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Surface Excavation Assessment in Non-bedded Rock Mass Based on Borehole Information and Seismic Survey

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Abstract

One of the most popular indirect methods for investigating the subsurface information is through borehole record. The information obtained from a bore log will provide the subsurface scenario with regard to the soil and rock mass profile, stiffness of the material, weathering grade and quality of the rock material. It is wise to obtain as much as possible useful information from it for any civil engineering design including its excavatability assessment. On the other hand, seismic velocity is also commonly used to describe subsurface information as it furnish actual profile of the subsurface along the survey line. Seismic survey is assumed to be relevant geophysical method to characterize the boundary of soil-rock. Although the field borehole information and seismic method has been widely applied in the ground investigation, their applicability in assessing excavation performance is still debatable, especially when it involves thick soil-rock interaction zone in tropical region. The objective of this study is to investigate the applicability of ground profile obtained from the field borehole information and the seismic survey in surface excavation works. Field studies were carried out ontwo on-going excavation sites namely Nilai and Kota Tinggi involving non-bedded -bedded rock masses, namely granite. This study aims to present the relationship between seismic refraction method and boreholes were to investigate their effectiveness in assessing the ground information for excavation purpose. A sets of boreholeswere drilled approximately on the same path of seismic linesto obtain relationship between those methods. The seismic survey results are evaluated with Standard Penetration Test (SPT), strength index, core recovery (CR) and Rock Quality Designation (RQD) information. Upon obtaining that information, trial excavation were carried out using different size of excavator machines to determine its productivity rate. This study provides useful information on the excavatability of ground materials by using various type of excavating machines, based on the most commonly used of ground investigation tools, which are boreholes and seismic velocity method.

Keywords: *Borehole, Ground Profile, Surface Excavation, Seismic Velocity and Weathering, Tropical*

1.0 Introduction

Boreholes and seismic survey are regarded as popular tools to investigate the subsurface characteristic for designing purposes. There are various geotechnical tests that could be carried out during borehole drilling, but commonly SPT N-value, core recovery and RQD information could be extracted from the bore logs. It will

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be a great benefit if such information could be translated to assess one of the civil engineering applications, such as the excavation work. On the other hand, seismic velocity method is used as an undisturbed testing during preliminary phase in understanding the ground profile. Both methods have their advantages and disadvantages. However, the challenge lies to gather the most effective and reliable results from those testing, which many practitioners are still struggling. Many Variations Order (VO) on earthworks were reported in this matter.

Subsurface material generally could be classified into soil and rock nature. These are made from natural processes which lead into complex characteristics in engineering perspective. In tropical region, the complexity become more severe as the weathered material is much thicker up to 200 m. In this situation, there are numerous issues affecting the subsurface excavatability such as rock mass characterization, machines and other factors (Edy Tonnizam *et al.*, 2017; Saptono, 2013). In general, rock mass properties such as weathering state, type of rock, seismic velocity and rock strength parameter influence excavation performance. Numerous researchers have studied the relation between borehole and seismic velocity in numerous rock nature, however, minimal studies have been carried out in the field of surface excavation. In addition, there are variants between those relations in the massive and bedded rock nature. There are also attempts being made to study the seismic velocity parameter and its relation to excavatability such as Caterpillar (2001). However, the relation is unclear for the non-bedded rock nature in the tropically weathered rock mass.

The weathering profile of rock masses in tropical weathered rock especially can be variable, unpredictable and can be predominant in controlling the behaviour of rock. There are several ground conditions such as weathering state and geological issues. Thus, various problems encountered related to various types of weathered rocks resulting in challenges and difficulties of carrying out surface excavation during earthworks on site.

Scoble and Muftuoglu (1984) suggested weathering, joints parameter and strength as the main parameters concerning sedimentary rock affecting excavation work. On the other hand, Pettifer and Fookes (1994) highlighted material properties, type of machinery used and methods as important criteria. The above researchers also recommended that rock strength can be derived by point load test. Again, they produced a comprehensive chart which is related to Franklin *et al*. (1971) proposal but their recommendation is also including the category of excavation methods to be used. McLean and Gribble (1985) predicted the relations between uniaxial compressive strength and Schmidt hammer hardness (rebound number) of intact rock and the rippability of rocks. Karpuz (1990) and Basarir and Karpuz (2004) recommended, to classify the rippability system for coal measures and marls that can be used in lignite minesbased on the seismic P-wave velocity, Schmidt hammer hardness, the average discontinuity spacing and the point load index or uniaxial compressive strength. Singh *et al.* (1987) has also introduced a rippability index for coal measures. In addition to the aboove statement, Church (1981) and Caterpillar (2001) are also used P-wave seisimic velocity as their parameter to introduce rippability charts.

