Estimation of S-wave velocity structures in Morioka area by dense microtremor array observations*

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1. Introduction

We try to estimate underground S-wave velocity structures by using microtremor array observation in order to understand S-wave velocity structures and site effects on strong motions. This research aims to find phase velocities and peak frequencies of microtremor vertical to horizontal (H/V) spectral ratios in order to get data for analyzing underground structures such as thickness and/or S-wave velocity of soil layers for predicting damage from earthquakes that may occur in the future. We did microtremor observations in Morioka City which is the main city of Iwate Prefecture. We observed microtremors by using a single three-component seismograph in a single point for estimating H/V spectral ratios and by using an array of velocity meters for estimating phase velocities.

2. Microtremor Observation

Fig.1 Microtremor Observation points at Morioka area in A, B and C lines.

We measured microtremors for 15 minute in the case of a miniature size array (60 cm) which is set in triangular form. And we need a longer time in a large size array. To calculate phase velocities, we use spatial autocorrelation (SPAC) method(Aki,19575). We calculated phase velocity by fitting SPAC coefficient to 0th order first kind Bessel function. Figure 1 shows microtremor array observation points. The red, green and yellow balloons show miniature array observation poits with a radius of 60 cm; the points indicated by a triangle shape show large size arrays. In the array observation, 47 sites were measured. In this research, the origin of observation lines A, B and C was set at Ueda 4 Chome near Iwate University. In the observation process, we used two types of tools to record microtremor data. In miniature array point we used velocity meters as a main device (4D-Geotek model). This tool includes four geo-phone sensors, AD data processing unit and Windows tablet. Figure 2 shows GDAQ4-s system. GDAQ-4s is a new system tool, it possible to customize an observation condition setting in real time (e.g. sampling rate, data length etc.) on site. In these miniature arrays, we set them in triangular form (60 cm of radius as shown in Fig. 3). However, an usage of GDAQ4-S has limits, the geo-phones sensor can only be set to miniature size and it's can record only vertical componants (UD Data). So in the large size array, we used the JU310 device from Hakusan Kogyo Co. Ltd.

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In this study, we also set a various size array in triangle form. At LA1 point we set 45m, 35m and 10m array sizes. At LA2 point we set 50m, 25m, 9m and 3m array sizes.

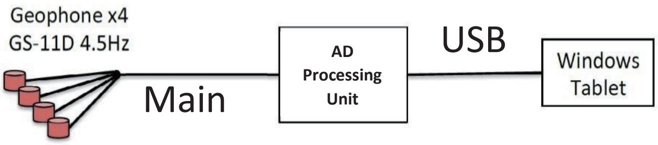

Fig.2 System of microtremor velocity observation tool GDAQ-4s that consists of geo-phone sensors, AD converting unit and Windows OS tablet.

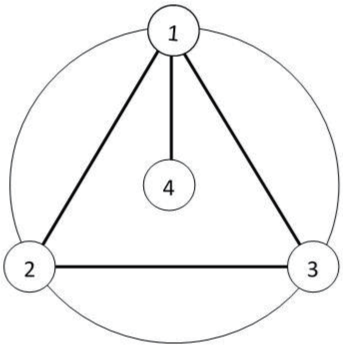

Fig.3 Triangular array setting form for miniature array. A number in small circles indicates a geo-phone sensor.

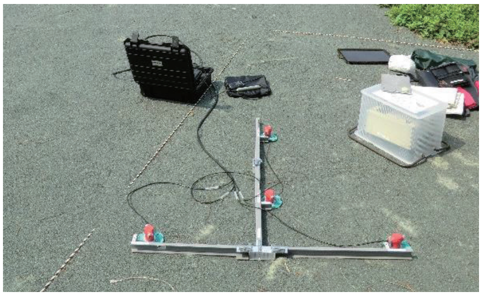

Fig.4 Observation photo a 60 cm microtremor array observation on a site at B5.

3. Estimation of S wave velocity structure by microtremor array observation

Figure 5 shows the waveforms of vertical components (UD) obtained with a 60 cm radius array at point C9. Since these four waveforms are very similar, it is indicated that these waveforms can be used for analysis. Figure 6 shows observed and calculates phase velocity dispersion curves at A2 point. From Fig 6, we can see that the phase velocities are slow (about 100 m / s) in the high frequency band and that velocities become faster in the low frequency band.

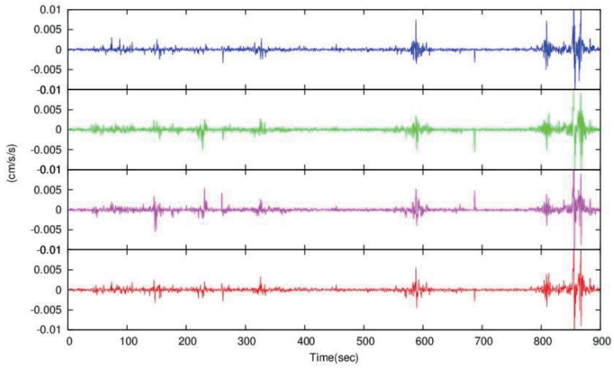

Fig.5 Velocity waveforms of 4 sensors of at observation point C11.

