Seismic vulnerability of the Campus II Universitas Syiah Kuala

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Abstract. Universitas Syiah Kuala (USK) is planning to develop a new campus (Campus II). The location of the study area is relatively close to the Seulimum fault which historically has generated a devastating earthquake. Therefore, a seismic vulnerability study is important to conduct in use for reference before the development. This study aims to determine the seismic vulnerability index in the Campus II development area of USK in Mesjid Raya District, Aceh Besar Regency using a Horizontal to Vertical Spectral Ratio (HVSR) method. Potential earthquake damage can be studied by analyzing the dominant frequency (f0), amplification (A0), seismic vulnerability (Kg), and Vs 30. The microtremor acquisition was carried out by using a Broadband seismometer with 100 sps at 37 measurement points with a distance of 500 meters for each station. We use the Geopsy software to analyze seismic data by applying Fourier transform and STA/LTA concept to Rayleigh waves and obtain the dominant frequency value. The 1D velocity inversion was derived by Dinver using the Neighborhood Algorithm (NA). The results of the analysis show that the dominant frequency value is higher around the STA17 point, while the amplification value and seismic vulnerability are highest in the north (at STA2 and STA3) and in the south (at STA28, STA29, and STA30). The higher amplification region is associated soft soil identified as alluvium (Qh). On the other hand, the 1D inversion results at a depth of 30 shows Vs values of 661.142 - 1106.31 m/s (at STA3 and STA17) which indicates the presence of bedrock, making it suitable for future development although more detail investigation is required.

1 Introduction

Along the Aceh Province, there are many fault lines resulting in high seismic activities. In the south, the seismic activities in Aceh occurred along the subduction zone several onshore earthquakes occurred along the Great Sumatra Fault and the Selimum Fault. In addition, there are also several secondary active faults, including the Tangse-Geumpang fault, Beutong fault, Lampahan fault, Geureudong fault, Pamue fault, and Nisam fault [1].

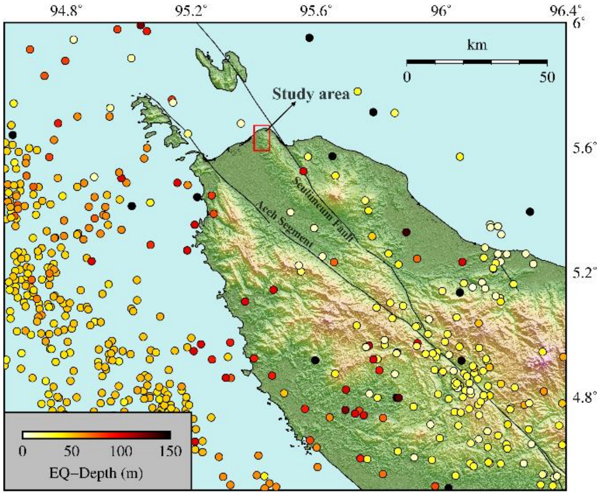

Figure 1. Aceh Seismicity Map for the Period 2000 - 2023 (ISC, 2023)

According to [2] and [3], earthquake damage is not only influenced by the magnitude of an earthquake but also by the influenced by geological conditions where the infrastructure is located. An area prone to earthquake damage is generally characterized by thick soft sedimentary rock [4]. The softer is the rock, the greater is the effect causing by the earthquake. This is because areas with soft rock composition have properties that are not yet compact, so they are easily decomposed and the potential damage is greater when an earthquake occurred Therefore, studies related to rock characteristics before development are important.

Universitas Syiah Kuala (USK) is one of the largest universities in the Aceh Province with a large number of students and the grow rapidly, thus requires future development. The construction plan of Campus II of Universitas Syiah Kuala has been agreed by the academic community. The development area of Campus II is located in Mesjid Raya District, Aceh Besar Regency. However, the Campus II is closely located with the Seulimeum fault area shown by the red square in Figure 1. Based on historical data, the Seulimeum fault has generated an earthquake with magnitude of Mw 6 in 1964 [5]. The Seulimeum fault is located to the north of Banda Aceh City (Figure 1), stretching from Tangse to Sabang. The Seulimeum Fault is classified as an active fault, which makes the area around the fault more vulnerable to seismic activities.

