Geotechnical Investigation Using Surface Waves Method: A Case Study of Sabet Bridge, Lamno, Aceh Province, Indonesia

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Geotechnical Investigation Using Surface Waves Method: A Case Study of Sabet Bridge, Lamno, Aceh Province, Indonesia

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Abstract. Sabet bridge is a connecting bridge between Lamno town and Jantho town in Aceh Province. The bridge is located in a mountainous area and geologically near to a karst formation. The surface is covered by a fluvial landscape which was deposited by coarse sand, gravels, pebbles, and boulders. The bridge foundation analysis consists of four points cone penetration test which capable to penetrate up to 2 meters. One borehole has an obstacle in penetrating due to gravel, pebble and boulder layers; which consume more drilling time and expensive. To solve this problem, a seismic surface waves method has been performed. Two seismic lines run above the planned site of bridge abutment. The investigation reveal the results, that the surface waves method can penetrate into subsurface more than 30 meters in depth; in which the requirement depth only 30 meters. The results from surface waves method reveal the suitability and high similarity with cone penetration test and borehole investigation methods.

1. Introduction

Jantho and Lamno are a small towns and it were located in different district in Aceh Province. Connecting both town at the short path will increase the quality of life the people in those area. Recently, the people on both side spent about 2.5 hours from Jantho to Lamno and they has to pass through Banda Aceh. The new short path/road which build by Aceh Goverment pass through several rivers and it compussory to build the bridge. Sabet bridge is one of a bridges on this path with a design length of 60 meters. The location of this bridge located in the upstream zone of Krueng Sabet river. Boulder, pebble gravel, and coarse sand layers make geotechnical drilling work difficult and stopped at 5 meters from the 30 meters are planned for the purpose of detailed engineering design. Cone penetration test were also conducted only up to 2.0 meters from the usual 20 meters. To solve this problem, geophysical methods were applied to investigate this site. The use of geophysical methods has been a long time in the field of oil and gas. For environmental, engineering geology and archeology problems, geophysical methods have started to exist in the last 10 years. The geo-electrical resistivity imaging, ground penetration radar and seismic wave methods have been used for shallow investigation purposes [1]; [2]; and [3]. The method used here is the seismic surface waves method which utilizes Rayleigh wave to determine the elasticity parameters of geology materials. Many advantages of surface waves in which as many as 67 % of the total energy of wave generation is absorbed into the surface waves and remainder being body waves [4]. Therefore, the use of surface waves as a method of subsurface investigation is potentially applied in the field of civil engineering or geotechnical [5]; [6]; [7]; [8]; [9] and [10].

The location of Sabet bridge is in a hilly area and located inside the tropical rain forest. The Jurasic to creatacius limestone was formed in southert part Sabet bridge area [11]. Barber and Crow [12], noted this limestone formed in late Jurassic to early Cretaceous and it a part of Gondwanaland. The investigated site located on the flood plain of Krueng Sabet river, Lamno, Aceh. The alluvial material in the flood plain consists of coarse sand, gravel, pebbles and boulders. The surface topography at test site is relatively flat. The pebbles and boulders make conventional sub-surface investigation more difficult than expected and a geophysical exploration method will solve the problems.

2. Methodology

Figure 1 show the location of site investigation and the orientation seismic lines. A total of 2 seismic lines (shown in yellow line) and shallow borehole location (red dot). The seismic lines of the surface waves were carried out transverse to each other. Seismic data acquisition was performed using a set of PASI-16S-24P equipment. 24 geophones were used to record the seismic wave. The geophones spacing used is 1.0 meter. The frequency of geophone is 10 Hz. To generate wave energy, 7 kg sledgehammer was used. The sledgehammer shoot performed in between of 24 geophones. Shooting on the offset was performed at a distance of 15 meters from the first and last geophone. Variable record time of 512 microseconds was used in the seismic wave data acquisition. To amplify the signal to noise ratio, 5 time stacking have been used at any location of shooting. Sampling time 250 microseconds was used. Data acquisition results are processed using seisImager program. For data processing, there are two stages: dispersion and inversion [13]; [14]. In dispersion processing, the transformation time domain into frequency domain using Fast Fourier Transform techniques. Each shot gathers between the geophone spacing and the offset able to produce one dimensional (1D) shear wave veolcity. A 1D shear wave velocity profiles were obtained by inversion process of dispersion curves. For two dimensional (2D) shear wave velocity imaging, 1D shear wave velocity profiles were interpolated using a Kriging method.

