Characteristics of Seismic Waves in Bedrock at the Higashi-Matsuyama Earthquake

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Synopsis

In the present paper, using 13 SMAC-records in Tokyo district at the Higashi-Matsuyama Earthquake (M=6.1, JMA intensity IV in Tokyo), seismic waves in bedrock were presumed by the multiple reflection theory, and their characteristics were examined in qualitatively and quantitatively.

Introduction

It has been said that seismic waves observed at some site contain much effect of local surface layers directly under the site. For this reason, it is rather difficult still now to evaluate the input seismic waves in wide area by using those observed waves. And moreover, we often hesitate to assume the adequate input waves to be used for dynamic design of structure at a certain site.

For the purpose of resolving these problems, following two points were studied in this paper from observed seismic records and microtremors at widely spreaded sites.

(i) Effects of surface layers during earthquakes and microtremors
(ii) Characteristics of incident waves at the bedrock in wide area

In this study, only NS component seismic records(1) of Higashi-Matsuyama Earthquake and microtremors(2) at thirteen sites in Tokyo Metropolitan area shown in Fig. 1 and Table-1 were used to analysis. But the effects of building structures to be contained in recorded waves were neglected herein.

The Effects of Surface Layers during Eartnquakes and Microtremors

Relations between the maximum acceleration or velocity amplitude and epicentral distance are given in Fig.2 and 3. These widely scattered values show the effect of local characteristics of observation sites.

By the way, frequency characteristics between earthquakes and microtremors generally have a good correlation as shown in Fig.4. (Fourier spectra of earthquakes) and Fig.5 (Fourier spectra and frequency distribution curves of microtremors) for example. From these studies, the local characteristics are seemed particular and stable nature for respective sites.

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Here we constructed ground models consisting from three to five surface layers for every site from the known boring data3) Soil constants were assumed as shown in Table-2. Assumed depths of bedrock were also decided from the same reference. By using these models, amplification characteristics calculated by the multiple reflection theory4) of S-wave in surface layers due to sine wave at individual site are shown in Fig.5. The curves mean the filtering effect during the earthquake input at bedrock. It was recognized that these amplification characteristics are well coincident with frequency characteristics of microtremors.

Characteristics of Incident Waves at the Bedrock in Wide Area

Incident waves at the bedrock were calculated by the multiple reflection theory4) of S-wave too, using above mentioned ground models and seismic records. Here, input waves should be observed records at the ground surface. But, in this study, base of the building where the accelerogram were obtained was assumed as free surface of the ground.

Resulting maximum acceleration and velocity of incident waves at bedrock are shown in Fig.2 and 3, and Fourier spectra are in Fig.4. Fig. 6 indicates superposition of all Fourier spectra at all sites. Where, the maximum velocity amplitude was defined as the maximum velocity response of one-mass system having T=1.0 sec and h=1.0 (critical damping).

As the results, it can be seen clearly in Fig.2 and 3, that the maximum amplitudes are separated by the difference of soil conditions, that is, alluvial or diluvial or tertiary (bedrock) deposit. Moreover, maximum amplitudes of incident waves at bedrock are almost on the same level throughout all sites. As for the frequency characteristics, on the other hand, there are almost no difference among all sites as shown in Fig.6 as flat through all frequency ranges of Fourier spectra having dimension of velocity amplitude.

Prof. K. Kanai has introduced following well-known empirical formula5) of velocity spectrum in bedrock using magnitude M and hypocentral distance X(km) from his standpoint, that is, the velocity spectrum is constant in bedrock.

$$V_0 = 10^{0.61M-\left(1.66+\frac{3.60}{X}\right)\log_{10}X-\left(0.631+\frac{1.83}{X}\right)}$$

If we apply this formula to present study, the value of maximum velocity amplitude almost coincides quantitatively with our analytical results.

Conclusion

At the bedrock which widely spreading just under each observation site as shown in this study, incident waves have commonly simple and flat frequency characteristics, and the values of their maximum velocity amplitudes are almost the same with those obtained from Kanai formula quantitatively.

It can be recognized to assume the input earthquake motions at a certain site from the observed records at another site, as far as both constructions of surface layers are known and as both sites are on the common bedrock.

References

1) Digitalized values of the Strong-Earthquake Motions at the Higashi-Matsuyama Earthquake by Prof. I. Sakamoto.
2) K.Kanai etc., Microtremors of Strong-Motion Earthquake Stations IV, specific Study by the Ministry of Education, 1967.
3) G.Kitazawa etc., Geological Investigation Diagram in Tokyo, Giho-Do, 1959.
4) H.Kagami & H.Kobayashi, Amplification of the Earthquake Motions in Multi-Layered Ground Caused by Multiple Reflection of Shear Waves, Transactions of the Architectural Institute of Japan, No. 173, 1970
5) K.Kanai, Improved Empirical Formula for the Characteristics of Strong Earthquake Motions, Proceedings of Japan Earthquake Engineering Symposium, 1966.

