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# WAVE PROPAGATION OF MICROTREMORS GENERATED BY MOTORCARS AT THE VICINITY OF A CLIFF

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## SUMMARY

This paper describes the characteristics of the wave propagation of microtremors generated by motorcars at the vicinity of a cliff. The data dealt with in this paper should be the data from which the wave propagation to a cliff can be ascertained. Hence, the determination of a measurement site is very important in this study. After confirmation of vibration sources, the translation of the Fourier amplitude spectra at various distances are investigated, in case waves propagate radially to a cliff and in case waves propagate parallel with a cliff.

## INTRODUCTION

It is reported that many structures stand at the vicinity of cliffs are damaged severly by earthquakes. The severity of these damages depend upon landform, geological structure, incident angle of earthquake wave and so on. In order to make clear the factors of these damages, many studies were carried out by observation and analysis (for example, Ref.1,2).

I deal with this theme by measurement of microtremors after making clear vibration sources. Considering from such a viewpoint, the determination of a measuerment site is very important. It was ascertained that trafic disturbances can propagate to a place about 300 meters apart from (Ref.3). On the basis of this result, I determined the measurement site of a cliff having the principal roads in the neighborhood. In this paper, I regard vibrations generated by motorcars, passing along roads near the vicinity of a cliff, as seismic sources, and microtremors propagating from these sources as surface waves, and also, I regard the weight of a motorcar as the size of source energy. Under these conditions, I investigate the characteristics of microtremors propagating to a cliff by means of Fourier spectra, orbital motions, propagating directions and phase velocities of waves, coherences, and Fourier spectral ratios.

## OUTLINE OF SUBSOIL AND MEASUREMENT

<u>Subsoil</u> The measurement site is located at near the Kinu river in Utsunomiya city. Fig.1 shows the site and it's vicinity. The measurement points are arranged at the top and at the foot of the cliff marked as ○ in Fig.1. Principal roads, where trucks pass along frequently before daybreak, run EW and NS direction at about 250 meters and 350 meters apart from the measurement site, respectiviely. The points marked as ● in Fig.1 are the places we investigated the trafic

conditions of these roads. The soil profiles and the results of a standard penetration test at the top of the cliff are shown in Fig.2. Physical constants of this site are unknown. A predominant frequency of this site is 2.5Hz (Ref.3).

Measurement The sensing instrument is 1-component (holizontal or vertical) moving coil type seismometer having a natural period of 1.0 sec, damping constant of 0.7 and sensitivity of 3 volts/kine. The signals from 12 seismometers are recorded in digital form on floppy disks at sampling frequency of 200 Hz, after being amplified while monitoring by a pen-oscilograph.

We measured three times before daybreak, avoiding noises caused by unknown sources as shown in Table 1. At the same time, we investigated motorcars, including their sizes, passing through the points A and B marked as ● in Fig.1. The representative locations of seismometers are shown in Fig.3. The measurement points are named F1,F2,M,T1,T2,T3, respectively.

## CHARACTERISTICS OF THE WAVE PROPAGATION

After investigating each data got by the measurements of three times, it becomes clear that the results of the characteristics of microtremors fluctuate widely with weather conditions and with time. In this paper, I treat with the data obtained on June 13 (Mo.),1988.

When investigating the following subjects, I set three cases on the trafic condition as shown in Table 2. The data should be grouped in accourdance with these three cases, to get an uniform data on the trafic condition. Therefore, a time length of 10.24 sec, in spite of it's shortness, is adopted for analysis.

Confirmation of Vibration Sources In case motorcars pass through the point A, that is, waves generated by motorcars propagate radially to the cliff (CASE 2), I will confirm the vibration sources by utilizing the data got from the location of seismomenters as shown in Fig.3(a).

