Excavation Assessment on Granitic Area at Ulu Kinta, Perak, Malaysia for an Earthwork Project

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Abstract Surface excavation work in tropically weathered rocks is challenging due to many uncertainties such as rock mass and material properties, environment, selection of best excavation method, machine characteristics, cost and production rate. The weathering profile of rock mass in the tropical region can be variable, unpredictable, and dominant in controlling rock behavior. Issues in confirmation on hard mass and rock mass in the surface excavation are discussed in this paper mainly in terms of definition and its relation to Jabatan Kerja Raya (JKR) Standard Specification Sect. 2:Earthwork, as essential references for practitioners related to surface excavation. It is crucial to ensure a reliable assessment on the most critical factors to reduce costs and unnecessary time delays. The study area is Ulu Kinta, Perak which is underlaid by granitic. This site was selected for this study because of the ongoing earthworks and exposure to rock outcrops. This study involved two geophysical methods, namely the 2D-Resistivity Method and Seismic velocity. Geophysical methods are beneficial for determining bedrock, type, and estimation of the volume of rock to be excavated for the areas, especially in the early stages of earthwork. The condition of the site consists of various grades where Grade I and Grade II granite was found at a depth of 33 m from the ground surface. Based on the correlation between borehole and seismic refraction, the overburden layer is dominated by low velocity values (<800 m/s) that correspond to low N values. This study also investigated the effect of moisture content on various grades of weathered granites, focusing on strength. It was found that moisture significantly affects weaker materials such as Grade IV and V was than stronger materials (Grade I and II). The trial excavation is carried out based on one type of excavator (EX 300); thus, confirmation can only be made to determine the hard mass for this area. The drilling method correlated well with the borehole result and proposed an alternative method in determining the hard

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and rock mass. Rock mass properties should be considered in the assessment, play a significant role in influenced excavatability and avoid problems that arise during excavation work.

Keywords Granite · Surface excavation · Drilling method · Geophysical methods · Trial excavation · Hard mass · Rock mass

1 Introduction

Reliable excavation assessment may significantly help the entire excavation process, incorporating the choice and improvement of the required methods or equipment. Unfortunately, this issue causes confusion among the contractor and clients on the best method to excavate. Furthermore, the lack of detailed information on the rock mass, such as weathering states, rock mass, and material properties, can significantly impact the project's feasibility. Therefore, comprehensive and systematic geological, geotechnical and geophysical information is crucial to help practitioners assess the relevant and significant parameters to consider in designing a method to use when facing this issue.

Ibrahim Komoo (1995) reported, among the primary difficulties in describing weathering descriptions is the weathering profile in Malaysia. It is formed due to highly intensive chemical weathering processes and then creates weathering processes for various rock lithologies (bedded and non bedded) very clearly. Weathering was observed to occur up to 100 m below the earth's surface. This view is supported by Khalil Abad et al. [1], who produced a combination of weather zones in granite profiles in the tropical region through field scale observations and geological studies. He proposed a typical mass weathering profile of tropically weathered granite rocks in the tropics, implemented in southern Malaysia. He found that the proposed weathering profile is a maximum thickness of 66 m. Excavation work in igneous origin is usually associated with the occurrence of boulders in a tropical region. Several researchers have studied rock weathering on granite boulders [2–4]. However, the relationship between the size, shape and distance of the rock from the base rock in the highly to a completely weathered rock where it formed is rarely studied and understood well. Md Dan et al. [5] conducted this study for the tropical region in Malaysia. Geological and geotechnical parameters are alternative methods used in civil engineering, essential in evaluating rock masses and determining suitable excavation methods. Therefore, by implementing the geophysical methods with conventional methods, site investigation problems maybe can be minimized. The cost and variation order (V.O) faced by the government on earthwork is bound to be the highest compared to other V.O, which has caused many losses to the government and delays in many projects.

1.1 Issues on Confirmation of Hard Mass and Rock Mass

The heterogeneity of rock mass causes great challenges and difficulties in performing surface excavation work. The condition of weak rocks (moderately (Grade III) to completely weathered (Grade V)) state often causing a different interpretation of the evaluation of the method of excavation to be made in tropical regions [6, 7]. This dispute involves contractors and clients due to cost and time factors between ripping and blasting methods [8]. Although many researchers have studied tropically weathered rock, there are still some loopholes for a dispute in quantifying changes in rock engineering properties due to weathering and its excavation method. Trial excavation is a direct method used to determine the easiness of excavation using types of machinery at the site studies.

