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The Observation of Microtremors Correlated with the Existence of Cracks at the Landslide Area

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Abstract

The observations of microtremors over the Kamenose landslide area were carried out in March and July, 1971. To examine the influence of the cracks existing in this area on the tremor, the observation with three components was applied. The tremors are classified into high frequency type, medium frequency type and low frequency type. The horizontal locus of medium frequency type shows the polarization to the direction perpendicular to crack. And it has been definitely shown that this type of microtremors may be affected strongly by the existence of cracks at the landslide area.

1. Introduction

There are numerous investigations which show that the observations of microtremors are one of the useful methods to determine the dynamic properties of the ground. Kanai et al. (1961)[1] made many observations of microtremors at various alluviums, and related the result to the subsoil conditions at the observation sites. According to them, the spectra of microtremors on firm ground have short predominant period and sharp peak amplitude, but on soft ground the peak frequency and amplitude become longer and broader, respectively.

At the landslide area many cracks are widely found. The spectrum of microtremors may be affected by these cracks which separate the ground structure into blocks in the lateral direction. Therefore, in order to interpret the observational result of microtremors at landslide area, it may be necessary to confirm the relation between the existence of cracks and the vibrational characteristics of such ground.

With these suppositions, the observations of microtremors were carried out twice at the Kamenose landslide area. During the first observation, the region where cracks appeared very clearly on the ground surface were surveyed for investigation of the effect of the existence of cracks in the ground structure on microtremors. On the basis of that result, the latter observation was carried out over a large region of the landslide area where the cracks may be either covered or unknown. In order to detect whether the ground is stable or unstable with regard to the landslide phenomena, it may be important to examine the character of these regions.

2. Observation sites and methods

The Kamenose landslide area is located on the north bank of the Yamato River which runs from east to west as if it divided the Ikoma-Katsurgi mountain chain into two parts. The Kamenose landslide area and the location of observation sites are shown in Fig. 1. The former observation of microtremors was carried out in March, 1971. Six temporary sites were chosen in the region called Busshōdō, where

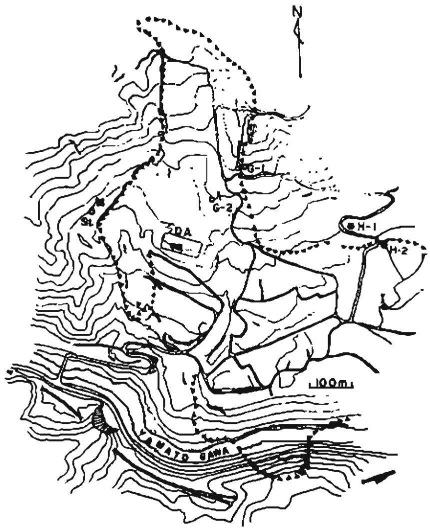

Fig. 1. Topographic map of the Kamenose landslide area and the position of the observation sites.

cracks appeared very clearly on the ground surface. In Fig. 1, the Busshōdō region is shown by a dotted line rectangle. The position of cracks in Busshōdō region and the six observation sites, named A–F, were shown in Fig. 2. The combination of

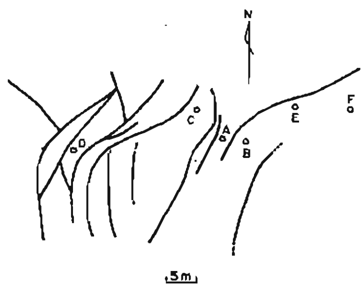

Fig. 2. Map of Busshōdō region where cracks appeared clearly. Cracks are shown by the thick line and observational points are shown by A to F.

three components of seismographs were applied for the observation at each site. The two horizontal components were set up parallel and perpendicular to each crack and are denoted by H$\parallel$ and H$\perp$, respectively. To show more clearly how the spectrum of microtremors were affected by the existence of cracks, one vertical component of the seismograph was set up in the region which was stable with respect to landslide motion and was located in about 300 m apart from Busshōdō region. That point was named the standard point and denoted by St. in Fig. 1.

