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CHARACTERISTICS OF GROUND MOTION IN KOBE AREA

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ABSTRACT

The 1995 Hyogoken-Nanbu Earthquake (magnitude M_{jma}=7.2, focal depth h=20km) of January 17, 1995, caused great disaster at Hanshin-Awaji area, Japan. The numbers of victims were over 6000. The heavily damaged areas correspond to JMA (Japan Meteorological Agency) seismic intensity 7, run parallel to coast of Osaka bay like a belt with 2 to 3 km width. The state of damage changes drastically between mountainous area and coast crossing this belt zone. The difference of ground motion on this area has been confirmed roughly by several evidences such as seismic record and the ratio of overturning tomb stones. The number of records observed during the 1995 Hyogoken-Nanbu Earthquake is not sufficient to explain distribution of damaged area. To understand the difference of ground motion, two types of microtremor measurements were made in Kobe city. First measurement is simultaneous measurement at Kobe Maritime Meteorological Observatory(KMMO). Office buildings of KMMO locate on the top of terrace about 30m high. To elucidate the effects of terrace on seismic record, microtremor was measured on the top and bottom of terrace simultaneously. Second one is mobile measurement along two traverse lines. The purpose of mobile microtremor measurement is to elucidate the site characteristic of this area using microtremor. Two traverse lines lay almost north-south direction and observation points locate on several conditions from almost mountainous zone to reclaimed land. The characteristics of ground motion related to ground condition are discussed in this paper.

KEYWORDS

1995 Hyogoken-Nanbu Earthquake; Kobe city; simultaneous microtremor measurement; mobile microtremor measurement; spectral ratios.

INTRODUCTION

The 1995 Hyogoken-Nanbu earthquake, that occurred at 5:46 a.m. local time on 17 January 1995, caused severe damage to the southern portion of the Hyogo Prefecture, particularly to the city of Kobe. Accelerograms with maximum amplitudes of 818 (N-S), 617(E-W) and 332(U-D) were recorded at Kobe Maritime Meteorological Observatory(KMMO). The severely damaged areas are located in a narrow band, parallel to coast line of Osaka bay extending from the northern part of Awaji island to Takarazuka city, including the cities of Kobe, Ashiya and Nishinomiya. These areas almost correspond to the area of JMA (Japan Meteorological Agency) seismic intensity, I_{jma} 7, that was Japanese intensity scale by JMA. It is important to understand what was the reason of peculiar damage distribution. During this earthquake, fairly numbers of seismic records are observed by several organizations, institutes and companies, but they are not sufficient to explain distribution of damaged area. The difference of ground motion on this area has been confirmed roughly by several evidences such as seismic record and the ratio of overturning tomb stones (Building Research Institute, 1995, Midorikawa S. *et al.*, 1995, Takemura M., 1995). Nevertheless it's difficult to relate the damage with intensity and characteristics of seismic motion. To elucidate site characteristic of this area, two types of microtremor measurements were performed. It is said that microtremor measurement is effective to understand characteristics of ground motion and many measurements have been carried out (for instance, B. A. Gaull *et al.*, 1995).

