DETERMINATION OF FAILURE ZONE OF VANE SHEAR TEST USING ARTIFICIAL TRANSPARENT SOIL

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To my beloved family

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ABSTRACT

The vane shear test method is used extensively in a variety of geotechnical exploration to determine the undrained shear strength fine grained clays and silts. A small scale physical model was developed to study the failure mechanism during the vane shear test. The soil was simulated using a mixture of amorphous silica and mineral oil, which becomes transparent when the refractive indices the oil and the silica are well matched. A special fabricated rowe cell equipped with vane shear device was developed to determine the strength of the transparent soil. One dimensional consolidation test was carried out to obtain the consolidation properties of the transparent soil. The laboratory vane shear test used is similar to the field vane shear test but is on smaller scale. The vane was mounted vertically at the centre of the rowe cell based which the vertical section aligned with the vane centerline was illuminated with laser light and sequence of digital image was recorded using a digital camera. Particle image velocimetry (PIV) was used to analyze the failure mechanism during vane shear test. The result obtained and the observation made in this study suggested that the failure zone was close to the conventional assumption of a uniform shear stress distribution at the vertical sides of the failure surface.

ABSTRAK

Ujian ram ricih digunakan secara meluas dalam pelbagai penerokaan geoteknikal untuk menentukan secara terperinci kekuatan ricih tak bersalir bagi tanah liat lembut. Kajian ini menggunakan model fizikal berskala kecil direka untuk mengkaji mekanisme kegagalan dalam ujian ram ricih. Tanah buatan yang digunakan dalam kajian ini dihasilkan daripada campuran amorfus silika dan minyak mineral. Hasil daripada campuran bahan ini, tanah buatan bersifat lutsinar terhasil kerana minyak mineral dan amorfus silika tersebut mempunyai indeks biasan (refraktif) yang sama. Kekuatan ricih tanah buatan lutsinar yang dihasilkan akan ditentukan menggunakan sel *Rowe* yang direkabentuk khas dengan bilah ram di dalamnya. Ujian pengukuhan 1-dimensi telah dijalankan untuk mendapatkan sifat-sifat pengukuhan tanah buatan lutsinar. Prinsip ujian ram ricih yang dijalankan di makmal adalah sama dengan ujian ram ricih yang dijalankan di tapak, tetapi ia dijalankan pada skala yang lebih kecil. Ram dipasang secara menegak di tengah sampel dalam sel *Rowe* dan bahagian tegak sejajar dengan garisan tengah bilah ram itu diterangi dengan cahaya laser dan turutan imej digital telah direkodkan menggunakan kamera digital. Kaedah *particle image velocimetry* (PIV) telah digunakan untuk menganalisis mekanisme kegagalan semasa ujian ram ricih. Berdasarkan keputusan dan pemerhatian yang diperolehi dalam kajian ini, bentuk zon kegagalan adalah menyerupai dengan andaian konvensional di mana agihan tegasan ricih yang seragam berlaku pada permukaan kegagalan .

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Early geotechnical engineers found difficulty in determining the shear strength of very soft and sensitive clays by means of laboratory tests due to the disturbance induced by poor-quality samplers. These difficulties lead to the development of vane shear test (VST). Since the late 1940s, the VST method is used extensively in a variety of geotechnical exploration to estimate the in situ undrained shear strength, c_u of a cohesive soil in saturated soft clays.

The test is routinely performed in conjunction with other field and laboratory tests. The VST is different from other method because it directly measures a specific soil property, the undrained shear strength, c_u of clay.

As the name implies, the undrained shear strength, c_u refers to a shear condition where water is not permitted to enter or leave the cohesive soil during the shearing process. Therefore, the water content remains constant during the process. (Day, 2006).

Although the VST is a simple and effective test to determine the undrained shear strength, c_u for soft clays, the interpretation of the results from the test is not an easy task. The results may be affected by several factors and this can underestimate the actual undrained shear strength, c_u of the soil.

In deducing the undrained shear strength, $c_{u,}$ from the VST, it is commonly assumed that the rectangular blades of the vane shear the soil along a circumscribing cylinder and the mobilized shear strength is uniform over the surface of rotation at the maximum torque (De Alencar et al. 1988).

Works by Chandler (1988), gives a comprehensive summary and issues related in measuring the insitu undrained shear strength $c_{u,}$ of clays using the field vane. He reviews the current understanding of the use of the field vane test to measure the insitu undrained strength, $c_{u,}$ of soft clays and the factors influenced the measurement.

