UNDRAINED SHEAR STRENGTH OF SOFT CLAY REINFORCED WITH ENCAPSULATED POLYPROPYLENE (PP) COLUMN

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

MAY 2019

ACKNOWLEDGEMENTS

First and foremost, I want to dedicate my praise to my God for the wisdom and health He showered on me during my thesis writing. Thanks for His graceful guidance along the way and granted me with a peaceful mind in overcoming all the challenges met.

Not forget to thank my advisor, Associate Professor Dr Muzamir Bin Hasan, who always tries his best in giving his professional advice from the beginning of my research. His tolerance and patience is the supports that I hold on to when I am miserable. Moreover, I would like to thank the coordinator of final year project, Dr Nurul Nadrah who had prepared a series of briefings, paper work format, documentation and also the reminder throughout these two semesters of final year project course.

Furthermore, I want to thank my fellow friends (Ling Sin Yie and Tan Kah Yee) who always share their knowledge unconditionally. Their helping hands and moral supports are much appreciated.

Last but not least, I would like to express my gratitude towards my parents. Thanks for their mentally support and their caring all the time when I am pursuing this research.

ABSTRAK

Kegunaan tiang dalam meningkatan kekuatan tanah liat semakin mendapat populariti dalam industri pembangunan. Banyak kajian tentang kecakapan tiang untuk menperbaiki prestasi tanah liat telah dikaji dan keputusannya agak memuaskan. Selain itu, amat banyak plastik dibuang merata-rata telah menjadi satu pencemaran yang serius terancam alam sekitar bumi. Dalam kajian ini, polipropilena, PP telah digunakan untuk menggantikan batu semula jadi untuk meningkatkan kekuatan tanah liat. Penggunaan PP dalam mengubati tanah bermasalah adalah alternatif yang lebih mampan dan kos efektif berbanding dengan bahan lain. Pertama, sifat bahan yang digunakan dalam kajian ini akan diuji dan dibincangkan. Kekuatan ricih sampel kaolin yang dirawat telah diperiksa dengan menggunakan ujian mampatan tak terkurung (UCT). 7 kumpulan sampel tanah akan diuji yang mana 1 sampel kawalan, 3 kelompok 14mm dan 3 kelompok 20mm diameter PP. Diameter lajur PP yang berbeza telah diperiksa masing-masing dengan ketinggian 60 mm, 80 mm dan 100 mm. Tanah liat akan diacuankan kepada sampel yang mempunyai 50mm diameter dan ketinggiannya adalah 100mm. Peningkatan kekuatan ricih kaolin adalah 33.82%, 46.51% dan 49.88% apabila ia ditanam dengan lajur PP yang mempunyai nisbah penggantian 7.84 dan nisbah penembusan 0.6, 0.8 dan 1.0. Sementara itu, tanah lembut yang dirawat dengan menggunakan nisbah penggantian 16.00 dengan nisbah penembusan 0.6, 0.8 dan 1.0 mempunyai peningkatan kekuatan ricih masing-masing sebanyak 25.22%, 33.39% dan 37.59%. Hasilnya, panjang kritikal bagi lajur PP jatuh dalam 4-8 yang mana sudah dijangka dalam kaji orang lain. Ringkasnya, peningkatan kekuatan ricih tanah liat kaolin sangat bergantung pada parameter lajur PP yang digunakan untuk menguatkan sampel.

ABSTRACT

Granular column is gaining popularity in current market as many researches had proven that it does enhance the strength of soft soil in certain degree. Also, abundant plastic had caused many environmental issues to the earth. Therefore, the main objective of this study is to investigate the effectiveness of encapsulated polypropylene (PP) column in enhancing the undrained shear strength of kaolin (soft clay). The usage of PP in treating problematic soil is a more sustainable and cost-effective alternative compared to other materials. In the construction site, installation of granular column can be done by using vibro replacement method. Firstly, several geotechnical tests to determine the properties of materials were done and the result was clearly discussed. The shear strength of treated kaolin sample was examined by using Unconfined Compression Test (UCT). There are 7 batches of soil sample in total which included a control sample, 3 batches of 14mm and 3 batches of 20mm diameter PP column. Different diameters of PP column were examined with 60 mm, 80 mm and 100 mm height respectively. The soil sample itself is 50mm in diameter and 100mm in height. The shear strength improvement of kaolin is 33.82%, 46.51% and 49.88% when it is implanted with PP column that is having 7.84 area replacement ratio and 0.6, 0.8 and 1.0 penetration ratio. Meanwhile, the soft soil treated by using 16.00 area replacement ratio with 0.6, 0.8 and 1.0 penetration ratio has a shear strength increment of 25.22%, 33.39% and 37.59% respectively. From the result, the H_c/D_c ratio was found to be within 4-8 which is same as the one recommended by previous researchers. In short, the shear strength improvement of the kaolin clay is very depending on the parameter of the PP column that used to reinforce the sample.

