PAPER • **OPEN ACCESS**

Engineering characterisation of weathered rock at Sri Jaya, Pahang, Malaysia

To cite this article: H Awang *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **682** 012016

Engineering characterisation of weathered rock at Sri Jaya, Pahang, Malaysia

H Awang[1*], A F Salmanfarsi[2], A Arizam[3] and M I Ali[1]

[1]College of Engineering, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia
[2]PhD candidate, College of Engineering, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia
[3]Undergraduate student, College of Engineering, Universiti Malaysia Pahang, 26300 Gambang, Pahang, Malaysia

[*] Corresponding author: haryatiawang@ump.edu.my

Abstract. Erosion and weathering are major processes that may reduce the strength of rock slope material or may cause significant change in the physical state of the slope. These can lead to landslide or slope failure, bringing significant risk in terms of properties damage and/or human safety. In Sri Jaya, Pahang, a large body of granite is exposed as cut rock slope, which shows different zones of weathering grade. Field and laboratory tests were carried out to determine the mechanical properties and the physical properties of weathered rocks of the slope, which involved a number of testing for the Schmidt rebound hammer test, point load test, moisture content, water absorption and specific gravity. From the tests, the study has determined the engineering properties of weathered rock of the slope where weathering grade and engineering properties of rock were correlated. A strong correlation was found between the weathering grade and engineering properties where they showed significant correlations for this site. It is proven that the engineering properties could be used as reliable parameters in determining the weathering grade of material in the field.

Keywords: Weathering, Weathered rock, Physical and mechanical properties

1. Introduction

Rock is commonly degraded as a result of the hydrologic cycle, which involves fresh water and sea water, through the process of weathering [1]. Classification of rocks and soils on engineering geological maps should be based on the principle that the physical or engineering geological properties of a rock in its present state are dependent on the combined effects of mode of the formation of the rock, followed with weathering processes. This principle of classification makes it possible not only to determine the origin for the lithological and physical characteristic of soils and rocks, but also for their spatial distribution. This is a basic principle of engineering geological, which implies not only the classification of individual rock samples, but also the use of many individual rock samples, field observations and measurements to delineate uniform and continuous rock units [2].

The process of rock weathering increases the degree of geological complexity in rock masses. Weathering profiles are highly variable and confusing, and sometimes surface characteristics on which the engineer or geologist has to rely for basic mapping are not always solid indicators of what lies below. An important feature that has recently not been considered in discussions of weathering and weathering profiles is the distinction between the weathering of rock material and the weathering of rock mass. This distinction is important because descriptions of rock material are basically on the scale of the hand specimen, while descriptions of rock mass are on the scale of the mass [3].

The earliest stages of weathering are usually defined by rock material discoloration, which increases from slightly to highly discoloured as the weathering degree increases [4]. Weathering brings about changes in engineering properties, leading to an increase in bulk (and porosity), with a corresponding reduction in density and strength. The degree of weathering is usually shown by the amount of discolouration of the rock: in other words, a slightly discoloured rock's engineering properties may differ significantly from those of the same highly discoloured rock [5].

The aim of this study is to investigate the characterisation of weathered rock of the studied slope, and whether the weathering process played role in the performance of rock in engineering application. Different type of rock has their specific characteristic of strength. The strong and stable rock is important when it is comes to a slope stability and especially for expressway. When the strength is weak, the stability will be affected that can cause cracking, sinking and settlement effect. In this study, it can be observed that different section of rock slope exhibit different composition and texture. The aim of this study is to investigate the engineering characterization and physical properties of the weathered rock along section of the slope.

2. Geological description

The selected site of the study area is an exposed slope in Sri Jaya area, Pahang. The rock type of the slope in study area is identified as that of granitic rock (Figure 1 – Figure 2), which forms the high topographic point of Bukit Berkelah in the vicinity of the area (Figure 3). The granite of the area is graded ranging from coarse grained, primary textured equigranular, to porphyrytic biotite and hornblende granite [6]. Biotite granite is reported to make up most of the granite, which consist of medium-grained to medium to coarse-grained with subhedral-granular texture, made up of quartz, K-feldspar, plagioclase, muscovite, and biotite [7]. Different weathering grade of the granite is found along the slope, ranging from slightly weathered (Grade II) and all the way to highly weathered (Grade IV). The texture of the rock and the presence of the minerals show significant changes across the weathering grade, with the feldspar and biotite altered to clayey minerals in the higher weathering grade section under thin section of the samples (Figure 4- Figure 5).

