

ULTIMATE BEARING CAPACITY OF CEMENT  
COLUMNS TREATED PEAT SOIL USING  
PHYSICAL MODEL

LOI SHI JUN

B. ENG (HONS.) CIVIL ENGINEERING  
UNIVERSITI MALAYSIA PAHANG

## UNIVERSITI MALAYSIA PAHANG

### DECLARATION OF THESIS AND COPYRIGHT

Author's full name : LOI SHI JUN  
Date of birth : 26 DECEMBER 1992  
Title : ULTIMATE BEARING CAPACITY OF CEMENT  
COLUMNS TREATED PEAT SOIL USING PHYSICAL  
MODEL  
Academic Session : 2015/2016

I declare that this thesis is classified as:

- CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)\*
- RESTRICTED** (Contains restricted information as specified by the organization where research was done)\*
- OPEN ACCESS** I agree that my thesis to be published as online open access (Full text)

I acknowledge that Universiti Malaysia Pahang reserve the right as follows:

1. The Thesis is the Property of University Malaysia Pahang
2. The Library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified By:

\_\_\_\_\_  
(Student's Signature)

921226-04-5073

New IC / Passport Number

Date : 23 JUNE 2016

\_\_\_\_\_  
(Signature of Supervisor)

YOUVENTHARAN DURAISAMY

Name of Supervisor

Date : 23 JUNE 2016

### NOTES:

\*If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

ULTIMATE BEARING CAPACITY OF CEMENT COLUMNS TREATED PEAT SOIL  
USING PHYSICAL MODEL

LOI SHI JUN

Thesis submitted in fulfilment of the requirements for the award of the degree of  
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources  
Universiti Malaysia Pahang

June 2016

### **SUPERVISOR'S DECLARATION**

I/We\* hereby declare that I/We\* have checked this thesis/project\* and in my/our\* opinion, this thesis/project\* is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering (Hons) Civil Engineering.

Signature : \_\_\_\_\_  
Name of Supervisor : YOUVENTHARAN DURAISAMY  
Position : LECTURER  
Date : 23 JUNE 2016

**STUDENT'S DECLARATION**

I hereby declare that the work in the thesis entitled “Ultimate Bearing Capacity of Cement Columns Treated Peat Soil using Physical Model” is my own except for quotations and summaries which have been duly acknowledged. The thesis/project\* has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature : \_\_\_\_\_  
Name : LOI SHI JUN  
ID Number : AA12173  
Date : 23 JUNE 2016

## ACKNOWLEDGEMENTS

I would like to take this opportunity to thank all the parties who helped me in completing this research. First and foremost, I would like to acknowledge Universiti Malaysia Pahang (UMP) for giving me this opportunity to conduct this research and providing well equipped facilities to complete the research in the given time.

Besides that, I would like to express my sincere gratitude to my research supervisor, Youventharan Duraisamy for his guidance and support during the planning and development of this research work. His willingness to give his time so generously has been very much appreciated. Moreover, I would to thank LKPP Corporation Sdn. Bhd. and Kilang Sawit LCSB Lepar for their kindness in supplying the palm oil fuel ash for this research.

Next, I would like to express my very great appreciation to all my friends and teammates who willing to assist and support me in conducting the laboratory tests throughout the research. This research would not have been possible without their helps. Assistance provided by them for the collection and preparation of the soil samples for the physical modelling.

I would also like to extend my thanks to the technicians of the soil mechanics and geotechnics laboratory for their help in offering me the resources in running the program. Mohd. Ziunizan Bin Hamzah always give me advices and guidance whenever I need helps such as the purchase of equipment and laboratory testing procedures.

Most importantly, none of this would have been possible without the love and patience of my family. I would like to express my heartfelt gratitude to my family who always stand by there and support me throughout the research.

