SITE AMPLIFICATION CHARACTERISTICS IN MIYAZAKI PREFECTURE, JAPAN USING MICROTREMOR AND SEISMIC RECORDS

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ABSTRACT

The seismic records from 52 stations of the seismic network deployed in Miyazaki Prefecture, Japan, are currently used to grasp the distribution of seismic intensity of the prefecture immediately after the occurrence of an earthquake. However, the number of instruments may not be large enough to capture the detailed intensity distribution. Hence, microtremor measurements were conducted to estimate site response characteristics of the seismic stations and other locations. The horizontal-to-vertical (H/V) Fourier spectral ratios were calculated for seismic records and microtremor. In some stations having geological survey data, the transfer functions for S-wave and H/V amplitude ratio of Rayleigh wave were also calculated. Comparing all these functions, possibility is suggested that the H/V spectral ratio of microtremor can be used as a quasi-transfer function to predict the seismic motion at the location without instruments.

Introduction

The seismic network consisting of 52 stations has been deployed in Miyazaki Prefecture, Kyushu Island, Japan as shown in Figure 1. Twenty stations of them were set up by the Science and Technology Agency of Japan (STA) as a part of the Kyoshin Network (K-NET), and other 32 stations were a part of the national seismic network established by the Fire and Disaster Management Agency of Japan (FDMA). Using the information from the seismic network, we can grasp the distribution of JMA seismic intensities and peak ground accelerations (PGA) of the prefecture immediately after the occurrence of an earthquake. Moreover the seismic records from these stations can be collected later through the telecommunication line. Since the number of instruments is not large enough to estimate the spatial distribution of strong motion in the prefecture, some methods to interpolate the observed records may be necessary. In this regard, the site amplification characteristics of the ground should be known spatially.

In this study, the site response characteristics were examined using the seismic records from the stations in the prefecture. First, the horizontal-to-vertical (H/V) Fourier spectral ratios of the earthquake records were calculated. Microtremor measurements were carried out at these

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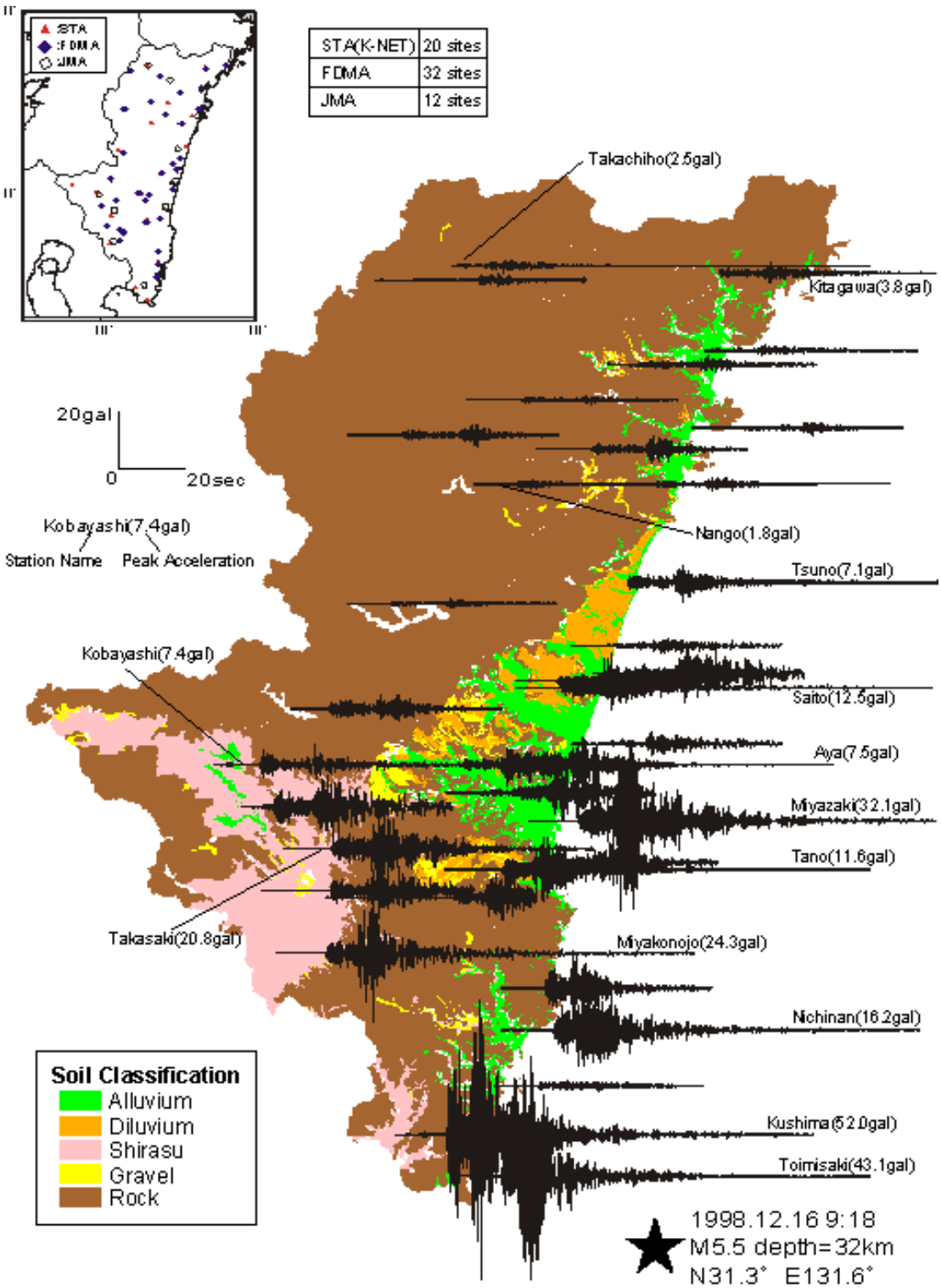