According to Tsiambaos and Saroglou (2010), even though a variety of rock excavation method are available to determine the excavatability, none of the proposed method is universally accepted to assess the excavatability due to unvailability data of previous case studies with regard to difficulties in determine input parameters and suitability of geological profile. A proper classification system should be available (quantifiable data, easy to determine, user friendly) and updated information to follow suit latest technology of soil investigation.

Classification of rock mass is one of the important parameters to assess excavatability. Weaver's (1975) has introduced a rock mass classification is based on the RMR system (Bieniawski 1974). As for Kirsten (1982) proposal, the excavatability assessment shall take into consideration of rock mass characteristics such as mass strength, joint walls strength, relative to orientation of geological structure and block size. His proposal is based on engineering properties from the weakest soil condition to the hardest rock condition. Kirsten (1982) formulated the excavatability index (N) is determined by the use of suitable parameters based on Barton *et al.* (1974) Q system. Fowell and Johnson (1982), Smith (1986), MacGregor *et al.* (1994) and Hadjigeorgiou and Poulin (1998) have also developed.

Tsiambaos and Saroglou (2010) used Geological Strength Index as an attempt to investigate the excavatability of rock mass. Relatively, the intact rock strength was taken into consideration and the discontinuity sets and fracture spacing (controlling the size of rock blocks) were evaluated. The proposed classification is an advantage for rock mass excavatability assessment. The rock mass type is the most influencing factor in the assessment of the excavation method, as it is most related to the numerous of discontinuities of the rock mass profile.

Physical and mechanical properties of the hard mass and rock mass play an important role in the productivity and methods of excavation to be chosen. The consideration is always aimed to achieve optimum productivity and reasonable cost. It is always acceptable to achieve decision when it deals with solid rock mass or normal soil. As reported by Siti Norsalkini (2019), arguments on the cost and best excavation method always arise when it deals with hard mass. Hard mass is a general term to describe soil-rock or rock-soil alike materials which are not quantitatively described in tender documents.

Homogeneous and non-bedded rock mass is more predictable especially in moderately to fresh zone. In this zone, the intact joint behaviour and high strength material governed the excavatability. However, the weathering effect that weaken the interlocking behaviour in highly and completely weathered zone create a more complex set of significant parameters for the excavation purpose. Liang *et al.* (2016) highlighted this issue in the sedimentary or bedded rock masses. JKR (2005) defined hard material as the material that could not be excavated using track excavator with the mass of 44 tan and 321 BHP. This material could be found in the completely to highly weathered zones. The confusion to choose whether to excavate by a normal excavator machine, ripper machine or even blasting method always arise in this unique zone.

Studies were carried out at Nilai and Kota Tinggion the actual excavation trials in the attempt to understand this issue. Those sites represent non-bedded rock masses. Bore logs will be analyzed together with seismic velocity results to investigate the relevant parameters to be best used as an excavation assessment tools.

2.0 Site Description and Geological Background

The sites selected in this study are Nilai and Kota Tinggi. All sites are categorized as granitic which could be identified and verified from the exposed outcrop and the rock material character. The bore logs and the ongoing drilling works also provide the information required for the non-bedded rock mass classification. One of the main criteria for the site selection is the site could be easily assessed and ongoing earthwork activities are being carried out. This would allow the excavation performance test to be carried out easier using the available machines at site. Brief of the site geology is described in the following section:

The geology of Nilai, Negeri Sembilan composed of the intrusion of Main Range Granite. Based on Liew and Page (1985), the intrusive age of the plutons of the Main Range Granite indicated by U-Pb zircon data is 198–220 Ma and included into Late Triassic to Early Jurassic. The granite is identified as a medium to coarse-grained biotite-muscovite granite. The NW-SE structural grain of Peninsular Malaysia includes prominent faults, commonly filled by major. The major fault found on this site are one of the series of from The Klang Gates Quartz Ridge. The Klang Gates Quartz Ridge is a 14 km long quartz dyke and it was believed as the longest quartz ridge in the world. The quartz dyke is composed of pure quartz and formed when residual magma crystallized. The intrusion of quartz vein is repeated many times in geological history (Gobbett, 1964; Tjia, 1984). The dyke was exposed as the surrounding granite material weathered away revealing massive milky quartz.

