UNIVERSITI PUTRA MALAYSIA

COMPRESSIBILITY BEHAVIOR OF TROPICAL PEAT REINFORCED WITH CEMENT COLUMN

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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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Dedicated to My Parents:

Mr. and Mrs. Duraisamy - Rajamah

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: **Bujang B. K. Huat, PhD**

Faculty: **Engineering**

One of the most serious problems encountered by civil engineers these days are when it comes to construction on peat soil. Peat soil poses a difficult problem, which has the tendency to subside especially when its moisture content is high. The moisture content may come from rain flooding, leaking from water or sewer lines or from reduction in surface evapo-transpiration when an area is covered by building or pavement. Peat soil causes cracking, settlements and break-up of pavements, railways, highways, embankments, roadways, building foundations, reservoir linings, water lines and sewer line. These entire problems can be solved if the engineering properties of the problem soil are improved to make them suitable for construction.

The main objective of this research is to evaluate the effect of cement column on compressibility when installed in peat soil. Apart from that the researcher also found it important to examine the peculiar engineering behaviour of tropical peat with respect to their compressibility characteristics due to variation in fiber content and organic content.

In addition, the researcher is also interested to identify the influences of other factors like diameter, length, curing time, number of cement columns and amount of cement in cement columns in reducing compressibility.

Undisturbed sample of peat soils were taken from Banting, which is situated in the West coast of Peninsular Malaysia. A suitable auger was designed and fabricated to collect undisturbed peat sample of 150 mm diameter and 230 mm in length. Specimens with 45 mm diameter (area ratio = 0.09) and 60 mm diameter (area ratio = 0.16) of cement column were cured for 7, 14 and 28 days, after which they were subjected to Rowe Cell consolidation test. Results are also presented from test conducted on groups of cement columns using four (area ratio = 0.04) and nine (area ratio = 0.09) columns of 15 mm diameter each to investigate the influence of number of cement columns on compressibility of peat soil.

Based on the results obtained, it shows that the cement columns can successfully reduce the compressibility of tropical peat. Compression index of fibric sample was reduced by 60% using cement column of 45 mm diameter and 80% with cement column of 60 mm diameter. Hence, it suggests that larger diameter cement column (or high area ratio) has a higher reduction effect in the compression index. The trend is similar in hemic and sapric peat. A group of cement columns had a significant impact in reducing the compressibility parameters compared to a single cement column due to higher surface area. Using 100% amount of cement in columns recorded the best performance. Compressibility parameters (compression index and coefficient of secondary compression) were significantly improved (lowered) with cement column.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

KELAKUAN KEBOLEHMAMPATAN TANAH GAMBUT TROPIKAL APABILA DIKUATKAN DENGAN TIANG SIMEN

Oleh

YOUVENTHARAN A/L DURAISAMY

Januari 2008

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Salah satu masalah besar yang dihadapi oleh jurutera awam pada masa kini adalah apabila terlibat dengan pembinaan atas tanah gambut. Tanah gambut memberi masalah yang rumit dimana ia berupaya mendap apabila kandungan air tinggi. Kandungan air yang tinggi kemungkinan datang daripada air hujan, kebocoran paip air dan paip kumbahan ataupun pengurangan penyejatan-pemelowapan akibat daripada litupan sesuatu kawasan dengan bangunan dan jalan raya. Tanah gambut menyebabkan retakan, pemendapan dan kerosakan turapan, landasan, lebuhraya, benteng, jalanraya, asas bangunan, laluan tadahan, laluan paip air dan paip kumbahan. Keseluruhan masalah ini dapat diatasi sekiranya ciri-ciri kejuruteraan tanah bermasalah ini ditambahbaik bagi menyesuaikannya untuk pembinaan.

Objektif utama kajian ini adalah untuk menilai kesan tiang simen pada kebolehmampatan apabila dipasang pada tanah gambut. Selain daripada itu, penyelidik

juga berminat untuk menguji kelakuan kejuruteraan yang pelik pada tanah gambut yang berkaitan dengan ciri-ciri kebolehmampatan disebabkan oleh variasi dalam kandungan fiber dan kandungan organik. Disamping itu, penyelidik turut berminat untuk mengenalpasti pengaruh faktor seperti diameter, panjang, masa rawatan, bilangan tiang simen dan kandungan simen dalam tiang untuk mengurangkan kebolehmampatan.

Sampel tanah gambut yang tidak terusik telah diambil di Banting, yang terletak di Pantai Barat Semenanjung Malaysia. Satu pengorek yang sesuai telah direkabentuk dan dihasilkan untuk mengambil sampel tanah gambut tidak terusik sebesar 150 mm diameter dan 230 mm panjang. Spesimen dengan tiang simen yang berdiameter 45 mm (nisbah luas = 0.09) dan yang berdiameter 60 mm (nisbah luas = 0.16) telah dirawat selama 7, 14 dan 28 hari sebelum ujian pengukuhan Rowe Cell dijalankan. Ujian juga dilakukan keatas sekumpulan empat tiang simen (nisbah luas = 0.04) dan sembilan tiang simen (nisbah luas = 0.09) dengan 15 mm diameter setiap satu bagi mengkaji pengaruh sebilangan tiang simen keatas kebolehmampatan tanah gambut.

