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UNIVERSITI PUTRA MALAYSIA

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NUR IRFAH MOHD PAUZI

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By

NUR IRFAH MOHD PAUZI

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SHEAR STRENGTH CHARACTERISTICS AND MICROCRACK PATTERN OF GRANITE FROM POS SELIM, PERAK, MALAYSIA

By

NUR IRFAH BINTI MOHD PAUZI

May 2007

Chairman : Associate Professor Husaini bin Omar, PhD.

Faculty : Engineering

Granite bodies can fracture in various characteristic ways relative to the density of fractures, the number of joints sets and their distribution, and the type of fractographic features on fracture surfaces. Granite commonly involves complex composite microcrack systems which are caused by different geologic processes under varying condition. Microscopic studies of cracks under shear stress in granite samples have been carried out using Robertson shear testing and Scanning Electron Microscope (SEM) to study the shear strength parameters and their interaction between microcrack propagation patterns. Shear strength parameters such as friction angle and cohesion, Joint Roughness Coefficient (JRC) and Joint Compressive Strength (JCS) has been studied on granite at Pos Selim area. Microcrack propagation patterns for granite at Pos Selim has been proposed to be categorized into two type which are type A and type B. Type A is microcrack propagation pattern for granite grade II and type B is microcrack propagation pattern for granite grade III. Griffith theory states that fracture material is caused by stress concentration, causing the crack to propagate and ultimately

contributing to microscopic failure of the material. The result show that type A and type B microcrack propagation patterns do comply with Griffith theory. Type A microcrack propagation pattern does not lead to failure and consists of minor crack surface. This is because type A material has higher strength compared to type B. Type B material show microcrack pattern that propagates from the left side of the sample leading towards the right side of the sample which caused failure of the material. The relationship between the microcrack pattern and the shear strength parameters proves that an increase in shear stress and normal stress would result in increase of microcrack area. Therefore, the knowledge from these studies show that the understanding in microcrack propagation patterns can improve our understanding of damaging process and failure of intact rock.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

CIRI-CIRI KEKUATAN RICIH DAN CORAK REKAHAN MIKRO PADA BATUAN GRANIT DARI POS SELIM, PERAK, MALAYSIA

Oleh

NUR IRFAH BINTI MOHD PAUZI

Mei 2007

Pengerusi : Professor Madya Husaini bin Omar, PhD

Fakulti : Kejuruteraan

Batuan granit boleh merekah dengan pelbagai cara bergantung kepada ketumpatan rekahan, jumlah set-set belahan dan taburannya, dan ciri-ciri permukaan fraktografiknya pada permukaan retak. Lazimnya, granit mempunyai proses komposit yang kompleks pada sistem retakan mikronya kerana perbezaan proses geologi yang berlaku disebabkan oleh pelbagai situasi. Kajian retakan mikro yang disebabkan oleh tekanan ricih telah diuji dengan menggunakan ujian kekuatan ricih Robertson dan mikroskop pengimbas elektron pada sampel granit untuk menguji parameter-parameter kekuatan ricih dan kaitannya dengan bentuk retakan mikro. Parameter-parameter kekuatan ricih ini termasuklah sudut geseran dan kejeleketan, pemalar kasar rekahan (JRC) dan kekuatan mampatan rekahan (JCS) yang dikaji pada batuan granit di kawasan Pos Selim. Bentuk retakan mikro telah dicadangkan untuk dibahagikan kepada dua kategori iaitu jenis A dan jenis B. Jenis A ialah bentuk retakan mikro untuk granit gred II and jenis B ialah bentuk rekahan mikro untuk granit gred III. Teori Griffith telah menyatakan bahawa retakan pada bahan adalah disebabkan oleh konsentrasi tekanan, yang boleh menyebabkan retakan menular dan akhirnya terbentuklah retakan mikroskopik pada

