STRENGTH CHARACTERISATION OF SHALE USING MOHR-COULOMB AND HOEK-BROWN CRITERIA

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Thank you

Allah S.W.T for your blessing,

My beloved parent, the symbol of love and giving,

My whole family who encourage and support me,

My friends who always have my back,

All the people in my life who touch my heart.

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ABSTRACT

Strength parameters of rock material are usually determined from laboratory test on intact rock samples. Uncertainties arise in predicting the behaviour of a rock mass under confinement due to the presence of discontinuous. Compared with the intact rock, discontinuity such as joint induces inhomogeneous and anisotropic behaviour in the rock mass. Several empirical approach such as Rock Mass Rating (RMR) is available to classify and evaluate the strength of rock mass. However, the RMR method is not suitable to be applied for the very poor quality of rock such as shale, due to its limitation. This study attempts to verify the strength parameters of intact rock using Hoek-Brown (H-B) and Mohr-Coulomb (M-C) failure criterion. The RocData software is utilised to evaluate and assess the strength parameter of the shale. Result obtained indicates that H-B criterion, which describe a non-linear increase of strength compared to M-C. Hence, H-B criterion shows better presentation of shale under field condition in comparison to M-C method.

ABSTRAK

Kekuatan untuk bahan batuan kebiasaan-nya ditentukan melalui ujikaji makmal ke atas sampel utuh batuan tersebut. Dalam menentukan sifat-sifat batuan tersebut, ketidakpastian akan timbul disebabkan oleh ketidakselanjaran batu yang terjadi secara semulajadi. Berbanding dengan batu utuh yang bersaiz kecil, ketidakselanjaraan pada massa batuan akibat dari kecatatan seperti sesar, mendorong kepada sifat *inhomogenous* dan *anisotropic*. Beberapa sistem empirikal seperti *Rock mass Rating* (RMR) boleh digunakan untuk mengkelas dan menilai kekuatan massa batuan. Walau bagaimana pun, kaedah RMR adalah tidak sesuai untuk digunapakai dalam menilai batuan yang berkualiti rendah seperti *Shale* kerana kekangan di dalam sistem tersebut. Kajian ini adalah bertujuan untuk menilai kekuatan utuh batu dengan menggunakan dua kriteria kegagalan berbeza iaitu *Hoek-Browm* (H-B) dan *Mohr-Coulomb* (M-H). Kedua-dua kriteria dianalisa menggunakan perisian *RocData.* Keputusan ujikaji dan analisa yang diperolehi menunjukkan kriteria *Hoek-Brown* menunjukkan peningkatan kekuatan yang tidak sekata (*non-linear*) berbanding dengan *Mohr-Coulomb*. Kesimpulannya, H-B kriteria memberikan gambaran keadaan *Shale* dibawah tekanan mengurung yang lebik baik berbanding dengan kaedah M-C.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

α	-	Rock mass constant
β	-	Inclination angle
c	-	Interlocking
c_w	-	Interlocking of weakness plane
D	-	Rock mass disturbance factor
Q	-	Tunnelling Quality Index
J_n		Joint set number
J_r	-	Joint roughness number for critical joint set
J_a	-	Joint alteration number (weathering) for critical joint set.
J_w	-	Joint reduction factor due to presents of water.
M	-	Material constant
m_i	-	Intact rock constant
σ_1	-	Peak stresses/axial stress
σ_2	-	Intermediate principal stress
σ_3	-	Confining pressures
σ_c	-	Compressive strength
σ_t	-	Tensile strength
σ_n	-	Normal stress
σ_{cm}	-	Global rock mass strength
σ'_1	-	Effective peak stresses/axial stress
σ'_3	-	Effective confining pressures
σ'_{ci}	-	Effective uniaxial compressive strength of intact rock
θ	-	Angle of failure plane under compression
s	-	Intact rock material constant

CHAPTER 1

INTRODUCTION

1.1 Background

Rock failure has been studies in a co-ordinate way since the 1960s. The way in which rock fails can be studied by examination of natural rock formations that have been stressed and strained over geological time, by laboratory experiments on rock samples, through in situ experiments, and by observing the result of rock excavation and loading during engineering construction. It is very difficult to visualize the rock failure under confinement deep below the ground surface, and it almost impossible to test a rock mass. Hence it is vital to study the strength criteria of rock with a precise test such as triaxial test. The conventional triaxial strength criterion is the basis of all true criteria, and is on the safe side for rock engineering after neglecting the effect of intermediate stress.