Figure 1. Distribution of seismometers in Miyazaki prefecture and seismic records in a magnitude 5.5 earthquake.

stations and the H/V spectral ratios of microtremor were also calculated, and they were compared with those of seismic records. The site amplification characteristics of the ground were further

examined using the H/V amplitude ratios of Rayleigh waves and one-dimensional wave propagation theory.

Data and Analysis

Since the number of seismic records obtained is few for FDMA's network, we used only data from the 20 K-NET stations in Miyazaki Prefecture in this study. The records were observed in 68 earthquakes which occurred from 1996 to 1999. The Fourier spectra were calculated for the initial 20.48 seconds from the arrival of S-wave and they were smoothed by Parzen window with bandwidth 0.4 Hz. Then the H/V spectral ratios were calculated by

$$R = (F_{NS}^2 + F_{EW}^2)^{1/2} / F_{UD} \quad (1)$$

where R is the H/V spectral ratio and F is the smoothed Fourier spectrum with suffix indicating two horizontal and vertical components.

Microtremor observations were conducted at all the seismic stations in Miyazaki Prefecture from April to September in 1999. A portable measurement system with velocity sensors of natural period 1 second was used. In each measurement, about 5 minutes recording was carried out for the three components. Ten sets of records with duration 20.48 seconds were used to calculate Fourier spectra in the same way as for the seismic records.

Comparison of H/V Spectral Ratios for Microtremor and Seismic Motion

As an example of seismic records, Figure 1 shows acceleration records observed in the earthquake on December 16, 1998 (magnitude=5.5, depth = 32 km). Generally, the amplitudes of seismic waves are large at stations near the hypocenter. As the hypocentral distance gets large, the acceleration becomes small. However, in some sites, large amplitudes are observed in spite of far distances from the hypocenter. For example, the amplitude in Miyazaki City is larger than those of the surrounding stations. This observation may be explained by the fact that the station is located on a thicker sediment than those of the surrounding stations. It is considered that the seismic motion is highly affected by soil condition. Hence it is necessary to grasp the site response characteristics for the prediction of distribution of seismic motion.

As a simple method for estimating site characteristics, the method using H/V Fourier spectral ratios of microtremor was proposed and the method was demonstrated to be effective in determining the predominant period of a site (Nakamura, 1989). This method was also employed for earthquake records (e.g. Maruyama et al., 2000). Yamazaki and Ansary (1997) explained the stability of the H/V ratio of earthquake records, independent of the magnitude and depth of an earthquake and the source-to-site distance, based on the attenuation relations of the response spectra.

