Implementing Innovative Ideas in Structural Engineering and Project Management
Edited by Saha, S., Zhang, Y., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-1-7

ESTIMATION OF PREDOMINANT PERIOD OF GROUND SURFACE LAYER USING THE INVERSE DISTANCE WEIGHTING METHOD

HAYATO NISHIKAWA[1] and TOMIYA TAKATANI[2]

[1]*Education and Research Supporting Centre, Nat'l Institute of Tech., Maizuru, Japan*
[2]*Dept of Civil Engrg. & Architecture, Nat'l Institute of Tech., Maizuru, Japan*

The evaluation of a site amplification effect is very important in the earthquake engineering when an earthquake damage distribution of wooden house will be predicted by an accurate estimation of seismic intensity. A predominant period in the microtremor *H/V* spectral ratio at ground surface corresponds to the natural period of surface ground layer. The microtremor *H/V* spectral ratio measurement was applied to the east district in Maizuru city. Both horizontal and vertical microtremors at 75 sites in the east district in Maizuru city were measured by servo type accelerometers, and the microtremor *H/V* spectral ratio and its predominant period at each site were evaluated from microtremor accelerations. Also, the predominant periods at 353 sites were numerically evaluated from the predominant periods measured at 75 sites by the Inverse Distance Weighting method.

Keywords: Microtremor *H/V* spectral ratio, Earthquake disaster prevention, Seismic hazards.

1 INTRODUCTION

The evaluation of a site amplification effect is very important in the earthquake engineering when an earthquake damage distribution will be predicted by an accurate estimation of seismic intensity. In general, the site amplification effects have been analytically evaluated by the multiple reflection theory using a surface ground layer model with soil characteristics at each site. However, it is so difficult to uniformly evaluate site amplification effects for a wider area, because there is a limited and available information data and this evaluation procedure needs a great amount of work. Therefore, site amplification effects can be evaluated from a relationship between the geological features/topography obtained from much simpler information and ground amplification characteristics.

An estimation method of not only the average ground S-wave velocity from geophysical classification including the digital national land information but also the site amplification effects using a peak velocity was proposed by Midorikawa *et al*. (1995). In recent years, a microtremor measurement has been easily employed in order to evaluate a predominant period at each site. Nakamura *et al*. (1988) reported that a spectral ratio of horizontal and vertical microtremors (hereinafter referred to as "microtremor *H/V* spectral ratio") may be artificially assumed to be a spectral amplification rate of ground surface.

It is very important in the earthquake disaster prevention to evaluate the predominant period at ground surface. The evaluation of predominant period needs the ground information of such as PS logging and boring data. However, the sites with ground information are limited. On the other hand, it is well known that the microtremor measurement method has been widely applied to the evaluation of a site effect above the engineering base rock with S-wave velocity of 300m/s. A predominant period in the microtremor *H/V* spectral ratio of ground surface corresponds to the natural period of ground surface. An estimation method of S-wave amplification spectrum using the microtremor *H/V* spectral ratio at ground surface has already proposed by Senna *et al*. (2008).

In this paper, this proposed method is applied to the east district in Maizuru city, and S-wave amplification spectrum at the site without any ground information is estimated based on the microtremor measurement results. Both horizontal and vertical microtremors at 75 sites in the east district in Maizuru city were measured by servo type accelerometers, and the microtremor *H/V* spectral ratio and its predominant period at each site were evaluated from microtremor accelerations. Also, the predominant periods at unmeasured 353 sites are numerically estimated from the measured 75 sites by the Inverse Distance Weighting method proposed by Shepard (1965).

2 OUTLINE OF MICROTREMOR MEASUREMENT

2.1 Microtremor Measurement System

A microtremor measurement system (Photo 1) consists of two servo-type accelerometers. Sampling frequency of a microtremor measurement is 160 Hz, and the measurement time is 51.2 s per one set (8,192 data numbers). Table 1 shows an outline of the microtremor measurement instruments which were used in the microtremor *H/V* spectral ratio measurement at 75 sites in the east district in Maizuru city.

