A METHOD FOR PRESUMING DEEP GROUND SOIL STRUCTURES BY MEANS OF LONGER PERIOD MICROTREMORS

by
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SUMMARY

A method for presuming deep ground soil structures by using Rayleigh-wave components of longer period microtremors and the value of time-term obtained from seismic prospectings was proposed. This method was applied to the investigation of the deep ground soil structure of Ukishima, Kawasaki. As results, it was found that longer period microtremors are composed mainly of Rayleigh-waves, and the amplitude ratio of the vertical to horizontal motion of longer period microtremors holds good for the investigation of deep ground soil structure.

INTRODUCTION

It is very important to elucidate deep ground soil structures and understand the ground characteristics of period range up to 10 seconds during earthquakes, because high rise buildings and huge structures are common in the urban area, at present. For this purpose, seismic prospectings by means of explosion were carried out in Tokyo Metropolitan Area(1). As results, it has been made clear that the deep ground soil structure of Tokyo Metropolitan Area consists of three layers, and three dimensional feature of the seismic bedrock is expressed by the time-term method. However, the thickness of each layer cannot be determined only from time-term, because time-term of this case is related to the two layers above the seismic bedrock. On the other hand, for the purpose of the application of longer period microtremors to earthquake engineering, systematic observations of longer period microtremors were carried out by Ohta et al.(2), and it has been pointed out that longer period microtremors can be interpreted as an ensemble of dispersive waves; Rayleigh-waves are particularly dominant.

In this paper, the author tried to presume deep ground soil structures by using Rayleigh-wave components of longer period microtremors and time-term obtained from seismic prospectings, and ascertained an application possibility of longer period microtremors to earthquake engineering technique.

A METHOD FOR PRESUMING DEEP GROUND SOIL STRUCTURES

A characteristic of Rayleigh-waves is that the amplitude ratio of the vertical to horizontal motion on multi-layered ground is decided from subsoil structure. For the investigation of the amplitude ratio of Rayleigh-waves, the deep ground soil structure of Tokyo Metropolitan Area was modeled as three layered model shown in Fig.1, where the value D means the depth of the seismic bedrock and the value k means the ratio of the thickness of the 1st layer to the depth of the seismic bedrock. For this model, the shape of the amplitude ratio depends only on k value and is independent of

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D value, and the amplitude ratio for each mode indicates the minimum value at a certain period, as shown in Fig.2. The period corresponding to the minimum amplitude ratio can be expressed as a function of D and k value. When k value is equal, this period is proportional to D value. Fig.3 shows the relation between the period corresponding to the minimum amplitude ratio and k value, when D value is 1 km.

On the other hand, time-term Tm is expressed by the following equation.

$$Tm = \Sigma\ Hi \times \cos\Theta / Vi \qquad \Theta = \sin^{-1} Vi / Vi{+}1$$

where Hi and Vi are the thickness and the velocity of the i-th layer, respectively. In this case, it is given as follows.

$$Tm = D \times (0.117 \times k + 0.309)$$

From the facts mentioned above, if the period corresponding to the minimum amplitude ratio is given, D value can be expressed by a function of k value. On the other hand, D value can be expressed by a function of k value from time-term, independently. And the depth of the seismic bedrock D and the ratio of the thickness of the 1st layer to the depth of the seismic bedrock k can be finally determined on the crossing point of two lines which represent the above two functions.

PRESUMPTION OF DEEP GROUND SOIL STRUCTURE

Longer period microtremors were measured every 6 hours during 12 days at Ukishima, Kawasaki. For their analyses, Fourier orbital analysis(3) was adopted, using three components of record simultaneously. The amplitude ratio of the vertical to horizontal motion at individual periods is shown in Fig.4. The full circle shows the amplitude ratio at midnight of 16th Feb., when the atmospheric pressure was low, and the open circle shows the amplitude ratio at the predominant period in conditions of high atmospheric pressure. Both of them showed the same trends, and indicated the minimum at about 5.8 sec period. Fig.5 shows the frequency of the amplitude ratio during 12 days, where Arabic numerals indicate the frequency. The amplitude ratio showing the high frequency at individual periods was well fitted with that of 16th Feb.. The author assumed longer period microtremors of 16th Feb. as the M_{II} mode of Rayleigh-waves. On the other hand, time-term at Ukishima was inferred to be about 0.95 sec from the seismic prospecting at Yumenoshima, Tokyo(P-wave velocity of the seismic bedrock being assumed as 5.1 km/sec)(4).

These data were used for presuming the deep ground soil structure of Ukishima. The result is shown in Fig.6, where the full line was determined from longer period microtremors, and the broken line was determined from time-term. The zone indicated with oblique lines represents the deep ground soil structure of Ukishima, that is, the depth of the seismic bedrock is about 2.5 km and the ratio of the thickness of the 1st layer to the depth of the seismic bedrock is about 0.35. Fig.7 shows the comparison between the observed amplitude ratio and the theoretical one calculated from the presumed layered subsoil structure shown in the upper part of this figure. The theoretical amplitude ratio is well fitted with the observed one. And this presumed layered subsoil structure is consistent with the results from the seismic prospecting carried out at Ohgishima, Kawasaki(5).

