STRENGTH OF SOFT CLAY REINFORCED WITH GROUP CRUSHED POLYPROPYLENE (PP) COLUMNS

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ABSTRACT

The use of granular columns as soil reinforcement technique has proved useful in problems of foundation stability and settlement, as well as improving soft clay for foundation construction. The purpose of this study is to investigate the enhancement of shear strength of soft kaolin clay when it is reinforced with group crushed polypropylene (PP) columns. Since PP is a waste material, the cost of soil improvement can be reduced which currently was disposed totally in large quantity into landfill. In order to proceed the study, physical and mechanical properties of materials used that are kaolin (soil sample) and PP (reinforcing columns) must be identify first. Then, consolidated kaolin as soft clay was reinforced with group crushed PP columns, and subsequently tested under Unconfined Compression Test (UCT). A total of 7 batches of kaolin sample including control sample had been tested to identify the shear strength. Each batches involved of four samples to find the average value of maximum stress. The variables used for the columns installation were the column height that are 60 mm, 80 mm and 100 mm, where the column penetrating ratio are 0.6, 0.8 and 1.0 respectively. In addition, different values of columns diameter had been used that are 6 mm and 10 mm for every different height of columns. A total of 28 unconfined compression tests had been conducted on kaolin samples. The kaolin samples had the dimensions of 50 mm in diameter and 100 mm in height. For the group PP reinforcement, shear strength increased about 2.13%, 13.51% and 12.84% for 1.44% area replacement ratio and 6.85%, 14.26% and 13.79% for 4% area replacement ratio at sample penetration ratio 0.6, 0.8, 1.0 respectively. In the other hand, the relationship of the increment of shear strength with the various column penetration ratio show different pattern. The shear strength of both area replacement ratio increases constantly as the column penetrating ratio increased, but after it reach 80mm height of column, the shear strength decrease slightly and this support the ‘critical column length’ idea. It can be concluded that the shear strength parameters were affected by the diameter and the height of the columns and the presence of PP column greatly improve the shear strength.

ABSTRAK

Penggunaan tiang granular sebagai teknik pengukuhan tanah telah terbukti berguna dalam masalah kestabilan asas dan mendapan, serta memperbaiki tanah liat lembut untuk pembinaan asas. Tujuan kajian ini adalah untuk menyiasat peningkatan kekuatan ricih tanah liat kaolin lembut apabila ia diperkuatkan dengan tiang berkumpulan polipropilena (PP) hancur. Memandangkan PP adalah bahan buangan, kos pembaikan tanah boleh dikurangkan yang kini telah dilupuskan sama sekali dalam kuantiti yang besar ke tapak pelupusan. Untuk meneruskan kajian ini, sifat-sifat fizikal dan mekanikal bahan-bahan yang digunakan iaitu kaolin (sampel tanah) dan PP (tiang pengukuhan) mesti dikenal pasti terlebih dahulu. Kemudian, kaolin yang disatukan sebagai tanah liat lembut diperkukuh dengan tiang berkumpulan PP hancur, dan kemudiannya diuji di bawah Ujian Mampatan Tak Terkurung (UCT). Sebanyak 7 kumpulan sampel kaolin termasuk sampel kawalan telah diuji untuk mengenal pasti kekuatan ricih. Setiap kumpulan mempunyai empat sampel untuk mencari nilai purata tekanan maksimum. Pemboleh ubah yang digunakan untuk pemasangan tiang tersebut ialah ketinggian tiang iaitu 60 mm, 80 mm dan 100 mm, di mana nisbah ruang menembusi adalah 0.6, 0.8 dan 1.0. Di samping itu, nilai-nilai garis pusat tiang yang berbeza telah digunakan iaitu 6 mm dan 10 mm untuk setiap ketinggian tiang yang berbeza. Sebanyak 28 ujian mampatan tak terkurung telah dijalankan ke atas sampel kaolin. Sampel kaolin mempunyai dimensi garis pusat 50 mm dan ketinggian 100 mm. Bagi kumpulan PP tetulang, kekuatan ricih meningkat kira-kira 2.13%, 13.51% dan 12.84% untuk nisbah penggantian kawasan 1.44% dan 6.85%, 14.26% dan 13.79% bagi nisbah penggantian kawasan 4% pada nisbah penembusan sampel 0.6, 0.8, 1.0. Di sisi lain, hubungan antara kenaikan kekuatan ricih dengan pelbagai nisbah penembusan ruangan mempunyai corak yang berbeza. Kekuatan ricih kedua-dua nisbah penggantian kawasan sentiasa meningkat apabila nisbah ruang menembusi meningkat, tetapi selepas ia mencapai ketinggian tiang 80mm, kekuatan ricih menurun sedikit dan ia disokong oleh idea 'panjang tiang kritikal'. Dapat disimpulkan bahawa parameter kekuatan ricih terjejas oleh garis pusat dan ketinggian tiang dan kehadiran tiang PP banyak meningkatkan kekuatan ricih.