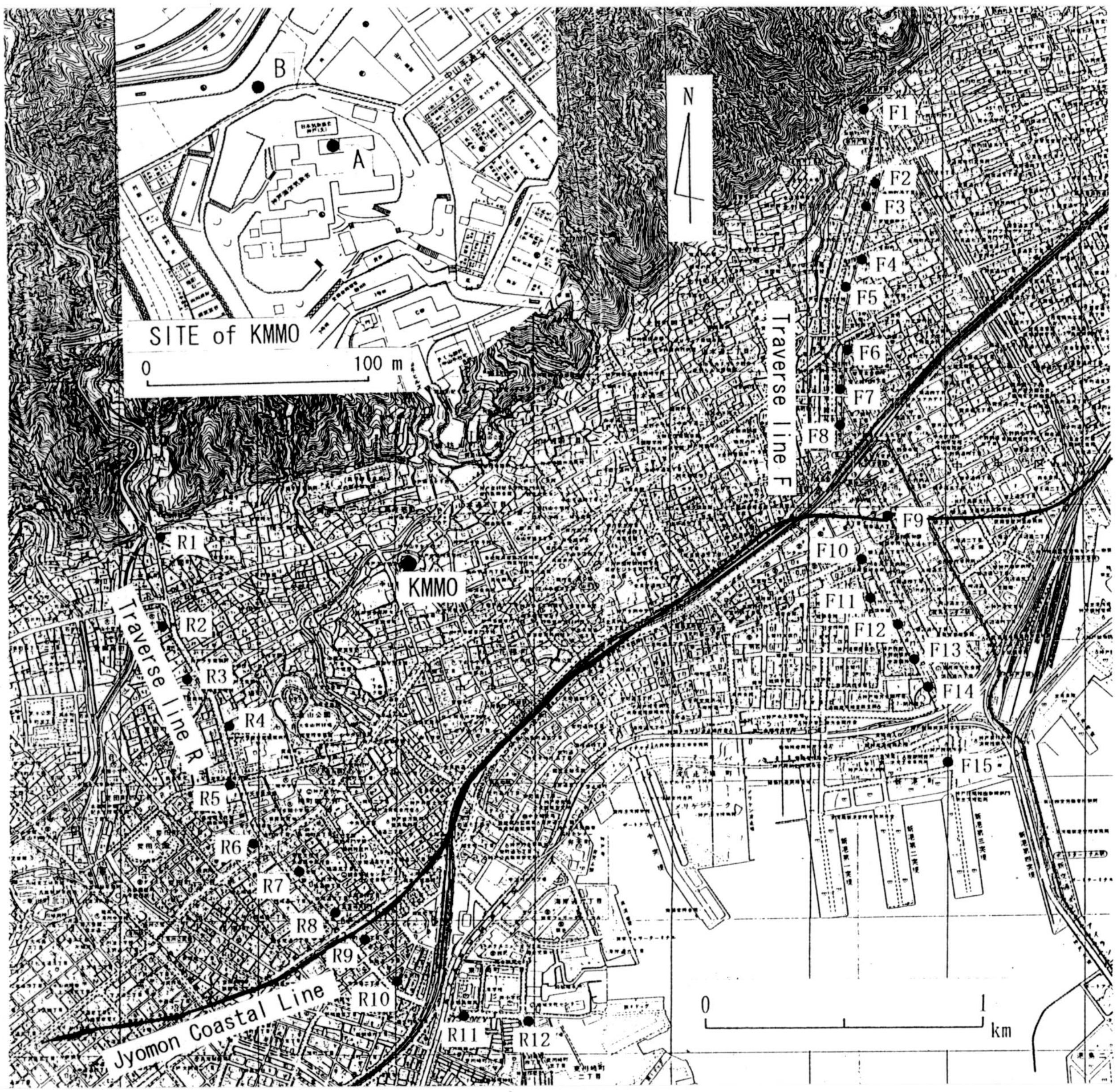


Figure 1 Location of observation sites (Jyomon Coastal Line is also depicted)

SURFACE GEOLOGY OF KOBE CITY

The southern part of Kobe city, suffered severely damaged area, is located between Rokko mountainous district and coast line of Osaka bay. The width of this area is approximately 2 to 3 km in east part and 5 km at maximum part. Rokko mountainous district is outcrop of granite bedrock, and is crossed by many faults. Maximum height is over 900 m above sea level. The surface geology of this area organized hilly zone, plateau, alluvial lowland and reclaimed land. Jyomon Coastal Line (a Holocene Coast line), that was actual coastal line about 6,000 years ago, depicted in Fig. 1, correspond to the boundary between diluvium and allubium (City of Kobe, 1980, Kansai Branch of Geotechnical Engineering Society, 1992). The reclamation had been operated in the past 100 years and such as Maya wharf, Rokko and Port Island, etc., were reclaimed. There are so many alluvial fans, most soils are gravels and sands, made by rivers, flow from Rokko mountainous district to Osaka Bay, in diluvium area.

