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INVESTIGATION OF MICROTREMOR MOTION VARIATION BY NAKAMURA'S H/V SPECTRAL RATIO METHOD

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ABSTRACT: In this study, the variation of microtremor motion is investigated using observation data in Hanoi and Vung Tau cities. The results of observation conducted by times and by seismometers are processed using the Nakamura's H/V spectral ratio method and compared. For investigation, the observations have been conducted with frequency of 27 observations per hour, 22 observations per month, 4 simultaneous observations using both Servo and K2 seismometers, and 12 simultaneous observation using 7 Servo seismometers. The results of data analysis show that the values of dominant frequency and shapes of the H/V spectral ratio obtained are similar in the frequency range from 0.4 Hz to 5 Hz, especially on the dominant frequency domain. The results confirm that the microtremor variation observations can be carried out with one observation time or by multiple seismometers.

Keywords: H/V spectral ratio (HVSR), microtremor, seismometer.

INTRODUCTION

Microtremor is a natural vibration near surface with very small amplitude (variation of amplitude of displacement is about 10^{-7} to 10^{-5} m; variation of amplitude of velocity is about 10^{-7} to 10^{-6} m/s). They are created from such sources as: earthquake, sea wave, human activities, traffic, wind,... Microtremor is measured by the seismometer with high sensitivity (over 100 V/m/s) and high-resolution (over 20 bit). Microtremor is usually measured and processed by two following techniques:

(1) The reference measurement technique, using a fixed seismometer, which measures continuously by time, and another mobile seismometer, which only measures the signal during the observation time. Using the seismic recording of fixed and mobile seismometers at the same time to remove local noise effect to the mobile seismometer. The dominant period of the ground during measurement is determined by function $T_i = t/n_i$, where t is time interval of microtremor with T_i period, n_i is number of microtremors in time interval t. In fact, the dominant period determined by this technique depends on local noise, the dominant period is usually unstable and inaccurate.

Therefore, this technique is rarely applied in the microzonation nowadays [1].

(2) *Nakamura's H/V spectral ratio method* (Nakamura, Y. (1989)), which is using only one seismometer with three components (2 horizontal components and 1 vertical component) to measure the signal during observation time. The dominant frequency is determined by Fourier spectral ratio of 02 horizontal components and 01 vertical component by function $\sqrt{(NS*EW)}/V$, where *NS*, *EW* and *V* are the Fourier spectra of north-south component, east-west component, and vertical component, respectively. The spectral ratio is called *H*/*V* spectral ratio (HVSR). According to Nakamura, this technique allows reducing the effect of local noise at observation point. In addition, this technique also determines the dynamic properties of ground motion at observation point. This means that each observation point has its own characteristics, which do not depend on the number of observations or seismometers. So, microtremor observation can be done with one observation. Due to the advantages of this method, it is widely used in the world and Vietnam for microzonation, determination of shear wave velocity structure and site effect estimation. It has been proved by many studies that this method is well applicable for the areas where the hard rock is covered by young and soft deposits [2- 9].

Since 2003, the Nakamura's *H/V* spectral ratio method (1989) has been widely used in Vietnam for microtremor investigation, site effect to serve construction planning of city and importance areas. So that, the investigation of microtremor is very necessary. In fact, most of microtremor observations have to be carried out at the site of difficult traffic condition, so it is difficult to make loop measurements. Furthermore, to reduce the cost and observation time in the field, the microtremor observations are usually carried out by different seismometers. Therefore, the investigation of microtremor measurements is very necessary. In order to do this, we have conducted the investigation of microtremor measurements in Hanoi and Vung Tau cities, fig. 1.

