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

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

By

AZURA AHMAD

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

November 2002
Specially Dedicated to My Family

Ahmad Hassan
Zabedah Yakob
Aniza Ahmad
Khairul Nizam Ahmad
Khatijah Azlina Ahmad
Azmira Ahmad
Mohd Haziq Fitri Ahmad
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 $\sigma_{HO}$ is tensile strength from H-Ometer test and $\sigma_{FE}$ 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.

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Satu kajian perbandingan telah dijalankan untuk menguji kekuatan kekuatan tegangan tak lansung di antara ujian H-ometer dan kaedah unsur tak terhingga. Ujian H-ometer telah dijalankan ke atas batuan lumpur terluluhawa pada kedudukan model paksi. Kaedah yang digunakan untuk unsur tak terhingga adalah perisian SIGMA/W bagi simulasi ke atas ujian H-ometer. Dalam kajian ini model paksi dianalisa secara paksi-keterikan dua dimensi. Dari kajian ini, keputusan ujikaji yang dijalankan ke atas 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 di antara tegangan tidak langsung dari pengujian H-ometer dan kaedah unsur tak terhingga ialah \( \sigma_{FE} = 1.132 \sigma_{HO} \) dimana \( \sigma_{HO} \) kekuatan tegangan tak lansung H-ometer dan \( \sigma_{FE} \) ialah kekuatan tegangan tak langsung dari kaedah unsur tak terhingga. Hasil dari statistic analysis telah membuktikan, bahawa keputusan korelasi di antara ujikaji H-ometer dan kaedah unsur tak terhingga yang berkait rapat dengan parameter tersebut boleh di jalankan ke atas ujian H-ometer terhadap batuan lembut.
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In the name of ALLAH the most Beneficent, and the Merciful

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I certify that an Examination Committee met on 1st November 2002 to conduct the final examination of Azura Ahmad on her Master of Science thesis entitled “Verification of Indirect Tensile Strength of Weathered Mudstone from H-Ometer Test Using SIGMA/W Model” 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 are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, 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.

AZURA AHMAD

Date: 15/11/2002
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>v</td>
</tr>
<tr>
<td>APPROVAL SHEET</td>
<td>vi</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xvi</td>
</tr>
</tbody>
</table>

## CHAPTER

### I INTRODUCTION

- Background                                          1
- Problem statement                                   1
- Objectives                                          3
- Scope and Limitations                                4
- Expected Outcome of the Research                     4

### II LITERATURE REVIEW

- Introduction                                         5
- H-Ometer
  - The development of H-Ometer                        7
  - Testing and Calibration                             11
  - Indirect Tensile strength                           14
  - Application of H-Ometer                             17
  - H-Ometer Modulus                                     19
- Weak Rocks
  - Classification of Weak Rock                        26
  - Sampling of Weak Rock                               27
  - Weathering Classification                           32
Weathered Mudstone 35
Finite Element Method 36
Propagation of Crack Model 37
Numerical analysis on Tensile Strength of Weak Rock 46

III METHODOLOGY 51
Introduction 51
Sampling Technique 53
Proposed Equipment 54
Selection of Weak Rock 55
Weathering Grade 55
H-Ometer Test 56
Calibration 57
Sample Preparation 57
Determination of Indirect Tensile Strength 59
Finite Element Study 60
Finite Element Tool 60
Modelling of Specimen 61

