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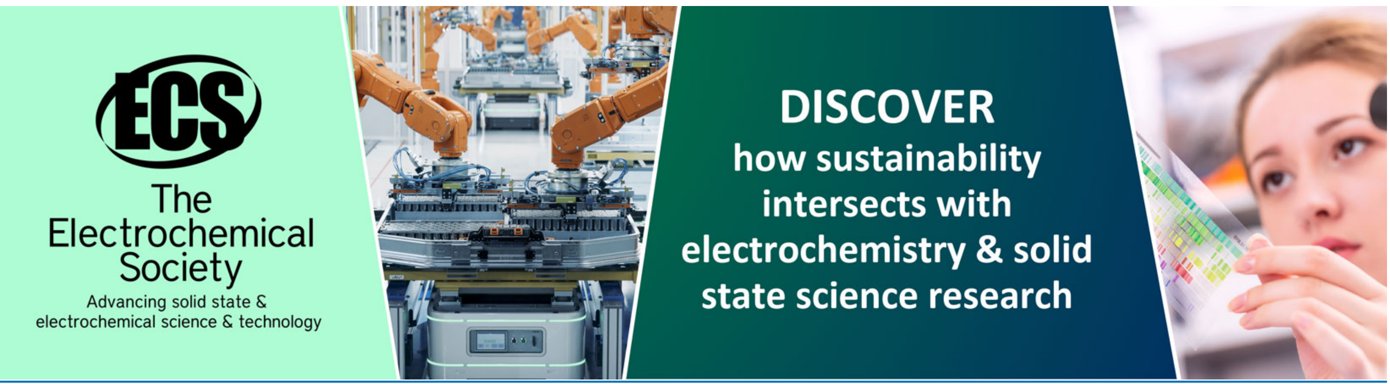

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Inversion of shallow subsurface structure from Rayleigh ellipticity beneath a station in Tangerang, Indonesia

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Abstract. Horizontal to vertical spectral ratio (HVSR) method has been widely used for estimating site effects and soil properties beneath a station. Recent studies have shown that it is possible to extract Rayleigh wave ellipticity from the record of seismic noise or vibration. In this study, we applied HVSR method to obtain frequency resonance and site amplification beneath a seismic station in Tangerang, Indonesia. We applied time frequency analysis (HVTFA) using a continuous wavelet transform to extract Rayleigh ellipticity. We carried out inversion from the computed Rayleigh ellipticity to estimate shallow subsurface structure. We applied non linear inversion using two layers as initial model to obtain the best fit subsurface structure. We obtained that the layer boundary between two layer model is found at depth of about 100 m.

1. Introduction

One method to estimate site response and soil properties with a single station is Horizontal-Vertical Spectral Ratio (HVSR) proposed by Nakamura in late 80s [1,2] Site response or \site effect is an important factor in describing earthquake hazard mitigation. Site response gives information site amplification factors. HVSR uses continuous ambient noise or vibration records for the computation. Sources of the ambient noise or vibration can be from human activities or natural excitations and it may consist of body and surface waves composition [3]. The calculated HVSR curve shows a frequency peak that provides information on fundamental or resonance frequency of the site [4,5]. Amplification factor from the HVSR method is still debatable and several studies suggested the peak amplitude might show a lower bound estimation of the actual amplification factor [6,7].

Inversion of HVSR curve for shallow subsurface structures have been carried out by several studies [8-10]. Inversion of the HVSR curve considers the curve as observation of Rayleigh ellipticity. However, there is a trade-off in the inversion between layer thickness and its velocity. Several studies suggested that Love waves can also affect the HVSR curve and the affect can vary with frequency and time [5,11]. Estimating Rayleigh ellipticity can be carried out from a record of ambient noise or vibration from a single station. Several studies suggested applied time-frequency analysis using a wavelet transform or random decrement technique [12-14]. It has been found that the right side from the ellipticity peak may contain informative part to get information for the soil structure [14].

Sunda Arc is one of the most active tectonic regions in the world. It consists of Java Trench, forearc ridge, fore-arc basin, and active volcanic arc in Sumatra and Java Islands. The region has generated several large earthquakes in the last 15 years, such as 2004 Mw 9.1 Sumatra-Andaman, 2005 Mw 8.7 Nias Island. In addition to strong motion, the earthquakes also pose tsunami hazard that may cause

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large casualties such as 2004 Mw 9.1 Sumatra-Andaman and 2006 Mw 7.7 Pangandaran. Western Java is part of Java Island and the most populous region in Indonesia with a population is of approximately up to 50 million. In this preliminary study, we investigated shallow structure beneath a station located in Tangerang using Rayleigh ellipticity estimated from time-frequency analysis and possible site-specific amplification factor and resonant frequencies from HVSR curve. Figure 1 shows location of the station used in this study.

