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Dominant weathering profiles of granite in southern Peninsular Malaysia

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ABSTRACT

One of the most important challenges in the study of slope stability, foundations, and excavation of rocks is to understand their weathering states. This issue is more important in tropical climates, where severe weathering produces thick weathering profiles with different sequences of weathering. Thick weathering profiles are normally classified or graded, based on field observation, geological studies, and the material properties of the rocks. This paper presents the results of an extensive study of changes in the geological and morphological characteristics of granite in a tropical region due to severe weathering. A total of 40 panels of rock exposure were studied in four active granite quarries located in Johor, southern Peninsular Malaysia. The proposed dominant weathering profiles of granite are mainly based on the sequences of weathering zone, topography and geological conditions, joint characterization, and the dominant color of rock material. In addition, two additional weathering subzones are introduced in the completely and the highly weathered zones based on the presence of corestones (boulders). It is believed that the proposed dominant weathering profiles can contribute to engineering design and the classification of weathered granitic rock in the tropical region.

1. Introduction

Identification of dominant weathering profiles is important to engineering works related to weathered rock masses (Moye, 1955; Ruxton and Berry, 1957; Anon, 1995; Komoo, 1998; Raj, 2010). In engineering fields (such as civil or mining activities) rock mass weathering profiles are useful for the preliminary stages of design and planning (Verma and Singh, 2009; Jahed Armaghani et al., 2013; Kalatehjari et al., 2013). Weathering effects may vary from place to place because of rock types and structure, topography, rate of erosion, and regional climate variations. Weathering is more intense in tropical regions due to heavy rains and hot and humid climatic conditions, which develop weathering effects to greater depths than elsewhere (Komoo, 1995). Weathering profiles in tropical regions have specific features such as abrupt changes between different weathering zones and the presence of fresh rock blocks (corestones) within a matrix of severely weathered rock material, which are difficult to predict. Despite the mentioned complexities, the recognition of the dominant weathering profiles of granite in these regions is still in its early stages, and only few studies have been carried out on it (e.g. Komoo, 1985; Zhao et al., 1994; Raj, 1998). Therefore, to provide a basic understanding of the complex behavior of weathered granite in tropical regions, more studies are needed to determine the dominant weathering profiles and their characteristics. Based on the dominant profiles, preliminary site investigation for any civil engineering projects such as slope, foundation and excavation can be more effectively carried out. In addition, the dominant weathering profiles can be used later to develop a typical weathering profile for a rock mass.

Dearman (1974, 1976) played an important role in the classification of weathered rock masses by suggesting that for complicated conditions weathering zones could be mapped into the rock mass based on different weathering zones. Several attempts have been conducted to give a complete description of rock weathering based on the type of rocks and the associated engineering problems (Moye, 1955; Ruxton and Berry, 1957; Dearman, 1976; Matula, 1981; Murphy, 1985). Generally, the classification systems of engineering geology have been qualitative descriptions of weathered rock masses, which are typically related to granitic rocks (Arel and Önalp, 2004). Komoo (1987) proposed that the dominant mass weathering profiles for granitic rock in Peninsular Malaysia are types A and B. The main difference between these types is the distribution of corestones in different weathering zones. Moreover, abrupt changes of weathering zones were only reported in type A. In addition, a material weathering profile was proposed for granitic rock in tropical regions by Komoo et al. (1991). This profile is based on the discoloration of material, textural preservation, mineral composition, and the strength or friability of material. Zhao et al. (1994) studied Bukit Timah granite in Singapore to develop a weathering profile and determine a method for estimating the strength indices of granitic rock mass. This profile included both material and mass descriptions.

Lee and De Freitas (1989) reviewed the schemes that have been introduced for the classification of weathered granitic rocks. They also discussed the most common problematic issues in the classification

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and the description of weathering grades and their distribution in the rock masses. Overall, the few studies of weathered granite in the tropical regions are able to provide a comprehensive description of the dominant weathering profiles of granite required at the early stages of engineering design.

This paper proposes the dominant weathering profiles of granitic rock in southern Peninsular Malaysia, an area that has tropical climatic conditions. Field mapping, joint surveys, and observations were conducted on 40 panels of rock exposures located in four active quarries: Segamat, Seri Alam, Trans Crete, and Wax Green. The results of the study were used to propose the dominant weathering profiles of granitic rock in the studied region.

2. Site investigation and data analysis procedure

The study of rock mass was conducted in four areas of weathered granite located in Johor, the southernmost province of Peninsular Malaysia, to establish the dominant weathering profiles. The geological map of the studied area, which is from the late Cretaceous to early Tertiary period, is presented in Fig. 1 (Rajah et al., 1982).

The location of the quarries of Segamat, Seri Alam, Trans Crete, and Wax Green are shown in Fig. 2. This study included observation and field mapping, the division of selected rock exposures into panels, the identification of weathering zones, determination of the topography and geological conditions, the survey of the discontinuity characteristics, and the preparation of sketches of weathering zones for each panel. Four selected rock exposures including 40 panels were surveyed and investigated in this study: 13 panels at Segamat, 11 panels at Seri Alam, and 8 panels each at Trans Crete and Wax Green quarries.

