OBSERVATION OF LONG-PERIOD MICROTREMORS WITH SPECIAL REFERENCE TO AN EVALUATION OF LONG-PERIOD SEISMIC MOTIONS ON THE EXTREMELY DEEP SOIL DEPOSIT

Hiroshi KAGAMI[I)], C.Martin DUKE[II)], George LIANG[II)] and Jun HORITA[I)]

SUMMARY

Long-period microtremors observations were carried out in Niigata Plain and Los Angeles Basin to evaluate predominated long-period strong motions recorded on extremely deep soil deposits during the 1964 Niigata Earthquake and the 1971 San Fernando Earthquake. Through simultaneous and repeated observations, it is indicated that amplitudes of microtremors in long-period range increase systematically from bedrock outcrop to deposit sites corresponding to the depth to bedrock. This relationship coincides with that derived from accelerograms obtained on extremely deep soil deposits in each area. These indicate long-period microtremors observation is powerful to clarify deep ground conditions and to estimate long-period seismic motions.

INTRODUCTION

It has been recognized that long-period waves predominate in strong motions obtained on extremely deep soil deposits. For a practical evaluation of long-period seismic input motions, it is necessary to reveal the dynamic characteristics of such deep soil deposits. Investigations of soil dynamic properties involve much efforts especially in case of deeper deposits. Recently an observation of long-period microtremors has been introduced as one of the convenient methods for clarification of deep soil natures.

By the authors, using long-period microtremors at Hachinohe, Aomori and Miyako, Japan, an interpretation was performed (Ohta,Kagami and et al, 1978) that predominated long-period strong motions of the 1968 Tokachioki Earthquake were mainly caused by site effects. In the above cases, thicknesses of soil deposits are degrees of several hundred meters, but there are many urban areas which situate on much deeper deposits. For typical examples, Niigata Plain in Japan and Los Angeles Basin in USA can be cited. In each area, predominated long-period seismic motions were recorded during the Niigata Earthquake of 1964 or the San Fernando Earthquake of 1971.

In this paper, an explanation why these long-period strong motions predominate is tried by measuring long-period microtremors in Niigata Plain and Los Angeles Basin.

I) Department of Architectural Engineering, Faculty of Engineering, Hokkaido University, Sapporo 060 JAPAN
II) School of Engineering and Applied Science, University of California at Los Angeles, California 90024 USA

LONG-PERIOD SEISMIC MOTIONS ON THE EXTREMELY DEEP SOIL DEPOSITS

Niigata Plain

Niigata Plain is alluvial one facing the Japan Sea. Total thickness of Quaternary layers in this area is almost 1 kilometer. Niigata City, of which population is about 430,000, is situated on the thickest deposit in this plain and was severely damaged by the Niigata Earthquake of June 16, 1964. The Richter Magnitude of this earthquake is 7.5 and the location of epicenter is plotted in Fig.1(a). During this earthquake strong motions were recorded by SMAC-type accelerograph installed at Kawagishi-cho, one of the most severely damaged areas in Niigata City. In this records, very large acceleration, as large as 100 gals, of which period is 5-6 seconds is remarkable as shown in Fig.1(b). And also in its Fourier spectrum peaks of 5-6 seconds are predominated (Fig.1(c)).

Los Angeles Basin

It is known that depth of soil deposits in Los Angeles Basin is also more than several kilometers. This Basin spreads south of Los Angeles and many urban areas, such as Long Beach, are located. In this area, many strong motion records were obtained during the San Fernando Earthquake of February 9, 1971, of which Magnitude was reported as 6.6. The location of epicenter and accelerograph sites in Los Angeles Basin and its vicinity are shown in Fig.2(a). From the reported Fourier spectrum of this earthquake motions (Hudson and et al, 1972), the maximum spectral amplitude at each site in period range of 1-10 sec is plotted in a map and Fig.2(b) is obtained. These values generally decrease with epicentral distance but the values in Long Beach area are relatively large. So, assuming that the amplitude attenuation with epicentral distance is denoted by the equation of " $-1.25 \cdot \log_{10}\Delta$ (Δ:epicentral distance),(after Espinosa,1977)", these values are normalized to the values at 100 km in epicentral distance and plotted in Fig.2(c). This new contour map clearly shows that the values at the sites in Los Angeles Basin are several times larger than those at bedrock outcrop sites of its environs.

