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Assessment of Weathering Effects on Rock Mass Structure

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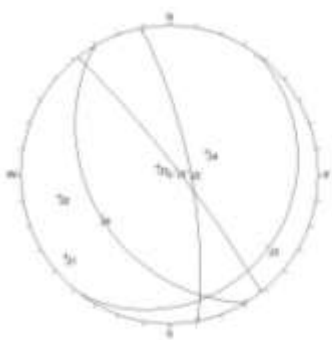
Graphical abstract



Abstract

This paper presents an assessment of weathering effect to the rock mass structure by studying the joint characteristics of tropically weathered granite. Joint survey was performed by scanline method and the results were analyzed statistically by stereographic projection plots. The overall trend of mean joint spacing followed a sharp decrement from fresh to moderately weathered zone and then a slight increment to highly and completely weathered zones, whereas the overall trend of mean joint trace length showed a gradual decrement over progress of weathering. In addition, the degree of joints inclination and weathering zones revealed an increasing trend in the percentage of horizontal joints from fresh to completely weathered rocks, while no specific relation was found between the numbers of major joint set and different weathering zones. The results of this study may contribute to understanding the behavior and better classification of weathered granitic rock mass as a heterogeneous mass in engineering works.

Keywords: Joint characteristics; stereographical projection; joint orientation; weathering zone

Abstrak

Kertas kerja ini membentangkan hasil kajian tentang penilaian luluhawa kepada struktur jasad batuan granit dalam iklim tropika. Kajian struktur batuan ini telah dijalankan dengan menggunakan kaedah garis imbas dan keputusan telah dianalisis secara statistik dengan plot unjuran stereografik . Hasil kajian mendapati jarak antara ketakselanjaran menyusut dengan ketara daripada zon segar kepada terluluhawa sederhana. Trend jarak antara ketakselanjaran ini bertambah secara beransur apabila zon luluhawa berubah daripada luluhawa tinggi kepada luluhawa sepenuhnya. Trend jarak antara ketakselanjaran ini mengecil apabila tahap luluhawa semakin tinggi. Di samping itu, ketakselanjaran ini didapati dominan dalam arah horizontal apabila tahap luluhawa bertambah. Bagi set ketakselanjaran yang bukan horizontal, tiada trend tertentu yang jelas dilihat. Keputusan kajian ini boleh menyumbang kepada pemahaman tingkah laku dan klasifikasi yang lebih baik berhubung jasad batuan granit sebagai bahan heterogen dalam kerja-kerja kejuruteraan awam.

Kata kunci: Ciri-ciri bersama; unjuran stereografikal; orientasi bersama; zon luluhawa

1.0 INTRODUCTION

The complexity of engineering behavior in weathered rocks that exist abundantly in the wet tropical region has become one of the major issues in foundation, slope stability, embankment failure problems and excavation which they are often associated. Weathering of surface rocks in tropical climates has produced thick weathering profiles. A thick weathering profile normally consists of a number of sub classifications or weathering grades which are based on their different characteristics.

Granites are amongst the most common rocks found in Johor Bahru area and large portion of Southern Peninsular Malaysia. As a result of quick and disordered development of urban areas, their weathering profiles are commonly related to several engineering problems such as landslides.

There are several studies attempting to describe rock weathering according to the type of rock and purpose of the associated engineering problem [1] such as Murphy [2], Moye [3], Ruxton and Berry [4], Dearman [5], Irfan and Dearman [6] and IAGE [7]. These engineering geology classification systems have generally been qualitative, and mostly related to granitic rocks [1]. Beside qualitative approaches, rock mass and rock mass weathering classification schemes are used. Such classification schemes mainly based upon some simple tests obtained through a large number of field data and statistical procedure [8].

Two of the earliest attempts to classify weathered rocks are derived from the classification for engineering purposes used by Moye [3] on the Snowy Mountains Scheme, Australia and the geological classification developed by Ruxton and Berry [4] for the Hong Kong granite. Both regions are dominated by chemical weathering although the full effects also include an important element of physical disintegration. Ruxton and Berry [4] considered the sequences of changes involving both chemical decomposition and physical disintegration of granite as a material, and also the distribution of these changes represented by the weathering profile in the rock mass.

