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Impact of Weathering on Rock Strength by Schmidt Hammer Test

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ABSTRACT

Rock strength is an important parameter of rock mechanics properties. Uniaxial Compressive Strength test has been widely applied to analyses the rock strength. However, this method is time consume and expensive. In this research, another method was proposed to predict the rock strength by Schmidt Hammer test based on the rebound values. Fourteen rock samples of Basalt have been collected from Gowa district South Sulawesi, Indonesia. The rock samples were classified as four types based on weathered degree by petrographic analysis, from the fresh to weathered rocks including Slightly Weathered (SW) class II, Moderately Weathered (MW) class III, Highly Weathered (HW) class IV and Completely Weathered (CW) class V. Schmidt Hammer test was applied to predict the rock strength by the rebound values. The result shows that the rock strength influenced by weathered rock. The rock strength decrease when the degree of weathering of rock increases.

Key Words: Rock strength, UCS, Schmidt Hammer, Weathered rock, Petrography

INTRODUCTION

Compressive strength is an important parameter of rock mechanics properties. Rock engineers widely use the Uniaxial Compressive Strength test (UCS) of rocks in mining and infrastructure activities. For measuring this rock strength, the procedure has been standardized by both the International Society for Rock Mechanics (Brown, 1981) and American Society for Testing and Materials (ASTM, 2001). The rock sample should be prepared into some requirements, therefore the method is time consuming and expensive. Schmidt hammer is a simple test to predict the UCS. This test is easier to carry out because it necessitates less or no sample preparation, non-destructive, and the testing equipment is mobile. Also, it can be used easily in the field (Schmidt, 1951). Some researchers have been developed application of Schmidt hammer to predict the rock strength such as Brown, 1981, Cargil and Shakoor, 1990, Torabi, 2005, Torabi et al., 2010, and ASTM, 2005.

Index to strength conversion factors between UCS method and Schmidt hammer have been proposed by a number of researchers and have been found to be rock dependent. Those researches applied only in one condition of fresh rock (Aggistalis, 1996, Katz et al., 2000, Yilmaz and Sendir, 2002, Yasar and Erdogan, 2004, Fener et al., 2005, and Kilic and Teymen, 2008). There is no reported research in this regard for weathered rock condition from Indonesia. The aim of this study is to find influence of the rock weathered grade on rock strength that predicted by Schmidt hammer.

For these purpose fourteen rock samples of basalt collected from Gowa district, South Sulawesi, Indonesia. The weathering grades of rock identified at field area, and analyzed by petrographic analyses. The rock strength is then predicted by Schmidt hammer for every rock weathering grades.

METHODS

Field Investigation and Sample Collection

The field area is conducted at a rock quarry mine located in Gowa district, Sulawesi Selatan province, Indonesia. The rock sample is Basalt a member of Baturape Cindako volcanic rock Formation. The rock condition is identified to classify the weathering grade.

Rock samples were taken for every different condition of rocks for petrographic analyses. In addition, Schmidt hammer test also investigated for every weathering condition of rock based on horizontal test.

Sample Preparation

The rock samples were prepared for laboratory Schmidt hammer test and also for thin section to analyze mineral content.

Mineralogy Analysis

The rock weathering grades were classified based on altered mineral as a result of weathering process. The analysis uses petrographic to identify the mineral contents.

Rock Physical Properties Test

There are two physical properties were measured i.e. density and porosity of the rock. The test results were applied to find correlation between rock weathered grade to physical properties.

Schmidt Hammer Test

The Schmidt hammer test was performed in accordance with ISRM standard methods. The test was measured at the field location on in-situ rock and also into laboratory test. For the laboratory test the rock sample was prepared as a block sample 10x10x10 cm^3 dimension. The test measured for 20 times and the results were averaged.

RESULTS and DISCUSSION

Characterization of Weathering Grade of Rock

Field observation identified four weathering grades of basalt occur at the field area. The classification of weathering grades based on the visual observation show different discoloration, discontinuity, and hardness of rock occur on different the weathering grades. The results obtained from the field investigation allowed us to classify the weathering grades into four (4) grades (Anon, 1995) i.e. Slightly Weathered (SW) as class II, Moderately Weathered (MW) as class III, Highly Weathering (HW) as class IV, and Completely Weathering (CW) as class V.