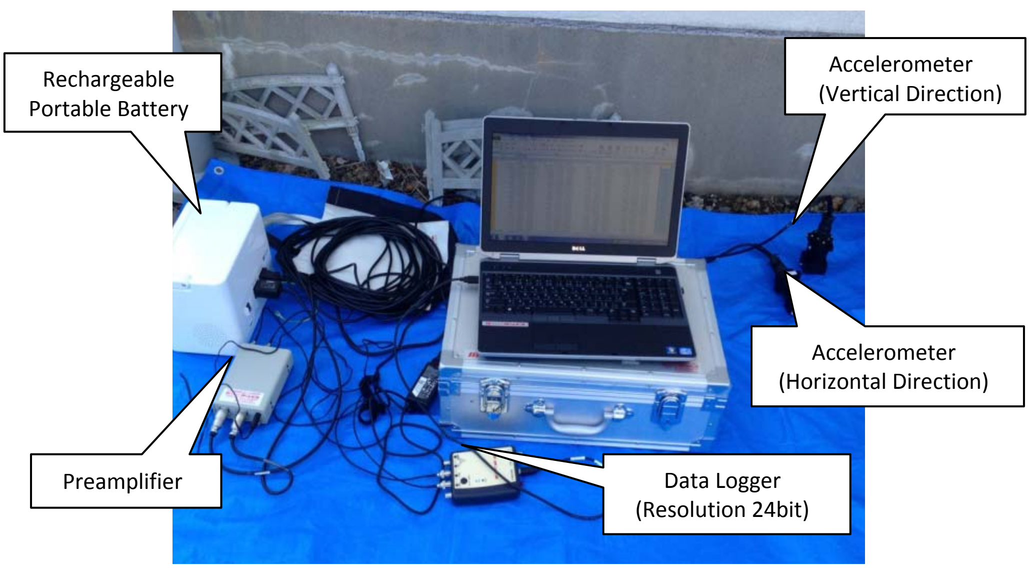


Photo 1. Microtremor measurement system.

Table 1. Outline of instruments used in microtremor measurement.

Instrument Name	Outline
Real Time Vibration Analysis Device (DSA-PHOTON)	Frequency Range : Maximum 21,000Hz A/D Transformation : 24-bit resolution D/A Transformation : 24-bit resolution
Real Time Vibration Wave Controlling System (DSA-RTPro)	Vibration Output Function, FFT Analysis Function, Long Term Vibration Recording Function, Measurement Data Editing Function
Servo-type Accelerometer (V405-BR)	Measurement Range : +-30m/s^2, Resolution 1x10^{-6} m/s^2
Preamplifier (PA-9102)	Frequency Range : 0.3 – 45 Hz

2.2 Microtremor H/V Spectral Ratio

In this paper, Fourier spectrum of microtremor acceleration is numerically obtained by the microtremor acceleration data of 10s section selected from microtremor measurement data. Microtremor *H/V* spectral ratio can be obtained from both horizontal and vertical components of Fourier spectrum of microtremor acceleration, and then Fourier spectrum of microtremor can be smoothed by Parzen window with 0.4Hz band width. The microtremor *H/V* spectral ratio used in this paper is given by the following equation. *H/V* is an average spectral ratio, $(H/V)_{NS-UD}$ and $(H/V)_{gw-UD}$ are NS and EW components of spectral ratio, respectively.

$$\frac{H}{V} = \sqrt{\left(\frac{H}{V}\right)^2_{NS-UD} + \left(\frac{H}{V}\right)^2_{EW-UD}} \qquad (1)$$

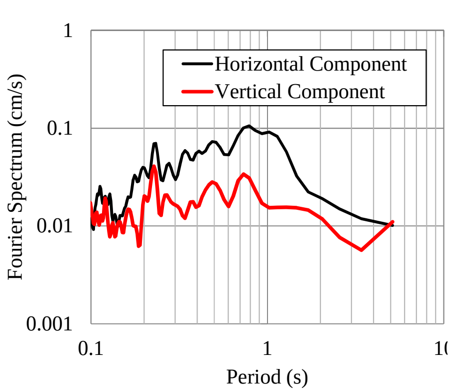


Figure 1. Fourier spectra of microtremor accelerations wave.