Figure 1. Granite in the field (grade II)

Figure 2. Granite in the field (grade IV)

IOP Conf. Series: Earth and Environmental Science **682** (2021) 012016 doi:10.1088/1755-1315/682/1/012016

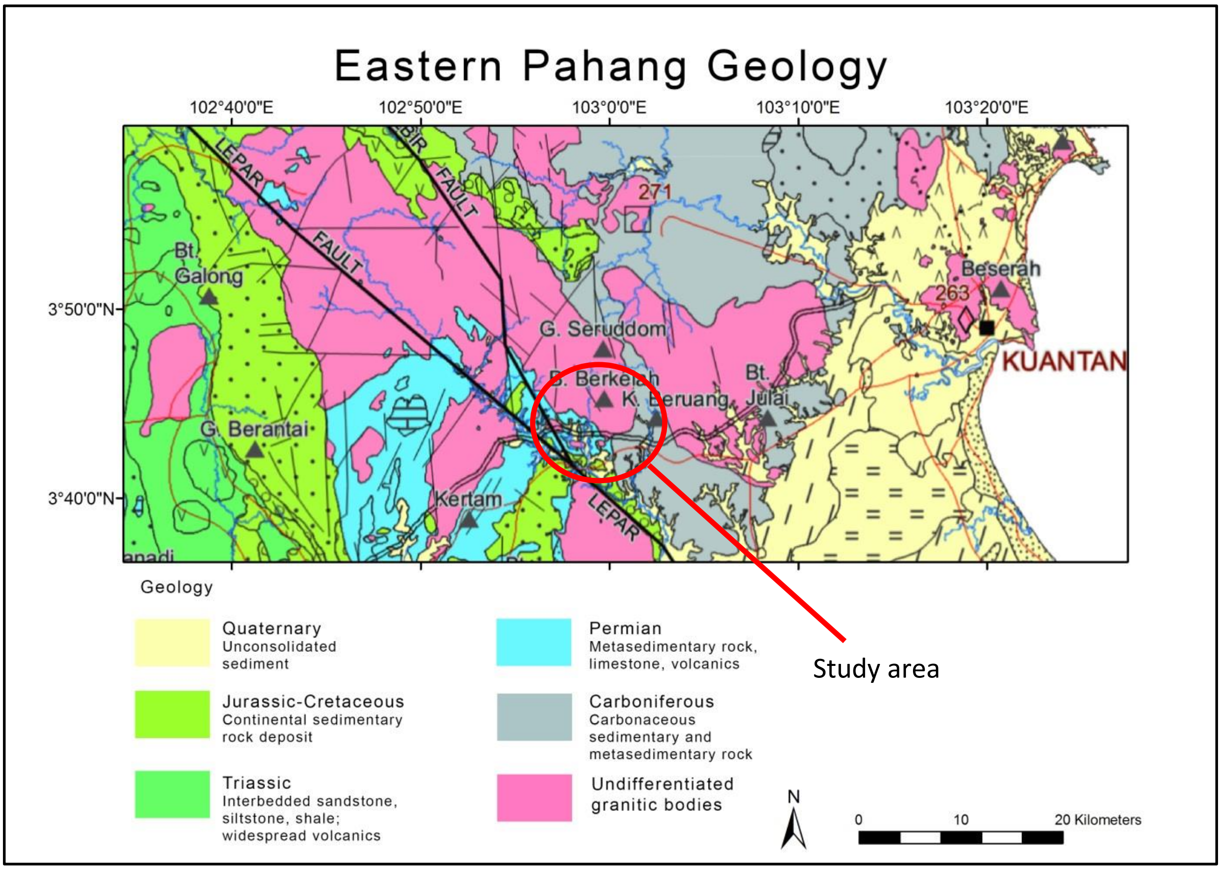


Figure 3. Geology of eastern Pahang, showing the granite body in the study area. Geology modified from [8]