The latter observation was carried out in July, 1971. And observation sites were chosen throughout the landslide area. In Fig. 1, the new observation sites are shown by G–1, G–2, H–1, H–2 and I, and ⊥ marks show the fault scarp. This fault scarp was created by the landslide motion in 1967 and has a maximum dip displacement of about 3 m. At the inner side of this fault the ground slided due to landslide motion, but at the outer side the ground remained without sliding. To compare the vibrational characteristics beteeen both sides of the fault, G–1 and H–1 points were chosen at the outer side, and G–2 and H–2 points at the inner side. At these four sites it may be inferred that the cracks have been created by landslide motion. I point was surveyed as the typical region where landslide motion has not yet occurred. Of course, cracks have not been identified in this region. Moreover, points A and D of the Busshōdō region were surveyed as a check of the former observation. And a new standard point from same point of view as in the former observation was established on the base of weathered granite rock. This new standard point may be at a more stable region as regards landslide phenomena than the former standard point. Observations were carried out at all observation sites by using the combination of three components of seismographs, except for D point where only the vertical component was used. Three components of seismographs were set up north-south, east-west direction and vertically at most observation sites, but at point A of the Busshōdō region they were set up in the same direction as in the former obersvation.

Considering that setting of the seismographs was difficult due to uneven and soft ground, as shown by the experience of the first observation, the stainless bars of about 50 cm length were prepared and applied for points H–1, H–2 ,G–2 and I, and the seismographs were set up on these bars.

The seismographs used were the moving coil type of which the natural period was 1 sec., and the attenuation constant, h, was adjusted 1.0 at the former observation and 0.64 at the latter observation in order to examine in more detail that part of the frequency below 1 Hz. The microtremors were recorded on magnetic tape using the data recorder through DC amplifiers. The magnification of DC amplifiers adopted was between 1,000 and 10,000 times, considering the noise level at each observation sites. The data recorders used are 4–ch at the former observation and 7–ch at the latter observation, so at the former one vertical component of the standard point and three components of one site were recorded at the same time, but in the latter the microtremors of three sites, which consisted of two sites of three components and another vertical component, could be recorded simultaneously by means of the data recorder of 7–ch.

The both observations were carried out over two days and at midnight to avoid the influence of traffic. Recording time was above 5 minutes per one site.

3. Analysis and results

The records played back from the data recorder were classified into various frequency domains using an analogue filter with an attenuation rate of 30 db/oct., and the wave form and amplitude at each site were compared. Examples of the unfiltered and filtered records were shown in Fig. 3. Furthermore, the 20 Hz low-passed records were made A–D conversion by sampling intervals of 62.5 Hz. Fourier spect-

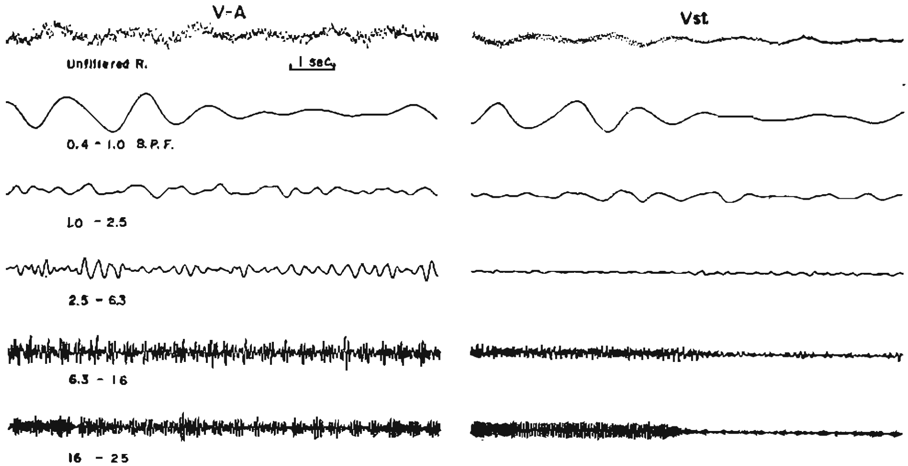

Fig. 3. Examples of the unfiltered and filtered seismograms classified into various frequency ranges from 0.4 to 25 Hz at A and standard points.
left: vertical component of A point.
right: vertical component of standard point

ral analysis for 2,048 data, equivalent to the duration of 33 seconds, were made by using the Cooley-Turkey method. The Fourier amplitude spectrum for each site are shown in Fig. 4 and 5. Fig. 4 shows the results of the former observation and Fig. 5, the latter observation. The amplitude of the low frequency part of spectrum in these figures was corrected by using instrumental magnification response curve.

