Figure 3.7.2-94: Reactor Building Locations Selected for Relative Displacement

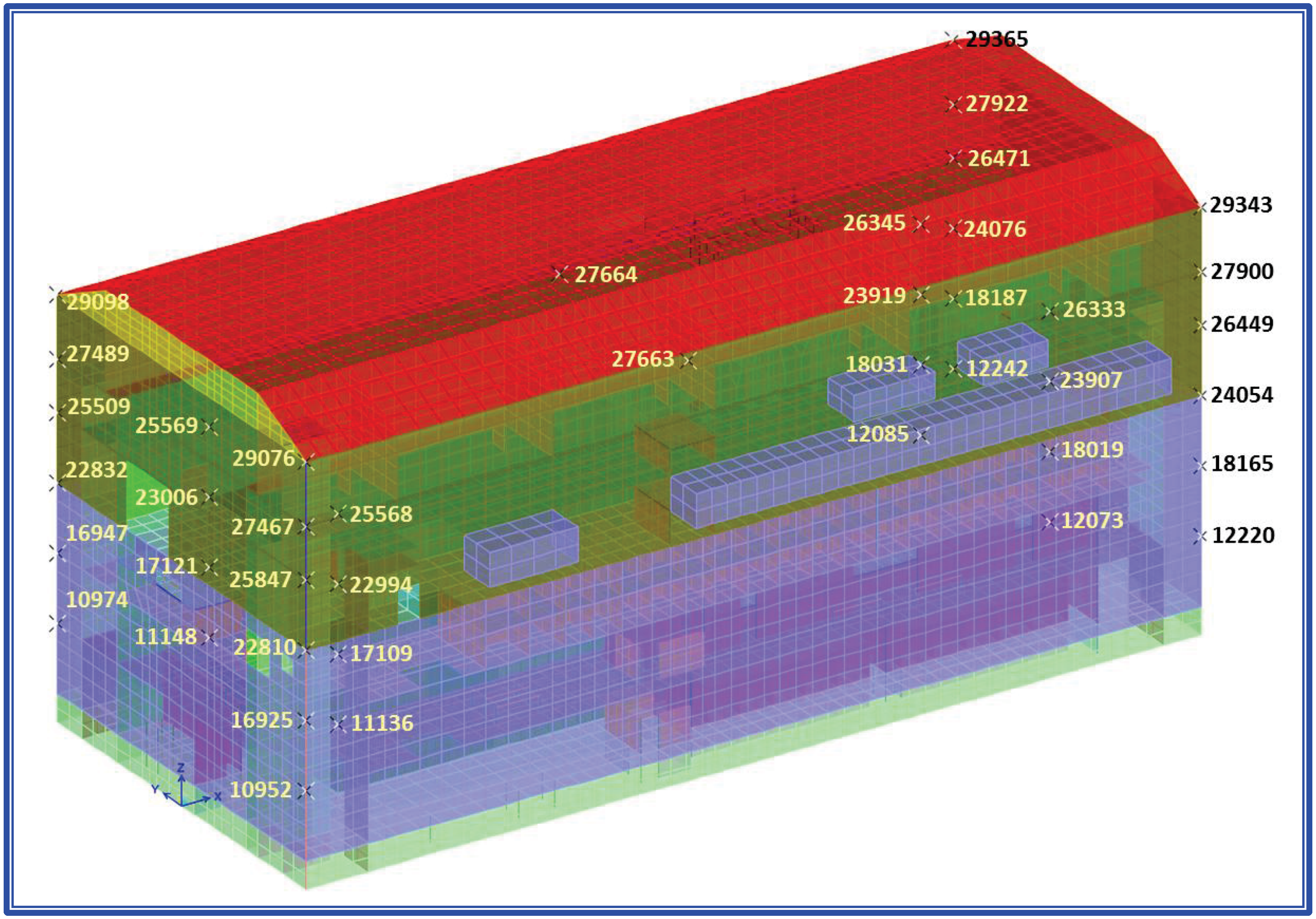


Figure 3.7.2-95: Control Building Locations Selected for Relative Displacement

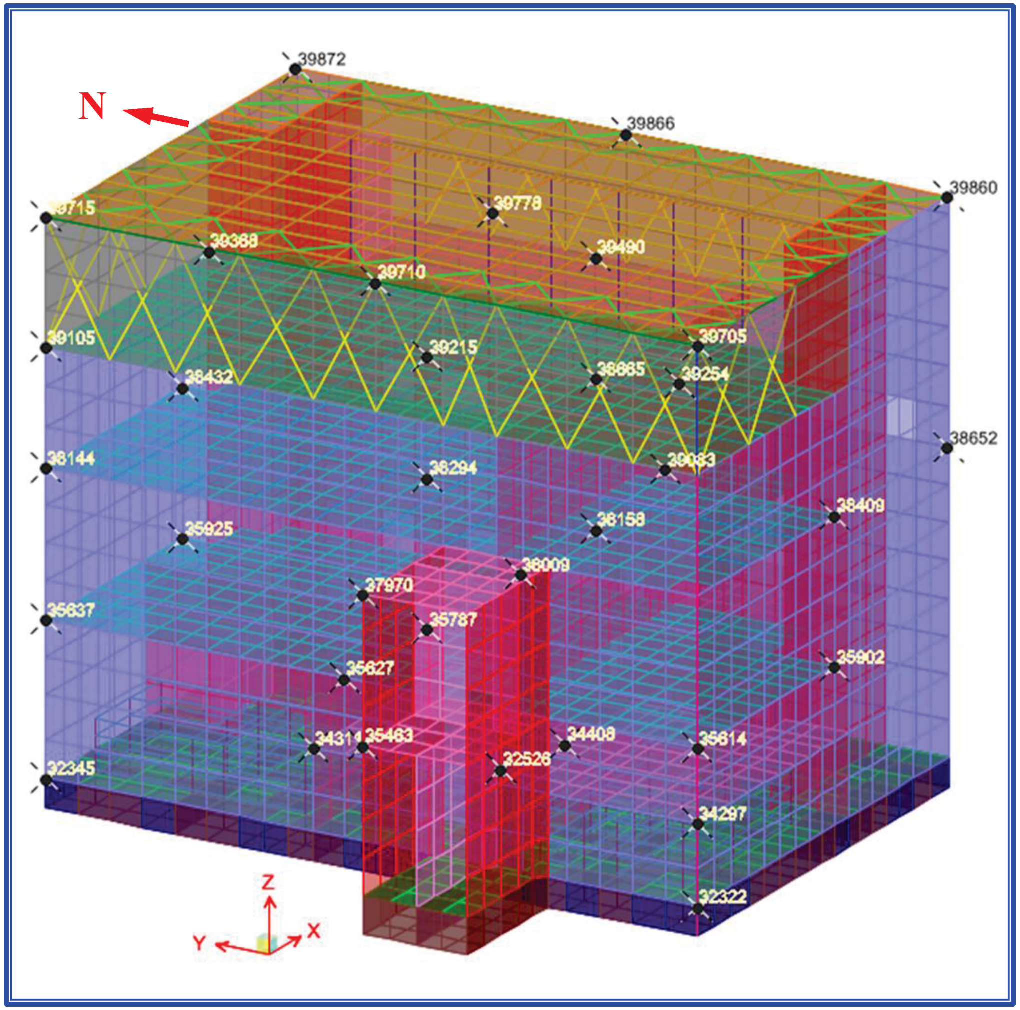


Figure 3.7.2-96: Not Used

Figure 3.7.2-97: Not Used

Figure 3.7.2-98: Location of NPMs for 7 Module Case Study

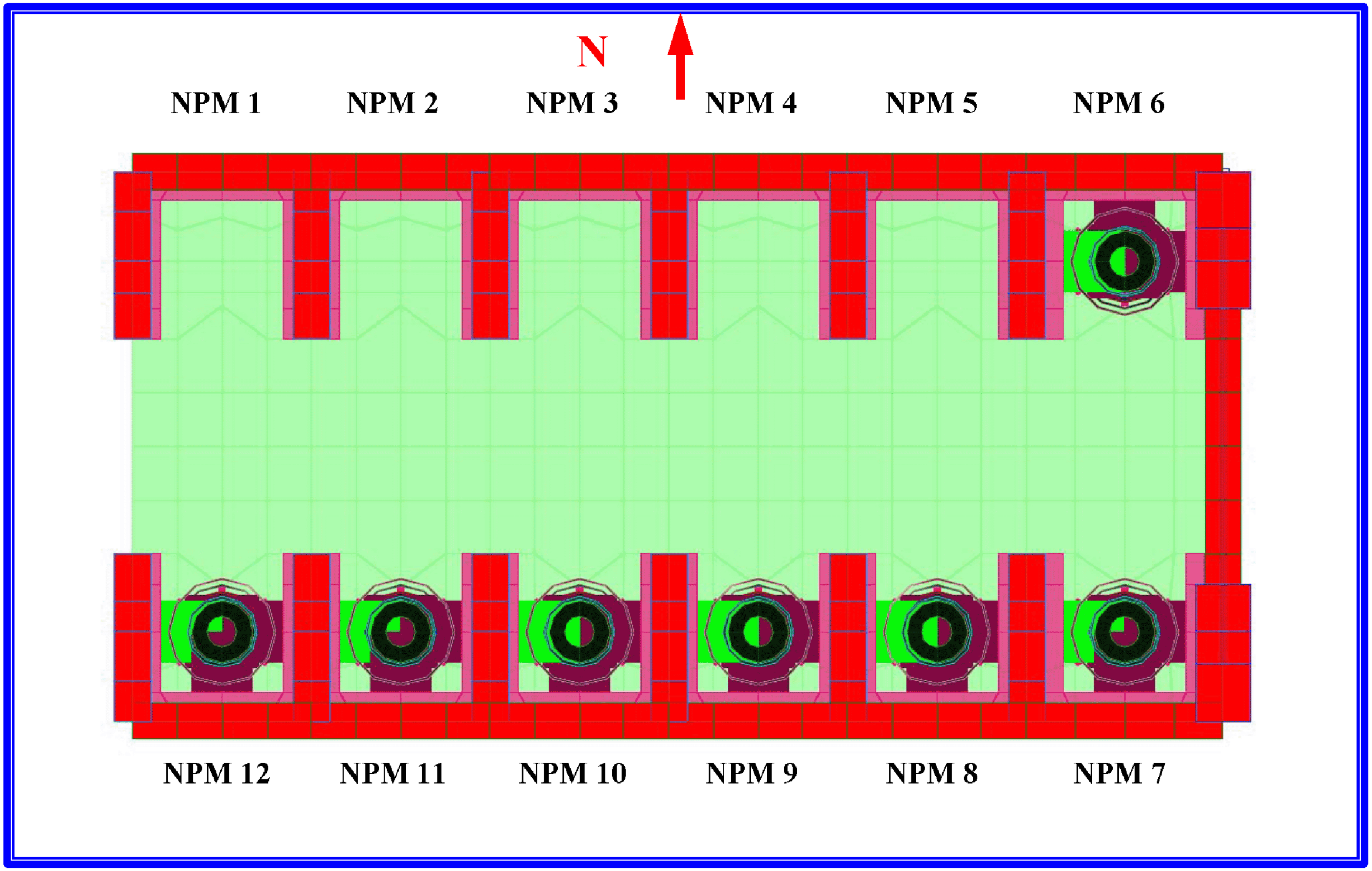


Figure 3.7.2-99: Example ISRS from CSDRS compatible Time Histories for Soil Type 7

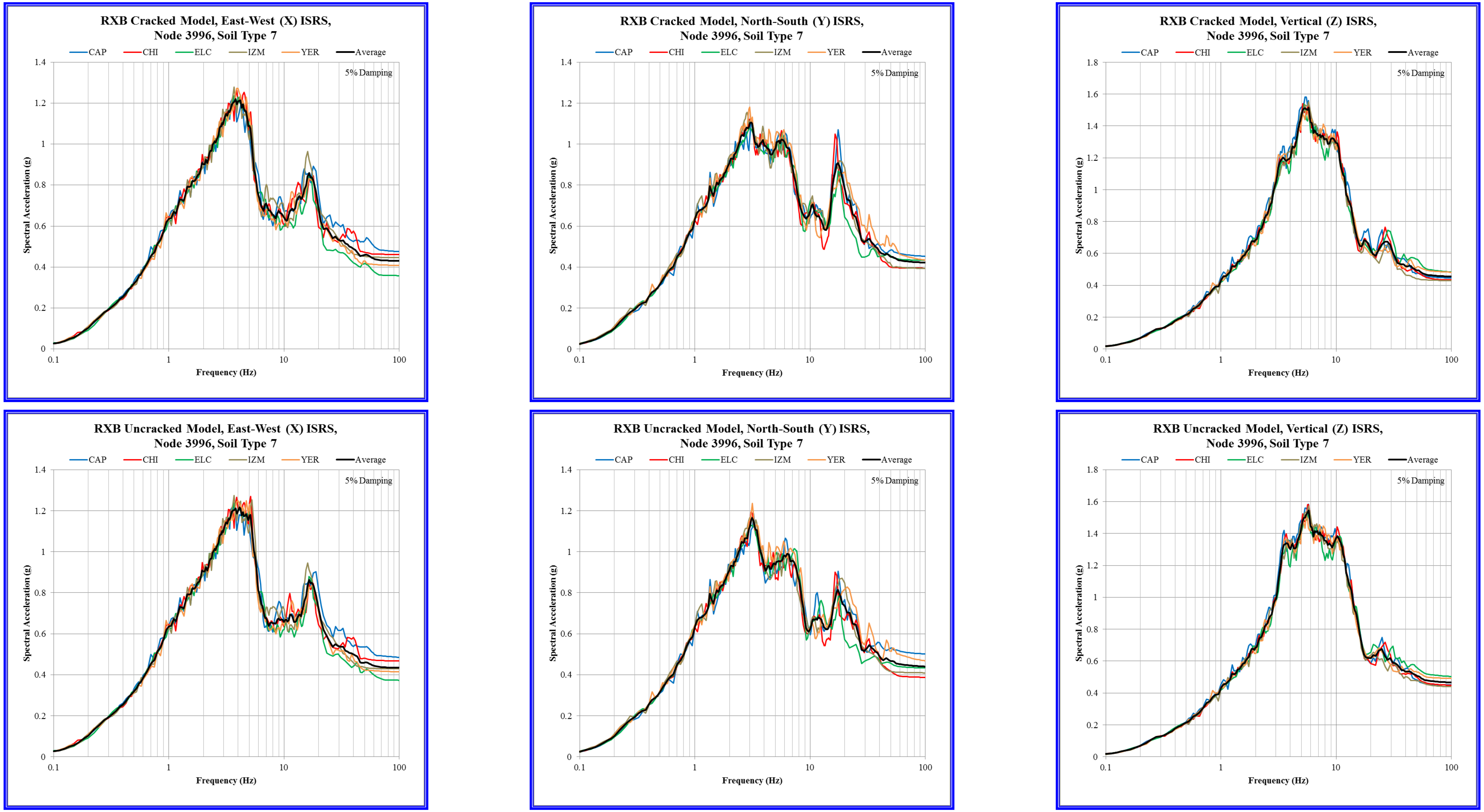


Figure 3.7.2-100: Example ISRS from CSDRS compatible Time Histories for Soil Type 8

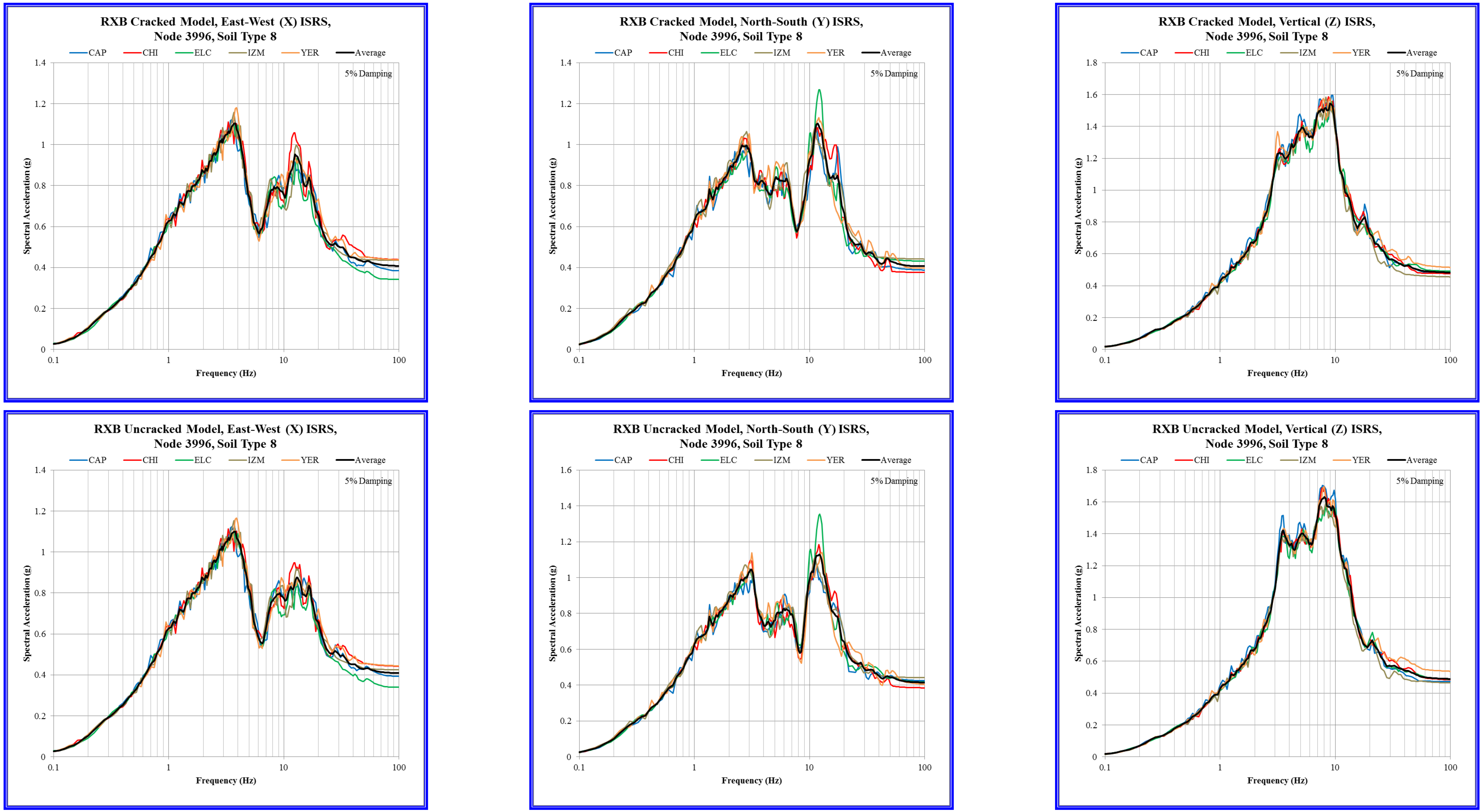


Figure 3.7.2-101: Example ISRS from CSDRS compatible Time Histories for Soil Type 11

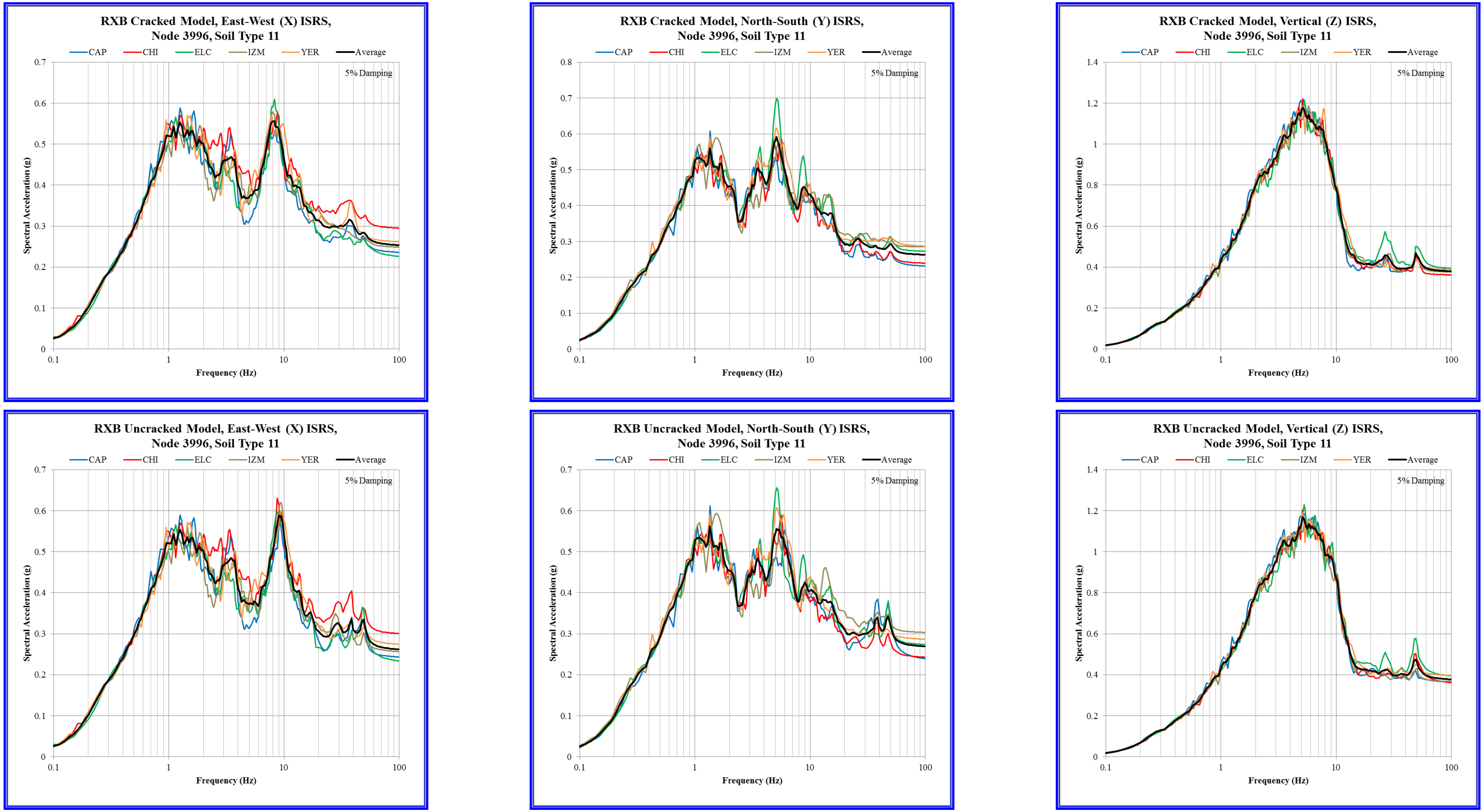


Figure 3.7.2-102: Example Combined and Enveloped ISRS

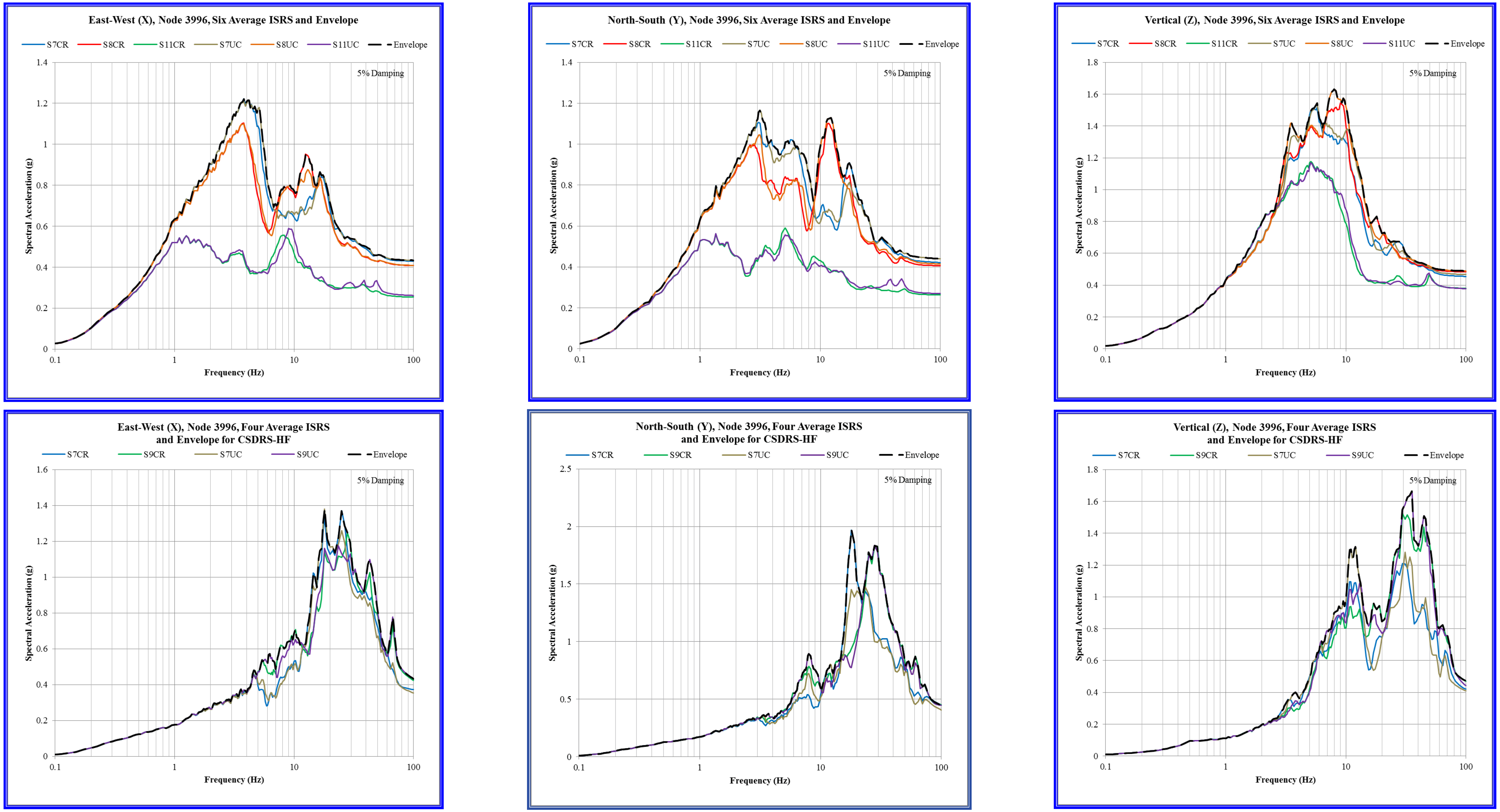


Figure 3.7.2-103: Exampled Broadened ISRS at Multiple Damping Ratios

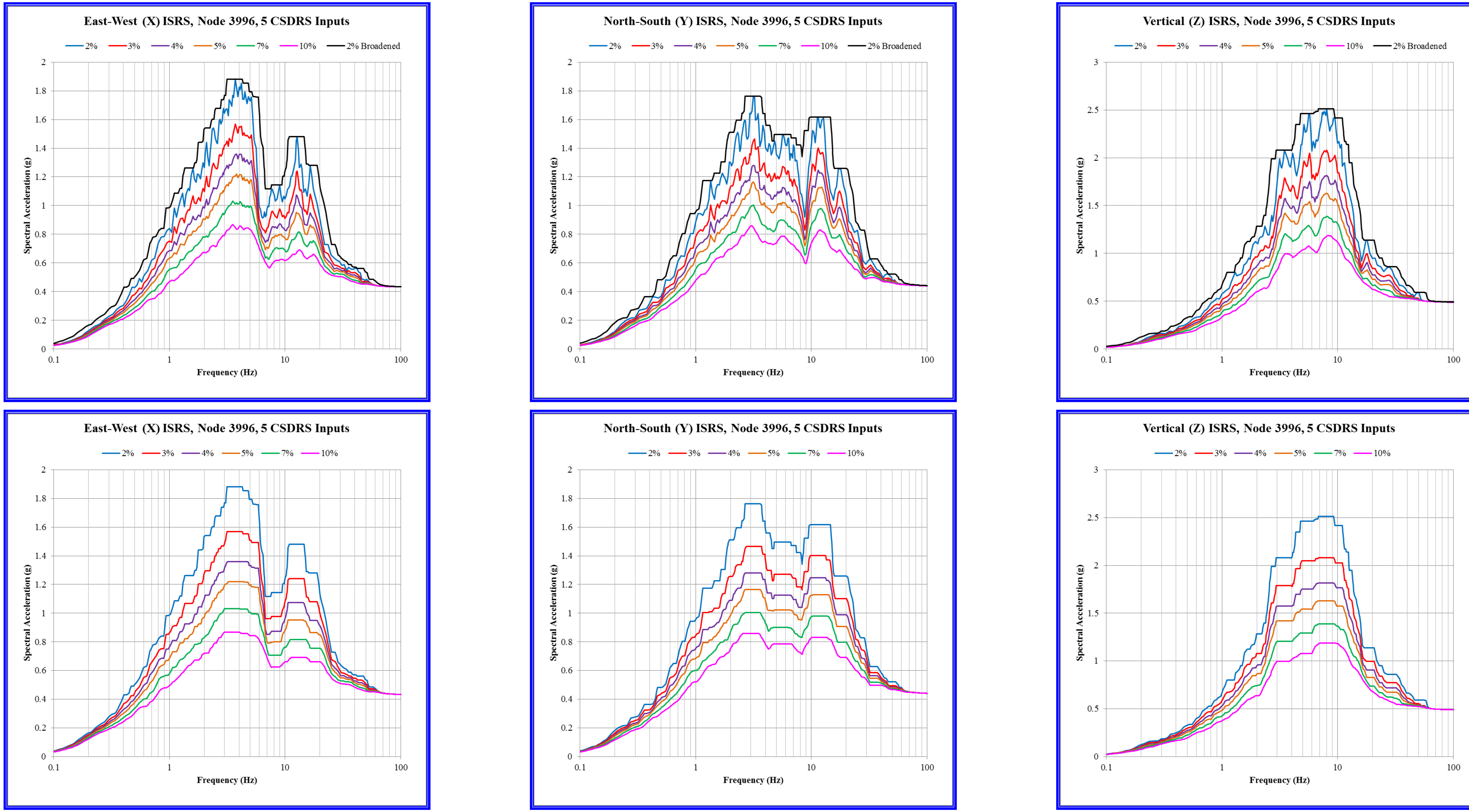


Figure 3.7.2-104: Comparison between Standalone Reactor Building Model and Triple Building Model, ISRS at Northwest Corner, Top of Basement

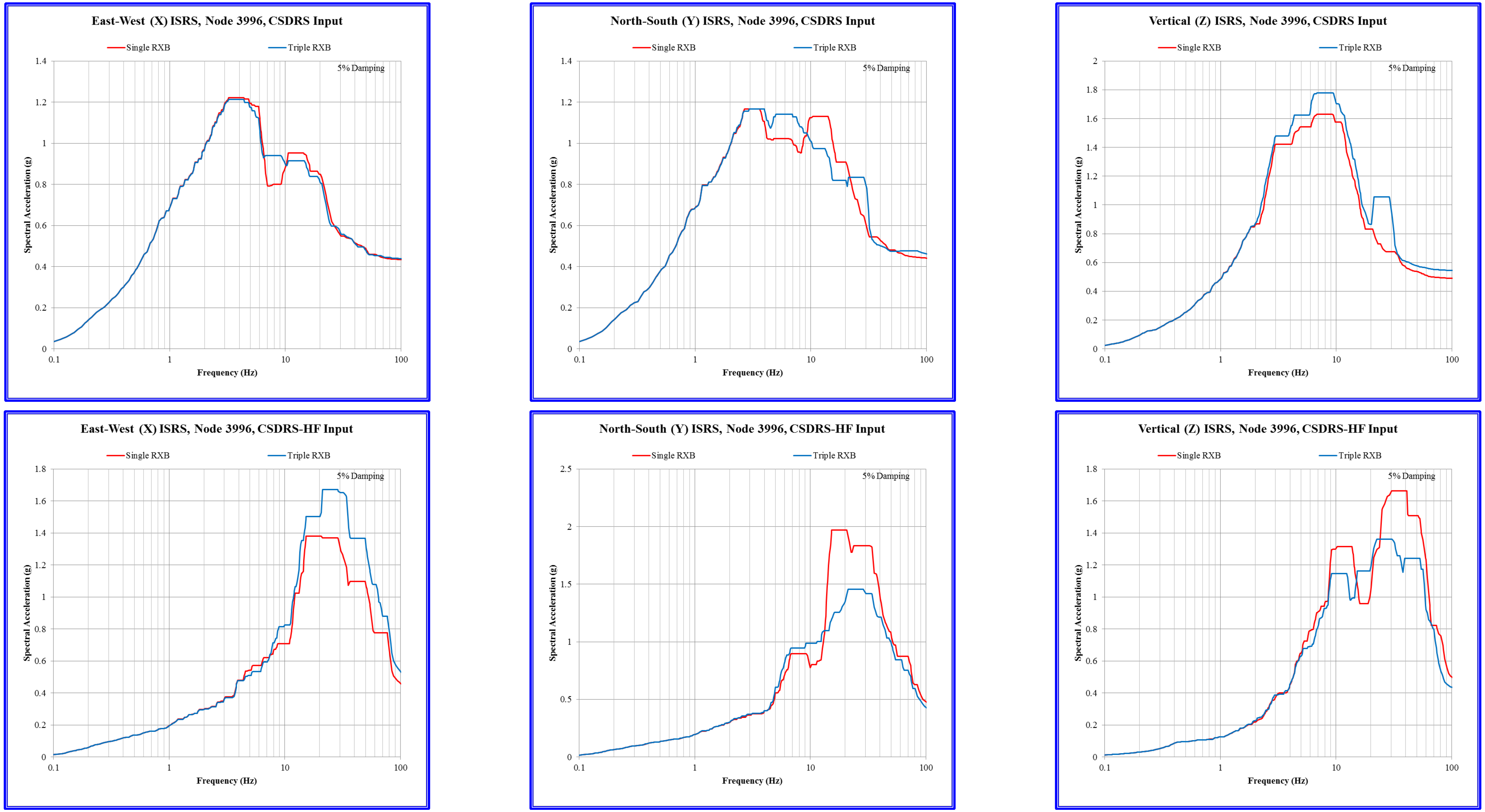


Figure 3.7.2-105: Comparison between Standalone Reactor Building Model and Triple Building Model, ISRS at Northwest Corner, Top of Exterior Wall

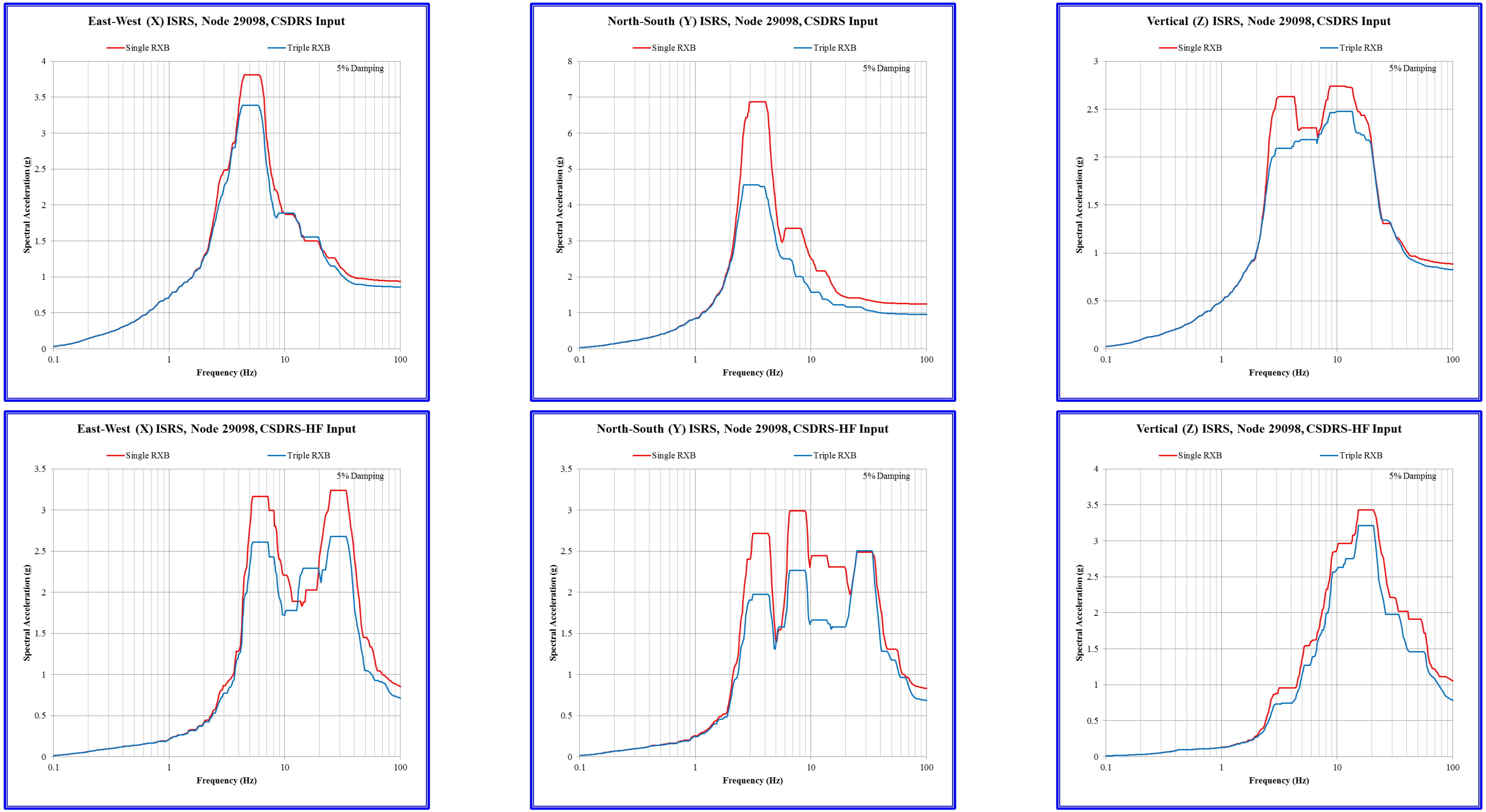


Figure 3.7.2-106: Comparison between Standalone Reactor Building Model and Triple Building Model, ISRS at Corner or Roof Slab

