Structure-Soil-Structure Interaction Analyses and Results for the PS/B, R/B Complex and A/B Analyses

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Abstract

The purpose of this report is to investigate the seismic response of the structure-soil-structure interaction (SSSI) effects among the US-APWR standard plant structures. The investigation adopts a phased approach by which the need for investigation in subsequent phases is determined from the results of the investigation(s) from the previous phase or phases. The initial investigation conducted as described in this report involves the investigation of SSSI effects among West Power Source Building (PS/B), Reactor Building (R/B) Complex and Auxiliary Building (A/B) of the standard plant. The focus of the study is on the response of the West PS/B which is the lightest among the US- APWR standard plant buildings.

Revision 0 of this report presents the analysis methodology to be used for the initial investigation of SSSI effects among the buildings described above. Revision 1 of this report will present the results for the initial investigation of SSSI effects among the buildings described above.

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List of Acronyms

The following list defines the acronyms used in this document.

A/B	Auxiliary Building
AC/B	Access Building
ARS	Amplified Response Spectra
CIS	Containment Internal Structures
COL	Combined License
CSDRS	Certified Seismic Design Response Spectra
ESWPT	Essential Service Water Pipe Tunnel
EW	East-West
FE	Finite Element
ISRS	In-Structure Response Spectra
LMS	Lumped Mass Stick
MHI	Mitsubishi Heavy Industries
NRC	Nuclear Regulatory Commission
NS	North-South
PCCV	Pre-stressed Concrete Containment Vessel
PS/B	Power Source Building
PSFSV	Power Source Fuel Storage Vaults
R/B	Reactor Building
RG	Regulatory Guide
SG	Steam Generator
SSE	Safe Shutdown Earthquake
SSI	Soil-Structure Interaction
SSSI	Structure-Soil-Structure Interaction
T/B	Turbine Building
TR	Technical Report
V	Vertical

1.0 INTRODUCTION

This report documents the analyses performed and results obtained for the initial investigation of coupled dynamic structure-soil-structure interaction (SSSI) effects on the seismic response of the US-APWR standard plant design. In order to explicitly assess the SSSI effects, a combined dynamic soil-structure interaction (SSI) model is required that includes all US-APWR plant structures capable of capturing the through soil structure-to-structure interaction effects. The size of such a combined SSSI model would be very large and would require an extensive computational effort. Thus, a phased approach is adopted by which the need for subsequent investigations is determined from the results and conclusions of the investigation in the previous phase or phases. The focus of the initial phase of the investigation is on the seismic SSSI effects among the smallest and lightest US-APWR West Power Source Building (PS/B), the heaviest Reactor Building (R/B) Complex, and their adjacent Auxiliary Building (A/B). From the analyses results and assessment conclusions obtained from this initial investigation, the need for further investigations of the SSSI effects among the West and East PS/B, R/B Complex, A/B, and Turbine Building (T/B) will be determined and further SSSI analyses and result assessments will be made in subsequent phases, as required. The proposed analysis steps, in phases for assessment of SSSI effects on the US-APWR standard plant structures are outlined in Table1.0-1.

Revision 0 of this report presents the analysis methodology to be used for the initial stage of investigation of the SSSI effects among the standard plant structures as described above.

Table 1.0-1 Analysis Steps for Assessment of SSSI Effects on the US-APWR Standard Plant Structures

Analysis Step No.	Concrete Modulus		SSI / SSSI Model				Generic Site Profile							
	Un-cracked	Cracked	R/B(FEM) + A/B(LMS)	R/B(LMS) + A/B(LMS) + PS/B(FEM)	T/B(LMS)+ PS/B(FEM)	R/B(LMS) + T/B(LMS) + PS/B(FEM)	270-200	270-500	560-100	560-200	560-500	900-100	900-200	2032-100
1		X	X				X		X					
2		X		X			X		X					
3		X	X					X		X	X			
4		X		X				X		X	X			
5	X		X									X	X	X
6	X			X								X	X	X
7		X			X		X		X					
8		X				X	X		X					
9		X		X				X		X	X			
10		X			X			X		X	X			
11	X					X						X	X	X
12	X			X								X	X	X

Note: All cases will be analyzed for three directions of input.

2.0 DESCRIPTION OF THE US-APWR STANDARD PLANT LAYOUT

Figure 2.0-1 below presents a schematic layout of the US-APWR standard plant. The standard design of US-APWR includes three Seismic Category I buildings, i.e. the R/B Complex and the East and West PS/Bs. The standard plant design also includes two Seismic Category II buildings, i.e. the T/B and the A/B, as well as the Access Building (AC/B) which is categorized as non-seismic. The Essential Service Water Pipe Tunnel (ESWPT), East and West Power Source Fuel Storage Vaults (PSFSV) that are in vicinity of US-APWR standard plant buildings are also classified as Seismic Category I buildings, but their design is conducted on a site-specific basis. The Seismic Category I and II structures of the US-APWR standard plant design are separated from each other and from the other site-specific buildings by a minimum of a 4" gap. Therefore, the SSSI effects are manifested in the seismic response of US-APWR standard plant structures only through interaction of the building foundations through their supporting subgrade i.e. only through soil structure-to-structure interaction effects.

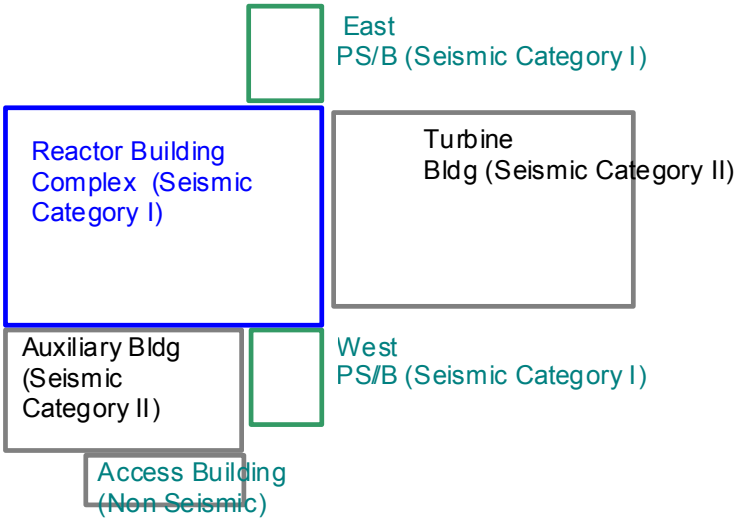

Figure 2.0-1 Plant Layout of the US-APWR Standard Plant

From the SSSI effects perspective, it is anticipated that the seismic response of the larger and heavier structure will have a more significant effect on the seismic response than that of the smaller and lighter adjacent structures. The R/B Complex that includes the Pre-stressed Concrete Containment Vessel (PCCV), Containment Internal Structures (CIS) and the R/B supported by a common basemat is the heaviest structure of the US-APWR standard plant buildings with large footprint dimensions. The West and East PS/Bs are the smallest and lightest standard plant structures and are separated from the R/B Complex by air gaps. Air gaps also separate the A/B from the R/B Complex and West PS/B. Thus, the initial phase is focused on the assessment of the SSSI effects among the R/B Complex and the closest adjacent West PS/B and A/B.

The T/B of the US-APWR standard plant design, which is situated adjacent to the south

side of the R/B Complex, has a relatively large foundation footprint comparable to that of the R/B Complex but is lighter and more flexible. The SSSI effect of the T/B on the adjacent East PS/B is expected to be less than that of the R/B Complex and A/B on the West PS/B. If the assessment in the initial phase indicates that the SSSI effects among the R/B Complex, West PS/B, and A/B are significant (based on guidelines provided in Sections 3.3.1 and 3.3.2 in this report), then further assessment of SSSI effects among the R/B Complex, T/B, and East and West PS/B will be made in the subsequent phases, as indicated in Table1.0-1.

3.0 STRUCTURE-SOIL-STRUCTURE INTERACTION

3.1 SSSI Analyses Methodology

The first priority in assessing the coupled dynamic SSSI effects is to investigate the effect of the heavier A/B and R/B Complex buildings on the seismic response of the nearby West PS/B which has much smaller dimensions and less weight. The main focus of the analyses is to assess the effect of SSSI on the in-structure response spectra (ISRS) used for the design of Seismic Category I and II systems and components located in the West PS/B. For that purpose, the SSSI analyses will use the same dynamic finite element (FE) model of PS/B as that used for generating the seismic responses from the site-independent SSI analyses of the standalone PS/B that serve as the basis for development of the standard plant design input. To develop the combined SSSI model in a manageable size, the lumped mass stick (LMS) models of the R/B Complex and A/B are coupled through soil with the PS/B dynamic FE model, to represent the global dynamic properties of the adjacent buildings. The development and calibration of LMS models against the dynamic FE models for R/B Complex and A/B to be used for these SSSI analyses are documented in MUAP-11006 (Reference 3) and MUAP-11001 (Reference 4) respectively.

The analyses of SSSI effects of the PS/B, R/B Complex and A/B use surface-supported foundation models that neglect the effect of foundation embedment. Due to the large coupled ACS SASSI (Reference 6) models involved, neglecting the embedment effect is currently the only viable approach that can be used to study such SSSI effects.

The initial focus of the SSSI study described in this report is the generic site profiles that represent softer subgrade conditions, i.e. 270-200 and 560-100 profiles, that are most likely to have more significant SSSI effects. The results from the site-independent SSI analyses of the standalone PS/B dynamic FE model with different stiffness and damping levels for these soil cases will be evaluated to determine which structural stiffness level governs the response. The stiffness properties of the PS/B model in the combined SSSI model will be based on the most critical stiffness level determined from this evaluation. The SSSI analyses will use stiffness properties for the R/B Complex and A/B that are compatible with the stiffness of the subgrade profiles considered. That is, reduced (cracked concrete) structural stiffness properties will be used for the SSSI analyses for the softer generic site profiles, and full (uncracked concrete) stiffness properties will be used for the harder generic rock profiles.

3.2 Combined Model of PS/B, R/B Complex and A/B

To couple the LMS models of the R/B Complex and A/B to the standalone FE dynamic model of PS/B, the coordinate system of the standalone PS/B model, will be used as the reference coordinate system for the combined R/B Complex, A/B, and PS/B SSSI model. The numbering of the nodes of the dynamic FE model is preserved to simplify the post-processing of the results of SSSI analyses and for comparison of their results with the results of the SSI analyses of the standalone PS/B model. In order to reflect the actual configuration of the buildings, the numbering and coordinates of the nodes of the R/B Complex and A/B LMS models are modified from the location and orientation of their

respective coordinate systems relative to the reference coordinate system of the PS/B model.

Figure 3.2-1 presents the configuration of the combined SSSI model to be used for initial-phase SSSI analyses of the PS/B, R/B Complex and A/B. ACS SASSI is used for the time history frequency domain seismic response analyses of the combined model. Before SSSI production runs are performed, fixed-base seismic response analyses are performed of the combined model of PS/B, R/B Complex and A/B resting on the surface of an elastic half space with very high stiffness to simulate fixed-base conditions. These analyses provide acceleration response transfer function results at selected locations that serve to ensure that the dynamic properties of the standalone PS/B, R/B Complex and A/B remain unaffected by the coupling of the models used in the SSSI analyses.

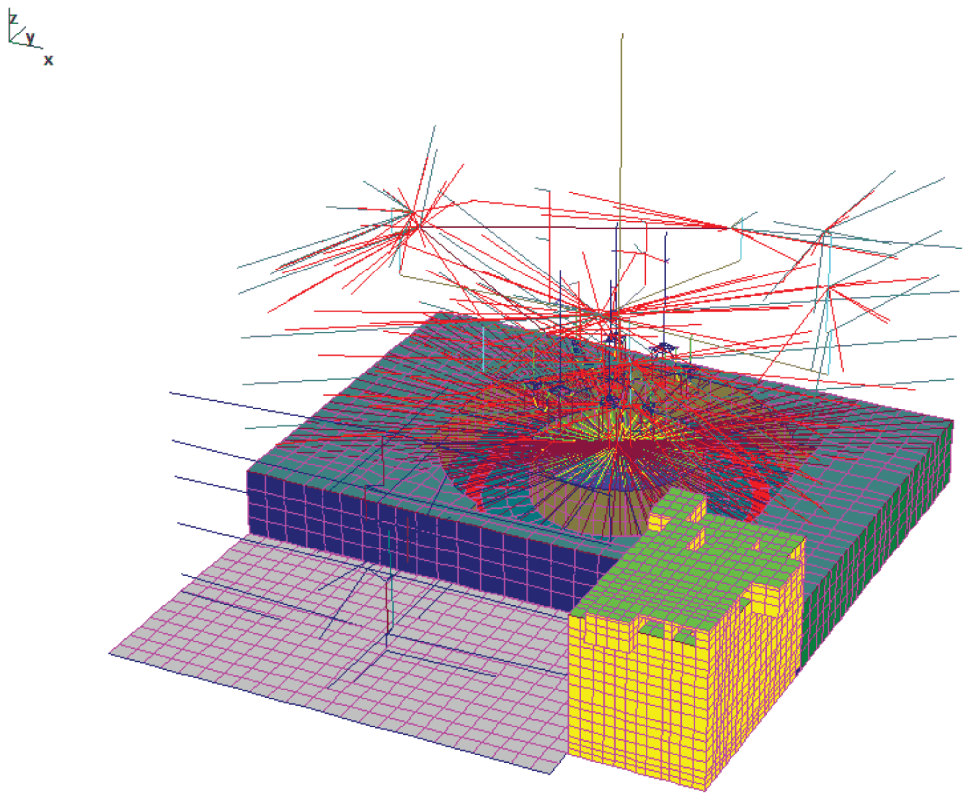

Figure 3.2-1 Combined ACS SASSI Model for Initial-Phase SSSI Analyses of PS/B, R/B Complex and A/B

3.3 SSSI Analysis Methodology for the US-APWR Standard Plant Design

This section describes the analysis methodology used to assess the SSSI effects on the US-APWR standard plant design. The SSSI effects on the Seismic Category I structures that are not part of the US-APWR standard plant design are addressed on a site-specific basis in the Combined License (COL) application.

