EVALUATION OF STRUCTURE-SOIL-STRUCTURE INTERACTION (SSSI) EFFECTS OF THE APR1400 STANDARD PLANT

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ABSTRACT

This technical report provides an evaluation of the structure-soil-structure interaction effects on the seismic response of the APR1400 standard plant structures. The APR1400 standard plant structures consist of the reactor containment building and auxiliary building, located in the Nuclear Island and founded on a monolithic common basemat, and the emergency diesel generator building.

For evaluation of the structure-soil-structure interaction effects on the Nuclear Island structures and emergency diesel generator building due to the presence of adjacent structures, structure-soil-structure interaction analyses are performed using a coupled model for all structures in the power block to investigate the variation in maximum seismic response (demand) parameters such as in-structure response spectra under the design basis seismic ground motion input. In the structure-soil-structure interaction analysis, three generic site profile cases representing the soft, medium, and hard soil case profiles are considered.

Due to model size limitation of the Fast Solver Version of the ACS-SASSI computer program, the coupled structure-soil-structure interaction model is developed assuming a surface-supported foundation condition. This approximation substantially reduces the number of degrees of freedom, thus eliminating the structure-soil-structure interaction model size limitation problem. Since Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses (DC/COL-ISG-017) addresses the analysis case of “Embedded Structures Analyzed as Surface Structures in the Certified Design,” and since using surface structures provides more conservative seismic responses than using embedded structures, this approximation is acceptable.

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List of Acronyms

AB	Auxiliary Building
COL	Combined License
CPB	Compound Building
CS	Containment Structure
CSDRS	Certified Seismic Design Response Spectra
DFOST	Diesel Fuel Storage Tank
DOF	Degree Of Freedom
DRS	Design Response Spectra
EDGB	Emergency Diesel generator Building
EPRI	Electric Power Research Institute
FEM	Finite Element Model
FVM	Flexible Volume Method
IS	Internal Structure
ISRS	In-Structure Response Spectra
ISG	Interim Staff Guidance
NI	Nuclear Island
NRC	U.S. Nuclear Regulatory Commission
OBE	Operating Basis Earthquake
PGA	Peak Ground Acceleration
PSW	Primary Shield Wall
RCB	Reactor Containment Building
RCS	Reactor Coolant System
RG	Regulatory Guide
SFG	Structural Fill Granular
SGA	Switch Gear Area
SRP	Standard Review Plan
SRSS	Square-Root-of-the-Sum-of-Squares
SSCs	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
SSI	Soil-Structure Interaction
SSSI	Structure-Soil-Structure Interaction
SSW	Secondary Shield Wall
TGB	Turbine Generator Building
TGP	Turbine Generator Pedestal
TI	Turbine Island

1.0 INTRODUCTION

The purpose of this technical report is to present the structure-soil-structure interaction (SSSI) analysis methodologies and results for the APR1400 standard plant structures, which consist of the reactor containment building (RCB), auxiliary building (AB), and emergency diesel generator building (EDGB). It describes the seismic ground motion input, site conditions, dynamic models, and analysis methodology and procedures used in carrying out the seismic SSSI analysis. The key analysis results obtained from the analysis are also presented.

The APR1400 Nuclear Island (NI) structures include RCB and AB, founded on a monolithic common basemat. The RCB is structurally separate from the AB with a minimum seismic gap of 2 in above the common basemat. The RCB, which is a seismic Category I structure, consists of a prestressed concrete cylindrical shell and hemispherical dome and reinforced concrete internal structure, which are supported on a reinforced concrete mat foundation. The AB wraps around the RCB, leaving a space for the seismic gap above the common basemat. The AB, which is a seismic Category I structure, consists of reinforced concrete shear walls and floor slabs, which are lateral load-resisting systems and steel frames that support the vertical loads. The EDGB, which is a seismic Category I structure, consists of reinforced concrete shear walls and floor slabs that are lateral load-resisting systems. The EDGB is separated from the AB with a typical 3 ft building gap.

For evaluating the SSSI effects of NI structures and the EDGB due to presence of adjacent structures, SSSI analyses are performed using a coupled model for all structures in the power block to investigate the variations in maximum seismic response (demand) parameters such as in-structure response spectra (ISRS) under the design basis seismic ground motion input.

For the APR1400 standard plant design, a total of nine generic site soil profile cases and two concrete stiffness cases (uncracked and cracked), have been considered for the design basis soil-structure interaction (SSI) analysis. The assessment of the SSSI effects can be considered as a parametric sensitivity study. For such a study, a subset of the nine soil profile cases combined with the more conservative uncracked concrete stiffness case is considered adequate. Three soil cases (soft, medium, and hard) are selected for assessing SSSI effects. However, it is anticipated that the SSSI effects will be more noticeable for the soft soil case and less sensitive for the hard soil case, but the hard soil case generally controls the responses.

This technical report consists of seven sections. Section 1 provides an introductory note and background information. Section 2 describes the seismic Category I and II structures that are located in the APR1400 power block and are considered in SSSI analyses. Section 3 describes seismic design bases including design ground motion, and selected generic site soil profiles for SSSI analysis. Section 4 describes the SSSI analysis methodology using the coupled structure model. Section 5 provides SSSI analysis results and SSSI effects on the standard plant structures. Section 6 provides additional SSSI analysis results and SSSI effects on the EDGB. References cited in this technical report are listed in Section 7.

2.0 DESCRIPTION OF STRUCTURES IN POWER BLOCK

This section describes the APR1400 seismic Category I structures (RCB, AB, and EDGB) and seismic Category II structures, such as the compound building (CPB) and turbine generator building (TGB), that are located in the power block. The schematic layout of APR1400 power block is shown in Figure 2-1.

The AB is bordered on its west side by the TGB, on part of its south side by the CPB, and on part of its east side by the EDGB. The gaps provided between the AB and TGB, between AB and CPB, and between AB and EDGB are all 3 ft. These gaps below the plant's finished grade are backfilled with compacted structural fill granular (SFG).

2.1 Description of Nuclear Island

The NI structures are classified as safety-related seismic Category I structures. The RCB and AB are separated from each other above the basemat with a minimum 2 in. seismic gap. In plant layout, the AB wraps around the RCB completely. The plant's finished grade is at El. 98'-8". The top of the NI common basemat is at El. 55'-0". Thus, the AB exterior walls are embedded to a depth of about 44 ft below the plant's finished grade. The thickness of the NI reinforced concrete basemat is nominally 10 ft.

2.1.1 Reactor Containment Building

The RCB is a safety-related seismic Category I structure and is composed of three concrete substructures:

- Containment structure (CS)
- Primary shield wall (PSW)
- Secondary shield wall (SSW)

The CS is also called the prestressed concrete containment vessel. The PSW and the SSW are combined to form the reinforced concrete internal structure (IS), and are the supporting structures for the reactor coolant system (RCS).

The CS and IS are separated by a 2-in. gap and only connected at their basemat at El. 78'-0". Therefore, there is no interaction between the two structures except through this common basemat.

Figure 2-2 shows a typical section view of the RCB.

2.1.2 Auxiliary Building

The AB is a safety-related seismic Category I structure with an embedment depth of approximately 54 ft. It encloses the RCB in the center without structural connection except at the common basemat.

The AB is a rectangular reinforced concrete structure. The building includes the electrical and control area, main steam valve house, chemical and volume control system areas, emergency diesel generator area, spent fuel pool, cask loading pit, refueling canal, and auxiliary feedwater tanks.

The AB structure system is composed of reinforced concrete shear walls in both east-west (EW) and north-south (NS) directions for lateral load resistance, and the composite of reinforced concrete walls and slabs with steel columns and girders for vertical load resistance.

Figure 2-3 shows a typical section view of the AB.

2.2 Emergency Diesel Generator Building

The EDGB is a safety-related seismic Category I structure and is composed of two separate concrete structures:

- Emergency diesel generator building (EDGB)
- Diesel fuel oil storage tank (DFOST) room

The EDGB is one of the APR1400 standard plant structures with an embedment depth of approximately 9 ft. The DFOST room is an APR1400 standard plant structure with an embedment depth of approximately 39 ft. The EDGB is separated from the AB by a typical 3 ft building gap and from the DFOST room by a typical 3 ft gap.

The EDGB structural system consists of shear walls in both EW and NS directions, and two major floor slabs. These walls and slabs are made of reinforced concrete. The DFOST room consists of reinforced concrete shear walls and roof slabs. Steel girders are used to support the DFOST room roof.
Figure 2-4 shows a typical section view of the EDGB.

2.3 Compound Building

The CPB is a non-safety-related seismic Category II structure with an embedment depth of approximately 42 ft. The CPB is separated from the AB by a typical 3 ft gap. The CPB exterior walls are embedded at approximately 36 ft.

The shape of the CPB is rectangular. The major dimensions of the CPB are 216 ft long and 178 ft wide. The CPB is composed of rectangular reinforced concrete walls, steel columns, steel girders, and reinforced concrete slabs. The CPB structure is designed to preclude a structural failure that results from the safe shutdown earthquake (SSE) and that degrades the structural integrity of the adjacent AB.

The CPB is a five-story structure. The major floors are located at El. 63'-0", 85'-0", 100'-0", 120'-0" and 139'-6". The labyrinth walls that create numerous compartments used for the radwaste management system components are arranged in the basement and first two floors.

Figure 2-5 shows a typical section view of the CPB..

2.4 Description of Turbine Island

The three structures of the Turbine Island (TI), namely (1) turbine generator building (TGB), (2) switchgear area (SGA), and (3) turbine generator pedestal (TGP), are separated above their common basemat. The TGB and TGP are structurally completely separated above the common basemat by a seismic gap. The

TGB and SGA are structurally connected below the plant's finished grade but are also structurally separated above grade by a seismic gap.

The top surface of the TI common basemat is mostly at El. 73'-0", but some areas of the basemat descend to El. 55'-0". The configuration of the TI structures is approximately rectangular, having maximum plan dimensions of about 340 ft in the plant EW direction and about 195 ft in the plant NS direction. The TGB has an overall height of about 127 ft above the plant grade and the TI outside walls are embedded to a depth of approximately 50 ft below grade.

A section view of the TI structures is presented in Figure 2-6.

2.4.1 Turbine Generator Building

The TGB is a composite of braced steel frames and concrete shear wall structures. The TGB structure above grade is a braced steel frame structure, consisting of 11 transverse frames, each of which is in a plane aligned in the plant NS direction, and eight longitudinal frames aligned in a plane in the plant EW direction. The TGB structure below grade is primarily a concrete shear wall structure. Some interior steel columns above grade for the steel frame structure extend further down below grade to the top of the basemat.

The TGB has two floors above the basemat, the tops of which are at El. 100'-0" and El. 136'-6". The floor slab of each of the two floors is a reinforced concrete slab fully composite with a grid of slab-supporting steel girders and beams for carrying out-of-plane vertical loads. The slab at El. 100'-0" has a rectangular opening in its central area. Similarly, the slab at El. 136'-6" has a rectangular opening in the same central area. These openings on the two floor slabs accommodate the reinforced concrete TGP frame structure.

The roof truss is about 11 ft tall from El. 216'-3" to El. 227'-0". Two (main and auxiliary) overhead cranes oriented in the plant NS direction service the TGB open bay above the floor at El.136'-6". Each over-head crane is supported on two longitudinal crane girders. When the cranes are not in service, they are positioned and parked at the east end of TGB.

2.4.2 Switchgear Area

The SGA is a rectangular reinforced concrete shear wall structure with two levels of reinforced concrete floor slabs at El. 100'-0" and 122'-0", and a reinforced concrete roof slab at El. 145'-0". The structure is situated at the north-east (NE) corner of the TI structures.

The structure measures about 73 ft in the plant NS direction and about 101 ft in the plant EW direction. The overall structure has a height of 45 ft above grade. The east-end portion of the SGA, which covers a below-grade common tunnel, is one story shorter than the rest of the SGA. The roof slab of this portion is at El. 122'-0".

There are four interior steel columns, which are supported on top of the basemat and extend to the bottom side of the roof slab, supporting the interior portions of the SGA floor and roof slabs. Similar to the TGB floor slabs, the SGA reinforced concrete floor and roof slabs are supported by steel girders and beams that have full composite action with the reinforced concrete slabs for resisting vertical loads on the slabs.

2.4.3 Turbine Generator Pedestal

The TGP is a rectangular reinforced concrete moment-frame structure, that is approximately 229 ft long in the plant EW direction and about 51 ft wide in the plant NS direction. The structure is supported on top of the TI common basemat.

The TGP structure consists of six transverse (in the plant NS direction) rows of two columns lined up longitudinally (in the plant EW direction). The columns have rectangular cross-section shape and are rigidly connected at their top ends to a horizontal reinforced concrete frame, which is composed of two longitudinal girders and six transverse beams. The top of the horizontal frame is flush with the TGB operating floor at El. 136’-0”.

The TGP columns supported on top of the TI common basemat have different heights. The two columns on the east and west ends are supported on top of the basemat at El. 73’-0. The four interior rows of TGP columns are supported on an area of basemat that extends lower, its top surface at El. 55’-0”. TGP frame structure is completely separated from the TGB structure above the basemat.

3.0 APR1400 SEISMIC ANALYSIS BASES

This section describes the APR1400 seismic analysis bases including the design ground motions, generic site soil profiles, and groundwater table elevation.

3.1 Design Ground Motion

The basic seismic design input parameters used in the seismic analysis of the APR1400 standard plant structures consist of (1) design ground motion for the safe shutdown earthquake (SSE) and operating basis earthquake (OBE) conditions and (2) design time histories to be used for the seismic analysis.

For the APR1400, the design ground motion for OBE considered for design is set equal to one-third (1/3) of SSE. Thus, in accordance with the U.S. Nuclear Regulatory Commission (NRC) Standard Review Plan (SRP) Section 3.7.1, Revision 3 guidelines (Reference 5), an explicit seismic analysis or design for OBE is not required. Hence, only the design ground motion for SSE need be considered for the seismic analysis of the safety-related structures.

For the APR1400, the design ground motion for SSE considered in seismic design consists of two sets of ground motion parameters, (1) horizontal and vertical design (ground motion) response spectra of the site-independent SSE, referred to as the certified seismic design response spectra (CSDRS) and anchored to peak ground acceleration (PGA) of 0.3g, and (2) horizontal and vertical design time histories compatible with the CSDRS.

The spectral CSDRS values for frequencies below 9 Hz are the same as the spectral values of the NRC Regulatory Guide (RG) 1.60 design response spectra (Reference 8) anchored to PGA value of 0.3g. The spectral values of the CSDRS for frequencies in the higher range between 9 and 50 Hz are enhanced from the corresponding spectral values of the NRC RG 1.60 design response spectra. At 25 Hz, the CSDRS spectral values are increased from the corresponding spectral values of the RG 1.60 spectra by 30%. Spectral values for frequencies between 9 and 50 Hz are obtained by linear interpolation in log-log scale of enhanced spectral values at 25 Hz and the RG 1.60 spectral values at 9 and 50 Hz. Figures 3-1 and 3-2 show the horizontal and vertical CSDRS, respectively. The digitized values of the resulting horizontal and vertical CSDRS are provided in Table 3-1.

For the APR1400 standard design, the CSDRS control point is defined at the surface of the plant’s finished grade.

The three design acceleration time histories, composed of two horizontal (H1 and H2) and one vertical components (VT) that envelop the CSDRS, are applied to the APR1400 seismic analysis. The initial seed recorded motions that are modified to create the design time histories are actual recorded Northridge earthquake time histories.

The design time histories are generated with a time step size of 0.005 second. Figures 3-3, 3-4, and 3-5 show the acceleration, velocity, and displacement time histories for H1, H2, and VT components for each time step, respectively. The design time histories, H1, H2, and VT, are applied in the EW, NS, and vertical directions, respectively. The design time histories are statistically independent because the correlation coefficients between the design time histories are less than 0.16 as specified in SRP 3.7.1. Therefore, the representative maximum response of interest for the APR1400 systems, structures, and components (SSCs) can be obtained either by performing separate analyses for each of the three components of design time histories, or by performing a single analysis with all three components of design time histories applied simultaneously. The design time histories have a total time duration equal to 20.48 seconds and a corresponding stationary-phase, strong-motion duration defined as the time required for the Arias Intensity rise from 5% to 75% greater than 6 seconds.

The details of CSDRS and the CSDRS-compatible design time histories are provided in technical report APR1400-E-S-NR-13001-P, titled, “Seismic Design Bases for the ARP1400 Standard Plant Design” (Reference 2).

3.2 Generic Site Profiles

The APR1400 standard plant design considers that the plant is supported by various generic site profiles. Nine generic site profiles and one fixed-base support condition are considered. The nine generic site profiles are horizontally layered sites with site shear wave velocities that vary from soft to medium to firm soil sites and soft to medium to hard rock sites.

The nine generic site profiles considered for the APR1400 standard plant design of are divided among six site-layering categories, labeled Site-layering Categories A through F with site-layer thicknesses and depths from the ground surface as follows:

Site-layering Category	Layer Thickness (ft)	Layer Depth Range (ft)
A	55	0 ~ 55
B	45	55 ~ 100
C	100	100 ~ 200
D	300	200 ~ 500
E	500	500 ~ 1000
F	Infinite	Halfspace > 1000

In addition to six site-layering categories, five average shear wave velocity categories, labeled P1 through P5, are considered,. The categories and associated average shear wave velocity values as follows:

Average-Shear-Wave-Velocity Category	Average Shear Wave Velocity (ft/sec)
P1	1,200
P2	2,000
P3	4,000
P4	6,000
P5	9,200

The site soil/rock material unit weight (weight density), Poisson’s Ratio, and types of shear-strain-dependent modulus degradation and damping value variation curves for the soil/rock material (sand, soft rock, and rock) considered for each of the categories P1 through P5 are shown in Table 3-2.

The nine generic site profiles considered for the APR1400 standard plant design, designated S1 through S9, were developed with combinations of the site-layering categories A through F and the average shear wave velocity categories P1 through P5, as shown in Table 3-3. Figure 3-6 shows the low-strain shear wave velocity profiles vs.. depth for the nine generic site profiles considered.

The shear-strain-dependent soil/rock modulus degradation and damping value variation curves for the soil/rock materials (sand, soft rock, and rock) considered for the nine generic site profiles are shown in Figure 3-7 for sand, Figure 3-8 for soft rock, and Figure 3-9 for rock. The curves used for sand, as shown in Figure 3-7, adopt the sand curves published in the Electric Power Research Institute (EPRI) report (Reference 11). The curves used for soft rock, as shown in Figure 3-8, adopt the curves for soft rock published in Silva's report (Reference 14). The curves used for rock, as shown in Figure 3-9, adopt the curves for rock used in the SHAKE computer program (Reference 15).

3.3 Groundwater Table Elevation

For the APR1400 standard plant design, the design ground water table elevation is 2 ft below the ground surface at El. 96'-8". The extreme ground water table elevation considered in the design is at the ground surface at El. 98'-8". If the compression wave velocity of subgrade soil has a value less than the compression wave velocity of water (4,800 ft/sec), the compression wave velocity value of the soil is taken to be not less than 4,800 ft/sec.

4.0 STRUCTURE-SOIL-STRUCTURE INTERACTION ANALYSIS

For the APR1400 standard plant design, a total of nine generic site soil profile cases and two concrete stiffness cases are considered for the design basis soil-structure interaction (SSI) analysis. The assessment of structure-soil-structure interaction (SSSI) effects can be considered as a parametric sensitivity study. For such a study, a subset of the nine soil profile cases combined with the more conservative uncracked-concrete stiffness case is considered adequate. Therefore, three soil cases (soft, medium, and hard) are selected for assessing the SSSI effects. Generally, the SSSI effects are more noticeable for the soft soil case and less sensitive for the hard soil case, but the hard soil case controls the seismic responses.

This section describes the scope for the assessment of seismic SSSI effects on the APR1400 standard plant structures, the SSSI analysis methodologies, and the adopted SSSI analysis models.

4.1 Design Basis Soil-structure Interaction Analysis

The design basis SSI analysis is performed for all nine generic site profile cases S1 through S9 plus a 10th analysis case with a very rigid uniform half-space supporting medium simulating the fixed-base analysis case, labeled S10. In addition, both uncracked- and cracked-concrete stiffness cases are considered in the design basis SSI analysis.

For the APR1400 standard plant design, seismic SSI analyses considering the actual embedment of structures are performed using the SASSI analysis methodology (Reference 16) and its associated SASSI computer program (Reference 18). Following the SASSI analysis methodology, the foundation embedment of individual structures is considered in the SASSI analysis using the Direct Method of substructuring.

Since the Direct Method is adopted for the SASSI analyses of the embedded standard plant structures, which are modeled using finite element models (FEMs), the resulting SASSI analysis models developed for the SASSI analysis contain a large number of dynamic degrees of freedom (DOFs) along with a large number of SSI nodal DOFs below grade. As a result, to generate seismic SSI responses for all analysis cases described above, the presently available large-capacity Fast Solver Version of the ACS-SASSI computer program (Reference 18) is adopted to perform the design basis SSI analysis.

4.2 Structure-Soil-Structure Interaction Analysis Methodology

This subsection describes the analysis methodology used to assess the SSSI effects on the APR1400 standard plant design. The Combined License (COL) applicant is to confirm that any site-specific non-seismic Category I structures are designed to not degrade the function of seismic Category I structures to an unacceptable safety level due to their structural failure or interaction.