Kota Tinggi, Johor consists of primarily forests, very rugged topography and is situated at high land up to approximately 185 m. The geology of the region is of Jurassic-Cretaceous, Permian and Permian-Jurassic age. The Jurassic-Cretaceous was composed of thick continental deposits, cross-bedded sandstone with subordinate conglomerate and shale or mudstone. The volcanic rocks were also present locally. During Permian age, the region consists of phyllite, slate and shale with subordinate sandstone and schist. The evolution of limestone through the succession was distinguished. The volcanic rocks also occured during Permian which were rhyolitic to andesitic. As for Permian-Jurassic age, the period comprised the intrusive rocks which were mainly granite with minor granodiorite (JMG, 1985).

3.0 Field Works

Borehole exploration were conducted along seismic line to construct the relationship. At Nilai site, the boreholes had been completed by the previous contractor and the recorded borelogs were used for this study. Meanwhile, for the seismic survey, actual exploration works were carried out for Kota Tinggi site while for Nilai site, the results were furnished by the contractor. At Nilai site, there were three boreholes and two seismic lines, whereas, at Kota Tinggi site, two boreholes and five seismic lines were provided.

Subsequently, samples were collected and being tested to obtain the strength parameter. Furthermore, on site excavation trial were carried out using two types of

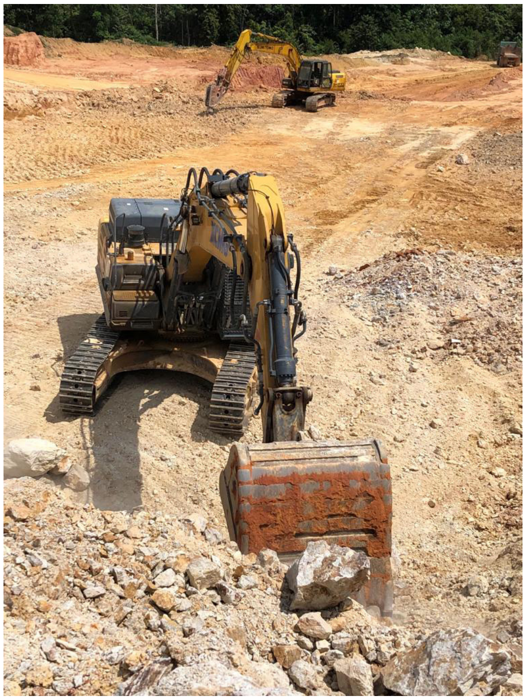

Figure 1. Excavation trial at the studied site.

excavator namely EX200 and EX300 and were monitored for its excavating performance and productivity. In this study, the number of buckets per hour were observed using EX200 and EX300 excavator machines. The excavation rate was evaluated in order to correlate with SPT, RQD, CR and strength index.

4.0 Methodology

4.1 Borehole Exploration

Boreholes are regarded as popular tools to understand the subsurface characteristic. There are various geotechnical tests could be carried out during borehole drilling, but commonly SPT N-Value, core recovery and RQD information could be extracted from the borehole. Borehole explorations are conducted at the sites depending on the availability and ongoing excavation works. Also, its data give an extensive information with regard to type of soil in rock, stiffness of material, weathering grade and quality of rock mass. As ground exploration tools that are widely used, borehole method provides standard parameters that should be translated and interpreted well for all kind of civil application design, including excavation work.

Figure 2. Overview of Nilai site.

Figure 3. The location of boreholes at Nilai site.

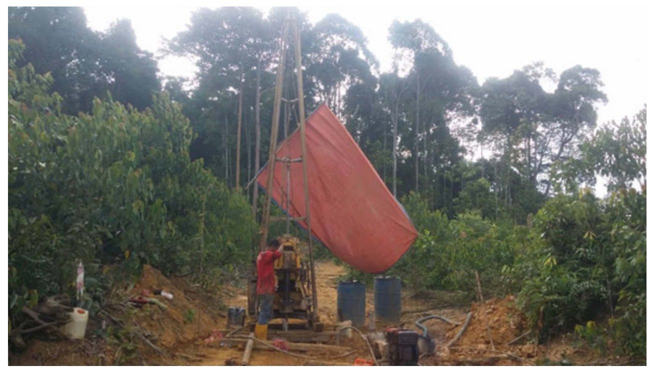

Figure 4. Overview of Kota Tinggi site.