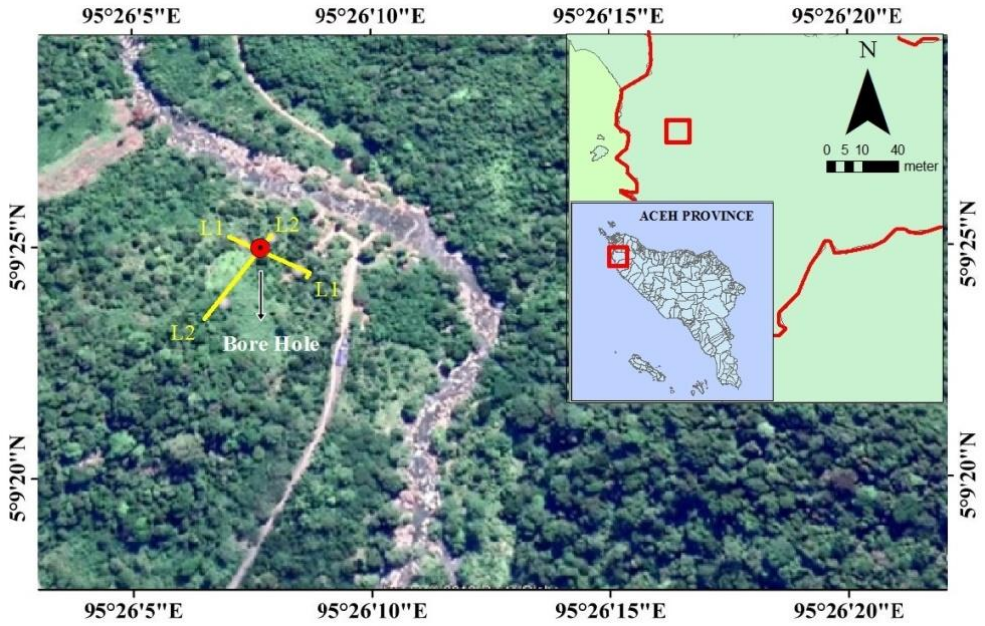

Figure 1. Situation around the area of investigation and lines on abutment bridge plan and the location of bore hole point (red dot).

3. Results and Discussion

Line 1

The 2D image of shear wave velocity in line 1 as shown in Figure 2. Three types of layers was found at this line. The layers were medium dense, hard and bedrock layers. The layers classification based on criteria which introduced by Thaker [15]. At this location, the limestone is predicted as the bedrock and it found at the third layer. The bedrock is not flat and form in undulation. The sediment deposit fill on top of this limestone which is transported by the Krueng Sabet river, this layer recognize as the alluvial deposit. The first layer shows flat from surface to 8 meter in depth. The shear wave velocity at this first layer in range of 160 to 250 m/s, this layer categorize as dense sediment. Based on data from the drilling, the material consists of a mix sedimentation from coarse sand to gravel. The first layer is also uniform from the position of 0 meter to the end of the line survey. The second layer with the characteristic medium dense shows no flat as the first layer. This layer is a soft material sediment into the shallow limestone basin. The third layer is a bedrock and part of limestone in this area.

