STRONG MOTION OBSERVATION IN METRO MANILA, PHILIPPINES

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SUMMARY

The Philippine archipelago is surrounded by several subduction zones. Because of this special tectonic environment, many destructive earthquakes occurred in the Philippines. In this paper, we describe a strong motion observation network deployed in Metro Manila for providing basic materials used in strong motion prediction due to future major events near Metro Manila. Strong motion accelerographs have been installed at 8 sites with various geological conditions in the area. We found that long-period motion at a period of 3 sec is dominant at center of Metro Manila due to surface waves amplified by the sedimentary layers.

INTRODUCTION

The Philippines is considered to be one of the most earthquake-prone countries of the world. This can be attributed to the fact that it lies along the Circum-Pacific Seismic Belt where most of the seismic activities are concentrated. The Philippine archipelago is bounded by oppositely-dipping subduction zones, as well as transected by a number of fault lines, where movements are periodically detected through the recordings of tectonic earthquakes. Because of such situation, significant numbers of earthquake disasters have already plagued the country since the 16th century. The most recent destructive earthquake was the 16 July 1990 Luzon earthquake (Ms=7.8) which was generated by movement along the northern segment of the Philippine Fault Zone.

Metro Manila that is capital in the Philippines is composed of 17 cities. Its population stands at ten million distributed in a land area of 920 sq. km. area. In the last few decades, Metro Manila have been industrialized with in chasing factories, facilities and infrastructures.

Several of seismic risk evaluations for whole area in the Philippines have been already done. Villaraza (1991), Molas and Yamazaki (1994) estimated the distribution of the maximum acceleration by statistical methods from different earthquake catalogs. According to these results, the cities where earthquake damage was experienced in comparatively recent years are classified into high seismic risk area. However, because destructive earthquake did not occur in the last 100 years around Metro Manila, the seismic risk for the Metro Manila belongs to comparatively low level area. Since the earthquake catalogs used in these studies have been made from earthquakes which occurred during recent 200 - 300 years, it is very difficult to evaluate seismic risk appropriately from the viewpoint of seismic activity. Daligdig and Besana (1993) evaluated seismic risk including active fault data. According to this study, the influence of Marikina fault in the east and west edges of

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Malikina plain, it is very large for Metro Manila. Especially, it is necessary to consider the difference in ground condition because of complicated topography and subsurface geology in Metro Manila.

In this paper, strong ground motion observation in Metro Manila to obtain basic information is introduced

GEOLOGY AND TOPOGRAPHY IN METRO MANILA

Metro Manila is located on Central Valley in the Luzon Island, and it is sandwiched between Zambales range in the east and Sierra Madre range in the west. The topography of Metro Manila can be classified into three types as shown in Fig. 1; Coastal Lowland along Manila Bay, Central Plateau and Marikina Plain. The surface geology of Central Plateau consists of Guadeloupe formation in Tertiary. On the other hand, Coastal Lowland and Marikina Plain mainly consist of Quaternary alluvium deposit. Marikina Plain is a pull-apart basin, and surrounded by Eastern Marikina fault and Western Marikina fault.

