# Frequency Analysis and Seismic Vulnerability Index by Using Nakamura Methods at a New Artery Way in Porong, Sidoarjo, Indonesia

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***Abstract*—Microtremors measurement in Kebon Agung area (deltaic area of Porong river) which is located in the district of Sidoarjo, Indonesia using short period seismometer type TDL-303S (three components) was conducted at 23 sites with sampling rate of 100 Hz. Geologically, this location is a deltaic sedimentation which will be used as a new artery way of Porong. This area will replace the Porong toll road which is broken, caused by Mud Volcano in Sidoarjo. Measurements spacing used in this research was 400 m with average recording time was 30 minutes.**

**Microtremors analysis is performed using Horizontal to Vertical Spectral Ratio (HVSR) to understand dynamic characteristic of sediment layer, such as natural frequency ($f_0$) and peak ratio of HVSR (A). This analysis is very useful for mapping of seismic microzonation, amplification factor, and vulnerability of seismic index.**

**The results showed that the range of natural frequency in Kebon Agung area is between 0,573 and 1,264 Hz with average is below of 1 Hz. Spectral ratio of H/V ranges from 6,265 to 12,356. By using natural frequency and peak of HVSR summation, it is concluded that Kebon Agung area has moderate potential of seismic risk. The values of seismic index vulnerability range from 43 to 150. From these three analysis, it is estimated that a site in the northern part of the river has the highest vulnerability of seismic risk.**

***Index Terms*—HVSR, natural frequency, vulnerability of seismic index, microtremors, seismic microzonation.**

## I. INTRODUCTION

Microtremor is a ground vibration, caused by natural or artificial events, such as wind, waves, or vibrations of a vehicle that can reflect the geological conditions near the surface. Microtremor is used in seismic techniques to estimate the shear wave velocity profile (Vs). In addition, Microtremor also dominated by surface waves that can be used to determine the Rayleigh wave dispersion curve without the need for an artificial source.

Microtremor analysis can be performed using HVSR method (Horizontal to Vertical Spectral Ratio). This method is one of the easiest and most inexpensive ways to understand the properties of the subsurface layer structure without causing disruption to the structure. HVSR method is a method that is used as an indicator of subsurface structure, which shows the relationship between the ratio of the spectrum of H / V with the ellipticity curve of Rayleigh waves. Comparison of the spectral of H / V is the ratio between the amplitude of Fourier spectral of horizontal and vertical components of microtremor [1]. Rayleigh Ellipticity is the ratio of the amplitude of spectral components of the horizontal to the vertical [2]. Ellipticity curve that is used in earthquake engineering is to determine the fundamental frequency of earthquake locations, and is very responsive to the location and depth of a layer.

Over the last twenty years, several large earthquakes have claimed thousands of casualties, damage to facilities and infrastructure with huge losses. Level of damage caused by earthquakes in the local scale is influenced by the magnitude, epicenter distance, return period, structure, and subsurface lithology. Several destructive earthquakes in the world show that the damage is more severe in the alluvial plain in comparison to hilly areas [3]. Many urban areas with large populations are on soft-sediment (as in the valley and estuary), the soil structure tends to reinforce the seismic waves [4]. The soft lithology tends to respond a long period of vibration (low frequency), and vice versa.

Geologically, the area of Sidoarjo has the potential greatly to the disaster, the first is the existence of the mudflow in Sidoarjo and the second is to be built new Porong artery road that passes through the soft zone, because the rock types in the Sidoarjo area is mud and clay. Therefore it is necessary for determination of subsurface structure based on the wave velocity of microtremor using ellipticity curve, and results are expected to provide the information needed to estimate the danger of earthquakes and vibrations that may occur in the Sidoarjo region, so as to reduce the risk of further damage.

## II. FIELD SITE STUDY

The study was conducted in the area Sidoarjo, Indonesia, close to a new mudflow in the word, in Indonesia. Map of study sites was seen in the Fig. 1.

Fig. 1. Research location in new artery way of porong sidoarjo, Indonesia.