TYPE OF MICROTREMOR MEASUREMENTS AND INSTRUMENTATION

Type of microtremor measurement

Two types of microtremor measurement were made. First one was simultaneous microtremor measurement at KMMO, where accelerograms with maximum amplitudes of 818 (N-S), 617(E-W) and 332(U-D) were observed during main shocks of Hyogoken-Nanbu earthquake. KMMO stands on top of Tertiary terrace. This terrace is about 25m higher than circumference. At KMMO, brick construction office building next to the observation house was collapsed by this earthquake. To elucidate topographical effect of terrace on seismic ground motion, this measurement was carried out. It was performed in the day time (about 3 to 5 o'clock in daytime) on Feb. 26, 1995. Second one was mobile measurement (consisted of 2 traverse lines), made along two streets, i.e., Route 428 and Flower road. Along Flower road, passes San'nomiya, one of the biggest downtown Kobe, all of buildings were investigated and understood feature of damage (Building Research Institute, 1995). Surface geology of measurement points F1 to F9 and R8 to R10 is Gravel, points F10 to F14 and R1 to 7 is clayey soil or sand-clay, and F15, R11 and R12 are reclaimed site. These measurements were made during midnight on Feb. 25 and 26, 1995 to avoid direct noise by human activity. It took about 6 hours and 3 hours for each traverse line. Measurement sites of simulations and mobile measurements are depicted in Fig. 1.

Equipment used microtremor measurement

The equipment used microtremor measurement consisted of high sensitive seismometers with moving coil system, amplifier and digital recorder. The natural period of the instrument is 1 sec, and could be extended electrically to 5 sec. The signals, after being amplified and digitized, are recorded on a disk of a lap top computer, enabling on site preliminary analysis. The overall response curve for this system is given in Fig. 2. This system works using car battery.

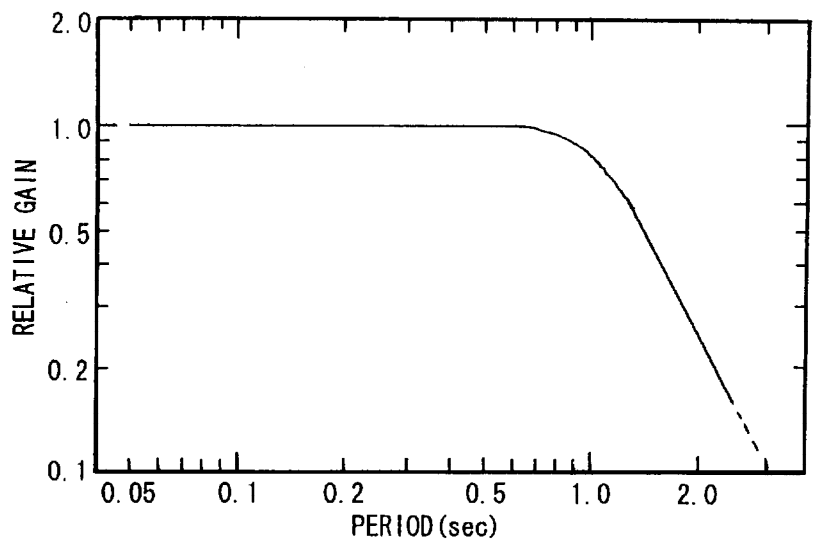


Figure 2 Overall response curve of microtremor measurement system

CHARACTERISTICS OF GROUND MOTION

Each measured record has a length of 60 to 120 sec. Fourier analysis of the records was done by dividing each record into 4 to 10 sections with 20.48 sec length, taking their mean. The band width of Parzen window used smoothing was 0.5 Hz. A 2-dimensional horizontal component was computed by taking geometric average of NS and EW components. The sections with very high direct noise cause by traffic were removed in the analysis.