Based on the APR1400 standard plant layout shown in Figure 2-1, the coupled model for all structures in the power block (NI structures, EDGB, CPB, and TI structures) is developed and used in the SSSI analysis. Soil cases S1, S5, and S9 are selected to represent the soft, medium, and hard soil cases, respectively, in SSSI analysis.

Due to model size limitation of the Fast Solver Version of the ACS-SASSI computer program, the coupled SSSI models are developed assuming a surface-supported foundation condition. This approximation substantially reduces the number of DOFs, thus eliminating the SSSI model size limitation problem. Since NRC Interim Staff Guidance on Ensuring Hazard-Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses (DC/COL-ISG-017) addresses the analysis case of “Embedded Structures Analyzed as Surface Structures in the Certified Design” (Reference 10), and since surface structures provide more conservative seismic responses than embedded structures, this approximation is acceptable.

This approximation, however, has the drawback that, unless the structures are truly surface-supported, the seismic responses obtained from their design basis SSI analyses performed previously could not be compared directly with the seismic responses from SSSI analysis using surface-supported foundation condition. Therefore, SSI reanalyses for stand-alone structures with surface-supported SSI models are required to enable assessment of SSSI effects.

The procedure for SSSI analysis of embedded APR1400 structures to be analyzed as surface structures is as follows:

- Assume the bottom elevation of NI common basemat, El. 45’-0”, as the ground surface.
- Remove the soil layers corresponding to the embedment depth of NI structures in the site response analysis to compute site response motions at foundation level in the free-field.
- Perform individual SSI analysis for the site response motion computed at foundation level with each structure model assuming the structure is founded at El.45’-0”.
- Perform coupled SSSI analysis for the site response motion computed at foundation level with the model for all structures in the power block assuming the surface-supported structures founded at El.45’-0”.

To assess the SSSI effects, the seismic responses obtained from individual SSI analysis and coupled SSSI analysis are compared.

4.3 Free-field Site Response Analysis

For the evaluation of SSSI effects, the free-field site response analyses adopting the concept specified in DC/COL-ISG-017 (Reference 10) are performed for three selected generic layered soil profiles: S1, S5, and S9.

In accordance with DC/COL-ISG-017, the site response motion at foundation level is computed when the seismic analyses of structures as surface structures with no embedment are considered in the SSI analysis. For computation of site response motion at foundation level, (1) the free-field site response analysis is performed for the soil column analysis for the full soil column with no truncation to include these effects and to develop the set of strain-compatible soil velocity and damping profiles, and then (2) using the strain-compatible soil profiles obtained, the soil layers corresponding to the embedment depth of the structure are removed, and (3) the second round of soil column analysis is performed with the truncated soil columns with no further iteration on soil properties. The resulting response motions at the truncated surface are used as input motion in individual SSI analyses and coupled SSSI analyses.

Horizontal free-field site response analyses have been carried out for the nine generic site profiles, S1 through S9, subjected to the free-field seismic ground motion input at the ground surface at El. 98'-8" in the design basis SSI analysis. The free-field seismic ground motion input is the CSDRS-compatible acceleration time histories H1 and H2 applied in the plant EW and NS directions, respectively. The shear-strain-compatible shear wave velocity profiles obtained from the analyses using H1 and H2 seismic inputs have been averaged to produce the averaged shear-strain-compatible shear wave velocity profile for each generic site profile. Based on the averaged shear-strain-compatible shear wave velocity profiles and the associated compression wave velocity profiles obtained for site profiles S1, S5, and S9 as given in Tables 4-1 through 4-3, the soil layers from the plant's finished grade to the NI common basemat bottom elevation are removed, and then the horizontal and vertical site response analyses are performed with the truncated soil column models without further iteration on soil properties to generate free-field site response motions that are convolved up to the NI foundation level, El.45'-0".

The resultant site response motions at the truncated surface to be used as the seismic inputs to the individual SSI analyses and coupled SSSI analyses for S1, S5, and S9 cases are shown in Figure 4-1.

4.4 Individual SSI Analysis Models

The individual SSI analysis models developed to assess the coupled SSSI effects on APR1400 standard plant structures consist of two substructure models, namely, (a) free-field site model, and (b) structure models.

<u>Free-field Site Models</u>

The SASSI free-field site models for individual SSI analysis are the same as the truncated soil column models to generate free-field site response motions convolved up to the NI foundation level, El.45'-0", i.e. the average strain-compatible soil profiles given in Tables 4-1 through 4-3 eliminating soil layers 1 to 11.

<u>Structure Models for Power Block</u>

NI (RCB, AB) and EDGB as seismic Category I structures, and CPB and TI (TGB, TGP, SGA) as seismic Category II structures are located in the power block. The structure model for the NI structures which is the combined SASSI FEM for the RCB and AB supported on the common basemat is shown in Figure 4-2. The methodology and results of developing FEMs for the APR1400 NI are presented in the Technical Report APR1400-E-S-NR-13002-P, "Finite Element Seismic Models for SSI Analyses of the NI Buildings of the APR1400 Standard Plant" (Reference 3). The structure model for the SASSI EDGB FEM is shown in Figure 4-3. The structure model for SASSI CPB FEM is shown in Figure 4-4. The structure model for the TI structures, which is the combined SASSI FEM for the TGB, TGP, and SGA supported on the common basemat, is shown in Figure 4-5. The major base elevations of all structure models are at El.45'-0".

4.5 Coupled SSSI Analysis Model

<u>Free-Field Site Models</u>

The SASSI free-field site models for coupled SSSI analysis are the same as the truncated soil column models to generate free-field site response motions convolved up to the NI foundation level, El.45'-0", i.e.

the average strain-compatible soil profiles given in Tables 4-1 through 4-3 eliminating soil layers 1 to 11.

Coupled SASSI Model for Power Block

The coupled model for NI structures, EDGB, CPB, and TI structures located in the power block is shown in Figure 4-6. The coupled model is developed by combing each structure model with actual gaps.

The coupled SASSI model for power block has the following attributes:

Total number of nodes	=	82,250
Total number of interaction nodes	=	3,770
Total number of solid elements	=	26,294
Total number of shell elements	=	29,498
Total number of beam elements	=	7,600
Total number of spring elements	=	2,078

The SASSI model data are coded using the Fast Solver Version of the ACS-SASSI computer program.

4.6 Individual SSI and Coupled SSSI Analysis Cases

To evaluate the SSSI effects on the APR1400 standard plant structures, individual SSI analyses for stand-alone structures and coupled SSSI analyses for the power block are performed for a total of three soil cases. The three soil cases analyzed with uncracked-concrete condition are designated cases S1U, S5U, and S9U.

For each of the three analysis cases, SASSI analyses are performed separately for the three directions of seismic input, (1) horizontal EW direction with the seismic input of the EW response time history, (2) horizontal NS direction with the seismic input of the NS response time history, and (3) vertical direction with the seismic input of the vertical response time history at the NI foundation level.

Due to the different seismic wave passage cutoff frequencies and different SSI system frequencies for each site profile case considered, the number of frequencies within the seismic wave passage cutoff frequency used for each SASSI analysis case varies. The total numbers of frequencies analyzed for the different analysis cases considered are summarized in Table 4-4.

To validate that the surface structure gives more conservative seismic responses than the embedded structure as mentioned in Section 4.2, the ISRS at AB El.156’-0” obtained from the design basis SSI analysis are compared to those obtained from the individual SSI analysis assuming the surface structure. Figures 4-7 through 4-9 show the results for the embedded structure case and Figures 4-10 through 4-12 show the results for surface structure case. As can be seen in the figures, the ISRS for surface structures are absolutely greater than those for embedded structures.

5.0 ANALYSIS AND ASSESSMENT RESULTS

Results of SASSI analyses obtained from the individual SSI analyses and coupled SSSI analysis described previously in Subsection 4.6 are post-processed to generate the ISRS for assessment of SSSI effects.

Post-processing procedures used to generate ISRS are described in the Technical Report No. APR1400-E-S-NR-13003-P, “SSI Analysis Methodology and Results of NI Buildings of the APR14000 Standard Plant” (Reference 4). The ISRS plots generated from the post-processing are presented and compared in this section.

Since SASSI analyses are performed separately for the three directions (EW, NS, and vertical) of seismic input, the ISRS are first generated from the results of SASSI analyses obtained for the individual direction of seismic input. Then, the maximum ISRS from the combined three directions of seismic input are combined using the square-root-of-the-sum-of-squares (SRSS) combination rule.

5.1 In-Structure Response Spectra

The SASSI analysis output-acceleration-response time histories obtained for each analysis case at selected nodal points of the SASSI FEM on the designated elevations of the RCB (CS, PSW, and SSW), AB and EDGB are used to compute the ISRS. The ISRS are computed for constant spectral damping value of 5%.

The ISRS generated for individual SSI analysis of each stand-alone structure at all selected nodal points on each designated structure elevation are first enveloped to generate the enveloped ISRS for the elevation, then widened by ± 15% in frequency. The ISRS generated for coupled SSSI analysis of all structures in the power block, however, are enveloped only. This is done because the individual SSI analysis is considered similar to design basis SSI analysis, while coupled SSSI analysis is considered as a parametric sensitivity study.

The comparisons of 5%-damped ISRS generated in both analyses are presented in Figures 5-1 trough 5-96.

The selected nodal points on each of the designated RCB structure elevations are summarized in Tables 5-1 through 5-3. Table 5-1 provides the selected nodal points in the CS, Table 5-2 in the PSW, and Table 5-3 in the SSW. The selected nodal points on each designated floor area of each designated floor elevation in the AB are summarized in Tables 5-4 and 5-5. Table 5-4 lists the selected nodal points on each designated floor area at the shear wall locations of each designated floor elevation for which ISRS are generated for seismic response motions in all three directions, EW (X), NS (Y), and vertical (Z). Table 5-5 lists the selected nodal points on floor slabs of each designated floor area of each designated floor elevation for which ISRS for the vertical (Z) seismic response motions are generated. The selected nodal points on each designated floor area of each designated floor elevation in the EDGB are summarized in Table 5-6.

The locations of the selected nodes on the designated elevations in the FEM are shown in Figures 5-97 through 5-124.

5.2 SSSI Effects on APR1400 Standard Plant Structures

The individual SSI analyses for each stand-alone structure and coupled SSSI analyses for all structures in the power block are performed using three selected generic site soil profiles, one soft (S1), one medium (S5), and one hard (S9) soil cases. The comparison results between individual SSI and coupled SSSI analyses are used to evaluate the SSSI effects on the APR1400 standard plant structures.

The 5%-damped ISRS that are obtained from the individual SSI and coupled SSSI analyses at key locations throughout the APR1400 standard plant structures (RCB, AB, and EDGB) are compared to each other. Comparisons of the ISRS for each analysis case indicate that the adjacent structures have insignificant effects on the seismic responses of NI structures. Comparisons of the ISRS, however, indicate that NI structures have noticeable effects on the EDGB vertical seismic responses for the soft soil case, S1, while NI structures have no significant effects on the EDGB seismic responses for the medium and hard soil cases, S5 and S9. An increase of approximately 30% on the EDGB vertical ISRS is observed for soft soil case S1U only.

In terms of the nodal maximum accelerations, the RCB and AB seismic responses obtained from the coupled SSSI analysis are generally reduced. The presence of the EDGB, CPB, and TI structures has insignificant effects on the seismic responses of NI structures.

Based on the preceding assessment, it can be concluded that the NI structures have negligible effects on their seismic responses due to adjacent structures such as the EDGB, CPB, and TI structures. EDGB vertical seismic responses, however, are significantly affected by the NI structures for soft soil cases.

6.0 ADDITIONAL SSSI ANALYSES AND ASSESSMENT

According to the assessment of SSSI effects in Section 5.2, the adjacent structures, including NI structures, have noticeable effects on the EDGB seismic responses for the soft soil case, S1, while they have no effects on the EDGB seismic responses for the medium and hard soil cases, S5 and S9.

To evaluate the SSSI effects on the EDGB in detail, individual SSI analyses for stand-alone EDGB and coupled SSSI analyses for all structures in the power block are performed for three additional soft soil cases. The additional three generic soil profiles analyzed with uncracked-concrete condition are designated cases S2U, S3U, and S4U. The SASSI free-field site models for individual SSI analyses are the same as the truncated soil column models to generate free-field site response motions convolved up to the NI foundation level, El. 45’-0”, i.e. the average strain-compatible soil profiles given in Tables 6-1 through 6-3, eliminating soil layers 1 to 11.

The number of frequencies within the seismic-wave-passage cutoff frequencies used for each SASSI analysis case varies due to the different seismic-wave-passage cutoff frequency and the different SSI system frequencies for each site profile case considered. The total number of frequencies analyzed for the additional analysis cases are summarized in Table 6-4.

6.1 Analysis Results

Seismic response parameters important to EDGB design consist of ISRS and maximum structural response forces. The results of SASSI analyses for SSE obtained for each analysis case are post-processed to generate these seismic response parameters. The results are then enveloped to produce the analysis-cases-enveloped seismic response parameters, and to determine the amplification factors for design basis EDGB seismic response parameters.

Since SASSI analyses for each analysis case are performed separately for the three directions (EW, NS, and vertical) of seismic input, the maximum seismic response parameters of interest are first generated from the results of SASSI analyses performed for each direction of seismic input. Then, the maximum seismic response parameters of interest from the three directions of seismic input are combined using the SRSS combination rule.

ISRS

The enveloped EDGB ISRS obtained from the SSSI analyses using the coupled model for all structures in the power block are compared with the enveloped ISRS obtained from the individual SSI analyses using the stand-alone EDGB model for soft soil cases S1 through S4. As comparison results, the ratio of enveloped 5%-damped EDGB ISRS between the SSSI analyses and individual SSI analyses is presented in Figure 6-1. The ratio of enveloped 5%-damped DFOST room ISRS is presented in Figure 6-2. The ISRS ratios, which are smaller than 1.0, are modified to 1.0 to prevent reduction of the design basis ISRS.

The 5%-damped ISRS ratios in Figures 6-1 and 6-2 are considered as amplification factors to be applied to increment the design basis EDGB and DFOST room ISRS for soft soil cases S1 through S4.

Structural Response Forces

The maximum seismic response forces (axial and shear) are generally governed by the response accelerations at the ISRS zero period. Figures 6-1 and 6-2 indicate that the ratio of response accelerations at zero period between the SSSI analyses and individual SSI analyses for soft soil cases are lesser than or equal to 1.0 except for the vertical direction ISRS at the basemat level of the EDGB and DFOST room. In other words, the adjacent NI structures have negligible effects on the EDGB horizontal shear forces for the soft soil cases, while the NI structures have significant effects on the EDGB vertical axial forces for the soft soil cases.

The amplification factors of the vertical ISRS at zero period reach 4% for the EDGB and 19% for the DFOST room. Therefore, the EDGB and DFOST room vertical axial forces for the soft soil cases need to be increased to consider the SSSI effects.

The enveloped design basis EDGB and DFOST room seismic axial forces are, however, governed by the axial force obtained from fixed-base analysis among nine SSI analysis and one fixed-base analysis cases. The enveloped EDGB and DFOST room axial forces for the design basis SSI analysis cases S1 through S4 are 1,376 kips and 497 kips, respectively, while the EDGB and DFOST room axial forces for the design basis fixed-base case are 1,576 kips and 591 kips, respectively. The ratios of the axial forces of the design basis fixed-base analysis case and the enveloped axial forces of design basis SSI analysis cases S1 and S4 for the EDGB and DFOST room are 1.15 and 1.19, respectively. These ratios are greater than or equal to the ISRS amplification factors determined from the SSSI analyses for the soft soil cases. Therefore, the design basis seismic response forces need not be increased to consider the SSSI effects on the EDGB.

6.2 Reflection of SSSI effects on EDGB

Based on the assessment of SSSI effects, it can be concluded that the NI structures have negligible effects on their seismic responses due to adjacent structures. EDGB seismic responses, however, are affected by the adjacent structures, including NI structures, for soft soil cases only, as described in Section 5.2.

The results of the assessment of dynamic SSSI effects are used as the basis to increase seismic design parameters such as enveloped ISRS, which are obtained from the design basis SSI analyses using the stand-alone EDGB model.

Based on the comparisons between the ISRS of individual SSI analyses and coupled SSSI analyses for soft soil cases, the ISRS amplification factors for each designated major floor elevation and each direction are computed to incorporate the SSSI effects on EDGB seismic response. The final enveloped design basis EDGB ISRS are increased by multiplying these amplification factors by ISRS obtained from design basis SSI analyses for 20 analysis cases, for conservatism.

7.0 REFERENCES

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Table 3-1. APR1400 Certified Seismic Design Response Spectra (CSDRS)

Horizontal

Damping Ratio (%)	Amplification Factor for Controlling Frequencies						
	0.1 Hz	0.2 Hz	0.25 Hz	2.5 Hz	9 Hz	25 Hz	50 Hz
2	0.0276	0.111	0.171	1.275	1.062	0.511	0.300
3	0.0254	0.102	0.159	1.125	0.939	0.498	0.300
4	0.0238	0.096	0.147	1.020	0.852	0.487	0.300
5	0.0226	0.090	0.141	0.939	0.783	0.479	0.300
7	0.0207	0.084	0.129	0.816	0.681	0.464	0.300
10	0.0188	0.075	0.117	0.684	0.570	0.447	0.300

Vertical

Damping Ratio (%)	Amplification Factor for Controlling Frequencies						
	0.1 Hz	0.2 Hz	0.25 Hz	3.5 Hz	9 Hz	25 Hz	50 Hz
2	0.0184	0.075	0.114	1.215	1.062	0.511	0.300
3	0.0170	0.069	0.105	1.074	0.939	0.498	0.300
4	0.0159	0.063	0.099	0.972	0.852	0.487	0.300
5	0.0151	0.060	0.093	0.894	0.783	0.479	0.300
7	0.0138	0.057	0.087	0.777	0.681	0.464	0.300
10	0.0125	0.051	0.078	0.651	0.570	0.447	0.300

Table 3-2. Dynamic Properties of Generic Soil/Rock Materials for Site Average Shear Wave Velocity Categories P1 through P5

Average-Shear Wave-Velocity Category No.	Average-Shear Wave-Velocity (ft/sec.)	Soil/Rock Unit Weight (lb/ft^3)	Poisson's Ratio (ν)	Degradation Curve type (EPRI)
P1	1,200	125	0.40	Sand
P2	2,000	130	0.38	Sand
P3	4,000	135	0.35	Soft Rock
P4	6,000	145	0.33	Rock
P5	9,200	155	0.33	Rock

Table 3-3. Site Layering and Average Shear Wave Velocity Categories Considered for the Nine Generic Site Profiles

Layer Site Category Depth from Ground Surface (ft)	Generic Soil Profile No.								
	S1	S2	S3	S4	S5	S6	S7	S8	S9
	Average Shear-wave Velocity No.								
A 0 ~ 50 ft	P1	P1	P2	P2	P3	P2	P2	P4	P4
B 50 ~ 100 ft	P1	P1	P2	P2	P3	P3	P3	P4	P4
C 100 ~ 200 ft	P1	P2	P2	P3	P4	P3	P4	P4	P5
D 200 ~ 500 ft	P2	P3	P3	P4	P4	P5	P5	P5	P5
E 500 ~ 1,000 ft	P3	P4	P5	P5	P5	P5	P5	P5	P5
F > 1,000 ft	P5	P5	P5	P5	P5	P5	P5	P5	P5

Table 4-1. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S1

Layer No.	Soil Type	Thick. (ft)	Depth Layer Top (ft)	Depth Layer Bottom (ft)	Weight Density (kcf)	Strain-Compatible Avg. V_s (fps)	Strain-Compatible V_p (fps)	Avg. Damping	Poisson's Ratio
1	Sand	5	0	5	0.125	1155	4800	0.020	0.47
2		5	5	10	0.125	1132	4800	0.031	0.47
3		5	10	15	0.125	1102	4800	0.041	0.47
4		5	15	20	0.125	1087	4800	0.048	0.47
5		5	20	25	0.125	1142	4800	0.037	0.47
6		5	25	30	0.125	1138	4800	0.042	0.47
7		5	30	35	0.125	1138	4800	0.046	0.47
8		5	35	40	0.125	1141	4800	0.050	0.47
9		5	40	45	0.125	1144	4800	0.053	0.47
10		5	45	50	0.125	1149	4800	0.056	0.47
11		5	50	55	0.125	1224	4800	0.043	0.47
12		5	55	60	0.125	1234	4800	0.044	0.46
13		5	60	65	0.125	1246	4800	0.046	0.46
14		5	65	70	0.125	1257	4800	0.047	0.46
15		5	70	75	0.125	1271	4800	0.047	0.46
16		5	75	80	0.125	1285	4800	0.048	0.46
17		5	80	85	0.125	1299	4800	0.048	0.46
18		5	85	90	0.125	1314	4800	0.049	0.46
19		5	90	95	0.125	1328	4800	0.050	0.46
20		5	95	100	0.125	1342	4800	0.050	0.46
21		5	100	105	0.125	1357	4800	0.050	0.46
22		5	105	110	0.125	1373	4800	0.051	0.46
23		5	110	115	0.125	1389	4800	0.051	0.45
24		5	115	120	0.125	1406	4800	0.051	0.45
25		5	120	125	0.125	1489	4800	0.039	0.45
26		5	125	130	0.125	1506	4800	0.039	0.45
27		5	130	135	0.125	1523	4800	0.039	0.44
28		5	135	140	0.125	1540	4800	0.039	0.44
29		5	140	145	0.125	1556	4800	0.039	0.44
30		5	145	150	0.125	1573	4800	0.039	0.44
31		5	150	155	0.125	1590	4800	0.039	0.44
32		5	155	160	0.125	1608	4800	0.039	0.44
33		5	160	165	0.125	1625	4800	0.039	0.44
34		5	165	170	0.125	1642	4800	0.039	0.43
35		5	170	175	0.125	1659	4800	0.039	0.43
36		5	175	180	0.125	1676	4800	0.039	0.43
37		5	180	185	0.125	1692	4800	0.039	0.43
38		5	185	190	0.125	1709	4800	0.039	0.43
39		5	190	195	0.125	1725	4800	0.039	0.43
40		5	195	200	0.125	1742	4845	0.039	0.43
41		10	200	210	0.13	2780	6650	0.022	0.39
42		10	210	220	0.13	2814	6732	0.022	0.39
43		10	220	230	0.13	2845	6813	0.022	0.39
44		10	230	240	0.13	2876	6894	0.023	0.39
45		10	240	250	0.13	2907	6973	0.023	0.39

