Preliminary Results of Horizontal to Vertical Spectral Ratio (HVSR) Across Lembang Fault, Bandung, Indonesia

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Abstract. Lembang Fault is located in the Bandung basin with is a thick sedimentary of volcanic rocks and the depositional remnants of an ancient lake. Bandung region has a dense population and infrastructure that possible to be vulnerable of seismic hazard. Based on geological studies, Lembang fault is an active fault that possibility to produce a magnitude more than 6.0. Seismic hazard estimation is one of some method to identification of hazard potential due to the Lembang Fault activity. Horizontal to Vertical Spectral Ratio (HVSR) method is one of way to seismic microzonation that identified the dominant frequency \( F_0 \). We deployed 6 seismometers across Lembang Fault area for about 3 months observation. Then we computed the seismic response that correlated with physical properties inside the basin. The variation of seismic susceptibility index around Lembang area indicates the vulnerability of seismic hazard. LEM01 and LEM06 have relatively lower of natural frequency, its about 1.22 (LEM01) and 1.49 (LEM06). The number of natural frequency indicate thick of sediment and vulnerable of seismic hazard.

1. Introduction

Lembang Fault is an active fault which is about 10 km north of the Bandung. The existence of the Lembang Fault provides a potential seismic hazard for the Bandung area and its surroundings. Morphologically, Lembang Fault extends from east to west along 22 km which is divided into 6 segments, namely Cimeta, Cipogor, Cihideung, Gunung Batu, Cikapundang and Batu Lonceng [1]. Based on geodetic observations [2] the slip rate of Lembang Fault is 6 mm / y. At least there were two earthquakes occurred around Lembang Fault. The magnitude M2.9 on July 22, 2011 and M3.3 on August 28, 2011 [2]. M3.3 Earthquake causes damage to several houses in Cisarua District, West Bandung.

In addition to building structure, building damage due to earthquakes is affected by local geological conditions and poorly consolidated rock conditions [3]. Local geological conditions that have impacted on building damage have been assessed using HVRS such as in Yogyakarta [4] which was compare to damaging caused by the 2006 earthquake. [5] shown the regional HVSR calculation in Bandung basin based on 64 seismic stations around Bandung area. Seismic vulnerability index (Kg)
values obtained from HVSR calculations provide information about the condition of the structure on the surface banana, the level of solidity of the rock and the thickness of the sediment layer.

Since April to June 2016, ITB installed 6 seismographs (Figure 1) for 3 months closed to the Lembang Fault and its surroundings. The main purpose of installing the seismograph network is to monitor seismicity due to activity of the Lembang Fault. In addition to monitoring, the existence of this seismograph network can be used to understand the local geological conditions around the Lembang Fault by applying HVSR method.

![Figure 1](image.png)

**Figure 1.** Location of the Bandung basin area. The study area is situated in the central part of West Java, Indonesia about 150 km southeast of Jakarta. Lembang and Cimandiri Fault indicated by black line, ITB seismograph network marked by invert black triangle, BMKG seismograph station marked with invert black triangle, then the two red dots are earthquake events across Lembang Fault.

### 2. Geological Setting

Geological setting of the Lembang fault is related to evolutionary process of the Bandung basin [6]. Morphological formations of the Bandung region consist of volcano chains. The process of rock formation in the Bandung basin began in the Miocene era (about 20 million years ago), this is indicated by the presence of limestone outcrops in Rajamadala [7].

Morphologically, Bandung area is composed of the Sunda-Tangkuban Perahu volcanic complex. The existence of Mt. Tangkuban Perahu in the North of Bandung which is one of the active volcanoes
in the ancient caldera [8]. In the southern part of Mt. Tangkuban Perahu is a relatively flat area but is cut by structures in the east and adjacent to the Lembang city. The expression of continuity provides an illustration of the existence of faults with east-west orientation. [8] mentioned its expression as Lembang Fault (Figure 2).

Figure 2. Sketch map vertical cross section of south to north West Java. This figure showing the structural setting of some volcanic chain, Bandung basin dan Lembang Fault that marked by red arrow (modified from [9]).

