EFFECTS OF GROUND STRUCTURES WITH LATERALLY STEEP VARIATIONS ON SEISMIC MOTIONS

BY

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SUMMARY

Microtremors and earthquake motions are observed at an area where the underground structure is estimated to contain horrizontally irregular interfaces. The spatial correlation characteristics of microtremors are significantly affected by the horizontal irregularity of surface layers and lateral variations of the amplitudes of microtremors are explainable by transmission and reflection of surface waves at a vertical discontinuity. Amplification characteristics by the ground structures, estimated through a comparison of spectra of earthquake motions at the rock site to those at the alluvium sites, are dependent not only on the structures immediately below the given sites but also those under adjacent areas.

1. INTRODUCTION

The reports of the earthquake damages have been frequently noted that damage regions are sometimes confined to small zones, where local geological configulations have steeply lateral variation. For example, intense damages at Skopie earthquake in 1963 are recorded along a belt which is defined by an abrupt change of the thickness of the alluvium (Poceski,1969).

Also the damage regions at the northern Yamanashi earthquake in 1976 are remarkably apparent along the Tsurukawa fault belt (Murai, 1977). In this study the following two problems are discussed. One is to deduce the method of detecting the area having lateral irregularity of ground structures by using microtremors data obtained readily. The other is to deduce directly the amplification effects by observing earthquake motions in those areas.

2. OBSERVATIONAL RESULTS OF MICROTREMORS

An area of the south-eastern part of Kyoto basin provides a good condition to examine this problem. The underground profile of the cross section from east to west in this area is estimated by Kitsunezaki, at el. (1971) by means of refraction method of P waves as shown in Fig.3. It has been inferred that the place where the surface layer's thickness changes steeply, is located to the extension of Obaku fault.

Microtremors are observed at 11 points, indicated as S2 to S12 by open circles in Fig.1. Simultaneous observations are made at evey 3 points selected appropiately to examine the amplitudes and phases of microtremors from point to point over this area. In Fig.2,

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the p ver spectral ratios between the appropriate 2 points are arrar ed to show where the power spectra of microtremors change most remar ably. The left figures show power spectral ratios between the two points, which are located at the west side to the fault and the right figures show those between the two points, which are located at the east side to the fault. The middle figures show those between the two points, which are inferred to be across the fault. These figures suggest abruptly horizontal irregularities of the ground structures between S8 and S7D point.

The lateral variations of the power spectra of microtremors are approximately explainable in terms of transmissions and reflections of Rayleigh waves at vertical discontinuities in the propagation from thick to thin surface layers, i.e. from the west to the east side of the fault. The theoretical transmission coefficients are calculated using the method developed by Gregersen and Alsop (1974), as shown in the bottom of the middle figures.

3. OBSERVATIONAL RESULTS OF EARTHQUAKE MOTIONS

Earthquake motions are observed at 5 points indicated with (+) marks in Fig.3. C_1 points, located at about 1 km west to the fault, is underlied by the thick soft layers, O_1 point, about 1 km east to the fault, is on rock outcrop, and the 3 points, G_1, G_2 and G_3, are set in the immediate vicinity of the fault, where the thicknesses of the soft surface layers change steeply between G_1 and G_3.

An analyzed example of the earthquake motions from a deep earthquake is shown in Fig.4. The wave-form and the Fourier spectrum of S wave motion at each point are compared, and the spectral ratios of the ground motion at each point underlied by soft layers to the rock motion at O_1 point are computed to estimate the amplification effects owing to the ground structures. In the case of a deep earthquake from near-distance, the seismic waves approach to these points at nearly vertical incidence. The three spectral ratios of NS components, G_1/O_1, G_2/O_1, and G_3/O_1 have significantly a common peak around 1.5 Hz. Those of EW components do not always have so significant common-peaks. The ratios, C_1/O_1 show a different tendancy, having two significant peaks around 0.5 Hz and 1.5 Hz. In Fig.5, the spectral ratios are compared with the theoretical responses owing to the ground structures immediately beneath each site, assuming flat layers. C_1 model is in a good agreement with the observed results. However, G_1 and G_3 models are not consistent with the observed. (G) model is assumed as an ⟨average⟩ media by making a reference to the ground structures of both sides of the fault. The spectral ratios, G_1/O_1, G_2/O_1 and G_3/O_1 tend to be consistent with (G) model, assumed as an average, rather than G_1 and G_3 model, estimated by seismic prospecting and boring data.

In Fig.6, analyzed examples of earthquake motions from shallow earthquake are shown. The seismic waves are considered to approach to these sites at oblique incidence. The left figures show the cases arriving from the west, that is, propagating from thick layers to thin ones, and the right figures show the cases from the opposite directions. The ratios, G_1/O_1, show significantly larger factors than do the ratios, G_3/O_1, in the lower frequency ranges (lower than 5 Hz in Fig.6), although they show the factors of the same order in the higher frequency ranges. This is considered to cause to the lateral variations of the thicknesses of surface layers. The peak frequencies of the spectral ratios have a tendancy of shifting to lower frequencies in the case of thick to thin layers than those in the case of thin to thick layers.

These results observed show that the amplification characteristeics of a given site are not only determined by the underground structures immediately below the site but also influenced by the structures involving the adjacent area in propagation of the seismic waves.

REFERENCE

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Poceski,A. (1969). The ground effect of the Skopie July 26 1963 earthquake, Bull.Seism.Soc.Am.59,pp.1-22.