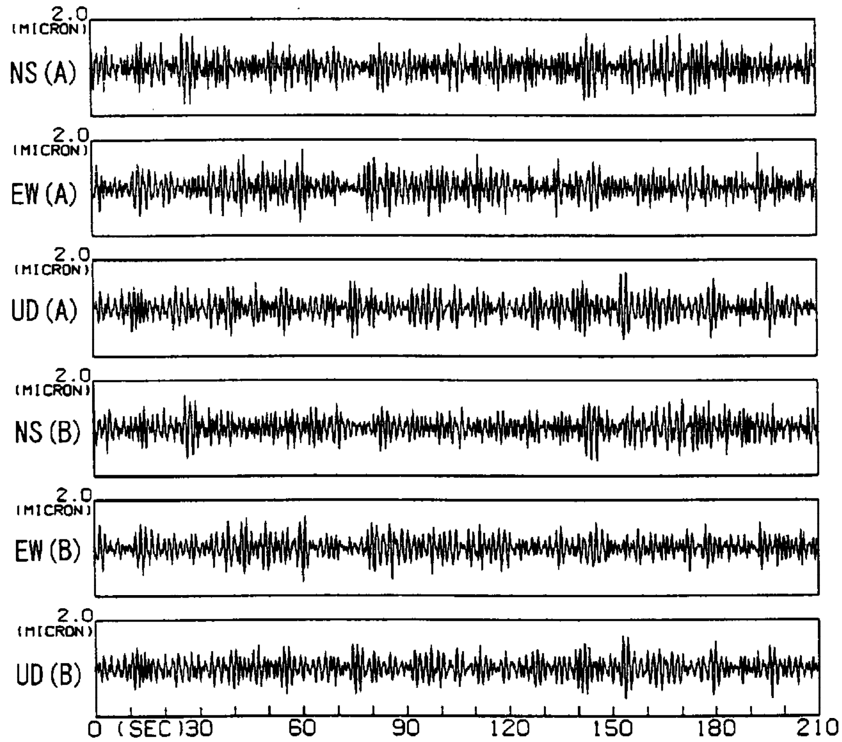


Figure 3 Wave-forms of simultaneous measurement at KMMO. Upper and lower three waves were measured at site A and B respectively.

Simultaneous measurement

Figure 3 shows wave form of measured microtremor. The amplitude of all components at Site B is slightly bigger than that of Site A, but clear phases with 1.5 sec apparent period are coincident each other component. Fourier spectra and spectral ratios (A/B) are shown in Figures 4 and 5. Solid lines and open lines in Fig. 4 correspond to Site A and B respectively. Concerning about horizontal components, the Fourier spectrum amplitude at Site A is approximately one fifth in shorter than 0.2 sec period range, double in 0.2 to 0.8 sec period range, and equal in longer than 0.8 sec period range compared to Site B. On the other hand about vertical component, the difference in 0.2 to 0.8 sec period range was not recognized. The short period range was affected by traffic vibration because Site B located more close to main street. Precisely, direct noise caused by traffic predominated in less than 0.2 sec period range was confirmed from other point data. Consequently, it is considered that the difference in 0.2 to 0.8 sec period range was affected by position of sites, i.e., the topographical effect of terrace.