One of the Fourier Spectra of waves at the measurement point T1 are shown in Fig.4. The solid, chain and broken lines are the Fourier spectra at the time when a truck, a motorcar and none of car pass along the road, respectively. When a truck passes along this road, the Fourier Amplitudes at the foot and at the top of the cliff grows in a high-frequency range (10-15Hz) and in a low-frequency range (3-4Hz), respectivily. Even if a motorcar passes along, the shapes of the spectra do not change, as compared with the one obtained at the time when cars do not pass along(CASE1). From this fact, It would be considered that the influence of the vibration generated by a truck reveals the change of the Fourier spectra at the foot and at the top of the cliff.

In order to confirm this consideration, I have made following some investigations. Using the same data measured at the time when a truck passes along the road, I obtained motion products and orbital motions at a frequency range of 3.3-4.5Hz, at the foot, at the midslope, and at the top of the cliff. (Fig.5(a),(b),(c)). The size of orbital motions are normalized by the maximum amplitude in one second. These figures show the existance of the Rayleigh type waves at the time when a truck goes through the point A. Furthermore, I obtained directions and phase velocities of propagating waves at the foot and at the top of the cliff as shown in Fig.6. At the time marked as ▼ in this figure, directions of waves follow the movement of a truck. Still more, coherences between three measurment points (T1, M and F1) show high level at around the same frequency marked as ▼ , especially in the vertical component as shown in Fig.7. From these investigations, the vibrations generated by a truck have certainly an influence on wave motions at the top of the cliff.

In case motorcars pass through the point B, that is, wave propagate parallel with the cliff(CASE3), I obtained almost the same results.

Translation of the Fourier amplitude spectra at various distances from vibration sources In CASE2, we measured microtremors by the seismometer location type as shown in Fig.3(b). The Fourier spectra of vertical and radial components are shown in Fig.8(a) and Fig.8(b), respectively. The spectral peak at around 2.5Hz marked as ▽ in Fig.8 is seen in each spectrum. This is a predominant frequency of the soil of this district. The spectral peak at around 3.5Hz marked as ▼ in Fig.8 is seen in spectra of the top of the cliff, especially in vertical component. This is the infuluence from the vibration generated by a truck passes along the road running under the cliff, after the former chapter. The amplitude of high-frequency range (around 10Hz) is predominant at the foot of the cliff. This power around 10Hz disappears gradually as approaching get nearer to the cliff, and vanishes at the top of the cliff in each component.

In order to investigate a translasion of Fourier amplitude spectra, I take ratios of spectra relative to the spectra obtained at the measurement point T1, in each component (Fig.9). By taking ratios of spectra, we can compare the amplitude translation, althrough dealing with various data got in different times. In these figures, paying attention to the frequency around 2.5Hz and 3.5Hz, I investigate the translation of amplitudes of vertical, radial and transverse components in Figs.10,11,12, respectively. A broken line shows an average of 6 data obtained in CASE1. The amplitudes at the top of the cliff are always large as compared with those at the foot of the cliff. Amplitude ratios of vertical, radial and transverse components of T1 to F1 are about 2-5 times as shown in Table 3. Solid lines show amplitude ratios of CASE2. From these figures, a tendency of the CASE2 is very similar to that of the CASE1. Only a transverse component has a tendency to be amplified at the midslope of the cliff.

The results of the CASE3, are also shown in Figs.13,14,15, in the same way. In this case, amplitudes at around 3.5Hz have a tendency to be largely amplified, especially in radial and transverse compoments, therefore,the waves are composed of, not only Rayleigh type, but also SH type surface waves.

## CONCLUDING REMARKS

The results of this measurement are as follows:

On the characteristics of the propagating waves at the vicinity of the cliff:

- The vibrations generated by a truck have an influence on the soil apart from about 300 meters.
- In case waves propagate radially to the cliff (CASE2), amplitudes of frequency range from 10 to 15 Hz grow at the foot of the cliff apart from vibration sources about 150 meters, and disappear gradually as approaching get nearer to the cliff, and finally vanish at the top of the cliff apart from vibration sources about 250 meters, in each component.
- When a truck passes along the principal roads, a peak grows in the Fourier spectra of the top of the cliff, at around 3.5 Hz, except a predominant frequency of 2.5 Hz at this district. These waves having component of 3.5 Hz predominantly, certainely propagate from vibration sources to the measurement site. The waves are composed of,not only Rayleigh type, but also SH type surface waves.