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LIST OF SYMBOLS

A_c	Area of PP Column
A_s	Area of Kaolin Clay Specimen
Al^{3+}	Aluminium Ion
CaO	Calcium Oxide
D_c	Diameter of PP Column
D_s	Diameter of Kaolin Clay Specimen
D_r	Relative Density
Fe^{2+}	Ferrous Ion
Fe^{3+}	Ferric Ion
G_s	Specific Gravity
g/cm^3	Gram per Centimetre Cube
H_c	Height of PP Column
H_s	Height of Kaolin Clay Specimen
kN	Kilo Newton
kN/m^2	Kilo Newton per Metre Square
kPa	Kilo Pascal
m	Metre
Mg	Mega Gram
Mg^{2+}	Magnesium Ion
Mg/m^3	Mega Gram per Metre Cube
mm	Millimetre
m/s	Metre per Second
Q_p	Point Bearing Load
Q_s	Soil Surface Frictional Resistance
q_u	Unconfined Compression Stress
R^2	Correlation Cohesion
Si^{4+}	Silicon (IV) Cation
SiO_2	Silicon Dioxide
s_u	Undrained Shear Strength
Δs_u	Undrained Shear Strength Improvement
V_c	Volume of PP Column
V_s	Volume of Kaolin Clay Specimen
w_{opt}	Optimum Moisture Content

Zn^{2+}	Zinc Ion
µm	Micrometre
γ	Unit Weight
γ_{min}	Minimum Unit Weight
γ_{max}	Maximum Unit Weight
ρ_d	Dry Density
%	Percent
°C	Degree Celsius

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BPA	Bisphenol A
BS	British Standard
BSCS	British Soil Classification System
CL	Lean Clay
HCL	Hydrochloric Acid
HDPE	High Density Polyethylene
LDPE	Low-Density Polyethylene
LL	Liquid Limit
PE	Polyethylene
PET	Polyethylene Terephthalate
PI	Plastic Index
PL	Plastic Limit
PS	Polystyrene
PVC	Polyvinyl Chloride
PP	Polypropylene
SPI	Society of the Plastics Industry
TO layer	A Layer of Tetrahedral Sheet with A Layer of Octahedral Sheet
TOT layer	2 Layers of Tetrahedral Sheet with A Layer of Octahedral Sheet
UCT	Unconfined Compression Test
US	United Stated
USCS	Unified Soil Classification System
USDA	United State Department of Agriculture
VOC	Volatile Organic Compounds

CHAPTER 1

INTRODUCTION

1.1 Background of Research

Initiation of a construction project is normally started by selecting a suitable site. In order to maximize profit, developers prefer to choose those sites with strong and stable soil. Therefore, the land that is available for construction nowadays is getting lesser compared to the old days. According to Hasan *et al*. (2015), soft soil areas are needed to cope with the massive development in Malaysia especially when it comes to the coastal of Peninsular Malaysia. There are lots of soft soil in this area so the use of soft soil for the construction industry is definitely inevitable for future generation.

Clay soil is one of the members of soft and problematic soils other than peat soil and loamy soil. It can be found especially in the coastal environment. Clay soil is actually good for the foundation of the structure because it retains excessive water. This characteristic of clay soil can prevent the foundation to be eroded by retaining water and thus increases the sustainability of the entire building. However, the untreated soft clay is not suitable for any construction. This is because the ability to absorb water makes clay soil swells when the environment is wet and shrink when it is dry.

There are different types of soil improvement methods in market to treat different types of soft soil. Ground improvement can be generally classified into three main categories which are ground improvement, ground treatment and ground reinforcement. The selection of soil improvement method is shown in Figure 1.1. According to Mani and Nigee (2013), installation of stone columns as soil improvement is gaining popularity in this era because of its reasonable cost and its ability in solving different types of problematic soil. Stone columns can effectively reduce water table and mitigate massive change in soil volume which makes the soil more sustainable to soil settlement.

