9. Verification of identifying velocity structures from H/V spectral ratio of microtremor

Hao Wu, Kazuaki Masaki, Kojiro Irikura

1. Introduction

On March 11, 2011, the 2011 off the Pacific coast of Tohoku earthquake, an interplate mega-thrust event with Mw0.9, hit the east coast of Pacific in Japan. During this earthquake, about 1200 strong motion stations operated by National Research Institute of Earth Science and Disaster Prevention (NIED) were triggered, but the ground motions are still unknown at many sites where buildings were subjected to damage but no strong motion stations are installed. It is necessary to estimate the ground motions at these sites to clarify the relationship between building damage and ground motion characteristics. However, in order to properly estimate ground motions, reliable underground velocity structures are desirable. In this study, one method of identifying velocity structures from H/V spectral ratio of microtremor is developed. It is expected to be used in the estimation of ground motions at damaged sites.

2. Methodology

H/V spectral ratio is defined as the square root of power spectrum in the horizontal component to that in the vertical component. It is dependent on the velocity structures. Inversely, velocity structures can be identified by matching theoretical H/V spectral ratio with observed one. Theoretically, there are two kinds of H/V spectral ratio in general, one is for earthquake ground motions, the other is for microtremor.

Kawase et al (2011) [(1)] presented that H/V spectral ratio of earthquake ground motions can be theoretically calculated as the amplitude ratio between transfer functions for the horizontally polarized S-wave incidence and the vertically polarized P-wave incidence based on diffused field theory, with a coefficient as a function of the square root of the P-wave to S-wave velocity on the half-space.

On the other hand, it is believed that microtremor is mainly composed of surface waves, i.e. Rayleigh waves and Love waves, as the source is usually distributed on the surface. Arai and Tokimatsu (2000) [(2)] pointed out that the microtremor H/V can be expressed as the square root of power spectra of sum of Rayleigh and Love waves in the horizontal component to power spectra of Rayleigh waves in the vertical component.

3. Case study

3.1 Data processing for observed H/V spectral ratio

3.1.1 H/V spectral ratio of earthquake ground motions

Small earthquake ground motions are used to calculate H/V spectral ratio in order to eliminate the nonlinear effect. For each earthquake ground motion, the data from S-wave onset with duration of 10.24s are taken from the observed record. H/V spectral ratio is calculated for each record respectively, and then is averaged over the number of earthquake ground motions used. Finally, the averaged H/V is smoothed in the lognormal scale which is suggested by Konno and Ohmachi (1998) [(3)].

3.1.2 H/V spectral ratio of microtremor

The method of obtaining H/V spectral ratio of microtremor is the same as that of earthquake ground motions. The observed microtremor is divided into many segments with a length of 40.96s. However, attention should be paid to the noise in microtremor data. Those data with extremely large amplitude in the time domain may be taken as noise and excluded from the original record before obtaining H/V spectral ratio.

3.2 Identification method

Simulated annealing method is used to obtain the optimal velocity structures. The optimal velocity structures are determined by minimizing the misfit function, as is shown in Eq.(1). The target period range is set to be 0.05s~3.0s (corresponding to 0.3Hz~20.0Hz), as building damage is related with this period range. Identified parameters include S-wave velocity, thickness in each layer. As attenuation is considered for theoretical H/V spectral ratio of earthquake motions, Qso and n in each layer is also identified by assuming Qs=Qso*f^n.

$$E_m = \frac{\sum_{f_{\min}}^{f_{\max}} \left| \frac{(H/V)^{cal} - (H/V)^{obs}}{f_i} \right|}{\sqrt{\sum_{f_{\min}}^{f_{\max}} \frac{(H/V)^{cal}}{f_i} \sum_{f_{\min}}^{f_{\max}} \frac{(H/V)^{obs}}{f_i}}} \tag{1}$$

3.3 Identification of velocity structures

MYGH06 is a KiK-net station, situated in a hill northeast of Osaki City, Miyagi Prefecture, as is shown in Fig.1. The observed earthquake records can be directly downloaded from the website of NIED. The microtremor was observed from Nov.22, 19:00 to Nov. 23, 12:00, 2012. Fig.2 is the photo of microtremor observation at MYGH06 station. Velocity seismometer with 100Hz was adopted in the microtremor observation.

