THE UNDRAI[illegible] OFT CLAY REINFORCED [illegible] METER OF GROUP BOTTOM ASH COLUMN

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ABSTRACT

Soft clay soil can be categorized as problematic soil. A constructing structure which is constructed on a poor ground such as soft clay can affect the stability and settlement of the structure. Soft clay consists of a low shear strength, low ability permeability and high compressibility characteristic and that are the major reasons why a careful design analysis could be taken for any structure built on it. There are various method that been approach to improve the strength of the soft clay soil and the most popular method that is being used in the construction field is stone column. In another view, large production of bottom ash from coal burning in Malaysia has resulted in waste problem. This study is to present suitability in terms of shear strength by using bottom ash to replace sand or stone in columns for ground improvement technique using the laboratory scale model. As we know that sand is one of the non-renewable materials so by utilize by-product or waste which is bottom ash, we can reduce utilization of sands and at the same time we can prevent pollution and sand from disposing. The first stage is to determine the physical and mechanical properties, the test that is being conducted to determine these terms are Atterberg limits, specific gravity, direct shear test, constant head permeability test, standard compaction test and hydrometer test. Kaolin is used as soil sample and bottom ash as the reinforced columns. In the second stage of the study, consolidated kaolin as soft clay were reinforced with group of 3 bottom ash columns and tested for shear strength using Unconfined Compression Test.

ABSTRAK

Tanah lembut adalah tanah yang dikategori dalam tanah yang bermasalah. Satu struktur pembinaan yang dibina di atas tanah lembut seperti tanah liat lembut boleh menjejaskan kestabilan dan pemendapan struktur tersebut. Ciri-ciri tanah liat lembut terdiri daripada kekuatan ricih yang rendah, keupayaan kebolehtelapan yang rendah dan ciri kebolehmampatan yang tinggi dan ini adalah sebab-sebab utama mengapa analisis reka bentuk yang terliti perlu diambil kira untuk apa-apa struktur yang dibina di atasnya. Terdapat pelbagai kaedah yang boleh digunakan untuk meningkatkan kekuatan tanah liat lembut dan kaedah yang paling popular yang digunakan dalam bidang pembinaan adalah tiang batu pengeluaran abu bawah dalam kuantiti yang banyak daripada pembakaran arang batu di Malaysia telah menyebabkan masalah bahan buangan. Kajian ini adalah untuk membentangkan kesesuaian dari segi kekuatan ricih dengan menggunakan abu bawah untuk menggantikan pasir atau batu dalam ruangan teknik pembaikan tanah menggunakan model skala makmal. Seperti yang kita tahu bahawa pasir adalah salah satu daripada bahan-bahan yang tidak boleh diperbaharui, oleh demikian, dengan menggunakan bahan buangan seperti abu bawah, kita boleh mengurangkan penggunaan pasir dan pada masa yang sama kita boleh mencegah pencemaran udara dan dapat mengelakkan pasir daripada pupus. Peringkat pertama adalah untuk menentukan sifat-sifat fizikal dan mekanikal, ujian yang sedang dijalankan untuk menentukan syarat-syarat ini adalah ujian had Atterberg, ujian graviti tentu, ujian serakan (hidrometer), ujian analisis ayakan kering, ujian kebolehtelapan, ujian ricih dan ujian pemadatan tanah. Kaolin digunakan sebagai sampel tanah dan abu bawah akan diletakkan didalam lubang yang di korek sebagai teknik pembaikan tanah. Pada peringkat kedua kajian ini, kaolin sebagai sampel tanah liat lembut telah diperkukuhkan dengan melakukan tiga tiang abu bawah pada sampel yang disediakan dan diuji untuk kekuatan ricih dengan menjalankan uji kaji kuat tekan bebas.