Based on the Jabatan Kerja Raya (JKR) earthwork specifications published in 2013 (SPJ 2013 JKR), rock mass is stated as any hard material which can be excavated using an excavator with a minimum weight of 44 tonnes and net horsepower rating of 321 brake horsepower. While a production rate is not exceeding 50 m^3/hour. Problems that are often encountered when dealing with construction sites consisting of weathering rocks in the tropics. Several issues are often associated with the specifications, such as difficulty obtaining a 44-tonne excavator machine, which is limited in the market. Besides that, choosing the appropriate method to decide the best excavation method for weathered rock in a tropical region is complex. Furthermore, this issue causing difficulty for engineer and practitioners on site in determining the material in the category of hard mass or rock mass type under the criteria in the existing specifications. Therefore, there is an urgent need for a more effective and reliable determination method to solve the problems on the site.

According to Standard Specification for Road Works published by the Public Work Department of Malaysia (PWD) in year 2020, hard mass is defined as the material that can loosen with an Excavator (Series 400) with a minimum weight of 41.4 tonnes which a net horsepower rating of 321 brake horsepower (BHP). While production rate not exceeding 50 m^3/hour. Suppose the contractor is unable to provide the specified machine. In that case, he may suggest a similar machine for trial excavation purposes with an equivalent machine production rate calculated in Table 1 and Table 2. The calculation for the equal production rate is based on the method introduced by [9]. The actual production of the equipment is derived according to the various type of analysis, namely long-range, ratio and variance analysis.

When the direct method cannot confirm hard mass and rock mass classification based on the trial excavation method, the indirect method carried out a point load test on excavated material. Therefore, a minimum of ten (10) irregular samples from the excavated material resulting from trial excavation as indirect method (i) above shall be tested. The interpretation of the results is shown in Table 3.

The issue of hard mass or 'rock-soil' characteristics needs to be given due attention because it can lead to disaster and cause failure if not understood and dealing with properly, even for strong rocks such as granite.

Table 1 Equivalent production rate of hard mass based on type of excavators

Excavator series	Weight (Tonnes)	Engine horsepower (HP)	Factor compared with 41.4 tonnes (excavator series 400)	Equivalent production rate for hard mass (m^3/hr)
150	15.4	99	0.33	16.5
200	21.2	170	0.58	29.0
250	27	188	0.63	31.5
300	31	242	0.67	33.5
350	36	271	0.75	37.5
400	41.4	321	1.0	50.0

Table 2 Equivalent production rate of rock mass based on types of track-type tractors with ripping equipment (Bulldozer Ripper)

Dozer	Flywheel power (kW)	Operating weight (Tonne)	Factor compared with 37 tonnes (Bulldozer Riper)	Equivalent production rate for rock mass (m^3/hr)
D6,D7	200 – 240	20 – 25	0.54	11.0
D8	303	37	1.0	20.0
D9	405	48	1.3	26.0

Table 3 Category of excavation based on corrected point load test index ($Is_{(50)}$)

Type of excavation	Corrected point load test index $I_{s(50)}$
Common excavation	Not applicable (no solid sample can be tested)
Hard mass	80% of the samples obtain result < 2 MPa
Rock mass	80% of the samples obtain result ≥ 2 MPa

2 Site Location

2.1 Geology of the Site Area

The eastern part of Kinta Valley is bordered by the Granitic Main Range, which forms the backbone of Peninsular Malaysia, which runs north–south for more than 400 km. Meanwhile, the western part is bordered by Kledang Range. These ranges formed a reverse-V shape in topography. Figure 1 shows the location of the study area bordered by Main Granite Range and Kledang Range. The average age for the granite is 230–207 Ma. Generally, karstic limestone outcrops meet in the eastern part of the Kinta Valley. In the Kinta Valley and nearby areas, massive rock bodies

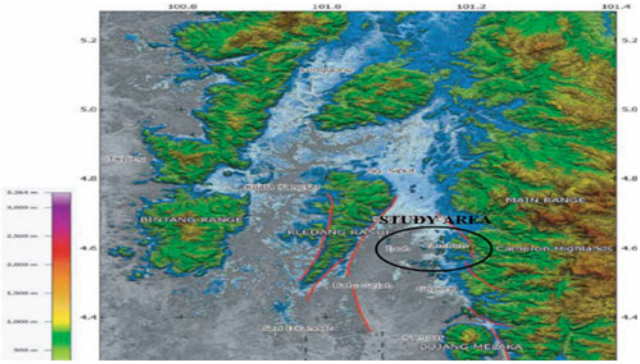

Fig. 1 Geological map showing the geological information of the studied site

were found, usually highly fractured. As a result, the normal faults form north–south (N-S) to north northeast-south southwest (NNE-SSW) trending belts [10].

