PAPER

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Overburden determination for quarry prospecting using seismic refraction: a case study

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Abstract. Aggregate is one of quarry product that is widely used in constructions industry. This raw material that produced from the fresh rock under the earth surface is the most important materials in construction that come from quarry. In order to obtain the quality material of quarry product the overburden material on the top of the fresh rock should be removed. However before going to this production stage the amount of the quality material should be determined. Overburden removal is very important to help the quarry operator to identify the only area that will be actively used for extraction. This paper presents the technique used in determining the thickness of the overburden for quarry prospecting using a geophysical method called as seismic refraction method. The non-destructive technique of seismic refraction was applied in producing the subsurface profile of the potential quarry area. Based on the seismic image the layer of bedrock and the thickness of overburden to be removed was determined. Result from borehole drilling also showed that the lithology of borelog data matched to the seismic result, to proved that seismic refraction can be used as a method in identifying the depth of bedrock.

1.0 Introduction

Quarry is a place which rock, sand, gravel, dimension stone and construction aggregates are being produced and excavated from the ground. Quarry products are used daily for buildings, roads and railways construction. Overburden is a soil or rock layer by the weight of the overlying layer. In order to obtain quality quarry products the overburden on the top of the fresh rock should be removed. However the thickness and the volume of the overburden material for to removed should be determined before the quarry operation. It helps to identify the only area that will be actively used for extraction. Besides that, the quarry management can plan their operation wisely including transportation of the overburden, travel distance, numbers of suitable heavy machineries and rehabilitation process after extraction of the source is done. One of the method used to determine the amount of overburden of the quarry is by using geophysical survey. According to previous study, seismic reflection , electromagnetic and electrical resistivity have been used in mapping the bedrock[1-3]. Seismic refraction survey method is geophysical survey commonly used in exploration of groundwater, depth of water table, determine the depth of bedrock, determine the bedrock competency, mining, site investigation and engineering. This survey provides information to the geotechnical engineers related to the design process, resources management, or planning works. Seismic refraction survey is capable in providing detailed information on thickness of subsurface layer and subsurface materials based on characteristic of seismic velocities of materials. The information related to the overburden and bedrock can be determined by the images produced as the end final product of seismic refraction survey. Even though seismic refraction is widely used for underground exploration [4-7], research on the reliability of the overburden detection for quarry prospecting is still less. For the purpose of achieving this research objective, seismic refraction survey is used to determine the overburden thickness, which it is one of the famous geophysical surveys with adequate capability.

2.0 Site Location and Geological Setting

The study area is located at Gunung Bongsu, Kulim, Kedah (Figure 1). The highest peak of Gunung Bongsu is 658 meters. The site is a former palm plantation. In term of environmental effect, this area is suitable place for quarry due to its location is far from residential area where quarry activities may cause noise and air pollution due to sound of blasting and large amount of dust release to the surrounding area.