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Ac	Area of column
As	Area of sample
c	Cohesion
C_c	Compression index
C_c	Coefficient of gradation
C_u	Uniformity coefficient
e	Void ratio
ε	Strain
G_s	Specific gravity
H_c	Height of column
H_s	Height of sample
i	Hydraulic gradient
k	Permeability coefficient
m	Moisture content
S_e	Elastic settlement
S_c	Primary consolidation settlement
S_s	Secondary consolidation settlement
S_T	Total settlement
P_c	Maximum pressure the soil has been subjected to in past
ρ_d	Dry density
$\rho_{d\text{-}max}$	Maximum dry density
$\rho_{d\text{-}min}$	Minimum dry density

q	Deviator stress
q_{max}	Maximum deviator stress
R_d	Relative density
S_o	Sorting coefficient
s_u	Undrained shear strength
v	Velocity
γ_d	Dry unit weight
γ_t	Wet unit weight
γ_{sat}	Saturated unit weight
φ	Angle of internal friction
σ	Normal stress

LIST OF ABBREVIATIONS

ABS	Acrylonitryl Butadien Styrene
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BS	British Standard
BSCS	British Soil Classification System
CL	Clay low plasticity
CH	Clay high plasticity
EPR	Ethylene-propylene rubber
FYP	Final Year Project
HDPE	High-density polyethylene
HPP	Homo-polymer Polypropylene
LL	Liquid limit
LDPE	Low-density polyethylene
MDPE	Medium-density polyethylene
MH	Silt high plasticity
ML	Silt low plasticity
MPMA	Malaysian Plastics Manufacturer Association
NP	Non-plastic
PC	Polycarbonate
PE	Polyethylene
PI	Plasticity index

PL	Plastic limit
PP	Polypropylene
PS	Polystyrene
PT	Peat
SL	Shrinkage limit
UCT	Unconfined Compression Test
USCS	Unified Soil Classification System

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND OF RESEARCH

Recently, due to urbanization and industrialization that increase the development, the building construction such as housing and commercial are being built massively. Soft clays exist in most coastal plains of Peninsular Malaysia and all land including soft soil has to utilize to overcome the massive construction. Clay is widely distributed, abundant mineral resources of major industrial importance for an enormous variety of uses (Ampian, 1985). Development of activities on those sites such as road embankment, earth dams and others involve problems of stability and excessive settlement. There are many available methods to improve the properties of soft clay soil since this type of soil usually causes problems to the civil engineer as it has high compressibility and low shear strength.

The settlement behavior of soil must be understand to find the solution for it because it may impose stability problem to the superstructure where the rate of settlement is different all over the area of the developed ground if the uneven settlement occurred. Uneven settlement might cause toppling of the said superstructure, meanwhile for uniform settlement, foundation settlement problem can occur in excessive settlement (Halim, 2012). Thus, settlement of soil must be solved before the superstructure being constructed.

Therefore, ground improvement techniques may be necessitated to modify the soil properties. There are many available methods to improve the properties of soft clay such as sand drain, piling, stone (granular) column, using admixtures and many more. Recently, stone column are gaining acceptances in geotechnical field and have been widely used all around the world including Malaysia. This method is applied commonly for road embankments and railway area, lightly loaded foundation, and storage tanks (Murugesan and Rajagopal, 2010). Besides it promotes the compaction of the soil and allows water to rise up by acting as a channel, additional bearing capacity is also provided to the soil.

This Final Year Project (FYP) concentrates on the strength of soft clay reinforced with group crushed Polypropylene (PP) columns. Basically, concept of crushed PP columns with stone column is the same, but the result from this process is slightly different depends on the properties of the PP itself. However, this ground improvement technique has been successfully applied to reduce the settlement as well as increasing the bearing capacity of the soils and accelerating the settlement process (Ambily and Gandhi, 2007).