Table 4-1. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S1

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
46		10	250	260	0.13	2992	7051	0.018	0.39
47		10	260	270	0.13	3022	7128	0.019	0.39
48		10	270	280	0.13	3053	7204	0.019	0.39
49		10	280	290	0.13	3083	7279	0.019	0.39
50		10	290	300	0.13	3113	7353	0.019	0.39
51	Sand	10	300	310	0.13	3142	7426	0.019	0.39
52		10	310	320	0.13	3172	7498	0.019	0.39
53		10	320	330	0.13	3200	7569	0.019	0.39
54		10	330	340	0.13	3229	7639	0.019	0.39
55		10	340	350	0.13	3258	7707	0.019	0.39
56		10	350	360	0.13	3286	7775	0.019	0.39
57		10	360	370	0.13	3314	7842	0.019	0.39
58		10	370	380	0.13	3342	7907	0.019	0.39
59		10	380	390	0.13	3369	7972	0.019	0.39
60		10	390	400	0.13	3396	8035	0.019	0.39
61		10	400	410	0.13	3423	8098	0.019	0.39
62		10	410	420	0.13	3449	8159	0.019	0.39
63		10	420	430	0.13	3475	8220	0.019	0.39
64		10	430	440	0.13	3501	8279	0.019	0.39
65		10	440	450	0.13	3526	8337	0.019	0.39
66		10	450	460	0.13	3550	8395	0.019	0.39
67		10	460	470	0.13	3574	8451	0.019	0.39
68		10	470	480	0.13	3598	8506	0.019	0.39
69		10	480	490	0.13	3621	8560	0.019	0.39
70		10	490	500	0.13	3644	8613	0.019	0.39
71	Soft Rock	20	500	520	0.135	5748	12029	0.035	0.35
72		20	520	540	0.135	5792	12120	0.035	0.35
73		20	540	560	0.135	5833	12208	0.035	0.35
74		20	560	580	0.135	5872	12292	0.035	0.35
75		20	580	600	0.135	5909	12372	0.035	0.35
76		20	600	620	0.135	5944	12448	0.035	0.35
77		20	620	640	0.135	5978	12520	0.035	0.35
78		20	640	660	0.135	6009	12588	0.035	0.35
79		20	660	680	0.135	6038	12653	0.035	0.35
80		20	680	700	0.135	6066	12714	0.035	0.35
81		20	700	720	0.135	6092	12771	0.035	0.35
82		20	720	740	0.135	6115	12824	0.035	0.35
83		20	740	760	0.135	6136	12873	0.035	0.35
84		20	760	780	0.135	6157	12919	0.036	0.35
85		20	780	800	0.135	6175	12960	0.036	0.35
86		20	800	820	0.135	6191	12998	0.036	0.35
87		20	820	840	0.135	6206	13032	0.036	0.35
88		20	840	860	0.135	6218	13062	0.036	0.35
89		20	860	880	0.135	6229	13089	0.036	0.35
90		20	880	900	0.135	6238	13111	0.036	0.35

Table 4-1. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S1

Layer No.	Soil Type	Thick. (ft)	Depth Layer Top (ft)	Depth Layer Bottom (ft)	Weight Density (kcf)	Strain-Compatible Avg. V_s (fps)	Strain-Compatible V_p (fps)	Avg. Damping	Poisson's Ratio
91		20	900	920	0.135	6245	13130	0.036	0.35
92		20	920	940	0.135	6251	13145	0.036	0.35
93		20	940	960	0.135	6254	13156	0.036	0.35
94		20	960	980	0.135	6256	13163	0.036	0.35
95		20	980	1000	0.135	6255	13166	0.037	0.35
96	Rock		1000	0	0.155	9200	18264	0.004	0.33

Table 4-2. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S5

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
1	Soft Rock	5	0	5	0.135	4048	8427	0.033	0.35
2		5	5	10	0.135	4071	8474	0.033	0.35
3		5	10	15	0.135	4086	8521	0.035	0.35
4		5	15	20	0.135	4103	8568	0.036	0.35
5		5	20	25	0.135	4139	8615	0.031	0.35
6		5	25	30	0.135	4161	8662	0.031	0.35
7		5	30	35	0.135	4183	8708	0.031	0.35
8		5	35	40	0.135	4205	8754	0.031	0.35
9		5	40	45	0.135	4227	8800	0.031	0.35
10		5	45	50	0.135	4249	8846	0.032	0.35
11		5	50	55	0.135	4271	8891	0.032	0.35
12		5	55	60	0.135	4293	8936	0.032	0.35
13		5	60	65	0.135	4314	8981	0.032	0.35
14		5	65	70	0.135	4336	9026	0.032	0.35
15		5	70	75	0.135	4357	9070	0.032	0.35
16		5	75	80	0.135	4378	9114	0.032	0.35
17		5	80	85	0.135	4399	9158	0.032	0.35
18		5	85	90	0.135	4420	9202	0.032	0.35
19		5	90	95	0.135	4441	9245	0.032	0.35
20		5	95	100	0.135	4462	9288	0.032	0.35
21	Rock	5	100	105	0.145	6719	13465	0.009	0.33
22		5	105	110	0.145	6735	13506	0.009	0.33
23		5	110	115	0.145	6751	13546	0.009	0.33
24		5	115	120	0.145	6767	13587	0.009	0.34
25		5	120	125	0.145	6783	13627	0.009	0.34
26		5	125	130	0.145	6800	13667	0.009	0.34
27		5	130	135	0.145	6816	13706	0.009	0.34
28		5	135	140	0.145	6832	13746	0.010	0.34
29		5	140	145	0.145	6848	13785	0.010	0.34
30		5	145	150	0.145	6864	13824	0.010	0.34
31		5	150	155	0.145	6880	13862	0.010	0.34
32		5	155	160	0.145	6896	13901	0.010	0.34
33		5	160	165	0.145	6913	13939	0.010	0.34
34		5	165	170	0.145	6929	13977	0.010	0.34
35		5	170	175	0.145	6945	14015	0.010	0.34
36		5	175	180	0.145	6961	14053	0.010	0.34
37		5	180	185	0.145	6977	14090	0.010	0.34
38		5	185	190	0.145	6993	14127	0.010	0.34
39		5	190	195	0.145	7009	14164	0.010	0.34
40		5	195	200	0.145	7025	14200	0.010	0.34
41		10	200	210	0.145	7048	14255	0.011	0.34
42		10	210	220	0.145	7080	14327	0.011	0.34
43		10	220	230	0.145	7110	14398	0.011	0.34
44		10	230	240	0.145	7141	14468	0.011	0.34

Table 4-2. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S5

Layer No.	Soil Type	Thick. (ft)	Depth Layer Top (ft)	Depth Layer Bottom (ft)	Weight Density (kcf)	Strain-Compatible Avg. V_s (fps)	Strain-Compatible V_p (fps)	Avg. Damping	Poisson's Ratio
45		10	240	250	0.145	7172	14537	0.011	0.34
46		10	250	260	0.145	7202	14605	0.011	0.34
47		10	260	270	0.145	7232	14673	0.011	0.34
48		10	270	280	0.145	7261	14739	0.011	0.34
49		10	280	290	0.145	7291	14805	0.011	0.34
50		10	290	300	0.145	7319	14869	0.011	0.34
51	Rock	10	300	310	0.145	7347	14933	0.011	0.34
52		10	310	320	0.145	7375	14996	0.012	0.34
53		10	320	330	0.145	7402	15058	0.012	0.34
54		10	330	340	0.145	7429	15119	0.012	0.34
55		10	340	350	0.145	7456	15179	0.012	0.34
56		10	350	360	0.145	7483	15238	0.012	0.34
57		10	360	370	0.145	7508	15296	0.012	0.34
58		10	370	380	0.145	7534	15353	0.012	0.34
59		10	380	390	0.145	7559	15410	0.012	0.34
60		10	390	400	0.145	7584	15465	0.012	0.34
61		10	400	410	0.145	7608	15520	0.012	0.34
62		10	410	420	0.145	7632	15573	0.012	0.34
63		10	420	430	0.145	7656	15626	0.012	0.34
64		10	430	440	0.145	7679	15678	0.012	0.34
65		10	440	450	0.145	7702	15729	0.012	0.34
66		10	450	460	0.145	7724	15779	0.012	0.34
67		10	460	470	0.145	7746	15828	0.012	0.34
68		10	470	480	0.145	7768	15876	0.012	0.34
69		10	480	490	0.145	7789	15923	0.012	0.34
70		10	490	500	0.145	7809	15970	0.012	0.34
71		20	500	520	0.155	9200	18264	0.010	0.33
72		20	520	540	0.155	9200	18264	0.010	0.33
73		20	540	560	0.155	9200	18264	0.010	0.33
74		20	560	580	0.155	9200	18264	0.010	0.33
75		20	580	600	0.155	9200	18264	0.010	0.33
76		20	600	620	0.155	9200	18264	0.010	0.33
77		20	620	640	0.155	9200	18264	0.010	0.33
78		20	640	660	0.155	9200	18264	0.010	0.33
79		20	660	680	0.155	9200	18264	0.010	0.33
80		20	680	700	0.155	9200	18264	0.010	0.33
81		20	700	720	0.155	9200	18264	0.010	0.33
82		20	720	740	0.155	9200	18264	0.010	0.33
83		20	740	760	0.155	9200	18264	0.010	0.33
84		20	760	780	0.155	9200	18264	0.010	0.33
85		20	780	800	0.155	9200	18264	0.010	0.33
86		20	800	820	0.155	9200	18264	0.010	0.33
87		20	820	840	0.155	9200	18264	0.010	0.33
88		20	840	860	0.155	9200	18264	0.010	0.33
89		20	860	880	0.155	9200	18264	0.010	0.33

Table 4-2. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S5

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
90		20	880	900	0.155	9200	18264	0.010	0.33
91		20	900	920	0.155	9200	18264	0.010	0.33
92		20	920	940	0.155	9200	18264	0.010	0.33
93		20	940	960	0.155	9200	18264	0.010	0.33
94		20	960	980	0.155	9200	18264	0.010	0.33
95		20	980	1000	0.155	9200	18264	0.010	0.33
96	Rock		1000	0	0.155	9200	18264	0.004	0.33

Table 4-3. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S9

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
1	Rock	5	0	5	0.145	4692	9315	0.003	0.33
2		5	5	10	0.145	4709	9348	0.005	0.33
3		5	10	15	0.145	4722	9382	0.006	0.33
4		5	15	20	0.145	4730	9415	0.007	0.33
5		5	20	25	0.145	4741	9448	0.007	0.33
6		5	25	30	0.145	4753	9481	0.008	0.33
7		5	30	35	0.145	4765	9513	0.008	0.33
8		5	35	40	0.145	4778	9546	0.008	0.33
9		5	40	45	0.145	4785	9578	0.008	0.33
10		5	45	50	0.145	4793	9610	0.009	0.33
11		5	50	55	0.145	4802	9642	0.009	0.34
12		5	55	60	0.145	4811	9674	0.009	0.34
13		5	60	65	0.145	4821	9706	0.009	0.34
14		5	65	70	0.145	4832	9737	0.010	0.34
15		5	70	75	0.145	4842	9768	0.010	0.34
16		5	75	80	0.145	4853	9799	0.010	0.34
17		5	80	85	0.145	4864	9830	0.010	0.34
18		5	85	90	0.145	4875	9861	0.010	0.34
19		5	90	95	0.145	4886	9892	0.011	0.34
20		5	95	100	0.145	4897	9922	0.011	0.34
21		5	100	105	0.155	9200	18264	0.010	0.33
22		5	105	110	0.155	9200	18264	0.010	0.33
23		5	110	115	0.155	9200	18264	0.010	0.33
24		5	115	120	0.155	9200	18264	0.010	0.33
25		5	120	125	0.155	9200	18264	0.010	0.33
26		5	125	130	0.155	9200	18264	0.010	0.33
27		5	130	135	0.155	9200	18264	0.010	0.33
28		5	135	140	0.155	9200	18264	0.010	0.33
29		5	140	145	0.155	9200	18264	0.010	0.33
30		5	145	150	0.155	9200	18264	0.010	0.33
31		5	150	155	0.155	9200	18264	0.010	0.33
32		5	155	160	0.155	9200	18264	0.010	0.33
33		5	160	165	0.155	9200	18264	0.010	0.33
34		5	165	170	0.155	9200	18264	0.010	0.33
35		5	170	175	0.155	9200	18264	0.010	0.33
36		5	175	180	0.155	9200	18264	0.010	0.33
37		5	180	185	0.155	9200	18264	0.010	0.33
38		5	185	190	0.155	9200	18264	0.010	0.33
39		5	190	195	0.155	9200	18264	0.010	0.33
40		5	195	200	0.155	9200	18264	0.010	0.33
41		10	200	210	0.155	9200	18264	0.010	0.33
42		10	210	220	0.155	9200	18264	0.010	0.33
43		10	220	230	0.155	9200	18264	0.010	0.33
44		10	230	240	0.155	9200	18264	0.010	0.33
45		10	240	250	0.155	9200	18264	0.010	0.33

Table 4-3. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S9

Layer No.	Soil Type	Thick. (ft)	Depth Layer Top (ft)	Depth Layer Bottom (ft)	Weight Density (kcf)	Strain-Compatible Avg. V_s (fps)	Strain-Compatible V_p (fps)	Avg. Damping	Poisson's Ratio
46		10	250	260	0.155	9200	18264	0.010	0.33
47		10	260	270	0.155	9200	18264	0.010	0.33
48		10	270	280	0.155	9200	18264	0.010	0.33
49		10	280	290	0.155	9200	18264	0.010	0.33
50		10	290	300	0.155	9200	18264	0.010	0.33
51	Rock	10	300	310	0.155	9200	18264	0.010	0.33
52		10	310	320	0.155	9200	18264	0.010	0.33
53		10	320	330	0.155	9200	18264	0.010	0.33
54		10	330	340	0.155	9200	18264	0.010	0.33
55		10	340	350	0.155	9200	18264	0.010	0.33
56		10	350	360	0.155	9200	18264	0.010	0.33
57		10	360	370	0.155	9200	18264	0.010	0.33
58		10	370	380	0.155	9200	18264	0.010	0.33
59		10	380	390	0.155	9200	18264	0.010	0.33
60		10	390	400	0.155	9200	18264	0.010	0.33
61		10	400	410	0.155	9200	18264	0.010	0.33
62		10	410	420	0.155	9200	18264	0.010	0.33
63		10	420	430	0.155	9200	18264	0.010	0.33
64		10	430	440	0.155	9200	18264	0.010	0.33
65		10	440	450	0.155	9200	18264	0.010	0.33
66		10	450	460	0.155	9200	18264	0.010	0.33
67		10	460	470	0.155	9200	18264	0.010	0.33
68		10	470	480	0.155	9200	18264	0.010	0.33
69		10	480	490	0.155	9200	18264	0.010	0.33
70		10	490	500	0.155	9200	18264	0.010	0.33
71		20	500	520	0.155	9200	18264	0.010	0.33
72		20	520	540	0.155	9200	18264	0.010	0.33
73		20	540	560	0.155	9200	18264	0.010	0.33
74		20	560	580	0.155	9200	18264	0.010	0.33
75		20	580	600	0.155	9200	18264	0.010	0.33
76		20	600	620	0.155	9200	18264	0.010	0.33
77		20	620	640	0.155	9200	18264	0.010	0.33
78		20	640	660	0.155	9200	18264	0.010	0.33
79		20	660	680	0.155	9200	18264	0.010	0.33
80		20	680	700	0.155	9200	18264	0.010	0.33
81		20	700	720	0.155	9200	18264	0.010	0.33
82		20	720	740	0.155	9200	18264	0.010	0.33
83		20	740	760	0.155	9200	18264	0.010	0.33
84		20	760	780	0.155	9200	18264	0.010	0.33
85		20	780	800	0.155	9200	18264	0.010	0.33
86		20	800	820	0.155	9200	18264	0.010	0.33
87		20	820	840	0.155	9200	18264	0.010	0.33
88		20	840	860	0.155	9200	18264	0.010	0.33
89		20	860	880	0.155	9200	18264	0.010	0.33
90		20	880	900	0.155	9200	18264	0.010	0.33

Table 4-3. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S9

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
91		20	900	920	0.155	9200	18264	0.010	0.33
92		20	920	940	0.155	9200	18264	0.010	0.33
93		20	940	960	0.155	9200	18264	0.010	0.33
94		20	960	980	0.155	9200	18264	0.010	0.33
95		20	980	1000	0.155	9200	18264	0.010	0.33
96	Rock		1000	0	0.155	9200	18264	0.004	0.33

Table 4-4. Total Number of Frequencies and Highest Frequency for Each Analysis Case

Analysis Cases	S1U	S5U	S9U
Total Number of Frequencies	71	116	116
Highest Frequency Analyzed (Hz)	20.07	71.01	71.01

Table 5-1. Selected Nodal Points on Designated Structure Elevations of Containment Structure (CS) for Generation of ISRS

Elevation	Identification	SASSI Node Numbers
78'-0"	CS base at interface with concrete pedestal	13663, 13704, 13694, 13699, 13679, 13674,13682
100'-0"	CS shell	19988, 20015, 20016, 20025, 20030, 20037, 20011, 19992
156'-0"	Bottom ring at equipment hatch	28225, 28234, 28229, 28226, 28202, 28232, 27207, 28242
254'-6"	CS spring line	31939, 31943,31968, 31931, 31949, 31969, 31941, 31974
331'-9"	Dome apex	32522

Table 5-2. Selected Nodal Points on Designated Structure Elevations of Primary Shield Wall (PSW) for Generation of ISRS

Elevation	Identification	SASSI Node Numbers
78'-0"	4 corners at RV pit walls (top)	13581, 13585, 13586, 13595
100'-0"	Top of concrete pedestal	19674, 19341, 19665, 19354, 19194, 19275, 19375, 19265, 19189, 19168
156'-0"	Operating Deck	28097, 28124, 27764, 27264, 27607, 28039, 28007, 27886
191'-0"	PZR corners	30307, 30352

Table 5-3. Selected Nodal Points on Designated Structure Elevations of Secondary Shield Wall (SSW) for Generation of ISRS

Elevation	Identification	SASSI Node Numbers
78'-0"	SSW at concrete pedestal bottom	13318, 13328, 13338, 13349, 13353, 13323, 13333, 13345
100'-0"	SSW at interface with the concrete pedestal top	19698, 19712, 19334, 19724, 19719, 19705, 19717, 19729
156'-0"	Operating deck	27225, 27761, 27280, 27466, 27387, 27237, 27224, 27768
191'-0"	Top elevation of SSW	30301, 30323, 30331, 30298, 30299, 30341

Table 5-4. Selected Nodal Points at Shear Wall Locations on Designated Floor Elevations of Auxiliary Building for Generation of ISRS

Floor Elevation	Floor Identification	SASSI Model Node Numbers
55'-0"	Basemat	10600, 10642, 10647, 10715, 10717, 10751, 10803, 10806, 10863, 10876, 10884, 10936, 10942, 10946, 11021, 11025
100'-0"	Ground Floor	18085, 18140, 18165, 18173, 18289, 18382, 18488, 18496, 18526, 18532, 18632, 18692, 18812, 18820, 18856, 18950
156'-0"	Fourth Floor	27250, 27256, 27273, 27281, 27453, 27474, 27546, 27660, 27666, 27739, 27791, 27791, 27804, 27817
195'-0"	Sixth Floor Areas 1 and 3	30375, 30443, 30542, 30545, 30556, 30557, 30590, 30837
213'-6"	Fuel Handling Area	31421, 31470, 31519, 31525
114'-0"	Intermediate Floor Area 2, Fuel Handling Area	21680, 21693, 21770

Table 5-5. Selected Nodal Points on Floor-Slab Panels on Designated Floor Elevations of Auxiliary Building for Generation of Vertical ISRS