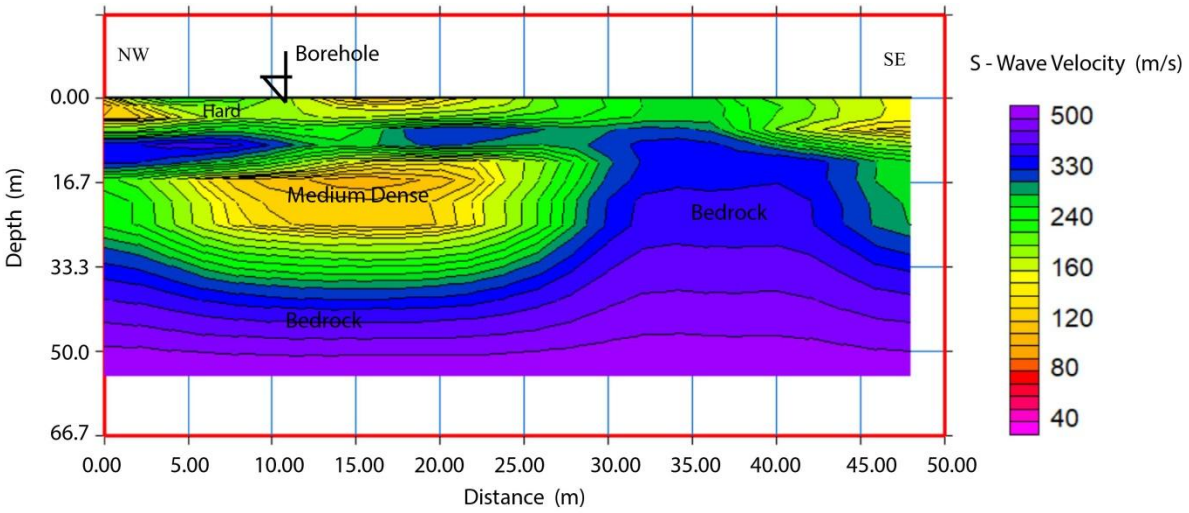

Figure 2. 2D shear wave velocity model reveal from line 1.

Line 2

2D shear wave velocity model of line 2 shows more uniform layer of bedrock from 30 meters down to depth compares to line 1. The position of 0 to 15 meters is a dense layer up to the depth of 30 meters. This dense sediment layer consists of gravel and coarse sand materials. At the position of 15 meters to the end of the line survey, the model shows the characteristics of medium dense. Medium dense has a shear wave velocity value in the range of 160 to 250 m/s as defined in line 1. These characteristics correspond as on borehole data. The image is shown in Figure 3.

The borehole data as shown in Figure 4 found two layers of sub-surface lithology. The first layer down to 2 meters was obtained as coarse gravelly sand with medium dense until dense. At this layer, the standard penetration test (N-SPT) data show an increasing result from 10 to 35 at a depth of 0.5 to 2 meters. Based on N-SPT data, the density of the first layer is a medium dense to dense. The second layer at a depth of 2 to 5 meters of material obtained in borehole is coarse sand, gravel and boulder. The density of the dense to very dense in second layer corresponding to N-SPT data which resulting value from 35 to 60 until the end boring. Comparison of two data lines of shear wave velocity imaging shows suitability of borehole data and N-SPT value. Data from surface waves method obtained elasticity level of medium dense to dense. The borehole method also obtained same elasticity and it conclude that these two data shown the suitability of each others.