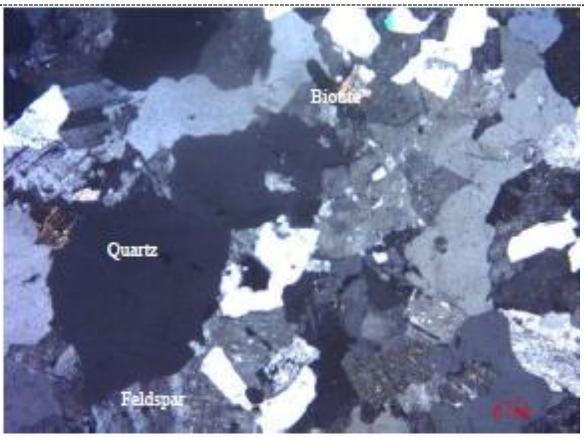


Figure 4. Photomicrograph of granite (grade II)

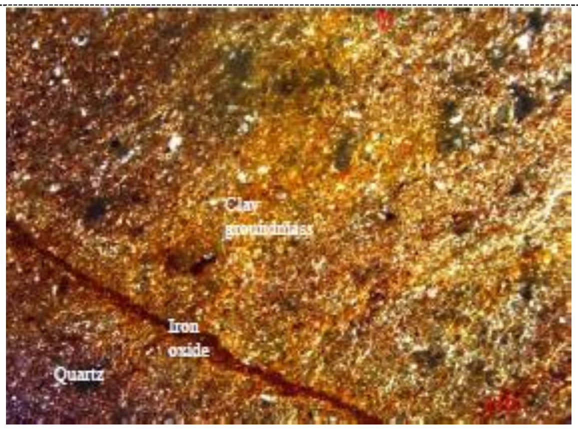


Figure 5. Photomicrograph of granite (grade IV)

3. Methodology

3.1. Field works and measurements

The field works were carried out for the purpose of samples collection and field test. Along the slopes, readings were taken at an interval to map the changes of the weathering grade of the rock. Samples representative of the different weathering grade of the granite were collected from the foot of the slopes with hammer and chisel for further laboratory testing. The field test involve Schmidt rebound hammer (SRH) test on the surface along the rock slope to determine the rebound hardness. The rebound hardness value (RH) is known to be most recently used as an index in rock mechanics practice for estimating the uniaxial compressive strength (UCS) and the modulus of elasticity (E) of intact rock both in laboratory conditions and in-situ. The operating of Schmidt rebound hammer is shown in Figure 6 – Figure 7.

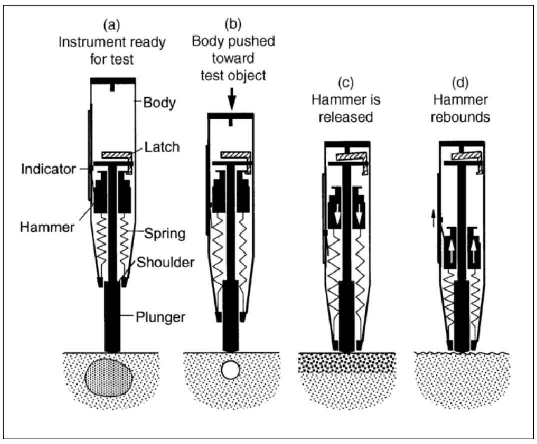


Figure 6. Operation of the rebound hammer as schematic [9]

Figure 7. Using the Schmidt rebound hammer in the field

3.2. Laboratory tests

The laboratory test for this study includes the point load test, moisture content and specific gravity tests.

3.2.1. Point load test

The point load test (PLT) is intentional as an index test for the strength classification of rock materials. It may also be used to forecast other strength parameters, with which it is correlated, for example uniaxial tensile and compressive strength. [10]