2.2 Methodology

The geological structure, rock material and properties are essential to determine the engineering properties of tropically weathering granite. In this study, field work and laboratory testing were carried out. The fieldwork was conducted in Ulu Kinta, in the state of Perak state of Malaysia. The site is selected because earthwork is ongoing and the excavation work has been exposed to the weathering profile. During the fieldwork, assessment of weathering properties, rock material properties and mass properties were executed at a distance of 200 m. All the procedures and forms related to the assessment process for field and laboratory works were determined following the International Society of Rock Mechanics (ISRM 1981).

3 Field Work

3.1 Field Mapping

A complete range of weathering zones from slightly weathered rock to completely weathered rock was present in the site. A weathered rock classification was done based on the most broadly used system proposed by ISRM. The scanline survey was used to measure the outcropped rock surface and all the properties of discontinuities in this study. The weathering grade for rock material consists of an individual or particular set of discontinuities. Thus, weathering conditions can be characterized by profiling methods. This method is implemented by first determining the weathering zones available on the site. The profile is selected based on the weathering change in the vertical section, and this change can be gradually changing. The profile was made by sketching each change in weathering levels and other geological features of the rock based on overall observations on site. Samples for each weathering level will be collected to provide a representative sampling to determine the rock material properties later [11].

3.2 Geophysical Investigation -Resistivity Method

Borehole drilling is widely used as a site investigation method to obtain soil stratification and soil type but only at discrete locations. Bacic et al. [12] pointed that the traditional borehole method guarantees more reliable geotechnical parameters, relying on human factors conducting the test in addition to time and financial aspects. Therefore, some concerns about geophysics may be among the suitable alternatives to address this emerging issue. Olona et al. [13] believes that geophysical methods have an advantage over the limitations of traditional methods, which give an inadequate characterization of heterogeneous soil and rock conditions in the area. Geophysical methods obtain spatial sampling and geotechnical parameters in the study area better. Besides, an alternative method of giving more detailed and precise information such as bedrock depth, cavities, dissolution features in carbonate rocks and boulders with a low cost and effective method [14–16]. The seismic refraction can generate information on stratigraphy and geomaterials features in two-dimensional (2D) [17]. He proved that the seismic method has a good correlation with borehole and promises more benefits.

3.3 Geophysical Investigation -Seismic Refraction Method

The main components of seismic refraction equipment are a source, detector and record. A seismic signal was recorded using ABEM Terraloc MK-6 Seismograph powered by a 12 V external battery. A 12 -pound sledge hammer generated the energy source and the 24 channel 28 Hz vertical geophone used as the detector. Geophysical investigation using seismic and resistivity results is shown below. Two (2) seismic lines of 115 m and four (4) resistivity lines of 200 m were carried out at the excavation area.

3.4 Drilling Method

Drilling is one of the common and accurate methods used, especially during earthworks, to obtain the properties of rock masses and geological exploration. The penetration rate is the most crucial parameter in rock mass characterization and drilling performance optimization. However, some parameters related to drilling need to be considered, such as power consumption and bit wear [18]. The penetration rate is the depth of penetration achieved during the drilling operation, expressed in (m/min). It is a parameter that gives the level of performance and efficiency of drilling. Therefore it is essential to maximize the rate of penetration [19]. Scoble et al. [20] conducted a study on drill monitoring. There found a correlation between drill performance parameters and changes in intact rock strength and other parameters. The parameters can be determined through empirical equations related to penetration rate, thrust on a bit, rotary speed, rotary torque and hole area. They also pointed out that laboratory tests can minimize the site's cost, time, and effort if MWD information obtains during drilling. Adebayo and Mukoya [21] reported a drilling machine problem of inappropriate parameters in rock formations, causing increased drilling costs due to the long time to make a blast-hole. A broadly similar point has also recently been made by [22]. He developed a model on rock mass strength estimation based on drilling information. It is beneficial for determining UCS and RQD values, especially for weak rocks, where specimens are relatively difficult to obtain.