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The equipment used is this research as follows:

1) A set of computer hardware
2) Operating system Windows XP SP2
3) Some supporters of Geopsy Software, Datapro and Surfer.
4) A set of portable short-period Seismometer type TDL-303S (3 components)
5) GPS (Global Positioning System), Portable

Primary data acquisition is done by recording microtremor directly in the field using portable short period seismometers equipment TDL-303S type, consisting of digitizer, sensors, laptops, accumulator and support equipment. Acquisitions carried out during six days (15-20 0f May, 2010) to 23 points. The location of the measurement is in Table I.

TABLE I: LOCATION OF EACH MEASUREMENT OF MICROTREMOR.

| Point | Latitude ($^0$ S) | Longitude ($^0$ E) | Level (ASL m) | Wind speed (Knot) |
|---|---|---|---|---|
| LPS 00 | 07.54621 | 112.68420 | 3 | 8-10 |
| LPS 01 | 07.55151 | 112.67677 | 4 | 18-20 |
| LPS 02 | 07.54811 | 112.67940 | 3 | 8-10 |
| LPS 03 | 07.54576 | 112.68906 | 8 | 6-8 |
| LPS 04 | 07.54535 | 112.69389 | 7 | 8-9 |
| LPS 05 | 07.54482 | 112.68952 | 4 | 4-6 |
| LPS 06 | 07.54512 | 112.68570 | 5 | 8-10 |
| LPS 07 | 07.54605 | 112.68150 | 5 | 6-8 |
| LPS 08 | 07.54582 | 112.67990 | 4 | 12-14 |
| LPS 09 | 07.54719 | 112.67242 | 5 | 4-6 |
| LPS 10 | 07.55027 | 112.68817 | 5 | 12-14 |
| LPS 11 | 07.55163 | 112.68544 | 4 | 6-8 |
| LPS 12 | 07.55632 | 112.68472 | 5 | 10-12 |
| LPS 13 | 07.54901 | 112.68156 | 4 | 2-4 |
| LPS 14 | 07.54678 | 112.69592 | 4 | 8-10 |
| LPS 15 | 07.55007 | 112.69327 | 3 | 8-10 |
| LPS 16 | 07.55116 | 112.69569 | 5 | 5-6 |
| LPS 17 | 07.55317 | 112.69178 | 5 | 10-12 |
| LPS 18 | 07.55365 | 112.68961 | 4 | 15-18 |
| LPS 19 | 07.55771 | 112.68787 | 6 | 8-10 |
| LPS 20 | 07.54977 | 112.68682 | 5 | 10-12 |
| LPS 21 | 07.55249 | 112.68285 | 4 | 8-10 |
| LPS 22 | 07.54977 | 112.68682 | 4 | 10-14 |

At each point, it was measured during 30 minutes microtremordata with 100 Hz sampling rate, so that for each data point, there will be 180000 data. Elections for 100 Hz sampling rate is intended to ease the data processing, and also refers to other research studies [3], which mostly use 100 Hz as the sampling rate.

## III. DATA PROCESSING

The next step is the processing that is composed of the FFT process, involving the smoothing process. Smoothing process is done by using algorithms Konno and Omachi (1998) with bandwidth b coefficient of 40. It is also made the process of cosine taper to minimize the effects of borders or boundaries due to window selection process. Konno-Omachi algorithm is stated in the following equation:

$$W_B(f, f_c) = \frac{\sin\left(\log_{10}(f/f_c)^b\right)}{\left(\log_{10}(f/f_c)4\right)}$$

where:

