VOT 75055

LABORATORY STUDY OF WEATHERED ROCK FOR SURFACE EXCAVATION WORKS

(KAJIAN MAKMAL KE ATAS BATUAN TERLULUHAWA UNTUK KERJA-KERJA PENGOREKAN PERMUKAAN)

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2007

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ABSTRACT

This research focuses on the most problematic rock type for ripping works in Malaysia particularly weathered sedimentary rocks. The weathering zone that normally requires ripping are zone II-V and these zones has always be problematic zone for excavation in term of selecting the most suitable method and cost evaluation. This research is to examine the relationship of rock material properties and the weathering grades. The information gathered from the monitoring was used for determining the rippability of rocks. Monitored ripping tests were conducted at Bukit Indah which consisted of sandstone and shale. Samples which have been known for their rippability were collected and brought back to the laboratory to determine their parameters for their uniaxial compressive strength test, Brazillian tensile strength, point load test, slake durability and Pundit test. Results from the laboratory tests are presented and their relation with the weathering grade was established. Some of the standard strength tests were not able to test very weak materials with weathering grade V (completely weathered), due to sampling difficulties. By measuring the ripping process, the relationships between the rock properties and the rippability were established. It was revealed that, the laboratory test results alone would not represent the actual behaviour of rock material during rippability assessment. Some of the material found to be weak, are found to be not rippable and vice versa. Thorough field assessments, which need to include discontinuity analysis, are vital and these data are to substantiate the laboratory results.

ABSTRAK

Kajian ini memfokus kepada batuan sedimen terluluhawa yang selalu menjadi masalah di Malaysia dalam penentuan kaedah pengorekan yang sesuai. Masalah berkenaan batuan terluluhawa ini adalah signifikan bagi gred terluluhawa sedikit (II) sehingga terluluhawa lengkap (V) di dalam profil luluhawa. Data-data daripada keputusan makmal digunakan bagi menilai keboleh korekan batuan sedimen terluluhawa ini iaitu dari jenis batu pasir dan syal. Kajian kebolehkorekan dilakukan di Bukit Indah, Johor di mana samplel-sampel telah dipungut dan di bawa balik ke makmal untuk kajian selanjutnya. Jenis-jenis ujian yang dilakukan adalah ujian mampatan sepaksi, ujian ketegangan Brazillian, ujian beban titik, keperoian dan ujian Pundit. Keputusan daripada ujian-ujian tersebut telah dinilai dengan gred luluhawa masing-masing. Semasa ujian dilakukan, didapati bahawa ujian piawai mekanik batuan tidak dapat dilakukan kepada sampel dari gred V (terluluhawa lengkap) kerana sampel yang mudah pecah. Dengan data-data yang didapati, dapat disimpulkan bahawa penilaian makmal sahaja tidak cukup bagi menilai kebolehkorekan batuan kerana data-data ini memerlukan sokongan dengan data lapangan seperti jarak kekar.

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(To be completed by Project Leader submission of Final Report to RMC or whenever IP protection arrangement is required)

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Laboratory Studies of Weathered Rock For Surface Excavation Works

Vote No: 75055

2. **PROJECT LEADER** :

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5. LIST OF EQUIPMENT BOUGHT USING THIS VOT

Laser printer hp 1100, External Hard Disk,External Drive A (RM 2250)

6. STATEMENT OF ACCOUNT

a) APPROVED FUNDING RM : ……19,000.00..………

b) TOTAL SPENDING RM : ……19,652.49..………

c) BALANCE RM : …… (652.49) ……..…

7. TECHNICAL DESCRIPTION AND PERSPECTIVE

Please tick an executive summary of the new technology product, process, etc., describing how it works. Include brief analysis that compares it with competitive technology and signals the one that it may replace. Identify potential technology user group and the strategic means for exploitation.

a) Technology Description

The result shows that the strength and qualities of mateial deteriorates with increasing of weathering grade. Testing and analysis of weathered rock material should be given special attention as most of the standard rock mechanics testing equipment are designed for testing the hard rock material. It is also found that the laboratory data alone is not sufficient to assess the rippability of weathered rock masses accurately. Field data is essential to estimate the rock mass properties.

b) Market Potential

The determination of material properties of weathered rock is a challenging task. Advancement and modification of standard rock mechanics testing equipment is required.

…………………………………………. Name : ……………………………….

Signature and stamp of Date : ……………………………….
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c) Commercialisation Strategies

None at the moment

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8. RESEARCH PERFORMANCE EVALUATION

a) FACULTY RESEARCH COORDINATOR

	Excellent	Very Good	Good	Satisfactory	Fair	Weak
Research Status	( )	( )	( )	( )	( )	( )
Spending	( )	( )	( )	( )	( )	( )
Overall Status	( )	( )	( )	( )	( )	( )

Comment/Recommendations :

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Signature and stamp of Date : ……………………………………….

JKPP Chairman

b) RMC EVALUATION

	Excellent	Very Good	Good	Satisfactory	Fair	Weak
Research Status	( )	( )	( )	( )	( )	( )
Spending	( )	( )	( )	( )	( )	( )
Overall Status	( )	( )	( )	( )	( )	( )

Comments :-

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Recommendations :

- ☐ Needs further research
- ☐ Patent application recommended
- ☐ Market without patent
- ☐ No tangible product. Report to be filed as reference

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BORANG PENGESAHAN
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TAJUK PROJEK : **LABORATORY STUDY OF WEATHERED ROCK FOR SURFACE EXCAVATION WORKS**

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In tropical region where thick profile of weathered zone can be encountered, ripping works is always accepted as the limit of mechanical breaking before blasting works is opted due to the economical reason. However, as we know, the nature of rock type and its weathering profile plays a very significant role in evaluating the excavation assessment. Great challenges in ripping works can be expected in sedimentary area where the occurrence of discontinuity such as bedding thickness, folding, foliation and the inhomogeniety of rocks can greatly influence its excavatability

Excavation assessment on rippability can be assessed by using two different methods that is direct and indirect method. Direct method is where ripper machine will be tested on the actual ground and the assessment will be based on the productivity. Indirect excavation assessment includes seismic velocity, graphical and grading method. Grading system was introduced by Weaver (1975), by taking into account various geotechnical parameters in the assessment. Since then, this type of assessment being further developed by Kirsten (1982), Muftuoglu (1983), Smith (1986), Abdullatif and Cruden (1983), Singh et al (1987), Karpuz (1990), MacGregor et al. (1993), Kramadibrata (1996) and Basarir and Karpuz (2004).

Excavatability of rocks is believed to be depending on numbers of geomechanical properties of intact rock and rock mass such as discontinuities, weathering grade, grain size and strength. The mechanical properties can be determined by field and laboratory test such as rebound tests, rock strength index tests, wave velocity and durability testing. Apart from the geo-properties, working condition and the equipment variables may influence the excavatability. Based on these factors, rock mass and rock material properties are graded with respect to their importance in excavatability in the grading method. This research tries to establish the laboratory data for the rock material sampled during the ripping works.

1.2 Objective of Study

The objectives of this research are: -

i. To determine engineering characteristic of weathered rock mass related for ripping works.
ii. To establish engineering parameter those are related to rock excavation.

