Microzonation of the seismically active region along the Seulimum fault

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Abstract. Banda Aceh and Aceh Besar regency is located between the two active faults, the Seulimeum and Aceh segments. In the near future, a large infrastructure development will be constructed in an area closed to the Seulimum fault. One of the development areas is the Campus II of Universitas Syiah Kuala. To prevent possible damage of infrastructure by a devastating earthquake, the developer needs to consider soil and rock types where the building is located. A region characterized by soft soil can lead to seismic amplification which can cause the damage of buildings and infrastructure. The objective of the research is to investigate the types of soil and rocks, called microzonation, in a seismically active region closed to the Seulimum fault. The types of rocks or soils can be classified based on the values of shear wave velocity (Vs) derived from the microtremor data. The acquisition of seismic data was carried out using a 4.5 Hz triangle array geophone at 35 measurement points. The microtremor data at each location was analysed by using the Spatial Autocorrelation (SPAC) to obtain the Rayleigh wave dispersion curve. The Vs values are then classified based on SNI 1726:2019. The results of the microtremor analysis showed that the Vs values are relatively high ranging from 300 m/s – 1500 m/s at different depths associated with hard rock as also observed in the field. At depth of 30 km, Vs30 is higher in the west and in the southeast while in the north the velocity is lower at around 300 m/s. It is suggested to investigate more detail and local type of rocks before infrastructure development to mitigate possible damages.

1 Introduction

The Aceh region, located in northernmost Sumatra, is one of the most seismically active regions in the world. Earthquakes in Aceh can occur along subduction zones and active faults [1, 2]. Onshore earthquakes occurring along active faults generally cause more damage compared to offshore ones because the epicenter of the onshore earthquakes is close to populated areas such as the Pidie Jaya earthquake [3] and the Central Aceh earthquake [1].

The Seulimum fault is among the active faults that have not generated devastating earthquakes in the last four decades. An earthquake occurred in Kreung Raya along the Seulimum Fault in 1964 with magnitude of Mw 6.0 [4]. The earthquake caused significant damage to the houses. Potential damage can increase significantly as the population in northernmost Sumatra, especially in Banda Aceh City, has increased significantly. One of the development plans for the near future is Campus II Universitas Syiah Kuala and sports facilities in Aceh. The location of Campus II and the sports facility are shown in Figure 1, which is situated close to the Seulimum fault.

The damages of buildings or infrastructure is not only influenced by the distances to the earthquake sources but also influenced by the types of rocks or soil where the building is situated. Buildings situated in the soft rocks regions are normally more vulnerable to be damage by earthquake shaking [5].

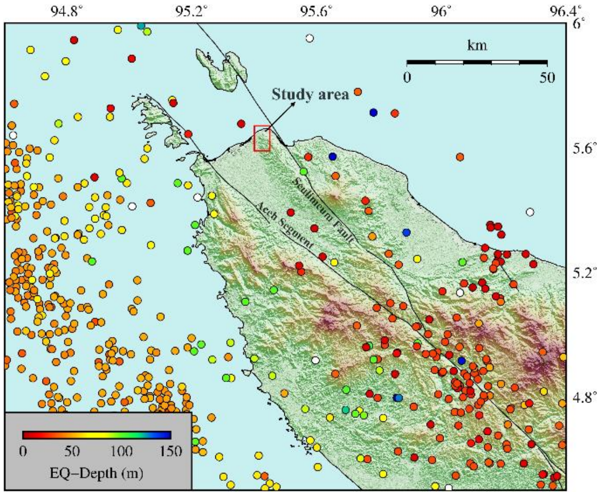

Fig. 1. Tectonic setting of Aceh dan its seismic activities. The location of Campus II of USK is indicated by the study area (red box).

The physical properties of rocks or soil, such as stiffness and porosity, play an important role in the level of infrastructure damage. Engineers use shear wave velocity Vs to investigate the stiffness of soils and also referred to in building standards [6]. Investigation of Vs properties is important to have an overview of rock types prior large development [5, 7].