The Baram Dam, also known as Baram 1 Dam (Baram Hydroelectric Dam Project) is a proposed gravity dam on the Baram River in the Malaysian state of Sarawak. The site of the Dam is 250 kilometers inland from Miri, the second largest city in Sarawak. The proposed Baram Hydroelectric Project (HEP) with a

capacity of 1,200MW is located on the stretch of the Baram River between Long Naha'a and Long Keseh, subject to confirmation of the site investigations and the SEIA study, which are now being carried out. An earlier feasibility study carried out by an independent consultant (Fichtner GmbH & Co KG) commissioned by Sarawak Energy estimates that 6,000 to 8,000 people will be directly affected by the Baram dam from 32 longhouses. This number has also been verified by the Miri Resident's office (sarawaksynergy.com.my).

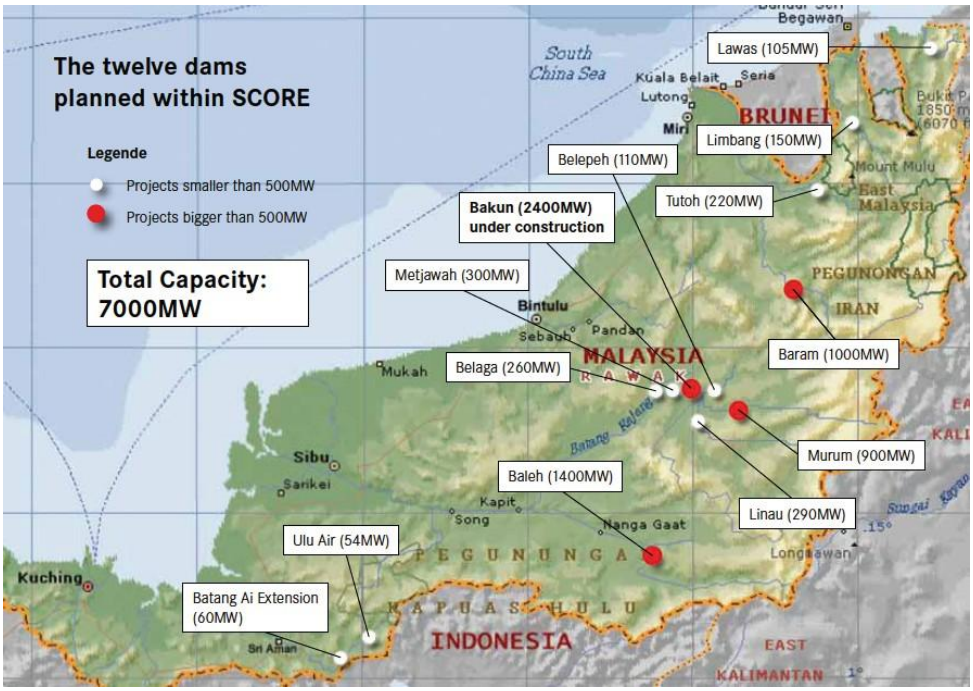

Figure 1.1 Location of the Twelve Dams planned under SCORE (www.sarawaksynergy.com)