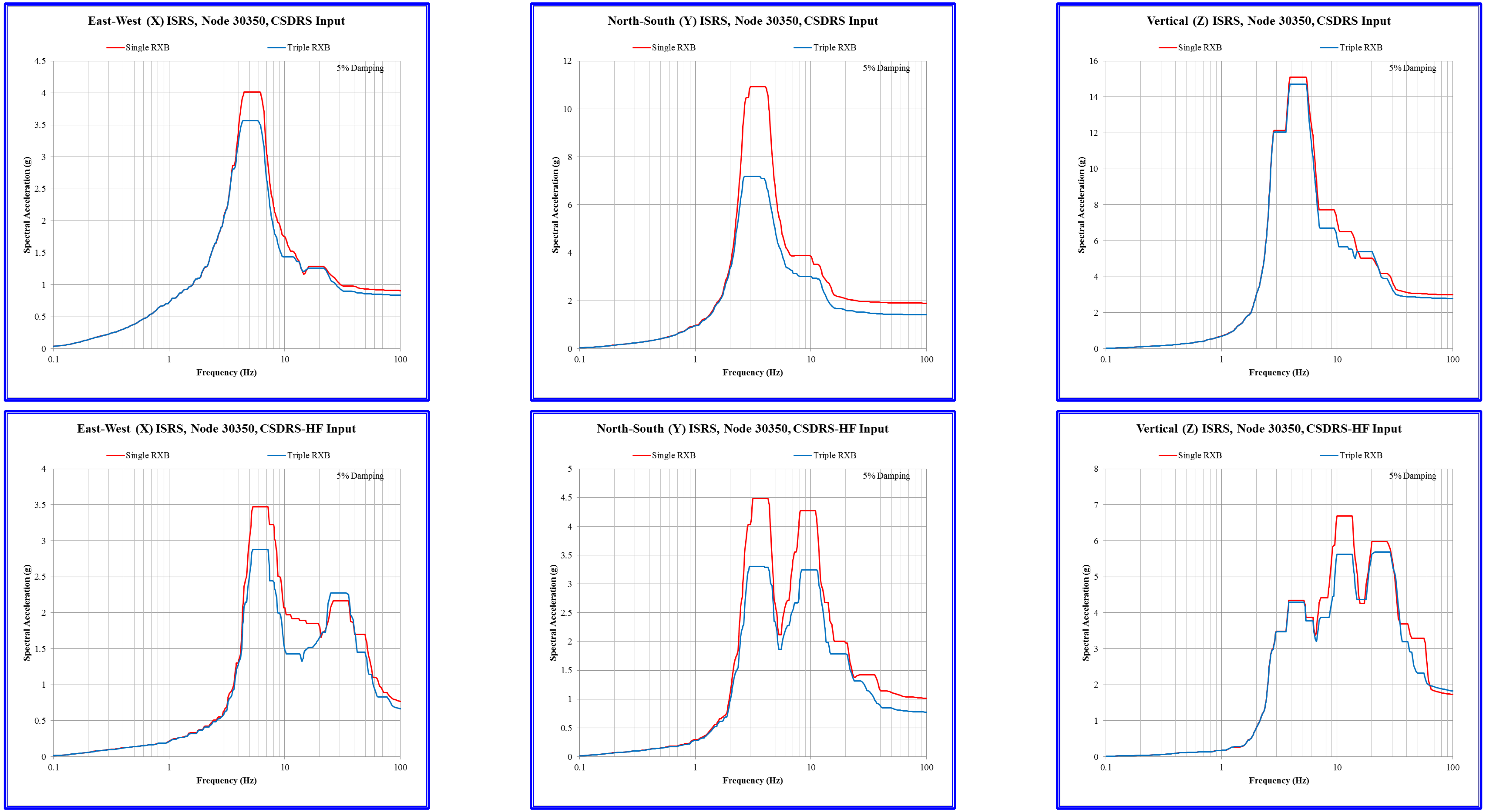


Figure 3.7.2-107: Reactor Building ISRS for Floor at El. 24′ 0″

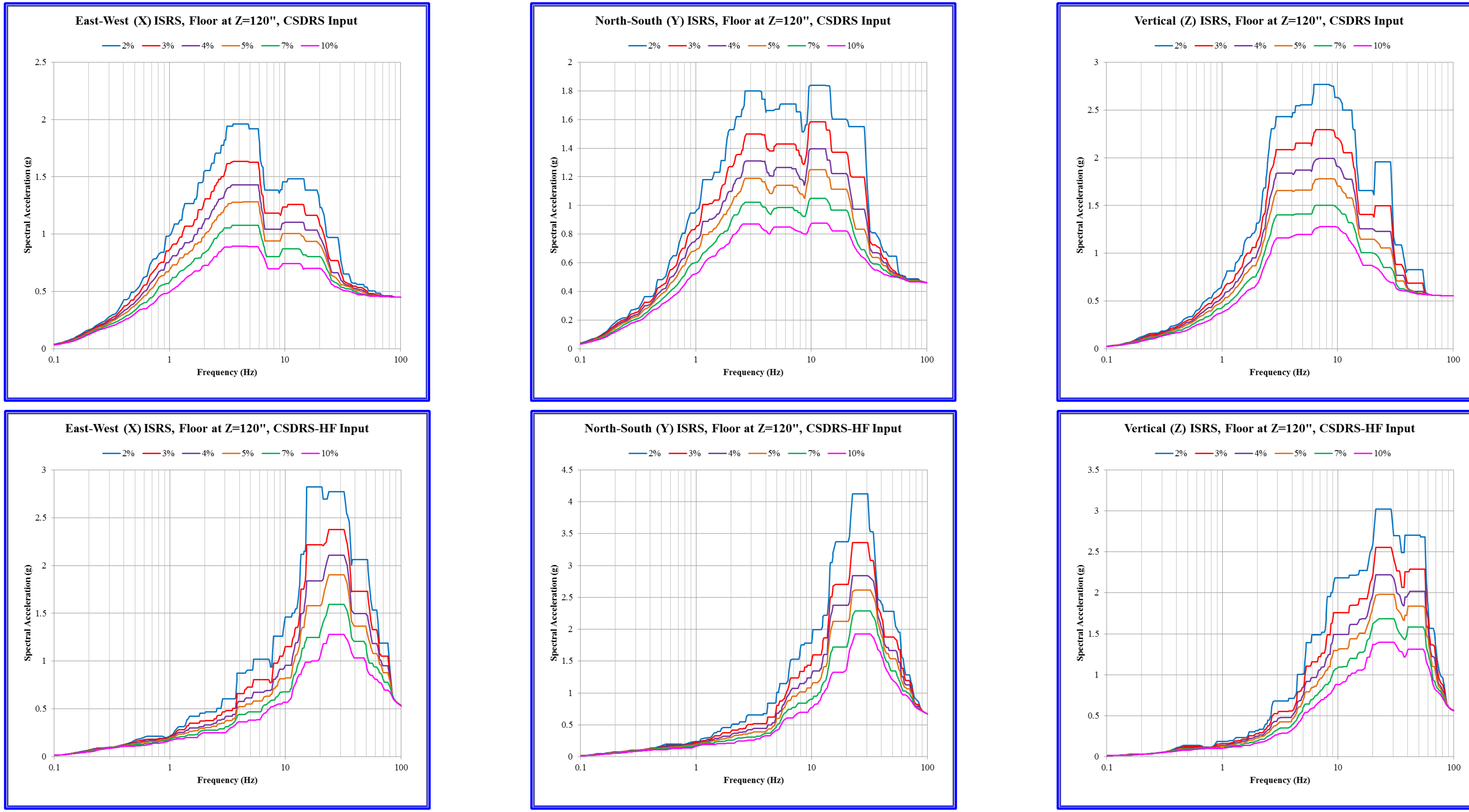


Figure 3.7.2-108: Reactor Building ISRS for Floor at El. 25′ 0″

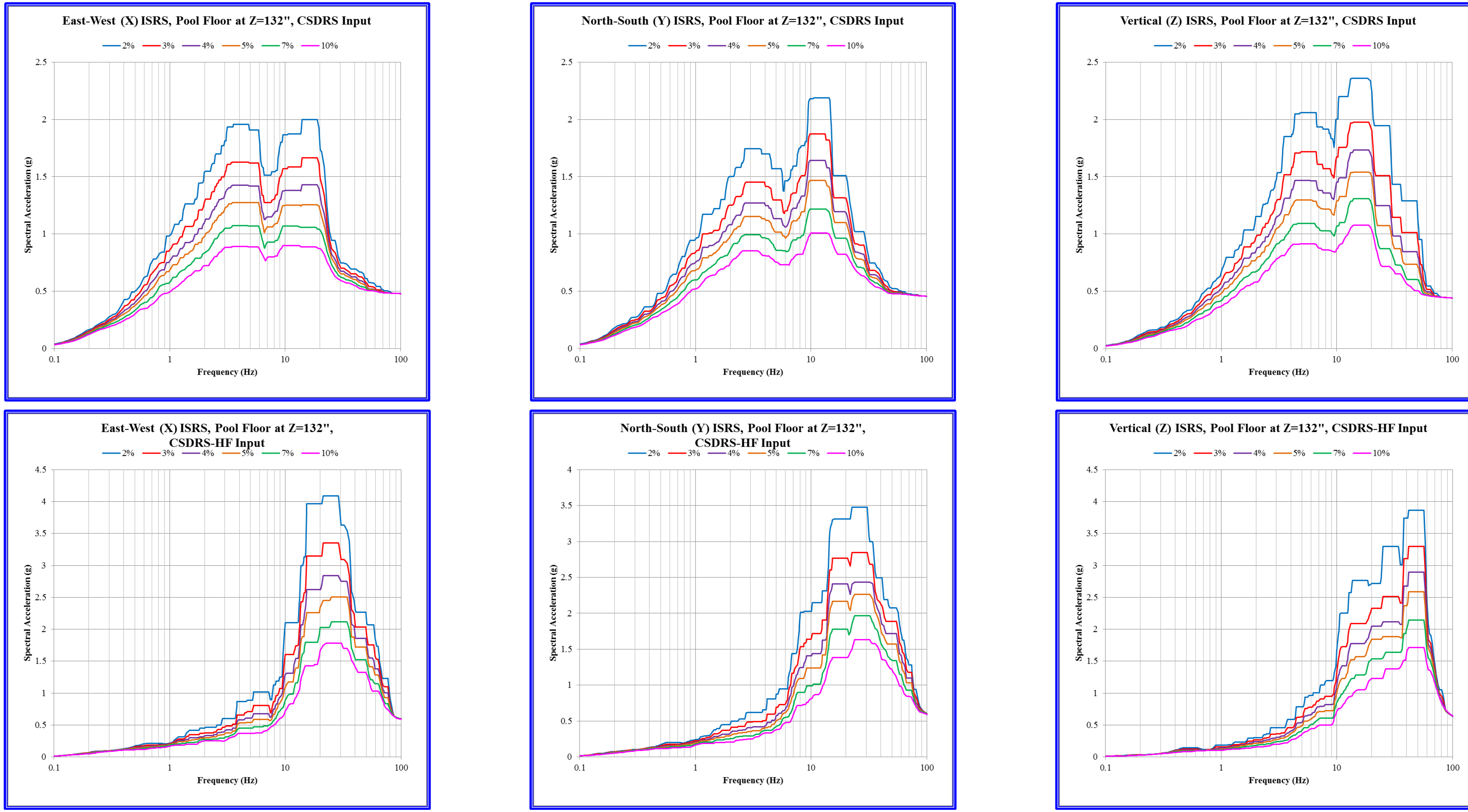


Figure 3.7.2-109: Reactor Building ISRS for Floor at El. 50′ 0″

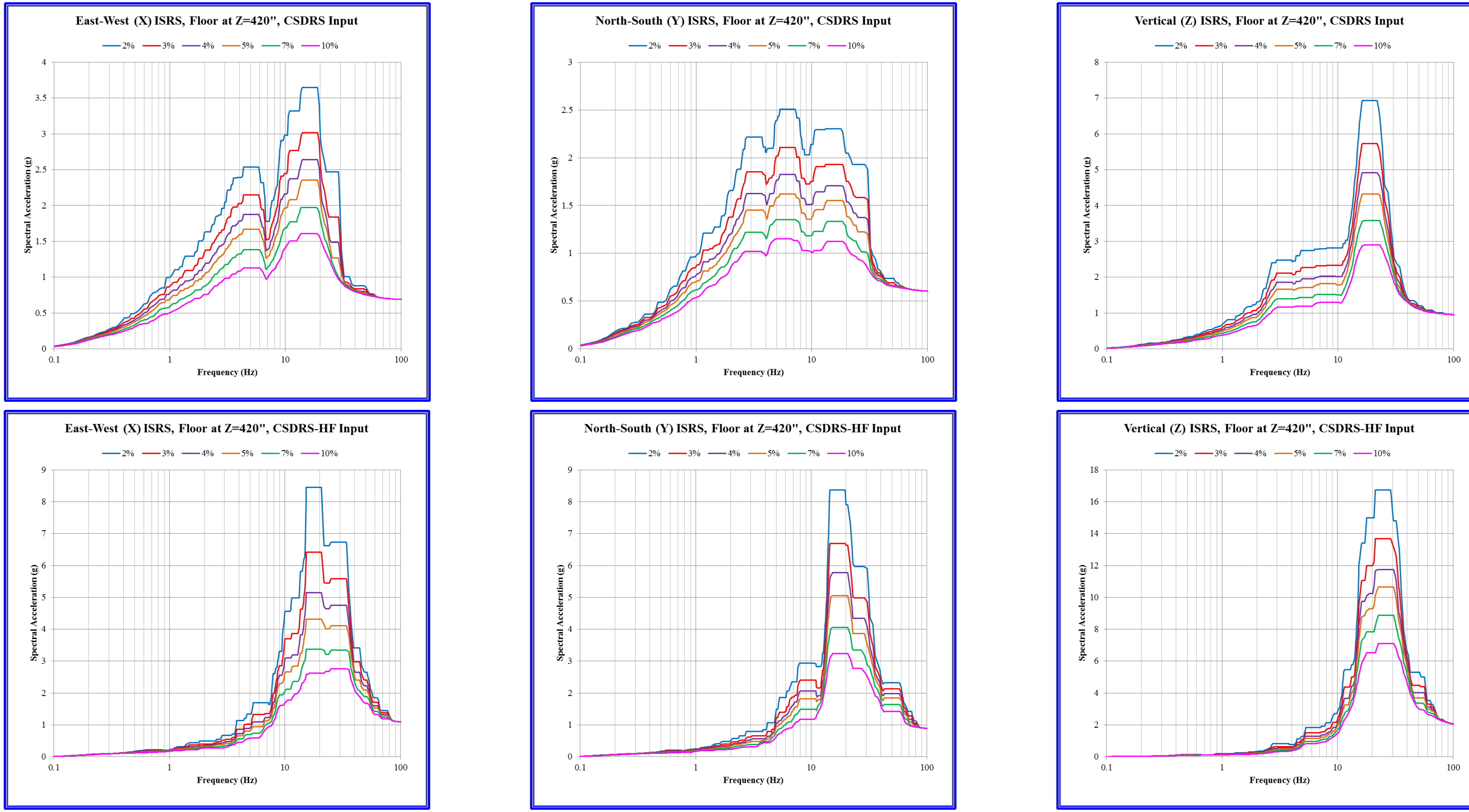


Figure 3.7.2-110: Reactor Building ISRS for Floor at El. 75′ 0″

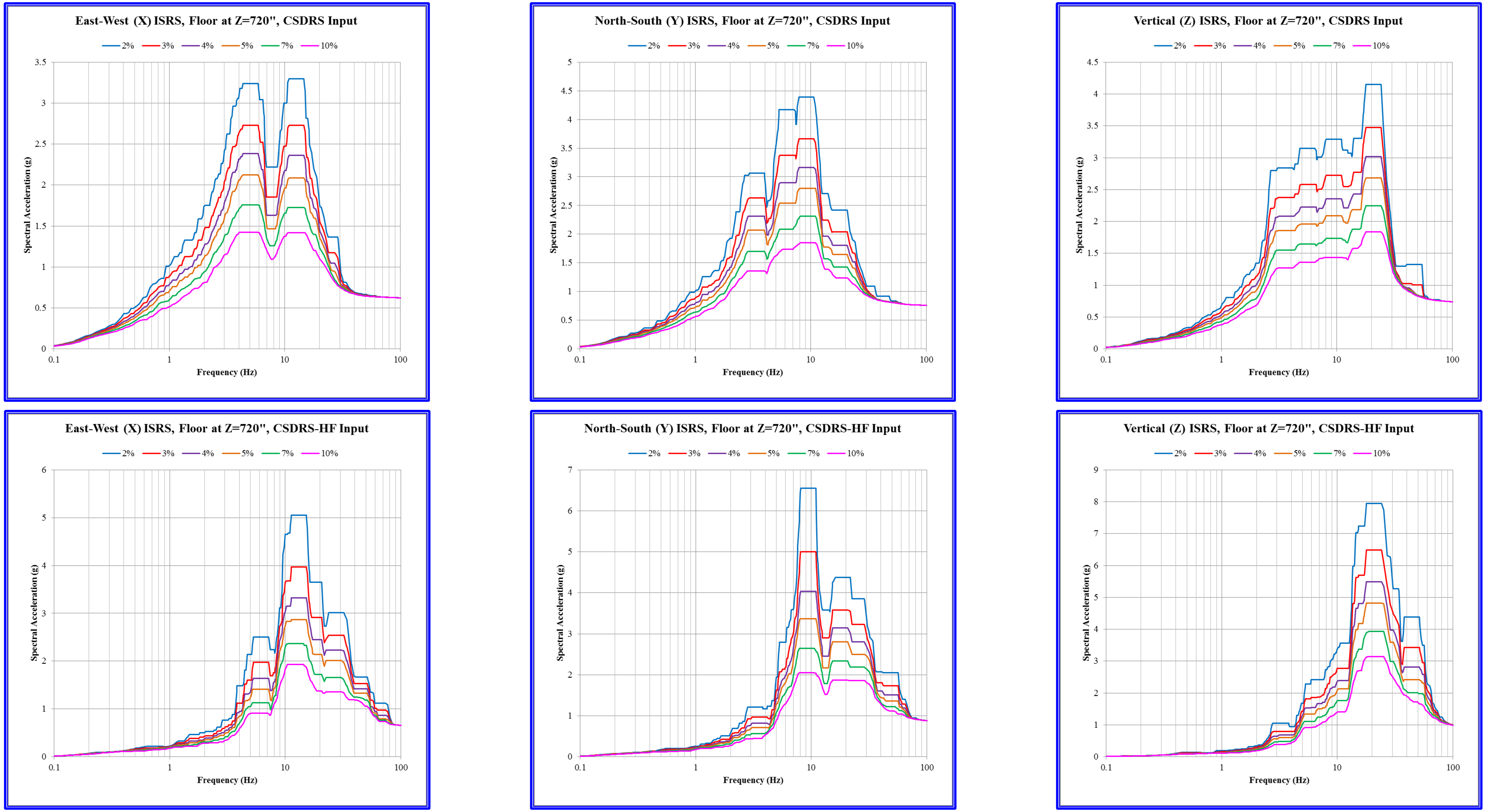


Figure 3.7.2-111: Reactor Building ISRS for Floor at El. 100′ 0″

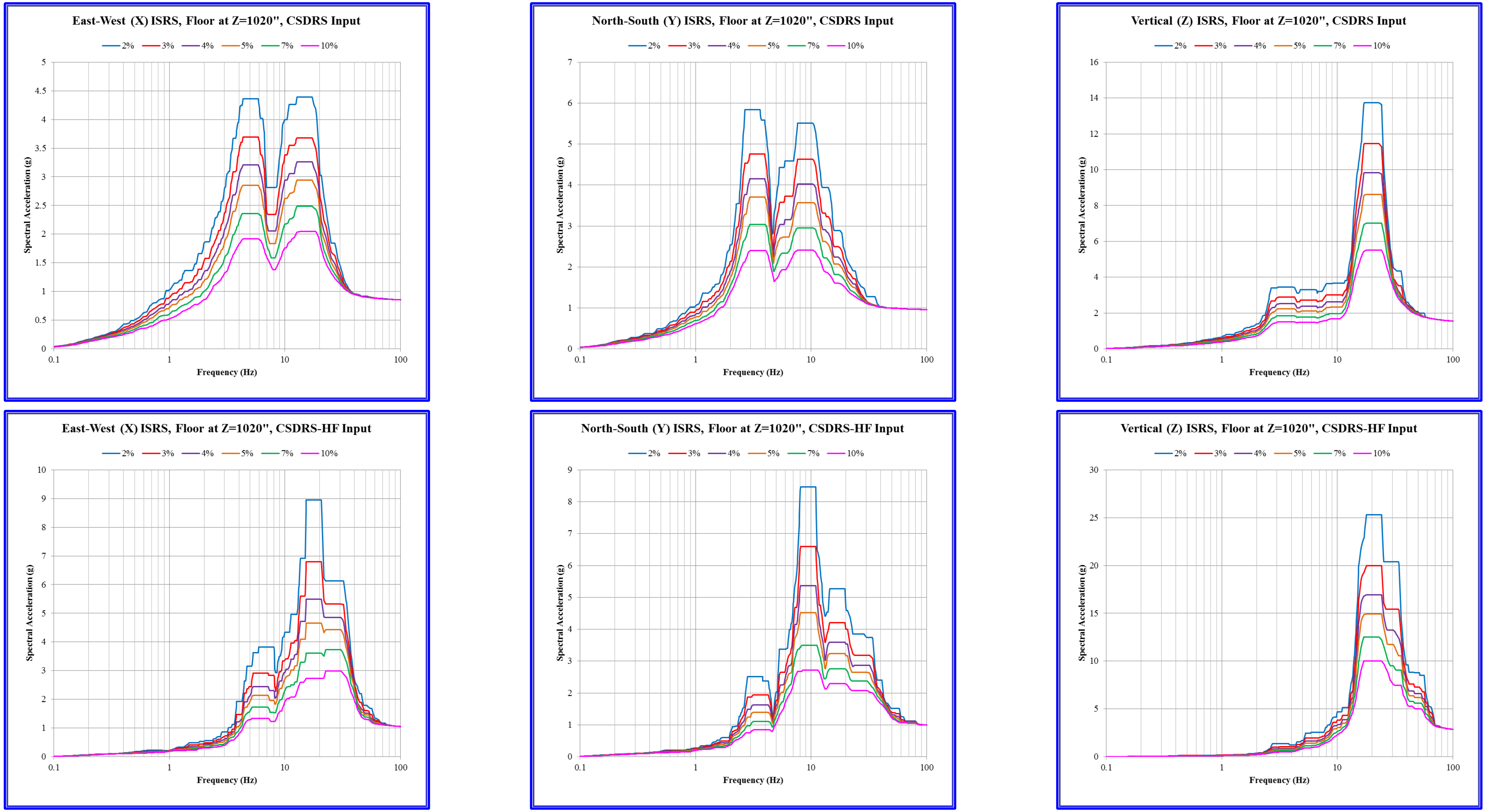


Figure 3.7.2-112: Reactor Building ISRS for Floor at El. 126′ 0″

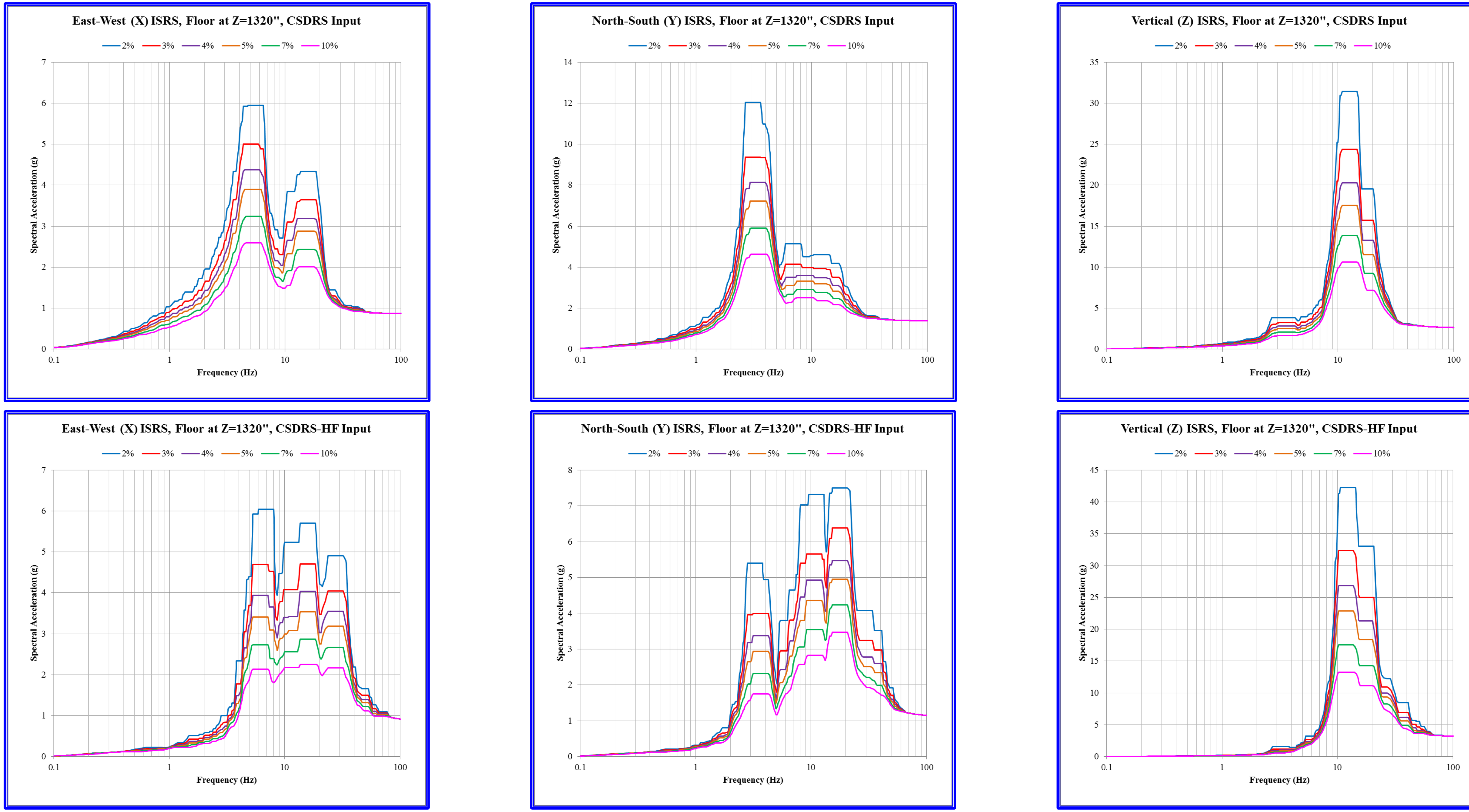


Figure 3.7.2-113: Reactor Building ISRS for Roof at El. 181′ 0″

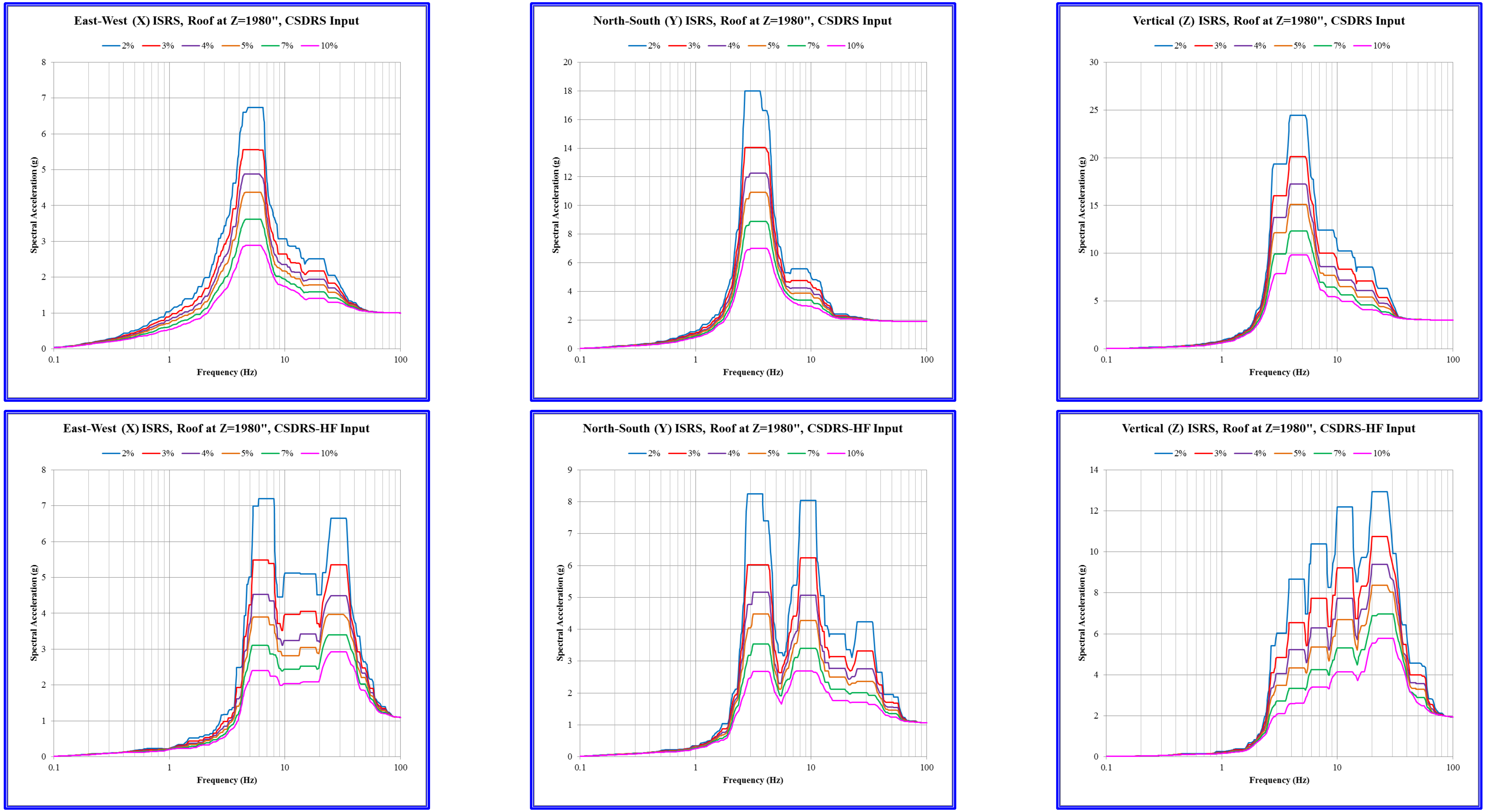


Figure 3.7.2-114: In-Structure Response Spectra at Reactor Building Crane Wheels at El. 145′ 6″

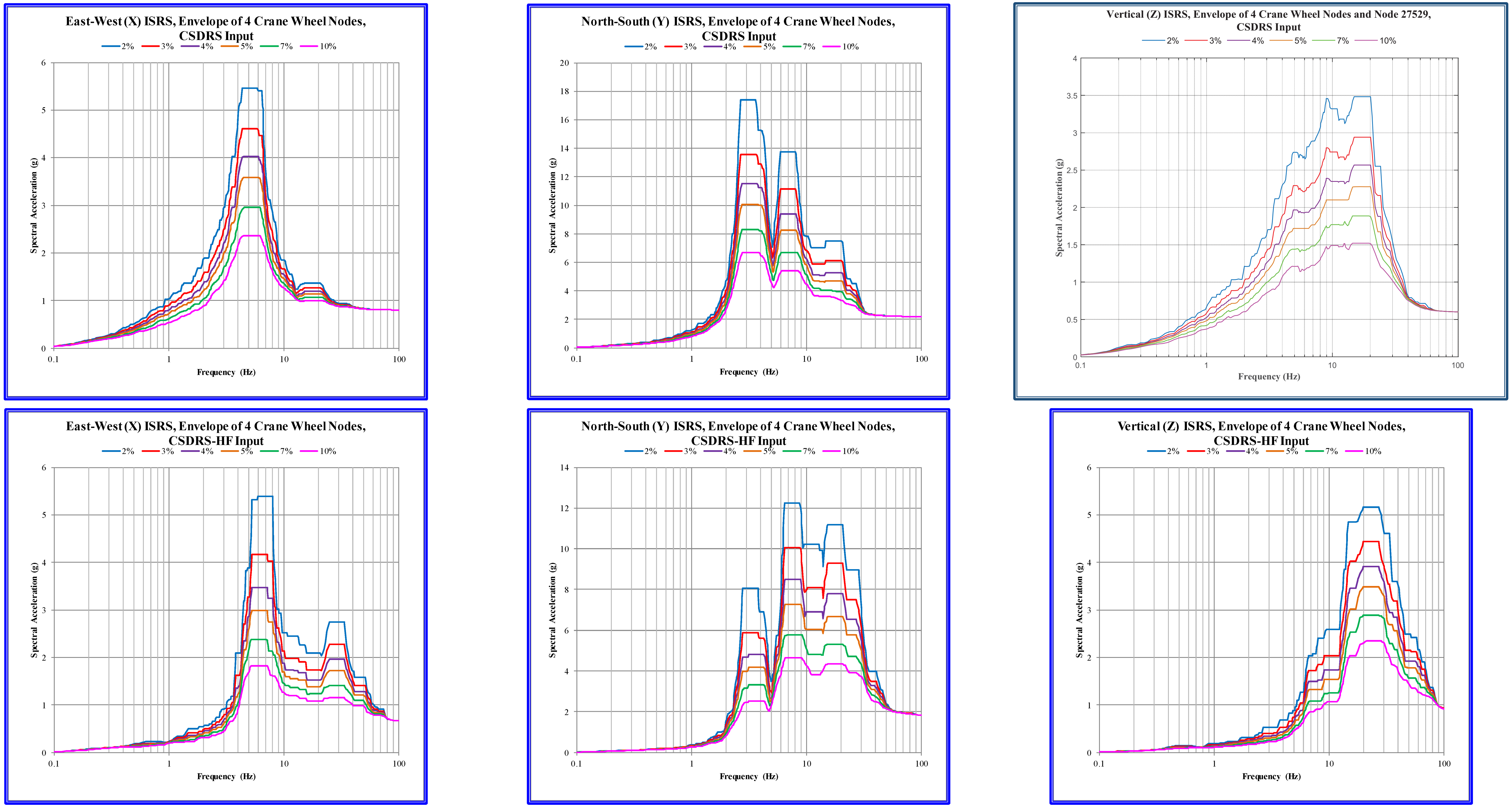
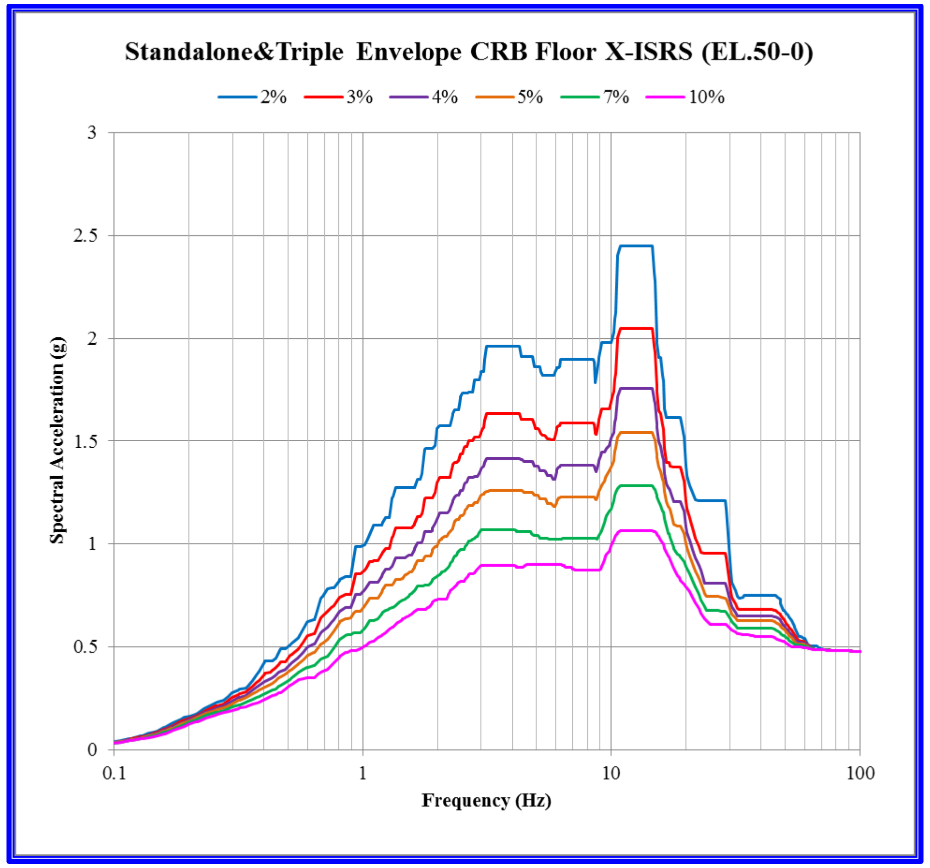


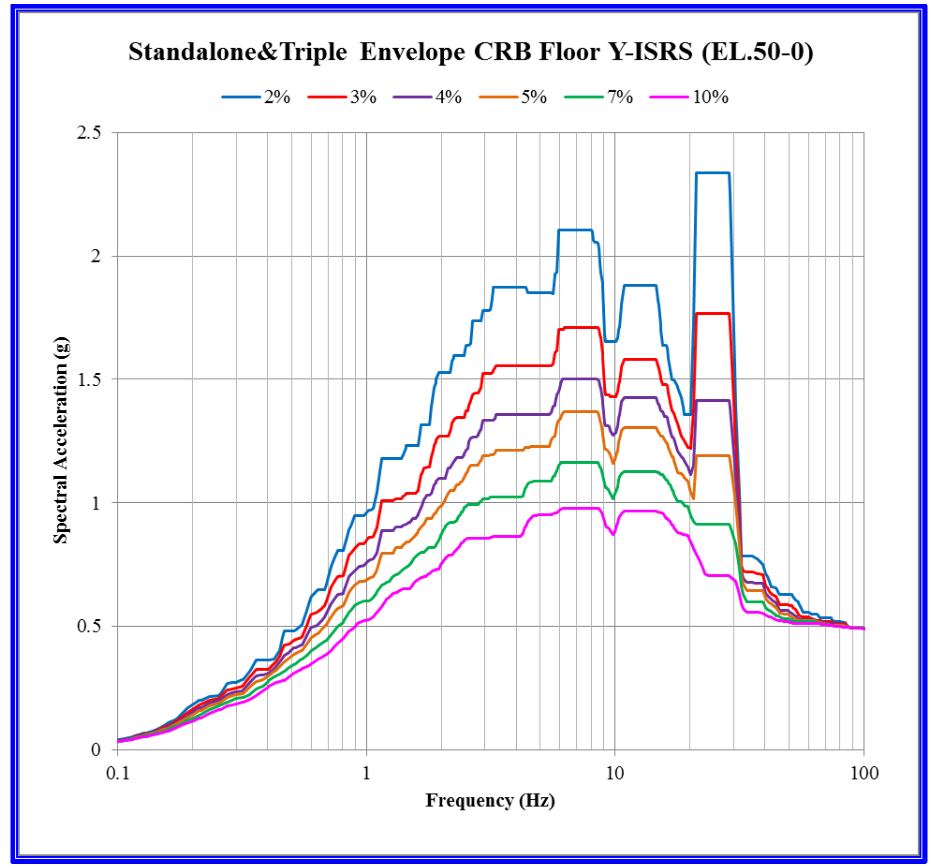
Figure 3.7.2-115: Not Used

Figure 3.7.2-116: Not Used

Figure 3.7.2-117: Not Used

Figure 3.7.2-117a: CRB - ISRS at El. 50'-0" (Z=405"), 5 CSDRS Inputs





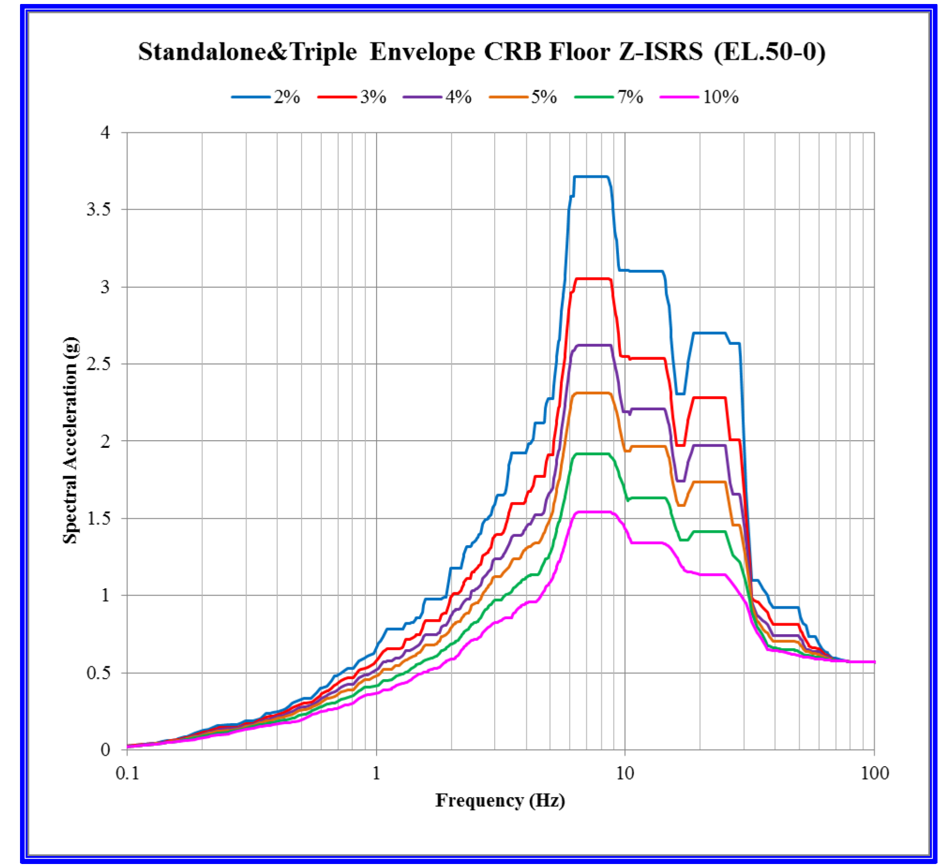
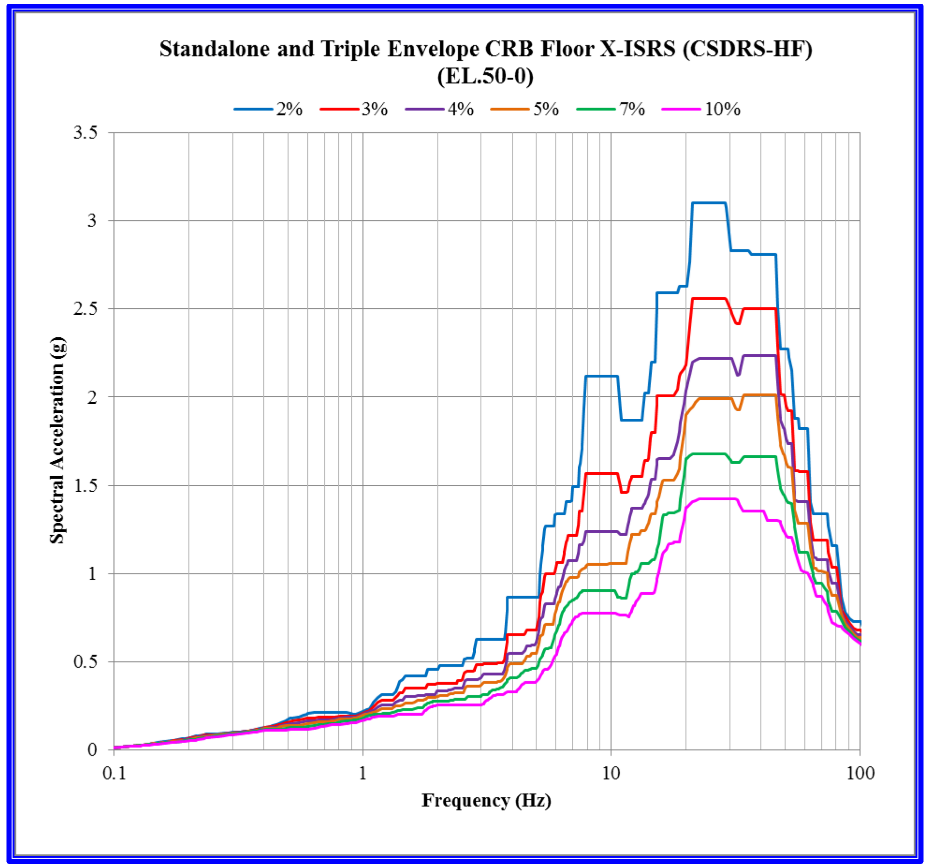
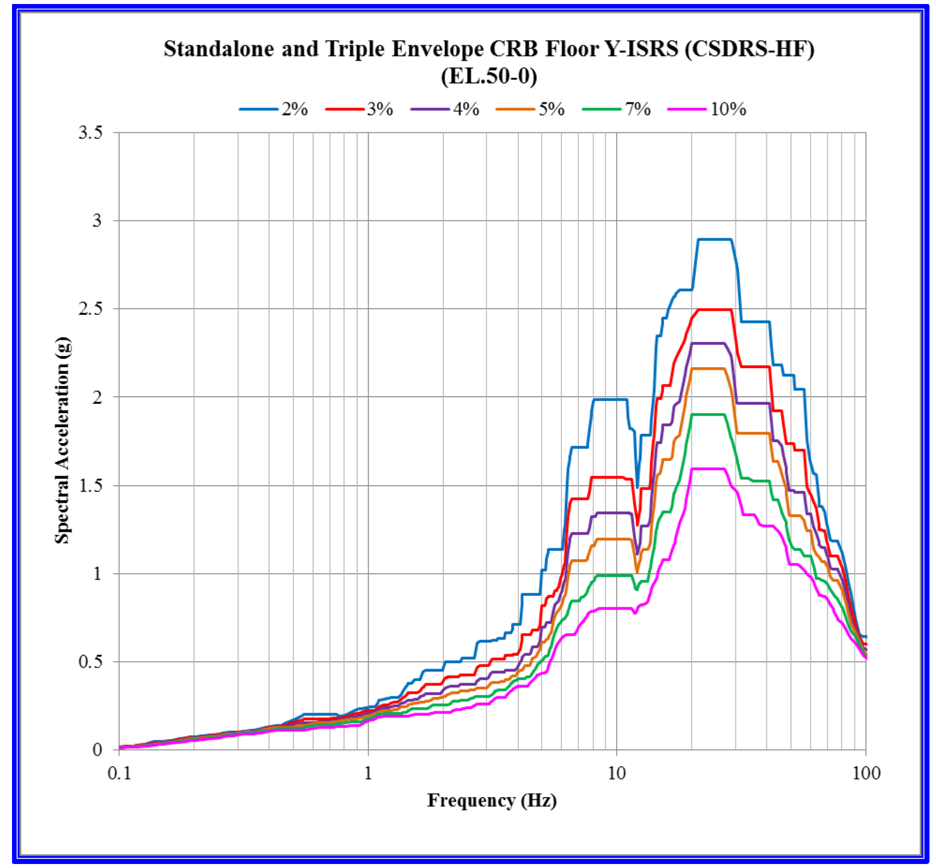


Figure 3.7.2-117b: CRB - ISRS at El. 50’-0” (Z=405”), CSDRS-HF Inputs





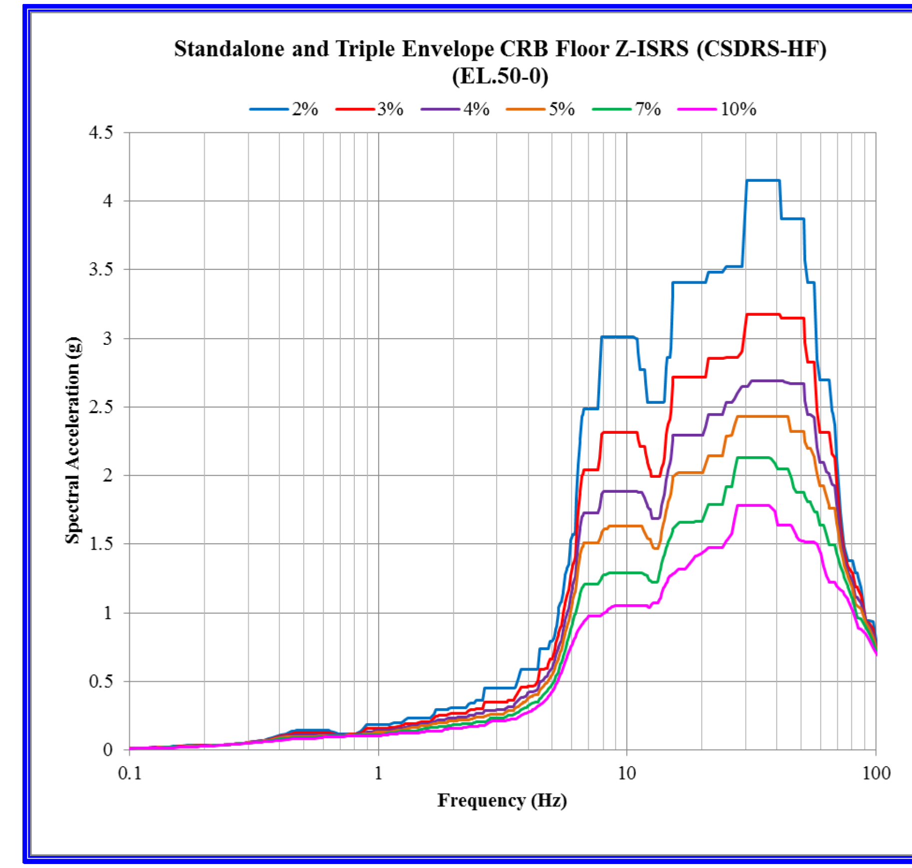


Figure 3.7.2-118: Not Used

Figure 3.7.2-118a: Control Building - In-Structure Response Spectra at El. 63’-3” (Z=570”), 5 CSDRS Inputs

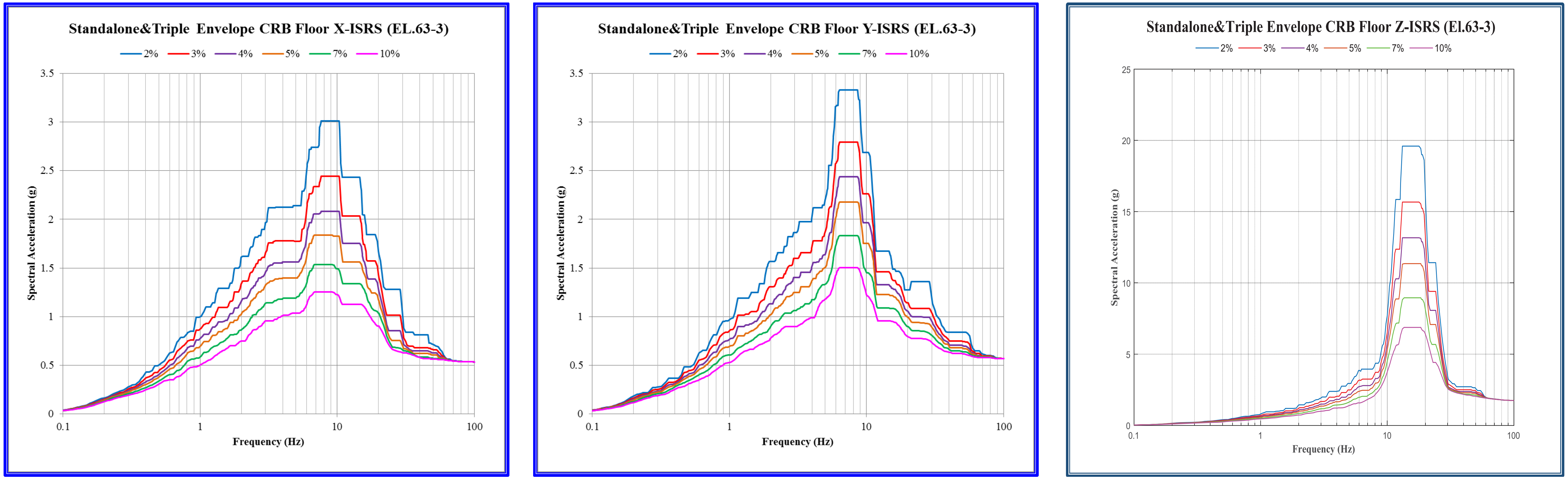
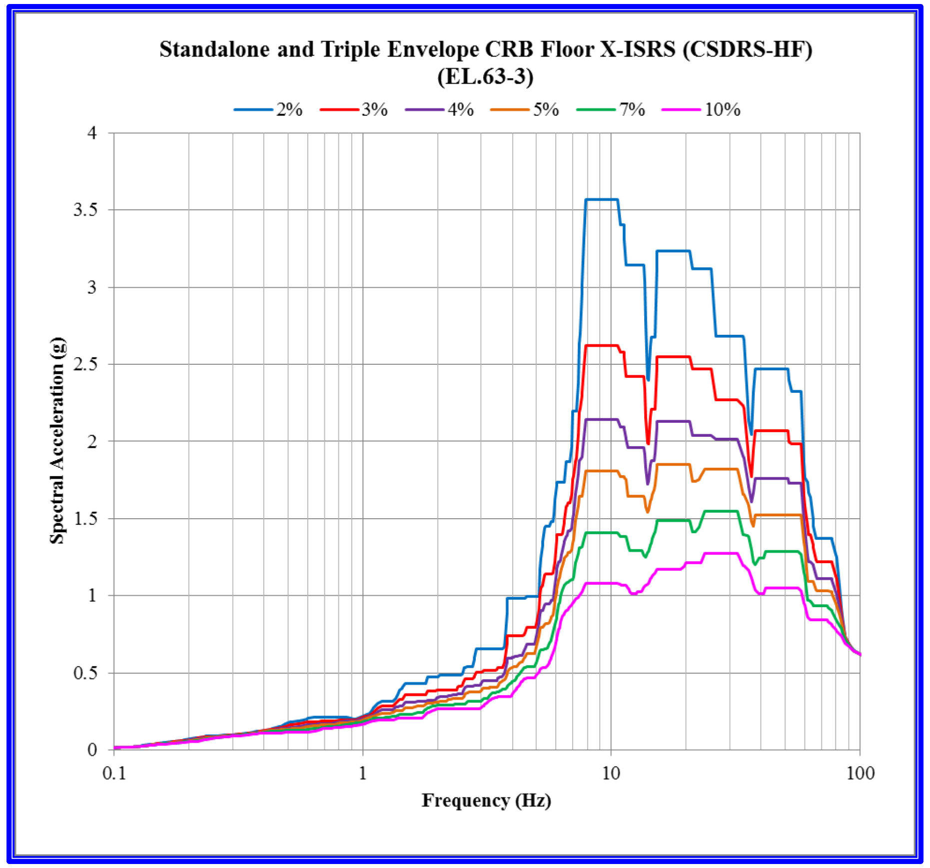
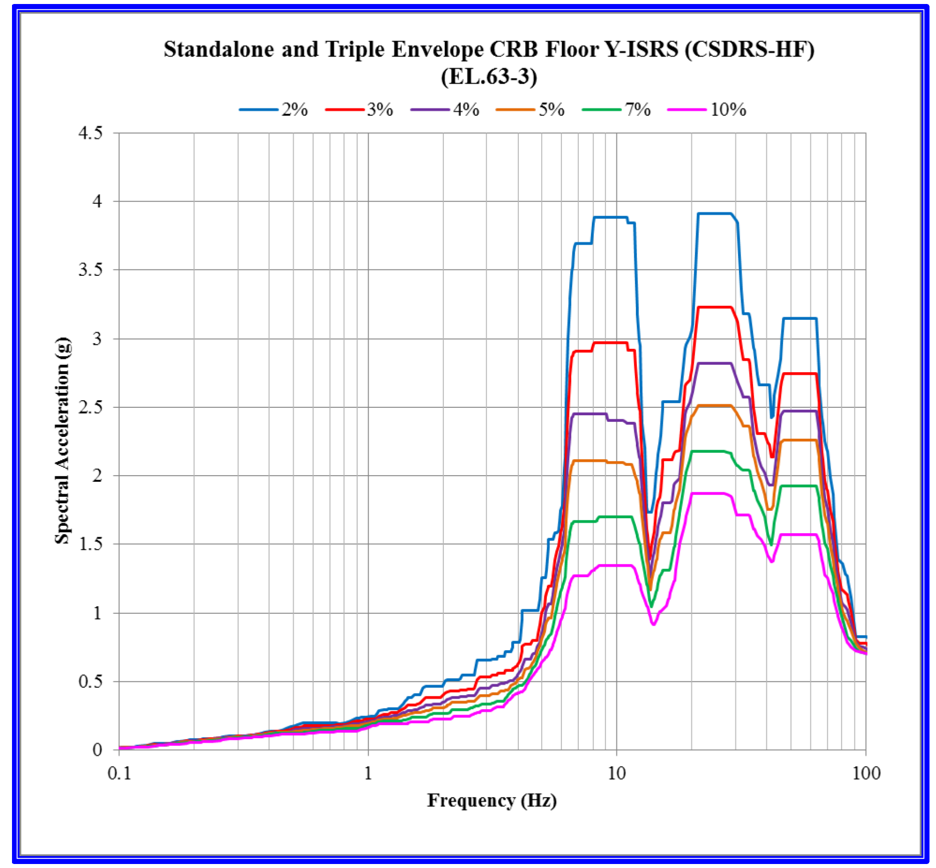


Figure 3.7.2-118b: Control Building - In-Structure Response Spectra at El. 63’-3” (Z=570”), CSDRS-HF Input





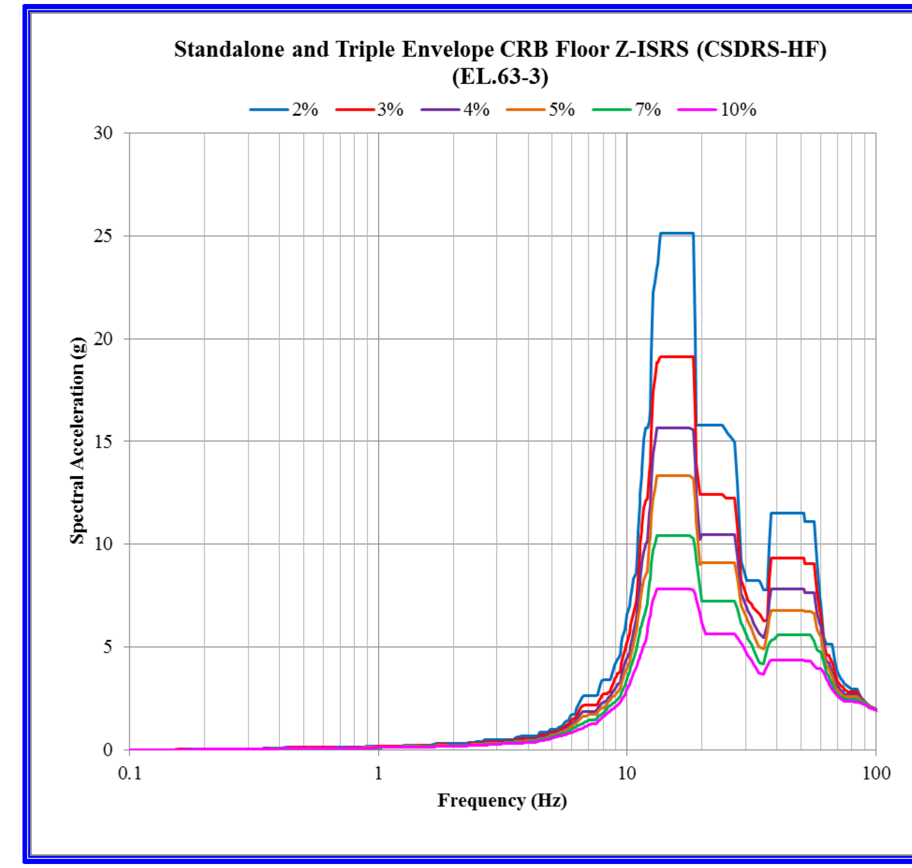
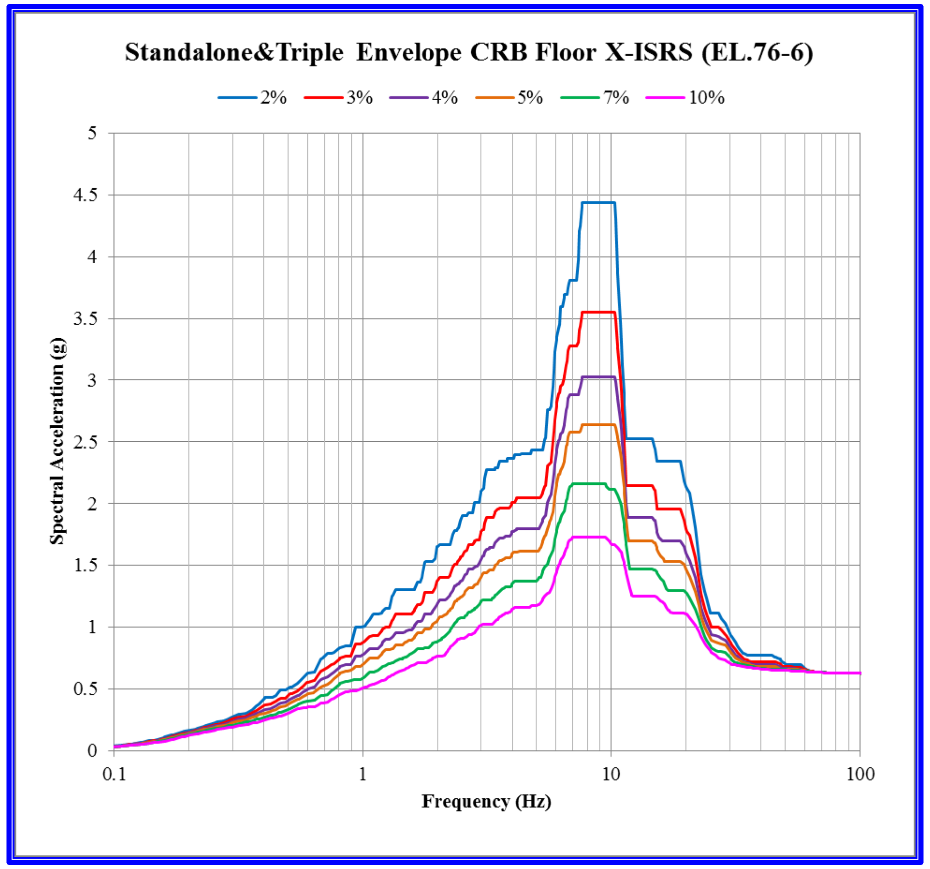
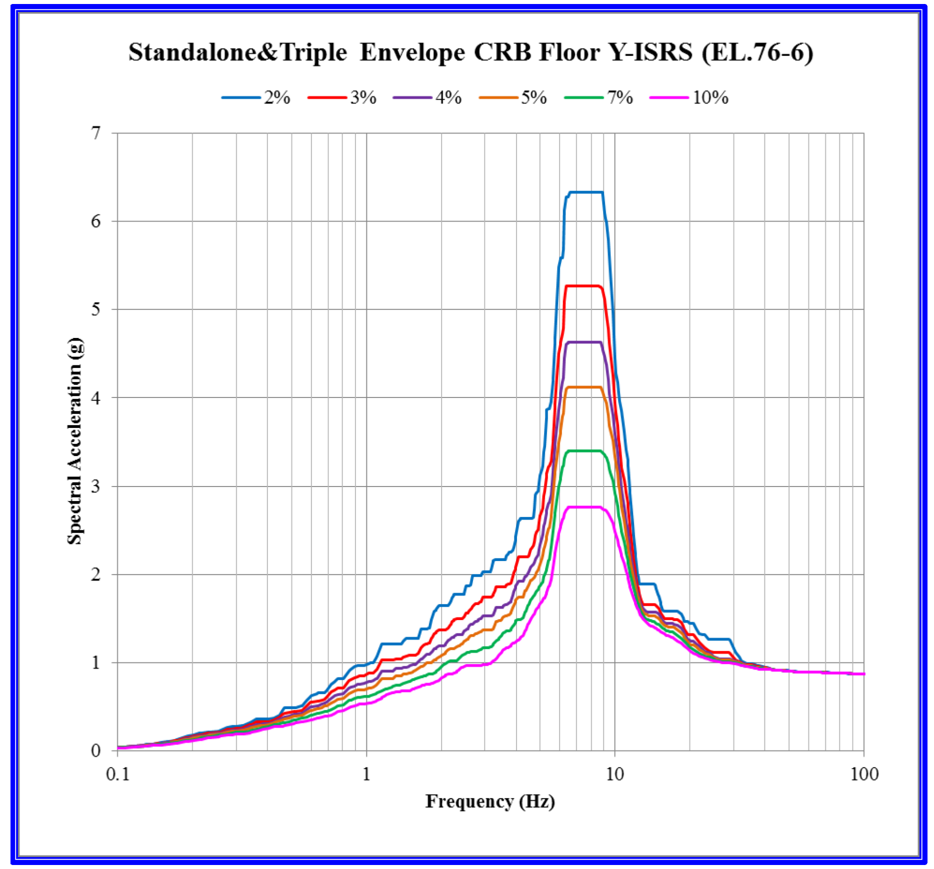


Figure 3.7.2-119: Not Used

Figure 3.7.2-119a: Control Building - In-Structure Response Spectra at El. 76'-6" (Z=720"), 5 CSDRS Inputs