The H/V Fourier spectral ratios for all the seismic records at the 20 K-NET stations in Miyazaki Prefecture were calculated. Figure 2 shows the horizontal and vertical Fourier spectra observed at K-NET Miyazaki station (located in Miyazaki City) and their ratios. Although the Fourier spectra of the horizontal and vertical components for different events show wide variability in their amplitudes and some variation in their shapes, the H/V spectral ratios at the site fall in a narrow range of the amplitude and shape. In the figure, a peak around 0.7 second is found and the peak corresponds to the predominant period for the shear vibration at the site. The

shape of H/V spectral ratio is different from each site and reflects site response characteristics.

The H/V Fourier spectral ratios were also calculated for microtremor measured at the K-NET stations. Figure 3 shows the horizontal and vertical Fourier spectra at K-NET Miyazaki station and their ratios. In the figure, each shape of the Fourier spectra of the two components and the H/V spectral ratio is very stable. A peak period around 0.7 second is found and corresponds to that of earthquake records.

Figure 4 shows the comparison of H/V spectral ratios for seismic ground motion and microtremor. In the figure, the shape and amplitude of the H/V spectral ratio of microtremor at each site is found to be similar to those for the seismic motion. The reason for this similarity can be explained by the following two ways: 1) If microtremor is mostly composed of the body waves, its H/V ratio may be similar as that for earthquakes; or 2) If microtremor mainly consists of surface (Rayleigh) waves, the H/V ratio for mode shapes of Rayleigh wave should be discussed. An example for the second interpretation is shown later.

However, in several stations, e.g. Shiiba and Tano stations, some difference between of the H/V spectral ratios of microtremor and earthquakes is observed. Although the reason of the difference is not so clear, the effects of local topography may be one of the possible reasons.

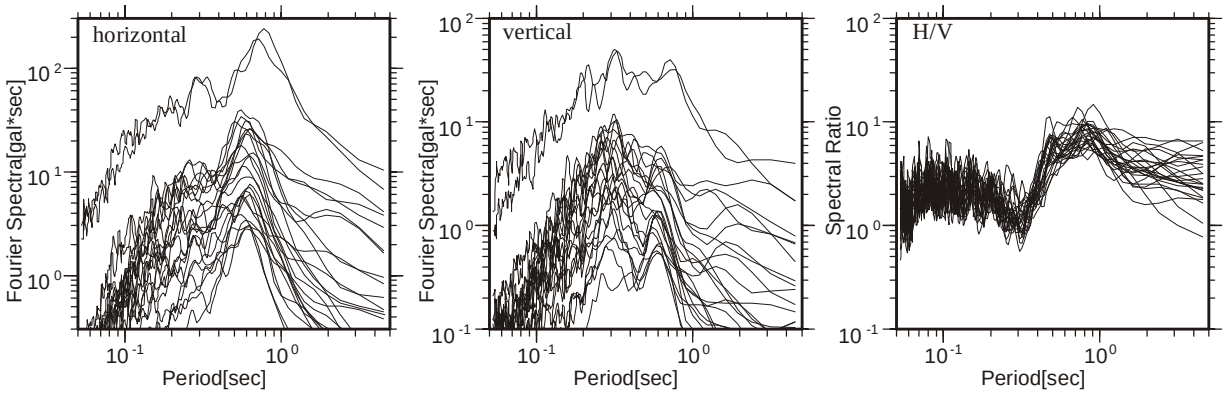

Figure 2. Horizontal and vertical Fourier spectra, and H/V Fourier spectral ratios of seismic ground motion at K-NET Miyazaki station in Miyazaki City.