Previous studies have been proven that when the granular column is inserted into soft soil as shown in Figure 1.1, a composite soil mass that has a greater strength and improved stiffness will be produced compared to the unreinforced soil. The columns act as piles that transfer the structure load to greater depth. Thus, this is one of the most practical techniques to improve the mechanical properties of soft soil (Black *et al.*, 2007).

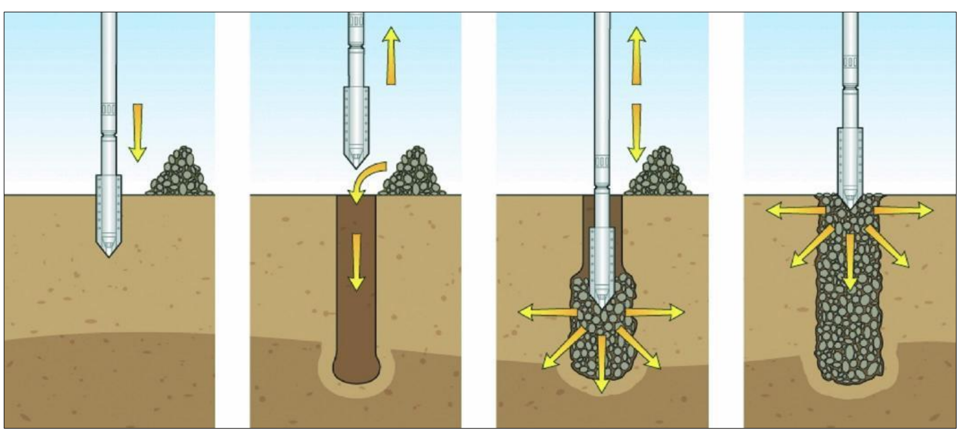

Figure 1.1: Installation of granular column

Source: Juan Manuel *et al.* (2010)

PP is a thermoplastic which means those materials can be melted again and again and also can be heated to a certain temperature and will harden again as they cool. It has an intermediate level of crystallinity which located between low-density polyethylene (LDPE) and high-density polyethylene (HDPE). It is known for its low strength to density ratio compared to HDPE and LDPE which the density can range from 0.90 to 0.92 g/cm^3. PP yields the greatest volume of fibre for a given weight because of its low specific gravity which means that PP provides good bulk and cover while being lighter in weight. The porous PP molecule has a series of CH3 groups that oriented on one side of the carbon backbone which is making PP stiffer, creates higher degree of crystallinity and more resistance to the tendency to flow under stress as compared to polyethylene (PE). It is also harder and more opaque to withstand somewhat higher temperature up to 160 °C, or 320 °F without melting.

The rapid economic growth in Malaysia has generated 0.5-08 kg waste material/person/day and in rural areas the figure increased to 1.7 kg/person/day (Kathirvale *et al.*, 2003). The authors noted that plastics materials constitute the largest component of waste material by weight at 18.9 %, apart from food and paper. Findings from study indicated that plastics materials are disposed at rate of 2.943 kg/day, an approximation of 5 % from the daily consumption of plastics material. This finding is in agreement with the results obtained by Rossbach (1979) at 5.3 %. The results from Malaysian Plastics Manufacturer Association (MPMA) (2004) clearly indicated that polyolefin such as polypropylene (27 %) and polyethylene (10 %) monopolized the plastics industry in Malaysia and it reported that the consumption of poly olefins as the highest, at 67.7 %. Figure 1.2 and Table 1.1 show the consumption rate for different types of plastics resin (MPMA, 2004). Currently, the recycling and fully utilization of waste materials have attracted great attention in construction field to fulfill the current interest in long term and sustainable development, as well as to reduce the cost of managing the landfill.

Table 1.1: Consumption rate for different types of plastics resin per day of the respondent companies

Plastic resin	**kg day^{-1}**
Polypropylene (PP)	12827
Polyethylene (PE)	4588
Polystyrene (PS)	9413
Polycarbonate	1825
Acrylonitrile butadiene styrene (ABS)	13218
Others	4966
Total consumption per day	46837

Source: Malaysian Plastics Manufacturers Association, MPMA (2004)