1.3 Scope of Study

Scopes of this study are focus on the most problematic rock type for ripping works in Malaysia particularly weathered sedimentary rocks. The weathering zone that normally requires ripping are zone II-V and these zones has always be problematic zone for excavation in term of selecting the most suitable method and cost evaluation. Samples which have been known for their rippability were collected and brought back to the laboratory to determine their parameters.

CHAPTER 2

PREVIOUS RESEARCH ON EXCAVATION ASSESSMENT

2.1 Introduction

Most researchers agree that rippability depends on numerous geomechanical properties of intact rock and rock mass (Thuro et al., 2003). Factors that are influencing an excavating machine are suggested by the International Society of Rock Mechanics – Commision on Rock Borability, Cuttability and Drillability and other sources (Fowell et al., 1991 and Braybrooke, 1988). Although most of them suggested different variables involved, most of them agree that material strength and discontinuity characteristics play an important role in rippability. Although rock mechanical properties play a key role in excavation, geological parameters are more significant than varying rock properties (Thuro et al., 2002).

One of the requirements in assessing rippability of a rock mass by grading method, is by determination of the rock material properties. Parameters that are related to excavation such as compressive strength, tensile strength, density and sonic wave velocity are used in these assessments. Previous researches found that there are many factors affecting the rippability of ground such as the rock mass behaviour, strength of rock material, size of machineries employed and the economical factors. Bozdag (1988) found that among the rock mass properties involved are the rock type, strength, and degree of alteration, structure, fabric abrasiveness, moisture content and the seismic velocity. Pettiffer et al. (1994) suggested that the ripping operations are greatly influenced by the strength of the intact rock and the joint behaviour of the rock mass. In rippability assessment, the significant rock mass and intact rock parameters should be included and examined to predict rock mass behaviour.

2.2 Relevant Rock Material Properties Related To Excavation

From the literatures, it is noted that the excavatability of rocks are depending on numbers of geomechanical properties of intact rock and rock mass such as discontinuities, weathering grade, grain size and strength. The properties can be determined by rebound tests, rock strength index tests, rock mass classifications and other specific tests. Basically, no single test can uniquely define rock material properties. Instead, there are numerous tests giving either direct or indirect value to each property. Derivation of strength values for the assessment of rock cuttability has always been one of the most frequently cited indices.

Other than the geo-properties, working condition and the equipment variables also may influence the excavatability. Based on these factors, rock mass and rock material properties are graded with respect to their importance in excavatability. The importance of certain parameters used for this system is noted for different researchers, perhaps due to the difference of rock nature. Table 2.1 lists some other factors that are considered relevant for assessing the engineering design in rock performance. References and influence of variables on excavation are also provided in the table.

Table 2.1: Summary of rock material properties influencing the excavation design in surface mines

Rock Property	Variables	Reference	Influence on design of surface mines
Intact Rock Properties			
Physical Properties	-Moisture content -Density	ISRM, 1981 ISRM, 1981	SS, EXC. SS, EXC.
Rock Substance Hardness	-Dynamic rebound tests Shore sclerescope Schmidt rebound hammer Modified Schmidt hammer	ISRM, 1981 Gehring, 1992	EXC. EXC & SS
Standard Rock Strength	-Unconfined compressive strength-UCS -Brazillian tensile strenth	ISRM, 1981 ISRM, 1981	SS, EXC. EXC.
Constitutive behaviour pf UCS test	-Young's Modulus -Specimen Specific Fracture Energy -Toughness Index (Singh et al., 1983)		EXC. EXC. EXC.
Rock Strength Index	-Pont Load Index-PLI	ISRM, 1985	EXC.
Dynamic Property	-Laboratory seismic velocity	ISRM, 1981	EXC.

The influence of geology is not only relevant during the equipment selection, but also during the operations stage. Table 2.2 shows a list of variables considered relevant for assessing the engineering design and geotechnical parameters used by researchers respectively. In majority of the systems proposed, uniaxial compressive strength (UCS) and seismic velocity are the two most common parameters used. These system proposed by Weaver (1975), Kirsten (1982), Muftuoglu (1983), Smith (1986), Singh et al. (1987) and Karpuz (1990).

Table 2.2: Summary of parameters considered for excavation assessment

Parameters			Strength					Joint/Discontinuity										
	SV	Grain size	UCS	Point Load Test	SH	TS	RQD	No of joint sets	Volumetric joint count	Joint roughness	Joint alteration	Joint orientation	Joint spacing	Joint continuity	Joint gouge	BedS	A	W
Caterpillar (2001)	X																	
Atkinson (1971)	X																	
Franklin et al. (1971)			X	X									X					X
Bailey (1975)	X																	
Weaver (1975)	X		X									X	X		X			X
Church (1981)	X																	
Kirsten (1982)			X				X	X	X	X	X	X	X					
Muftuoglu (1983)			X	X									X			X		X
Abdullatif et al. (1983)				X									X					
Smith (1986)			X									X	X	X	X			X
Anon (1987)	X																	
Singh et al. (1987)	X			X		X							X				X	X
Bozdag's (1988)				X									X					
Karpuz (1990)	X		X		X								X					X
Mac Gregor et al.(1993)	X	X	X					X		X			X			X		X
Pettifer et al. (1994)				X								X	X					X
Kramadibrata (1996)			X	X			X			X			X		X		X	
Hadjigeorgiou (1998)				X				X	X									X
Rucker (1999)			X				X											
Basarir and Karpuz (2004)	X		X	X	X								X					

SV-seismic velocity, UCS-uniaxial compressive strength, PLT-point load test, SH-schmidt hammer, TS-tensile strength
RQD-rock quality designation, BedS-bedding spacing, A-abrasiveness, W-weathering

2.3 Rock Weathering

Since this research is regarding the weathered rock material properties, thus it is useful to understand about the rock material weathering processes. Rock weathering process is a dynamic process and multi is factors involve in the physical and chemical reactions to weathering agents and conditions. Chemical weathering is defined as a decaying process of rocks cause by reactions to water, carbon dioxide and humidity of rock composition mineralogy. Whereas, physical weathering is a slaking and fragmentation process cause by force from water, air movements and the changes of inner stress. Continuous weathering process that occurred during this geologic period has caused the decreasing in rock physical nature.

Primary weathering process is when the rock mass undergoes chemical and physical weathering process which the effect will change its color, fabrics, mineralogy, texture, sizes and decompose to residual soil. The chemical and physical weathering may happen at the same time, or otherwise. Chemical and, or physical weathering rate is determine through the factors of lithology, climate, topography, and groundwater. Tropical weathering on rock minerals is far more aggressive but it is less effective in cool climate. High humidity in air causes chemical weathering process can be more aggressive in decreasing physical behavior than crushing and erosion.

