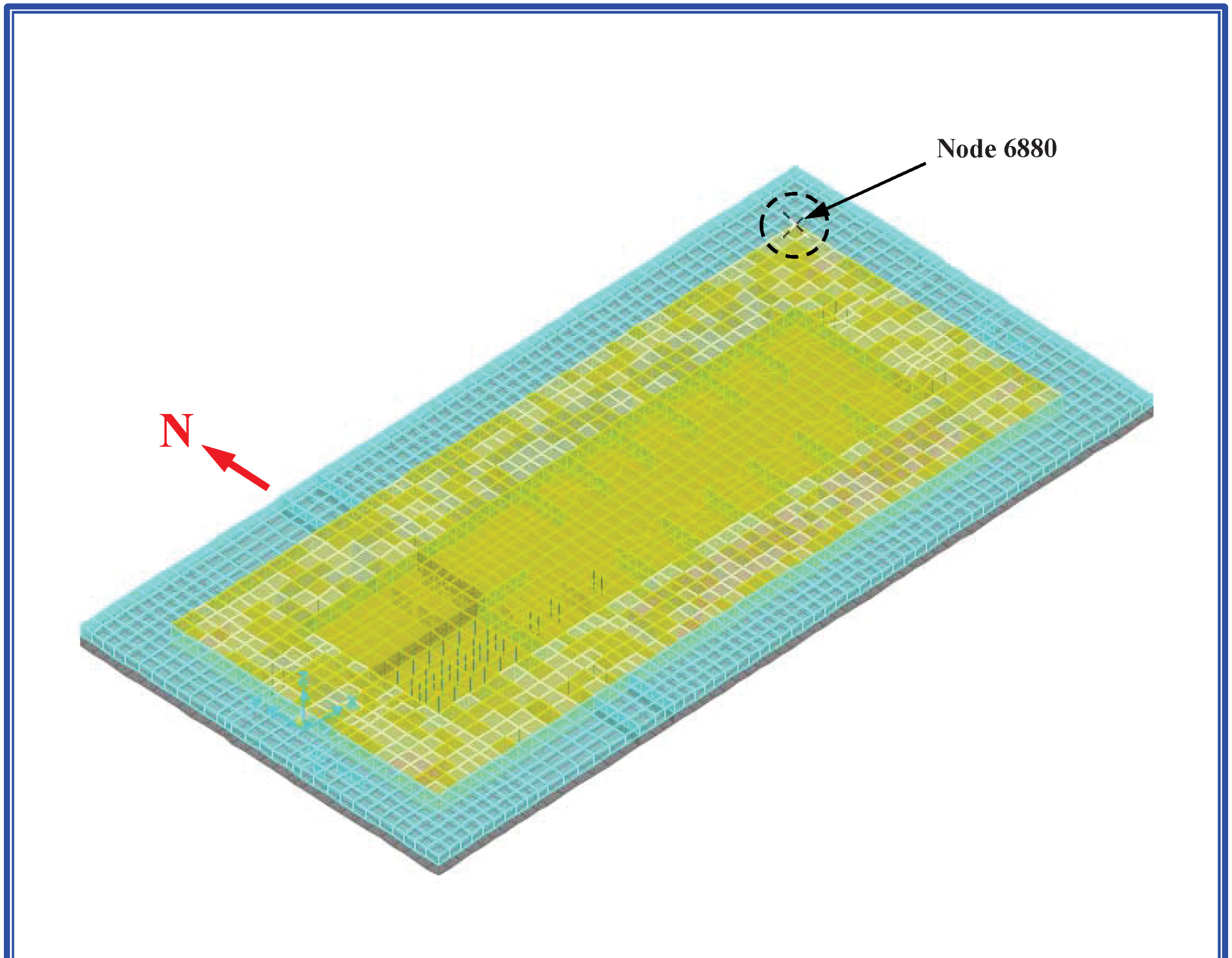


Figure 3.7.2-6: Location at NPM 1 East Wing Wall at Lug Support used for 7P versus 9P Comparison