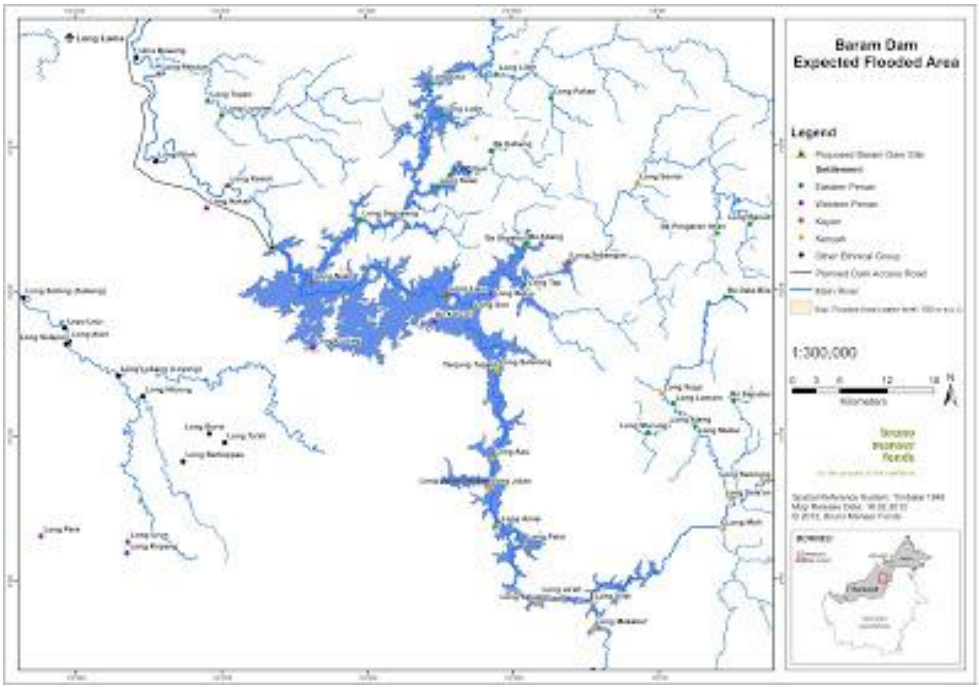

Figure 1.2 Baram Dam expected flooded area (www.sarawaksynergy.com)

The development of the Baram HEP gives a direct benefit to the people in the interior of Baram. The project is set to spur the overall development of Baram with a focal administrative township of Bandar Baru Telang Usan. The township will be a landing point for development, economically and socially. In a nutshell, the Baram HEP will be a catalyst for development in Baram and will provide the local communities with benefits that include work opportunities, new and better homes, roads, schools and infrastructure development. Few borehole explorations has been done at the located area to determine the condition of the foundation. It has been discovered that underneath the dam location is shale. Hence, it is crucial to determine the shear strength of shale as it is known to be very poor in term of quality.

1.2 Problem Statement

Strength envelope should describe failure of rock under common stresses in construction. For instance, tensile, uniaxial compression and triaxial compression. So, this study embark at producing strength for shale in Baram, Sarawak. There are two failure criteria namely Mohr-Coulomb and Hoek-Brown. With regard to failure criterion, these are 2 common approaches used namely Mohr-Coulomb and Hoek-Brown. This study will look into strength envelope produces by each criterion.

Uncertainties arise in predicting the behaviour of a rock mass under confinement due its discontinuities nature. Discontinuity such as joint induces inhomogeneous and anisotropic behaviour in the rock mass, in contrast to the behaviour of intact rock samples used in the lab tests. Several empirical approach such as Rock Mass Rating (RMR) are available to classify and to evaluate the mass strength of discontinuous rock. However RMR suffers from several limitations for it is not suitable for very poor quality rock mass such as shale. For this reason, it is vital to evaluate strength parameter through analysis of Hoek-Brown and Mohr-Coulomb.

1.3 Objective of the Study

This study attempts to verify the strength parameters of the rock using different failure criterion. The objective of the study comprises of the following:

(i) To study the strength envelope and failure criterion of shale using Mohr-Coulomb and Hoek-Brown.
(ii) To determine engineering properties of shale from the laboratory test

(iii) To compare the rock behaviour under Mohr-Coulomb and Hoek-Brown method failure criteria.

1.4 Scope of the Study

Generally, this study focuses on highly laminated rock known as shale which was collected from Baram, Sarawak where a dam will be built. To construct a dam above the very weak rock, the shear strength parameter need to be determined carefully to ensure a good design. Basically there are two types of criterion that involve in strength parameter of intact rock which are Hoek-Brown and Mohr-Coulomb criterion. Both criteria are used to describe the failure criteria by using analysis thru RocData software.

In order to gather the data required for analysis purpose, three different laboratory test will be conducted which are uniaxial compression test (UCT), triaxial test and also Brazilian test. Thru these laboratory test, the parameters such as uniaxial compression strength, maximum stress at failure and tensile stress can be determined. All the data then will be use in RocData software and analyze to get the strength parameters.

1.5 Significance of the Study

Parameters on rock material strengths are usually determined from laboratory test on the intact rock samples. It is very difficult to predict the behaviour of rock

mass under confinement due to its discontinuities nature. Therefore, by having a close prediction of Hoek-Brown failure criterion with the laboratory test result, the Geological Strength Index (GSI), which reflect to the rock mass strength can be predicted.

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