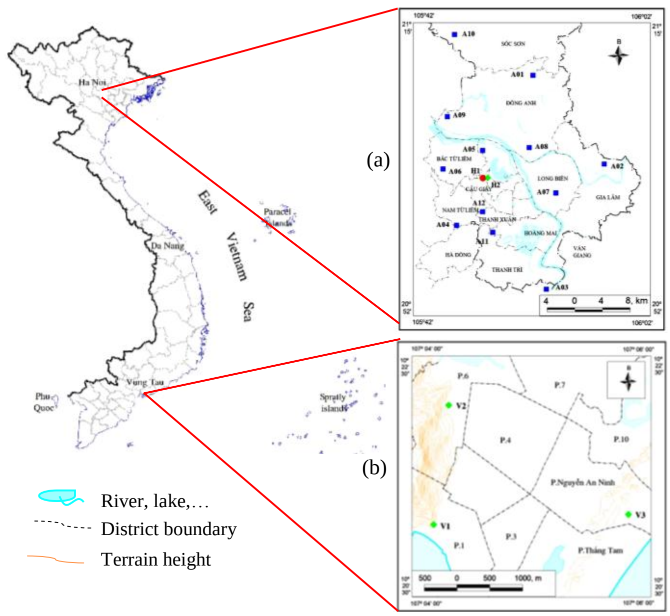


Fig. 1. Distribution of measurement points in the study areas: (a) Hanoi city, (b) Vung Tau city. The red circle symbol is the loop measurement point using one Servo seismometer; The green diamond symbols are simultaneous measurement points using both Servo and K2 seismometers; The blue square symbols are simultaneous measurement points using 7 Servo seismometers

The results of microtremor measurement investigation and data analysis are described in detail in this paper.

METHODOLOGY

Data collection

The seismometers are used in this research: (1) The Servo seismometer includes a recorder which has resolution of 24-bit and the sensor which has six channels (three velocities and three accelerations) with frequency ranging from 0.1 Hz to 50 Hz; (2) The K2 seismometer includes a K2 recorder with resolution of 24-bit and 3 SS-1 sensors (two horizontal sensors and a vertical sensor) with natural frequency around 1 Hz, fig. 2.

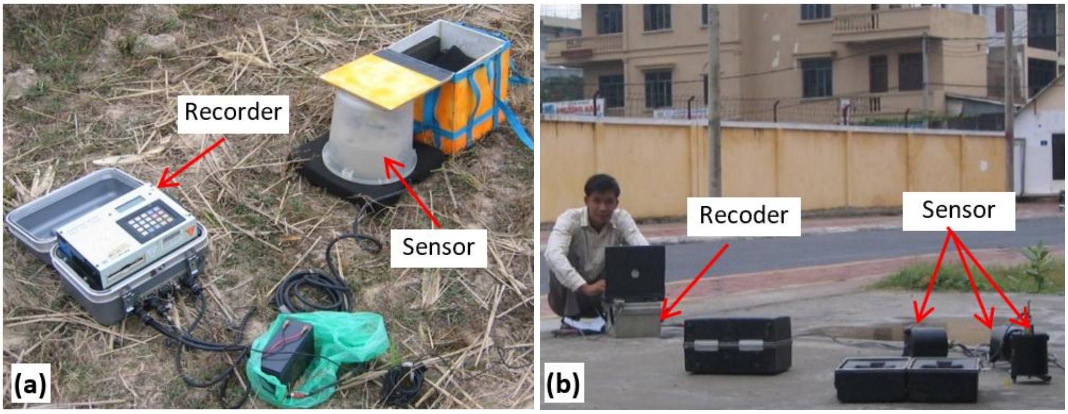


Fig. 2. The seismometers used in this research. (a) The Servo seismometer, which includes a SAMTAC recorder and a VSE-355EV sensor, (b) The K2 seismometer, which includes a K2 recorder and 3 SS-1 sensors

The dataset used in this paper is the 03 component velocity of microtremor motions, consisting of 2 horizontal components (*NS* and *EW*) and one vertical component (*V*). Each observation time is 18 minutes (continuous), the sampling rate is 200 samples/second for loop measurements and 100 samples/second for simultaneous measurements. Measurement time and procedure were set automatically, namely:

(1) The loop observation dataset obtained at the Institute of Geophysics in Hanoi during 2009 and 2010, which includes: (i) 27 hourly observations, each of which measured once per hour within about 18 minutes, from 17h40’ on 02/May/2009 to 20h05’ on 03/May/2009; (ii) 22 monthly observations, which were conducted twice per month, at 10h00’ and 11h00’ on every first day of the month, from June/2009 to April/2010, fig. 1a.

(2) Simultaneous observation dataset obtained by using difference seismometers in Hanoi and Vung Tau cities, which includes: (i) 4 simultaneous observations using both Servo and K2 seismometers, of which 3 measured in Vung Tau and 1 measured in Hanoi [9]; (ii) 12 simultaneous observations using 7 Servo seismometers in Hanoi [8], fig. 1b.

