Barren Acidic Soil Assessment using Seismic Refraction Survey

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Abstract. Seismic refraction method is one of the geophysics subsurface exploration techniques used to determine subsurface profile characteristics. From past experience, seismic refraction method is commonly used to detect soil layers, overburden, bedrock, etc. However, the application of this method on barren geomaterials remains limited due to several reasons. Hence, this study was performed to evaluate the subsurface profile characteristics of barren acidic soil located in Ayer Hitam, Batu Pahat, Johor using seismic refraction survey. The seismic refraction survey was conducted using ABEM Terraloc MK 8 (seismograph), a sledge hammer weighing 7 kg (source) and 24 units of 10 Hz geophones (receiver). Seismic data processing was performed using OPTIM software which consists of SeisOpt@picker (picking the first arrival and seismic configureuration data input) and SeisOpt@2D (generating 2D image of barren acidic soil based on seismic velocity (primary velocity, Vp) distribution). It was found that the barren acidic soil profile consists of three layers representing residual soil (Vp= 200-400 m/s) at 0-2 m, highly to completely weathered soil (Vp= 500-1800 m/s) at 3-8 m and shale (Vp= 2100-6200 m/s) at 9-20 m depth. Furthermore, result verification was successfully done through the correlation of seismic refraction data based on physical mapping and the geological map of the study area. Finally, it was found that the seismic refraction survey was applicable for subsurface profiling of barren acidic soil as it was very efficient in terms of time, cost, large data coverage and sustainable.

Keywords: Seismic refraction method, primary velocity, barren acidic soil, soft soil.

1. Introduction

Subsurface profiling is an important data for soil investigation which is required for each proposed construction. The seismic refraction method is often presented to engineering and environmental professionals as an inexpensive and easy method for civil engineering projects [1].

Seismic refraction investigates the subsurface by generating arrival time and offset distance information to determine the path and velocity of the elastic disturbance in the ground. The disturbance is created by shot, hammer, weight drop, or some other comparable method for putting impulsive energy into the ground.

Detectors are placed at regular intervals to measure the first arrival of the energy and time needed. The data are plotted in time versus distance graphs from which the velocities of the different layers and their depths can be calculated [2]. On the other hand, a body wave is a seismic wave that moves through the interior of the earth, as opposed to surface waves that travel near the earth's surface. P and S waves are body waves. Each type of wave shakes the ground in different ways [3].In addition, the seismic refraction method provides the velocity of compressional P-waves in subsurface materials. Although the P-wave velocity is a good indicator of the type of soil or rock, it is not a unique indicator [4].

The velocity of sound travelling through the sub-surface varies according to material composition and compaction. Seismic energy from a source at the surface transmits waves through soils. It will then undergo refraction at boundaries between different media and eventually return to the surface. Seismic refraction surveying makes use of this phenomenon to determine ground structure by observing the time taken for energy to travel through the subsurface [5].Therefore, the objective of this study is to determine the subsurface profile of barren acidic soil.

2. Methodology

This study was performed at Ayer Hitam, Batu Pahat, Johor. A single line of seismic refraction survey was performed using ABEM Terraloc MK8 equipment set as shown in Figure. 1. According to Figure. 2, Ayer Hitam is located at the Triassic zone (blue pale) which consists of interbedded sandstone, siltstone, shale and volcanic rock. The raw data obtained from the field measurement was analysed using OPTIM software which consist of SeisOpt@picker and SeisOpt@2D software package.

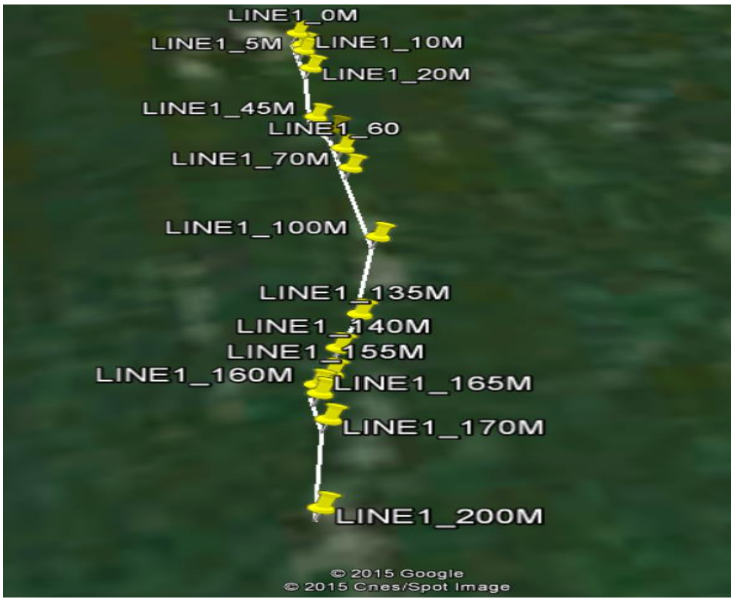

Figure 1. Spread line of seismic refraction survey.