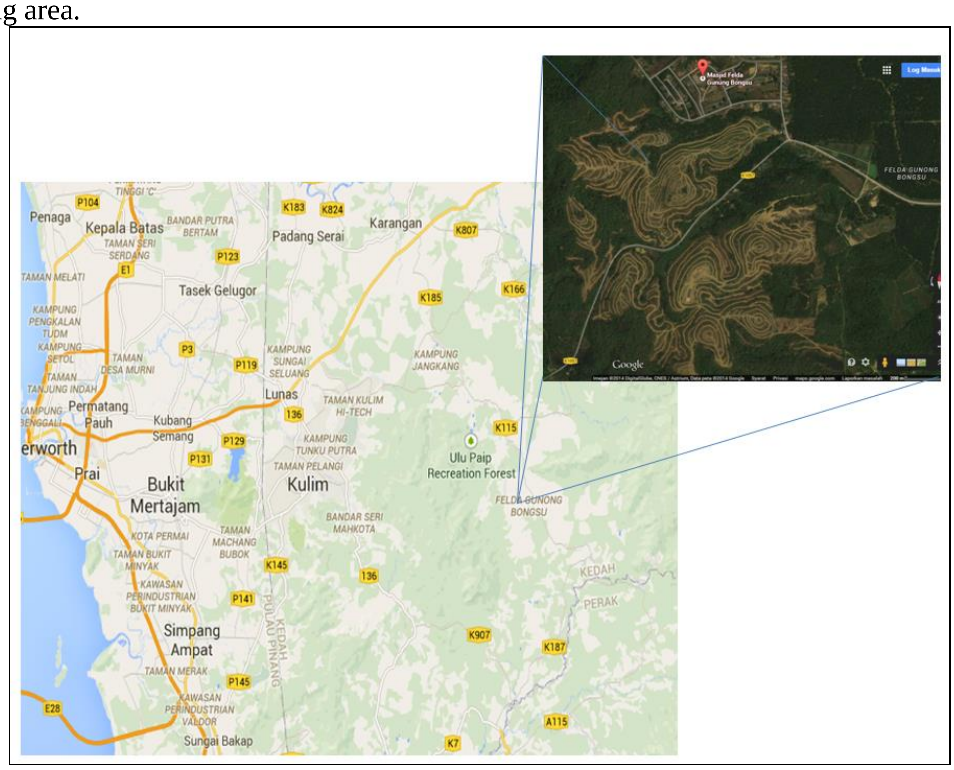

Figure 1. Study area at Gunung Bongsu, Kedah

Geologically the proposed quarry site area consists of S-Type granitoids which also known as S-type granite in the Western Belt of the Peninsular Main Range [8]. The Western belt granites is described by a huge mountain range widening from South of Malacca to the North of Thailand which the area covers more than 15000 km^2. Two main batholith masses can be differentiated in the Western Belt Granite where the small intrusive centers can be seen on the Bukit Mertajam- Kulim, Penang, and Langkawi complexes. In term of minerals and rock types, it covers 90% of the total western belt granite volume consist of coarse to very coarse grain megacrytic biotite muscovite granite. It manages to develop almost everywhere on the western belt area.

3.0 Methodology

3.1 Seismic Refraction Field Survey

To set up the seismic refraction measurement, a series of 24 geophones were placed along the proposed line with 5m interval between the geophones. The spread line was selected near to the existing borehole. The elevation of position of each geophone is recorded including the latitude and longitudinal. The seismic waves are induced using 12lbs sledge hammer and steel plate. The Seismic Terraloc equipment was placed at the middle of the lines as a main unit to collect seismic wave travel time and distance, and to record the wave propagation through the ground materials. Five shot points were identified along the line where the seismic waves need to be induced using hammer hitting on the steel plate. The first and the last offset, located 2.5 meters away from the first and last geophones. The second, third and fourth hit points were located between the fifth and sixth, at the centre of the line and between the eighteenth and nineteenth geophones accordingly. Figure 2 shows the setting of the seismic survey lines and location of the shot points. For best result, the study area should be free from any noises, sounds, or big movement on surface as it can cause disturbance on the seismograph data reading.

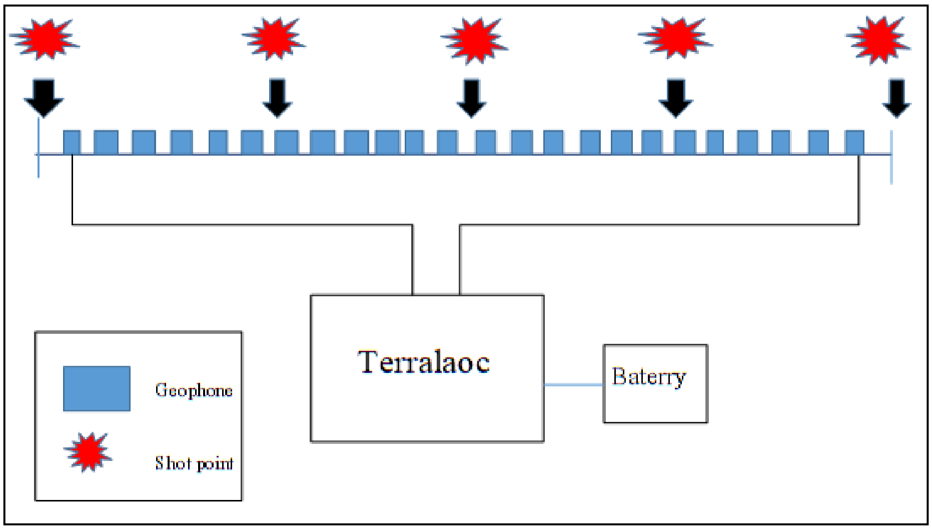

Figure 2. The setting of the seismic survey lines and location of the shot points

3.2 Seismic Data Processing

From the field work measurement, the results of five main data of seismograph reading were obtained. The data processed by using a software called Optim. This software is capable in providing accurate velocity analysis within laterally complex geology environments. There are two types of Optim software are going to be used which are SeisOptPicker and SeisOpt@2D. These two Optim software helped in converting the seismograph digital data into 2D subsurface image. The data was analysed by picking the first arrival of wave in the seismograph signal.