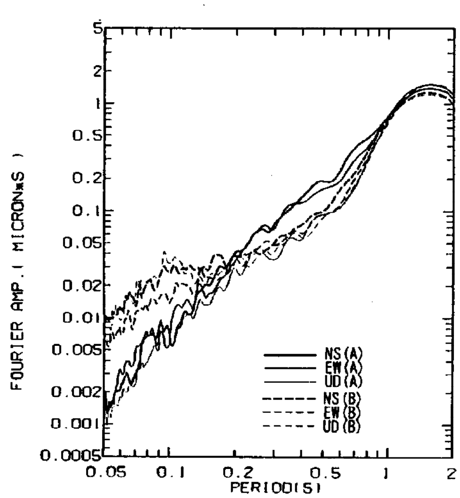


Figure 4 Comparison of Fourier spectra

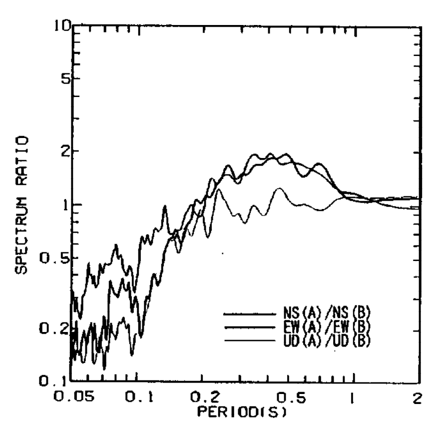
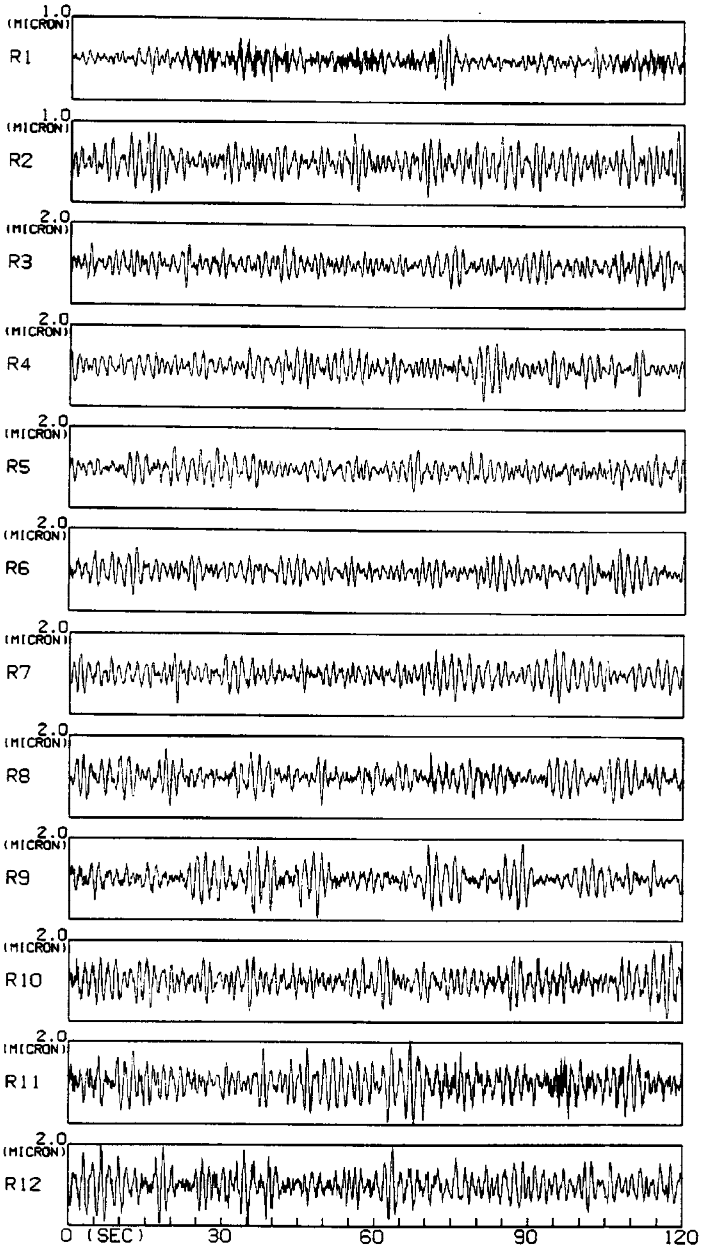


Figure 5 Spectra ratios (site A / site B)