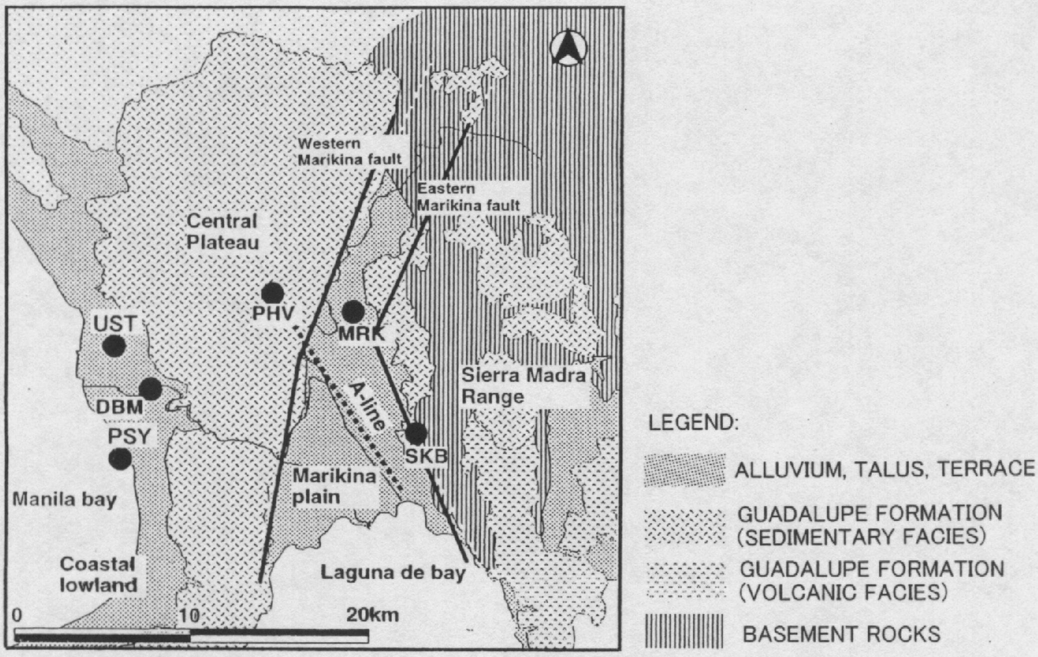

Fig. 1 Map showing the topography and locations of strong ground motion sites. A-line shows seismic explosion surveying line.

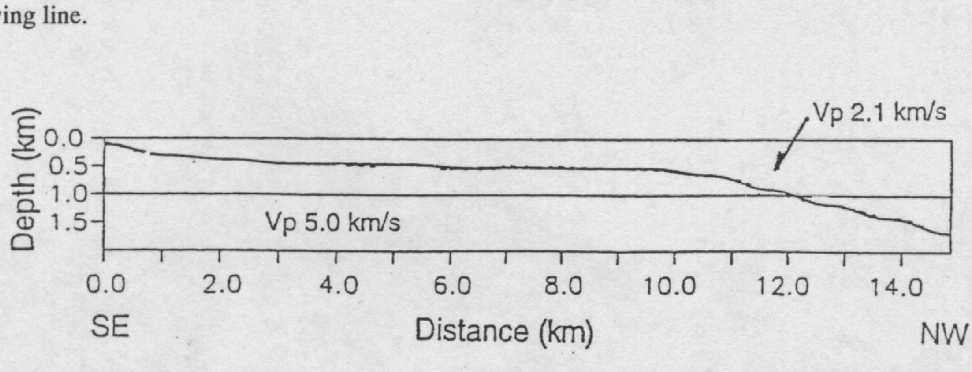

Fig. 2 Deep subsurface structure along a dotted line in Fig. 1

The thickness of the soft alluvium deposit in Coastal Lowland and Marikina Plain was roughly estimated (Diligdig and Basana, 1993; Matsuda, 1998). The alluvium deposit shows a valley shape along Pasig River, and the alluvium deposit in Coastal Lowland is estimated to be 30 meters or more. However, there is little information about S-wave velocity. The depth to the bedrock with a P-wave velocity of 5 km/s was investigated by seismic explosion survey (Abeki et al. 1997). Figure 2 shows a profile of deep underground structure by a travel time analysis of initial P-wave (Yamanaka and Hirano, 1998). The Tertiary sedimentary layer is shallow at the eastern part of Marikina Plain. It becomes gradually deep to the north-west, and depth is about 1.5 km at Central Plateau near PHV.

STRONG GROUND MOTION NETWORK

Observation System

A digital strong motion accelerograph network was established in Metro Manila in 1992 by PHIVOLCS (Banganan, 1998). Four units of accelerographs have been installed at sites that underlain the different subsurface structure of the metropolis. As a part of cooperative research between PHIVOLCS and Kanto Gakuin University, the velocity type strong motion seismograph was installed at Manila Observatory, Ateneo de Manila University (Maeda et al., 1998). However, Because of very complicated topography and geology in Metro Manila, the deployment is not enough. Thus, a new strong motion accelergraph network has been constructed as shown in Fig. 1.

