THE UNDRAINED SHEAR STRENGTH OF SOFT CLAY REINFORCED WITH 20MM DIAMETER SINGLE ENCAPSULATED BOTTOM ASH COLUMN

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B. ENG (HONS.) CIVIL ENGINEERING

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A thesis submitted in fulfilment of the requirement for award of the degree of

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Faculty of Civil Engineering & Earth Resources

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JUNE 2016

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LIST OF SYMBOL

A_c	Area of a column
A_s	Area of a sample
H_c	Height of a column
H_s	Height of a sample
V_c	Volume of a column
V_s	Volume of a sample
D_c	Diameter of a column
G_s	Specific gravity
m_1	Mass of bottle water
m_2	Mass of bottle soil water
m_3	Mass of bottle dry soil
m_4	Mass of density bottle
Dr	Relative density
γ	Unit weight of current sample
γ_{min}	Minimum unit weight
γ_{max}	Maximum unit weight
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
USCS	Unified Soil Classification System
AASHTO	American Association of State Highway and Transportation Officials
ML	Low plasticity silt
UCT	Unconfined Compression Test
ASTM	American Society of Testing Material
BS	British Standard
ACAA	American Coal Ash Association
UU	Unconsolidated Undrained Test

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ABSTRACT

Nowadays, due to limited availability of construction sites, developers take an effort to construct a building on a soft clay soil. Ground improvement methods are used to reduce the weakness of soft clay which is low strength and high compressibility characteristics. Stone column is a method where some of the soil is being replaced with granular material such as crushed rocks or sand. The stone column technique is a very efficient method of improving the strength parameters of soil like bearing capacity and reducing consolidation settlement. Bottom ash being used as substitute of fine aggregate as it has almost similar properties as sand. An effective utilization of bottom ash in construction materials will significantly reduce the accumulation of the by product in landfills and thus reduce environmental pollution. This study is to determine the undrained shear strength of soft clay reinforced with 20 mm diameter single encapsulated bottom ash column with various lengths. The first stage of the study was determination of the physical and mechanical properties of the material used such as soft clay and bottom ash. At the second stage, three batches of samples with each batch consists of five samples were prepared by using compaction method. All specimens of 50 mm in diameter and 100 mm in height soft kaolin clay with single encapsulated bottom ash columns with various lengths which are 60 mm, 80 mm, and 100 mm was subsequently tested under Unconfined Compression Test. The result shows that the shear strength of samples increases as the height and volume of encapsulated bottom ash column increases.

ABSTRAK

Pada masa kini, disebabkan oleh tapak pembinaan yang terhad, pemaju mengambil inisiatif untuk membina bangunan di atas tanah liat lembut. Kaedah penambahbaikan tapak digunakan untuk mengurangkan kelemahan tanah liat lembut yang mempunyai kekuatan yang rendah dan ciri-ciri kebolehmampatan yang tinggi. Tiang batu adalah satu kaedah di mana sebahagian daripada tanah itu digantikan dengan bahan berbutir seperti batu yang dihancurkan atau pasir. Teknik tiang batu adalah satu kaedah yang sangat berkesan untuk meningkatkan parameter kekuatan tanah seperti keupayaan galas dan mengurangkan enapan pengukuhan. Abu bawah digunakan sebagai pengganti batu halus kerana ia mempunyai ciri-ciri yang hampir sama seperti pasir. Penggunaan abu bawah yang berkesan dalam bahan-bahan pembinaan akan mengurangkan pengumpulan produk di tapak pelupusan sampah dan dengan itu mengurangkan pencemaran alam sekitar. Kajian ini bertujuan untuk menentukan kekuatan ricih tidak tersalir tanah liat lembut yang diperkukuhkan dengan 20 mm diameter tiang abu bawah dengan menggunakan panjang yang berbeza. Peringkat pertama kajian ini adalah penentuan sifat-sifat fizikal dan mekanikal bahan yang digunakan seperti tanah liat lembut dan abu bawah. Pada peringkat kedua, tiga kumpulan sampel dengan setiap kelompok terdiri daripada lima sampel telah disediakan dengan menggunakan kaedah mampatan. Semua spesimen 50 mm dan 100 mm tinggi tanah liat kaolin lembut yang mengandungi tiang abu bawah dengan pelbagai panjang yang berbeza iaitu 60 mm, 80 mm, dan 100 mm kemudiannya diuji di bawah uji kaji kuat tekan bebas. Hasil kajian menunjukkan bahawa kekuatan ricih sampel bertambah apabila ketinggian dan isi padu tiang terkandung abu bawah bertambah.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Earth will be home to more than 9 billion people in 2050, a jump of 2.3 billion over four decades (Solidia Technologies, 2015). This global milestone will have a pronounced urban penchant. Two-thirds of the world population will reside in mega cities, urban centers with 10 million inhabitants. Rapid population growth and urbanization will have a dramatic effect on the increased demand for jobs, housing, energy, clean water, food, transportation infrastructure, and social services. The urbanization of the planet over the coming decades will exert intense pressure on the agility and responsiveness of industry to innovate. The building materials and construction industries must adapt new practices to meet the increased demand for materials to build the housing and transportation infrastructure.

