UNDRAINED SHEAR STRENGTH OF OVERCONSOLIDATED COHESIVE SOIL USING MODIFIED ROWE CELL

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DEDICATION

"Dedicated to my family especially to my beloved mum
and dad, my sister and my brother, and my
friends for their support, encouragement and
concern… I really appreciate it and love you all…..
"Also not forgotten to all my lecturers and course mates for their
help and cooperation while completing my study"
MAY GOD BLESS US ALL.....

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ABSTRACT

The relationship between the undrained shear strength, s_u, and overconsolidation ratio, *OCR*, of clay material (kaolin clay) is important in order to estimate the material strength for preparing the ground model for small scale physical modeling test. In this study, the relationship between these parameters is determined using a modified Rowe cell equipped with a vane shear blade. Kaolin samples were prepared under different consolidation ratios and the unit weight of kaolin is measured using the modified Rowe cell device, while the undrained shear strength, s_u, was determined using the vane shear apparatus. It was found that the values of the consolidation ratio, *CR*, were inversely proportionate to s_u. A correlation between s_u and *OCR* was established based on the laboratory results and validated with several previous studies. In addition, a comparison was made between the developed equation and some existing equations from the literature. It was found that the proposed equation provide a close prediction to the previous laboratory results with a Root Mean Square Error less than 1.2. A difference arose due to the different types of clay used between previous and current studies. A positive relationship is established between the unit weight and *OCR* values for kaolin clay.

ABSTRAK

Hubungan antara kekuatan ricih tak tersalir, s_u dengan nisbah lebih penyatuan, *OCR*, untuk bahan tanah liat (tanah liat kaolin) adalah penting dalam menganggar kekuatan tanah bagi ujian pemodelan fizikal berskala kecil. Dalam kajian ini, hubungan antara kedua-dua parameter tersebut ditentukan dengan menggunakan sel Rowe yang telah diubahsuai dan dilengkapi dengan bilah ricih. Sampel kaolin telah disediakan di bawah nisbah penyatuan yang berbeza dan berat unit kaolin diperolehi dengan menggunakan alat sel Rowe, manakala kekuatan ricih tak tersalir, s_u, telah ditentukan dengan menggunakan peralatan bilah ricih. Kajian ini mendapati bahawa nilai nisbah penyatuan, *CR*, adalah berkadar songsang dengan s_u. Satu korelasi di antara s_u dan *OCR* telah dihasilkan berdasarkan keputusan makmal dan disahkan dengan beberapa keputusan daripada kajian sebelumnya. Tambahan pula, satu perbandingan telah dibuat berdasarkan persamaan yang telah dicadangkan dengan beberapa persamaan yang sedia ada daripada pembacaan. Ia didapati bahawa, persamaan yang telah dicadangkan telah memberi ramalan yang hampir dengan keputusan makmal dengan ralat punca min kuasa dua kurang daripada 1.2. Perbezaan yang wujud adalah disebabkan oleh tanah liat yang berbeza digunakan dalam kajian sebelumnya dengan kajian sekarang. Hubungan positif antara berat unit dengan nilai *OCR* tanah liat kaolin telah ditubuhkan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

BS	-	British Standard
c_v	-	Coefficient of consolidation
c_c	-	Compression Index
CR	-	Consolidation Ratio
LL	-	Liquid Limit
OCR	-	Overconsolidation Ratio
PI	-	Plasticity Index
PL	-	Plastic Limit
p	-	Pressure
p'	-	Effective pressure
SL	-	Shrinkage Limit
Gs	-	Specific Gravity
s_u	-	Undrained Shear Strength
USCS	-	Unified Soil Classification System
e	-	Void ratio
w	-	Water Content
ϕ	-	Angle of internal friction
τ	-	Applied torque
tan ϕ	-	Coefficient of friction
°C	-	Degree Celsius
%	-	Percentage
c	-	Soil cohesion
σ	-	Stress
γ	-	Unit weight

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

The relationship between undrained shears strength, s_u and overconsolidation ratio (*OCR*) for cohesive material is one of the important relation in geotechnical field where it is used to estimate the behavior settlement of clay material under different consolidation ratio and to prepare a ground model under a targeted strength for small scale physical modeling test. From the past, laboratory scale tests were carried out to establish this relationship using oedometer apparatus (Terzaghi, 1925), centrifuge equipment (Springman, 1989) and Rowe consolidation cell (Rowe and Barden, 1966). Several researchers have conducted studies to establish the relationship between undrained shear strength, s_u, and overconsolidation ratio (*OCR*) for clay material (Nunez, 1989; Springman, 1989, 2004; Sheahan *et al.*, 1996; Pant, 2007; Abdulhadi, 2009) and sand (Phillips and Valsangkar, 1987).

Although several studies have been conducted, the techniques suggested by previous researchers are having problems dealing with it. Those techniques need special handling while moving the samples from the consolidation device, longer consolidation time after removing it from the consolidation device, expensive facilities to conduct the test, vane shear installation problem and etc. (Sheahan *et al.*, 1996; Almeida and Parry, 1988; Springman, 1989). Therefore, a new device should be developed to provide a better and cheaper method in measuring the undrained shear strength and establishing the relationship between *OCR* and s_u of cohesive soil.