This network consists of 8 sites with different subsurface geological conditions. Small observation houses were constructed at five sites. The equipments at the other three were installed on the basement, third and fifth floors in the head office of PHIVOLCS. The locations of the observation sites were shown in Fig. 2. Table 1 shows ground conditions of the observation sites. SKB is located at east edge of Marikina plain near Sierra Madre range. Because the thickness of sedimentary layer is very thin at the site, this site can be a reference point for understanding site effects.

Table 1 List of strong motion network sites

Station name	Code	Subsurface Geology
Libertad Pumping Station	PSY	Reclaimed land
University of Santo Thomas	UST	Costal low land
Dept. of Budget and Management	DBM	Costal low land
Philippine Ins. Volc. and Seism.	PHV	Central plateau
Marikina Elementary School	MRK	Marikina plain
Smith-Kline Beecham Factory	SKB	Sierra Madre range

The equipments used are ETNA (Kinemetrics, Inc.) with three orthogonal component accelerographs. The sensor has a natural frequency of 50 Hz and a damping of 70% of the critical. The sampling rate to record signal is 100 samples/sec. Recording is started by a trigger system. The time stamp attached on each record file is generated from an internal oscillator with accuracy of 5 microseconds from GPS satellite signal. The equipments are maintained by a remote control via telephone line.

Small House for Observation

Accelerographs are generally installed inside of building basement because of security of equipment. Recorded ground motion includes some influence of interaction between ground and building. Ideally, it had better to put an accelerograph on a foundation without influence from building. We made a small house for observation to record true ground motion.

The plan of the observation house is shown in Fig. 3. The seismograph foundation was constructed in the center of the house, and the recorder was installed on a shelf. A photo for the Marikina station is shown in Fig. 4