The vertical components of D and E points and the three components of F point at the former observation, and H-1 and H-2 points at the latter observation could not be recorded well since the seismographs were not settled tightly due to uneven and soft ground. Therefore, these records were not suitable to be analyzed in detail.

From Figs. 3, 4 and 5 the microtremors may be classified into the three kinds of frequency type: (1) high frequency type (above 10 Hz), (2) medium frequency type and (3) low frequency type (lower than 1 Hz).

Each type is described in some detail below:

(1) high frequency type (above 10 Hz)

As seen in Fig. 4, the spectra of the former observation have a sharp peak in 15–16 Hz at all sites containing the standard point. However, as seen from Fig. 5, at all sites the spectra of the latter observation have no peak in high frequency range above 10 Hz. This may be explained from the fact that the high frequency part of microtremors were affected by the electric motors used in the construction work to prevent landslides. These motors were turned on and off in the first observation but rested during the latter observation. This is also evident from the records passed through the high pass filter of 16 Hz shown in Fig. 3. Moreover, the amplitude of this frequency range became large especially when the wind blew and the rain fell, as well as when the seismographs were settled on soft ground surface as at the G-2 and H-2 points. Therefore, this frequency range of tremors may be affected strongly by some local source near the ground surface and may not reflect the main structure

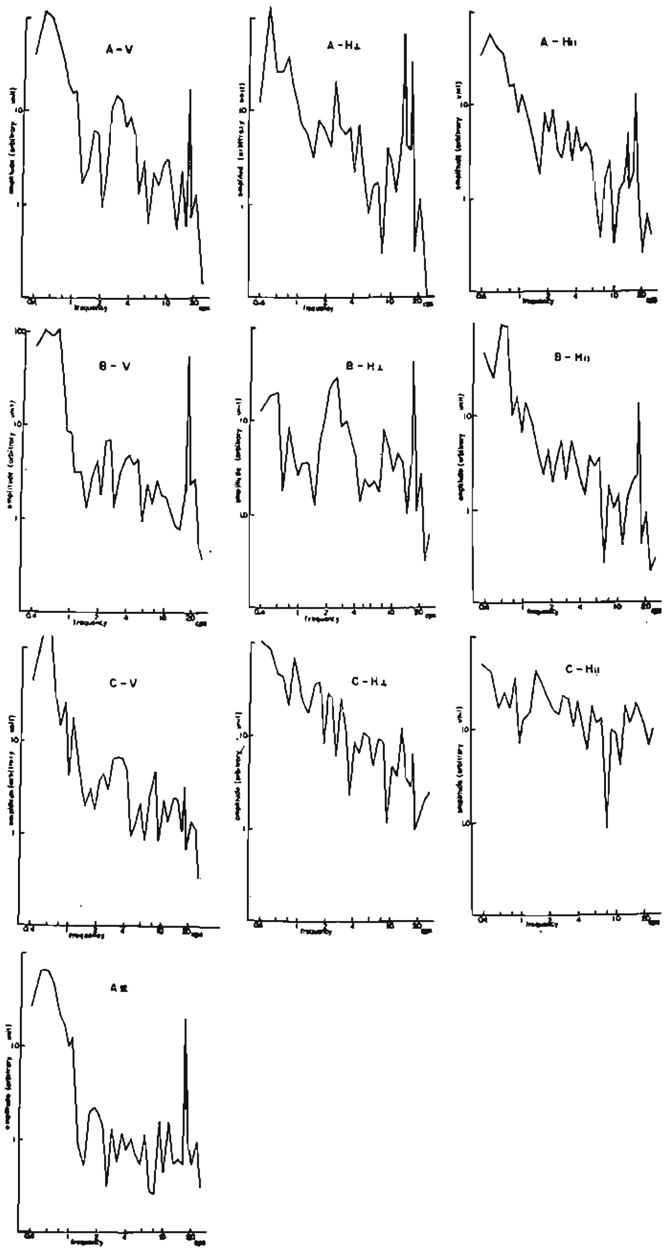

Fig. 4. Fourier amplitude spectrum of three components at A, B, C points and vertical component of St. point. H⊥ and H∥ show the horizontal components of setting up in the direction perpendicular and parallel to crack, respectively.

of the landslide area.