The evaluation described in this report is performed in two steps, each assessing two different aspects of the SSSI effects. The evaluation uses the SSI models and results from the site-independent SSI analyses of the standalone R/B Complex, PS/B and A/B.

The two different aspects of SSSI effects investigated are:

1. Effect on Ground Motion at Adjacent Structure Foundations (kinematic SSSI effect) : The influence of the SSI response of a standalone building on the ground motions at the adjacent structure foundations is assessed in the first step, and
2. Coupled Dynamic SSSI effect: A coupled SSSI model, formed as an integral dynamic system, is used to generate coupled seismic responses of adjacent structures, taking into account their mutual interaction through the supporting subgrade. The coupled dynamic SSSI effect combines the kinematic SSSI effect and the inertial SSSI effect.

The assessments of these two SSSI effects are further described below.

3.3.1 Effect on Ground Motion at Adjacent Building Foundation Locations

The first step in assessing SSSI effects is to investigate how the R/B Complex, which is the heaviest building (approximately 870,000 kips) among the US-APWR plant buildings, affects the near-field site response ground motions at the foundation locations of the adjacent standard plant buildings.

The dynamic FE model of the standalone R/B Complex includes interaction nodes at the surface of the adjacent ground (near-field) located at 10 feet or more from the foundation of the R/B Complex as shown in Figure 3.3.1-1. These additional near-field ground surface interaction nodes provide the site response adjacent to the R/B Complex at the locations selected. An additional free-field ground interaction node is established more than 1000 feet away from the R/B Complex foundation, which provides the free-field response without the SSI effect from the R/B Complex and serves to check the ground motion input. To assess the kinematic SSSI effects on the ground surface motions at the nearby foundations of the East and West PS/Bs, the acceleration transfer functions for the responses of the site at the near-field ground interaction nodes (located at the center and at the corners of the PS/B, A/B, and T/B foundations) are computed. The 5%-damped Amplified Response Spectra (ARS) results at these near-field ground surface interaction nodes, obtained from the site-independent SSI analyses of the eight generic layered soil profiles, are computed and compared with the 5%-damped ARS of the free-field input motion and the 5%-damped US-APWR Certified Seismic Design Response

Spectra (CSDRS).

The main objective of this evaluation is to assess the significance of the effects of SSI response on seismic input ground motion to adjacent structures and the variation with respect to the eight different generic site subgrade conditions considered in the standard plant design. The comparisons of the field response ARS results with the ARS for the input motion provide the basis for assessing the kinematic SSSI effects. The significance of the kinematic SSSI effects for a particular generic site profile is determined based on the following guideline:

> *The effects on ground motion are considered insignificant if the amplifications of the seismic input motion due to SSI response of the standalone building are such that the 5%-damped ARS of the near-field site response motions at the near-field ground surface locations within the footprint of the adjacent structure foundation are not more than 10% higher than the corresponding 5%-damped ARS of the input ground motion for any frequency window of ± 10% centered on the frequency.*

The above guideline is based on the NUREG-0800 (Standard Review Plan) Section 3.7.1 and 3.7.2 (References 1 and 2 respectively) and Regulatory Guide (RG) 1.208 (Reference 5) tolerances set for the generation of artificial time histories for use as input for seismic response analyses. RG 1.208 permits the 5%-damped ARS of the generated artificial acceleration time histories to be 10% (or less) below the target spectra and 30% (or less) above the target spectra for frequency window of ± 10% centered on the frequency. As an example, Figure 3.3.1-2 presents a comparison of the 5%-damped ARS of the CSDRS compatible acceleration time histories in two orthogonal horizontal directions (H1 and H2) that are used for the site-independent SSI analyses. The plots show that the differences between the 5%-damped ARS of the two horizontal components can be more than 20%. Therefore, the established guideline for assessing significance of the kinematic SSSI effect is within the ARS amplitude variations of the input ground acceleration histories.

The site-independent SSI analyses using the standalone R/B Complex dynamic FE model also provide the site calculated responses at ground locations close to the R/B Complex foundation that are within the perimeter of the adjacent A/B and T/B foundations. The results for the site responses at these locations can be used to assess kinematic SSSI effects from the R/B Complex foundation on the input ground motion of the Category II A/B and T/B. Examples of such comparisons for the R/B Complex are shown in Figures 3.3.1-3 through 3.3.1-19. As indicated in these comparisons, the kinematic SSSI effects on the horizontal near-field ground surface site response motions are relatively small at the locations near the centers of the East and West PS/B, A/B, and T/B. However, the effects on the vertical near-field ground surface site response motions are more significant.

Similarly, the site-independent SSI analyses using the dynamic FE models of the stand-alone PS/B and A/B also provide results for the near-field site responses at locations within the perimeter of the R/B Complex foundation. These calculated near-field site response motions can be used as the basis for assessment of kinematic SSSI effects on the input ground motion for the R/B Complex due to the SSI responses of the standalone A/B and PS/B.

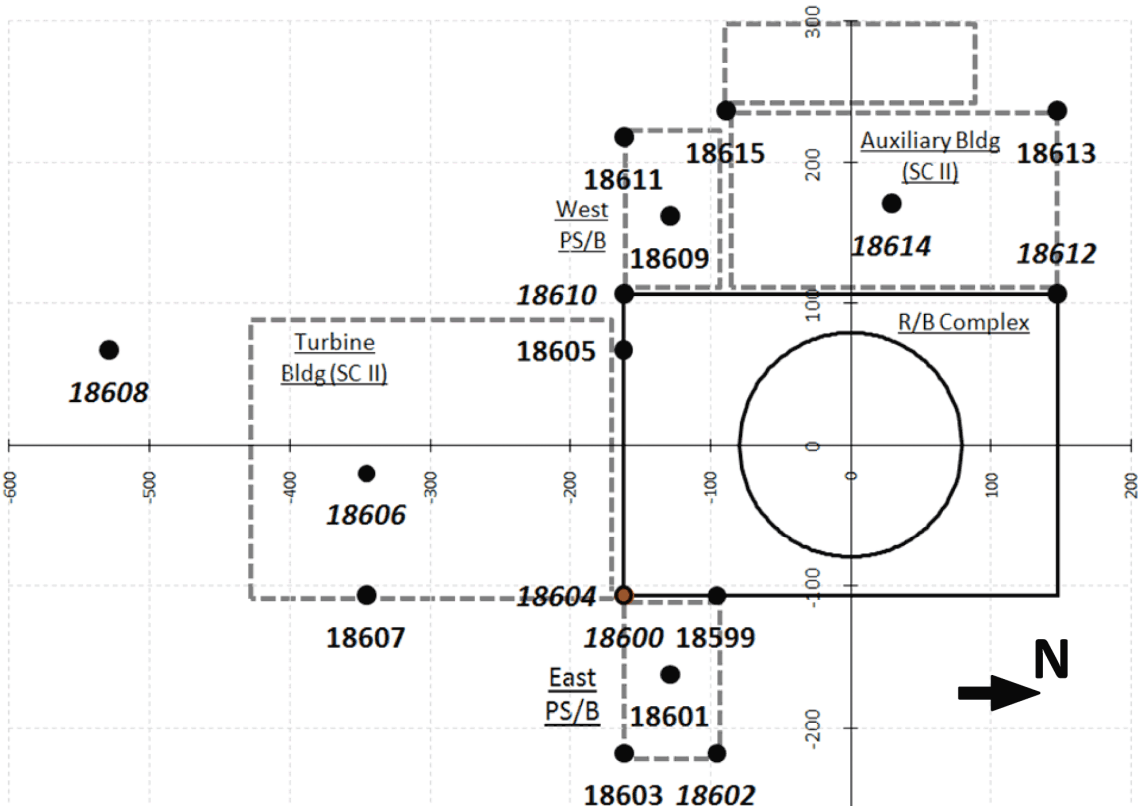

Figure 3.3.1-1 Nodal Locations in the Near-Field Ground Surface Adjacent to the R/B Complex

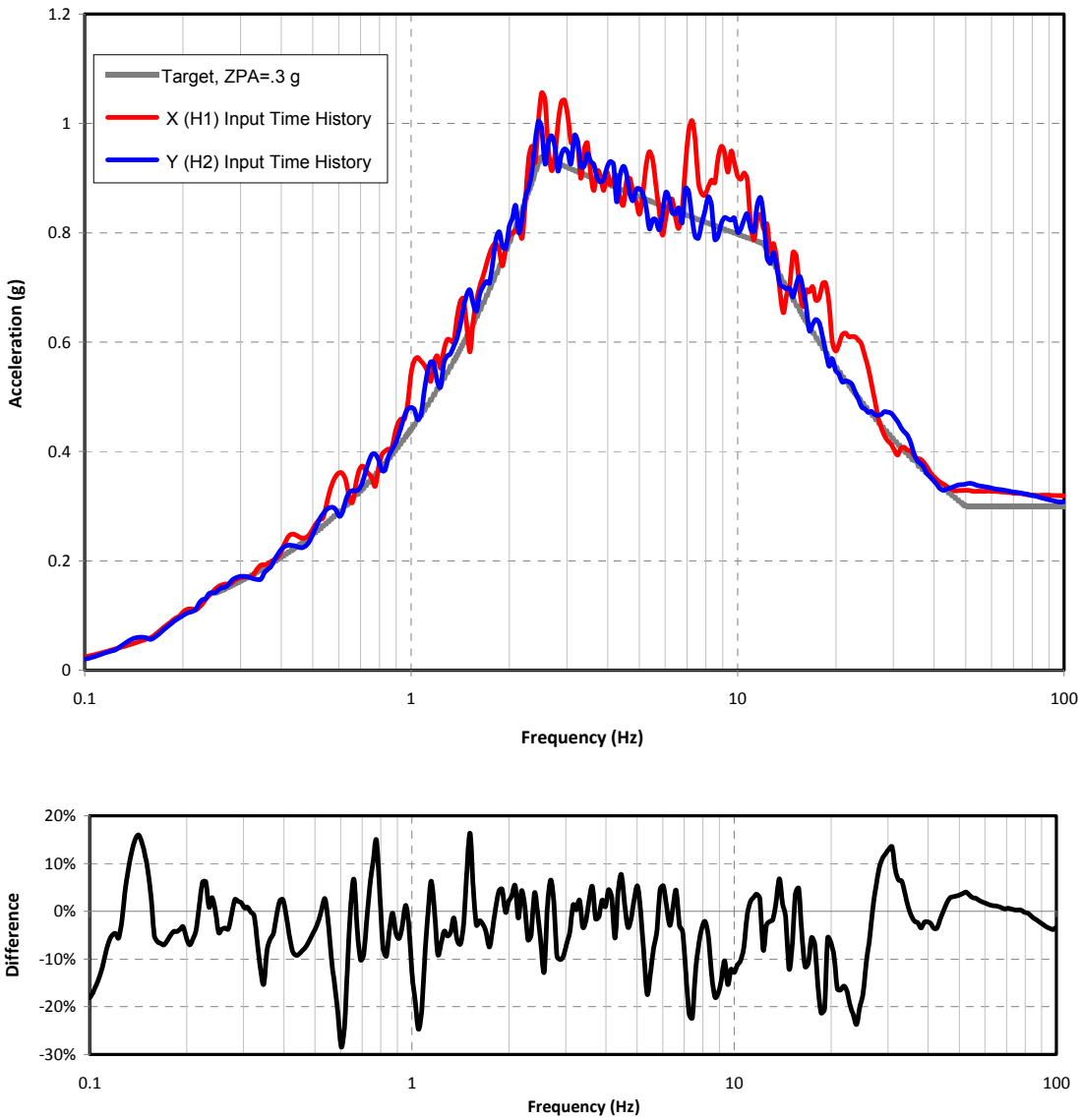

Figure 3.3.1-2 Differences in 5% ARS of CSDRS Compatible Input Ground Motion

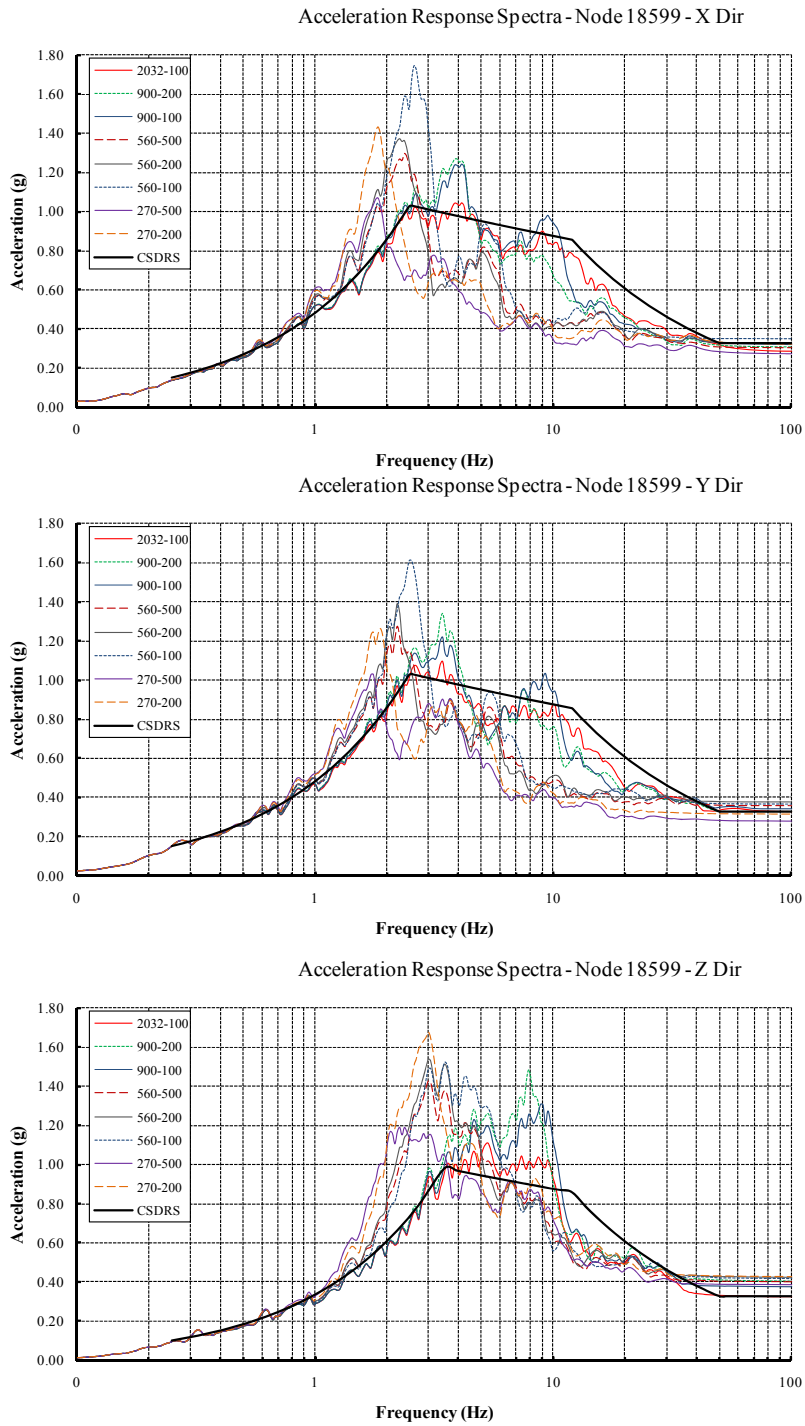

Figure 3.3.1-3 5%-Damped Acceleration Response Spectra at Node No. 18599 in the Near-Field Ground Surface Adjacent to the R/B Complex