OBSERVATION OF MICROTREMORS IN NIIGATA PLAIN

Observation of long-period microtremors were carried out in Niigata Plain in August 1977. Following observation system was prepared. The pickup is a conpact size moving-coil type velocity seismometer of which natural period is 10 seconds. Using a RC-filter, short-period microtremors and noises are cut off so that the velocity sensitivity can be flat in the period range of 2-8 seconds. And signals are amplified about several hundred times and recorded to cassette magnetic tape.

Observations were done at 9 points on the line of which length is about 30 kilometers as shown in Fig.3(a). Geological section along this line is illustlated in Fig.3(b). Observation point No.1 was chosen near the accelerograph site, and No.9 was set up on the outcrop of Palaeozoic rock. A total depth to the bedrock is the deepest at No.1 and decreases generally in an ascending order of point number. But near No.5 the thickness of alluvial layer is very thin. Simultaneous observation at 9 points were carried out in every 8 hours for 5 days, then totally 15 times 9 simultaneous records were obtained.

Fourier spectra of these records were calculated and typical ones are displayed in Fig.4. It is obvious from this figure that spectral amplitude at deep deposit site (No.1 and 2) is several tens times larger than that at bedrock site (No.9). For each simultaneous observation, maximum spectral amplitudes at 9 points are drawn in Fig.5(a) by a fine zigzag line. Although those values at each point widly change with time, these lines show same pattern each other, and it is suggested that microtremors at all points are caused by a common source. In other words this means that ratios of the amplitudes between any two observation points show respectively almost a constant value against time variation and it is considered that these ratios correspond to difference of subsoil conditions between the both sites. Assuming that microtremors observed at bedrock outcrop'site have no soil effect, the amplitude ratio at each point to bedrock site (No.9) was introduced. These values were calculated for three period ranges (1-2, 2-5 and 5-10 seconds) and are shown in Fig.5(b). The values at No.1, nearest point to the accelerograph site, are the largest of all. This ratios to bedrock site generally decrease from No.1 to No.9, and No.5 these ratios are rather smaller. This relation is more emphasized in case of shorter period. These results are corresponding to subsoil conditions shown in Fig.3.

OBSERVATION OF MICROTREMORS IN LOS ANGELES BASIN

In Los Angeles Basin, observation of microtremors were done in December 1978 with same observation system used in Niigata Plain. As shown in Fig.6, 4 observation lines (A, B, C and D) were chosen from bedrock outcrop to deposit sites so that they include many accelerograph sites. Total number of observation points were 25, and points No.A-1, C-9 and D-5 were set on the outcrop of bedrock. A following observation method was taken with two sets of systems. One set is fixed at a certain place as "Reference Point" to watch the time variation of microtremors and with the other set sequential observations were repeatedly performed from point to point. The reference point was set up at the University of California Irvine Campus, and microtremors were periodically recorded for 15 minutes duration at every 90 minutes.

Fourier spectra were calculated, and typical spectra in various sites are shown in Fig.7(a). All the spectra show same pattern each other having a remarkable peak in the period range of 6-7 seconds. Spectral amplitudes are larger at deposit sites than those at bedrock sites. Spectra at the reference point also have remarkable peak of 6-7 seconds like in other points as shown in Fig.7(b). As for the time variation of spectral amplitude, in the period range of 1-3 seconds the spectral amplitude of December 8 are a little larger than those of other days, but in other period ranges there are no significant difference among the spectra.

From above matters, the time variation of microtremors is not so large in this observation period, so assuming a steadiness of microtremors in this duration, it will be possible to compare directly these spectra observed at various points each other by cancelling the effect of small time variation, even though these are obtained at different time. Spectral values at each point were divided by that of reference point of corresponding time, and these ratios which togethered to 3 period ranges are plotted in Fig.8. For all period ranges, these ratios are larger at deposit sites and are smaller at bedrock sites. The ratios on the D-line which lies hilly area show smaller values. This inclination is very similar to that shown in Fig.2(c), which was evaluated from the strong motion data, and also shows good correlation with deep soil conditions.

CONCLUDING REMARKS

Microtremors observation has the advantage of convenience,although spectra of long-period microtremors widly change with the meteorological conditions. Therefore a comparative observation at several points along an observation line is essential, where an outcrop of bedrock and gradually changing soil structures can be expected, and observations should be performed simultaneously and repeatedly.