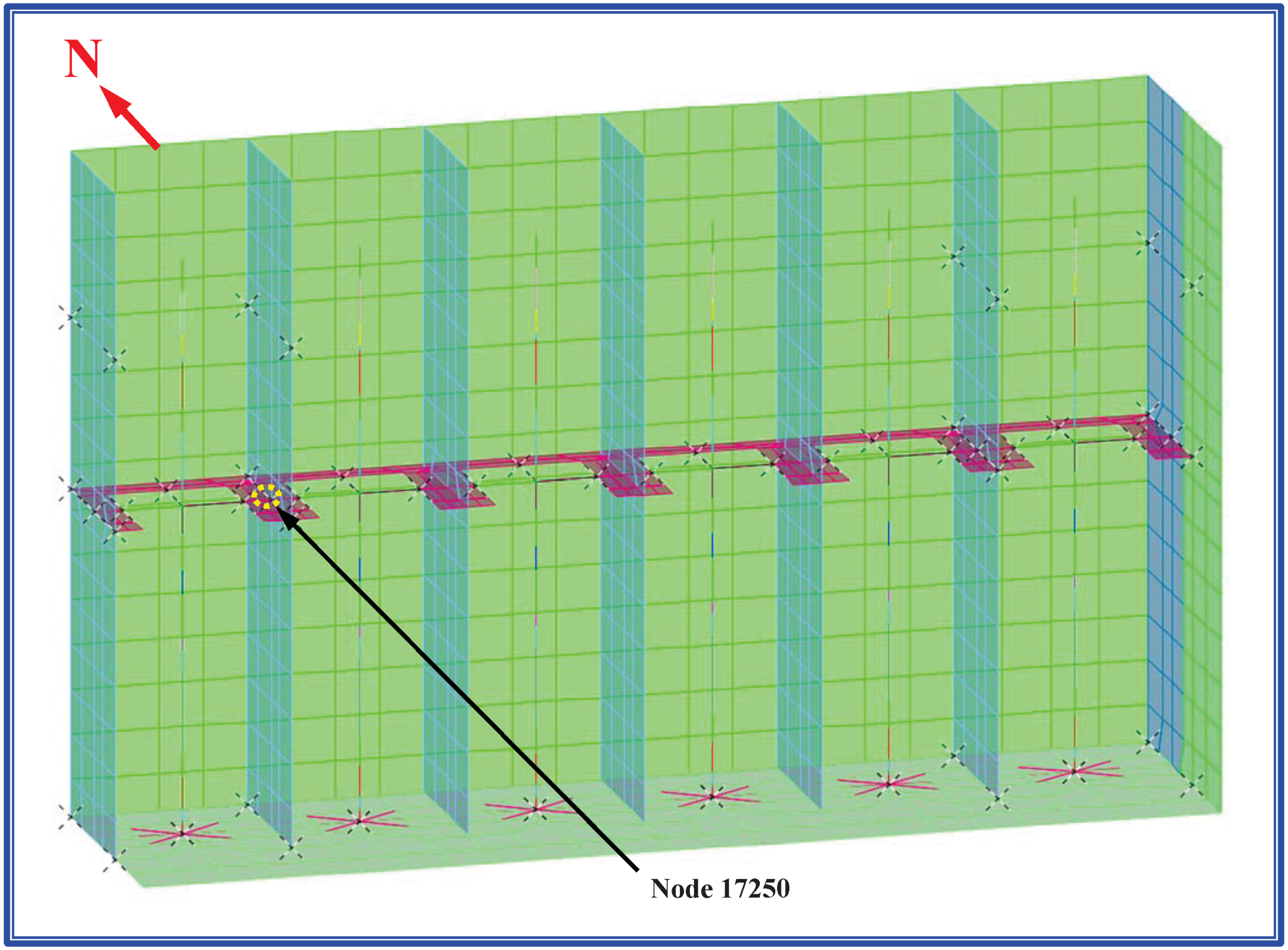


Figure 3.7.2-7: Location at Center of Roof Slab used for 7P versus 9P Comparison