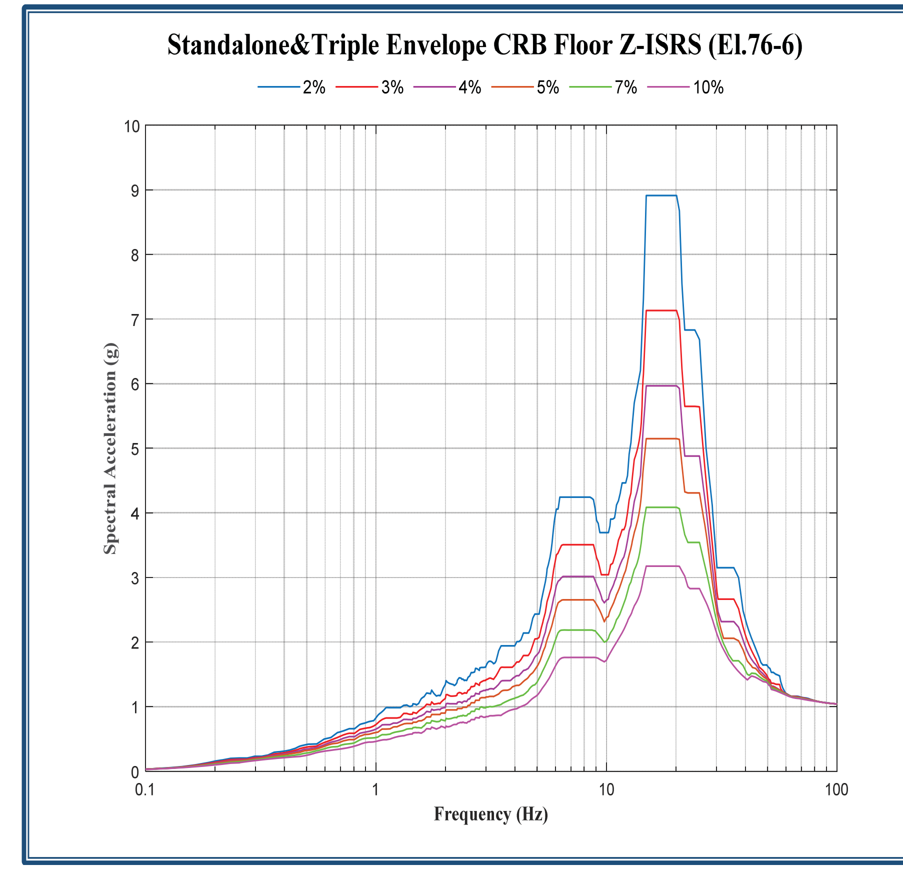


Figure 3.7.2-119b: CRB - East - West (X) ISRS at El. 76'-6" (Z=720"), CSDRS-HF Input

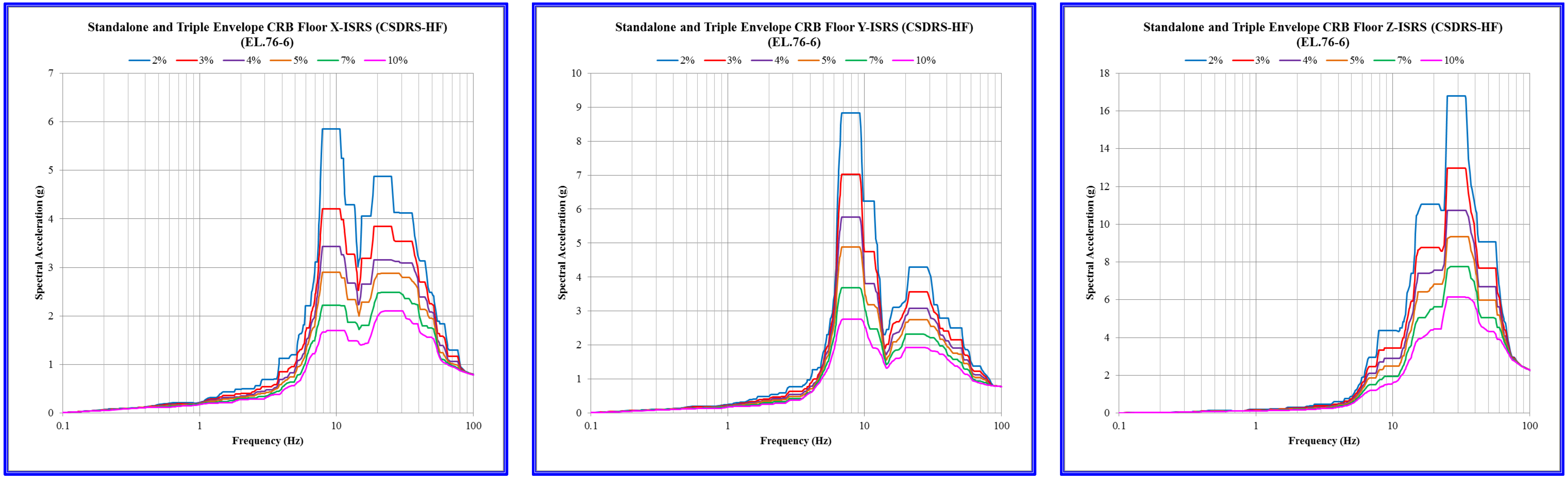
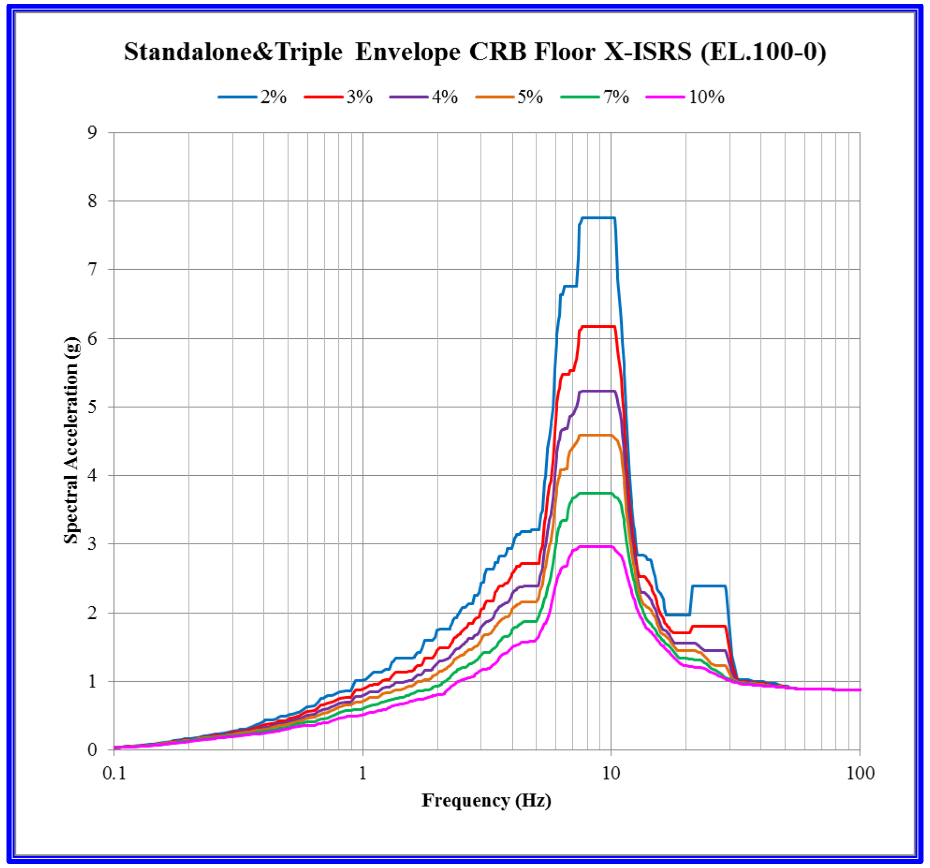
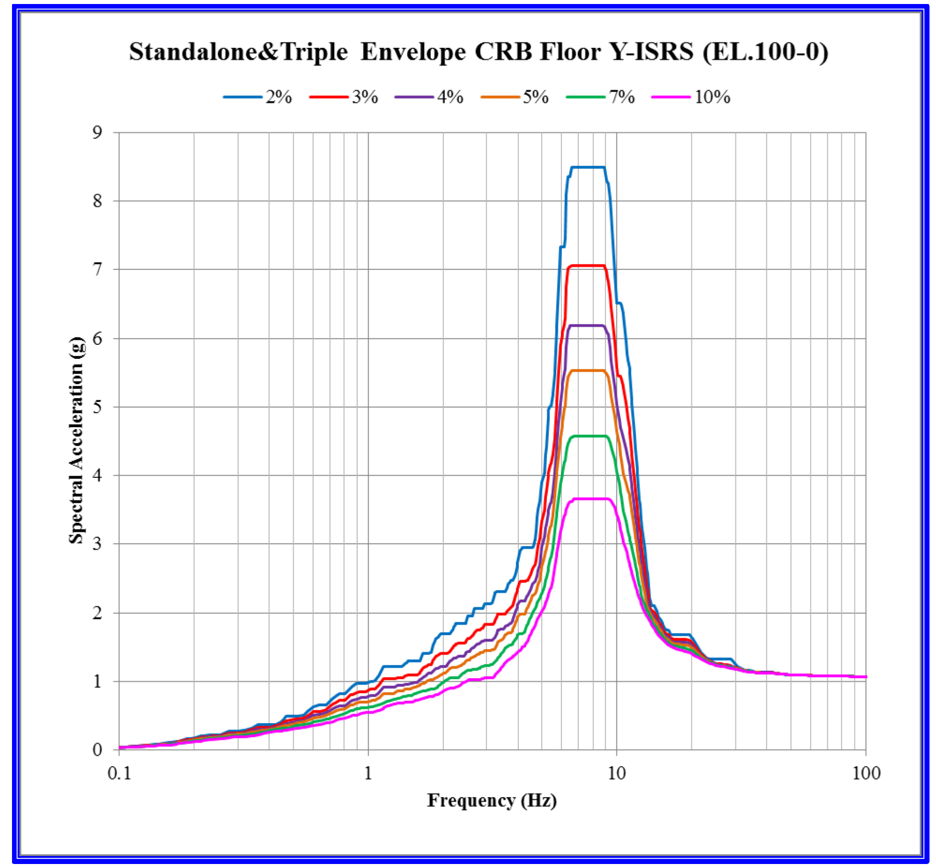


Figure 3.7.2-120: Not Used

Figure 3.7.2-120a: CRB - ISRS at El. 100’-0” (Z=1020”), 5 CSDRS Inputs





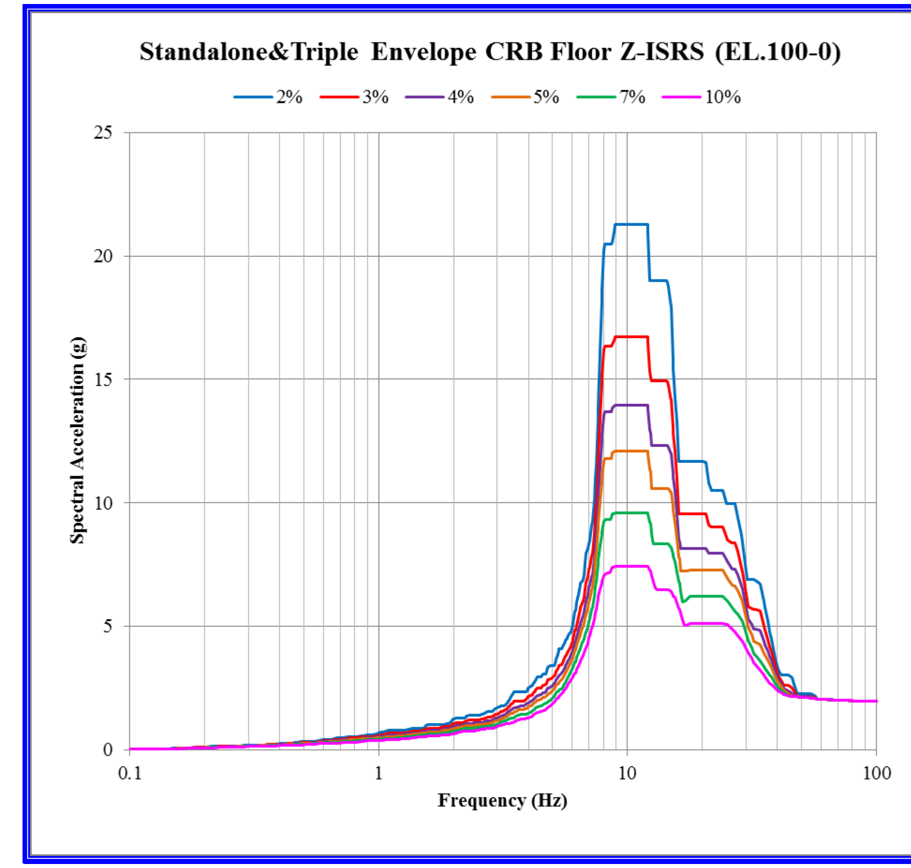


Figure 3.7.2-120b: CRB - ISRS at El. 100’-0” (Z=1020”), CSDRS-HF Input

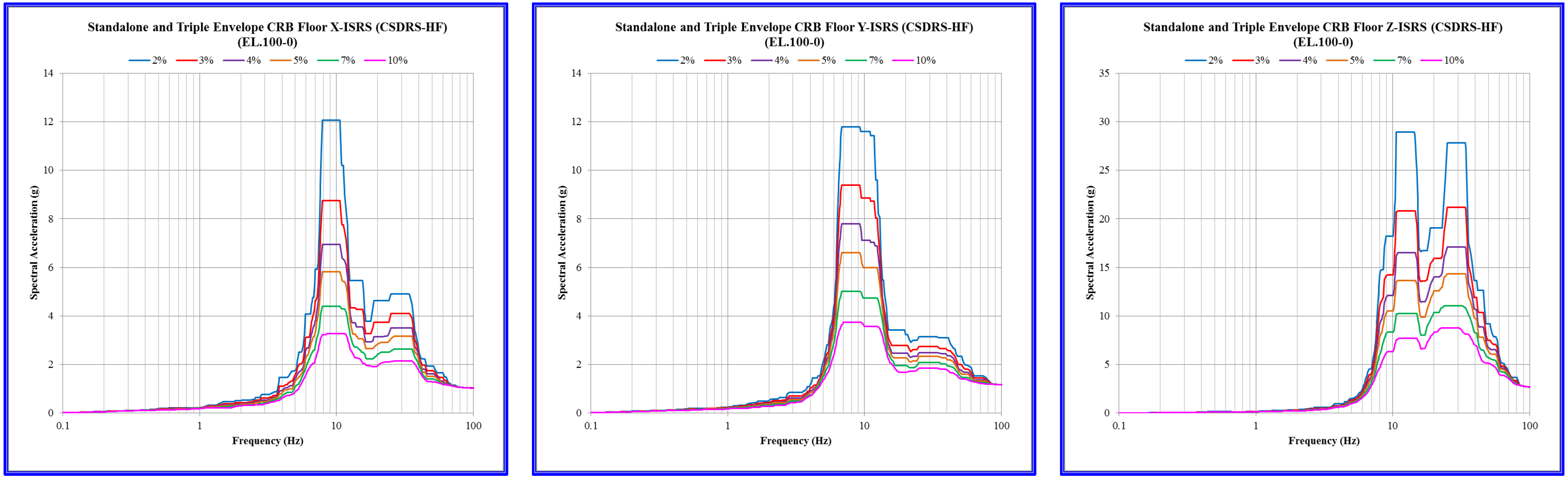


Figure 3.7.2-121: Not Used

Figure 3.7.2-121a: CRB - ISRS at El. 120’-0” (Z=1260”), 5 CSDRS Inputs

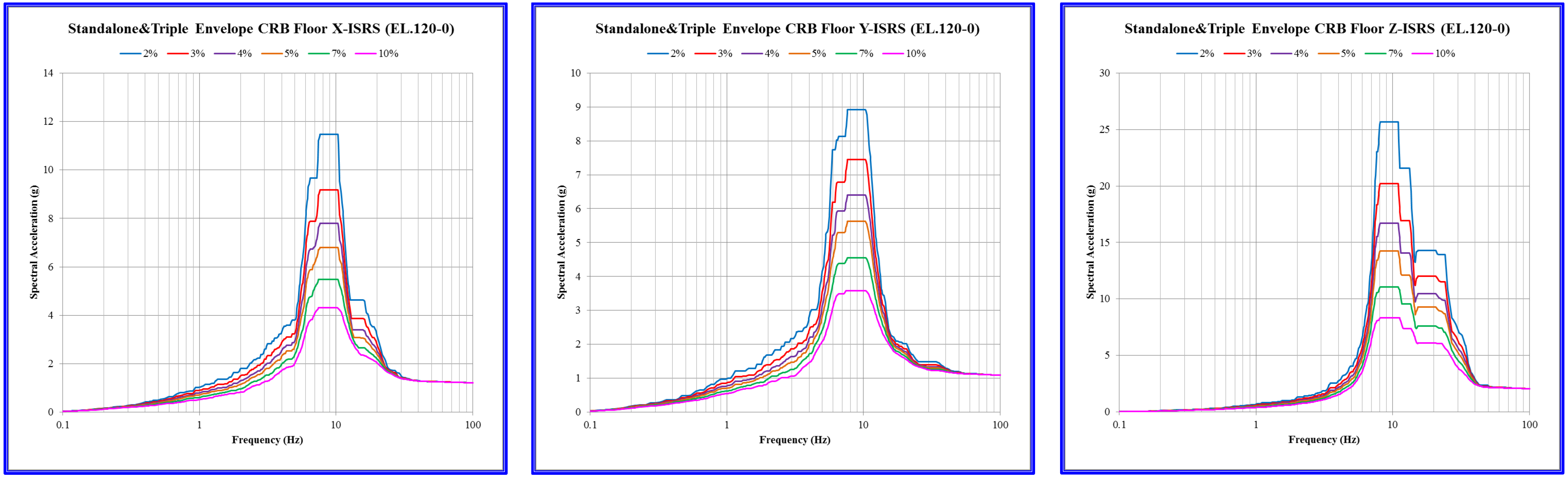


Figure 3.7.2-121b: CRB - ISRS at El. 120′-0″ (Z=1260″), CSDRS-HF Input

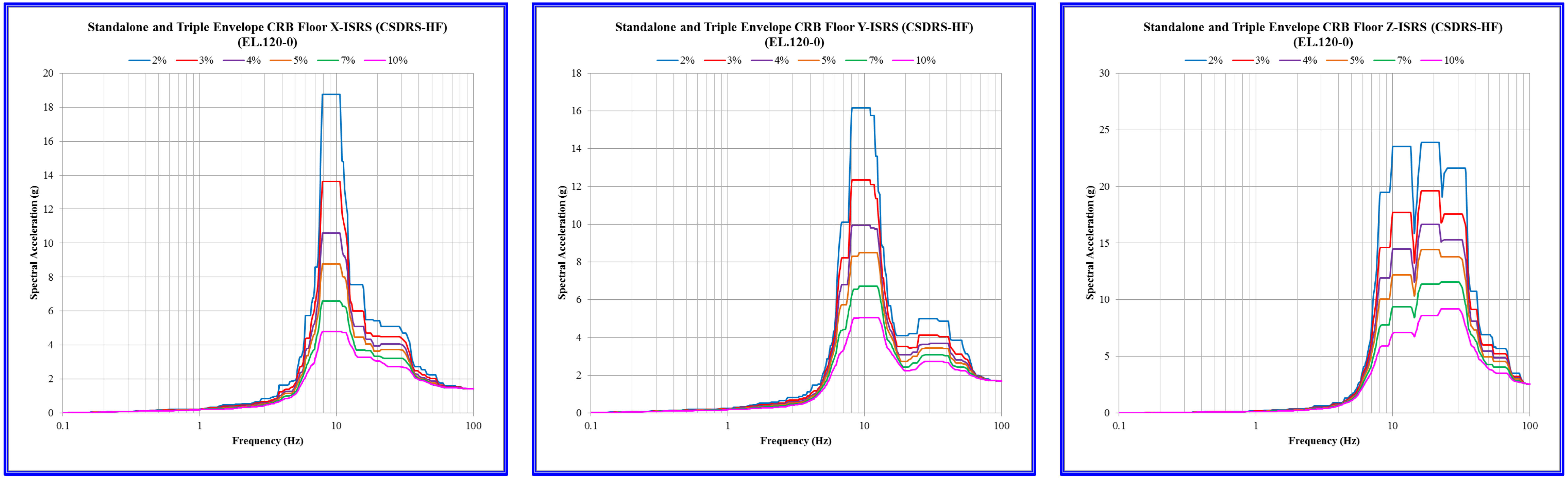
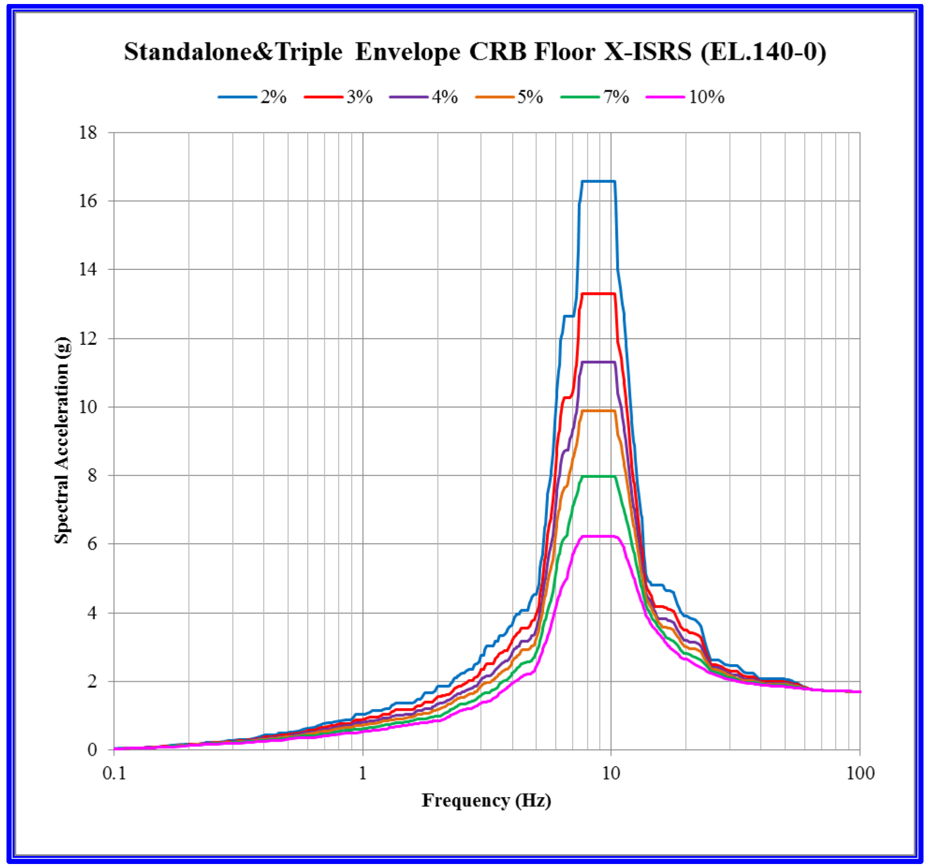
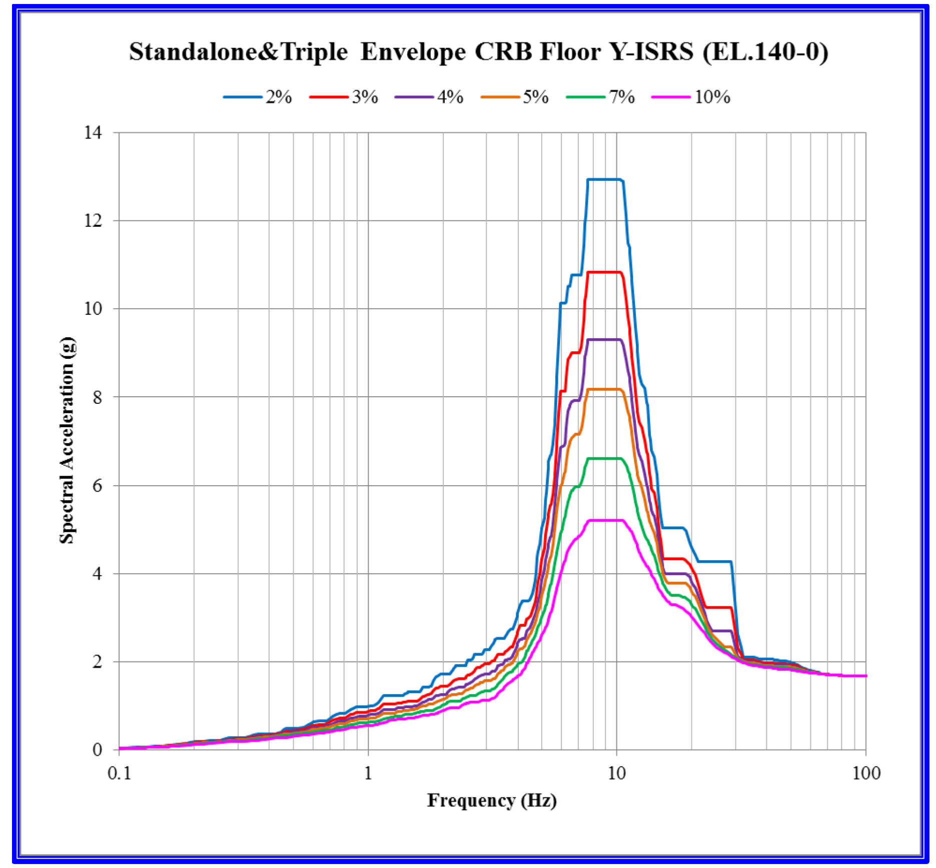


Figure 3.7.2-122: Not Used

Figure 3.7.2-122a: CRB - ISRS at El. 140’-0” (Z=1518”), 5 CSDRS Inputs





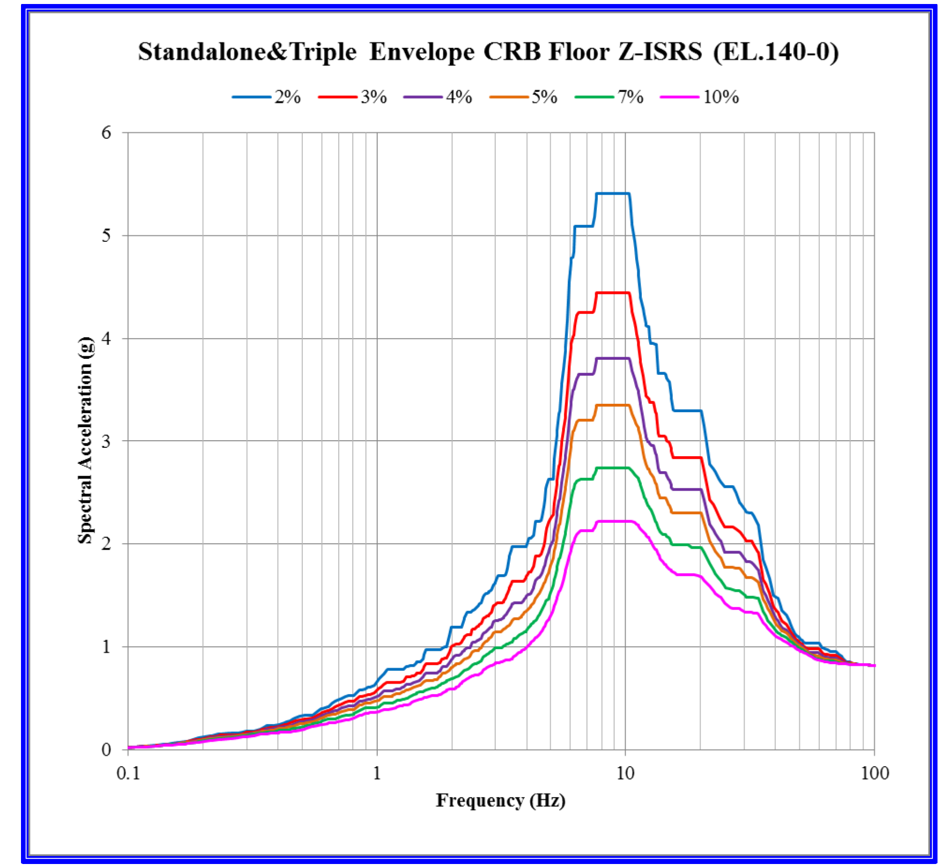
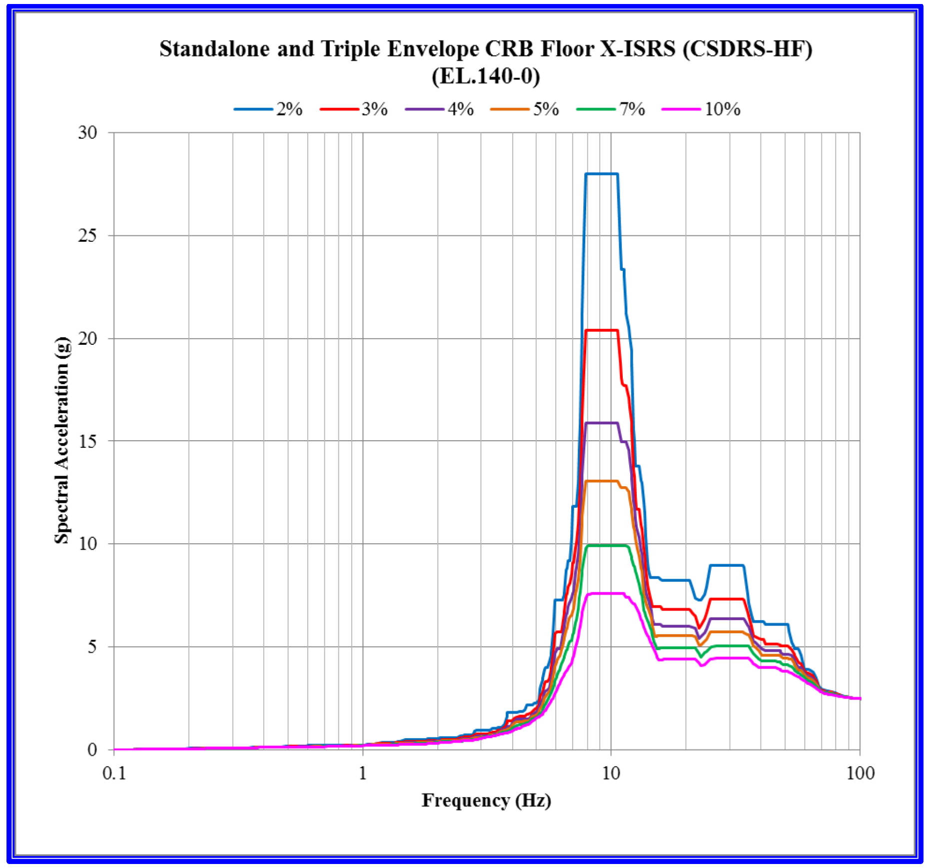
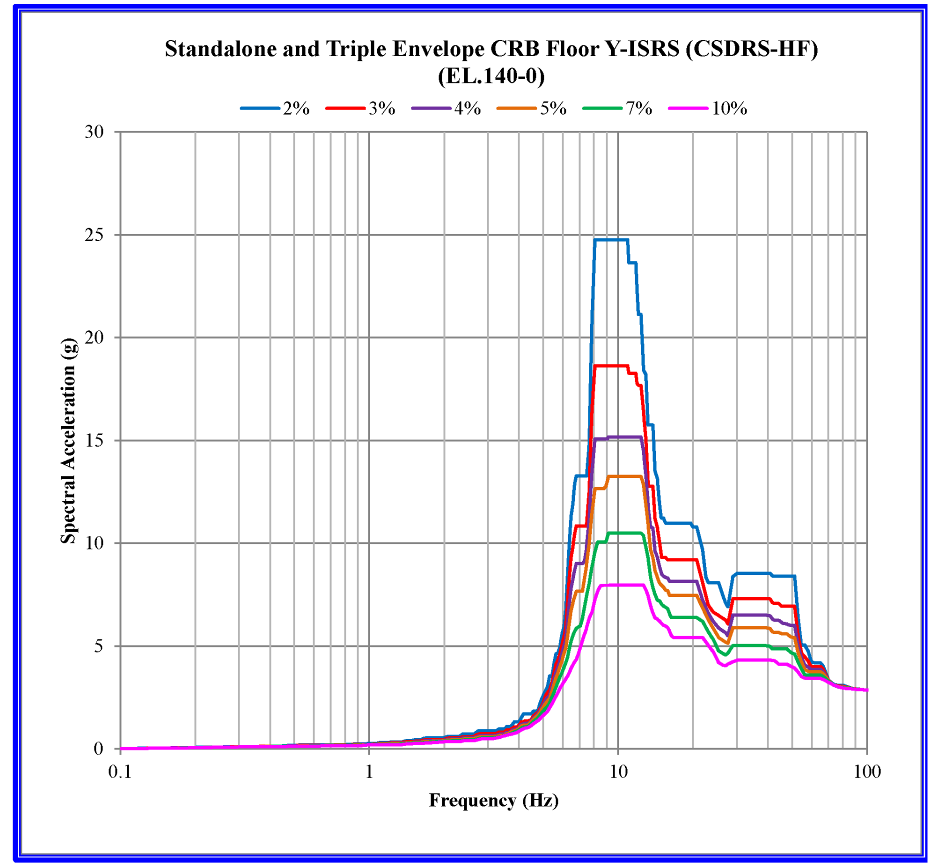


Figure 3.7.2-122b: CRB - ISRS at El. 140'-0" (Z=1518"), CSDRS-HF Input





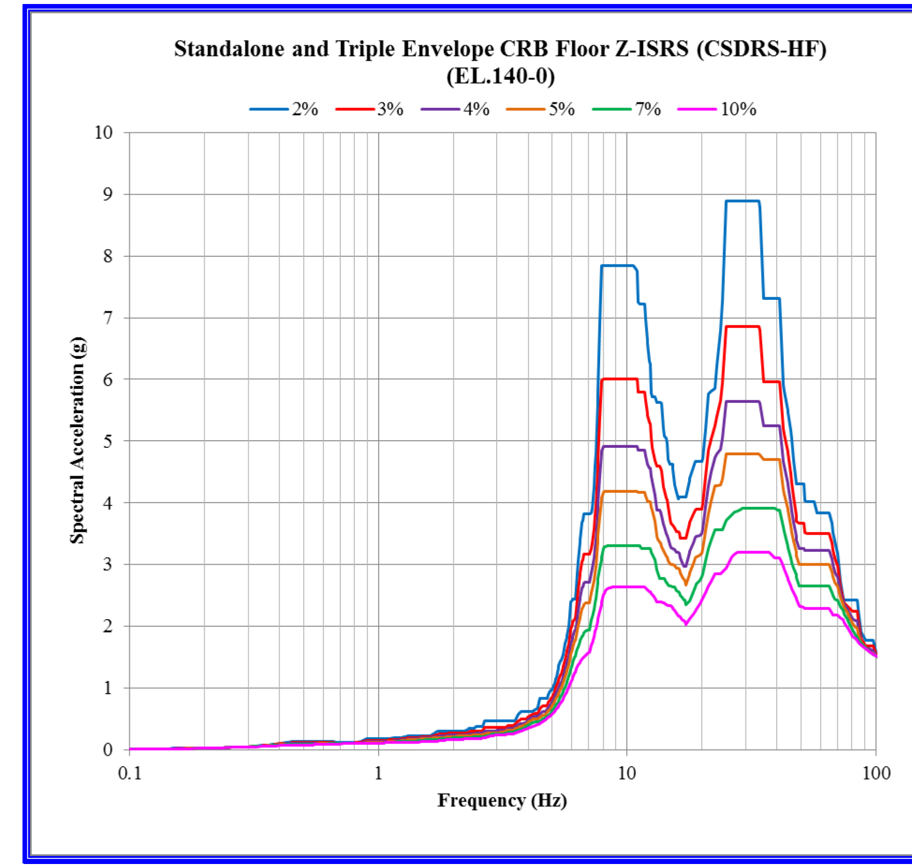


Figure 3.7.2-123: Comparison of 12 NPM and 7 NPM Model Results at Northwest Corner on Top of Basement (EL. 24'-0")

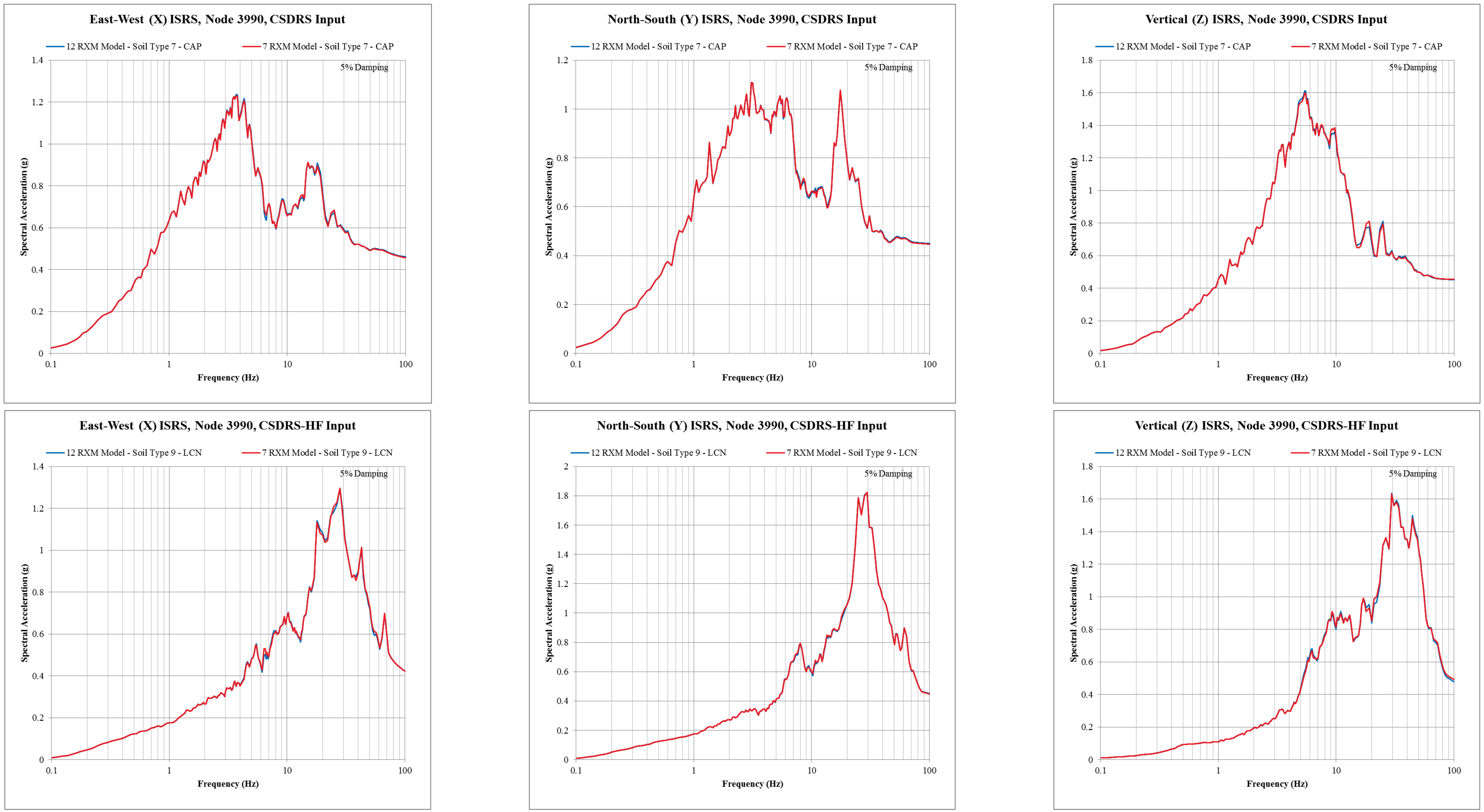


Figure 3.7.2-124: Comparison of 12 NPM and 7 NPM Model Results at Mid-Span of North Wall on Top of Basement (EL. 24'-0")

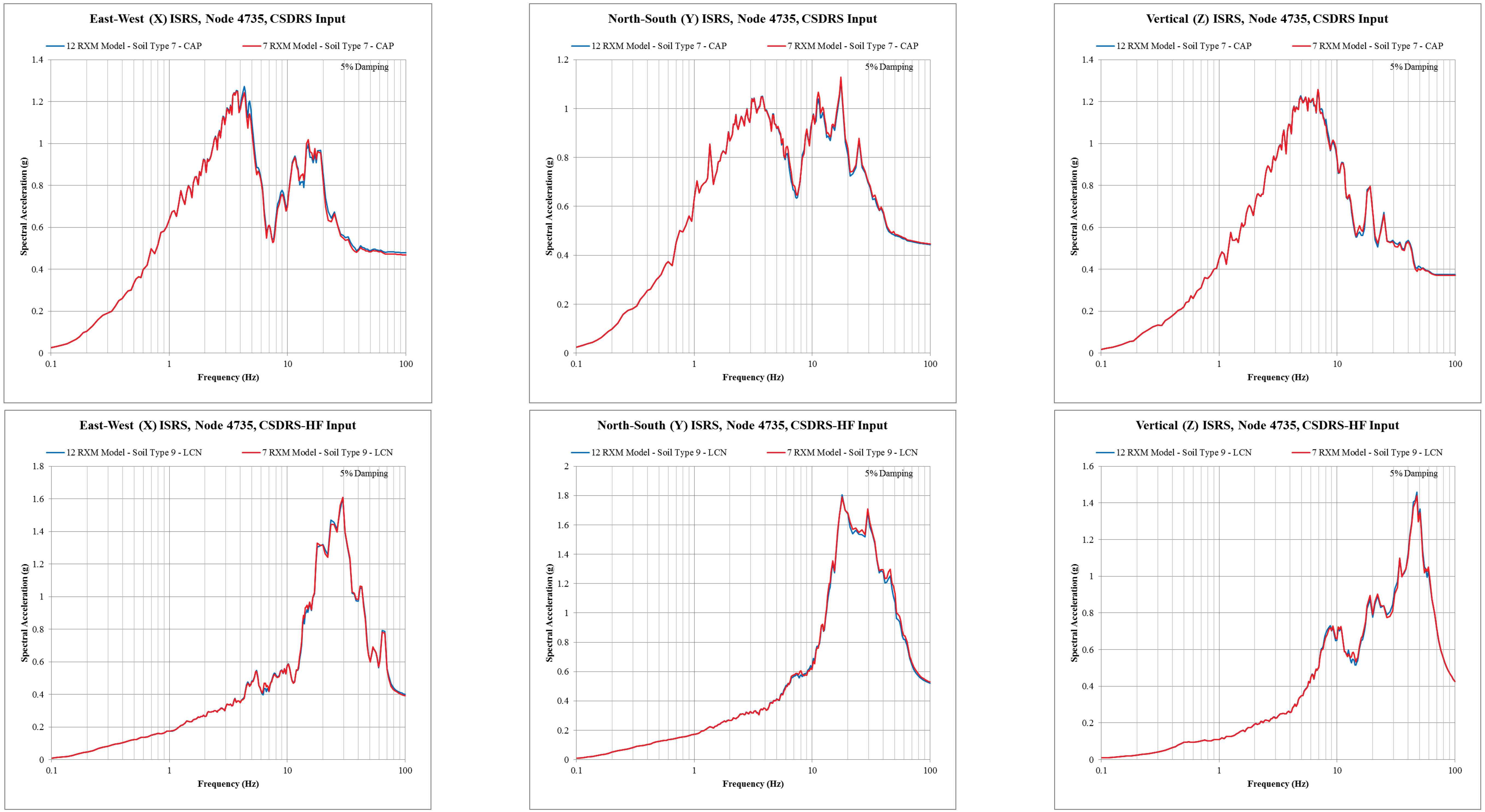


Figure 3.7.2-125: Comparison of 12 NPM and 7 NPM Model Results at Northeast Corner on Top of Basement (EL. 24'-0")

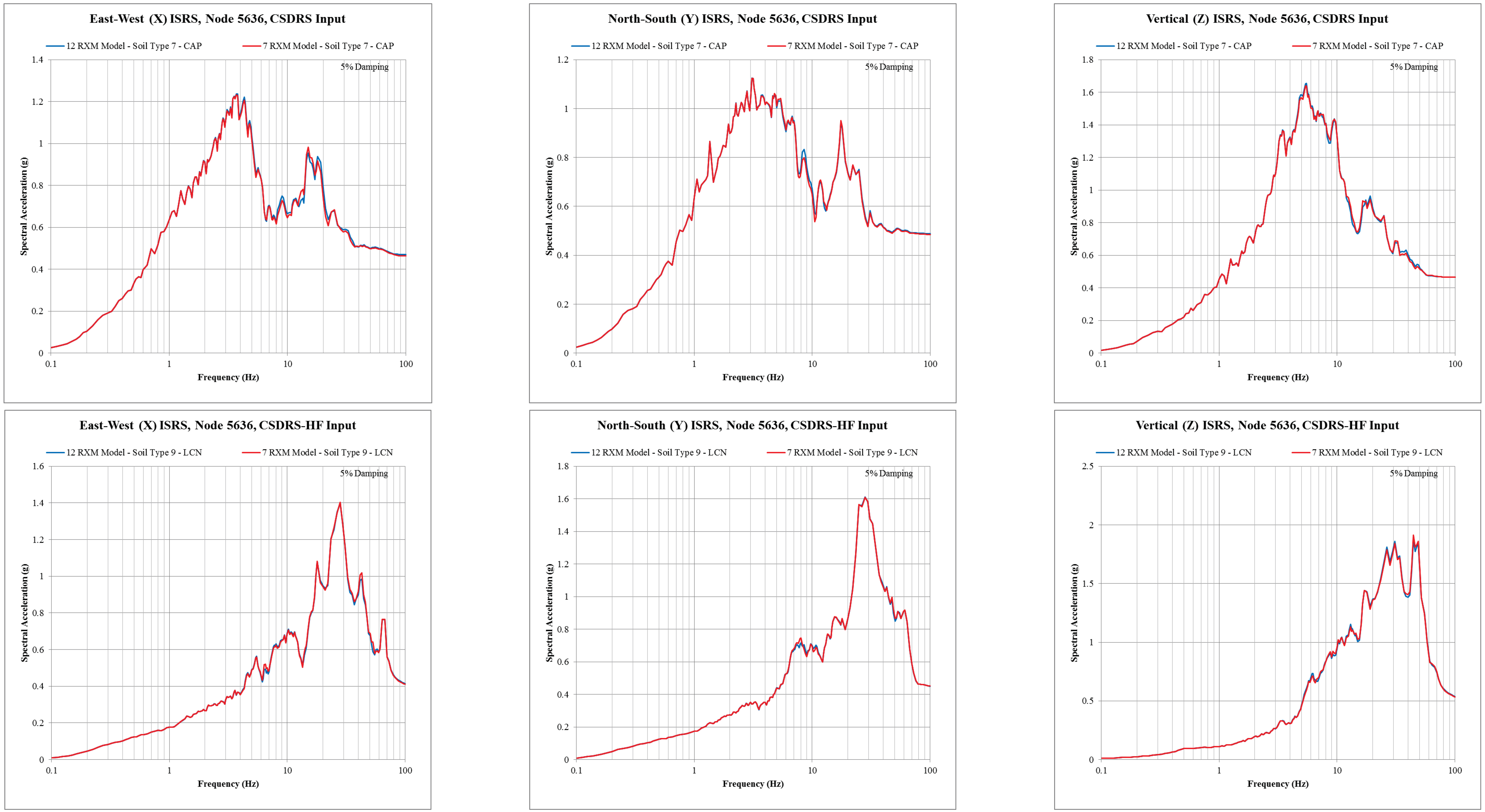


Figure 3.7.2-126: Comparison of 12 NPM and 7 NPM Model Results at Northwest Corner on Top of Roof Slab (EL. 181′-0″)

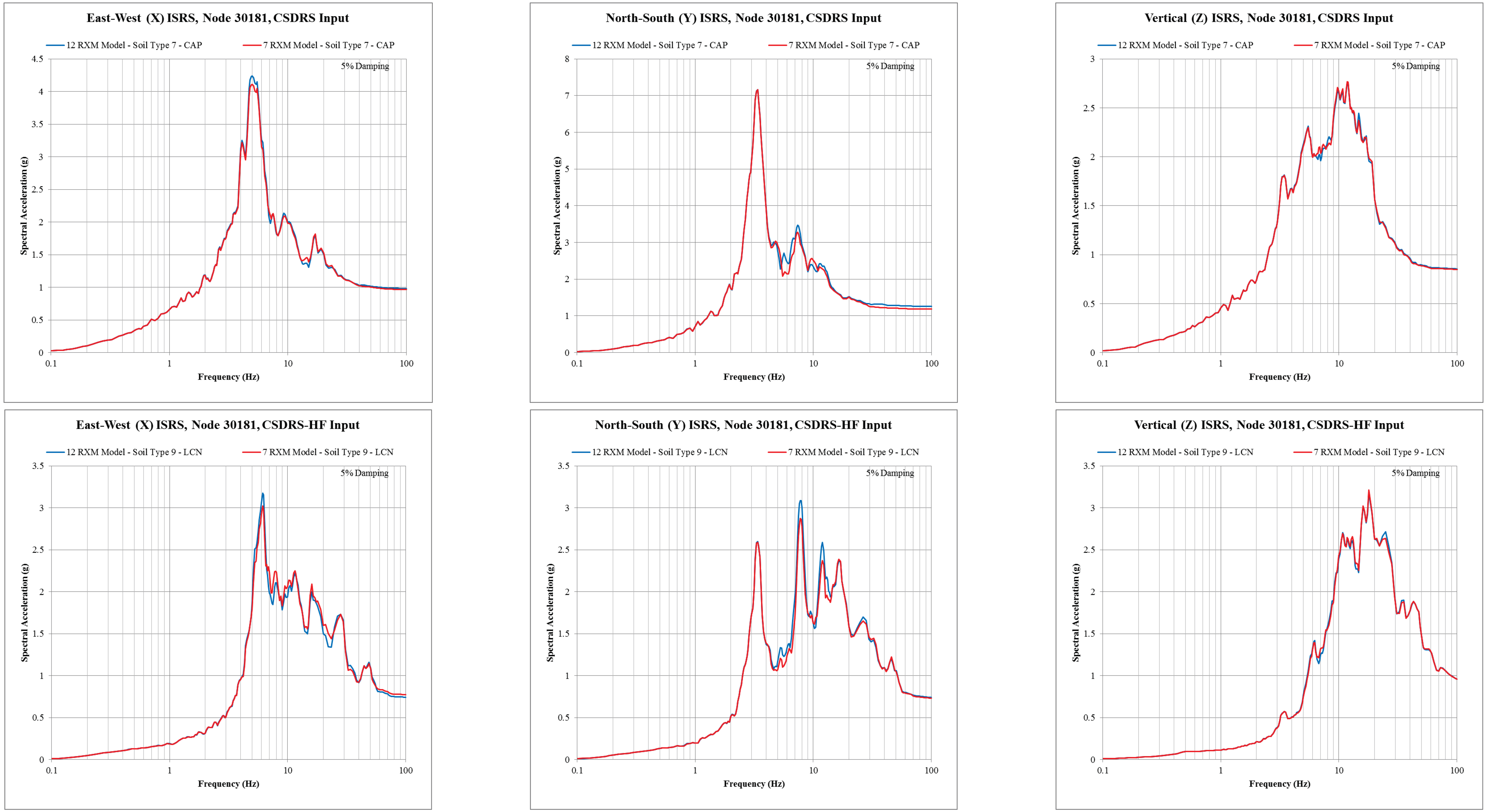


Figure 3.7.2-127: Comparison of 12 NPM and 7 NPM Model Results at Mid-Span of Roof Slab (EL. 181′-0″)

