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CHARACTERIZATION OF TROPICAL GRANITE PROPERTIES BASED ON THE DEGREE OF WEATHERING

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Abstract
Weathering process weakens the cementation and bonding conditions between particles and changes the properties of rock such as strength, p-wave velocity, porosity and electrical conductivity. All of these properties are representative physical, engineering and dynamic properties which show the particle formation changes due to the weathering process. Thus, the study on the characterization of tropical granite properties wascarried outtaking into consideration the degree of weathering. Granitic rock samples were prepared according to the various degrees of weathering. Micro level porosity was estimated by using the analytical image processing technique from the images which were taken from the electro microscope. Amacro level porosity was also determined by the saturation and caliper techniques with the same specimen. Uniaxial compressive strength tests were conducted in order to determine the strength of the intact rock specimen. Meanwhile, p-wave velocity and electrical conductivity test was conducted to measure the p-wave velocity and the resistance ability of rock specimens. In conclusion, as the degree of weathering increases the porosity of the granite increases, p-wave velocity decreases, resistivity decreases. It was found that strength of granite decreases as the weathering degree increases since contact forces acting on the particle skeleton increases as the porosity increases.

Keywords: Micro and macro porosity, P-wave velocity, Electrical conductivity, Weathering degree

1. Introduction

Weathering of rock mass is the unique phenomena occur especially for the tropic climate country as such Malaysia. It is then produce very unique weathering profiles and also develop heterogeneous physical deterioration of rock mass (Zainab et al., 2007) which eventually influence the rock strength. This weathering process become more aggressive due to the climate of Malaysia which received high intensity of rain and the tropics condition which dry and wet all over the year will caused this process occurred more rapidly. The weathering process is effective in presence of water due to its reactivity and high temperature (Singh and Huat, 2004) and it is very much related to the tropical climate. The understanding on the weathering process is ultimately important and essential especially for geotechnical engineers in order to them to quantify the weathered rock parameters to be incorporated in the design as well as construction works.

The weathering process has produced a complex inter-relation between all the properties of rock both physical and mechanical. The study on this inter-relationship is highly important in order to quantify the true value of the tropical weathered rock. The characterization and classification of weathered granite is tremendously importance as such for substructures and any kind of design works because of it is involving the safety of the public. Total rock assessment have to be conducted in order to fully classify the rock mass characterisation and it requires a comprehensive method of engineering characterization in such to quantify the physical deterioration of tropical weathering rocks (Zainab *et al.*, 2007). The appropriate approach as to characterize the weathered rock also is significantly important as to produce a comprehensive rock characterization and classification.

2. Literature Review

The weathering profile is product of the weathering process. It is represent the grading of rocks due to the process of disintegration and decomposed of rocks. The grade reflects the deterioration of rock strength vertically from fresh rock (bedrock) up to the soil (surfaces). Fresh rock represent the strongest material and the strength will reduces since it move upward until reach top which is soil layer represent the weakest material. The grading is highly depending on types of rocks which it is based on the study by previous researchers.

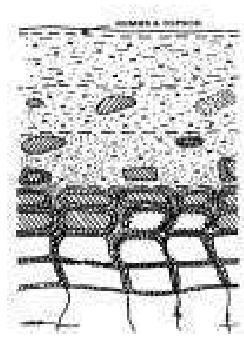


Figure 1: Typical weathering profile in granitic rock soil profile (Little, 1969)

In most rocks the main factors controlling rock strength are porosity, grain size, and grain shape (Shelley, 1993). All three of these factors affect the surface area of the interlocking bond forces at mineral grain to grain contacts. The effect of weathering caused the progressive changes to the strength of the rock. The occurrence of physical and chemical changes in the weathering process can lead to significant reduction in strength value (Sadisun et al., 2001). The weak zones will be further developed depending on the process and degree of weathering.