CONCLUSION

The author proposed a method for presuming deep ground soil structures by using Rayleigh-wave components of longer period microtremors and the value of time-term obtained from seismic prospectings, and confirmed its adequacy. It was found that the amplitude ratio of the vertical to horizontal motion of longer period microtremors holds good for the investigation of deep ground soil structure.

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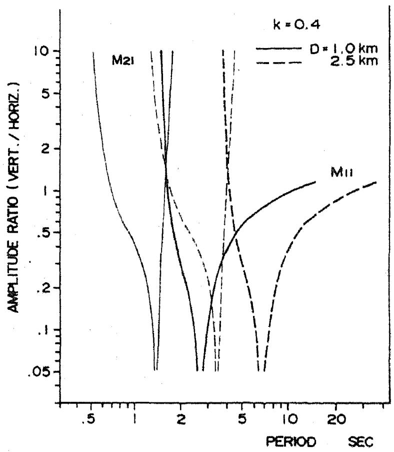
V_p (km/s)	V_s (km/s)	ρ (t/m^3)	DEPTH
			0
1.8	0.68	1.9	
			k×D
2.8	1.5	2.2	
			D
5.6	3.0	2.5	

D: DEPTH OF SEISMIC BEDROCK

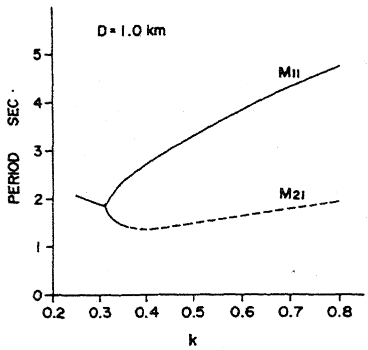
k: RATIO OF DEPTH OF INTERFACE BETWEEN 1st LAYER AND 2nd LAYER TO DEPTH OF SEISMIC BEDROCK

DEEP SOIL STRUCTURE

Fig.1



THEORETICAL RATIO OF VERTICAL TO HORIZONTAL AMPLITUDE OF RAYLEIGH WAVES



PERIOD CORRESPONDING TO MINIMUM VALUE OF THEORETICAL RATIO OF VERTICAL TO HORIZONTAL AMPLITUDE OF RAYLEIGH WAVES

Fig.3

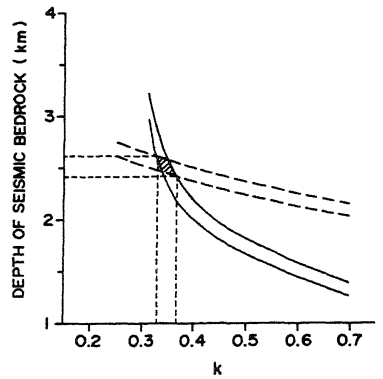
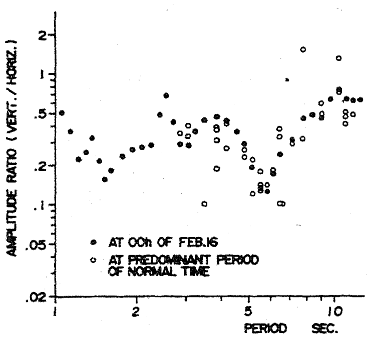
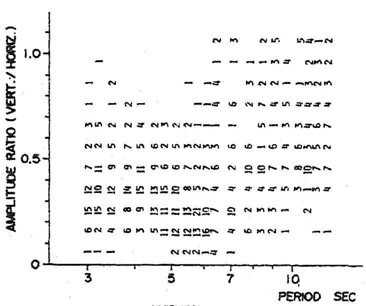


Fig.6



AMPLITUDE RATIO OF VERTICAL TO HORIZONTAL COMPONENT

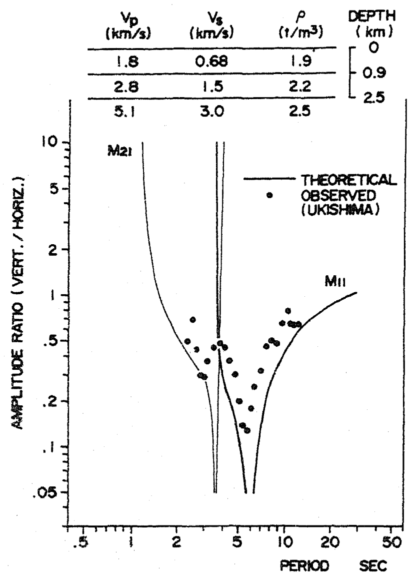
Fig.4



UKISHIMA

FREQUENCY DISTRIBUTION OF AMPLITUDE RATIO OF VERTICAL TO HORIZONTAL COMPONENT

Fig.5



COMPARISON OF OBSERVED RATIO WITH THEORETICAL RATIO OF VERTICAL TO HORIZONTAL AMPLITUDE

Fig.7