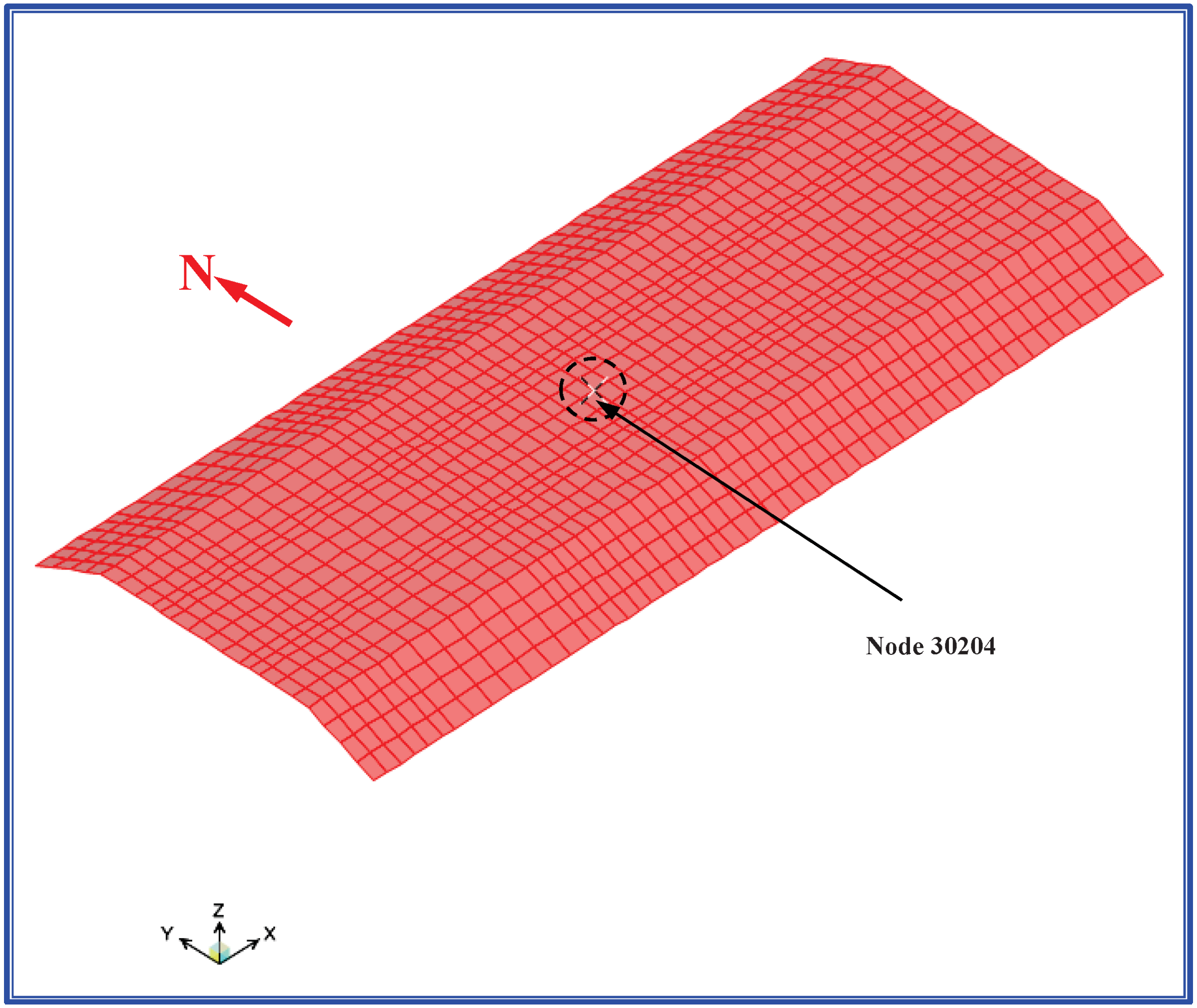


Figure 3.7.2-8: 7P Versus 9P Comparison at Northeast Corner on Top of Basemat

