Preliminary Result of Horizontal to Vertical Spectral Ratio using Hilbert Huang Transform to Seismic Hazard Analysis on Lembang Fault, West Java, Indonesia

Rimawanto Gultom[1]*, Zulfakriza Z[2,3], Andri Dian Nugraha[2,3], Awali Prayono[2], David P. Sahara[2], Aditya Lesmana[1], Wahyu Hidayat[1]

[1]*Geophysical Engineering Study Program, Faculty of Mining and Petroleum Engineering, Institute Technology of Bandung*
[2]*Global Geophysics Research Group, Faculty of Mining and Petroleum Engineering, Institute Technology of Bandung, Bandung, Indonesia.*
[3]*Center for Earthquake Science and Technology, Institute Technology of Bandung, Bandung, Indonesia*

**email: rimawanto@gmail.com*

Abstract. The Lembang Fault is one of the active faults which has more potential earthquake hazards in the Bandung area. The location of the Lembang Fault in the northern of the Bandung basin which is dominated by thick sedimentary volcanic rock also caused it to become vulnerable to seismic hazards. On 22nd July 2011, an earthquake event with M2,9 was felt by villagers near the Cisarua, Lembang, and on 28th August 2011 M3,3 the earthquake caused around 103 non-engineered houses to be damaged. These earthquake events clearly provide evidence of the activity of the Lembang Fault. We need to investigate the seismic hazard potential using a seismological approach. We use the Horizontal to Vertical Spectral Ratio on the microtremor data observation using 44 station temporary seismic station from December 2020 to June 2021 and the length waveform in this research is 2 hours at midnight recording (23.00-01.00). The microtremor data recording still contains a local noise signal, and we need to apply Hilbert Huang Transform (HHT) to reduce the noise and allow us to enhance the resolution of the HVSR curve. In the preliminary result, we use the value of the average shear-wave velocity on the depth of rocks 30 meters (Vs30) to show the geological condition around the station. It shows that mostly for each station is constructed by the soil profile with soft clay. This preliminary result then will be used for analyzing and mapping the amplification and seismic vulnerability in the Lembang fault.

Keywords: Lembang fault, HVSR, Hilbert Huang Transform, Vs30

1. Introduction

Bandung has a strategic geographical location that can support the economic growth of the community that support geostrategy and geopolitics for the arrangement of the city of Bandung [1]. North of Bandung consist of mountains that located in the northwest part of Bandung Basin which have quaternary volcanic landforms [2]. The Bandung basin also indicated several active faults, result of the reactivation process with tertiary age [3,4]. The active faults were stretched from Sukabumi-Padalarang which continuous to Cicalengka and Lembang fault [5]. This condition caused some earthquake around Bandung area happen [4]. Because of this reason, it is important to know the risks that can be caused in Bandung by studying seismic activity [6]. The activity of Lembang fault was recorded on 22nd July 2011 with M2.9 and on 28th August 2011 M3.3. This earthquake caused damage with several houses in Cisarua District, West Bandung [7]. This condition also can be caused because the condition of the rocks of the area which are dominated by sedimentary rock, which potentially provide a higher amplification [8]. Because of these reasons, we need to find out the further research doing the geophysical method namely Horizontal to Vertical Spectral Ratio (HVSR). Mostly, the previous research used HVSR method analysis using Fast Fourier Transform (FFT) [9,10,11,12]. Nevertheless, this analysis method is used only for the stationary signal. When it's used for microtremor that is nonstationary signal, it will cause the result of the time and frequency resolution HVSR will be counterfeit harmonic wave [13]. The resolution time and frequency can be increased by a Hilbert Huang Transform (HHT), namely using the space and frequency which include the Empirical Mode Decomposition (EMD) and Hilbert Transform whose frequency is adaptive [14].

2. Data and Methodology

Data

This study was conducted by using three component seismograms around the Lembang Fault starting December 2020 to June 2021. This study used data sampled with a duration of one day from a total of seven months data, that was cut with average time duration of two hours at 23.00-01.00. The number of research station is 44 stations with a sampling of 250 Hz that showed by Fig 1(a). Geologically, the station research has formed at the end of the Middle Pleistocene era [15]. The location also dominated by volcanic rocks and volcanic deposits [5]. The specific geological formation is showed by [6].

