ESTIMATION OF THE GROUND PREDOMINANT PERIODS BY APPLYING NAKAMURA METHOD TO DATA PROCESSING OF MICROTREMOR OBSERVATIONS IN HO CHI MINH CITY, VIETNAM

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Estimation of dynamic characteristics of subsurface such as predominant period, amplification factor, shear wave velocity…etc plays an important role in the research of the effects of long-period ground motion earthquakes to high-rise buildings in big cities. In this paper, the results of applying the Nakamura Method to data processing of microtremor observations in Ho Chi Minh City of Vietnam are presented. By using this method, the predominant period of the ground at the sites can be estimated from the horizontal to vertical (H/V) spectral ratios of microtremor. The obtained results show that the ground of Ho Chi Minh City has considerable potentiality in resonating with long-period ground motions.

***Key words**: Microtremor, dynamic characteristics, predominant period, long-period ground motion*

1. INTRODUCTION

1.1. Overview of the earthquake situation all over the World and in Vietnam

In recent years, several large earthquakes have occurred in the world caused severe damage on people, houses and buildings as well as technical infrastructure even for countries with economic potential and experienced in earthquake resistant construction, such as Japan, America, Russia, China, New Zealand, etc … Typical examples are the earthquake Sumatra – Indonesia in 2004 with a magnitude 9.1 Richter scale; Tu Xuyen – China earthquake in 2008 with a magnitude 7.8 on the Richter scale; Christchurch – New Zealand in 2011 and most recently, the earthquake in the island Honshu – Japan on 11/3/2011 with magnitude up to 9 on the Richter scale – was the biggest earthquake within past 140 years in this country.

So far, earthquakes have occurred throughout the territory of Vietnam (fig 1), which has many strong earthquakes in some localities, such as earthquakes in 1935 at Dien Bien with magnitude 6.8 on the Richter scale, causing seismic level VIII; earthquake in Tuan Giao – Lai Chau in 1983 with magnitude 6.7 on the Richter scale, seismic level VIII caused landslides, ground cracks in large areas, large landslides on the mountains, property damage in radius 35km; earthquake Do Luong – Nghe An in 2006 with magnitude 4.9 on the Richter scale, seismic level IV. Recently, strong earthquake with magnitude 5.3 on the Richter scale occurred on 19/02/2001 on the mountains of Nam Oun – Laos, a city located 15km in the west of Dien Bien, the epicenter was 12km deep. Although this earthquake did not cause human death, some building structures in Dien Bien were severely damage; strong earthquake happened on 03/24/2011 with magnitude

7.0 on the Richter scale near the border with Myanmar – Laos – Thailand, this earthquake caused shock seismic level V in Hanoi and seismic level VI (MSK scale - 64) in some localities in north western of Vietnam.

In the southern provinces of Vietnam, on 28/11/2007, a strong earthquake with magnitude 5.1 on the Richter scale occurred with hypocenter off the coast of Vung Tau province about 30 km, this earthquake caused seismic level IV in the area of Ho Chi Minh city. On 23/6/2010, another earthquake happened off the coast of Vung Tau area – Phan Thiet with magnitude 4.7 on the Richter scale, caused seismic level IV in Ho Chi Minh City, Vung Tau and Dong Nai.

To actively prevent the land and constructions to deal with the frequency of earthquake increased, recently, the Department for the quality of construction work has conducted the survey, inspection and review of the current seismic resistant standard systems along with conducting many inspection teams of the implementation of seismic resistant standards in some local areas with high possibility of earthquakes such as Hanoi, Ho Chi Minh, Da Nang, Ba Ria – Vung Tau province, Dien Bien and proposed some necessary solutions to improve the shock resistance for the buildings. (Source: Seismic report of Department for the quality of construction work to the Minister of Construction) [1)]