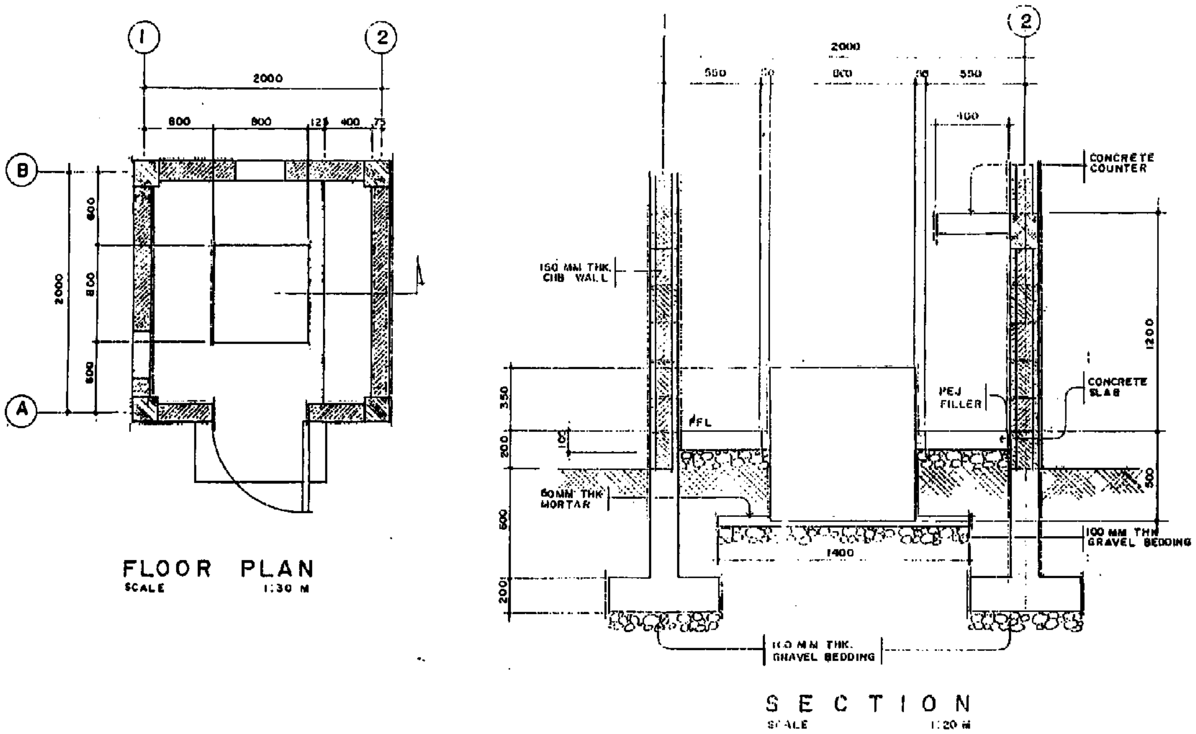

Fig. 3 Foundation of strong motion pad and house

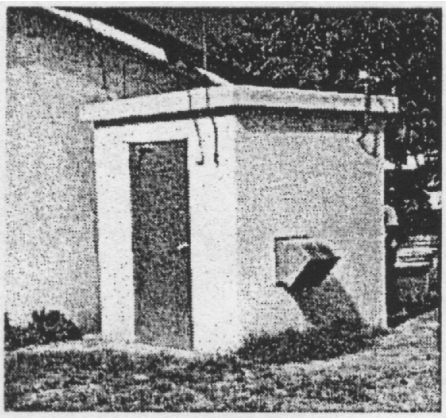

Fig.4 Photo of MRK strong motion station

EXAMPLE OF SEISMOGRAMS

The strong ground motion observation has been in operation since April, 1998, and 5 events have been obtained up to now. The largest earthquake among the observed events occurred at a southwest part of Luzon Island on August 23, 1998.

In this earthquake, the seismic intensity at PHV located in Quezon City was ‡W on the PHIVOLCS intensity scale. According to source information by automatic estimation system for source mechanism by Earthquake Research Institute (ERI), University of Tokyo, moment magnitude (Mw) was 5.8, focal depth (h) of 80 km and epicentral distance of about 150 km from PHV. The seismic intensity in Subic City located near the source region was ‡Y, and slight damaged was reported. The velocity seismograms recorded at PHV are shown in Fig. 5. The long-period ground motion can be identified after arrival of S-waves. The velocity response spectra with

5% damping are shown in Fig. 6. The long-period ground motion with a period of 2-5 sec was significantly dominant in the horizontal and vertical components. A large spectral peak at a period of 0.4 sec can be found only in the two horizontal components. The duration of long-period ground motion seems to be more than 100 sec.