Seismic vulnerability indexes of Banda Aceh City and Aceh Besar Regency have been previously investigated by Simanjuntak et al [1], Simanjuntak et al [6], and Asnawi et al [7] by using an HVSR method. In the research performed by Simanjuntak et al [6], microtremor surveys were conducted surrounding the Seulimeum fault area at 20 points with an interval of 1 km between each point. The parameters reviewed from the study are the dominant frequency and the H/V spectrum value indicating seismic vulnerability. The conclusion obtained from the research is that the area around the Seulimeum fault has a low amplification so the soil vulnerability index at that location is low. In the next study by Simanjuntak et al [1] in Banda Aceh city, a microtremor survey was conducted for 20 points with a data recording duration of 45 minutes. The dominant frequency obtained is ranging between 0-6 Hz with the amplification values of 0-5. The results of the seismic vulnerability around the study area are 0.1 - 0.5. The lastest research conducted by Asnawi et al [8] in the Darul Imarah sub-district focused on estimating shear wave velocity (Vs) closed to the Seulimum fault. Although, the microtremor surveys were conducted at 19 points, the analysis process was only applied for four points.

The objective of this study is to calculate more detailed values of dominant frequency, amplification, and Vs for the USK's Campus II construction area and to enhance the microzonation information of Aceh Besar region. The study of dominant frequency, amplification and seismic vulnerability index at smaller scales is necessary for pre-development surveys. In addition, the geological setting in the measurement area is still regional, so a more detailed study of the local geology structure is needed. The HVSR method is an efficient and non-destructive method, therefore it is suitable to use in assessing the development area which is important for disaster mitigation.

2 Data and Methodology

The research area is bordered by Ujong Batee Beach in the north, Gampong Durung in the east, Gampong Lam Ujong in the south, and Gampong Baro in the west. This research area covers the construction area of USK's campus II. The experiment was performed by using a Broadband type seismometer with 100 sps at 37 measurement points with a distance of 500 meters between each station (Figure 2).

We calculated the f0, H/V, and seismic vulnerability values by using the Geopsy tool. The first step is to input the 3 component seismic data. Secondly, windowing was performed to convert the data into the frequency domain using the fast Fourier transform (FFT) technique. Each component that has been transformed produces a north-south and east-west horizontal and a vertical component spectrum. The horizontal component spectra were averaged, then divided by the vertical component following equation:

$$\frac{h}{v} = \sqrt{\frac{SH(N-S)^2 + SH(E-W)^2}{SV}} \quad (1)$$

where SH(N-S) is the north-south horizontal component spectrum, SH(E-W) is the east-west horizontal component spectrum, and SV is the vertical component spectrum [9]-[10]. The H/V value was obtained at a specific natural frequency. The seismic vulnerability value (Kg) is calculated as □0^2/□0.

The 1D inversion process was performed using the Dinver tool from Geopsy. The first step, the H/V curve data from the previous observations was inputted. The initial inputs are model parameters such as P-wave velocity, S-wave velocity, Poisson ratio, and density. The ground profile calculations of shear waves (Vs) were performed based on the Neighbourhood Algorithm (NA) method using the Monte Carlo principle by minimizing the ellipticity curve misfit function [11]. The inversion results in a new 1D velocity model for each measurement point.

