UNIVERSITI PUTRA MALAYSIA

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By

JURAIDAH AHMAD

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Engineering
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Specially Dedicated to My Beloved

Late Father
Allahyarham Hj. Ahmad Ujod

Mother
Hjh. Che Rose Dewa

Husband
Ahmad Kailani Muhammad

Children
Abdul Azim Al-Abrar Ahmad Kailani
Muhammad Al-Fateh Ahmad Kailani
Ainul Faqihah Ahmad Kailani
Anis Munibah Ahmad Kailani

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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June 2001

Chairman : Ir. Salihudin Hassim

Faculty : Engineering

A method of testing for the tensile strength of weak rock from H-Ometer is presented. H-Ometer tests are carried out on artificial weak rock specimen to test for the accuracy of the model. The weak rock is a simulation of weakly cemented sandstone, which is assumed homogeneous and isotropic and contains no discontinuities. Presently, the existing method of indirect tensile testing using the H-Ometer test is carried out on diametrical specimen model. In this study, efforts to determine a suitable method of testing are carried out on both axial and diametrical model position. The test was conducted on both model specimens, which is subjected to incremental load until failure occurs, and at each load response, the deformation, crack pattern and tensile strength were determined.

In this study, a 3-Dimensional elasto-plastic analysis of the experimental work using commercially available LUSAS Finite Element Method is carried out to simulate

the performance of H-Ometer on both axial and diametrical model specimens. The ability of the simulated models to predict the tensile strength and crack pattern from H-Ometer will validate the experimental results. Comparison of results for both diametrical and axial model specimen will determine the appropriate model specimen that will give accurate results from H-Ometer test.

Throughout this investigation, results of both model specimens carried out using H-Ometer testing device is found to be reliable with indirect tensile strength values ranging from 0.256 MPa to 0.218 MPa. As for the numerical analysis, tensile strength results of both models differ by 1.3%, which is almost negligible and indicates that ideally, either testing position is appropriate. However, experimentally, the axial model agreed more closely to the finite element analysis, which differs by 3.6% compared to 11.3% for the diametrical model.

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

UJIAN KEKUATAN TEGANGAN TAK LANGSUNG KE ATAS MODEL GARISPUSAT DAN PAKSI MENGGUNAKAN H-OMETER DAN SIMULASI KAEDAH UNSUR TAK TERHINGGA

Oleh

JURAIDAH AHMAD

Jun 2001

Pengerusi : Ir. Salihudin Hassim

Fakulti : Kejuruteraan

Satu kaedah telah digunakan untuk menguji kekuatan tegangan tak langsung ke atas batu lembut buatan menggunakan H-Ometer. Batu lembut yang digunakan dalam kajian ini adalah simulasi bagi batu pasir bersimen lembut yang homogen, isotropi dan tidak mempunyai ketakselanjaran.

Buat masa kini, model garispusat digunakan untuk menguji kekuatan tegangan tak langsung bagi batuan lembut. Dalam kajian ini, usaha untuk menentukan kaedah terbaik untuk menguji batu lembut dengan menggunakan H-Ometer dijalankan ke atas dua model iaitu model garispusat dan model paksi. Kedua-dua model dikenakan beban tokokan sehingga berlakunya kegagalan dan pada setiap tahap beban, ubah bentuk, corak retakan dan kekuatan tegangan ditentukan.

Selain dari ujian yang dijalankan di makmal, analisa menggunakan kaedah unsur tak terhingga menggunakan perisian LUSAS digunakan untuk menjalankan simulasi ujian H-Ometer. Dalam kajian ini, kedua-dua model dianalisa secara bahan anjal-plastik tiga dimensi. Keputusan dari analisa unsur tak terhingga ini akan mengesah dan menentukan kekuatan tegangan dan corak retakan dari ujian H-Ometer di makmal. Perbandingan yang dilakukan akan menentukan model yang terbaik untuk digunakan dengan H-Ometer yang akan memberikan keputusan yang tepat.

Dari kajian ini, keputusan ujikaji menunjukkan bahawa kedua-dua model memberikan keputusan yang munasabah dimana nilai kekuatan tegangan adalah di antara 0.256 MPa hingga 0.218 MPa. Keputusan dari analisa unsur tak terhingga pula menunjukkan peratus perbezaan nilai kekuatan tegangan antara kedua model adalah 1.3%. Ini menunjukkan secara idealnya kedua-dua model boleh digunakan untuk ujikaji H-Ometer. Walau bagaimanapun, keputusan dari ujikaji model paksi menunjukkan peratus perbezaan yang lebih kecil iaitu 3.6% dibandingkan dengan analisa unsur tak terhingga manakala sebanyak 11.3% bagi model garispusat.

