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A Study on the Acquisition Technique of SH Waves Refraction Seismic

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Abstract

Refraction seismic method is a common seismic method for geotechnical investigations. This method is a popular tool for bedrock depth measurement in construction projects such as highways, bridges, skyscrapers building etc. This methods uses geophone as receiver to record the travel time of incoming refraction waves from a known source. Usually P-waves are the main signal of this method due to its higher velocity compared to the S-waves. But, in practice, it is more useful to have S-waves as the main source. This research proposes a relatively low cost acquisition technique to get the S-waves refraction using a normal P-wave geophone with some modifications. A modified source is also used to produce the S-waves signal. A 3-component seismometer is also used as a validation tool to see whether the source-making method is able to produce the S-waves signal.

Keywords: Refraction seismic, S-waves, SH-waves, Acquisition, Low-cost technique.

Introduction

Refraction seismic method is one of the geophysical methods frequently used in geotechnical investigations. This method usually uses P wave signal as the main data. P waves which have higher velocity than the S waves are the first signal detected by the receiver in the refraction seismic method. This arrival termed first break is then used to determine the seismic velocity of the subsurface layers. The seismic velocity gathered from this method is the P wave velocity or Vp.

In applications however, it is more beneficial to have the S-wave velocity (Vs) data. Franklin (1979) stated that the S-wave velocity data is needed as the input to assess seismic structure like skyscrapers, bridges, and dams. Sukanta & Prakoso (2010) further stated that when an earthquake occurs, S wave of the earthquake will interact with the free surface and producing the Love Waves. This type of surface waves is one of the most destructive waves. Prakoso et al. (2011) also stated that sites that have low S-wave velocity are prone to experience higher earthquake amplification.

Based on the reasons mentioned before, it is clear that S-wave velocity hold a very important role in geotechnical assessment. There are a number of new methods available to derive the S-wave velocity like MASW method, SPAC and other surface waves-based method. But, those method basically is not a direct measurement as the Vs is derived from the inversion of surface waves dispersion curve. A direct method which employs the S waves is preferred. The problem is: not all equipment is capable of doing the S-wave measurement readily. A whole new set of sensors may need to be bought to be able to do an S-wave refraction survey. This research will try to give a low-cost solution to this problem. In this research, a set of regular P-wave refraction seismic equipment is modified to be able to detect the SH-waves.

Data and Method

This research can be divided into a number of steps: source design, geophone modification, testing, and data analysis. The design of the S-wave source in this research is based on the S-wave source previously used by Franklin (1979). The source is a wooden block with cleat mounted on one side to produce coupling between the wooden block and ground surface. The source design was adapted because it is relatively low-cost and easy to carry. It was made using a wooden block sized 15cm x 15cm wide and 50cm long. 4 pieces of L-shaped iron bars the mounted on a side of the wooden block. These 4 pieces of L-shaped bars acted as the cleats to keep the block from sliding when it is placed on the ground. The cleats also providing coupling as the block will be struck by a hammer from sideways.

The next step is the modification of geophones. In this research standard vertical GS-11D geophones were used. The geophones were then modified to be used as S-waves receivers. To detect S-waves with horizontal displacement, the vertical geophones must be placed horizontally. The procedure was achieved by mounting each geophone to an L-shaped iron bars. The geophone “needle” was removed and moved to the bottom part of the L-shaped bars. GS-11D is a geophone which uses an electromagnetic rotating coil system (Geospace, 2012) so it is assumed that this geophone can still detect the horizontal movement of the ground when it is placed horizontally.

The testing step was done using a similar procedure to a regular P-wave refraction seismic survey. For the test, a DoReMi Seismograph unit was used as the data logger. End-on spread geometry was used in the test. The source was placed in front of an array of receivers. 24 geophones were used in the test. Figure 1 shows the illustration of the test.

To test if the geophone is capable to detect the horizontal ground motion produced by the source, the source was struck twice from different angle. The second and first strike have a 180 degree angle difference. This test can also be used to see if the source really produces the desired ground motion.

As comparison, a 3-component Lennartz LE-3D/20s seismometer was also used to record the ground motion. This seismometer was connected to a data logger with a 300Hz sampling rate for each component. The seismometer was placed inline with the receiver array so it can detect the ground motion traveling through the refraction seismic array.

Result and Discussion

The test was conducted in 3 different locations: 1. The Grha Sabha Pramana Field; 2. Pancasila Sports Complex of Universitas Gadjah Mada; and 3. Srimartani, Piyungan, Bantul. Location 1 has a relatively medium to hard soil with sand at the top. Some of the area were covered by grass. The weather are relatively windy when the test was conducted which resulted in high frequency noise included in the data. In this first location, the angle of hammer strike to the source seems to change the polarity but because of the noise the data may be distorted. The relatively hard soil made the cleat did not penetrate the soil properly, this may result in poor coupling so the energy from the hammer strike did not transferred fully to the ground.