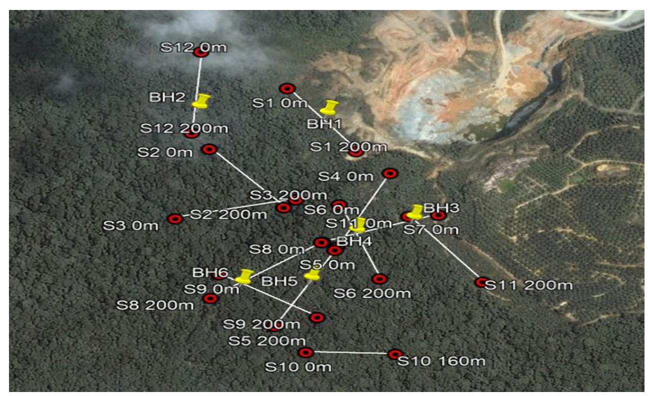

Figure 5. The location of boreholes at Kota Tinggi site.

4.2 Seismic Survey

The fundamentals of seismic method are the implementations of equipment include energy source, detector and recorder. In seismic refraction survey, seisgun with eight to twelve palette bullet and sledgehammer with 16 lbs weight were employed as energy sources. Metal striker plates were used to transfer the energy that attained from sledgehammer. Seismograph ABEM Terraloc MK6 that powered by 12 V external battery are used as recording the seismic waves. Trigger cable are used to connect seismograph to the energy sources.

Raw data from seismic refraction survey on the site is filtered by IX Refract Interpex Seismic Refraction software. The data processing started with the removal of direct DC for noise reduction. SeisOptPicker 1.5 software was operated to pick the first arrival time of P-waves travel. There is limitation for this step due to confusion in determining the first arrival. Next, the corrected data is imported to SeisOpt2D to develop 2D profile of seismic refraction. Last step, the processed data was imported to Surfer9 software for detailed interpretation and understanding.

5.0 Results and Discussion

5.1 Nilai Site

Table 1 presents the results of field and laboratory works of the Nilai site. There are various geotechnical tests which have been carried out upon obtaining borehole record and seismic velocity result, such as material strength test, SPT N-value, CR and RQD information. Also, excavation trial being conducted and the productivity rate were recorded as below.

Rock mass from BH 1 of Nilai site is covered with sandy silt from 0 m to 13.9 m with no value of core recovery and RQD, while the N-value is increased from 8 to 29. Highly weathered granite was distinguished from the depth of 13.9 m to 19.9 m, whereas no N-value whenever the core recovery is ranging from 50% to 97% and the RQD value are ranging from 40% to 60%.

Table 1. Summary of Nilai Site Measurement

Borehole	Depth (m)	Material	Borehole			Laboratory Test	Seismic Velocity (m/s)	Excavation Rate (m^3/h)
			SPT	CR	RQD	PLT (MPa)		
BH1	1.5	Sandy Silt	8	0	0	0	200-250	60
	3	Sandy Silt	9	0	0	0	250-300	60
	4.5	Sandy Silt	10	0	0	0	350-400	60
	6	Sandy Silt	16	0	0	0	350-400	60
	7.5	Sandy Silt	18	0	0	0	400-500	60
	9	Sandy Silt	27	0	0	0	400-500	50
	10.5	Sandy Silt	29	0	0	0	400-500	50
	12	Sandy Silt	28	0	0	0	400-500	50
	13.5	Sandy Silt	24	0	0	0	400-500	50
	13.8	Sandy Silt	26	0	0	0	400-500	50
	13.9	Highly weathered granite	0	50	40	2.15	450-500	10
	15.4	Highly weathered granite	0	75	43	1.36	500-550	10
	16.9	Highly weathered granite	0	80	60	0.95	550-600	0
	18.4	Highly weathered granite	0	90	33	0.25	600	0