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σ_h	Horizontal stress
a_o	Initial cavity radius
P	Applied load
a_o	Radius of cavity
a_i	Expansion of the cavity
δr	Linear element of length
ε_o	Tensile circumferential strain
σ_r	Radial stress
σ_θ	Tangential stress
$\Delta\sigma_r$	Change in radial stress
$\Delta\sigma_\theta$	Change in tangential stress
σ_t	Tensile strength
σ_{HO}	Tensile strength from H-Ometer test
P_f	Pressure at failure
E	Elastic Modulus
ν	Poisson's Ratio
P_f	Failure Pressure
P_o	Initial pressure
$\sigma_{HO(ax)}$	Axial tensile strength from H-Ometer test
$\sigma_{FE(ax)}$	Finite element axial tensile strength
$\sigma_{HO(dia)}$	Diametrical tensile strength from H-Ometer test
$\sigma_{FE(dia)}$	Finite element diametrical tensile strength

CHAPTER I

INTRODUCTION

General

Pressuremeter has been a standard tool used widely as an in-situ measuring device to obtain deformation properties of soils and over recent years a variety of pressuremeters have been developed since its first creation in 1955 (Clarke, 1995). Major developments have taken place since then with regard to pressuremeter capacity, robustness and resolution to permit weak rocks to be easily and reliably tested (Ervin et al., 1980, Clarke et al., 1989 and Haberfield, 1996). In the past, the pressuremeter test has been modelled as the expansion of a long cylindrical cavity in a semi-infinite, elasto-plastic medium. (Gibson & Anderson, 1961, Baguelin et al., 1972, Ladyani, 1972, Vesic, 1972 and Hughes et al., 1977). All of these models assumed that the material adjacent to the pressuremeter probe fails in shear, and as such, failure is only dependent on the cohesive or frictional properties of the material tested. However, studies have demonstrated that, under the conditions which normally apply to pressuremeter testing in weak rocks, failure can be influenced by the development of tension cracks initially at the cavity wall and propagate radially into the surrounding material (Haberfield & Johnston, 1986). It was suggested that the extent of any tensile failure was dependent on the relative tensile strength and brittleness of the weak rock, and on the in-situ horizontal stress at the start of each test. This shows that the occurrence of tensile failure invalidates the assumptions made by current interpretation techniques, which considered shear failure only (Haberfield & Johnston, 1990).

As a result of recent development in pressuremeter technology, a newly developed testing device known as the H-Ometer were developed by Mountainous Terrain Development Research Centre, Universiti Putra Malaysia, to test for indirect tensile strength on hard soils and weak rocks in the laboratory, which has gained various accreditation locally and also at international level. Development of the H-Ometer device is a bonus to the site investigation industry due to the portability of the equipment which can be used in both laboratory and insitu testing. In South Afirca a smaller pressuremeter (PENCEL pressuremeter) as developed principally to test pavement layers where holes are easily predrilled in materials. The size of this device is 32 mm and 22.5 mm in diameter. Studies have shown that the tensile testing device available in the market is not applicable to test the tensile strength of weak rock, hard soil or highly weathered material. Hence, an attempt was made to develop the H-Ometer for that purpose. The determination of tensile strength of weak rock particularly is a difficult task due to the inherent variability of natural weak rocks. In this study, an artificial weak rock simulated as weakly cemented sandstone, which is assumed isotropic, homogeneous and contains no discontinuities was prepared. The properties of these weak rocks are similar to the naturally occurring weak sedimentary rocks, which can be controlled and accurately determined in laboratory. These rocks can also be reproduced within very high tolerances of geometry and well-defined material properties.

Modelling of geotechnical problems using finite element method has been used extensively, but very little attention has been directed to the analysis of tensile failure (Haberfield and Johnston, 1990). In this study, a numerical technique to simulate the experimental work using LUSAS Finite Element Method is carried out. The ability of the simulated models to predict the performance and failure pattern of H-Ometer can be verified by conducting various tests in laboratory using H-Ometer probe.

Research Objectives

The aim of this research is to study the suitability and reliability of the H-Ometer to measure the indirect tensile strength of artificial weak rock in both axial and diametrical testing position. The experimental study is further verified by analysing the simulated model using the finite element method. The specific objectives of this study will include:

1. Simulation of the different testing position method of weak rock and observation of crack patterns from both H-Ometer test and LUSAS Finite Element Method.
2. Evaluate and determine the indirect tensile strength of weak rock in both axial and diametrical testing position from H-Ometer and finite element method.

Scope and Limitations

H-Ometer is a device, developed by a group of researchers at the Mountainous Terrain Development Research Centre, Faculty of Engineering, Universiti Putra Malaysia. Initially, few testing have been carried out using the H-Ometer to obtain geotechnical parameters on soft soil, hard soil and weak rock (Husaini et al., 2000a) and also unconfined compression test on compacted soil (Husaini et al., 2000c). The study focuses on two aspects of determining the indirect tensile strength of artificial weak rock. Firstly, an experimental work is conducted using the H-Ometer to determine the indirect tensile strength of artificial weak rock. A diametrical and axial model of a cylindrical weak rock specimens are used in this test to determine the appropriate model suitable for use with the H-Ometer.