Nowadays, due to limited availability of construction sites, developers take an effort to construct a building on a soft clay soil. Soil is a naturally occurring mixture of mineral and organic ingredients with a definite form, structure, and composition. It is composed primarily of minerals which are produced from parent material which is broken into small pieces by weathering. Larger pieces are stones, gravel, and other rock debris. Smaller particles are sand, silt, or clay. Clay particles are smaller than 0.002mm and cannot be seen

with the unaided eye. Because of the small particle size, clay soils can sometimes experience large amounts of expansion and contraction in volume with changes in moisture content. Soft clay soil can be categorized as and problematic soil due to its weakness which are low strength and high compressibility characteristics. Settlement can occur if the structure was constructed on a poor ground.

A soil shear failure can result in excessive building distortion and even collapse. Excessive settlements can result in structural damage to a building frame nuisance such as sticking doors and windows, cracks in tile and plaster, and excessive wear or equipment failure from misalignment resulting from foundation settlements. It is necessary to investigate both base shear resistance and settlements for any structure. The ground improvement is necessary 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. Various techniques had been used to improve the soft soil, for example lime treatment, acceleration of pre-consolidation using pre-fabricated vertical drains and the most popular method is vertical granular column.

Researchers had mixed clay with waste material to enhance its engineering quality. The selected waste material is bottom ash. It is a byproduct from electric power plant. These waste material is disposed and generally have no economic value. Bottom ash is physically course, porous, glassy, granular, greyish and incombustible materials that are collected from the bottom of furnaces that burned coil. It is found that it has pozzolonic properties which make it possible to replace cement in deep soil mixing.

1.2 PROBLEM STATEMENT

Soft clay is a problematic soil because of the soft clay weakness in strength characteristic and high compressibility. Due to this weakness, ground improvement need to be conducted in order to increase and improve the soft clay strength. Bottom ash column was not only increased the bearing capacity of soil, but also reduces the settlement of structure's foundation. A characteristic of clay soil is that they swell in volume when they get wet and reduce in volume as they dry. The magnitude and direction of shrink and swell displacements are affected by a variety of factors. The displacements would cause serious impacts on some buildings and structures. It will be more dangerous if the structure built in a weak condition of the soil and at the same time it can cause failure to the structure. Bottom ash is formed in coal furnaces. It is made from agglomerated ash particles that are too large to be carried in the flue gases and fall through open grates to an ash hopper at the bottom of the furnace. Bottom ash is mainly comprised of fused courser ash particles. These particles are quite porous and look like volcanic lava. Bottom ash forms up to 25% of the total ash while the fly ash forms the remaining 75%. One of the most common uses for bottom ash is as structural fill. There is a strongly possibility of bottom ash being used as substitute of fine aggregate such as sand. Its use in concrete become more significant and important in view of the fact that sources of natural sand as fine aggregates are getting depleted gradually. The engineering and construction community has now taken up the challenge for the use of green and recycled byproduct in construction. One of those byproduct is the bottom ash from thermal power plant that faces an increasing production running into hundreds of thousand tonnes in Malaysia alone, and its method of disposal is relegated to landfills alone with no other commercial usage. An effective utilization of bottom ash in construction materials will significantly reduce the accumulation of the byproducts in landfills and thus reduce environmental pollution.

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