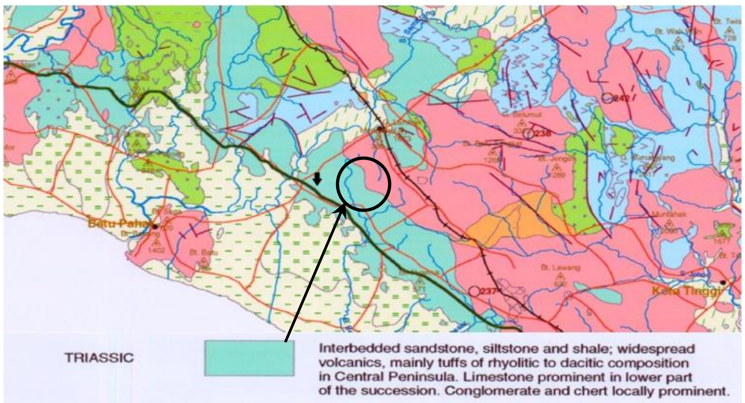

Figure 2. Geological map of the study area [6].

In the beginning, a site survey was conducted at the study area for data collection. The spread line location was determined prior to the data acquisition (field measurement). The seismic refraction survey was applied using a sledge hammer weighing 7 kg, hammering on a striker plate as a source. For receiver, a 24 channel vertical geophone was used based on 10 Hz of frequency. Meanwhile, ABEM Terraloc MK8 seismograph was used for field data recording. The spread line was arranged and the geophones were spaced at 5 m interval as given in Figure. 3. Seven shot points were performed along each profile representing five (in line) plus two (offset) of the shot point total number.

During the test setup, the geophone should be place at the best possible straight line alignment in order to obtain an optimum results during the data acquisition. Moreover, the geophones were placed on a clear area on top of ground surface due to the noise minimization purposes. The seismograph was placed at the centre of the spread line (G12 and G13) connected with both seismic land cables (cable 1 for G1-G12 & cable 2 for G13-G24). Seven shot point locations including two offsets was conducted at the interval of G1 and G2, G6 and G7, G12 and G13, G18 and G19, and G23 and G24 geophones as shown in Figure. 3.

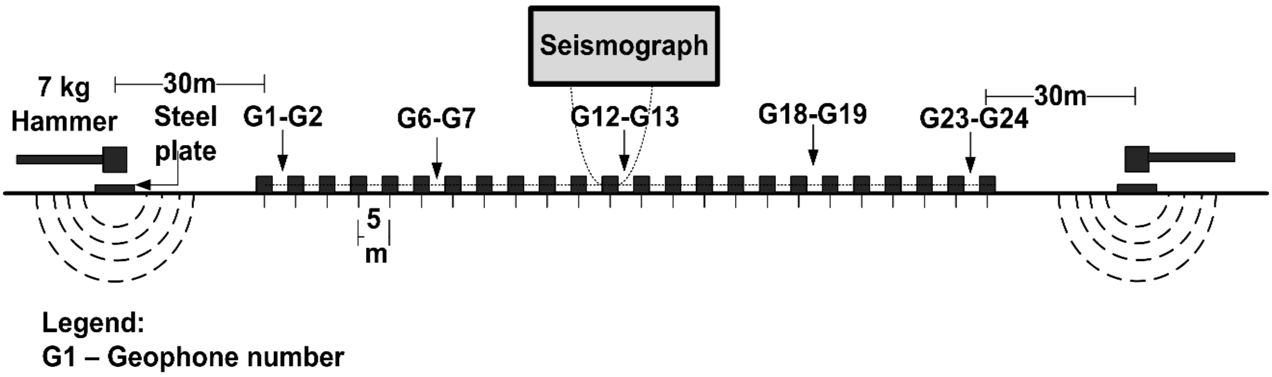

Figure 3. Seven seismic shot points along the spread line.

