

BEHAVIOR OF S-WAVES IN SOFT GROUND

by

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SYNOPSIS

This research is study used the data observed in Matsushiro area, Central Japan. The data used come from 9 underground seismometers -1m, -15m and -28m, respectively 3 components. Considerations using these data are done about spectra and amplitude ratios for seismic wave forms observed in different depths.

INTRODUCTION

Since seismic observation in a well has been by J. Milne⁽¹⁾, there are many reports of seismic observations in underground.

The records of S-waves using this paper are obtained in near Ochiai bridge over across the Chikuma.

DATA, OBSERVATION POINT AND INSTRUMENT.

Number of seismograms are about 50, and 8 records of them are analysed in this study. Fig.1 shows epicenters and depths of these earthquakes and observation point. Table 1 is elements of these earthquakes using analyses. Fig.2 shows the geological structure near the observation point. From this figure, it is thought that this area consists of nearly uniform gravel.

The instrument operate automatically when seismometers perceive acceleration more than 10 gals. Therefore, records observed by this instrument are mainly available for study of S-waves. Table 2 shows the sensitivities of each seismometer. H_1 and H_2 of this table show the directions of each seismometer, that is, right angle and parallel for the bridge, respectively, and V is vertical direction. These seismometers have flat frequency characteristics in 0.5-30 Hz domain.

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SEISMOGRAMS

Fig.3 is seismograms of one earthquake of them. Order of this record is V, H₁, and H₂ for every 3 traces from the top, and every 3 traces show the record at -1m, -15m and -28m, respectively.

From these records, we can see reflected waves of S-wave by surface. One of 8 seismograms is recorded P-waves, therefore we can estimate roughly velocity of P-wave. The result is almost 410m/sec. We are able to recognize that velocity of S-wave is almost 205m/sec by using reflection waves. Therefore, Poissons ratio is about 1/3.

SPECTRA OF S-WAVES

There are spectra of S-waves for each component and depth of records of 8 earthquakes, and Fig.4 is one of them.

From these spectra, we can consider as the following:

- (1) In general, the deeper the position of seismometer becomes, the smaller components of spectra become.
- (2) As the magnitudes of the data used are small and hypocintral distances of them are short, we guess that these seismograms include high frequencies, but the peaks of spectra are in the frequency range 5-10 Hz, and the components decrease abruptly in frequency range more than about 10 Hz. This cause will owe that the foci of the earthquake swarm distribute in the crust smashed by themselves, and seismic waves pass in the smashed crust. This phenomenon is related to the theory of stress drop. It also will be supposed that the observation point is laid in gravel for another cause.
- (3) It doesn't always follow that the deeper the positions become, the smaller the amplitude become. This matter differs by frequencies of seismic waves. For example, the ratios becomes small at about 5 Hz in this area (see Fig.4), and this shows that amplitudes at middle point (-15m) becomes small by the interference between incident and reflected waves. Thus, amplitude ratios of spectra between different positions are very complicated.

AMPLITUDE RATIOS

In semi-infinite elastic media, if the wave with amplitude 1 is incident for the surface, the amplitude is 2 at the surface. From the records used for this study, the relation between the depth and the amplitude at that point is shown in Fig.5. The amplitude ratio of the surface and the deepest point is about 10. This result is one of the most important problems for the behavior of S-waves in soft ground. Fig.6 shows one of the spectral ratios $-1m/-28m$, and $-15m/-28m$. $-15m/-28m$ become small in near 5 Hz. It supports that incident and reflected waves cancel their amplitudes each other.

The deeper the position of seismometer becomes, the smaller amplitudes become. That is, the ratio of amplitude $(-1m)/$ amplitude $(-28m)$ is about 10 (see Fig.3). But, the amplitude ratios for same frequencies between surface $(-1m)$ and underground $(-28m)$ motions are not so (refer(3) of the foregoing paragraph). This phenomenon may relate to different damages of structures having different natural periods and standing on the same ground.

BIBLIOGRAPHY

(1) Milne, J. : Trans. Seism. Soc. Japan, 10 (1887), 1.

Fig.1:

Epicenters, depths and observation point. Numbers 1:4:7, 2:5:8 and 3:6:9 with arrows of the upper corner show the number of seismographs and their orientations.

