A Study on the Effect of the Basin Geometry on Directionally Dependent Horizontal-to-Vertical Spectral Ratios for Site Effect Assessment in Kyoto Basin

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1. Introduction

For locations where underground structure changes rapidly and/or are complex, such as at the edge of a basin, it is known that the irregular subsurface structure has a large effect on ground motion in the vicinity of the structure, emphasizing the necessity to interpret the relationship between underground structure and ground motion characteristic for mitigating damage due to earthquakes. Microtremor is a simple and economical method to estimate the subsurface structure and the method for estimating the spatial variability of seismic ground motion. The Horizontal-to-Vertical spectral ratios of microtremors (MHVRs) has been used by many researchers to characterize local conditions in terms of the fundamental frequency. Based on the Diffuse Filed Theory (DFT)[1], we can numerically calculate Green's function to study 3D cases with laterally heterogeneous elastic layers, in order to interpret MHVRs for sites that show directional dependency. The results of reflection and borehole surveys can be used as reference, and the results of microtremor surveys can be used to interpolate or extrapolate points based on the interpretations of the observed data, to construct relatively reliable two- or three-dimensional subsurface structures.

In this study, we conducted microtremor observations in the Kyoto basin where the subsurface structure has been investigated by Kyoto City[2] as well as where reflection survey has not been conducted. We investigated the relationship between subsurface structure and the characteristics of observed MHVRs, and based on this, we examined the relationships between basin geometry and subsurface structure by performing numerical calculation with different basin shapes. By checking the difference of the observation results and numerical results, we confirmed the validity of using SEM to calculate numerical MHVRs based on DFT for sites with lateral heterogeneity.

2. Overview of the microtremor observation

In order to examine the effects of lateral heterogeneity and the relationship between basin geometry and MHVRs, microtremor measurements were conducted for several days in December 2020 and October 2021 in the central and eastern part of Kyoto Basin. The duration of observation for each point was 30 minutes. Fig. 1 shows the observation points in Kyoto Basin.

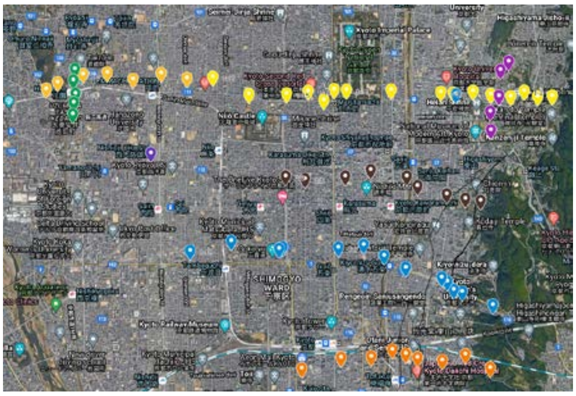

Fig. 1 Microtremor observation sites in Kyoto Basin

3. Results of microtremor observation

The MHVRs were calculated by separating the total duration to time segments of 40.98 sec overlapping 50%, and then averaged for all time segments. The Fourier spectrum of each component for each time section was calculated and a Parzen window with a bandwidth of 0.1 Hz was used to smooth the spectrum. Then MHVRs for each duration of the observed data was calculated by dividing the NS and EW components with the UD component separately, without averaging the two horizontal components as done in conventional MHVR studies.

For both survey lines k1 and k3, the variation trend of depth of the bedrock and the magnitude of the peak frequency generally corresponds which is as depth goes shallower the peak frequencies get higher. However, the detailed irregularities of the bedrock such as at observation point k3-9 do not appear in the MHVR. At observation point k1-5, it can be inferred that the effect of the step-like structure of the bedrock structure appears in the shape of the MHVR.

4. Model for numerical calculation

In this study, five simplified models with different shapes were assumed to investigate the relationship between basin geometry and numerical MHVRs. A relatively detailed model which is based on the section profile from the information of reflection/refraction survey by Kyoto City was made to verify the validation of calculation by comparing with observed results. Fig. 2 shows the fundamental model which was generated and meshed by CUBIT[3].

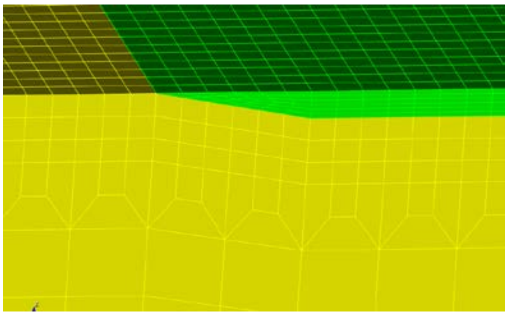

Fig. 2 Mesh of fundamental model for numerical calculation

5. Results of numerical MHVRs

In this study, we use the 3D spectral element method (SEM) code ÉFISPEC3D[4] to calculate the Green's function for 2D or 3D subsurface structure. The results of MHVRs show for locations where bedrock changes rapidly the difference in amplitude between NS/UD and EW/UD is clear.

6. Summary

Assuming various shapes of bedrock, we simulated numerical MHVRs using SEM and studied the relationship between basin geometry and MHVRs. It was confirmed that there are large differences in the characteristics of MHVRs, depending on the basin bedrock shapes. Furthermore, the MHVRs observed in Kyoto Basin showed directional dependency which corresponds to the bedrock shape.

Acknowledgments

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Reference

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