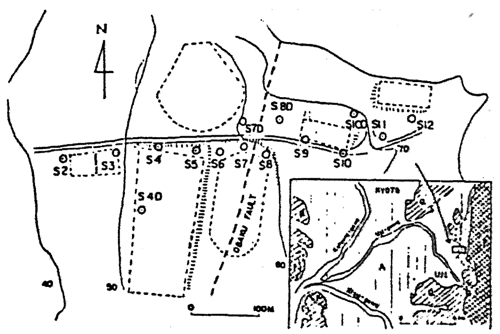


Fig.1 Topographical map in vicinity of observational points of microtremors. P: Paleozoic rocks. Q: Terrase deposits of dilivium. A: Alluvial deposits.

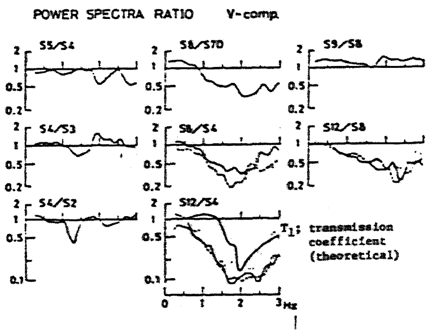


Fig.2 Left, Right: Power spectral ratios of microtremors between the two points at the west side and east side of the fault. Middle: Power spectral ratios between the two points across the fault.

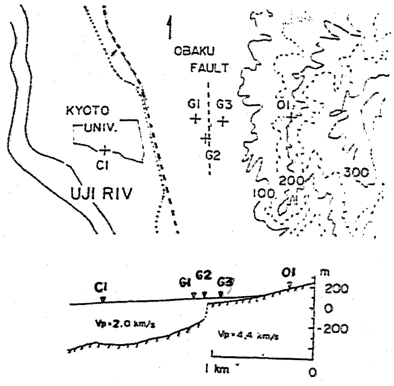


Fig.3 Observational points, C_1, G_1, G_2, G_3 and O_1 for earthquake motions and vertical cross section of underground structures.

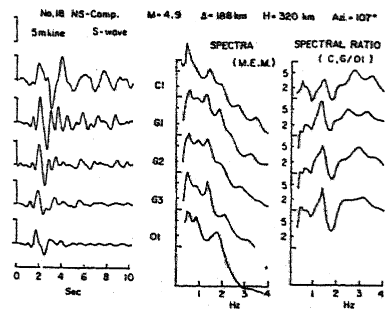
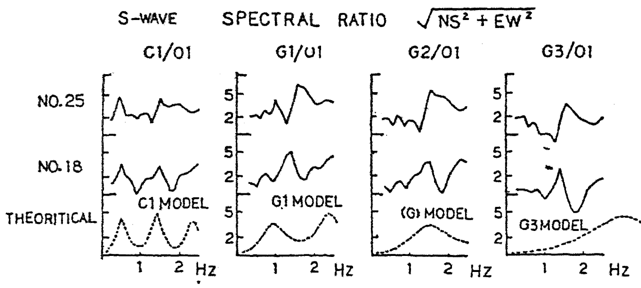


Fig.4 Waveforms and Fourier spectra of S waves' motions from a deep earthquake and spectral ratios, C_1/O_1, G_1/O_1, G_2/O_1 and G_3/O_1.



LAYERED MODEL
(S VELOCITY (m/s) : DENSITY (g/cm³) : THICKNESS (m))

C1			G1			(G)			G3		
250	1.7	3	250	1.7	5	250	1.7	5	250	1.7	5
440	1.8	12	500	1.9	50	500	1.9	20	500	1.9	20
320	1.8	6	750	2.1	150	750	2.1	100	750	2.1	20
580	1.9	11	2400	2.5		2400	2.5		2400	2.5	
460	1.9	8									
580	2.0	80									
750	2.1	250									
2400	2.5										

Fig.5. The comparison of the spectral ratio at each point with the theoretical response. The observed values are estimated for 2 deep earthquakes (No.25 and 18).

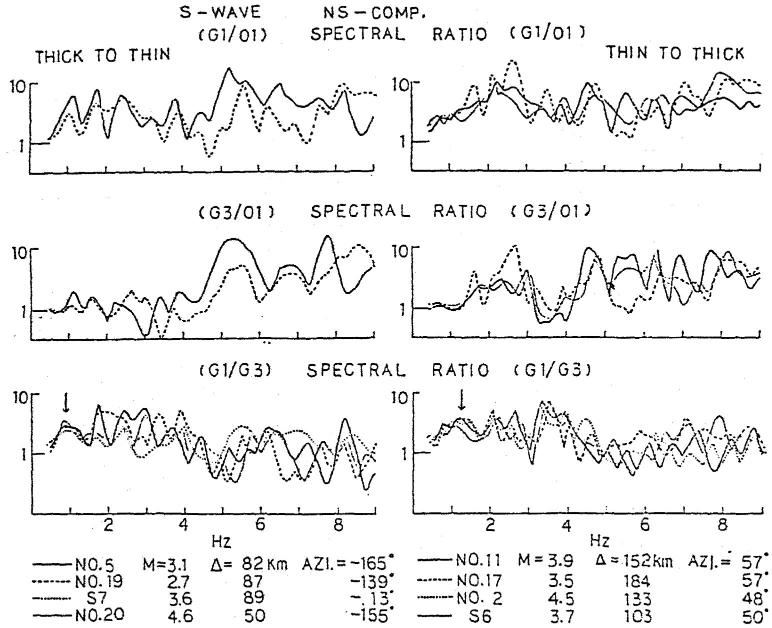


Fig.6 The spectral ratios of seismic waves, G_1/O_1, G_3/O_1 and G_1/G_3, from shallow earthquakes. Left is the case of seismic waves arriving from west, i.e. thick to thin layers and Right is the case, from east , i.e. thin to thick layers.