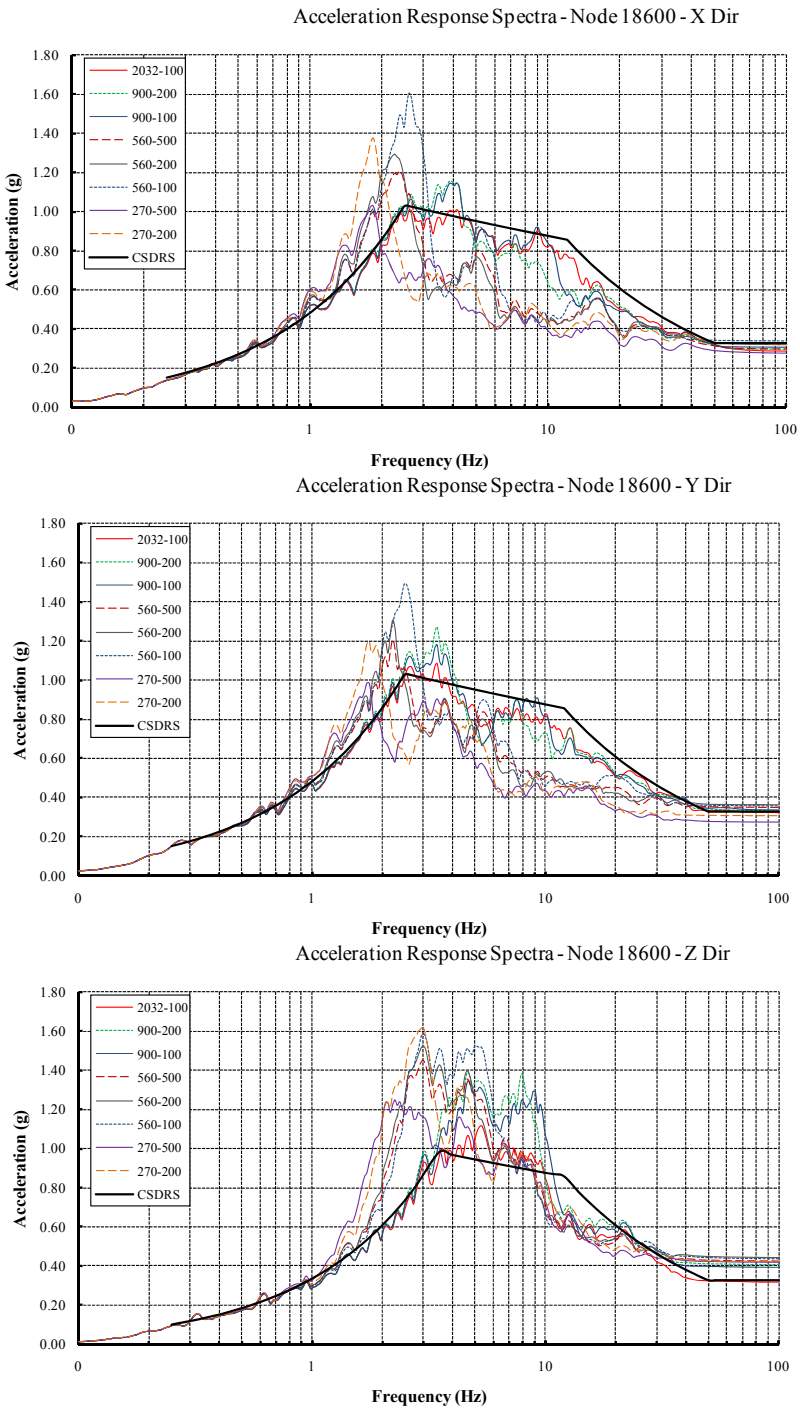

Figure 3.3.1-4 5%-Damped Acceleration Response Spectra at Node No. 18600 in the Near-Field Ground Surface Adjacent to the R/B Complex

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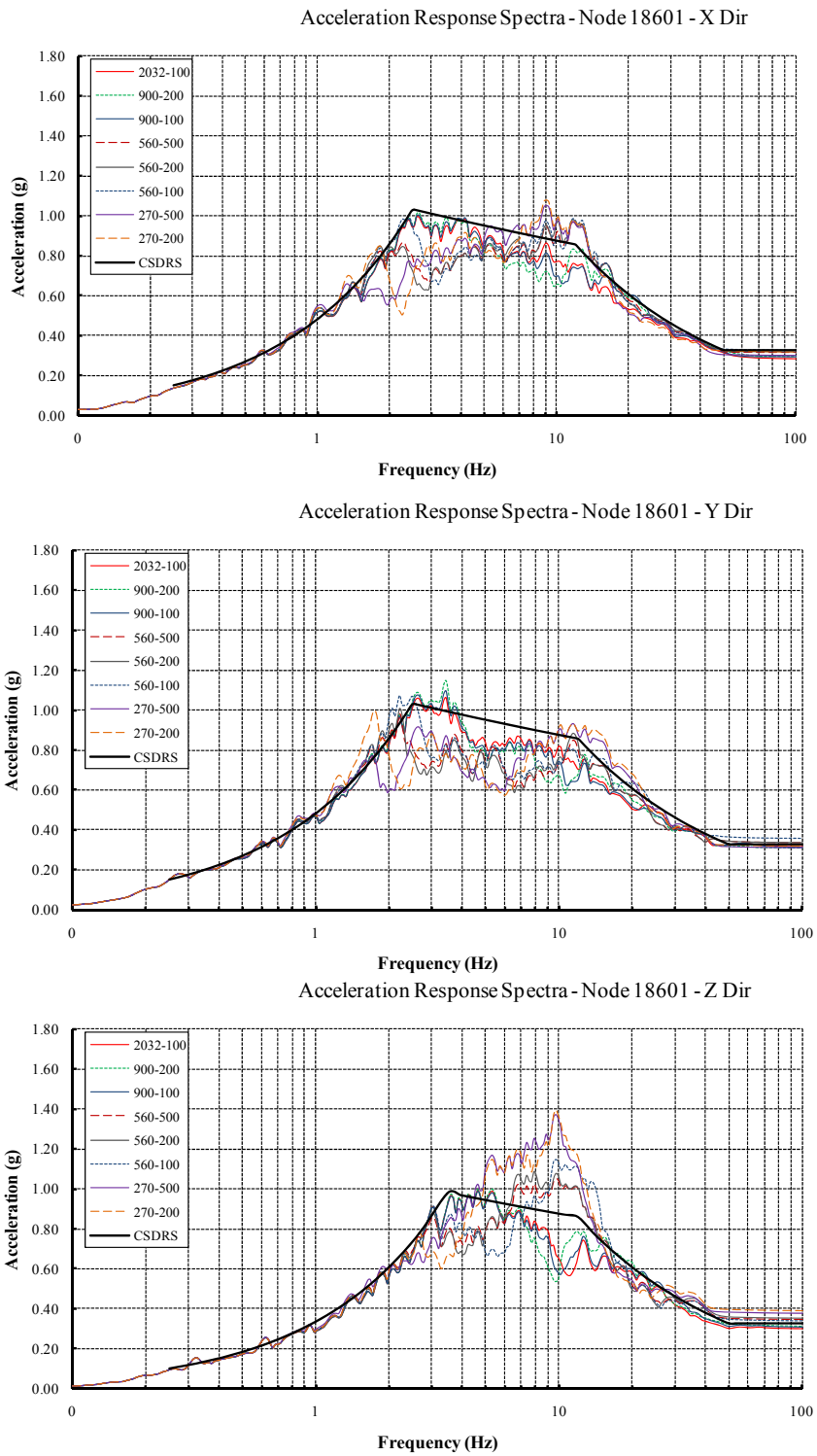

Figure 3.3.1–5 5%-Damped Acceleration Response Spectra at Node No. 18601 in the Near-Field Ground Surface Adjacent to the R/B Complex

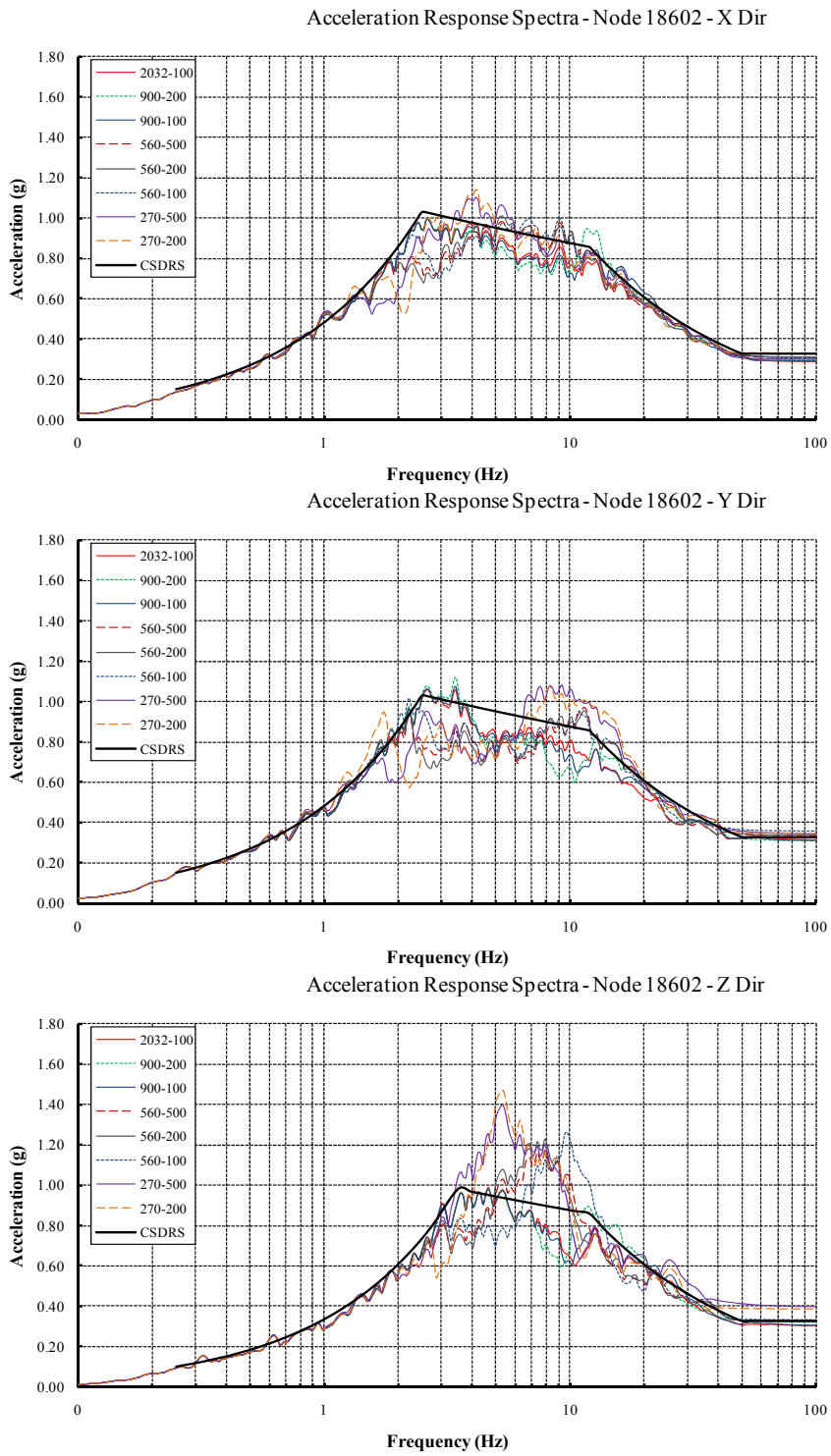

Figure 3.3.1–6 5%-Damped Acceleration Response Spectra at Node No. 18602 in the Near-Field Ground Surface Adjacent to the R/B Complex