The subsurface of information based on a region's shear wave velocity Vs value is called microzonation. The higher the shear wave velocity value Vs, the stiffer the rock is in a region. The objective of this research is to investigate shear wave velocity Vs of the subsurface beneath the Campus II area of Universitas Syiah Kuala. The results of the microzonation can be used for future development in order to reduce the risk of disaster.

2 Tectonic and Geology of the Study Area

The Campus II of Universitas Syiah Kuala, located in Aceh Besar Regency, is situated on the west side of the Seulimum fault as shown in Fig. 2. However, so far there is no detail geological study of the study area.

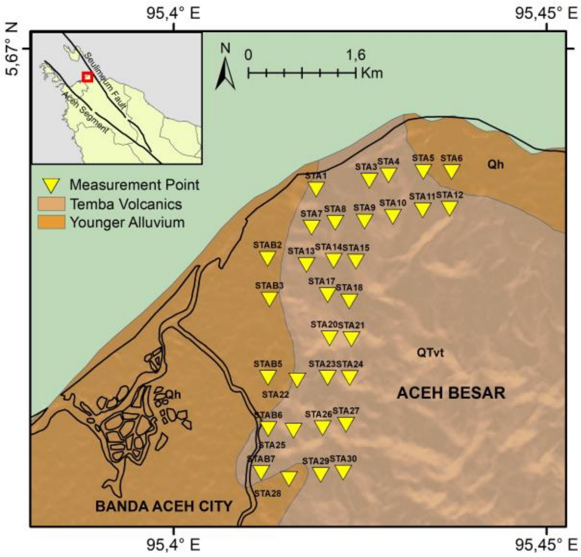

Fig. 2. Geology of the study area modified from Bennett et al [8] and the location of the SPAC measurement points indicated by yellow triangle.

The Campus II area is located at the boundary of Banda Aceh basin in the west and high elevation region. The Banda Aceh basin is a valley characterized by Quaternary-era rocks covered by undifferentiated alluvium deposits. Apart of the study area is a coastal zone consisting of Alluvium formation (Qh) with sedimentary deposits including mud, sand and gravel. In the surrounding area there are also Lamteuba volcanic rocks (QTvt) consisting of andesite, dacite, stony breccia, tuff, agglomerate and ash flows (Fig. 2).

The active Seulimum fault is located on the right-hand side of the USK's Campus II. A major earthquake occurred along the Seulimum fault with a magnitude of M 6.4 ([4], [9]) caused significant damages to the Krueng Raya region which passed by the fault.

3 Data and Methods

The Vs velocity models were derived from the microtremor data. The microtremor measurement were conducted using the microtremor array method [10]. Measurements were made using geophones arranged in a triangular array as shown in Fig. 3. The principle of measurement is by connecting 4.5 Hz 3 geophones on the ground to a Cube datalogger. The Cube datalogger recorded the seismic data at 100 sample per second. The measurement points were chosen in very low noise locations.

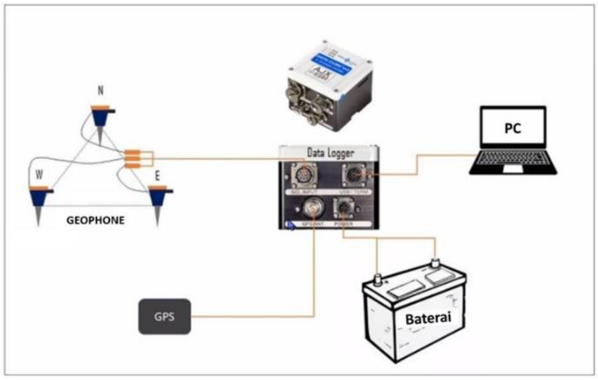

Fig. 3. The microtremor seismic recording schemes by using a triangle seismic array.

The seismic records were segmented with 10 seconds long windows. A STA/LTA procedure (as explained in Khalqillah et al [11]) were used to exclude a seismic window containing a significant transient noise. Each seismic trace was transformed from time domain into frequency domain by using a Fast Fourier Transform scheme as explained in Khalqillah et al [12].

