STUDY OF THE STRENGTH OF SOFT CLAY REINFORCED WITH SQUARE AND TRIANGULAR ENCAPSULATED BOTTOM ASH COLUMN

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ABSTRAK

Tanah liat lembut yang dikenali sebagai tanah bermasalah yang terdiri daripada kekuatan ricih yang rendah, kebolehtelapan yang rendah dan kebolehmampatan yang tinggi di mana tanah yang sedia ada di laman web ini diberikan tidak dapat membawa beban yang dicadangkan struktur dengan sendirinya, jadi penggunaan pembaikan tanah adalah perlu. Ruangan batu semakin digunakan sebagai teknik pembaikan tanah untuk menyokong pelbagai struktur termasuk bangunan dan struktur yang fleksibel. Dalam amalan, keupayaan galas di gelanggang tanah liat lembut boleh diperbaiki dengan lapisan pasir yang dipadatkan atau kerikil. Abu bawah sebagai hasil sampingan daripada pembakaran arang batu yang mempunyai ciri-ciri yang serupa dengan bahan berbutir boleh memohon sebagai salah satu kaedah untuk menstabilkan tanah yang sedia ada. Oleh itu, dengan menggunakan abu bawah sebagai pemain gantian, kos pembinaan dapat dikurangkan dan membuat kemajuan besar kesedaran yang semakin meningkat pertimbangan alam sekitar. Kertas kerja ini membincangkan hasil peningkatan dalam kekuatan ricih tanah liat lembut selepas diperkuatkan dengan sekumpulan persegi dan segi tiga terkandung tiang abu bawah. Sifat-sifat fizikal dan mekanikal bahan yang digunakan seperti kaolin dan abu bawah telah ditentukan terlebih dahulu. Keputusan menunjukkan bahawa kaolin boleh diklasifikasikan iklan tanah liat dan abu bawah mempunyai persamaan ciri dengan bahan berbutir. Sebanyak 52 ujian mampatan tak terkurung telah dijalankan ke atas spesimen kaolin untuk menentukan kekuatan ricih. Garis pusat untuk spesimen adalah 50mm dan 100mm tinggi. Diameter tiang abu bawah masing-masing 10mm dan 16mm dan ketinggian tiang adalah 60mm, 80mm dan 100mm. Ruangan kumpulan telah disusun dalam corak persegi dan segi tiga. Dapat disimpulkan bahawa parameter kekuatan ricih telah bertambah baik berdasarkan diameter yang berbeza dan ketinggian tiang.

ABSTRACT

Soft clay is known as problematic soil that consists of low shear strength, low permeability and high compressibility where the existing soil on the given site is unable to carry the load of proposed structure by itself, so the use of ground improvement is necessary. The stone columns are increasingly being used as ground improvement technique for supporting a wide variety of structures including buildings and flexible structures. In practice, the bearing capacity on soft clay can be improved by a layer of compacted sand or gravel. Bottom ash as by product of coal burning that has similar properties to granular material can be apply as one of the stabilizing method to the existing soil. Hence, by using bottom ash as substitute, the cost of construction can be reduced and make great progress of a growing awareness of the environmental consideration. This research discusses the results of the improvement in the shear strength of soft clay after being reinforced with a group of square and triangular encapsulated bottom ash columns. The physical and mechanical properties of the materials used such as kaolin and bottom ash were determined first. The results show that kaolin can be classified ad clayey soil and bottom ash has similarities of characteristic with granular material. A total of 52 unconfined compression tests had been conducted on kaolin specimens to determine the shear strength. The diameter for specimen is 50mm and 100mm in height. The diameter of bottom ash columns are 10mm and 16mm respectively and the height of the column are 60mm, 80mm and 100mm. The group columns have been arranged in square and triangular pattern. It can be concluded that the shear strength parameters were improved based on the different diameter and the height of the column.