3.5 Material Strength

A total of 50 rock samples were taken from the excavated material during the trial excavation method at the site. These samples were tested using a point load tester apparatus to obtain point load strength values for various types of rock weathering in this area. The dimensions of the rock samples were measured using a measuring tape and recorded using this test form. A load is applied to the rock sample until it fails and the load recorded. The test is performed by assessing the strength in a rock sample, whereby assessing the resistance load of the sample strength placed between two loading cones or bits that can adjust to grip. Point load index is useful in determining the strength properties of rock materials, but have a limitations.

3.6 Trial Excavation and Direct Assessment

The trial excavation was performed using machinery to obtain the production rate for the excavation work. Excavation performance was assessed to establish a relationship between geological and geophysical parameters. Each zone's production rates (Q) were recorded as a cubic meter per hour (m^3/h), dividing the volume by the excavation

Table 4 Specification of Komatsu PC 300–6 hydraulic excavator

Specification	Value
Engine power	134.3 kW
Operating weight	29,000 kg
Max travel speed	5.5 km/h
Track gauge	2590 mm
Reference bucket capacity	1.8 m^3

time. Observations and measurements made during the trial excavation measure and record several parameters such as ripping time, maneuvering time, ripping length, ripping width, and ripping depth [23]. Assessments of trial excavation and information such as the number of a bucket, bucket capacity and time of excavation were recorded and measured for different lithological and weathering grades, also used by Liang et al. [24]. The excavator operational specifications and properties were identified from the manufacturer (i.e., engine power, operating weight, maximum travel speed, track gauge and reference bucket capacity). The practical excavation rate (Q) is obtained for each excavator, which has various properties. The excavation operation was carried out by Komatsu PC300-6 hydraulic excavator. The properties and operational specifications of the selected excavator presented in Table 4.

4 Laboratory Works

4.1 Moisture Content

Samples collected from various lithological zones and weathering conditions were brought to the laboratory to test moisture content. The results of this test will establish a relationship between rock properties and excavatability. Two methods were conducted to achieve the desired level of moisture content in a test sample. First, a sample from each weathering grade was tested in initial/dry condition, 10, 30 and 60 min immersion. Second, the time was selected from dry to 60 min because the weathering grade IV and V samples were easily destroyed.

5 Results and Discussion

5.1 Field Mapping

Rock outcrops were studied to identify different rock mass and material characteristics for each weathering zone. The rock mass and material characteristics are joint directions, joint orientation, joint number, spacing, moisture content and other conditions recorded for each weathering zone. The size and shape of boulders and relevant data will be recorded and analyzed to obtain significant parameters for rock excavation for the granitic area. Figure 2 shows an overview of the studied site. Five panels were classified from slightly weathered to completely weathered granite. The outcrop is 200 m in length and 15 m in height. Geological mapping, including identifying weathering zones, studying geological features, and measuring joint characteristics.

Table 5 tabulates the description of the studied panels. Five panels were classified based on the type of rock and the weathering state. It was found that at least two (2) joint sets characterized the rock mass with joint spacing varies from 0.01–2.0 m. The average joint spacing varies from 0.06 to 0.42 m (completely to slightly weathered zone). Alavi Nezhad et al. [25] reported a typical weathering of granite profile in the tropical region was established. The weathering zone has been divided into

Fig. 2 The overview of the studied site

Table 5 Description of studied panels at Ulu Kinta

Panel	Weathering zone	Joint set	Joint SPACING (m)	Average joint spacing (m)
1	II	2 joint sets: 070/80 265/05	J1 – 0.5–0.8 m J2 – 1.0–1.5 m	0.42
2	III	3 joint sets: 263/70 090/60 274/10	J1 – 0.3–2 m J2 – 0.2–1.5 m J3 – 0.3–1 m	0.28
3	III	3 joint sets: 260/62 070/68 302/70	J1 – 0.3–2 m J2 – 0.2–2 m J3 – 0.1–1 m	0.26
4	IV	3 joint sets: 235/60 089/16 269/12	J1 – 1.1–1.4 m J2 – 0.05–0.6 m J3 – 0.01–0.8 m	0.15
5	V	3 joint sets: 050/60 240/10 239/02	J1 – 0.05–0.3 m J2 – 0.08–0.2 m J3 – 0.1–0.3 m	0.06

subcategories to simplify rock mass structure and can be completed with or without boulders. He also reported that the mean joint trace length decreases as the weathering grade increases, which may be due to the rock undergoing disintegration and decomposition.