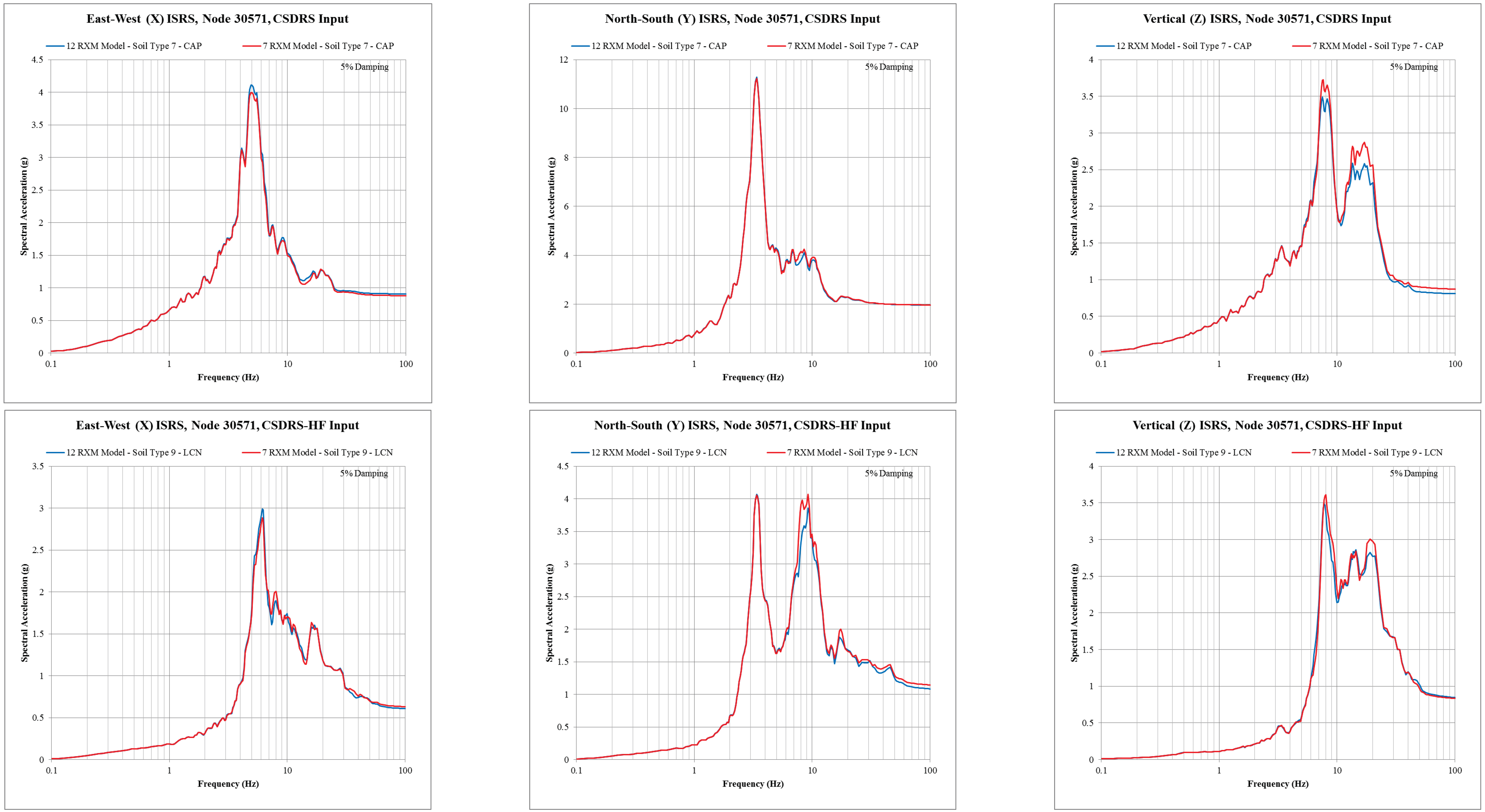


Figure 3.7.2-128: Comparison of 12 NPM and 7 NPM Model Results at Northwest Corner of Roof Slab (EL. 181′-0″)

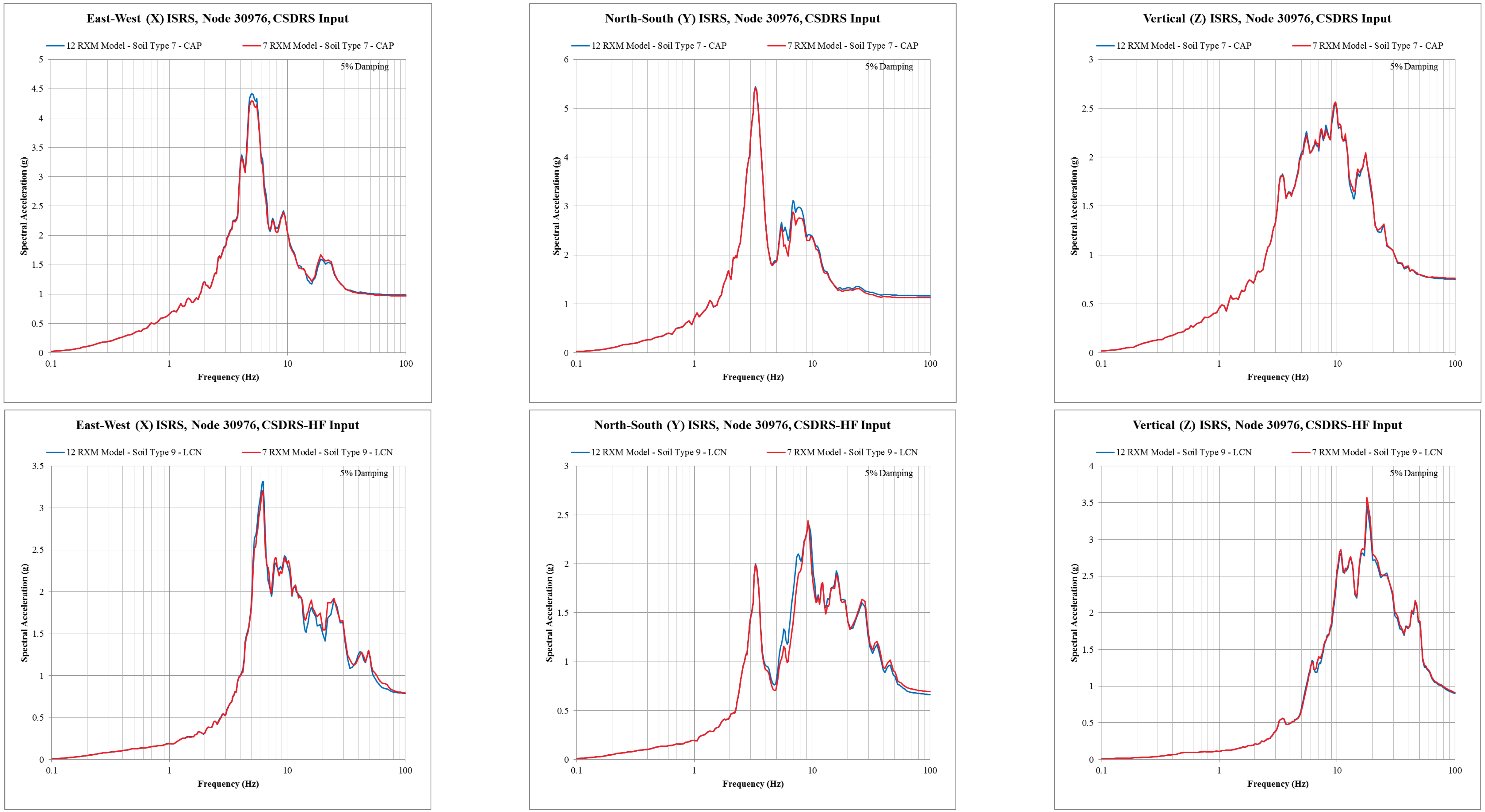


Figure 3.7.2-129: Development of Average Static Pressure of 4.20 psi at Mid Height of Pool Water for SAP2000 Model to Account for 3D FSI Effects

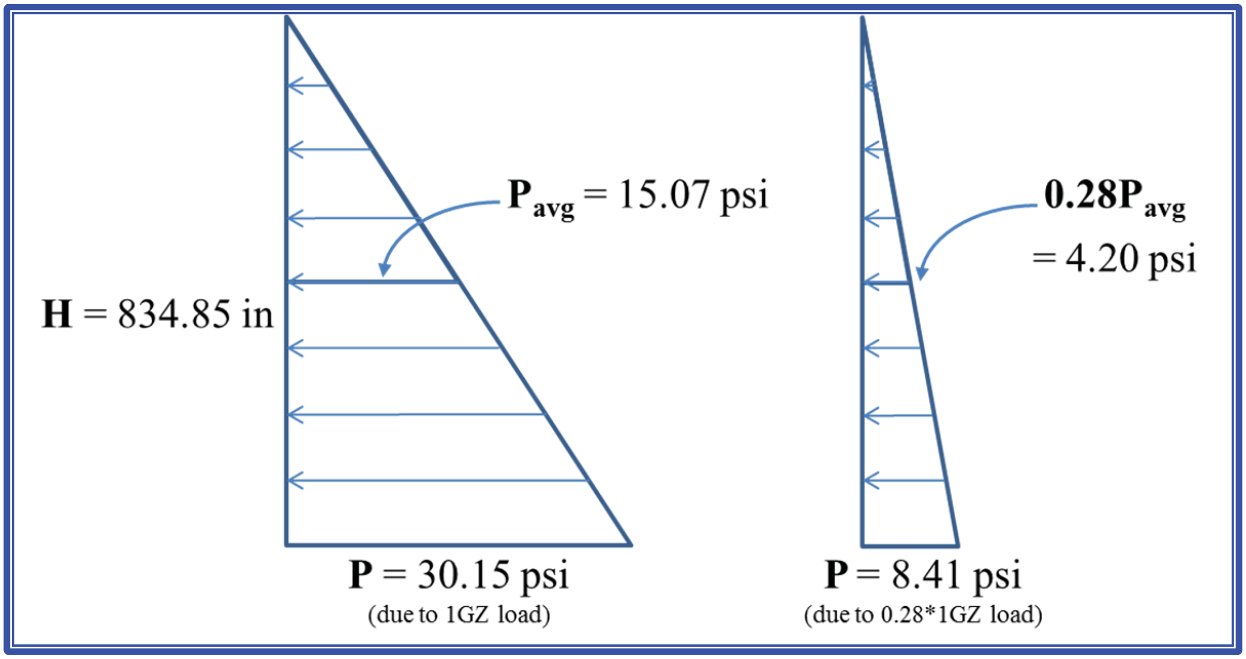


Figure 3.7.2-130: RXB Node 3996, NW Corner on Top of Basemat, X-ISRS Comparison, Cracked Model

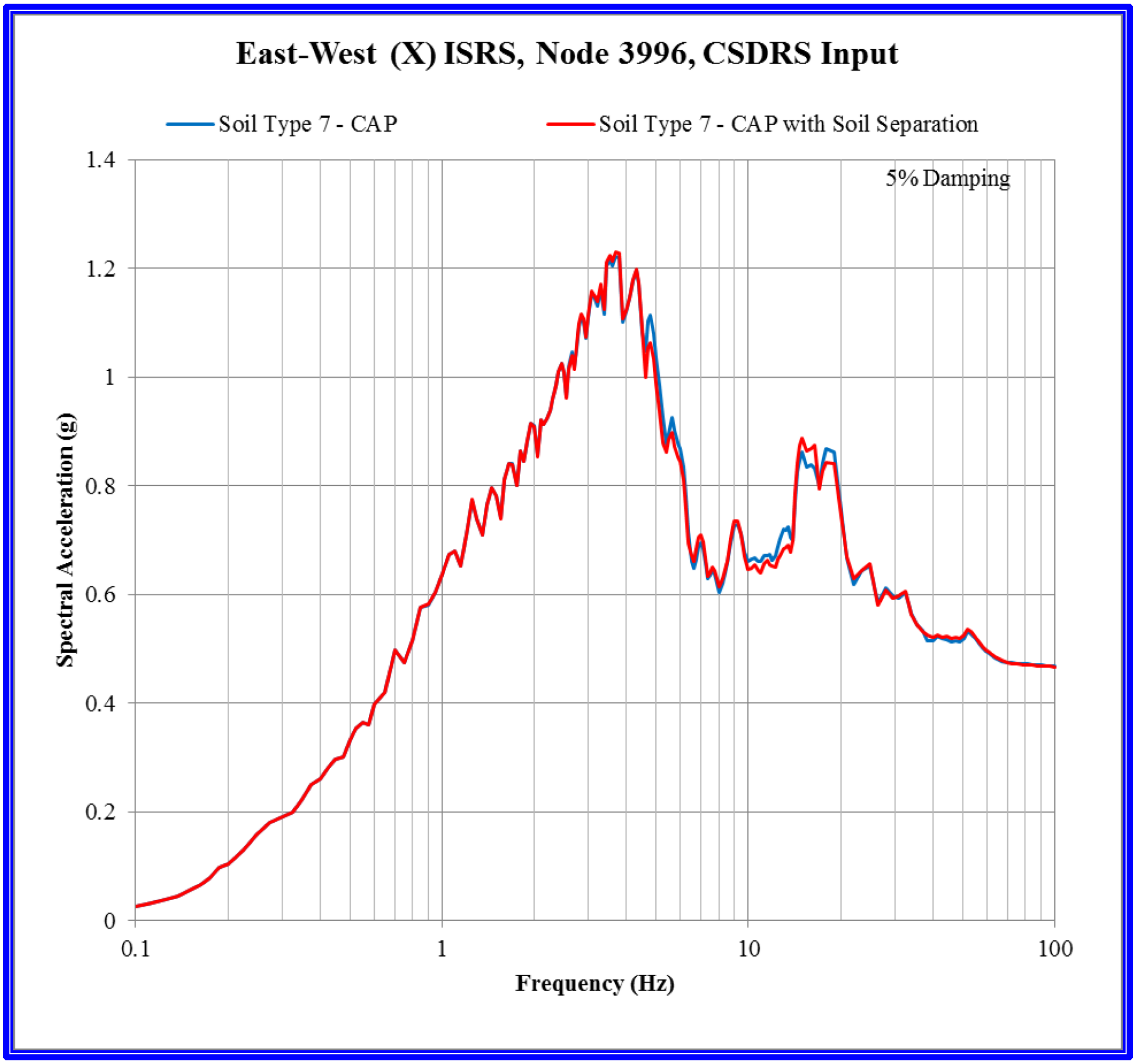


Figure 3.7.2-131: RXB Node 3996, NW Corner on Top of Basemat, Y-ISRS Comparison, Cracked Model

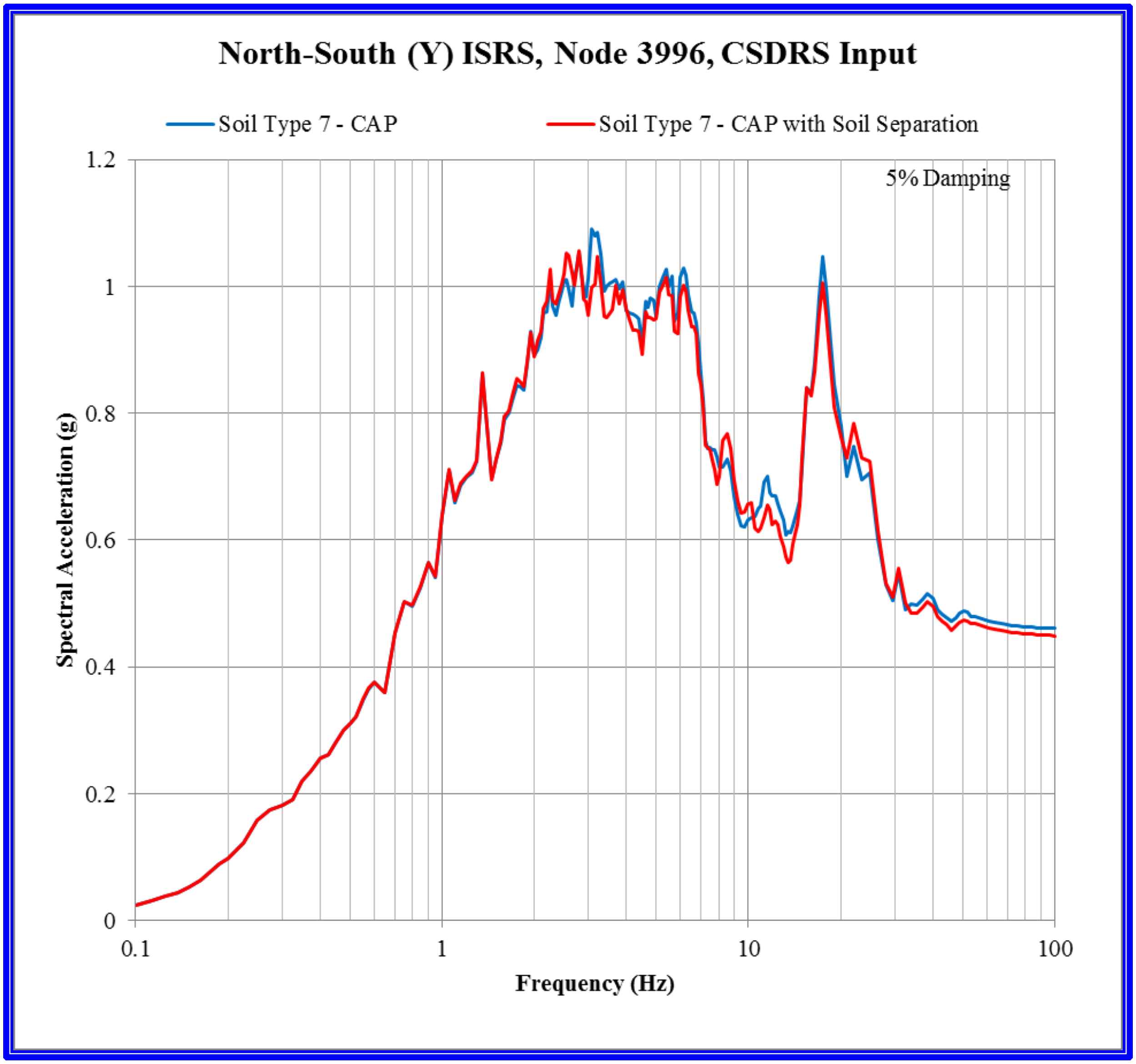


Figure 3.7.2-132: RXB Node 3996, NW Corner on Top of Basemat, Z-ISRS Comparison, Cracked Model

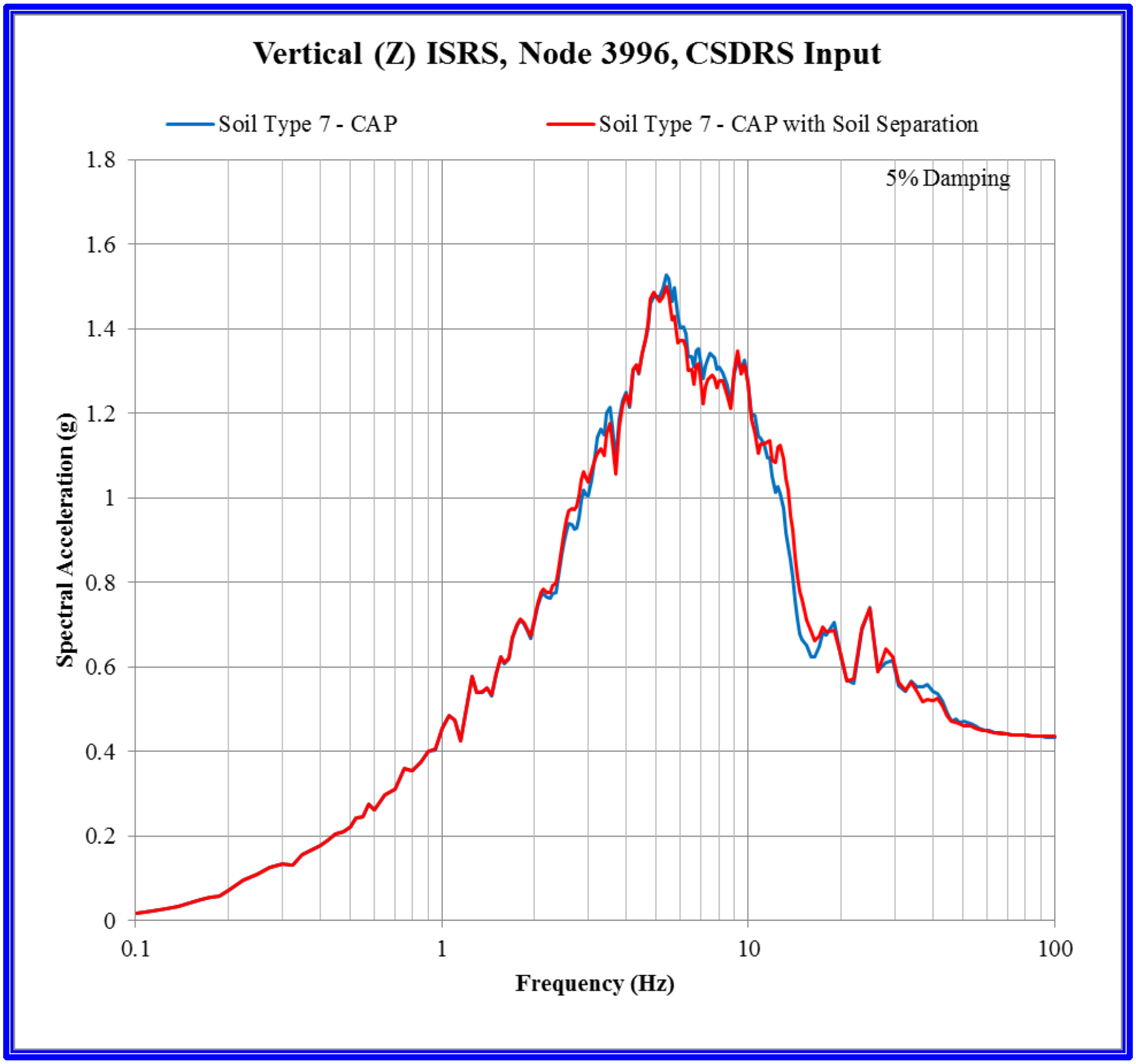


Figure 3.7.2-133: RXB Node 3996, NW Corner on Top of Basemat, X-TF Comparison, Cracked Model

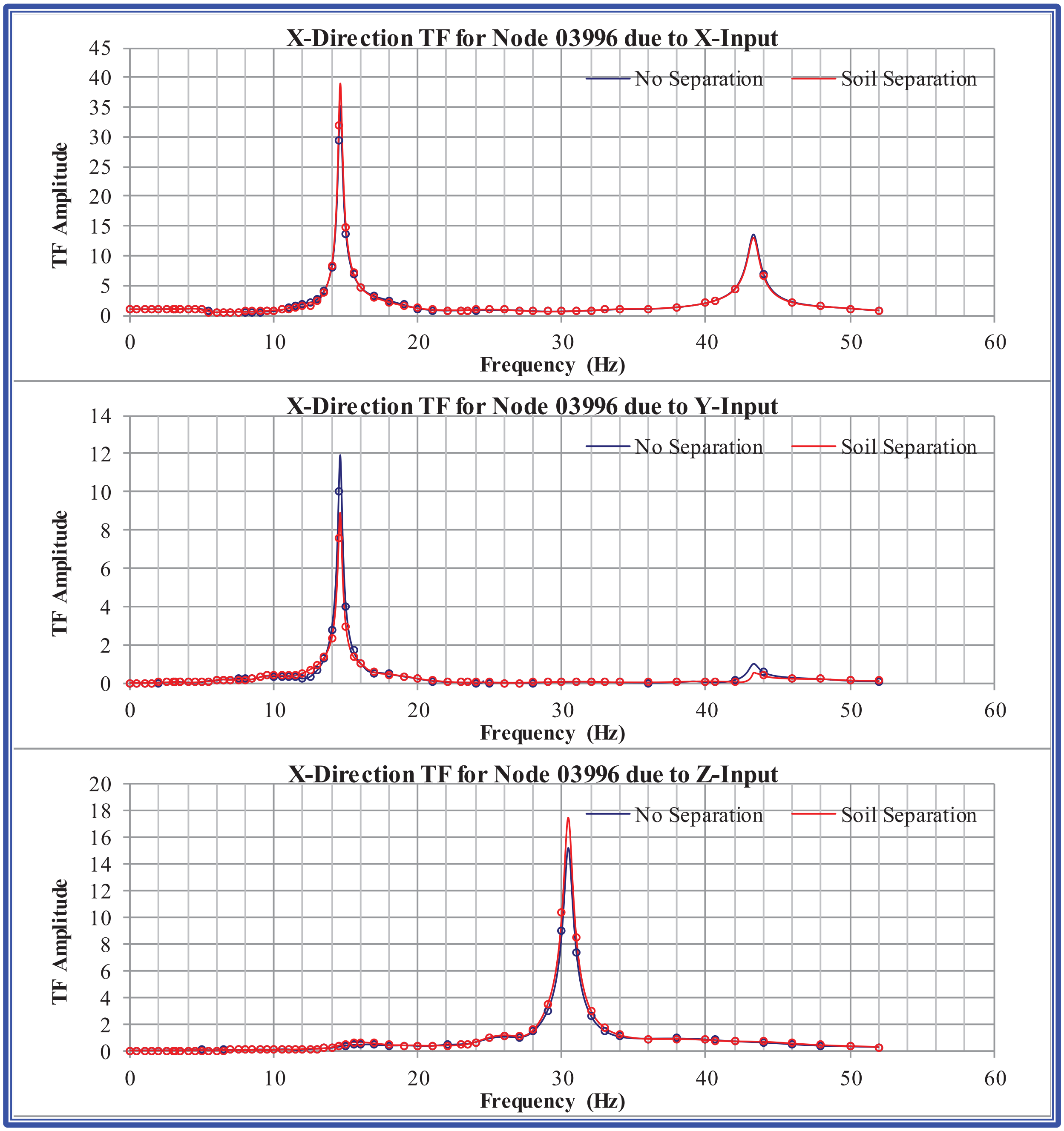


Figure 3.7.2-134: RXB Node 3996, NW Corner on Top of Basemat, Y-TF Comparison, Cracked Model

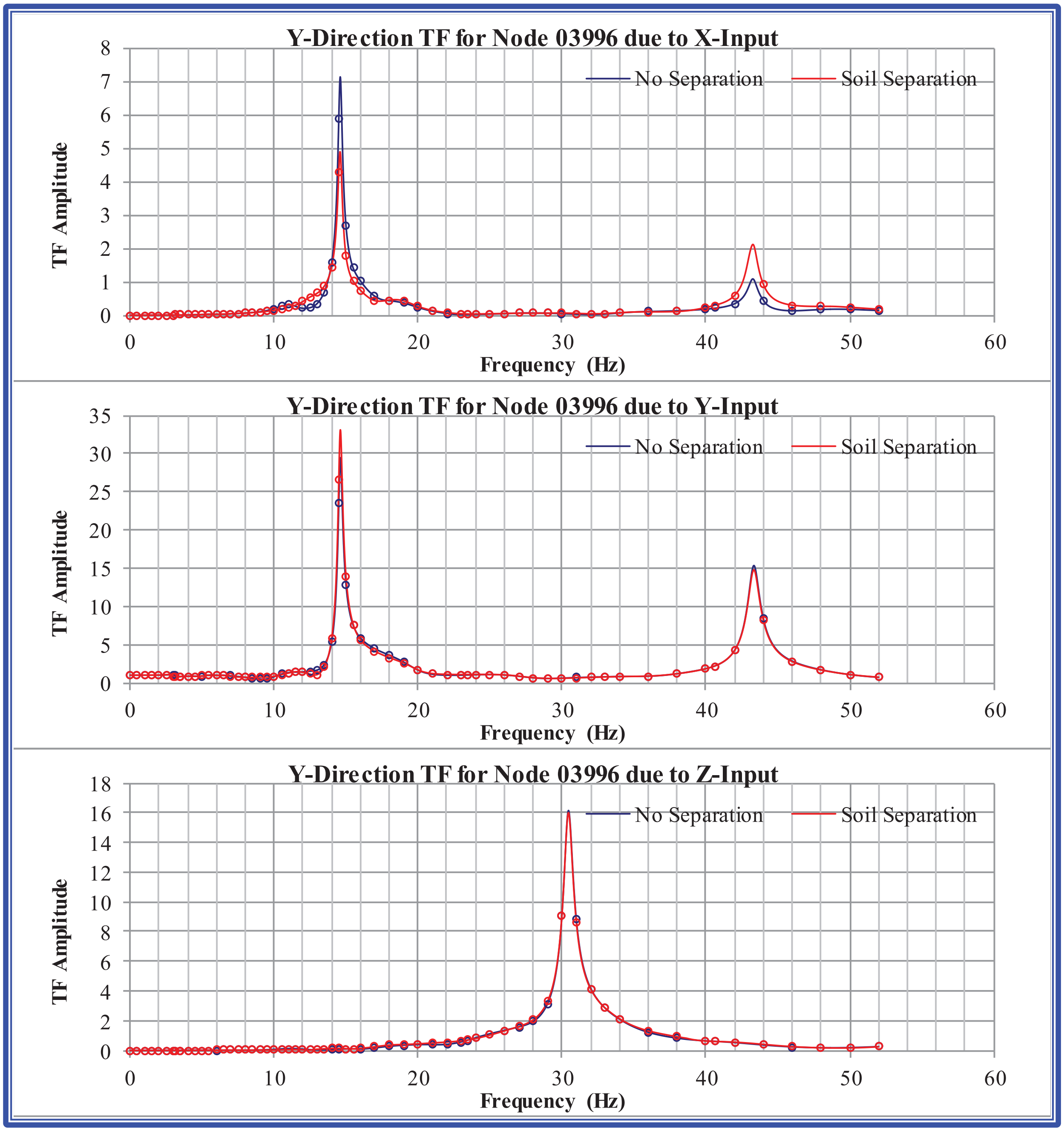


Figure 3.7.2-135: RXB Node 3996, NW Corner on Top of Basemat, Z-TF Comparison, Cracked Model

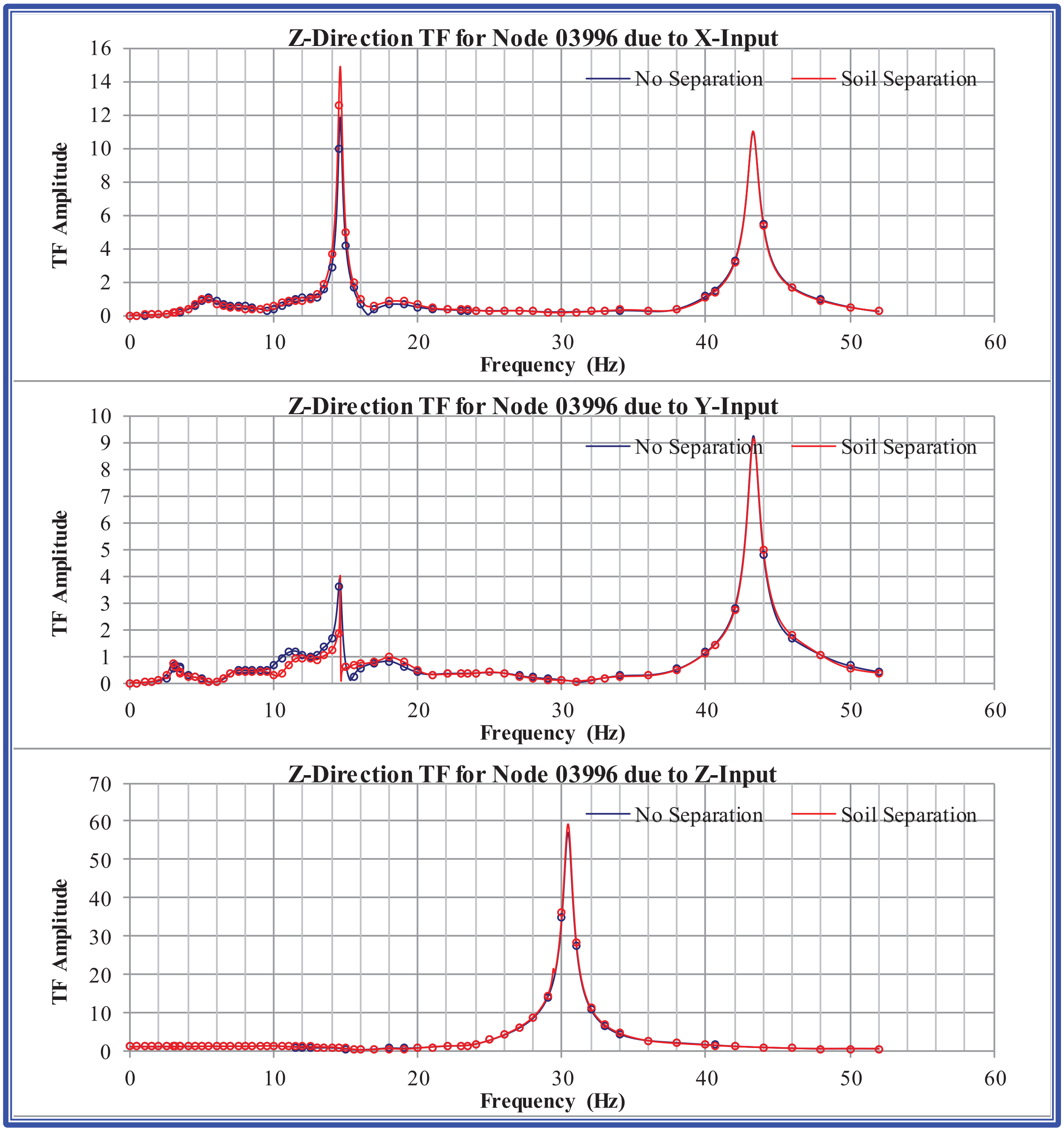


Figure 3.7.2-136: CRB - East-West (X) ISRS, Node 34380, Slab between Grid Line CB-D and CB-E at El. 63', Capitola Input

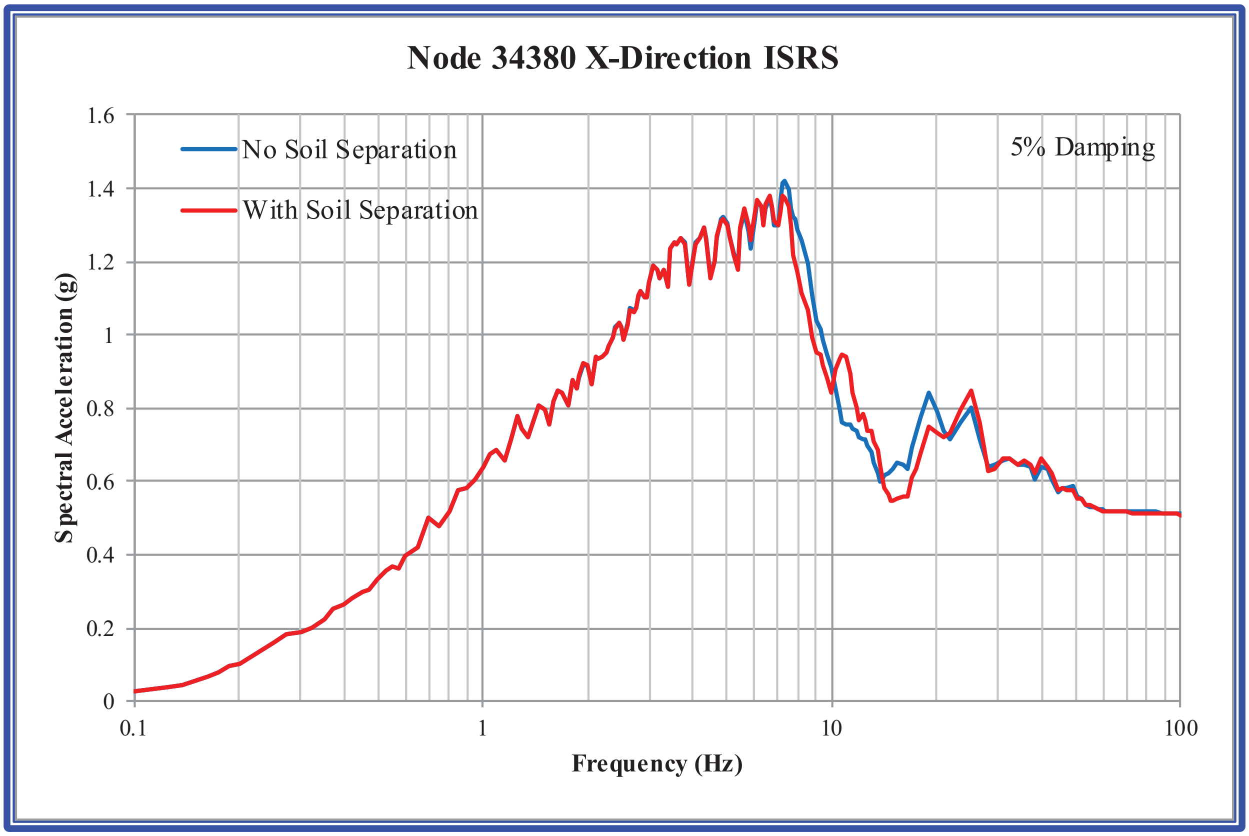


Figure 3.7.2-137: CRB - North-South (Y) ISRS, Node 34380, Slab between Grid Line CB-D and CB-E at El. 63', Capitola Input

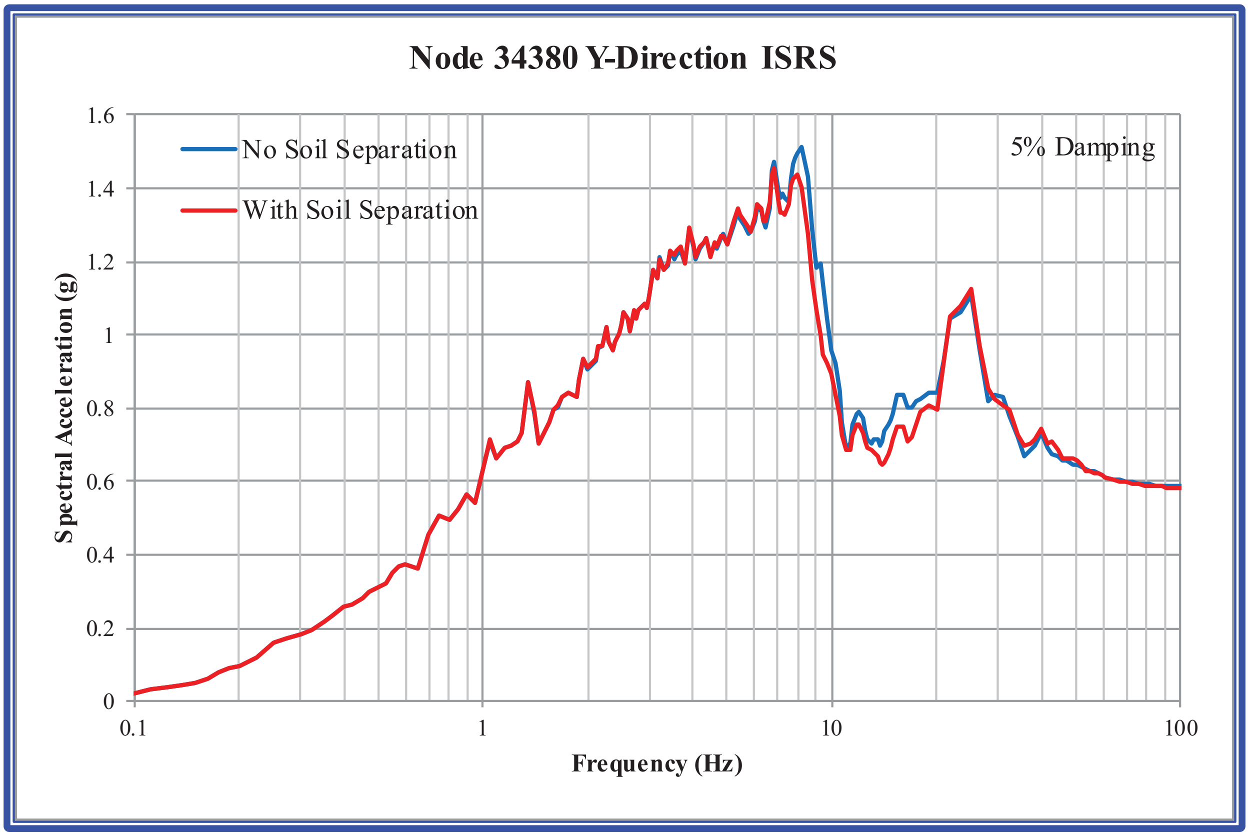


Figure 3.7.2-138: CRB - Vertical (Z) ISRS, Node 34380, Slab between Grid Line CB-D and CB-E at El. 63', Capitola Input

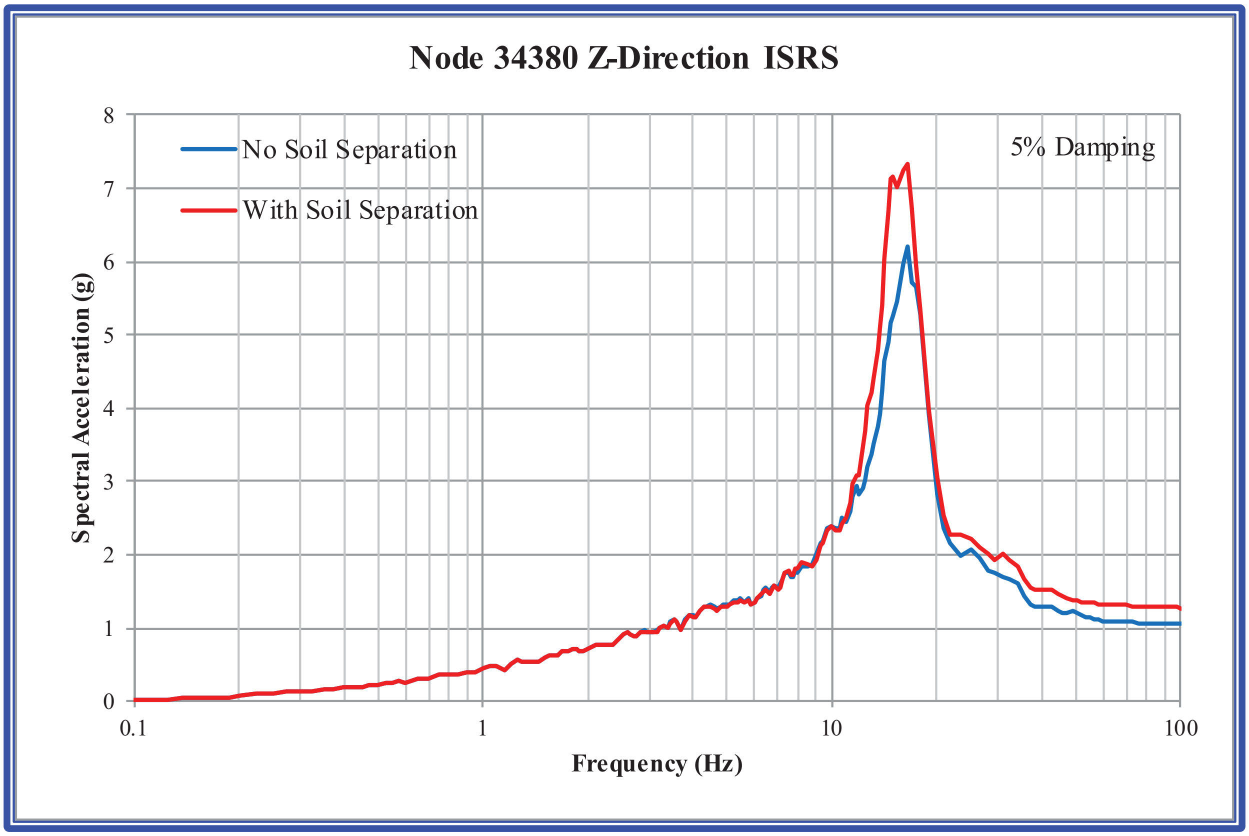


Figure 3.7.2-139: Cracked CRB Transfer Function Amplitudes, X Response at Node 34380, Slab Between Grid Line CB-D and CB-E at El. 63' for Soil Type 7

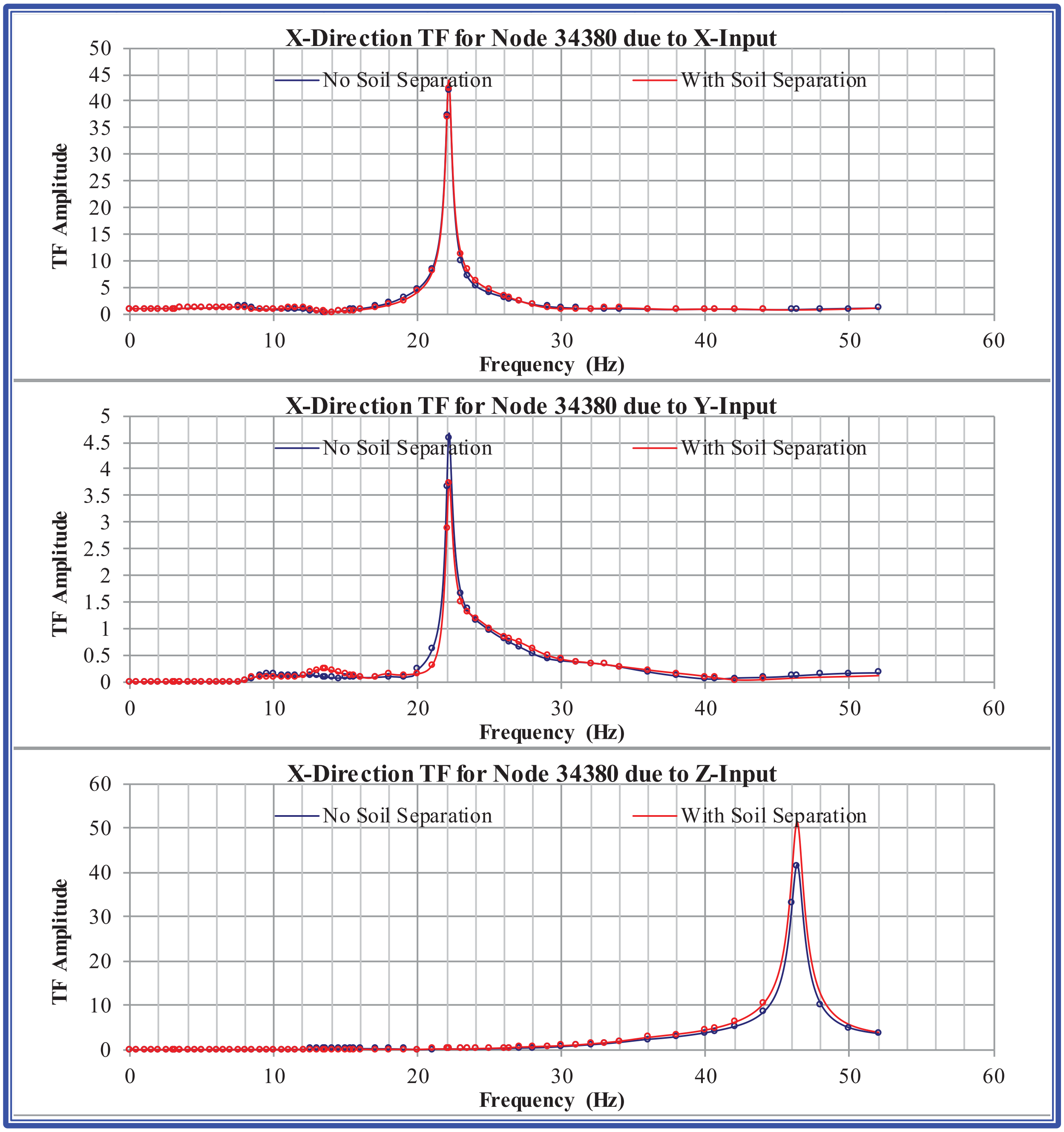


Figure 3.7.2-140: Cracked CRB Transfer Function Amplitudes, Y Response at Node 34380, Slab Between Grid Line CB-D and CB-E at El. 63 for Soil Type 7

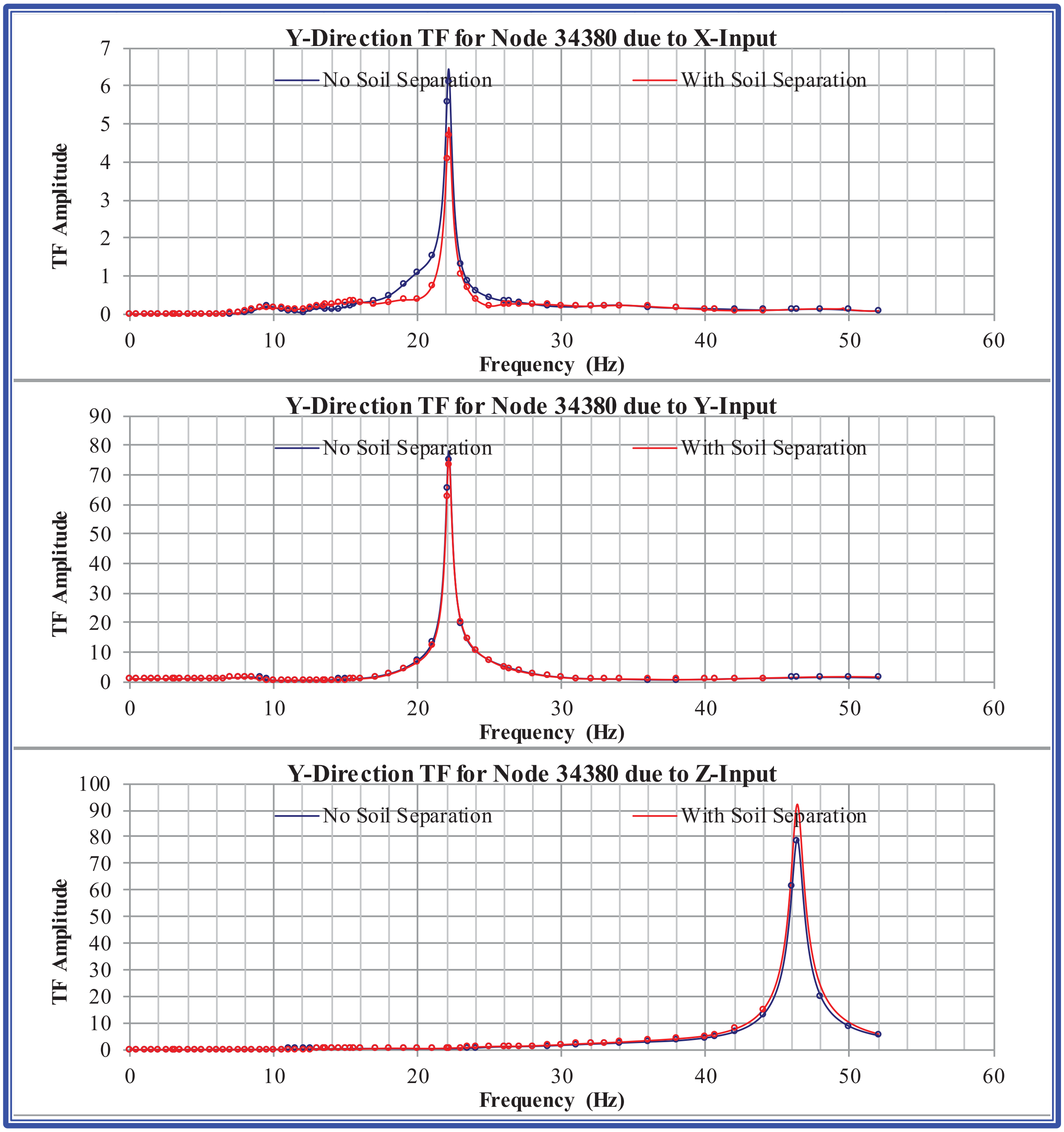


Figure 3.7.2-141: Cracked CRB Transfer Function Amplitudes, Z Response at Node 34380, Slab Between Grid Line CB-D and CB-E at El. 63 for Soil Type 7