## TABLE OF CONTENTS

<b>SUPERVISOR' S DECLARATION</b>		ii
<b>STUDENT' S DECLARATION</b>		iii
<b>DEDICATION</b>		iv
<b>ACKNOWLEDGEMENT</b>		v
<b>ABSTRACT</b>		vi
<b>ABSTRAK</b>		vii
<b>TABLE OF CONTENTS</b>		viii
<b>LIST OF TABLES</b>		xi
<b>LIST OF FIGURES</b>		xii
<b>LIST OF ABBREVIATIONS AND SYMBOLS</b>		xiv
<b>CHAPTER 1</b>	<b>INTRODUCTION</b>	<b>1</b>
1.1	Introduction and Background	1
1.2	Problem Statement	2
1.3	Research Objectives	3
1.4	Research Questions	3
1.5	Scope and Limitation	4
<b>CHAPTER 2</b>	<b>LITERATURE REVIEW</b>	<b>5</b>
2.1	Overview of Chapter	5
2.2	Peat	5
	2.2.1 Definition and Background of Peat	7
	2.2.2 Distribution of Peat	7
2.3	Classification of Peat	10
2.4	Properties of Peat	13
2.5	Types of Stabilisation Materials	17
	2.5.1 Ordinary Portland Cement	17
	2.5.2 Palm Oil Fuel Ash	17
2.6	Soil Improvement	18
2.7	Deep mixing method- Cement Column	18

2.8	Previous Research Results	19
2.8.1.	Peat Soil Stabilisation using Cement as Stabilization Agent	19
2.8.2	Peat Soil Stabilisation using Palm Oil Fuel Ash as Stabilization Agents	21
2.8.3	Peat Soil Stabilisation using Different Types of Ash as Stabilization Agents	23
2.8.4	Peat Soil Stabilisation using Lime as Stabilization Agents	23
<b>CHAPTER 3</b>	<b>METHODS AND MATERIALS</b>	<b>25</b>
3.1	Overview of Chapter	25
3.2	Sampling Work Method	27
3.2.1	Peat Sample Location	27
3.2.2	Field Soil Sampling	27
3.3	Peat Soil Characterisation Methods	29
3.3.1	Field Test	29
3.3.2	Moisture Content	31
3.3.3	Organic Content	32
3.3.4	Fiber Content	32
3.3.5	Specific Gravity	34
3.3.6	Liquid Limit and Plastic Limit	34
3.3.7	pH Value	36
3.4	Materials	37
3.4.1	Peat Soils	37
3.4.2	Binders and Admixtures	37
3.4.3	Preparation of Binder Mixtures for Cement Column	38
3.5	Set Up of Physical Model	39
3.5.1	Modelling	39
3.5.2	Column Installation Method	40
3.5.3	Loading Phase	41
3.6	Unconfined Compressive Strength	42



<b>CHAPTER 4</b>	<b>RESULTS AND DISCUSSIONS</b>	43
4.1	Overview of Chapter	43
4.2	Classification of Soil	44
4.3	Soil Properties	45
	4.3.1 Engineering Properties	45
4.4	Chemical Composition and Properties of Admixtures	49
4.5	Model Test Results	51
	4.5.1 Overview of the Model Test Results	51
	4.5.2 Effect of Binders towards the Ultimate Bearing Capacity of Stabilised Soil	52
	4.5.3 Effect of Area Improvement Ratio towards the Ultimate Bearing Capacity of Stabilised Soil	55
4.6	Unconfined Compressive Strength	56
	4.6.1 Effect of Binders Dosages towards the Unconfined Compressive Strength of Peat Soil	58
<b>CHAPTER 5</b>	<b>CONCLUSIONS AND RECOMMENDATIONS</b>	60
5.1	Introductions	60
5.1	Conclusions	60
5.2	Recommendations	61
<b>REFERENCES</b>		63
<b>APPENDICES</b>		66
A	Engineering Properties of Soil Sample	66
B	XRF Results for POFA	68
C	Ultimate Bearing Capacity Results	70
D	Unconfined Shear Strength Results	71

## LIST OF TABLES

<b>Table No.</b>	<b>Title</b>	<b>Page</b>
2.1	Peatland Area Distribution Around the World	8
2.2	Classification of Peat Soil based on Von Post Scale	11
2.3	Classification of Peat with Different Criteria using ASTM Standard	12
2.4	Summary of Physical Properties for Different Types of Peat	13
2.5	Basic Properties and Results for Shear Box Test and Field Vane Shear Test	16
2.6	Chemical Properties of Palm Oil Fuel Ash	18
2.7	Comparison of Unconfined Compressive Strength Test Results	21
2.8	Mix Design of Peat Soil Sample using OPC and POFA	22
3.1	Research Design for the Modelling	39
3.2	Applied Loads on Footing	41
4.1	Physical Properties of Peat	44
4.2	Engineering Properties of soil	45
4.3	Field Density of Soil	48
4.4	Chemical Composition and Properties of Admixtures	50
4.5	Ultimate Bearing Capacity of Soils in Different Models	51