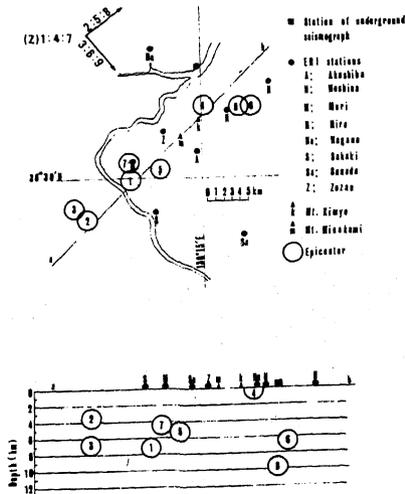


Fig.2:

Ground formation nearby observation point.

STATION NO.	DEPTH (m)	NAME OF SOIL	THE NUMBER OF BLOWS N IN STANDARD PENETRATION TEST		SPECIFIC GRAVITY
			10	30	
0	0.40	FINE SAND	10	30	1.70
1	1.00	COARSE SAND WITH GRAVEL	10	30	1.70
2	1.50	MEDIUM SAND	10	30	1.70
3	2.00	GRAVEL WITH BOULDER	10	30	1.70
4	2.50	GRAVEL WITH BOULDER	10	30	1.70
5	3.00	GRAVEL WITH BOULDER	10	30	1.70
6	3.50	GRAVEL WITH BOULDER	10	30	1.70
7	4.00	COARSE SAND	10	30	1.70
8	4.50	GRAVEL WITH BOULDER	10	30	1.70
9	5.00	GRAVEL WITH BOULDER	10	30	1.70
10	5.50	COARSE SAND WITH GRAVEL	10	30	1.70
11	6.00	GRAVEL WITH BOULDER	10	30	1.70
12	6.50	GRAVEL WITH BOULDER	10	30	1.70
13	7.00	CLAY	10	30	1.70
14	7.50	GRAVEL WITH BOULDER	10	30	1.70
15	8.00	GRAVEL	10	30	1.70
16	8.50	GRAVEL WITH BOULDER	10	30	1.70
17	9.00	GRAVEL WITH BOULDER	10	30	1.70
18	9.50	GRAVEL WITH BOULDER	10	30	1.70
19	10.00	GRAVEL WITH BOULDER	10	30	1.70
20	10.50	GRAVEL WITH BOULDER	10	30	1.70
21	11.00	COARSE SAND	10	30	1.70
22	11.50	GRAVEL	10	30	1.70
23	12.00	GRAVEL WITH BOULDER	10	30	1.70
24	12.50	GRAVEL WITH BOULDER	10	30	1.70
25	13.00	GRAVEL WITH BOULDER	10	30	1.70
26	13.50	COARSE SAND	10	30	1.70
27	14.00	GRAVEL	10	30	1.70
28	14.50	GRAVEL WITH BOULDER	10	30	1.70
29	15.00	GRAVEL WITH BOULDER	10	30	1.70
30	15.50	GRAVEL WITH BOULDER	10	30	1.70

Fig.3:

Seismograms (earthq. No.1).

In every figures (a-h):

- (i) Righthand numbers of the each trace show earthq. No. (1st number) and seismograph number (2nd number).
- (ii) See Table 1 and 2 for earthq. No. and seismograph number.
- (iii) Upper, middle and lower 3 traces show the records of vertical, horizontal NE-SW and NW-SE components, respectively.
- (iv) In the every components, upper, middle and lower traces show the records on surface and in underground -15m and -28m, respectively.

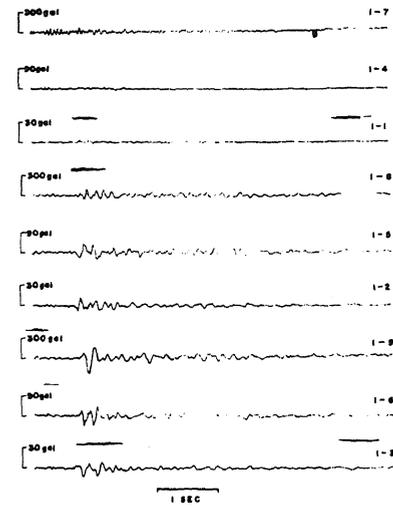


Fig.4:

Spectra of S-waves

(NW-SE component of earthq. No.2).