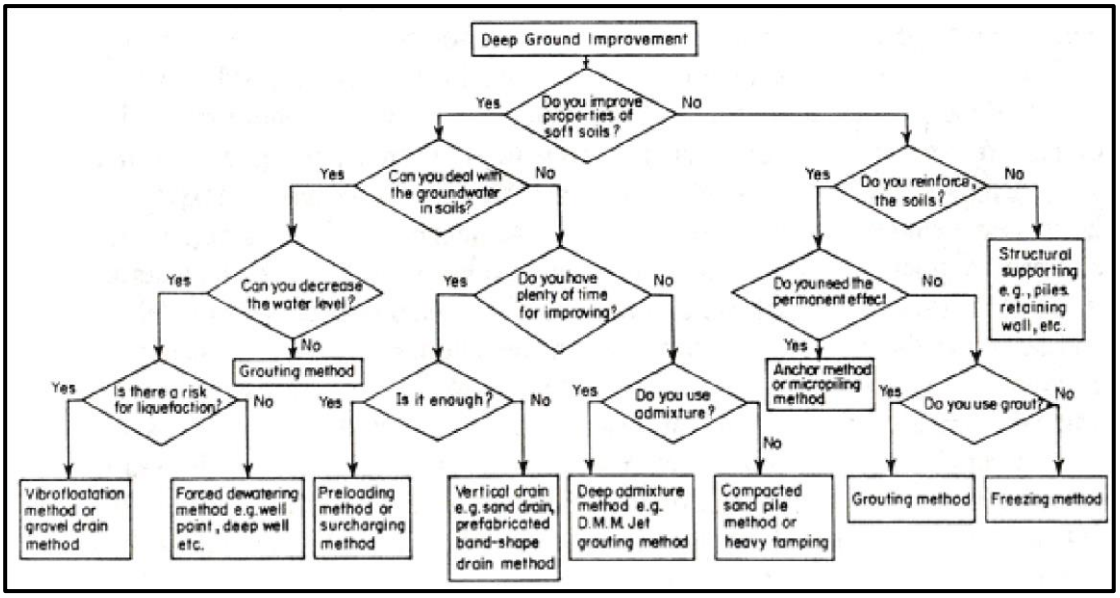

Figure 1.1 Selection flow of deep ground improvement technique

Source: Saroglou *et al.* (2009)

Plastic is not a stranger to every human being on earth. There are different types of plastic which serve different purposes worldwide likes polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC), polystyrene (PS) and the others. Because of its lightweight, stability, durability and cost, the amount of plastic grows rapidly after its publication. Refer to the result of oceanographic model from Eriksen *et al.* (2014), more than 5.25 trillion particles weighting 268940 tons floating plastic on the surface of our ocean.

1.2 Problem Statement

The competition among construction industry is getting intense because site with strong and stable soil for construction is mostly occupied. There are more developers in Malaysia facing challenges where their sites are covered with soft clay soil. This is because the volume of soft clay soil alters with the water contents. Rapid change of soil volume leads to uneven settlement causing severe structural damage to foundation of construction (Smethurst and Clarke, 2008). As the foundation fails, the whole structure can be unsafe. Cracking of the structure is one of the significant signs of foundation failure and without proper solution, the structure tends to fall apart. The failure first occurs in a sign of hairline crack and the crack will grow larger if there is no proper treatment applied to the structure or the soil. Figure 1.2 clearly shows the effect of untreated soft clay soil to the structure constructed on it.

Figure 1.2 Structure failure due to swell and shrink of soft clay
Source: Lee (2011)

Plastic is one of the main contributors to pollution in this era. It is hard to be biodegraded and its demolishment brings negative effect to our environment. Abundant plastic wastes are floating on the ocean and many of them end up in landfill. Although there are many activities on plastic reduction been arose but the amount of plastic worldwide is too overwhelming. Recently, plastics are sent to be recycled and processed into other products. Amidst the recycled products, granular plastic is one of the products that have the characteristic similar to aggregate. Thus, it has the potential to become the filler of granular columns in the soil improvement sector. It is pleasure if this study gives a positive result as it can solve both problematic soil and abundant plastic crisis.

1.3 Objective of Research

This research focuses mainly on investigating the effect of encapsulated PP as column in strengthening the soft clay. There are three main objectives for this research which area;

1. To determine the physical properties of kaolin clay and polypropylene.
2. To determine the undrained shear strength of soft clay reinforced with encapsulated polypropylene (PP) column.
3. To analyze the correlation of undrained shear strength of kaolin clay with various dimensions.

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