Engineering Geological Characterization of the Weathering Profile of Low-Grade Metamorphic Rock with Particular Reference to the Soil–Rock Boundary, A Case Study at UKM, Malaysia

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Abstract: Weathering has affected most ground mass at shallow depth. This research approach is to determine rock and soil properties of low-grade metamorphic rock as well as to assign them according to their weathering grade and to delineate the soil and rock boundary. From the laboratory results it was found that soil samples from Universiti Kebangsaan Malaysia (UKM) are well graded silty sand with low to medium plasticity. From the laboratory analysis for rock, it was found that > 60% of the Schmidt hammer rebound values fall into the weathering grade III as well as the porosity ranges from 7.4% to 8.9% indicating that the rock samples are in weathering grade III. But the soil samples did not give any Schmidt hammer readings. Point load and UCS values of the samples range from I_{s50}, 0.90 to 1.51 MPa and UCS values, 15.03 to 26.06 MPa respectively. UCS value from the point load test was derived with the help of α = 18.6. From the slake durability test of rock samples, they showed greater durability index (Id_3%) > 88 and for the soil samples (Id_3%) range from 18 to 29% and some soil samples showed < 10%. Slake durability test indicates that the rock samples are in weathering grade III and some soil samples are in weathering grade IV, Vand VI. From the above observation, the rock and soil boundary is between weathering grade III and weathering grade IV.

Keywords: ***Weathering grade, Rock-Soil boundary.***

Introduction

In the tropical region like Malaysia most of the surface area is covered by weathered or weak rocks. The tropical climate such as Malaysia is known to produce the unique weathering profiles and heterogeneous physical deterioration of rock mass (Komoo 1995a, Fookes 1997, Zainab 2004). In Peninsular Malaysia, deep weathering profile is found over a wide variety of bedrock types and have developed largely because of prolonged weathering throughout the Cenozoic (Raj 1982). The weathered profile, consisting of layers of weathered rock topped by soil, develops in response to chemical, physical and biological processes at the Earth's surface. The strong interplay among these processes makes it difficult to disentangle their interactions in the weathered profile. Physical weathering processes expose fresh rock and mineral surfaces to chemical weathering, whereas chemical weathering reduces the strength of rock, making it more susceptible to physical breakdown. The interactions between these processes are widely recognized as critical in understanding the effects of changes in climate and of tectonic uplift rates on erosion (Raymo et al. 1988), landscape evolution (Anderson and Humphery 1989), and geochemical cycling (Gaillardet et al. 1999a). The balance between removal of debris by transport processes and breakdown of rock into movable material by weathering exerts a strong control on landscape evolution. G.K. Gilbert described the linkage between regolith production and erosion rates, now codified by geomorphologists who differentiate.

Objectives of Research

The main objective of this research is to study the geomechanical properties of soil and rock. This research was also designed to achieve the following objectives:

- To identify the engineering geological characteristic of weathering profile of low-grade metamorphic rock.
- To analyze the relationship between various parameters determining the strength of soil and rock.
- To differentiate soil and rock boundary.

Study area

The study area is in UKM campus and Kajang-2. The areas are respectively about 5 and 10 kilometers from Bandar Baru Bangi. Samples were collected from different locations in UKM campus and from the construction site of Kajang-2 which falls within the coordinate of latitude 2º55'08.40'' and longitude 101º46'13.03'' to latitude 2º58'04.10'' and longitude 101º48'16.29''. Based on the initial survey of the area, the lithology of the area is made up of weathered schist. This is shown in Geological map and in satellite image in Figure 1. The study area is located on the

Kajang Schist Formation. Kajang Schist Formation is in the range of Silurian age up to Devon.

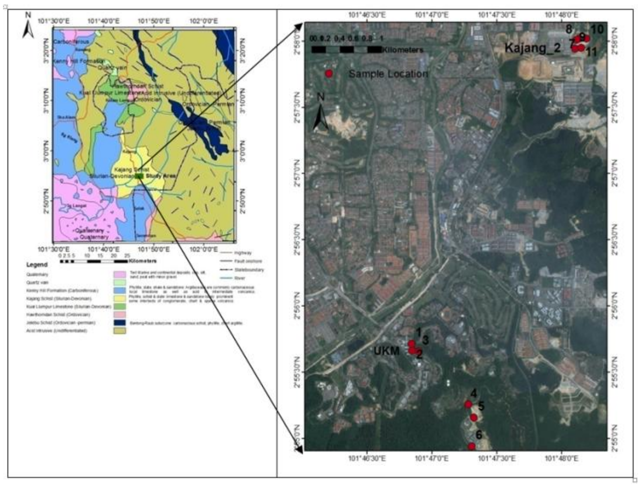

Figure 1, Geology map and Satellite image of the study area

Source: Geological Map of Peninsular Malaysia modified from Geological Survey Department of Malaysia (1985) and Google Earth 2014 date 05-11-2014.