On the translation of the Fourier amplitude spectra:

- The Fourier amplitudes around 2-5 Hz at the top of the cliff are always large as compared with those at the foot of the cliff by about 2 to 5 times.
- In case waves propagate radially to the cliff (CASE2), the translation of the Fourier amplitude spectra is very similar to that of the CASE 1 that obtained at the time when cars do not pass along.
- In case waves propagate parallel with the cliff (CASE3), the amplitudes of radial and transverse components are remarkably amplified.

## ACKNOWLEDGEMENTS

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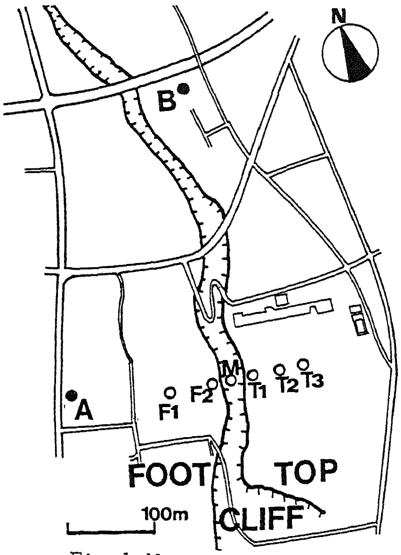
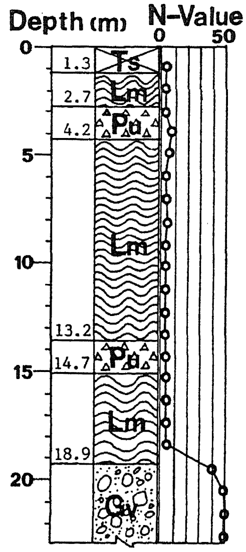
REFFERENCES

1) Komaki, S. and Toida, K., "Vibration Characteristics at The Vicinity of A Cliff", Proc. of the 17th Symp. on Natural Disaster Science, 601-604, 1980.
2) Kobori,T. and Shinozaki, Y., "Scatttering of SH Waves from Surface Irregularities ", Zishin, 2, Vol.30, 127-142, 1977.
3) Irie, Y. and Sugiyama, K., "The Characteristics of Microtremors Caused by The Trafic Disturbance", Proc. of the 7th Japan Earthq. Eng. Symp., 289-294, 1986.