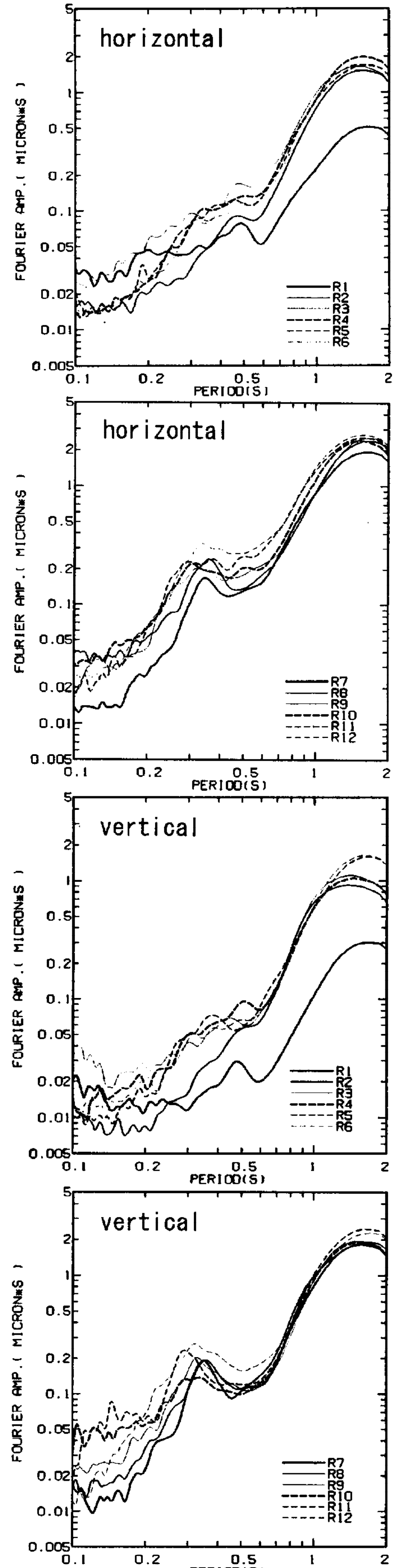
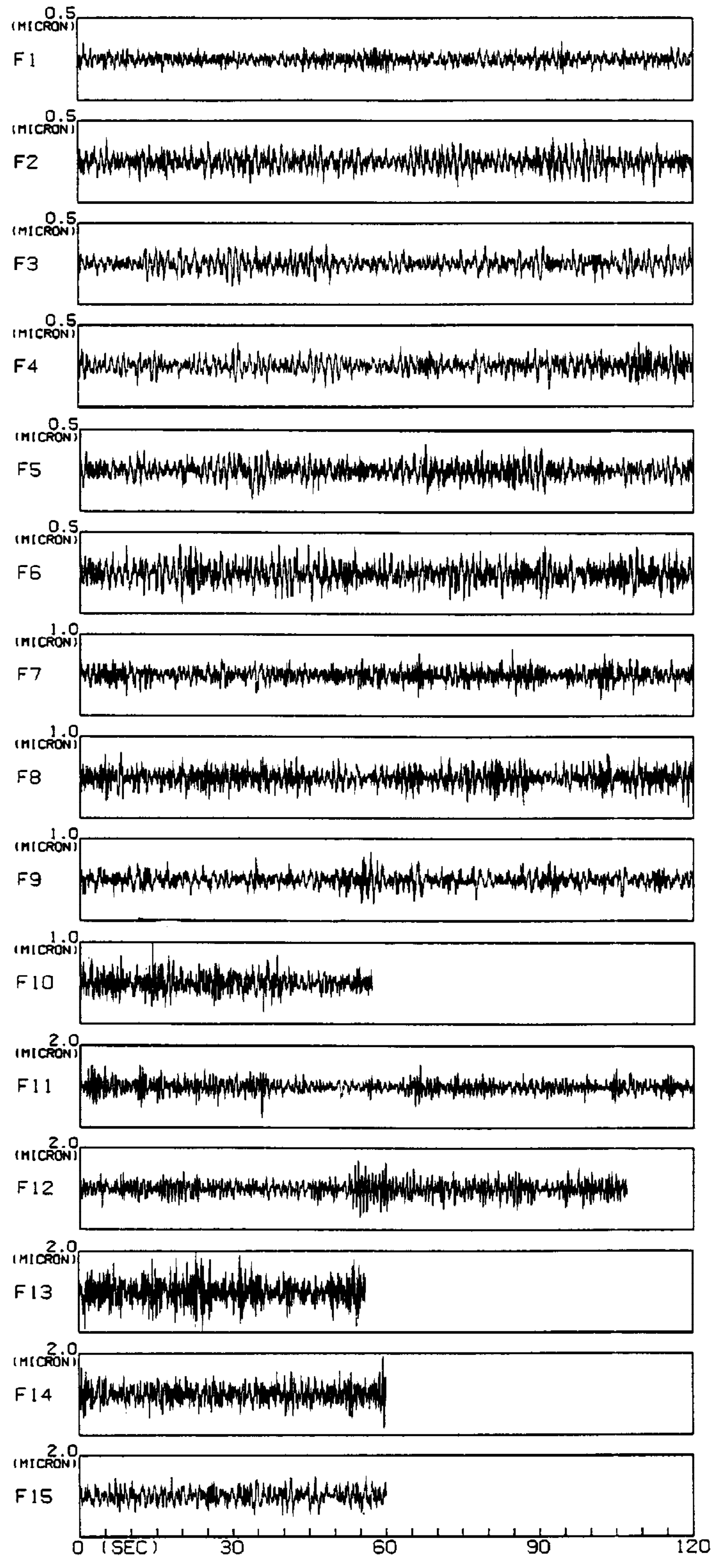


Figure 6 Wave-forms measured along R line and Fourier spectra
(2-dim horizontal comp. and vertical comp.)