5.2 Seismic Refraction Result

Figure 3 shows a seismic line of S3. From the image, we can conclude that there are five zones. First zone is lower than 800 m/s (0–15 m); Second zone between 800–1200 m/s (15–22.5 m); Third zone is in between 1200–2400 m/s (22.5–27.5); Fourth zone is in between 2400–3200 m/s (27.5–33 m); Fifth zone is in more than 3200 m/s (>33 m). The first and second zone with seismic velocity values of less than 1200 m/s is residual soil, confirmed during the excavation test.

Figure 4 shows a seismic line of S6. From the image, there are five zones. First zone is lower than 800 m/s (0–10 m); Second zone is in between 800–1200 m/s (0–12 m); Third zone is in between 1200–2400 m/s (12–30 m); Fourth zone is in between 2400–3200 m/s (30–35 m); Fifth zone is in more than 3200 m/s (>35 m).

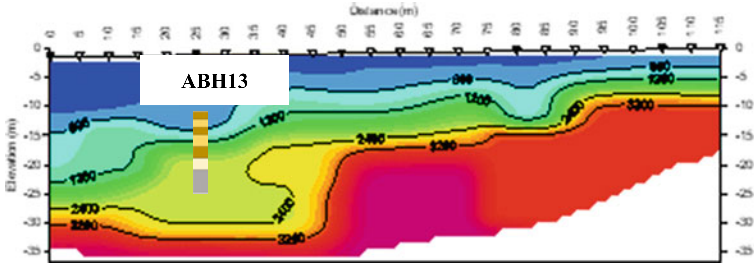

Fig. 3 Seismic line of S3

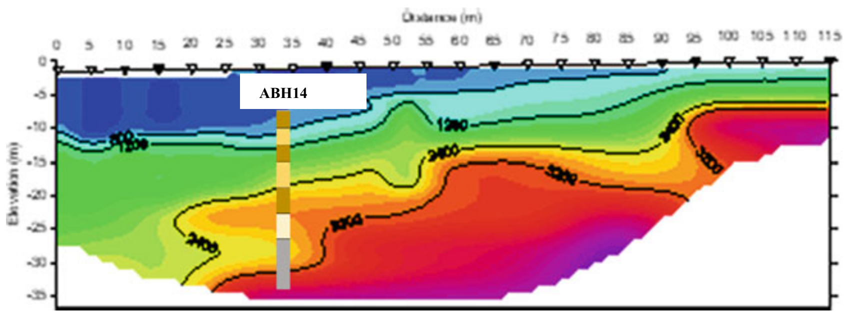

Fig. 4 Seismic line of S6

The first and second zones are residual soil. The excavation test found that the fourth and fifth zones are Grade I and II granitic rock.

In summary, the resistivity profiles obtained from the survey have a range of values between 1000–7,500 Ωm. In this study, three (3) types of significant resistivity values were found and were divided into three fields, as shown in Table 6. While Table 7 shows, a seismic value was divided into five ranges. It can be concluded that the ground conditions in this area show various levels of granite weathering. However, Grade I and Grade II fresh rock is estimated to be found at depths exceeding 33 m from the ground surface around high topographic areas. This finding matched the borehole profile where the granite was identified at 15–30 m depth. The results of the resistivity image study for Grade I and II showed a good correlation with the granite depth found in the borehole. This agrees with a statement made by Md Dan et al. [2], who made a study of boulders occurrence in tropical granite rocks. Grade I and II boulders are usually found at 1 to 30 m depth. However, fresh granite in the form of boulders is sometimes misinterpreted as bedrock in the borehole profile.

The borehole result in ABH13 (Fig. 5) shows that the site is underlained by soil type sandy SILT, and sandy CLAY to medium dense soil profile refers to soil properties based on SPT. The SPT reached 50 at depth 19.5 m, shown that a hard layer is found. However, this is not considered a bedrock. The soil profile in borehole ABH 14 is slightly similar to ABH 13, consisting of sandy SILT and sandy CLAY and a hard layer found at a depth of 28.0 m. The SPT values generally increase until each N = 50 at depth 28.0 m. From the observations in bore log ABH 13, the RQD values are 60, 65, and 67%, classified as fair rock quality. On the other side, RQD values in ABH 14 show a range of 55 to 63%, which the rock quality is also in the ranking as fair.