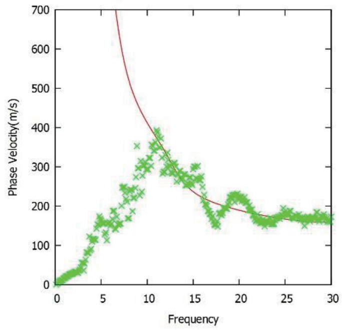

Fig.6 Phase velocity at A2. A red solid line indicates theoretical one and green crosses are observed one.

4. Microtremor H / V

Figure 7 shows the microtremor spectra and spectral ratio obtained at point C11. These are three component spectra, namely, the north-south, the east-west, and the up-down motion components. A band pass filter of 0.1 Hz to 20 Hz was processed. The H/V peak was picked up in the range up to 10 Hz. From Fig. 7, it is possible to identify the peak at 1.1 Hz (0.909 sec). Peak periods were picked up at all observation points.

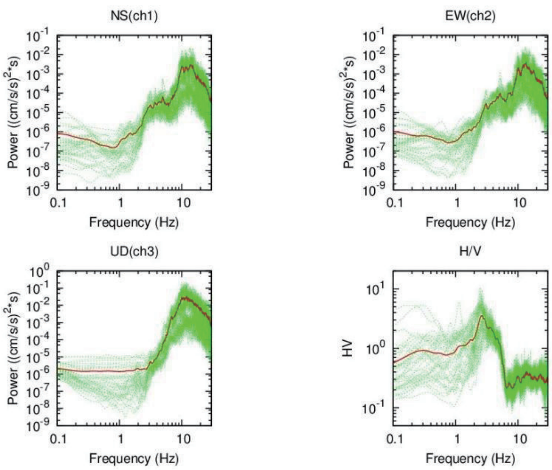

Fig.7 Power spectra and H/V spectra ratio at observation point A2. Red solid lines indicate average lines of power spectra and H/V spectra ratio and green lines are individual observed data.

Figure 8 shows peak periods along B- line. We can see that the peak period gradually decreases. Figure 9 shows peak periods in all observation points in the area. From this figure we can see that B line and C line shows that peak periods are around 0.4 to 0.1 seconds because these observation points locate near mountains area. So we can predict that underground basements in these areas are shallow.

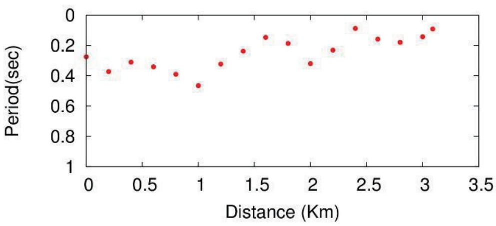

Fig.8 Distribution of peak period against distance along B-line.

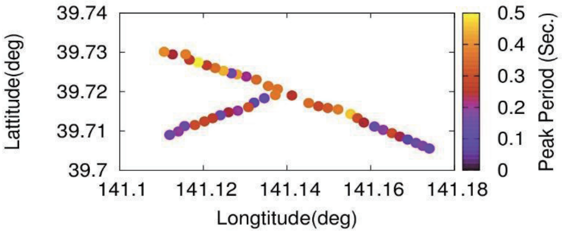

Fig.9 Peak period distribution in at all observation points.

5. Estimation of S wave velocity structure by both dispersion curves and H/V Spectral ratio

The S-wave structure that we obtained from phase velocity calculated by using miniature array may not be complete. Because the array size is limited within 60cm, so we can know S-wave structures at shallow depth not deeper than 10m. However, we can calculate S-wave structure of deeper part by using H/V spectral ratio too. Figure 10 shows an average H/V peak frequency (Red line) at A2 point fitting with a theoretical line (Black line). The theoretical H/V curve we are calculated from the model shown in Fig. 11, we can obtain deep structures by using both dispersion curves and H/V spectral ratio.

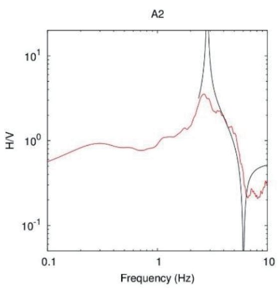

Fig.10 A red solid line is an average H/V spectral ratio and black line indicates theoretical one at A2 point.

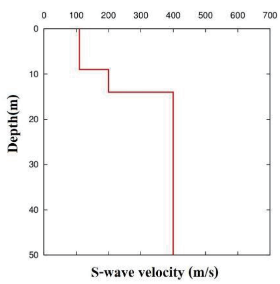

Fig.11 Estimated S-wave structure from calculating H/V Spectral ratio. A red solid line is S-wave velocity.