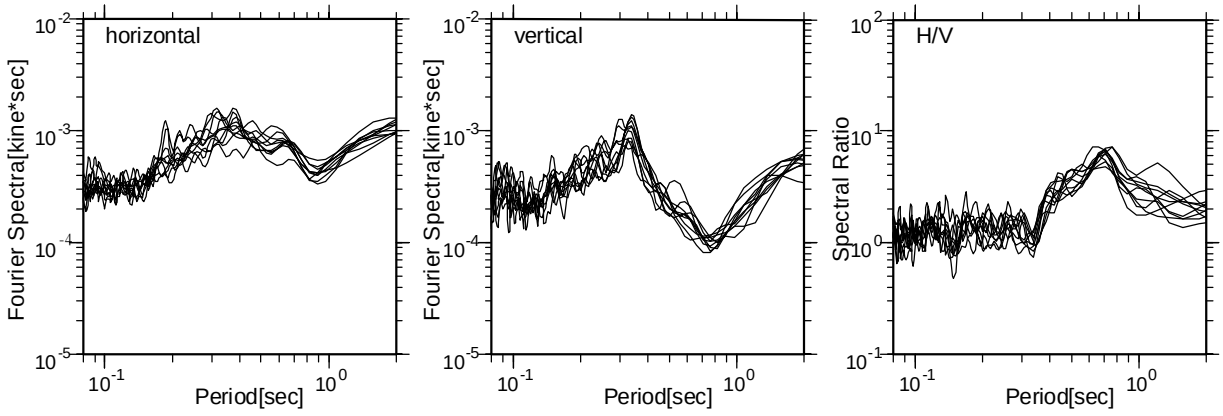

Figure 3. Horizontal and vertical Fourier spectra, and H/V Fourier spectral ratios of microtremor at K-NET Miyazaki station in Miyazaki City.