Floor Elevation	Floor Slab Identification	SASSI Model Node Numbers
55'-0"	Basemat	9501,9579,9604,9709, 9743,9861,9905
100'-0"	Ground Floor	18163, 18183, 18187, 18218, 18264, 18268, 18302, 18325, 18378, 18431, 18460, 18470, 18557, 18582, 18603, 18608, 18638, 18676, 18680, 18700, 18702, 18717, 18750, 18766, 18796, 18827, 18852, 18871, 18879, 18913, 18914, 18944, 18954, 18974, 18987, 19024, 19035, 19039, 19049, 19051, 19056, 19062, 19066, 19068, 19076, 19095, 19105, 19111, 19120, 19133
156'-0"	Fourth Floor	27317, 27325, 27343, 27423, 27488, 27516, 27551, 27582, 27620, 27656, 27693, 27750, 27760, 27779, 27785, 27798, 27802, 27813, 27822, 27833, 27880, 27892, 27895, 27896, 27904, 27910, 27926, 27968, 27974, 27980, 28020, 28023, 28036, 28088, 28108, 28119
195'-0"	Roof at Area 1 & 3 Roof at Main Control Room	30367, 30393, 30416, 30417, 30550, 30587, 30597, 30604, 30621, 30631, 30651, 30667, 30771, 30860, 30597, 30604
213'-6"	Fuel Handling Area Roof	31477, 31527
195'-0"	Roof at Area 2	30462, 30751
100'-0"	Ground Floor, Fuel Handling Area, Area 2	18676, 18700, 18913
114'-0"	Spent Fuel Pool Bottom Slab, Area 2	21699, 21731, 21738

Table 5-6. Selected Nodal Points on Designated Structure Elevations EDGB for Generation of ISRS

Elevation	Identification	SASSI Model Node Numbers
63'-0"	DFOST Room Wall	60127, 60131, 60135, 60221, 60226, 60231, 60243, 60248, 60253
	DFOST Room Slab	60127, 60135, 60181, 60187, 60234, 60240, 60243, 60253
100'-0"	DFOST Room Wall	60506, 60510, 60514, 60587, 60592, 60598, 60626, 60636
	DFOST Room Slab	60506, 60514, 60526, 60530, 60610, 60615, 60626, 60636
	EDGB Wall	60637, 60640, 60643, 60663, 60665, 60679, 60682, 60685, 60695, 60707, 60722, 60725, 60728
	EDGB Slab	60637, 60643, 60646, 60649, 60674, 60690, 60717, 60720, 60722, 60728
135'-0"	EDGB Wall	61045, 61049, 61053, 61078, 61079, 61093, 61096, 61099, 61107, 61129, 61139, 61143, 61147
	EDGB Slab	61045, 61053, 61056, 61060, 61072, 61082, 61083, 61110, 61111, 61115, 61132, 61136, 61139, 61147

Table 6-1. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S2

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
1	Sand	5	0	5	0.125	996	4,800	0.022	0.48
2		5	5	10	0.125	958	4,800	0.037	0.48
3		5	10	15	0.125	930	4,800	0.048	0.48
4		5	15	20	0.125	902	4,800	0.059	0.48
5		5	20	25	0.125	954	4,800	0.047	0.48
6		5	25	30	0.125	950	4,800	0.052	0.48
7		5	30	35	0.125	948	4,800	0.056	0.48
8		5	35	40	0.125	947	4,800	0.061	0.48
9		5	40	45	0.125	948	4,800	0.064	0.48
10		5	45	50	0.125	950	4,800	0.067	0.48
11		5	50	55	0.125	1,025	4,800	0.051	0.48
12		5	55	60	0.125	1,034	4,800	0.052	0.48
13		5	60	65	0.125	1,044	4,800	0.053	0.48
14		5	65	70	0.125	1,054	4,800	0.054	0.47
15		5	70	75	0.125	1,065	4,800	0.055	0.47
16		5	75	80	0.125	1,075	4,800	0.056	0.47
17		5	80	85	0.125	1,086	4,800	0.057	0.47
18		5	85	90	0.125	1,098	4,800	0.057	0.47
19		5	90	95	0.125	1,110	4,800	0.058	0.47
20		5	95	100	0.125	1,123	4,800	0.059	0.47
21		5	100	105	0.130	2,044	4996	0.029	0.40
22		5	105	110	0.130	2,055	5,037	0.03	0.40
23		5	110	115	0.130	2,065	5,077	0.031	0.40
24		5	115	120	0.130	2,074	5,117	0.031	0.40
25		5	120	125	0.130	2,134	5,157	0.024	0.40
26		5	125	130	0.130	2,147	5,197	0.025	0.40
27		5	130	135	0.130	2,160	5,236	0.025	0.40
28		5	135	140	0.130	2,174	5,275	0.025	0.40
29		5	140	145	0.130	2,188	5,314	0.026	0.40
30		5	145	150	0.130	2,202	5,353	0.026	0.40
31		5	150	155	0.130	2,216	5,392	0.026	0.40
32		5	155	160	0.130	2,229	5,430	0.026	0.40
33		5	160	165	0.130	2,242	5,468	0.027	0.40
34		5	165	170	0.130	2,255	5,506	0.027	0.40
35		5	170	175	0.130	2,267	5,543	0.027	0.40
36		5	175	180	0.130	2,280	5,581	0.027	0.40
37		5	180	185	0.130	2,293	5,618	0.027	0.40
38		5	185	190	0.130	2,306	5,655	0.028	0.40
39		5	190	195	0.130	2,319	5,692	0.028	0.40
40		5	195	200	0.130	2,332	5,728	0.028	0.40
41	Soft Rock	10	200	210	0.135	4,219	8,834	0.035	0.35
42		10	210	220	0.135	4,248	8,900	0.035	0.35
43		10	220	230	0.135	4,277	8,965	0.035	0.35
44		10	230	240	0.135	4,305	9,029	0.035	0.35
45		10	240	250	0.135	4,333	9,092	0.036	0.35

Table 6-1. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S2

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
46		10	250	260	0.135	4,361	9,154	0.036	0.35
47		10	260	270	0.135	4,387	9,215	0.036	0.35
48		10	270	280	0.135	4,413	9,276	0.036	0.35
49		10	280	290	0.135	4,440	9,336	0.036	0.35
50		10	290	300	0.135	4,466	9,395	0.036	0.35
51		10	300	310	0.135	4,492	9,453	0.036	0.35
52		10	310	320	0.135	4,517	9,510	0.037	0.35
53		10	320	330	0.135	4,542	9,566	0.037	0.35
54		10	330	340	0.135	4,567	9,622	0.037	0.35
55		10	340	350	0.135	4,592	9,677	0.037	0.35
56		10	350	360	0.135	4,616	9,731	0.037	0.35
57		10	360	370	0.135	4,639	9,784	0.037	0.35
58		10	370	380	0.135	4,663	9,836	0.037	0.36
59		10	380	390	0.135	4,686	9,887	0.037	0.36
60		10	390	400	0.135	4,709	9,938	0.037	0.36
61		10	400	410	0.135	4,732	9,988	0.037	0.36
62		10	410	420	0.135	4,754	10,037	0.038	0.36
63		10	420	430	0.135	4,776	10,085	0.038	0.36
64		10	430	440	0.135	4,797	10,132	0.038	0.36
65		10	440	450	0.135	4,819	10,178	0.038	0.36
66		10	450	460	0.135	4,839	10,224	0.038	0.36
67		10	460	470	0.135	4,859	10,269	0.038	0.36
68		10	470	480	0.135	4,879	10,313	0.038	0.36
69		10	480	490	0.135	4,898	10,356	0.038	0.36
70		10	490	500	0.135	4,918	10,398	0.038	0.36
71	Rock	20	500	520	0.145	6,847	13,946	0.012	0.34
72		20	520	540	0.145	6,881	14,022	0.012	0.34
73		20	540	560	0.145	6,914	14,094	0.012	0.34
74		20	560	580	0.145	6,945	14,164	0.012	0.34
75		20	580	600	0.145	6,976	14,230	0.012	0.34
76		20	600	620	0.145	7,004	14,293	0.012	0.34
77		20	620	640	0.145	7,032	14,353	0.012	0.34
78		20	640	660	0.145	7,057	14,410	0.012	0.34
79		20	660	680	0.145	7,081	14,463	0.012	0.34
80		20	680	700	0.145	7,103	14,514	0.012	0.34
81		20	700	720	0.145	7,124	14,561	0.012	0.34
82		20	720	740	0.145	7,143	14,605	0.012	0.34
83		20	740	760	0.145	7,162	14,646	0.012	0.34
84		20	760	780	0.145	7,178	14,684	0.012	0.34
85		20	780	800	0.145	7,191	14,718	0.012	0.34
86		20	800	820	0.145	7,203	14,750	0.012	0.34
87		20	820	840	0.145	7,214	14,778	0.013	0.34
88		20	840	860	0.145	7,223	14,803	0.013	0.34
89		20	860	880	0.145	7,232	14,825	0.013	0.34
90		20	880	900	0.145	7,238	14,843	0.013	0.34

Table 6-1. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S2

Layer No.	Soil Type	Thick. (ft)	Depth Layer Top (ft)	Depth Layer Bottom (ft)	Weight Density (kcf)	Strain-Compatible Avg. V_s (fps)	Strain-Compatible V_p (fps)	Avg. Damping	Poisson's Ratio
91		20	900	920	0.145	7,244	14,859	0.013	0.34
92		20	920	940	0.145	7,247	14,871	0.013	0.34
93		20	940	960	0.145	7,250	14,880	0.013	0.34
94		20	960	980	0.145	7,250	14,886	0.013	0.34
95		20	980	1000	0.145	7,249	14,889	0.013	0.34
96	Rock		1000	0	0.155	9,200	18,264	0.004	0.33

Table 6-2. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S3

Layer No.	Soil Type	Thick. (ft)	Depth Layer Top (ft)	Depth Layer Bottom (ft)	Weight Density (kcf)	Strain-Compatible Avg. V_s (fps)	Strain-Compatible V_p (fps)	Avg. Damping	Poisson's Ratio
1	Sand	5	0	5	0.130	2,090	4,800	0.015	0.38
2		5	5	10	0.130	2,090	4,809	0.019	0.38
3		5	10	15	0.130	2,081	4,861	0.023	0.39
4		5	15	20	0.130	2,082	4,912	0.026	0.39
5		5	20	25	0.130	2,126	4,963	0.021	0.39
6		5	25	30	0.130	2,129	5,014	0.023	0.39
7		5	30	35	0.130	2,130	5,065	0.025	0.39
8		5	35	40	0.130	2,134	5,115	0.027	0.39
9		5	40	45	0.130	2,140	5,165	0.028	0.40
10		5	45	50	0.130	2,148	5,215	0.030	0.40
11		5	50	55	0.130	2,213	5,264	0.024	0.39
12		5	55	60	0.130	2,226	5,314	0.024	0.39
13		5	60	65	0.130	2,241	5,363	0.025	0.39
14		5	65	70	0.130	2,255	5,412	0.025	0.39
15		5	70	75	0.130	2,270	5,460	0.026	0.40
16		5	75	80	0.130	2,285	5,508	0.026	0.40
17		5	80	85	0.130	2,300	5,556	0.026	0.40
18		5	85	90	0.130	2,315	5,604	0.027	0.40
19		5	90	95	0.130	2,331	5,651	0.027	0.40
20		5	95	100	0.130	2,345	5,699	0.028	0.40
21		5	100	105	0.130	2,358	5,745	0.029	0.40
22		5	105	110	0.130	2,372	5,792	0.029	0.40
23		5	110	115	0.130	2,386	5,839	0.029	0.40
24		5	115	120	0.130	2,400	5,885	0.030	0.40
25		5	120	125	0.130	2,466	5,931	0.023	0.40
26		5	125	130	0.130	2,482	5,976	0.024	0.40
27		5	130	135	0.130	2,498	6,021	0.024	0.40
28		5	135	140	0.130	2,514	6,067	0.024	0.40
29		5	140	145	0.130	2,530	6,111	0.024	0.40
30		5	145	150	0.130	2,546	6,156	0.025	0.40
31		5	150	155	0.130	2,562	6,200	0.025	0.40
32		5	155	160	0.130	2,578	6,244	0.025	0.40
33		5	160	165	0.130	2,594	6,288	0.025	0.40
34		5	165	170	0.130	2,609	6,332	0.025	0.40
35		5	170	175	0.130	2,624	6,375	0.026	0.40
36		5	175	180	0.130	2,640	6,418	0.026	0.40
37		5	180	185	0.130	2,655	6,461	0.026	0.40
38		5	185	190	0.130	2,670	6,503	0.026	0.40
39		5	190	195	0.130	2,685	6,545	0.026	0.40
40		5	195	200	0.130	2,700	6,587	0.026	0.40
41	Soft Rock	10	200	210	0.135	4,860	10,160	0.034	0.35
42		10	210	220	0.135	4,893	10,235	0.034	0.35
43		10	220	230	0.135	4,926	10,309	0.034	0.35
44		10	230	240	0.135	4,959	10,383	0.035	0.35
45		10	240	250	0.135	4,991	10,455	0.035	0.35

Table 6-2. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S3

Layer No.	Soil Type	Thick. (ft)	Depth Layer Top (ft)	Depth Layer Bottom (ft)	Weight Density (kcf)	Strain-Compatible Avg. V_s (fps)	Strain-Compatible V_p (fps)	Avg. Damping	Poisson's Ratio
46		10	250	260	0.135	5,023	10,527	0.035	0.35
47		10	260	270	0.135	5,055	10,598	0.035	0.35
48		10	270	280	0.135	5,087	10,667	0.035	0.35
49		10	280	290	0.135	5,117	10,736	0.035	0.35
50		10	290	300	0.135	5,147	10,804	0.035	0.35
51		10	300	310	0.135	5,178	10,871	0.036	0.35
52		10	310	320	0.135	5,207	10,936	0.036	0.35
53		10	320	330	0.135	5,237	11,001	0.036	0.35
54		10	330	340	0.135	5,266	11,065	0.036	0.35
55		10	340	350	0.135	5,294	11,128	0.036	0.35
56		10	350	360	0.135	5,322	11,190	0.036	0.35
57		10	360	370	0.135	5,349	11,251	0.036	0.35
58		10	370	380	0.135	5,377	11,311	0.036	0.35
59		10	380	390	0.135	5,403	11,370	0.036	0.35
60		10	390	400	0.135	5,430	11,429	0.036	0.35
61		10	400	410	0.135	5,456	11,486	0.036	0.35
62		10	410	420	0.135	5,481	11,542	0.036	0.35
63		10	420	430	0.135	5,506	11,597	0.037	0.35
64		10	430	440	0.135	5,530	11,652	0.037	0.35
65		10	440	450	0.135	5,554	11,705	0.037	0.35
66		10	450	460	0.135	5,577	11,757	0.037	0.35
67		10	460	470	0.135	5,601	11,809	0.037	0.35
68		10	470	480	0.135	5,624	11,859	0.037	0.35
69		10	480	490	0.135	5,646	11,909	0.037	0.36
70		10	490	500	0.135	5,668	11,958	0.037	0.36
71	Rock	20	500	520	0.155	9,200	18,264	0.010	0.33
72		20	520	540	0.155	9,200	18,264	0.010	0.33
73		20	540	560	0.155	9,200	18,264	0.010	0.33
74		20	560	580	0.155	9,200	18,264	0.010	0.33
75		20	580	600	0.155	9,200	18,264	0.010	0.33
76		20	600	620	0.155	9,200	18,264	0.010	0.33
77		20	620	640	0.155	9,200	18,264	0.010	0.33
78		20	640	660	0.155	9,200	18,264	0.010	0.33
79		20	660	680	0.155	9,200	18,264	0.010	0.33
80		20	680	700	0.155	9,200	18,264	0.010	0.33
81		20	700	720	0.155	9,200	18,264	0.010	0.33
82		20	720	740	0.155	9,200	18,264	0.010	0.33
83		20	740	760	0.155	9,200	18,264	0.010	0.33
84		20	760	780	0.155	9,200	18,264	0.010	0.33
85		20	780	800	0.155	9,200	18,264	0.010	0.33
86		20	800	820	0.155	9,200	18,264	0.010	0.33
87		20	820	840	0.155	9,200	18,264	0.010	0.33
88		20	840	860	0.155	9,200	18,264	0.010	0.33
89		20	860	880	0.155	9,200	18,264	0.010	0.33
90		20	880	900	0.155	9,200	18,264	0.010	0.33

Table 6-2. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S3

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
91		20	900	920	0.155	9,200	18,264	0.010	0.33
92		20	920	940	0.155	9,200	18,264	0.010	0.33
93		20	940	960	0.155	9,200	18,264	0.010	0.33
94		20	960	980	0.155	9,200	18,264	0.010	0.33
95		20	980	1000	0.155	9,200	18,264	0.010	0.33
96	Rock		1000	0	0.155	9,200	18,264	0.004	0.33

Table 6-3. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S4

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
1	Sand	5	0	5	0.130	1,813	4,800	0.016	0.42
2		5	5	10	0.130	1,802	4,800	0.021	0.42
3		5	10	15	0.130	1,794	4,800	0.026	0.42
4		5	15	20	0.130	1,790	4,800	0.029	0.42
5		5	20	25	0.130	1,820	4,800	0.025	0.42
6		5	25	30	0.130	1,817	4,800	0.027	0.42
7		5	30	35	0.130	1,818	4,800	0.029	0.42
8		5	35	40	0.130	1,820	4,800	0.031	0.42
9		5	40	45	0.130	1,826	4,800	0.033	0.42
10		5	45	50	0.130	1,832	4,800	0.034	0.41
11		5	50	55	0.130	1,898	4,800	0.026	0.41
12		5	55	60	0.130	1,909	4,800	0.027	0.41
13		5	60	65	0.130	1,921	4,800	0.027	0.40
14		5	65	70	0.130	1,930	4,800	0.029	0.40
15		5	70	75	0.130	1,939	4,800	0.029	0.40
16		5	75	80	0.130	1,949	4,800	0.030	0.40
17		5	80	85	0.130	1,958	4,831	0.032	0.40
18		5	85	90	0.130	1,967	4,873	0.033	0.40
19		5	90	95	0.130	1,975	4,914	0.033	0.40
20		5	95	100	0.130	1,984	4,955	0.034	0.40
21	Soft Rock	5	100	105	0.135	3,892	8,114	0.033	0.35
22		5	105	110	0.135	3,908	8,151	0.034	0.35
23		5	110	115	0.135	3,922	8,188	0.034	0.35
24		5	115	120	0.135	3,937	8,225	0.034	0.35
25		5	120	125	0.135	3,953	8,262	0.034	0.35
26		5	125	130	0.135	3,968	8,298	0.035	0.35
27		5	130	135	0.135	3,983	8,334	0.035	0.35
28		5	135	140	0.135	3,998	8,370	0.035	0.35
29		5	140	145	0.135	4,013	8,406	0.035	0.35
30		5	145	150	0.135	4,027	8,441	0.035	0.35
31		5	150	155	0.135	4,042	8,476	0.035	0.35
32		5	155	160	0.135	4,057	8,512	0.036	0.35
33		5	160	165	0.135	4,072	8,546	0.036	0.35
34		5	165	170	0.135	4,087	8,581	0.036	0.35
35		5	170	175	0.135	4,102	8,616	0.036	0.35
36		5	175	180	0.135	4,116	8,650	0.036	0.35
37		5	180	185	0.135	4,131	8,684	0.036	0.35
38		5	185	190	0.135	4,145	8,718	0.036	0.35
39		5	190	195	0.135	4,160	8,751	0.036	0.35
40		5	195	200	0.135	4,175	8,785	0.037	0.35
41	Rock	10	200	210	0.145	6,120	12,396	0.011	0.34
42		10	210	220	0.145	6,147	12,458	0.011	0.34
43		10	220	230	0.145	6,173	12,520	0.011	0.34
44		10	230	240	0.145	6,200	12,581	0.011	0.34
45		10	240	250	0.145	6,225	12,641	0.011	0.34