LIST OF SYMBOLS

A_c	-	Area of Bottom Ash Column
A_s	-	Area of Sample
C_c	-	Coefficient of Curvature
D_c	-	Diameter of Bottom Ash Column
H_c	-	Height of Bottom Ash Column
H_s	-	Height of Sample
m	-	Meter
m^3/s	-	Meter cubes per second
min	-	minutes
kN	-	Kilo Newton
kPa	-	Kilo Pascal
q_{max}	-	Maximum deviator stress
w_{opt}	-	Optimum water content
ρ_d	-	Dry density
$\rho_{d(max)}$	-	Maximum Dry density
Φ	-	Internal Friction Angle
c'	-	Cohesion

LIST OF ABBREVATIONS

ACCA	-	American Coal Ash Association
ASSHTO	-	American Association of State Highway and Transportation Officials
ASTM	-	American Society for Testing and Materials
BS	-	British Standard
PI	-	Plastic Index
PL	-	Plastic Limit
LL	-	Liquid Limit
UCT	-	Unconfined Compression Test
USCS	-	Unified Soil Classification System

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In recent years, an enhancement of embankment and structures have to be erected in soft soil. The soil improvement depends on the stress distribution between soil and column. In many cases, expansive and collapsible soils may be present on a given site because it may be not suitable for supporting the proposed structures. Indraratna *et al.* (2013) stated that reducing long-term settlement of infrastructure and providing cost-effective foundations with sufficient load-bearing capacities are national priorities for infrastructure if proper ground improvement is not carried out. One of the most versatile and cost effective technique of the ground improvements for improving the weak strata conditions is stone columns. There are a few methods to improve the properties of soft clay such as piling, sand drain and many more. Among several method available for improving the weak strata, stone columns is the most preferable and widely used for several applications. Other than increasing the strength and stiffness of soft soil, stone columns technique also act as reinforcing material to achieve consolidation through effective drainage.

The stone column technique, also known as vibro-replacement or vibro-displacement, is a ground improvement process where vertical columns of compacted aggregate are formed through the soils to be improved. Pivarc (2011) stated that the stone column technique has adopted in European countries in the early 1960s. The stone columns technique is one of the most used techniques for ground improvement processes all over the world among various methods of soft soil improvement. In practice, the bearing capacity on soft clay can be improved by a layer of compacted sand or gravel.

Many researchers have developed theoretical solutions for estimating the bearing capacity and settlement of foundations reinforced with stone columns. Stone columns in compressive load in two different mode. On the research done by Hughes and Withers (1974), it is found that bulging is the one of the mode to show the characteristic of stone column. The experimental and numerical analysis on singles and group stone column were conducted by Ambily *et al.* (2007), Black *et al.* (2007) and Hasan *et al* (2011).

Ground improvement techniques continue to make great progress of a growing awareness of the environmental and economic consideration. The significant aspect is to protect environment since more solid waste are produced from day to day. The selection of the correct ground improvement technique can have significant effect on foundation choice and can often lead to more economical solutions when compared to traditional approaches. It is noted that by nature, the existing soil on the given site unable to carry the load of proposed structure by itself, so the use of ground improvement is necessary. Considering for instance a soft clay with a relatively low shear strength, two kinds of column reinforcement techniques might be envisaged. One of the technique is stone column technique which consists in introducing within the soft clay a vibro-compacted stone or ballast material.

The soil improvement directly depends on the stress distribution between soil and column. Stone columns act mainly as rigid inclusions with a higher stiffness, shear strength and permeability than the natural soil and the effects or improvements caused by these three properties were independently studied by different solutions (Castro *et al.*, 2012).The soil types need to be enhanced in order to allow building and other heavy construction, so it is necessary to create stiff reinforcing elements in the soil mass (Zahmatkesh and Choobbasti, 2010) The stone column consists of granular material such as crushed aggregates or sand.

Coal is being one of the main sources of energy in our country fuelling about 40% of the total. Two kind of coal waste products consists of fly ash and bottom ash. Based on the fact from Singh and Siddique (2012), bottom ash forms up to 25% of the total ash while the fly ash forms the remaining 75%. Muhardi *et al.* (2010) has reported that the Tanjung Bin power station is one of the four coal power plant in Malaysia, producing 180 tons/day of bottom ash and 1620 tons/day of fly ash from 18000 tons/day of coal burning As well known, coal bottom ash is formed in coal furnaces. Bottom ash by product of coal burning as stone column can be apply as one of the stabilizing method to the existing soft soil before construction to reduce the unacceptable settlement and improve the load bearing capacity of the foundations.

Figure 1.1: Location of coal power station in Malaysia

The other benefit that can be achieved in term of quality by the utilization of bottom ash is sustainability in construction. Abubakar and Baharudin (2012) stated that in engineering practice, sustainability does not stop at the development of new and environmental friendly materials for construction purposes, but also the reutilization of materials that were erstwhile considered as waste by-products of industrial processes. Since bottom ash has same properties as granular material, then bottom ash could be used as substitute of natural material on concrete. Compared to natural sand, bottom ash has more lighter and brittle characteristic. Therefore, its suitability as replacement for natural material in concrete and their durability properties are being evaluated in construction industry.