Through the systematic observations of long-period microtremors in Niigata Plain and Los Angeles Basin, we arrived at the following results. Spectral amplitude of long-period microtremors increases systematically with a total thickness of deposits from bedrock outcrop site to deposit sites. Similarly long-period motions also predominate in accelerograms in relation to depth of deposit. These indicate long-period microtremors observation is available both to clarify deep soil dynamic properties, and to estimate long-period seismic motions.

In this report, the relation between amplitudes of microtremors and thickness of deposit was mentioned. For further improvement of long-period microtremors applicability in earthquake engineering, theoretical treatment by elucidating their generation, propagation (attenuation) and amplification due to ground layers should be required.

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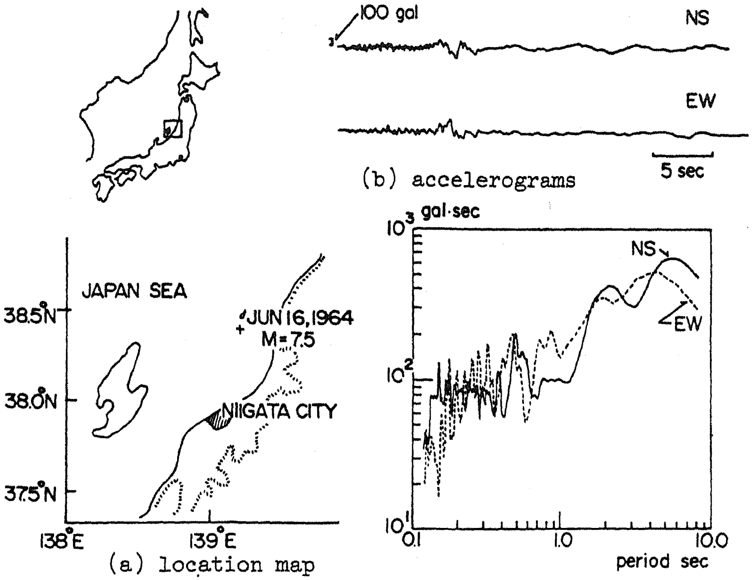
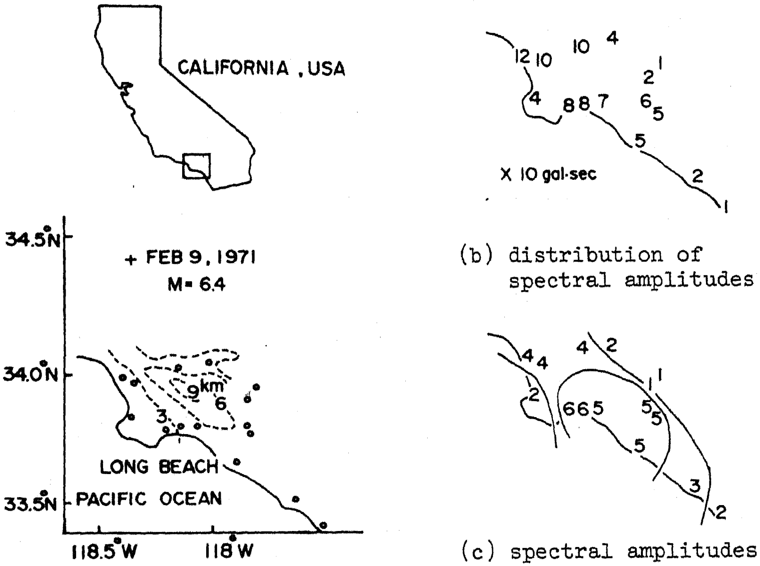


