Determining Soft Layer Thickness Using Ambient Seismic Noise Record Analysis in Kota Baru, South Lampung

Vico Luthfi Ipmawan  
*Department of Physics, Faculty of Sciences, Institut Teknologi Sumatera, Lampung 35365, Indonesia*,  
vico.luthfi@fi.itera.ac.id

Ikah N. P. Permanasari  
*Department of Physics, Faculty of Sciences, Institut Teknologi Sumatera, Lampung 35365, Indonesia*

Rahmat Nawi Siregar  
*Department of Physics, Faculty of Sciences, Institut Teknologi Sumatera, Lampung 35365, Indonesia*

Follow this and additional works at: [https://scholarhub.ui.ac.id/science](https://scholarhub.ui.ac.id/science)

**Recommended Citation**
Ipmawan, Vico Luthfi; Permanasari, Ikah N. P.; and Siregar, Rahmat Nawi (2019) "Determining Soft Layer Thickness Using Ambient Seismic Noise Record Analysis in Kota Baru, South Lampung," *Makara Journal of Science*: Vol. 23 : Iss. 1 , Article 5.  
DOI: 10.7454/mss.v23i1.10802  
Available at: [https://scholarhub.ui.ac.id/science/vol23/iss1/5](https://scholarhub.ui.ac.id/science/vol23/iss1/5)

This Article is brought to you for free and open access by the Universitas Indonesia at UI Scholars Hub. It has been accepted for inclusion in Makara Journal of Science by an authorized editor of UI Scholars Hub.
Determining Soft Layer Thickness Using Ambient Seismic Noise Record Analysis in Kota Baru, South Lampung

Cover Page Footnote
This work is funded by Riset Hibah ITERA 2018.

This article is available in Makara Journal of Science: https://scholarhub.ui.ac.id/science/vol23/iss1/5
Determining Soft Layer Thickness Using Ambient Seismic Noise Record Analysis in Kota Baru, South Lampung

Vico Luthfi Ipmawan*, Ikah N. P. Permanasari, and Rahmat Nawi Siregar

Department of Physics, Faculty of Sciences, Institut Teknologi Sumatera, Lampung 35365, Indonesia

*E-mail: vico.luthfi@fi.itera.ac.id

Received September 13, 2018 | Accepted January 19, 2019

Abstract

The local site effect of an earthquake can be calculated through an analysis of short period ambient noise, known as microtremors. The fundamental frequency and amplification factors can be identified by analyzing microtremors using the Horizontal to Vertical Spectral Ratio (HVSR) method. This information can then be used to determine the thickness of the soft layers of sediment. This study analyzed microtremor recordings made in Kota Baru, South Lampung. The amplification factor range according to the HVSR method was 2.3 to 6.17, and the fundamental frequency range was 0.56 Hz to 1.46 Hz. Some spectrums exhibit two peaks with $f_0 > f_i$. We suggest that these locations have two layers with significant impedance contrast, which aligns with the geological conditions. The center of the Kota Baru area, especially the region around T11 and T15, has a thicker soft layer than the outskirts; in the central area, the soft layer is approximately 85 to 102 meters thick. The western part of the analyzed area has a shallower soft layer of about 32 to 46 meters. The analysis indicates that the western part has less amplification because it is shallower than the other parts of the analyzed region.

Keywords: amplification, fundamental frequency, HVSR, layer thickness, sediment

Introduction

Kota Baru, located in South Lampung, has been chosen as the new capital of Lampung Province. This means that the population of Kota Baru will increase significantly over a short period of time. Lampung Province, located near the Semangko Fault (or the Great Sumatran Fault), has one of the highest earthquake risks of any province in Indonesia. Two of the most damaging earthquakes in Lampung were 7.3 and 6.9 on the Richter scale, in 1933 and 1994, respectively. The latter caused the loss of 207 human lives and serious structural damage. Significant structural damage has been directly attributed to local conditions in almost every major earthquake in Indonesia; examples are the 2006 earthquake in Yogyakarta [1] and the 2009 earthquake in Padang [2].

Local conditions at a site can be described by the fundamental frequency ($f_0$) and amplification factors ($A_0$). Both contribute to structural damage during an earthquake. If the building’s frequencies are close to the fundamental frequencies measured at the site, then seismic motion will create resonance with the building, which can greatly increase the stresses to the structure [3]. Amplification factors refer to the amplification of the wave propagated in the middle sedimentary layer when an earthquake occurs.