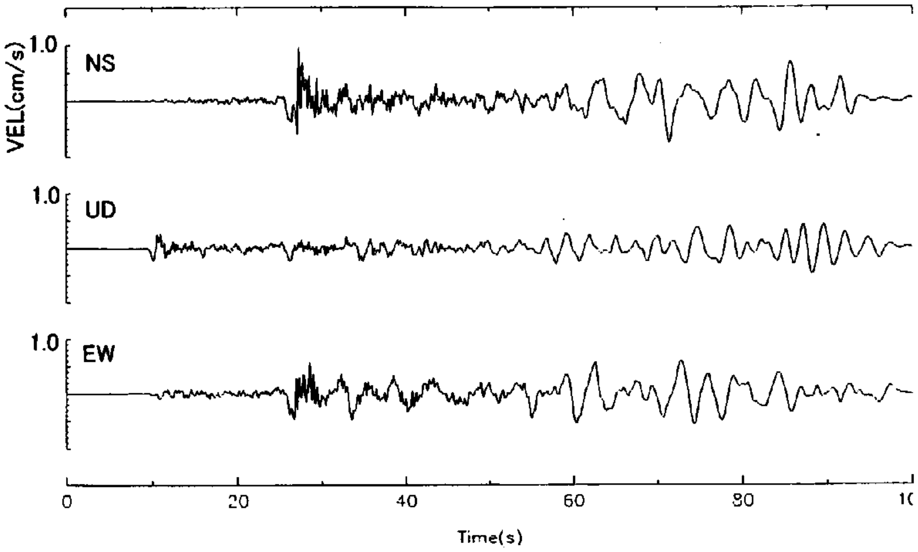

Fig. 5 Velocity seismograms of earthquake of August 23, 1998 observed at PHV

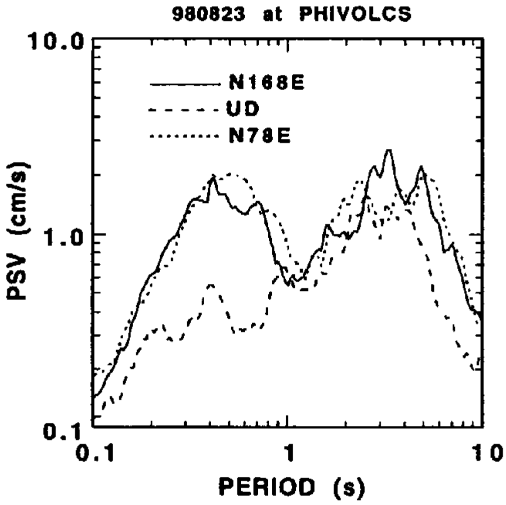

Fig.6 Velocity response spectra of earthquake of August 23, 1998 at PHV

Polarization analysis (Vidal, 1986) was applied in order to understand the characteristics of the later-phases. The data through band-pass filter at a center period of 3 sec, which is a predominant period in the vertical component, was used in this analysis. Figure 7 shows the result of the polarization analysis. Here, ? and ? mean directions of strike and dip of maximum polarization, respectively. PE means a parameter of elliptical component of polarization. PE is 1 for circularly polarized motion, but PE is 0 for linearly polarized motion. The polarization of the later phases in Fig. 7 changes with time. The polarization parameters of the A part are ?> 0 and PE>0. It suggests that the long-period ground motion at the A part consists of Rayleigh wave (Table 2) and propagates in direction from north to south or from south to north. Since the location of the earthquake epicenter from ERI is temporally information, the true epicenter direction is investigated by particle orbit of the S-waves. The direction of the epicenter by the particle orbit of the initial S-waves is northwest direction (Fig. 8). That is, propagation directions of the S-waves and later phases are different. According to previous study (ex. Toriumi, 1975), the long-period ground motion in a sedimentary layer is generated by a conversion of S-waves to surface waves near an edge of a basin, and amplified by a deep sedimentary layer. The polarization parameters???and ? of the B part are drastically changed with PE>0. When more than 2 different phases are identified at same time, polarization parameters do not always suggest the relations shown in Table 2. However, the vertical long-period ground motion can be identify clearly. It suggests that the B part may be mixtures of Raylegh and another type of waves. The about results indicated that the long-period ground motion observed at PHV may be the surface waves by the conversion from S-waves near the edge of basin by the deep underground sedimentary layer.