Borehole	Depth (m)	Material	Borehole			Laboratory Test	Seismic Velocity (m/s)	Excavation Rate (m^3/h)
	19.9	Highly weathered granite	0	97	33	0.35	600	30
BH2	1.5	Gravelly sand	5	97	50	0	400-450	50
	3	Gravelly sand	6	76	50	0	450-500	50
	4.5	Sandy Silt	14	0	45	0	450-550	60
	6	Sandy Silt	16	0	45	0	450-550	60
	7.5	Sandy Silt	18	0	46	0	450-550	60
	9	Sandy Silt	21	0	40	0	450-550	60
	10.5	Sandy Silt	23	0	40	0	450-550	60
	12	Sandy Silt	18	0	45	0	600	60
	13.5	Sandy Silt	22	0	30	0	600	60
	15	Sandy Silt	29	0	20	0	600	60
	16.5	Sandy Silt	50	0	0	0	600	60
	18	Sandy Silt	50	0	0	0	600	60
	18.1	Sandy Silt	0	0	50	0	600	60
BH3	1.5	Sandy Silt	9	0	0	0	400-450	50
	3	Sandy Silt	10	0	0	0	450-500	50
	4.5	Sandy Silt	12	0	0	0	450-550	50
	6	Sandy Silt	13	0	0	0	450-550	50
	7.5	Sandy Silt	15	0	0	0	450-550	50
	9	Silty Sand	38	0	0	0	450-550	50
	10.4	Highly weathered granite	20	80	13	2.15	600	20
	11.9	Highly weathered granite	24	70	9	1.36	600	20
	13.4	Highly weathered granite	45	40	9	0.56	600	30
	14.9	Highly weathered granite	46	50	9	0.36	600	30
	16.4	Highly weathered granite	47	93	0	0.26	600	30
	18.0	Highly weathered granite	48	100	0	0.25	600	30
CR: Core Recovery, RQD: Rock Quality Designation, PLT: Point Load Test								

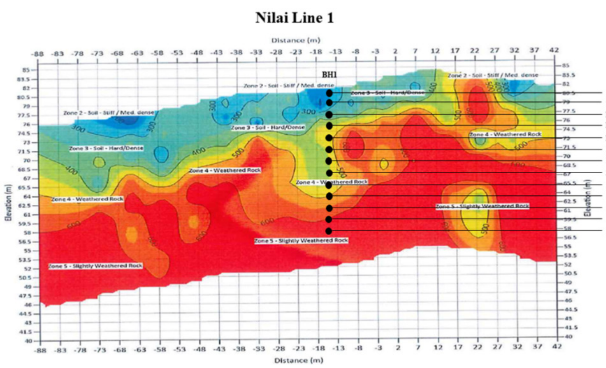

Figure 6. Seismic analysis of Line 1.

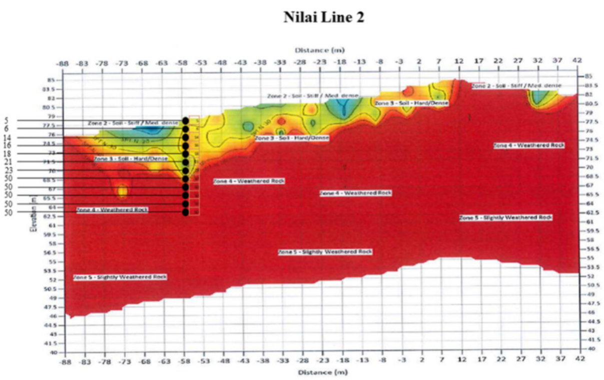

Figure 7. Seismic analysis of Line 2.

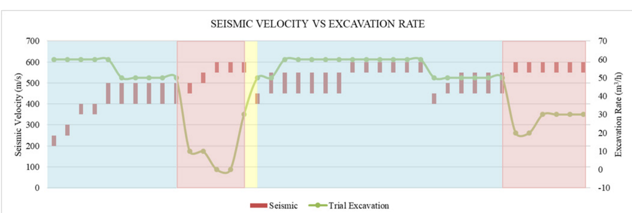

Figure 8. The relationship between seismic velocity and excavation rate at Nilai site.

As referred to the description of BH 2 of Nilai, the rock mass covered with gravelly material until 4.5 m depth from the ground with 5 to 6 N-value, core recovery is ranging from 76% to 97% and the RQD of 50%. The lithology from 4.5 m to 18.1 m are sandy silt. The average of N-value, core recovery and RQD at the depth 4.5 m until 18.1 m are 50, 86 and 46 respectively.

Again, the description of BH 3 of Nilai, the rock mass covered with sandy silt material from 0 m to 10.4 m. The N-value ranging from 9 to 38 and no value for core recovery and RQD. Highly weathered granite was recognized from the depth of 10.4 m to 18 m. However, the N-value are from 20 to 48. The trend of N-value increased along the depth. Core recovery of highly weathered granite ranging from 40% to 100%, while the RQD ranging from 0% to 13%.

Compressive strength of the collected samples and point load strength index are measured as it commonly refers as one of the criteria to evaluate of excavation performance as stated by Kramadibrata (1996) and Basarir and Karpuz (2004). Mode of failure was recorded, and the point load strength index results are tabulated in Table 1. Based on the point load strength index result, highly weathered granite is ranging from 0.25 MPa to 2.15 MPa.