Analysis

The microtremor data processing procedure was implemented as follows: (i) to divide the microtremor recording into multi segments, each segment consists of 4096 data points (which corresponds to the record length of 20.48 s or 40.96 s); (ii) to remove the bad and whimsical segments; (iii) to apply the fast Fourier transformation to each component of each segment; (iv) to calculate the Fourier amplitude ratios, which is the *H*/*V* ratio (HVSR), of each segment using the formula:

$$\sqrt{(NS*EW)}/V \tag{1}$$

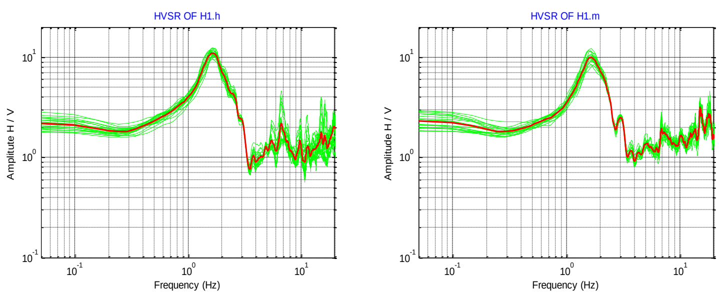
Where *NS*, *EW*, *V* are the Fourier amplitude ratios of north-south, east-west, vertical components, respectively; (v) to average the HVSR of all segments to receive the final HVSR. The Matlab software then was used to create the HVSR graphs. Finally, the HVSR graphs have been compared to assess the differentiation on the full response range of the seismometer.

DISCUSSION

The variation of microtremor observation results obtained in Hanoi and Vung Tau cities from both one-seismometer and multi-seismometer measurement methods have been investigated. After processing of microtremor observations, HVSR graphs were constructed for each observation by the Nakamura's *H/V* spectral ratio method (1989). The HVSR variation was assessed based on the HVSR graphs.

Fig. 3 illustrates the HVSR graphs obtained from the loop measurements in order to observe the HVSR variation by time. The picture shows that: (i) The values of dominant frequency by both measurement methods are similar; (ii) The shapes of the HVSR graphs obtained from both measurement methods are similar on the whole frequency range of the seismometer; (iii) On the frequency range from 0.2 Hz to 5.0 Hz, the shapes of the HVSR graphs from both observation methods are slightly different. This may be explained by the influence of local noise around microtremor observation point (regarding the frequency above 5.0 Hz) or the influence of temperature, or because the observation time is not long enough (regarding the frequency less than 0.2 Hz).

Fig. 4 illustrates the HVSR graphs obtained from the simultaneous observations using Servo and K2 seismometers in order to observe HVSR variation by seismometers. The picture shows that: (i) The values of dominant frequency measured by both seismometers are similar; (ii) The shapes of the HVSR graphs obtained from both seismometers are similar on the whole frequency range of seismometers; (iii) Within the dominant frequency range, the value of amplification amplitude measured by the Servo seismometer is one amplification unit larger than the corresponding value measured by the K2 seismometer.



a) b)

Fig. 3. The HVSR graphs created from the loop observation by one Servo seismometer at Institute of Geophysics, to observe the HVSR variation by time. Dark red line is the HVSR average of the loop observations: (a) 27 observations per hour, from 17 h 40' on 2/5/2009 to 20 h 05' on 3/5/2009, (b) 22 observations per month, from 6/2009 to 4/2010

Figures 5, 6, 7 illustrate the HVSR of the simultaneous observations using 7 Servo seismometers, to observe the HVSR variation by seismometers. The pictures show that: (i) The values of dominant frequency observed by these 7 seismometers are similar; (ii) The shapes of the HVSR graphs obtained from the seismometers are similar on the whole frequency range of seismometers; (iii) On the frequency ranges less than 0.4 Hz and higher than 5.0 Hz, the shapes of the HVSR graphs obtained from the seismographs are slightly different. This may be due to the influence of the direction of local noise to seismometers (regarding the frequency above 5.0 Hz) or the influence of temperature, not long enough observation time (regarding the frequency less than 0.4 Hz).