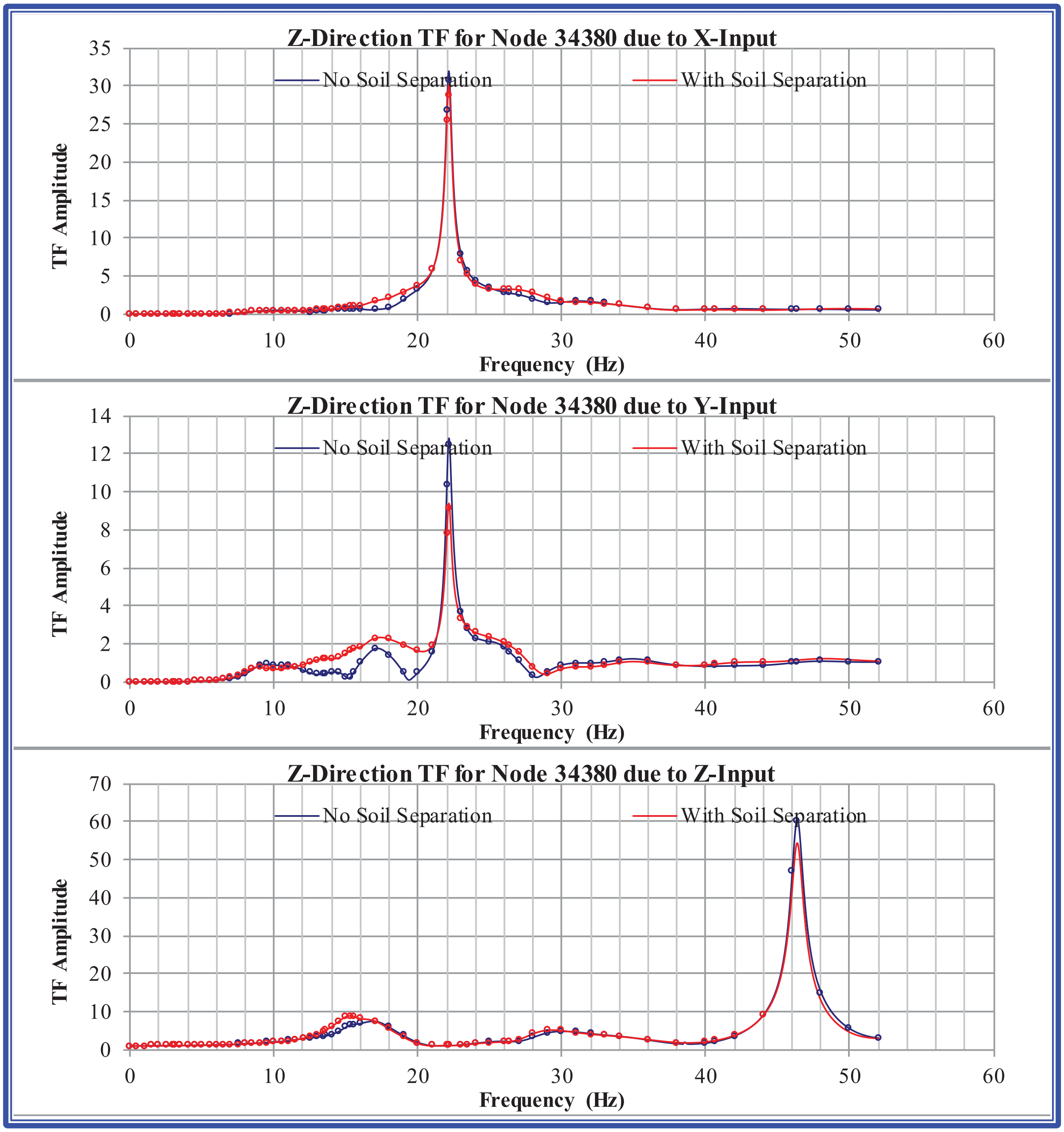


Figure 3.7.2-142: Floor ISRS Locations at TOC EL 24'-0"

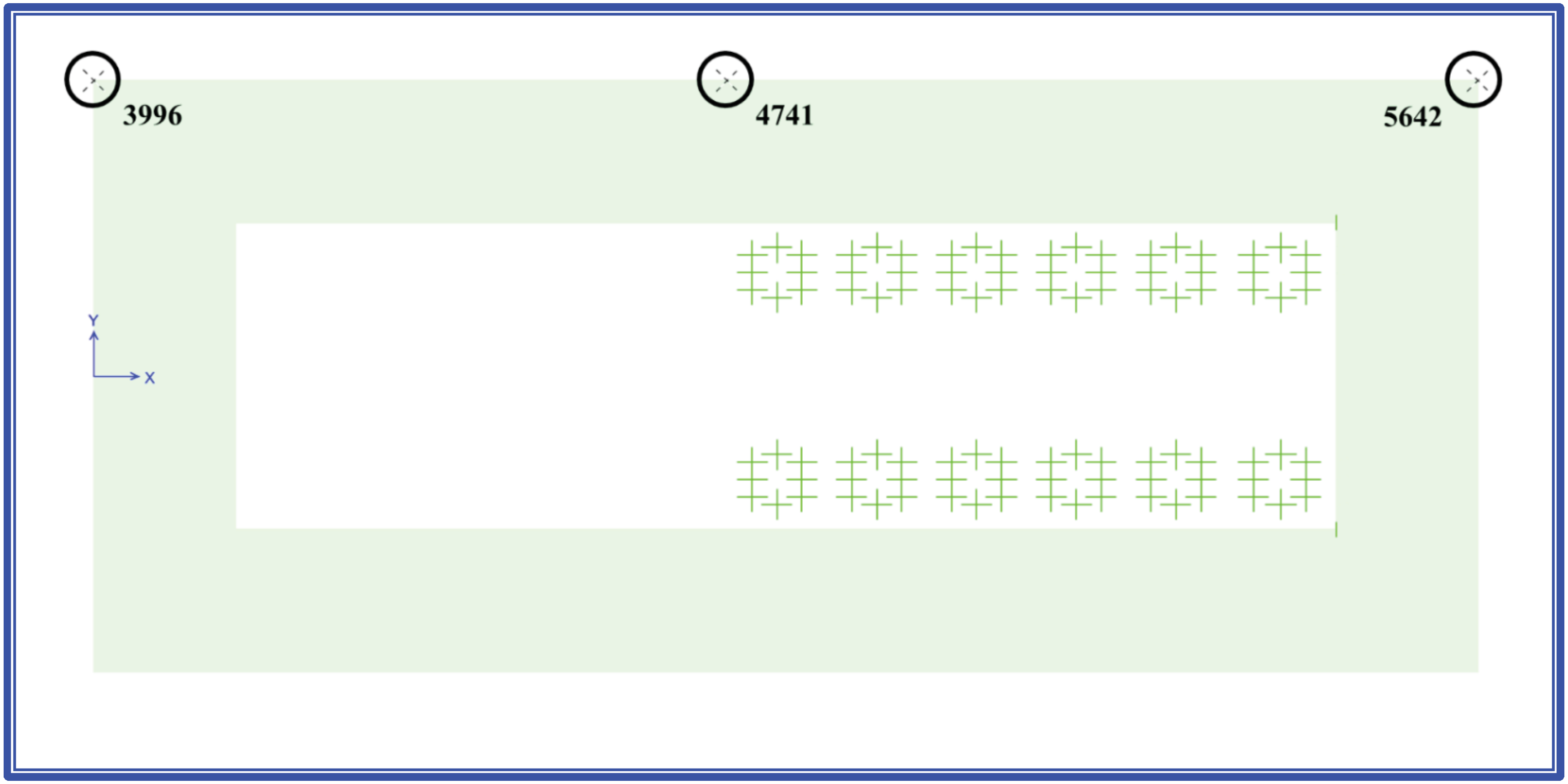


Figure 3.7.2-143: Floor Locations at TOC EL 25'-0"

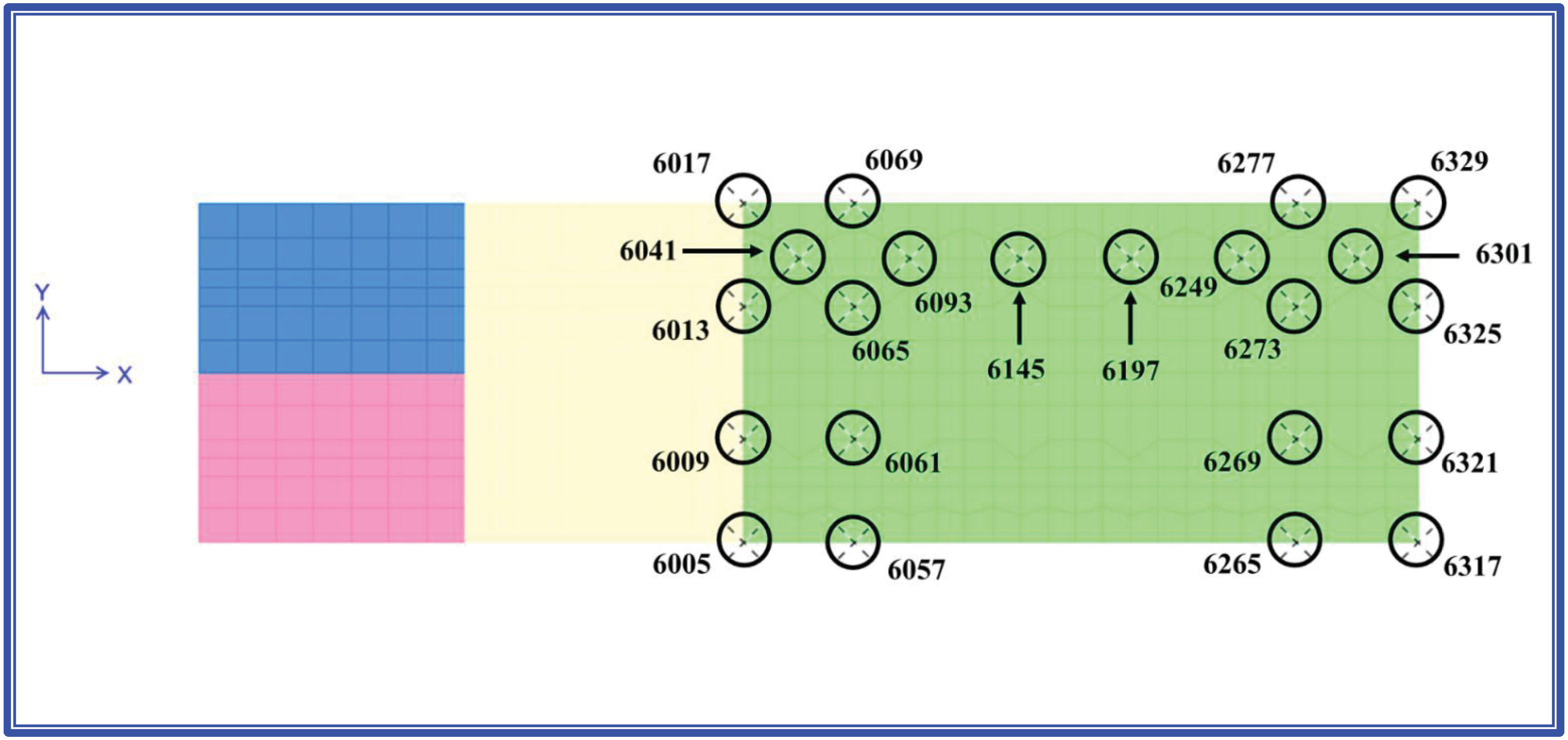


Figure 3.7.2-144: Floor ISRS Locations at TOC EL 50'-0"

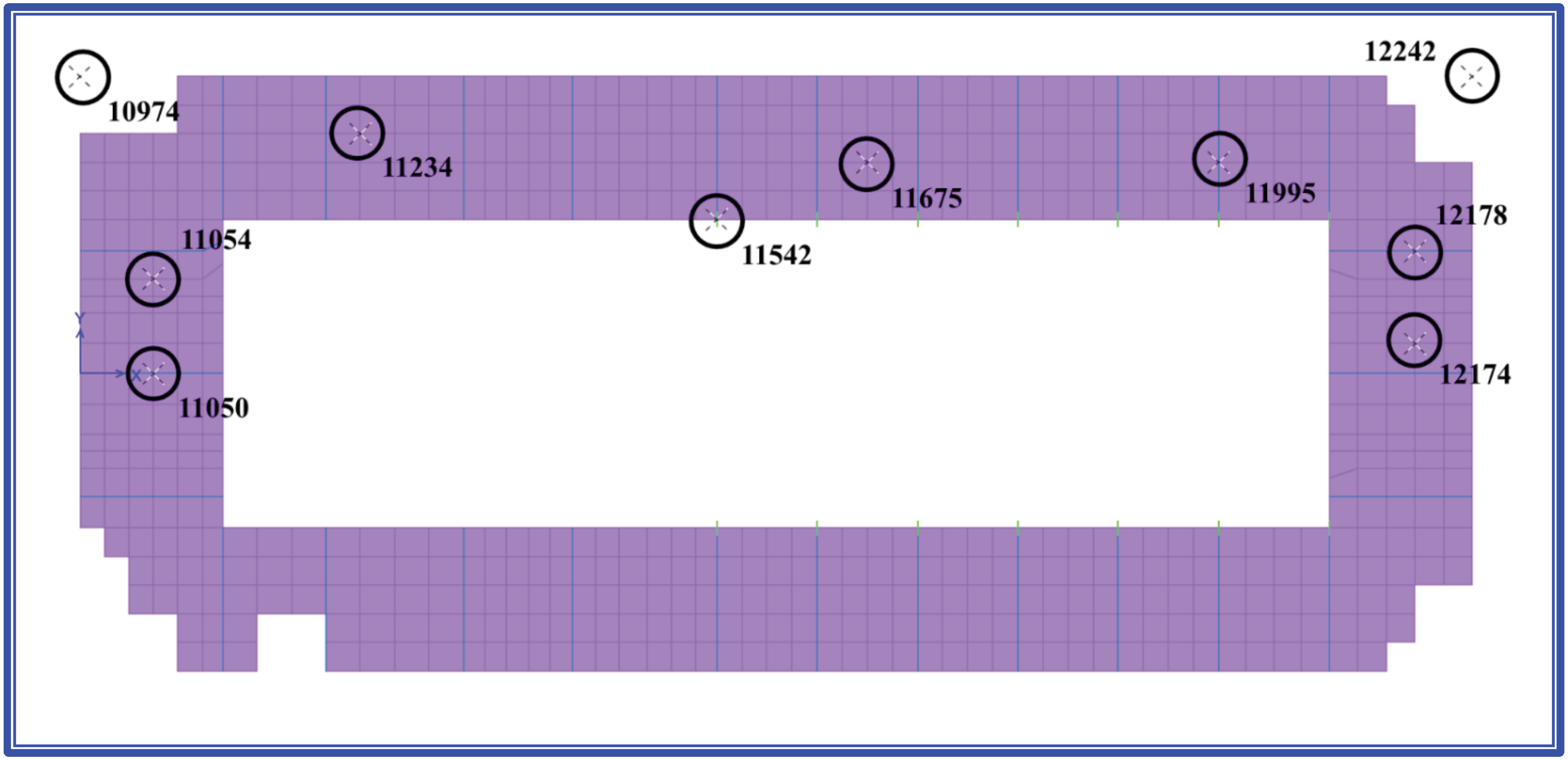


Figure 3.7.2-145: Floor ISRS Locations at TOC EL 75' - 0"

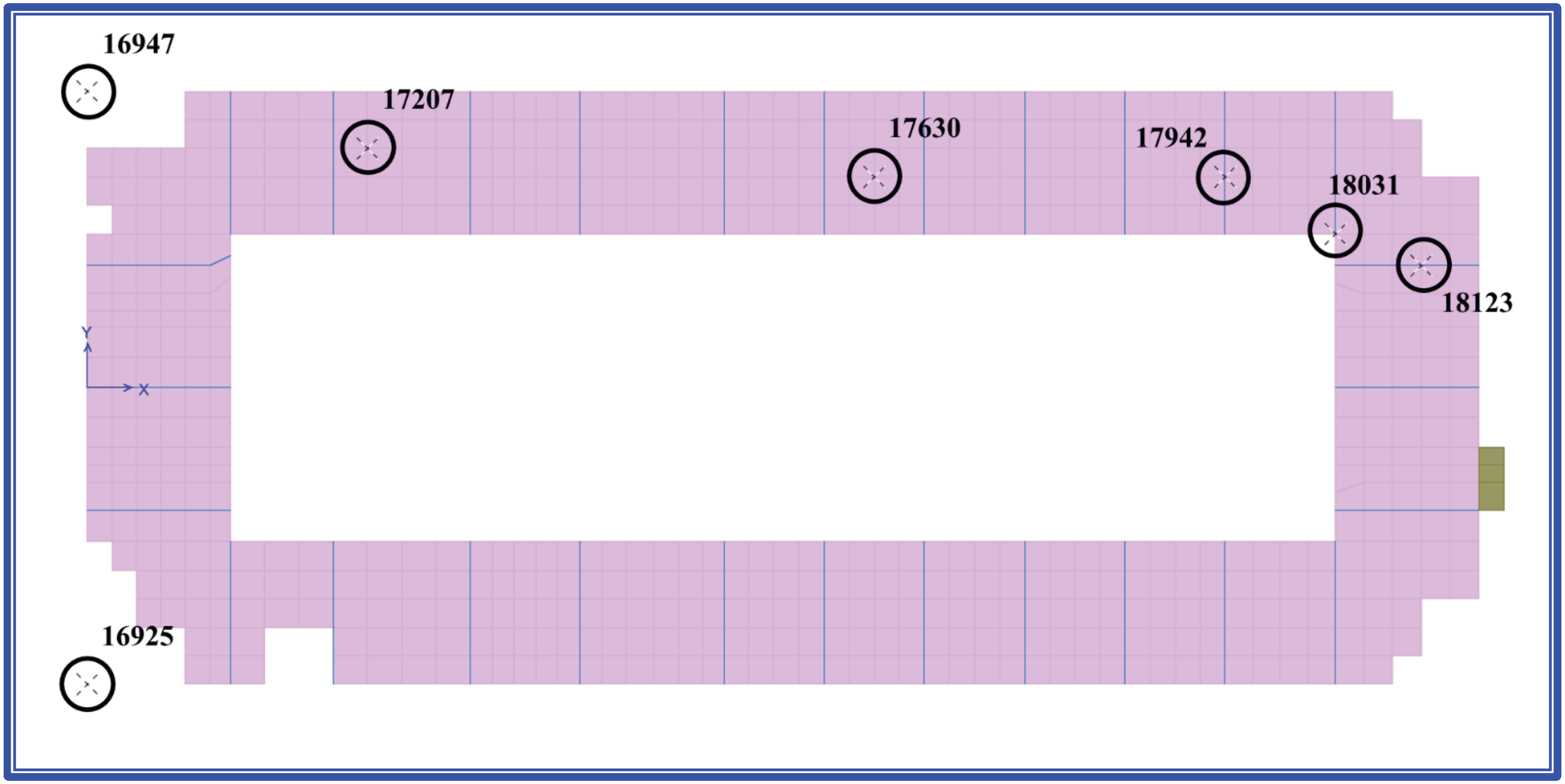


Figure 3.7.2-146: Floor ISRS Locations at TOC EL 100'-0"

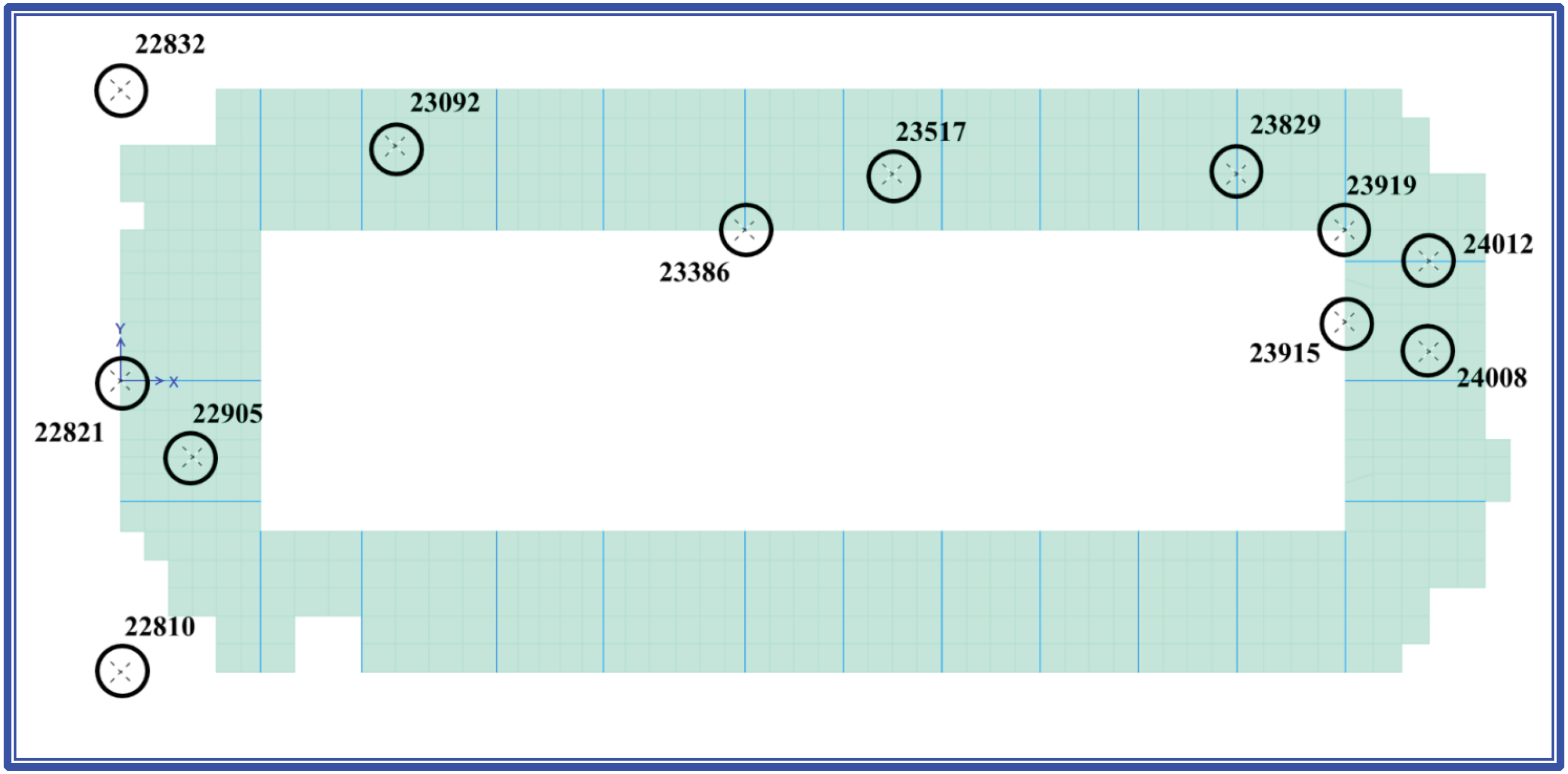


Figure 3.7.2-147: Floor ISRS Locations at TOC EL 126'-0"

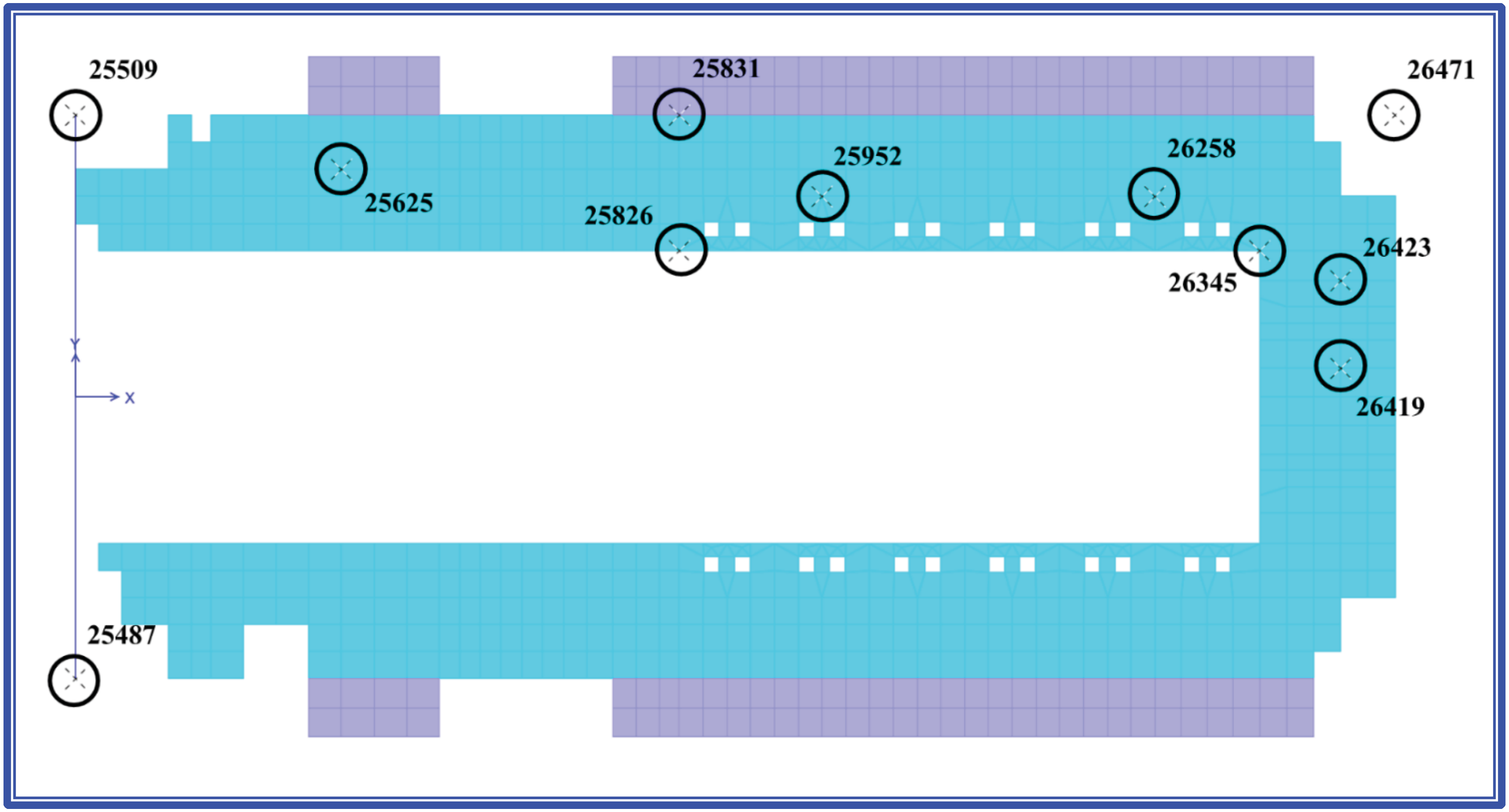


Figure 3.7.2-148: Roof ISRS Locations at TOC EL 181'-0"

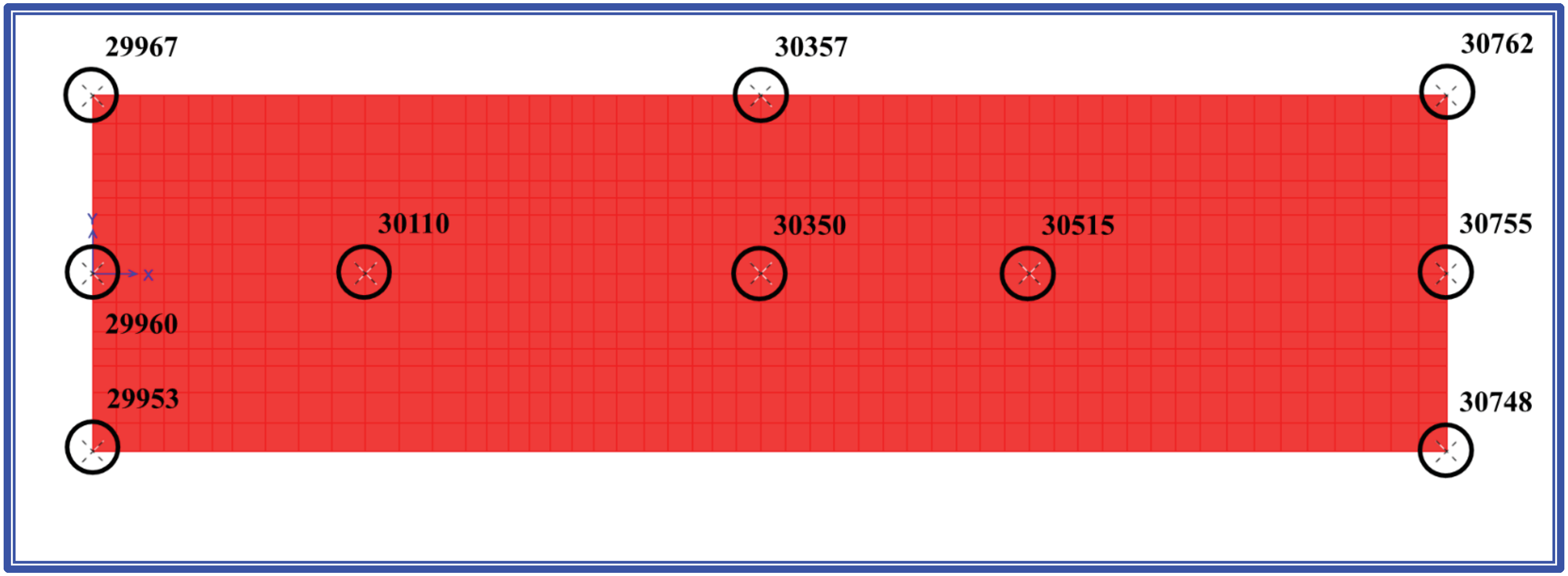


Figure 3.7.2-149: Non-Vertically Propagating Seismic Wave RXB Sensitivity Analysis Cases

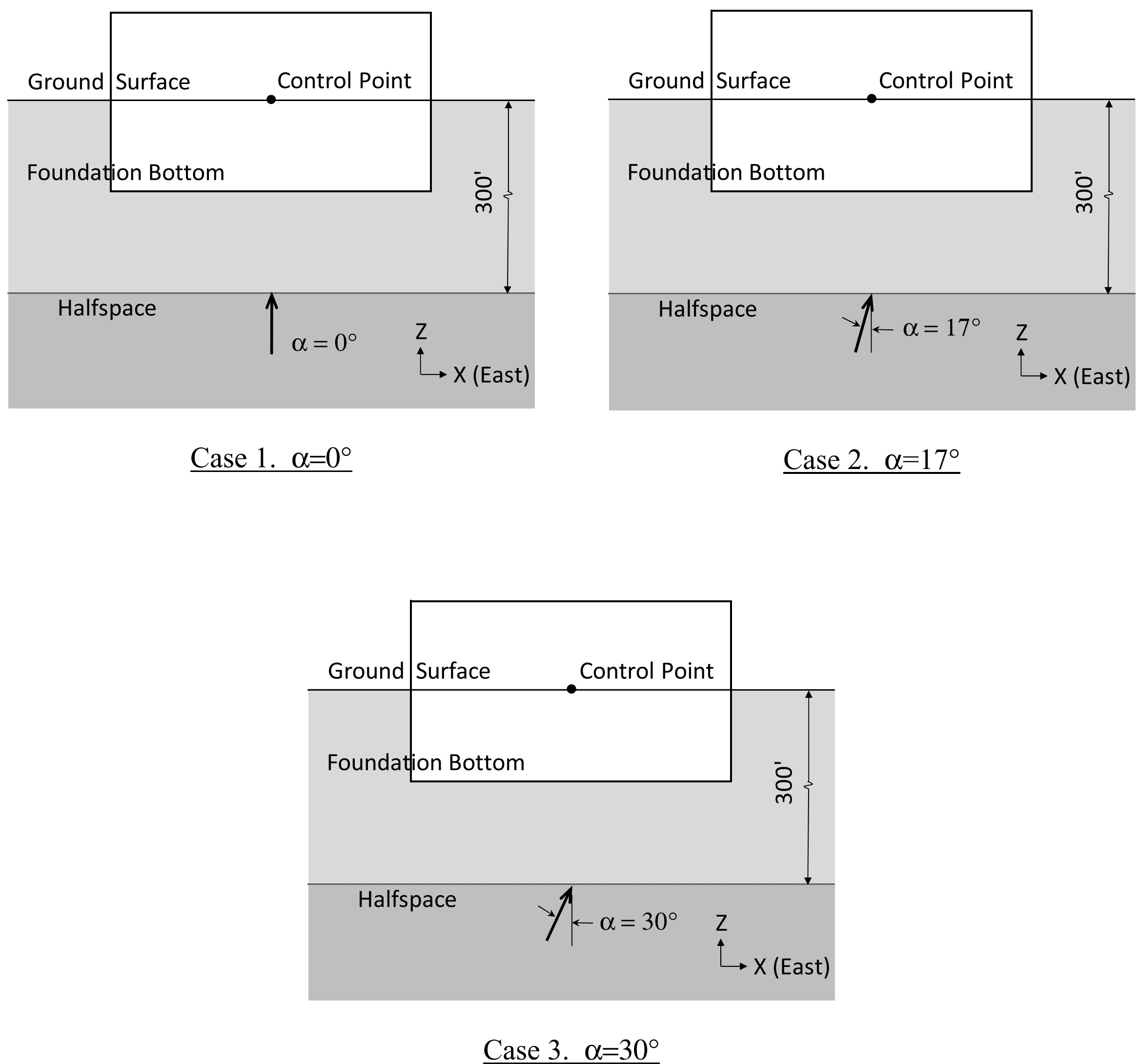


Figure 3.7.2-150: Non-Vertically Propagating Seismic Wave Sensitivity Study with Soil Type 7 - Free Field Uncoupled East-West (X) ARS at Surface, Capitola Input

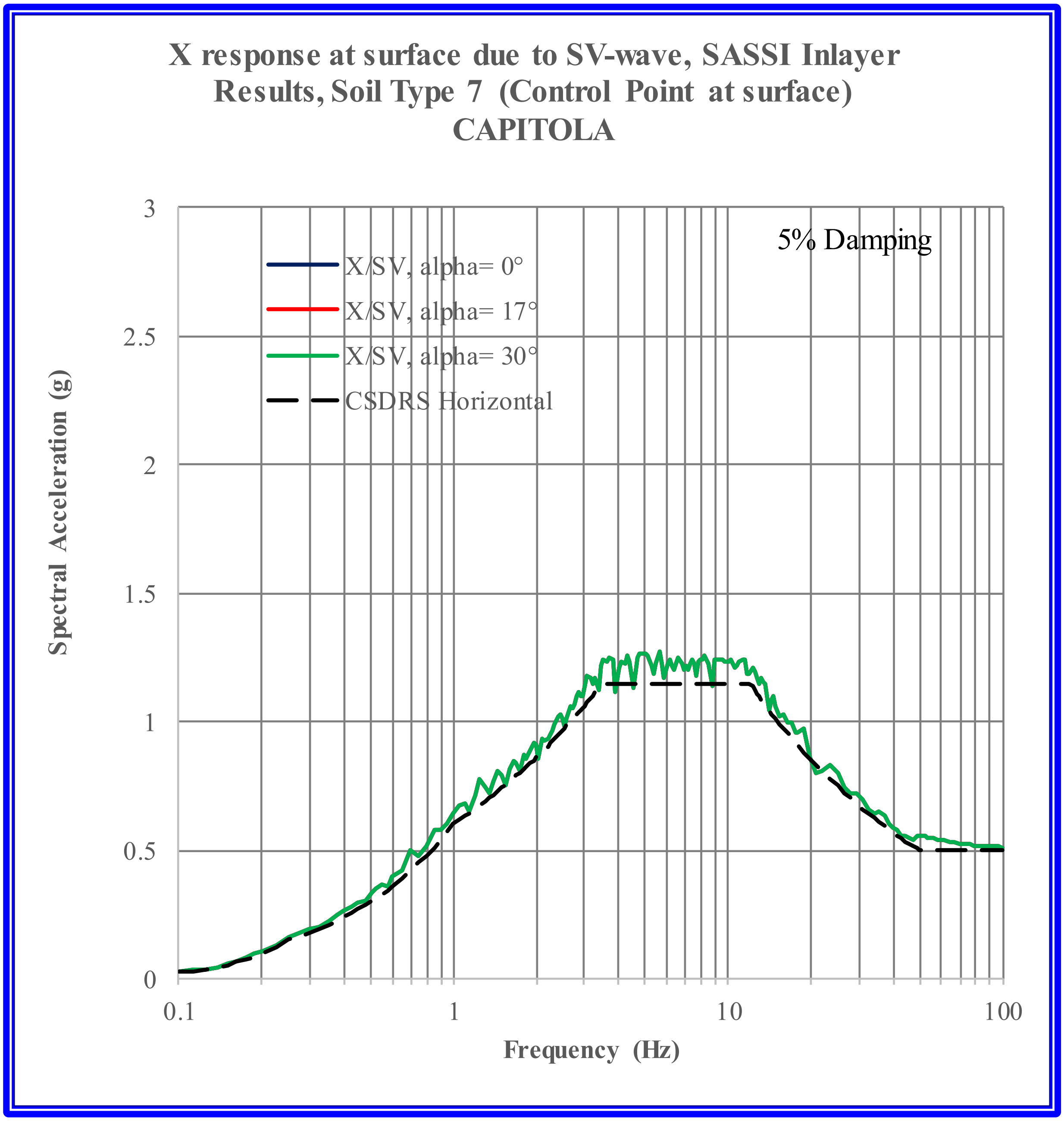


Figure 3.7.2-151: Non-Vertically Propagating Seismic Wave Sensitivity Study with Soil Type 7 - Free Field East-West (X) ARS Depth 85', Capitola Input, Alpha = 30 degrees

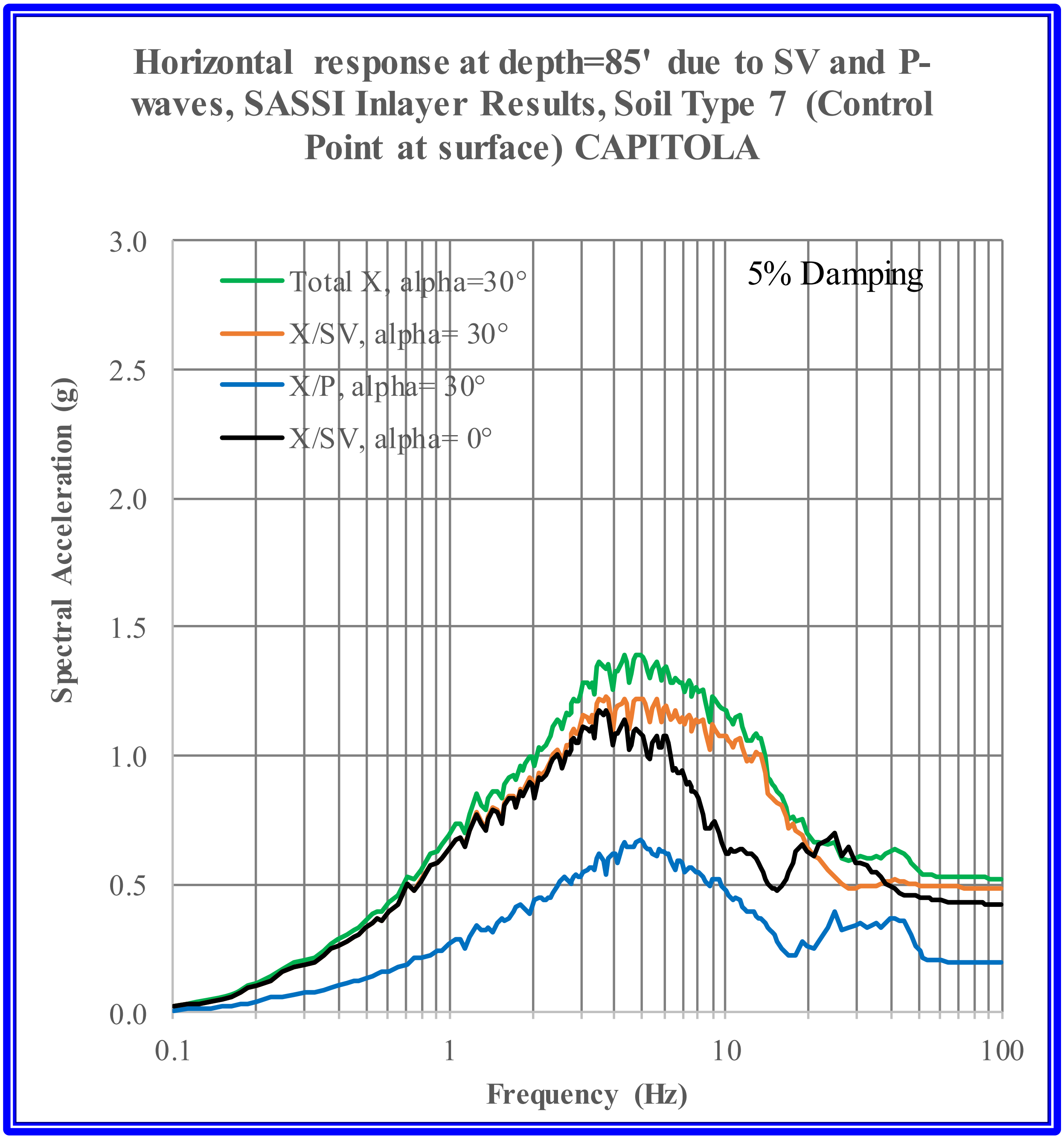


Figure 3.7.2-152: Non-Vertically Propagating Seismic Wave Sensitivity Study with Soil Type 7 - Comparison of Combined Free-Field East-West (X) ARS at Depth 85', Capitola Input, Alpha = 0 Degrees, 17 Degrees, 30 Degrees

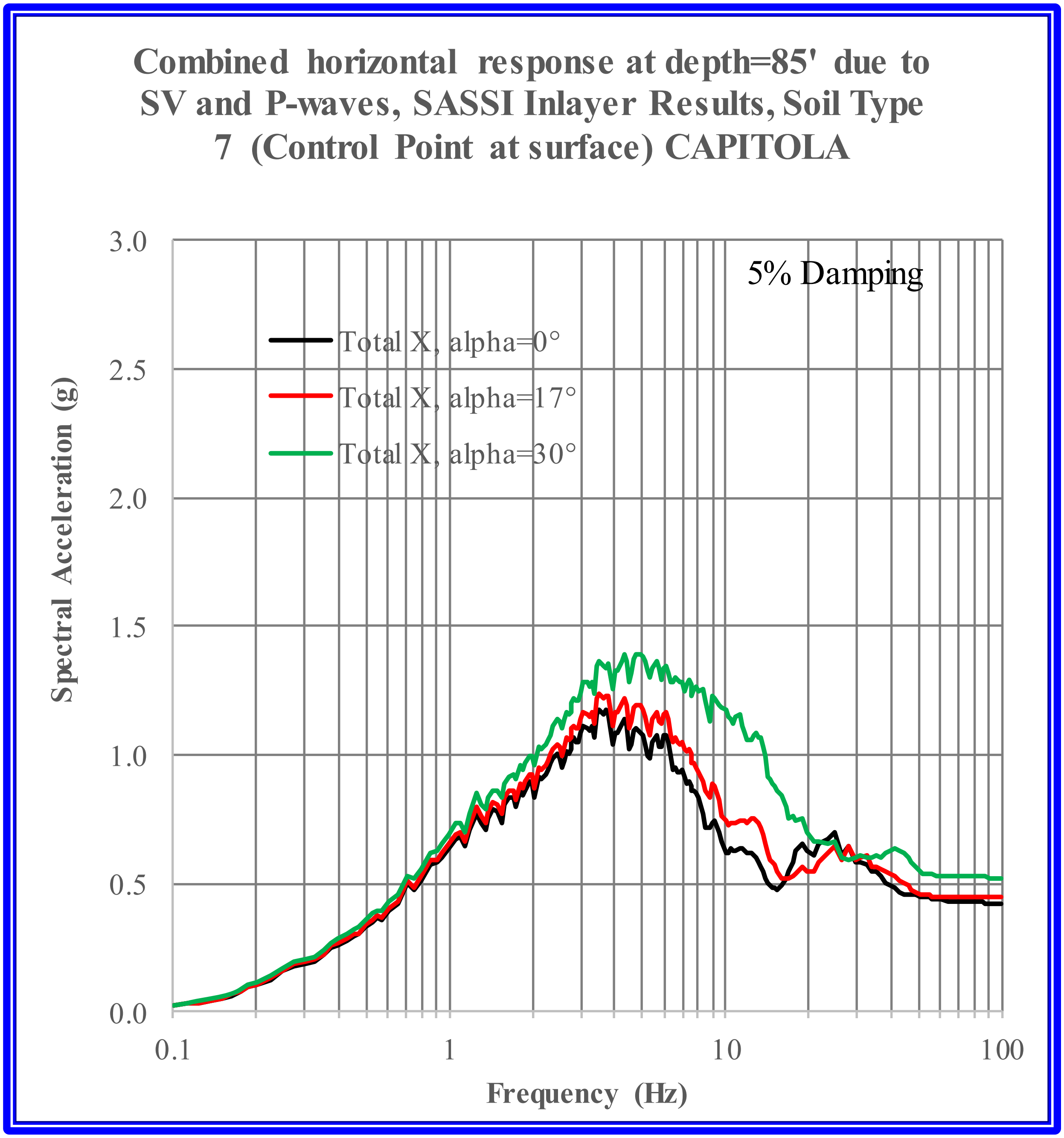


Figure 3.7.2-153: Non-Vertically Propagating Seismic Wave Sensitivity Study for the RXB - Uncombined East-West (X) ISRS, Node 3996, Top of Basemat, NW Corner, Capitola Input

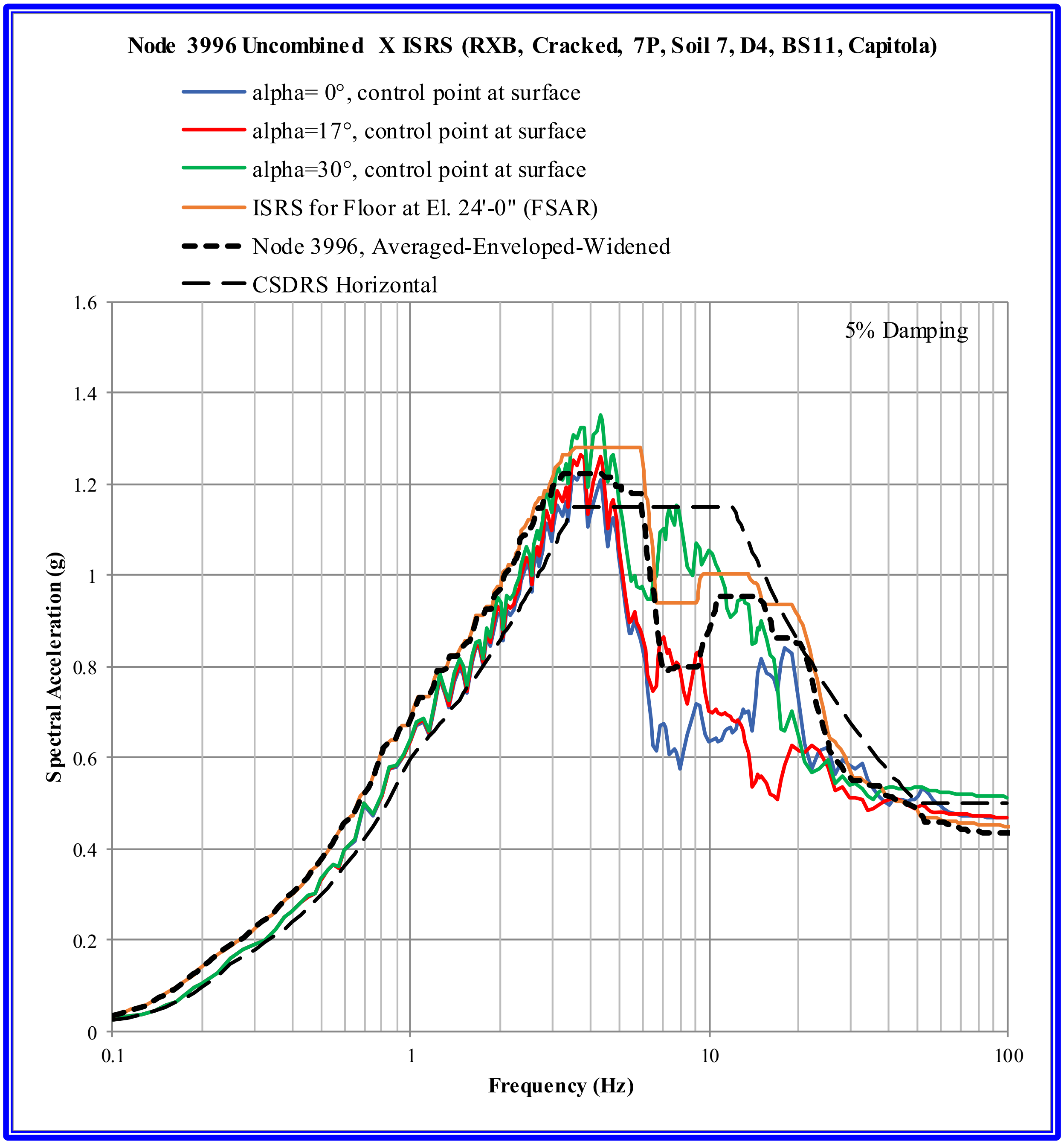


Figure 3.7.2-154: Non-Vertically Propagating Seismic Wave Sensitivity Study for the RXB – Uncombined North-South (Y) ISRS, Node 3996, Top of Basemat, NW Corner, Capitola Input

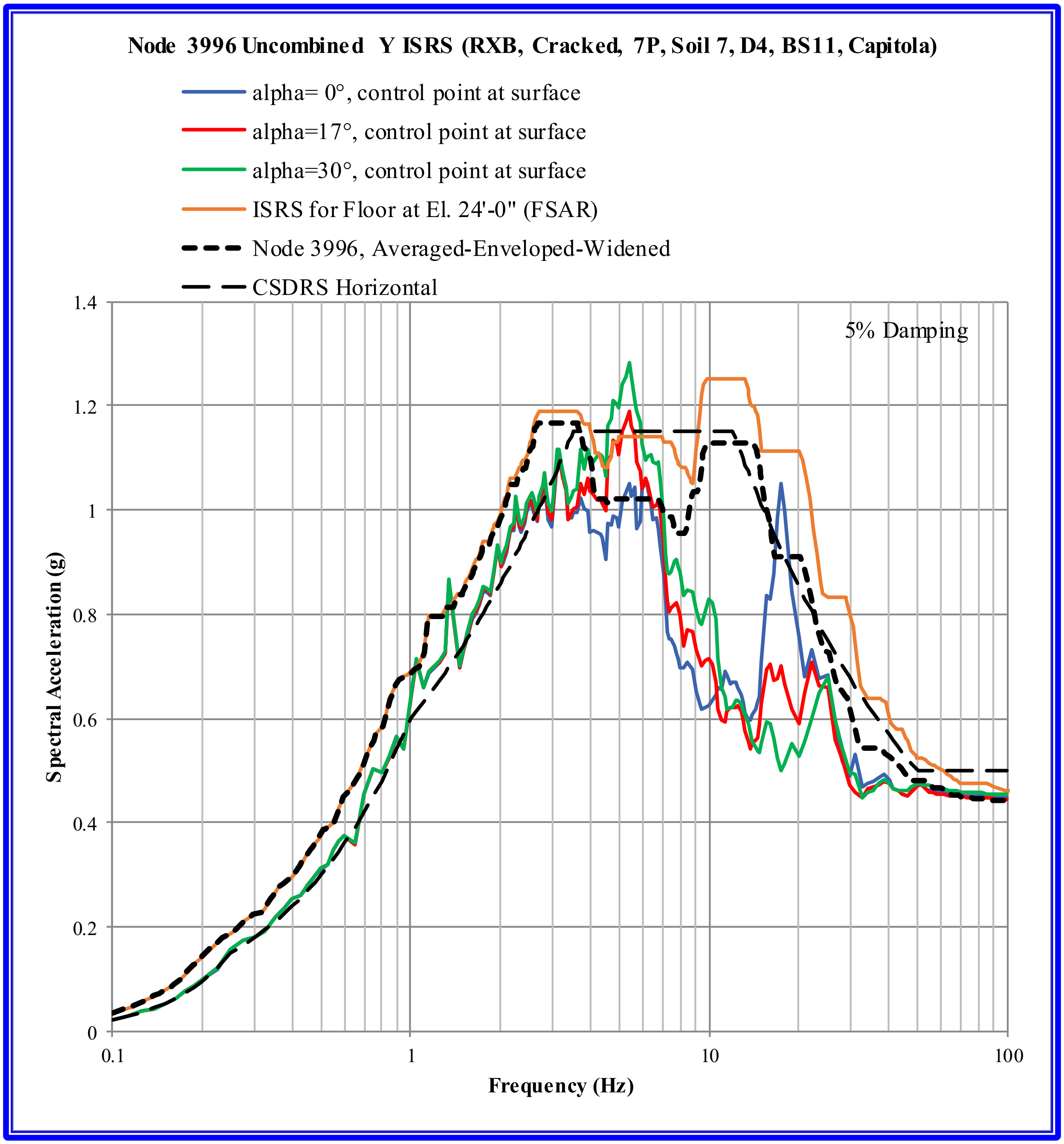


Figure 3.7.2-155: Non-Vertically Propagating Seismic Wave Sensitivity Study for the RXB – Uncombined Vertical (Z) ISRS, Node 3996, Top of Basemat, NW Corner, Capitola Input

