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Effect of Adjacent Structures on Foundation Response of Tower Building from SSI Analysis Incorporating Wave Incoherence

Joo-Hyung Kang [a], Sang-Hoon Lee [a]
[a] *Korea Power Engineering Company, Inc., 360-9 Mabuk-dong, Giheung-gu, Yongin-si, Gyeonggi-do, South Korea*
frame365@kopec.co.kr, shljrl@kopec.co.kr

1. Introduction

Seismic response at foundation of large building caused by strong ground motion has tendency to be less intense than corresponding free-field motion, especially in high frequency range. To explain this phenomenon and to apply it to practical soil-structure interaction (SSI) analysis, concept of wave incoherence (or spatial variation) was introduced. The spatial variation of ground motion can be quantified by coherency function, and several coherency functions have been developed for engineering purpose [1-3]. However, there is little investigation about their application to SSI analysis and design for buildings influenced by adjacent structures.

This paper is focused on the seismic response of a building whose foundation lies between those of nearby structures. Specifically, a tower building consisting of steel and concrete is modeled, and the building is assumed to be located on rock media. Analyses are categorized into four cases according to the type of foundation and the existence of adjacent structures. For each case, the results from incoherent SSI analysis are compared with those from coherent analysis to investigate the effect on the seismic response of the building.

2. Methodology

2.1 Coherency Function

To quantify the effect of wave incoherence, the concept of coherency function is widely used. The mathematical and theoretical definition of coherency function is a ratio of cross power spectrum to geometric mean of auto power spectra. However, its application to practical problems is difficult because recognition and determination of individual input motions are not easy. Instead, coherency functions developed by empirical base are more frequently used in engineering problems for NPP structures.

Abrahamson proposed a coherency function for hard-rock site in 2007 using Pinyon Flat array data [2]. The functional form of the coherency model is completed by regression analysis, and it is defined as follows.

$$\gamma(f,\xi)=\left[1+\left(\frac{f\,tanh(a_3\xi)}{a_1 f_c(\xi)}\right)^{n1(\xi)}\right]^{-1/2}\left[1+\left(\frac{f\,tanh(a_3\xi)}{a_2}\right)^{n2}\right]^{-1/2} \qquad (1)$$

Main factors of the function are wave frequency f and separation distance ξ. The ground condition in this study is assumed to be uniform rock media with shear wave velocity of 3,938 ft/s, and the coherency function of Equation (1) is applied to both surface-supported and embedded foundation models.

2.2 Analysis Model

Three-dimensional beam-stick lumped-mass model representing a tower building is developed as shown in Fig. 1. To include responses of rocking and torsion, a couple of edge points and rigid beam elements are added to the model. The foundation of the model is supposed to have relatively large stiffness comparing to the super-structure and to have rectangular shape with the size of 60 ft × 38.5 ft.

First, a single surface-supported foundation model as shown in Fig. 2(a) is prepared to obtain coherent and incoherent analysis results. Then, to consider the effect of adjacent structures, two additional foundations with same properties are modeled and located just next to the tower building foundation as shown in Fig. 2(b). The space between them is two inches respectively, and it is a typical value for minimum gap in nuclear power plant. In the other cases, the foundations are embedded into the ground to identify composite effect of adjacent structures and foundation embedment as shown in Figs. 2(c) and 2(d).