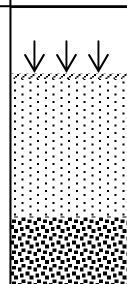
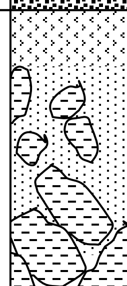
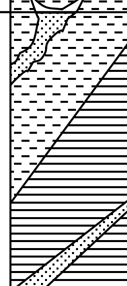
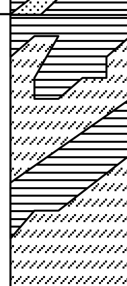
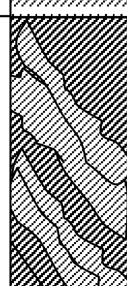
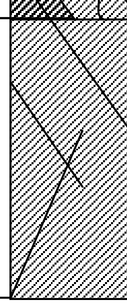
Weathering of rock takes place under the influence of the hydrosphere and atmosphere. Weathering I either in the form of mechanical disintegration or chemical decomposition or both. Mechanical weathering leads to opening of discontinuities by rock fracture, opening of grain boundaries and the fracture on cleavage of individual mineral grains, whereas chemical weathering results in chemical changes in the mineral. Under the influence of weathering, the strength, density and volumetric stability of the rock will be educed, whilst deformability, porosity and weatherability is increased. This can lead to significant reductions in rock strength and assist the excavation process (Hadjigeorgiou, 1988). The need to establish the weathering zones in the classification was made clear by Hadjegeorgiou (1988) to help the assessment process. The weathering classification, as recommended by the Core Logging Committee of South Africa (1976), ranks from unweathered, via slightly, medium and highly weathered to completely weathered. It is clear from the table that the classification takes extent of discoloration, and conditions of discontinuities i.e. filling and separation, into consideration.

Tropic country has sunny flux all the year (22^0-32^0 C), high moisture content in air and underground, high quantity of rain (>1200 mm) and underground water of 28^0C (Thomas, 1994). With these characters, climate has great influence to exogenic process especially to chemical weathering process where the high intensity of rain and high temperature will accelerate the weathering process.

Several studies have been done to understand geotechnical properties of weathered sedimentary rock in Peninsular Malaysia (Ibrahim Komoo, 1995a). The results showed that material properties deteriorate from the fresher material as more intense weathering taken place. The weathering effect can take place up to 100m down from the earth surface in tropical area (Ibrahim Komoo, 1995b). IAEG (1981) classified the weak rock will have uniaxial compressive strength from 1.5 – 50 MPa.

Generally, sedimentary rock mass consists of more than a type of rock and always forms alternate laminated because of natural forming process and also exposed to tectonic effect and pressure. The weak rock in grade III to V (please see Table 2.3) has always been the grey area in ripping and excavation. This is because the layer where grade III to V is found to be interbedded or sandwiched between different layers.

Table 2.3: Weathering profile classifications of rock mass (Ibrahim Komoo, 1995)

Classification	Weathering Zone	Log	Description
Residual Soil	VI		**Upper Soil** **All rock materials changed into soil. No texture or rock mass structure preserved. Homogenic.**
Completely Weathered	V Vc Vb Va		**Zone is rich in Iron Concretion. Unclear texture, less than 25% preserved fabric. Preserved structure. Whole materials changed to soil. Stained.** **Whole Materials changed into soil. Reddish color, Stained with original material 25-75% fabrics are preserved. Materials disintegrate in water or crushable by hand.**
Highly Weathered	IV IVb IVa		**Materials changed into soil preserving original color and textures. >75% preserved texture, easy to disintegrate in water and crushable by hand. Slaking.** **Material is in transition to IVb condition. Texture & structure intact. Small fragments formed when crush in hand or immerse in water. Geology Hammer does not rebound**
Moderately Weathered	III		**Color changes in all earth materials (original color increases). Whole texture & structure of rock mass unchanged. Edges of rock material are hard to break by hand. Schmidt Hammer average value is less than 30. Geology Hammer rebounds by hit but does not rings, discontinuity filled with iron oxide.**
Slightly Weathered	II		**Slightly changes of color in material. Most materials are still fresh. Changes of color on discontinuity clearly exceed 1cm. Schmidt Hammer average value is more than 30. Geology Hammer rebounds and rings. Discontinuity spacing is filled with iron oxides.**
Fresh Rocks	I		**No changes of forms or color in earth materials. Slightly or no iron stains in discontinuity spacing. Geology Hammer rebounds and rings on hit.**

Mohd For et al. (2003) and Tajul et al. (2000) reported that, hard material has always become an argument issues by contractors and clients if it cannot be classified as rock or soil. This statement always refers to grade III (moderately weathered) to V (completely weathered) in the weathering scale. Existing excavation assessments have always considered the strength factor to be one of its major factors in deciding whether the material can be ripped or otherwise. However if strength is the only parameter considered, overall results may be ambiguous especially if sandstone and shale is evaluated separately as both materials may not have the same strength even though they are in one massive rock body.

Weathering impacts is not limited to rock surfaces; it reaches deeper with water flows and reactions to atmosphere. Whereas, weathering rates are determined by the free flows of weathering agents, usual temperature and compositions of rock minerals. Ibrahim Komoo (1995c) found that humidity in air and earth has always become the main agent of weathering reactions and pathogenesis to tropical climate. The basic of silicate decomposition in weathering process is the formation of hydrate aluminous silicate minerals.

Although weathering of rock mass occur in geological periods, the importance to understanding the changes of physical behavior and mass engineering must be given much attentions. This is because demands of infrastructural developments for a country's development often expose outcrops and cuttings of rock mass in varying weathering zones.

2.4 Rock Weathering Quantitative Classification

Many efforts have been done to measure the rock weathering degree systematically and not just relying on individual skills. A few of engineering practitioners has suggested that rating system are to be given to certain weathering grades.

Ibrahim Komoo (1995c) suggested that civil engineering practitioners should give special attentions to tropical terrains such as in Malaysia. This is because there are conspicuous differences of climate surroundings where heavy rain pours conditions, wide variation of temperature and high humidity happens all year round. This encourages intensive chemical weathering rate and high erosions on the rock surface. There are big differences in weathering characteristics between different climates. In wet tropical climate, we may find very thick of overburden as a result of extensive chemical weathering (Ibrahim Komoo, 1995b). Weathering profile in this tropical climate has very distinctive difference as existence of boulders is difficult to be predicted and the zonation between the grades might be in sudden changes. The study of weathering profile is still in early stage in Malaysia and the need to understand the behaviour of this weathered rock is vital as majority of construction works are in these zones (Ibrahim Komoo, 1995c).

A comparison about rock mass weathering grades classification contained in standard documents; ISRM (1981), IAEG (1981) and BSI (1981) was done by Ibrahim Komoo (1995). Following the comparison done, it was found that there is similarity of rock mass weathering grade classification between IAEG (1981), ISRM (1981) and BSI (1981) except for grade III and IV. IAEG suggested that grade IV is identified by percentage one per third of mass decomposed to soil while ISRM and BSI counted half of rock mass decomposed into soil. However, he found that the basic and explanation of rock weathering details in the three documents developed in subtropical climate are almost the same. His attempts to use the reference for explaining weathering profile in damp tropical region in Malaysia was found unsuitable.

The main issue is focused on rock types; classification method limited to knowledge of practitioners, and finally the importance and needs for engineering index. The rock mass strength nature is found to be one of important rock mass classification index and is very meaningful in engineering works. Most of rock mass classification for engineering purposes is done based on strength of rock material.

Classification of weathered rock material begins with the sampling problems because it is too weak and easily broken caused by chemical weathering. The main issue often discussed is the sampling ability of high lamination materials such as shale, soft rocks like clay or highly weathered granites. Furthermore, the research cost will be higher as the samples need to be brought back to the laboratory for strength testing. Until now, few efforts have been carried out to classify weathered rocks for engineering purposes (Santi, 1995).