Little [9] modified Moye's [3] classification by introducing rock soil ratios into a series of grades numbered from one for fresh rock to six for the residual weathered soil. Newbery [10] also adapted the Moye scheme to the granites of the Cameron Highlands of Malaysia. Fookes and Horswill [11] also adopted the Ruxton and Berry [4] approach by using both material and mass characteristics as diagnostic feature of distinctive mass weathering grades. The classification, published by Fookes et al. [12] with the addition of an indication of the engineering properties of each grade based on Little [9] was later recommended for mapping purposes [13].

Lee and De Freitas [14] presented a review of classification schemes proposed for granitic rocks and discussed commonly occurring difficulties associated with the description and classification of weathering grades and their distribution in rock masses. Important contributions were also made by Dearman [5, 15]. This author has shown that, for complex situations, the concept of weathering zones should be substituted by the mapping of weathering grades into the rock mass.

Initially, the study of the morphology of weathering profiles for granitic rocks was based on the division of notably different zones into the rock mass, through three parameters: soil/rock ratio, rock discoloration degree, and the presence of original structures, with no attention to rock matrix changes. However, partially because the model did not completely express field behavior and partially because of some confusion in the use of the method, the philosophy of the study changed and more attention to rock matrix was introduced. Several authors, institutions and technical associations have proposed their weathering classification schemes by considering rock matrix such as Anon [16], IAEG [7], and ISRM [17].

In general, most weathering classifications did not address the joints characteristics in different weathering zones. They were classified based on the engineering properties of weathered materials and typically describe the appearance and condition of the rock material (e.g. whether or not it is friable), the condition of individual minerals (e.g. degree of pitting and micro-cracking), changes in mineral composition (e.g. the disappearance of existing minerals and appearance of new ones), and the degree of staining on joint surfaces and/or the distance that staining extends into the rock from joints.

This paper assesses the effect of weathering on rock mass structure particularly joint characteristics in weathered granitic rock mass. Therefore, parameters of joint characteristics including joint spacing, joint trace length and orientation are considered.

2.0 SITE LOCATION

This study was carried out on a rock exposure of two active quarries in Masai, Bandar Seri Alam, Johor, Malaysia, as shown in Figure 1. Figure 2 shows the overview of quarry face in Masai and Putri Wangsa.

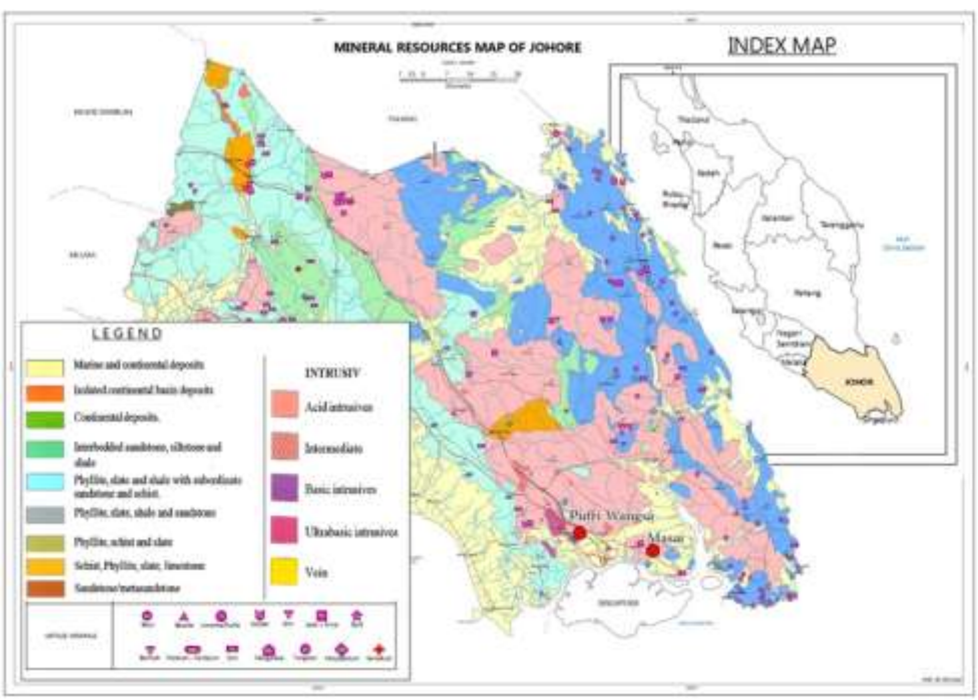


Figure 1 Geological map of the studied area [18]