Ambient noise can be used to measure fundamental frequencies and amplification factors. Since ambient noise can be measured quickly over a large area, the ability to link features extracted from background noise recordings to the seismic response of the soil makes ambient noise a suitable topic for many geological studies [4]. Another piece of data that can be extracted from ambient noise measurements is the thickness of the soft layer of sediment, which is also linked to damage to buildings in an earthquake. The thickness of the soft layer affects amplification [5]. The thicker the soft layer, the higher the amplification.

Ambient noise can be divided into two types: microseisms, which are generated by a natural source and have a long period (more than 1 s); and microtremors, which are generated by living things and have a short period (less than 1 s) [6].

In this study, microtremor recordings from Kota Baru, South Lampung were analyzed using the Horizontal to
Vertical Spectral Ratio Method (HVSR). The fundamental frequencies and amplification factors were determined, and then the thickness of the soft layer at Kota Baru was estimated. A map showing the distribution of the thickness of the soft layer was also created.

Materials and Methods

Recordings. Microtremors were recorded at 15 locations in Kota Baru using a seismometer. Kota Baru is located from 105.374° E to 105.428° E and 5.28064° S to 5.29936° S. The recording locations are shown in Figure 1. A short-period, 1 Hz, three-component seismometer was used. The duration of the recordings is 35 minutes on average per location. Shear wave velocity at a depth of 30 meters, or V_s30 data, was obtained from United States Geological Surveys (USGS) data. All of these data were used to determine the thickness of the soft layer.

Horizontal to Vertical Spectral Ratio Method (HVSR). This method can be used to determine the local site effect of an earthquake by identifying the fundamental frequency and amplification factors. In this method, the ratio of the Fourier spectra of the horizontal and vertical components of seismic noise recorded on a three-component seismometer (H/V ratio) is calculated. The spectrum must be smoothed before the H/V ratio can be computed. In this study, the Konno and Ohmachi smoothing function was used [7]. Each time window produces one H/V ratio; the average H/V ratio was then calculated. The average H/V peak curve can be associated with fundamental frequencies to indicate the amplification. The HVSR method is based on the following assumptions: 1) the environment consists of a rigid substratum covered by a layer of soft soil, and 2) microtremors are formed by Rayleigh waves [8]. From these assumptions, the transfer function (HVSR) of a site can be derived from the spectral ratio of the horizontal and vertical components of microtremors recorded at a given point [4]. The following equation is used:

\[ HVSR(f) = \frac{H_s}{V_s}, \]

where \( H_s \) is the spectral amplitude of the horizontal components of the microtremors measured at the surface of the soil layer and \( V_s \) is the spectral amplitude of the vertical components of microtremors measured at the surface of the soil layer.

Soft Layer Thickness. The thickness of the soft layer can be determined using shear wave velocity. The thickness (h) can be obtained with the following equation [11]:

\[ h = \frac{V_{s30}}{4f_s} \]

Figure 1. Recording Locations Denoted by Solid Green Squares. The Dashed Black Line in the Southwest of the Research Area Indicates the Approximate Location of the Fault. The Entire Research Area is Part of the Same Geological Formation, the Quartenary Tuff Lampung
This equation is based on the principal of a closed pipe organ. If resonance occurs, the amplitude will be increased, so it will be greater than the initial amplitude. When the wave’s amplitude reaches its maximum, tuning thickness occurs. The maximum amplitude occurs when the thickness is a quarter of the wavelength [9].

Results and Discussion

The HVSR method was used to analyze the microtremor recordings. The software GEOPSY was used to process the recordings. The most stationary recording was manually identified and then used for further analysis. Some parameters must be considered to produce a reliable, clear H/V curve. In this study, almost all time windows were set to 15 s; the smoothing constant was 10. Sometimes a longer or shorter time window was used, depending on the recording data, in order to produce a reliable, clear curve. The SESAME project [10] outlines a process for evaluating the reliability of the HVSR curve using the following criteria: (i) for the peak to be significant, \( f_0 \) should be \( > 10 \) divided by the window length \( (l_w) \); (ii) the number of significant cycles should be greater than 200; and (iii) the standard deviation of the amplitude of the HVSR curve, at frequencies between 0.5\( f_0 \) and 2\( f_0 \), should be less than two when \( f_0 > 0.5 \) Hz and less than three when \( f_0 < 0.5 \) Hz. All of these criteria must be satisfied for a curve to be considered reliable and used for further analysis. The SESAME project also suggests some methods for computing HVSR [10].