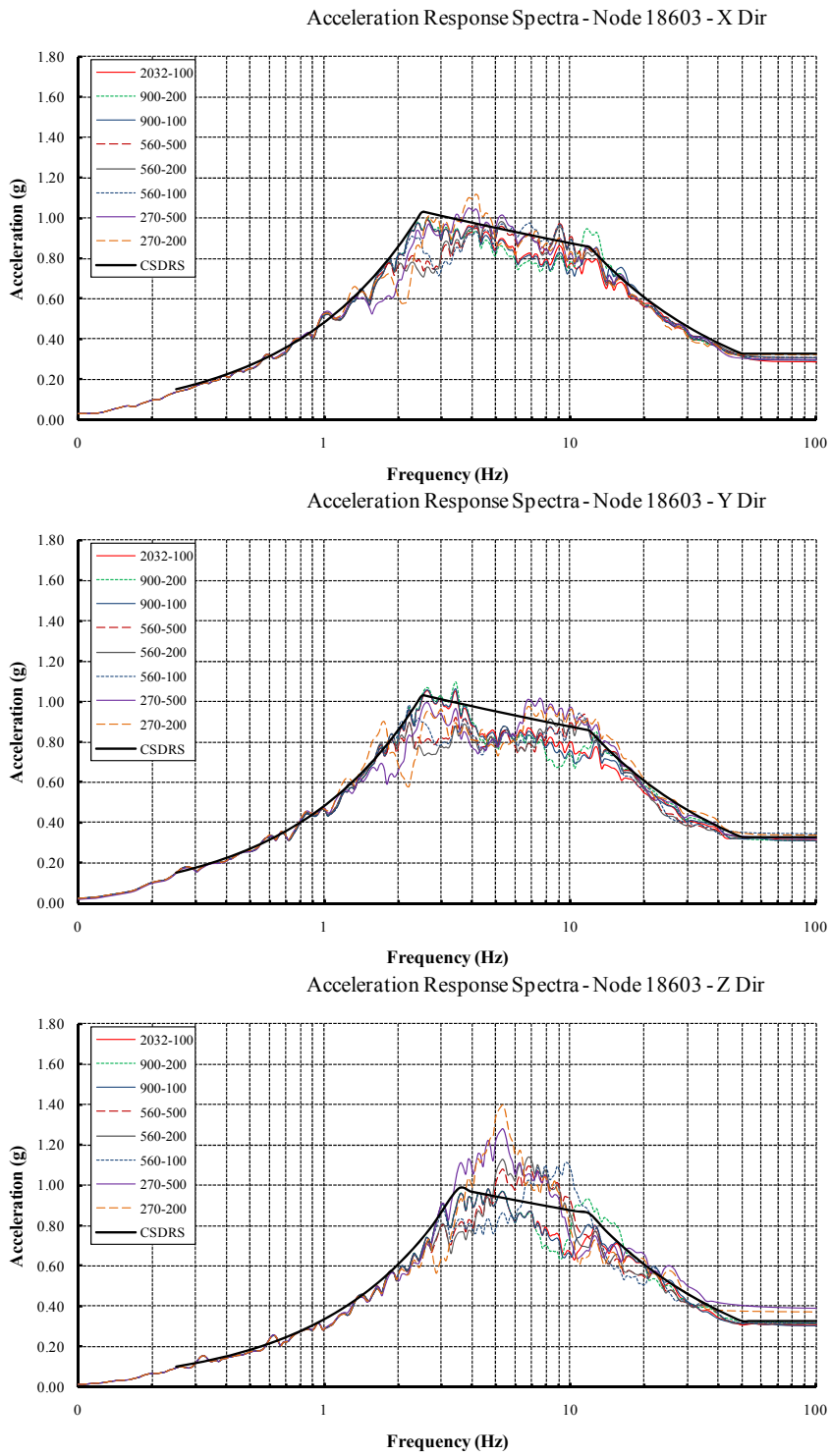

Figure 3.3.1–7 5%-Damped Acceleration Response Spectra at Node No. 18603 in the Near-Field Ground Surface Adjacent to the R/B Complex

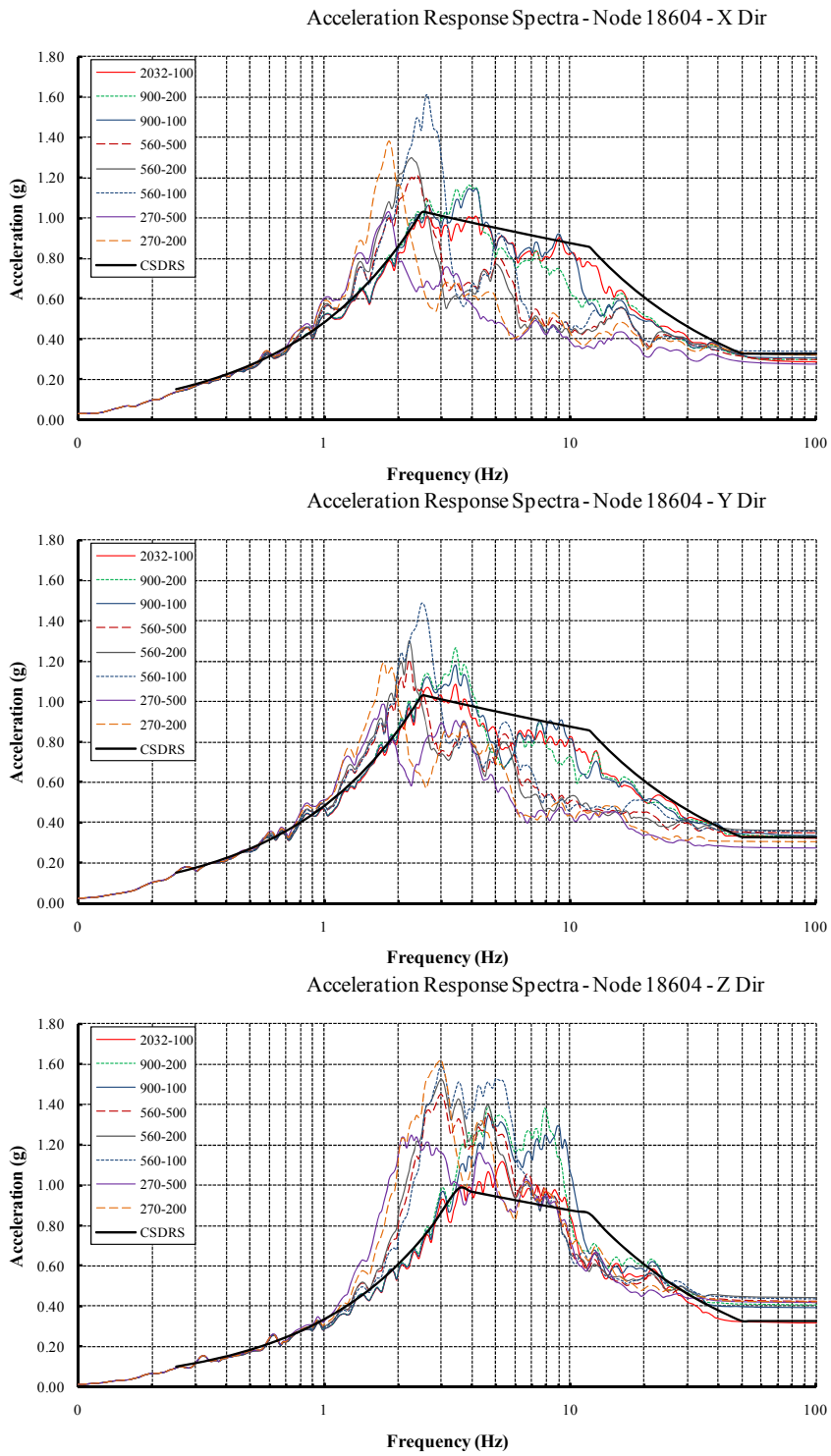

Figure 3.3.1–8 5%-Damped Acceleration Response Spectra at Node No. 18604 in the Near-Field Ground Surface Adjacent to the R/B Complex

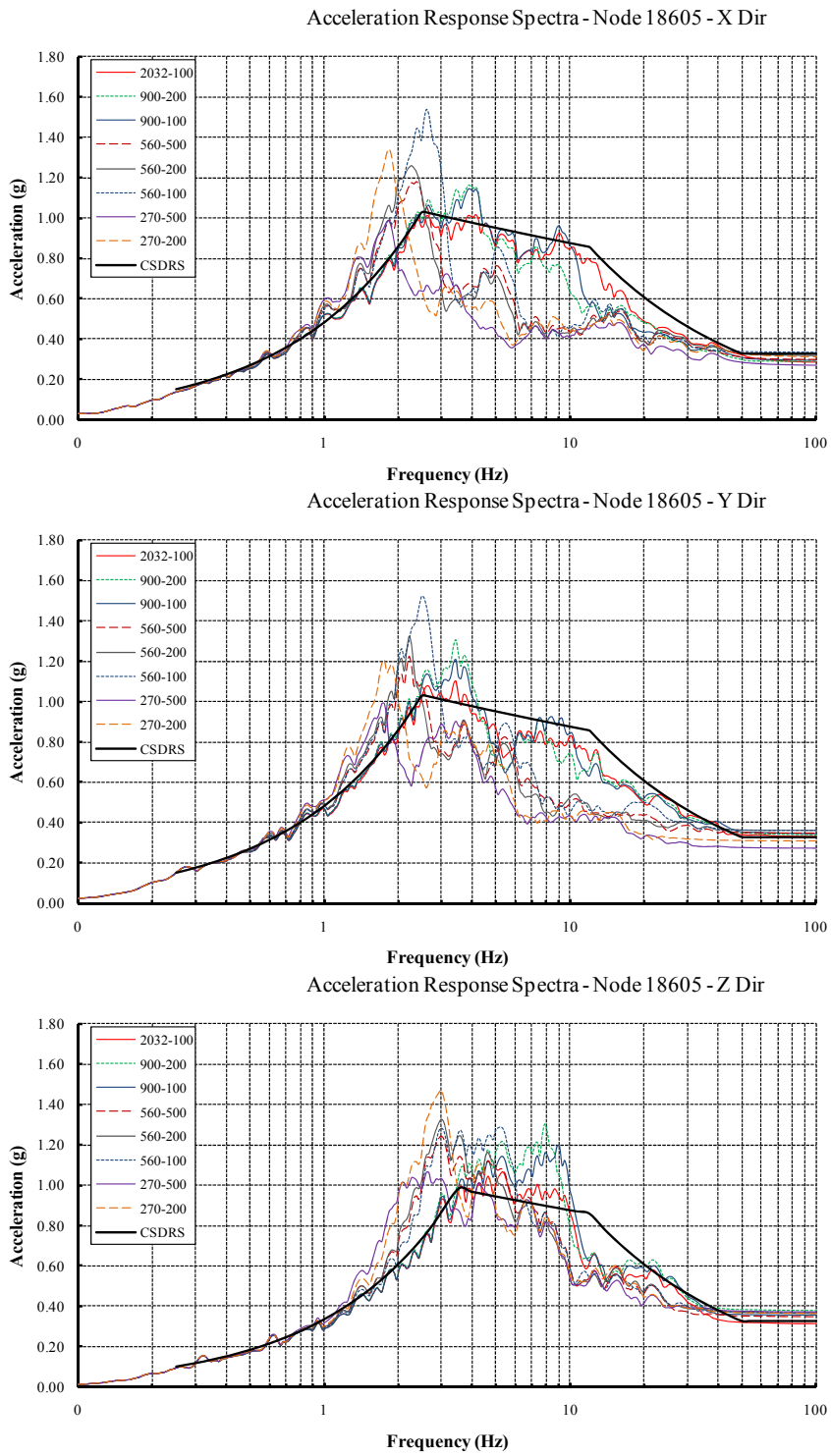

Figure 3.3.1–9 5%-Damped Acceleration Response Spectra at Node No. 18605 in the Near-Field Ground Surface Adjacent to the R/B Complex

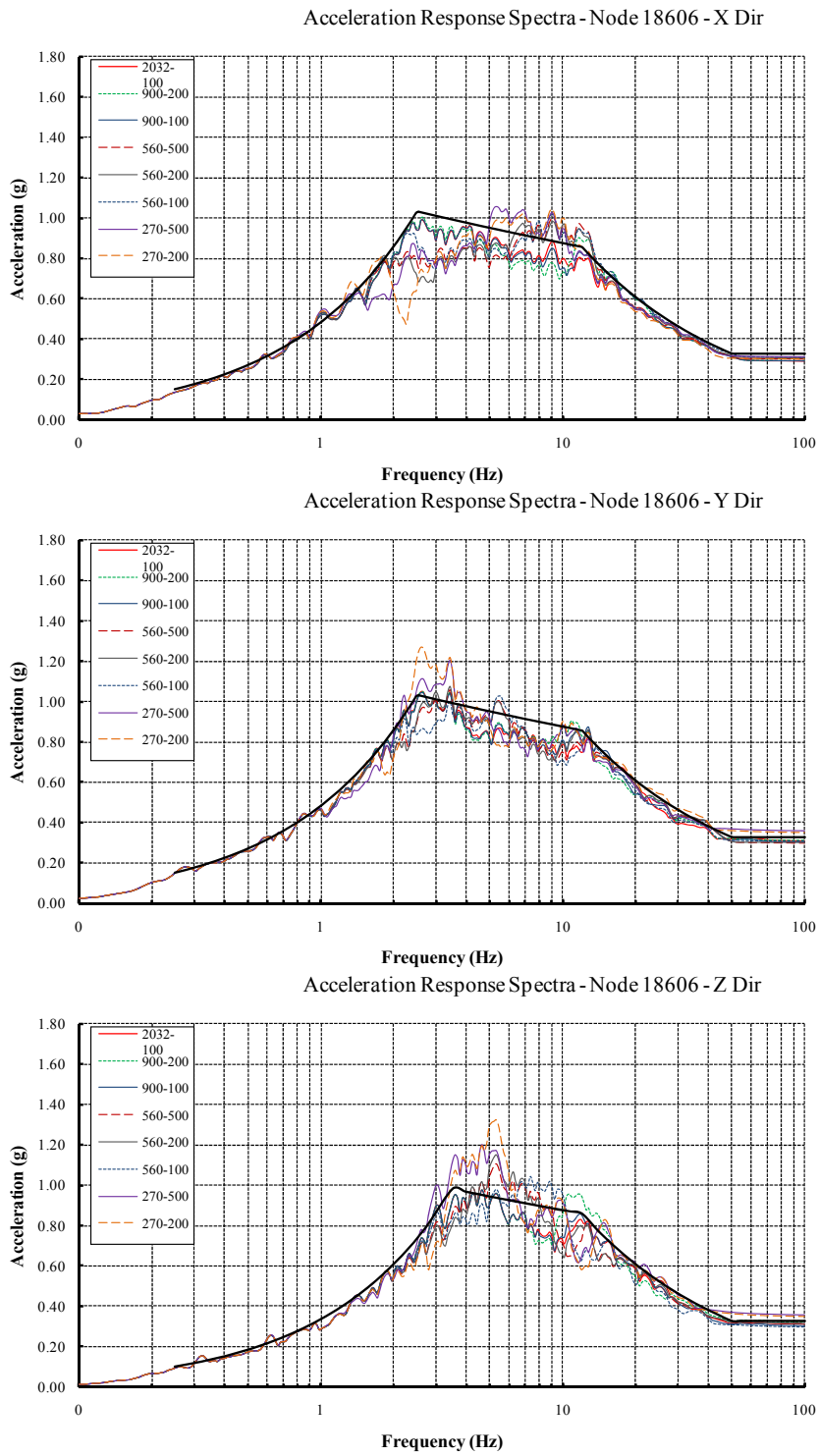

Figure 3.3.1–10 5%-Damped Acceleration Response Spectra at Node No. 18606 in the Near-Field Ground Surface Adjacent to the R/B Complex