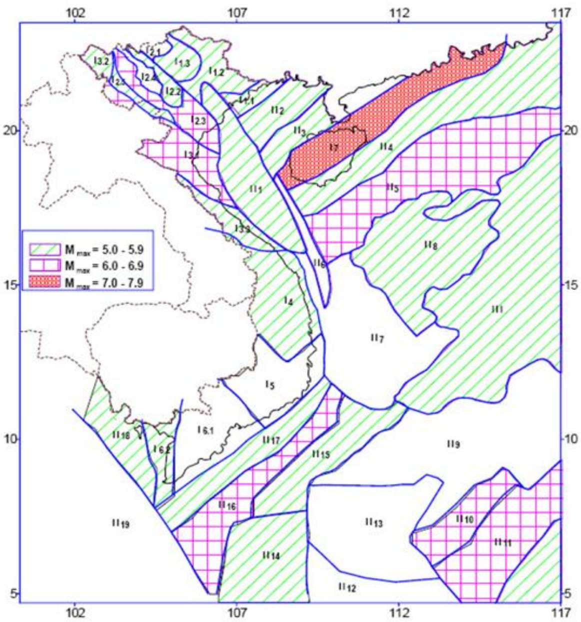

Figure 1. Maximum credible earthquakes in Vietnam (Source: Project: "Research and Forecasting Earthquakes and Ground Movements in Vietnam" by Vietnam Institute Geophysics

1.2. Introduction of long-period ground motion of the occurred earthquakes

Nowadays, with the increasing in the number of large-scale structures, such as high-rise buildings and oil storage tanks, many designers have to face several big problems that relevant to seismic design. Recently, one of the most noticeable problems is long-period ground motion with the periods vary from 1 to 10 seconds or longer. Long-period ground motions are divided into 2 types: far-source and near-fault long-period ground motion. Far-source long-period ground motion can be generated by large subduction-zone earthquakes and moderate to large crustal earthquakes in distant sedimentary basins with the help of path effects. On the other hand, the source effects of forward rupture directivity can generate near-fault long period ground motion. Far-source long-period ground motions consist primarily of surface waves with longer durations than near-fault long-period ground motions. They were first recognized in the seismograms of the 1968 Tokachi-oki and 1966 Parkfield earthquakes, and their identification has been applied to the 1964 Niigata earthquake and earlier earthquakes. Through the investigation of tank damage by liquid sloshing, we can identify far-source long-period ground motions, even if there is no seismogram.

Because of certain path effects, and site effects amplify the long-period component of seismic ground motion generated by earthquakes in distant basins so that they can cause destruction over a much greater range, besides their initial damages in near-fault regions through source effects such as the directivity effect of rupture propagation and the near-field term of body wave radiation.

In the past, most structures might only be resonant with relatively short-period (1 s or shorter) ground motions because in earthquake-prone regions, they were low-profile structures. Thus short-period ground motions were important with the past structures. Nevertheless, nowadays, with the unremitting increasing number of large structures that have long-period fundamental periods such as high-rise buildings, oil storage tanks, suspension bridges, off-shore oil drilling platforms, and recent base-isolated structures, long-period (1 to 10 s or longer) ground motions have been increasingly important (e.g., Kanamori 1979; Fukuwa 2008).

The worst example of destruction caused by longperiod ground motion occurred in Mexico City, 400 km from the 1985 Michoacan earthquake (Mw= 8.0; e.g., Beck and Hall 1986). Another example is the 2003 Tokachi-oki earthquake (Mw=8.3) that occurred in Hokkaido, Japan (e.g., Koketsu et al. 2005) [2)].

Return to Vietnam, this country is located in the southeast Asia that is very near many countries with high probability of occurring earthquakes for example China, Indonesia, Philippine, Thailand, Japan ...etc. Moreover, in Vietnam, because of the unstopping requirement of house for the citizens and the offices for many companies, more and more high-rise buildings are being constructed in the metropolitan area of big cities such as Hanoi, Ho Chi Minh City. Those high-rise buildings are categorized into long-period structures; consequently, the research of long-period ground motion in Vietnam is very necessary.

1.3. Introduction of microtremor and Nakamura method [3)]

Microtremor observations based on measurements of ground vibrations caused by natural phenomena such as wind, waves, transport, industrial plants ... etc. In the world, this kind of measurement is one of the important data in the study of seismic microzonation, the partition map of the earthquake. In Vietnam, there were several researches conducted in a few cities such as Hanoi [4)], Dien Bien ...etc and some construction sites of important projects. The Nakamura technique are used for calculating the spectral ratio of horizontal and vertical component of seismic waves (in this study, the component is the acceleration component) of the microtremor observation. In his theory, Nakamura said that, based on the ratio of this spectrum, we can evaluate the resonant frequencies and the amplification factors of the ground.