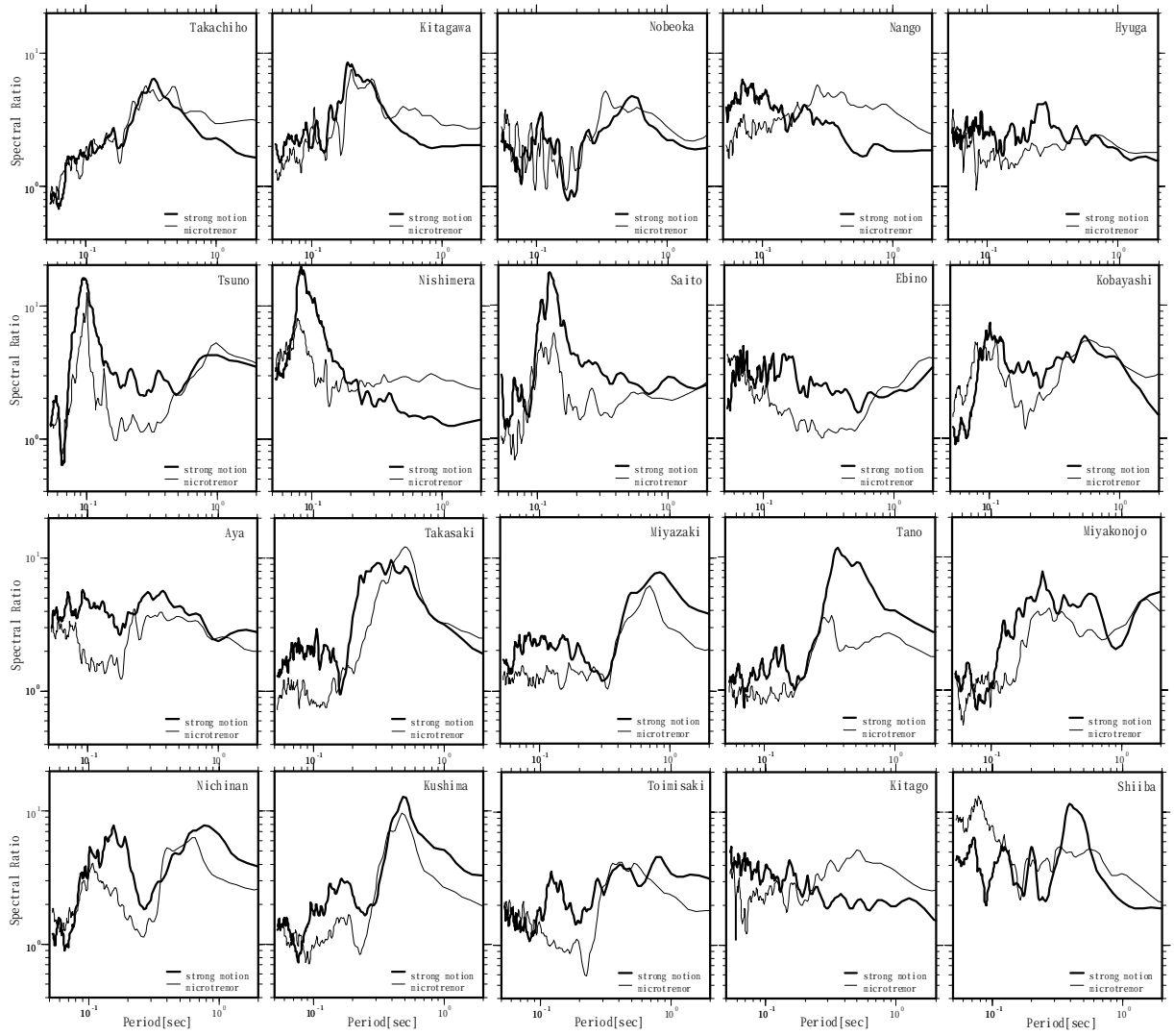

Figure 4. Comparison of the H/V Fourier spectral ratios for strong motion and microtremor.

Examination of Amplification Characteristics

The soil profile including S- and P-wave velocities up to –20 m was investigated by STA for all the K-NET stations. The H/V amplitude ratios for the fundamental mode of Rayleigh waves were calculated using the soil profile and compared with the H/V spectral ratios of microtremor and seismic motion as shown in Figure 5 for K-NET Miyazaki station. In the figure, the transfer function for S-wave propagation with respect to the outcrop (layer at -20 m) was also shown. In this station, all the four curves show good agreement in their peak periods. There are arguments about the interpretation of microtremor, whether body waves (Nakamura, 2000) or surface waves (Konno and Ohmachi, 1998) are dominant in it. In spite of the different interpretations, however, the predominant period of microtremor and seismic motion correspond to the peak period of the H/V ratio of the fundamental mode of Rayleigh wave and the transfer function of S-wave, for the site with large impedance ratios. Hence we would like to emphasis

that microtremor is a useful and convenient tool to estimate site response characteristics.

Conclusions

The site amplification characteristics were investigated using earthquake records and microtremor observed at twenty K-NET stations in Miyazaki Prefecture in Japan. The H/V Fourier spectral ratios for earthquake ground motions were found to be stable and unique to the sites although the Fourier spectra of the horizontal and vertical components for different events show wide variability. The H/V spectral ratio for earthquake records was found to be similar to that for microtremor. The periods showing the peaks of the H/V ratios were almost coincidental with of the H/V amplitude ratio for the fundamental mode of Rayleigh wave and the transfer function for S-wave with respect to the outcrop. Hence the H/V ratio technique can be employed for the estimation of site response characteristics and microtremor may be a useful tool to predict strong motion distribution over the area without seismometers.

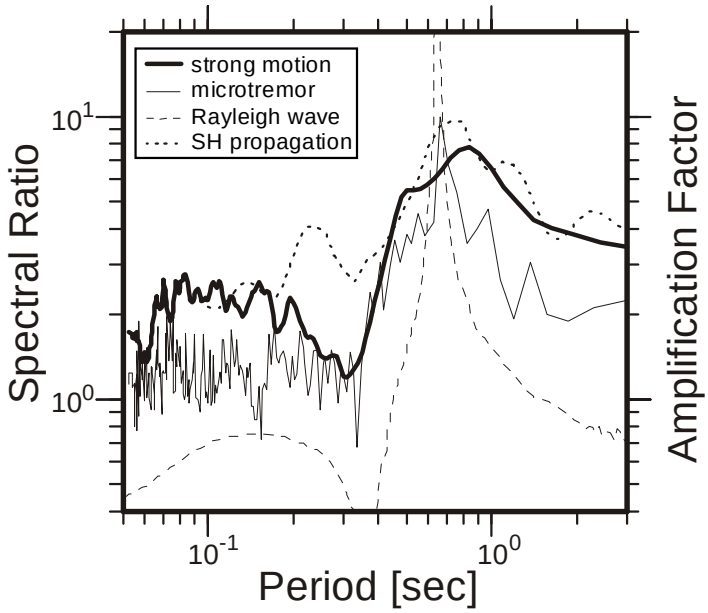

Figure 5. Comparison of the H/V Fourier spectral ratios of strong motion and microtremor, H/V amplitude ratio Rayleigh wave and the transfer function for S-wave propagation for K-NET Miyazaki station.

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