## LIST OF FIGURES

<b>Figure No.</b>	<b>Title</b>	<b>Page</b>
2.1	Peat Distribution in the World	9
2.2	Distribution of Peat in Sarawak, Malaysia	9
2.3	Plot of Vane Shear Strength versus Moisture Content	16
2.4	Stress- Strain Curve for Peat Soil Treated with Lime	20
2.5	Stress- Strain Curve for Peat Soil Treated with Cement	21
2.6	Curve of UCS Value versus Curing Period	22
2.7	Comparison between Average UCS of Original Peat and Stabilized Peat-PA Specimens (28days)	23
2.8	Effect of Lime on the Unconfined Compressive Strength of Peat	24
2.9	Effect of Curing Time on the Unconfined Compressive Strength of Peat	24
3.1	Flow Chart of Research Methodology	26
3.2	Bird's Eye View of the Sampling Site	27
3.3	Sampling Site	28
3.4	Peat Soil Sampling	28
3.5	Sand Cone Replacement Method for Field Density Test	30
3.6	Classification of Soil by using Von Post Scale	30
3.7	Industrial Oven for Moisture Content Test	31
3.8	Hydrochloric Acid	33
3.9	Filtered Soil for Fiber Content Determination	33
3.10	Cone Penetrator with Soil Sample in the Cup	35
3.11	Stirring of the Mixture of Distilled Water and Soil Sample	36
3.12	Determination of Soil pH Value using pH Meter	36
3.13	Palm Oil Fuel Ash from Kilang Kelapa Sawit LCSB LEPAR	38

3.14	Physical Model with Dimension of 335x525x300 mm	40
3.15	Plan View of Physical Model with Dimension of 335x525x300 mm	40
3.16	PVC Pipe with Dimension 25 mm Diameter and 200 mm in Length	41
3.17	Position of Dial Gauge during the Loading Phase	42
3.18	Unconfined Compressive Strength Machines	42
4.1	Peat Soil	44
4.2	Plot of Moisture Content versus Cone Penetration Depth	47
4.3	Location of Soil Samples	49
4.4	Stress-settlement Curve for Models with 4 Cement Columns	52
4.5	Stress-settlement Curve for Models with 6 Cement Columns	53
4.6	Ultimate Bearing Capacity of Soil Stabilised with 4 Cement Columns	53
4.7	Ultimate Bearing Capacity of Soil Stabilised with 6 Cement Columns	54
4.8	Ultimate Bearing Capacity of Peat Stabilized with Different Density of POFA	54
4.9	Ultimate Bearing Capacity of Peat Stabilized with Different Area Improvement Ratio, $\alpha$	55
4.10	Stress and Strain Curve for Different Dosages of Binders	57
4.11	Ultimate Bearing Capacity of Peat Stabilized with Different Area Improvement Ratio, $\alpha$	58

## LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British Standard
CDM	Cement Deep Mixing
$G_s$	Specific gravity of soil solids
LL	Liquid Limit
M	Initial total mass of specimen
$m_a$	Mass of required replacement sand to fill the hole in gram
$M_{DS}$	Mass of dry soil
$M_f$	Dry mass of soil after washing
$M_{OC}$	Mass of organic content
$M_s$	Initial dry mass of specimen
$m_w$	Mass of soil excavated from the hole in gram
OPC	Ordinary Portland cement
PI	Plasticity Index
PL	Plastic Limit
POFA	Palm Oil Fuel Ash
UBC	Ultimate Bearing Capacity
UCS	Unconfined Compressive Strength
V	Volume of the hole in $m^3$
$\alpha$	Area Improvement ratio
$\phi$	Internal friction angle
$\gamma$	Unit weight of soil
$\gamma_{dry}$	Dry unit weight of soil
$\rho_o$	Density of the replacement sand in $Mg/m^3$
w	Moisture content of soil
$\rho$	Bulk density of soil

ULTIMATE BEARING CAPACITY OF CEMENT COLUMNS TREATED PEAT SOIL  
USING PHYSICAL MODEL

LOI SHI JUN

Thesis submitted in fulfilment of the requirements for the award of the degree of  
B. Eng (Hons.) Civil Engineering