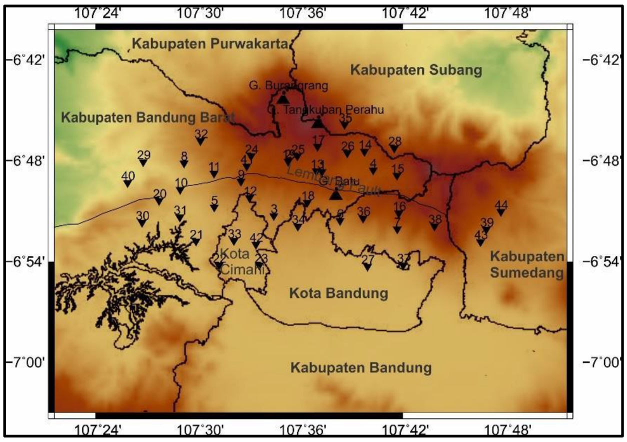


Figure 1. Map of experiment area around the Lembang fault. The invert black triangle indicates as the seismic stations.

Methodology

2.1 FFT (Fast Fourier Transform)

To get the ratio of the Horizontal to Vertical spectrum of signal with miniSEED data, *Geopsy software* is used to get the H/V curve. The curve shows the frequency dominant and factor amplification. The curve was got by obtained the data is divided into several windows with a certain sampling rate. The range of STA/LTA values used is 0.5-2.0 [16].

2.2 HHT (Hilbert Huang Transform)

The HHT-HVSR processing is carried out by decomposition the signal on each component using Empirical Mode Decomposition (EMD) which decomposes into several IMFs. Then, for each IMF generated, a Hilbert transformation is performed to obtain the values of the dominant frequency and amplitude which are used to determine the signal response that passes through many layers of rock below the surface. The Hilbert Transform $\mathcal{H}(t)$ from IMF can be generated by equation [17]:

$$\mathcal{H}(t) = \frac{-1}{\pi} P \int_{-\infty}^{\infty} \frac{x(t)}{t-\tau} d\tau \quad (1)$$

Where P is the Cauchy and $x(t)$ is the IMFs value. By using the Hilbert transform, the amplitude *a(t)* can be determined by using the equation:

$$a(t) = \sqrt{x(t)^2 + \mathcal{H}\ (t)}$$

And by using the instantaneous phase, the frequency $\omega(t)$ value show the equation below:

$$\omega(t) = d\varphi d(t)$$

2.3 HHT Inversion (Hilbert Huang Transform)

We used the OpenHVSR software to do the inversion that designed to the simultaneous modeling and inversion of large HVSR spectral ration data sets to build the subsurface models. The optimal subsurface physical model can be determined based on an objective function, which is a function that can access the suitability of the data and the model. The objective function (E) can be expressed in by the following equation [18]:

$$\mathrm{E(m)} = \mathrm{aM(m)} + \mathrm{bS(m)} + \sum_{1}^{5} \mathrm{a_j R_j(m)}$$

With $\mathrm{M(m)}$ is the misfit function, $\mathrm{S(m)}$ the gradient difference for calculated and observed HVSR curve, and $\mathrm{R_j(m)}$ is the regulation factor.

2.4 Vs30

Shear wave velocity is one of the important parameters to determine the dynamics characteristics of the soil. Classification of the soil types can be carried out using the shear wave velocity from surface to a depth of 30 meters [14]. that show by equation [19]:

$$V_{s30} = \frac{30}{\sum_{i=1}^{N} \left(\frac{d_i}{V_{si}}\right)}$$

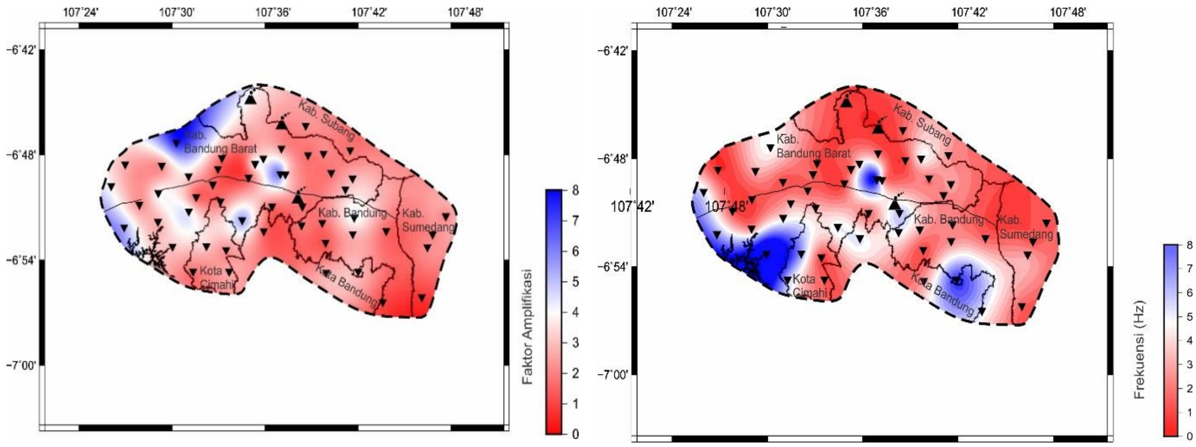
Where d_i is the thickness of layers and V_{si} is the value of the shear wave velocity. Determination of soil type classification using recommendations from the National Earthquake Hazard Reduction Program (NEHRP), which fully shown in Table 1. [20].