3.3 Borehole log

The borehole data was retrieved by third party by conducting the standard penetration test (SPT) as in Figure 3. One borehole was drilled at the centre of the 200 meters spread line. The SPT was conducted during the borehole drilling to measure the stiffness of the soil layers.

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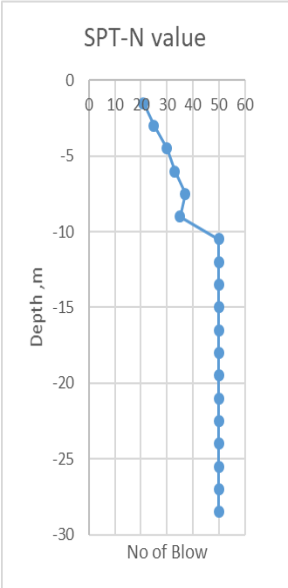

Figure 3. SPT-N value of the site from borehole

4.0 Results and discussions

4.1 Seismic refraction profile

The seismic refraction profile is a result that was produced after processing the collected data of time travelling via ground medium. It was calculated as seismic velocity of each ground layer. The seismic velocity of each ground layer is importance to provide information of ground stiffness. The wave generally travels faster in denser, wet, more consolidated materials compared to loose and weathered materials. The denser the material the higher the seismic velocity [9]. Figure 4 shows the result of seismic refraction under the seismic line (SL). Generally, the seismic velocity increases with increasing of the depth. From the figure, it can be interpreted that the seismic velocity at the shallower depth (Bluish colour) is lesser compared to the deeper depth (yellow to reddish colour).

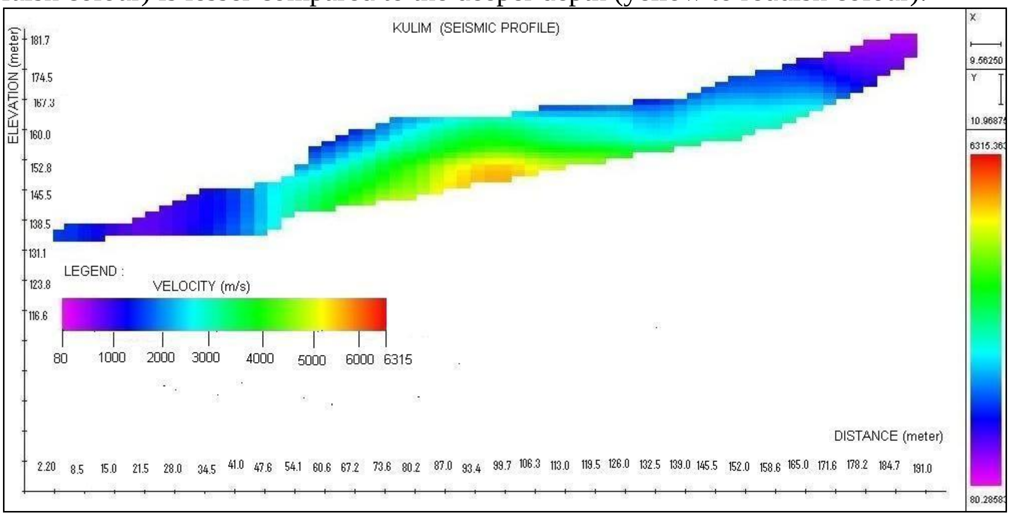

Figure 4. Subsurface profile under seismic line

4.2 Seismic Profile of Different Zones of Weathering

Seismic velocity varies in different types of ground material at different ground layers [10]. In this study the seismic profile displays layers that can be divided into various zonal which are Zone 1, Zone

2, Zone 3 and Zone 4 with different seismic velocity as shown in Figure 5. Zone 1 is a near ground surface layer named as layer 1 that has velocity of 2200 m/s with thickness approximately between 0m to 10m. Zone 2 has velocity about 3300m/s where the thickness of the layer is approximately 6m to 10m. Next, Zone 3 where the velocity of the layer is between s 3500 to 4200m/s with the thickness of the layer is about 6m thick. The velocity of Zone 4 is 6200m/s was found at the depth 12m from the surface. From this seismic profile and seismic velocity index [11] the fresh granite (average seismic velocity more than 5000 m/s) or bedrock could be found at the depth of 12m from ground surface. The velocity of weathered zones with depth is summarised in Table 1.