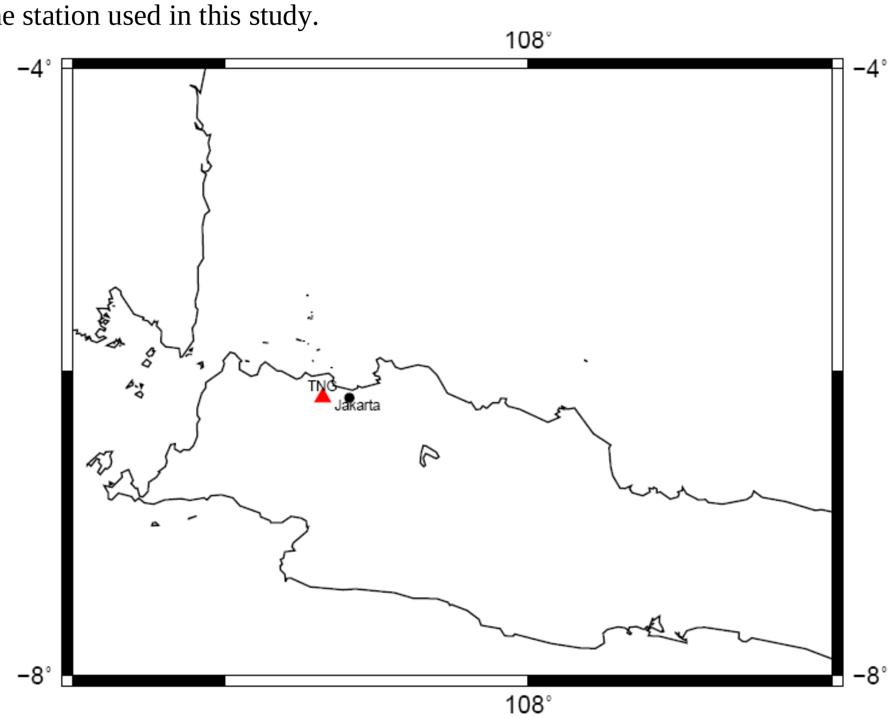

Figure 1. Map of Java Island with broadband station used in this study (red triangle).

2. Experimental Methods

Three component seismometer used in this study is part of permanent seismic network of IA-Net. Period of the ambient noise or vibration record used in this study and the location of the seismometer are given in Table 1.

Table 1. Station information used in this study.

Station Code	Latitude (N)	Longitude (E)	Period
TNG	-06.1719	106.6469	2008/09/08 02:53-04:03

To investigate the site response, HVSR curve was processed using Geopsy software. Document of SESAME (Site Effects Assessment using Ambient Excitations) was used for the processing. First, instrument correction was applied to the data records. To remove non stationary signals, we applied STA/LTA anti trigger algorithm. We computed spectra for each 25 s window length with 5% cosine taper. Spectra from two horizontal components were averaged, then we computed H/V spectral ratio for each window. Finally, all computed H/V spectral ratio were averaged. The HVSR curve was computed in the 0.5 - 10 Hz. Figure 2 shows the ambient seismic records from the seismometer and the window used in this study.

To investigate shallow subsurface structure, we inverted Rayleigh ellipticity. Rayleigh ellipticity was calculated using time frequency analysis module (HVTFA) from Geopsy. We selected Morlet wavelet parameter of 8 and calculated in the frequency range of 0.5 - 10 Hz. To inverse obtained Rayleigh ellipticity for shallow subsurface structure, we used conditional neighbourhood algorithm implemented in Geopsy.

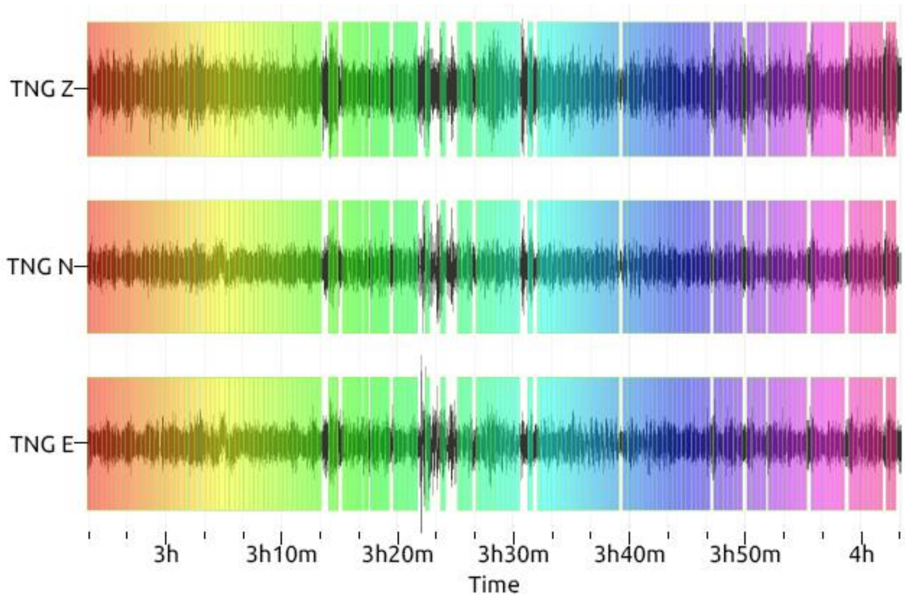

Figure 2. Seismic noise or vibration record at station TNG used in this study.