sampel. Hasil daripada kajian menunjukkan jenis A dan jenis B memenuhi kehendak teori Griffith. Retakan mikro Jenis A tidak mengalami kegagalan dan terdiri daripada permukaan retakan yang minor. Ini adalah kerana jenis A mempunyai kekuatan batuan yang lebih tinggi berbanding dengan jenis B. Retakan mikro pada bahan jenis B menunjukkan retakan menular daripada satu sudut tepi kepada satu sudut tepi yang lain dan memecahkan sampel kepada dua bahagian. Hubungan di antara bentuk retakan mikro dengan parameter kekuatan ricih menunjukkan dengan meningkatnya tekanan ricih dan tekanan normal akan menyebabkan peningkatan pada keluasan bentuk retakan mikro. Dengan ini, pengetahuan daripada kajian ini menunjukkan bahawa kajian retakan mikro boleh menambahkan lagi kefahaman kita dalam mengkaji proses kerosakan dan kegagalan pada batuan.

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I certify that an Examination Committee has met on 9th May 2007 to conduct the final examination of Nur Irfah Mohd Pauzi on her Master of Science thesis entitled "Shear Strength Characteristics and Microcrack Pattern of Granite from Pos Selim, Perak, Malaysia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee were as follows:

Mohd Salleh b. Jaafar, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Jamaloddin b. Noorzaei, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Azlan b. Abdul Aziz,
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Faisal b. Haji Ali, PhD
Professor
Civil Engineering Department
Faculty of Engineering
Universiti Malaya
(External Examiner)

_____

HASANAH MOHD GHAZALI, PhD.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 3 August 2007

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Husaini Omar, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Bujang Kim Huat, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Shukri Maail
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

_____
AINI IDERIS, **PhD**.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 9 August 2007

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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NUR IRFAH MOHD PAUZI

Date: 25 June 2007

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LIST OF ABBREVIATIONS

c	cohesion
CH	Chainage
FOS	Factor of safety
Ft	feet
H, h	Height
i	Roughness Angle
inch	inches
JCS	Joint Compressive Strength
JRC	Joints Roughness Coefficient
km	kilometers
kN	kilo Newton
L, l	Length
MPa	Mega Pascal
m	meters
mm	millimeters
SEM	Scanning Electron Microscope
w	width
τ	shear stress
σ_n	normal stress
α	Slope angle
Φb	Basic friction angle
ϕ	Angle of internal friction

CHAPTER 1

INTRODUCTION

1.1 Background

Granite is characterized by microstructures including microcrack and microcavities whose evolution and interaction under stress called the micro-damage process that determine the macroscopic mechanical response. Granite commonly involves complex composite microcrack systems which are caused by different geologic processes under varying conditions (Kranz, 1983).

Granite bodies can fracture in various characteristic ways relative to the density of fractures, the number of joints sets and their distribution and the types of fractographic features on fracture surfaces. These microcrack fracture studies are of increasing interest in geophysics and engineering related to underground radioactive waste repositories. Physical properties of rocks are not only affected by the constituent minerals and their preferred orientation, but also by the microcracks (Ahrens and Rubin, 1993; Shen et al, 1995; Li et al, 1998; Wong and Chau, 1998; Eberhardt et al, 1999, and David et al, 1999). Since microcracks play an important role in physical properties of rock, microcracks are also studied to know its relation with the engineering properties such as the shear strength parameters that could affect the stability of slopes.

Many researches [Hoek and Bray (1981), Barton (1971) and Rengers (1971), Barton (1973) Barton and Choubey (1977) Zainuddin et al (2001), Lan et al (2003), Komoo et al., 2004) and Jiang et al (2006)] have done studies on the shear strength parameters of rock. However their rock strength parameters data are based on the rock from their respective countries. It is not known whether their rock has the same shear strength parameters as the rock in Malaysia. To ensure the safety of cut slopes in Malaysia, there is a dire need to establish Malaysian data of shear strength parameters of rock. This research is carried out to fulfill this need. The outcome from this research will provide data on the shear strength parameters of Malaysian rock required by slope designers.