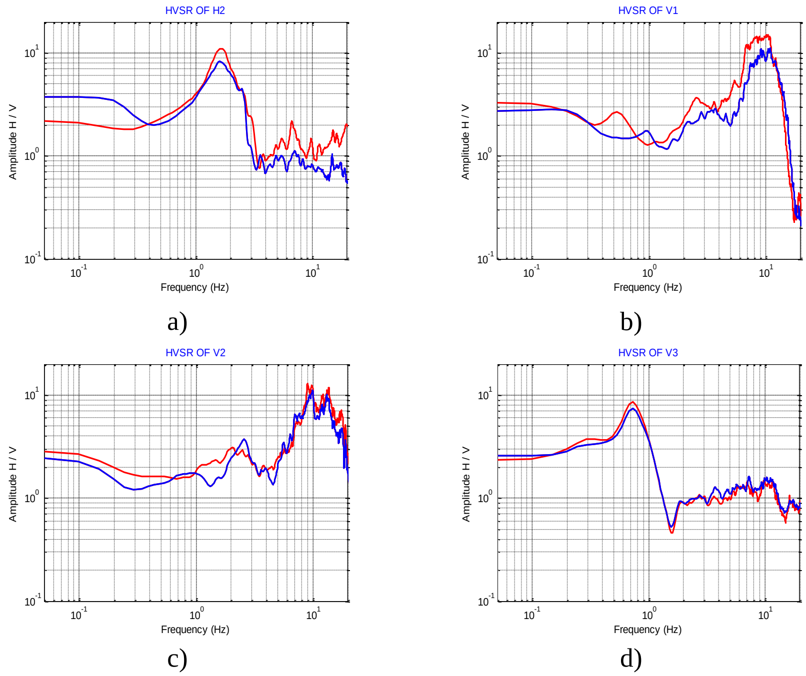


Fig. 4. HVSR graphs obtained from the simultaneous observations points using the Servo and K2 seismometers, to observe the HVSR variation by seismometer. The blue line is the HVSR measured by K2 seismometer, and the red line is HVSR measured by Servo seismometer: (a) at Institute of Geophysics, Hanoi; (b), (c), (d) at Vung Tau city

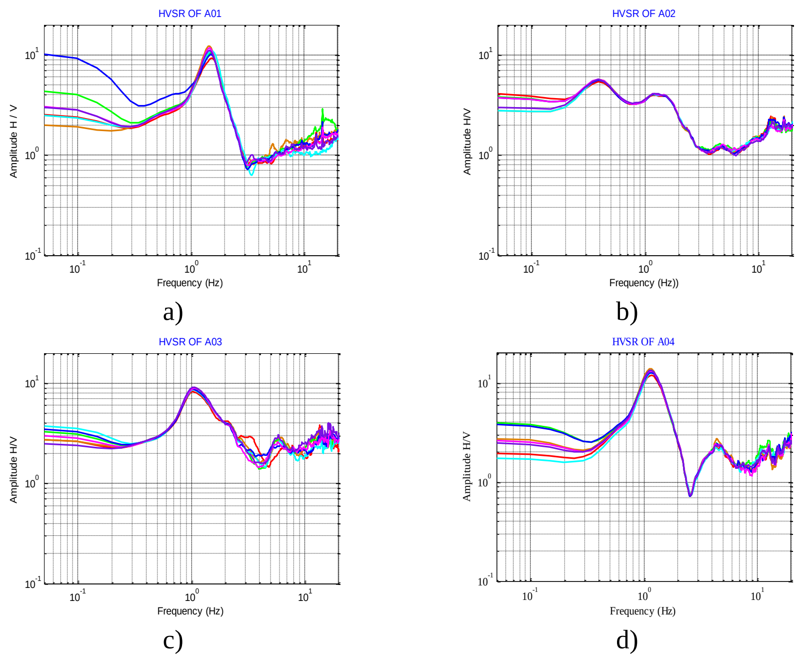


Fig. 5. The HVSR of the simultaneous observation using 7 Servo seismometers in Hanoi in 2009, to observe the HVSR variation by seismometers: (a) Dong Anh; (b) Gia Lam; (c) Thanh Tri and (d) South of Tu Liem