The test measures the Point Load Strength Index ($I_{s(50)}$) of rock specimens, and their Strength Anisotropy Index ($I_{s(50)}$) which is the ratio of point load strengths in directions which give the greatest and least values. Rock specimens in the form of either core (the diametric and axial tests), cut blocks (the block test), or irregular lumps (the irregular lump test) are tested by application of concentrated load through a pair of spherically truncated, conical platens (Figure 8). Little to no specimen preparation is needed. The test follows the standard by [11] where calculation for the value follows the formula:

$$I_{s(50)} = P/D^2 \qquad (1)$$

where P is peak load at failure, and D is the diameter of the tested core sample (typically 50 mm). As the samples are prepared from irregular lump, correction factor, F, need to be applied. Here, the formula is as follows:

$$I_s = P/D_e^2 \qquad (2)$$

where D_e is the equivalent core diameter. The corrected strength is then calculated using the formula:

$$I_{s(50)} = F \text{ X } I_s \qquad (3)$$

where F can be calculated by the following equation:

$$F = (D_e/50)^{0.45} \qquad (4)$$

Figure 8. Sample being run through a PLT machine

3.2.2. Moisture content

Water content is an index of the amount of water present in soil or rock. By definition, water content is the ratio of the mass of water in a sample to the mass of solids in the sample and express as a percentage. The porosity of soil affects the moisture content and the moisture content increase when the porosity of soil increases. This test conducted is to measure the mass of water contained in a rock sample as a percentage of the oven dry sample mass, following the standard of [12] by using the given formula:

Water content, w = pore water mass, M_p / grain mass, M_g (5)

3.2.3. Specific gravity
The test is conducted to measure the porosity, the dry density and related properties of a rock sample in the form of lumps or aggregate of irregular geometry. It is practically suitable if the rock material is liable to swell or disintegrate if immersed in water. The test may also be applied to regularly shaped rock specimens or to coherent rock materials. The procedure follows the standard of [12] where the formulas for the calculation are as follows:

Pore volume, $V_v = (M_{sat} - M_s) / \rho_w$ (6)

Porosity, $n = 100V_v / V$ (7)

Dry density of rock, $\rho_d = M_s / V$ (8)

Dry relative density (specific gravity), $d_d = \rho_d / \rho_w$ (9)

Saturated-surface-dry mass, M_{sat} = (mass of saturated-surface-dry sample – mass of container) (10)

Grain, M_s = (mass of oven dry sample+container – mass of container) (11)

4. Results and discussion

4.1. Schmidt rebound hammer test
The type and weathering grade of rock can be identified from visual and properties observed in the field [13]. The test has been carried out along the length of the slope, on a 5 meter interval, in order to map the extent of the weathering grade. Five out of total test sets is shown in Table 1, representing the collected samples that have been subjected to engineering tests in the laboratory:

Table 1. Summary of Schmidt rebound hammer result

Sample at Chainage (m)	Rock type	Average of SRH reading	Weathering grade
10	Granite	44.6	II
40	Granite	27	III
60	Granite	60.4	II
225	Granite	62	II
280	Granite	12	IV

The value of the Schmidt rebound hammer show a decrease in value along with the increase of the weathering grade of rock. This properties have made it an acceptable field method for determining the weathering grade of rock material [9]. However, in material that are weathered into soil (weathering grade V – grade VI) the Schmidt rebound hammer does not produce any reading. Thus, the usage of the test is only applicable for certain range of weathering grade of rock material.

4.2. Point load test
From the result shown in in Table 2, the strength of rock can be classified based on the value of $I_{s(50)}$. The strongest rock among the samples is at chainage 225m, with the value of 8.73 MPa. The strength for most of the remaining material is around the range of 5 MPa. The lowest $I_{s(50)}$ is for sample at chainage 280m, with 0.3 MPa. The trend of the test values show a general decrease along with the increase of weathering grade of the rock material, with a drastic reduction of the value in grade IV material. The process of weathering have been linked with the decrease of strength in the rock material due to the moisture content of the weathering grade [14].

Table 2. Summary of point load test

Sample at Chainage (m)	*Average of $I_{s(50)}$ (MPa)*
10	4.68
40	5.83
60	5.67
225	8.73
280	0.3

4.3. Moisture content

The result of the moisture content is tabulated in Table 3. From the result, the sample at distance 225m records as the highest percentage of water contained, which shows that the sample is of very high of porosity compared to the rest. The samples are also tested for their water absorption, in order to calculate the effect of weathering to the amount of water that can be retained by the sample in wet condition. It is shown that there is an increase of water absorption alongside the increase of weathering grade in the rock, which would be the result of the increase of pores in the highly weathered material. The increase of pores could also be observed in the thin section of the granite, where most of the original mineral in the rock have been altered to form fine clay groundmass of the material (Figure 5). The increase of clay content along with an increase of weathering grade of granite have similarly been reported by [15], which also affects the strength of the weathered material.