The Vs structure were determined by using a Spatial Auto Correlation (SPAC) method [13]. The SPAC method provides a frequency – phase velocity relationship called a dispersion curve. The 1D velocity values were inferred from the relation between frequency and velocity [7].

4 Results and Discussion

The result of the data analysis for each site consists of Power Spectra Density Curve, Dispersion Curve, and 1D velocity model. All 1D velocity models were then interpolated to obtain 2D velocity models at different depths.

An example of the Power Spectra Density (PSD) profile for Site B7 is shown in Fig. 4. The PSD curve explain that the frequency of the excitation energy of the seismic wave is between 3 – 40 Hz. Thus, we can only further analyse the seismic data for the corresponding frequency.

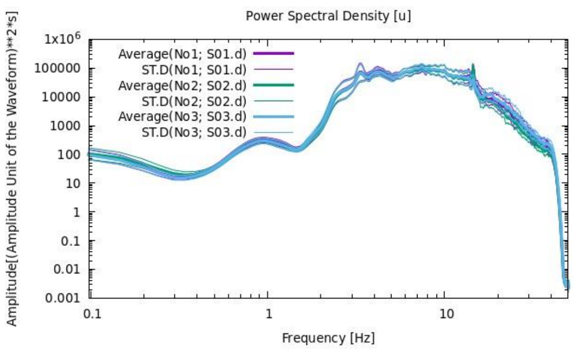

Fig. 4. Power Spectra Density showing the frequency of the excitation energy is between 3 – 40 Hz.

An example of the Dispersion Curve for the seismic data recorded at Site B7 is shown in Fig. 5. The Dispersion Curve describes the average velocity models at different depths. Fig. 5 shows that the resulted dispersion curve can provide the value of the average velocity model. From the average value of the velocity model the value of 1D model a specific depth can be derived following the procedure explained by Asnawi et al [7].

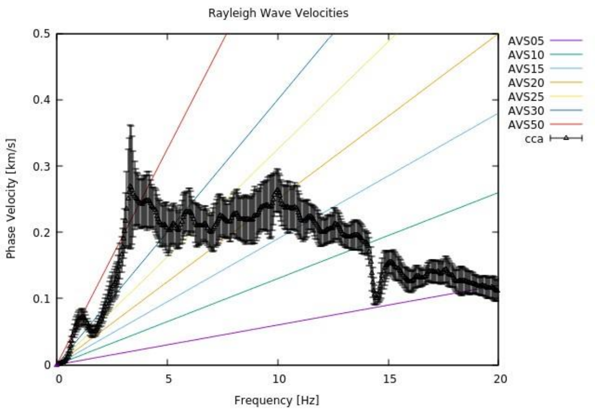

Fig. 5. The dispersion curve to derive the average velocity model below Site B7.

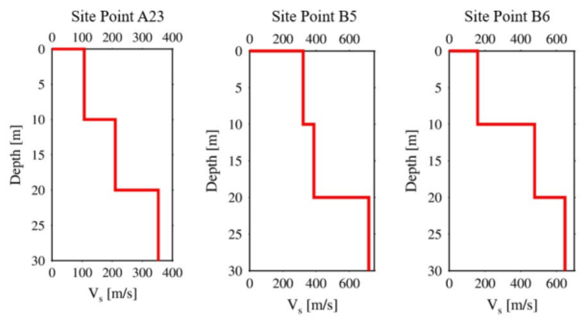

Fig. 6. Examples of the 1D velocity models recorded below Site A23, B5, and B6.

The 1D velocity models below all measurement sites have been calculated as exemplified in Fig. 6 for Site A23, B5, B6. The results exhibit a common pattern of the 1D velocity structure which is the velocity value is higher for deeper layer. At depth of 10 – 20 m, the velocity value ranges from 100 – 300 m/s which is categorized as soft soil (). On the other hand, the value of the Vs model is between 350 – 1200 m/s which categorized as medium to hard types of soils [6, 14].