Table 1: Classification by Uniaxial Compressive Strength (Attewel and Farmer, 1976)

Strength classification	*Strength range (MPa)*	*Typical rock types*
Very weak	10-20	Weathered and weakly-compacted sedimentary rocks
Weak	20-40	Weakly-cemented sedimentary rocks, schists
Medium	40-80	Competent sedimentary rocks; some low-density coarse-grained igneous rocks
Strong	80-160	Competent igneous rocks; some metamorphic and fine-grained sandstones
Very strong	160-320	Quartzite; dense fine-grained igneous rocks

Weathering process causes progressive alteration of rock porosity due to the changes in pore distribution, pore geometry, pore infilling and pore formation (Tugrul 2004). Such weathering process is more rapid in tropical climate due to the high temperature and high humidity. The boundary crack that has been developed during weathering process contributes to the porosity of weathered rock mass. The fracture of mineral grains (grains boundary) is continuously developed and creates bulk of crack line all over the rock mass. Those cracks can be subdivided into two categories as micro-cracks and macro-cracks.

The non-destructive test which utilizes the use of dynamic properties of rock is very beneficial. It is an environmental friendly engineering works. The electrical resistivity and wave propagation in a rock mass is being utilized to determine the dynamic properties of rock. Gokceoglu et al., (2009), has done a study on determination of P-wave velocity with respect to degree of weathering. The rock sample is igneous rock which is granite. Five (5) different degree of weathering has been tested in order to determine the P-wave velocity and other engineering properties. The study shows that the P-wave velocity is decreasing along with the increasing of weathering degree.

Density of rock can be assumed as its unit weight. It can be calculated by the total dry or wet mass of rock material divided by the volume. Density is very much related to the percentage of air void inside the rock. The porosity and density have a significant relation where the low density of rock usually has high porous (Brown, 1981). The density of weathered rock is various depending on the degree of weathering. The relation between density, porosity, strength and degree of weathering is very close. The strength of rock is also depending on its density. If a rock has internal space, its cohesion will obviously be affected by the amount of internal contact between its constituent's fractions (Farmer, 1968).

3. Experimental Study

3.1 Specimen preparation

Tropical granite rock collected at a typical quarry in Sungai Buloh, Selangor state, Malaysia was used for the experimental study. Only rocks with no presence of bedding were selected to avoid any anisotropic and heterogeneous effects on testing results. Rebound hardness was used as an initial identification of the weathering degree of granitic rock mass. Fig. 2 shows rebound number and dry density of collected granite samples and corresponding weathering degree (hereafter, WD) based on the classification by Brand and Philipson (1984). As presented in Fig. 2, dry density increases as rebound number increases.

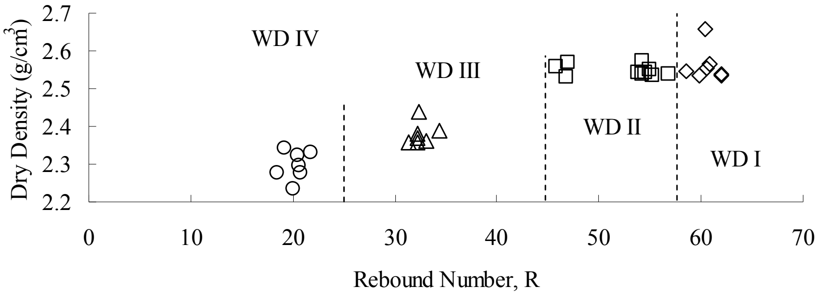


Figure 2: Rebound number and dry density of collected granite samples. Note: WD denotes weathering degree.

3.1.1 Porosity test

i) Saturation and caliper method

Saturation and caliper method (ISRM 1981) conducted to determine the porosity of granitic rock entailed the following steps: 1) Density, dry and saturated unit weights were determined by saturation and caliper method; 2) The pore volume values were obtained by the water saturation procedure; 3) Porosity values were measured by fluid displacement in pycnometers, using crushed samples. This approach is considered as macro scale porosity since liquid is used to obtain pore structure in the respective rock sample.

ii) Analytical image processing from petrographic thin section slide

By using the electro microscope, the micro properties of the granite such as texture, structure, and mineral content can be observed depending on the weathering degree. Furthermore, analytical image processing technique to determine the porosity from the images taken from the petrographic thin section is newly suggested in this study. The description of calculation process is presented in Fig. 3. The original images taken from petrographic thin section were digital images that consisted of pixels. Those images can be loaded to the analysis software such as MathCad and grayscale pixel information can be scanned. Threshold function can extract void pixels (crack and boundary of mineral grain) from the grayscaled images. Thus, the total number of extracted pixels multiplied by unit pixel area present represents the void area of unit window. So, the ratio of the void area to the total area of the unit window can be considered as porosity. Porosity calculated in this approach can be considered as micro scale porosity.