The most popular strength test that is often be used as design index is the uniaxial compression strength. However, the uniaxial compression strength can only be carried out on cylindrical shaped samples (ISRM 1981). Alternatively, point load strength is prefered for irregular shaped samples.

2.5 Rock Type

Basically, there are three rock types by origin that are

i) Igneous rock are formed by cooling of molten magma or lava originated within the earth such as granite and basalt. This type of rock is known to be very difficult to rip especially in highly weathered zone due to the lack of stratification and weakness planes (Weaver, 1975). In Malaysia, most parties will opt for blasting in this rock type area as presence of boulders is significant and due to economical reason. Intense weathering in this tropical area decayed this rock type unevenly, hence leaving abundant boulders.

ii) Sedimentary rock consist of material derived from destruction of previously existing rocks (Weaver, 1975) such as sandstone and shale are usually the most easily ripped material due to the presence of weakness planes. Their most prominent characteristic is bedding or stratification. In Malaysia, most ripping works are done in this rock type area.

iii) Metamorphic rock can be igneous or sedimentary rocks origins, which have undergone severe changes in pressure, stresses, chemical or temperature. The changes of this extreme condition may change the original mineral and texture or both, producing different type of rock, namely gneiss (originated from granite), shale, slate and quartzite (from sedimentary origins). Depending on the origins, ripping may be possible in sedimentary originated rock type where degrees of lamination or cleavage are present.

Basically, the identification of basic type of rock may provide immediate indications for likely engineering behaviour of rock (Muftuoglu, 1983).

2.6 Strength

Compressive and tensile failures of rock are both involved in the fracture mechanism generated during ripping. Tensile strength is believed to be more significant than compressive strength when classifying rock in terms of its rippability (Singh, 1986). It is worth noting that tensile and compressive strengths for a given rock are closely correlated with each other, thus either of them can be selected as material strength. Smart et al. (1982) have found a close correlation between the uniaxial strength and quartz content. He found that the increase of quartz in rock material would increase the strength of rock material. Hadjigeorgiou et al. (1988) suggested that point load test offers both technical and logistic advantages in estimating the strength of rock material.

2.7 Abrasiveness

Abrasiveness of rock is a complex function of various properties including rock competency, harness and the mineralogical composition and proportions. The parameters affecting abrasiveness are therefore, as follows (Singh, 1986): -

(a) Mineral composition and proportions including hardness of constituent minerals, grain shape and size, harness and strength of matrix material. This is determined by petrographic examinations.

(b) Physical properties of rocks including strength and hardness.

2.8 Material density

Density is also another factor to be considered in assessing the rippability of rock material. Kramadibrata (1996) has used this parameter in his study.

2.9 Rock fabric

Fabric is a term used to describe the micro structural and textural features of rock material. Researchers have found that rock fabric is another factor affecting the rippability (Weaver, 1975). Coarse-grained rocks (grain size > 5mm) such as pegmatite, coal and sandstone can be generally more easily ripped than fine-grained rocks (grain size < 1 mm) such as quartzite, basalt and limestone. It can also generally be assumed that acidic rocks are more easily ripped than basic rocks (Weaver, 1975). A most widely accepted grain size classification, based on British Standard Methods of Test for Soils for Civil Engineering Purposes (BS 1377, 1981) is given in Table 2.4.

Table 2.4: Grain Size Classification

Description	Size (mm)	Recognition	Equiv Soil Type	Equiv Rock Type
Very grained	< 0.06	Individual grains cannot be seen with a hand lens	Clays & Silts	Claystone & Siltstone
Fine grained	0.06 - 0.2	Just visible as individual grains under hand lens	Fine sand	Sandstone
Medium Grained	0.2 - 0.6	Grains clearly visible under hand lens, just visible to naked eye.	Medium Sand	
Coarse Grained	0.6 - 2.0	Grains clearly visible to naked eye	Coarse sand	
Very Coarse Grained	> 2.0	Grains measurable	Gravel	Conglomerate

CHAPTER 3

METHODOLOGY

3.1 Introduction

The strength properties of weathered shale and sand stone are studied to quantify the weathering impact to these materials. The standard testing procedures will become more difficult as rock material become weaker. This research focused on the basic physical properties of sedimentary rock, which can be the basic to compare the behavior of shale and sandstone. One of the main scopes in this research is focused on field study. Field study concentrates field recognition on nature of different type of rock to problems in excavation. Samples were collected from the field in accordance to the field study and classification. Samples representing particular group of weathering classification had been brought back to the laboratory for further study.

3.2 Laboratory work

After the samples have been collected, it has been brought to the laboratory to be tested as in Figure 3.2. In order to analyse rock mass character and its behaviour an extensive laboratory test programme has been performed throughout the research project. The test programme included the follows: -

i) Uniaxial Compression Strength (using rock core)
ii) Indirect Tensile (Brazilian) Test
iii) Point Load Test (Sand Stone and Mud Stone)
iv) Slake Durability Test
v) Pundit Test

Figure 3.1: Samples collected from site for laboratory work preparation

3.2.1 Uniaxial Compression Strength

Universal Testing Machine (UTM) has the persistent loading about 1000kN and capable to bounce movement of the failure rock. This machine has the characteristic of 'servo control', which makes the procedure of testing easier and applicable. Besides, it gives flexible rate of loading with accurate data till two decimal points.
The Universal Testing Machine is very usable for any rock strength testing such as Uniaxial Compressive Testing, Point Load Test and Brazillian Test.

Uniaxial Compression Strength is the most widely used in measuring strength with the method clearly standardized (ISRM 1981). Whilst the determination of compressive strength appears quite simple, practically, difficulties occur in creating a uniform stress field in a rock specimen. Principally this due to end effects associated with the elastic mismatch between the rock and the testing machine. There are four main factors, which control the test result other than rock properties.

i. Friction between platen and the end surface
ii. Specimen geometry
   - Shape
   - Height to diameter ratio
   - Size
iii. Rate of Loading
iv. Water Content

The Uniaxial Compressive Strength is probably the most universally applied rock test especially when combined with other functions such as the determination of Young's modulus or rock toughness. However the test does require a significant amount of rock in order to produce sufficient cores to give the test the required significance. This can lead to a prohibitively long preparation time and high cost

This is the most common method in measuring strength, deformation and fracture characteristics of rock. The strength of rock material is identified by the stress value at failure and given by the relationship (ISRM, 1981):

$$\sigma_c = P / A$$

In which,

P is failure load and

A is cross section area

A height to diameter ratio of 2 will be employed and testing procedure will follow ISRM, 1981 suggested method. Testing on fresher samples will be conducted as guidance to the strength of weathered rocks (weathered rock samples may be broken during sample preparation).

The core samples were compressed in the Universal Testing Machine (UTM). The stiff press rather than the ordinary soft press is used because the controlling computer continually downloads displacement and load data to disc.

Due to the problems in establishing a uniform stress field associated with the elastic mismatch between the platens and the specimen and specimen geometry, a standardised test procedure has been proposed (ISRM 1981) in order to minimise these effects.

