Soil-Structure Interaction Effects in Seismic Analysis of Turbine Generator Building on Rock-like Foundation

Chi-Seon Park, Sang-Hoon Lee, Kwang-Hoon Yoo
Korea Power Engineering Company, Inc., 360-9 Mabuk-ri, Guseong-eup, Yongin-shi, Gyeonggi-do
cspark@kopec.co.kr, shljrl@kopec.co.kr, yh@kopec.co.kr

1. Introduction

Soil properties supporting structure may become criteria determining methodologies for seismic response analysis of a structure. Regulatory Guide describes that a fixed-base assumption is acceptable for structures supported on rock or rock-like materials defined by a shear wave velocity of 3,500 ft/sec or greater at a shear strain of 10^{-3} percent or smaller when considering preloaded soil conditions due to the structure [1]. Seismic analyses for the Korean nuclear power plant (NPP) structures satisfying the above site soil condition have been completed through the fixed-base analysis. However, dynamic responses for relatively stiff structures such as NPP structures still have soil-structure interaction (SSI) effects. In other words, the fixed-base analysis does not always yield conservative results to be compared with SSI analysis. The SSI effects due to different stiff soil properties for Turbine Generator Building (TGB) structure to be constructed at Kori site of South Korea are investigated in views of floor response spectra (FRS) and member forces.

2. Analysis Procedure

2.1 Site Condition

Rock profile depth defined in free-field site response analysis program, SHAKE [2], is 18.9 m, which is the averaged depth of the investigated bore-holes at the TGB site. The SSI effects due to rock profile depth are not considered in this study. The shear wave velocities of rock property used in the analyses are 3,500 ft/sec and 10,000 ft/sec to simulate fixed-base condition.

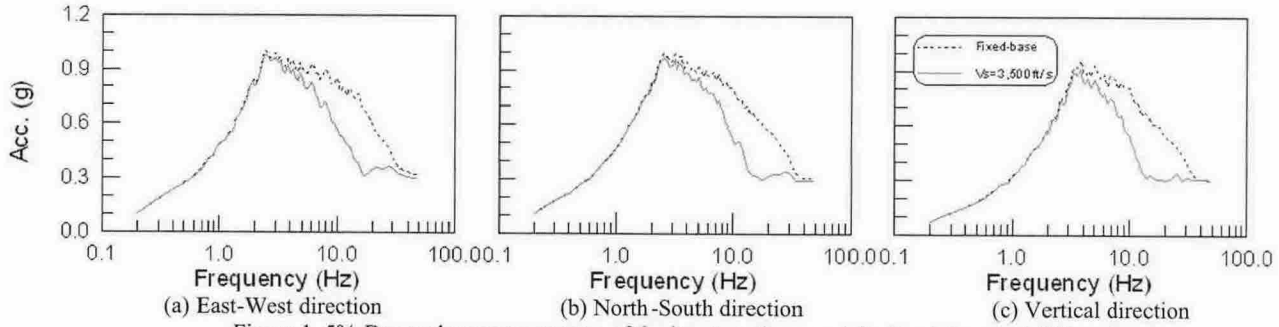
2.2 Seismic Input Ground Motions

The design-basis ground motion time histories used for the seismic response analysis of the TGB are a set of three-component (two horizontal designated as horizontal NS and EW components and one vertical component), uncorrelated, synthetic acceleration time histories having response spectra closely compatible and enveloping the corresponding the design ground response spectra, satisfying the response spectrum and power spectral density function enveloping requirements specified in the U.S. NRC Standard Review Plan, Section 3.7.1, Revision 2 [3] for the single time history option. For input to seismic response analyses, these ground motion time histories were digitized uniformly at a time interval of 0.005 seconds.

The design time histories described above are treated as free-field surface (i.e., outcrop) control motions prescribed at the elevation corresponding to the base of the TGB basemat. For the horizontal seismic input, the free-field horizontal NS and EW control motions are assumed to be resulting from vertically propagating plane seismic shear waves; whereas, for the vertical seismic input, the free-field vertical control motion is assumed to be resulting from vertically propagating plane seismic compression waves. Figure 1 shows 5% damped acceleration response spectra of the input motions used for fixed-base and SSI analyses.

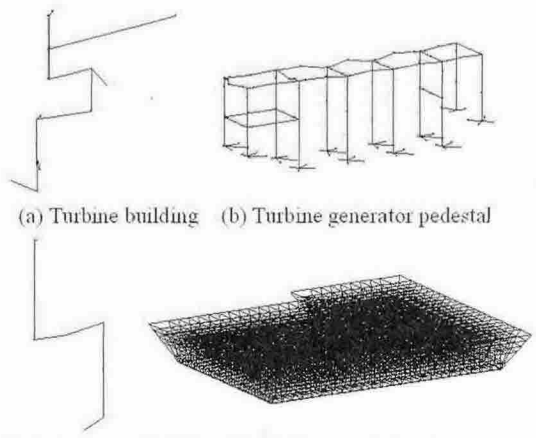
2.3 Soil-Structure Interaction Model

For evaluation of the seismic response of the TGB taking into account three-dimensional SSI effects, an equivalent linear SSI analysis methodology utilizing the 3-D finite



(a) East-West direction (b) North-South direction (c) Vertical direction

Figure 1. 5%-Damped response spectra of the input motions used for fixed-base and SSI analyses.