Faculty of Civil Engineering and Earth Resources  
Universiti Malaysia Pahang

June 2016

## ABSTRACT

Peat soil is classified as soft soil and problematic soil due to its natural properties of high compressibility, low shear strength and high initial water content. Cement column method is commonly used to stabilise the soil by changing the properties of soil. This research aimed to study the unconfined compressive shear strength and ultimate vertical bearing capacity of stabilized tropical peat of East Coast of Peninsular Malaysia by a group of deep mixed cement column using a series of physical model test. To study the strength behaviour of peat soil with or without the cement stabilization, a series of physical laboratory models were conducted with different factor of variables, the number of cement column, proportion of binders (Ordinary Portland Cement) and pozzolanic materials (Palm Oil Fuel Ash). In this research, a total of 9 physical models of peat soil including one without the stabilized cement column as the control sample were conducted. A group of 4 and 6 cement columns with 25 mm diameter and 200 mm in length was considered. All the sample was cured for 28 days after the mixing of cement column. After the curing process, a series of axial loads were applied uniformly on the pre-fabricated steel plate footing from the top of the cement column in order study the ultimate bearing capacity of the stabilised soil. The change in strength of the samples was evaluated using Unconfined Compressive Strength (UCS) test. Based on the results from the tests, the highest recorded ultimate bearing capacity is in Model 6 with 6 cement columns with the area improvement ratios of 18.83 %. This research found that the sample with  $300\text{kg/m}^3$  OPC has the highest UCS value of 106.88 kPa. However, the cement columns mixed with OPC and POFA aided in improving the strength and the ultimate bearing capacity of the peat soil.

## ABSTRAK

Tanah gambut dikategorikan sebagai tanah lembut dan tanah bermasalah disebabkan ciri-ciri tanah seperti kebolehmampatan yang tinggi, kekuatan mampatan yang rendah dan kandungan air yang tinggi. Tiang simen merupakan salah satu kaedah yang biasa digunakan untuk mengukuhkan tanah lembut. Tesis ini bertujuan untuk menyelidik kesan penggunaan tiang simen terhadap keupayaan galas muktamad dan kekuatan mampatan tak terkurung tanah gambut tropika dari Pantai Timur Semenanjung Malaysia dengan menggunakan ujikaji model fizikal. Sebanyak 9 model yang terdiri daripada factor pembolehubah yang berbeza seperti bilangan tiang simen, dos bahan tambah (simen) dan bahan pozzolanik (abu kelapa sawit) telah disediakan untuk mengkaji kekuatan tanah gambut sebelum dan selepas penstabilan oleh simen tiang. Dalam kajian ini, hanya kumpulan yang terdiri daripada 4 dan 6 tiang simen yang berdimensi 25 mm diameter dan 200 mm ketinggian telah dikaji. Semua sampel telah dirawat selama 28 hari dalam model selepas pemasangan tiang simen. Selepas proses pengawetan, tekanan yang berbeza telah dikenakan pada tapak besi dari bahagian atas tiang simen untuk pengajian keupayaan galas muktamad tanah gambut selepas penstabilan. Perubahan kekuatan tanah telah dikajikan dengan menggunakan kajian kekuatan mampatan tak terkurung. Berdasarkan keputusan yang diperolehi daripada kajian, Model 6 yang mempunyai 6 tiang simen dan nisbah peningkatan kawasan sebanyak 18.83 % mempunyai keupayaan galas muktamad yang tertinggi. Selain itu, kajian ini juga mendapati sampel tanah yang mengandungi  $300 \text{ kg/m}^3$  simen portland biasa menunjukkan nilai kekuatan mampatan yang paling tinggi berbanding dengan sampel yang lain. Nilai yang diperolehi oleh sampel tersebut ialah sebanyak 106.88 kPa. Walaubagaimanapun, tiang simen yang mengandungi simen portland biasa dan abu kelapa sawit juga meningkatkan kekuatan dan keupayaan galas muktamad tanah gambut.