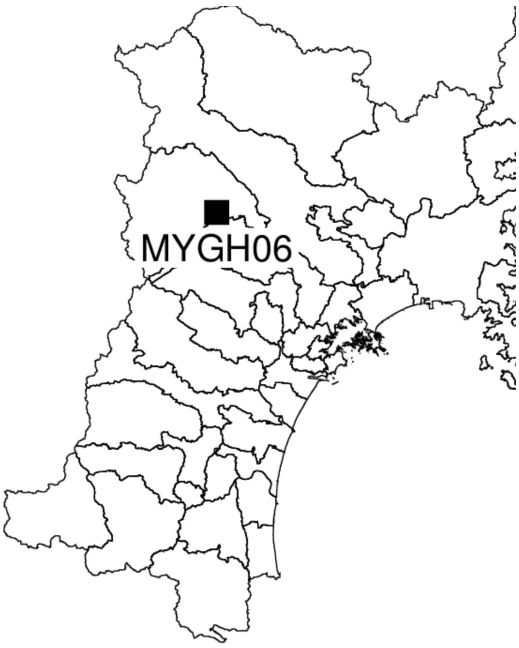
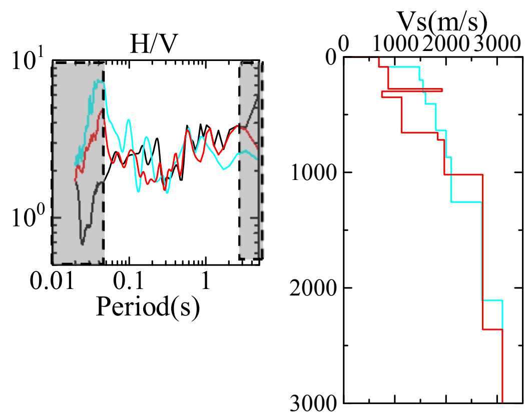
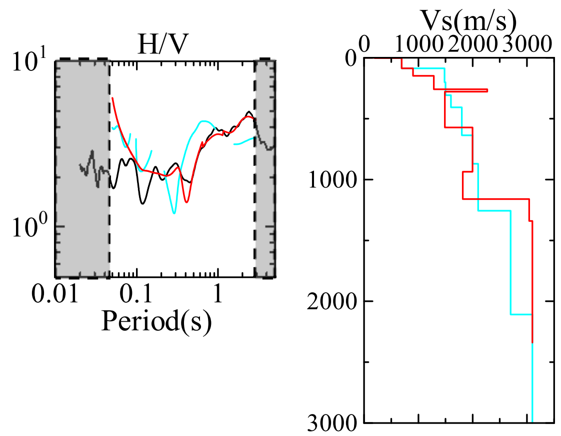


Fig.1 MYGH06 KiK-net station in Osaki City, Miyagi Prefecture

Fig.2 Microtremor observation at MYGH06 station





(a) Velocity structures identified from H/V spectral ratio of earthquake

(b) Velocity structures identified from H/V spectral ratio of microtremor

Fig. 3 Idenfication of velocity structures from H/V spectral ratio (black one is the observed H/V, cyan one is initial H/V, and red one is identified H/V) at MYGH06 station in Osaki City, Miyagi Prefecture

Fig. 3 shows the identified result. Fig.3(a) is the identification from H/V spectral ratio of earthquake ground motions, Fig.3(b) is the identification from H/V spectral ratio of microtremor. The optimal velocity structures(red) are determined by fitting observed H/V(black). On the other hand, initial H/V spectral ratio(cyan) calculated with given initial velocity structures is also shown. It can be seen that the identified H/V spectral ratio is well consistent with the observed one over period of 0.05s~3.0s. It suggests that the velocity structures are the optimal ones.

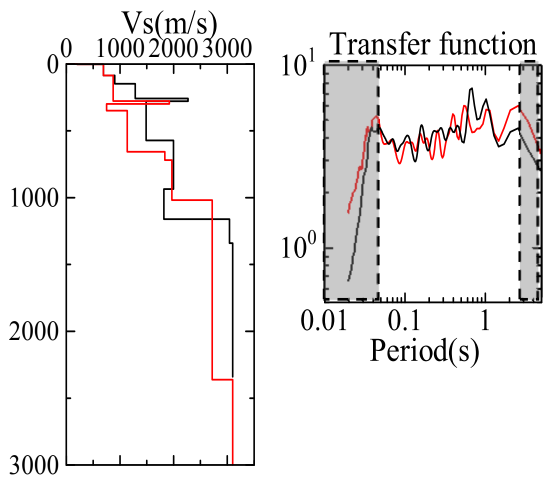


Fig.4 Comparison of velocity structures and transfer functions (black one corresponds to microtremor, red one corresponds to earthquake)

Fig.4 shows the difference of velocity structures identified from H/V spectral ratios of earthquake ground motions(red) and microtremor (black) at MYGH06 station in Osaki City, Miyagi Prefecture. Transfer functions, the surface response to the incidence wave on the bedrock (S-wave velocity is 3.1km/s), calculated with identified velocity structures are also shown in Fig.4. It can seen that the transfer functions are in good agreement between 0.05s and 3.0s, although velocity structures show different. It suggests that H/V spectral ratio of microtremor can be used to identify the velocity structures.

4. Conclusions

Velocity structures can be identified from H/V spectral ratio of microtremor, as well as that of earthquake ground motions. Transfer functions calculated with velocity structures identified from H/V of microtremor and earthquake ground motions are almost the same. It suggests that it may be reasonable to identify the velocity structures only from microtremor H/V spectral ratio. The identified velocity structures are expected to be used to estimate ground motions at the damaged sites.

Reference

(1) Kawase, H., Sánchez-Sesma, F. J. and Matsushima, S.(2011).The Optimal Use of Horizontal-to-Vertical Spectral Ratios of Earthquake Motions for Velocity Inversions Based on Diffuse-Field Theory for Plane Waves, Bull. Seism. Soc. Am. 101: 2001-2014.

(2) Arai, H. and Tokimatsu, K. (2000). Effects of Rayleigh and Love waves on microtremor H/V spectra. In: Proceedings of the 12th world conference on earthquake engineering, paper 2232, CD-ROM

(3) Konno, K. and Ohmachi, T. (1998). Ground-motion characteristics estimated from spectral ratio between horizontal and vertical components of microtremor, Bull. Seism. Soc. Am. 88, 228-241.