3.3.2 Indirect Tensile (Brazilian) Test

The diametric loading of a small rock disc is performed by a Universal Testing Machine (UTM), which complies with the ISRM requirements for the indirect testing of tensile strength.

The test method consists of loading the disc until failure occurs along its diametric axis. The disc is prepared from 48mm core samples with a thickness to diameter ratio of 1:2.

There is a danger that the failure of the specimen may occur in a biaxial rather than uniaxial stress field. In order to ensure a uniaxial failure and hence the validity of the test, the failure of the disc should initiate at the centre of the specimen. In additions of the problems of establishing a pure uniaxial stress field, and effects problems (similar to those) for the uniaxial compressive strength test can exist. Due to the induction of high shear stresses at the point of contact, it is recommended that this test is only for specimens with a high shear to tensile stress ratio (Aleman 1982).

It was noted that during the testing or rocks with a high tensile strength, the failure often takes place with considerable violence. This violent failure is often accompanied by the shattering of the specimen into several smaller pieces. On the RDP testing machine, the disc always split into two pieces with no violent displacement of either fragment. Since the only difference between the two test machines is the unloading rate, the violent fragmentation must therefore be accounted for by the release of energy stored within a conventional soft press. Figure 3.3 shows the design of Brazilian apparatus and Figure 3.4 shows sample are tested using Brazilian Test apparatus.

There are many difficulties with performing a direct uniaxial tensile test on rock and this has led to a number of indirect methods being proposed. The most common of these, the Brazilian test, involves loading a rock cylinder diamerally between two platens.

The measurement of the tensile strength by the tensile strength by the Brazilian method gives reproducible results that are found with direct methods. Because of the smaller size of specimen required for the test, a smaller initial sample is required. However the necessity for machining and grinding make the preparation time inconvenient.

The tensile strength of the specimen σ_t, has been calculated using the following formula:

$$\sigma_t = 0.636\, P / Dt$$

In which,

P is the load at failure (N),

D is the diameter of the test specimen (mm), *t* is the thickness of the test specimen measured at the centre (mm).

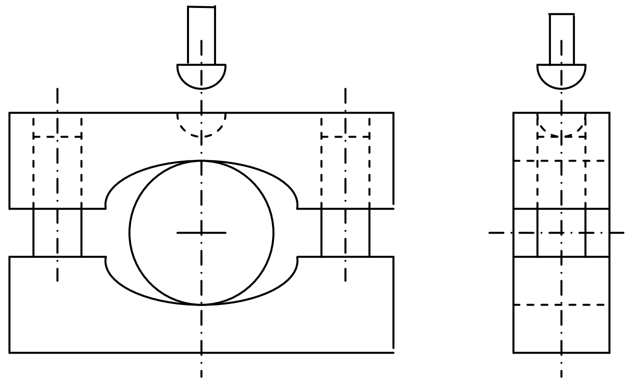


Figure 3.2: Apparatus for Brazillian Test (Tensile Strength Test)

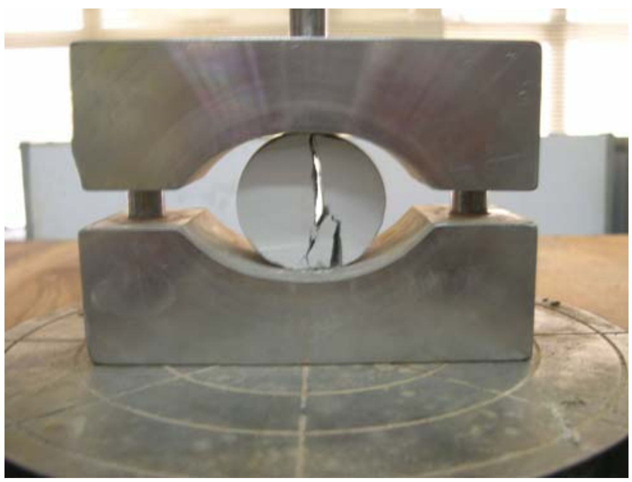


Figure 3.3: Sample tested using Brazilian Test apparatus

3.3.3 Point Load Test

The point load test is an indirect measure of failure of a rock specimen between two points. Also, the point load strength test is a versatile field based index method capable of deriving values, which show excellent correlations with both UCS and tensile strength (Broch and Franklin, 1972; Hassani 1980). Unlike the Brazillian test, which uses a line load on a machined rock disc, the point load can be applied to either rock

CHAPTER 4

ANALYSIS OF LABORATORY RESULT

4.1 Introduction

It is important to consider that the mechanical and physical properties of rock may be inter-related. It may be possible to relate these properties by either in-situ or laboratory testing techniques. Using the linear regression techniques the laboratory test data are examined to evaluate the effectiveness with which one rock property may be estimated from another known property or alternatively to define the degree of influence that one rock property may have on others. Assessment of weathered sedimentary mass is quite difficult as the weathering grade increased. The lacking of physical quality on sedimentary rock such as sand stone and shale effectuate the difficulty on sampling work. The samples were brought back to the laboratory and tested to determine the engineering characteristic of weathered rock mass related for ripping works.

4.2 Discussion of Test Result

Several samples of sandstone and shale have been tested and the result is discussed in subtopic below. Table 4.1 and Table 4.2 show the listed sample of sandstone and shale which is observed on site

Table 4.1: The list sandstone observed on site

No. Sample	Grade	Remark
RL 3 A L3	IVa	Unrippable
RL 1 (b) L3	IVa	Unrippable
RL 3 A L1	IVa	Unrippable
RL 1 (b) L2	III	Rippable
RL 1 L6	III	Rippable
RL1 L5	III	Rippable
RL 3 C L2	III	Rippable
RL 3 C L1	II	Rippable
RL 3 E L1	III	Rippable
RL 3 Slope Area 2 L3	III	Rippable
RL 3 Slope Area 2 L2	IVa	Unrippable
RL 3 Slope Area 1 L5 (Zone B)	IVa	Unrippable
RL 3 Slope Area 1 L5 (a)	IVa	Unrippable
RL 3 Slope Area 1 L1	IVb	Unrippable

Table 4.2: The List of shale observed on site

No. Sample	Grade	Remark
RL 1 L3	II	Rippable
RL 1 (a) L3	III	Rippable
RL 1 (b) L1	III	Rippable
RL 1 L1	IVa	Unrippable
RL1 L4	IVa	Unrippable
RL1 L7	IVa	Unrippable
Along foliation	Va	Rippable
RL 1 L2	Va	Rippable

4.2.1 Point Load Test

Point load test is an alternative method to determine the strength of material, which cannot be sampled specifically. All the 14 samples of sandstones ranging from grade IVa to II and 8 samples of shale (Grade IVa – III) were ale to be tested using this method. Table 4.3 and Table 4.4 show the result of the test. From the result, it shows that Is_{50} of material increased with the weathering grade for sandstone and shale. This shows that the material strength increase with the quality of samples. For grade III sandstone, the Is_{50} ranges from 1.028 to 2.898. Whereas for shale the Is_{50} is 1.496. The grade II sandstone gives the highest value of Is_{50} of 3.669 and the shale gives 3.445. The lowest value of Is_{50} was to grade Va, which carry the value of 0.033.