Methodology

Methodology of this research includes the laboratory tests conducted to determine the mechanical properties and durability of low-grade metamorphic rock and soil. The equations which were applied for data analysis were also given together. The main problem when conducting laboratory testing for low grade metamorphic rock is that most techniques and tests have been designed for soil and hard rock materials. Since the weak rocks are fragile and prone to break along with their lamination, cylindrical coring of the rock sample was minimized, and rectangular cutting sample was preferred. The soil mechanics laboratory tests are conducted for the determination of soil properties. These laboratory tests include Grain size analysis test and Atterberg limit test. Laboratory tests for rocks are conducted to determine the mechanical properties of rock and physical properties of rock. Rock mechanics laboratory test consists of Schmidt hammer rebound hardness test, Point Load Index Strength (PLS) test, Uniaxial Compressive Strength (UCS) test. The physical properties test conducted include porosity test, dry density test. Uniaxial compressive strength is the most popular strength test for geotechnical design. This is because most empirical geotechnical design is based on uniaxial compressive strength. As for weak rock it was found that point load strength test has greater advantages due to its flexibility on sample size and shapes.

Samples were collected in the proper way from different excavated sites of UKM and from Kajang-2 and brought back to the laboratory for characterization and comparison through different mechanical testing. All the rock mechanics laboratory tests were performed according to International Society of Rock Mechanics (ISRM) Suggested Methods (2007). Table 1 shows the standard geotechnical laboratory tests to determine soil and rock properties.

Table 1, Standard geotechnical laboratory tests for soil and rock.

Test	Properties determined	Reference
Soil index properties		
Particle-size analysis	Grading, soil fractions, classifications	ASTM D 422
Atterberg limits	Plasticity charts, soil classification	ASTM D 4318
Rock physical properties laboratory test		
Porosity test	Porosity of the tested sample	ISRM (2007)
Dry density test	Dry density of the tested sample	ISRM (2007)
Rock mechanics laboratory test		
Schmidt hammer rebound test	Hardness determination of rock	ISRM (2007)
Point load test	Strength classification of rock	ISRM (2007)
Uniaxial compressive test	Strength classification of rock	ISRM (2007)
Slake durability test	Rock durability	ISRM (1981)

Result

For soil samples, grain size analysis with sieve analysis and hydrometer analysis gave the soil classification and their gradation as the soil samples are well graded in the UKM study area. Through Atterberg limit test liquid limit and plasticity index were determined. Liquid limit of the tested samples ranges from 32 – 40 and plasticity index from ranges 5.5 to 16. Schmidt rebound hammer values were taken against the rock samples which varies from 12 to 43, from which according to the standard gradation more than 60 % to 92.5% of the rebound values fall into the weathering grade III. Point load test values of Is_{50} for the tested samples varies from 0.6 to 1.5 MPa and UCS values of the tested samples range from 17 to 29 MPa. Dry density and porosity of the rock samples have also been determined and their dry density ranges from 2.04 to 3.09 (g/cm3) and their porosity ranges from 7.43 to 8.98 %. Porosity of the rock is high, and their range makes them as weathering grade III rock type. Slake durability test was performed on rock and soil samples to determine their durability as well as their weathering grade. Through the test rock samples durability index Id_2% and Id_3% were found to range from 90 - 93% and 88 - 91% respectively. Which makes the rock sample fall into weathering grade III and for the soil samples, three of them showed the durability $Id_2\%$ and $Id_3\%$ ranging from 27 to 39% and 16 to 29% respectively letting them fall into weathering grade IV and the rest of the sample did not survive > 10%, which makes them fall into weathering grade V and VI (Table 2).

Table 2, Summary table to identify weathering grade and rock and soil boundary.

Weathering grade	Porosity %	Schmidt hammer reading (SH)	Durability class	Slake durability index ($Id_1\%$)	Slake durability index ($Id_2\%$)	Slake durability index ($Id_3\%$)	Remark	
I	< 1	> 49	Very high durability	> 99	> 98	-	Rock	
II	1 – 5	33 - 49	High durability	98 - 99	85 - 98	-	Rock	
III	5 -10	10 - 33	Medium high durability	94 -95	90 - 93	88 - 91	Rock	Rock
IV	-	-	Medium durability	58 - 73	27 - 39	16 - 29	Soil	Soil
V	-	-	Low durability	-	-	-	Soil	Boundary
VI	-	-	Very low durability	-	-	-	Soil	

Correlation of rock and soil samples through their durability index $Id_2\%$ and $Id_3\%$ showed that rock samples can stand up to 10 to 12% loss of original weight whereas some soil samples have lost as much as 60 to 85% of their original weight and others have completely lost their original weight. Correlation of slake durability index $Id_3\%$ and point load test showed that this rock having Is_{50} values ranges from 0.6 to 1.5 MPa. As well as correlation of slake durability and UCS and correlation of UCS and point load test have been shown.

To differentiate soil and rock boundary through the hand sample experiment and through the Schmidt rebound hammer test, porosity analysis and through slake durability tests. Rock samples have the Schmidt rebound values whereas soil samples have no or < 10. Porosity ranges from 7 to 9% of the rock samples indicating the rock is in weathering grade III. For the slake durability test rock samples showed high durability > 85% which makes them fall into weathering grade III and for the soil samples, they showed the low durability < 50%, making them fall into weathering grade IV. From the above observations and test results it can be said that the soil and rock boundary is in between weathering grade III and weathering grade IV.

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