(a) location map

(b) accelerograms

(c) Fourier spectra

Fig.1 Strong motion records of the 1964 Niigata Earthquake

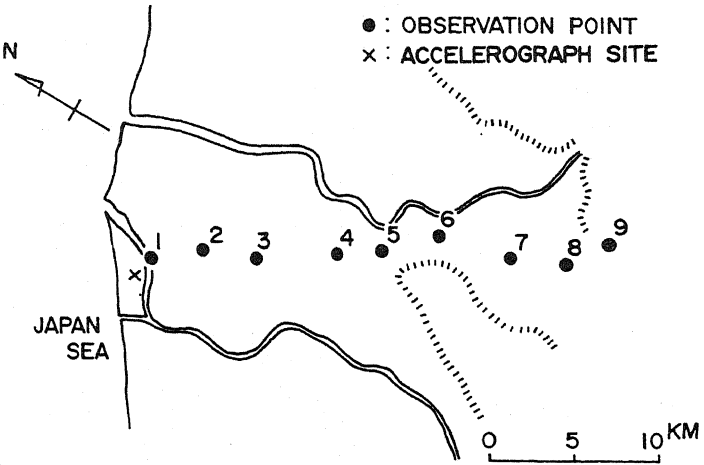


(a) location map

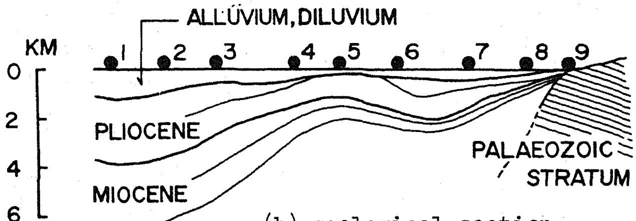
(b) distribution of spectral amplitudes

(c) spectral amplitudes normalized to 100 km in epicentral distance

Fig.2. Spectral amplitudes of strong motions due to the 1971 San Fernando Earthquake



(a) location map



(b) geological section

Fig.3 Observation points of long-period microtremors in Niigata Plain

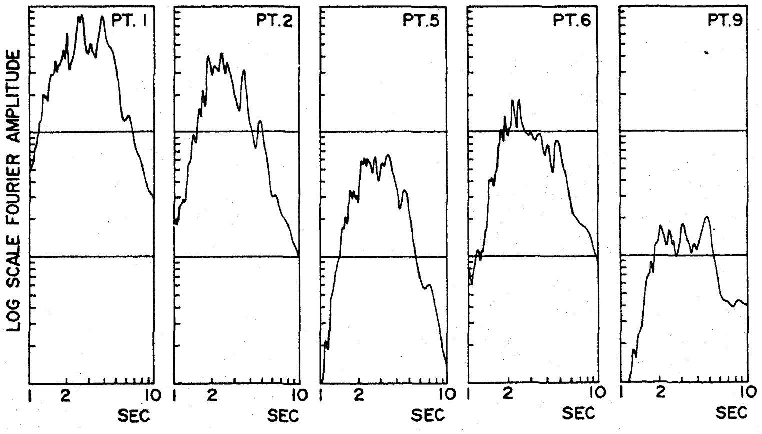
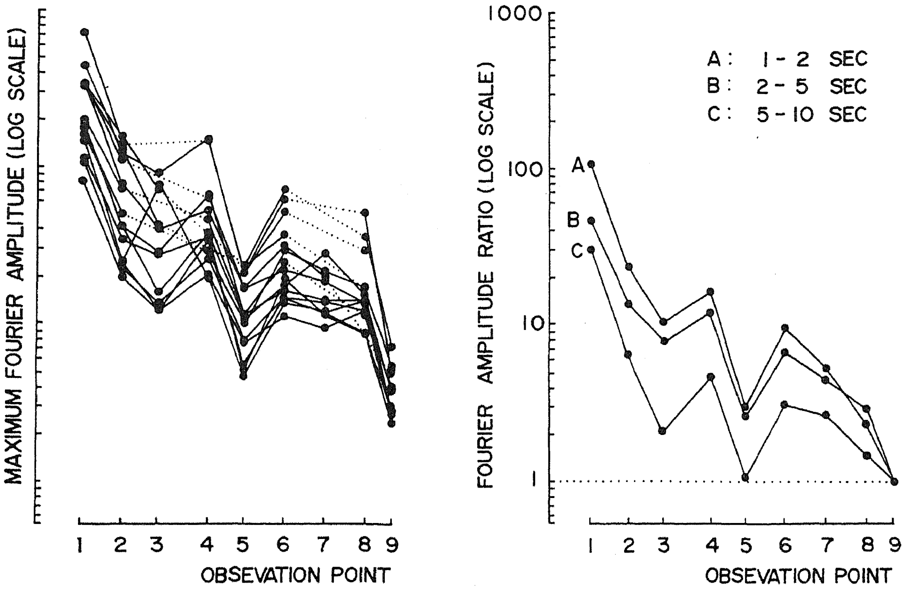


Fig.4 Examples of Fourier spectra in Niigata



(a) maximum amplitudes at each observation time

(b) amplitude ratios at each point to bedrock site in three period ranges

Fig.5 Presentation of spectral amplitudes at each point from deep deposit to bedrock site