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A_c	Area of a column
A_s	Area of the sample
H_c	Height of a column
H_s	Height of a sample
V_c	Volumes of the column
V_s	Volumes of the sample
D_c	Diameter of column
Si	Immediate settlement
Sc	Primary consolidation
τ	Shear strength of the soil
σ	Effective normal stress
ϕ	Cohesion.
w_L	Liquid limit
w_P	Plastic limit
I_P	Plastic index
w_{opt}	Optimum moisture content
q_u	Deviator stress
s_u	Undrained shear strength
Δs_u	Improvement of undrained shear strength
ρ_d	Dry density
R^2	Correlation cohesion

LIST OF ABBREVIATIONS

BA	Bottom Ash
FA	Fly Ash
MSW	Municipal Solid Waste
USCS	Unified Soil Classification System
AASHTO	American Association of State Highway and Transportation Officials
ACAA	American Coal Ash Association
ML	Low plasticity silt
SW	Well graded sand
UCT	Unconfined compression test

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The development of urban area is increasing quickly around the world nowadays, there is a vast growth in the development of industrial, housing and other infrastructure facilities due to the increase of population. The government wants to make sure that all of the people in this country can live in a comfortable place. However, due to the limited availability of construction sites, prices of land keep on increasing. The developers take an effort to construct a building on a soft soil which is more economical.

Often project sites are located in areas with soft or weak soils. Soft soil can be categorized as problematic soil. The low strength and high compressibility characteristic the soil had are the major reasons why a careful design analysis could be taken for any structure built on it. Settlement and the stability of the structure can be effected if the structure is constructed on a poor ground. Therefore, cracking on main structure or pavement could happen if the structures such as building, road pavement, runways, embankment, dam and shallow foundation are constructed on low strength of soil. This can induce a high cost to reconstruct or repair the engineering structure.

The ground improvement is necessitated to modify the soil properties. Ground improvement techniques are used to prepare the ground for new construction projects and to reduce the risk of liquefaction in areas of seismic activity. Without a properly interpreted soil improvement, hazard which lie on the ground beneath the site cannot be known. Various techniques had been used to improve the soft soil, for example reinforcement with geosynthetics, lime treatment, acceleration of pre-consolidation using pre-fabricated vertical drains, and the most popular method is a vertical granular column.

The method of vertical granular column consists of forming a vertical hole in the ground which are filled with compacted crushed stone, gravel and sand or a mixture which shown in Figure 1.1 to improve the strength of the soft soil. In general, vertical granular columns are either constructed as fully penetrating through a clayey soil layer overlying a firm stratum or partially penetrating with their tips embedded within the clayey soil layer (Shahu and Reddy, 2011).

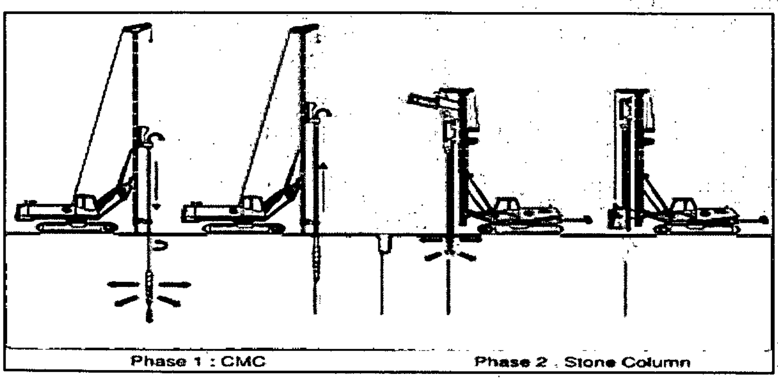

Figure 1.1: Installation of vertical granular column

Source: Kempfert and Gebreselassie, 2006

The method of the vertical granular column proven that installation of the sand column had successfully and effectively improves bearing capacity of weak soft soil, reduces the post-construction settlement of the structure built and reduction in total settlement, reduce the liquefaction potential of clean sands, improves the stability of the embankment and natural slopes, and accelerates the consolidation process (Castro and Sagaseta, 2008). The columns act as vertical drains which reduce the path length for the dissipation of excess pore water pressure that generated during loading. Therefore, the consolidation process became more faster (Maakaroun *et al.*, 2009).

Kumar and Stewart (2003) stated that properties of sand are similar to a properties of bottom ash. As we know that sand is a non-renewable material, there is a good opportunity to reuse waste of bottom ash as a replacement material in sand column. The physical properties of bottom ash are porous, course, granular, grayish and glassy. Bottom ash that is being used in this study is collected at Tanjung Bin Power Plant in Pontian, Johor. Tanjung Bin Power Plant has produced 180 ton/days of bottom ash and 1620 ton/day fly ash from 18000 ton/day of coal burning (Muhardi *et al.*, 2010).