As for Seismic Survey Line 1, the borehole recorded the upper layer of subsurface consists of sandy silt material. The seismic velocity of the material is suggested to be 200 m/s to 500 m/s with the depth of 0 m to 15.4 m. While the seismic velocity is 600 m/s to 800 m/s is for highly weathered granite with the depth of 15.4 m to 19.9 m.

As for Seismic Survey Line 2, the borehole recorded the layer of subsurface consists of sandy silt at upper layer and granite at the lower layer. The seismic velocity of sandy silt is suggested to be 450 m/s to 600 m/s with the depth of 0 m to 10.4 m while, the seismic velocity is more than 600 m/s is suggested to be highly weathered granite with the approximately depth is 18.0 m.

This study performed excavation assessment as the site is ongoing excavation works to the reduce level of the designed platform. The excavation performances were evaluated based on the panels divided by weathering grade by using scanline method. Generally, highly weathered material exhibits high production rate compared to slightly weathered material. The other factor influencing the higher production rate whenever the excavations are employed through horizontal beds. The sandy silt and gravelly sand material exhibit the highest excavation rate performance with 50 m^3/h. Based on the site observation, sandy silt and gravelly material are the description of residual soil of the granitic rock masses. The weathering process degraded the rock masses to soil form with loosen interaction between grains that ease the excavation. Excavation rate of highly weathered granite ranging from 0 m^3/h to 30 m^3/h.

Table 2. Summary of Kota Tinggi site measurement

Borehole	Depth (m)	Material	Borehole			Laboratory Test	Seismic Velocity (m/s)	Excavation Rate (m³/h)
			SPT	CR	RQD	PLT (MPa)		
BH1	0.3	Soil layer	0	0	0	0	500-800	50
	20	Soil layer	0	0	0	0	1000-1500	50
	24	Soil layer	0	0	0	0	1500-2000	50
	27.8	Soil layer	0	0	0	0	1500-2000	50
	28.4	Soil layer	0	0	0	0	1500-2000	50
	30	Boulder	50	100	100	4.45	4500-5000	0
	30.74	Soil layer	0	0	0	0	500-800	50
	39	Boulder	50	100	100	4.45	4500-5000	0
	40.11	Soil layer	0	0	0	0	500-800	50
	45.3	Boulder	50	100	100	4.45	4500-5000	0
	46.8	Granite	48	100	95	4.45	4500-5000	0
	48.3	Granite	49	100	96	4.45	4500-5000	0
BH2	0.3	Soil layer	0	0	0	0	500-800	50
	15	Soil layer	0	0	0	0	800-1000	50
	20	Soil layer	0	0	0	0	800-1000	50
	40	Soil layer	0	0	0	0	800-1000	50
	46.8	Soil layer	0	0	0	0	800-1000	50
	48.3	Granite	45	100	87	4.45	4500-5000	0
	49.8	Granite	40	100	83	4.45	4500-5000	10
CR: Core Recovery, RQD: Rock Quality Designation, PLT: Point Load Test								

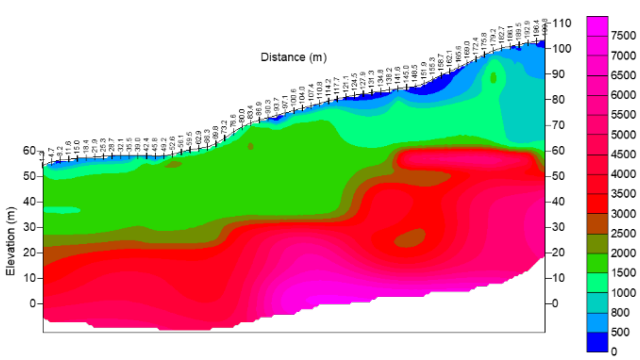

Figure 9. Seismic analysis of Line 1.

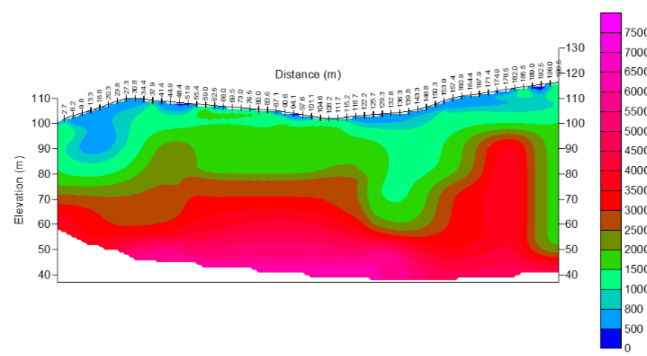

Figure 11. Seismic analysis of Line 3.