Table 6-3. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S4

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
46		10	250	260	0.145	6,252	12,700	0.011	0.34
47		10	260	270	0.145	6,278	12,759	0.011	0.34
48		10	270	280	0.145	6,303	12,817	0.011	0.34
49		10	280	290	0.145	6,328	12,874	0.011	0.34
50		10	290	300	0.145	6,353	12,930	0.011	0.34
51		10	300	310	0.145	6,378	12,985	0.012	0.34
52		10	310	320	0.145	6,401	13,040	0.012	0.34
53		10	320	330	0.145	6,596	13,094	0.012	0.34
54		10	330	340	0.145	6,622	13,147	0.012	0.34
55		10	340	350	0.145	6,649	13,199	0.012	0.34
56		10	350	360	0.145	6,674	13,250	0.012	0.34
57		10	360	370	0.145	6,700	13,301	0.012	0.34
58		10	370	380	0.145	6,725	13,351	0.012	0.34
59		10	380	390	0.145	6,750	13,400	0.012	0.34
60		10	390	400	0.145	6,774	13,448	0.012	0.34
61		10	400	410	0.145	6,798	13,495	0.012	0.34
62		10	410	420	0.145	6,821	13,542	0.012	0.34
63		10	420	430	0.145	6,845	13,588	0.012	0.34
64		10	430	440	0.145	6,867	13,633	0.012	0.34
65		10	440	450	0.145	6,890	13,677	0.012	0.34
66		10	450	460	0.145	6,911	13,721	0.012	0.34
67		10	460	470	0.145	6,933	13,763	0.012	0.34
68		10	470	480	0.145	6,954	13,805	0.012	0.34
69		10	480	490	0.145	6,975	13,846	0.012	0.34
70		10	490	500	0.145	6,995	13,887	0.012	0.34
71	Rock	20	500	520	0.155	9,200	18,264	0.01	0.33
72		20	520	540	0.155	9,200	18,264	0.01	0.33
73		20	540	560	0.155	9,200	18,264	0.01	0.33
74		20	560	580	0.155	9,200	18,264	0.01	0.33
75		20	580	600	0.155	9,200	18,264	0.01	0.33
76		20	600	620	0.155	9,200	18,264	0.01	0.33
77		20	620	640	0.155	9,200	18,264	0.01	0.33
78		20	640	660	0.155	9,200	18,264	0.01	0.33
79		20	660	680	0.155	9,200	18,264	0.010	0.33
80		20	680	700	0.155	9,200	18,264	0.010	0.33
81		20	700	720	0.155	9,200	18,264	0.010	0.33
82		20	720	740	0.155	9,200	18,264	0.010	0.33
83		20	740	760	0.155	9,200	18,264	0.010	0.33
84		20	760	780	0.155	9,200	18,264	0.010	0.33
85		20	780	800	0.155	9,200	18,264	0.010	0.33
86		20	800	820	0.155	9,200	18,264	0.010	0.33
87		20	820	840	0.155	9,200	18,264	0.010	0.33
88		20	840	860	0.155	9,200	18,264	0.010	0.33
89		20	860	880	0.155	9,200	18,264	0.010	0.33
90		20	880	900	0.155	9,200	18,264	0.010	0.33

Table 6-3. Average Strain-Compatible Shear Wave and Compression Wave Velocity for Site Profile S4

Layer No.	Soil Type	Thick. (ft)	Depth Layer		Weight Density (kcf)	Strain-Compatible		Avg. Damping	Poisson's Ratio
			Top (ft)	Bottom (ft)		Avg. V_s (fps)	V_p (fps)		
91		20	900	920	0.155	9,200	18,264	0.010	0.33
92		20	920	940	0.155	9,200	18,264	0.010	0.33
93		20	940	960	0.155	9,200	18,264	0.010	0.33
94		20	960	980	0.155	9,200	18,264	0.010	0.33
95		20	980	1000	0.155	9,200	18,264	0.010	0.33
96	Rock		1000	0	0.155	9,200	18,264	0.004	0.33

Table 6-4. Total Number of Frequencies and Highest Frequency for Each Analysis Case

Analysis Cases	S2U	S3U	S4U
Total Number of Frequencies	70	94	89
Highest Frequency Analyzed (Hz)	20.07	41.09	35.23

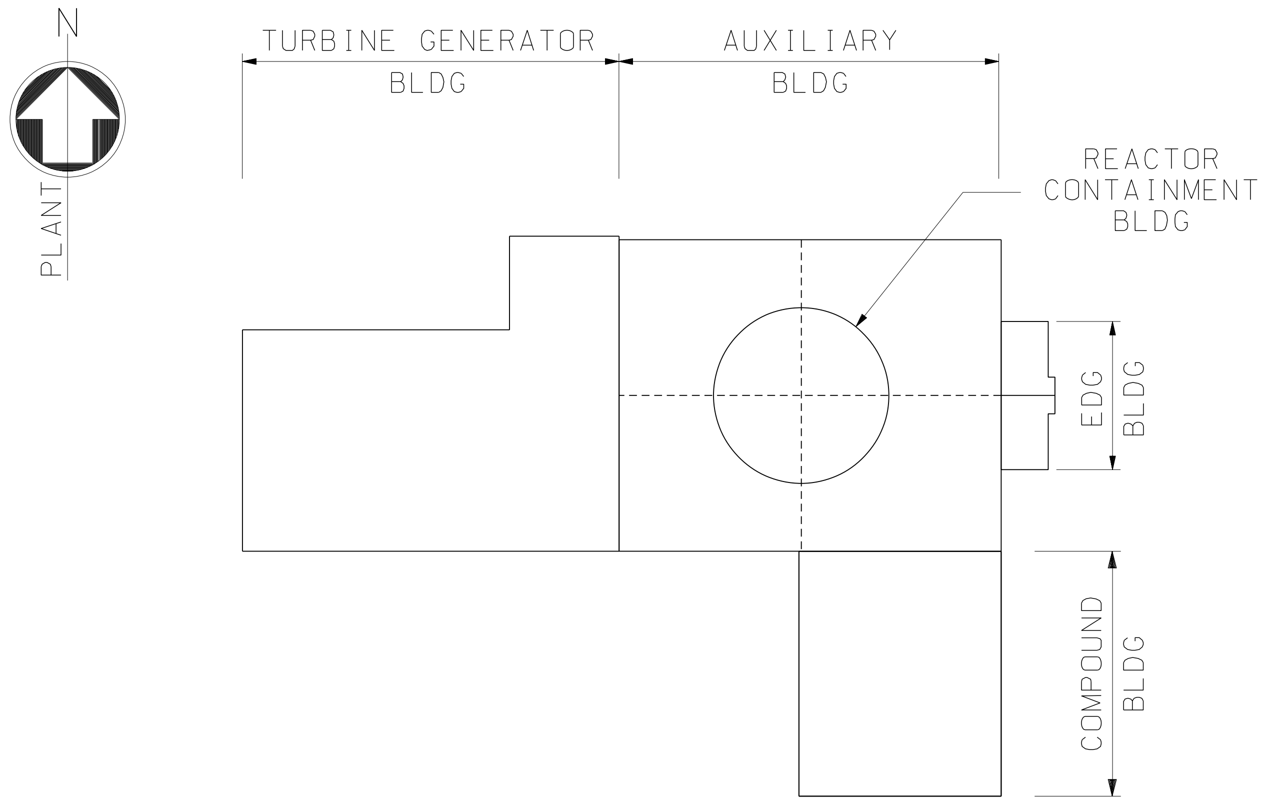


Figure 2-1. Plan Layout of APR1400 Power Block

Security-Related Information – Withheld Under 10 CFR 2.390

Figure 2-2. Typical Section View of Reactor Containment Building

Security-Related Information – Withheld Under 10 CFR 2.390

Figure 2-3. Typical Section View of Auxiliary Building

Security-Related Information – Withheld Under 10 CFR 2.390

Figure 2-4. Typical Section View of Emergency Diesel Generator Building

Security-Related Information – Withheld Under 10 CFR 2.390

Figure 2-5. Typical Section View of Compound Building

Security-Related Information – Withheld Under 10 CFR 2.390

Figure 2-6. Typical Section View of Turbine Island

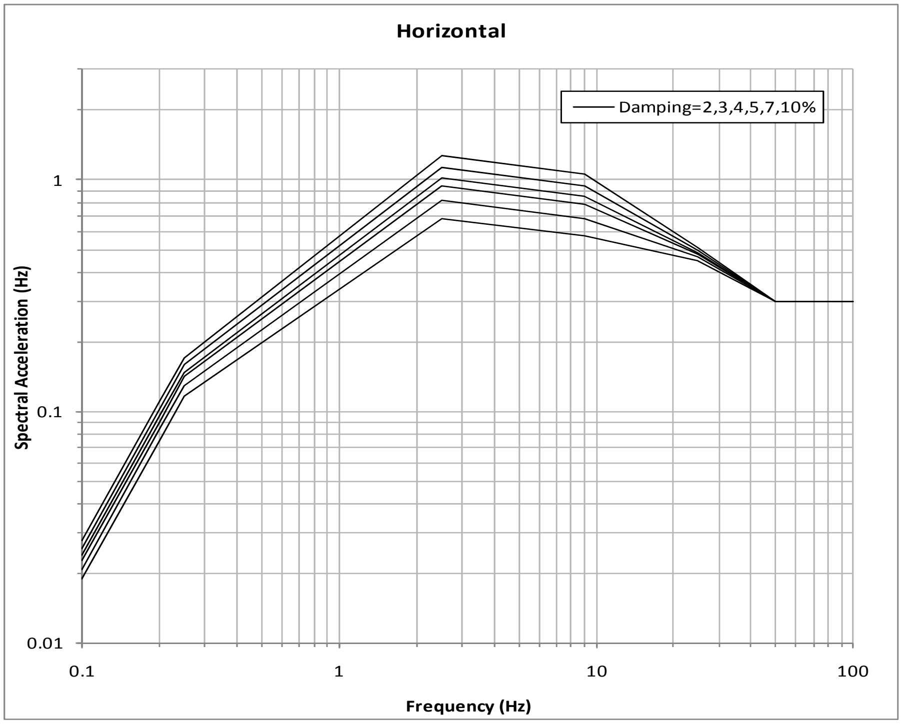


Figure 3-1. APR1400 Horizontal Certified Seismic Design Response Spectra (CSDRS)

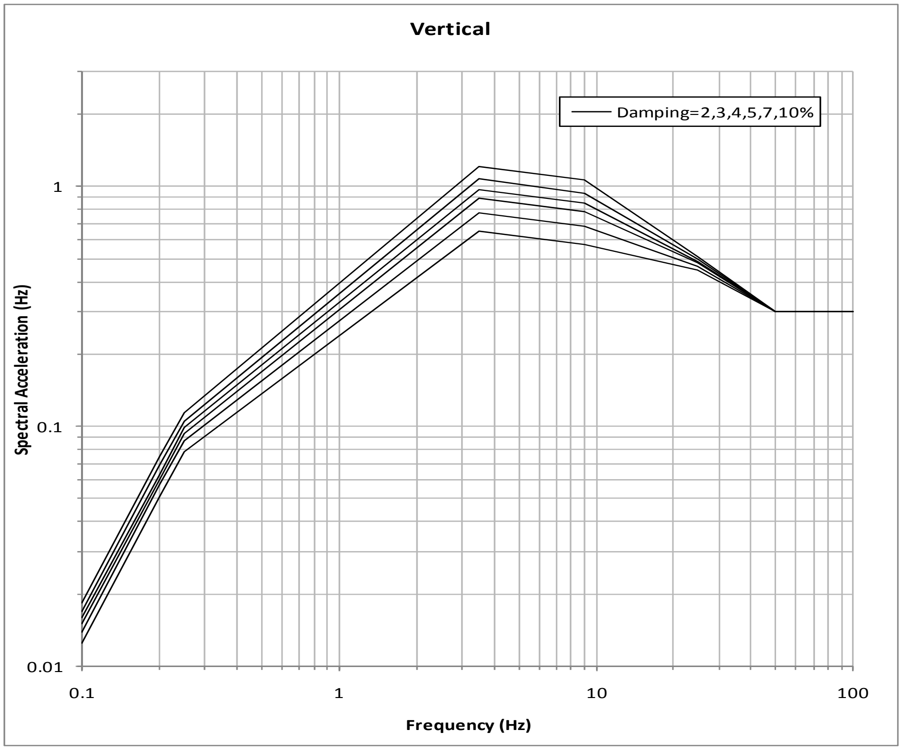


Figure 3-2. APR1400 Vertical Certified Seismic Design Response Spectra (CSDRS)

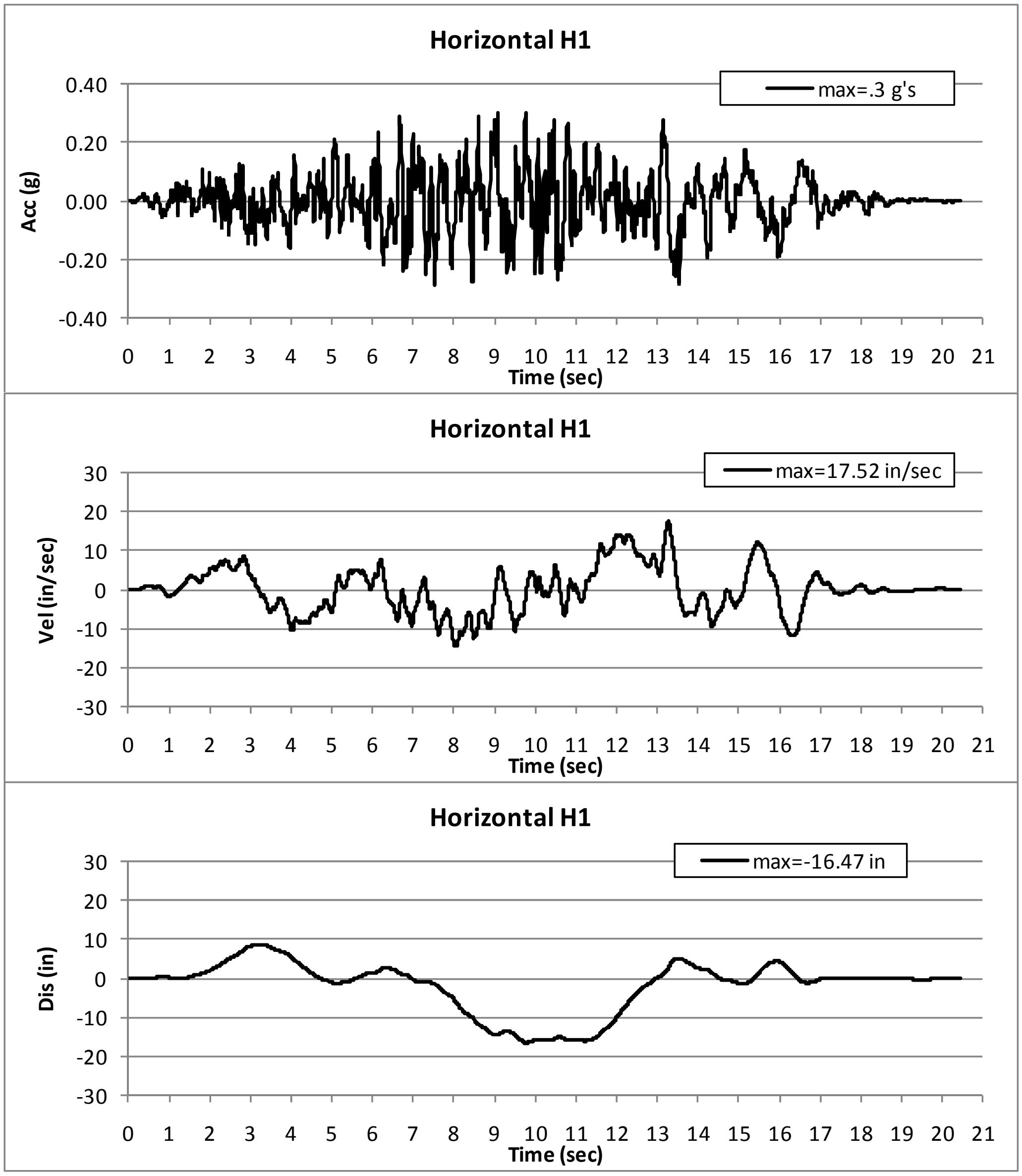


Figure 3-3. CSDRS-Compatible Design Acceleration, Velocity, and Displacement Time Histories - H1 Component

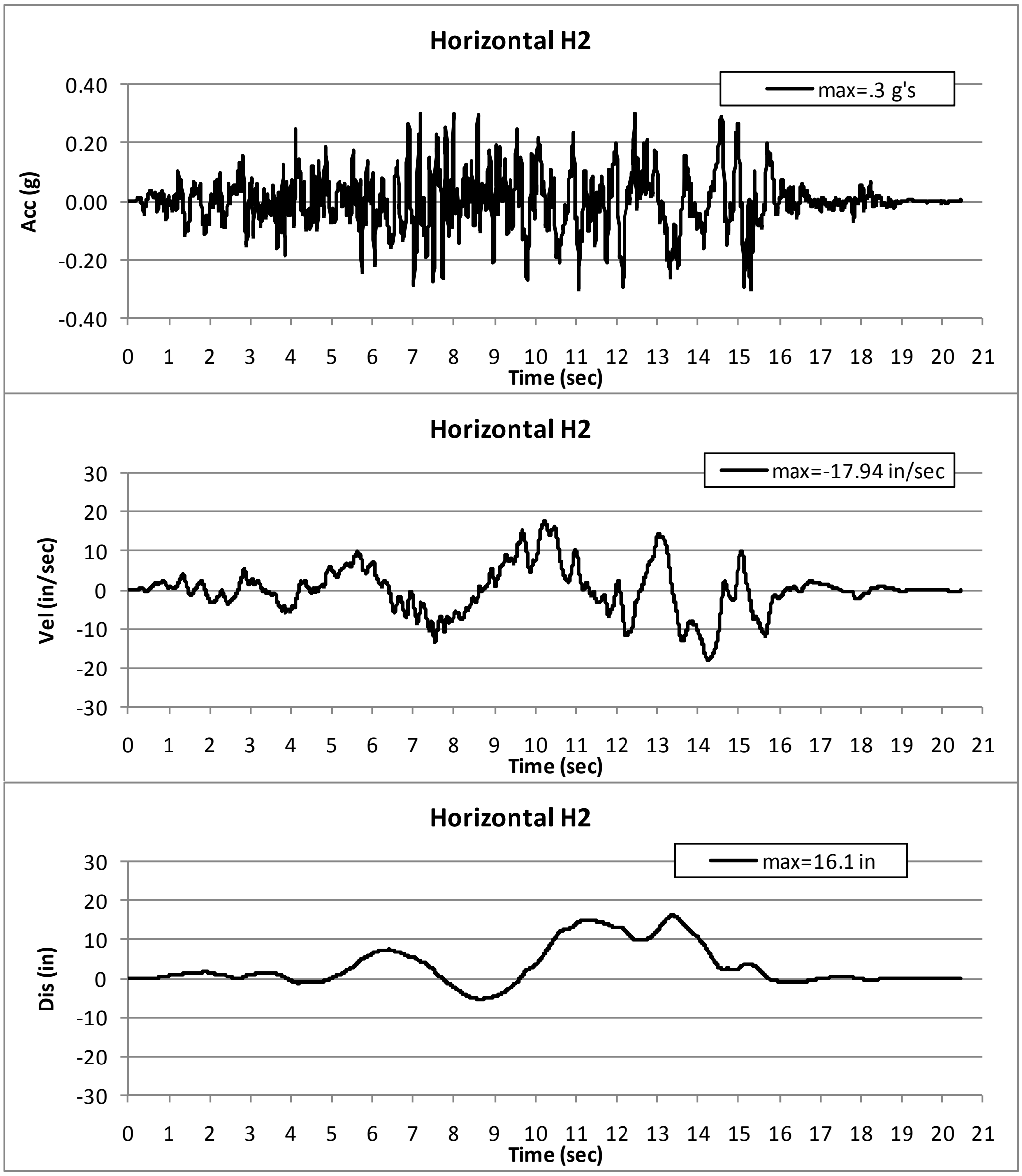


Figure 3-4. CSDRS-Compatible Design Acceleration, Velocity, and Displacement Time Histories - H2 Component

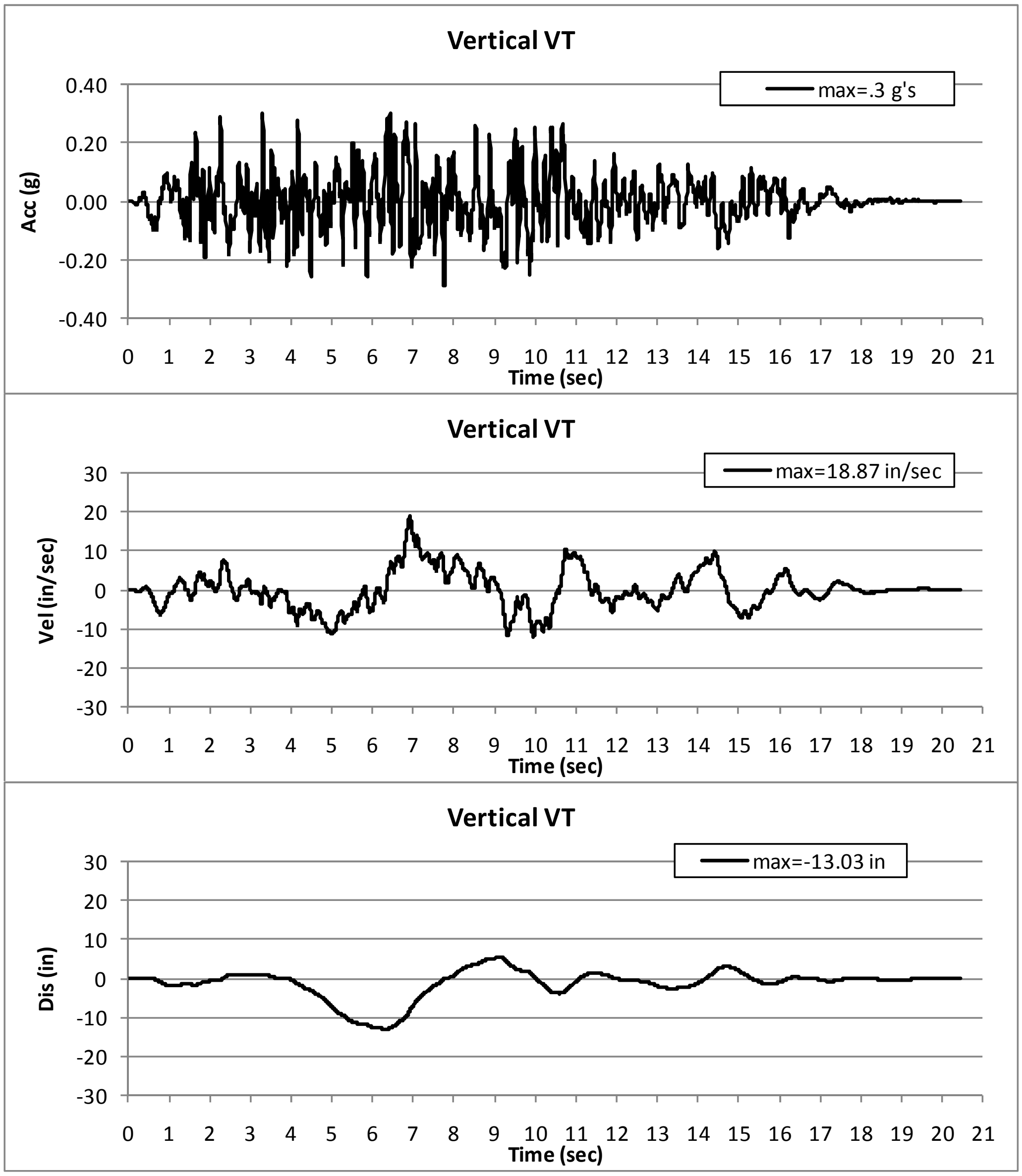


Figure 3-5. CSDRS-Compatible Design Acceleration, Velocity, and Displacement Time Histories - VT Component