In the present study, the estimation of the ground predominant periods by applying Nakamura method to data processing of microtremor observations in Ho Chi Minh City that were carried in March of 2011 by the author and the advisor.

2. MICROTREMOR OBSERVATIONS IN HO CHI MINH CITY, VIETNAM

2.1. Experiment sites of microtremor measurement in Ho Chi Minh City, Vietnam

Microtremor measurements were carried out in Ho Chi Minh City from 23rd March 2011 to 29th March 2011 by author and the advisor – Professor Masakatsu Miyajima of Kanazawa University. The local weather was sunny, sometimes it had small rain, and the temperature varied around 30^{o}C (Celsius degree).

The chosen experiment sites were 5 sites that is located in the center area of Ho Chi Minh City (Metropolitan) Fig 2 & Table 1:

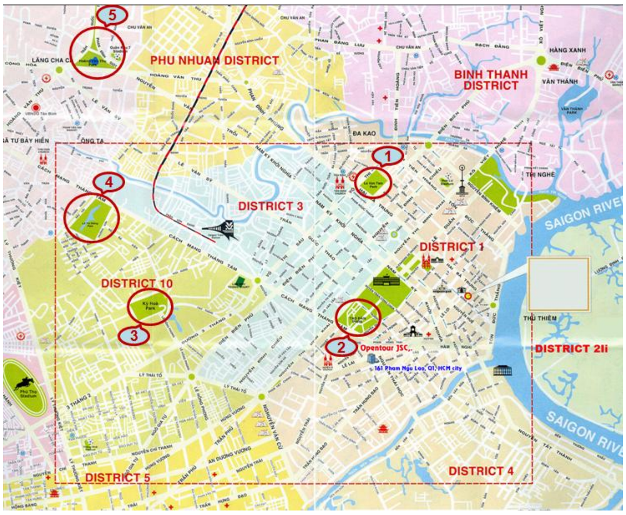

Figure 2. Microtremor Experiment Sites

Table 1 Microtremor Experiment Sites

Site 1:	Le Van Tam Park
Site 2:	Tao Dan Park
Site 3:	Ky Hoa Travel Area
Site 4:	Le Thi Rieng Park
Site 5:	Hoang Van Thu Park

The reasons for those sites selection:

The topic research of the author in doctoral course in Kanazawa University is “Long-period Ground Motion Earthquake Effects to High Rise Building”. Thus, the behavior of high-rise buildings located in the center area as well as the dynamic characteristics of the soil will be examined carefully. The first step is to examine the dynamic characteristics for example: predominant period, amplification factor, shear wave velocity...etc. In this paper, only the predominant period and frequency are examined and introduced.

Microtremor measurement is carried out in the center of each site. The sites of experiment are parks or natural land areas that have the minimum activities of traffic. Ho Chi Minh City is a very big city with very high density of traffic activity; consequently, those sites were selected to reduce the noise as much as possible (Fig 3).


Figure 3. One Experiment Site

2.2. Experiment description

The model microtremor device is GPL-6A3P that was manufactured by Akashi Company (Fig 4&5). For each site, microtremor measurement was done 6 times that included 3 times with noise filter and 3 times without noise filter. The time duration for each measurement was 3 minutes and the directions were 3 channels (Up-Down, North-South, and East-West) (Fig 6).

Figure 4. Devices of Experiment

Figure 5. GPL-6A3P Portable Receiver - Microtremor Device

Figure 6. 3 receiver units

In the present study to measure the small vibration of microtremor portable data logger manufactured by Akashi GPL-6A3P (Ltd) (Fig 5) was used. This fine gauge, type accelerometer over damping small and relatively is easy to handle (fewer sensors). The device was consisted of data logger, and batteries and lightweight, which was housed in a robust aluminum case. Fine gauge is built in three components (two horizontal components, one component of the vertical: Fig 6). The electrical output proportional to acceleration from the high sensitivity of the sensor, data logger recorded in the data. Besides, without the need for an external power supply from a battery that has been observed to make it easier to navigate than the old one. In addition, seismic safety has been the fact that the sensor is built in an aluminum case, transportation and handling does not require great care and installation can be easy to use.