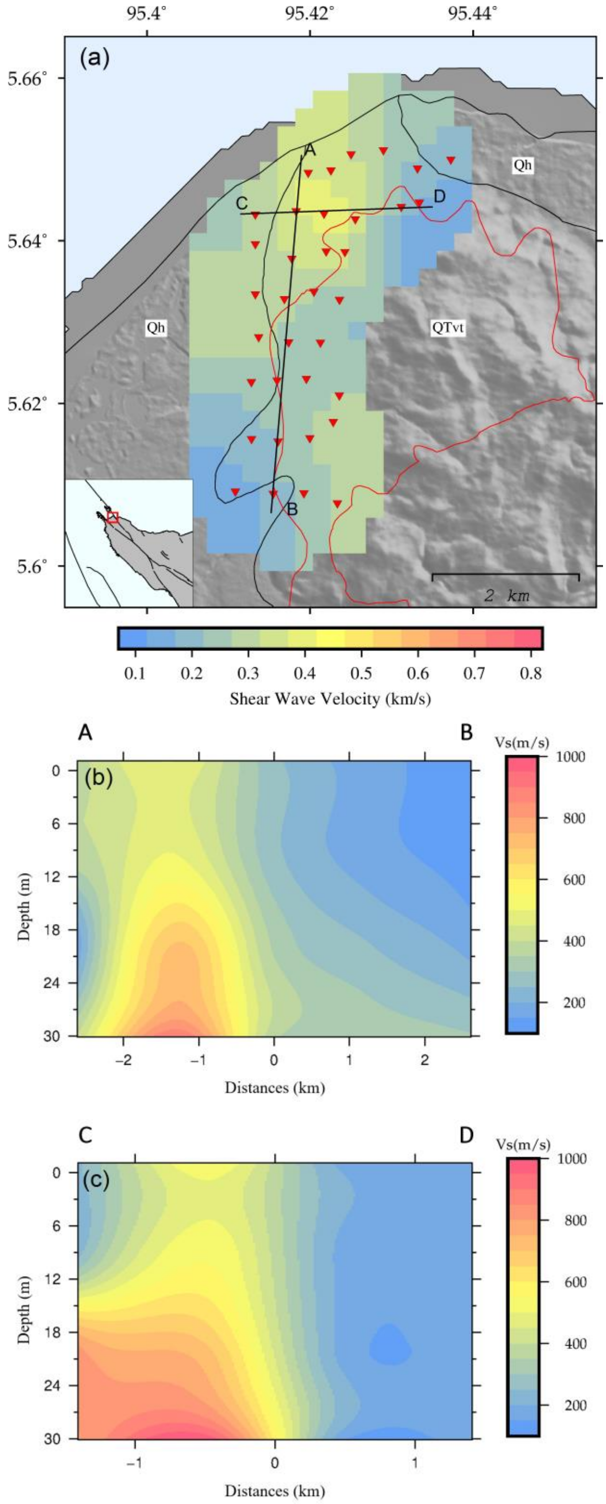

Fig. 7. (a) The map view of the velocity model at depth of 10 m, (b) the 2D velocity profile along Line A-B, and (c) the 2D velocity profile along Line C-D.

In general, the velocity model below Campus II of USK ranges from 350 to 1200 m/s as shown in Fig. 7(a). According to the Indonesian National Standard (SNI 1726:2019) soil with Vs between 350 and 1200 m/s is categorized as stiff soil (SC) and rock (SB). In the east of the region, the velocity model below Campus II is lower at around 350-400 m/s or called medium type of soil in terms of the stiffness. The soil is stiffer in the middle of Campus II but maybe difficult to build infrastructure in high elevation region.

Fig. 7(b) and (c) describe that the soil is stiffer as the layer is deeper as indicated by higher seismic wave velocity. Again, region along Line C-D which is along the middle of Campus II of USK has higher seismic wave velocity. The area with higher velocity value is suitable for future development of infrastructure.

5 Conclusion

A spatial auto correlation method has successfully revealed the physical properties of soil and rock below Campus II of niversitas Syiah Kuala. In the east of the Campus II region, the rock is a little bit softer indicated by lower Vs value of around 350-400 m/s. However, in general region can be used as a region for large future development indicated by high velocity structure at depth of 30 km.

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