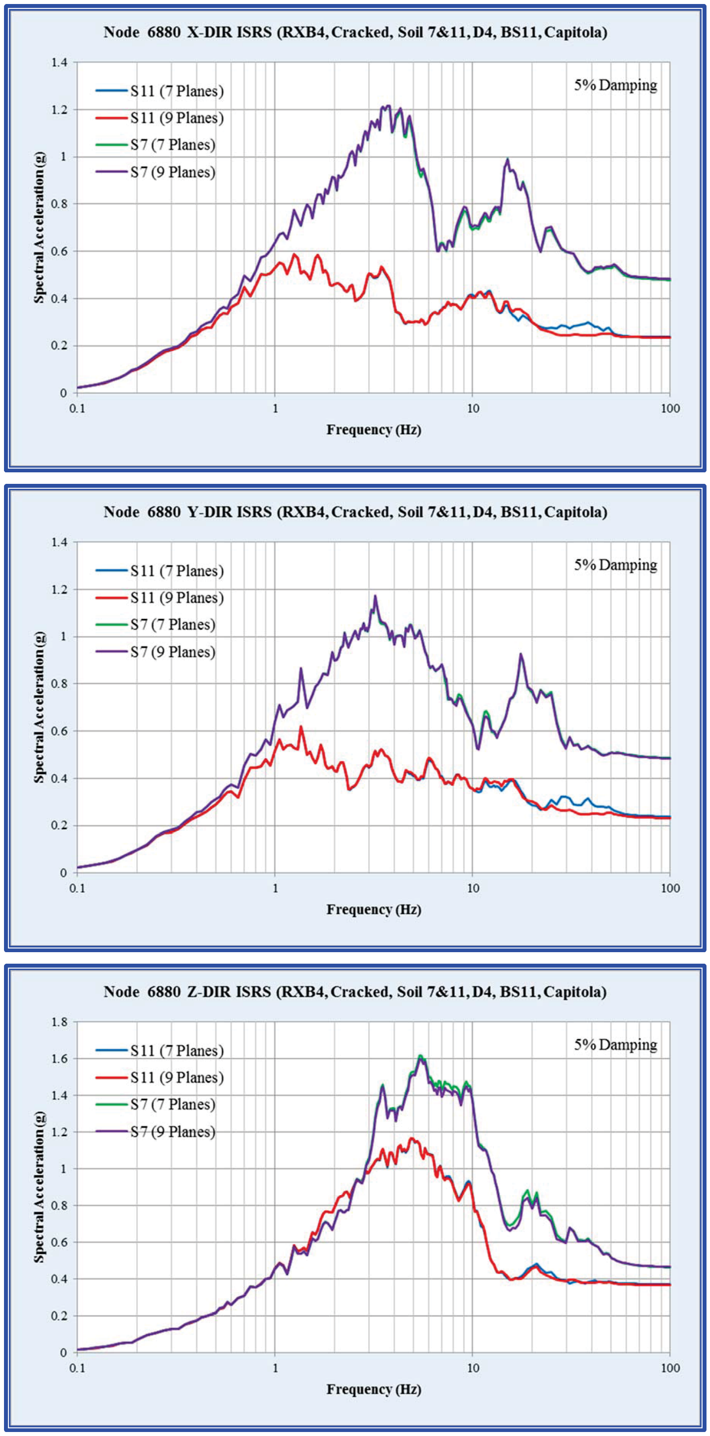
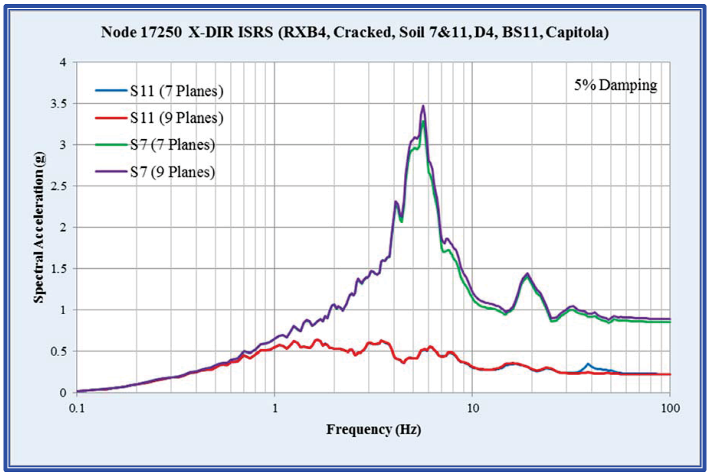
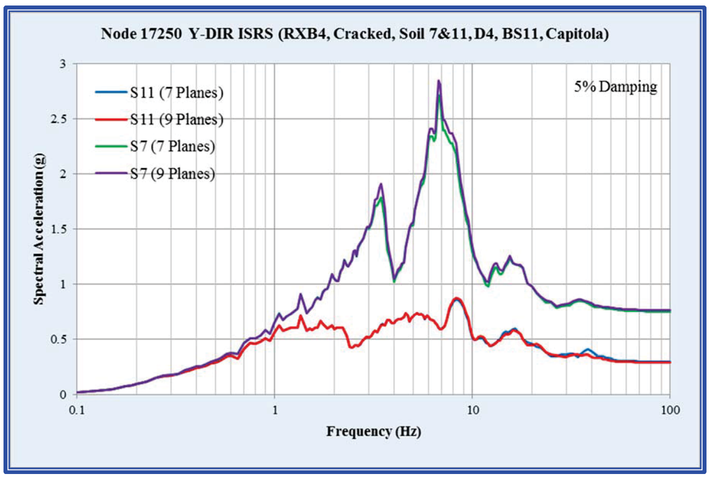