Secondly, to determine the accuracy of tensile strength obtained experimentally, a finite element method is used to simulate the test mention model, which will enable a better evaluation of the laboratory tests. Both diametrical and axial model is analysed as a 3-dimensional non-linear model which will enable a better evaluation and verification of the accuracy of the H-Ometer test.

Structure of Thesis

The thesis is divided into five chapters. A literature survey of research work in various areas relevant to this research is presented in Chapter 2. The structure of methodology for both experimental work and simulation using the LUSAS Finite Element Method software and modelling techniques of artificial weak rocks is outlined in Chapter 3. Chapter 4 presents a complete account of results and analysis of study obtained from both experimental work and finite element simulation. The conclusion and recommendations of this study are presented in Chapter 5. Figure 1 summarises the flow of research process to be carried out in general.

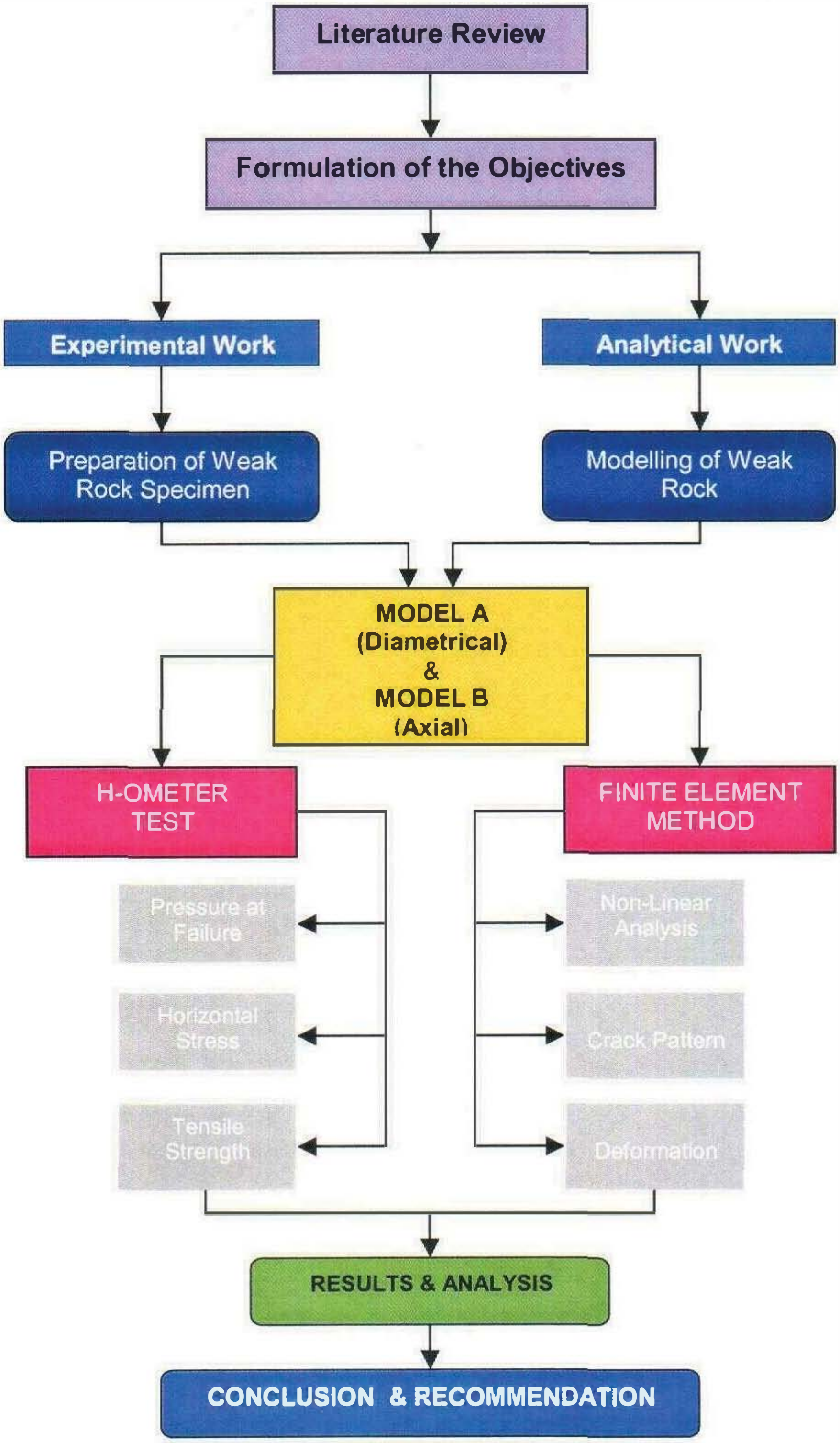

Figure 1: Flow Chart of Research Work