$f$ = frequency

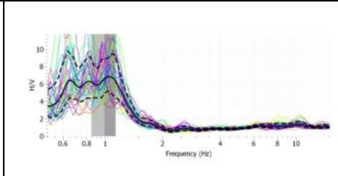
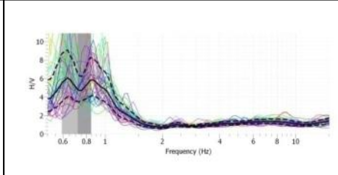
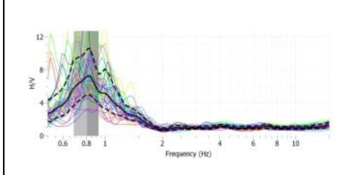
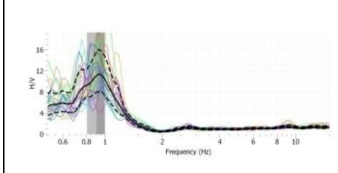
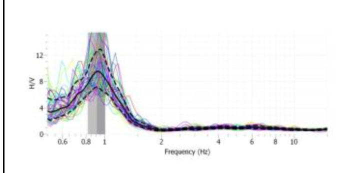
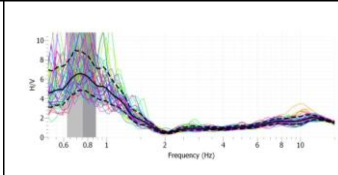
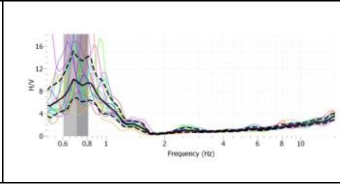
$fc$ = the central frequency where the smoothing is done

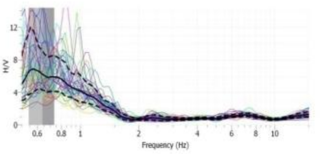
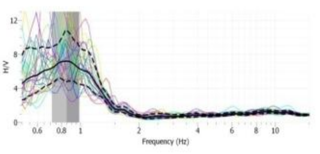
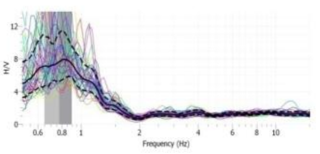
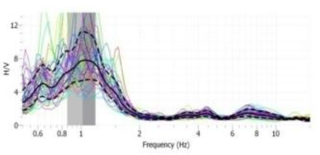
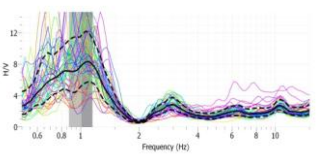
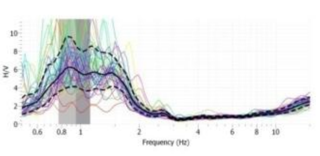
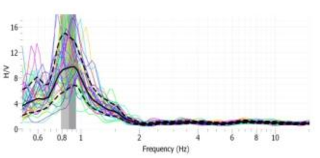
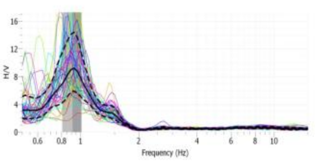
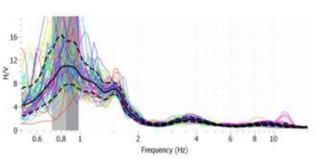
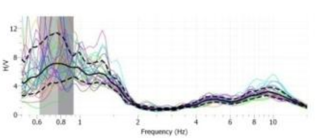
$b$ = bandwidth coefficient

To obtain the spectral ratio of horizontal and vertical components, then the two horizontal components must be one value, using the average of the square, before divided by the horizontal component. This process is performed for every window that is selected. Spectral ratio value of H / V is obtained from the average ratio of H / V of all the selected window. To obtain a low standard deviation, then the value of H / V must be either a value of more than 0.4 because values below 0.4 will have a very high standard deviations.

## IV. RESULTS

There are 23 results of data processing. One of the result is shown in Fig. 2.

| | HVSR Spectral | HVSR Analysis |
|---|---|---|
| **LPS 00** |  | Window : 46<br>$f_0$ :1,065<br>A : 6,842 |
| **LPS 01** |  | Window : 51<br>f0 : 0,636<br>A : 6,058 |
| **LPS 02** |  | Window : 46<br>f0 : 0,809<br>A : 7,241 |
| **LPS 03** |  | Window : 30<br>f0 : 0,928<br>A : 11,431 |
| **LPS 04** |  | Window : 54<br>f0 : 0,928<br>A : 9,570 |
| **LPS 05** |  | Window : 54<br>f0 : 0,730<br>A : 6,576 |
| **LPS 06** |  | Window : 19<br>f0 : 0,681<br>A : 10,136 |