At the second site, the soil is a weathered bedrock of sandstone and volcanic tuffs. The soil is very shallow and to gain a good coupling between the source and the ground, a narrow pit was made in the place where the cleats were to be placed. This made the source relatively steady when the hammer struck. The result of different angle strikes produce a couple of seismic data which shows reverse polarity to another. This may indicate the S-waves but when compared to the P-wave it shows a very little difference in arrival time. This is maybe due to the thin weathering layer over a hard bedrock.

At the third site where the soil was relatively soft the result is better. The resulted trace from the different hammer strike angle shows reversed polarity. When compared to the regular P wave refraction data, the arrival time of the recorded signal from the tilted geophone shows a slight delay. This delay may indicates that the signal is dominated by the S-waves. The result of this site test can be seen on Figure 2.

Conclusions

The result shows that the seismic source made in this research can produce the horizontal ground motion. The modified geophone can detect the horizontal ground motion produced by the source, but a good coupling is needed. The source needed to be modified so that a good coupling can be achieved.

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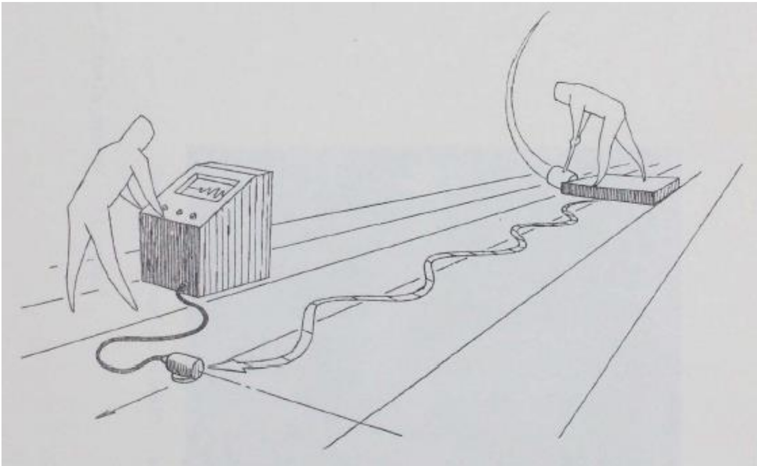

Figure 1: 1Illustration of the S-wave refraction survey (Franklin, 1979)

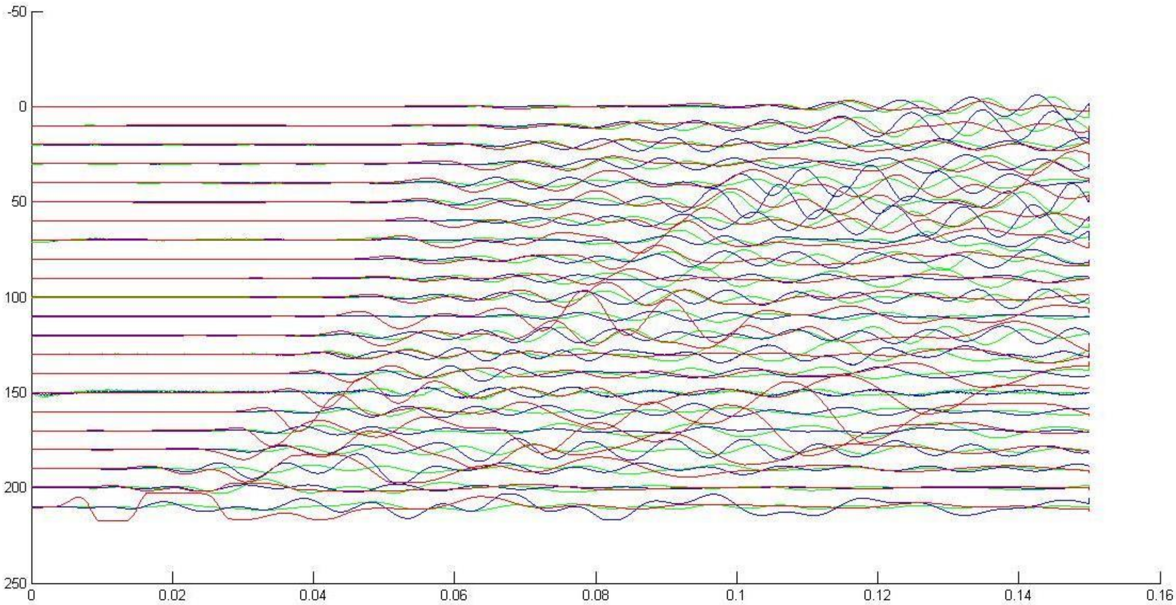

Figure 2: The data from test site 3. Red lines are the seismic trace from the P-wave refraction, green lines are the result of hammer strike at the right side of the source, and blue lines are the trace from the hammer strike at the left side