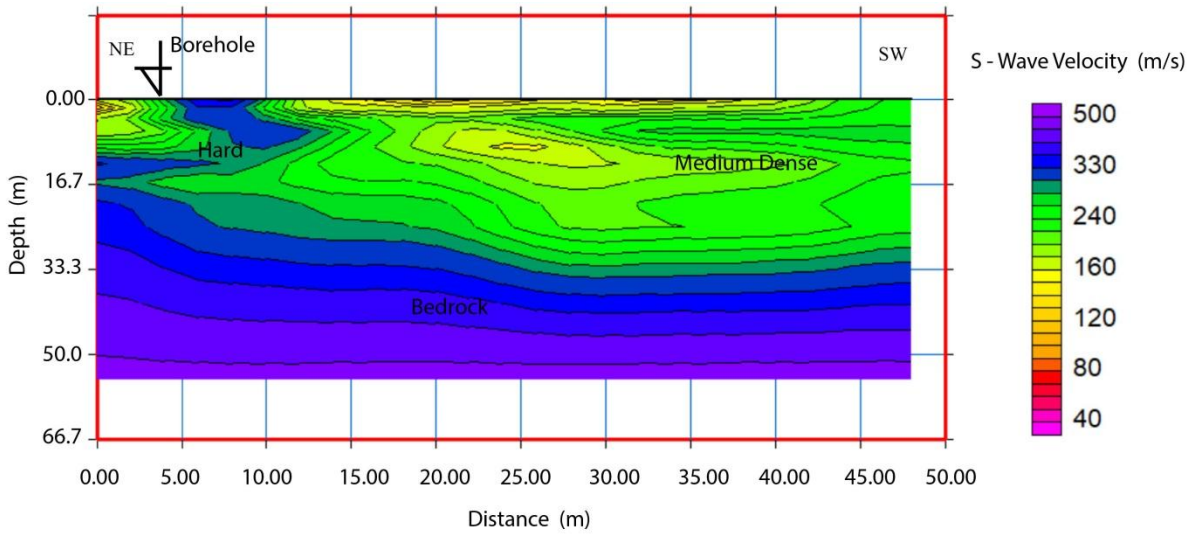

Figure 3. 2D shear wave velocity model reveal from line 2.

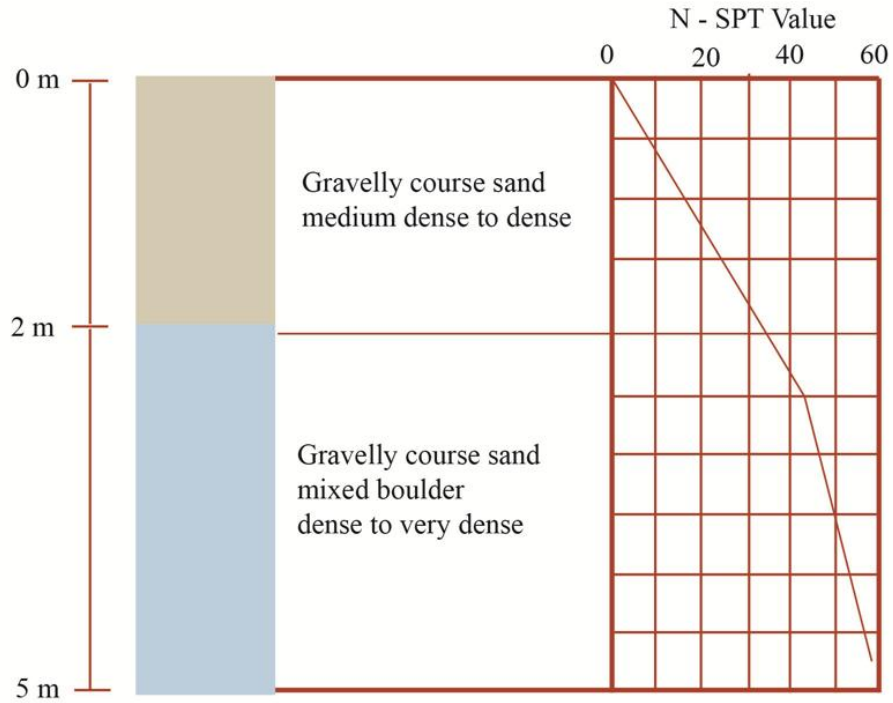

Figure 4. Borelog drilling data down to a depth of 5 meters and N-SPT value.

4. Conclusions

Survey and subsurface investigation for detail engineering design of Sabet bridge, Lamno, Aceh province were conducted successfully. Because there are some deficiencies in the use of borehole, a surface waves method was applied to this survey. The results of interpretation and analysis shown that the surface waves method shows the suitability of elasticity parameters to the results of borehole data. Therefore, surface-waves method can be considered to be one as additional method in geotechnical site investigation.

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