Analog data obtained in the measurement, to perform computer analysis, it is necessary to convert analog data into digital data values. High-resolution data logger recorded the type of A / D converter (24bit A / D) conversion by performing. When the digital waveform analyzed, the minimum period of one time interval is adopt to about 10. It is sufficient to take samples of 10 points or one wavelength. The target period microtremor ground in this study, it is about 0.1 to about 10 seconds, the sampling frequency set to 100Hz. In other words, it will record a number of analog data every 0.01-second intervals. In total, 3 minutes, 18,000 pieces of data were recorded.

2.3. Precautions for observation

Tremor, as mentioned earlier, is thought to represent a period characteristic of the ground. However, because the ambient vibration is very low level of vibration, non-susceptible period characteristic of the ground observation point due to a total installed fine. Therefore, the measurement was carried out at above mentioned sites also recording the noise and vibration being transmitted to the surface forces caused by vehicles and machinery are very close to the measurement location. The installation is also possible to ground the outcrop, and to select around the absence of large structures, such as when the obstacle was placed in the impossible position possible to meet this requirement. (Fig 3)

3. DATA PROCESSING AND OBTAINED RESULTS

3.1. Data processing

In this section, a technique is described to process data obtained from the analysis of microtremor observations.

Since the observation data recorded by an integer value for us to analyze acceleration (gal) needs to be converted. Conversion the output integer value to the acceleration is made by performing this following equation (1):

Integer ÷ 5242879 ÷ 1.122(mV/gal) ÷ Magnification
= Acceleration value (cm/s^2) (1)

Where:
5242879 ÷ 1.122(mV/gal) is AD Full scale; Magnification is 200 in this case.

Figure 7 shows a flowchart of the present analysis. Observation for 3 minutes or 18 000 points, after converting acceleration values, one for each component, the stable part of 2048 points tremor (20.48 seconds) to 8 data files created by one unit. These 8 time-domain data after the Fourier transform to reduce noise, the following formula for averaging bandwidth of 0.4Hz further smoothed by a Parzen Window.

$$S_i = \frac{S_1 + S_2 + S_3 + S_4 + S_5 + S_6 + S_7 +}{8} \quad (2)$$

Here, S_i of NS, EW, and UD is the average Fourier spectral amplitude components.
Geometric mean by the following equation for the amplitude Fourier spectrum of two horizontal components were obtained, the average horizontal spectral amplitude and the SH:

$$S_H = \sqrt{S_{N\acute{S}}\ S_E} \quad (3)$$

Here, S_{NS}, S_{EW}, are respectively NS, EW components of the amplitude Fourier spectrum. Finally, the microtremor H / V spectral ratio ($S_{H/V}$) are defined by the following equation:

$$S_{H/V} = S_H / S_U \quad (4)$$

Here, S_{UD} is the amplitude Fourier spectrum of vertical component.

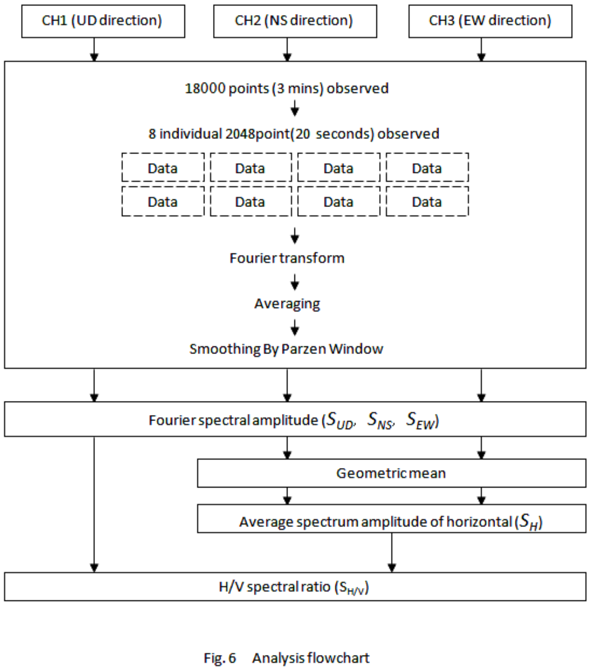

Figure 7. Analysis flowchart

3.2. Obtained results

In this section, after processing the output data, the results of spectral ratios of 5 sites are presented.