Table-1 List of the SMAC Sites used in this Study

	SMAC NO.	Name	Obs.Site
A	101-2	Earthq. Res. Inst., Univ. of Tokyo	B 1F
C	116-2	Bldg. Res. Inst.	1F
D	102	Akashi-Seisakusho Bldg.	1F
F	113	Parco Bldg.	B 3F
G	141	Keio Bldg.	B 2F
I	131	Higashi-Shinjuku Den-Den Bldg.	B 2F
J	134	Hotel New-Otani	B 2F
M	105-1	Metropolitan Municipal Office, No.1 Bldg.	B 2F
O	120	Hibiya Den-Den Bldg.	B 4F
R	117	Shimizu Construction Bldg.	B 1F
S	123	Ohbayashi-Gumi Bldg.	B 1F
W	119	Koto Telephone Office	B 1F
X	121	Bokuto Hospital	1F

Table-2 List of Soil Constants

soils	density(ton/m^3)	N-value	velocity of S-wave (m/sec)
alluvial deposit	1.3-1.5	0-10	70-160
diluvial deposit	1.5-1.7	30-100	270-540
tertiary deposit (bedrock assumed)	1.93	200	1000

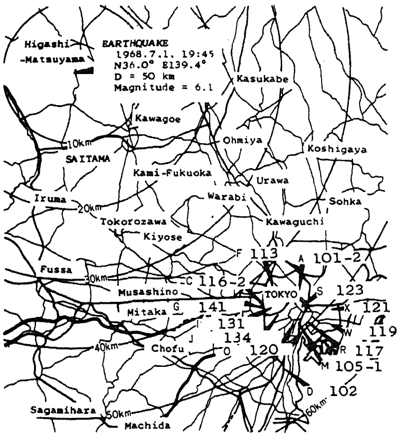

Fig.-1

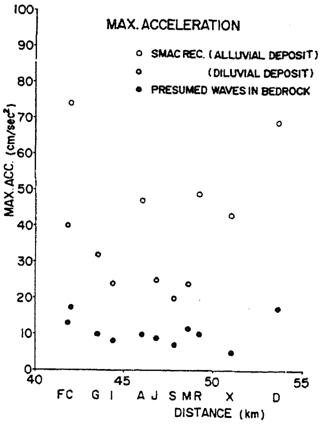

Fig.-2

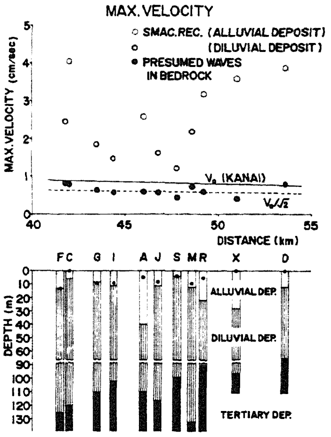

Fig.-3

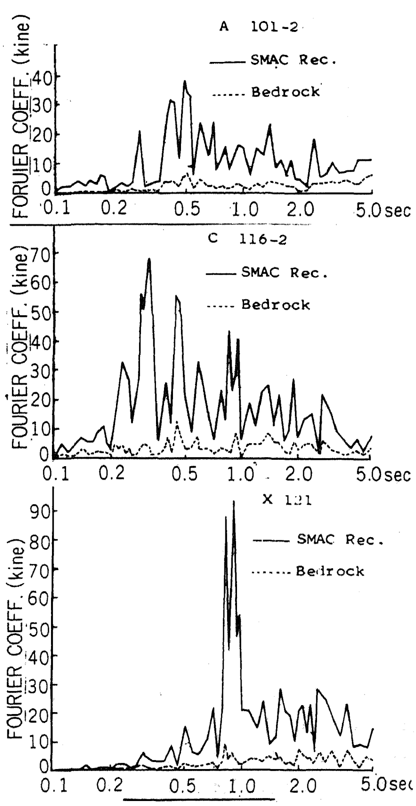

Fig.-4

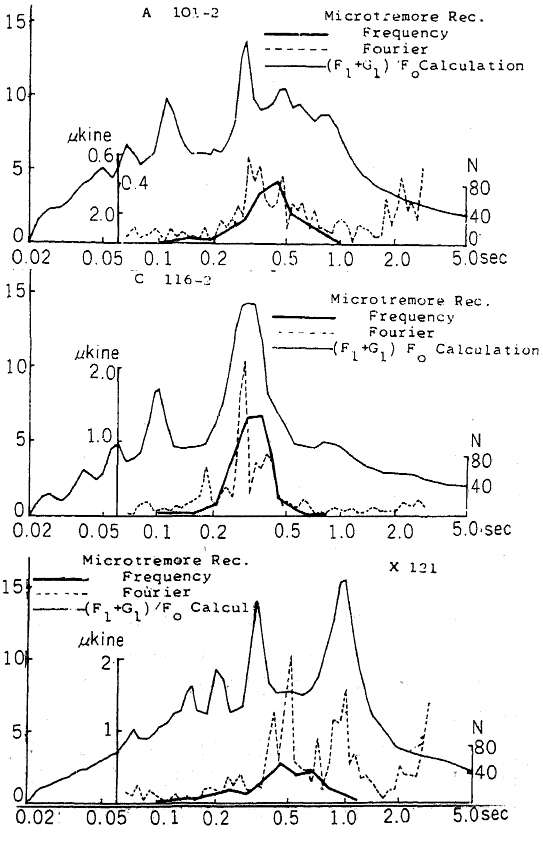

Fig.-5

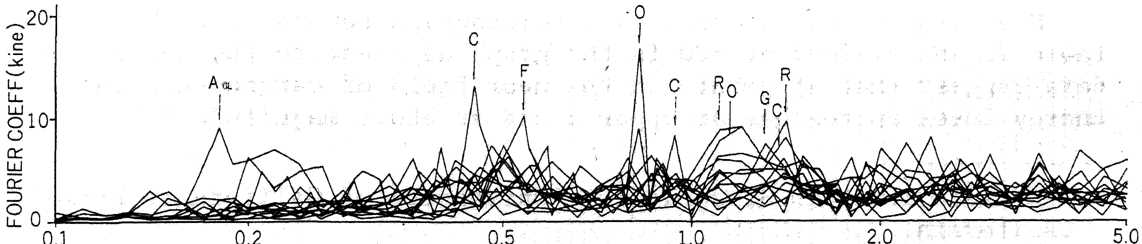

Fig.-6