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Dynamic characteristic identification of slope ground subjected to earthquake: frequency domain decomposition

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ABSTRACT: The seismic response of sloping ground at is dependent of physical aspect of ground surface, so call topography effect. To investigate these topographic effects, dynamic centrifuge model tests with a slope ground model were performed. To accurately identify the topographic and ground frequencies of a single-sided slope model, the frequency domain decomposition (FDD) method was utilized. The frequencies identified from the FDD method were compared with the period calculated based on the measured shear wave velocity, confirming their similarity. The FDD also successfully identifies the mode shapes of slope ground.

1 INTRODUCTION

In regions with mountainous terrain and extensive hilly, topographic effects are one of the key aspects in altering seismic response. The centrifuge tests have been widely used to verify topographic effects. However, the inherent noise generated by mechanical vibration caused by a spinning machine and boundary reflection in soil containers often makes it difficult to identify natural frequencies. This study performed a dynamic centrifuge test on a ground model with a single-sided slope, and applied the frequency domain decomposition (FDD) method to more precisely identify the topographic frequency.

2 METHODOLOHY

2.1 Frequency Domain Decomposition

The FDD method is a widely used in structural systems identification in the structural engineering field that can separate and identify the mode characteristics of a structure in the frequency domain using multi-point measurement signals. For more details, refer to the Brincker et al. (2000).

2.2 Centrifuge model tests

The centrifuge tests were conducted at the Korea Advanced Institute of Science and Technology. The model ground was conducted in the equivalent shear beam container using an air-pluviating system. The applied centrifugal acceleration was 60 g, and the prototype dimensions of the container is 50.4 m × 37.8 m × 36.0 m (L × B × H) The relative density was 86%, and its cross-section is shown in Fig. 1. The input motions used is the Northridge earthquake (Station: Santa Monica; Fig. 2). The shear wave velocity of the ground measured is V_{S0} = 221.56 m/s in 60 g using a set of bender element array (Fig. 3).

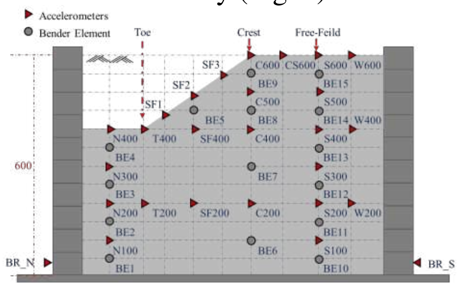


Figure 1. Centrifuge model setup (unit: mm). Includes information on the accelerometer and bender elements embedded in the soil

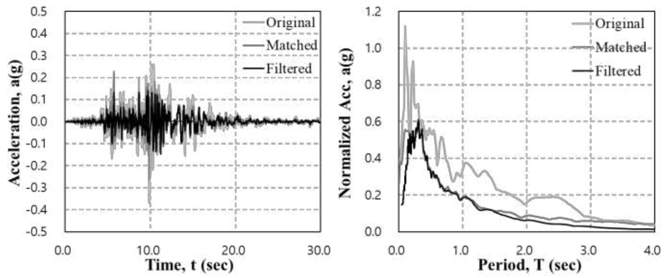


Figure 2. The input motion used in this study

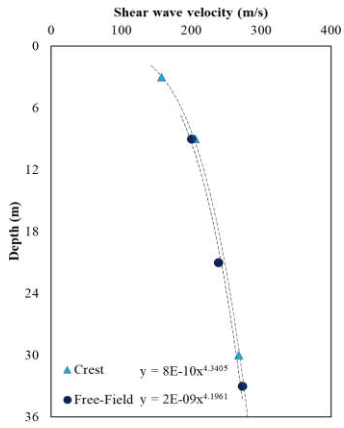


Figure 3. Shear wave velocity profile

The time-history acceleration data groups measured by performing a centrifuge test (e.g., the Crest group consists of C200 to C600 embedded in a column in Fig. 1) are analysed using FDD.

3 RESULTS AND DISCUSSION

Fig. 4 presents the relative amplitudes at the ground frequency ($f_{g\_FDD} = \mathrm{V_{S0}}/4Z$ = 1.45 Hz) and topographic frequency ($f_{t\_FDD} = \mathrm{V_{S0}}/5H$ = 3.67 Hz). Here, Z and H are the soil layer height of the higher side free field and slope height, respectively. The vertical axis of Fig. 4 indicates the height of the accelerometers embeddedin the ground from the container bottom (titled "vertical location in the ground, z-axis"). The horizontal axis, titled "Accelerometer array location, x-axis," represents the horizontal distance from the center of the container to the accelerometers. Additionally, the “relative amplitude” is calculated as the components of the eigenvector as a singular value decomposition (SVD) and represents the relative magnitude of the ground response at each measurement location to a reference point (i.e., bedrock here).

At each frequency, the maximum of relative amplitude occurs at the ground surface and the profile of the relative amplitudes shows a fundamental mode shape at the ground and topographic frequencies (Dafni and Wartman, 2021a). The topographic (f_t) and ground (f_n) frequency suggested by Ashford et al. (1997) were calculated from the shear wave velocity and were 1.53 Hz and 3.66 Hz, respectively.

Table 1. Comparison of identified frequencies

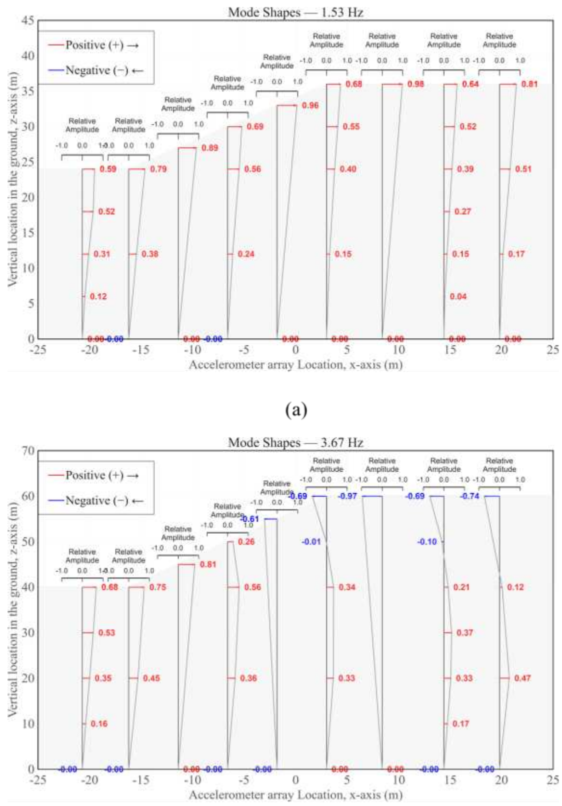
Method	f_n (Hz)	f_t (Hz)
FDD-based	1.53	3.67
V_s-based	1.53	3.66

These are similar to the frequencies identified from FDD (Table 1), demonstrating the excellent performance of FDD in frequency identification.

4 CONCLUSIONS

This study performed a dynamic centrifuge test on a single-sided slope without structures to accurately identify the ground and topographic frequencies, applying the FDD method.

The FDD results indicate fundamental mode shapes in the ground and topographic frequencies at 1.53 Hz and 3.67 Hz, with maximum relative amplitudes at ground surface among entire depths. These identified frequencies is consistent with the theoretically calculated frequency.



(a)

(b)

Figure 4. FDD results (a) mode shape at the ground frequency and (b) at the topographic frequency

The FDD method can be applied to input motion analysis containing various frequency components, and shows excellent performance in identifying not only the mode shape of the ground but also the period based on it.

ACKNOWLEDGEMENTS

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