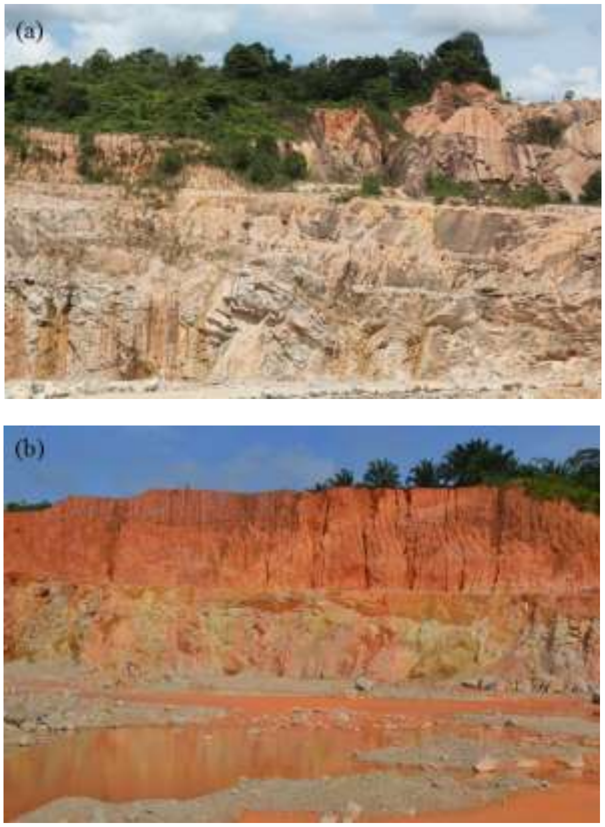


Figure 2 The overview of the quarry faces in (a) Masai and (b) Putri Wangsa

3.0 METHODOLOGY OF THE STUDY

Site investigation including observation and joint survey were performed in two areas of weathered granitic rock located in southeastern Asia. In both quarries a complete range of weathering zones from fresh rock (F) to completely weathered rock (CW) was present. Classification of weathered rock was done based on the most widely used scheme proposed by ISRM, International Society of Rock Mechanics [17].

Figure 3 Example of scanline sampling for joint survey

The scanline sampling scheme [19] was used to measure joint properties in this study. Joints to be measured were intersected with scanline in the outcrop, where a measuring tape was utilized as a scanline (Fig 3). Joints orientation, spacing and trace length were surveyed for each weathering grade in each quarry face.

The measured data from geological survey were combined in order to analyze joint characterization in different weathering zones by using Excel and Dips. In addition, mean joint spacing and trace length in each weathering zone were calculated and plotted.

Percentage of different types of joints including horizontal (<30°), inclined (30-70°), and vertical (>70°) were calculated [20-23]. Orientations of joints were input in Dips data sheets and major joint sets were determined for each weathering zone. The results were plotted on the rose diagrams.

4.0 RESULTS AND DISCUSSION

The scanline survey was applied to the quarry face of the mentioned quarries to obtain joints characterization. Joint spacing was measured as the distance between two joints which have intersected with a measuring line. The minimum joint spacing values were 10, 5, 5, 13, and 2 cm in fresh, slightly, moderately, highly, and completely weathered rocks, respectively. The minimum trace length captured for fresh to completely weathered rocks were respectively 23, 15, 14, 18, and 8 cm. Table 1 illustrates number of measured data, mean joint spacing, and mean joint trace length in different weathering zones in each studied site.

Figure 4 and 5 show the mean joint spacing and mean joint trace length in different weathering zones, respectively. Based on statistical analysis of combined data, mean joint spacing suddenly drops from fresh to slightly weathered and continues a decrement to moderately weathered and then increases slightly to highly and completely weathered zone. Mean joint trace length decreases gradually over progress of weathering from fresh to completely weathered zone.

