THE SHEAR STRENGTH OF SOFT CLAY REINFORCED WITH SINGLE CRUSHED BRICK COLUMN

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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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ABSTRAK

Tanah liat lembut sering dikenali sebagai tanah yang bermasalah dalam pembinaan kerana kekuatan yang rendah dan sifat mampatan tinggi. Sebelum pembinaan bermula, penambahbaikan tanah perlu dilakukan untuk meningkatkan keupayaan galas tanah supaya struktur super boleh diletakkan di atasnya dan mengurangkan penyelesaian dan penyatuan. Dalam kajian ini, tanah liat lembut akan diperkuat dengan tiang batu bata yang dihancurkan yang merupakan sebahagian daripada sisa pembinaan yang dihasilkan semasa peringkat pembinaan untuk mencapai pembinaan mampan. Kajian ini bertujuan untuk mengkaji keberkesanan lajur bata tunggal yang dihancurkan untuk meningkatkan kekuatan ricih dengan menggunakan model skala makmal. Kaolin digunakan sebagai sampel tanah manakala bata dihancurkan sebagai lajur bertetulang. Beberapa ujian makmal dijalankan untuk menentukan sifat tanah liat kaolin dan bata dihancurkan. Ujian mampatan yang tak terkurung (UCT) juga digunakan untuk menguji kekuatan ricih sampel kaolin bertetulang. Dimensi spesimen yang digunakan adalah diameter 50mm dan ketinggian 100mm dan sejumlah 3 kelompok sampel kaolin diuji dan setiap kumpulan mengandungi sampel kawalan dan sampel diperkuat dengan 10mm dan 16mm dengan nisbah penembusan lajur yang berlainan. Terdapat dua jenis diameter diameter bata tunggal dihancurkan yang digunakan dalam kajian ini iaitu 10mm dan 16mm. Ketinggian lajur dipasang ke tanah liat lembut adalah 60mm, 80mm dan 100mm. Peningkatan kekuatan ricih lajur bata yang dihancurkan tunggal dengan nisbah penggantian kawasan 4.00% (diameter lajur 10mm) adalah 3.34%, 4.60% dan 1.07% pada nisbah penembusan sampel, H_c / H_s 0.6, 0.8 dan 1.0 manakala untuk penggantian kawasan daripada 10.24% (diameter lajur 16 mm) adalah 7.56%,%, 16.37% dan 4.97% pada nisbah penembusan yang sama. Dapat disimpulkan bahawa kekuatan ricih tanah liat lembut dapat ditingkatkan dengan pemasangan lajur batu tunggal yang dihancurkan.

ABSTRACT

Soft Clay is often known to be a problematic soils in construction because of its low strength and high compressibility characteristic. Before construction begins, ground improvement needs to be done to improve the soil bearing capacity so that the superstructure can be placed on top of it and reduce settlement and consolidation. In this study, the soft clay is going to be reinforced with crushed brick column which is part of construction waste produced during construction stage to achieve sustainable construction. This study was aimed to investigate the effectiveness of single crushed brick column in improving the shear strength by using laboratory scale model. Kaolin is being used as soil sample while crushed brick as the reinforced column. Few laboratory tests are conducted to determine the properties of kaolin clay and crushed brick. Unconfined Compression Test (UCT) also used to test the shear strength of the reinforced kaolin samples. The dimension of the specimen used is 50mm in diameter and 100mm in height and a total 3 batches of kaolin samples were tested and each batch contains control sample and samples reinforced with 10mm and 16mm with different column penetration ratio. There are two different types of diameter of single crushed brick column used in this study which are 10mm and 16mm. The heights of the column installed into soft clay are 60mm, 80mm and 100mm. The improvement of shear strength of single crushed brick column with area replacement ratio of 4.00% (10mm column diameter) are 3.34%, 4.60% and 1.07% at sample penetration ratio, H_c/H_s of 0.6, 0.8 and 1.0 respectively while for area replacement of 10.24% (16 mm column diameter) are 7.56%, %, 16.37% and 4.97% at the same penetration ratio. It can be concluded that the shear strength of soft clay could be improved by installation of single crushed brick column.

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LIST OF SYMBOLS

A_c	Area of crushed brick column
A_s	Area of kaolin clay sample
c’	Apparent cohesion
C_c	Compression index
D_c	Diameter of crushed brick column
e	Void ratio
G_s	Specific gravity
H_c	Height of crushed brick column
H_s	Height of kaolin clay sample
V_c	Volume of crushed brick column
V_s	Volume of kaolin clay sample
kN	Kilo Newton
kPa	Kilo Pascal
M_g	Mega Gram
MN	Mega Newton
m/s	Metre per second
mm	Millimetre
µm	Micrometre
W_L	Liquid limit
W_P	Plastic limit
w_{opt}	Optimum moisture content
γ	Unit weight
γ_{max}	Maximum unit weight
q_u	Deviator stress
s_u	Undrained shear strength
ΔS_u	Improvement of shear strength
ρ_d	Dry density
R^2	Correlation cohesion
%	Percent
°	Degree