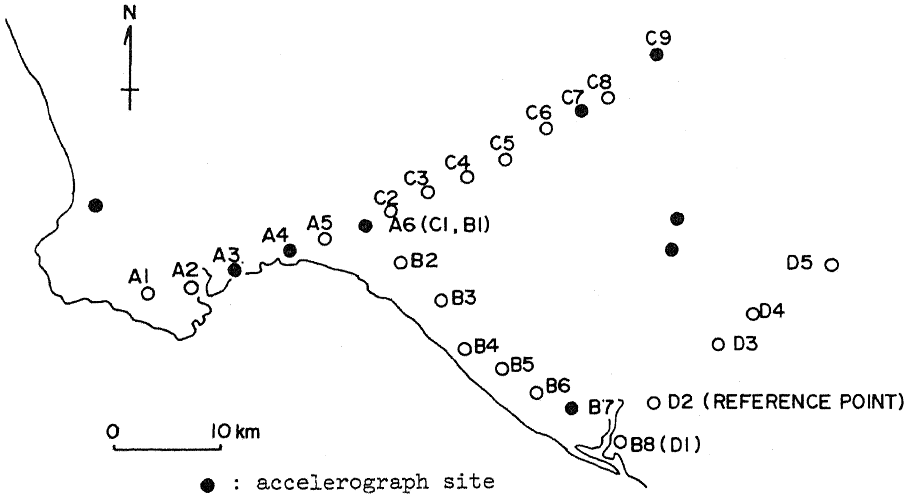
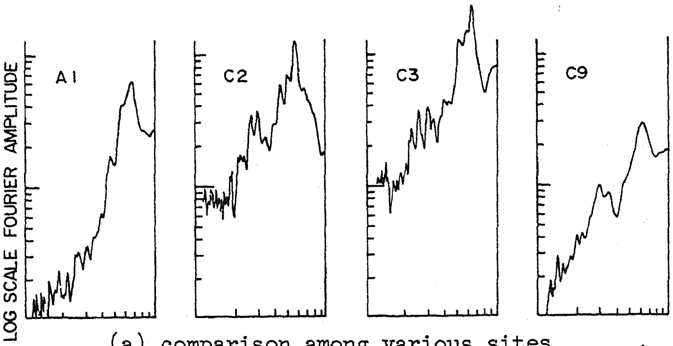
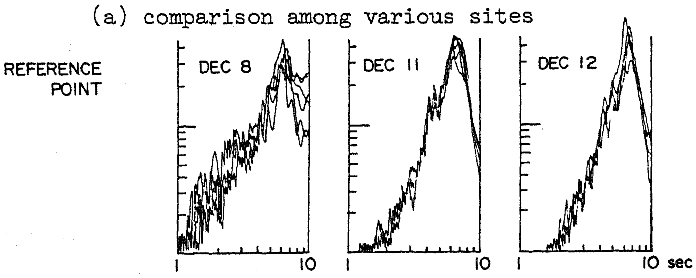


Fig.6 Observation points of long-period microtremors in Los Angeles Basin



(a) comparison among various sites



(b) time variation at reference point

Fig.7 Fourier spectra obtained in Los Angeles Basin

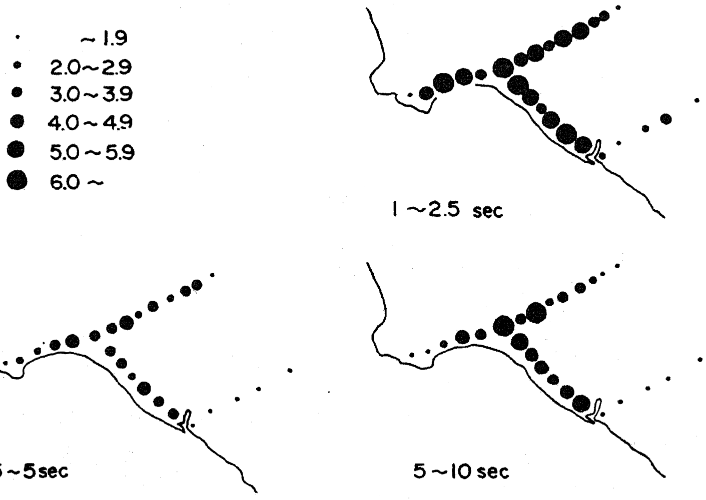


Fig.8 Maps showing ratio of spectral amplitude of microtremor at each point to reference point