5. ANALYSIS RESULTS

In this section, results of incoherent-input-motion SSI analysis performed for the seismic input motion of the HRHF response spectra are discussed (Reference 28 and 31).

5.1 Site Response Analysis

For the APR1400 NI structures and EDGB/DFOT room, the incoherent-input-motion SSI analysis with the HRHF-response-spectra-compatible seismic input motion is performed for the generic hard rock sites. The shear-wave-velocity profile of the Pinyon Flat Array site (the recorded data of this site provide the bases for developing the coherency functions for hard rock sites) is shown in Figure 5-1. Excluding the 5-m-thick softer surface layers, one can find from this shear-wave-velocity profile that the site has an average shear wave velocity of about 5,000 ft/sec for the top 50-m depth and about 9,800 ft/sec below the depth of 50 m.

Of the nine (9) generic site-shear-wave-velocity profiles S1 through S9 selected for design of the APR1400, the site profiles that can be classified as hard rock sites that have shear-wave-velocity profiles of the order or higher than that of the Pinyon Flat Array site are S8 and S9. Both S8 and S9 have site shear-wave-velocity profiles of the same order as the profile of Pinyon Flat site, as shown in Figure 5-2. For the site profile S8, the depth of bedrock where the rock shear-wave velocity (Vs) equal to 9,200 ft/sec is reached is at the depth of 61 m (200 ft). Whereas for S9, the bedrock where Vs = 9,200 ft/sec is reached is at the depth of 30.5 m (100 ft).

The horizontal site response analyses performed for S8 and S9 give the horizontal site response amplification (transfer) functions from the bedrock where Vs = 9,200 ft/sec to the ground surface, as shown in Figures 5-3 and 5-4, respectively. Comparing the site response transfer functions shown in Figures 5-3 and 5-4 with the horizontal HRHF response spectra shown in Figure 3-2, one can readily see that the generic site profile S9, which has the peak amplification of the site at higher frequency, is more critical when subjected to the horizontal HRHF seismic input motion than the site profile S8. Thus, from the controlling-seismic-response-motion-point-of-view, site profile S9 is the controlling case for the incoherent-motion SSI analysis performed with the HRHF- response-spectra-compatible seismic input motion input. Thus, the incoherent-motion SSI analysis of the APR1400 NI structures and EDGB/DFOT room, subjected to the seismic input of APR1400 HRHF-response-spectra-compatible seismic input motion, is performed for the generic S9 site profile.

5.2 INCOH Analysis Results

The INCOH program module computes the coherency matrix of the finite element mesh of the excavated soil volume on the ground surface and performs an eigenvalue analysis of the coherency matrix for each selected frequency for the SASSI analysis. Tables 5-1 and 5-2 present INCOH analysis results in terms of the eigenvalues and the participation factors of the first 15 principal coherency modes for selected representative frequencies 1, 10, 20, 30, 40, and 50, Hz. The participation factors shown in these tables are defined as, for mode j:

$Z_j = \lambda_j \times [\Sigma \phi_i]^2$ i=1, 2… number of nodes

$XX_j = \lambda_j \times [\Sigma \phi_i (Y_i - Y_o)]^2$ i=1, 2… number of nodes

$YY_j = \lambda_j \times [\Sigma \phi_i (X_i - X_o)]^2$ i=1, 2… number of nodes

$ZZ_j = XX_j + YY_j$

λ = square root of eigenvalues

ϕ = eigenvector

(X_o, Y_o) = (0.0, 0.0) (center of RCB)

The participation factors shown for each principal coherency mode are a measure of contribution of each principal coherency mode to the horizontal or vertical translation (Zj) and torsion (ZZj about the vertical Z-axis) or rocking (XXj for rocking about the X-axis or YYj for rocking about the Y-axis) rotation of the foundation.

Based on the INCOH principal coherency mode-shape plots, Mode 1 is a translational mode in X, Y, or Z direction. Modes 2 and 3 are torsional modes (when applied to the horizontal analysis) or are rocking modes (when applied to the vertical analysis). The mode-shape plot for each mode also shows the amount of spatial distortion in the mode shape, which increases as the frequency increases.

5.3 SSI Analysis

The incoherent-motion SSI analysis is performed using the methodology described in Section 2. Table 5-3 lists the SASSI calculated frequencies, i.e., the frequencies selected, for the incoherent-motion SSI analysis of the APR1400 NI structures.

5.4 Comparison of Incoherent-motion SSI Analysis Results Using 7 and 12 Modes

Comparison of incoherent-input-motion SSI analysis results obtained from the SRSS of the responses of Modes 1-7 versus the results of the SRSS of the responses of Modes 1-12 are provided in Appendix B. These results indicate that 7 modes are adequate for capturing the incoherent-motion SSI response of the structure, because the addition of the responses from modes greater than Mode 7 leads to insignificant increase of the computed ISRS to the incoherent seismic ground motion input.

5.5 Comparison of ISRS Based on CSDRS and HRHF Response Spectra

To show the significance of the HRHF response spectra, the seismic responses resulting from the coherent CSDRS compatible seismic input motion and the corresponding responses resulting from the incoherent HRHF-response-spectra compatible seismic input motion are compared. Figures 5-5 through 5-17 show such comparisons of the 5%-damped ISRS generated at a number of locations in the NI structures. As shown in these comparisons, there are some exceedances of the CSDRS-based ISRS, most of the exceedances occur in the frequency range above 10 Hz. The comparisons shown in Figures 5-5 through 5-17 are typical of the response comparisons found throughout the NI structures.

Figures 5-18 through 5-23 provide broadened (+/- 15%) ISRS from the coherent CSDRS, coherent and incoherent HRHF response spectra for the 5% spectral damping. The calculation procedures for the ISRS from the CSDRS and the HRHF seismic input motion can be found in References 30 and 31, respectively. ISRS plots of the walls are compared for each of the three direction (E-W, N-S, and vertical), whereas those of the slabs are compared for the vertical direction only. As shown in these comparisons, there are some exceedances of the CSDRS-based ISRS, and most of the exceedances occur in the frequency range above 10~20 Hz.

The exceedances of CSDRS-based ISRS by HRHF-based ISRS are addressed in this report as part of the sampling evaluation to confirm that high frequency seismic response has a marginal effect on the equivalent piping, and structures qualified by analysis for ISRS developed from the APR1400 CSDRS seismic input.