Cliff effects on ground motions at earthquake observation sites in Shikoku study by microtremor measurements

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1. Introduction

Amplification of ground motion in the presence of topographic irregularities is often advocated as one of the possible cause of damage. Destructive earthquakes often show higher damages intensity at top of hills, ridges, and canyons than at lower elevation, and on flat areas. In our previous studies, we found that there is influence of surrounding irregular topography on the recorded ground motion at earthquake observation stations that deploy by National Research Institute for Earth Science and Disaster (NIED), and this study was motivated by an interest in evaluating effects of cliffs at that sites. Among them, we selected four earthquake observation sites, which are very near a cliff. These sites are K-Net Niihama (EHM002), K-Net Uwajima (EHM012), KiK-Net Shinguu (EHMH03), and KiK-Net Ohzu (EHMH11).
In this paper, effects of cliff on ground motion recorded at earthquake observation stations have been investigated with microtremor measurements at and around station, and main objective of this study is to investigate the cliff effects on ground motions at earthquake observation sites in Shikoku, Japan.

2. Methodology

Microtremor measurements were carried out at earthquake observation site and around the site. Fig. 1 shows the locations of the sensor at sites. More than one sensor were used to record ground motions, among them one sensor was placed on the basement for earthquake observation station, other at tip of cliff, and another at free field where less influence of cliff and others like buildings, trees, electrical poles etc., to evaluate the possible effects of topography on ground motion at station. At some sites where the station is on the tip of cliff, only one sensor was used for station and tip of cliff. The ground motions were observed for 300 sec two times at all sites with sampling frequency of 100 Hz. Each set of continuous 2048 samples were selected avoiding unstable terms that seems to be influenced by near traffics during recoding time. Finally selected segments are used for FFT analysis and then smoothed by using Parzen window of 0.5 Hz bandwidth. The average of both horizontal motions was calculated by Root Mean Square method, and comparisons between the tip of cliff or station and free field were carried out in terms of Fourier spectrum of horizontal motions. The H/H ratios of Fourier spectrum of sensor at tip of cliff/ station to sensor at free field were obtained.

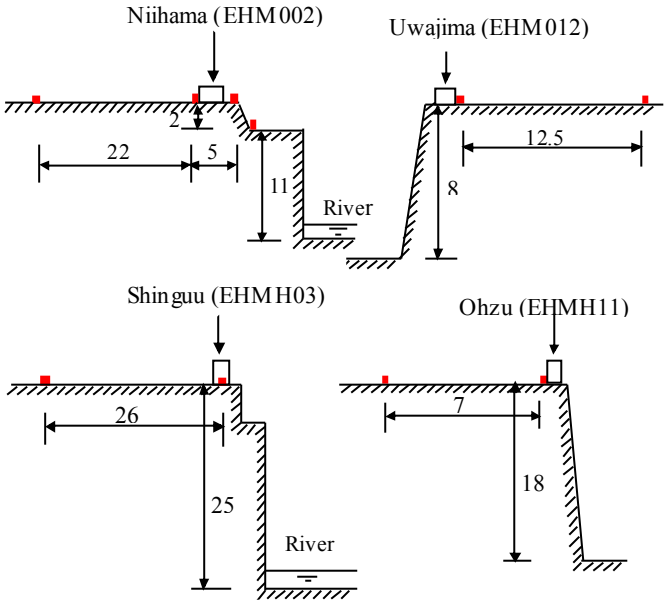

Fig.1 Cross section views at earthquake observation sites. Solid red rectangular indicates the position of sensor and open rectangular indicates earthquake observation sites (All dimensions in meter)

3. Results and Discussions

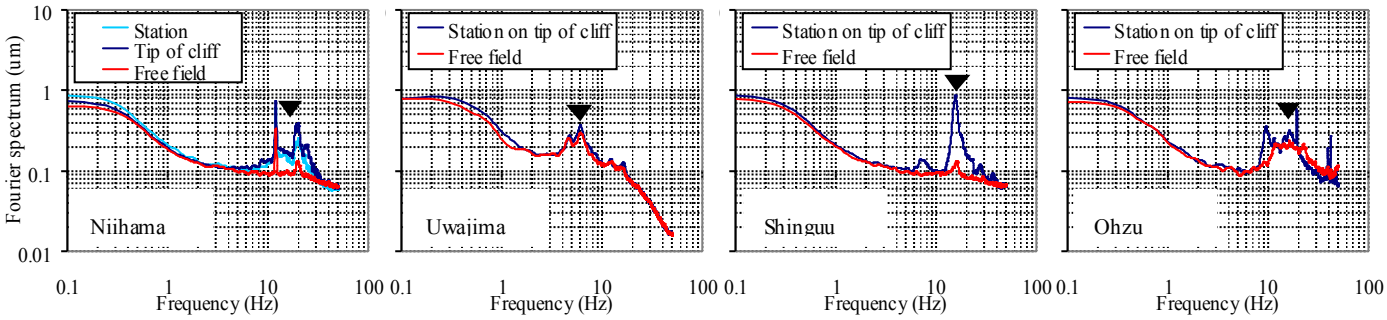

Fig.2 Averaged Fourier spectrum of horizontal motion of microtremors at and around earthquake observation sites