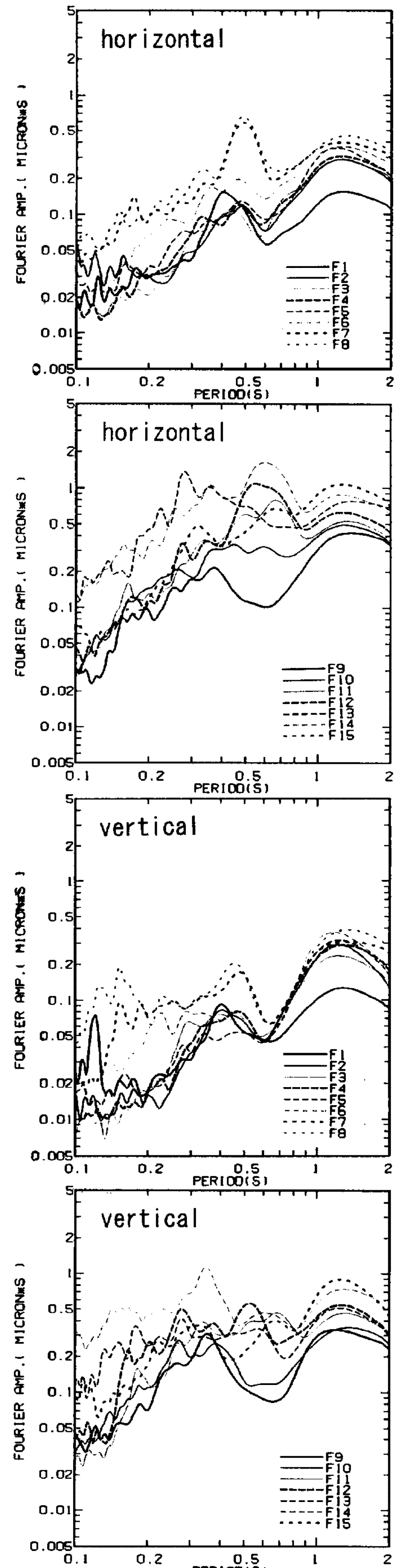


Figure 7 Wave-forms measured along F line and Fourier spectra
(2-dim horizontal comp. and vertical comp.)

Mobil measurements

Figures 6 and 7 shows NS component of measured microtremor. From both of figures, the amplitude is minimum at Site R1 and F1 and escalates as close to coastal line. The thickness of surface soil at points F1 and R1 are assumed shallow because they located close to mountainous district. Figures 6 and 7 also show Fourier spectra for each traverse line respectively. It was confirmed that the traffic vibrations affect short period range less than 0.2 sec. To make the differences of characteristics of ground motion more clear, spectral ratios about horizontal component are shown in Fig. 8.

About traverse line R, on both of horizontal and vertical components in longer than 0.3 sec period range, Fig. 6 shows that the amplitude of Fourier spectrum is minimum at Site R1 and escalates as close to coastal line from Site R2 to R12. By taking spectral ratios of each sites against R1, the minimum site, the characteristics appear more clear. In Fig. 8, the amplitude is increasing gradually from site R2 to R12 in all period range except less than 0.2 sec range. The small and clear peaks in 0.2 to 0.5 sec period range appear at site R3 to R6 and R7 to R12 groups. From the features of Fourier spectra and spectral ratios, these measurement sites are classified into three groups, i.e., R1 and R2 are in 1st group, R3 to R6 are in 2nd and R7 to R12 are in 3rd. Compared to Site R1, close to mountainous district, with quite shallow surface soil, it is expected that the shapes of Fourier spectra of other sites reflect the effect of surface soils. Especially, predominant period and its amplitude in the period range of 0.2 to 0.5 sec change drastically between R6 and R7. This change indicates that big differences of soil conditions exist between R6 and R7. Judging from geological information, the boundary of surface geology exists around R7.