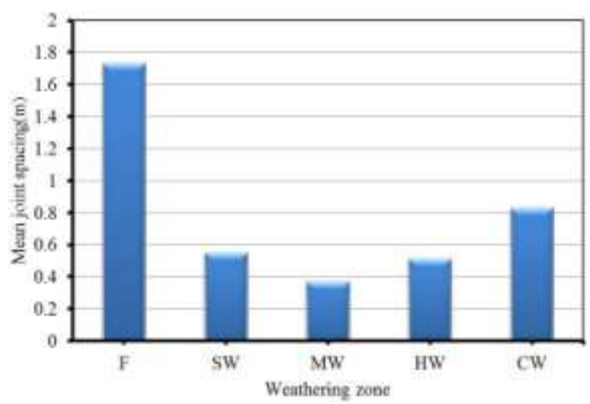


Figure 4 Mean joint spacing versus weathering zones

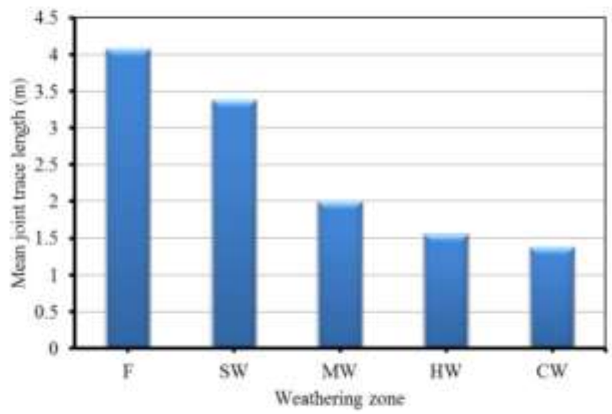


Figure 5 Mean joint trace length versus weathering zones

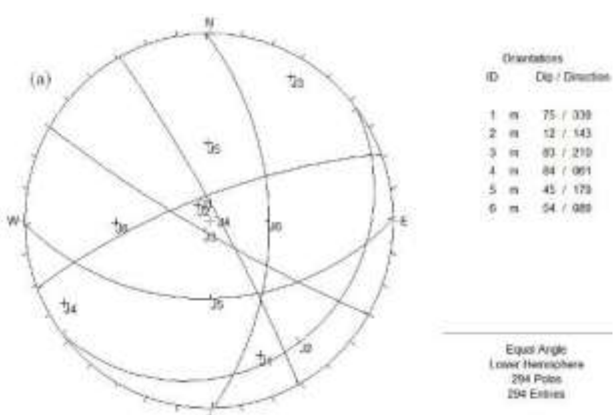
Based on stereographical projection analysis, the changes in number of joint sets and percentage of horizontal, inclined, and vertical joints were obtained.

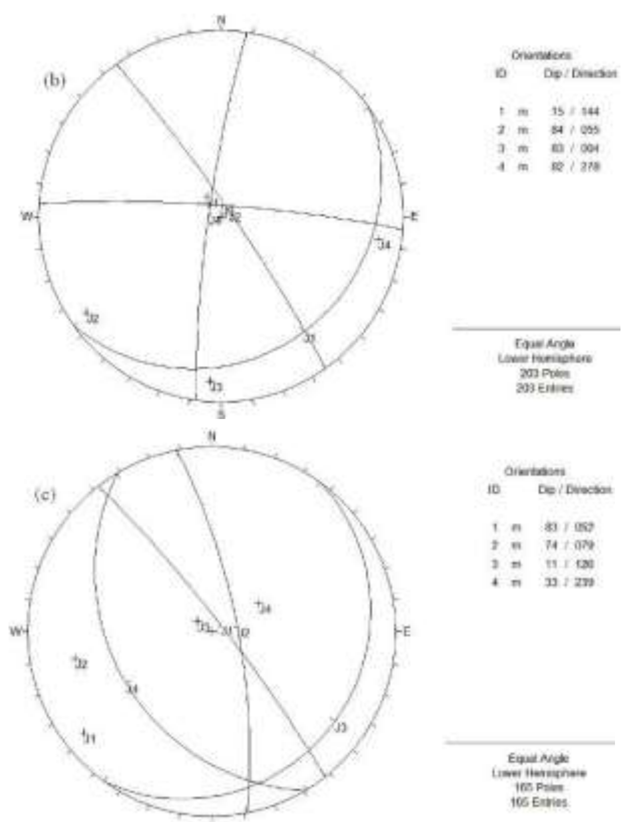
Table 1 Mean joint spacing and mean joint trace length in different weathering zone