Figure 2 shows the average of Fourier spectrum of horizontal ground motions measured by microtremor measurement at earthquake observation site and it's around. It presents the comparisons between the sensor at tip of cliff or station on the tip of cliff and free field site behind the tip of cliff. The magnitudes of Fourier spectrum of free field are significantly smaller than those of tip of cliff or station and also magnitude of spectrum of tip of cliff is the most dominant than others, which can be attributed principally to the effect of topography (cliff) on the ground motions. At all sites, we can see that

the most predominant amplitude of spectrum occurs at higher frequency range. At Niihama site, all sensors including free field show the dominant peak at 15 Hz that indicates the dominant frequency of embankment. The amplitude of spectrum of tip of cliff at 15 Hz is the most dominant; it's about 2 and 3 times greater than at station & tip of cliff, respectively. In case of Uwajima site, the amplitude of spectrum of sensor at station on tip of cliff is little difference than those of sensor at free field. Here the amplitude of station is not much greater than free field at range of 6 Hz dominant frequency due to lack of actual free field in the site. At site Shinguu, we can see the clear dominant peak of both sensors, at station on tip of cliff and free field, at 15 Hz where the amplitude of Fourier spectrum of horizontal ground motion at station is the dominant than those of free field in term of 6 times. Similarly at Ohzu site, we can see that the clear dominant peak of Fourier spectrum at higher frequency at 17 Hz, and also amplitude of spectrum of sensor at station on the tip of cliff is greater than those of free field at those frequencies.

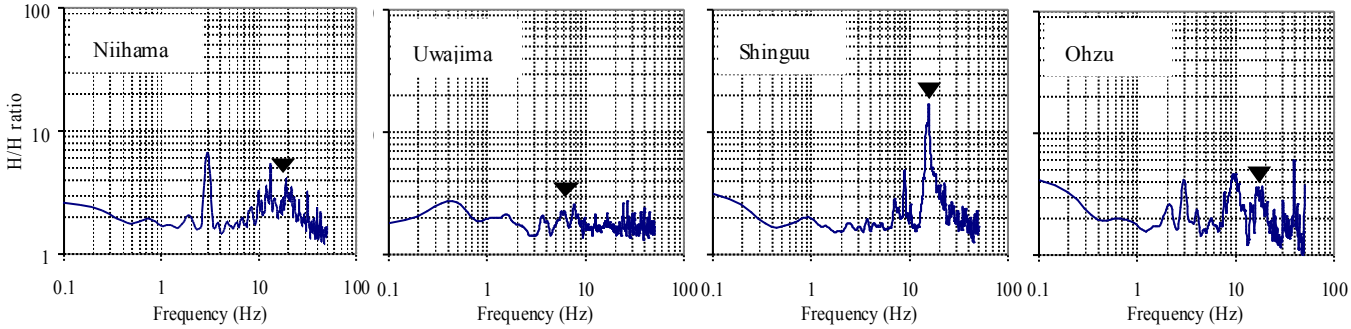

Fig. 3 Averaged H/H spectrum ratios of horizontal component of microtremors on the basement to free field

Figure 3 shows averaged H/H spectrum ratios of horizontal motions of microtremrs of earthquake observation station with respect to free field. The amplitude of H/H spectrum ratios at all sites indicate the amplification of ground motion due to presence of topographic irregularities near the station for consistence geology at higher frequencies range, and also the dominant frequencies show consistency with those of Fourier spectrum of horizontal ground motions. At Niihama site, H/H ratios exhibit clear dominant peak with amplitude of 4 at 15 Hz. Indeed, the amplitude of H/H ratio of EW component, perpendicular to a river i.e. cliff, is slightly greater than those of NS component. At Uwajima sites where we found lack of proper free field near the station, and we considered one place the most suitable place to compare between station and free field, the amplitude of H/H ratio is about 2.5 at 6 HZ. In case of Shinguu site, we can see the clear peak around 15 Hz having amplitude of 15. Similarly at Ohzu site, the amplitude of the H/H ratios is 3.5 at 17 Hz. Since, the amplitude of H/H spectrum ratio of sensor at station on tip of cliff to free field indicates the amplification of horizontal ground motions, especially higher frequencies excitation.

5. Conclusions

In this paper, the effects of cliff on the ground motions recorded at earthquake observation station are investigated with microtremor measurements at and around the sites. The microtremor measurements at station were compared with those measured at tip of cliff and point regarded as free field with respect to Fourier spectrum of horizontal ground motions, and H/H spectrum of station on tip of cliff to free field also observed. The Fourier spectrum of horizontal ground motion of tip of cliff is greater than free field at all sites, especially for high frequencies excitations, and the amplitudes of H/H spectrum ratio of station to free field are the most dominant at same range of frequencies which indicates that up to tens times amplification at tip of cliff with respect to free field behind tip of cliff within tens meters. This study shows that there is the possibility of amplification of recorded ground motions at earthquake observation station where presences of cliff near the station, and there needs to take consideration of such type of topographic effect during analysis of ground motion recorded at such sites.

6. Acknowledgements

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