Table 6 Summary of resistivity value of weathered material for the study area

Depth (m)	Resistivity value (Ωm)	Material	Grade
0–15	1000–2200	Completely Weathered Rock – residual soil	V–VI
15–30 m	<1000	Moderately Weathered Rock – Highly Weathered Rock	III–VI
>30	2200–7500	Fresh Rock – Slightly Weathered Rock	I–II

Table 7 Summary of seismic value of weathered material for the study area

Depth (m)	Seismic value (m/s)	Material	Grade
0–15	800	Residual Soil	VI
15–22.5	800–1200	Residual Soil	VI
22.5–27.5	1200–2400	Moderately Weathered Rock – Highly Weathered Rock	III–VI
27.5–33	2400–3200	Slightly Weathered Rock	II
>33	3200	Fresh Rock	I

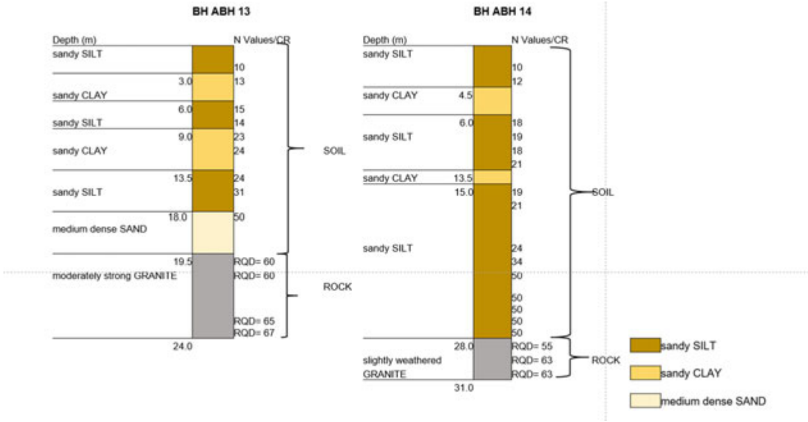

Fig. 5 Detail of borehole ABH 13 and ABH 14

The integration of analysis for resistivity and N value provides a more reliable and accurate subsurface relationship. These findings are similar to the conclusions of the study conducted by Mohamad, Alel et al. [26]. Correlation between geophysics and boreholes provides many advantages in terms of site investigation quality, reduces the risk of soil variation, provides more reliable results, and saves cost and time [15]. [27] Ismail et al. reported that this correlation can also determine the machines involved in excavation work to predict rock rippability. This statement was agreed by a researcher who also made a correlation between geophysics and site investigation.

From Tables 8 and 9 overall parameters comparing with core logs for BH1 and BH2, it is concluded that bit pounded and penetrates rocks read for measures parameter; feeding pressure and rotation pressure at above 2 MPa. However, for soils, the machine's feeding pressure and rotation pressure reading was below 2 MPa. While for the calculated parameter, the Furukawa Top Hammer Hydraulic Crawler HCR1200-DS bit penetrates rocks at a penetration rate calculated below 2.15 m/min for the calculated parameter. As for soils, the penetration rate estimates above 2.15 m/min as it is penetrated faster than in rocks.

Tables 8 and 9 showed that the range for UCS (24.0–38.0 N/mm^2) is low compared to the average value for granite in the tropical region. This condition is due to the high level of weathering in this area and causes mineral composition changes and rock color. High weathering causes the bonds of mineral structures to become weaker, further decreasing the UCS of these rocks. Both boreholes (BH1 and BH2) showed as UCS increases, decreasing penetration rate. The results of this test show the same results obtained by the researchers [28]; rocks with low UCS give higher penetration rate values. On the other hand, there are correlations between rock mass properties such as weathering grade and uniaxial compression strength (UCS) on the penetration rate. The penetration rate increases with increasing weathering grade, and in contrast, the penetration rate decreases linearly with increasing UCS. These findings are similar to the study conducted by Rathinasamy et al. [29].