The fundamental frequencies and amplification factors were obtained using the HVSR method. The H/V peaks from all 15 locations are reliable. Using these reliable peaks, \( f_0 \) and \( A_0 \) can be calculated. These values are shown in Table 1. The thickness \( h \) can be calculated using Eq. 2 and the USGS \( V_{s30} \) data. The thicknesses of the soft layers are shown on the map of Kota Baru in Figure 2.

One limitation of this study is that it makes it possible to estimate the thickness of the soft layer but not the depth of the thickness layer. Other geophysical methods can be used to determine the depth of the soft layer. These results can be validated with borehole data, but these data are not available for the study area.

The amplitude values obtained using the HVSR method range from 2.3 to 6.17, and the frequency values range from 0.56 Hz to 1.46 Hz. The spectra from all 15 recording locations are shown in Figure 3. The spectra for locations T1, T2, T4, T5, T6, T7, T8, T14, and T15 each exhibit two peaks with \( f_0 > f_i \). We suggest that these locations have two layers with significant impedance contrasts, at two different scales that are one shallow layer and one deep layer. This suggestion is in line with the geological map of the Tanjung Karang quadrangle by Mangga S.A. et al (Figure 4). The shallow layer is the Quaternary Tuff Lampung (QTI) formation, and the deep one is the Paleozoic Undifferentiated G. Kasih Complex (PZG formation, which is mainly composed of pelitic schist and minor gneiss).

Figure 3 shows that the center of the Kota Baru area has a thicker soft layer than the surrounding area. The soft layer is particularly thick near T11 and T15. The western part of Kota Baru has a shallower soft layer than the rest of the study area. Since it is shallower, the western part should have less amplification, which is confirmed by the amplification factors \( (A_s) \) shown in Table 1. The amplification factors for T1, T2, and T6 in the west range from approximately 2.30 to 3.07; in the center, T11, T9, and T12 have amplification factors of 5.39 to 6.16.

### Table 1. Soil Parameters Obtained using the HVSR Method

| Locations | Longitude (E) | Latitude (S) | \( f_0 \) (Hz) | \( A_0 \) | \( V_{s30} \) (m/s) | \( h \) (m) |
|-----------|--------------|--------------|---------------|--------|----------------|---------|
| T10       | 105.4188     | -5.28139     | 0.59          | 4.4    | 280.48         | 41.37   |
| T15       | 105.4189     | -5.29394     | 1.44          | 3.25   | 236.63         | 85.19   |
| T4        | 105.3931     | -5.28494     | 0.63          | 5.34   | 253.75         | 39.97   |
| T5        | 105.391      | -5.29336     | 0.66          | 3.81   | 253.75         | 41.87   |
| T6        | 105.3909     | -5.28442     | 0.78          | 3.55   | 226.03         | 44.06   |
| T1        | 105.3784     | -5.28064     | 0.56          | 3.47   | 228.88         | 32.04   |
| T2        | 105.3788     | -5.28689     | 0.59          | 3.22   | 234.75         | 34.63   |
| T3        | 105.374      | -5.29908     | 0.63          | 5.34   | 237.84         | 37.46   |
| T9        | 105.4062     | -5.29828     | 1.19          | 5.84   | 229.68         | 68.33   |
| T8        | 105.4053     | -5.288       | 0.8           | 4.14   | 239.08         | 47.82   |
| T7        | 105.4047     | -5.28208     | 0.75          | 2.3    | 239.08         | 44.83   |
| T11       | 105.4154     | -5.28889     | 1.46          | 6.17   | 280.48         | 102.38  |
| T12       | 105.4179     | -5.29936     | 1.17          | 5.58   | 243.34         | 71.18   |
| T14       | 105.428      | -5.28783     | 0.67          | 4.25   | 292.93         | 49.07   |
| T13       | 105.4289     | -5.28122     | 0.7           | 4.64   | 292.93         | 51.26   |
Figure 2. Map of Thickness Distribution in Kota Baru, South Lampung