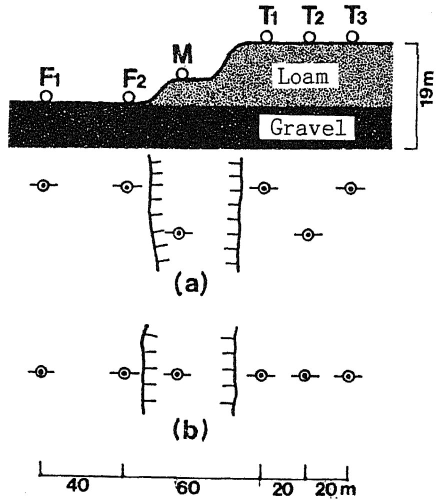



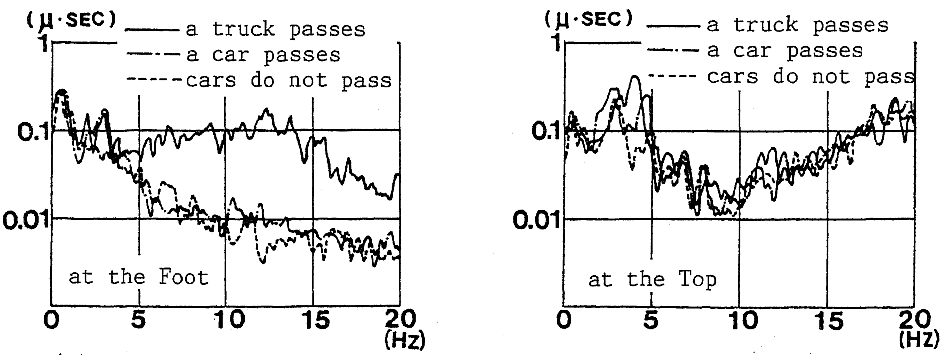

Fig.1 Measurement Site Fig.2 Soil Profiles Fig.3 Location of seismometers

Table 1 Measurement Schedules and Obtained Data

| | Day | Time | Time length of one datum(sec) | Number of Data |
|---|---|---|---|---|
| (1) | '87 7/28(Mo.) | Am4:00-6:00 | 100 | 14 |
| (2) | '88 6/ 5(Su.) | Am3:00-6:00 | 135 | 25 |
| (3) | '88 6/13(Mo.) | Am3:30-6:30 | 135 | 23 |

Table 2 Cases on the Trafic Condition

| CASE | Trafic Conditions |
|---|---|
| (1) | motorcars do not pass along the principal roads |
| (2) | trucks pass along the road running parallel to the cliff, that is, waves propagate radially to the cliff |
| (3) | trucks pass along the road running radial to the cliff, that is, waves propagate parallel with the cliff |




(a) at the Foot Fig.4 Fourier Amp. Spectra (b) at the Top

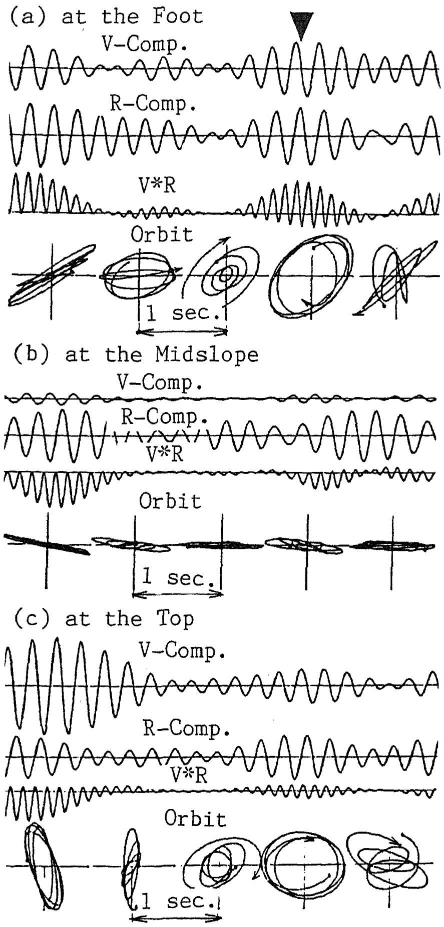



Fig.5 Motion Products and Orbital Motions (3.3-4.5Hz)

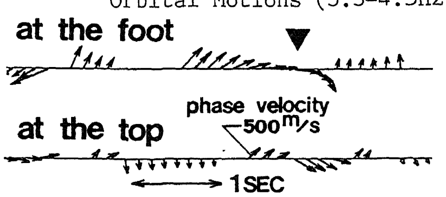
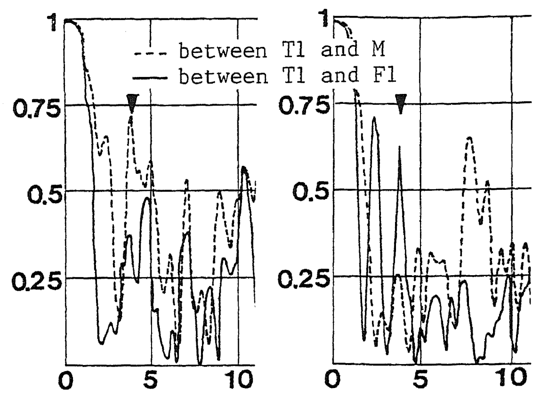
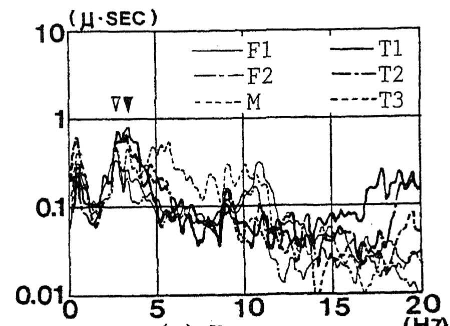