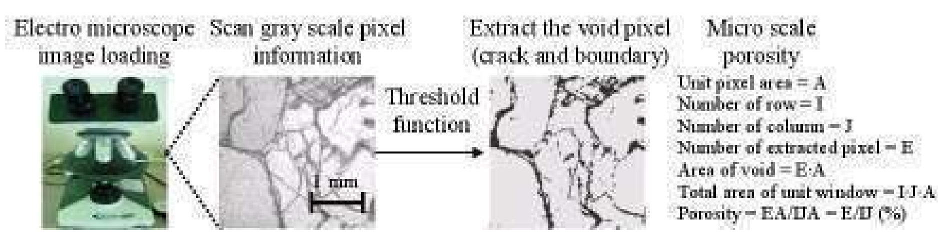


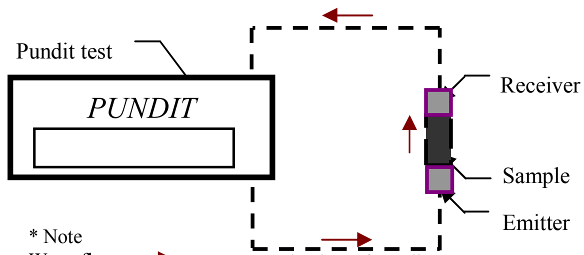
Figure 3: Analytical image processing from petrographic thin section slide

3.1.2 Uniaxial compression test

Unconfined compression test conducted to determine the Uniaxial compressive strength of granitic rock by referring to the ISRM 1981. This method of test is intended to measure the uniaxial compressive strength of a rock sample in the form of specimens of regular geometry. The test is mainly intended for strength classification and characterization of intact rock. A cylindrical core is loaded axially to failure, with no confinement (lateral support). Conceptually the compressive strength is measured by recording the peak stress (defined as the maximum load sustained by a specimen divided by its cross-sectional area). A total of 30 samples were tested which represents four (4) different grade of weathering degree. Each of the samples cored at size 110 mm x 55 mm according to the ISRM standard for sample size. The surface of the sample is ensuring to be flat and free from irregularities to avoid misinterpretation of the sample strength. Load is applied to the specimen continuously at a constant stress rate such that failure occurs within 5 to 10 minutes of initial loading – alternatively, the stress rate applied between 0.5 and 1.0 MPa/s.

3.1.3 P-wave velocity test

This laboratory test is aim to determine the compression or primary waves (P-wave) velocity. P-wave velocity Samples were prepared according to the various types of weathering degree. The equipment used in this laboratory test is a simple mechanism set-up (Figure 4) and this test is known as Pundit test method. Two cables were put at the surface of the rock core sample which one is emitter and the other is receiver. The main component of Pundit were generate wave and emit through the emitter which then the wave will go through the rock sample. The receiver will receive wave and the time taken of wave to travel per unit length is compression wave. Total 50 readings are taken for each sample in order to get the accurate average of compression wave.



chanism of Pundit test

3.1.4 Electrical resistivity test

This laboratory test is aim to determine the electrical resistivity of rock. Samples were prepared according to the various types of weathering degree. The equipment used in this laboratory test is a simple mechanism set-up. Samples clamped on the special base in order to make full contact between sample and conductor (copper plate). Two cables were clap at the copper plate on the surface of the rock core sample which consist emitter and receiver. The portable equipment were used to generate electric current emit through the emitter which then the wave will flow through the rock sample. Earth materials have different conductivity value and this will affect the resistance of that material. The receiver will receive electrical current and the conductivity of material is measured. Total 50 readings are taken for each sample in order to get the accurate average of resistivity value.