Figure 3. HVSR Spectrum Curves. Subfigure (a) Illustrates the Spectrum Curve for T1, (b) for T2, (c) for T3, etc.
The thickness of the soft layer is crucial in seismic hazard studies because it has been shown to play an important role in the alteration of seismic waves. Soft layer thickness mapping can be used to identify areas that are prone to amplifying the magnitude of an earthquake. The thicker the soft layer, the greater the amplification, so these areas are not ideal locations for building infrastructure. Therefore, we suggest that the center of Kota Baru is a more hazardous location for construction than the outskirts. Stakeholders must be aware of this hazard because Kota Baru will be the new capital of Lampung; this information is especially important regarding the construction of public facilities in the center.

**Conclusion**

This study used the HVSR method to identify amplitudes from 2.3 to 6.17 and frequencies from 0.56 Hz to 1.46 Hz in Kota Baru, South Lampung. Some spectra exhibited two peaks with $f_0 > f_1$. We suggest that these locations have two layers with significant impedance contrasts at two different scales that are one shallow layer and one deep layer. The center of Kota Baru, especially the region near T11 and T15, has a thicker soft layer than the outskirts. The western part of Kota Baru area has a shallower soft layer than other areas in the study area. Our analysis indicates that the western region has less amplification because it is shallower than the other parts of the study area.

**Acknowledgments**

This work is funded by Riset Hibah ITERA 2018.

**References**

[1] Laberta, S., Wibowo, N.B., Darmawan, D. 2013. Microzonation of vulnerability seismic index based on microtremor analysis in Jetis, Bantul, Yogyakarta (in Indonesian). Prosiding Seminar Nasional Penelitian, Pendidikan, dan Penerapan MIPA, Yogyakarta.

[2] Saaduddin, Sismanto, Mariyono. 2015. Vulnerability Seismic Index Mapping in Padang City, West Sumatra and its Correlation with 30 September 2009 Earthquake Damaging Points (in Indonesian). Proceeding Seminar Nasional Kebumian ke-8, Academia-Industrial Linkage, Yogyakarta.

[3] Herak, M., Allegretti, L., Herak, D., Kuk, K., Kuk, V., Marić, K., et al. 2009. HVSR of ambient noise in Ston (Croatia): comparison with theoretical spectra and with the damage distribution after the 1996 Ston-Slano earthquake. Bull. Earthquake Eng. 8(1): 483-499, https://doi.org/10.1007/s10518-009-9121-x.

[4] Mendecki, M.J., Bieta, B., Mycka, M. 2014. Determination of the resonance frequency – thickness relation based on the ambient seismic noise records from Upper Silesia Coal Basin. Contemp. Trends. Geosci. 3(1): 41-51, https://doi.org/10.2478/ctg-2014-0021.

[5] Ai-Lan C., Takahiro, I., Yoshiya, O., Xiu-Run, G. 2006. Study on the applicability of frequency spectrum of microtremor of surface grounding Asia Area. J. Jiang University. 7(11): 1856-1863, https://doi.org/10.1631/jzus.2006.A1856.

[6] Nakamura, Y. 1989. A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface. Q. of RTR. 130: 25-33.

[7] Konno, K., Ohmachi, T. 1998. Ground-Motion characteristics estimated from spectral ratio between horizontal and vertical components of microtremor. Bull. Seism. Soc. Am. 88(1): 228-241.

[8] Nakamura Y. 2008. On the H/V spectrum. The 14th World Conference on Earthquake Engineering Beijing, China.

[9] Ibs-von, M.S., Wohlenberg, J. 1999. Microtremor measurements used to map thickness of soft sediments. Bull. Seism. Soc. Am. 89(1): 250-259.

[10] SESAME European Research Project. 2004. Guidelines for the implementation of the H/V spectral ratio technique on ambient vibrations measurements, processing and interpretation.

[11] Setiawan, B., Jaksa, M., Griffith, M. Love, D. 2018. Estimating bedrock depth in the case of regolith sites using ambient noise analysis. Eng. Geol. 243: 145-159, https://doi.org/10.1016/j.enggeo.2018.06.022.