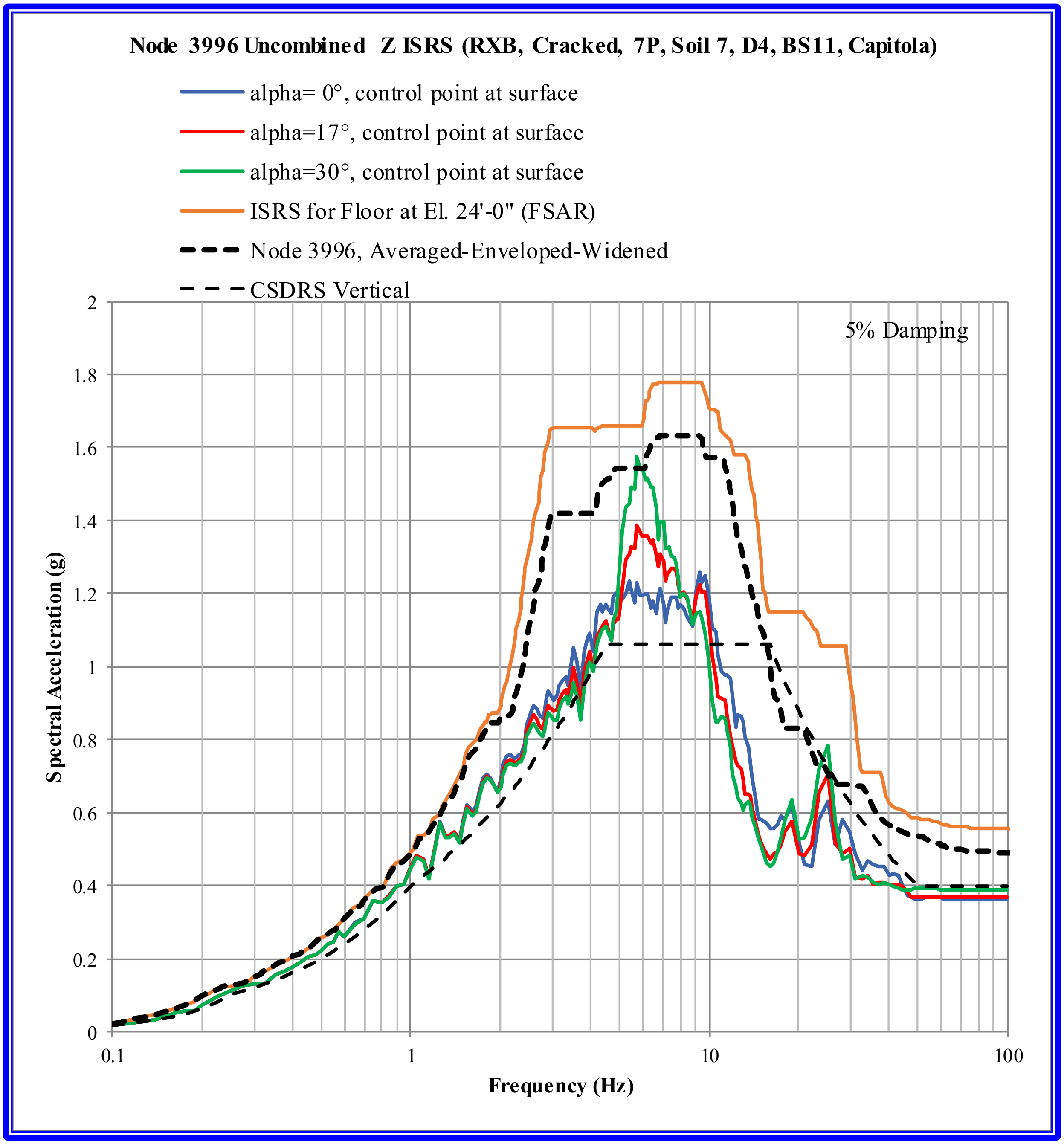


Figure 3.7.2-156: In-Structure Response Spectra at the Containment Vessel Skirt of NuScale Power Module 1, Capitola Input

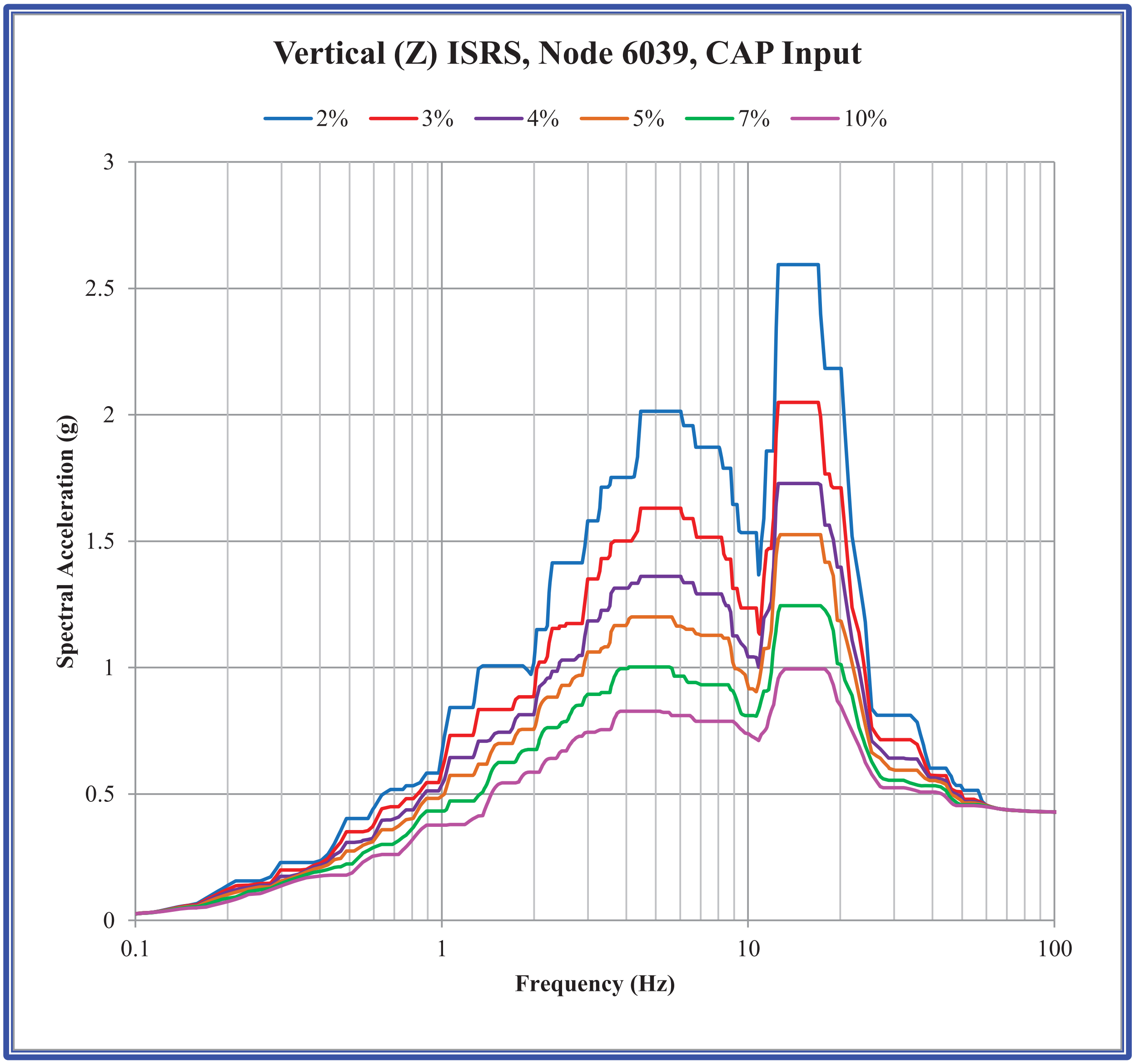


Figure 3.7.2-157: In-Structure Response Spectra at the Containment Vessel Skirt of NuScale Power Module 6, Capitola Input

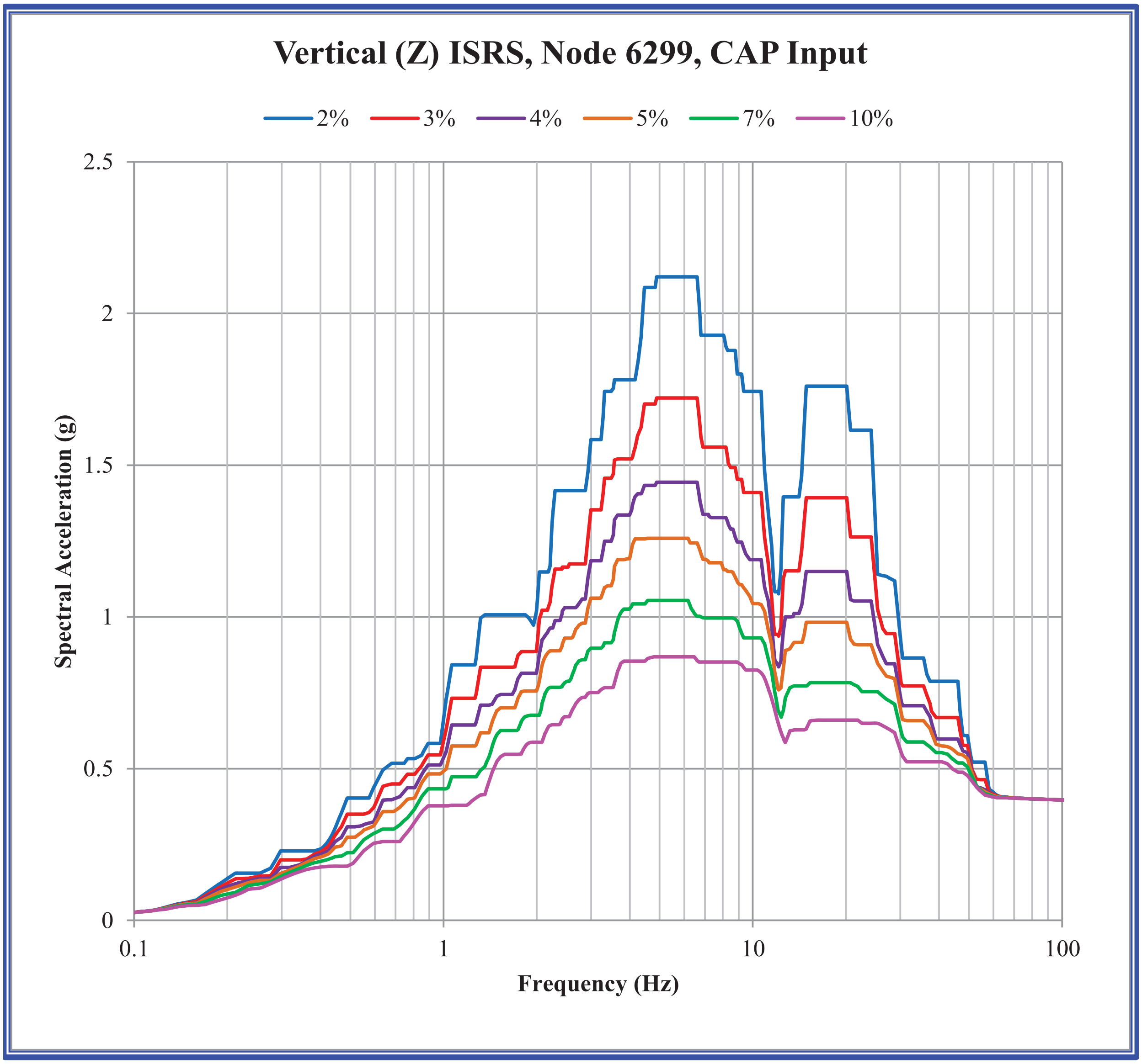


Figure 3.7.2-158: In-Structure Response Spectra at the East Lug of NuScale Power Module 1, Capitola Input

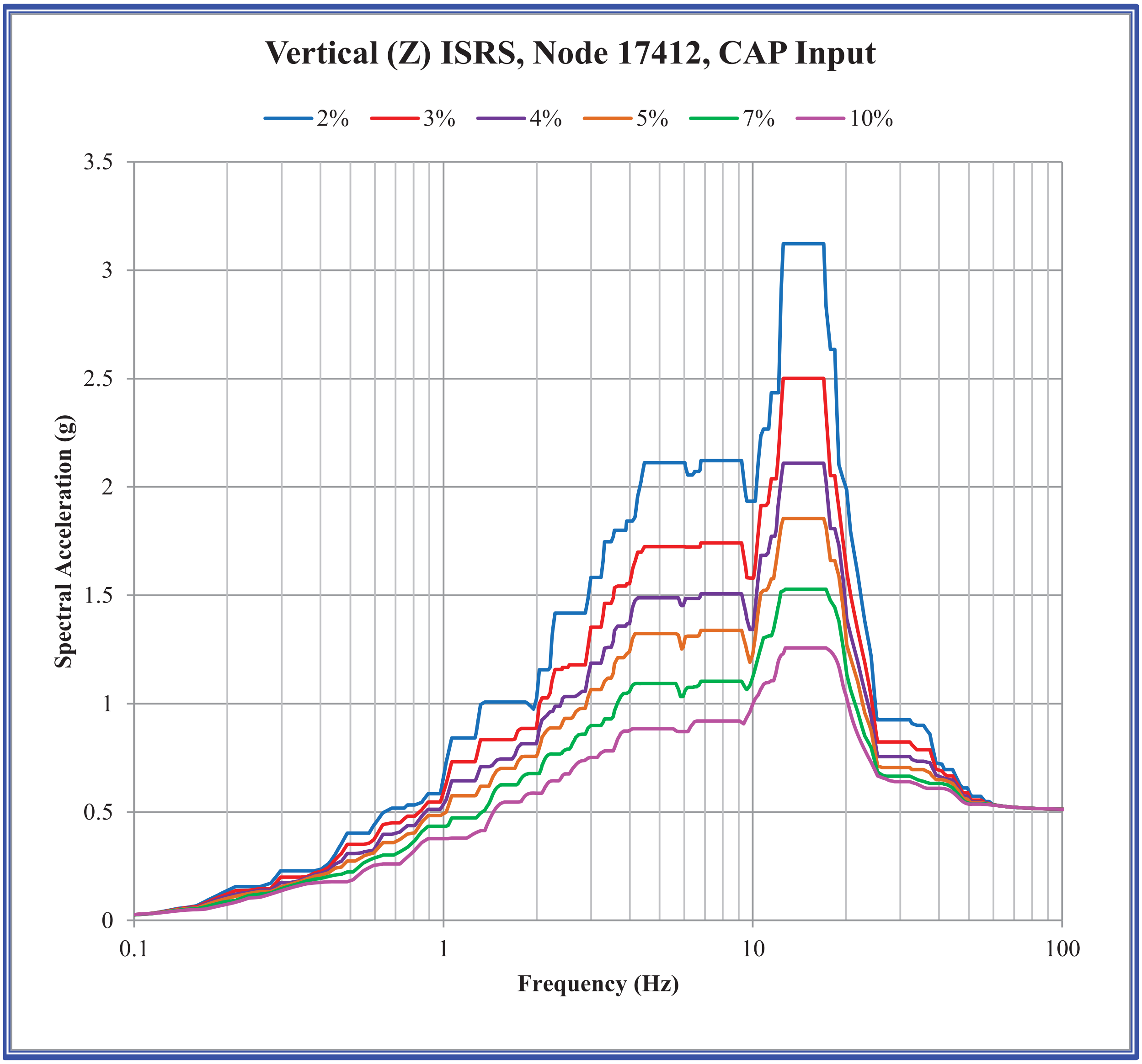


Figure 3.7.2-159: In-Structure Response Spectra at the North Lug of NuScale Power Module 1, Capitola Input

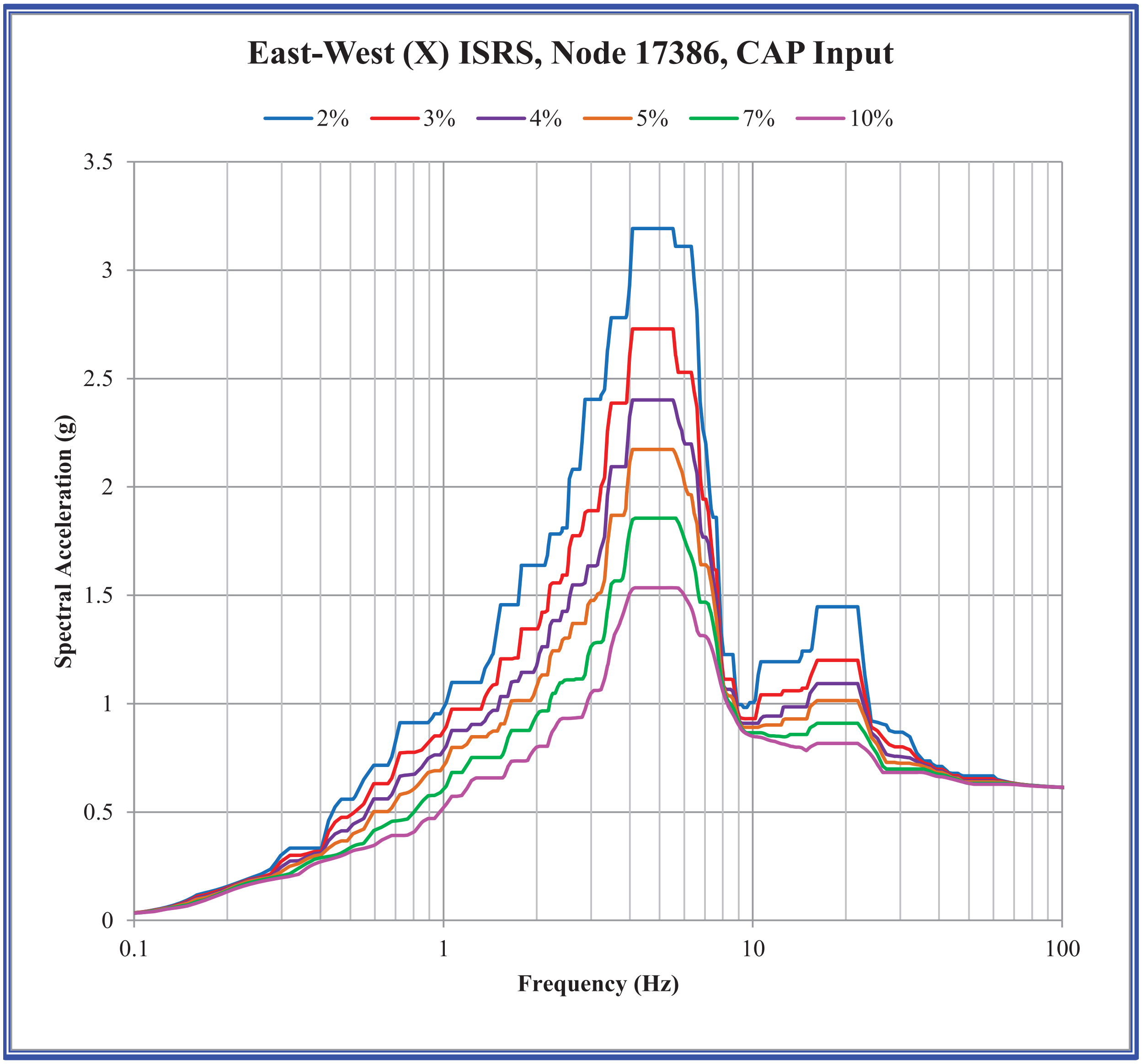


Figure 3.7.2-160: In-Structure Response Spectra at the West Lug of NuScale Power Module 1, Capitola Input

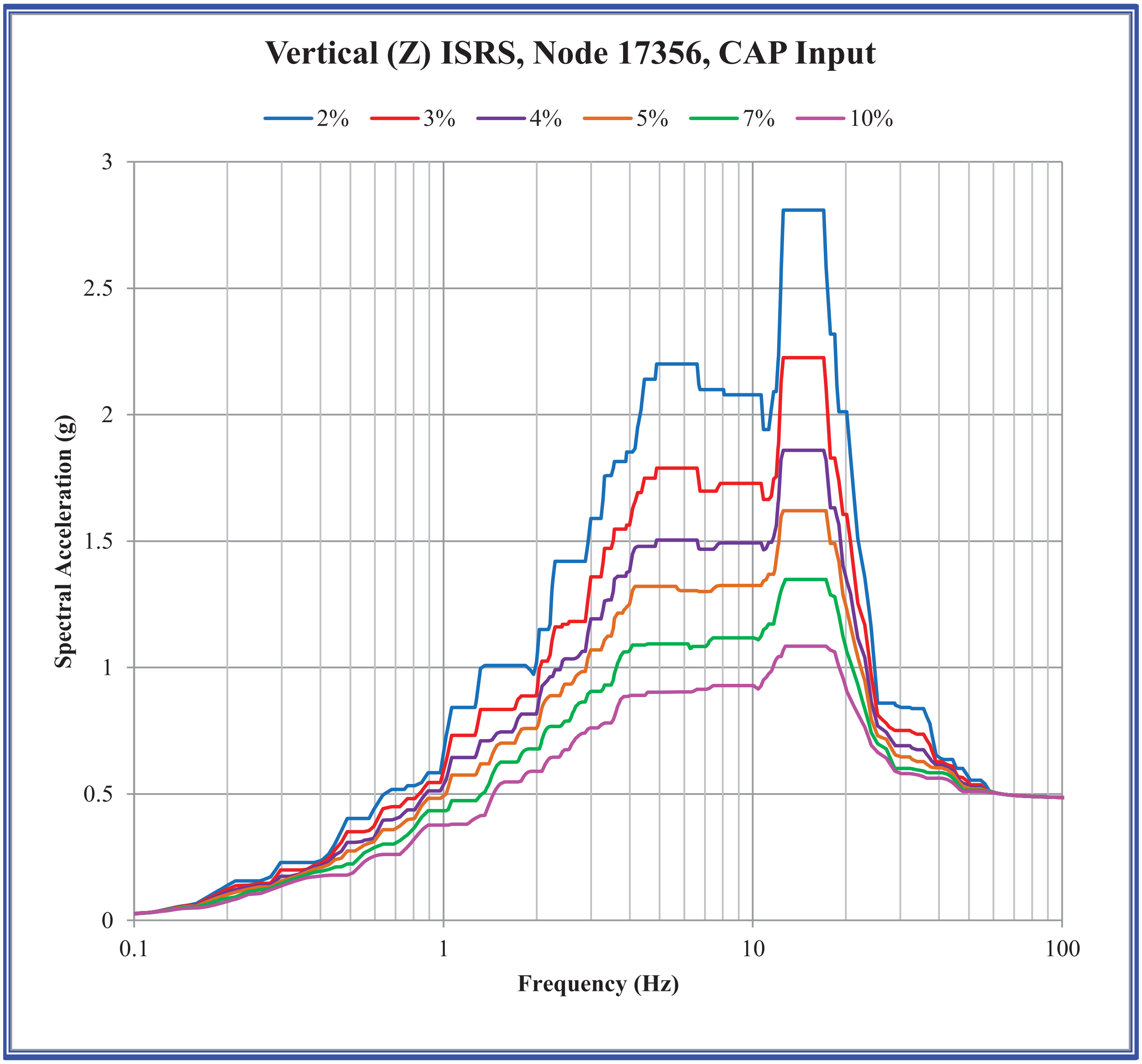


Figure 3.7.2-161: In-Structure Response Spectra at the East Lug of NuScale Power Module 6, Capitola Input

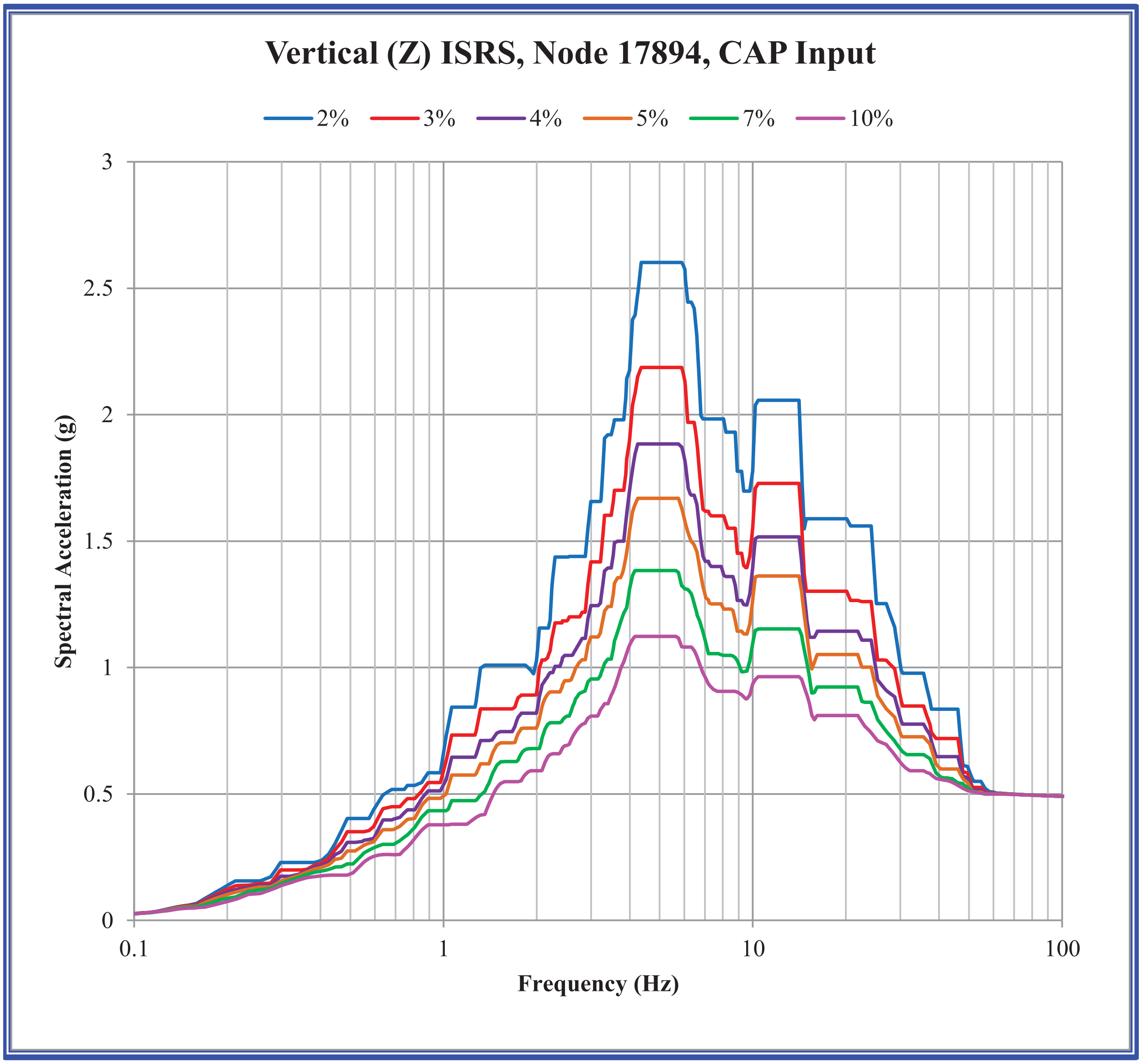


Figure 3.7.2-162: In-Structure Response Spectra at the North Lug of NuScale Power Module 6, Capitola Input

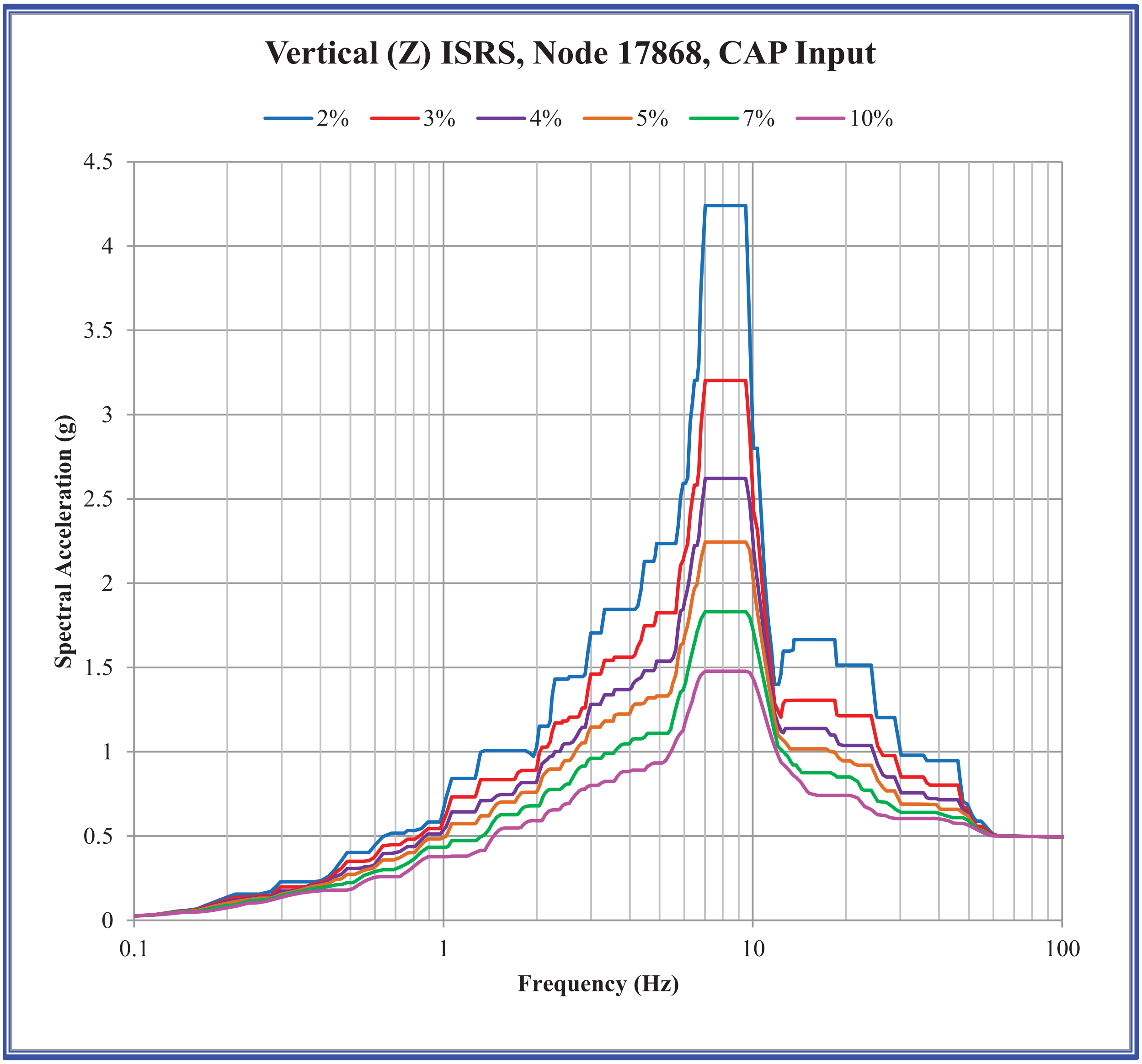


Figure 3.7.2-163: In-Structure Response Spectra at the West Lug of NuScale Power Module 6, Capitola Input

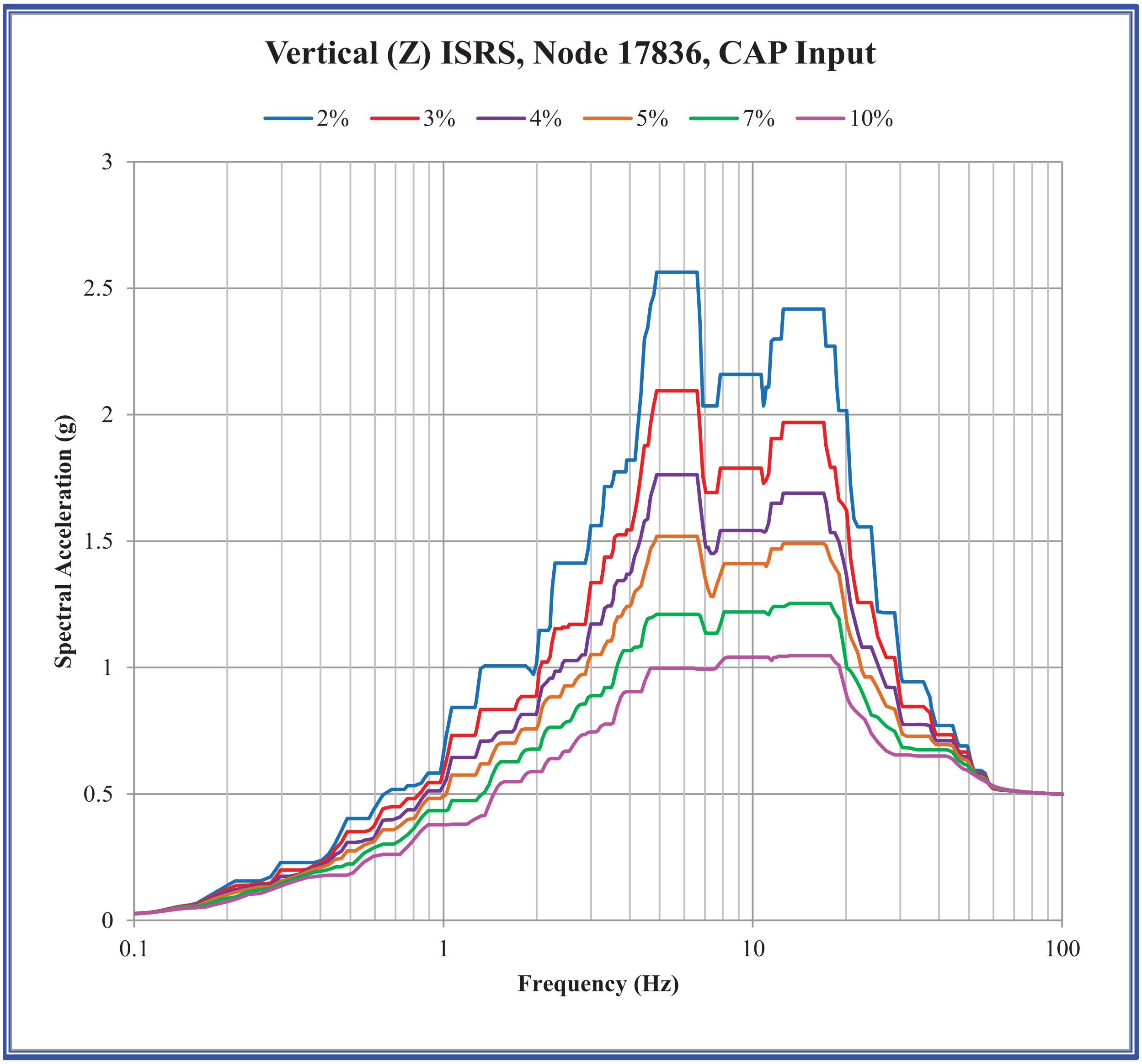


Figure 3.7.2-164: In-Structure Response Spectra at the Reactor Flange Tool Base, Node 6328, due to X, Y, and Z Inputs of Capitola Excitation for Soil Type 7, Uncracked Condition

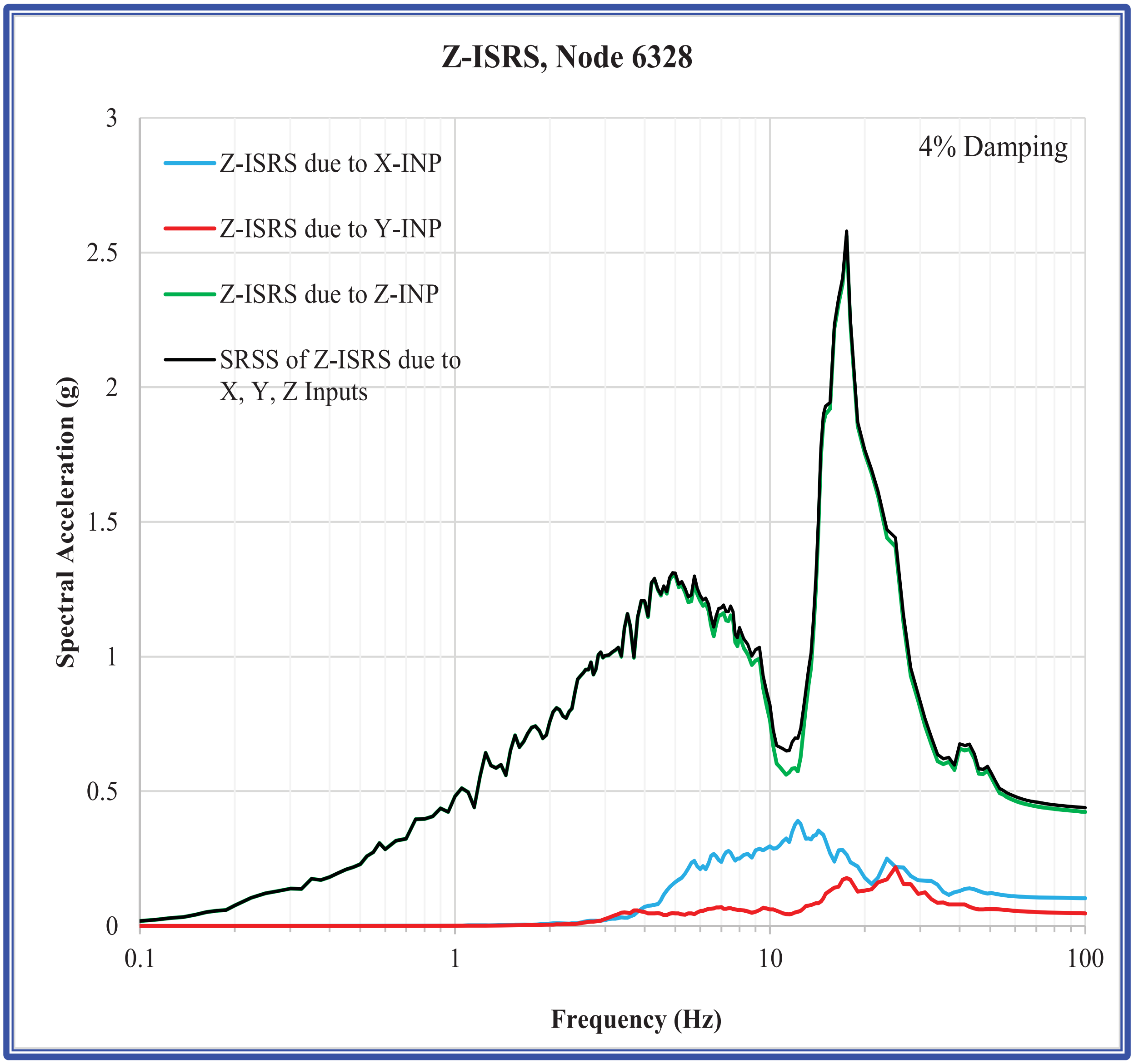


Figure 3.7.2-165: In-Structure Response Spectra at the Reactor Flange Tool Base, Node 6329, due to X, Y, and Z inputs of Capitola Excitation for Soil Type 7, Uncracked Condition

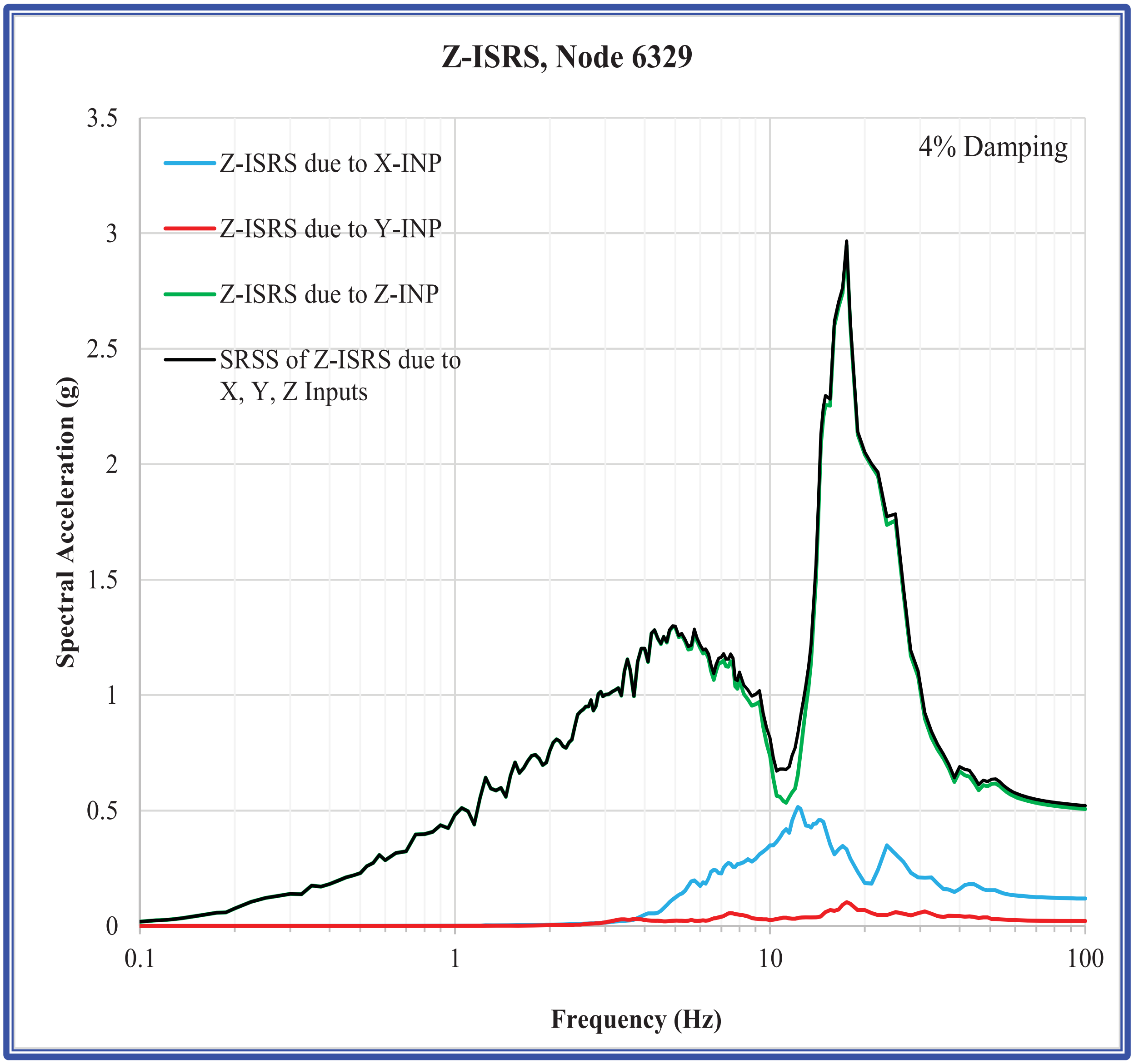


Figure 3.7.2-166: In-Structure Response Spectra at the Reactor Flange Tool Base, Node 6330, due to X, Y, and Z Inputs of Capitola Excitation for Soil Type 7, Uncracked Condition

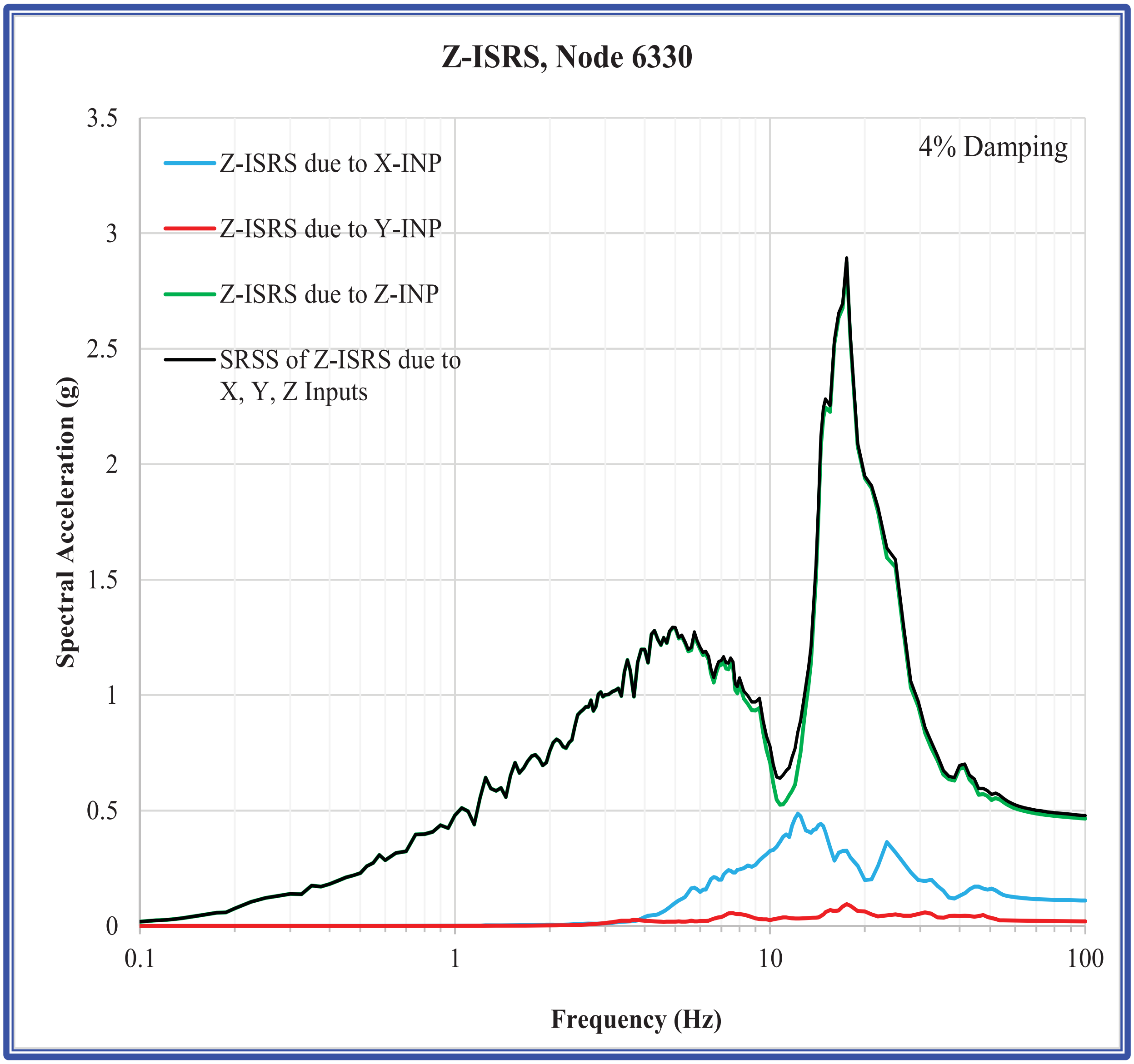


Figure 3.7.2-167: In-Structure Response Spectra at the Reactor Flange Tool Base, Node 6331, due to X, Y, and Z Inputs of Capitola Excitation for Soil Type 7, Uncracked Condition

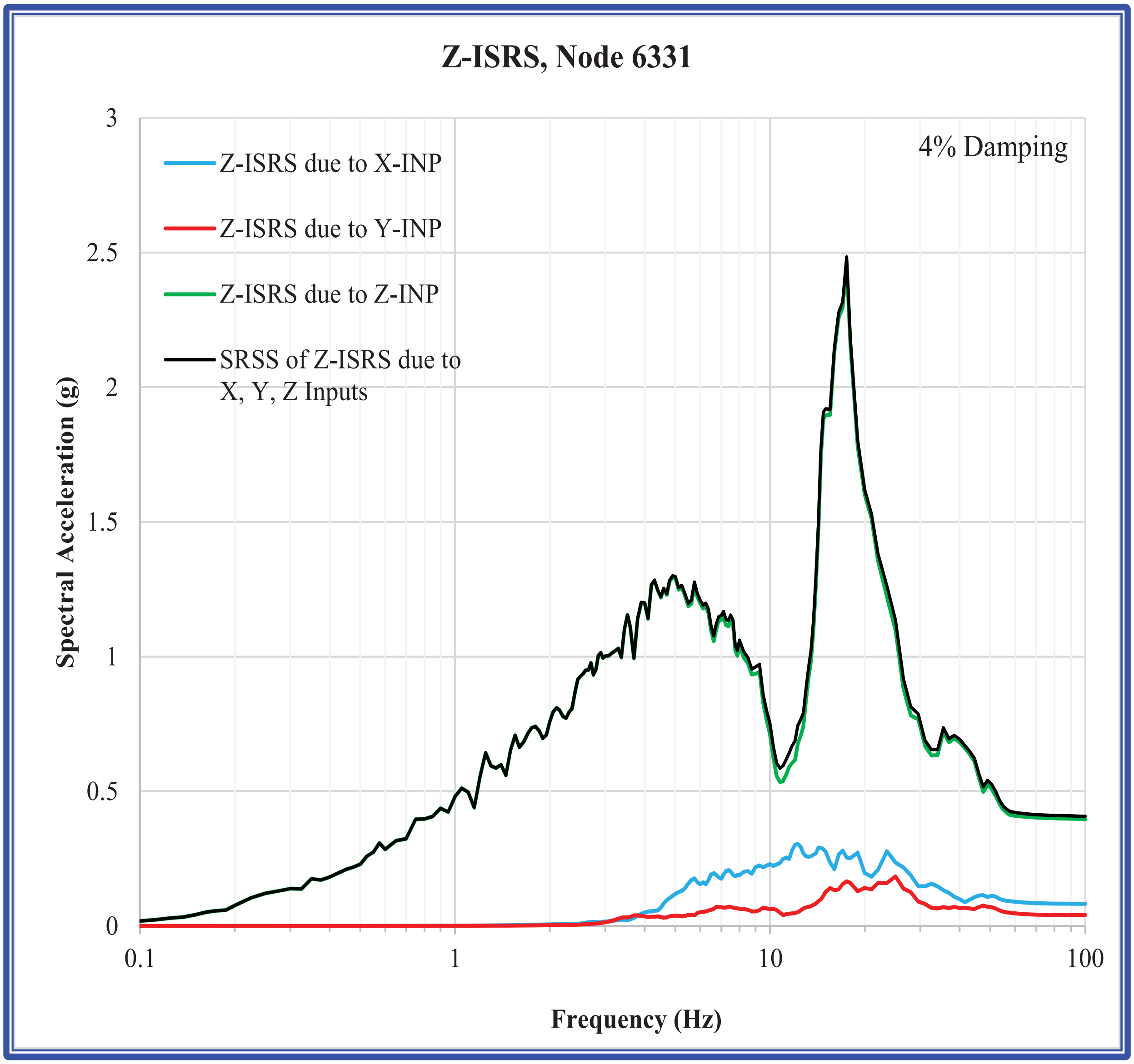


Figure 3.7.2-168: In-Structure Response Spectra at the Reactor Flange Tool Base, Node 6328, due to X, Y, and Z Inputs of Capitola Excitation for Soil Type 7, Cracked Condition