1.2 Problem Statement

A series of studies have been conducted to establish the relationship between undrained shear strength, s_u, and overconsolidation ratio (*OCR*). From the past decade, several researchers have conducted studies to develop the relationship between undrained shear strength and overconsolidation ratio of soil. The importance of establishing this relationship is to obtain the targeted strength of soil on small scale physical modeling. By establishing the equation, the value of undrained shear strength can be estimated under known values of consolidation pressure. The values of undrained shear strength can be determined through this equation and this make the process of determining the undrained shear strength easier and reduced the error while carrying out the test.

Based on the previous studies that have been made, the relationships between s_u and *OCR* are doubtful since the consolidation pressures on the sample were released in order to perform the vane shear tests. A series of vane shear tests inflight in the centrifudge on the kaolin clay has been conducted to propose this relationship between s_u and *OCR*. However, expensive facility was used to conduct the test and much experience is needed in order to conduct the centrifudge test made the process difficult to handle (Springman, 1989).

Furthermore, the potential of mishandling the soil sample might occur by using the technique suggested by Sheahan *et al.* (1996) and Abdulhadi (2009). Moreover, the technique suggested by Sheahan *et al.* (1996) need be conducted carefully while moving the samples from the consolidation device to further carry out the triaxial test. It may take a longer time to consolidate the soil samples in triaxial after it had been removed from the consolidation device. Meanwhile, Almeida and Parry (1988) determined the s_u values using a miniature vane and cone penetration tests on a consolidated kaolin and Gault clays in a normal gravity force. Since the vane shear equipments were inserted into the consolidated soil, a vane insertion error could arise from the installation. Therefore, a new equipment which is a modified Rowe cell with vane shear apparatus was developed in order to overcome the previous problem faced and also to establish the relationship between undrained shear strength and consolidation ratio for kaolin clay.

1.3 Objectives

The aim of this study is to develop a modified Rowe cell equipped with vane shear apparatus. By developing this method, a more reliable relationship between undrained shear strength, s_u, and overconsolidation ratio, *OCR*, for cohesive soil could be established. In order to establish the relationship between undrained shear strength and consolidation ratio for cohesive soil, there are some objectives that need to be achieved. The objectives are as follow:

(i) To develop a modified Rowe cell (firstly diaphragm concept and secondly piston concept) equipped with vane shear apparatus in preparing and measuring the undrained shear strength of kaolin clay.

(ii) To establish the relationship between undrained shear strength and consolidation ratio (normally consolidation and overconsolidation ratio) for kaolin clay.

(iii) To compare undrained shear strength from vane shear test with the previous proposed analytical equation and laboratory results.

1.4 Scope of the Study

This study is carried out to establish a modified Rowe cell equipped with vane shear apparatus. By using firstly, the diaphragm concept and later the piston concept, the modified Rowe cell was used to prepare the soil model under different consolidation ratio values. The piston concept modified Rowe cell was introduced due to the limitation of the diaphragm concept. The pressure controller of the diaphragm concept Rowe cell is instable and the extension of the diaphragm is limited. There are altogether four tests to be done under four different consolidation ratio values using these two concepts of modified Rowe cell. Kaolin clay was used as a material for preparing the sample. Vane shear device which is mounted inside

the Rowe cell was used to determine the, s_u, of the soil samples. A relationship between s_u and *OCR* was established from this study.

1.5 Importance of the Study

In this study, the establishment of the equation is to predict the s_u of the ground model for small scale physical modeling under consolidation test. Although several researchers have established the equation, however, the equation is still doubtful as mentioned in Section 1.2. In addition, expensive and sophisticated equipment was used to establish the relation. Therefore, a new method is developed which is a modified Rowe cell with vane shear apparatus and used to determine the s_u value under different consolidation ratio values. At the moment, there are still no attempt has been made to produce this type of equipment. By conducting this study, a relationship between undrained shear strength and consolidation ratio was established. The detail of the modified Rowe cell is later explained in Chapter 3.

1.6 Summary

Overconsolidation ratio (*OCR*) and undrained shear strength, s_u, are two most important engineering properties in preparing the ground model in small scale modeling test. Currently, to obtain these two parameters, for example, the samples were consolidated using Rowe cell to obtain different *OCR* values and then were trimmed and mounted on the triaxial base Sheahan *et al.* (1996). This procedure leads to disturbance the soil sample if it has not been handled carefully.

Nevertheless, the relationships between s_u and *OCR* are doubtful since the consolidation pressures on the previous samples were released after the consolidation test in order to perform vane shear tests (Sheahan *et al.*, 1996).

The purpose of carrying out this research is to develop a new equipment that could establish the relationship between undrained shear strength and consolidation ratio for soft cohesive soil based on the laboratory test. The establishment of the equation is to predict the undrained shear strength of the ground model for small scale physical modeling under consolidation test.

In this study, a modified Rowe cell with vane shear apparatus was used to determine the undrained shear strength value under different consolidation ratio. A step loading is applied based on Terzaghi's theory while carrying out the test. The vane shear test mounted inside the Rowe cell apparatus was used to determine the under strength of the soil model under constant pressure. By using this method, result of undrained shear strength can be obtained under different overconsolidation ratio (*OCR*) value. Currently, no attempt has been made to produce this type of equipment and procedures, which produces a more robust prediction of relationship between undrained shear strength and overconsolidation ratio.

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