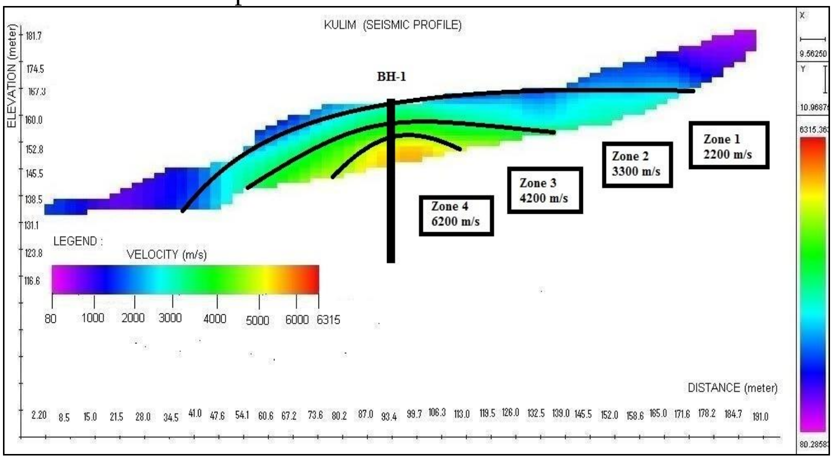

Figure 5. Seismic profile divided into four different zones

Table 1: Seismic velocity of granite weathered zones with depth

Weathering Zone	Depth (m)	Seismic Velocity (m/s)
1	0-10	2200
2	10-16	3300
3	16-22	4200
4	>22	6200

4.3 Correlation between Weathered Zones and Seismic Velocity with respect to depth

Table 2 shows correlation between weathered zones and seismic velocity with respect to depth. The seismic velocity of granite rock increased with the increase of the ground depth. It can be observed from the table at the 0m to 10m from the surface in weathered Zone 1 the seismic velocity is about 2200m/s. However, the seismic velocity is increased to 3300 m/s, 4200 m/s and 6200 m/s with respect to Zone 2, Zone 3 and Zone 4 when the seismic wave travel to deeper depth from 16m to more than 22m. This finding shows that the deeper is the granite the higher is the seismic velocity, therefore the Zone 4 that could be consist of fresh rock and the overburden that overlain the fresh rock could be determine.

4.4 Relationship between SPT-N value and Seismic Velocity

Figure 6 shows the results of SPT blows numbers at depth of the granite quarry area. As shown in Fig. 7, the seismic velocity increased with the increase of SPT-N value. The graph shows a significant relationship between SPT-N value and seismic velocity of granites rock mass as the R^2 value of the equation is 0.823. This relationship can be explained that the seismic velocity is depending on the stiffness of ground material. The loose material that considered as overburden has lower seismic velocity when compared to fresh rock at deeper depth.

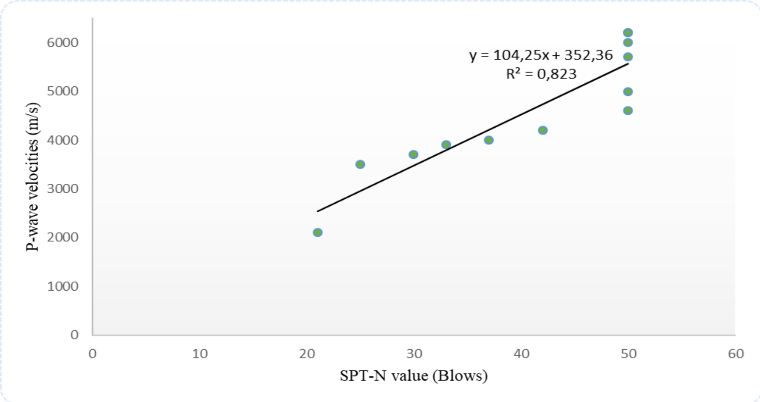

Figure 6. Relationship between SPT-N value and seismic velocity of granite

5.0 Conclusion

The depth of overburden that overlain the fresh granite which should be removed for high quality quarry product was determined in this study. Results showed that the use of seismic refraction method in investigating the depth of fresh granite resulted in good agreement with the SPT-N value as both methods showed that the good quality granite for quarry products could be found at the same depth.

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