Table 4.3: Is_{50} of sandstone

No. Sample	Grade	Grain Size	Is_{50}
RL 3 A L3	IVa	Very Fine	0.959
RL 1 (b) L3	IVa	Medium	0.033
RL 3 A L1	IVa	Medium	0.111
RL 1 (b) L2	III	Very Fine	1.143
RL 1 L6	III	Very Fine	1.028
RL1 L5	III	Very Fine	2.623
RL 3 C L2	III	Fine	1.143
RL 3 C L1	II	Very Fine	3.669
RL 3 E L1	III	Very Fine	2.898
RL 3 Slope Area 2 L3	III	Fine	2.009
RL 3 Slope Area 2 L2	IVa	Fine	0.713
RL 3 Slope Area 1 L5 (Zone B)	IVa	Fine	0.868
RL 3 Slope Area 1 L5 (a)	IVa	Very Fine	0.491
RL 3 Slope Area 1 L1	IVb	Medium	0.033

Table 4.4: Is_{50} of shale

No. Sample	**Grade**	**Is_{50}**
RL 1 L3	II	3.445
RL 1 (a) L3	III	2.682
RL 1 (b) L1	III	1.496
RL 1 L1	IVa	0.967
RL1 L4	IVa	0.402
RL1 L7	IVa	0.543
Along foliation	Va	0.033
RL 1 L2	Va	0.033

4.2.2 Uniaxial Compression Test

11 samples out of 14 of weathered sandstones and 8 samples of weathered shale sample that in grade Va, IVa, III, and II can be cored into cylindrical shape and compressed. Whereas medium grained sandstones, which fall in grade IVa, are more friable than the finer grained and easily broken during the coring. Thus performing UCS test on this samples are very difficult. As a result, there are no values for grade Va.

Summary of the test results are tabulated in Table 4.5 and Table 4.6. Parameters that been recorded are time, force and the displacement of samples during loading. The compressive strength of samples is calculated by dividing the maximum force with the area of cross-section. Previous research shows that ratio of L/D give a significant effect to the UCS value. ISRM (1980) recommended the UCS value should be determined from L/D of 2.5 to 3.0. However, it is quite impossible to get L/D of 2.5 to 3.0 for weathered rock mass as cylindrical sampling of that length can be easily broken. With equation from σmg of L/D $\neq 2$ can be adjusted to L/D = 2 value (σ 2p). From the result shown in Table , σ_2p are found to be lower than σmp with % to %. Most of the samples from grade IVa are unable to achieve L/D =2 showing that the sampling will be difficult as weathering grade increase. From the UCS result, it clearly shows the weathering grade of samples that determined from the field observation correlates well with the UCS volume. Weathering grade of II shows the highest volume of 52.331 Mpa and the value decrease as the weathering grade increase, proved that the weathering will weakened the strength of samples. Sandstone with grade IVa shows the lowest reading of 10.20 to 11.50 Mpa. Whereas shale, UCS value are ranging from 11.456 (grade IVb) to 12.730 (grade III). The variation of UCS is found less than in sandstones.

Table 4.5: Uniaxial Compression Test result of sandstone

No. Sample	Grade	Grain Size	UCS (Mpa)
RL 3 A L3	IVa	Very Fine	10.200
RL 1 (b) L3	IVa	Medium	-
RL 3 A L1	IVa	Medium	-
RL 1 (b) L2	III	Very Fine	14.093
RL 1 L6	III	Very Fine	21.258
RL1 L5	III	Very Fine	28.622
RL 3 C L2	III	Fine	15.747
RL 3 C L1	II	Very Fine	52.331
RL 3 E L1	III	Very Fine	28.622
RL 3 Slope Area 2 L3	III	Fine	21.258
RL 3 Slope Area 2 L2	IVa	Fine	11.068
RL 3 Slope Area 1 L5 (Zone B)	IVa	Fine	10.921
RL 3 Slope Area 1 L5(a)	IVa	Very Fine	11.538
RL 3 Slope Area 1 L1	IVb	Medium	-

Table 4.6: Uniaxial Compression Strength (UCS) Test result of shale

No. Sample	Grade	UCS (MPa)
RL 1 L3	II	59.000
RL 1 (a) L3	III	17.731
RL 1 (b) L1	III	12.730
RL 1 L1	IVa	11.456
RL1 L4	IVa	12.013
RL1 L7	IVa	11.975
Along foliation	Va	-
RL 1 L2	Va	-

4.2.3 Slake Durability

Table 4.7 and table 4.8 show the result of slake durability of Id_2 (%) for sandstones and shale that been tested. All samples were tested to second cycles (Id_2) and the weight retained after the second cycles were recorded against the original weight before slaking. From the result it shows that sandstones from grade II grade the highest reading of 94.32%, followed by grade III (78.98 - 90.24 %) grade IVa (43.28 - 57.10%) and 29.015 % for grade IVb. Generally, it found that the percentage of Id_2 decrease with increase of weathering grade.

After all in shale, the same phenomena were also noted 10.563 – 17.014 % (grade Va), 30.82 – 62.02 % (Grade IVa), 82.47 - 87.14 % (Grade III) and 91.57 %. The results suggested that the increase of weathering grade would decrease the quality of stones through the cementation and hardness of the material.

Table 4.7: Id_2 of sandstone

No. Sample	Grade	Grain Size	Id2 (%)
RL 3 A L3	IVa	Very Fine	49.03
RL 1 (b) L3	IVa	Medium	43.28
RL 3 A L1	IVa	Medium	45.74
RL 1 (b) L2	III	Very Fine	90.24
RL 1 L6	III	Very Fine	89.55
RL1 L5	III	Very Fine	89.47
RL 3 C L2	III	Fine	82.16
RL 3 C L1	II	Very Fine	94.32
RL 3 E L1	III	Very Fine	78.98
RL 3 Slope Area 2 L3	III	Fine	80.78
RL 3 Slope Area 2 L2	IVa	Fine	57.10
RL 3 Slope Area 1 L5 (Zone B)	IVa	Fine	48.65
RL 3 Slope Area 1 L5 (a)	IVa	Very Fine	50.63
RL 3 Slope Area 1 L1	IVb	Medium	29.015

Table 4.8: Id_2 of shale

No. Sample	Grade	Id_2 (%)
RL 1 L3	II	91.57
RL 1 (a) L3	III	87.14
RL 1 (b) L1	III	82.47
RL 1 L1	IVa	30.82
RL1 L4	IVa	62.02
RL1 L7	IVa	59.13
Along foliation	Va	17.014
RL 1 L2	Va	10.563

4.2.4 Pundit Test

Seismic velocity test is another test that were conducted in the laboratory. Table 4.9 and Table 4.10 show the result of the P wave velocity for the sandstones and shale tested. It found that the lowest reading is detected from grade IVa (medium sandstone), followed by grade Va shale and the highest readings were recorded in grade II and III materials. The results also show that the grain size of material plays an important role affecting the same grade gave higher velocity compared to coarser ones. This might suggest the wave travels faster in the more compacted material compared to the looser ones.