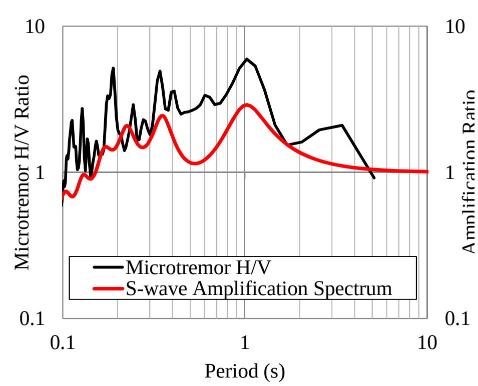
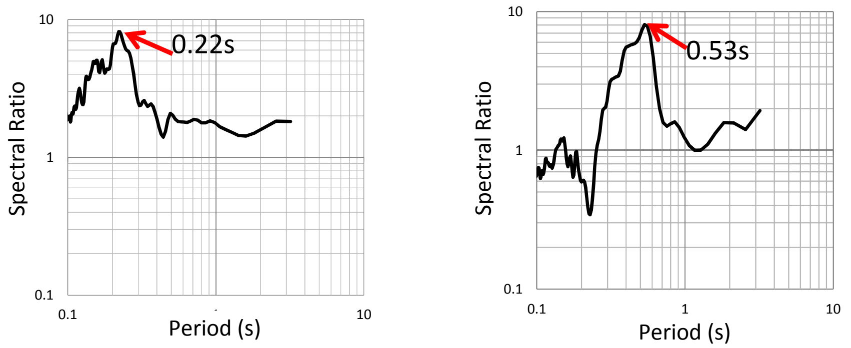


Figure 2. Microtremor *H/V* spectral ratio and S-wave amplification spectrum.

Figure 1 shows Fourier spectra of horizontal and vertical components of measured microtremors. Microtremor *H/V* spectral ratio, which is defined by a ratio of horizontal component to vertical one of Fourier spectra of measured microtremor, is indicated in Figure 2. S-wave amplification spectrum shown in Figure 2 can be analytically calculated by the multiple reflection theory using a ground surface layer model based on the boring data.



(a) A site. (b) B site.

Figure 3. Microtremor *H/V* spectral ratio.

Figure 3 shows microtremor H/V spectral ratios at A and B sites, which are obtained from Fourier spectra of horizontal and vertical components of measured microtremors. Microtremor *H/V* spectral ratio, which is defined by a ratio of horizontal component to vertical one of Fourier spectra of measured microtremor, is indicated in this figure. Predominant period shown in Figure 3 can be analytically calculated by the multiple reflection theory using a ground surface layer model based on the boring data.

In general, a peak period in microtremor *H/V* spectral ratio almost may accord with a peak period in S-wave amplification spectrum. Consequently, this implies that the predominant period at the site without any boring data or ground information can be easily and accurately evaluated from the microtremor *H/V* spectral ratio.

3 Estimation of H/V Spectral Ratio by the Inverse Distance Weighting Method

In this paper, a microtremor H/V spectral ratio at unmeasured site can be numerically estimated by the following Inverse Distance Weighting Method (Shepard 1968).

$$H/V = \sum_{i=1}^{N} w_i (H/V)_i \tag{2}$$

$$w_i = \frac{1/r_i^2}{\sum_{i=1}^{N} 1/r_i^2} \tag{3}$$

(*H/V*) is a microtremor *H/V* spectral ratio at *i*-th site, w_i is a weight at *i*-th site, r_i *is* a distance between *i*-th site and unmeasured one, and N is a total number of measured sites.

Figure 4 shows the microtremor (*H/V*) spectral ratios at 75 measured sites, and Figure 5 indicates a microtremor (*H/V*) spectral ratio distribution map evaluated by the Inverse Distance Weighting method described previously. Microtremor (*H/V*) spectral ratios at 335 estimating sites were numerically obtained from the (*H/V*) spectral ratios at 75 measured sites shown in Figure 4. It should be noted that (*H/V*) spectral ratio at estimating site can be obtained by these equations (2) and (3) under the limited microtremor observations of 75 sites. It is found from this figure that the microtremor *H/V* spectral ratio in the seaside area in the east district in Maizuru city trends to have a long predominant period, where an extensive damage to old wooden house structures may occur during a strong earthquake motion. This seismic prediction of old wooden house against a strong earthquake motion is not presented in this paper due to the limited space.