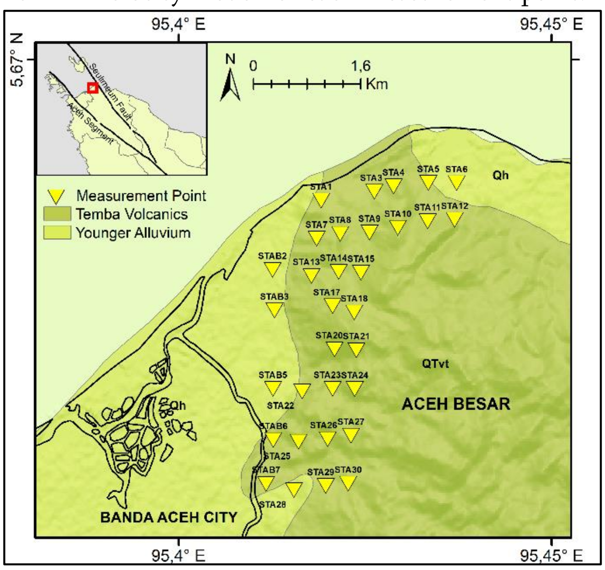

Figure 2. Geological setting and distribution of 32 HVSR measurement points around the Mesjid Raya Sub-district, Aceh Besar, Indonesia.

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3 Results and Discussions

3.1 Amplification and Seismic Vulnerability

The results obtained from microtremor analysis consisted of dominant frequency (f0) and amplification (A0). Those values can be used to derived the seismic vulnerability index (Kg). The examples of the H/V curves of the HVSR processing results for the two measurement points are shown in Figure 3.

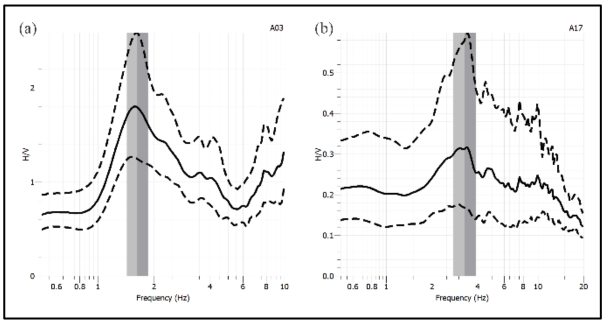

Figure 3. The H/V curves result of HVSR processing (a) at point STA3 and (b) at point STA17

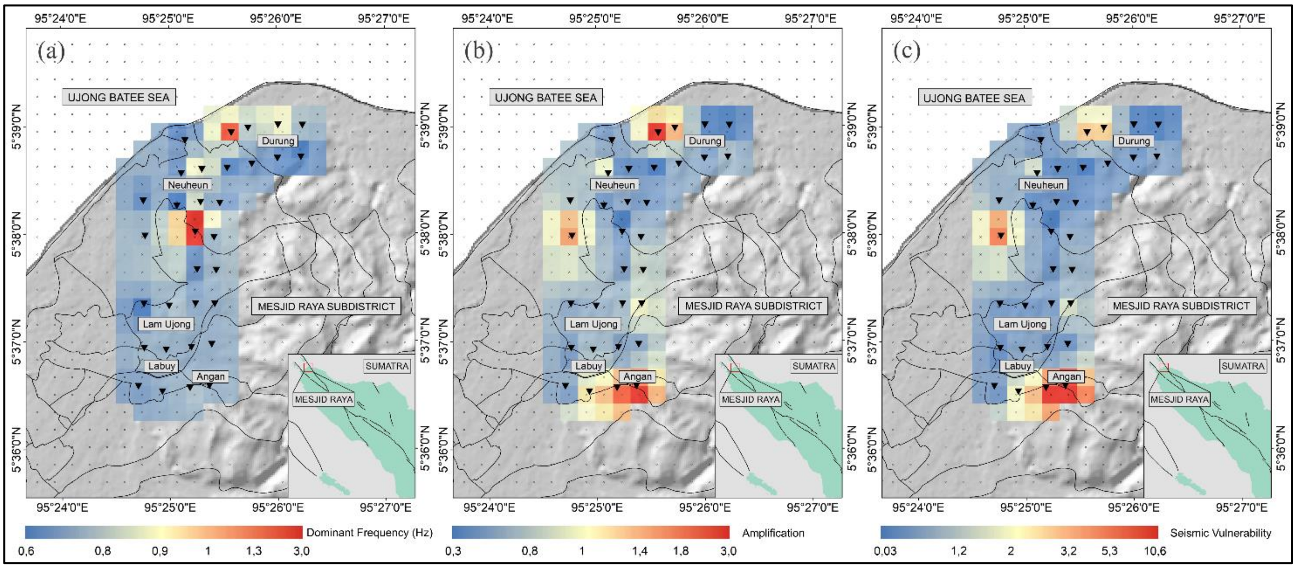

Figure 4. (a) Dominant frequency, (b) amplification, and (c) seismic vulnerability analyzed from 32 measurement points.