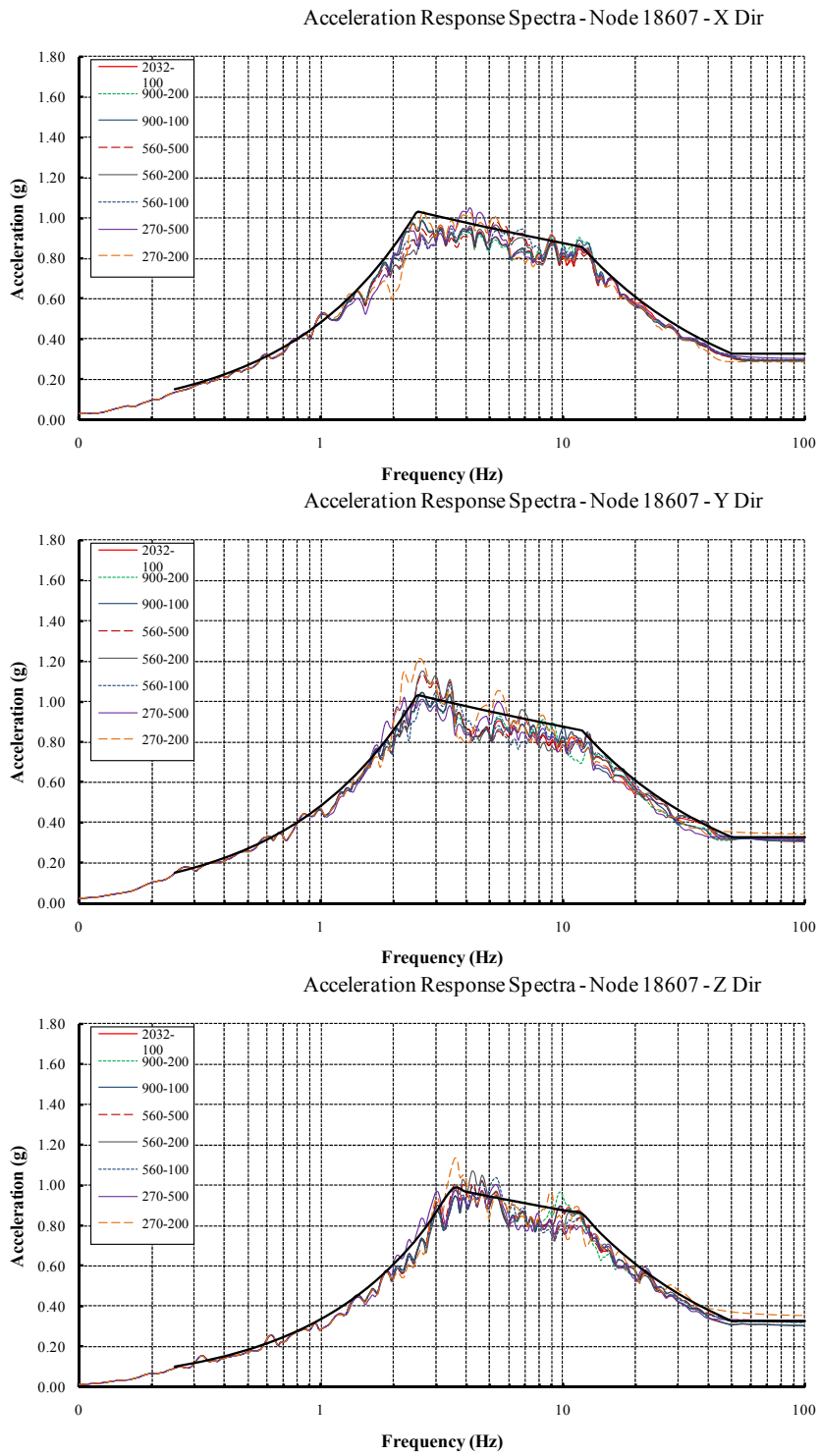

Figure 3.3.1–11 5%-Damped Acceleration Response Spectra at Node No. 18607 in the Near-Field Ground Surface Adjacent to the R/B Complex

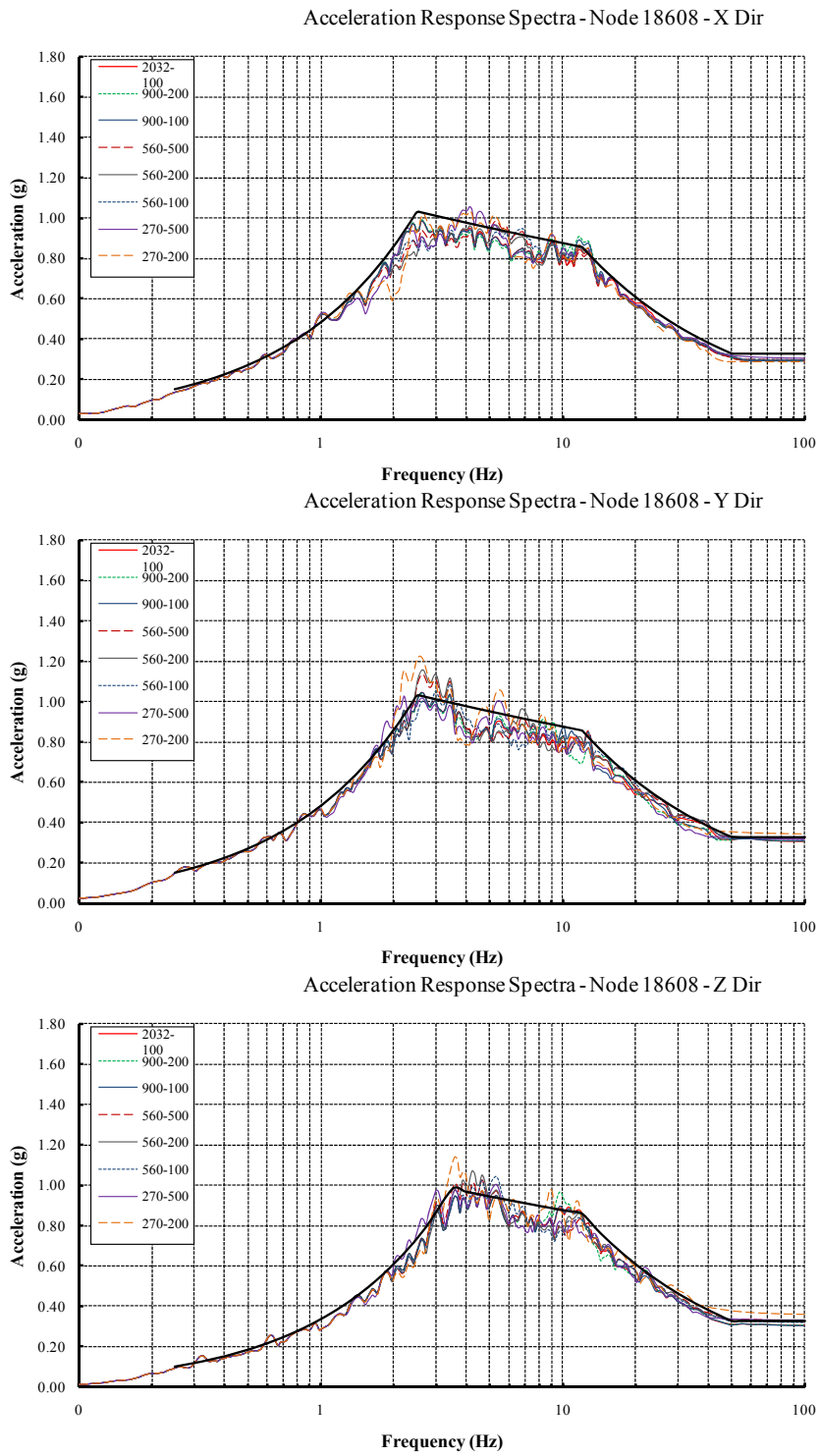

Figure 3.3.1–12 5%-Damped Acceleration Response Spectra at Node No. 18608 in the Near-Field Ground Surface Adjacent to the R/B Complex

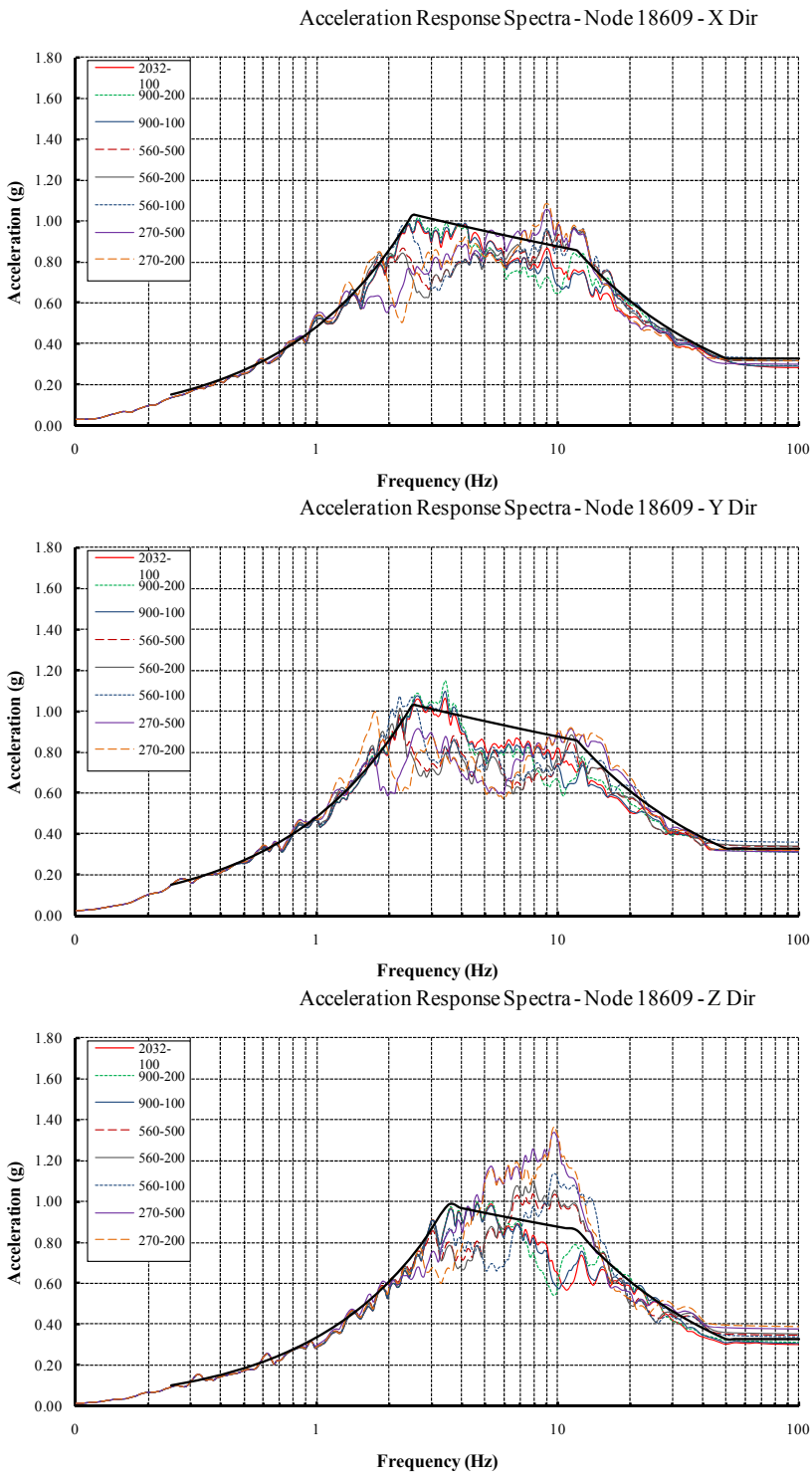

Figure 3.3.1–13 5%-Damped Acceleration Response Spectra at Node No. 18609 in the Near-Field Ground Surface Adjacent to the R/B Complex