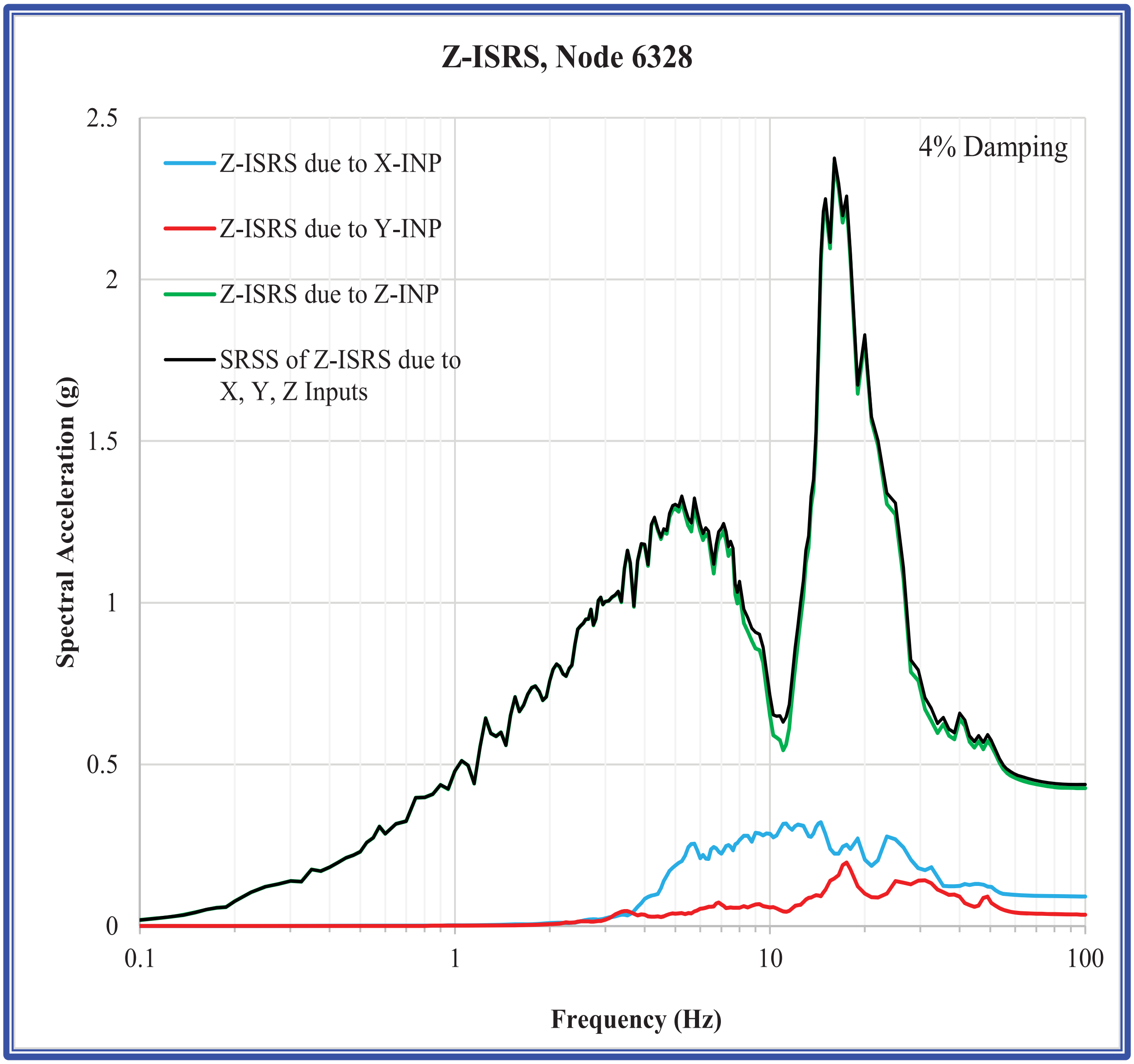


Figure 3.7.2-169: In-Structure Response Spectra at the Reactor Flange Tool Base, Node 6329, due to X, Y, and Z Inputs of Capitola Excitation for Soil Type 7, Cracked Condition

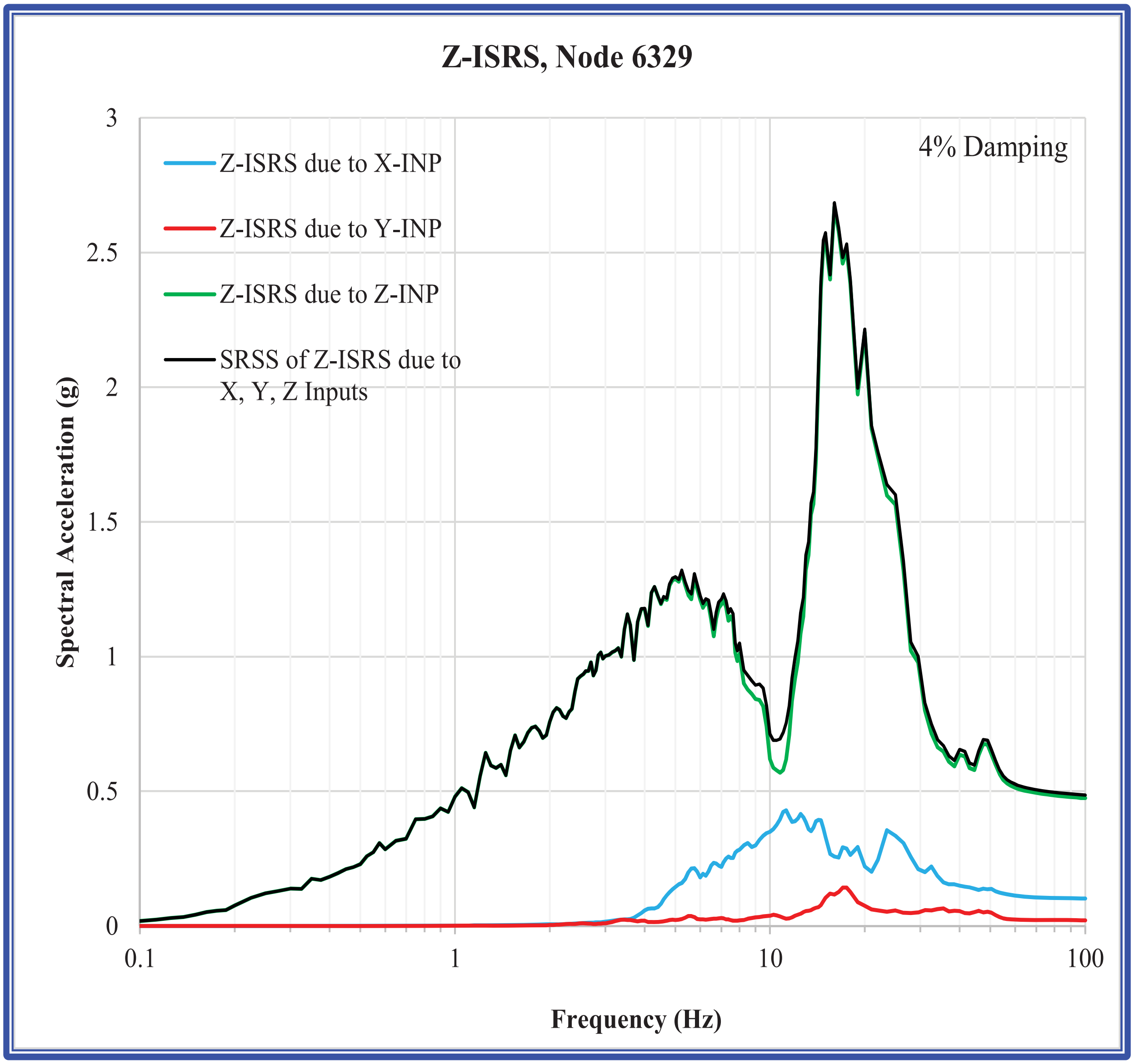


Figure 3.7.2-170: In-Structure Response Spectra at the Reactor Flange Tool Base, Node 6330, due to X, Y, and Z Inputs of Capitola Excitation for Soil Type 7, Cracked Condition

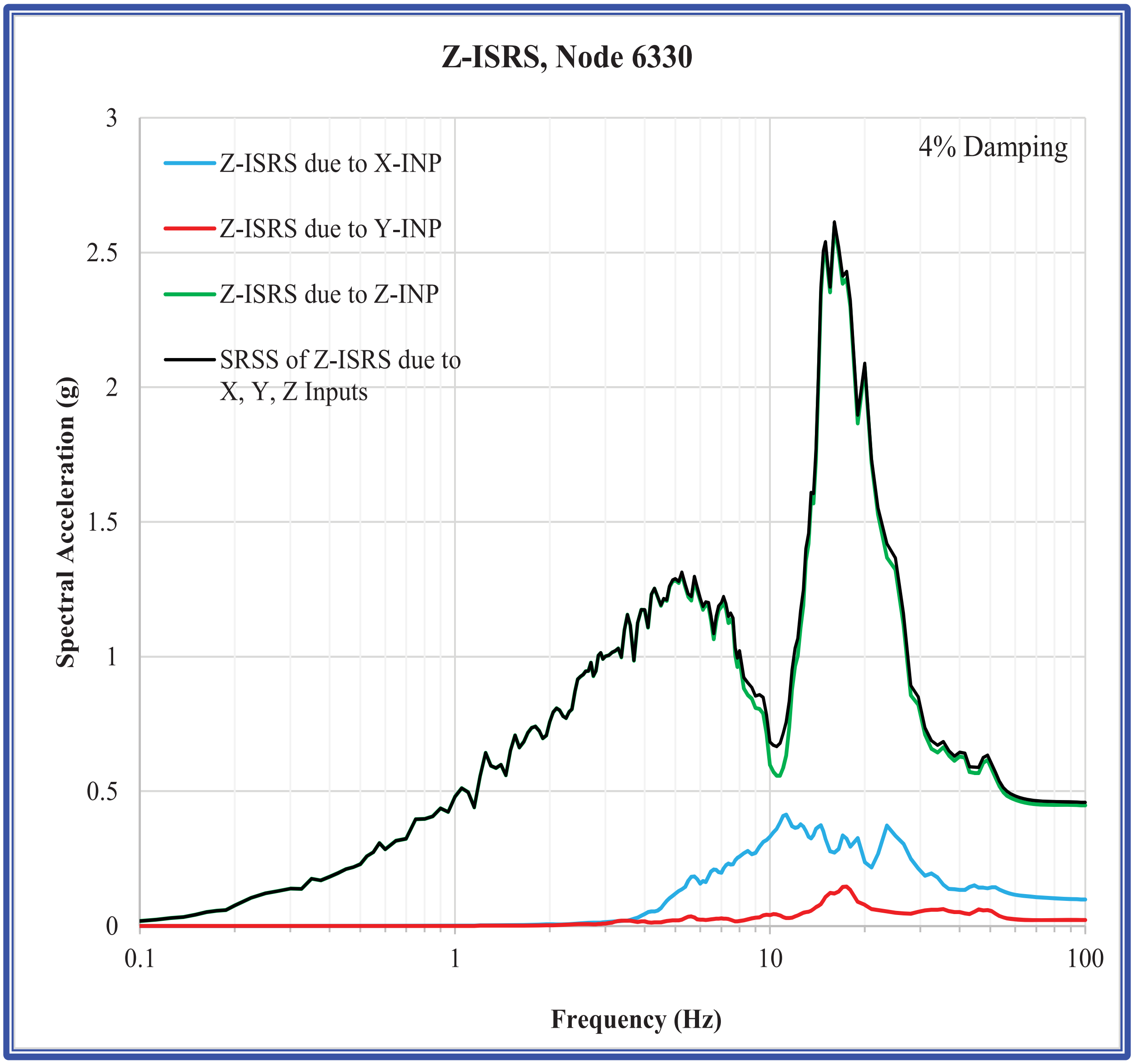


Figure 3.7.2-171: In-Structure Response Spectra at the Reactor Flange Tool Base, Node 6331, due to X, Y, and Z Inputs of Capitola Excitation for Soil Type 7, Cracked Condition

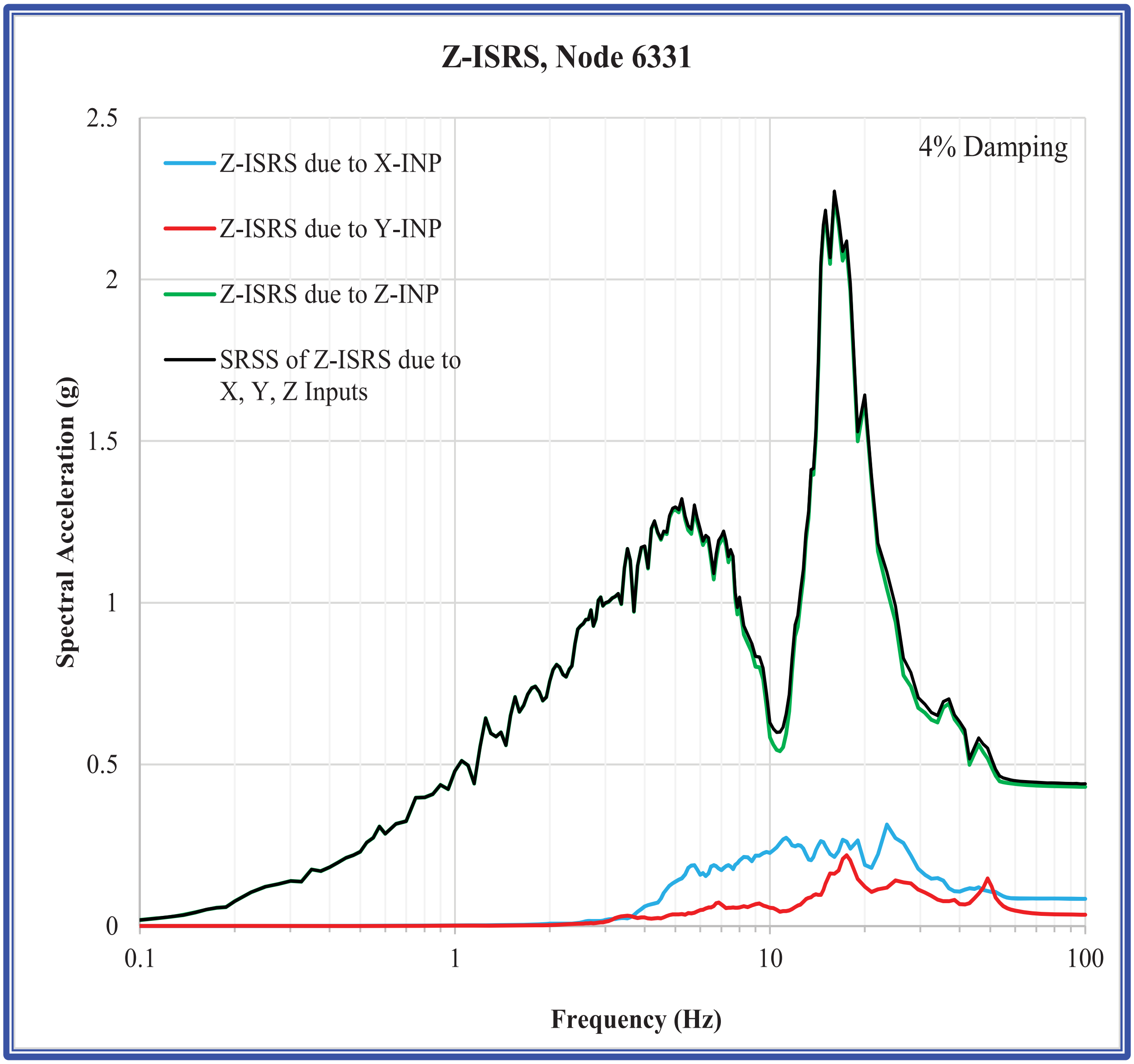


Figure 3.7.2-172: Floor In-Structure Response Spectra at El. 50 ft, (Z=420 in.) Comparing Full and Empty Dry Dock Conditions

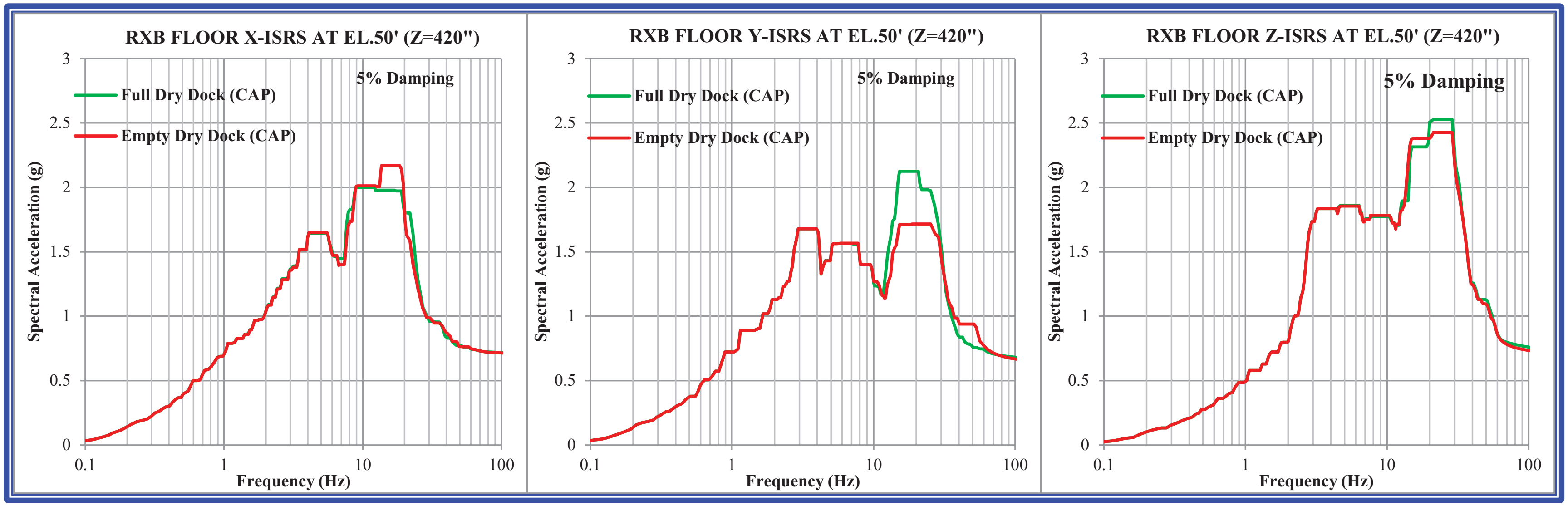


Figure 3.7.2-173: Floor In-Structure Response Spectra at El. 75 ft, (Z=720 in.) Comparing Full and Empty Dry Dock Conditions

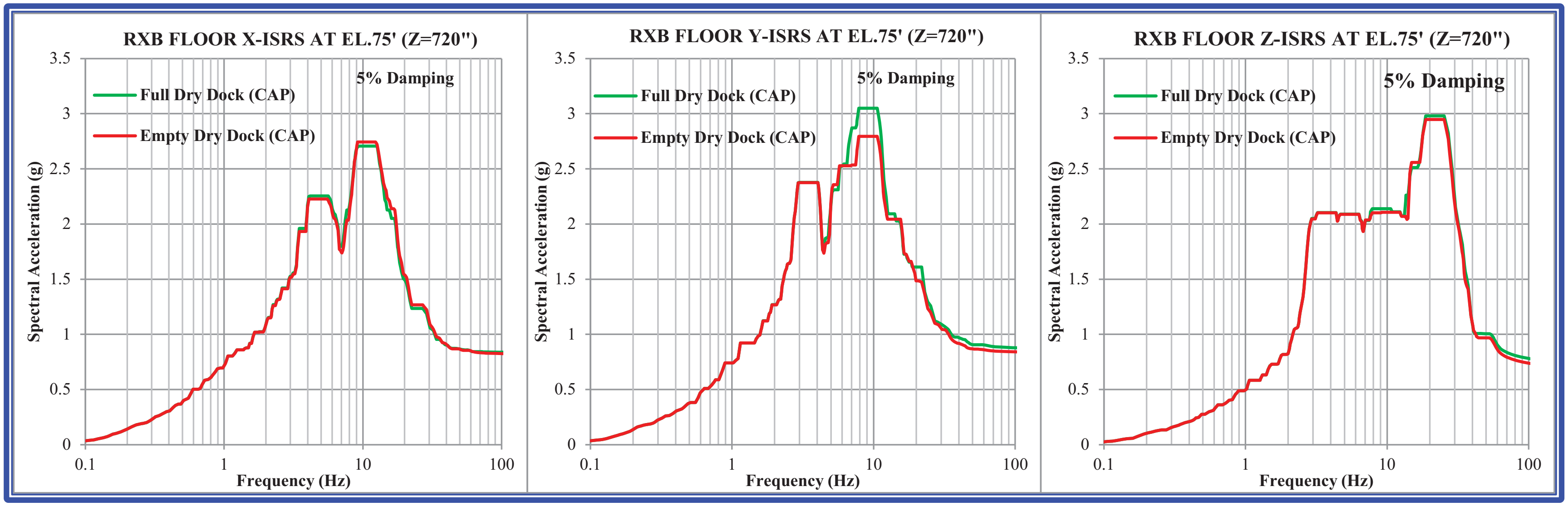


Figure 3.7.2-174: Floor In-Structure Response Spectra at El. 100 ft, (Z=1020 in.) Comparing Full and Empty Dry Dock Conditions

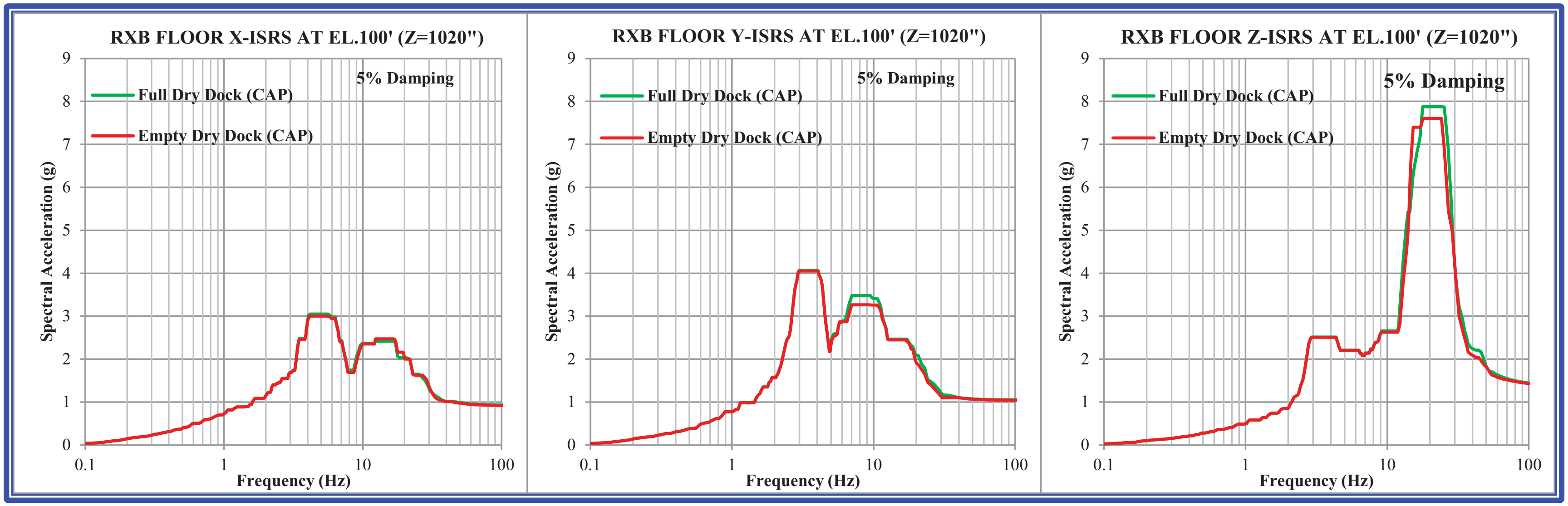


Figure 3.7.2-175: In-Structure Response Spectra at Reactor Building Crane Wheel Node 29545 Comparing Full and Empty Dry Dock Conditions

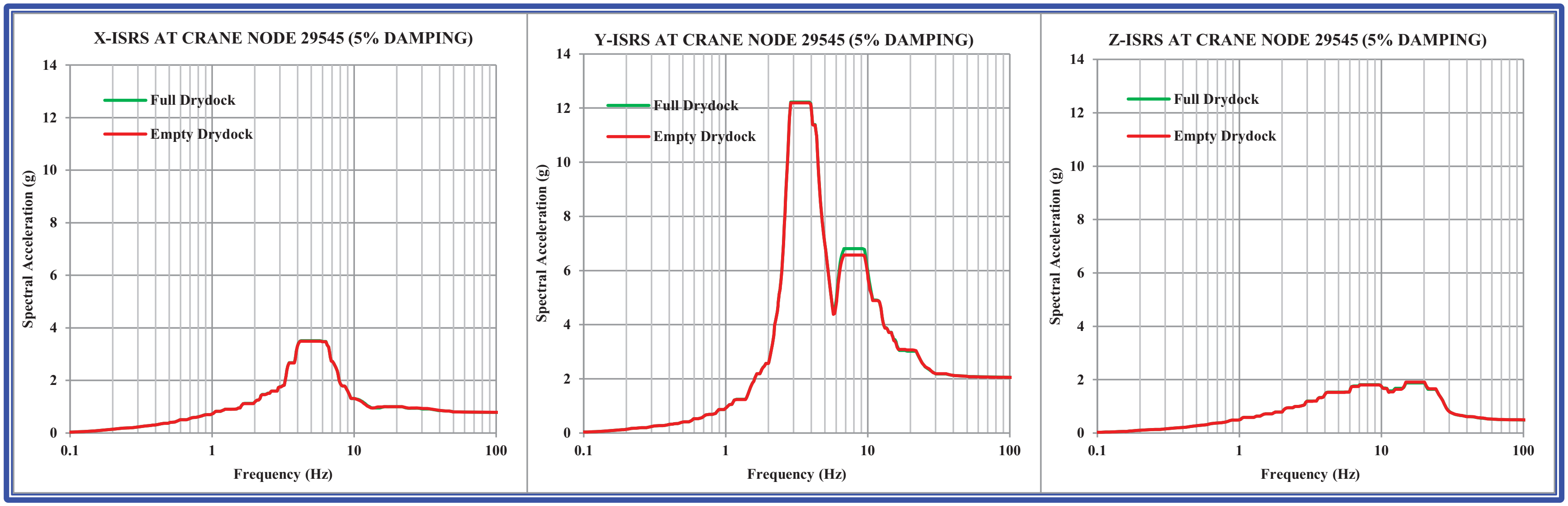


Figure 3.7.2-176a: In-Structure Response Spectra at the Northwest Corner of the Bioshield

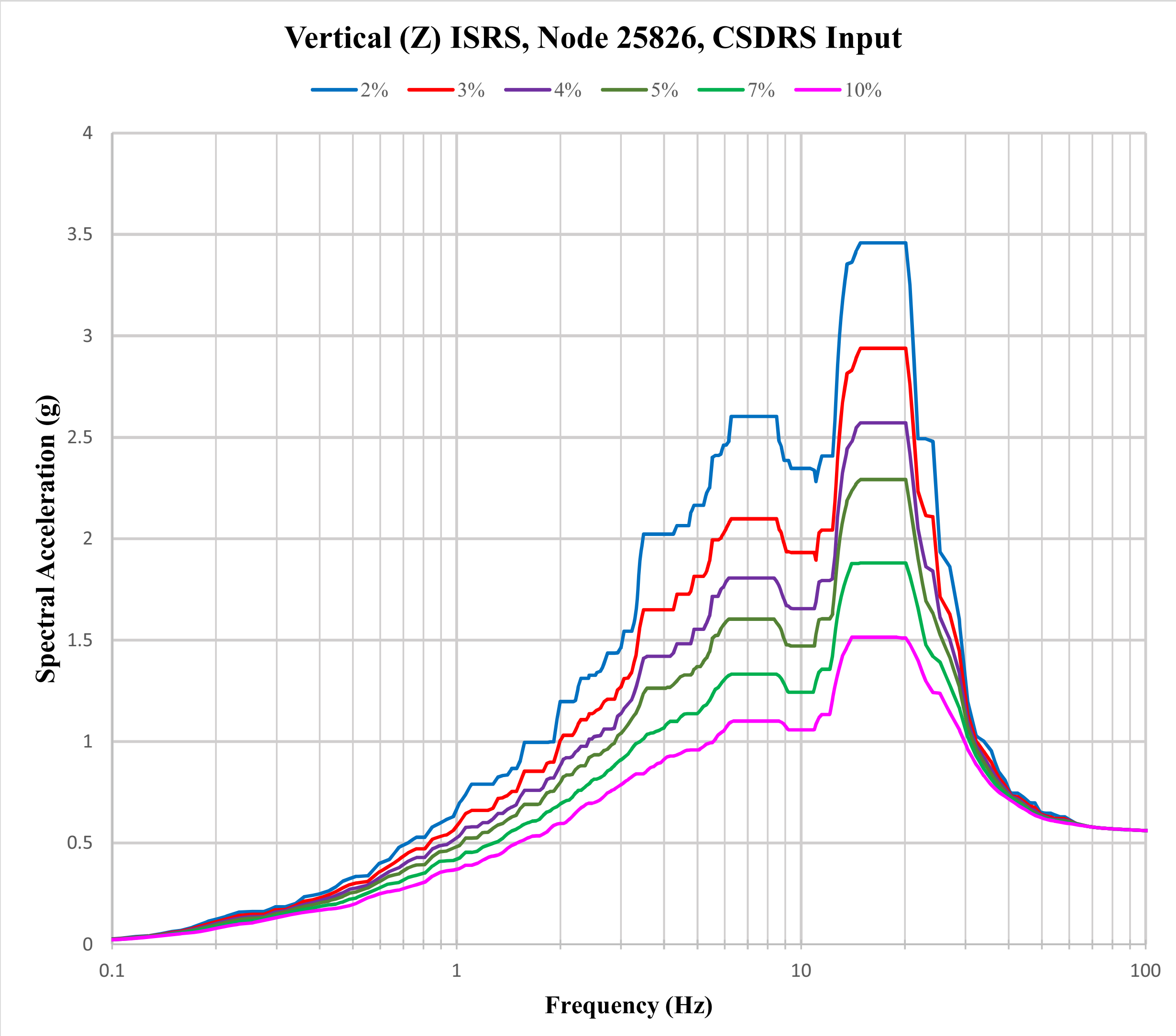


Figure 3.7.2-176b: In-Structure Response Spectra at the Northeast Corner of the Bioshield

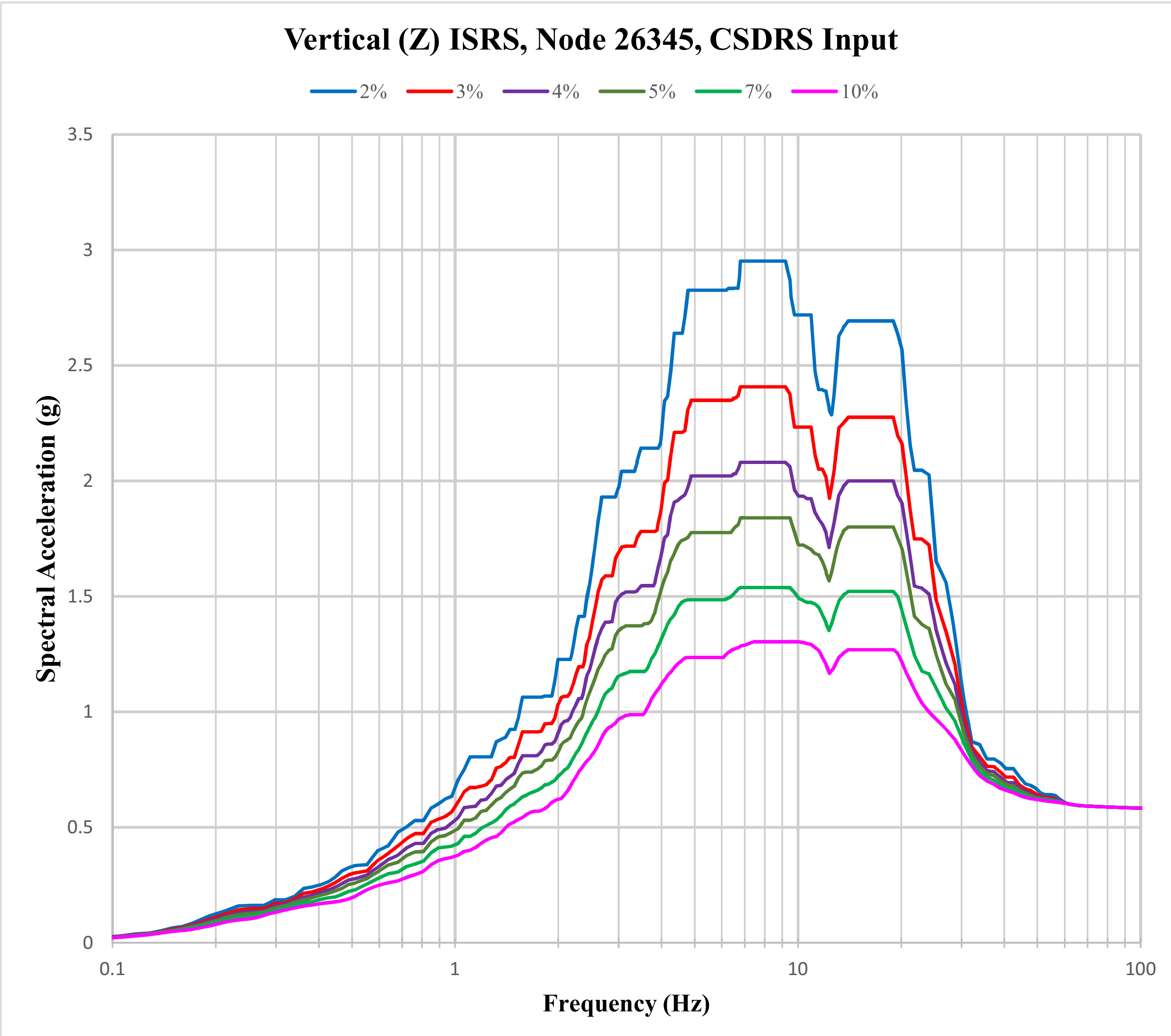


Figure 3.7.2-176c: In-Structure Response Spectra at the Northwest Corner of the Bioshield – High Frequency

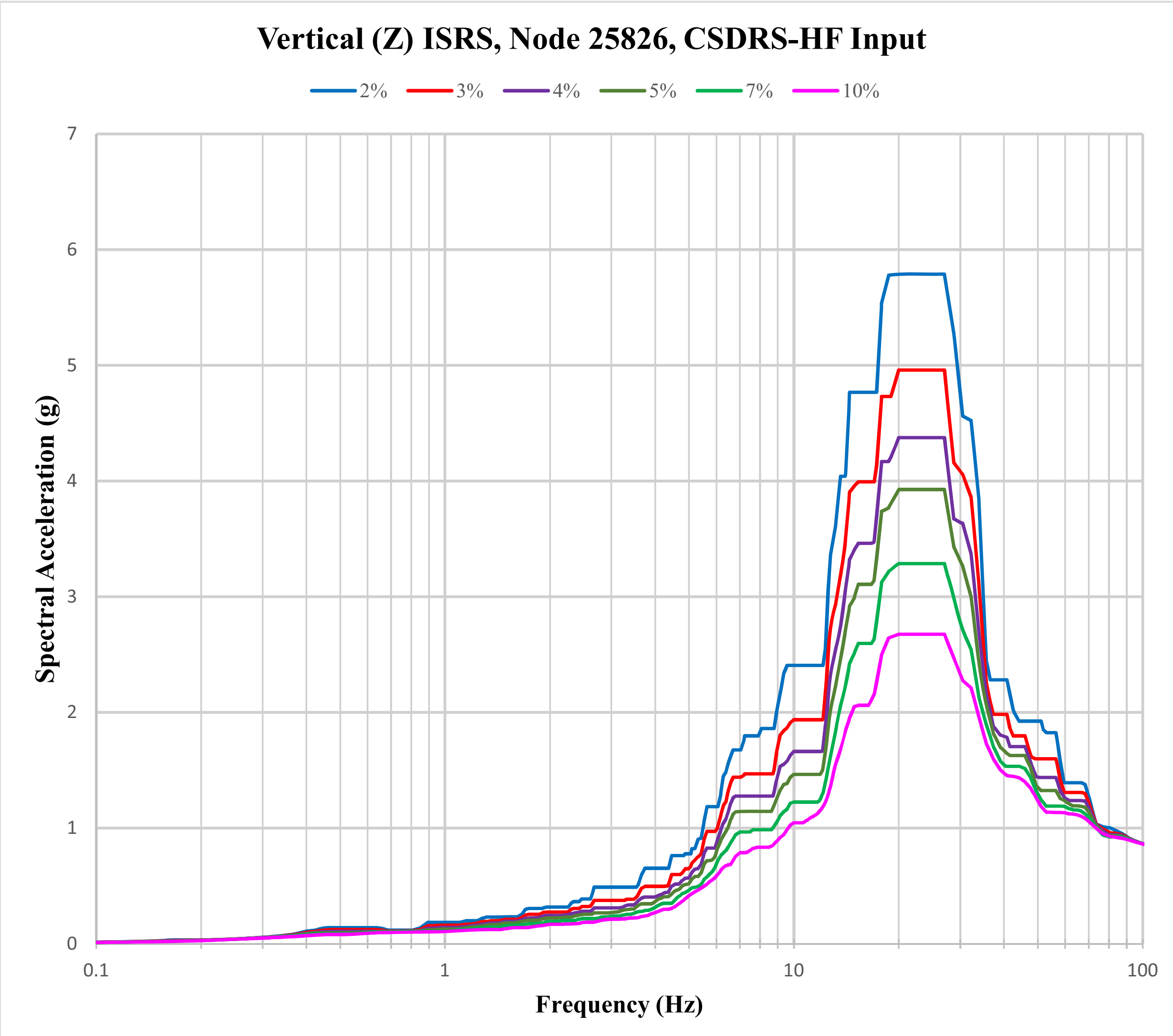
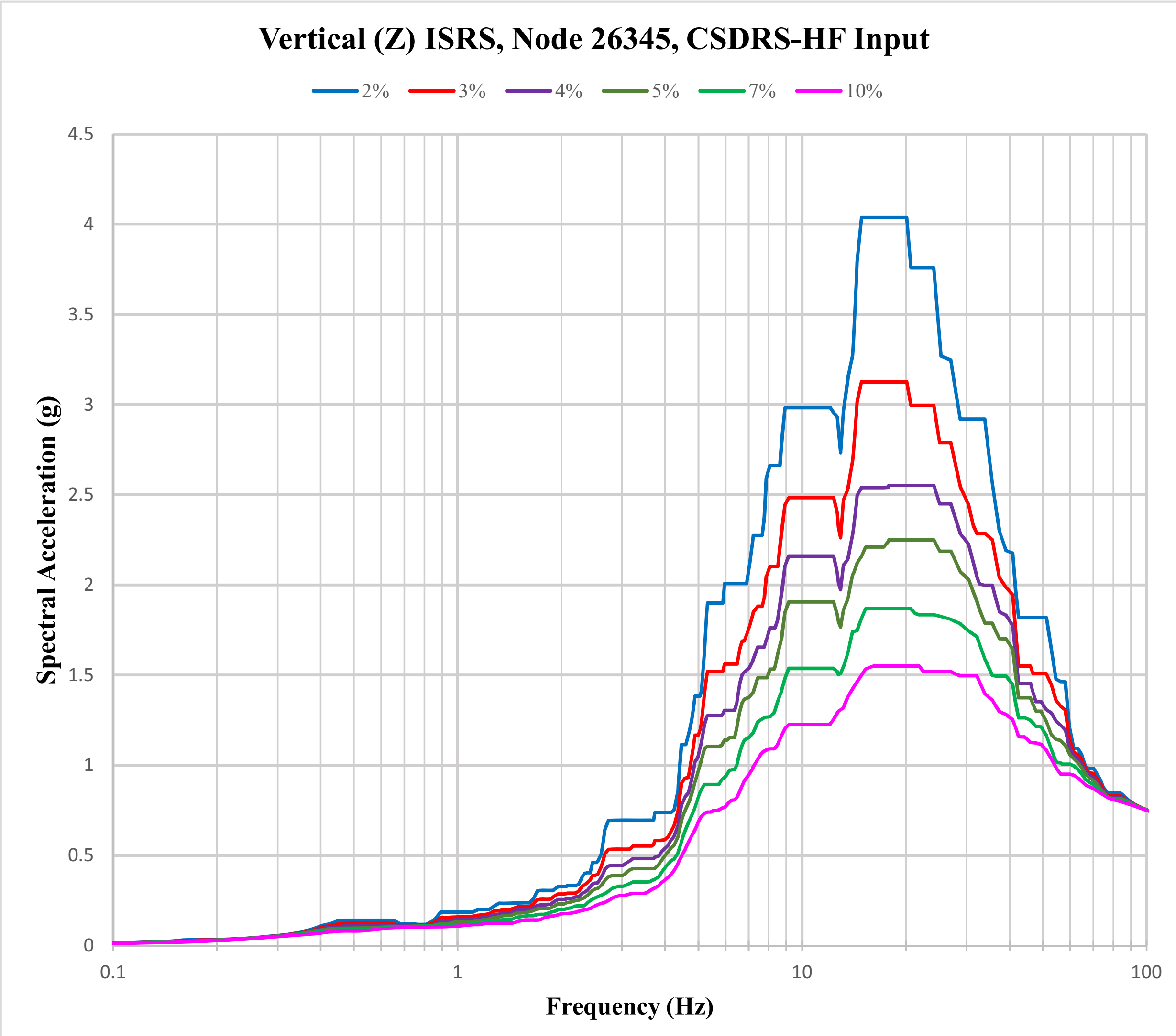


Figure 3.7.2-176d: In-Structure Response Spectra at the Northeast Corner of the Bioshield – High Frequency



3.7.3 Seismic Subsystem Analysis

Seismic subsystems are structures, systems, and components (SSC) for which the seismic forces are transmitted through the building structure as opposed to being imparted through the soil. The following are considered subsystems:

- structures, such as floor slabs, walls, miscellaneous steel platforms and framing
- equipment modules consisting of components, piping, supports, and structural frames
- equipment including vessels, tanks, heat exchanges, valves, and instrumentation
- distributive systems including piping and supports, electrical cable trays and supports, heating ventilation and air conditioning ductwork and supports, instrumentation tubing and supports, and conduits and supports. These distributed systems are predominantly Seismic Category II

In general, subsystems are evaluated as part of the detailed design using the analysis methodology described herein. Piping systems and their supports are further described in Section 3.12.

There are four seismic subsystems that are included in the certified design and specifically evaluated.

Each NuScale Power Module (NPM) is a subsystem. The seismic analysis of the NPMs is provided in Appendix 3A. The NPMs are included in the Reactor Building seismic model as beam elements as discussed in Section 3.7.2.

The fuel storage racks are a subsystem. The design of the racks is discussed in Section 9.1.2 and the details of the seismic analysis are provided in technical report TR-0816-49833 (Reference 3.7.3-1). The fuel storage racks are included in the seismic analysis of the building as a weight only.

The Reactor Building crane (RBC) is a subsystem. The design of the RBC is discussed in Section 9.1.5. The RBC is included in the Reactor Building seismic analysis as a beam and spring model as discussed in Section 3.7.2.

The bioshields are subsystems. The bioshields are included in the building model as weights only. The bioshield design and analysis is discussed in Section 3.7.3.3.1.

3.7.3.1 Seismic Analysis Methods

Subsystems are generally evaluated using response spectrum analysis. Simple substructures may be evaluated using the equivalent static load method. These methods are described below. The NPMs and fuel storage racks were evaluated using time histories as described in Appendix 3A and technical report TR-0816-49833 (Reference 3.7.3-1), respectively.

3.7.3.1.1 Response Spectrum Analysis Method

In the response spectrum method of analysis, loads, stresses, and deflections are determined for each mode of the SSC being analyzed from the in-structure response spectra (ISRS). The ISRS are developed from the building analysis for each of the three directions (east-west, north-south, and vertical) as described in Section 3.7.2.5.

Modal responses are determined by accelerating each mode with the spectral acceleration corresponding to the frequency of that mode. The representative maximum response of interest for design is obtained by combining the corresponding maximum individual modal responses.

Equipment and components in some cases are supported at several points by either a single structure or two separate structures. The motions of the structures at each of the support points may be quite different. Two approaches (uniform support motion method and independent support motion method) are discussed in Section 3.7.3.9 to address multiple supported equipment and components with distinct inputs.

3.7.3.1.2 Equivalent Static Load Method

This methodology is available for the analysis of simple SSC. The equivalent static load method may be used to evaluate:

- single-point-of-attachment cantilever models with essentially uniform mass distribution, or other simple structures that can be represented as single degree-of-freedom systems.
- cantilevers with non-uniform mass distribution and other simple multiple degree-of-freedom structures.

To obtain an equivalent static load for an SSC, a factor of 1.5 is applied to the peak spectral acceleration of the applicable ISRS. This force is applied at the center of mass of the SSC being evaluated. Results (loads, stresses, or deflections) are adjusted to account for the relative motion between all points of support.

Because the equivalent static load method is a simplified approach, each analysis contains justification that the use of a simplified model is realistic and the results are conservative.

3.7.3.2 Determination of Number of Earthquake Cycles

The operating basis earthquake (OBE) is defined to be one-third of the safe shutdown earthquake (SSE). As such, the OBE is eliminated from explicit design or analysis per 10 CFR 50 Appendix S. Therefore, the OBE is not used for primary stress evaluations and is not included in load combinations for the design of standard plant SSC.

However, the effects of the OBEs are accounted for in the fatigue analysis of SSC. During plant life one SSE and five OBEs, with 10 maximum stress cycles per event, are assumed. To meet this requirement, earthquake cycles included in the fatigue analysis for the standard plant are normally composed of two SSE events, with 10 maximum stress-cycles each, for a total of 20 full cycles. This is considered equivalent to the cyclic load basis of one SSE and five OBEs.

Alternatively, the number of fractional vibratory cycles equivalent to that of 20 full SSE vibratory cycles with an amplitude not less than one-third of the maximum SSE amplitude may be used when derived in accordance with IEEE 344 (Reference 3.7.3-8).

3.7.3.3 Procedures Used for Analytical Modeling

For the decoupling of the subsystem and the supporting system, the following criteria are used:

- if $R_m < 0.01$, decoupling can be done for any R_f
- if $0.01 \leq R_m \leq 0.1$, decoupling can be done if $0.8 \geq R_f \geq 1.25$
- if $R_m > 0.1$, a subsystem model should be included in the primary system model

where,

$$R_m = \frac{\text{total mass of supported subsystem}}{\text{total mass of supporting subsystem}}$$

$$R_f = \frac{\text{fundamental frequency of supported subsystem}}{\text{dominant frequency of support motion}}$$

The Reactor Building (RXB) structural weight is greater than 500,000 kips (see Table 3.7.2-13). As such, a subsystem can be decoupled if the weight is less 5000 kips. The larger subsystems, the NPM and the RBC, have weights on the order of 2000 kips and could be uncoupled. However, they are both coupled in the RXB model. The fuel storage racks have a loaded weight less than 2000 kips, and each bioshield is less than 230 kips. Therefore these SSC are decoupled.

Distributed systems (cable trays, piping, heating ventilation and air conditioning) and individual components will not have significant weights that would challenge the $R_m < 0.01$ criterion.

3.7.3.3.1 Bioshields

The bioshields are nonsafety-related, not risk-significant, Seismic Category II components that are placed on top of each module bay at the 125-ft elevation to provide an additional radiological barrier to reduce dose rates in the RXB and support personnel access. Bioshields are removed while a NPM is being detached and refueled. During that time, the removed bioshield is placed on top of an in-place bioshield. The bioshield lifting slings meet the requirements described in Section 9.1.5 under "Lifting Devices Not Specifically Designed."

COL Item 3.7-16: A COL applicant that references the NuScale Power Plant design certification will determine the means and methods of lifting the bioshield. A COL applicant will demonstrate that bioshield components and connections can withstand the bioshield loads and approriate load factors.

The bolts used for securing the horizontal portion of the bioshield to the operating bay and pool walls are safety related, and designed in accordance with ACI 349 as they anchor into a concrete structure. The bioshield is designed as a Seismic Category II structure, which is analyzed and designed to prevent its failure under SSE conditions, such that the bioshield will not collapse or fail and strike or impair the integrity of the safety related or Seismic Category I SSC under it.

Each bioshield is comprised of a horizontal slab supported by the bay walls and a hanging vertical assembly attached to the horizontal slab. The horizontal slab consists of 23.5-in. thick reinforced 5000 psi concrete. The concrete is encapsulated in 1/4-in. stainless steel plates for a total thickness of two feet. The vertical assembly is constructed of a stainless steel tube framing system and a series of radiation shielding panels. The radiation shielding panels are designed to help ensure occupational radiation exposure is as low as reasonably achievable as described in FSAR Chapter 12. Radiation shielding panels are composed of 4-inch borated HDPE panels with 5 percent boron content. The HDPE is encased in stainless steel plate and angle assemblies clamped together with bolts. The clamped assembly restricts flame and adequate oxygen from causing combustion of the HDPE panels. Off-gassing of the HDPE panels during operation is allowed as the clamped assemblies are not hermetically sealed. The encasement of the HDPE eliminates it as a fire load. The vertical assembly is vented for heat removal during normal operation as well as for heat and pressure mitigation in the event of a high energy line break and slow leak, high temperature event above the NPM. The vents are arranged on the vertical portion of the bioshield in a staggered manner, providing a minimum ventilation area of 52.8 ft^2 to allow continuous ventilation of the operating bay.

The bioshields are attached to the bay walls and outer pool wall using 2-in. diameter removable anchor bolts. Figure 3.7.3-1 shows 12 installed bioshields. Figure 3.7.3-2a shows an isometric view with the single bioshield configuration and Figure 3.7.3-2b shows an elevation view with the stacked bioshield configuration.

Reinforced Concrete Properties and Slab Capacity

Table 3.7.3-8 contains the section dimensions used for the design of the bioshield. Table 3.7.3-9 shows the concrete and reinforcement design values used for capacity calculations. The values are obtained from ACI 349 (Reference 3.7.3-4). The minimum concrete cover for cast-in-place members is based on Section 7.7.1 of ACI 349.

The capacities for the bioshield slab are shown in Table 3.7.3-10 and are calculated based on the provisions of ACI 349. The individual equations used for out of plane moment and shear capacity are referenced in Table 3.7.3-10. The anchor bolt capacities for tension and shear are developed using the equations from Appendix D of ACI 349.

Structural Steel Material Properties

The vertical assembly of the bioshield is constructed from steel tube members of HSS 5x5x1/2" in the horizontal and vertical directions. The tube steel material is SA-564 Type 630 condition H1150 high strength stainless steel with yield strength of 105 ksi and a tensile strength of 135 ksi. The stainless steel liner plate that protects the horizontal bioshield from corrosion and the radiation panel's ¼" closure plate is made from A240 Type 304. The framing members of the bioshield radiation panel are made from A276 stainless steel. The yield strength of A240 Type 304 is 25 ksi and the tensile strength is 70 ksi. A276 stainless steel has a yield strength of 25 ksi and a tensile strength of 70 ksi.

The welded connections between the vertical and horizontal component of the bioshield are designed based on the provisions of Chapter J of AISC 360 (Reference 3.7.3-5).

In-Structure Response Spectra

In-structure response spectra were developed for multiple locations in the RXB in Section 3.7.2. Two nodes from that model were selected to use for the design of bioshields. These nodes are shown in Figure 3.7.3-3. Plots of the ISRS with 4 percent damping at these nodes are shown in Figure 3.7.3-4a through Figure 3.7.3-4c. These figures envelop CSDRS and CSDRS-HF curves and include the effects of any sensitivity analysis cases such as considering the effects of soil separation and different soil-structure analysis (SSI) methods, i.e., the 7P Extended Subtraction Method (7P ESM) and the Direct Method (DM). The ISRS with multiple damping ratios for these nodes are shown in Figure 3.7.2-176a through Figure 3.7.2-176d also considering same effects.

3.7.3.3.1.1 Evaluation

The self-weight of the bioshield was calculated using material densities and the dimensional properties. There are two structural components of the bioshield: the horizontal slab and vertical assembly. The horizontal slab rests on the interior pool walls as shown in Figure 3.7.3-1. The vertical assembly is attached to the front edge of the horizontal bioshield through eight pins. Table 3.7.3-11 summarizes the weight of the slab and Table 3.7.3-12 summarizes the weight of the assembly. The bioshield slab is anchored to the NPM bay walls with four 2-inch vertical bolts on each wall. Two bolts are needed, at each corner of the bioshield slab, for both stacked and unstacked configurations.

The total weight of the bioshield used for design is twice the total calculated weight of each bioshield because they can be stacked on one another during refueling and maintenance. In addition, a 50 psf live load is included to account for the load due to plant personnel bolting and unbolting the bioshield during refueling and maintenance. The bioshield area is not expected to be a high traffic area during normal operation.