Three topography conditions, termed 'crest,' 'side,' and 'valley,' were defined for the highest, middle, and lowest elevations in the selected rock exposures, respectively. The rock exposures ranged from 4 to 31 m in height and were divided into panels of 12 m width. In addition, different zones were identified in each panel based on the existing weathering zones. The identification of weathering zones was carried out on the basis of the most widely used weathering classification, which is proposed by International Society for Rock Mechanics (ISRM, 2007), as presented in Table 1.

Although a complete range of weathering zones from fresh rock (F) to completely weathered (CW) rock was observed at selected rock exposures of Segamat, Seri Alam, and Wax Green quarries, moderately weathered (MW) rock was not found at the selected rock exposure at Trans Crete quarry. After the identification of weathering zones, visual inspection was carried out to identify other geological features including the faults and corestones in each panel. Based on corestone occurrence, highly weathered and completely weathered zones were divided into subzones, as indicated by the a and b indices. The thickness and dominant color of the rock material were recorded in each weathering zone. The dominant color of the rock material in each weathering zone was obtained by spinning the relevant rock sample like a color disc, or by looking closely at the sample to see a monochromatic color (Munsell, 2009). Fig. 3 provides illustrative sketches of rock exposures in the quarries prepared on the basis of the identified weathering zones and the geological features within each panel. The rose diagrams of panels illustrating the strikes of the major joint sets are presented below the panels.

In order to characterize the discontinuity of the selected rock exposures, the scanline method was employed; this was because it is simple and is able to provide more detailed data than alternative survey methods such as the window mapping method (Gumede and Stacey, 2007; Şen, 2013). The length of the scanline selected was between 2 to 15 m, based on the recommendations of Priest and Hudson (1976) and ISRM (1981), and through discontinuity survey orientation, spacing, trace length, aperture, infilling material, and roughness of joints were recorded.

The recorded orientations of joints were combined to analyze their dominant behavior in different weathering zones by using the Dips 5.0 software package (Rocscience, 2000). The distribution of other joint characterizations of the different weathering zones were determined by frequency histograms and simple statistics. In addition, the percentage of different types of joints were calculated, including horizontal (<30°), inclined (30–70°), and vertical (>70°).

3. Geology and weathering zones of the investigated sites

Based on the topographic conditions, the crest, side, and valley in Segamat quarry, the crest and side in Seri Alam and Trans Crete quarries, and the crest in Wax Green quarry were observed. Geological features including corestones and normal faults were identified in Segamat and Seri Alam quarries, whereas corestones were observed in Trans Crete and Wax Green quarries. The maximum corestone diameter of 6.5 m

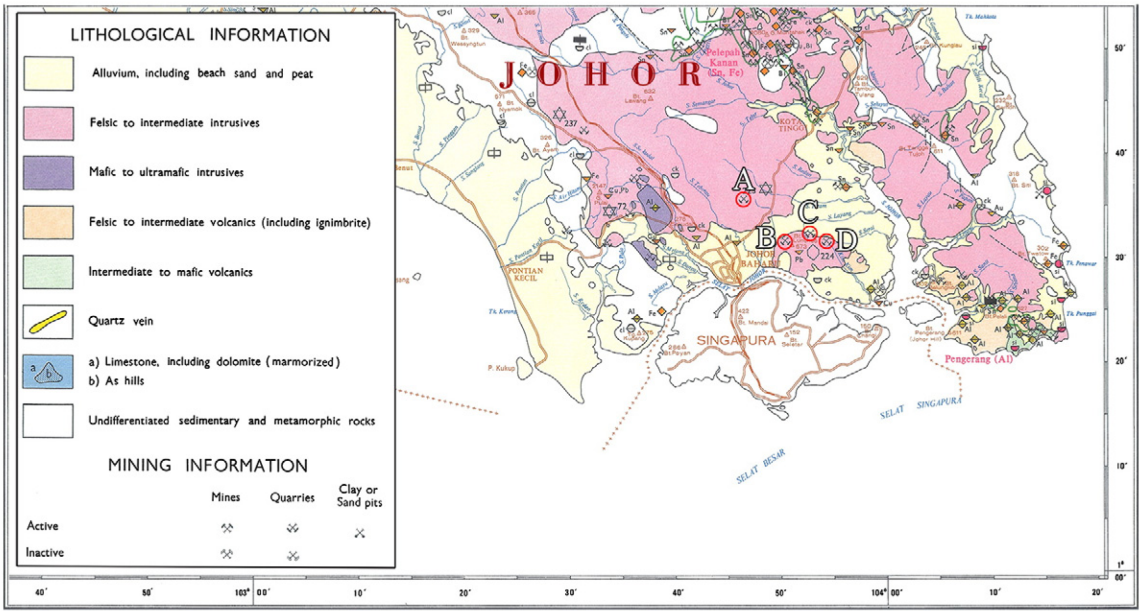

Fig. 1. Geological map Johor, Malaysia (Rajah et al., 1982). (A) Segamat quarry, (B) Seri Alam quarry, (C) Trans Crete quarry, and (D) Wax Green quarry.