Table 3. Summary of moisture content

Sample at Chainage (m)	Moisture content (%)	Mean porosity (%)	Mean water absorption (%)
10	0.28	0	0
40	0.45	2.66	1.05
60	0.43	3.50	1.37
225	0.6	1.98	0.91
280	5.93	20.75	10.23

4.4. Specific gravity

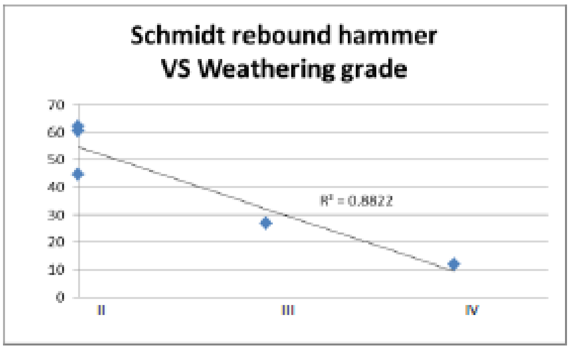
The results of SG are as shown in Table 4, with the highest value of SG recorded is at chainage 10m, at 2.62 g/cm^3. The lowest recorded is at distance 280m with 2.24 g/cm^3 The general trend of the specific gravity across the different weathering grade does not show a great range of values between grade II and III, whereas the range between grade III and grade IV shows noticeably large difference in range. This is result of the removal of feldspar minerals in the granite, where the original minerals were altered to clayey material, as exhibited in thin section of the samples (Figure 4 – Figure 5). Thus, it can be summarized that the process of weathering gradually reduce the density of the rock due to the alteration and removal of the original mineral grains.

Table 4. Summary of specific gravity

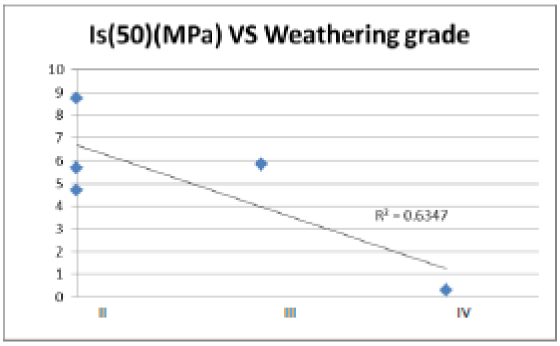
Sample at Chainage (m)	Specific gravity (g/cm^3)
10	2.62
40	2.55
60	2.59
225	2.54
280	2.24

4.5. Correlation analysis between variables

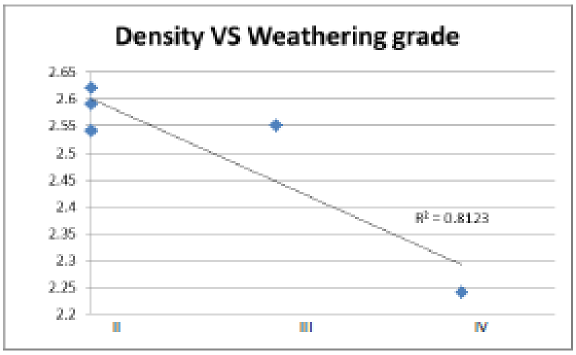
From the result obtained, a regression analysis was done in the software Microsoft Excel, where the coefficient of determination (R^2) values were calculated between the parameters with the weathering grade. The correlation is as shown in Figure 9 (a) to (f), with a summary of the correlation shown in Table 5.