Table 4.9: Pundit test result of sandstone

No. Sample	Grade	Grain Size	Pundit (m/s)
RL 3 A L3	IVa	Very Fine	2576
RL 1 (b) L3	IVa	Medium	1795
RL 3 A L1	IVa	Medium	1645
RL 1 (b) L2	III	Very Fine	2857
RL 1 L6	III	Very Fine	2857
RL1 L5	III	Very Fine	2994
RL 3 C L2	III	Fine	2620
RL 3 C L1	II	Very Fine	2857
RL 3 E L1	III	Very Fine	2620
RL 3 Slope Area 2 L3	III	Fine	2417
RL 3 Slope Area 2 L2	IVa	Fine	2030
RL 3 Slope Area 1 L5 (Zone B)	IVa	Fine	1795
RL 3 Slope Area 1 L5 (a)	IVa	Very Fine	2030
RL 3 Slope Area 1 L1	IVb	Medium	1366

Table 4.10: Pundit test result of shale

No. Sample	Grade	Pundit (m/s)
RL 1 L3	II	2857
RL 1 (a) L3	III	2576
RL 1 (b) L1	III	2417
RL 1 L1	IVa	1620
RL1 L4	IVa	2620
RL1 L7	IVa	1952
Along foliation	Va	1366
RL 1 L2	Va	1366

4.2.5 Dry Density

Table 4.11 shows the dry density of tested samples. Grade III sandstone has dry density of 2539 kg/m^3, followed by Grade IVa sandstone which has the highest value of 2248 kg/m^3. The dry density decrease to 1742 kg/m^3 for grade IVa and the lowest dry density is found in grade IVb that is 2150 kg/m^3. Whereas shale, the dry density between different grades does not show big variations as sandstone.

Dry density is one of the most important factors in assessing the mechanical properties of samples. The density of samples may tell us on the compactness of the grain, which will affect the overall properties of the rock.

From the result, it shows that certain range of value may overlap with samples for other grade. It also shows that the material from the same grade might not have the similar density. However, a very significant different can be detected from solid fresh sandstone with most friable (Grade IVb) that has the volume of to respectively.

The condition of shale does not show big different in which the value noted 1985 - 2205 kg/m^3 (grade Va), 2218 - 2861 kg/m^3 (grade IVa), 2266 -2268 kg/m^3 (grade III) and 2524 kg/m^3 for grade II.

Table 4.11: Dry density of sandstone

No. Sample	Grade	Grain Size	Dry Density (kg/m^3)
RL 3 A L3	**IVa**	Very Fine	2340
RL 1 (b) L3	**IVa**	Medium	1742
RL 3 A L1	**IVa**	Medium	1777
RL 1 (b) L2	**III**	Very Fine	2149
RL 1 L6	**III**	Very Fine	2248
RL1 L5	**III**	Very Fine	2539
RL 3 C L2	**III**	Fine	2097
RL 3 C L1	**II**	Very Fine	2286
RL 3 E L1	**III**	Very Fine	2437
RL 3 Slope Area 2 L3	**III**	Fine	2624
RL 3 Slope Area 2 L2	**IVa**	Fine	2130
RL 3 Slope Area 1 L5 (Zone B)	**IVa**	Fine	2248
RL 3 Slope Area 1 L5 (a)	**IVa**	Very Fine	2243
RL 3 Slope Area 1 L1	**IVb**	Medium	2150

Table 4.12: Dry density of shale

No. Sample	Grade	Dry Density (kg/m^3)
RL 1 L3	**II**	2524
RL 1 (a) L3	**III**	2268
RL 1 (b) L1	**III**	2266
RL 1 L1	**IVa**	2218
RL1 L4	**IVa**	2861
RL1 L7	**IVa**	2861
Along foliation	**Va**	2205
RL 1 L2	**Va**	1985

4.3 Correlation of Laboratory Index Test

Based on the laboratory work, the samples of sandstone that are found from the site are about 20 types with different size and different weathering grade. The samples sizes are consist of very fine, fine and medium.

4.3.1 Correlation of Slake Durability (Id_2) and Point Load Test (Is_{50})

Figure 4.1 shows a correlation between Slake durability and Point Load Test for sandstone and shale. Slake durability is a test which is describing a weathering process in real situation whereas point load test is a more flexible way to detect strength of material.

The graph is plotted from the Id_2 (%) and Is_{50} values of the same material tested. The grade of samples determined from the field tests were marked with different symbol to show if there is any relationship that can be drawn.

From the graph, it shows that the test of weathered material, give the higher Is_{50} and Id_2. The values for these two parameters deteriorate with the increase of the weathering grade. It also shows that the Is_{50} of 0.5 to 6 shows small variance in the Id_2 value. However value of Is_{50} that is lesser than 0.5, shows a significant variance in the Id_2 value. This might due to fresher and stranger material be able to resist the slaking better than the weaker ones. The weaker material may lose their weight faster through the slaking process compared to fresher material.

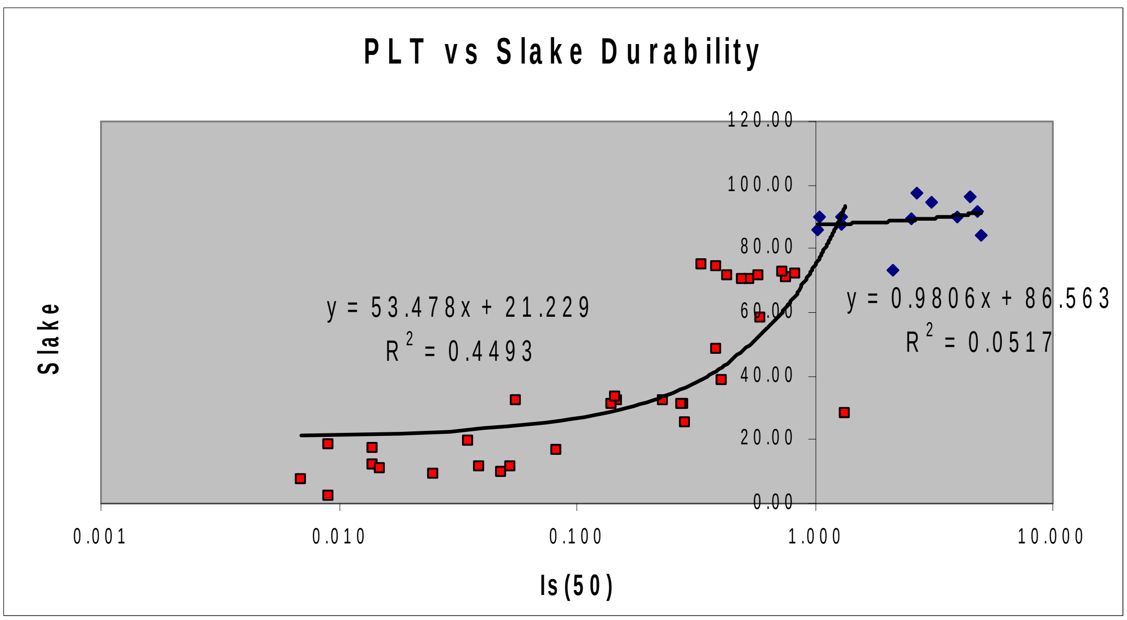


Figure 4.1: Graph Slake Durability vs Point Load Test (Is_{50})

4.3.2 Correlation of Uniaxial Compressive Test (UCS) and Point Load Test (Is_{50})

Figure 4.2 show a correlation between UCS and Is_{50} for sandstone. A graph is plotted to show the relationship of these two parameters. Many researcher trials to develop relationship of UCS and Is_{50}, value Is_{50} value is preferred to be used in the material strength test in weathered rock due to the flexibility in sampling.