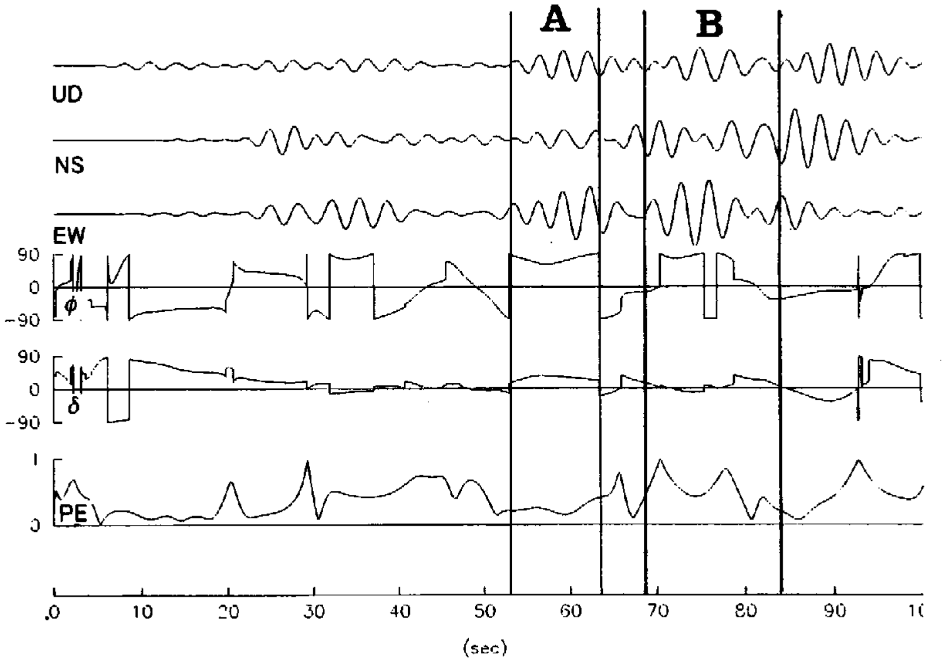

Fig.7 Polarization analysis of the velocity records through band-pass filter at the center period of 3 sec

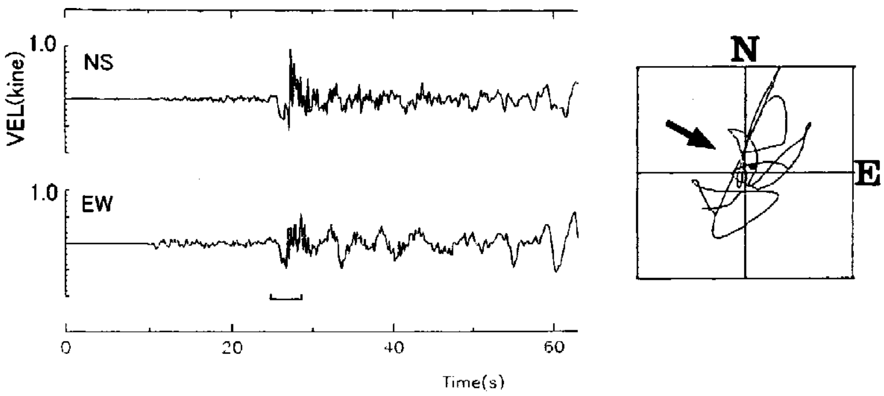

Fig.8 Velocity seismograms of earthquake of August 23, 1998 observed at PHV and particle motion of initial S-waves. The arrow shows the propagation direction of S-waves. It suggests that epicenter of this earthquake is in the north-west direction.

MICROTOREMOR OBSERVATION

Single Point Observation

To evaluate site effects in short-period band below 1 sec, microtoremors measurements were conducted at each site. The equipment with a flat characteristic below 1 sec was used for the observation. The microtremor spectra of three components at each site are shown in Fig. 9. The spectra at PSY located on reclaimed land show large amplitude with a predominant period of around 0.4 sec in the horizontal and vertical components. The spectral peaks in the horizontal components at UST are found at periods of around 0.1 and 0.3 seconds. Since there is heavily traffics around UST, the spectral amplitude at the short period is large. At DBM, the spectral peaks are found at periods of 0.3 and 0.8 second. The spectral peak at a period of 0.8 second is the longest among the sites. As for the spectra at MRK located on Marikina plain, the spectra are flat at periods from 0.1 to 0.4 seconds, and reduces the amplitude at periods the long-period range. On the other hand, the spectra at SKB with thin sedimentary layer have spectral peaks of 0.15 second in the three components. Because SKB is located in a plant, it is difficult to know if the cause is due to machine vibration or site effects. The spectra at PHV have peaks at periods of around 0.2 and 0.4 seconds. It is coincident to spectral peaks of the earthquake ground motion. This can be due to the influence of shallow geological structure.