Fig.6 Directions and Phase Velocities of Wave Propagation

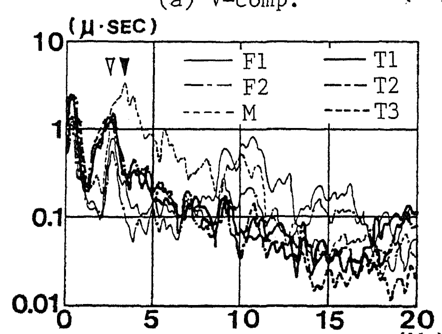



(a) V-comp. (b) R-comp.

Fig.7 Coherences

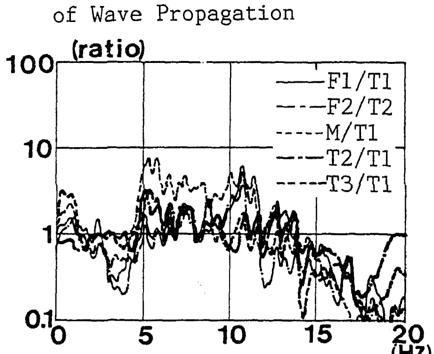


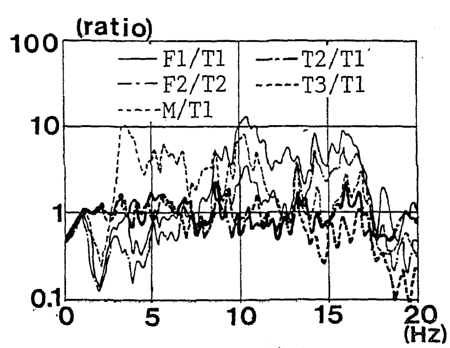

(a) V-comp.




(b) R-comp.

Fig.8 Fourier Amp. Spectra

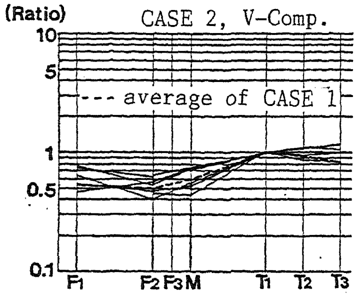


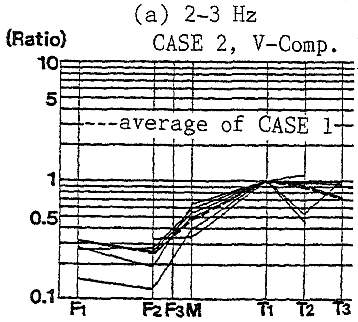

(a) V-comp. Fig.9 Fourier Amp. Spectral Ratios (b) R-comp.

Table 3 Amplitude Ratios of CASE1

| Ratio | Comp. | Freq. Range(Hz) | |
|---|---|---|---|
| | | 2-3 | 3-5 |
| T1 | V | 1.9 | 3.2 |
| — | R | 2.8 | 2.7 |
| F1 | T | 4.6 | 1.8 |