IV RESULTS AND DISCUSSIONS 63
Introduction 63
Sampling of Weathered Mudstone 64
Steel Mould 66
Sampling Process 67
Classification of Weak Rock 72
The degree of Weathered Mudstone 75
Sample Preparation for H-Ometer Test 77
Axial Model 78
Pre-drilled Hole the Axial Model 79
H-Ometer Test 80
Calibration 81
Indirect Tensile Strength 87
H-Ometer Modulus 95
Finite Element Analysis 101
Axial Model 101
Indirect Tensile Strength 110
Comparison of Indirect Tensile Strength From H-Ometer and Finite
Element Method 115
Statistic and Data Analysis 120
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Menard’s $\alpha$ factor</td>
</tr>
<tr>
<td>2.2</td>
<td>A guide to sampling methods</td>
</tr>
<tr>
<td>2.3</td>
<td>The physical characterization scheme of the weathering classification for metasediments</td>
</tr>
<tr>
<td>4.1</td>
<td>Summarized results of the uniaxial compressive strength</td>
</tr>
<tr>
<td>4.2</td>
<td>Summary of indirect tensile strength results of axial model</td>
</tr>
<tr>
<td>4.3</td>
<td>Summary of H-OMeter modulus results from H-OMeter test</td>
</tr>
<tr>
<td>4.4</td>
<td>Material properties on the model specimens</td>
</tr>
<tr>
<td>4.5</td>
<td>Summary of indirect tensile strength results from finite element method</td>
</tr>
<tr>
<td>4.6</td>
<td>Summary of indirect tensile strength results from the H-OMeter test and finite element method</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Components of H-Ometer</td>
</tr>
<tr>
<td>2.2</td>
<td>Membrane resistance calibration</td>
</tr>
<tr>
<td>2.3</td>
<td>Line calibration</td>
</tr>
<tr>
<td>2.4</td>
<td>A typical H-Ometer test curve</td>
</tr>
<tr>
<td>2.5</td>
<td>Relationship between measuring pressure and volume from H-Ometer test</td>
</tr>
<tr>
<td>2.6</td>
<td>The standard definitions for weak rocks</td>
</tr>
<tr>
<td>2.7</td>
<td>Development of radial tensile cracking during pressuremeter tests</td>
</tr>
<tr>
<td>2.8</td>
<td>Crack Propagation</td>
</tr>
<tr>
<td>(a) Elastic cracks initiate at cavity wall</td>
<td></td>
</tr>
<tr>
<td>(b) Cracks propagate in the weakest direction</td>
<td></td>
</tr>
<tr>
<td>2.9</td>
<td>The general pattern of major cracks</td>
</tr>
<tr>
<td>(a) Two</td>
<td></td>
</tr>
<tr>
<td>(b) Three</td>
<td></td>
</tr>
<tr>
<td>(c) Four</td>
<td></td>
</tr>
<tr>
<td>2.10</td>
<td>Mode of Failure</td>
</tr>
<tr>
<td>2.11</td>
<td>Stresses at crack tip for the opening mode I</td>
</tr>
<tr>
<td>2.12</td>
<td>Crack growth modelled by release of boundary restraints</td>
</tr>
<tr>
<td>2.13</td>
<td>Types of fracture found around circular openings in laboratory model tests</td>
</tr>
<tr>
<td>2.14</td>
<td>Dimensions of sample</td>
</tr>
<tr>
<td>(a)</td>
<td></td>
</tr>
<tr>
<td>(b) Finite element mesh of simulation</td>
<td></td>
</tr>
<tr>
<td>(c) Stress distribution in samples as a function of P/A for direct method</td>
<td></td>
</tr>
<tr>
<td>2.15</td>
<td>Test geometries for bending test method</td>
</tr>
</tbody>
</table>
3.1 Flow chart of research project 52
3.2 Schematic diagram of sampling equipment 54
3.3 Axial model 58
3.4 Sample with pre-drilled hole 58
3.5 Corrected and uncorrected curves from the H-Ometer test 59
3.6 Application of SIGMA/W finite element model 62
4.1 Location plan of sampling site 64
4.2 A schematic diagram area of sampling 65
4.3 Steel mould 66
4.4 Removing disturbed material 68
4.5 Driving the mould into the ground 69
4.6 Mould with sample 69
4.7 The extruder 70
4.8 Extrusion of sample 71
4.9 Sealing sample wrapping plastic 72
4.10 Specimen of uniaxial compressive test 73
4.11 Uniaxial compressive strength vs. the number of samples 74
4.12 Material texture of rocks are preserved 76
4.13 Sample can be broken by hand 76
4.14 Sample soaked in water 77
4.15 Axial model 78
4.16 Pre-drilled hole of specimen 79
4.17 Parts of the H-Ometer 80
4.18 Membrane resistance calibration 82
4.19 Membrane calibration curve 82
4.20 Line calibration 83
4.21 The H-Ometer test on axial model 85
4.22 Cracked specimens from the H-Ometer test 86
4.23 A typical corrected and uncorrected curve of the H-Ometer test 88
4.24 Variation of indirect tensile strength against moisture content 91
4.25 The general pattern of two major cracks 93
4.26 Crack propagation of axial model
   (a) Elastic expansion without crack
   (b) Minor Elastic cracks initiate at cavity wall;
   (c) Major Cracks propagate in the weakest direction 94
4.27 A typical H-Ometer test curve to determine H-Ometer Modulus 96
4.28 Two-dimension finite element schematic of the tested samples 104
4.29 Finite element mesh of the tested specimen 106
4.30 Finite element boundary condition of the tested specimen 107
4.31 Finite element mesh of the tested specimen 108
4.32 Finite element mesh for simulation of laboratory test 111
4.33 Draw stress contours 112
4.34 Results between indirect tensile strength from H-Ometer test and finite element method 117
4.35 Relationship tensile strength from H-Ometer test and finite element method 118
LIST OF ABBREVIATIONS

\( P_f \) Pressure at failure
\( \sigma_h \) Horizontal stress
\( \sigma_{HO} \) Indirect tensile strength from H-Ometer test
\( \sigma_{br} \) Indirect tensile strength from Brazilian test
\( \omega \) Water content
\( \alpha \) Rheological factor
\( \varphi \) Shear modulus
\( V \) Volume of the cavity
\( P \) Pressure in the cavity
\( \Delta P \) Change in pressure
\( \Delta V \) 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
\( \nu \) 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
$K_c$ Critical stress intensity factor
$L$ The effective length of the inflatable portion of the probe for testing
$E_{EM}$ Elastic modulus
$\sigma_{FE}$ indirect tensile strength from finite element method
$\sigma_{HO}$ 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 lithotypes 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 undertaken:

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.