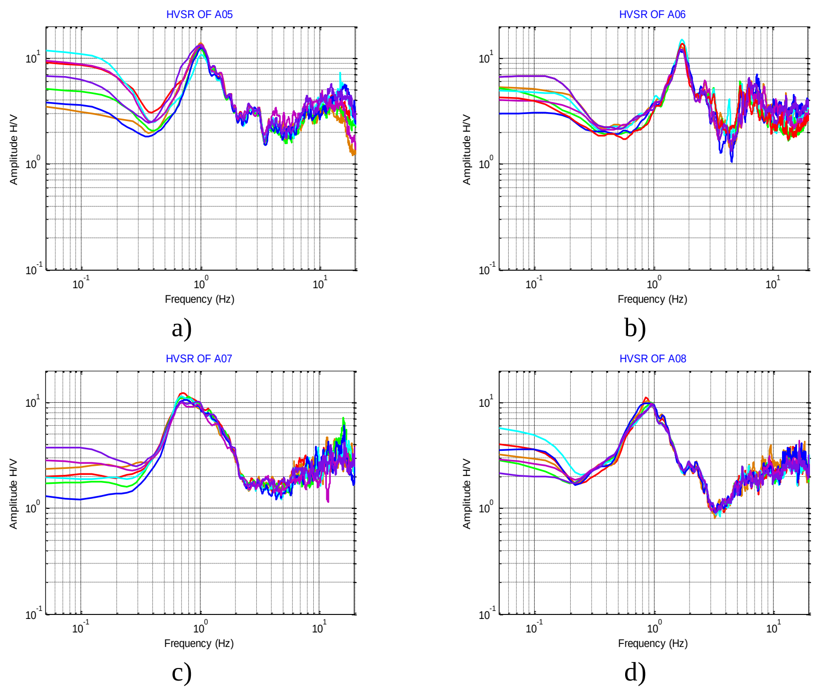


Fig. 6. The HVSR of the simultaneous observations using 7 Servo seismometers in Hanoi in 2012, to observe the HVSR variation by seismometers: (a) Cau Giay; (b) North of Tu Liem; (c) Long Bien and (d) Dong Anh

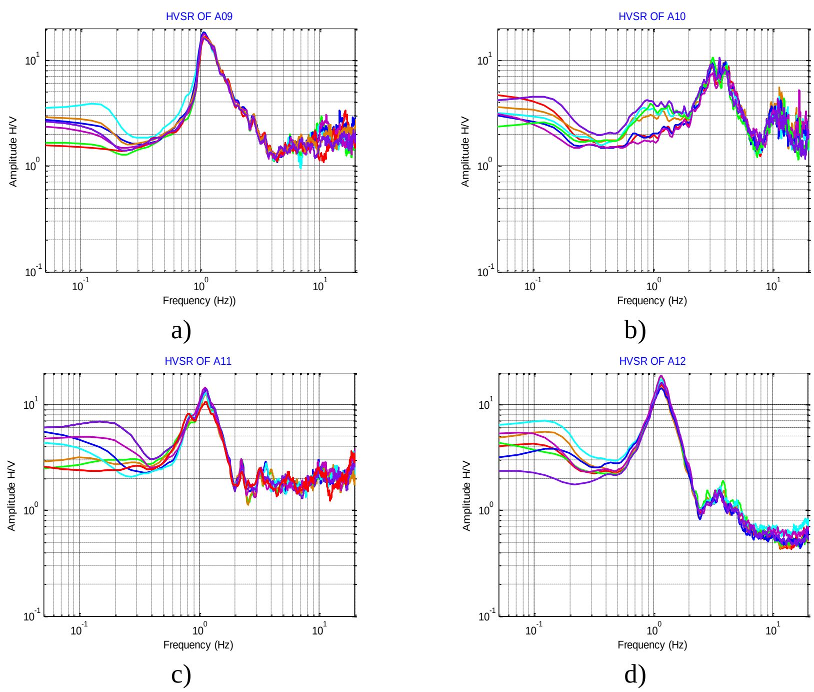


Fig. 7. The HVSR of the simultaneous observations using 7 Servo seismometers in Hanoi in 2013, to observe the HVSR variation by seismometers: (a) Dong Anh; (b) Soc Son; (c) Thanh Tri and (d) Dong Da

CONCLUSION

The results of analyzing a dataset of 27 hourly loop observations, 22 monthly loop observations at the same points show that the values of dominant frequency and shapes of the H/V spectral ratio obtained are similar. These results allow confirming that the microtremor observations can be carried out with just one observation time.

The results of 04 simultaneous observations using both Servo and K2 seismometers, and 12 simultaneous observations using 07 Servo seismometers show that the values of dominant frequency and shapes of the H/V spectral ratio obtained from both cases are similar. These results allow confirming that the microtremor observations can be carried out by multiple seismometers.

However, in some frequency bands (in this study above 5.0 Hz and below 0.4 Hz), the shapes of the HVSR graphs are slightly different. This may be due to the influence of local noise around microtremor observation point (regarding the frequency above 5.0 Hz) or the influence of temperature, not long enough observation time (regarding the frequency below 0.2 Hz). These issues need to be further studied in future.

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