Figure 3.7.2-9: 7P Versus 9P Comparison at NPM 1 East Wing Wall at Lug Support





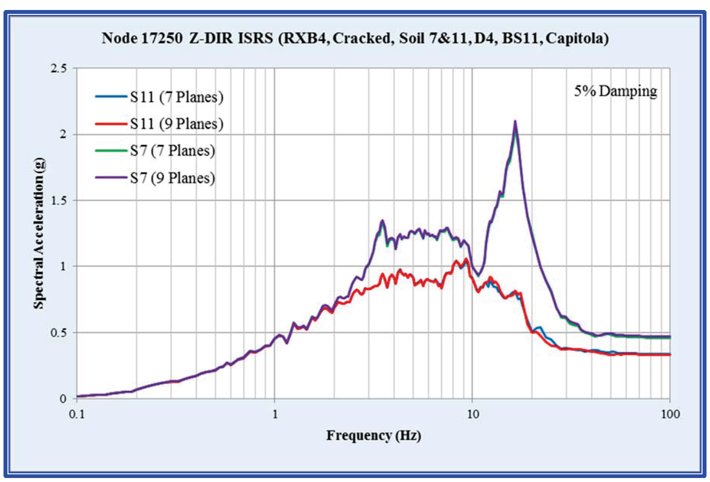


Figure 3.7.2-10: 7P Versus 9P Comparison at Center of Roof Slab

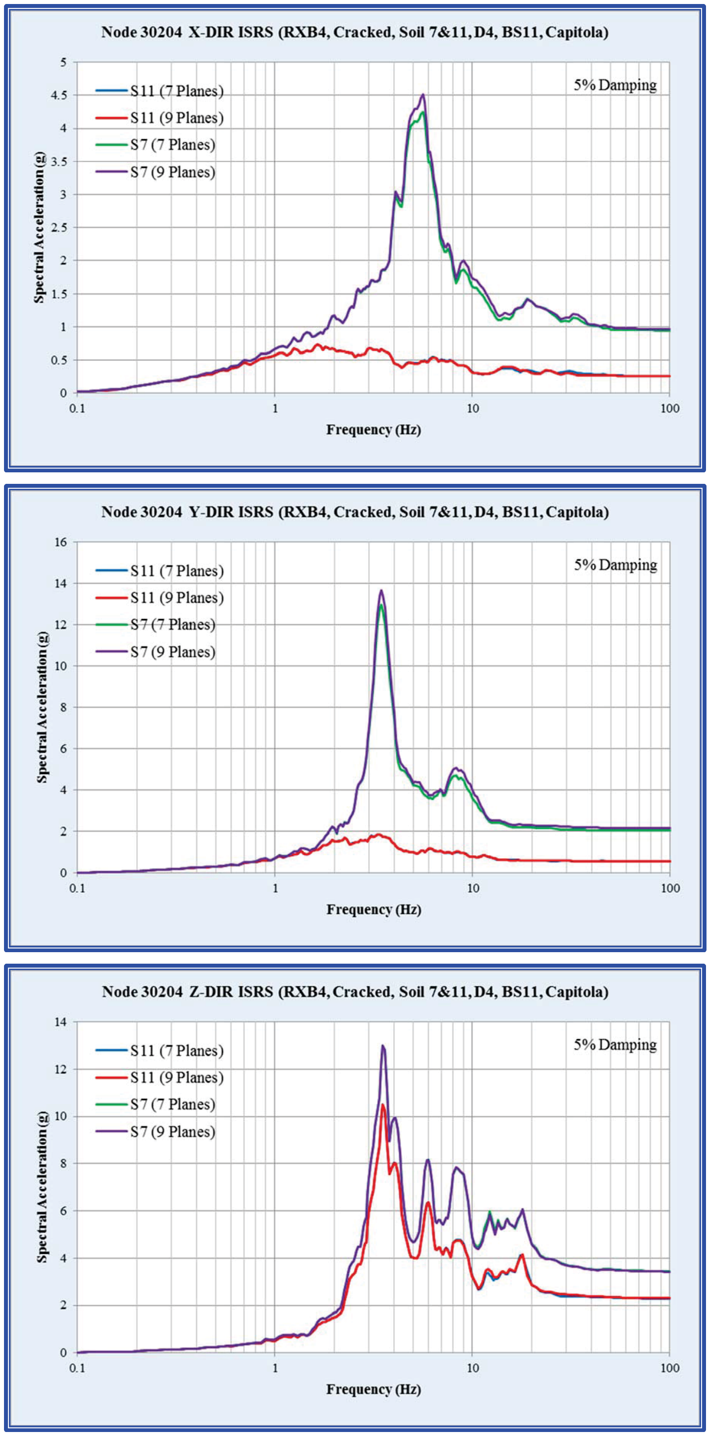


Figure 3.7.2-11: Reactor Building in Ground (Looking Northeast)