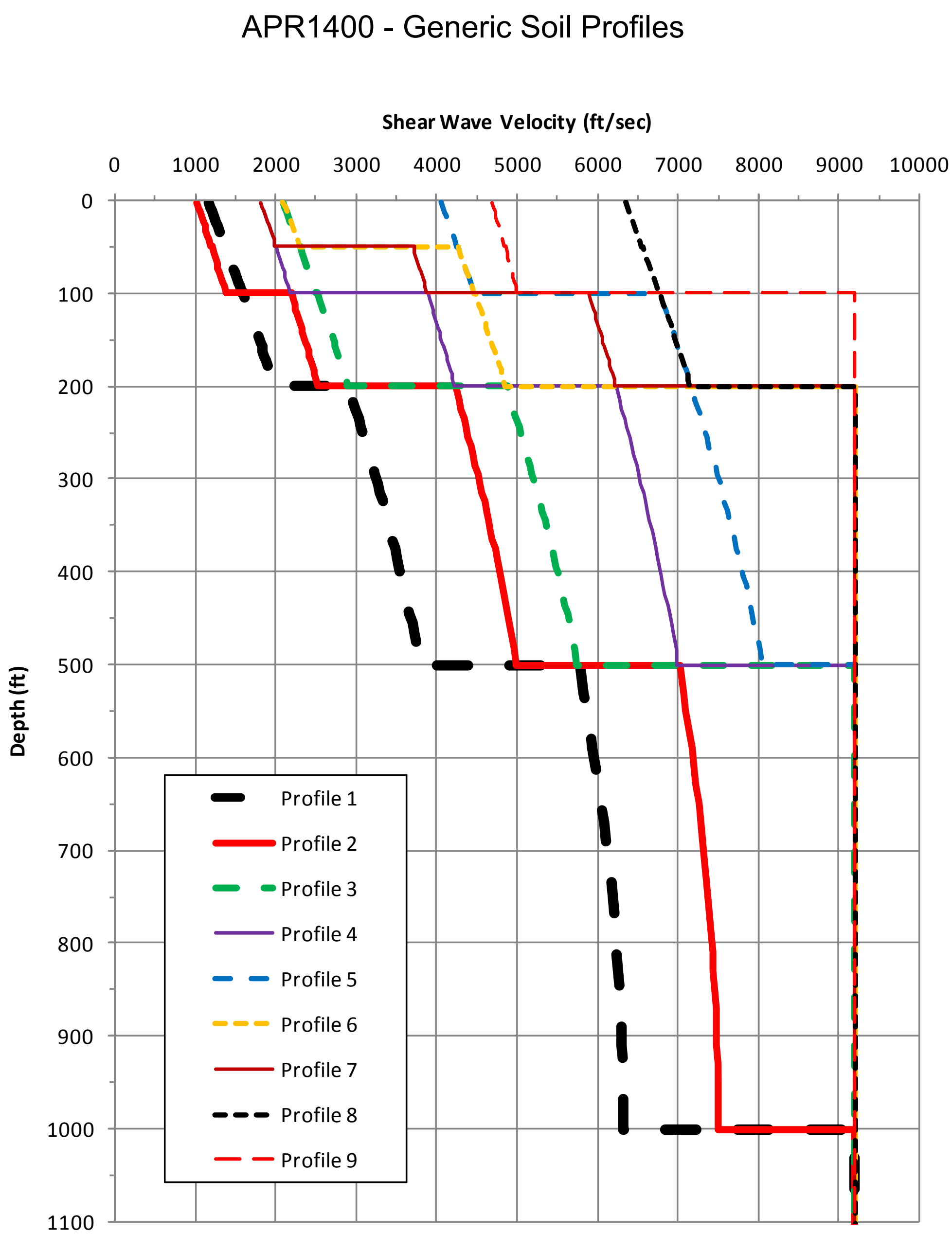


Figure 3-6. Low-Strain Shear Wave Velocity Profiles vs.. Depth for the Nine Generic Site Profiles Considered for APR1400

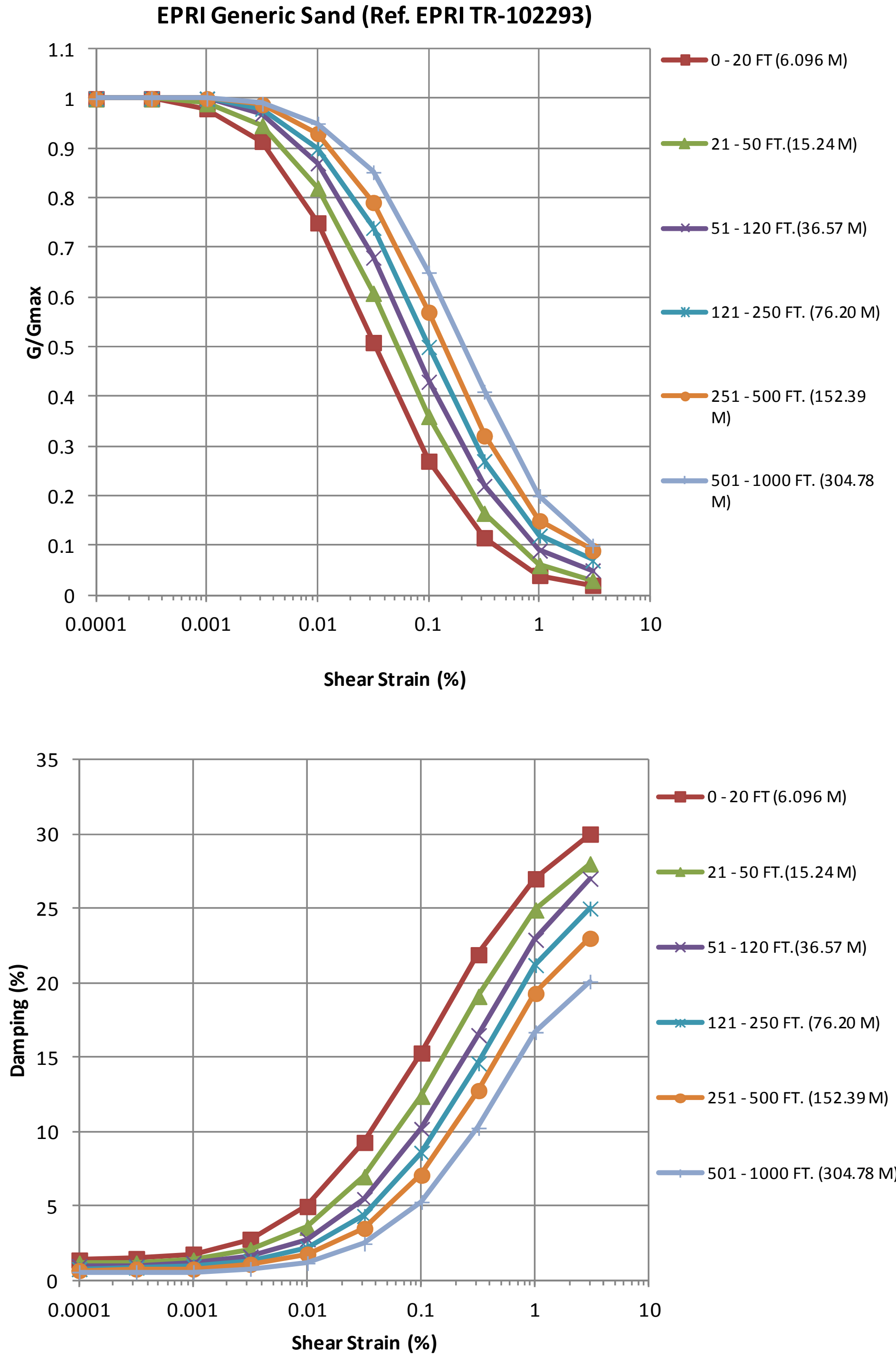


Figure 3-7. Shear-Modulus-Degradation and Damping-Value Variation Curves for Sand Considered for APR1400

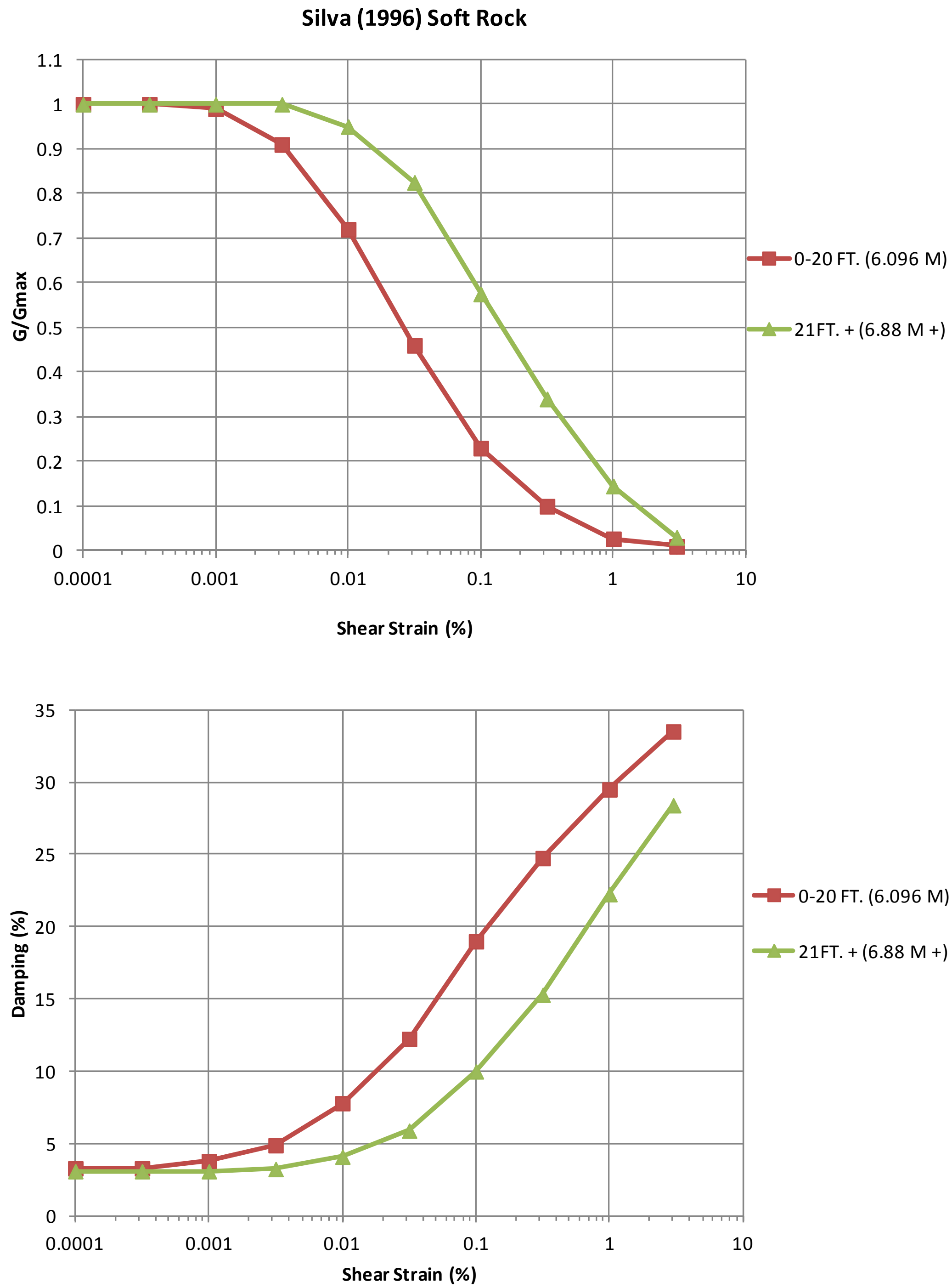
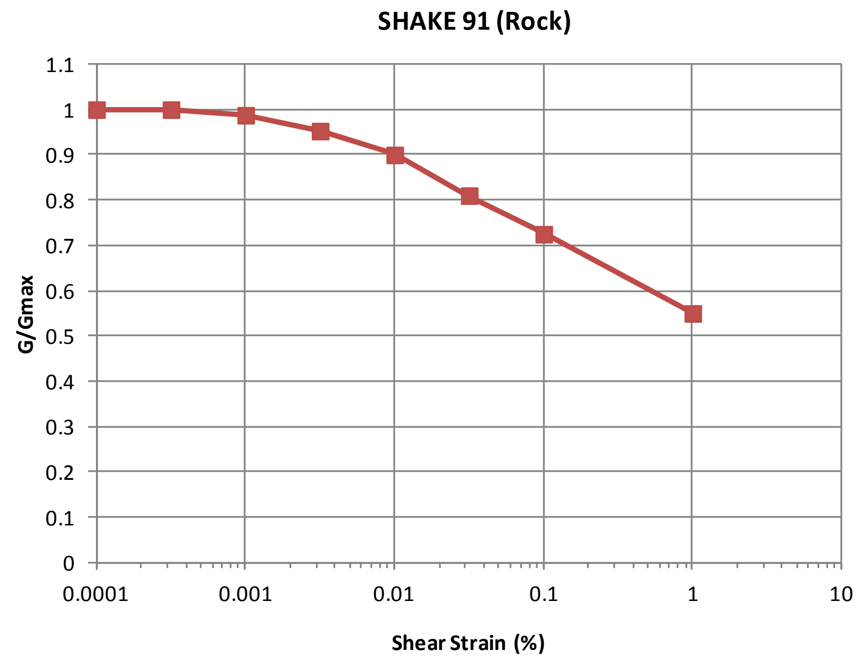


Figure 3-8. Shear-Modulus-Degradation and Damping-Value Variation Curves for Soft Rock Considered for APR1400



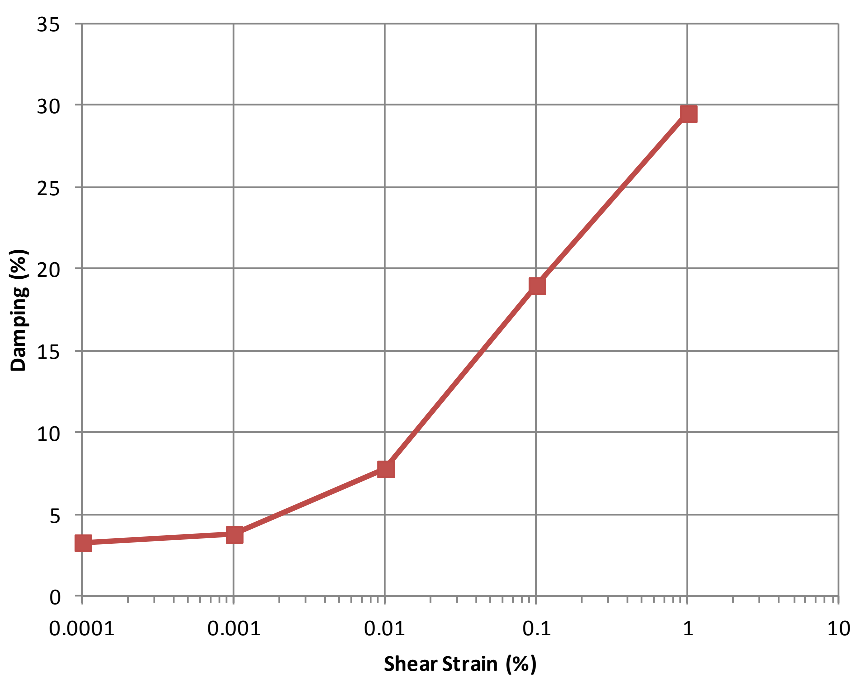
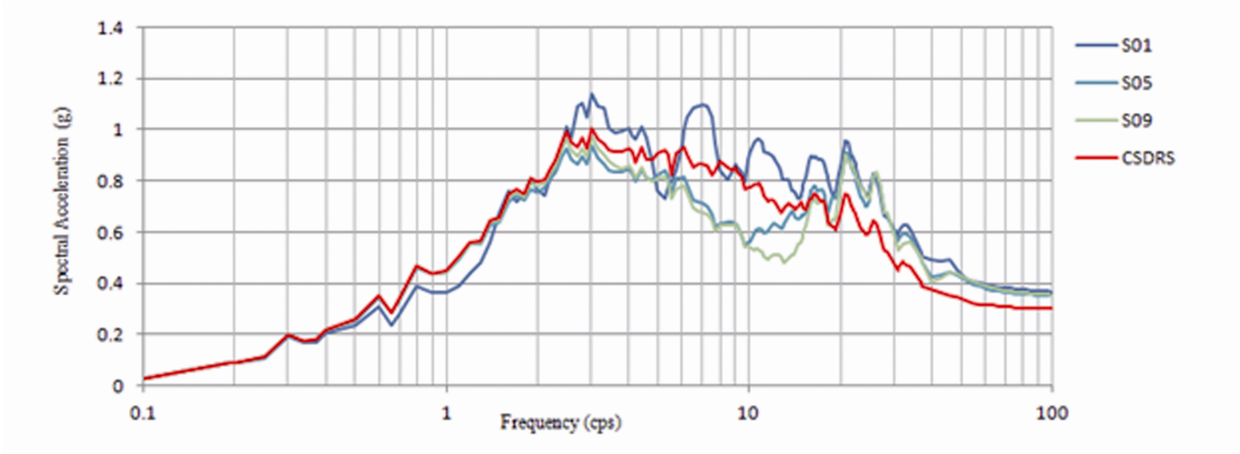
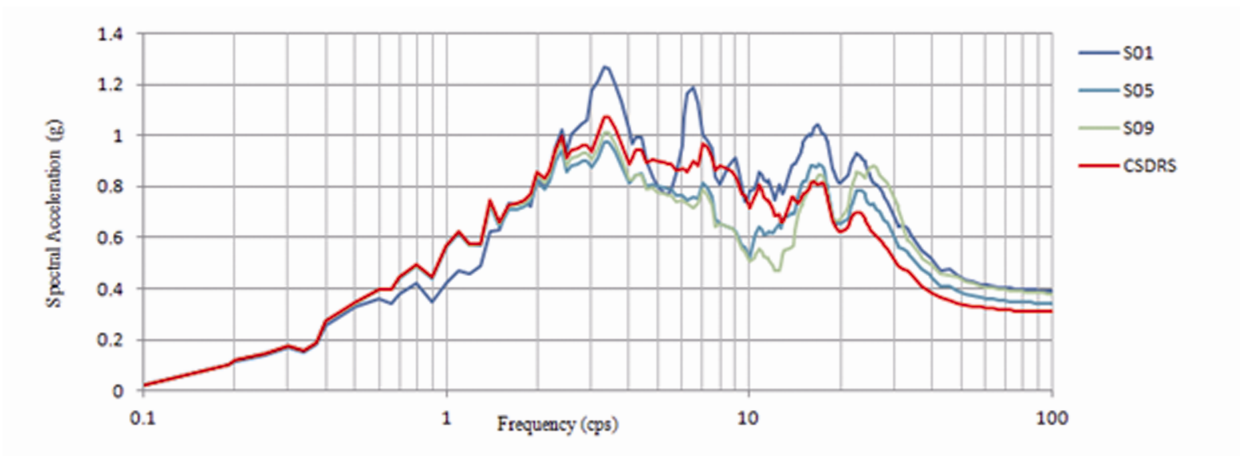