When analyzing the stability of a rock slope, there are three important factors that need to be considered, namely the geometry of the rock mass behind the slope face, the shear strength of potential failure surface and the groundwater flow in rock masses. The determination of reliable shear strength values is a critical part of a slope design because relatively small changes in shear strength can result in significant changes in the safe height or angle of a slope. Thus, an appropriate choice of shear strength values depends not only upon the availability of test data but also upon interpretation of these data in the light of the behaviour of the rock mass. This research hopes to provide the reliable shear strength data for Malaysian rock slope.

The stability of slopes varies with the inclination of discontinuity surfaces. Examples of discontinuity surface are faults, joint and bedding planes which are found within the

rock mass. When these discontinuities are vertical or horizontal, simple sliding cannot take place and the slope failure will involve fracture of intact blocks of rock as well as movement along some of the discontinuities. However, if the rock mass contains discontinuities surface dipping towards the slope face at angles of between 30 degrees to 70 degrees, simple sliding can occur and the stability of this slope is significantly unstable compared to those slopes which contain horizontal and vertical discontinuities.

Clearly, it can be said that the presence or absence of discontinuities has a very important influence upon the stability of rock slopes and the detection of these geological features are the most critical part of stability investigation. After recognizing the discontinuities on slope, the material properties such as friction angle and cohesion are the next most relevant properties in slope stability analysis. The friction angle and cohesion are determined in this study. Other than that the Joint Roughness Coefficient and Joint Compressive Strength are also determined in this study. These parameters are the main parameters to be used in the design of cut rock slope.

Shear stress mechanisms on the saw-cut surface which produce the crack surfaces after the shear stress is applied are studied. These crack surfaces may have relation to the shear strength parameters and contribute to the reliability of the design of the cut slope. The presence of crack surfaces, porosity and fractured characteristic which are considered as microscopic flaws can be observed microscopically with a Scanning Electron Microscope (SEM). SEM has become available as a commercial instrument

with a capability of imaging surface topography and morphology with unprecedented advantage of depth of field and a capability for studying any surface in its original, unaltered surface (Murr, 1991).

Thus, to investigate the microcrack propagation patterns and the shear strength parameters, SEM has been used as a tool. The microcrack pattern before and after the shear test is observed using SEM. The microcrack pattern that contains physical constituent of rock has been studied in detail to relate it with the shear strength parameters which are important for the analysis of slope stability. The knowledge from this studies show that the understanding in microcrack can improve our understanding of damaging process and failure of intact rock, and to prove that microcrack pattern does also contribute to the shear strength characteristics.

1.2 Problem Statement

Shear strength parameters such as friction angle and cohesion are the main parameters studied in this research. The reliability of this data is very important since the parameters affect the design of slope angle and height. Currently, the design shear parameters are assumed by the slope designer. This research hopes to give the range of data for the slope designer to use as a guide when selecting the friction angle and cohesion for the design of cut rock slopes in Malaysia.

In this research, granitic core samples tested. The two experiments done in this study were shear strength test and the microscopic fracture test. The shear strength test was carried out to obtain the shear strength parameters data and the microscopic fracture test was carried out to determine the crack fracture surface on sheared core sample using Scanning Electron Microscope (SEM). The SEM image would give the fracture characteristic and crack propagation on granitic rock. Then, this image was analyzed to obtain a microcrack propagation pattern analysis which can be used for fracture mechanics studies that must comply with Griffith theory of crack propagation.

1.3 Research Aim and Objectives

The main aim of this research is to investigate the shear strength parameters and its microcrack pattern on granite in Pos Selim, Perak. The objectives of the research are:-

1. To determine the shear strength parameters such as friction angle, cohesion, Joint Roughness Coefficient (JRC) and Joint Compressive Strength (JCS) of granitic rock
2. To study and analyze the microscopic crack and fracture using Scanning Electron Microscope
3. To propose the microcrack pattern of granite in Pos Selim area
4. To study the relationship between microcrack pattern and the shear strength parameters of granite at Pos Selim area