(2) medium frequency type

The records of A and the standard point classified into various frequency bands from 0.4 to 25 Hz are shown in Fig. 3. As seen in this figure, in the frequency range of 2–5 Hz, the amplitude at A point where cracks appeared clearly is much larger than that of the standard point. Moreover, the amplitude spectra have a peak around 2–3 Hz, as shown in Fig. 4. And the spectrum of horizontal component, settled perpendicularly to the crack shown by H⊥, is larger than H|| in this frequency range. Therefore, it may be expected that this frequency range of microtremors is affected by the existence of cracks. To examine this correlation in more detail, the particle motions in the horizontal plane at each site were drawn in the frequency range between 2.5 and 6.3 Hz. They are shown in Fig. 6. As seen in Fig. 6, the particle motions are strongly polarized in the direction perpendicular to crack. Moreover, in Fig. 5 the spectrum of point A of the latter observation has the same peak in about 2–3 Hz as the former's point A. Therefore, it is suggested that the vibrational characteristics of the medium frequency range of tremors depends on the ground structure which has been separated into many blocks by the development of cracks.

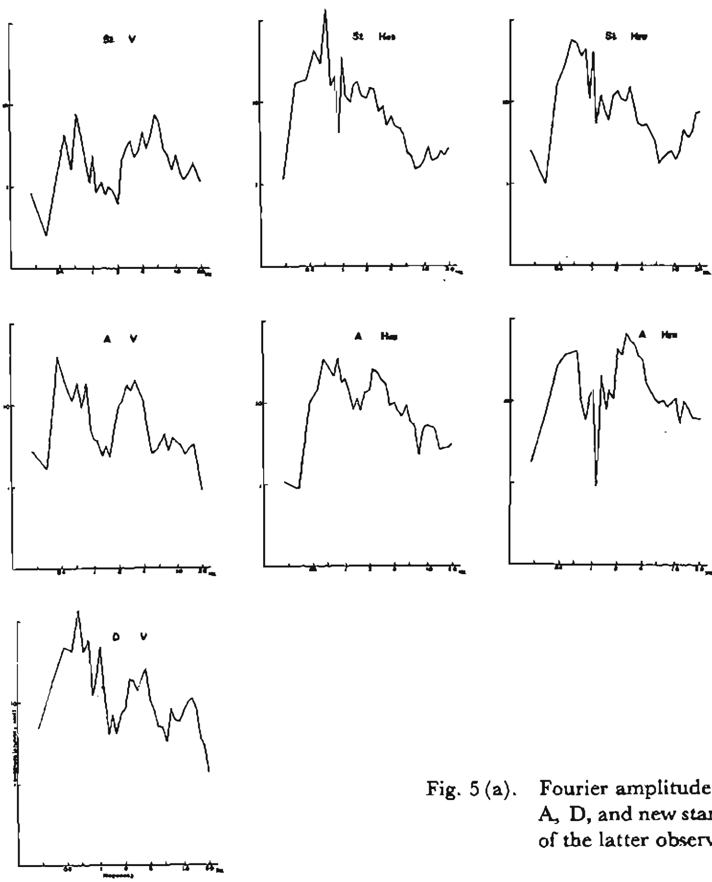

Fig. 5 (a). Fourier amplitude spectrum of A, D, and new standard points of the latter observation.