Table 8 Correlation between all parameters for BH1

RL	Depth	BH1 Lithology	RQD (%)	SPT	Max Load kN	UCS (N/mm2)	Percussive Pressure (MPa)	Feed Pressure (MPa)	Normalize Rotation Pressure (MPa)	Flushing Pressure (MPa)	Penetration Rate (m/min)
161	0 - 0.5						15	1	2	0.3	2.5
160.5	0.5 - 1.0						15	1	2	0.3	2.4
160	1.0 - 1.5						15	1	1	0.3	2.61
159.5	1.5 - 2.0	Sand, Soil		50			15	2	2	0.3	2.73
159	2.0 - 2.5			-	50	24	15	2.5	3	0.3	2.14
158.5	2.5 - 3.0	Moderately Weathered Granite	46	-	60	28	15	3	3	0.3	1.88
158	3.0 - 3.5			-	55	26	15	3	3	0.3	1.5
157.5	3.5 - 4.0			-	75	36	15	4	3	0.3	1.25
157	4.0 - 4.5	Slightly Weathered Granite	74	-	80	38	15	4.5	3	0.3	1.25
156.5	4.5 - 5.0			-	65	31	15	5	3	0.3	1.22
156	5.0 - 5.5			-	65	31	15	5	3	0.3	1.2
155.5	5.5 - 6.0	Fresh Granite	77	-	70	33	15	5	3	0.3	1.18
155	6.0 - 6.5			-	80	38	15	5	3	0.3	1.13
154.5	6.5 - 7.0			-	75	36	15	5	3	0.3	1.15
154	7.0 - 7.5	Fresh Granite	83	-	90	43	15	5	3	0.3	1.03
153.5	7.5 - 8.0			-	80	38	15	5	3	0.3	0.92

Table 9 Correlation between all parameters for BH2

RL	Depth	BH2 Lithology	RQD (%)	Max Load kN	UCS (N/mm^2)	Percussive Pressure (MPa)	Feed Pressure (MPa)	Normalize Rotation Pressure (MPa)	Flushing Pressure (MPa)	Penetration Rate (m/min)
155	0 - 0.5			55	26	15	5	3	0.3	2.00
154.5	0.5 - 1.0	Slightly Weathered Granite	49	120	57	15	5	3	0.3	1.88
154	1.0 - 1.5			75	36	15	5	3	0.3	1.33
153.5	1.5 - 2.0			110	52	15	5	3	0.3	0.77
153	2.0 - 2.5	Fresh Granite	93	80	38	15	5	3	0.3	0.61
152.5	2.5 - 3.0			80	38	15	5	3	0.3	0.61
152	3.0 - 3.5			50	24	15	5	3	0.3	0.65
151.5	3.5 - 4.0	Fresh Granite	90	80	34	15	5	4	0.3	0.75
151	4.0 - 4.5			70	33	15	5	4	0.3	0.76
150.5	4.5 - 5.0			95	45	15	5	3	0.3	0.74
150	5.0 - 5.5	Fresh Granite	91	70	33	15	5	3	0.3	0.75
149.5	5.5 - 6.0			80	38	15	5	3	0.3	0.69

In this case, this method is proposed because the contractor cannot provide the machine/equipment specified in the PWD Specification 2013 (in the determination of hard mass and rock mass) during the excavation work at the site. Therefore, this method is to be used as an alternative method to counter these issues. However, this method is not applicable and is used as a precedent for determining the rock for the area. Therefore, it suggested that geophysical tests such as seismic refraction and resistivity could be applied as an accurate method in determining the initial estimation of rock quantity.

6 Conclusion

1. Although the drilling method has not been described as a method for confirmation of hard mass and rock mass, it is believed to quickly provide geological and geomechanical information (i.e., rock mass characterization) and at a minimal cost. However, an improvement is needed, namely the prediction of RQD in situ rock mass properties. Therefore, an early penetration rate prediction is necessary for cost estimation and planning of engineering design projects.
2. The hard layer is determined through the borehole method with the first SPT value N = 50 in the borehole data. However, this layer does not indicate that it is rock. However, seismic methods cannot provide rock mass quality based on the RQD value of the borehole.
3. Rock mass excavation is greatly influenced by factors such as the joint sets number and direction of discontinuities; currently, a more straightforward graphical method Pettifer and Fookes (1994) is more suitable for determining the excavatability of rocks. This graph considers only two parameters, namely point load strength and discontinuities spacing. Therefore, the material and mass properties can be as acceptable in the assessment.
4. The trial excavation is carried out based on one type of excavator only; confirmation can only be made to determine the hard mass for this area. Therefore, a further inspection using various types of excavators should be considered. In this case, the indirect method using the Point load test has confirmed that the rocks for this area are rock mass. The same goes for the use of dozers to determine rock mass.

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