The weathering grade of Slightly Weathered (SW-class II) of basalt shows slight discoloration on rock surfaces. Oxidation occurs in a small part of rock fracture with brown discoloration. Spacing of discontinuities occurs between 0.5 to 1.5 m. The rock is hard and difficult to destroy by geological hammer.

Extensive discoloration occurs in classification of Moderately Weathered (MW-class III). Joints present extensive filled by clay minerals. Oxidation with brown color more extensive compare to the rock weathering grade of SW-class II. Discontinuities occur on 20 to 60 cm of spacing. The hardness of MW weathering grade also more weakness compare to SW class.

Characteristics of Highly Weathered (HW-class IV) can be seen as below: discontinuities occur on 5-15 cm of spacing filled by soil material. The color of rock material is dull gray-greenish green with brown color of fracture. The rock in this weathering grade is very weak and easily destroyed by geological hammer.

Most of the rock changes into soil with some original rock texture can be seen in the Completely Weathered (CW-class V). Discoloration occurs particularly around joint surrounding. On the top of the basalt outcrop, weathering process of basalt has been completely removes the rock texture to be soil. The soil material is very weak and easily to destroy. Figure 1 shows profile of weathering grade of basalt, and Figure 2 shows characteristic of rock weathering grade of basalt.

Based on petrographic analysis, secondary minerals occur due to weathering process. Clay minerals as a result from weathering process increase when the weathering grade of rock increases. Otherwise, plagioclase and pyroxene decrease when the weathering grade increases. Table 1 shows mineralogical percentage on weathering of basalt and Figure 2 shows photomicrograph of weathering grade of basalt.

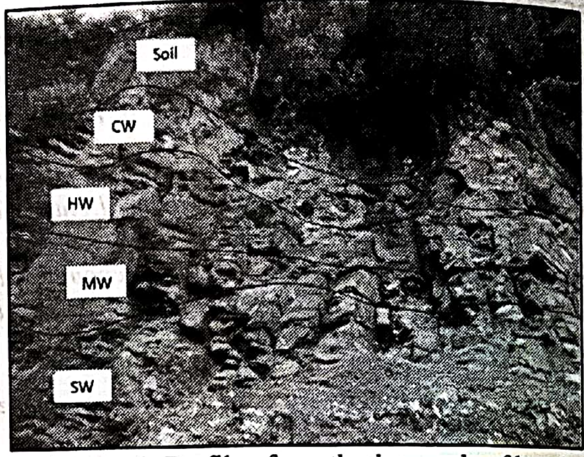


Figure 1. Profile of weathering grade of basalt

Rock Physical Properties

The rock physical properties test was measured for 4 rock samples of each weathering grade. The results of the rock physical properties are given in Table 2. Density values range 1.76 to 2.91 gr/cm^3 for completely weathered to slightly weathered, respectively. Those results shows that the density of basalt decrease when the weathering grade increase. Porosity values range 40 to 4.22 % for completely weathered to slightly weathered, respectively. Influence of the weathering grade of basalt on porosity values contrast with the density values. The porosity values of basalt increase when the weathering grade increase.

Schmidt Hammer Test

The Schmidt hammer test was conducted for 14 rock samples of basalt. The mean values of Schmidt hammer rebound values are listed in Table 3. The rebound values range from 14.22 to 34.80. In addition on the soil condition, there is no rebound values of Schmidt hammer can be measured.

On the class II of weathering grade, the values of Schmidt hammer rebound range from 30.48 to 34.80. Those values are the highest rebound values compare to other weathering grade class. The rebound values of Schmidt hammer decrease when the class of weathering grade increase. On the class III, the values of Schmidt hammer range from 24.15 to 28.50, and become 20.08 to 23.23 on the class of IV of weathering grade. On the class V of weathering grade, the values of Schmidt hammer range from 14.22 to 16.30. The values are the lowest rebound values compare to other weathering grade. In addition, on the soil condition the values of Schmidt hammer cannot be measured.