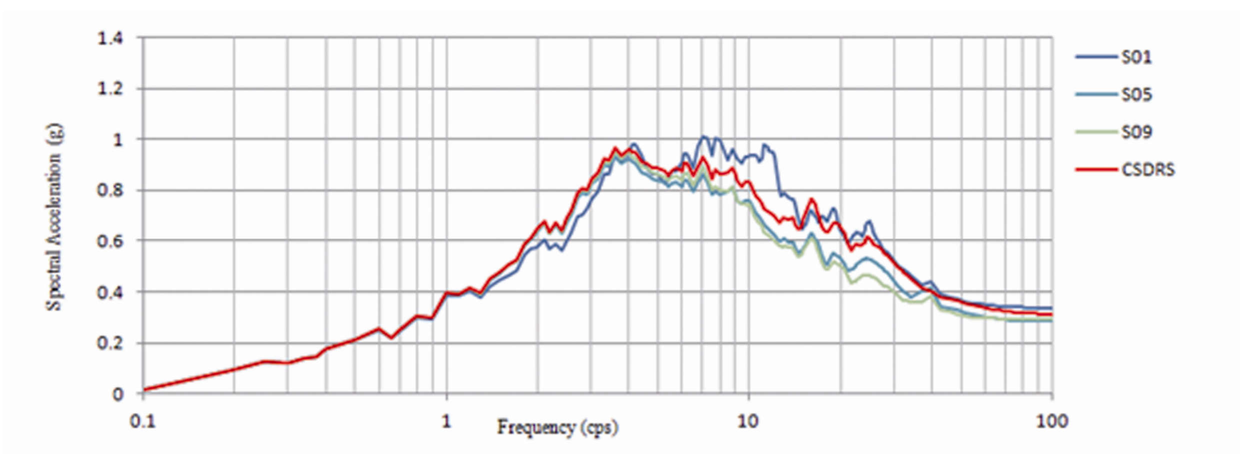
Figure 3-9. Shear-Modulus-Degradation and Damping-Value Variation Curves for Rock Considered for APR1400



(a) EW Motion



(b) NS Motion



(c) Vertical Motion

Figure 4-1. Site Response Motions at Truncated Surface for S1, S5 and S9 Cases

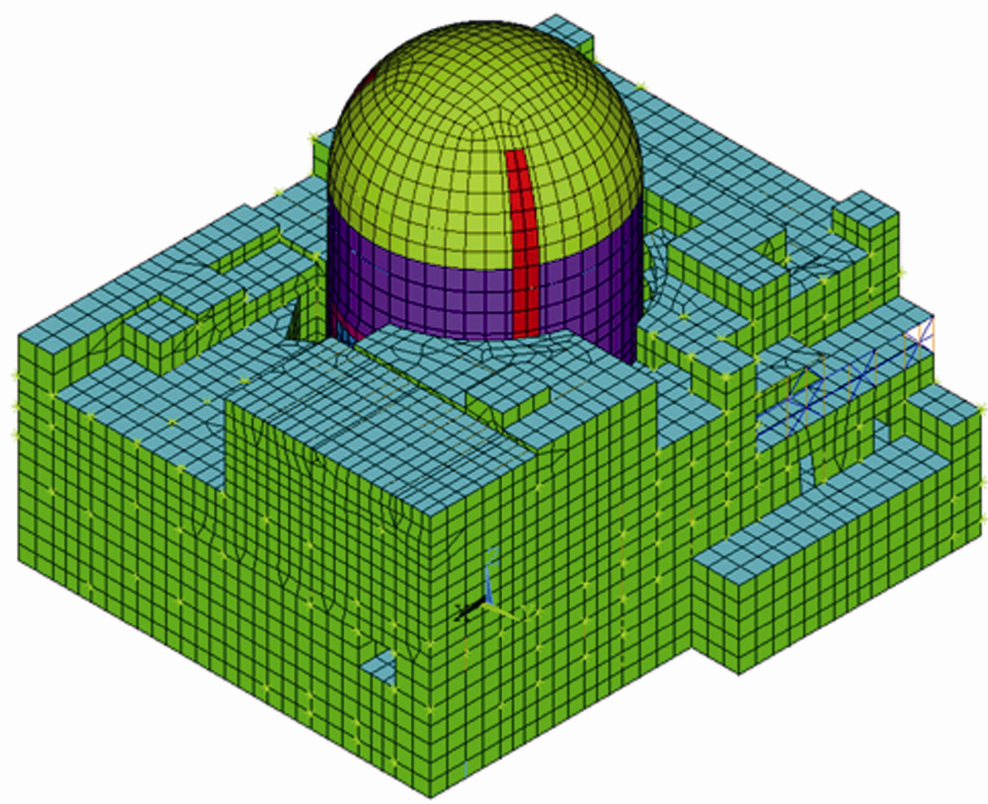
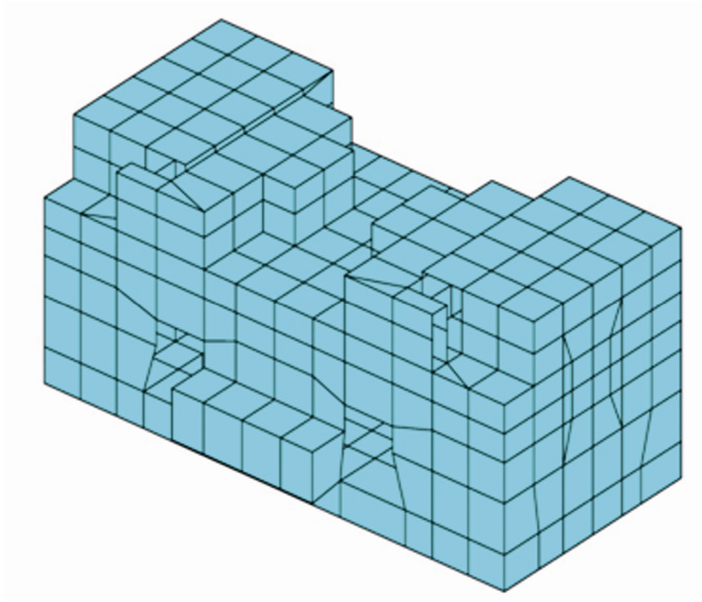
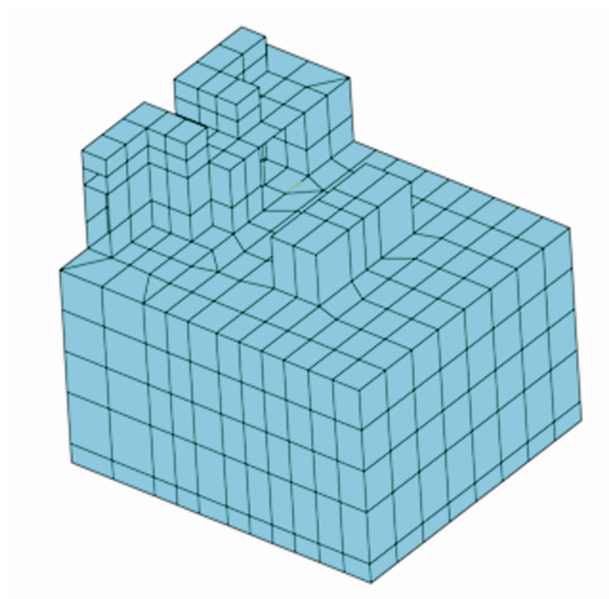


Figure 4-2. Combined SASSI SSI Finite Element Model of Nuclear Island



(a) Emergency Diesel Generator Building



(b) Diesel Fuel Oil Storage Tank Room

Figure 4-3. SASSI SSI Finite Element Model of Emergency Diesel Generator Building

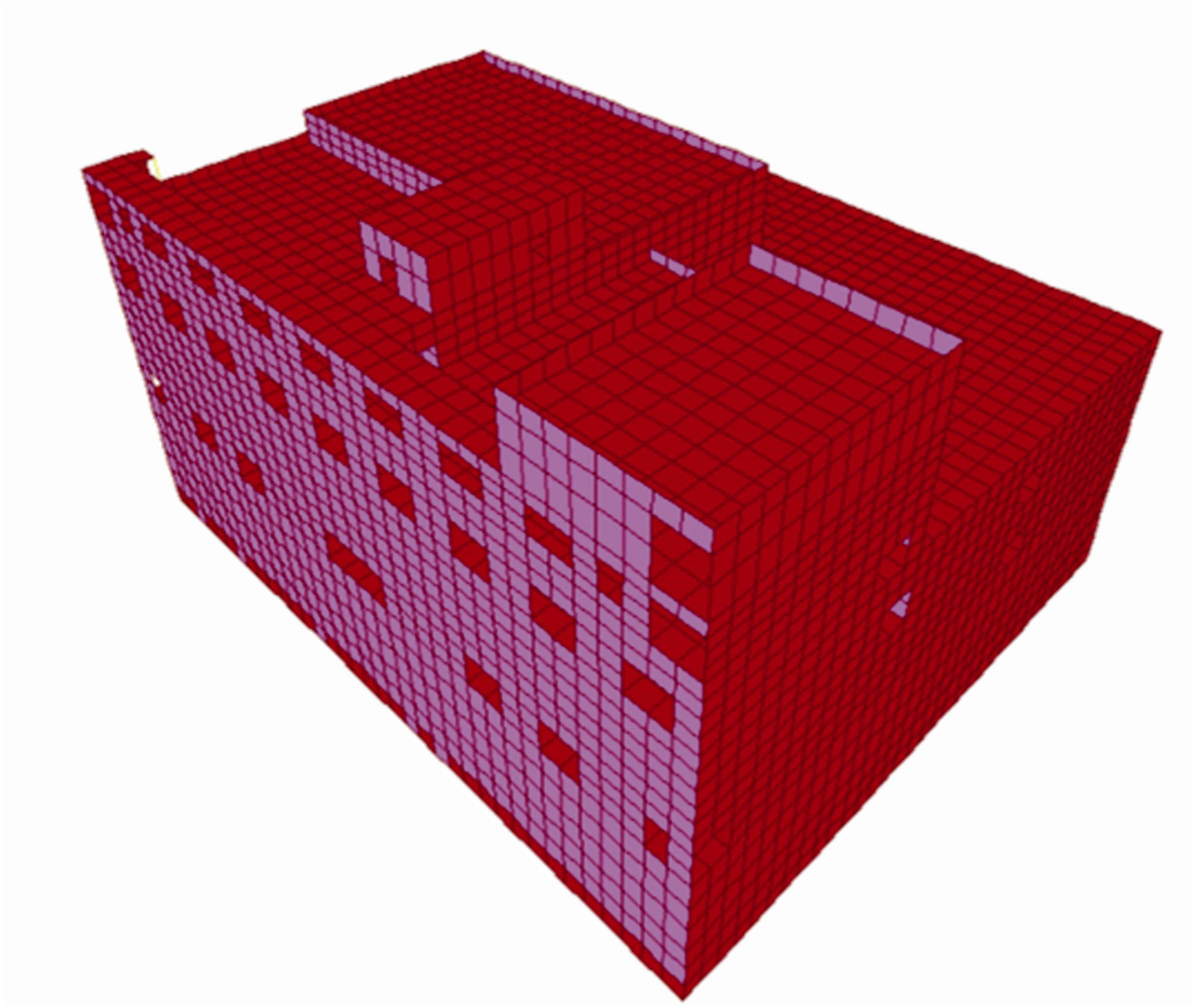


Figure 4-4. SASSI SSI Finite Element Model of Compound Building

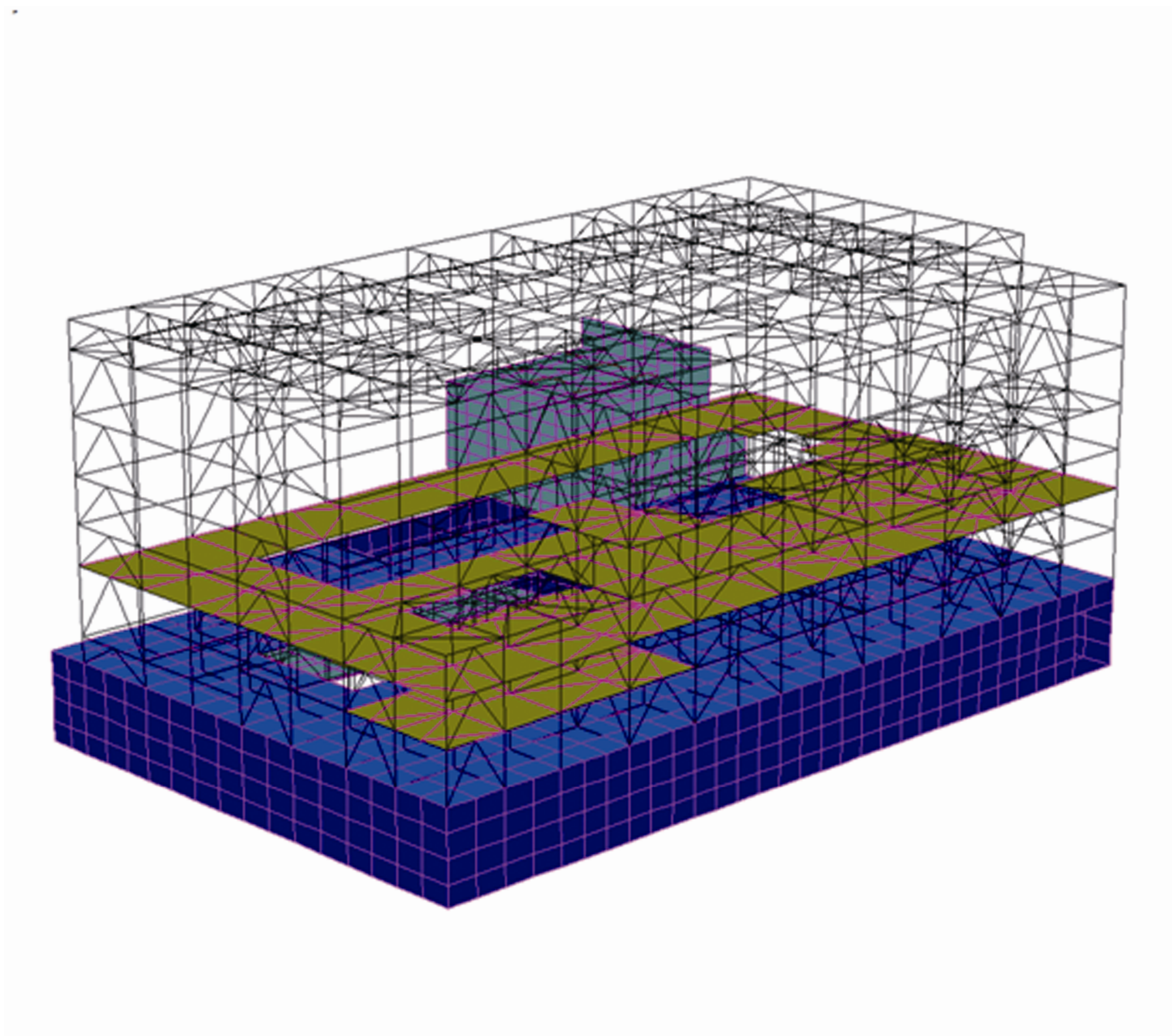


Figure 4-5. SASSI SSI Finite Element Model of Turbine Island

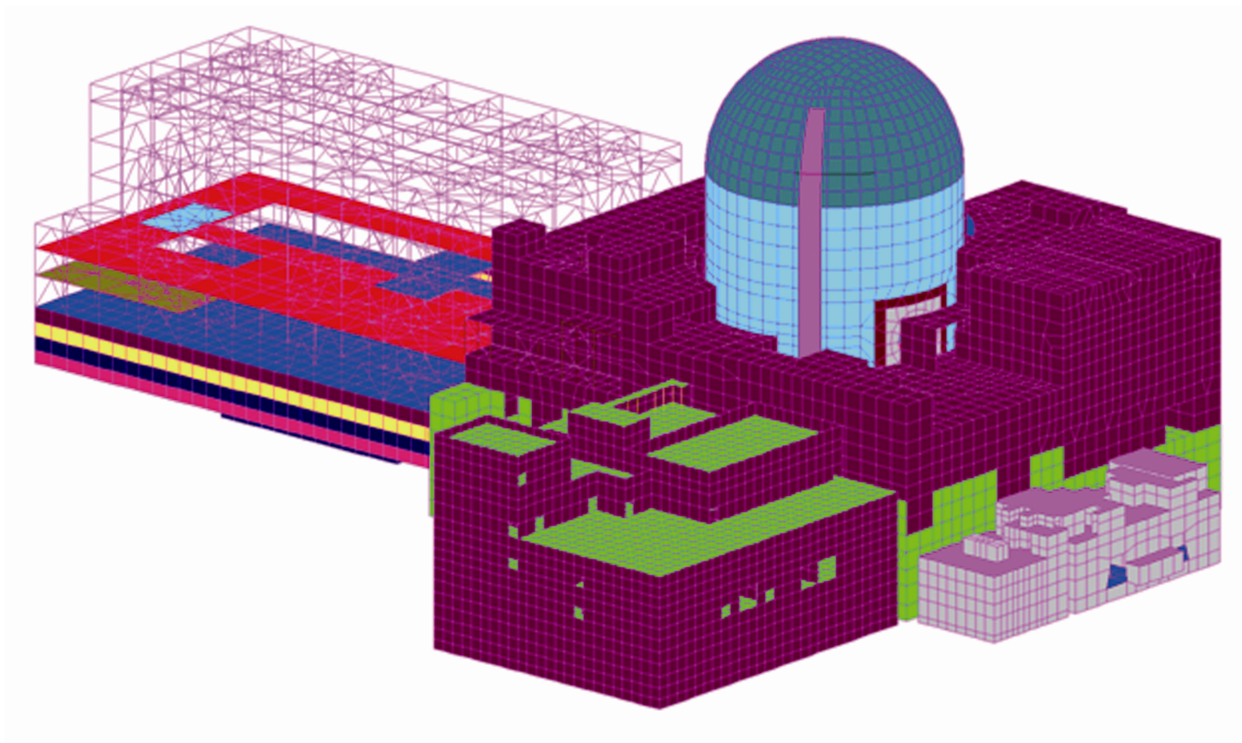


Figure 4-6. SASSI SSSI Finite Element Model of Power Block

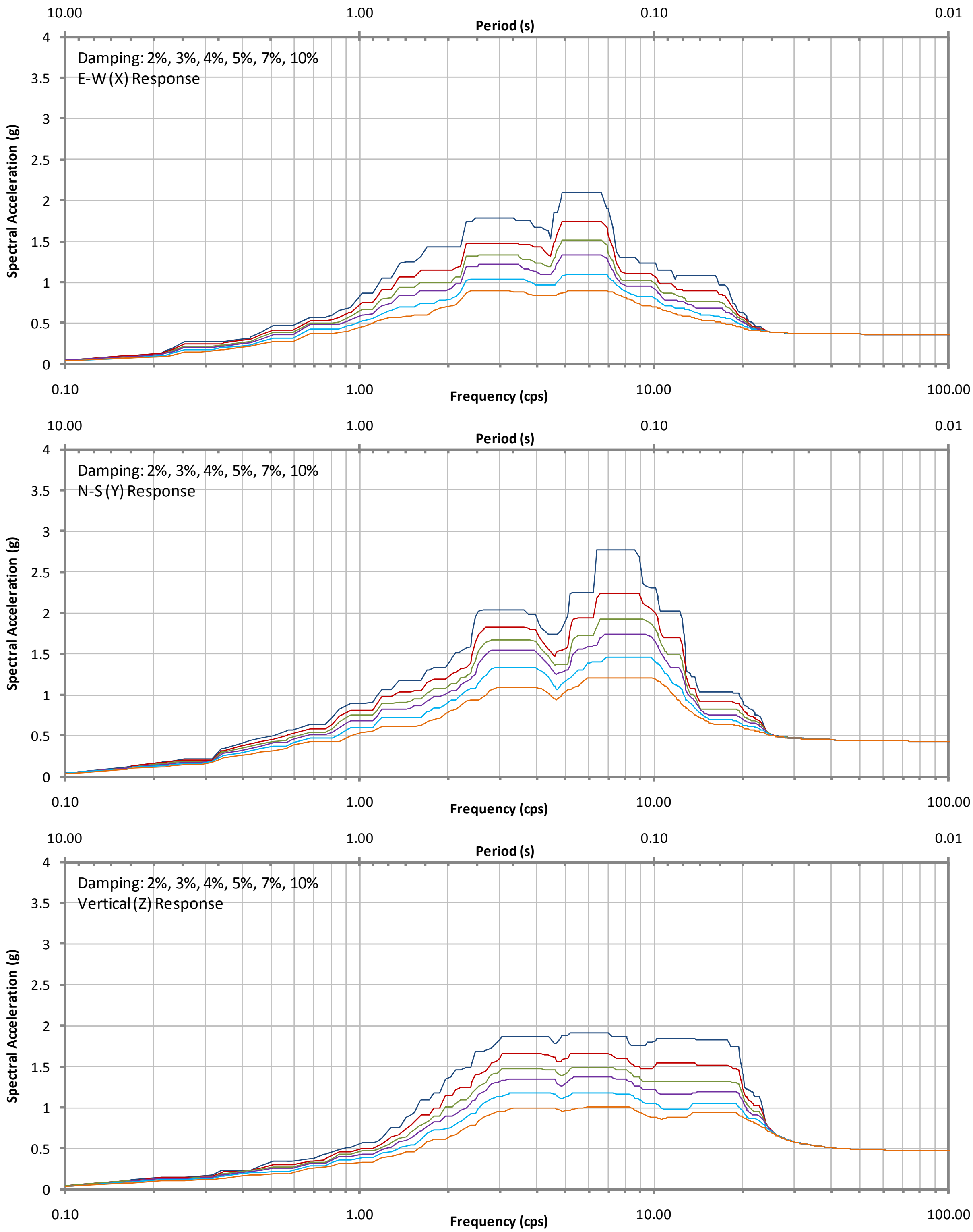


Figure 4-7. ISRS at AB El.156'-0" for Design Basis SSI Analysis (Embedded Structure) S1U