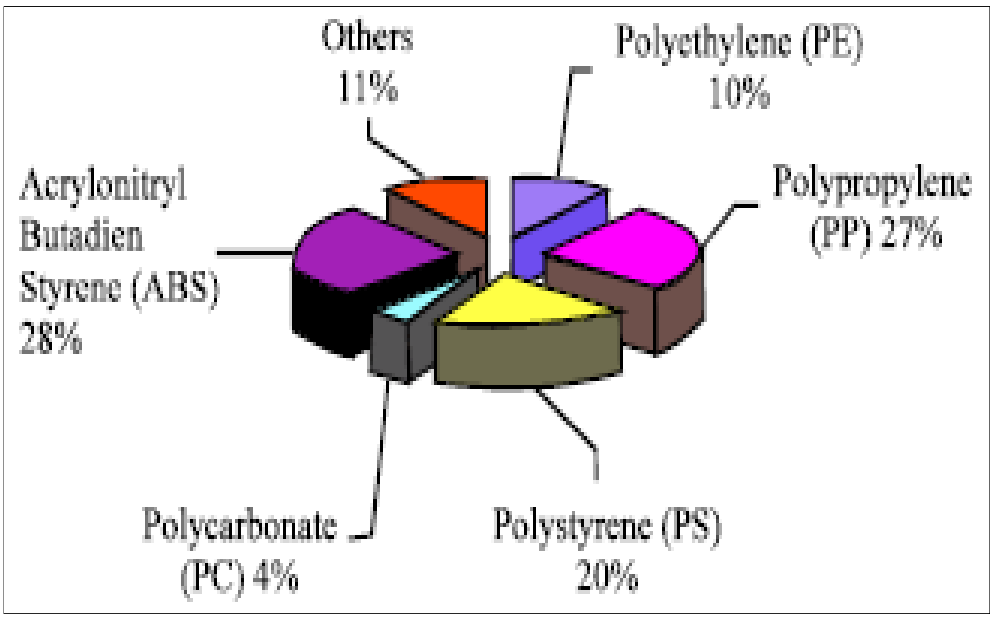

Figure 1.2: Consumption rate of plastics according to resin types

Source: Malaysian Plastics Manufacturers Association, MPMA (2004)

1.2. PROBLEM STATEMENT

Chen and Morriss (2000) stated that the design of foundation on soft clay has been the concern of engineers since the beginning of soil engineering. Therefore, structures constructed on soft soils may experience excessive settlements, large lateral flow and slope stability (Abdullah and Edil, 2007). This has leads to the findings and applications of various type of ground improvement, for example granular columns. This technique is preferable because it gives the advantage of reduced settlements and accelerated consolidation settlements due to reduction in flow path lengths. One of the major factors that could lead to high settlement is the high compressibility properties of soft clay. This condition due to finer particles of soft clay and the presence of water make it being too cohesive. High settlement is so dangerous because it affects the movement of whole structure and end up with structure failures.

Due to the rapid development of building construction and highway infrastructure, the settlement of soft soil become one of the main problems for foundation design. For example, there is an increase of stress in the soft ground as well as the strain or settlement when a road embankment is constructed over soft ground. Excessive yielding in vertical and lateral direction of the soft ground will occur if the surcharge load due to filling and constructions traffic load is high near the ultimate bearing capacity of the supported soft ground. Moreover, this situation will followed by tension crack, deep seated rotational or translational slip when the deformation is large and extensive.

Therefore, in this study, the strength of soft soils reinforced with group crushed PP as replacement material in granular column had been investigated. Expecting the analysis result may give the positive progress to the soil improvement such as the undrained shear strength of sample reinforced was greatly improved compared with that of the unreinforced samples. Indirectly, it will solve the PP disposal problem by reusing the material to reinforce the soft soils, besides, the landfill in Malaysia also have been limited due to the increasing of daily waste. Furthermore, since the PP is a waste material, the cost of soil improvement can be reduce and hopefully the analysis result will help to make further progress to the soil improvement of the soft clay.

1.3. OBJECTIVES

The aim of this study is to investigate the strength of soft clay reinforced with group crushed PP columns. The soft clay has been represented by compacting kaolin paste. This study is carried out to achieve the objectives as follow:

i. To determine the physical characteristics of kaolin clay and PP and morphological characteristics of PP;

ii. To determine the undrained shear strength of soft clay reinforced with various dimensions of group PP columns.

1.4. SCOPE OF STUDY

The materials used in this study were kaolin as soil sample and crushed PP as reinforcing columns. To determine the physical properties of kaolin and PP and the morphological characteristics of PP, the following laboratory tests were carried out:

i. Atterberg Limit Test
ii. Specific Gravity Test
iii. Sieve Analysis Test
iv. Hydrometer Test
v. Relative Density Test
vi. Standard Compaction Test
vii. Falling Head Permeability Test