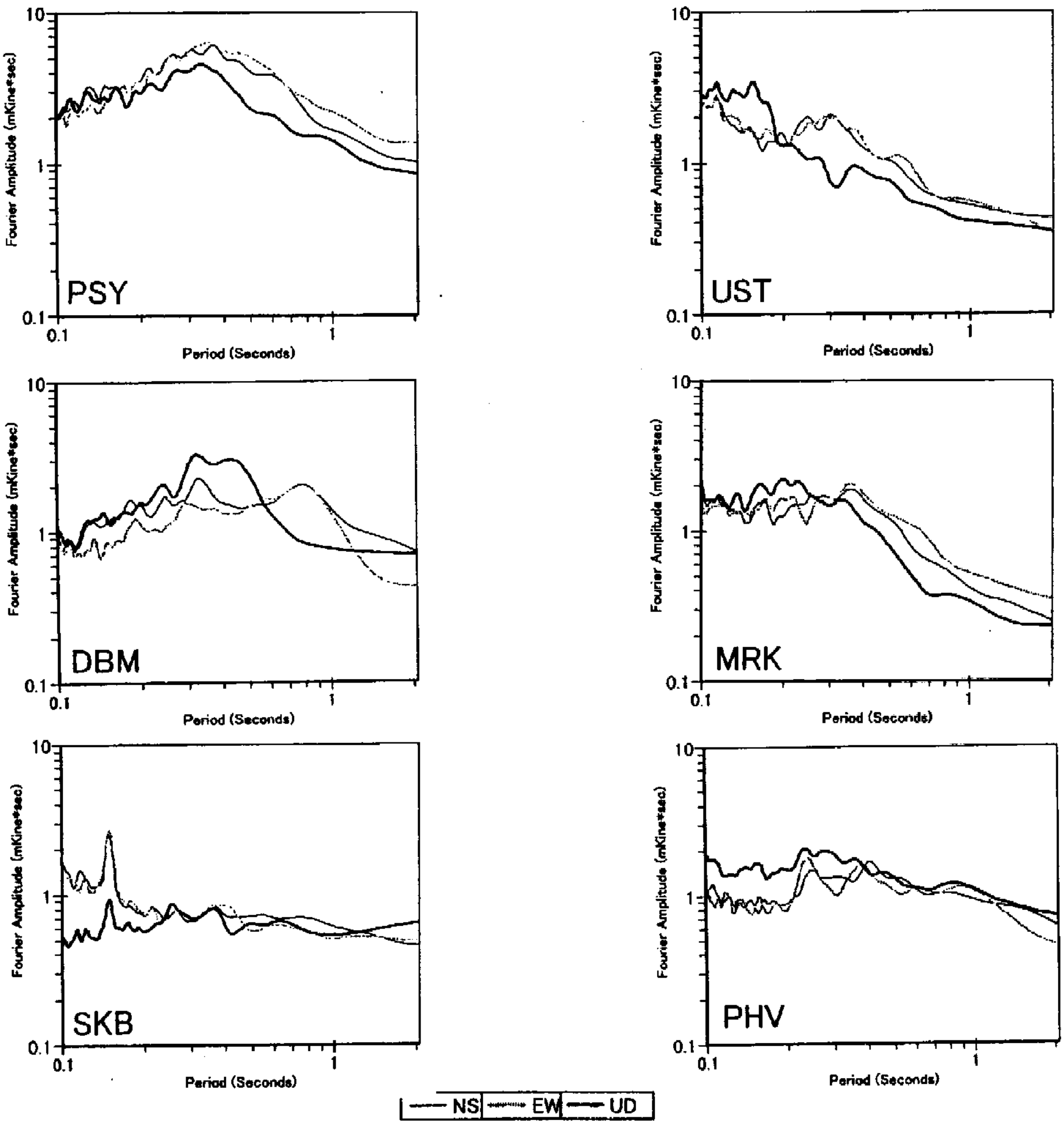

Fig. 9 Spectra of microtoremors observed at each strong ground motion observation site

CONCLUSION

To obtain basic information to evaluate earthquake risk in Metro Manila, a new strong motion accelerograph network was constructed. In observed seismograms at PHV, long-period later phases are identified. The long-period ground motion may be amplified by deep underground sedimentary layers. To clarify the site effects and the underground structure, microtremors were observed at each site.

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