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BS	British Standard
C	Controlled Sample
CIDB	Construction Industry Development Board
C&D	Construction and demolition
LL	Liquid Limit
PI	Plasticity Index
PL	Plastic Limit
S	Single Column
UCT	Unconfined Compression Test
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Soft clay is often known to be a problematic soil due to its low strength and high compressibility characteristic. Construction on soft soil is a great challenge for geotechnical engineers. Site investigation needs to be conducted and ground improvement technique needs to be applied. Ground improvement is the modification of existing site foundation soils to provide better performance under design and/or operational loading conditions. Ground improvement techniques are used increasingly for new projects to allow utilization of sites with poor subsurface conditions. Ground improvement is executed to increase the bearing capacity, reduce the magnitude of settlements and the time in which it occurs, retard seepage, accelerate the rate at which drainage occurs, increase the stability of slopes, mitigation of liquefaction potential, etc. (Hirkane *et al*., 2014). The final choice of ground improvement techniques used depend on the economic feasibility, time frame, type of soil, availability of equipment and skills required and environmental conditions such as erosion and water pollution. Engineers must consider all the factors carefully to choose the best method to be used.

One of the ground improvement techniques adopted for soft cohesive soils is the stone columns technique. It is a reinforcement of the soft soil with granular column which is then be compacted and normally used in clayey soft soils. The aim of the stone column techniques is to increase the soil bearing capacity and minimize the post construction settlement and consolidation. Because of the stone column is a type of granular column, therefore an alternative granular material can be considered to replace the stone to reduce the cost of project and reduce excavation of stone from quarry which will eventually help in reducing environmental impacts of stone mining.

Environmental issues is the major issue being discussed nowadays on a global scale and people are concerns about the impacts of human activities towards the environment. The environmental awareness level has been increasing since decades ago. The waste products generated in every human and industrial activity certainly bring disastrous impact to quality of living of human. Construction industry is one of the largest waste contributor. Construction waste generation is becoming a pressing issue in Malaysia (Begum *et al*., 2007; Begum *et al*., 2010). With the increasing demands for construction projects, large amount of waste is being generated annually. Malaysia generates 26,000 tonnes of wastes from construction and demolition (C&D) daily that further congest the already over-flowing landfills (Zulzaha, 2014). The common principles used in the reduction of C&D waste are reduce, reuse and recycle (3R) (Lu and Yuan, 2010). For sustainable and green construction, approaches have to be taken by adopting new method in construction technologies by reusing the waste as alternative construction material and recycling the material to minimize the waste generation.

	Amount of waste generated by weight (tones 100 m^{-2} floor space)	
Construction waste materials	Fully prefabricated	Conventional
Soil and sand	1.01	14.700
Brick and blocks	0.04	0.6300
Concrete and aggregate	0.27	36.000
Tiles	0.02	2.7200
Scrap metal	0.01	0.4500
Wood	0.04	0.1100
Plastic materials	0.01	0.0300
Packaging products	0.07	0.0020
Total	1.47	54.642

Figure 1.1 Waste generation and composition

Source: Begum et al. (2010)

According to Begum *et al*., (2010), 0.63 tonnes of brick and blocks are generated every $100m^2$ of floor space in conventional building system. Since there are huge amount of bricks waste being produced, these waste can be reused and recycled as substitute material for stone column used in ground improvement. Brick has a good compressive strength varies from 3 N/mm^2 to 40 N/mm^2 which depends on the raw material, manufacturing process and size of the brick. It can be compared to stone with that properties since crushed brick has same properties as granular material. The brick waste is crushed into granular form and inserted into ground just like stone. This method greatly reduces the mining and usage of natural resources. It reduces the construction waste by recycling the waste which is more environmental friendly and providing a cheaper and sustainable construction method.

1.2 Problem Statement

Soft clay being an expansive soil, also known as shrink-swell soil is a fine-grained soils which always brings problems to soil stability and settlement of soil. Expansive soil will increase in volume when water content increases and causes the soil to lose strength and becomes unstable which eventually brings problems to foundation of building. On the other hand, the soil will shrink when dry. The shrinkage will remove support from the foundation and cause structural failures. The expansion and contraction of soil will cause severe damage on the structure. Soft clay also known as problematic soil with low bearing capacity and high compressive strength which is known to has high chance of failure due to its weakness when compared to other type of soils. Malaysia’s climate is hot and humid throughout the year, with heavy rainfall during monsoon seasons. The drastic change in temperature and moisture cause the soil likely to fail if the soil is not treated especially at Malaysia coastal areas that are covered with soft soil deposits. Therefore, engineers need to carry out ground improvement technique which will improve the properties of soft soil so that building structure can be built on top. Besides, stone column is an effective and economic ground improvement technique that is being used widely in construction. However, the material used which is stone involving quarrying. The mining of stone will cause environmental impact such as permanently disfigure of the surrounding. The natural resources have been depleting and it is considered not very environmental friendly in using stone column. The best alternative is to use recycle material from waste material or industrial by-products. Due to the increasing demand in housing projects, more waste material are being produced daily in construction industry. The waste are leftovers material and wastage. That include huge amount of bricks that are thrown away. Since the use of brick in construction is unavoidable, but we can definitely reduce the waste generated. Instead of dumping the brick waste into landfill which will pollute the ground, the brick waste should be reused in other construction activity. In the era that highlight on green building process and sustainable construction and rising of environmental issue, alternative material that is environmental friendly should be used for the column. Therefore, the use of crushed brick

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