Hasil keputusan menunjukkan bahawa tiang simen berjaya mengurangkan kebolehmampatan tanah gambut tropika. Indeks mampatan sampel fibrik telah berkurangan sebanyak 60 % dan 80 % masing-masing dengan menggunakan tiang simen berdiameter 45 mm dan 60 mm. Maka, ia mencadangkan bahawa tiang simen yang berdiameter besar (atau nibah luas yang tinggi) mempunyai kesan pengurangan yang lebih tinggi terhadap indeks mampatan. Corak ini adalah sama bagi tanah gambut jenis hemik dan saprik. Kumpulan tiang simen mempunyai impak yang signifikan terhadap penggurangan parameter kebolehmampatan berbanding tiang simen yang tunggal

disebabkan oleh luas permukaan yang tinggi. Penggunaan 100% kandungan simen dalam tiang telah mencatatkan pengurangan parameter kebolehmampatan yang tertinggi. Parameter kebolehmampatan (indeks mampatan dan pekali mampatan sekunder) telah dibaiki dengan signifikan menggunakan tiang simen.

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Last but not least, I would like to express my gratitude to my parents and siblings for their moral support. Special thank for all friends whose contributions and encouragement cannot be expressed by mere words.

I certify that an Examination Committee has met on 16th January 2008 to conduct the final examination of Youventharan A/L Duraisamy on his Master of Science thesis entitled "Compressibility Behavior of Tropical Peat Reinforced with Cement Column" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not currently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

YOUVENTHARAN A/L DURAISAMY

Date: 29-01-2008

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INTRODUCTION

1.1 General

Peat and organic soil represents the extreme form of soft soil. They are susceptible to instability such as localized sinking and slip failure, and massive primary and long-term settlement when subject to even moderate load increase (Jarret, 1995). Buildings on peat are usually suspended on piles, but the ground around it may still settle. In addition, there is discomfort and difficulty of access to the sites, a tremendous variability in material properties and difficulty in sampling. These materials may also change chemically and biologically with time. For example further humification of the organic constituents would alter the soil mechanical properties such as compressibility, shear strength and hydraulic conductivity. Lowering of ground water may cause shrinking and oxidation of peat leading to humification with consequent increase in permeability and compressibility.

It is therefore understandable that constructions and buildings on these types of soils are often avoided whenever possible. However, these soils are found in many countries throughout the world. In the US, peat is found in 42 states, with a total acreage of 30 million hectares. Canada and Russia are the two countries with the largest area of peat, 170 and 150 million hectares respectively. For the case of tropical peat, or tropical peat lands, the total world coverage is about 30 million hectares, two thirds of which are in

Southeast Asia. Malaysia has some 3 million hectares (about 8%) of the country's land area covered with tropical peat. While in Indonesia peat covers about 26 million hectares of the country's land area, with almost half of the total peat found in Indonesia's Kalimantan. Since the coverage of these soil is quite extensive, utilization of these marginal soils are required in increasing number of cases in the recent years. Hence, suitable geotechnical design parameters and construction techniques need to be found for this type of ground condition. It is therefore necessary to expand our knowledge on the engineering or mechanical properties of the peat and organic soils.

1.2 Organic Soil and Peat

Technically any material that contains carbon is called 'organic'. However, engineers and geologist use a more narrow definition when applying the term to soils. An organic soil is one that contains a significant amount of organic material recently derived from plant remains. This implies it needs to be 'fresh' and still in the process of decomposition, and thus retains a distinctive texture, colour and odor. Some soils contain carbon, but are not recently derived from plants and thus are not considered organic in this context. For example, some sand contains calcium carbonate (calcite), which arrived as a chemical precipitate.

The term peat refers to highly organic soils derived primarily from plant remains. It normally has a dark brown to black color, a spongy consistency, and an organic odor. Plant fibers are sometimes visible but in the advance stages of decompositions, they may not be evident (Huat, 2004).

1.3 Problem Statement

Peat poses serious problems in construction due to its long-term consolidation settlements even when subjected to a moderate load. Hence, peat is considered unsuitable for supporting foundations in its natural state. Various construction technique have been carried out to support embankments and other structures over peat deposits without risking bearing failures but settlements of these embankments remains excessively large and continues for many years (Huat, 2004). Besides settlements, stability problems during construction such as localized bearing failures and slip failures need to be tackled.

1.4 Objective

The main objective of this research is to find out the effect of cement columns on the compressibility when installed in tropical peat soil. Apart from that the researcher is also interested to examine the peculiar engineering behavior of tropical peat with respect to their compressibility characteristics due to variation in fiber content and organic content. Meanwhile the index properties such as natural water content, organic content, liquid limit, specific gravity and density of various type of tropical peat were obtained to establish suitable correlation.

The specific objectives of this research are:

i) To study the effects of cement columns of various diameter, length and composition in reducing compressibility of peat of various fiber content.

ii) To evaluate the effects of a group of cement columns in reducing compressibility of peat of various fiber content.

iii) To construct preliminary design chart for cement columns in peat ground.

1.5 Scope of Study

The primary purpose of this research is to point out the possibility of stabilizing organic and peat that have caused problems during construction or resulted in poor performance of structures in service using cement columns. The scope and limitations of this research includes:

i) Peat samples are collected from three different locations in Banting (west coast of Peninsular Malaysia) with organic content more than 70 %.

ii) Only two compressibility parameters, compression index (C_c) and coefficient of secondary compression (C_α) are measured using Rowe Cell consolidation test.

iii) Cement column was formed using Ordinary Portland Cement (OPC) type I with dry mix method.

1.6 Significance of Study

The main aim of this study is to find out the effect of cement columns on compressibility control on tropical peat with respect to variation in fiber content and organic content. The researcher is also interested to examine the peculiar engineering behavior and compressibility characteristics of peat. The engineering properties and compressibility characteristics of tropical peat would aid the engineers in determining suitable method of ground improvement. Thus, proper construction and foundation design guide for various type of peat could be outlined for future developments in peat ground.

Below are some of the major contributions of this research towards the construction industry:

i) Reduce settlements in pavements, building foundations and embankments due to high compressibility of peat.

ii) Cut down maintenance cost of repairing cracks and settlements due to long term consolidation caused by peat.