ABSTRACT

Kaohsiung city is the most important harbor in Taiwan. Recently, there are many high-rise buildings and public transportation system are under construction in this area. Therefore, it is very important to know the surface geological conditions for many practical reasons especially after the strikes of 1999 Chi-Chi, Taiwan earthquake. To serve the purpose of earthquake hazard mitigation, it would be better to understand the soil amplification effect of the Kaohsiung-Pingtung area. We then conducted a research to study the site effects of the area, which includes analyze three newly installed borehole seismometer arrays, and perform very dense microtremor measurements in the study area. Most microtremor measurements were done during the midnight to reduce artifacts. After carefully selection, we pick 590 records and use the H/V ratio method to get information of soil amplification. From the result, we found it correlated to the basement depth very well.

For the purpose of earthquake resistant design, earthquake engineers must consider the site response at a specific period. For example, the structure period of a ten-flour building is at about 1 second. If the input ground motion is dominate at 1 Hz, then the building will has a resonant effect. Therefore, in this study, we select several frequencies to plot out the contour map for understanding the frequency responses in this area. For the 0.5 Hz, the contours show that main amplification effects occurred at the southern part of Kaohsiung area. With the frequency increasing to 2.0 Hz, the main amplification area move from the harbor and the southern part of Kaohsiung area to the hill area, which locates at the eastern part of Kaohsiung area. For the higher frequency (3.0 Hz), there are no obvious high contour areas. We pick the dominant frequency of each record and plot out the contour map. At the harbor and city area, the dominant frequency is about 0.5 ~ 0.9 Hz, and the northeastern part is about 1.3 ~ 1.7 Hz. We found that the basement structure can explain the contour very well. Yet, the H/V dominated frequency distribution map reveals more detail features.

INTRODUCTION

Taiwan is located on the Circum-Pacific seismic belt. The seismicity in Taiwan area is very high (Hsu, 1961). Therefore, defense lives and possessions from disaster earthquakes are a major concern of the people in this region. Strong ground shaking primarily causes the damaging effects of earthquakes. To reduce the loss of life and property from strong ground shaking, it requires conscientious application of construction codes and earthquake resistant design, enforcement of adequate land-use policies as well as implementation of appropriate retrofit measures. The implementation
of these mitigation measurements must be based in large part on the recordings from large earthquakes at distances from 0 to 100 km. Such data are crucial for designing earthquake resistant structures and understanding the source mechanism of earthquakes and the propagation of seismic waves from source to site, including the local site effects.

Amplification of strong ground motion by alluvial deposits during an earthquake has been documented on a lot of occasions and caused damage in recent large earthquakes, for example, 1985 Michoacan earthquake, 1989 Loma Prieta earthquake, 1994 Northridge earthquake, 1995 Kobe earthquake, and 1999 Chi-Chi, Taiwan earthquake. Many studies shown that the top alluvium layer will play an important role for site amplification effects (Boore et al., 1993; Boore et al., 1994; Anderson et al., 1996). Therefore, site effects study is very important for mitigating damage during an earthquake. Many methods have been used to characterize the site amplification. The Central Geological Survey had spent four years to bore more than 50 wells. And now, it is very clear to know the basement depth is changing from 120 to 40 meters for the western and eastern part of the Kaohsiung city. The harbor and commercial area locate at the western part of this area, and the eastern part is small hill area. In this study, we used the H/V ratio to analyze the site effect. The H/V ratio contours at some specific frequencies are selected to compare with the geological structures under the Kaohsiung area.

**MICROTREMOR SURVEY**

We perform a very dense microtremor survey in the study area. Most microtremor measurements were done during the midnight to reduce artificial effects in the urban area. The measurements are denser in the urban area than countryside. The seismometer which we use to do microtremor measurements is made by the Tokyo Sokushin. The mode of the recorder is the SAMTAC-801B and the sensor is the VSE-311C. We measure about 18 minutes at each site. The sampling rate is 200 pps. After carefully selection, we pick 590 records and use the H/V ration method to study the soil amplification in the Kaohsiung area.

We also had done microtremor array measurements at seven different sites. We set up 13 seismometers in several triangles at each microtremor array measurement, and receive microtremor at the same time. There is a time shift between the pulse at each station. We use the F-K analysis to get a dispersion curve. Then we get the S wave velocity structure by using the Genetic Algorithm Search. We can use the S wave velocity structure to modify the velocity structure of Kaohsiung-Pingtung area, and do the 3D simulation further.