1.2 Problem Statement

Malaysia is being serious about environmental issues and people starting to realize the important to protect the earth after there are too many hazard that we produce day by day. It is necessary to have a backup plan to satisfy the need of people but still need to prevent the pose of environmental hazard. Still, there are ground improvement technique by using waste material such as bottom ash and fly ash without imposed bad impact to the earth. As stated before, one of the effective method to improve the properties of soft clay is stone columns. Improvement of soft clay by using stone columns method is popular in most countries.

Soft clay is known as a problematic soil and the design of foundation on soft clay has been the concern of engineers since the beginning of soil engineering. Soft soil foundations can cause excessive settlement, initiating undrained failure of the infrastructure if proper ground improvement is not carried out (Indraratna et.al, 1992). The substitution of granular material with coal bottom ash can lead to the significant effect on soft clay improvement. According to Marto *et al.* (2013), coal is one of natural resources that existed due to the chemical and geological alteration of materials formed by plants over tents or hundreds of millions of year in the past.

The majority area of Malaysia are faced with shortage of construction materials. Use of coal ash in construction projects requiring large material volumes, such as highway embankment construction, back fill, soil improvement may offer an attractive alternative to recycle this materials. Besides that, using large volume of the coal ash in geotechnical application is a highly promising solution to the disposal problem (Awang *et al.*, 2012). Thus, the large volume of coal ash as solid waste will be produced if the utilization of coal is large.

The utilization of waste material is one of the best technique to achieved sustainable development (Hasan *et al*., 2011).Most of the waste disposal are being dumped near the factory. Hence, it will increase the expenses as there need to obtain large areas of dump yard. In construction industry, the utilization of coal ash which need large quantity of material shows the problem of coal ash disposal. Other than that, the power industry need to take responsibility of disposal unused coal ash and finally places a concern to the electricity consumer. It has been reported that the Tanjung Bin power plant needs about 18,000 tons/day of coal to generate electricity (Marto *et al.,* 2013).

However, the large quantity disposal of coal ash in landfills will be considerable concern to an environmental issues and creating to the increase requirement for disposal space. The disposal of coal ash becomes an environmental issues due to coal bottom ash is simply disposed of on open land. Environment concerns are increasing day by day because the disposal of bottom ash is risk to human health and the environment. The method of burning the residues create the fuss of environmental problem which it generates air pollution.

Previously, stated that there is strongly possibility of coal bottom ash being as substitute as granular material for ground improvement technique. The using of bottom ash as an alternative to replace the natural sand in produced concrete. Bottom ash use in concrete is important to show the fact that sources of natural sand are getting depleted gradually. The method of burning the residues often become an environmental issues which generates air pollution. But, if in the positive side, it is an alternative method that has provided to optimize the usage of waste as product in construction industry.

1.3 Objectives

The purpose of this project is to study the improvement of shear strength of soft clay encapsulated with triangular and square bottom ash column. The main objectives for this research are:

i. To determine physical and mechanical properties of soft clay and bottom ash.

ii. To determine the strength of soft clay reinforced with square and triangular pattern of group encapsulated bottom ash column.

1.4 Scope of Study

This study concentrated on improvement shear strength of soft clay reinforced with encapsulated bottom ash column of square and triangular pattern. The experimental and testing procedures were run and analyzed in the Soil Mechanic and Geotechnical Laboratory Faculty of Civil Engineering and Earth Resources (FKASA), University Malaysia Pahang (UMP).

i. The physical and mechanical properties of kaolin, were determined from the following laboratory tests:

a. Atterberg Limit Test
b. Specific Gravity Test
c. Standard Compaction Test
d. Falling Head Permeability Test
e. Hydrometer Test

ii. The physical and mechanical properties of bottom ash, were determined from the following laboratory tests:

a. Sieve Analysis Test
b. Specific Gravity Test
c. Standard Compaction Test
d. Constant Head Permeability Test
e. Relative Density Test
f. Direct Shear Test

iii. The shear strength of soft kaolin clay reinforced with triangular and square encapsulated bottom ash columns had been determined from Unconfined Compression Test with the following step:

1. Every batch of kaolin sample was produced by compaction method.
2. Diameter and height of each sample was 50 mm and 100 mm respectively.
3. Triangular and square columns kaolin were extracted from each sample and replaced by bottom ash with penetration ratio (0, 0.6, 0.8, and 1.0).
4. The diameter of triangular and square column were 10 mm and 16 mm, which were 12% and 30.72% of area displacement ratio. Meanwhile, the diameters of square column were 16 mm and 40.96%.