Table 1. Site classification based on the Value Vs30 (NEHRP, 1994)

Site Class	Description	Vs30 (m/s)
A	Hard rock	>1500
B	Rock	700-1500
C	Very dense sil and soft rock	360-760
D	Stiff soil	180-360
E	Soil profile with soft clay	<180
F	Site specific geotechnical investigation required	

3. Results and Discussion

This research was conducted by comparing the values between the vertical and horizontal spectrum ratios, which resulted in the values form of dominant frequencies. The dominant frequency is related to the structure of the surface layer [16]. The lower the dominant frequency of an area, the thicker the sedimentary layer is. The resulting dominant frequency value are in the range 0.5-8 Hz as shown in Fig 2(a). The frequency value is evenly distributed in almost all area West Bandung Regency, except in the south of Cimahi area and several areas which are close to Mount Batu and can be said far from Lembang fault have the high frequency value. Geologically, this area also closes to mountains, which generally have a thin layer of sediment.



(a) (b)

Figure 2. (a) Frequency dominant distribution map around the Lembang fault **(b)** Map of the factor amplification factors

The distribution of the amplification factor value produced with range 1-8 that showed in **Fig 2(b).** Based on this figure, the area that near the fault, such as west Bandung regency, especially the Lembang and Parongpong areas, have a high amplification factor. This is in line with the research conducted by by [21]. Some area in Cisarua and Ngamprah districts are also known to have quite high amplification value with 4-8. The high factor amplification factor because the area is composed of tuffaceous and reddish weathered lava and agglomerates. These results are in line with the previous studies by [22].

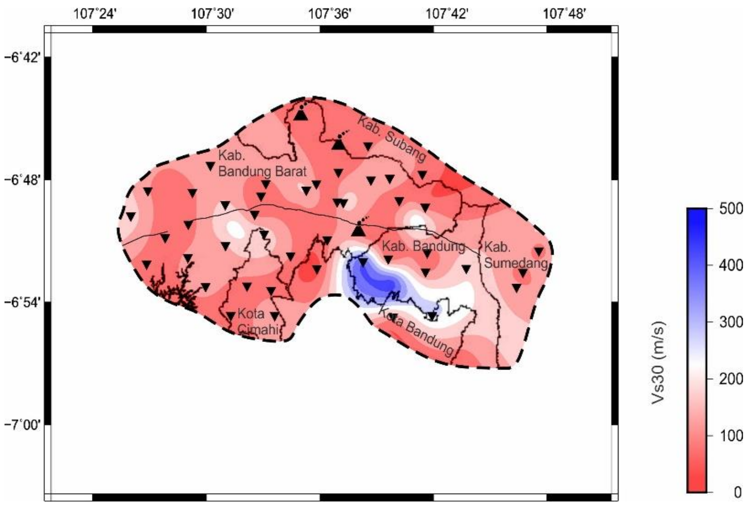


Figure 3. Vs30 distribution map around the Lembang fault. Blue color is for the high and the red is for the low value of Vs30

4. Conclusions

By using the HHIT-HVSR method, we conclude that the dominant frequency value is in range 0.5-8Hz. The lowest frequency is 0.5 Hz dominant in West Bandung Regency especially are which near to Lembang Fault, and the highest frequency is 8 Hz dominant in area which far from Lembang Fault. The amplification also found with range value 1-8. The highest factor amplification is found in West Bandung Regency especially in Cisarua and Ngamprah district with value 8. The low factor amplification value is distributed evenly throughout the station area with value under 3.

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