3. Results and Discussion

All results are presented in Figure. 4, Table 2, and 4 representing seismic refraction tomography, result summary of the seismic refraction survey and field density result. The seismic refraction tomography results that performed at the top of the barren soil profile was given in Figure. 4. Field observation regarding the seismic refraction survey performed at the barren soil outcrop was given in Figure. 5. It was found that this profile consist of three different range of primary velocity (Vp) representing three types of geomaterials with possible different characteristics as shown in Table 2. Those primary velocity (Vp) values in this study has been verified using Table 3 and was also supported by field observation, geological map (Figure. 1) and density results (Table 4 and 5). The core cutter method for the in-situ test was conducted specifically at the third layer and the result of field density test (core cutter) was given in Table 4. Consequently, the density value of common rock type was used for results verification as given in Table 5.

Based on the results obtained from Figure. 4, the first layer of the subsurface profile has the lowest primary velocity (Vp1: 200 – 400 m/s) which represents residual soil (Grade 6). The thickness of this layer was varied from 0 – 2 m from the ground surface. This weathering profile of Grade 6 was based on field observation which found that the original rock texture was completely destroyed together with the presence of vegetation. Furthermore, these velocities (Vp1: 200 – 400 m/s) were in good agreement according to ASTM [4] which stated that the residual soil has a lower velocity representing weathered rocks compared to the unweathered rocks. In addition, the lower primary velocity was also influenced by the stiffness of the geomaterials. The weathered fractured materials can disintegrate and decompose into fine grained materials such as mineral, sand, clay, silt, etc. The second layer of the subsurface profile has a primary velocity (Vp2: 500 – 1000 m/s) which represents highly to completely weathered soil (Grade 4-5). The thickness of this layer was approximately varied from 3 – 8 m. From the site observation, it was revealed that the soil is easily crushed by hand and the rock material plastic does not readily slake in water. It was found that the third layer from the spread line has the highest velocity (Vp3: 2100 – 6200 m/s) which represents slightly to moderately weathered shale (Grade 2-3). The thickness of this layer was approximately varied from 9 – 20 m. Based on site observation, it was found that the hammer blow gave a dull note and required more than one blow of the geological hammer to break the specimen.

Apart from the physical mapping, this study also performed a core cutter test in order to compare and correlate the geomaterials density results for verification purposes. As shown in Table 4, the average density for the third layer is 2.537 gcm^{-3} and is well within the range of density value for shale and sandstone as given in Table 5. Moreover, the interpretation result from seismic refraction regarding the third layer was also been supported by the existing geological map (see Figure. 1) which indicate that this area consist of sedimentary rock with particular reference to interbedded shale and sandstone. This result shows that seismic refraction is a good technique to be applied in geotechnical site investigation especially when the accessibility of site was complicated.

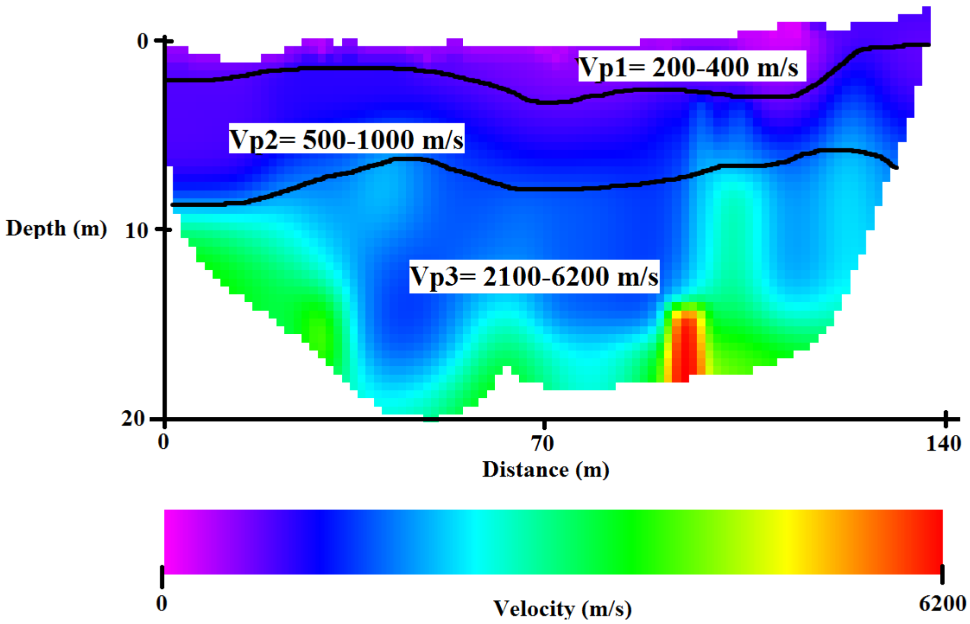

Figure 4. Seismic refraction tomography of the barren acidic soil.

