UNIVERSITI PUTRA MALAYSIA

VERIFICATION OF INDIRECT TENSILE STRENGTH OF WEATHERED MUDSTONE FROM H·OMETER TEST USING SIGMA/W MODEL

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

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Specially Dedicated to My Family

Ahmad Hassan

Zabedah Yakob

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Associate Professor Husaini Bin Omar, Ph.D.

Faculty : Engineering

This study presents the findings determine of a comparative study to indirect tensile strength from H-Ometer test and finite element method. H-Ometer tests were carried out on weathered mudstone specimens on the axial model. Two-dimensional plane strain analysis using SIGMA/W Finite Element Method was carried out to simulate the performance of H-Ometer test on the axial model. The relationship between indirect tensile strength of the H-Ometer Test and Finite Element Method for weathered mudstones are presented. The H-Ometer results on axial model specimens showed the average indirect tensile strength is 0.102 MPa and the finite element analysis is 0.116 MPa. Consistently, results of both methods indicate that indirect tensile strength from the finite element method is slightly higher compared to the H-Ometer test. It is proposed that the relationship between indirect tensile strength from H-Ometer test and finite element method is $\sigma_{FE} = 1.132\ \sigma_{HO}$ where σ_{HO} is tensile strength from H-Ometer test and σ_{FE} is indirect tensile strength from finite element method. From the statically analysis the results show a good relationship between H-Ometer test and finite element method in indicating that the related parameters can be used to predict the indirect tensile strength of weak rock.

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

MENENTUKAN UJIAN KEKUATAN TEGANGAN TAK LANGSUNG KE ATAS BATUAN LUMPUR TERLULUHAWA DARIPADA UJIAN H-OMETER MENGGUNAKAN MODEL SIGMA/W

Oleh

AZURA AHMAD

November 2002

Pengerusi : Profesor Madya Husaini Omar, Ph.D.

Fakulti : Kejuruteraan

Satu kajian perbandingan telah dijalankan untuk menguji kekuatan tegangan tak lansung diantara ujian H-Ometer dan kaedah unsur tak terhingga. Ujian H-Ometer telah dijalankan keatas batu lumpur terluluhawa pada kedudukan model paksi. Kaedah yang digunakan untuk unsur tak terhingga adalah perisian SIGMA/W bagi simulasi keatas ujian H-Ometer. Dalam kajian ini model paksi dianalisa secara paksi-keterikan dua dimensi. Dari kajian ini, keputusan ujikaji yang dijalankan keatas ujian H-Ometer pada puratanya ialah 0.102 MPa dan analisa unsur tak terhingga pula menunjukkan nilai purata bagi kekuatan tegangan tak lansung ialah 0.116 MPa. Dari kajian perbandingan ini, keputusan menunjukkan bahawa nilai kekuatan tegangan tak lansung daripada kaedah unsur tak terhingga sedikit tinggi berbanding dengan ujian H-Ometer. Oleh yang demikian, hubungkait diantara tegangan tidak langsung dari pengujian H-Ometer dan kaedah unsur tak terhingga ialah $\sigma_{FE} = 1.132\ \sigma_{HO}$ dimana σ_{HO} kekuatan tegangan tak lansung H-Ometer dan σ_{FE} ialah kekuatan tegangan tak langsung dari kaedah unsur tak terhingga. Hasil dari statistic analysis telah membuktikan, bahawa keputusan korelasi diantara ujikaji H-Ometer dan kaedah unsur tak terhingga yang berkaitrapat dengan parameter tersebut boleh dijalankan keatas ujian H-Ometer terhadap batuan lembut.

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LIST OF ABBREVIATIONS

P_f	Pressure at failure
σ_h	Horizontal stress
σ_{HO}	Indirect tensile strength from H-Ometer test
σ_{br}	Indirect tensile strength from Brazillian test
ω	Water content
α	Rheological factor
G	Shear modulus
V	Volume of the cavity
P	Pressure in the cavity
ΔP	Change in pressure
ΔV	Change in volume
V_o	The initial of volume
V_f	Volume at failure
V_m	Volume of the cavity at the mid-point of the straight line portion of the H-Ometer curve
V_c	Volume of the probe
E_p	Modulus of deformation
ν	Poisson's ratio
G_M	Pressuremeter shear modulus
E_{HO}	H-Ometer modulus
P_{corr}	Corrected pressure
P_a	Applied pressure from the gauge
P_{cal}	Calibrated pressure from the calibration curve
p_o	Initial pressure
E_M	Pressuremeter modulus
K	Stress intensity factor

Kc	Critical stress intensity factor
L	The effective length of the inflatable portion of the probe for testing
E_{EM}	Elastic modulus
σ_{FE}	indirect tensile strength from finite element method
σ_{HO}	indirect tensile strength from H-Ometer test

CHAPTER I

INTRODUCTION

Background

Rocks are natural, unique materials that need to be dealt with in any physical development of a particular area especially in the construction of tunnels, deep excavations and dams. The uniqueness of this material lies in its mineralogical content, degree of weathering, historical formation, topography and several other factors that affect its strength and behaviour. On the other hand soil is loose material extending from surface to solid rock, formed by weathering and disintegration of rocks. Between the solid rock and soil, a material lies. This material is not definitely lithic but has characteristics comparable to soil and it is termed as a soft rocks.