(a) Turbine building (b) Turbine generator pedestal

(c) Switch gear Building (d) TGB excavated soil volume

Figure 2. SASSI models for SSI analysis of TGB.

element SSI analysis computer program SASSI [4] has been employed. The TGB consists of three independent structures founded on a common basemat, that is, Turbine Building, Turbine Generator Pedestal, and Switch Gear Building as shown in Figures 2(a) through 2(c), respectively. All structures are modeled by beam elements with lumped masses except outer walls modeled by flat-shell elements. The geometric configuration of the soil volume to be excavated from the SASSI free-field site model includes the embedded portion of the TGB plus backfill outside the embedded TGB outer perimeter walls. The dynamic properties of the excavated soil volume have been modeled with 3-D solid finite elements. The finite element mesh of the excavated soil volume model is shown in Figure 2(d). The remaining space excluding the embedded portion of the Turbine Building structure is to be filled with structural fill granular, which is modeled with 3-D solid finite elements and included as a part of the SASSI structural model.

3. Results and Conclusions

Response spectra of the input motions used for fixed-base analyses were conservative to the response spectra of the strain-compatible free-field site input motions used for SSI analyses for the shear wave velocity of 3,500ft/sec. Especially, conservative margins between 2.5Hz and 30 Hz, closely related to the dynamic responses of the superstructures and equipments, were remarkable. The FRS and the forces for the TGB model were obtained using two different seismic input motions and site conditions. FRS calculated from fixed-base analyses and SSI analyses for the shear wave velocity of 3,500 ft/sec are similar each other. FRS from the fixed-base analyses were conservative at low elevation, but non-conservative responses at high level were slightly found in low frequencies as shown in Figure 3. Forces from the fixed-base analyses in this model were always conservative compared to ones from SSI analyses except for the basemat part. Non-conservative responses found from the fixed-base analyses can be resolved by seismic margins such as broadening and scale-up factors provided in design status. Moreover, fixed-base analyses gave conservative FRS and forces values except certain locations to be compared with SSI analyses, and there is no reason to exclude SSI analysis procedure for the rock-like foundation in order to reduce unnecessary seismic responses.

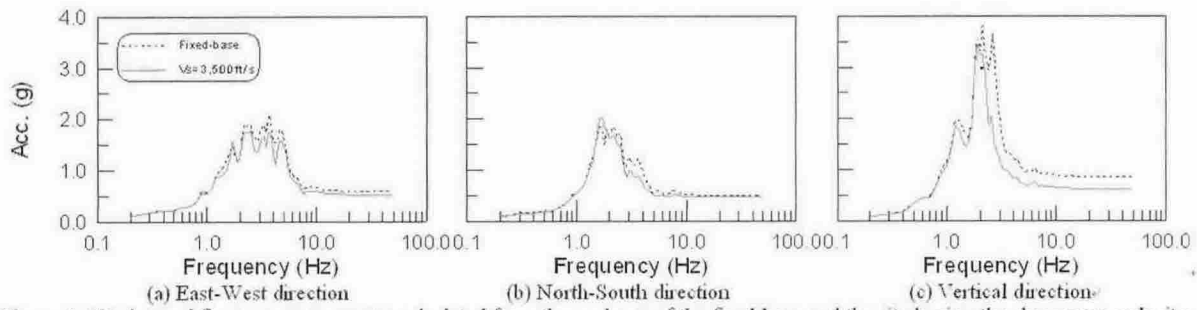
REFERENCES

[1] ASCE Standard 4-86, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures," American Society of Civil Engineers, 1986.

[2] Schnabel, P. B., Seed, H. B., and Lysmer, J., "SHAKE – A Computer Program for Earthquake Response Analysis of Horizontally Layered Sites," Report No. EERC 72-12, Earthquake Engineering Research Center, University of California, Berkeley, 1972.

[3] U. S. Nuclear Regulatory Commission, "Standard Review Plan," Sections 3.7.1 and 3.7.2, Revision 2, 1989.

[4] Lysmer, J., Tabatabai-Raissi, M., Tajirian, F., Vahdani, S., and Ostadan, F., "SASSI – A System for Analysis of Soil-Structure Interaction," Report No. UCB/GT/81-02, Department of Civil Engineering, University of California, Berkeley, 1981.



(a) East-West direction (b) North-South direction (c) Vertical direction

Figure 3. 5%-damped floor response spectra calculated from the analyses of the fixed-base and the site having the shear wave velocity of 3,500 ft/sec (El. 120ft).