1.5 Significant of Study

This study help to improve the properties of soft clay that is below of structure (raft and depth). The purpose is to determine the improvement of shear strength of soft clay after reinforced with encapsulated triangular and square bottom ash columns. It is imperative to apply requisite ground improvement method to the existing soft soil before construction which help to disallow differential settlement and at the same time will increase the bearing capacity of the foundation. This study will evaluate the potential of bottom ash as natural sand in concrete. Using waste material as replacement to natural aggregate in concrete making gained more attention especially among researches.

The utilization of coal bottom ash will present economic and ecological way that might contribute to reduce some waste problems and prevent pollution of their disposal and protect the natural resources since it is waste material that produced annually on combustion of millions tons of coal. In addition, by using waste as substitute instead of natural materials, the use of non-renewable natural material will be reduced hence, it conserving the natural resources. The waste material such as bottom ash, fly ash and boiler slag that was not reused was disposed in landfills In addition, it is a big concern to search environment friendly solutions for disposal of industrial waste to obtain clean environment. As stated before, a large volume of coal ash will be produced when the utilization of coal is increase. Then, it will be a global concern due to the increases for ash storage space.

The experimental study conducted is a step towards the productive design of stone column by used bottom ash as a substitute of natural sand in the manufacturing of concrete. Bottom ash has similar particle size to that of natural sand and because of this properties, it suitable to be used as sand replacement in concrete. The continuous research of concrete containing coal bottom ash as natural sand for their durability properties are needed before bottom ash accepted as construction products. The ACCA survey showed that almost 70% of bottom ash use was for concrete and structural fills. The remaining usage was as road base and as aggregate. The successful use of bottom ash in civil engineering construction not only would provide significant economic savings but also help to solve the disposal problem. The unutilized bottom ash might poses risk to environment hazard that can contaminate living organism, therefore it is essential and become a greatest concern to utilize the bottom ash.

CHAPTER 2

LITERATURE REVIEW

2.1 Soft Clay

Improvement of soft clay deposits by the installation of stone columns is one of the most popular techniques followed wide world. The stone columns not only act as reinforcing material increasing the overall strength and stiffness of the compressible soft soil, but they also promote consolidation through effective drainage (Indaratna *et al.*, 2013).Unified Soil Classification System (USCS) categorized soil into two groups, known as coarse grained soil and fine grained soil. Clay is fine grained soil containing more than 50% of total weight soil passing No.200 sieve. The vibro-replacement or vibro-displacement is another name for stone column, one of the ground improvement process where vertical columns of compacted aggregate are formed through soils to be improved. As stated by Kosho (2000), densification and or reinforcement of the soil with compacted granular is accomplished by either a top feed or a bottom feed method. The column installation was simulated for calculating the stresses due to compaction of soil.

Stone column are usually designed to improve bearing capacity and to reduce settlements of soft soils. Stone columns are formed by inserting a vibrating probe to incorporate granular aggregate into the ground, which is then re-compacted. This technology is well suited for the improvement of soft soils such as silty sand, silts and clays (Frikha *et al.,* 2014).

2.2 Bottom Ash

Coal is one of the most important sources of energy, fueling almost 40% of world's electricity. In Malaysia, coal was introduced as one of the sources of power generations since 1988. Production of coal ash is inevitable when coal is burnt for power generation, and with no attempt to re-use this material may lead to some negative impacts on the environment (Jorat *et al.,* 2011). Coal bottom ash (CBA) was formed in coal furnaces and made from an agglomerated ash particle and it was too large to be carried in the flue gases and then fall through the open grates to an ash hopper at the bottom of the furnace (Singh and Siddique, 2014). Based on research, the residual materials collected from the combustion coal mostly consists of fly ash and bottom ash.

In order to effectively put this by-product (bottom ash) into use in the industry, laboratory studies have been conducted to investigate the physical and mechanical properties of bottom ash such as grain size, specific gravity, compaction, shear strength, permeability as well as compressibility.