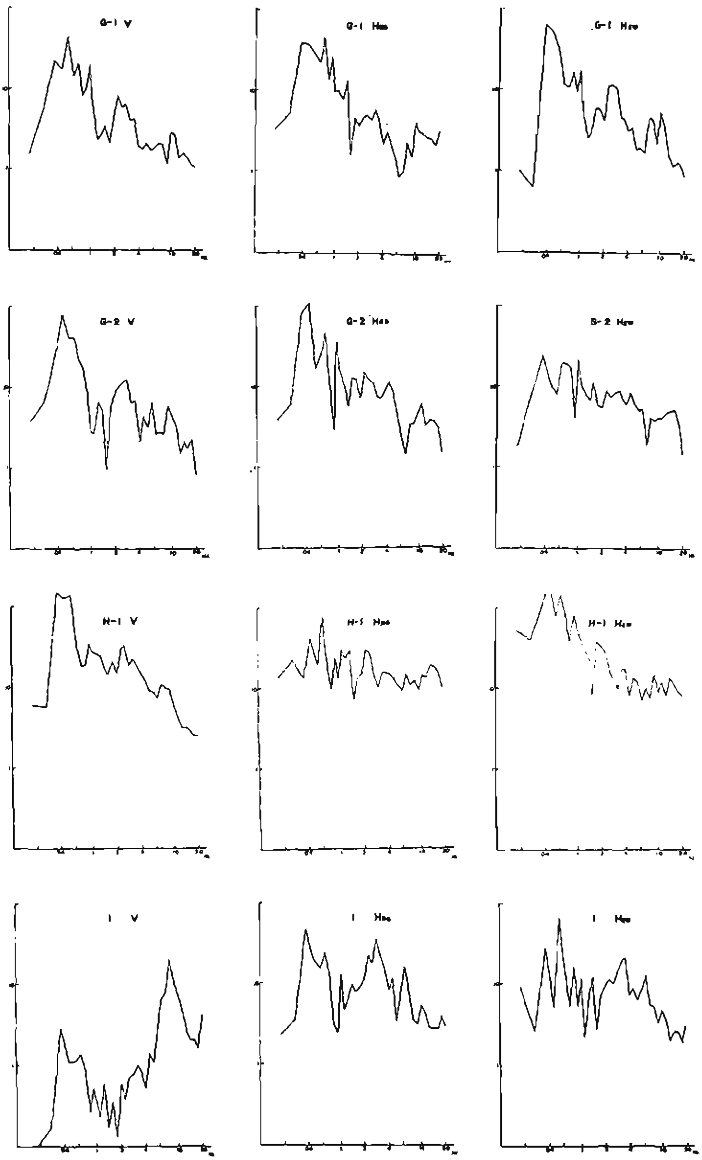

Fig. 5 (b). Fourier amplitude spectrum of G–1, G–2, H–1, and I.

As seen in Fig. 5, the peak of the speetrum at points G–1 and G–2, where the implicit existence of cracks is only inferred, is not so clear as that of point A and it shifts to the lower frequency range. But the spectrum certainly has its peak in the frequency range between 1.5 and 5 Hz and interesting particle motions, as shown in Fig. 7, are obtained. That is, the particle motion of G–2 polarizes almost perpendicularly to the crack, as shown by the broken lines in Fig. 7, which may be connected with the cracks seen at Busshōdō region. Further, the particle motion of G–1 po-

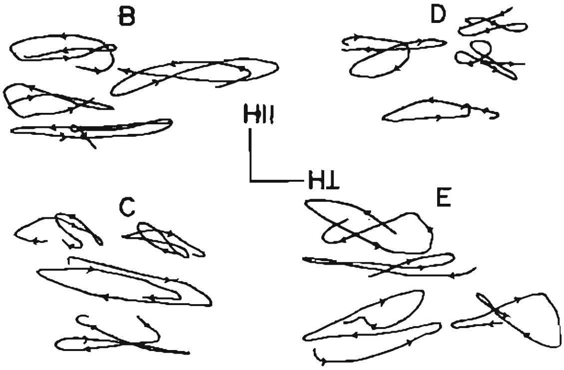

Fig. 6. Examples of particle motions of tremors in the frequency range from 2.5 to 6.3 Hz at B, C, D and E points.

