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Probabilistic Site Response Analysis for Estimating Ground Motion Incoherency

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1. Introduction

Ground motion incoherency significantly affects the seismic response of structures. The ground motion coherency function describes the spatial incoherency of ground motion with frequency and separation distance. Various ground motion coherency functions have been suggested based on dense seismic array recordings [1, 2, 3]. Ground motion coherency functions are significantly influenced by site conditions because the seismic wave incoherence is induced by scattering of the seismic wave in near-surface [2]. Therefore, ground motion coherency functions derived from dense seismic arrays may not adequately capture the site-specific conditions of the target structure. For this reason, various studies based on numerical simulations have been conducted to determine site-specific ground motion incoherency[4, 5, 6]. In this study, site-specific ground motion coherency functions were estimated using probabilistic site response analysis. An experimental program and dense seismic array recordings were employed to validate the analytical results.

2. Methods and Procedures

Fig. 1 summarized procedures used in this study. The spatial variability parameters (i.e., mean, coefficient of variation, and correlation length) of shear wave velocity were derived from the geophysical survey data. Thirty (30) 2-D random field numerical models were generated according to the derived spatial variability parameters. Meanwhile, Thirty (30) input ground motions were selected from earthquake recording database. A logic tree was organized using he generated random field models and the selected input ground motions. Site response analysis were conducted on each branch of the logic tree. The ground motion coherency function was determined by the regression analysis method described in Abrahamson (2007).

3. Experimental Program

The KOCED dynamic geo-centrifuge test setup was used in this study. The prototype of physical model and its properties are presented in Fig. 2 (a). For the physical model, the equivalent shear beam container was used to simulate semi-infinite soil layer responses [7]. The spatial variability parameters of the shear wave velocity were obtained from bender element test and lab-scale cone penetration test data [8]. The surface ground motion coherency was measured by the linear array consisted of 15 accelerometer. Fig. 2 (b) shows that The seismic wave incoherence estimated by numerical simulation was well matched with the experimental results.

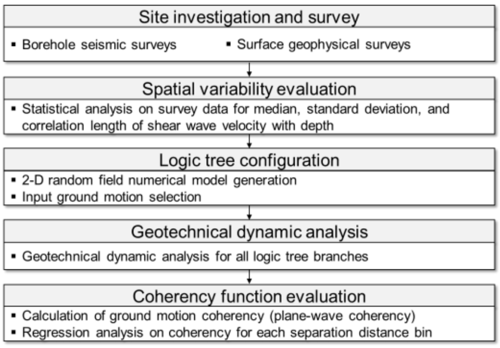
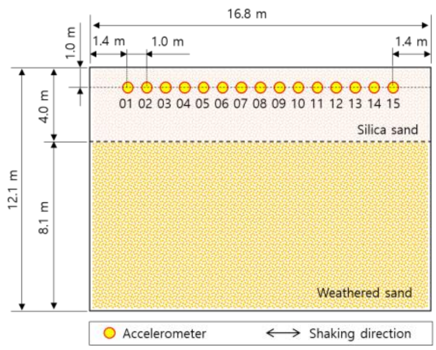
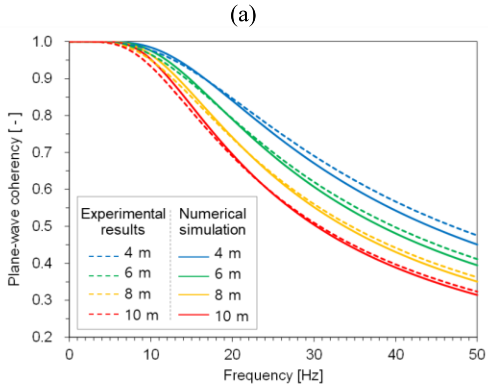


Fig. 1. Procedures used in this study



(a)

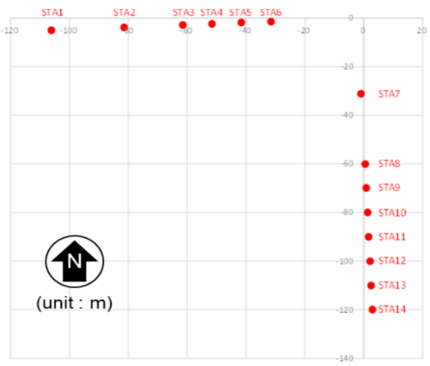


(b)

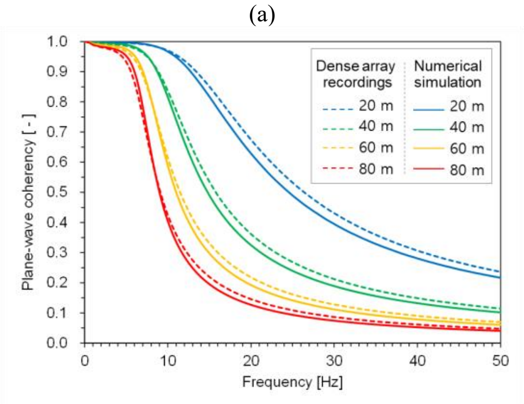
Fig. 2 The experimental program of this study. (a) The prototype of the physical model. (b) Ground motion coherency functions based on experimental results and the numerical simulation.

4. Dense Seismic Array

Korea Hydro and Nuclear Power Co. Ltd. (KHNP) installed a dense seismic array to develop ground motion coherency function in 2021 [9, 10]. The L-shaped dense seismic array consists of 14 seismometer (velocity sensor) and the total size of the array is 150 m × 150 m (Fig. 3 (a)). The bedrock consists mainly of fresh andesitic tuff, and it is classified as from 'fresh rock' to 'moderately weathered rock'. Geotechnical investigation and geophysical survey including borehole seismic surveys were performed to determine elastic wave structure beneath dense seismic array. The ground motion coherency function of the dense seismic array was evaluated using the procedures described in this study. Preliminary results shows ground motion coherency functions base on the dense seismic array and the numerical simulation (Fig. 3 (b)). For the frequency greater than 10 Hz, the coherency function based on numerical simulation results were well matched with that derived from the earthquake recordings of dense array.



(a)



(b)

Fig. 3 Dense seismic array program of this study. (a) Sensor locations of the dense seismic array. Red dots indicate sensor location. (b) Preliminary ground motion coherency functions based on dense seismic array and the numerical simulation.

5. Conclusions

In this study, procedures to estimate the site-specific ground motion coherency function using the geotechnical dynamic analysis were proposed. The dynamic geo-centrifuge test and dense seismic array recordings were used to validate the analysis results. For both of cases, ground motion coherency functions estimated by site response analysis were well matched with ground motion coherency functions based on experimental and dense seismic array program. This study demonstrates that probabilistic site response analysis provides a cost-effective approach to estimating site-specific ground motion incoherency.

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