**GROUND MOTION CHARACTERISTICS ANALYSIS**

Kagami et al. (1982; 1986) proposed that the ratio of the horizontal components of the velocity spectra at the sediment site to those at the rock site (Kagami’s ratio) can be used as a measure of microseism ground motion amplification. This proposition assumes a common source and similar paths for sediment and bedrock sites. Nakamura
(1989) proposed a hypothesis that microtremor site effects can be determined by simply evaluating spectral ratio of horizontal versus vertical components of motion observed at the same site (Nakamura’s ratio).

There had been installed three borehole seismometer arrays by the Central Geological Survey in the Kaohsiung area. Each array was installed three seismometers at different depth (surface, 50 m, 150 m). We had done the P-S velocity logging before the seismometer had installed in the deepest borehole (150 m). In order to check the H/V ratio method is suitable in this area or not, we use the microtremor data of the Fongshan borehole array to calculate H/V ratio for three different depths (Figure 1). Although the ratio of the 150m do not equal to one, but it is appropriate to a confidence. So we used the H/V ratio to analyze the site effect in the area. After all the borehole seismometer arrays had been set up, we have already received some earthquakes. We can use the earthquake records to calculate the transfer function between two different depths. And we have already had the S wave velocity by doing the P-S velocity logging. We use the S wave velocity and 1-D Haskell method to calculate the theoretical transfer function between two different depths and compare with the observed transfer function. Figure 2 shows the result of the Fongshan borehole seismometer array.

We perform a very dense microtremor survey in the study area. Figure 3 shows the locations of the microtremor survey. We use same process to get the contour of H/V ratio. In this study, we select several frequencies to plot out the contour map for understanding the frequency responses in this area. Figure 4 shows the contour of H/V ratio for some specific frequencies. For the 0.5 Hz, the contours show that main amplification effects occurred at the southern part of Kaohsiung area. With the frequency increasing to 2.0 Hz, the main amplification area moves from the harbor and the southern part of Kaohsiung area to the hill area, which locate at the eastern part of Kaohsiung area. For the higher frequency (3.0 Hz), there are no obvious high contour areas. In the Pingtung plane, the main amplification area moves around the Kaoping River at the frequency from 0.5 to 2 Hz. We pick the dominant frequency of each record and plot out the contour map (Figure 5). At the harbor and city area, the dominant frequency is about 0.5 ~ 0.9 Hz, and the northeastern part is about 1.3 ~ 1.7 Hz. We found that the basement structure (Figure 6) can explain the contour very well. Yet, the H/V dominated frequency distribution map reveals more detail features.

**CONCLUSIONS**

Usually, there are many high-rise buildings and public transportation systems in the urban area. Therefore, it is very important to know the surface geological conditions and the ground motion characteristics for structure design and hazards mitigation purposes. One way to get this site amplification is installed very dense seismometers and analyzed the ground motion records after had earthquakes recorded, like TSMIP project in Taiwan (Shin, 1993). In high seismicity area, you may only need 5 or 10 years to get enough records to finish this study. But it may need long-term observation in the low seismicity area. And it need very large budget in this case, including instrumentation, maintenance, and manpower. We use microtremor survey to study the ground motion characteristics in the urban area. It only need very short time for fieldwork and less money.
In the Kaohsiung area, with the frequency increasing, the main amplification area move from the harbor and the southern part of Kaohsiung area to the hill area, which locates at the eastern part of Kaohsiung area. For the higher frequency (3.0 Hz), there are no obvious high contour areas. In the Pingtung plane, the main amplification area moves around the Kaoping River at the frequency from 0.5 to 2 Hz. From the contour of the dominant frequency, We can find that the southwestern part of Kaohsiung city is about 0.5 ~ 0.9 Hz, and the northeastern part is about 1.3 ~ 1.7 Hz, and the basement structure can explain the site amplification result very well.

REFERENCES


Figure 1. The microtremor H/V ratio of the Fongshan borehole seismometer array.
Figure 2. The result of the 1D Haskell method of the Fongshan borehole seismometer array. The red line is the theoretical transfer function we calculate.
Figure 3. The distribution of the microtremor survey.
Figure 4. The contours of H/V ratio by using the microtremor survey data.
Figure 4. Continue.
Figure 4. Continue.
Figure 5. The contour map of the dominant frequency.

Figure 6. The basement structure in the Kaohsiung area.