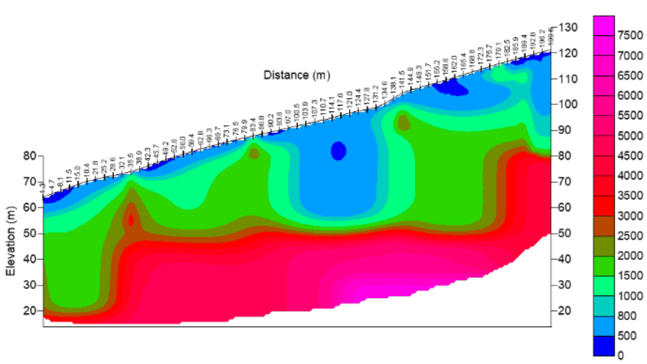

Figure 10. Seismic analysis of Line 2.

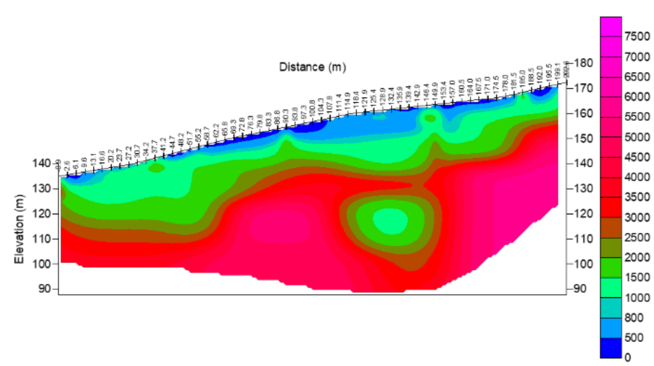

Figure 12. Seismic analysis of Line 4.

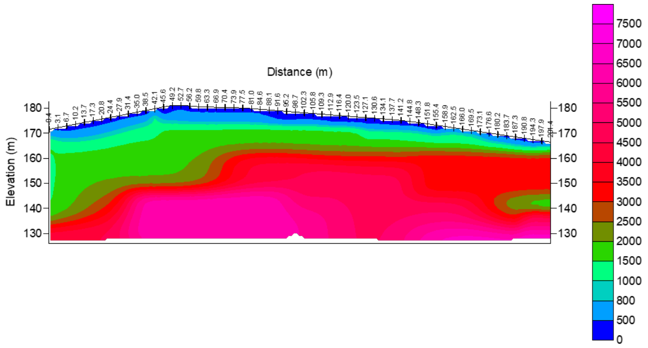

Figure 13. Seismic analysis of Line 5.

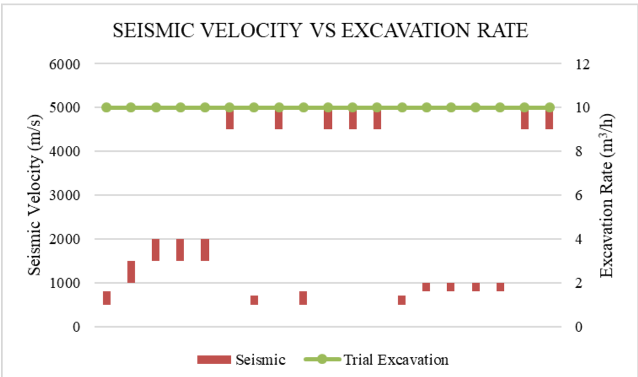

Figure 14. The relationship between seismic velocity and excavation rate at Kota Tinggi site.

5.2 Kota TinggiSite

Table 2 presents the results of field and laboratory works of the Kota Tinggi site. There are various geotechnical tests that have been carried out upon obtaining borehole record and seismic velocity result, such as material strength test, SPT N-value, CR and RQD information. Also, excavation trial being conducted and the productivity rate were recorded as below.

As referred to the description of BH 1 of Kota Tinggi site, the upper layer of subsurface are covered with soil layer from 0 m to 40.11 m. There are encountered boulders in between the soil layers at the depth of 30 m and 40.11 m. The lithology of BH 1 continued with granite from 46.80 m to 48.30 m. There is no RQD value of soil material and the RQD for boulders is 100, while the RQD of granite is ranging from 95 to 96. Subsequently, the N value of soil materials and boulders are 0 and 50 respectively, and N value of granites are ranging from 48 to 49. The value of core recovery for soil layer materials are 0, while value for boulders and granites are 100.