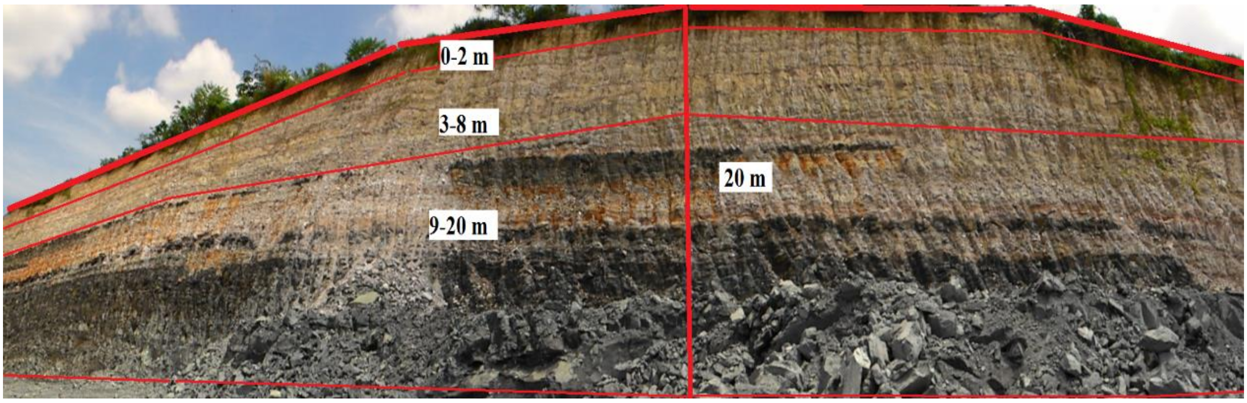

Figure 5. Seismic refraction survey performed at the barren soil outcrop.

Table 2. Result summary of seismic refraction survey.

Layer 1 (Vp1)	Layer 2 (Vp2)	Layer 3 (Vp3)	Primary velocity, Vp (m/s)	Thickness layer (m)
Residual Soil (Grade 6)	Highly to completely weathered (Grade 4-5)	Slightly to moderate weathered shale (Grade 2-3)	Vp1: 200-400 Vp2: 500-1000 Vp3: 2100-6200	Vp1: 0-2 Vp2: 3-8 Vp3: 9-20

Table 3. Primary velocity (Vp) of geomaterials [4].

Materials Natural Soil and Rock	Primary velocity, Vp (m/s)
Weathered surface material	240-610
Gravel or dry sand	460-915
Soil	100-500
Sand (dry, loose)	200-2000
Sand (saturated)	1220-1830
Shale	2000-3500
Clay (saturated)	915-2750
Water1	1430-1665
Sea water1	1460-1525
Sandstone	1830-3960
Limestone	2134-6100
Granite	4575-5800
Metamorphic rock	3050-7000

Table 4. Field density test.

Average moisture content , wave	21.7	22.2	18.8	18.4
Density, gcm^{-3}	2.427	2.618	2.769	2.843
Average density, gcm^{-3}	2.66			

Table 5. Density of common rock type [10]

Type	Rhyolite	Rock salt	Sandstone	Shale	Slate
Density, gcm^{-3}	2.4-2.6	2.5-2.6	2.2-2.8	2.4-2.8	2.7-2.8

4. Conclusion

The seismic refraction survey is a good technique to determine an overview of the whole subsurface profile with particular reference to soil profiling and characterization. Geophysical methods are useful in determining a variety of physical properties of soil and rock. The subsurface profile of barren acidic soil was successfully investigated using 2D seismic refraction tomography. The geometry and primary velocity distribution at localize outcrop in Ayer Hitam, Batu Pahat, Johor was determined by analyzing seismic refraction data obtained along the physical mapping and geological map of the study area which showed some good agreement. Hence, the objective of this study was successfully achieved based on results obtained. Finally, seismic refraction survey was applicable to be a good alternative method in shallow subsurface profiling due to its effective in terms of cost, time and quality provided that the technique is properly done by experienced and trained personnel.

Furthermore, this method used a surface method during the data acquisition which enable the preservation of site destruction thus contributing to our sustainable environment in construction industry.

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