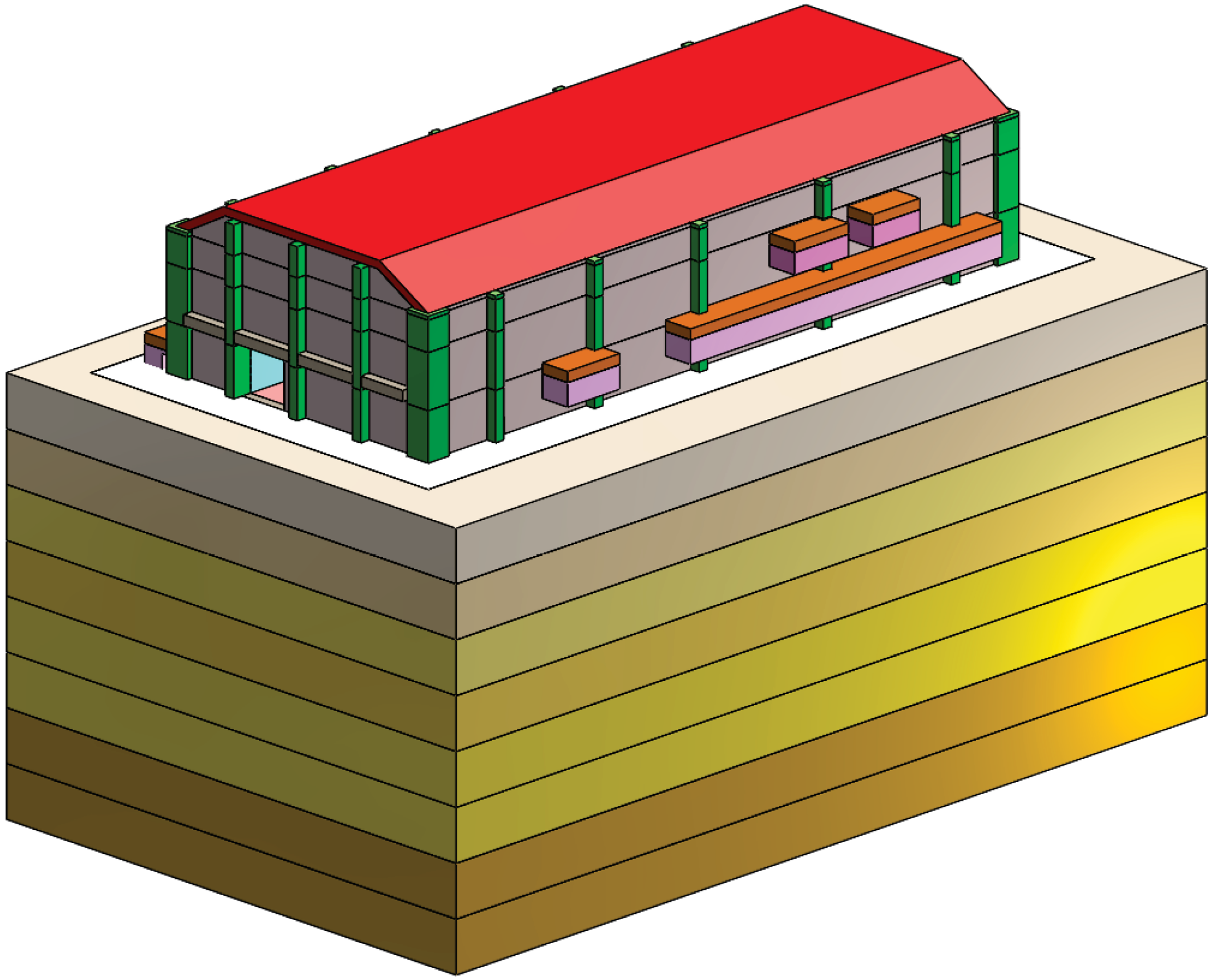


Figure 3.7.2-12: Quarter View of Reactor Building in Ground