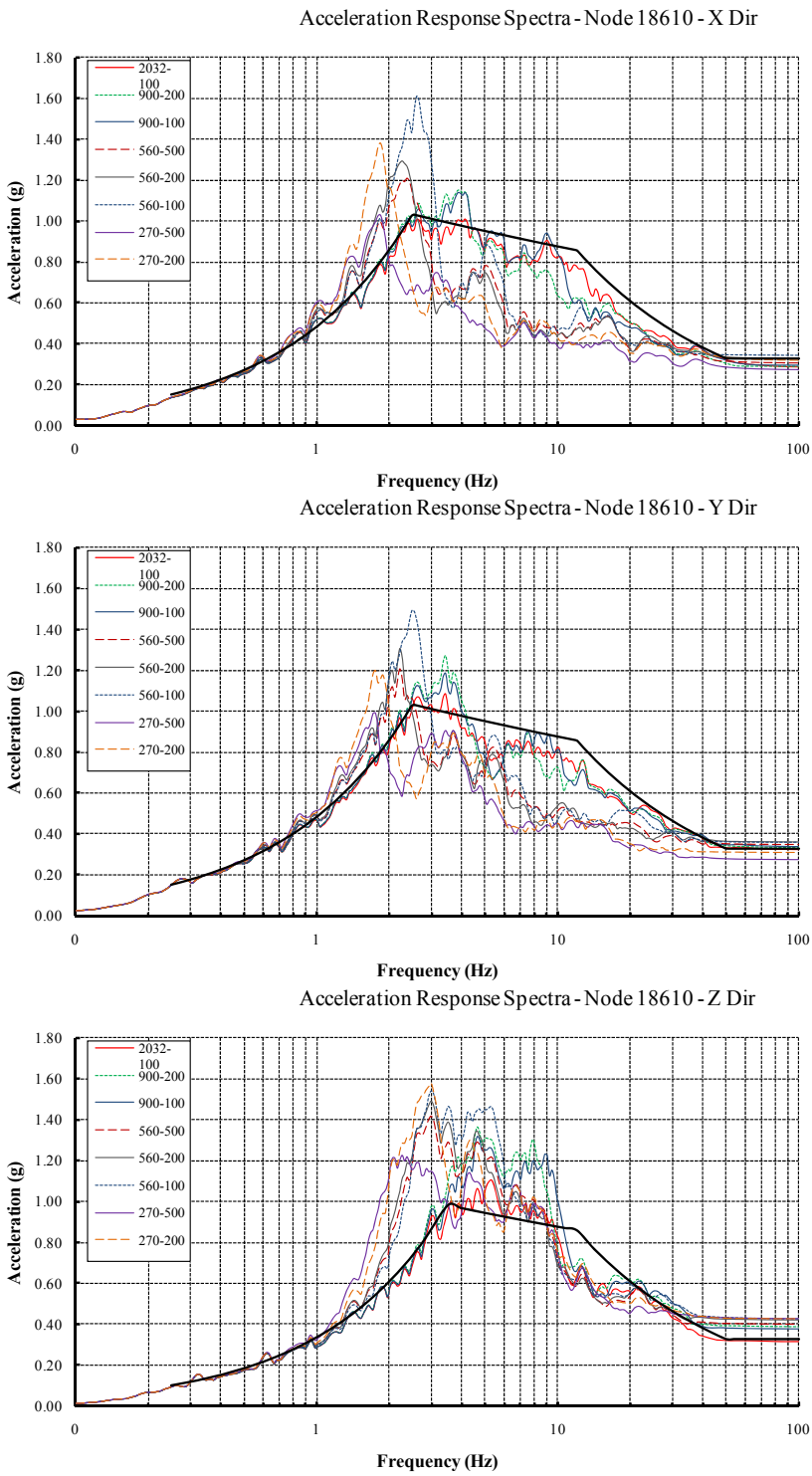

Figure 3.3.1–14 5%-Damped Acceleration Response Spectra at Node No. 18610 in the Near-Field Ground Surface Adjacent to the R/B Complex

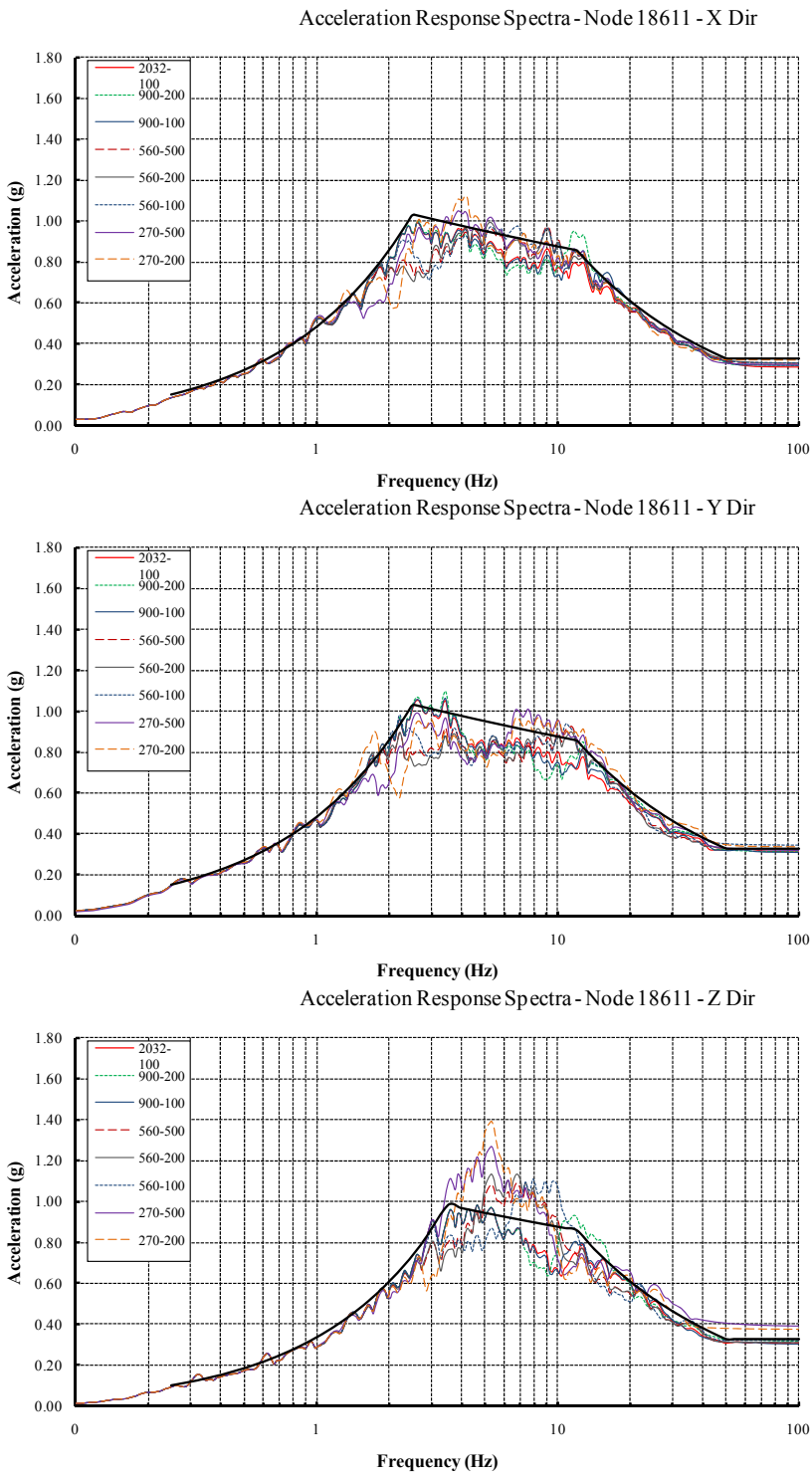

Figure 3.3.1–15 5%-Damped Acceleration Response Spectra at Node No. 18611 in the Near-Field Ground Surface Adjacent to the R/B Complex

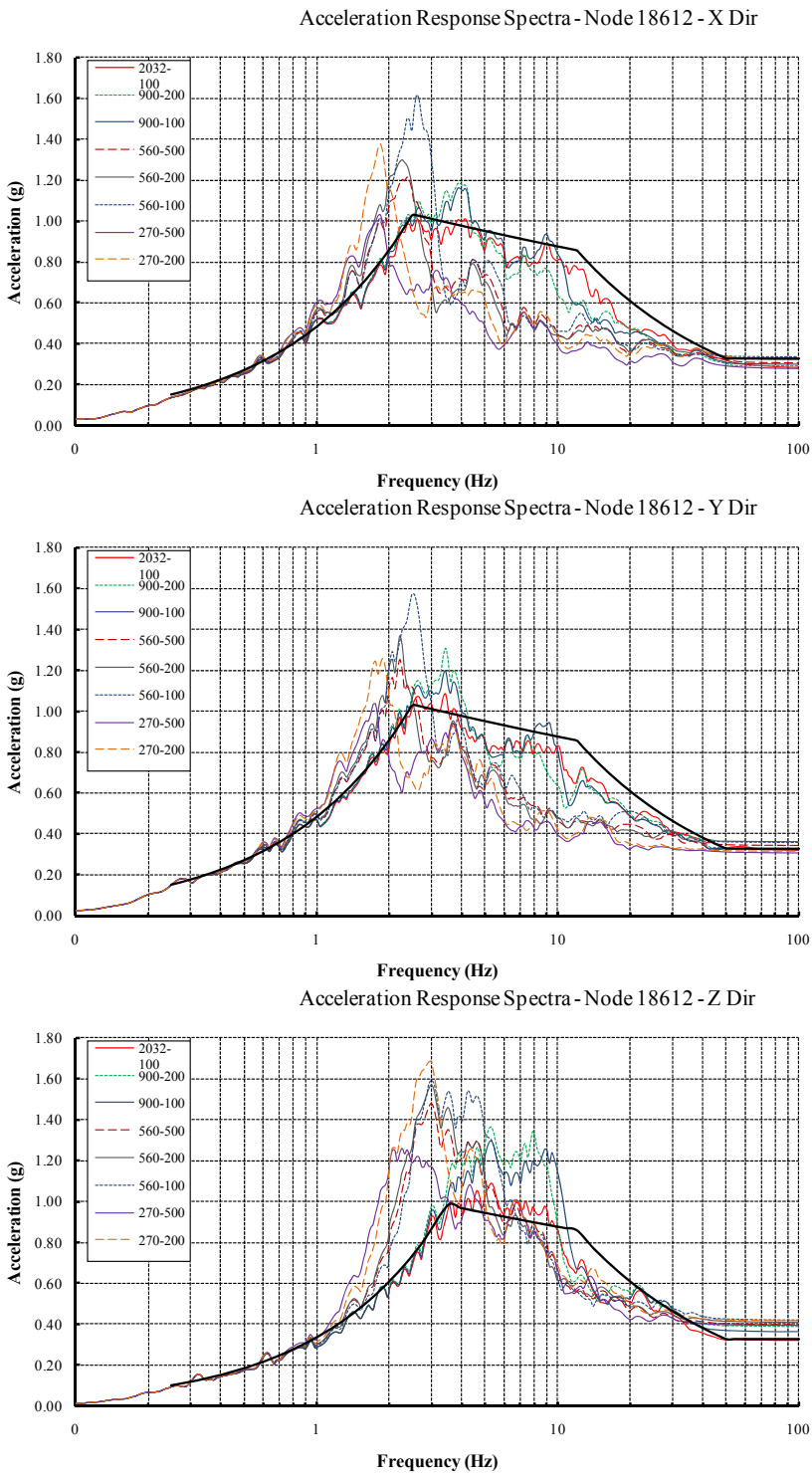

Figure 3.3.1–16 5%-Damped Acceleration Response Spectra at Node No. 18612 in the Near-Field Ground Surface Adjacent to the R/B Complex

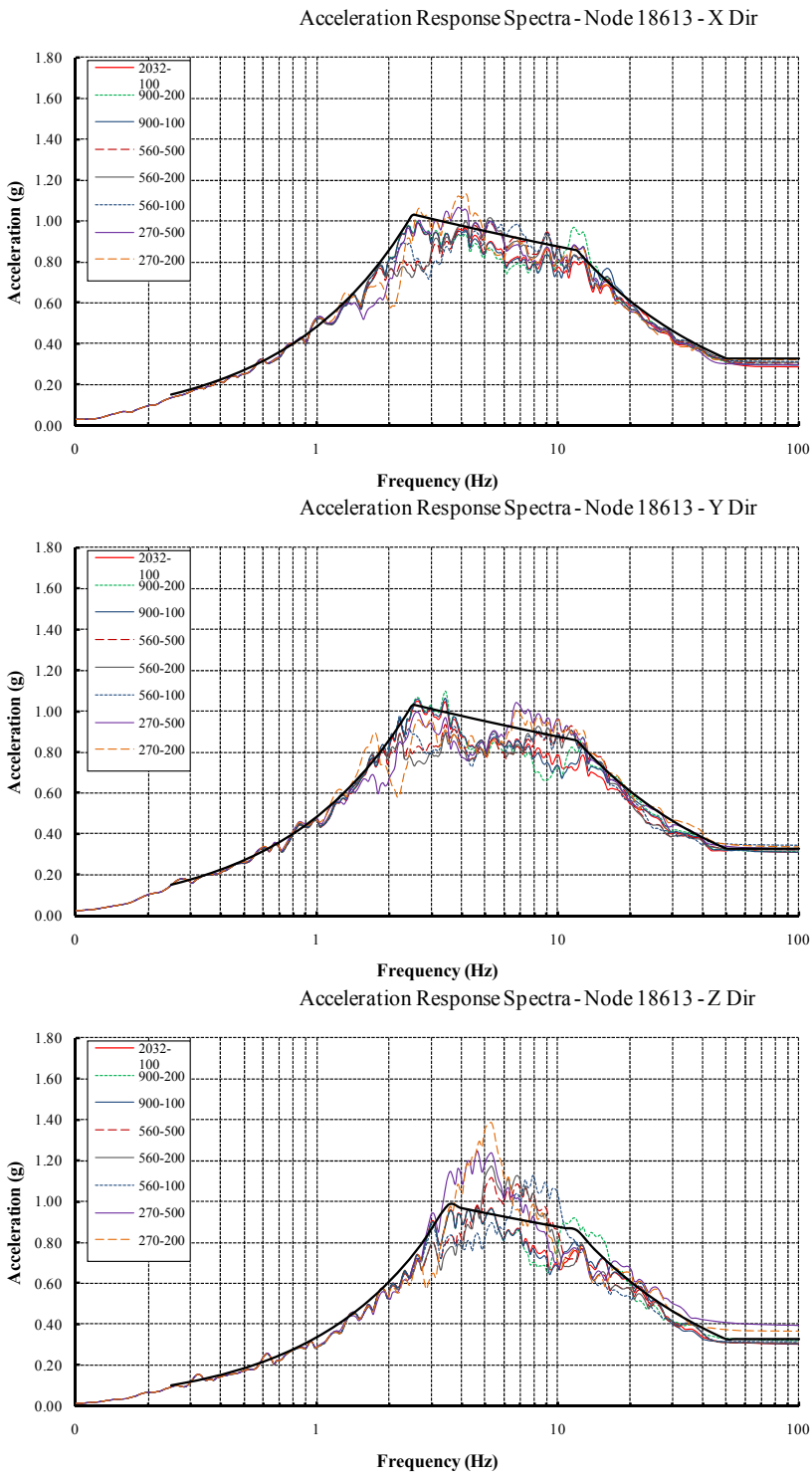

Figure 3.3.1–17 5%-Damped Acceleration Response Spectra at Node No. 18613 in the Near-Field Ground Surface Adjacent to the R/B Complex