Weathering zone	Joint spacing				Trace length			
	Masai		Putri Wangsa		Masai		Putri Wangsa	
	N	Mean (m)	N	Mean (m)	N	Mean (m)	N	Mean (m)
F	294	1.57	281	1.88	294	4.13	281	4.02
SW	203	0.61	305	0.51	203	3.36	305	3.39
MW	165	0.4	132	0.33	165	2.14	132	1.82
HW	253	0.53	314	0.49	253	1.45	314	1.64
CW	326	0.73	253	0.95	326	1.39	253	1.37

Figure 6 shows the number of major joint set and their orientations in each weathering zone. According to stereographical projection analysis, the number of major joint sets was 6, 4, 4, 6, and 3 in fresh to completely weathered zone, respectively. As a result, no significant relation was found between number of major joint set and different weathering zones.

The result of statistical analysis of joint inclination shows an increasing trend in the percentage of horizontal joints from fresh to completely weathered rocks. In contrast, a decreasing trend was found in the percentage of vertical joints for the same weathering progress. The percentage of inclined joint fluctuated in different weathering zones.





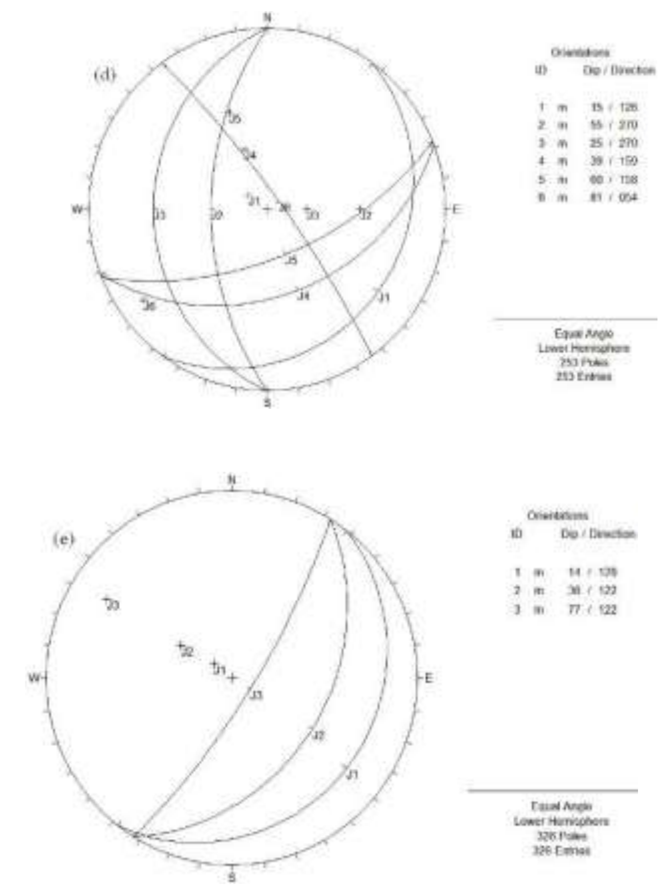


Figure 6 Major joint sets in (a) fresh, (b) slightly weathered, (c) moderately weathered zone, (d) highly weathered, and (e) completely weathered zones

■5.0 CONCLUSION

This paper assesses the weathering effect on rock mass structure by considering changes in joint spacing, joint trace length and joint orientation. The results show that minimum and maximum means of spacing belonged to moderately weathered and fresh zones, respectively. However, the overall trend of mean joint trace length had a gradual decrement from fresh to completely weathered zone. Another finding of the present paper was the relation between joints inclination and weathering zones. The results revealed an increasing trend in the percentage of horizontal joints along with the progress of weathering from fresh to completely weathered rocks. This finding can be significant in engineering activities such as excavation which are sensitive to inclination of joints. However, no specific relation was found between the numbers of major joint set and weathering zones. It is expected that the results of this study contribute to understanding the behavior and distribution of joint characteristics with respect to different weathering zones of granitic rock mass.

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