The f0 value ranges from 0.64 to 3.04 Hz, where the lowest value of f0 is recorded by STA1, STA15, and STAB5 points while the highest value of f0 was recorded at STA17. The amplification A0 values ranging from 0.31 to 3.06. At point STA17, the Kg value was recorded low while the highest value was found at STA3 as shown in Figure 4.

The distribution of dominant frequency values in the campus II area is classified as type IV soil (Kanai, 1983), where rocks with this type are alluvial rocks formed from delta sedimentation. Amplification values ranging from 0.31-3.06 are classified as type I of rocks where the amplification value is low (A0 < 3).

3.2 Velocity Models

The 1D inversion was only carried out at two measurement points, STA3 and STA17. These sample points were selected based on points with low (STA17) and high (STA3) amplification values to investigate the relationship between A0 and S-wave velocity (Vs). The inversion results show a pattern that converges to one model out of 30000 models used as shown in Figure 5, so that the inversion result is acceptable. A rock layer with very low Vs avlue may increase the disaster risk when an earthquake happens. At STA3, the amplification is found very high (A0 = 2.85) but the Vs value is found relatively low (Vs30 = 661.14 m/s)as shown in Table 1. and Figure 4. Te region at STA17 has low amplification and high Vs value where the rock around this point is harder than STA3.

The Vs value is very high at depth of 0 - 4 km because the measurement point is carried out on the surface of igneous rocks from ancient volcanoes in this area. Considering the distribution of amplification values at all observation points, the USK campus II building area has a Vs value that is quite suitable for future construction area.

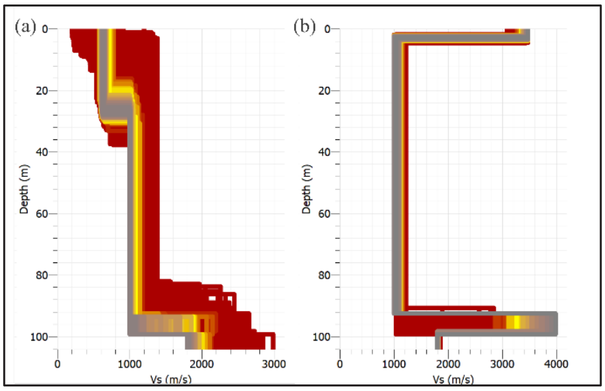

Figure 5. 1D velocity model of HVSR inversion result (a) at point STA3 and (b) at STA17

Table 1. Vs and Vs30 values at points STA3 and STA17

STA3		STA17	
Depth	Vs	Depth	Vs
10	634.321	10	1030.3
20	634.321	20	1030.3
30	1000	30	1030.3
Vs30 = 661.142		**Vs30** = 1106.31	

4 Conclusions

The dominant frequency value in the Campus II development area of Universitas Syiah Kuala ranging from 0.64 Hz to 3.04 Hz, where the highest dominant frequency is located in the central area and the lowest value is located in the southern area. Furthermore, the amplification values range from 0.31 to 3.06 where the highest amplification value is located in the south and the lowest amplification value is located in the northeast of the study area. The seismic vulnerability value ranges from 0.03 to 10.64. The highest seismic vulnerability value is located in the same area as the amplification value, this is because both parameters have a directly proportional relationship. The soil classification in the Campus II development area of Syiah Kuala University is mostly classified as soil type IV because it has a dominant frequency value of <2.5 Hz, which is characterized by a thick sediment surface. The amplification value distribution is generally low, and the Vs value at the high amplification point is relatively low. Based on the values of amplification, seismic velocity, and seismic vulnerability, the region is suitable The region is suitable for future development, however detailed investigation is required as the location is closed the Seulimum fault.

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