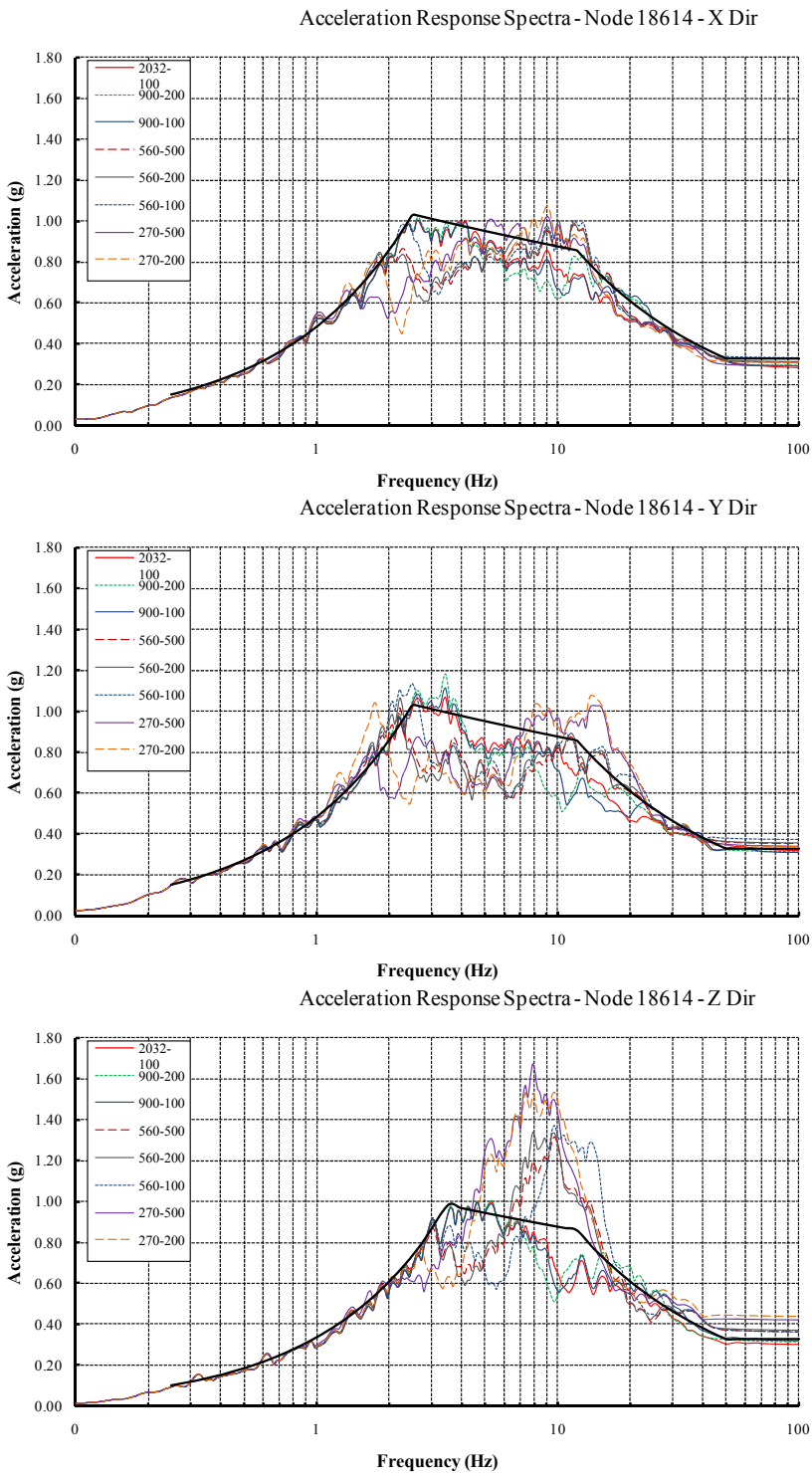

Figure 3.3.1–18 5%-Damped Acceleration Response Spectra at Node No. 18614 in the Near-Field Ground Surface Adjacent to the R/B Complex

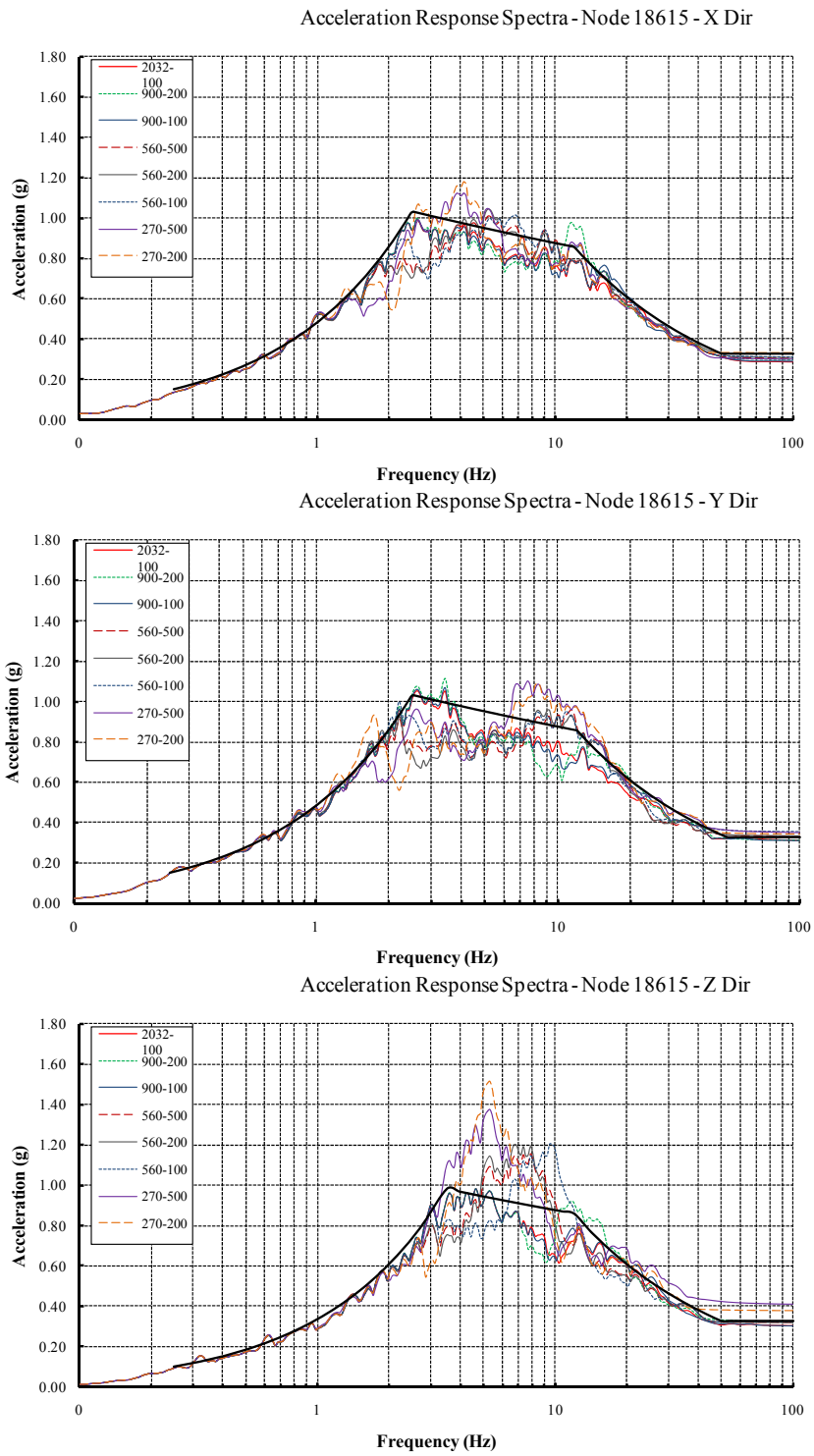

Figure 3.3.1–19 5%-Damped Acceleration Response Spectra at Node No. 18615 in the Near-Field Ground Surface Adjacent to the R/B Complex

3.3.2 Coupled Dynamic SSSI Effect

Assessment of the complete coupled dynamic SSSI effect on the seismic response of the US-APWR standard plant structures requires utilizing through soil-coupled SSI dynamic models of all adjacent buildings into an integrated dynamic system. Such analysis would require a very large size model of the coupled SSSI dynamic system which is difficult to be accommodated in the current practice. Thus, the coupled dynamic SSSI effect can practically be assessed by considering only two or three surface-supported adjacent buildings at a time.

As mentioned previously, the first priority in assessing the dynamic SSSI effect is to investigate the effect of the heavier A/B and R/B Complex buildings on the seismic response of the nearby PS/B which has much smaller dimensions and less weight. For that purpose, the dynamic FE model of the West PS/B is coupled with the LMS models of the R/B Complex and A/B in a through soil-coupled integrated ACS SASSI dynamic model. The initial focus of the study will be on the softer generic site profiles that are most likely to be affected by SSSI effects. The two softest generic site profiles, i.e. 270-200 and 560-100, represent site conditions of a shallow layer of softer soil supported by a hard rock formation, where the pronounced contrast of the layers' dynamic properties reduces dissipation of wave radiation energy, i.e. the radiation damping of the site.

The ARS results for the seismic response of the PS/B obtained from the SSSI analyses of the combined model are compared with the results obtained from the site-independent SSI analyses of the standalone PS/B. The following guideline is used to assess the coupled dynamic SSSI effects on the standard plant structures:

> *The 5%-damped ISRS obtained from the combined SSSI model are not more than 10% higher than the corresponding ±15%-frequency-band-widened 5%-damped ISRS envelope obtained from the site-independent SSI analyses of the standalone structure for all eight generic site profiles.*

The above guideline is based on the premise that the variations in the responses due to SSSI effects do not significantly exceed the uncertainty already introduced in the seismic design of the standard plant by the ±15% variations in the frequency content and variations in the generic site profile.

The results of the ACS SASSI analysis of R/B Complex dynamic FE model resting on a hard rock subgrade are used to illustrate the uncertainty in the calculated structural response that are due to the variations in the frequency content of the input acceleration time histories. For that purpose, two sets of 5%-damped ARS were calculated for the response at selected locations within the R/B Complex using two different CSDRS compatible horizontal acceleration time histories (H1) and (H2). For each of the selected locations, two sets (each consisting of two ARS) are calculated for each acceleration time history representing the response in the North-South (NS) (X) direction due to ground excitation in the NS (X) direction and the response in the East-West (EW) (Y) direction due to ground excitation in the EW (Y) direction. This is done in order to assess the variations in the ISRS amplitudes due to the differences in the two different

spectrum-compatible input motion time histories. The comparison of the 5%-damped ARS calculated using different acceleration time histories, shown in Figures 3.3.2-1a through 3.3.2-1d, indicate that differences in the ISRS resulting from the variations of the frequency content of the input acceleration histories, can be more than 30%. This demonstrates that the selected guideline for assessing the significance of the SSSI effects is well within the uncertainty introduced in the seismic design of standard plant due to the variations in the CSDRS-compatible input ground acceleration histories.

The results of the assessment of kinematic and dynamic SSSI effects described in this report are used as the basis to identify the critical generic site profile cases for which the SSSI effects is significant. The responses of PS/B obtained from the SSSI analyses of the identified critical site profile cases are enveloped with those of the SSI analyses of the standalone PS/B model. The enveloped ISRS and Safe Shutdown Earthquake (SSE) loads will be developed from the enveloped responses obtained from standalone SSI analyses and the SSSI analyses, to be used as the revised seismic design basis that accounts for the SSSI effects.

The findings of this initial study serve as a basis to determine whether additional assessments of SSSI effects are necessary between the R/B Complex and A/B, between T/B and PS/B, and between R/B Complex and T/B, in accordance with the phased approach as indicated in Table 1.0-1.

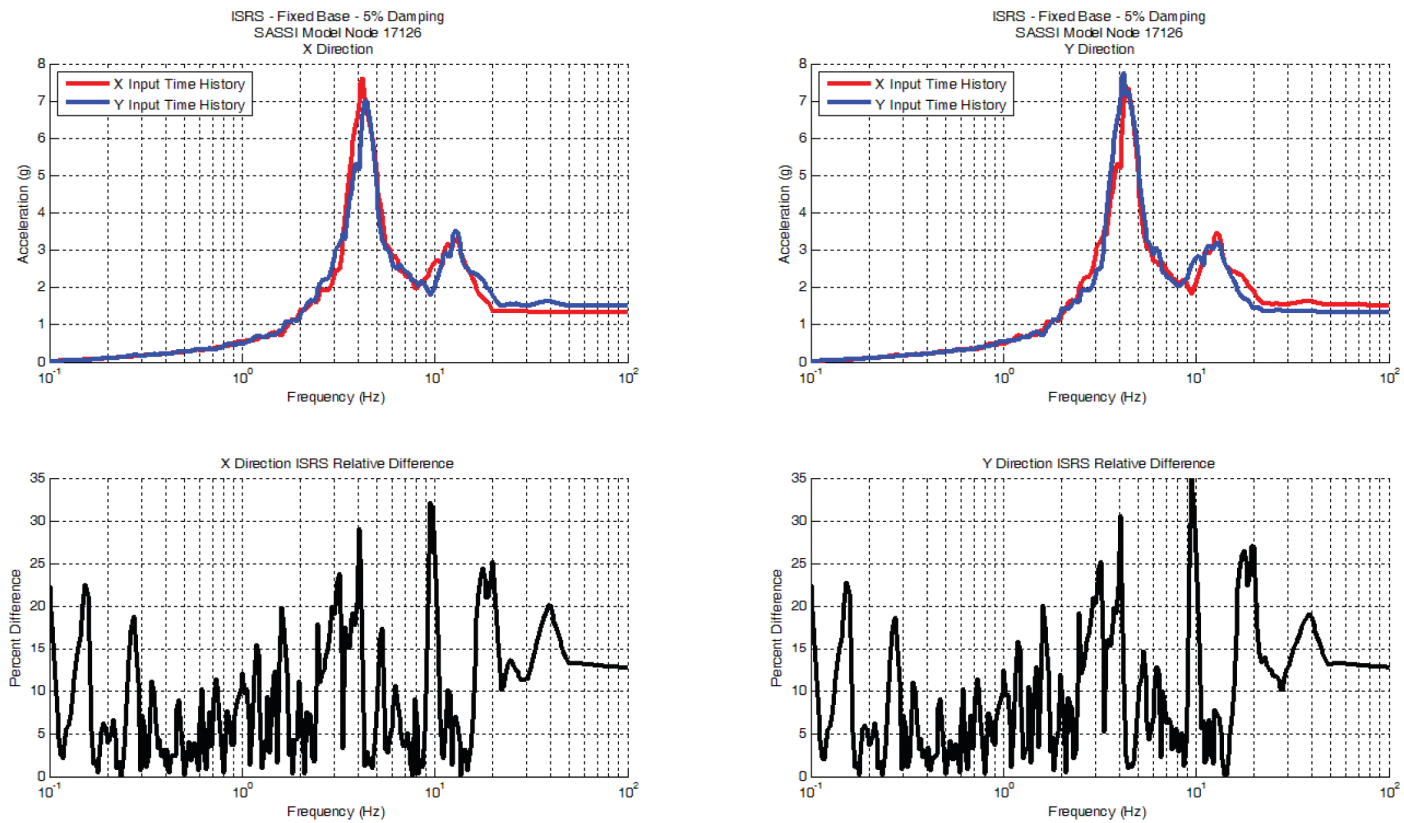

Figure 3.3.2-1a Amplitude Variations in the 5% Damping ARS Calculated using Two Different Horizontal CSDRS-Compatible Input Acceleration Time Histories