Indeed, the rapid pace of civil engineering work make the study of lithotpyes of soft rock either directly or indirectly imperative (Clerici, 1992). Efforts to obtain and establish engineering characteristics of soft rocks particularly its mass strength and deformation parameters which are ongoing necessary because they may serve as guidelines to geotechnical engineers.

The study of weak rocks and their properties is an important engineering problem because of its extensive application in construction (Oliveira, 1993).

Obviously, weak rocks fall into the category of material problem, as it is difficult in sampling and testing.

In the past, several researchers have investigated the behaviour of soft, weak and weathered rocks with particular objectives in mind. To the geotechnical engineers normally faced a problem in finding the strength and deformation parameters of weak rocks. They need to develop very careful testing procedures and interpretation techniques; however current techniques of investigation are tailored for either soft or weak rocks. The H-Ometer, which was developed, recently (Omar, 2001) should serve as a useful device to measure indirect tensile strength for hard soil, weak rock and also unconfined compression test on compacted soil (Omar et al., 2000a). The H-Ometer was designed for laboratory and field tests.

Due to the complexity of geometry, material behaviour, boundary condition and failure mechanisms associated with weak rock, it is necessary to be able to predict performance of weak rocks. So, numerical techniques such as the finite element method has been used to seek solution related to problems posed by weak rocks. Further appropriate analytical and numerical methods had also to be developed to describe the influence of the tensile strength of weak rocks.

The finite element method is a useful tool for solving numerous engineering problems and is widely used in many industrial fields. Thus the finite element method had been used extensively to model geotechnical problems, even though very little attention has been directed to use the finite element method for analysing the tensile failure (Haberfield and Johnston, 1990c).

Problem Statement

First H-Ometer indirect tensile strength was determined by using artificial weak rock specimens. Then, the effectiveness of the H-Ometer to determine indirect tensile strength was verified on actual weak rock specimens.

Objectives

The objective of this study is to determine the tensile strength of weak rock by using the H-Ometer test and also by finite element method. Towards this aim, the following task will be under taken:

1. Determination of the indirect tensile strength of weak rocks in axial testing position using the H-Ometer test.
2. Determination of the indirect tensile strength of weak rocks in axial model using Finite Element Method.
3. Comparison of the indirect tensile strength from H-Ometer with the finite element results.

Scope and Limitations

The study focused on two methods to determine tensile strength of weak rocks, experimental and numerical methods. First, in the experimental work, the H-Ometer test to be carried out for obtaining tensile strength of weak rocks. Second, a finite element model also to be applied to predict the indirect tensile strength of weak rocks. The model developed is a two-dimensional, and material is analysed as a linear-elastic, then validation for H-Ometer will be done.

Expected outcome of the Research

The expected outcome of the research is determination of the indirect tensile strength of weak rocks from the H-Ometer test and finite element model. The H-Ometer test is envisaged to be widely used to obtain geotechnical parameters in the laboratory particularly for weak rock specimens. A good correlation could allow for a quick and reliable method of ascertaining necessary parameters related to engineering properties.

CHAPTER II

LITERATURE REVIEW

Introduction

The original concept of the pressuremeter is attributed to Kogler in 1933, who developed a device consisting of a rubber bladder, clamped at both ends and which is lowered into a predrilled hole (Clarke, 1995). The instrument is gas inflated and a pressure-volume relationship is obtained. The idea of using an inflatable cylindrical device or pressuremeter is to measure in-situ soil or rock properties. It was first used in 1930s. Finally, with further work on it by Louis Menard in France, it became a practical reality in the late 1950s (Clarke, 1995)

The pressuremeter test has developed considerably since its first introduction by Menard in 1956 (Menard, 1957). It was first used in Chicago, to obtain ground properties for the design of structures. Since then, it has become one of the most widely used pressuremeters. In the 1950s, OYO Corporation of Japan developed independently, two types have Elastometer 100 and Elastometer 200. Their equipment was designed for use in pre-drilled holes. Pressure was applied either from a hand pump or from bottled gas. OYO Corporation used the Elastometer 200 mainly as a rock pressuremeter whilst the Elastometer 100 was used as a soil type pressuremeters (Clarke, 1995)

The standard pressuremeter is either inserted into a pre-bored hole or directly jacked or driven into the ground. A slotted tube protects the measuring cell, which consists of a cylindrical rubber membrane. In order to reduce the influence of soil or soft rock disturbance during probe insertion, a self-boring pressuremeter was developed (Clarke et al., 1989). The use of this type of pressuremeter is limited to fine-grained soils, while the standard pressuremeter can be used in most soil types. As the pressuremeter is an intermittent test, it cannot provide a continuous profile. The test is comparatively time-consuming and therefore not cost effective.

Today, there are several different types of pressuremeters. They are the preboring pressuremeter (PBPTM), the selfboring pressuremeter (SBPMT), the cone pressuremeter either pushed (PCPMT) or driven (DCPMT) in place, and the pushed Shelby tube pressuremeter (PSPMT). These various pressuremeters differ mainly by the way the probe is placed in the ground.

More general descriptions of the development of the pressuremeter and the associated theories are provided by Baguelin et al., (1978); Wroth (1984); Mair and Wood (1987); Briaud (1992); and Clarke (1995). Not only history of the pressuremeter covered well in these publications, but also information on the background, theory and practical applications has been provided.