Same material within the same grade was tested and the selections of samples that are going to be used are properly selected to minimize variance in sampling.
In the graph, the correlation is divided into two, i.e. when $Is_{50} < 1$ (for completely and highly weathered material) and $Is_{50} > 1$ (for slightly to moderately weathered material). In the section of $Is_{50} <1$, the linear correlation is simplified as follow: -

y = 12.228x + 1.7475

Whereas for $Is_{50} >1$, the linear correlation is simplified to:-

y = 14.451x + 0.0965

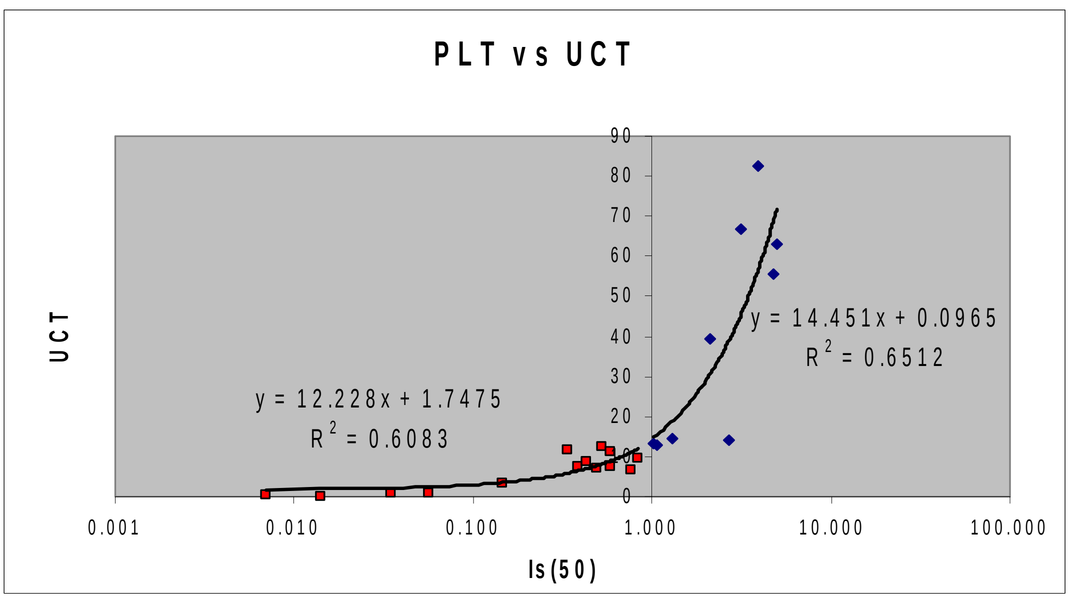


Figure 4.2: Graph Uniaxial Compressive Test (UCS) vs Point Load Test (Is_{50})

4.4 Summary of Laboratory Test Result

The result for each test is tabulated in Table 4.13 for sandstone and Table 4.14 for shale. The results show the quality of rock deteriorated with the increase of weathering grade. However, ripping results showed that grade IVa could not be ripped on site, not merely because of the rock materials properties but also being influenced by the joints developed in the rock mass. As such, field study is required to supplement the findings of the laboratory results.

Table 4.13: Summary of Test Results for Sandstone

No. Sample	**Grade**	**Grain Size**	**Is_{50}**	**UCS (MPa)**	**Id_2 (%)**	**Pundit (m/s)**	**Dry Density (kg/m^3)**	**Remark**
RL 3 A L3	IVa	Very Fine	0.959	10.200	49.03	2576	2340	Unrippable
RL 1 (b) L3	IVa	Medium	0.033		43.28	1795	1742	Unrippable
RL 3 A L1	IVa	Medium	0.111		45.74	1645	1777	Unrippable
RL 1 (b) L2	III	Very Fine	1.143	14.093	90.24	2857	2149	Rippable
RL 1 L6	III	Very Fine	1.028	21.258	89.55	2857	2248	Rippable
RL1 L5	III	Very Fine	2.623	28.622	89.47	2994	2539	Rippable
RL 3 C L2	III	Fine	1.143	15.747	82.16	2620	2097	Rippable
RL 3 C L1	II	Very Fine	3.669	52.331	94.32	2857	2286	Rippable
RL 3 E L1	III	Very Fine	2.898	28.622	78.98	2620	2437	Rippable
RL 3 Slope Area 2 L3	III	Fine	2.009	21.258	80.78	2417	2624	Rippable
RL 3 Slope Area 2 L2	IVa	Fine	0.713	11.068	57.10	2030	2130	Unrippable
RL 3 Slope Area 1 L5 (Zone B)	IVa	Fine	0.868	10.921	48.65	1795	2248	Unrippable
RL 3 Slope Area 1 L5 (a)	IVa	Very Fine	0.491	11.538	50.63	2030	2243	Unrippable
RL 3 Slope Area 1 L1	IVb	Medium	0.033		29.015	1366	2150	Unrippable

Table 4.14: Summary of Test Results for Shale

No. Sample	**Grade**	**Is_{50}**	**UCS (MPa)**	**Id_2 (%)**	**Pundit (m/s)**	**Dry Density (kg/m^3)**	**Remark**
RL 1 L3	II	3.445	59.000	91.57	2857	2524.80	Rippable
RL 1 (a) L3	III	2.682	17.731	87.14	2576	2268.36	Rippable
RL 1 (b) L1	III	1.496	12.730	82.47	2417	2266.00	Rippable
RL 1 L1	IVa	0.967	11.456	30.82	1620	2218.00	Unrippable
RL1 L4	IVa	0.402	12.013	62.02	2620	2861.00	Unrippable
RL1 L7	IVa	0.543	11.975	59.13	1952	2861.00	Unrippable
Along foliation	Va	0.033		17.014	1366	2205.65	Rippable
RL 1 L2	Va	0.033		10.563	1366	1985.21	Rippable

CHAPTER 5

CONCLUSION

5.1 Conclusion

From the results, it is shown that the strength and qualities of material deteriorates with increasing of weathering grade observed at the site. Testing and analysis engineering approach have given the attention on weathered matter issue and also resolving the sampling problem for weak weathered rock to obtain the aspired data. Therefore, throughout weathering grade spectrum with deteriorating of sandstone strength and shale have been formed. Initial development technique of uniaxial compressive test is most appropriate to be done to evaluate weak rock mass properties and weathered.

The laboratory test results alone would not represent the actual behaviour of rock material during rippability assessment. Some of the material found to be weak, are found to be not rippable and vice versa. Thorough field assessments, which need to include discontinuity analysis, are vital and these data are to substantiate the laboratory results.

From the site observation we knew that weak weathered rock which is affected by humid tropical climate specifically grade IVa, and IVb included V supposes can be ripped based on the rock mass properties. The result from this research denote that the weak weathered sample that been found could not be ripped. After through all tests involve in this research, the writer found that those type of weathered rock need supported from field data. The field data is significant, and the combination of field and laboratory result will ensure whether the rock can be ripped or not.

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