The lithology of BH2 in Kota Tinggi site is the same as BH1, where by most of the rock masses are covered with soil layers and granite. The depth for soil layers is from 0 m to 48.30 m, while granite rock appeared from 48.30 to 49.80 m. Unfortunately, there are no RQD, N-value and core recovery value for soil materials, however, as for granite, the RQD value is ranging from 83 to 87, N-value ranging from 40 to 45 and core recovery value between 40 to 45.

Compressive strength of the collected samples and point load strength index is measured as it commonly refers as one of the criteria to evaluate of excavation performance as stated by Kramadibrata (1996) and Basarir and Karpuz (2004). Mode of failure was recorded, and the point load strength index results are tabulated in Table 1. Based on the point load strength index result, the boulder exhibits 4.45 MPa, while granite exhibits the point load strength index between 4.45 MPa to 4.78 MPa.

As for Seismic Survey Line 1, the seismic velocity value ranging from 500 m/s to 2000 m/s is interpreted as soil layer which located between 0 m to 30 m. At the depth between 30 m to 65 m, the material has velocity of 3000 m/s to 7500 m/s, which represented by the granite.

As for Seismic Line 2, the velocity of 450 m/s to 2500 m/s is suggested to be soil layer which extends to a depth of 50 m from the surface. For velocity range of 3000 m/s to 6500 m/s at depth greater than 50 m, it is represented by the granitic rock.

In Seismic Line 3, the borehole consists of soil layer and granite. The soil layer is located at the depth up to 55 m from surface and exhibits velocity between 800 m/s to 2000 m/s. The granite situated at the depth between 40 m to 70 m with velocity between 3000 m/s to 6500 m/s.

Based on the analysis of Seismic Line 4, the borehole also consists both soil layer and granite. The soil layer has velocity between 800 m/s to 2500 m/s with depth between 0 m to 30 m. The velocity of 2500 m/s to 5500 m/s, it is interpreted as granite which located at depth higher than 30 m.

From Seismic Line 5, the velocity of soil layer ranges from 400 m/s to 2000 m/s at depth between 0 m to 20 m. As for the granite, it has velocity of 3000 m/s to 7500 m/s which situated at depth between 20 m to 40 m.

Based on the excavation trial that has been carried out, soil layer exhibits the greatest excavation rate which is 50 m^3/h. Meanwhile, the granite has excavation rate ranging from 0 m^3/h to 10 m^3/h. The excavation rate is high within the soil layer due to the loose interaction between grains which leads to the excavation process to become easier.

6.0 Conclusions

Numerous efforts have been made to evaluate the excavatability of rock. This study used seismic velocity and boreholes to improve rock mass classification and rock mass characterization. The parameters such as SPT, RQD, CR and strength index would take into considerations and the results were analyzed.

At Nilai site, the sandy silt has N-value between 5 to 50 and the highly weathered granite has N-value of 0 to 48. The sandy silt has no recovery value, meanwhile, the highly weathered granite exhibits core recovery value between 40 and 97. The range of RQD value for sandy silt is 0 to 50 and the highly weathered granite has RQD value between 0 to 60. The excavation rate of the sandy silt are ranging from 50-60m^3/h whenever seismic velocity are ranging from 200-600m/s however, further down formation the materials consist of hightly weathered granite it excavation rate are ranging from 20-30m^3/h whenever seismic velocity are ranging from 450-600m/s.At Kota tinggi site, the soil material has no N-value, SPT and core recovery value. The granite has N-value between 46.8 to 49.8, core recovery of 100 and RQD between 83 to 96. The boulder which is present in the borehole has N-value of 50, core recovery of 100 and RQD of 100. The soil (loose material) has an excavation rate of approximately 50 m^3/h whenever seismic velocity are ranging from 500-2000m/showever, further down formation, the materials consist of granite its excavation rate is approximately at 10m^3/h whenever seismic velocity are ranging from 4500-5000m/s.

Furthermore, whenever loose materials encounter at site, excavation work becomes easier and productivity rate is higher and it is vice versa to the hard rock material. The other factor influencing the excavatability is excavator/machine performance whereby the higher is performance of the machine, the higher will be the productivity rate. Thus, it will reduce the time and cost to the project. Implementation of borehole and seismic survey record on site are informative with regard to the characteristic of soil and rock mass classification. The geotechnical engineer then could make a proper planning in preparation of tender/contract documentation to avoid any disputes or delays to the contract. Time and cost are the major influencing factors and crucial in order to deliver the project in timely manner.

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