Verification and Improvement of the Three-Dimensional Basin Velocity Structure Model in the Osaka Sedimentary Basin, Japan, Using Inter-station Green’s Functions and H/V Spectral Ratios of Microtremors

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The Osaka sedimentary basin is filled by the Plio-Pliocene Osaka group, terraced deposits, and alluvial deposits with thickness of 1 to 2 km over the bedrock, and is surrounded by active fault systems. The Umekita active fault system underlies the Osaka urban area. The velocity structure of the Osaka basin has been extensively investigated by using seismic techniques such as gravity anomaly measurements, reflection surveys, borehole explorations, and microtremor measurements. Based on these surveys and ground motion simulations for observed moderate events, three-dimensional velocity structures of the Osaka basin have been improved and improved for decades (e.g., Kagawa et al., 1993; Horikawa et al., 2000; BAPD 2010). In this study, we are trying to verify the velocity structure model of the Osaka basin and to improve it incorporating new data sets. We have conducted two kinds of observations in the Osaka basin.

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1. Seismic Interferometry Analysis of Continuous Microtremor Records at 15 Temporary Sites

Fifteen temporary stations are installed in the Osaka sedimentary basin (Fig.1). The inter-station distance ranges from 3.1 km to 47.1 km. Three components of velocity sensor Takeda Sokuyaku VSC-150D (1 Hz per cm, flat response in 0.1-1.0 kHz) and 24-bit AD logger Hakuwak LS-8800 or LS-700IIT are used (Photo 1). The sensor is located on the ground surface outside or inside a garage or an observation house. The observed microtremor is continuously digitized at 100 Hz and stored in the logger. The temporary observation started in March 2011 and the continuous observation was ended in September 2011.

In this analysis, the cross-correlation of seismic wave fields at two stations can be estimated by a single-point force with a frequency domain. We divided continuous data into segments with a length of 30 minutes and applied a band-pass filter in 0.33-0.5 Hz. The cross-correlation of these surface waves were estimated (Fig.2) and conducted a set of FDM simulations to see the propagation characteristics of these surface waves (Fig.3).

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2. H/V Spectral Ratios of 100 Strong Motion Sites

In 2000, the Active Fault and Earthquake Research Center, AIST (Japan) conducted a seismic interferometry study and bedrock depth of the Osaka basin and compared the obtained values well except a single point force with a frequency domain. We divided continuous data into segments with a length of 30 minutes and applied a band-pass filter in 0.33-0.5 Hz. The cross-correlation of these surface waves were estimated (Fig.2) and conducted a set of FDM simulations to see the propagation characteristics of these surface waves (Fig.3).

We conducted two kinds of observations; inter-station Green’s function measurements estimated from continuous microtremor observations at 15 temporary stations and H/V spectral ratios from single-station microtremor observations at 100 strong motion sites. From seismic interferometric analysis using continuous temporal microtremor observation records, we could see the emergence of signals corresponding to Love and Rayleigh waves propagating inside Osaka basin. Its dispersion characteristics of group velocities are roughly consistent with present three-dimensional basin velocity structure model. We confirmed that the observed inter-station Green’s functions have good signal-to-noise ratio in the range from about 2 to 7 seconds (Fig.2). The predominant period of microtremor at Osaka city 15 sites which is almost equal to the bedrock depth and its bedrock depth in geology, bathymetry, faults, and landslides (Iwaki and Iwata, 2011) agreed well with the estimated depth of the bedrock in Osaka basin obtained by seismic interferometry analysis. The bedrock depth obtained by this study and bedrock depth of present basin velocity structure model is shown in Fig.2. It is also found that the bedrock depth obtained by this study is greater than the bedrock depths obtained by earlier studies (Ishii et al., 2008). In addition, these values are consistent with bedrock depth obtained by Iwaki and Iwata (2011) (left) and Osaka prefectoral government (2005) (right).

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3. Comparison with Theoretical Green’s Functions from Dziewonski and Anderson (1981) and Horikawa et al. (2000)

We compared the theoretical Green’s functions from Green’s functions and H/V spectral ratios of microtremors for more than 30 minutes with a sampling of 100 Hz at each station using Lemnertz LE-3D/20s (velocity sensor with natural period of 0.5-2.0 s). In the previous study (Asano et al., 2011), we found that observed H/V peak periods of microtremors at 39 stations agree well with theoretical Green’s functions and H/V spectral ratios at stations. The observed H/V spectral ratios at stations were measured at 0.1 Hz in each station by using station UEMC09 (osaka Prefectural Government, 1999). We compared the theoretical Green’s functions with observed H/V spectral ratios at each station and radii of Love wave and Rayleigh wave components. The group velocities of Rayleigh and Love waves propagating between two stations are estimated from them using the multiple filter analysis method. The observed inter-station Green’s functions at 100 strong motion stations of Osaka Prefecture government, JMA, K.IENT, KOK, and others, and the theoretical peak of H/V ratio from 0.1 to 7 s, and it is plotted in the bedrock depth at the observation site as previously pointed by Miyakoshi et al. (1997). Though the basin velocity model is modeled with H/V spectral ratios at 0.1 Hz, we found discrepancies between observed and predicted H/V peak periods at northern part of Osaka basin and hill area in southeastern part of the basin.

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4. Conclusions

In conclusion, we conducted a seismic interferometry study and bedrock depth of the Osaka basin obtained by seismic interferometry analysis. The bedrock depth obtained by this study is greater than the bedrock depths obtained by earlier studies (Ishii et al., 2008). In addition, these values are consistent with bedrock depth obtained by Iwaki and Iwata (2011) (left) and Osaka prefectoral government (2005) (right). We also conducted a seismic interferometry study and bedrock depth of the Osaka basin obtained by seismic interferometry analysis. The bedrock depth obtained by this study is greater than the bedrock depths obtained by earlier studies (Ishii et al., 2008). In addition, these values are consistent with bedrock depth obtained by Iwaki and Iwata (2011) (left) and Osaka prefectoral government (2005) (right).

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