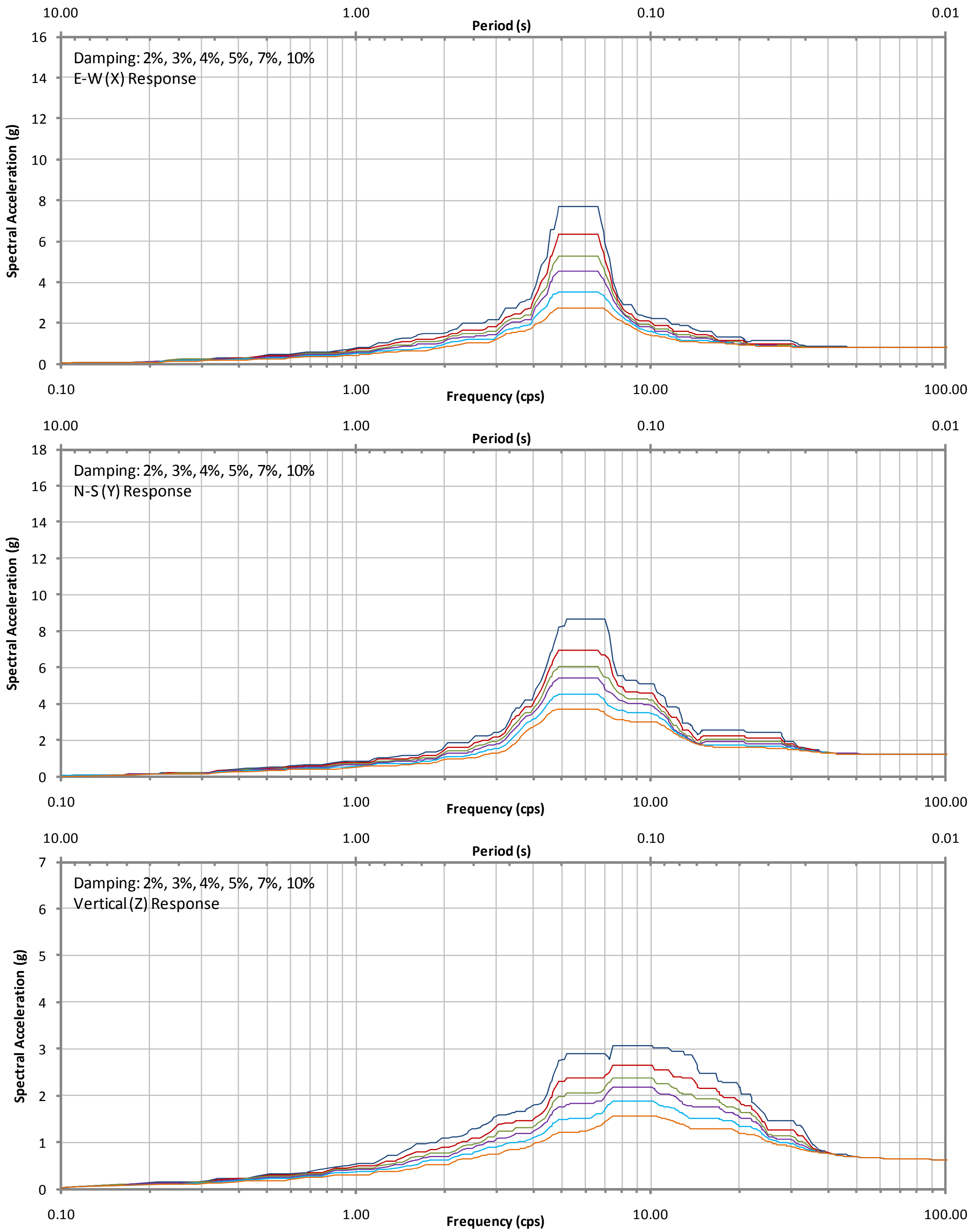


Figure 4-8. ISRS at AB El.156'-0" for Design Basis SSI Analysis (Embedded Structure) S5U

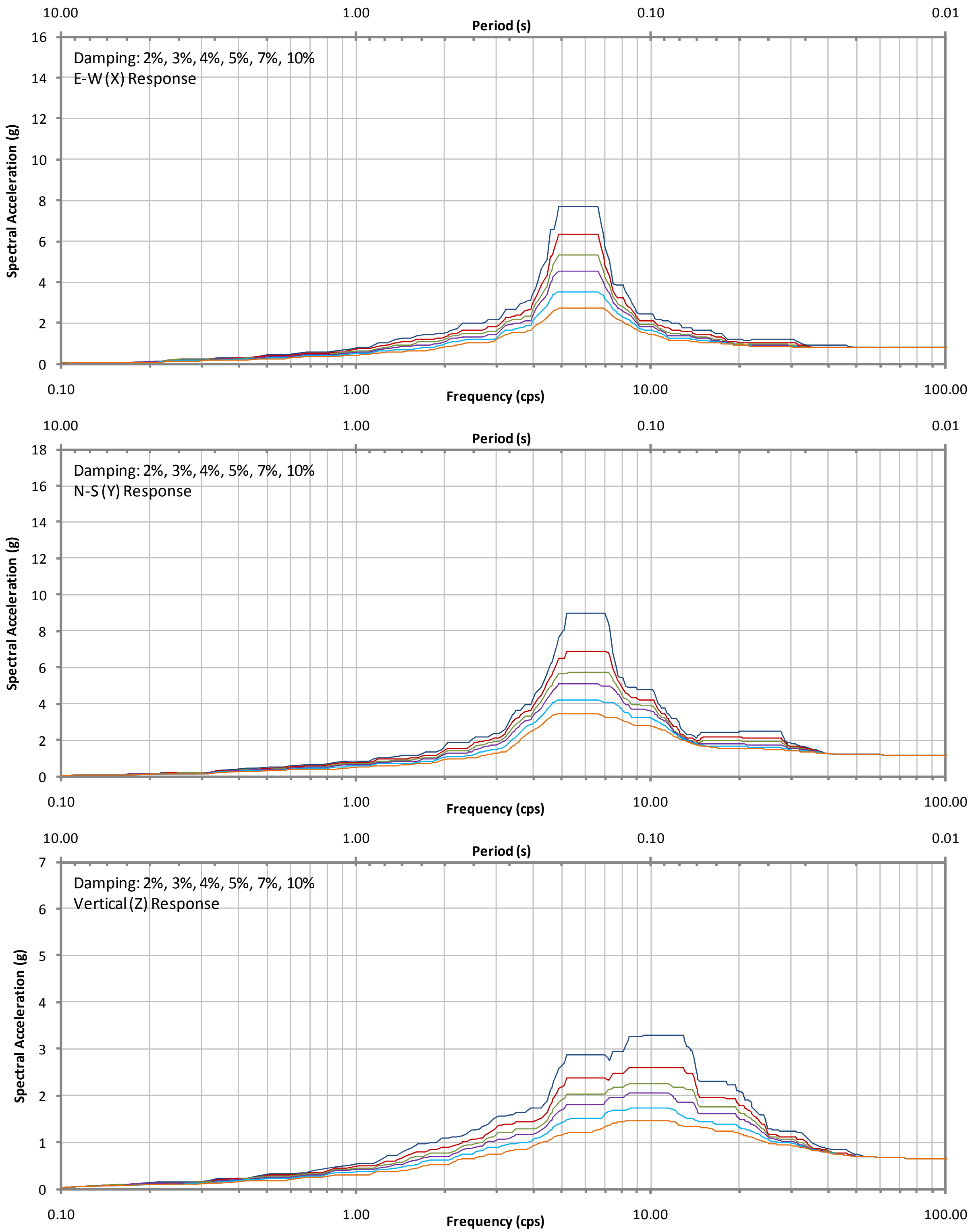


Figure 4-9. ISRS at AB El.156’-0” for Design Basis SSI Analysis (Embedded Structure) S9U

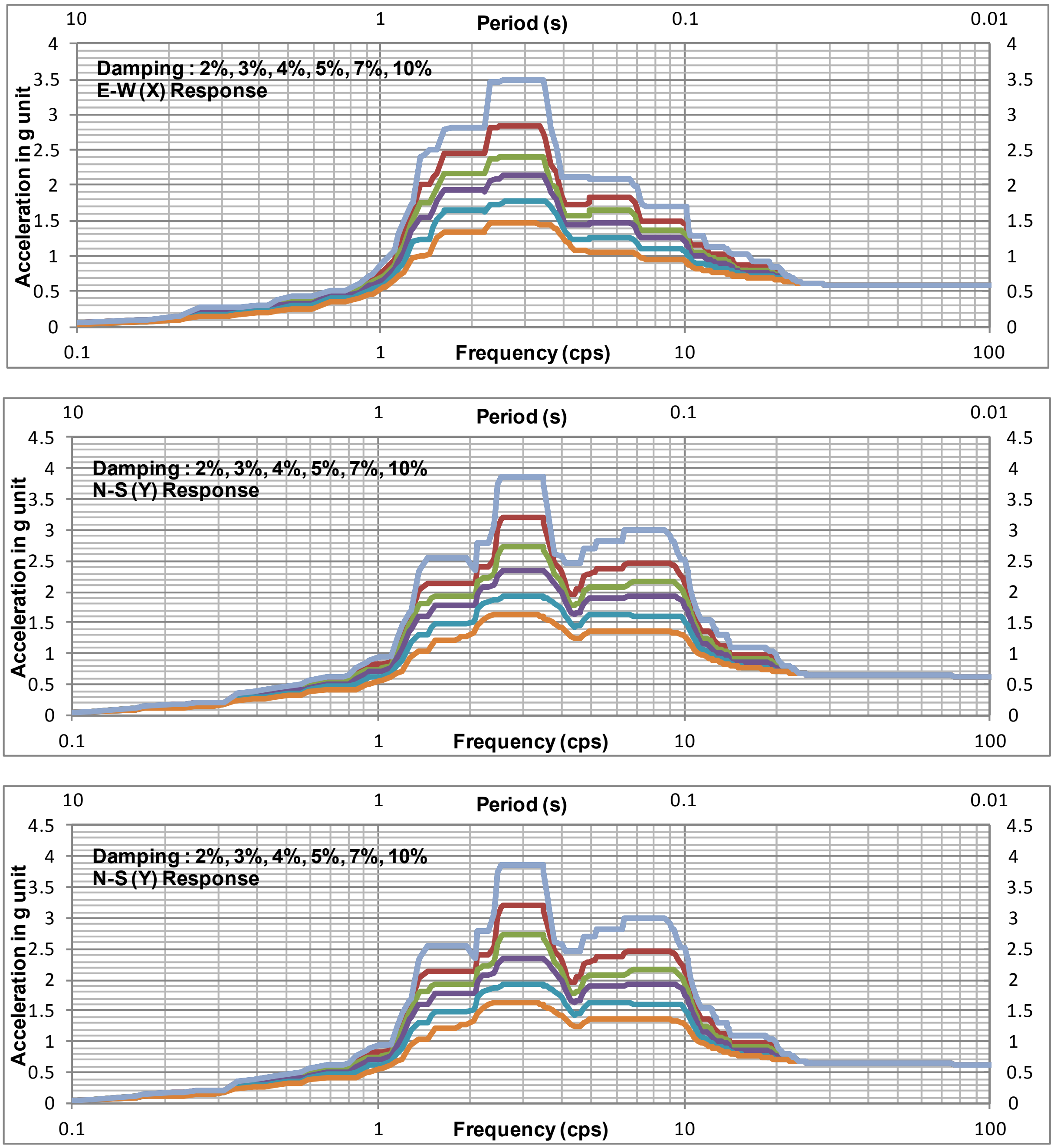


Figure 4-10. ISRS at AB El.156’-0” for Individual SSI Analysis (Surface Structure) S1U

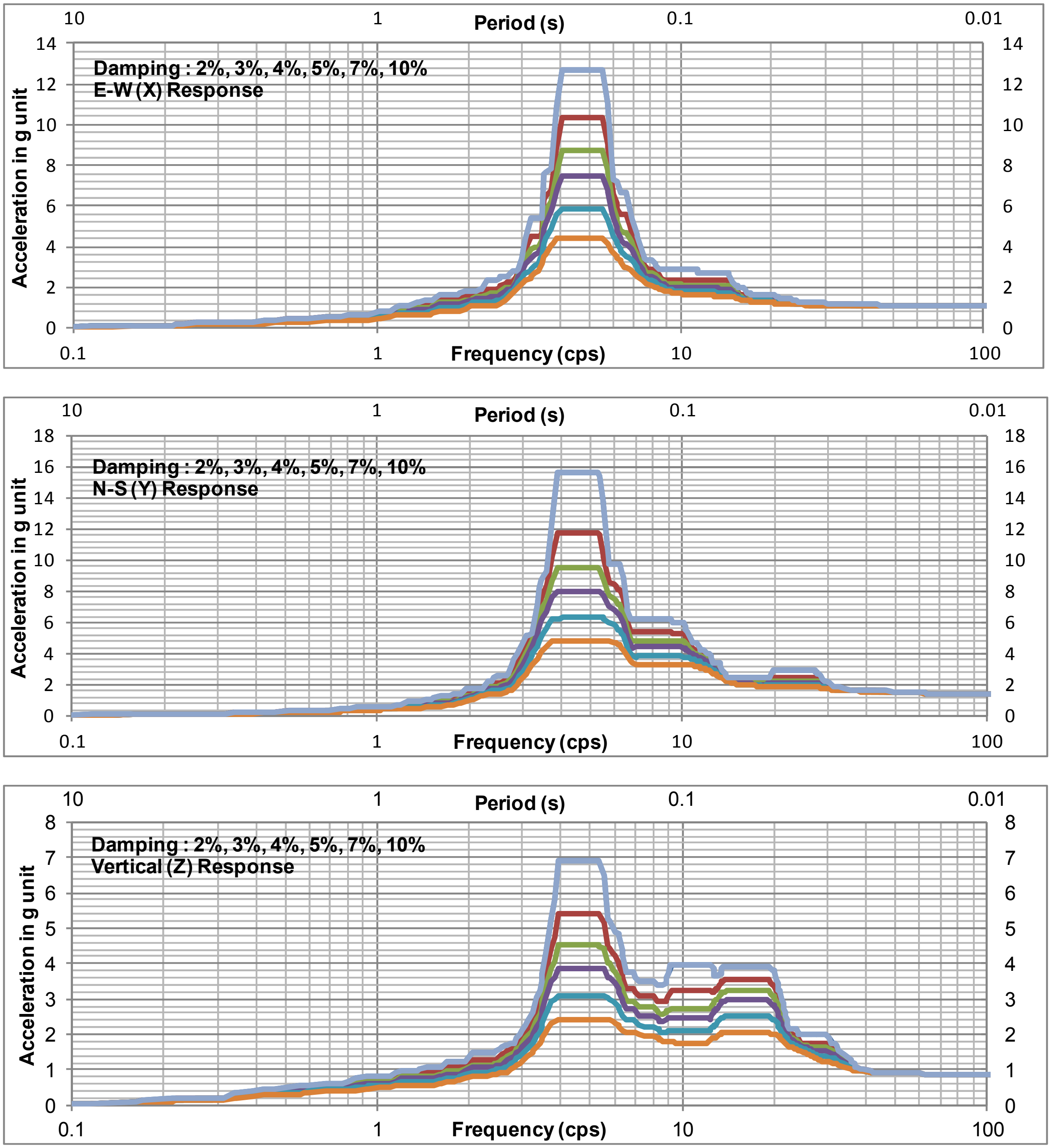
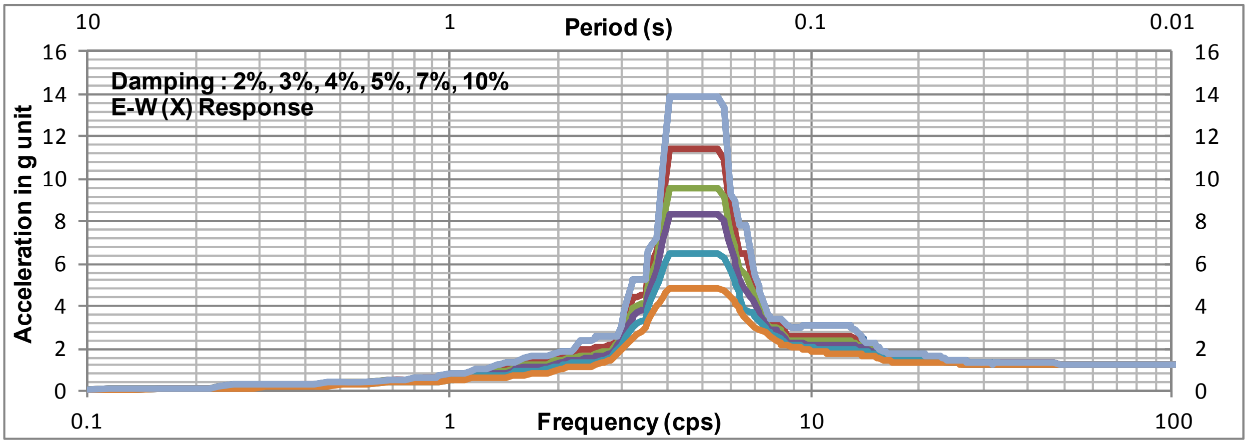
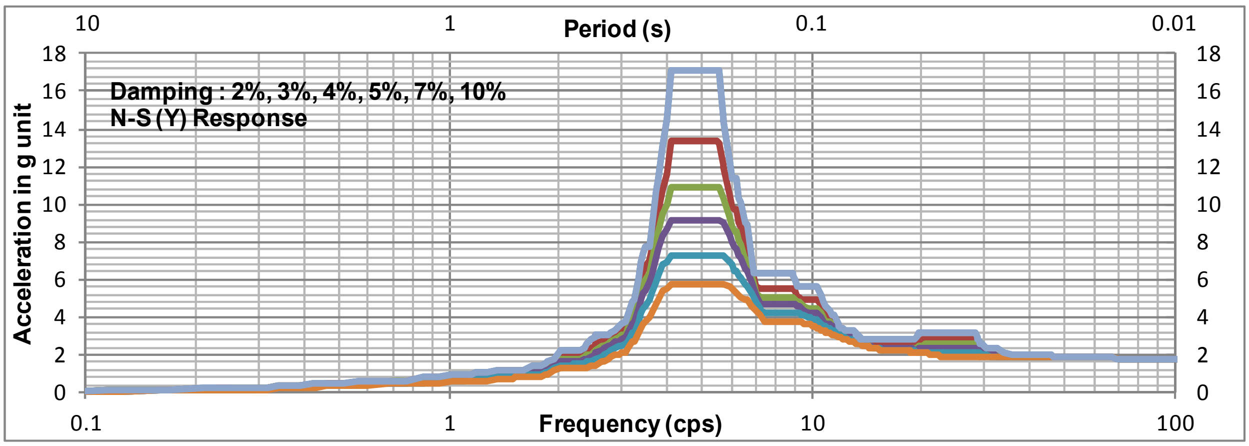


Figure 4-11. ISRS at AB El.156'-0" for Individual SSI Analysis (Surface Structure) S5U





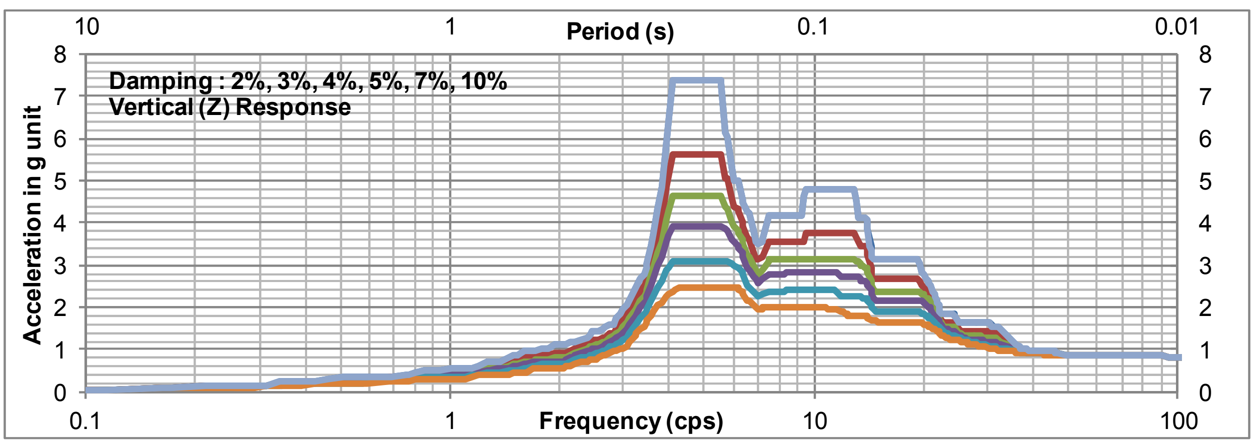


Figure 4-12. ISRS at AB El.156’-0” for Individual SSI Analysis (Surface Structure) S9U