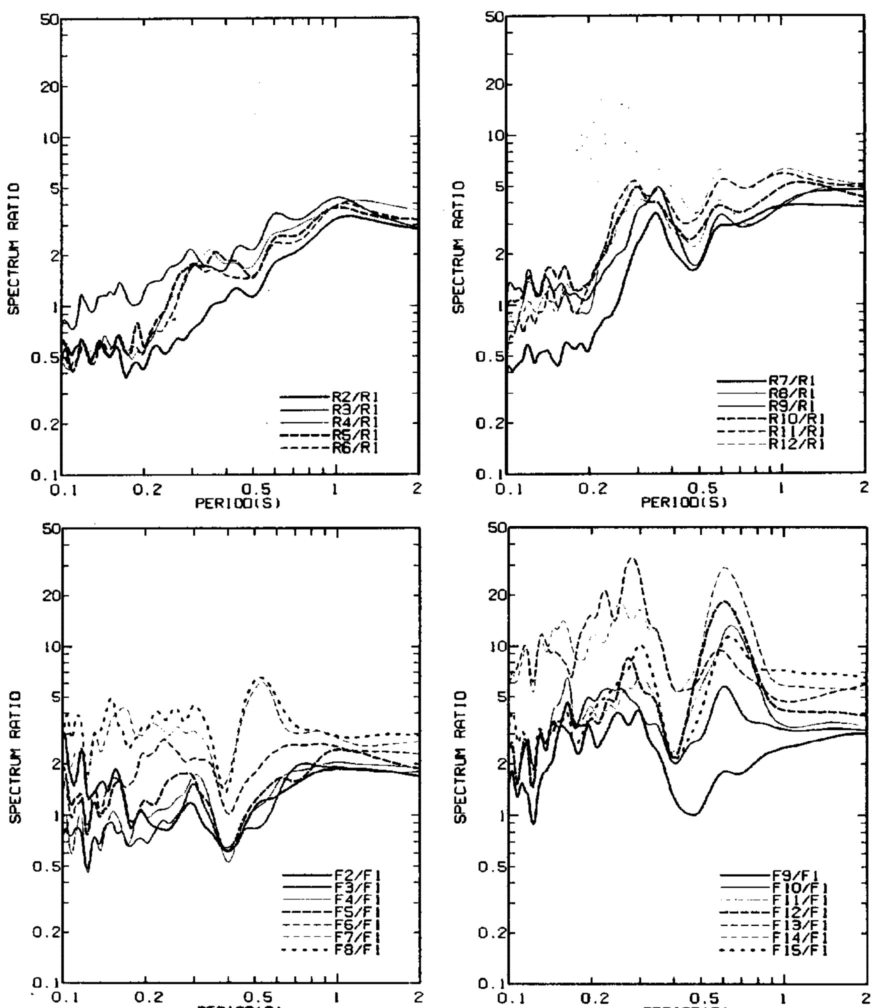


Figure 8 Spectral ratios about horizontal component
(Upper ; R line, Lower ; F line)

The shapes of Fourier spectra in horizontal component along F traverse line in Fig. 7 show that the amplitude at near coast is bigger than other sites, but the feature of escalation is not so smooth. For instance, the components of 0.5 to 0.7 sec range, appear as peaks on F7 to F15 except F9. Especially in F7 and 8, it might be affected adjacent buildings because clear predominant direction was recognized. Except these peaks in F7 and 8, the changes of features are quite same as the cases of R traverse line, i.e., the amplitude of Fourier spectrum in longer than 0.3 sec period range is minimum at Site F1 and escalates as close to coastal line from Site F2 to F15. From the spectral ratios in Fig. 8, two peaks, around 0.3 sec and 0.6 sec period, were recognized. The former peak appears from F9 to F15 and the latter one appear from F10 to F15. In case of vertical component, the amplitude and predominant period change systematically in 0.3 to 0.6 period range. From the features of spectra and spectral ratios, these measurement sites are classified into two groups from the 0.6 sec period, i.e., F1 to 9 are in 1st group and F10 to F15 are in 2nd. From geological information, Jyomon Coastal Line, the boundary of diluvium and alluvium pass around F9 (see Fig. 1).

CONCLUSION

Two types of microtremor measurements were performed to elucidate the characteristic of ground motion of Kobe area. After the simultaneous microtremor measurement, the Fourier spectrum amplitude of horizontal components at the top of terrace is approximately double in 0.2 to 0.8 sec period range. It is considered that this difference was affected by position of points, i.e., the topographical effect of terrace. By the mobile microtremor measurement, Fourier spectra and spectral ratios show that the characteristics of ground motion changes systematically corresponding to the ground condition. The alluvium and reclaimed sites show more amplification compared with diluvium sites. Especially, predominant period and its amplitude in the period range of 0.3 to 0.6 sec change drastically between points R6 and R7, point F9 and F10. Taking the results of microtremor measurement into consideration, it's possible to explain peculiar damage distribution.

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