The continuity of Lembang faults indicates a segmentation of Lembang fault morphology. Morphotectonics are influenced by morphological conditions and tectonic processes that occurred in the past. This condition is caused by the morphology has a spatial dimension and tectonics has a time dimension. Tectonic land forms will express topographic formations that can be used as indicators of active tectonic or tectonic movements. Topographic shapes that have undergone movement displacement can be seen and observed through satellite image that provide morphotectonics features in the form of river flow patterns, hills movement, river deflection, straightness, fault faulting, and river terrace appearance.

3. Data and Method

In this study, we used data from the seismometer network in the Lembang area that recording since April to June 2016 continuously using 6 stations of 3 component broadband seismometer with 250 Hz of sampling rate (Figure 3A). The seismometers distribution covered the Lembang Fault and some area that closed to the Fault, such as Cisarua, Parompong and Lembang City (Figure 1). we used a bunker for seismometer installation with 150 cm depth and mostly the waveform show the signal clearly. The digital recorder of seismometer was connected with a GPS antenna, thus allowing to received coordinate and timing daily. The recorded data is a time series waveform in miniSEED format (Standard Exchange of Earthquake Data).

For HVSR calculation, we used data waveform for 6 hours recording from 21.00 to 03.00. We assumed it would be possible to obtain the recording with low noise due to human and industrial activities (Figure 3B). We used GEOPSY software to calculate f0 with a frequency range of 0.5 - 20 Hz and 50 s time window. The output that will be generated from this processing is an HVSR curve that provides information on the dominant frequency value and amplification. HVSR curve is data segmentation. Segmentation is the process of dividing signals into several parts with different segment widths. In this study, the segment width used is 250 s. this is because in the segment width, it is stable
and does not contain noise or transient signal signals. At this value is used so that the variation in the frequency domain becomes more detailed.

![Figure 3. A. Waveform of LEM01 with 3 component that used for HVSR calculation. B. Time window selection 21.00 to 03.00 WIB.](image)

### 4. Results and Discussion

The spectrum of HVSR can be seen on the curve of frequency and H/V Amplitude. HVSR is a merging curve between horizontal and vertical components. We produced HVSR curve for each point LEM01, LEM02, LEM03, LEM04, LEM05 and LEM06 (Figure 4). The HVSR curve provides information in the form of natural frequency and soil amplification. HVSR is a merging curve between horizontal and vertical components. Extraction of the natural frequency and amplification of the HVSR curve is a reference for calculating the soil vulnerability index. [9] introduced the soil vulnerability index (Kg) equation. The vulnerability index (Kg) value can estimate the distribution of natural frequencies, soil amplification and soil susceptibility levels related to local geological conditions.

![Figure 4. HVRS curve for different station, (A) LEM01 with 1,22 of natural frequency, (B) LEM02 with 4,65 of natural frequency, (C) LEM03 with 2,54 of natural frequency, (D) LEM04 with 2,37 of natural frequency, (E) LEM05 with 7,22 of natural frequency and (F) LEM06 with 1,49 of natural frequency](image)
Based on the natural frequency of each station, the vulnerable zone around the Lembang fault can be identified. Refer to [9], the value of natural frequency is inversely proportional to the vulnerability of the soil. If the natural frequency value is low, thereby the soil vulnerability is higher. In consequence of sedimentary thickness and bedrock deeper. LEM01 and LEM06 have relatively lower of natural frequency, its about 1.22 (LEM01) and 1.49 (LEM06). LEM05 has natural frequency higher than others about 7.22. Figure 5 shows the distribution of natural frequency values for 6 observation stations. The areas with low natural frequencies indicate that has relatively deep bedrock depths and thicker of sediments. LEM06 is close to the Lembang fault line and has a low natural frequency value. It means this area belong to vulnerability class.

![Figure 5](image)

**Figure 5.** Map of natural frequency ($f_0$) across Lembang Fault and surrounding area. Black triangle indicate the seismic stations and black line indicate the fault line.

5. Conclusions

We have produced the natural frequency ($f_0$) to identify the sediment thickness across Lembang fault and surrounding area. Based preliminary result of the study, we found LEM01 and LEM06 have relatively lower of natural frequency, its about 1.22 (LEM01) and 1.49 (LEM06). The number of natural frequency indicate thick of sediment and vulnerable of seismic hazard.

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