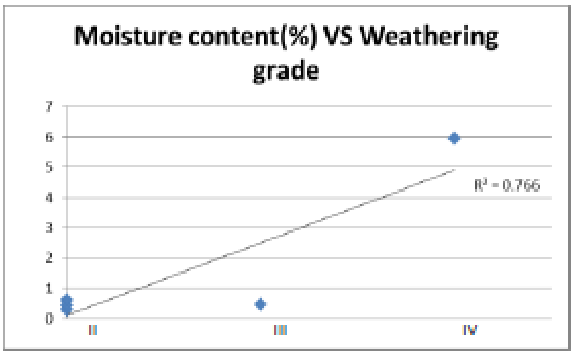
(a)



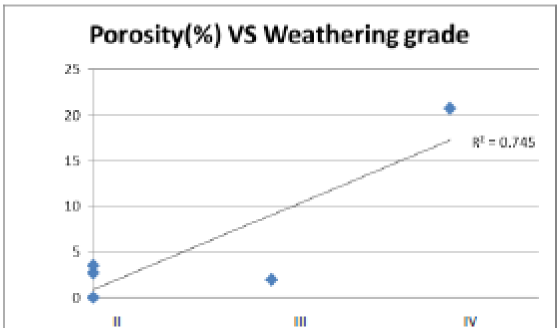
(b)



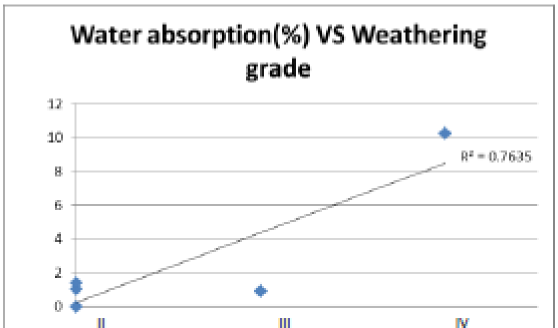
(c)



(d)



(e)



(f)

Figure 9. Relationship between weathering grade and Schmidt rebound hardness(a), point load strength(b), specific gravity (c), moisture content (d), porosity (e) and water absorption (f).

Table 5. Correlation between weathering grade with engineering properties of granite

Engineering properties	**Correlation value (R^2)**
Schmidt rebound hammer	0.93924
$I_{s(50)}$	0.79666
Specific gravity	0.90129
Moisture content	0.875206
Porosity	0.885251
Water absorption	0.883119

Figure 9 (a) to (f) shows the correlation made between the weathering grade and Schmidt rebound hardness, point load strength, specific gravity, moisture content, porosity and water absorption. The correlations of linear regression between weathering grade and rebound number, $I_{s(50)}$ and specific gravity show inverse correlation, with an increase of the weathering grade corresponding to decrease of rebound number, $I_{s(50)}$ and specific gravity, with correlation values of 0.93924, 0.79666 and 0.90129 respectively. The consistent field measurement is supported by [13, 16-17], where the values of Schmidt rebound hammer provides a good range for determining the weathering grade of rock materials. For field test, the Schmidt rebound hammer is a good field indicator for weathering grade of I-IV [17]. Apart from that, the laboratory tests are also very significant in the relationship between other engineering properties and weathering grade. The opposite trend is observed for the correlation between weathering grade and moisture content, porosity, and water absorption, showing that the weathering grade increase with the increase of the moisture content, porosity and water absorption, with correlation values of 0.875206, 0.88525 1and 0.883119 respectively.
Interpretation of the correlation values suggests that an increase in the weathering grade of the rock material leads to a decrease of the minerals grain size (Figure 5), leading to a decrease of the rock material’s density. This would affect the strength of the material, hence the lower value of $I_{s(50)}$ in the highly weathered material. With the increase in weathering grade, granite is susceptible to being broken down in its strength, with the high water absorption further weakening the material by retaining more water. The study on the relationship between moisture content and weathering grade in granite by [14] have reported a similar result, where an increase in weathering grade also correspond with an increase in moisture content. As Malaysia is a tropical country, with high amount of rainfall, the weathered material on the slope could pose further weakening of the exposed rock of the slope.