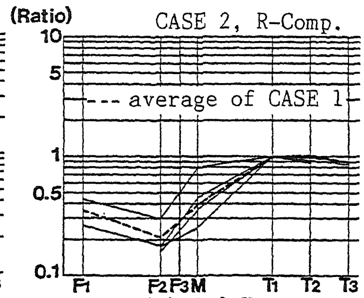


(a) 2-3 Hz

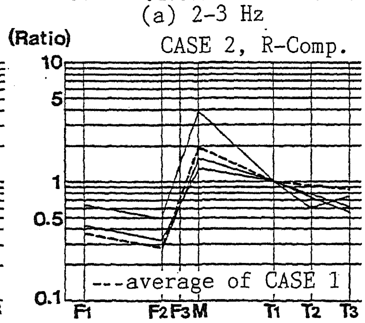


(b) 3-5 Hz

Fig.10 Fourier Amp. Spectral Ratios

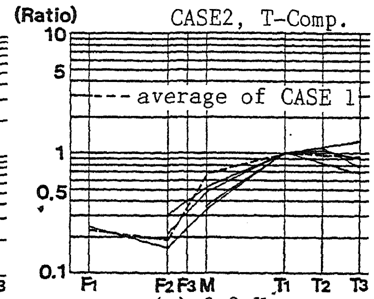


(a) 2-3 Hz

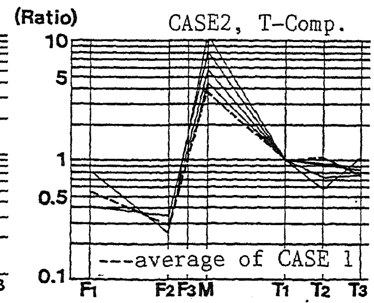


(b) 3-5 Hz

Fig.11 Fourier Amp. Spectral Ratios

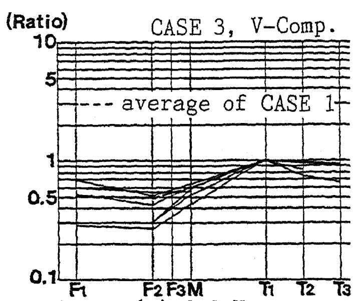


(a) 2-3 Hz

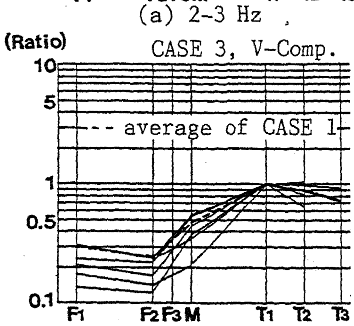


(b) 3-5 Hz

Fig.12 Fourier Amp. Spectral Ratios

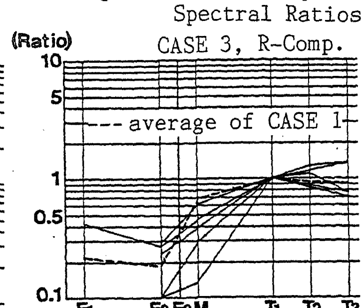


(a) 2-3 Hz

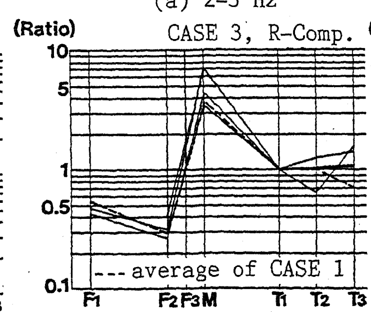


(b) 3-5 Hz

Fig.13 Fourier Amp. Spectral Ratios

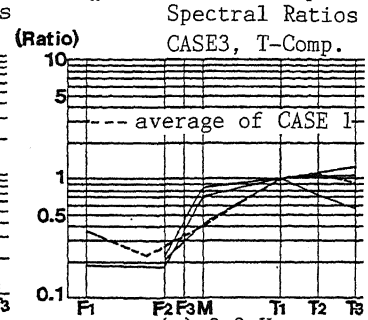


(a) 2-3 Hz

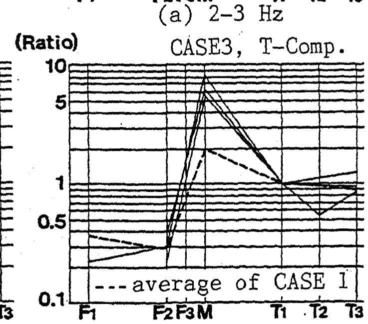


(b) 3-5 Hz

Fig.14 Fourier Amp. Spectral Ratios



(a) 2-3 Hz



(b) 3-5 Hz

Fig.15 Fourier Amp. Spectral Ratios