By recycling and utilize the bottom ash as a by-product to replace sand in a vertical granular column have attracted attention in a construction field to fulfill the current interest in long term and sustainable development. Thus, with the similar properties as sand, bottom ash is a suitable material to be used to substitute in a vertical granular column. At the same time, we can reduce the cost of construction and reduce the problem of disposal of waste material as bottom ash.

1.2 PROBLEM STATEMENT

Structures are meant to stand strong for many years to come and importantly it can provide a great strength to support the load within the structure. In the soil properties, soft clays are the unstable soil condition and believed to be the major circumstances for any structure to be built on it. By gaining or having the knowledge about the engineering characteristics of soft clay soil and studied into consideration as deep understanding of the analysis could help people which involved in this field to understand how critical the soil could become to the structure. In construction, building that built on the soft clay soil is adaptable to be constructed with weak foundation and for sure it can cause a structural failure.

Soft clay consists of a low shear strength, low ability permeability and high compressibility characteristic and that are the major reasons why a careful design analysis should be taken for any structure built on it. Soil which has a weak condition such as soft clay, the stiffness of the soil could easily be affected and this can make the soil become weak in strength and could not support high load on it. It will be more dangerous if the structure built on a weak condition of the soil and at the same time it can cause failure of the structure.

Power plant produces both bottom ash (BA) and fly ash (FA). Bottom ash is recovered from the combustion chamber of the inorganic material as well as some unburned organics while fly ash is the particular removed from the gaseous emissions. Considering both types of ash together, Municipal Solid Waste (MSW) combustion typically achieves a 75 % reduction in material by weight (and 95 % reduction by volume). Thus 25 % of the original mass are ash, with high density, of about 1200 to 1800 lb/yd3.. The sustainable amount of ash disposed in the landfills generates an environmental pollution from time to time

In the previous study, bottom ash has been identified as a coarse, with grand sizes spanning from fine sand to fine gravel. By recycling or reuse bottom ash as a replacement sand in a sand column can reduce utilization of non-renewable material as sand in site in order to save money as well to keep the environment safe. The cost of construction also can be reduced and this could be one of the techniques in achieving the sustainable development in the construction industry.

1.3 OBJECTIVE

This study it to determine the degree of improvement made for use of bottom ash columns in soft clay in a laboratory scale model. Soft clay has been represented by compacting kaolin. The objectives that had been identified are:

a) To determine physical and mechanical properties of bottom ash and kaolin clay sample.
b) To determine the shear strength of soft clay reinforced with group bottom ash column.
c) To establish correlations relating undrained shear strength with various dimensions.

1.4 SCOPE OF STUDY

The scope of study includes the process to identify the physical and mechanical properties of kaolin and bottom ash. Several laboratory tests are being carried out and the test that is being conducted is to determine the physical and mechanical properties of kaolin are liquid limit, specific gravity and hydrometer test. For physical and mechanical properties of bottom ash are specific gravity test, dry sieve test, direct shear test, constant head permeability test and standard compaction test.

Subsequently, this study also covers the determination of shear strength of soft clay reinforced with group bottom ash column. By using one-dimensional test the kaolin clay is prepared obtained from consolidating kaolin slurry. Five batches of kaolin sample with 50 mm diameter and 100 mm height was prepared. Next, Unconfined Compression Test was conducted to determine the shear strength of reinforced soft kaolin clay and the test was following the BS 1377-Part 7:1990.

One batch had 15 samples that are being prepared in this project with two different diameters (6 mm, and 10 mm) with three different heights of level. For 6 mm diameter, the height level are 24 mm, 36 mm, and 48 mm while for 10 mm diameter the height level are 40 mm , 60 mm, and 80 mm. Area replacement ratio (A_c/A_s) which is A_c is an area of a column and A_s is an area of the sample (1.44 %, and 4 %). The height penetration ratio (H_c/H_s) which is H_c is a height of a column and H_s is a height of the sample (0.4, 0.6, and 0.8). Volumes of bottom ash column (V_c) between the volumes of the sample (V_s) for 6 mm diameter are 0.35 %, 0.52 %, and 0.69 % while for 10 mm diameter are 1.6 %, 2.4 %, and 3.2 %.