The structural analysis and design of the horizontal slab and vertical assembly was performed by generating two sets of SAP2000 (Reference 3.7.3-7) finite element models. A time history analysis is performed for both model sets. The time histories are based on the synthetic time histories that were matched to the corresponding 4-percent ISRS in the same direction given in Figure 3.7.3-4a through Figure 3.7.3-4c.

The models incorporate compression-only gap elements to model concrete slab sitting on bay walls and tension-only elements to model anchor bolts. In the horizontal directions, friction forces between the slab and bay walls are conservatively ignored, and it is assumed that the only anchor bolts resist the shear. Thus, the only restraints in the horizontal directions are at the bolt locations. The north and south edges of the slab are free in all directions. Both cracked and uncracked concrete conditions are evaluated. The weight of the vertical bioshield is applied to the free edge of the slab.

For the horizontal slab model, stacked configuration of the bioshields during refueling is considered in addition to the single bioshield. Since the two horizontal bioshields are anchored together during the stacked configuration, there will not be any sliding between the two slabs; therefore, no friction forces are developed. Because the two slabs are only pinned on the two edges, they will not act as a composite section even though they move together in the vertical direction. The two slabs are compatible in all directions without acting as a composite section because there are no shear studs between the two slabs to resist the shear force. To model the stacked configuration, only one slab is modeled but the mass and stiffness of the slab is doubled to account for both slabs. To double the slab stiffness, the modulus of elasticity is doubled. For the stacked configuration, the weight of the vertical assembly applied to one edge is also doubled.

The analysis models for the vertical assembly are developed by incorporating the vertical bioshield finite element model to the previously defined horizontal bioshield model to accurately simulate the boundary conditions of the vertical bioshield. This model uses the same boundary conditions at the interface of the horizontal slab and bay wall. Compression-only gap elements are also used at the bottom corners of the vertical bioshield in the east-west direction where the structure is guided through C-channel supports. Both cracked and uncracked concrete conditions are evaluated for the horizontal slab. The stacked bioshield is also restrained to the wall with C-channel supports. Stacked configuration effects for the vertical bioshield show the same dynamic characteristics as a single bioshield configuration. There is no interaction between the stacked bioshields.

In all cases, the results of individual load cases are combined per applicable load combinations, and appropriate checks are performed per AISC and ACI standards for both members and connections.

3.7.3.3.1.2 Demand-to-Capacity Ratios

Table 3.7.3-14 shows the summary of demand-to-capacity ratios for the bioshield without any reduction for steel strength due to temperature. AISC N690 requires the decrease in steel strength to be taken into account when the structural component or system is exposed to sustained temperatures in excess of 250 degrees Fahrenheit. While this strength adjustment is not mandated by code as the maximum temperature of the bioshield will be 212 degrees Fahrenheit, the highest D/C of 0.88 for steel structural members would increase to 0.92.

3.7.3.4 Basis for Selection of Frequencies

When practical, components are designed (or specified) so that the fundamental frequencies of the component are less than one half or more than twice the dominant frequencies of the support structure. However, equipment will be tested or analyzed to demonstrate that it is adequate for design loads considering the fundamental frequencies of the equipment and the support structure.

3.7.3.5 Analysis Procedure for Damping

Damping values used for seismic analysis of SSC are in accordance with Table 3.7.1-6. Component modal damping of piping systems is described in Section 3.12.3.2.2.

3.7.3.6 Three Components of Earthquake Motion

Seismic demand is obtained for the three orthogonal (two horizontal and one vertical) components of earthquake motion from the ISRS. Each component of the earthquake motion is considered in the seismic analysis of subsystems. When the total response of the substructure is needed, it is normally obtained by combining the three directional responses using the SRSS method. The 100-40-40 rule, which typically produces higher demand, is an acceptable alternative to the SRSS method.

3.7.3.7 Combination of Modal Responses

For the response spectrum method of analysis, the maximum responses such as accelerations, shears, and moments in each mode are calculated regardless of time. If the frequencies of the modes are well separated, the SRSS method is used; however, where the structural frequencies are not well separated, the modes are combined in accordance with Regulatory Guide 1.92 "Combining Modal Responses and Spatial Components in Seismic Response Analysis," Rev. 3.

3.7.3.8 Interaction of Non-Seismic Category I Subsystems with Seismic Category I SSC

When non-Seismic Category I SSC (or portions thereof) could adversely affect Seismic Category I SSC, they are categorized as Seismic Category II and analyzed using one of the methodologies described in Section 3.7.3.1.

For non-Seismic Category I subsystems attached to Seismic Category I SSCs, the dynamic effects of the non-Seismic Category I subsystems are included in the modeling of the Seismic Category I SSC. The attached non-Seismic Category I subsystems, up to the first anchor beyond the interface, are designed in such a manner that the CSDRS does not cause a failure of the Seismic Category I SSC.

3.7.3.9 Multiple-Supported Equipment and Components with Distinct Input

Two methods are utilized to address multiple-supported equipment and components: the uniform support motion (USM) method and the independent support motion (ISM) method. The USM method is a simpler approach, but produces larger forces.

For USM analysis, a single response spectrum is created that envelopes the ISRS of all the support locations. This single response spectrum is then used at all locations to calculate the maximum inertial responses of the equipment. In addition, the relative displacements at the support points are taken into consideration in the analysis using conventional static analysis procedures. The support displacements are then imposed on the supported equipment in the most unfavorable combination. The modal and directional responses are combined using the methods described in Section 3.7.3.6 and Section 3.7.3.7.

The ISM method may be used in lieu of the uniform support motion method when systems are at multiple levels or spread between diverse locations. For ISM analysis, the guidance and criteria given in NUREG-1061, Volume 4 "Evaluation of Other Loads and Load Combinations" is used.

The responses caused by each group are combined by absolute summation. The modal and directional responses are combined using the methods described in Section 3.7.3.6 and Section 3.7.3.7.

3.7.3.10 Use of Equivalent Vertical Static Factors

Equivalent vertical static factors are not used in the design of the Seismic Category I and Seismic Category II structures. Vertical seismic loads are generated from the soil-structure interaction analysis.

3.7.3.11 Torsional Effects of Eccentric Masses

Torsional effects due to the presence of significant eccentric masses connected to a subsystem are included in the subsystem analysis. For rigid components (natural frequencies greater than 50 Hz), the lumped mass is modeled at the center of gravity of the component with a rigid link to the appropriate point in the subsystem. For flexible components, the subsystem model is expanded to include an appropriate model of the component.

Torsional effects of eccentric masses affecting the piping design are included in the analysis described in Section 3.12.4.2.

3.7.3.12 Buried Seismic Category I Piping, Conduits, and Tunnels

The design does not include buried Seismic Category I piping, or conduits. The tunnel between the Control Building and the RXB is analyzed as part of the Control Building.

3.7.3.13 Methods for Seismic Analysis of Category I Concrete Dams

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

3.7.3.14 Methods for Seismic Analysis of Aboveground Tanks

The design does not include any Seismic Category I aboveground tanks.

3.7.3.15 References

3.7.3-1 NuScale Power, LLC, "Fuel Storage Rack Analysis," TR-0816-49833-P, Revision 1.

3.7.3-2 Not Used.

3.7.3-3 Not Used.

3.7.3-4 American Concrete Institute, "Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary," ACI 349-06, Farmington Hills, MI.

3.7.3-5 American National Standards Institute/American Institute of Steel Construction, "Specification for Structural Steel Buildings," ANSI/AISC 360-10, Chicago, IL.

3.7.3-6 Not Used.

3.7.3-7 SAP2000 Advanced (Version 18.1.1) [Computer Program]. (2015). Walnut Creek, California: Computers and Structures, Inc.

3.7.3-8 Institute of Electrical and Electronics Engineers, "IEEE Recommended Practice for Seismic Qualification of Equipment for Nuclear Power Generating Stations," IEEE Standard 344-2004, Piscataway, NJ.

Table 3.7.3-1: Not Used

Table 3.7.3-2: Not Used

Table 3.7.3-3: Not Used

Table 3.7.3-4: Not Used

Table 3.7.3-5: Not Used

Table 3.7.3-6: Not Used

Table 3.7.3-7: Not Used

Table 3.7.3-8: Bioshield Nominal Dimensions

Parameter	Length
Gross section width (east-west)	24 ft 6 in
Gross section length (north-south)	20 ft 6 in
Vertical bioshield height	30 ft
Vertical bioshield width	22 ft 6 in
Bioshield distance between slab anchor bolts	22 ft 6 in
Clear distance between supports (NPM support walls)	19 ft 7 in
Depth of horizontal bioshield	2 ft

Table 3.7.3-9: Bioshield Concrete and Reinforcement Design Properties

Design Value	Parameters	Value
Concrete compressive strength	f_c' (psi)	5,000
Rebar yield strength	f_y (psi)	60,000
Strength reduction factor for flexure	ϕ_M	0.90
Strength reduction factor for shear	ϕ_V	0.75
Steel modulus of elasticity	E_S (ksi)	29,000
Concrete strain	ε_c	0.003
Coefficient defining the relative contribution of concrete strength to nominal wall shear strength	α_c	2.00

Table 3.7.3-10: Moment and Shear Capacity of Horizontal Slab

Description	Parameters	Value
Out-of-plane moment capacity $\phi M_N = \phi_M M_N$	ϕM_N (kip-ft/ft)	246
Shear capacity provided by concrete $\phi V_c = \phi_v 2bd\sqrt{(fc')}$	$\phi_v V_c$ (kip/ft)	25
Shear capacity provided by stirrups[1] $\phi V_s = \phi_v((A_{st(s)} f_y d)/s_s)$	$\phi_v V_s$ (kip/ft)	32
In-plane shear capacity by concrete[2] $\phi V_{conc}=\phi A_{cv}(\alpha_c\sqrt{(f_c')})$	$\phi_v V_{conc}$(kip/ft)	31
In-plane shear capacity[2] $\phi V_{in\text{-}plane}$=minimum of $\phi A_{cv}(\alpha_c\sqrt{(f_c')}+\rho_t f_y)$ or $\phi_v 8A_{cv}\sqrt{(f_c')}$	$\phi_v V_{in\text{-}plane}$ (kip/ft)	122

Note:
1. Section 11.5.7.2 of ACI 349 (Reference 3.7.3-4)
2. Section 21.7.4.1 of ACI 349 (Reference 3.7.3-4)

Table 3.7.3-11: Bioshield Slab Self-Weight

Material	Density (pcf)	Thickness (in)	Area (ft^2)	Weight (kips)
Concrete	150	23.5	502.25	147.5
Steel	490	0.25	1175.5	12.0
Misc.	N/A	N/A	N/A	8.4
Total				167.9

Table 3.7.3-12: Bioshield Vertical Assembly Self-Weight for Structural Analysis

Component	Quantity	Weight (lbs)	Total (lbs)
Radiation panels (HDPE density = 63 lb/ft^3)	9	4,700	42,300
Frame weldment	1	16,132	16,132
-	-	**Total**	**58,432 (60,000 used)**

Table 3.7.3-13: Not Used

Table 3.7.3-14: Summary of Bioshield Demand to Capacity Ratios

Component	Capacity Check	Demand	Capacity	Unit	D/C Ratio
Concrete slab	Rebar in the E-W direction	1.728	3.142	in^2/ft	0.55
Concrete slab	Rebar in the N-S direction	0.843	3.142	in^2/ft	0.27
Concrete slab	Out-of-plane shear (E-W)	34.1	54.559	kips/ft	0.63
Concrete slab	Out-of-plane shear (N-S)	19.3	54.471	kips/ft	0.35
Slab anchor bolt	Tension + shear	See note below	See note below		0.66
Bioshield connection between horizontal and vertical piece - pin	Shear (double-ended)	114.0	191.0	kip	0.60
Bioshield connection between horizontal and vertical piece - pin	Bearing	114.0	154.0	kip	0.72
Bioshield connection between horizontal and vertical piece - hinge plate on vertical piece; headed studs	Tension + shear	See note below	See note below		0.71
Bioshield connection between horizontal and vertical piece - hinge plate on vertical piece	Weld	8.1	31.5	ksi	0.26
Bioshield connection between horizontal and vertical piece - hinge plate on horizontal piece	The two hinge plates each 1" thick, are acceptable by comparison to the one 2" thick vertical hinge plate. The base of the horizontal hinge plates are wider than the vertical hinge plate.			N/A	OK
Bioshield connection between horizontal and vertical piece - hinge plate on horizontal piece	Weld	16.4	31.5	ksi	0.52
Bioshield connection between horizontal and vertical piece - edge plate on horizontal piece	Bending	576.0	1080.0	kip-ft	0.53
Steel structure member, HSS tube	Von Mises Stress	88.82	96.6	ksi	0.92
Steel structure member, HSS tube	Weld	7.25	31.5	ksi	0.23
Vertical bioshield panels	Von Mises Stress	16.95	22.0	ksi	0.77
Vertical bioshield seismic restraint	Weld	21.4	31.5	ksi	0.68
Vertical bioshield seismic restraint- concrete studs	Tension	216.6	353	kip	0.61
Vertical bioshield seismic restraint- concrete studs (stacked bioshield)	Tension	102.1	132.5	kip	0.77

Note: The D/C ratios are determined in real time and for each time step.

Figure 3.7.3-1: Cutoff View of Reactor Building to Depict Bioshields

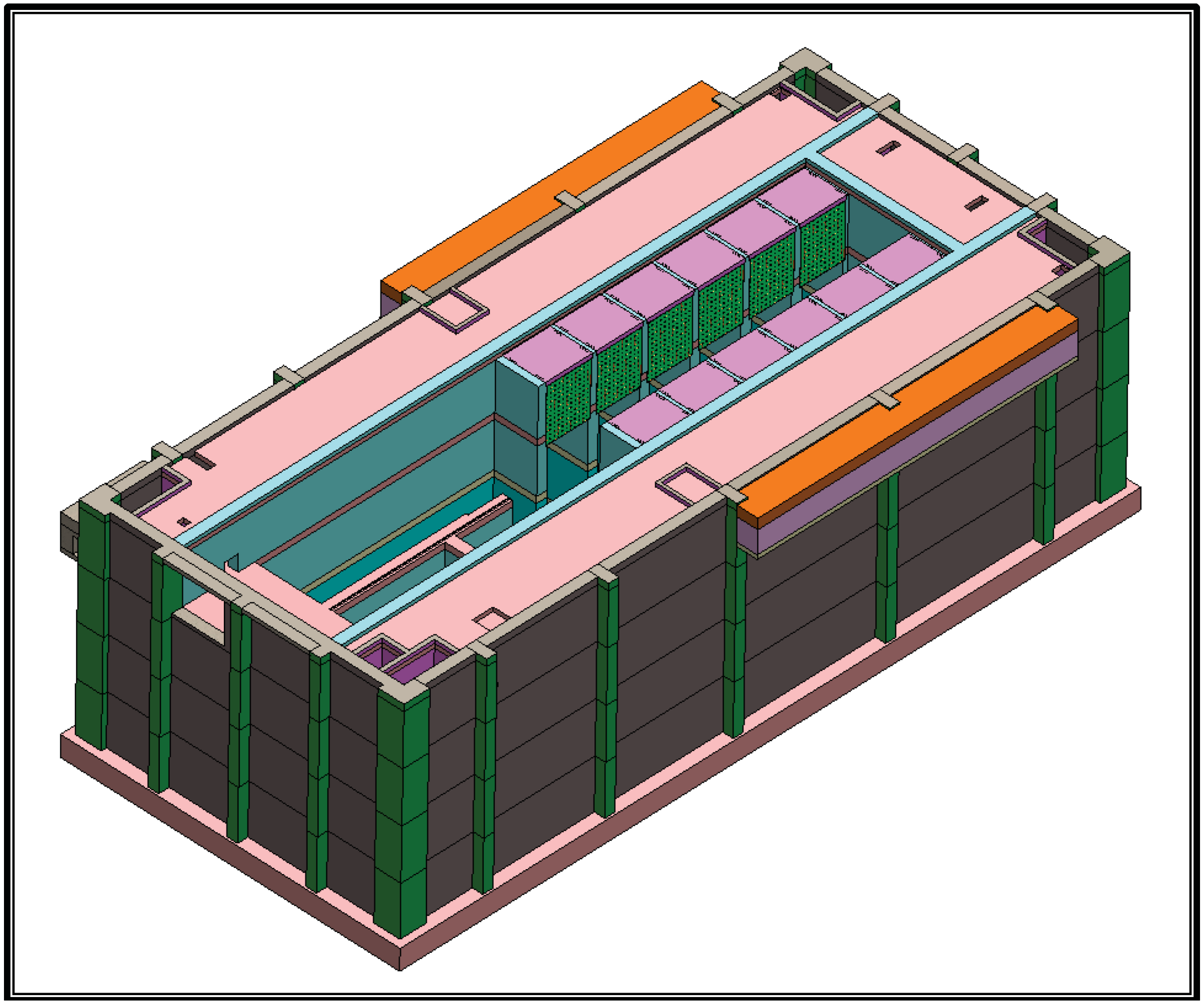


Figure 3.7.3-2: Not Used

Figure 3.7.3-2a: Bioshield Conceptual Design (Isometric View)

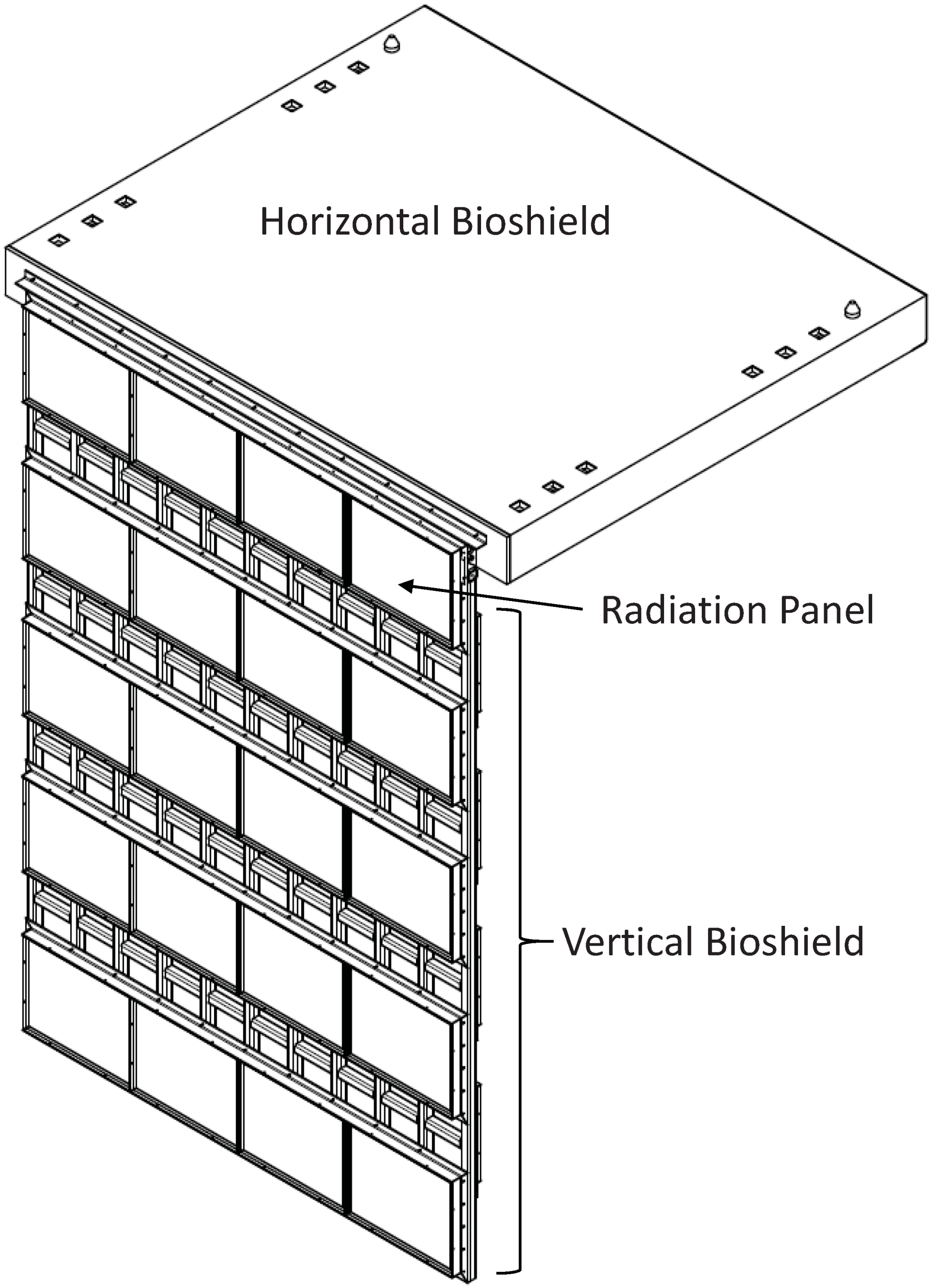


Figure 3.7.3-2b: Bioshield Conceptual Design (Elevation View During Stacked Configuration)

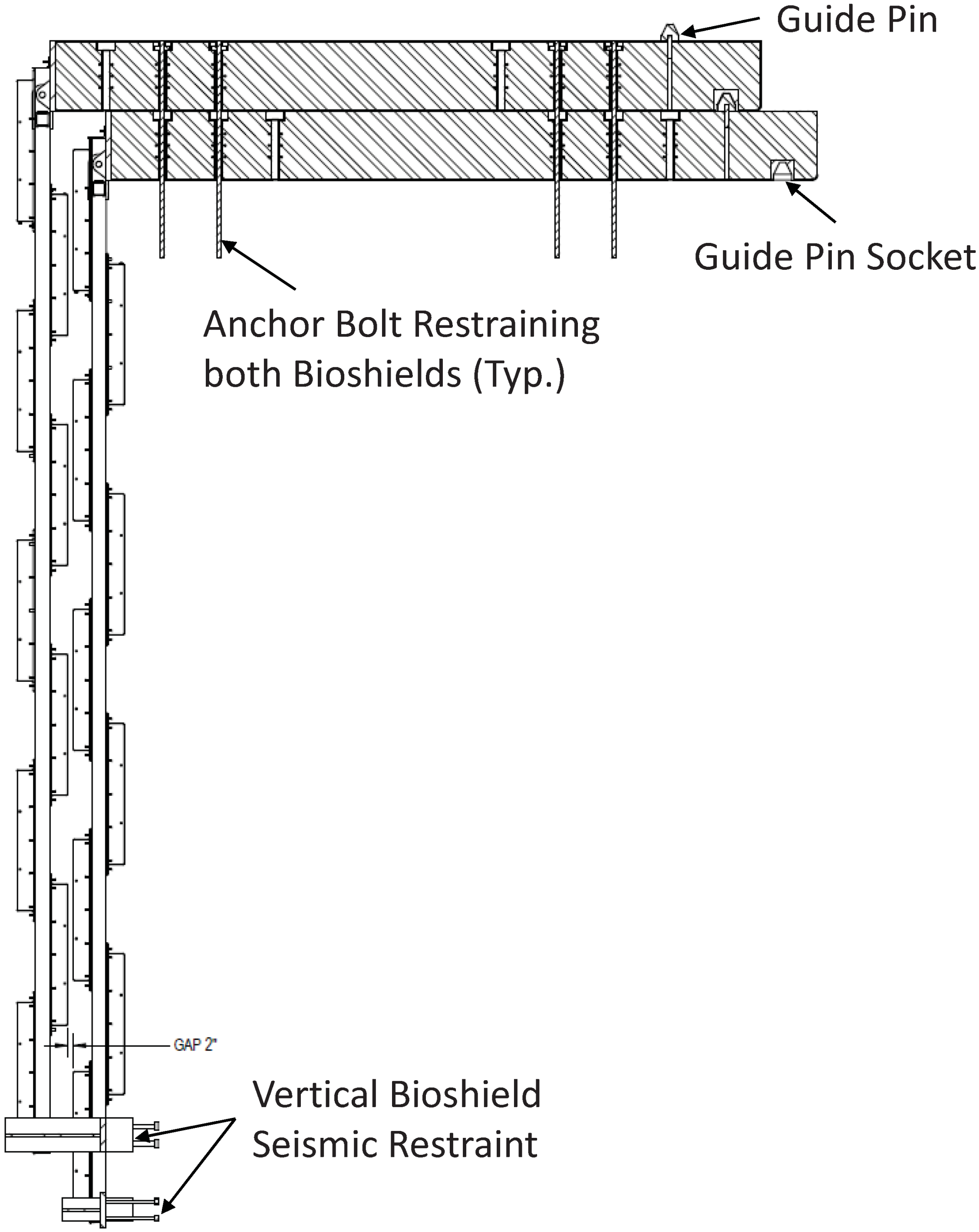


Figure 3.7.3-3: Location In-structure Response Spectra Nodes for Design of Bioshields

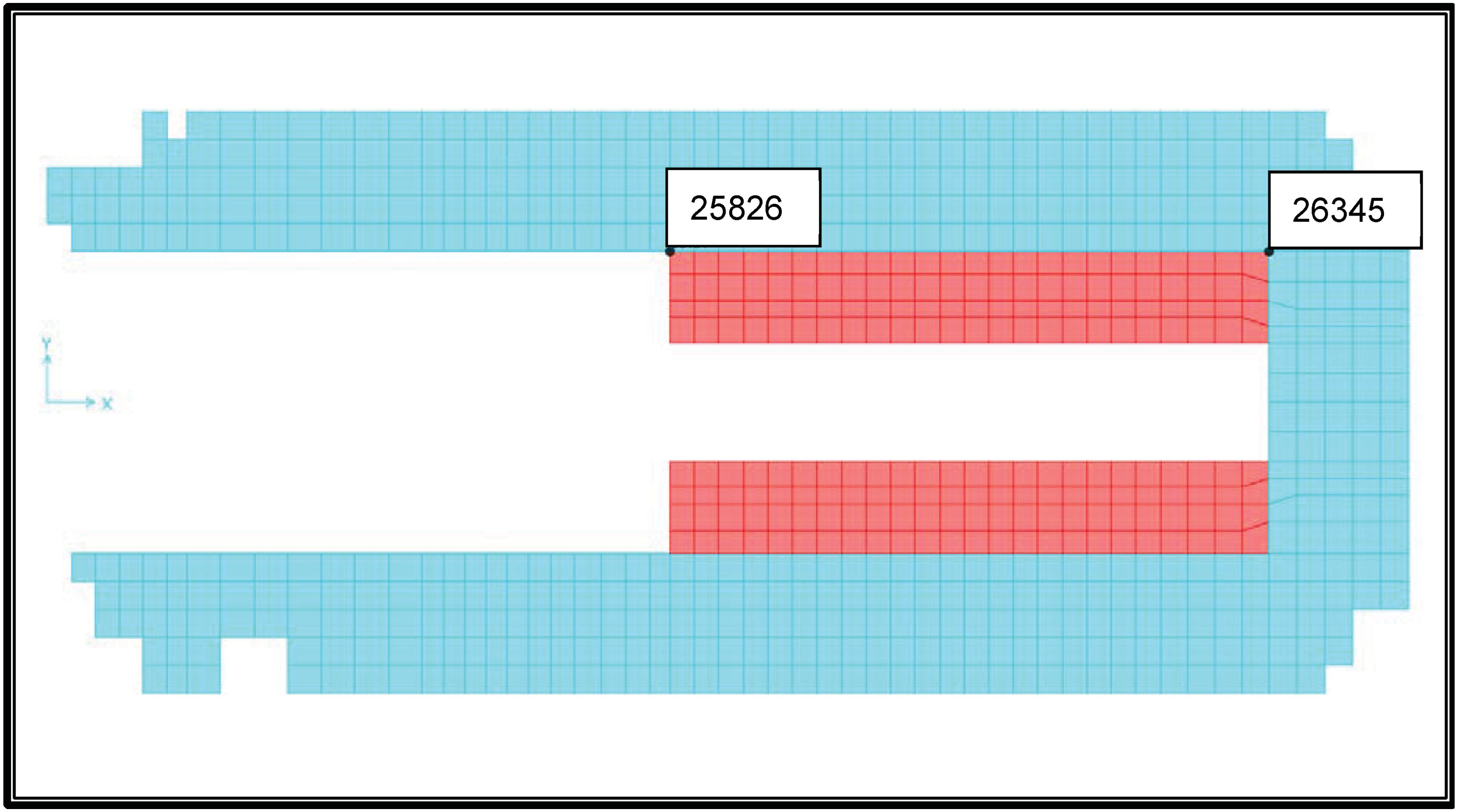


Figure 3.7.3-4: Not Used

Figure 3.7.3-4a: In-Structure Response Spectra at the Bioshield in X-Direction for Nodes 25826 and 26345 and the Enveloped ISRS using 4% Damping

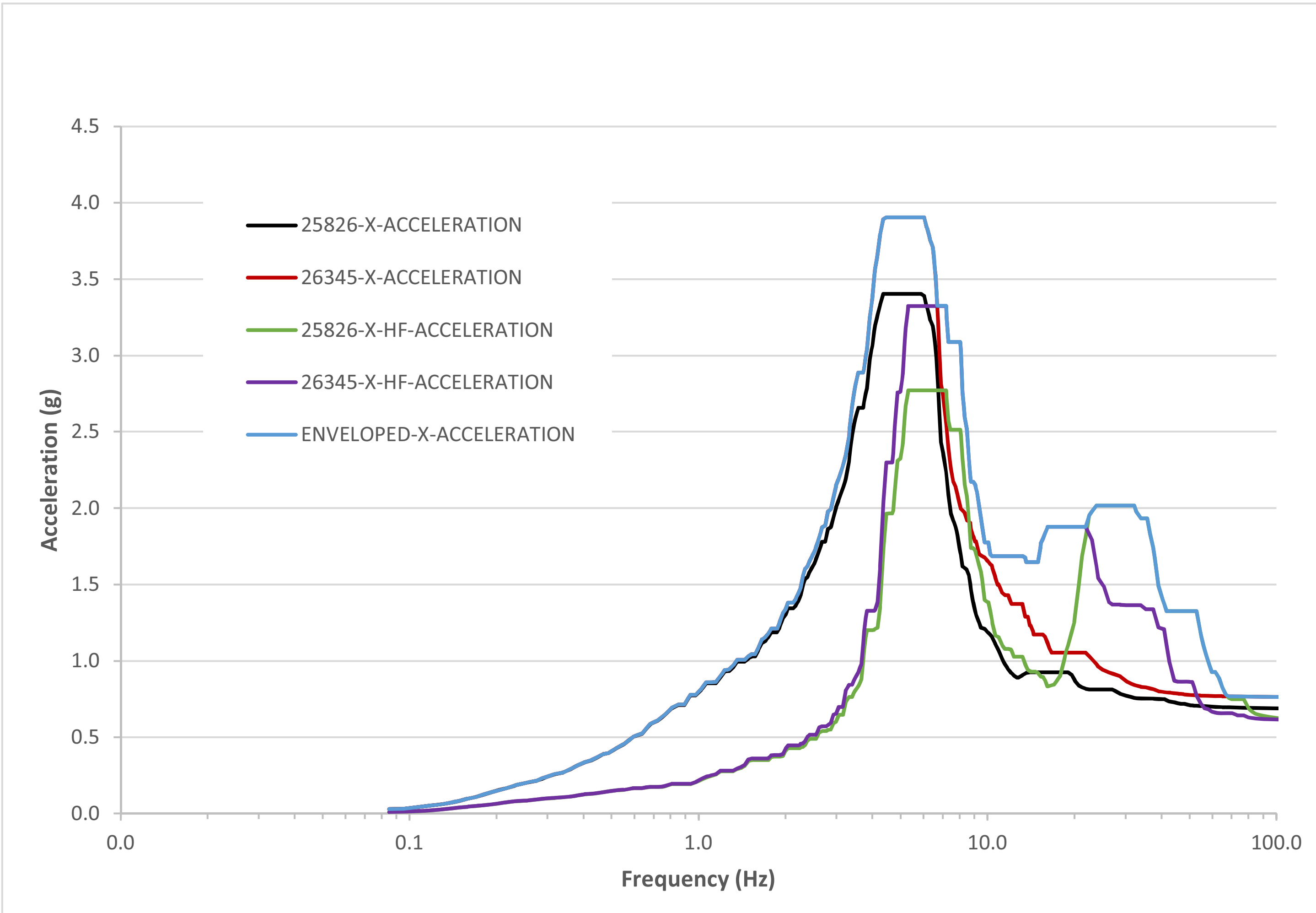


Figure 3.7.3-4b: In-Structure Response Spectra at the Bioshield in Y-Direction for Nodes 25826 and 26345 and the Enveloped ISRS using 4% Damping

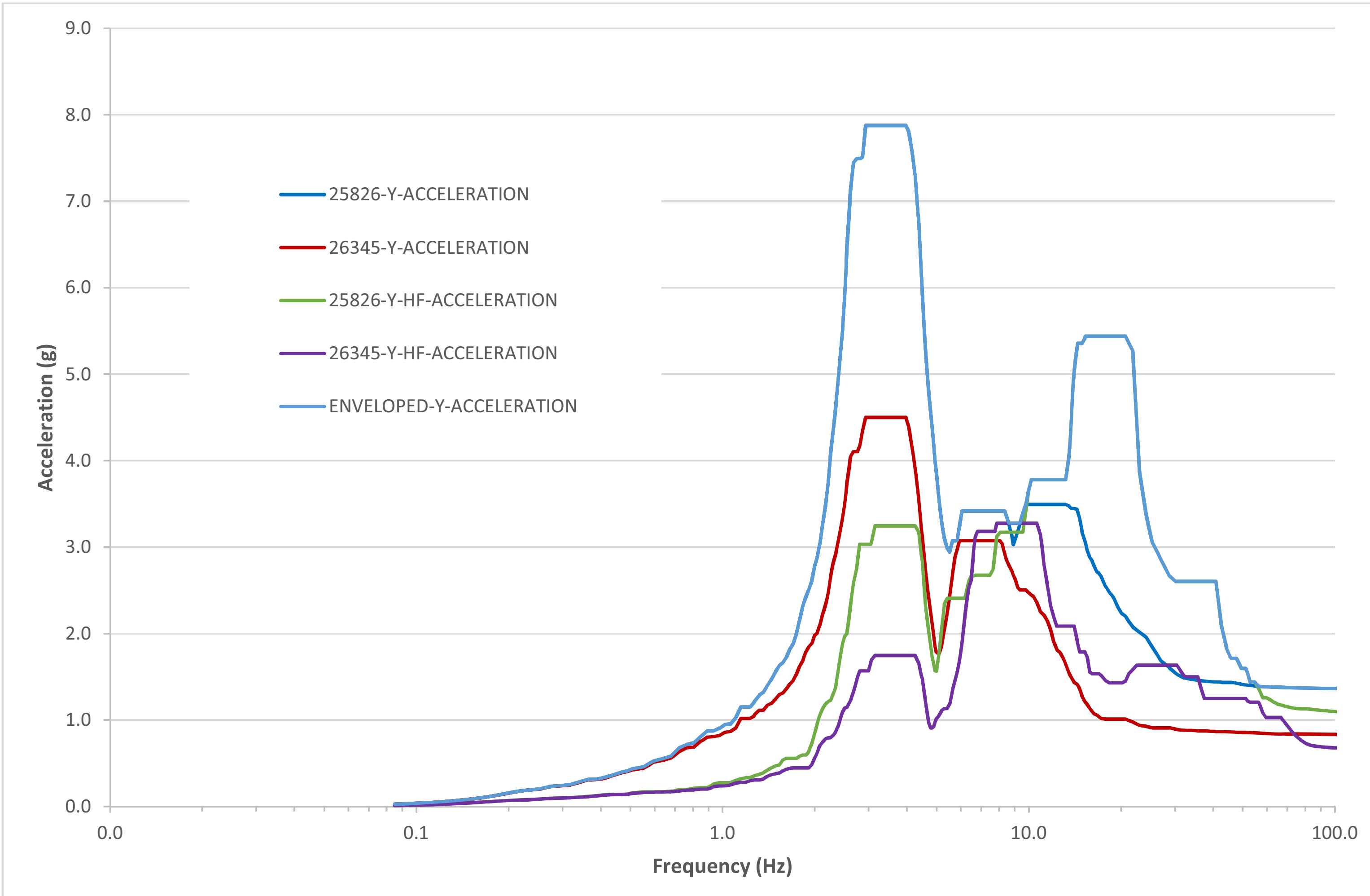
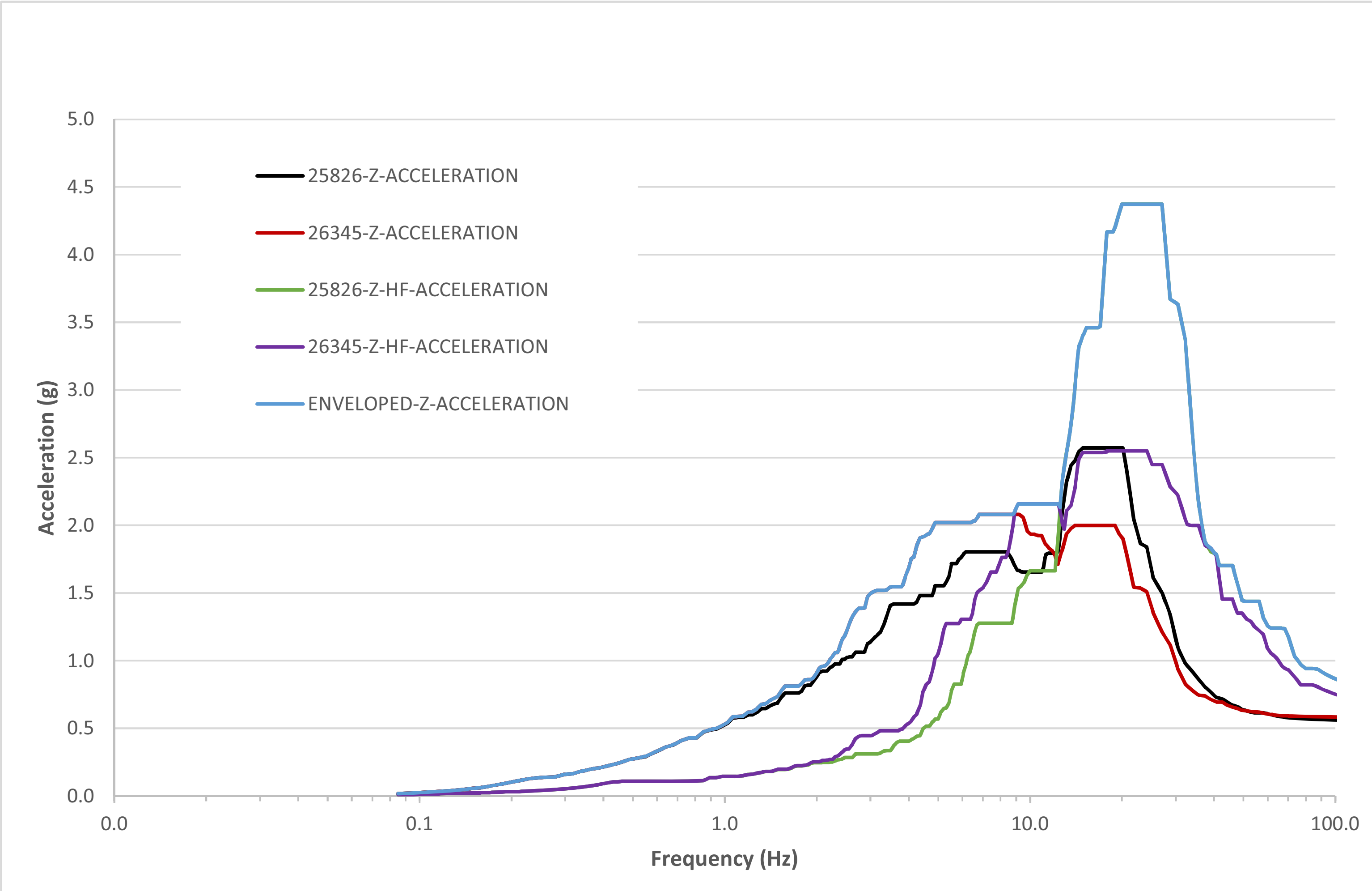


Figure 3.7.3-4c: In-Structure Response Spectra at the Bioshield in Z-Direction for Nodes 25826 and 26345 and the Enveloped ISRS using 4% Damping



3.7.4 Seismic Instrumentation

Appendix S to 10 CFR 50 requires a timely shutdown of a nuclear power plant if vibratory ground motion exceeding that of the operating basis earthquake occurs or if significant plant damage occurs. In addition, Appendix S requires that suitable instrumentation be provided so that the seismic response of nuclear power plant features can be evaluated promptly after an earthquake.

Conformance with these aspects of 10 CFR 50 Appendix S is provided by the seismic monitoring system (SMS).

The SMS is not safety-related or risk-significant. It has no interconnection to safety-related or risk-significant systems. The SMS consists of seismic instrumentation at various locations on the plant site, and data recorders and a controller located in a cabinet in the Reactor Building (RXB). The data recorders maintain a record of the seismic activity. The SMS is Seismic Category I. This includes the sensors, wiring between the sensors and the control cabinet, and the instrumentation in the control cabinet. The controller processes the data and provides alarm notification to the main control room (MCR) via the plant control system (PCS). Because the PCS is not a Seismic Category I system, additional Seismic Category I annunciation equipment is located in the MCR to alert operators of a seismic event. This annunciation is part of the SMS.

The SMS is a site-specific system.

COL Item 3.7-7: A COL applicant that references the NuScale Power Plant design certification will provide a seismic monitoring system and a seismic monitoring program that satisfies Regulatory Guide 1.12 "Nuclear Power Plant Instrumentation for Earthquakes," Rev. 2 (or later) and Regulatory Guide 1.166 "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," Rev. 0 (or later). This information is to be provided as noted below.

3.7.4.1 Comparison with Regulatory Guide 1.12

The NuScale design requires a deviation from the guidance in Regulatory Guide (RG) 1.12 "Nuclear Power Plant Instrumentation for Earthquakes," Rev. 2 in that seismic instrumentation cannot be included inside containment. There are twelve NuScale Power Modules (NPMs), each with an integral containment. The containments are flooded as part of the refueling process. The NPMs are all located within a single pool in the RXB, and are all at the same elevation in the building. Instead of locating seismic instrumentation in containment, it is located in the RXB.

The COL applicant will discuss site-specific conformance with RG 1.12 as part of the response to COL Item 3.7-1.

3.7.4.2 Location and Description of Instrumentation

Sensors are located in the free field, in the RXB, and in the Control Building (CRB). In the RXB and CRB, they are placed at locations that have been modeled as mass points in the building dynamic analysis so that the measured motion can be directly compared with the design spectra.

Exact sensor location is site-specific and will be discussed by the COL applicant as part of the response to COL Item 3.7-1.

In the selection of the exact sensor locations, the COL Applicant shall adhere to the following criteria to ensure the site, the RXB, and the CRB are adequately instrumented for a seismic event:

1) Two sensor units are located in the free field. One sensor is located at the free ground surface consistent with the site conditions and properties used to determine the site-specific GMRS. The second is a downhole instrument located at the foundation level as close as being directly over the first sensor as practical.

2) Two sensor units are located in the RXB on the basemat at elevation 24'-0". One sensor is located near the intersection of Grid Lines RX-1 and RX-A. The other sensor is located near the intersection of Grid Lines RX-7 and RX-A.

3) A fifth sensor unit is located in the RXB at elevation 75'-0" on the east face of Grid Line RX-6, between RX-B and RX-C.

4) A sixth sensor unit is located on the RXB roof near the intersection of Grid Lines RX-4 and RX-C.

5) A seventh sensor unit is located in the CRB on the basemat at elevation 50'-0" near the intersection of Grid Lines CB-4 and CB-A.

6) An eighth sensor unit is located in the CRB at elevation 100'-0" on the east face of Grid Line CB-1 between CB-B and CB-C.

Sensor type is site-specific and will be discussed by the COL Applicant as part of the response to COL Item 3.7-1.

3.7.4.3 Control Room Operator Notification

The SMS provides Seismic Category I annunciation in the MCR. Separately, the SMS provides information to the MCR via the PCS.

The COL applicant will discuss alarm levels based upon the site-specific operating basis earthquake as part of the response to COL Item 3.7-1.

3.7.4.4 Comparison with Regulatory Guide 1.166

The COL applicant will discuss site-specific conformance with RG 1.166 "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Postearthquake Actions," Rev. 0 as part of the response to COL Item 3.7-1.

3.7.4.5 Instrument Surveillance

The SMS is expected to be operable during all modes of plant operation, including periods of plant shutdown.

The COL applicant will discuss inservice inspection, calibration, and maintenance requirements as part of the response to COL Item 3.7-1.

3.7.4.6 Program Implementation

COL Item 3.7-8: A COL applicant that references the NuScale Power Plant design certification will identify the implementation milestone for the seismic monitoring program. In addition, a COL applicant that references the NuScale Power Plant design certification will prepare site-specific procedures for activities following an earthquake. These procedures and the data from the seismic instrumentation system will provide sufficient information to determine if the level of earthquake ground motion requiring shutdown has been exceeded. An activity of the procedures will be to address measurement of the post-seismic event gaps between the fuel racks and the pool walls and between the individual fuel racks and to take appropriate corrective action if needed (such as repositioning the racks or assuring that the as-found condition of the racks is acceptable based on the assumptions of the racks' design basis analysis). Acceptable guidance for procedure development is contained in Regulatory Guide 1.166 "Pre-Earthquake Planning and Immediate Nuclear Power Plant Operator Post-earthquake Actions," Rev. 0 (or later) and 1.167, "Restart of a Nuclear Power Plant Shut Down by a Seismic Event," Rev. 0 (or later).

3.7.5 Computer Programs Used in Section 3.7 Seismic Design

Only commercially available software packages were used for the analysis and design of the site-independent Seismic Category I and Seismic Category II structures. The primary software packages used are SAP2000 and SASSI2010.

The software validation and verification summary tests those characteristics of the software that mimic the physical conditions, material properties, and physical processes that represent the NuScale design in numerical analysis. It covers the full range of parameters used in NuScale design-basis seismic demand calculations including the discretization and aspect ratio of finite elements, Poisson's ratio, frequencies of analysis, and other parameters pertinent to seismic system analyses.

3.7.5.1 ANSYS

3.7.5.1.1 Description

ANSYS is a commercial, general use finite element analysis (FEA) software. ANSYS is used to determine demand loads and stresses in structures, supports, equipment, and components/assemblies. ANSYS Mechanical software offers a comprehensive product solution for structural linear and nonlinear and dynamic analysis. The product provides a complete set of element behavior, material models, and equation solvers for a wide range of engineering problems.

3.7.5.1.2 Version Used

ANSYS Computer Program, Release 14, 15, and 16.0, January 2015. ANSYS Incorporated, Canonsburg, Pennsylvania.

3.7.5.1.3 Validation and Verification

Software validation and verification was performed in accordance with the NuScale Quality Assurance program. This included confirmation that the software was capable of addressing the NuScale design conditions and performance of the ANSYS-provided verification testing package.

3.7.5.1.4 Extent of Use

ANSYS is used for fluid structure interaction applying input motions from SASSI2010 and using fluid elements to assess the fluid pressures on walls and sloshing heights. Factors are applied to SASSI2010 results to adjust for these effects.

3.7.5.2 SAP2000

3.7.5.2.1 Description

SAP2000 is a general-purpose, three-dimensional, static and dynamic finite-element computer program. Analyses, including calculation of deflections, forces, and stresses, may be done on structures constructed of any material or combination of materials.

It features a powerful graphical interface which is used to create/modify finite element models. This same interface is used to execute the analysis and for checking the optimization of the design. Graphical displays of results, including real-time animations of time-history displacements, are produced. SAP2000 provides automated generation of loads for design based on a number of National Standards.

The software can perform the following types of analyses: static linear analysis, static nonlinear analysis, modal analysis, dynamic response spectrum analysis, dynamic linear and nonlinear time history analysis, bridge analysis, moving load analysis, and buckling analysis.

3.7.5.2.2 Version Used

SAP2000, Version 18.1.1, Computers and Structures, Inc., Berkeley.

3.7.5.2.3 Validation and Verification

Software validation and verification was performed in accordance with NuScale Quality Assurance program. This included confirmation that the software was capable of addressing the NuScale design conditions and performance of the Computer and Structures Inc. verification problems.

3.7.5.2.4 Extent of Use

SAP2000 is used to develop the finite element models of the RXB and CRB and to perform general structural analysis of the building.

3.7.5.3 SASSI2010

3.7.5.3.1 Description

SASSI, a System for Analysis of Soil-Structure Interaction, consists of a number of interrelated computer program modules which can be used to solve a wide range of dynamic soil-structure interaction (SSI) problems in two or three dimensions.

3.7.5.3.2 Version Used

SASSI2010 Version 1.0, Berkeley, California

3.7.5.3.3 Validation and Verification

Software validation and verification was performed in accordance with NuScale Quality Assurance program. This included confirmation that SASSI2010 was capable of analyzing a model as large and complex as planned for the RXB, the CRB, and the RWB, and capable of using the earthquake profiles with the accelerations and frequency range of the CSDRS and CSDRS-HF. In addition, test problems were evaluated to confirm the adequacy of the program.

3.7.5.3.4 Extent of Use

SASSI2010 is used to obtain seismic design loads and in-structure floor response spectra for the Seismic Category I buildings accounting for the effects of SSI.

3.7.5.4 SHAKE2000

3.7.5.4.1 Description

The computer program SHAKE2000 computes the free-field response of a semi-infinite, horizontally layered soil column overlying a uniform half-space subjected to an input motion prescribed as the object motion in the form of vertically propagating shear waves. SHAKE2000 is used for the analysis of site-specific response and for the evaluation of earthquake effects on soil deposits. It provides an approximation of the dynamic response of a site. SHAKE2000 computes the response in a system of homogeneous, viscoelastic layers of infinite horizontal extent subjected to vertically traveling shear waves.

3.7.5.4.2 Version Used

SHAKE2000, a module of GeoMotions Suite, Version 9.98.0, Gustavo A. Ordonez.

3.7.5.4.3 Validation and Verification

Software validation and verification was performed in accordance with the NuScale Quality Assurance program. Sample problems were designed to test SHAKE2000 major analytical capabilities.

3.7.5.4.4 Extent of Use

SHAKE2000 is used to generate strain-compatible soil properties and free-field site response motions for use in seismic SSI analysis of the site-independent Seismic Category I and Seismic Category II structures.

3.7.5.5 RspMatch2009

3.7.5.5.1 Description

RspMatch2009 is used to generate spectrum-compatible acceleration time histories by modifying a recorded seismic accelerogram. The RspMatch2009 program performs a time domain modification of an acceleration time history to make it compatible with a user-specified target spectrum.

3.7.5.5.2 Version Used

RspMatch2009, Version 2009

3.7.5.5.3 Validation and Verification

Software validation and verification was performed in accordance with the NuScale Quality Assurance program. The program was validated by comparing the response spectrum calculated by RspMatch 2009 for an arbitrarily selected acceleration time history with one calculated by SAP2000 for the same acceleration time history.

3.7.5.5.4 Extent of Use

RspMatch2009 is used to generate the five CSDRS-compatible acceleration time histories by modifying the recorded seismic accelerograms of five different earthquakes and to generate the CSDRS-HF-compatible acceleration time history by modifying the recording of the time histories of a sixth earthquake.

3.7.5.6 RspMatchEDT

3.7.5.6.1 Description

RspMatchEDT is used to generate spectrum-compatible acceleration time histories by modifying a recorded seismic accelerogram. The RspMatchEDT Module for SHAKE2000 is a pre- and post-processor for the RspMatch2009 program, which is part of SHAKE2000.

3.7.5.6.2 Version Used

RspMatchEDT, a module of GeoMotions Suite, Version 9.98.0, Gustavo A. Ordonez.

3.7.5.6.3 Validation and Verification

Software validation and verification was performed in accordance with the NuScale Quality Assurance program. The program was validated by comparing the response spectrum calculated by RspMatchEDT with the spectrum calculated by RspMatch2009.

3.7.5.6.4 Extent of Use

RspMatchEDT is used to confirm the adequacy of the CSDRS and CSDRS-HF compatible time histories produced with RspMatch2009.