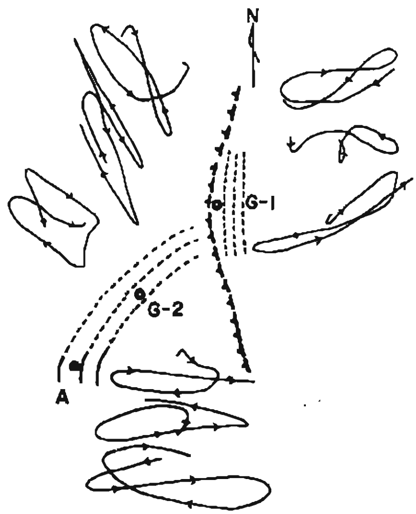

Fig. 7. Particle motions of the same frequency range as Fig. 6 at G–1, G–2 and A points:
upper right shows the particle motion at G–1
upper left shows the particle motion at G–2
lower shows the particle motion at A.
The broken line shows the implicit cracks inferred from the landslide motion. ⊥ marks show the fault which appeared due to the landslide motion in 1967.

larizes about perpendicularly to that of G–2 and to the fault shown by ⊥ in Fig. 7. This may be possible to explain if the cracks at G–1 were developed parallel to the fault. The distribution of cracks described above may also be confirmed from the topographical point of view and observation of landslide phenomena.

As for I point, the spectrum shows the remarkably different character from the other observation sites as seen in Fig. 5. That is, the spectra of the medium frequency range have higher peak than that of the lower frequency range, and especially that of the vertical component is remarkable. But the peak frequencies are 8 Hz at vertical component, and 2.8–4 Hz and 6–8 Hz at two horizontal components. Moreover, the polarization of particle motions is also not clear. Thus, the spectrum of I point shows a different pattern from other sites. However, the present data is insufficient for the further discussion.

(3) low frequency type (lower than 1 Hz)

The peak of the amplitude spectrum in low frequencies is in the frequency range of 0.5–0.7 Hz and the spectral amplitude is largest at all sites except I point. To examine the character of this frequency part, the waveform of the vertical components of G–1, D and the standard point in the tripartite net, shown in Fig. 8, may

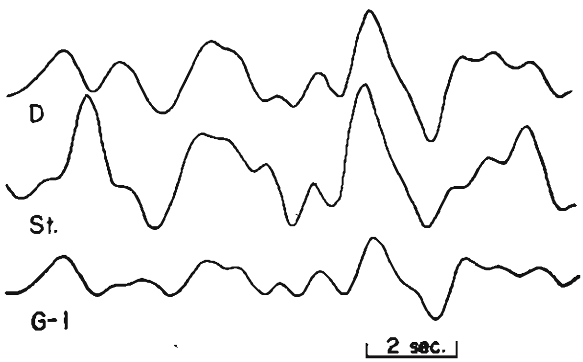

Fig. 8. Examples of the records of vertical components passed through the 1 Hz low pass filter at G–1, D and standard points, where the recordings were made at the same time.

be compared. These waveforms coincide entirely with each other together, with a small phase lag. Judging from the time difference of corresponding phases, it may be concluded that the wave arrived from the direction of about west-north-west.

On the other hand, as for the horizontal components, the phase correspondence is not so good and the spectra differ from each other.

Thus, although it is difficult to decide the nature of these wave precisely, it may be sure that this type of microtremors have reflected the characteristics of the global structure in Kamenose landslide area.

4. Conclusion

The following facts were obtained from analysis of the result of survey of microtremors at the Kamenose landslide area.

(1). Medium frequency type, which has the peak of amplitude spectrum in the frequency range from 2.5 to 5 Hz, is affected strongly by the existence of cracks distributed widely over the landslide area. This result may also be effective even if the cracks appeared implicitly.

(2). Low frequency type have the peak of spectrum in the frequency range from 0.5 to 0.7 Hz. And this type of tremors may have reflected the global ground structure all over the landslide area. More detailed examination with respect to the microtremors of this frequency region may be needed.

(3). If, in the ground with complex structure as a landslide area, one peak of the spectrum of tremors is interpreted with the ground structure of only the vertical direction, it will be in danger of error. Therefore, the analysis should be made in various frequency domains correlated with the ground structure of the various dimensions.

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Reference

1) Kanai, K. and T. Tanaka: On Microtremors. VIII, Bull. Earthq. Res. Inst., Vol. 39, 1961, pp. 97–114.