- (i) Attached number to spectrum corresponds to seismograph number.
- (ii) Solid line: surface, dotted line: underground(-15m) and dash-dotted line: underground (-28m).

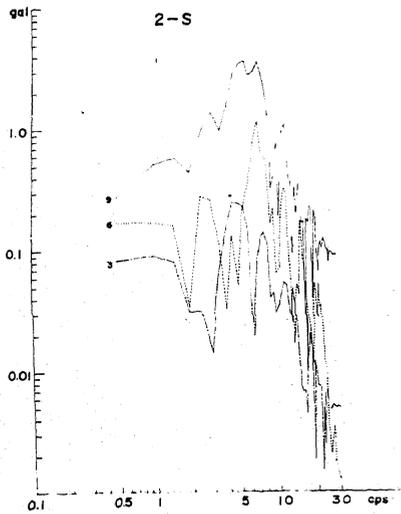


Fig.6:

Ratios between the spectra of surface and underground (-28m) motions (dotted line), and of underground (-15m) and (-28m) motions (solid line). NW-SE component of earthq. No.3.

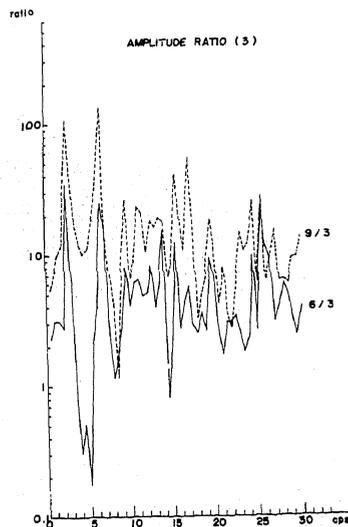


Fig.5:

Variation of amplitude between surface and underground motions (NW-SE component). Attached numbers correspond to earthquake numbers.

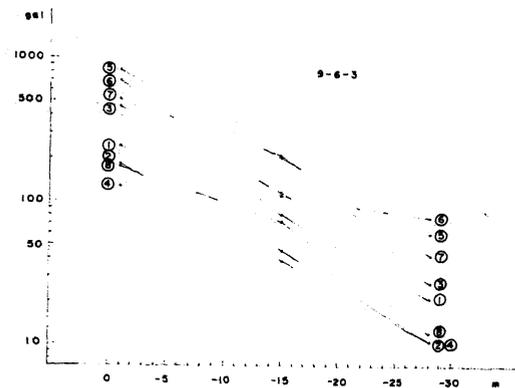


Table 1: Time of commencements, magnitudes, depths, epicentral distances and hypocentral distances of earthquakes.

Date	Time	M	H(km)	Δ (km)	h (km)	Remarks
1 67- 7- 9	23-30	4.8	7.4	16.4	18.0	
2 67- 9-14	13- 4	4.8	3.4	23.5	23.7	M/JMA=4.1 H/JMA=6.0
3 67- 9-14	19-38	5.4	0.3(ERI)	23.3	26.4	M/ERI=5.0 M/JMA=5.0 H/JMA=10.0
4 67- 9-27	3- 4	3.5	0.5(JMA)	4.9	5.0	
5 67-10-14	4-28	5.2	5.4(ERI)	13.6	14.6	M/ERI=4.9 M/JMA=5.3 H/JMA=10.0
6 67-11- 1	20-43	5.1	6.9	18.3	10.8	M/JMA=3.9 H/JMA=0.0
7 68- 1-26	16-55	5.2	4.5(ERI)	13.1	13.9	M/JMA=5.3 H/JMA=0.0
8 68-12- 4	22-24	4.7	10.0(JMA)	7.1	12.3	M/JMA=4.2

Table 2: Sensitivities and depths of seismographs.

NO	DEPTH	DIRECTION	SENSITIVITY	SENSITIVITY RATIO
9		H ₂	300gal/cm	1/10
8	-1m	H ₁		
7		V		
6		H ₂	90gal/cm	1/3
5	-15m	H ₁		
4		V		
3		H ₂	30gal/cm	1
2	-28m	H ₁		
1		V		