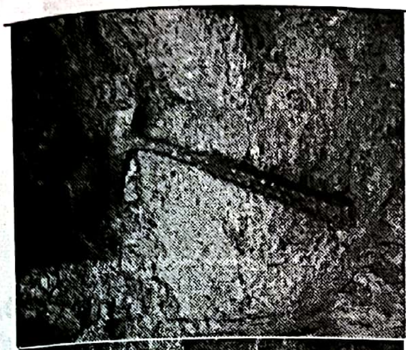
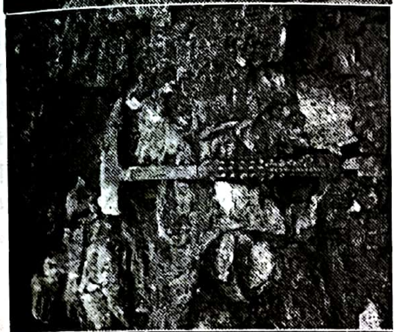
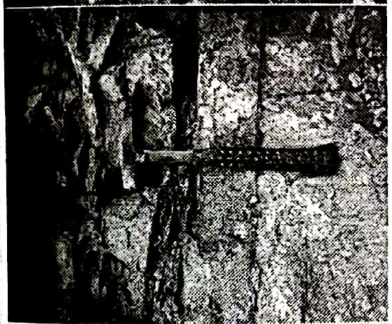
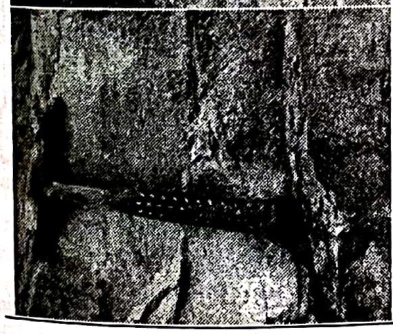
Rock Photos	Characteristics	Weathering grade
	Most of the rocks changes into soil, but still show the rest of the original rock texture. Discoloration particullarly occurs in all parts of the rock that is grayish white. Spheroidal weathering also present in this weathering condition. The mineral content has been disintegrated, therefore discontinuity is difficult to find. Rocks strength very weak and it can be destroyed by hand.	CW (class V)
	Discontinuity on this weathering is very tight between 5-15 cm with filled by material in the form of soil. The hallmark of this section is the presence of spheroidal weathering and corestone. The color of the rock material is a dull gray-greenish green with brown color suroinding the fracture. Rocks are very easily destroyed using geological hammers.	HW (class IV)
	Extensive discoloration in almost all rock surfaces and the development of more intensive discontinuity, so that the hardness of these rocks decreases. Rocks structure was block joint structure. Condition of this weathering grade is material dominated by rocks with a distance of discontinuity (20 - 60 cm) and joint filled with brown ground. The rocks are easily destroyed with geological hammers.	MW (class III)
	Slight discoloration on rock surfaces and discontinuity. Gray colors are duller (fresh gray bluish) and on some parts of the rock body undergoes oxidation that produces a brownish red color. Discolorations also occur in the burly boundaries of columns to a brown color spaced between 0.5 to 1.5 meters. Hard and compact, difficult to destroy using geological hammers.	SW (class II)

Figure 2. Characteristic of rock weathering grade of basalt

Table1. Mineralogical percentage of weathering grade of basalt

Sample	Weathering Grade	Mineralogical prosentage (%)				
		Plagioclase	Pyroxene	Clay	Opaque	Rock mass
AM_04	II	45	15	-	5	35
AM_03	III	37	15	5	3	35
AM_02	IV	32	13	20	5	30
AM_01	V	12	10	60	5	13