4. Result and Analysis

4.1 Porosity

As shown in Fig. 5, it can be generalized that the porosity increases as the degree of weathering increases (i.e., rebound number decreases). The macro scale porosity of weathered granite obtained from the saturation and caliper technique varies between 1.5 % and 14.0 %. It can be concluded that pore space expands and pore structure is developed due to the weathering process.

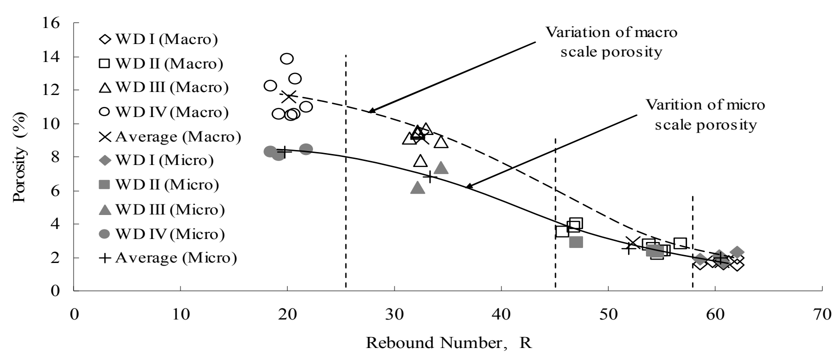


Figure 5: Variation of micro and macro scale porosity depending on the degree of weathering

The variation of micro scale porosity obtained from the analytical image process was slightly different from the variation of macro scale porosity. The micro scale porosities of tropical weathered granite ranged from 2 % to 8 %. The porosity of the relatively fresh rock (i.e., WD I and WD II) was as small as 4 % thus both approaches showed similar porosity range. On the other hand, porosity difference between two different methods became significant in moderate and highly weathered granite (i.e., WD III and WD IV): micro scale porosity was smaller than the macro scale porosity. From the electro microscopy images, it can be deduced that micro-cracks occur along the boundaries of mineral grain and contribute to the development of pore structure before the mineral grains begin to break.

4.2 Uniaxial compressive strength (UCS)

The uniaxial compressive strength of tropical granite is increases as the weathering degree increases as shown in Fig. 6. Reduction of strength is significant as the weathering degree in range of WD III and WD IV. The reduction of strength is approximately near 70% of its fresh state. Decomposition of rock properties caused by the alteration by chemical and physical disintegration has reduced the ability of rock to sustain the imposed load.

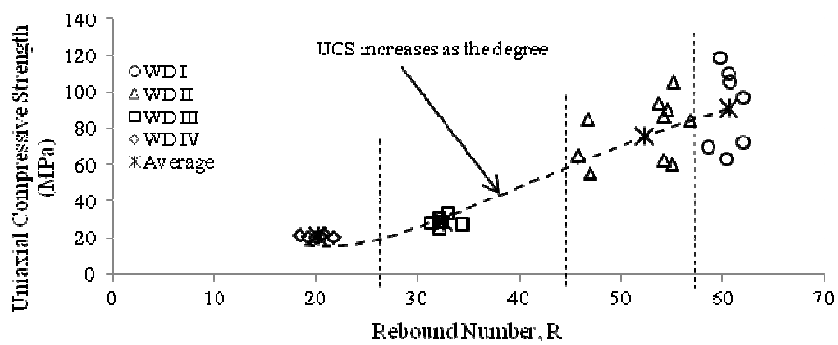


Figure 6: Uniaxial compressive strength of tropical granite depending on weathering degree

In fresh state, the properties of granite are properly preserved as the weathering process does not reduce the ability of rock to sustain the load, vertically and horizontally. As the weathering process take place, the ability of rock to sustain imposed load is gradually decreases as the property of tropical granite has changed. The present of secondary porosity (*n*) is the main factors that contributed to the strength reduction in tropical granite. In tropical humid climate, the process of chemical weathering is faster thus the rate of reduction in granitic rock strength increases.