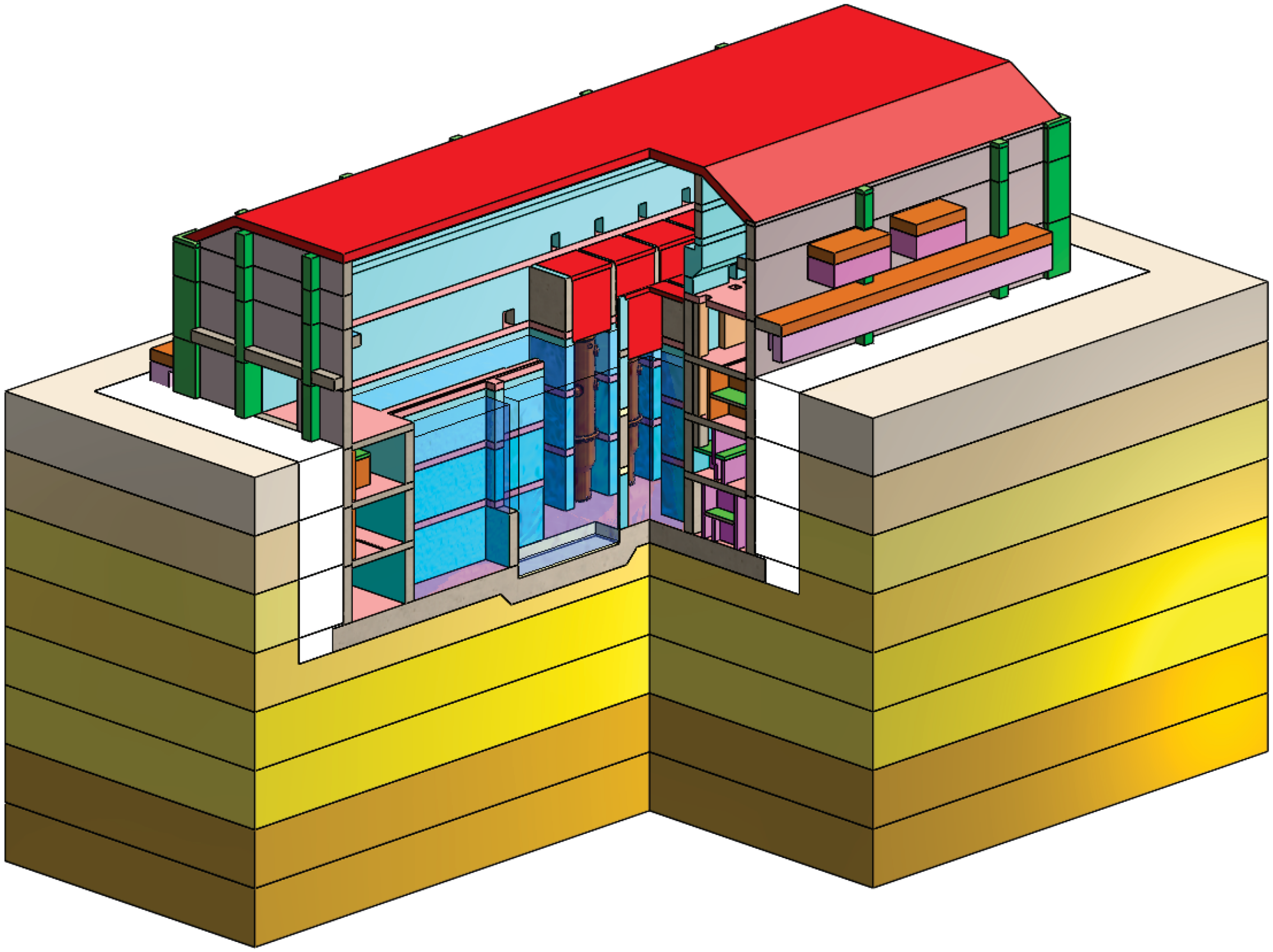


Figure 3.7.2-13: Longitudinal View of Half of Reactor Building in Ground