5. Conclusion

From the result findings of the study, it can be concluded that the weathering of the granite leads to significant changes in the engineering properties of the material. The grade of weathering can be identified by visual descriptions such as texture and colour changes in both field material and thin section of the rock material. The engineering properties of the weathered rock granite is able to be verified through several laboratory test such as Schmidt rebound hammer, PLT, moisture content test, and specific gravity test. The increase of weathering grade in the granite show a decrease of Schmidt rebound hammer value, with the values falling along specific range for the different weathering grade. From this result, the Schmidt rebound hammer is proven to be a reliable method in determining the weathering grade of the rock material. Similarly, the increase of the weathering grade of the granite also lead to the decrease of value for $I_{s(50)}$ and specific gravity of the rock material. On the other hand, the increase of the weathering grade leads to the increase of value of the moisture content, porosity, and water absorption of the rock material. The change of mineral content in the weathered granite is thought to influence the engineering properties of the rock material, where most of the original minerals in the granite were altered to clay material in the high weathering grade. A correlation of weathering grade of rock and engineering properties shows inverse correlation of weathering grade with the Schmidt rebound hammer, $I_{s(50)}$ and specific gravity of the granite, while direct correlation is observed for the correlation of weathering grade with moisture content, porosity, and water absorption. Overall, the engineering properties of the granite showed significant relationship with the weathering grade. For future studies of weathered granite, the analysis can be improved by using larger sample size across the weathering grade of the rock material. Further laboratory tests such as uniaxial compression strength test and slaking test could be carried out to further study the correlation between engineering properties with the weathering grade of granite.

References

[1] Lee J S and Yoon H K 2017 Characterization of rock weathering using elastic waves: A Laboratory-scale experimental study *Journal of Applied Geophysics* **140** 24–33
[2] UNESCO/IAEG 1976 *Engineering geological maps. A guide to their preparation* (Paris: The Unesco Press) p 79

[3] Raj J K 1985 Characterisation of the weathering profile developed over a porphyritic biotite granite in peninsular Malaysia *Bulletin of the International Association of Engineering Geology - Bulletin de l'Association Internationale de Géologie de l'Ingénieur* **32** 121–129
[4] Little A L 1969 The engineering classification of residual tropical soils *Proc. of 7th Intern. Conf. Soil Mech.& Found. Engineering vol 1* (Mexico) pp 1–10
[5] Dearman W R 1975 Weathering classification in the characterisation of rock: A revision *Bulletin of the International Association of Engineering Geology* **14** 123–127
[6] Cobbing E J, Pitfield P E J, Darbyshire D P F and Mallick D I J 1992 *The granites of the South-East Asian tin belt* (London: HMSO)
[7] Schwartz M O, Rajah S S, Askury A K, Putthapiban P and Djaswadi S 1995 The Southeast Asian Tin Belt *Earth Science Reviews* **38** 95–293
[8] Tate R B, Tan D N K and Ng T F 2008 *Geological Map of Peninsular Malaysia* (Kuala Lumpur: Geological Society of Malaysia & University Malaya)
[9] Aydin A and Basu A 2005 The Schmidt hammer in rock material characterization *Eng Geol* **81** 1–14
[10] Atkinson R H, Bamford W E, Broch E, Deere D U, Franklin J A, Nieble C, Rummel F, Tarkoy P J and van Duyse H 1978 Suggested Methods for Determining Hardness and Abrasiveness of Rocks *International Journal of Rock Mechanics and Mining Sciences* **15** 89–97
[11] International Society for Rock Mechanics 1985 Suggested method for determining point load strength *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts* **22** 51–60
[12] International Society for Rock Mechanics 1979 Suggested method for determining water content, porosity, density, absorption and related properties and swelling and slake-durability index properties *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts* **16** 141–156
[13] Komoo I 1995 Weathering as an important factor in assessing engineering proper-ties of rock material *Forum on Soil and Rock Properties. Geological Society of Malaysia* (Universiti Malaya, Kuala Lumpur) 31–35
[14] Mohamad E T, Md Isa M F, Md Amin M F, Komoo I, Gofar N and Saad R 2011 Effect of moisture content on the strength of various weathering grades of granite *Electronic Journal of Geotechnical Engineering* **16H** 863–886
[15] Mohamad E T, Latifi N, Arefnia A and Isa M F 2015 Effects of moisture content on the strength of tropically weathered granite from Malaysia *Malaysian Journal of Civil Engineering* **20** 137–144
[16] Fookes P G 1997 *Tropical Residual Soils* (London: The Geological Society London)
[17] Arikan F, Ulusay R and Aydin N 2007 Characterization of weathered acidic volcanic rocks and a weathering classification based on a rating system *Bulletin of Engineering Geology and the Environment* **66** 415–430

Acknowledgments
The authors would like to acknowledge the research support provided by Universiti Malaysia Pahang under Geran Universiti Malaysia Pahang, grant number RDU190345.