| | | |
|---|---|---|
| LPS 07 |  | Window : 51<br>f0 : 0,574<br>A : 6,887 |
| LPS 08 |  | Window : 32<br>f0 : 0,837<br>A : 7,193 |
| LPS 09 |  | Window : 57<br>f0 : 0,809<br>A : 7,944 |
| LPS 10 |  | Window : 59<br>f0 : 1,065<br>A : 7,801 |
| LPS 11 |  | Window : 49<br>f0 : 1,102<br>A : 8,335 |
| LPS 12 |  | Window : 50<br>f0 : 0,866<br>A : 6,265 |
| LPS 13 |  | Window : 43<br>f0 : 0,897<br>A : 9,755 |
| LPS 14 |  | Window : 52<br>f0 : 0,928<br>A : 9,232 |
| LPS 15 |  | Window : 59<br>f0 : 0,866<br>A : 10,996 |
| LPS 16 |  | Window : 36<br>f0 : 0,781<br>A : 7,133 |

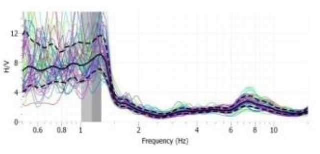
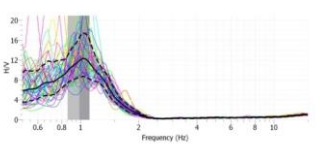
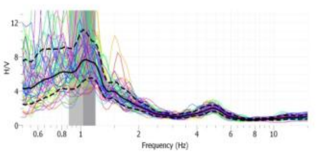
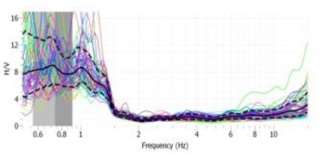
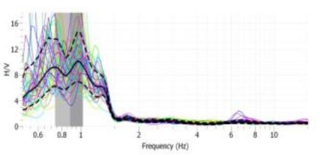
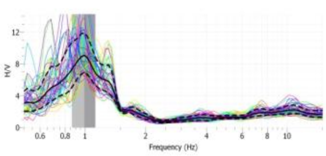
| | | |
|---|---|---|
| LPS 17 |  | Window : 60<br>f0 : 1,264<br>A : 9,152 |
| LPS 18 |  | Window : 55<br>f0 : 1,029<br>A : 12,356 |
| LPS 19 |  | Window : 58<br>f0 : 1,0647<br>A : 7,711 |
| LPS 20 |  | Window : 67<br>f0 : 0,705<br>A : 8,987 |
| LPS 21 |  | Window : 46<br>f0 : 0,960<br>A : 10,130 |
| LPS 22 |  | Window : 52<br>f0 : 0,994<br>A : 9,085 |

Fig. 2. Results of the calculation of HVSR.

The complete result of dominant frequency is in Fig. 3.

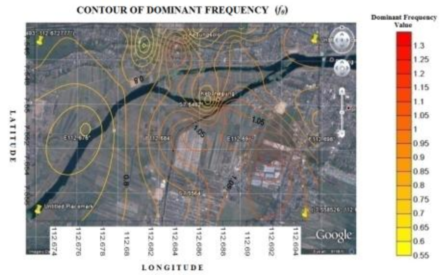



Fig. 3. Map of dominant frequency (Hz).

HVSR or Amplification is found when the data are processed using FFT. The results of HVSR is in Fig. 4.

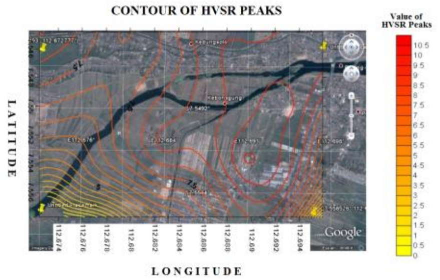



Fig. 4. Map of distribution of HVSR value.

## V. Conclussions

Based on research results, some conclusions can be outlined as follows:

1) Fundamental frequency value for Kebon Agung and the surrounding area is between 0.573 to 1.264 Hz with an average of under 2 Hz. HVSR or amplification of the peak value ranged from 6.265 to 12,356.
2) From the consideration between f0 and A shows that the potential damage from earthquakes is quite low. This corresponds to the value of the seismic vulnerability index (Kg) ranging from 43 to 150. From analysis of these three parameters, it was found that the highest potential in the vicinity of the point of LPS 06.

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