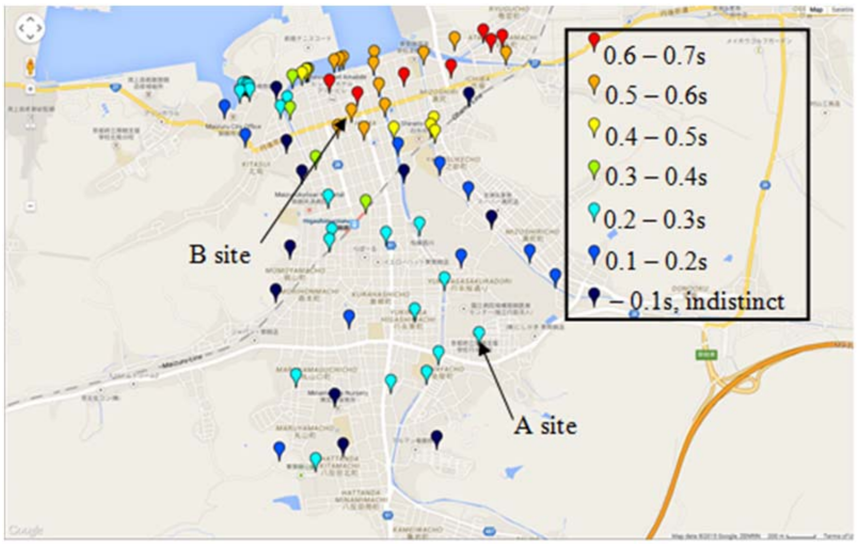


Figure 4. Microtremor measurement sites in east district in Maizuru city.

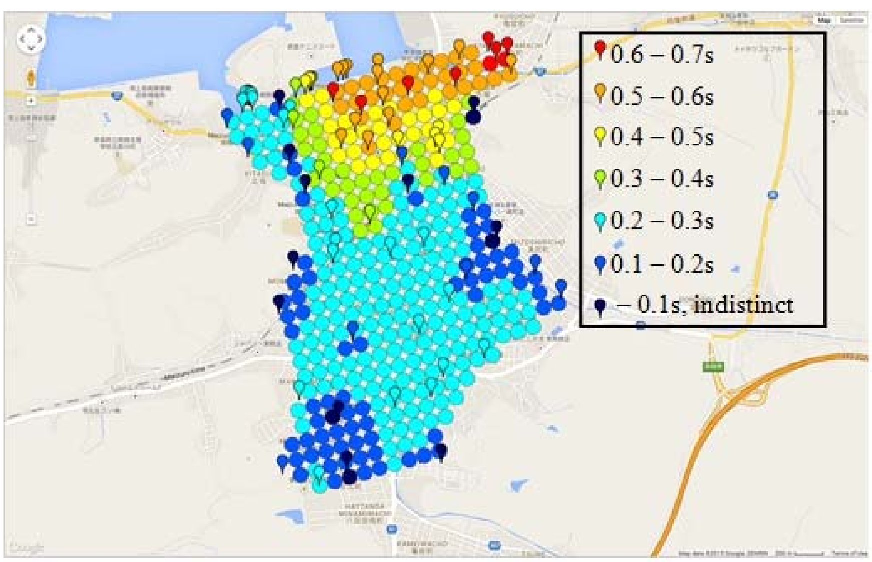


Figure 5. Evaluation of predominant period distribution using microtremor *H/V* spectral ratio.

4 CONCLUSIONS

In this paper, both horizontal and vertical microtremor observation at 75 sites in the east district in Maizuru city was conducted by servo-type accelerometers and the microtremor *H/V* spectral ratio and its predominant period at each site were evaluated from microtremor accelerations. Microtremor *H/V* spectral ratios at 335 unmeasured sites were numerically obtained from the microtremor *H/V* spectral ratio at 75 measured sites.

The summary obtained in this paper is as follows:

(1) A predominant period at the site without any ground information can be easily evaluated from microtremor *H/V* spectral ratio.

(2) The microtremor *H/V* spectral ratio in the seaside area in the east district in Maizuru city trends to have a long predominant period, where an extensive damage to wooden house structures may occur during a strong earthquake motion.

(3) Using a predominant period at unmeasured site evaluated by the Inverse Distance Weighting method under the limited microtremor observation values, a distribution map of predominant period can be numerically evaluated.

References

Midorikawa, S., and Matsuoka, M., GIS-based Integrated Seismic Hazard Evaluation Using the Digital National Land Information, *Journal of Society of Exploration Geophysics of Japan*, 48(6), 519-529, 1995 (in Japanese).

Nakamura, Y., A Method for Dynamic Characteristics Estimation of Surface Layer Microtremor on the Surface, *Quarterly Report of Railway Technical Research Institute*, 2(4), 18-27, 1988 (in Japanese).

Senna, S., Midorikawa, S., and Wakamatsu, K., Estimation of Spectral Amplification of Ground Using H/V Spectral Ratio of Microtremors and Geomorphological Land Classification, *Journal of Japan Association for Earthquake Engineering*, 8(4), 1-15, 2008 (in Japanese).

Shepard, D., A Two-dimensional Interpolation Function for Irregularly-spaced Data, *Proceedings of the 1968 23rd ACM National Conference*, 517-524, 1968.