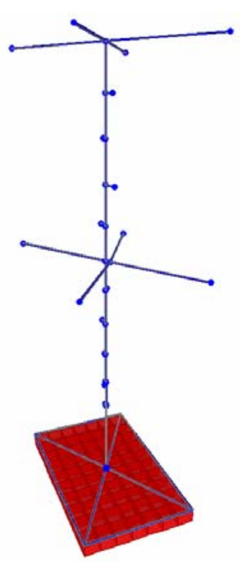
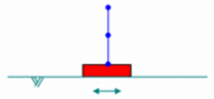
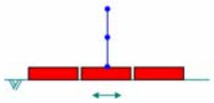


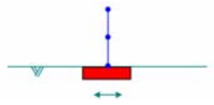
Fig. 1. Analysis model



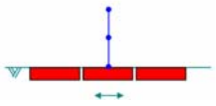
(a) C1: surfaced, single



(b) C2: surfaced, multiple



(c) C3: embedded, single

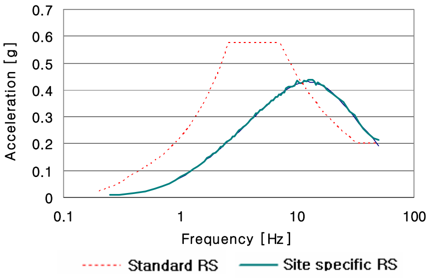


(d) C4: embedded, multiple

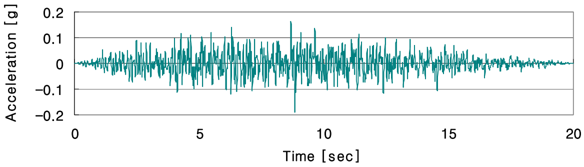
Fig. 2. Analysis case

2.3 Input Motion

For input motion, five acceleration time histories are artificially generated by a numerical simulation method. They comply with a specific ground response spectrum that is developed for the rock site where the tower building is located. Level of the spectrum in high frequency range exceeds standard spectrum anchored to 0.2g as shown in Fig. 3(a). The following Fig. 3(b) shows the acceleration time history of one of the five sets.



(a) Response spectrum

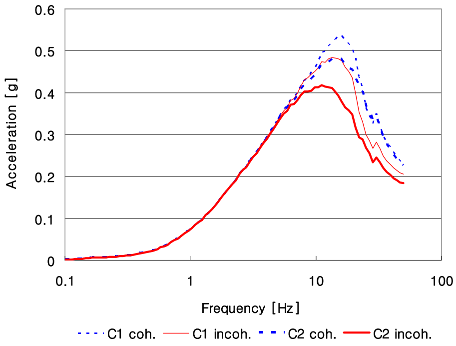


(b) Acceleration time history

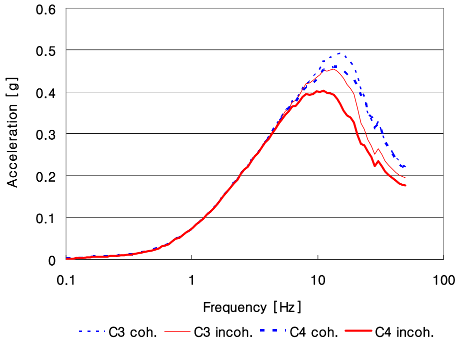
Fig. 3. Input Motion

3. Result

Coherent and incoherent SSI analyses are performed for four cases shown in Fig. 2: C1 surface-supported building only, C2 surface-supported building with adjacent structures, C3 embedded building only, and C4 embedded building with adjacent structures. All the results for the five input motion sets are averaged to obtain more reliable output statistically. The response spectra at the center of the foundations are as follows.



(a) Comparison of C1 with C2



(b) Comparison of C3 with C4

Fig. 4. Effect of adjacent structures

4. Conclusion

To consider the effect of adjacent structures on the seismic response of a building, analyses incorporating wave incoherence can be performed for the model including the nearby structures. From SSI analysis for the tower building models with surface-supported and embedded foundation, this paper presents a couple of findings about seismic response of the structure as follows.

(1) Adjacent structures can lower the peak level in seismic response of the considered building.

(2) Incoherent effect, that is, response reduction in high frequency range, appears in both single and multiple foundation cases.

(3) Incoherent effect can be strengthened by the interaction with adjacent structures.

(4) For embedded structure, similar aspects such as (1)~(3) are expectable to be superposed on the effect of embedment.

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