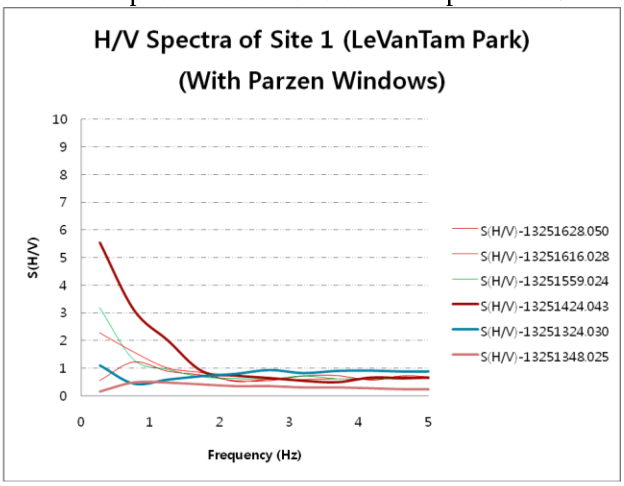

Figure 8. Spectral ratio $S_{H/V}$ of site 1 (Le Van Tam Park)

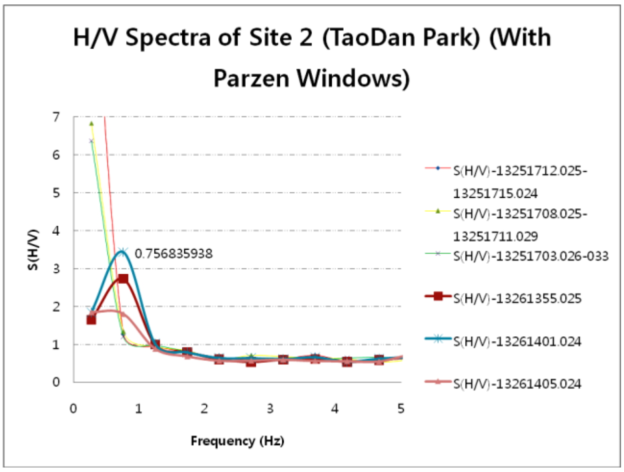

Figure 9. Spectral ratio $S_{H/V}$ of site 2 (Tao Dan Park)

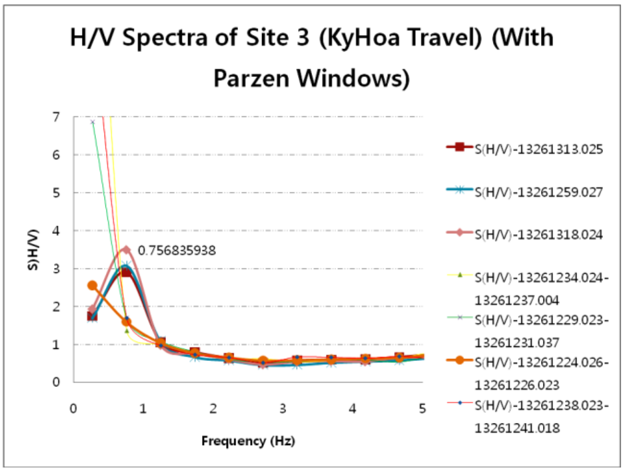

Figure 10. Spectral ratio $S_{H/V}$ of site 3 (Ky Hoa Travel Area)

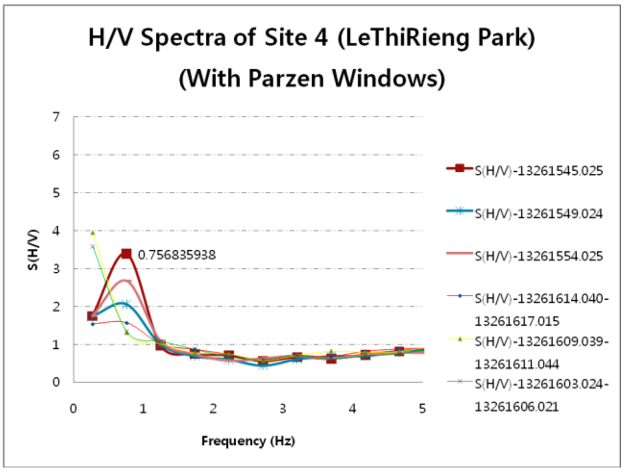

Figure 11. Spectral ratio $S_{H/V}$ of site 4 (Le Thi Rieng Park)