1.5 SIGNIFICANCE OF STUDY

The aim of this study is to identify the improvement shear strength of soft clay after reinforced with group of three bottom ash columns in a small scale model. Thus, there are some laboratory experiment were carried out to determine whether the bottom ash is a suitable material for replacing sand or stone in columns for ground improvement technique.

The use of bottom ash column material to replacing sand or stone was not only increased the bearing capacity of soft soil, it also reduces the settlement of the structure's foundation. Without question, this would increase the significantly the availability of marginal sites for cheaper and long term construction.

Besides that, it can cut of the utilization of non-renewable material which is sand and also reducing the waste problem of bottom ash which currently was disposed in a huge quantity into the landfill. Other than that, it was expected by reused bottom ash as a replacement of sand or stone in columns can reduce cost because bottom ash is a waste material from coal combustion, compared to the expensive sand or stone.

In this developing country, we should require to have effort to recycle or reuse material that can save costs but at the same time it can keep the environment safe from polluted so that it can last long in future. This study was hopefully being part of the effort to help our country be more developed and success in every sector in future.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In today's construction industry, Geotechnical engineers usually faced a problem where they have to construct a building on a very complex and problematic soil. This problematic soil is soft soil. This situation had led to the findings and applications of various types of ground improvement method such as sand column. Sand column that had a similar properties as bottom ash. To save our environment from pollution, we can take initiative such as to reuse or recycle waste materials such as bottom ash to replace and substitute sand in the vertical granular column. Other than that, we can reduce costs and the land use is optimized.

2.2 SOFT CLAY

According to Liu and Evett (2005), particle sizes of soft clay are less than about 0.002mm or it can easily break down to this size. Soft clay is the finest of all and even it can only be clearly monitored by using microscopic tools. Soft clay is part of fine grained soil, with soil grains finer than 0.075 mm. Unified Soil Classification System (USCS) has stated that the soft soil is categorized as small particle soil that 50 % pass sieve No.200

Specification US (0.075 mm). A structure that built on soil is exposed to settlement, however, the possibility for the settlement occur are very high for the soft soil condition. Excessive settlement is tipped to be a big problem as it often exceeds the permissible limits (Craig, 2004).

Soft soils can be defined as clay or silt which is geologically young and under a constant condition since its formation to its own weight yet not undergone significant secondary consolidation. Moreover, the soils are just capable of carrying its own overburden weight and ay imposed additional load will result in relatively large deformation. Soil which had not completed the consolidation under their own weight are also can be included in this group (Kempfert and Gebreselassie, 2006).

In Peninsular Malaysia, the coastal deposits have been classified as quaternary deposits from Cenozoic era which shown in Figure 2.1 as being shown by Jamal *et al.* (1997). A few type of soil material that can be found in the quaternary deposit which are clay, silt, sand, seashell and decayed wood. The quaternary deposit is widespread along the coastline. The thick deposit of the clay occurs near to the coastal area and major river mouth. According to Huat (1994), the thickness is around ranged 5 m to 30 m. Characteristic of soft clay is more alike to a typical characteristic of soft soil which is high compressibility, low shear strength and low permeability. In this study, a few past researcher that had conducted this study to identify the engineering behavior of the soft clay in Peninsular Malaysia such as Klang based on the geotechnical site investigation (Tan *et al.*, 2005), Bukit Raja on the determination of undrained shear strength (Jamal *et al.*, 1997). Hence, it indirectly showed that the appropriate site for construction is so limited and the utilization of ground improvement technique is important to enhance the mechanical properties of the soft soil in Malaysia.