4.3 P-wave velocity

From the Fig. 7, it is clearly shows that the compression wave velocity (P-wave) is increasing along the increase in number of rebound (R). It means that, the wave propagation is depending on the hardness of the material in which the wave travel in shorter time in harder material while it took more time to travel in material that have low hardness. Granite WD I is harder than WD IV, thus the compression wave value is higher. Moreover, it can be conclude that the compression wave is really depending on the degree of weathering. Thus, based on this situation it has the possibilities to characterize the degree of weathering based on the compression wave travel time in a rock mass.

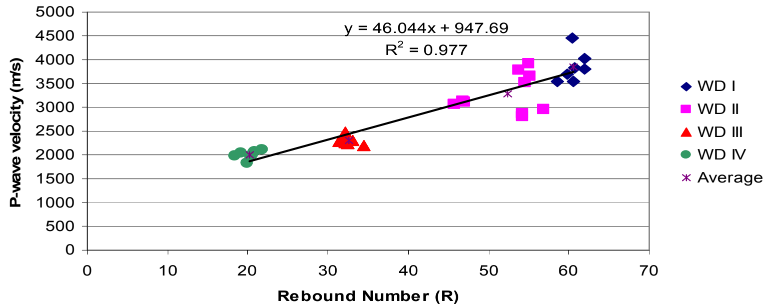


Figure 7: P-wave velocity depending on weathering degree

4.4 Electrical resistivity

Fig. 8 shows that the resistivity of samples is increases along with the rebound number for both dry and saturated state. Therefore it represents that for WD I the resistivity value is higher than the WD IV. Granite WD I have higher resistance ability to resist the current flow through its body compared to the Granite WD II, WD III and WD IV. Porosity, composition (clay mineral and metal content), salinity of the pore water, and grain size distribution is the factor contributing to the variation in resistivity. Resistivity of tropical granitic rock is depending on its state, whether it is dry or saturated. Water is one of the properties that affect the resistivity of the material. Table 4.6 shows the resistivity value of tropical granite in dry and saturated condition. Dry samples of granite has resistivity value from 2.48E+05 Ωm to 3.80E+06 Ωm while for saturated samples the resistivity value ranges between 1.20E+04 Ωm and 1.27e+04 Ωm. It shows that the resistivity of saturated samples is much lower compared to the dry samples.

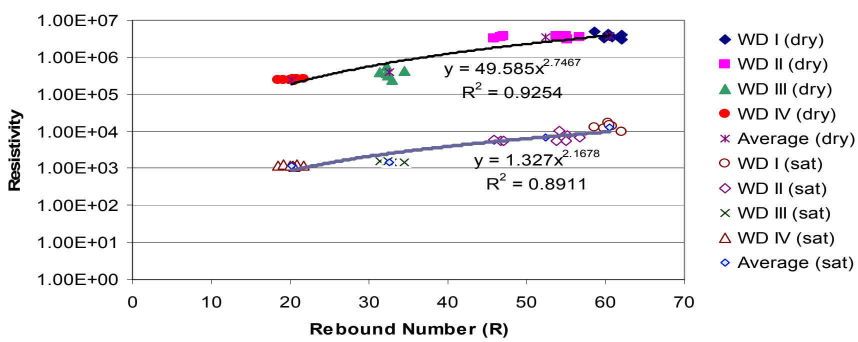


Figure 8: Electrical resistivity depending on weathering degree

5. Conclusion

The evaluation process of weathering of granitic rock by using specific methods of testing such as analytical image processing, uniaxial compressive strength test, P-wave velocity test and electrical resistivity test by taking into consideration the degree of weathering is presented in this study. The salient findings obtained from this study can be summarized as follows:

- Porosity increases as the weathering degree increases.
- Uniaxial compressive strength of rock decreases as the weathering of rock increases.
- Porosity has significant influence on the engineering properties: As porosity increases, compressive wave velocity, resistivity, and uniaxial compressive strength decrease.
- P-wave velocity is increases as the weathering degree decreases and the electrical resistivity of weathered rock is lower than the fresh state of rock.

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