3. Results and Discussion

Computed HVSR curve from station TNG is shown in Figure 3. Station TNG is located on the top of tuff, pumice tuff, and tuffaceous sandstone. We expect the stations will show a strong peak in the HVSR curve. However, the station shows relatively low peak amplitude in the HVSR curve. We suggest that it may indicate a low impedance contrast beneath the station. From the computed HVSR curve, we estimate that the observed peak amplitude is about 1.98 with peak frequency of 0.82 Hz. The observed HVSR peak amplitudes are generally smaller than the actual site amplification. Although the peak amplitude cannot be assumed to be the true amplification of the soil, it may indicate a minimum value of the site amplification due to occurrence of an earthquake [7,15]. The difference could be caused by the different composition and proportion of waves from the vibration sources. Several studies have shown that HVSR curve may provide information on the fundamental frequency of the rock site [16, 17]. An analytical study has shown that frequency peak on the HVSR curve may represent shear wave resonance in the medium [17].

We computed Rayleigh ellipticity at station TNG using HVTFA method. Figure 4a shows Rayleigh ellipticity at station TNG. By comparing with computed HVSR curve, we observed that there is a slight change in the amplitude at frequency of about 1.4 Hz. The peak amplitude at about 0.8 Hz is quite similar with we obtain from the HVSR curve. Knapmeyer-Endrun et al. [18] suggested that if only fundamental mode data are available, both sides of Rayleigh ellipticity may provide constraint better than using only the right flank. In this study, we inverted both sides of the fundamental mode to extract information on the subsurface structure. Inversion of the subsurface structure is nonlinear with a trade-off between medium velocity and thickness. One method to minimize these problems is using model based on available borehole data. Unfortunately, in this study we do not have borehole data at station TNG or surrounding area. We used two layer model for initial model and applied conditional neighbourhood algorithm to extract subsurface structure. Subsurface model from the inversion using Rayleigh ellipticity is shown in Figure 5. Lowest misfit value indicates that there is layer boundary at depth of about 100 m. Relatively high *S*-wave velocity at this depth may indicate that the bedrock beneath station TNG may down to a depth of about 100 m.

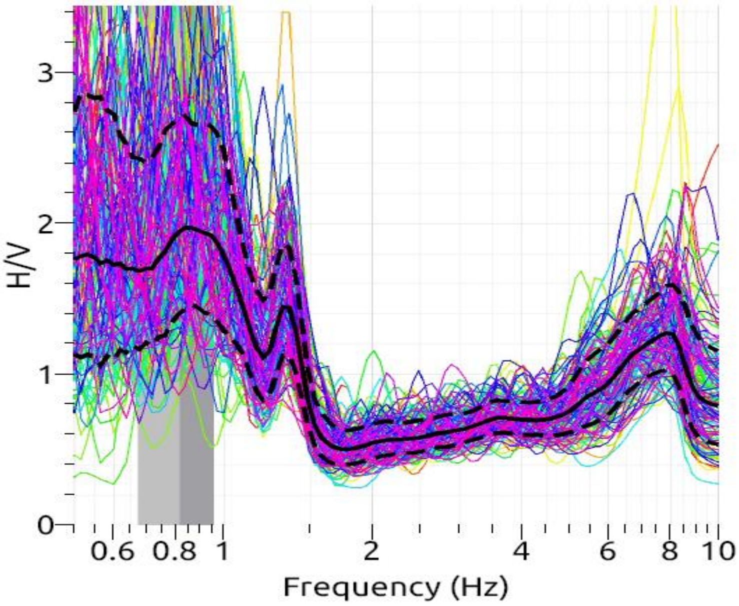

Figure 3. Observed HVSR curve at station TNG. Black solid line represents mean HVSR curve and solid lines represent the standard deviation.