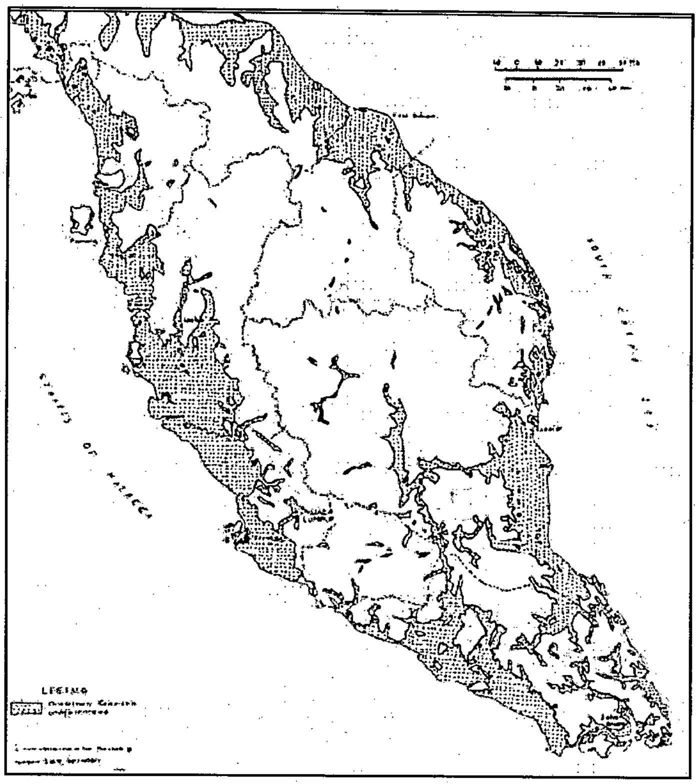

Figure 2.1: Quaternary sediment in Peninsular Malaysia

Source: Chin and Gue (2000)

2.2.1 Compressibility and Consolidation

A deformation and compression will be occurring when a load is applied on the saturated soil. Water will be dissipated out of the soil, the particles of the soil will move closer and the density will increase. Wesley (2010) has stated that, consolidation is a process to increase stress and causing squeeze out of water. Consolidation can be divided into two parts which are immediate settlement (S_i) and primary consolidation (S_c). The total settlement is expressed as in equation (2.1).

$$S = S_i + S_c + S_s \tag{2.1}$$

Immediate settlement in clay happens when air is expelled from the voids upon application of stress on saturated soil. The properties of clay which is low permeability can lead to the less drainage of water in clay. The elastic displacement theory is being used to estimate the immediate settlement (Tan *et al.,* 2005).

Primary consolidation is a process when the excess pore water pressure would cause water to dissipate and further settlement occurs in clay. According to Tan *et al.* (2005), the volume of soil changes as the pore pressure is eliminated and in turn, an effective stress exerts in the soil. The process conducted continuously until the excess pore water pressure is completely drained out and the loads were carried by the soil skeleton. Oedometer test also known as one-dimensional consolidation test which is conducted to estimate the amount of the settlement and the time needed for the consolidation process.

Based on the statement that being carried out from Craig (2004), the secondary consolidation is based to the gradual rearrangement of the clay particles into a more stable configuration. The deformation of soil skeleton is actually caused by the settlement and this process is much longer compared to primary consolidation.

2.2.2 Shear Strength

Shear strength defines as the soil's ability to resist sliding along the internal surface within a mass of the soil. The estimation of shear strength can be expressed by the Coulomb equation (Liu and Evett, 2005):

$$\tau = \sigma \tan \phi + c \qquad (2.2)$$

τ is define as a shear strength of the soil, σ is defined as an effective normal stress, while ϕ defines as a cohesion.

By conducting an unconfined compression test, cone penetration test, field vane test or standard penetration test can predict the shear strength of the soft clay (Jung *et al.*, 2010). Unconfined compression strength of clay which less than 50 kPa is classified as soft clay and clay which less than 25 kPa is classified as very soft clay.

According to Tan *et al.* (2004), Klang clay is being categorized as soft soil because the undrained shear strength (s_u) was in the range of 18 kPa to 50 kPa. Based on a study of the past researcher Jamal *et al.* (1997) stated that, the value of the undrained shear strength in Bukit Raja in Klang area is found the range is around 6 kPa to 23 kPa. Hence, the soil at Bukit Raja is classified as very soft clay.

2.3 BOTTOM ASH

Fly ash and bottom ash produced as a by- product material from coal combustion in coal fired power plant. This material is actually a group of highly scatting tiny particles and made up of silicon oxide glass spheres. It has two different shapes based on sizes and shape of the particles. Fly ash is in spherical particles while for bottom ash is in irregular particles (Tai Lv *et al.*, 2009).

In Figure 2.2(a) shows that fly ash is consisting of fine-grained sizes range between fine silt and fine sand while bottom ash which shown in Figure 2.2(b) consists of coarse angular particles ranging in size from sand to small gravel. Both materials have a unique morphological characteristic and it is different from the typical soils.