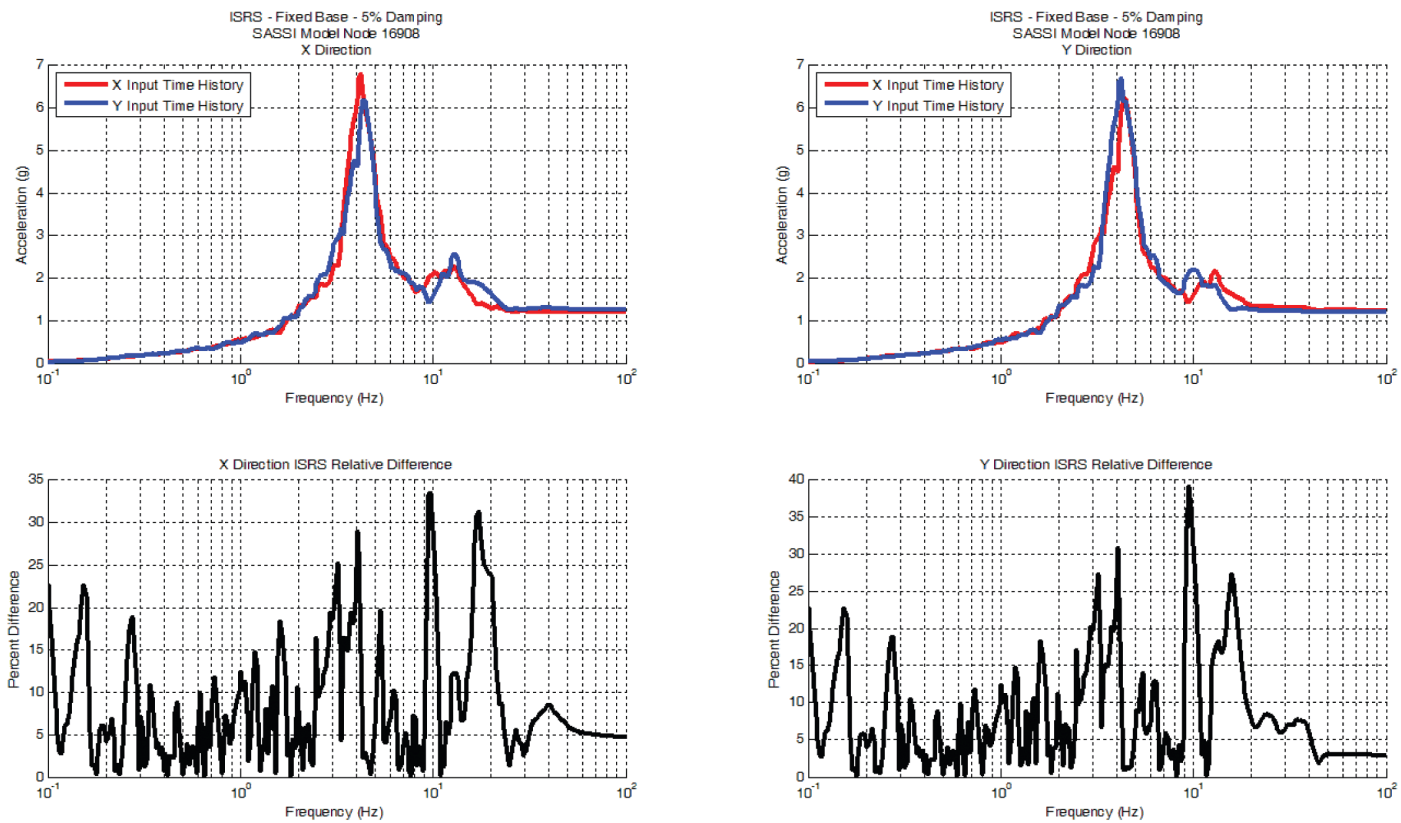

Figure 3.3.2-1b Amplitude Variations in the 5% Damping ARS Calculated using Two Different Horizontal CSDRS-Compatible Input Acceleration Time Histories

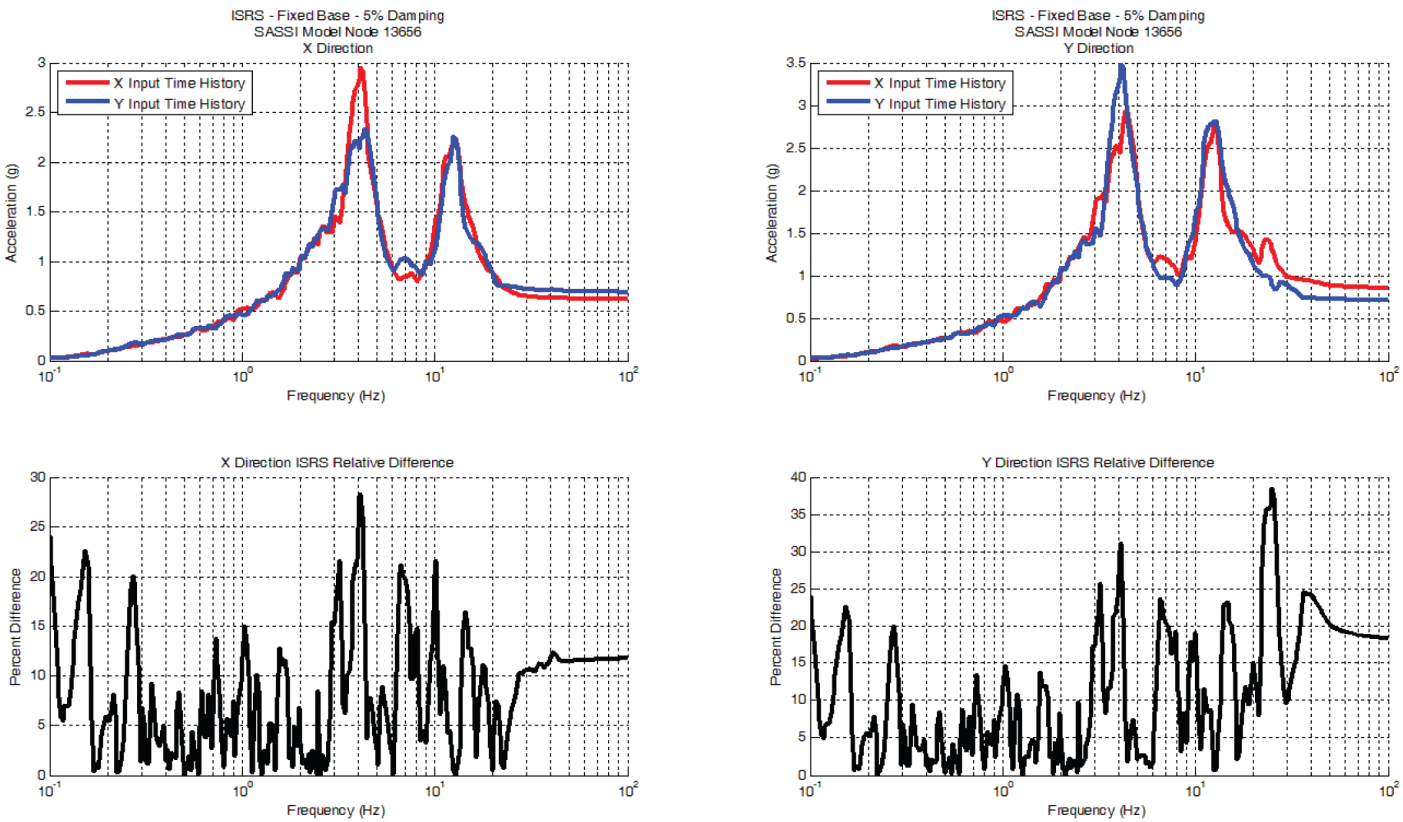

Figure 3.3.2-1c Amplitude Variations in the 5% Damping ARS Calculated using Two Different Horizontal CSDRS-Compatible Input Acceleration Time Histories

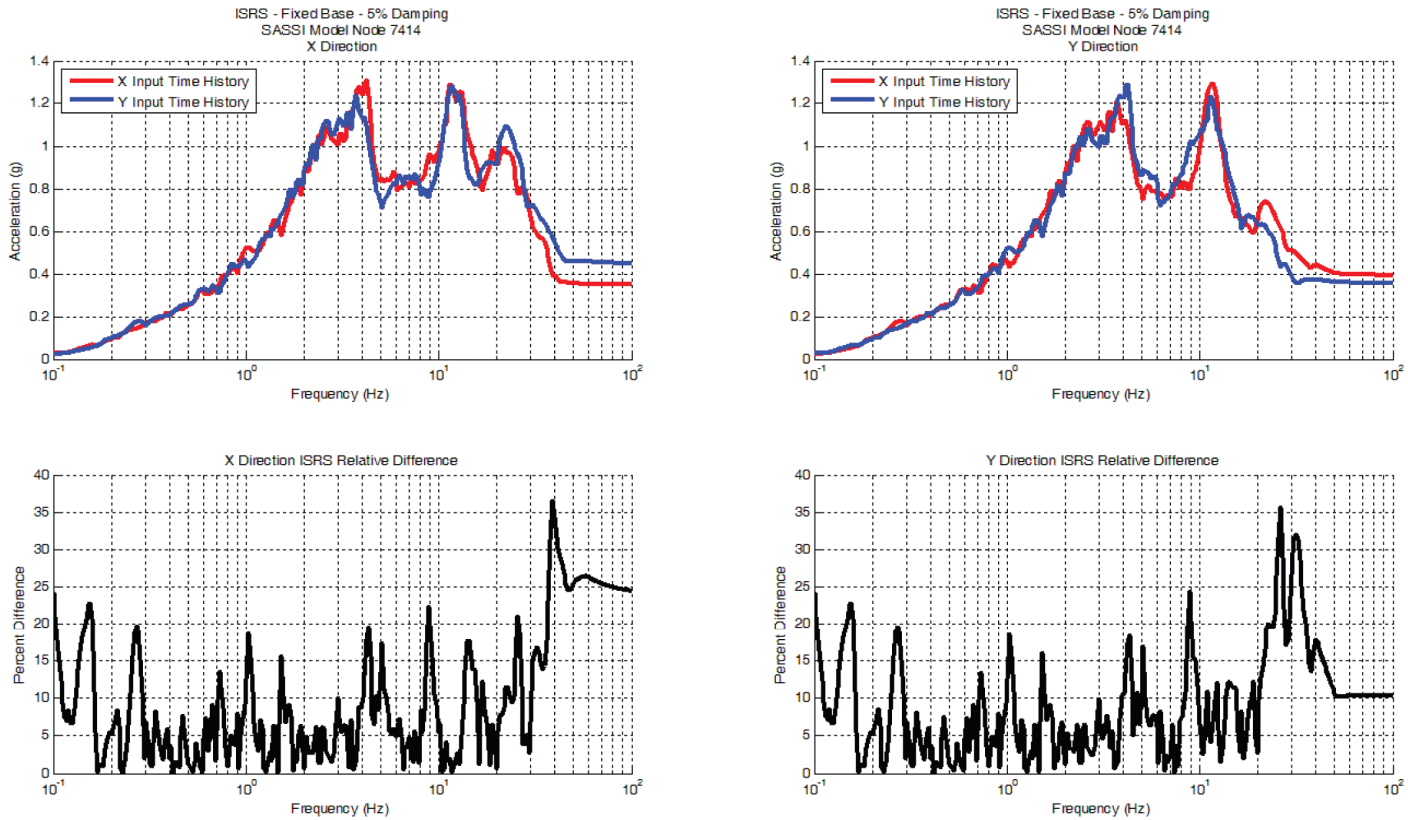

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Figure 3.3.2-1d Amplitude Variations in the 5% Damping ARS Calculated using Two Different Horizontal CSDRS-Compatible Input Acceleration Time Histories

4.0 CONCLUSION

RESERVED.

Will be included in Revision 1.

5.0 REFERENCES

1. Seismic Design Parameters, NUREG-0800 Section 3.7.1, Revision 3, U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

2. Seismic System Analysis, NUREG-0800 Section 3.7.2, Revision 3, U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

3. Lumped Mass Stick Model of US-APWR Reactor Building Complex, MUAP-11006, Revision 0, Mitsubishi Heavy Industries, Ltd., June 2011.

4. Auxiliary Building Model Properties, SSI Analyses, and Structural Integrity Evaluation, MUAP-11001, Revision 1, June 2011.

5. A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion, Regulatory Guide 1.208 Revision 0, U. S. Nuclear Regulatory Commission, March 2007.

6. ACS SASSI, NQA Version 2.3.0 Upgrade including “Option A”, Ghiocel Predictive Technologies, Inc., December 2010.