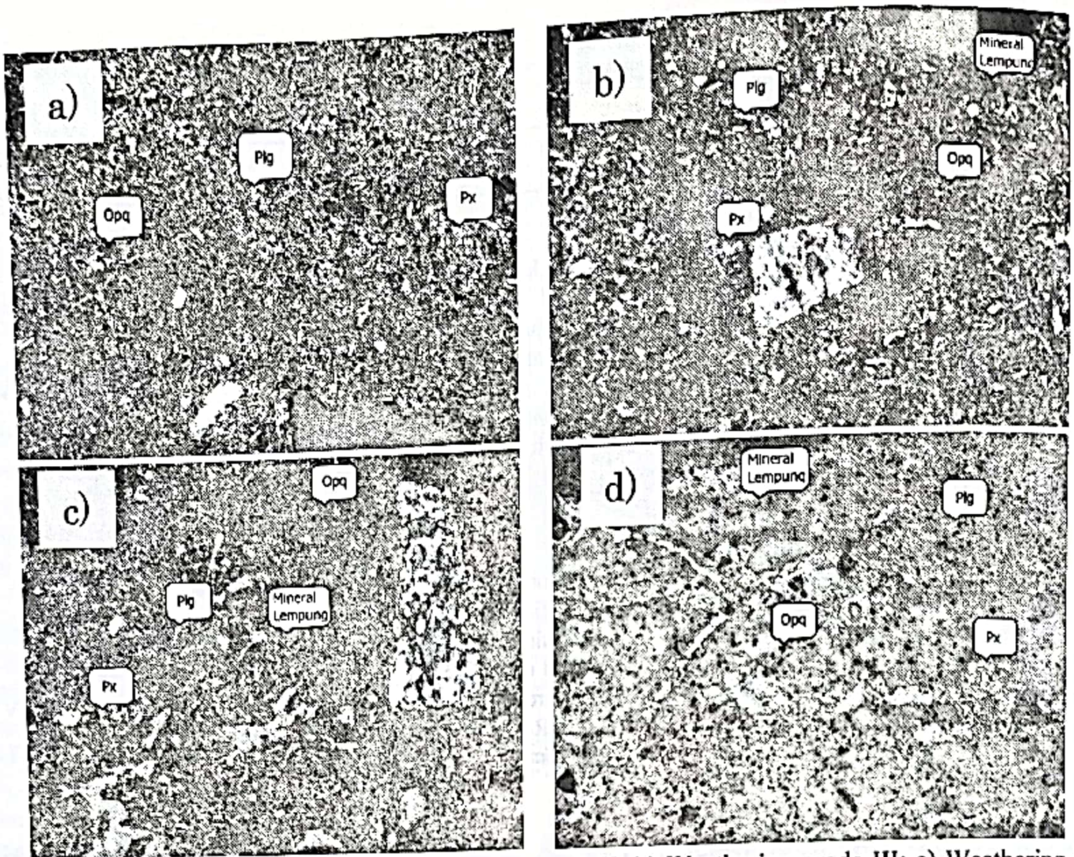


Figure 2. Photomicrograph of basalt: a) Weathering grade II; b) Weathering grade III; c) Weathering grade IV; and d) Weathering grade V

Table 2. Physical properties

Sample	Weathering grade	Density (gr/cm^3)	Porosity (%)
AM_1.1	V	1,76	40,00
AM_2.1	IV	2,16	19,82
AM_3.1	III	2,66	4,27
AM_4.1	II	2,91	4,22

Table 3. Schmidt hammer values of basalt

Sampel	Weathering grade	*Schmidt Hammer*
AM_1.1	V	14.22
AM_1.2	V	15.20
AM_1.3	V	16.30
AM_2.1	IV	23.23
AM_2.2	IV	20.10
AM_3.1	III	27.45
AM_3.2	III	26.30
AM_3.3	III	25.00
AM_3.4	III	24.15
AM_3.5	III	28.50
AM_4.1	II	34.80
AM_4.2	II	30.48
AM_4.3	II	32.00
AM_4.4	II	31.20

Correlation between weathering grades of basalt and the Schmidt hammer values can be seen in

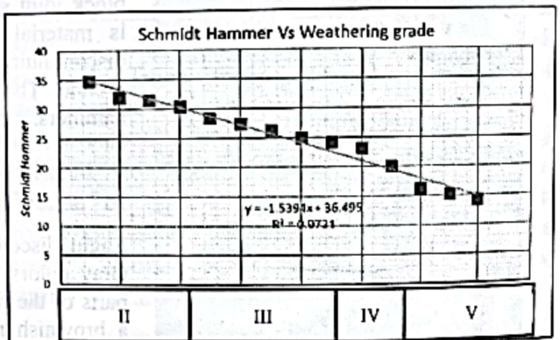


Figure 3. Correlation between weathering grade and Schmidt hammer rebound values

Figure 3 shows graphic influence of weathering grade on Schmidt hammer rebound values. The high regression coefficient is indicative of the effect of weathering grade condition on the rock strength that measured by Schmidt hammer rebound. The values of Schmidt hammer decrease when the weathering grade increase.

CONCLUSION

In this paper, the impact of weathering on basalt was investigated, and the conclusions of the study are as follows:

1. There are four weathering grades in the studied basalt. Discontinuity characteristics and discoloration obtained during field studies. In addition soil also occurs on the top of outcrop of basalt. Based on petrographic analyses, the

weathering grades were characterized by decreasing plagioclase but increasing clay as secondary mineral due to weathering process.

2. Influence of weathering on physical properties of basalt shows that weathering grade increases porosity of rock but the weathering grade decreases rock density.
3. Impact of weathering grade on rock strength that obtained by Schmidt hammer rebound is founded. The values of Schmidt hammer rebound decrease when the rock weathering grade increase.

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