Discussion about these factors (vane insertion procedure, the rest period before shear, rate of rotation , undrained condition and stress distribution) are also presented by looking at the previous studies done by other researchers (e.g, Torstensson,1977; Menzies and Merrifield, 1980; Wroth, 1984; Roy and Le Blanc, 1988).

In reviewing the influence of the shear stress distribution around the vane, Chandler (1998), concluded that the distribution of shear stress around vane may be assumed to be uniform on the vertical edges of the vane blades but are probably highly non uniform on the top and bottom surfaces.

Incorrect assumption about the stress distribution around the vane can lead to uncertainty in determining the undrained shear strength c_{u},.The displacement and failure mechanism is not easy to observe in natural soil mass whether doing the field or laboratory test.

Ni et al. (2010) states that development of transparent synthetic soils (Iskander et al., 1994; Sadek et al., 2002) made it possible to see the movement inside the body of soil in laboratory test. The transparent soil is created by mixing the amorphous silica particles and pore fluid with a matched refractive index (RI). The material produced is almost transparent and has geotechnical properties similar to the clay soil.

White et al. (2003) developed techniques of using particle image velocimetry (PIV) and photogrammetry to measure deformation in geotechnical models. These techniques are widely used in geotechnical engineering research.

Thus, this study attempts to model the failure zone of VST using artificial transparent soil and a closer look at the impact towards the formulation of the undrained shear strength c_{u}, was also considered.

1.2 Problem statement

The development of a synthetic material by Iskander et al (1994) and PIV techniques developed by White et.al (2003) has made it possible to observe the displacement and quantify the movement in a soil mass.

However, there has been relatively little research concerning the displacement caused by VST using this artificial transparent soil. In VST, since the cylinder has different strains along the edge and towards the centre at the failure, the shear stress distribution may not be uniform as assumed and several types of shear distribution may exists.

Thus, this study attempts to model the failure zone using artificial soil for VST with the aim of having closer look at the failure mechanism and the impact towards the formulation of the undrained shear strength, $c_{u.}$

1.3 Objectives

The main objective of this study is to model the failure mechanism occurs during VST in artificial transparent soil and its impact towards the formulation of the undrained shear strength, $c_{u,}$.

To meet this objective the following goals were developed using which the success of the investigation may be measured:

1. To design small scale physical modelling experiments that maximise the modeling capacity of transparent soils and allows observation of the failure mechanism of VST

2. To assess the capability of transparent soils for the investigation of geotechnical problems using small scale physical modelling by conducting a thorough review of published literature.

3. To measure accurately the displacement and shear strain fields generated during VST using particle image velocimetry (PIV) and photogrammetry.

1.4 Scope and limitation of study

The methods of producing the transparent material and the optical measurement system will follow the same procedure which has been developed by previous researcher (Hird et al., 2010; Ni et al., 2010; Stanier, 2011). The soil sample used in this study is artificially made with mixing amorphous silica with a blend of two mineral oil.

The undrained shear strength, $c_{u,}$ obtained from this study is from the VST only and the scope of study will combine the use of artificial transparent soil and PIV in laboratory physical modeling.

1.5 Significance of study

This study attempt to model the failure mechanism occurs during vane shear test in artificial transparent soil and its impact towards the formulation of the undrained shear strength, $c_{u,}$.

The undrained shear strength $c_{u,}$ is calculated based on the assumption of an uniform stress distribution developed around the vane during VST From the failure zone, the actual shape of failure will be observed and the assumption of a uniform distribution stress will be validated.

Different stress distribution will have a different impact in calculation of undrained shear strength, $c_{u,}$. Thus, this research will help geotechnical engineers in determining the actual failure surface obtained during the laboratory VST

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Society for Testing and Material
BS	-	British Standard
c_u	-	Undrained shear strength
Cv	-	Coefficient of consolidation
C*c*	-	Compression index
C_s	-	Swelling index
D	-	Diameter
e	-	Void ratio
H	-	Height
k	-	Hydraulic coductivity
M	-	Moment
M_s	-	Resisting moment of the shear force along the side surface of the soil cylinder
M_e	-	Resisting moment of the shear force at each end of the soil cylinder
Mv	-	Coefficient of compressibility
PIV	-	Particle image velocimetry
PTV	-	Particle tracking velocimetry
r	-	Radius
RI	-	Reflective index
T	-	Torque

S_t	-	Sensitivity
VST	-	Vane shear test

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