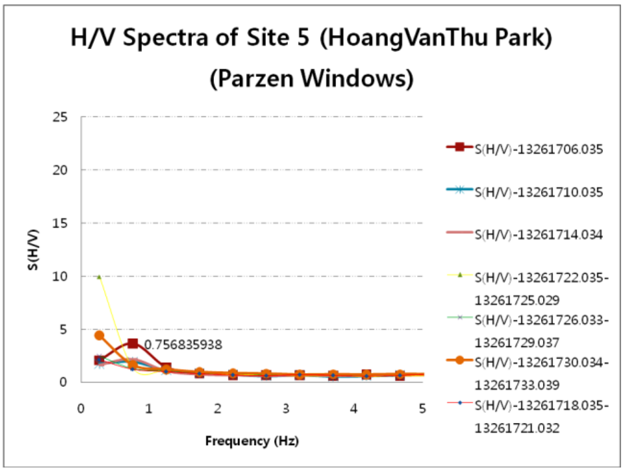

Figure 12. Spectral ratio $S_{H/V}$ of site 5 (Hoang Van Thu Park)

Figures 8 to 12 show the results of spectral ratios of 5 microtremor measurement sites. In the charts, the horizontal axis is the frequency with unit Hz, the vertical axis is the spectral ratio between horizontal and vertical spectral components of microtremor.

From the results, the predominant frequency of 4 sites can be estimated (site 2, 3, 4, 5), however, for the first site, we cannot find the reasonable value predominant frequency for this site because the chart of the first site shows no peak value. The total results are summarized into the following table:

Table 2 Predominant frequencies and periods

Site	Predominant Period (s)	Predominant Frequency (Hz)
1.Le Van Tam Park	N/A	N/A
2.Tao Dan Park	1.321	0.757
3.Ky Hoa Travel Area	1.321	0.757
4.Le Thi Rieng Park	1.321	0.757
5.Hoang Van Thu Park	1.321	0.757

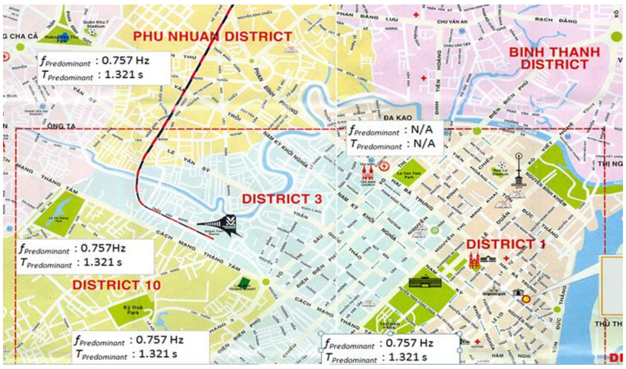

Figure 13. Predominant frequencies and periods of sites

4. CONCLUSIONS

In this paper, the brief overviews of the earthquake situation in the world and in Vietnam were introduced. With the unremitting increasing of high-rise building and large scale structures in big cities in Vietnam, the researches of long-period ground motion effects to them are necessary.

This paper is only the first attempt to estimate one of the dynamic characteristics of the ground: the predominant frequencies of the ground in 1 city in Vietnam (Ho Chi Minh City).

The obtained results show that the ground of Ho Chi Minh City has considerable potentiality in resonating with long-period ground motions. Especially, with the ground motions have the period vary around 1.3 seconds.

In the future researches, more dynamic characteristics of the ground for example: amplification factor, shear wave velocity ...etc in other big cities should be estimated. Moreover, the behaviors of the high-rise buildings in those cities should be examined carefully as well.

For the first site: Le Van Tam Park, we could not obtain a reasonable result of predominant frequency. The reasons for this problem were the big noise of the traffic activity and the low-level of power supply; thus, in the next experiments in other cities improvements in the preparation of experiment sites and the portable battery are required to overcome this limitation.

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