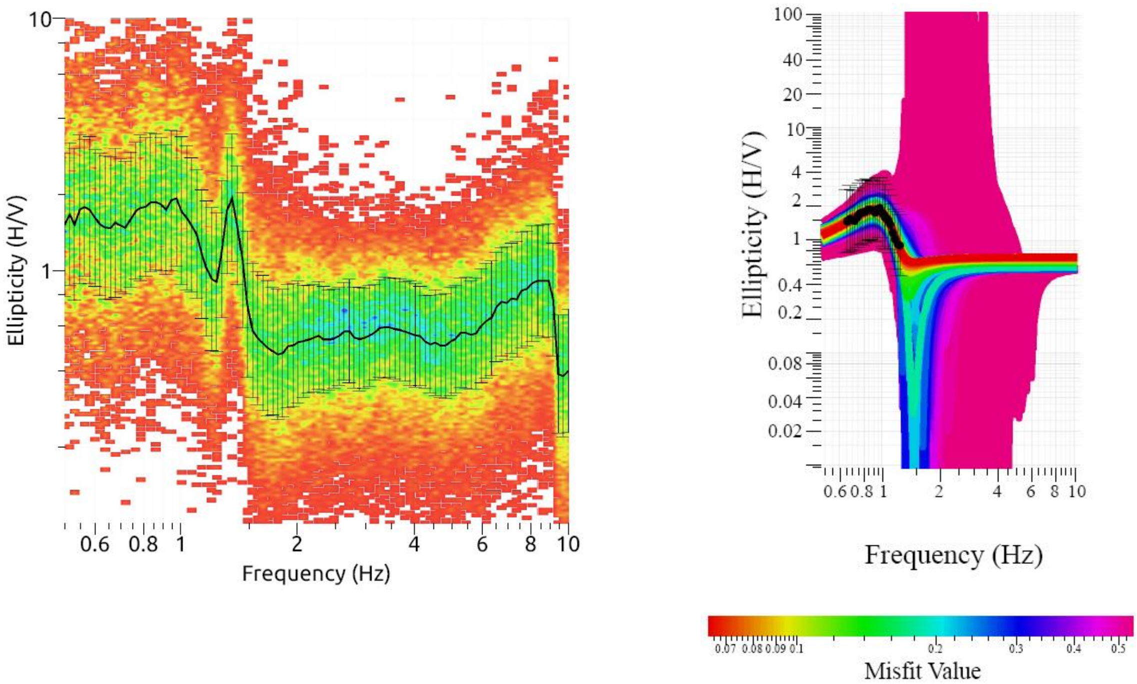

Figure 4. (a) Obatined HVTFA curve with its standard deviation (green). (b) Modeled Rayleigh ellipticity from the inversion result. Black circles with error bars are selected ellipticity curves used inversion.

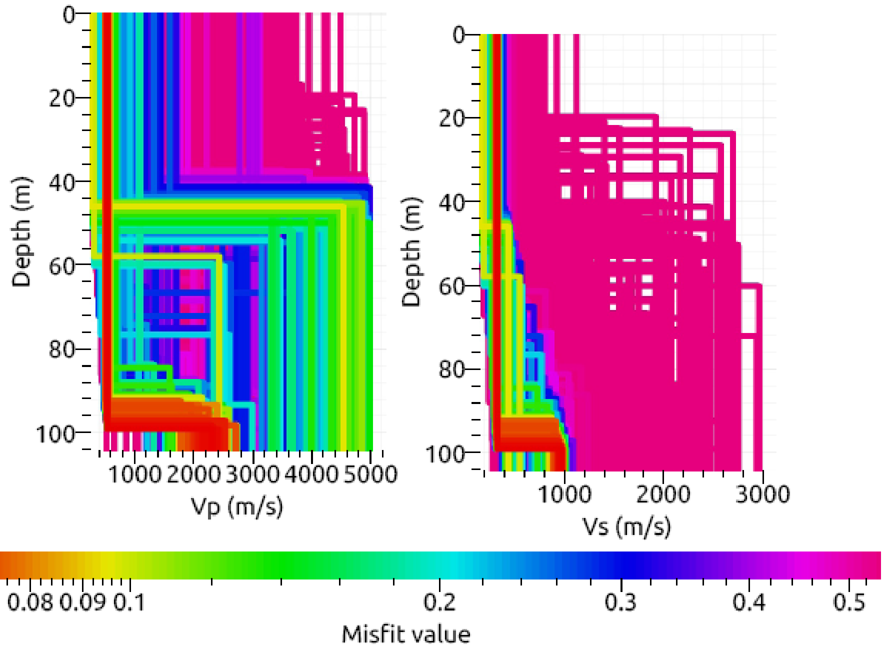

Figure 5. Subsurface velocity profile beneath station TNG obtained from inversion of Rayleigh ellipticity.

4. Conclusions

We have estimated frequency resonance and site amplification at station TNG using ambient seismic noise or vibration of about one hour data. The frequency resonance obtained may provide information on the soil structure that may help in assessing soil amplification due to a ground motion. We also have extracted subsurface velocity profile using HVTFA method. From the inversion result, we obtained layer boundary at depth of about 100 m.

5. Acknowledgment

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