## CHAPTER 1

### INTRODUCTION

#### 1.1 Introduction and Background

In Malaysia, there is around 3 million hectares or approximately 8 % of the land is covered with peats. In state of Sarawak, 1.66 million of the land is covered with peat soil (Huat, Prasad, Asadi, & Kazemian, 2014). Peat is an organic soil where the organic content is higher than 75%. The formation of peat soil layer is due the rate of accumulation of plant's remaining is higher and faster the rate of decomposition. Peat represents an accumulation of disintegrated plant remains which have been preserved under conditions of incomplete aeration and high water content. The formation of peats is more favourable when the area is waterlogged, with excess rainfall and low permeability ground, irrespective of latitude or altitude (Huat et al., 2014). The peat soil is classified as problematic soil due to its natural properties of high compressibility, low shear strength, high initial water content. The high compressibility of peat soil will poses problem of secondary settlement and even tertiary settlement in long term due to the further decomposition of peats. It is found that peat has the potential to be decomposed further and its decomposition rate could be accelerated by controlling the influencing factors like oxygen supply, C:N ratio, pH value and temperature for optimum condition (Pichan & O'Kelly, 2012). The high water content rendering the soil unsuitable for construction. The water content of peat normally varies from 500 % to 2000 % while for those peat where the water content of less than 500 % are usually indicates that there are high mineral fractions within the peat sample (Huat et al., 2014). According to Hwang, Humphrey, Bobet, & Santagata (2005), when dealing with organic and peat soil, few options are available to improve or strengthen the soil, the engineer or owner can choose to strengthen the foundation, eliminate the problem soil (cut & replace), soil treatment or relocate the project. The second and last option are always selected by owner or engineer.

This is because the peat soil is hard to deal with and further consolidation and stability problem may occur in future due to high compressibility and further decomposition of peat. Problem arise when the country facing limitation or shortage of land for development. Hence, solution in strengthening or improving the peat soil plays an important in future development of the country like Malaysia. Several methods such as surface reinforcement, preloading, vertical drain, deep stabilization, piling and chemical stabilization had been introduced by previous researcher in order to improve organic soil and peat soil. Dry Deep Soil Mixing (DSM) also referred to Cement Column is a common method for soft soil stabilization. This in-situ stabilization method involves the mechanical mixing of cementitious compound such as Ordinary Portland cement (OPC) and lime with weak/soft soil.

## **1.2 Problem Statement**

Peat soil is considered as problematic soil due to its natural properties of low shear strength, high compressibility and high initial water content. It is suitable for plantation and agricultural purpose but when comes to construction field, it becomes unsuitable and unfavourable for the engineer to construct the structure like road, building and foundation on it. This is because construction problems like secondary settlement and stability problem may occur when the structure is built on the peat soil. Construction on peat soil is always the last option for engineer and developer as it is very costly and the effectiveness of existing treatment is questionable. However, due to the rapid development in country, lack of land for construction becomes another issue. Thus, solution for the strengthening and improving the peat soil is essential and important in future country development. It is important to understand the properties of peat soil in order to overcome and improve the properties of peat.

Many methods and approaches have been introduced in order to improve the peat soil. However, some of them require huge amount of budget and yet the effectiveness of the ground improvement method is questionable. Hence, elements like environment friendliness, cost, effectiveness, reliability and durability should be considered in selecting the best method of ground improvement.

Cement column stabilization is a common method for soft soil stabilization. In construction industry, OPC is always the first choice cementitious materials for the cement column stabilization because it economically-friendly and high accessibility. However, OPC is highly not environmental friendly and it will contributes to climate changes and global warming. The huge amount of carbon dioxide due to the production of Cement contributes to global warming.

### **1.3 Research Objectives**

The main purpose of this research is to study the effectiveness of cement column in increasing the shear strength and ultimate vertical bearing capacity of homogenous stabilized tropical peat of East Coast of Peninsular Malaysia (Pekan Peat). Three specific objectives have been listed below in order to achieve the aim of this research.

Objective 1: To determine the properties of Tropical Peat.

Objective 2: To measure the shear strength of soil cement column after the stabilization.

Objective 3: To measure the ultimate vertical bearing capacity of footing on stabilized tropical peat.

### **1.4 Research Questions**

This study aimed to address the following research questions

- 1 What is the effect of cement column which consisting of different proportion of OPC and Fly Ash towards the shear strength of peat soil?
- 2 What is the effect of cement column which consisting of different proportion of OPC and Fly Ash towards the shear strength of peat soil?