Figures 12 to 14 show S-wave structures at all sites in A-Line, B-line and C-Line. From these results, we can see basements beneath these areas are shallow. At A-line we found phase velocities in this area around 100-150 m/s especially at middle of the observation line around A5 to A8 points. When we inverted these data to S-wave velocity models, we found these S-wave structures are gradually changed. Velocities of S-wave are changed to faster at shallow section at observation point near the origin point. High impedance contrast interface depths become deeper from A1 to A6 point, and the depths become shallower from A7 to A10 point.

At B observation line, phase velocities in this area are relatively higher than other observation lines, around 200 m/s at a frequency of 10 Hz. Inverted S-wave structures in this line show us that high impedance contrast interface depths are shallow. However, at some observation points of this B line, the depths are abruptly changed. And from Fig. 8 peak periods at these points are around 0.4-0.5 sec, slower than those at other points.

And at C line, S-wave structure in this area are not so different. For this line, high impedance contrast interface depths are gradually changed. At Just only C2 to C4 points, the depths in these points are shallow.

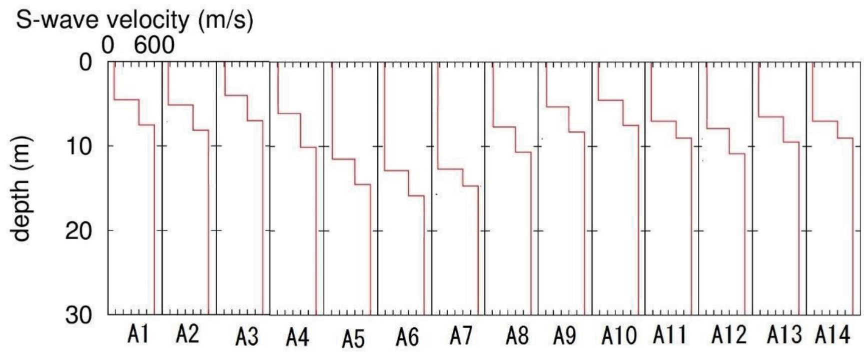

Fig.12 Distribution of S-wave structures along A-Line.

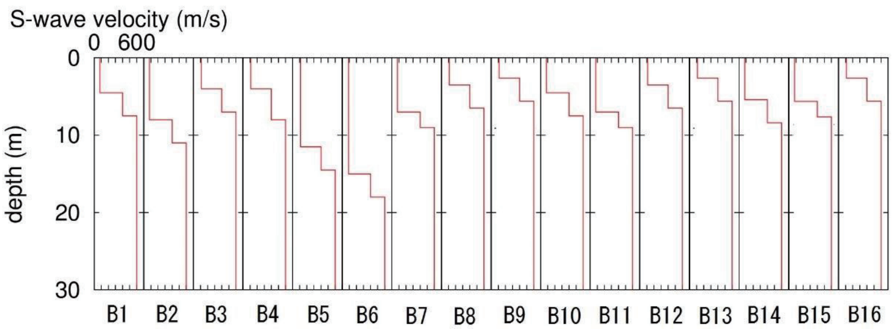

Fig.13 Distribution of S-wave structures along B-Line.

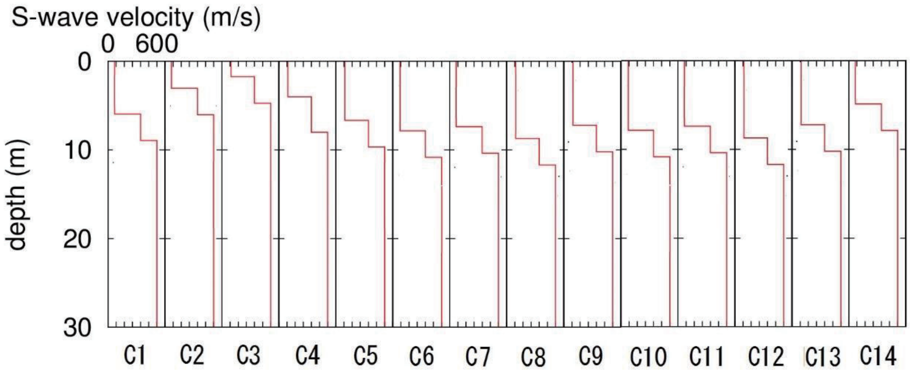

Fig.14 Distribution of S-wave structures along C-Line.

6. Conclusion

From microtremor array observation results we found that phase velocities in the target area are relatively slow, almost around 100-150 m/s except in some places such as B line; phase velocities in this place are higher around 200 m/s. H/V peak period distribution also shows in this area around 0.4-0.1 seconds, in range of medium to fast especially if the place is located in a mountain area. S-wave forms show that high impedance contrast interface depth in this area are not so deep.

However, the observation areas are in a city location, so some obtained data are strange - which might be an effect on the observation process such as traffic noise or local industrial activity near the observation points.

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