

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

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**Faculty of Civil Engineering & Earth Resources
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JUNE 2016

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TABLE OF CONTENT

SUPERVISOR’S DECLARATION		ii
STUDENT’S DECLARATION		iii
ACKNOWLEDGEMENTS		v
ABSTRACT		vi
ABSTRAK		vii
TABLE OF CONTENT		viii
LIST OF TABLES		xi
LIST OF FIGURES		xii
LIST OF SYMBOLS		xiv
LIST OF ABBREVIATION		xvi
CHAPTER 1	INTRODUCTION	
1.1	Background of Study	1
1.2	Problem Statement	3
1.3	Objective	4
1.4	Scope of Study	4
1.5	Significance of Study	6
CHAPTER 2	LITERATURE REVIEW	
2.1	Soft Clay	7
	2.1.1 Undrained Shear Strength	9
	2.1.2 Compressibility	11
2.2	Bottom Ash	12
	2.2.1 Chemical Properties of Bottom Ash	13
	2.2.2 Physical Properties of Bottom Ash	14
	2.2.3 Particle Size Distribution	14
	2.2.4 Specific Gravity	16
	2.2.5 Permeability	17
	2.2.6 Compaction	17
	2.2.7 Shear Strength	18

2.3	Bottom Ash Utilization	19
2.4	Geotextile	21
2.5	Vertical Granular Column	22
2.6	Small Scale Modelling	23

CHAPTER 3 RESEARCH METHODOLOGY

3.1	Introduction	26
3.2	Selection of Materials	28
3.3	Laboratory Works	28
3.4	Determination of Physical and Mechanical Properties of Materials	29
3.5	Determination of Physical Properties of Soft Clay	30
	3.5.1 Hydrometer Test	30
	3.5.2 Standard Compaction Test	30
	3.5.3 Falling Head Permeability Test	31
	3.5.4 Specific Gravity Test	31
	3.5.5 Atterberg Limit Test	32
3.6	Determination of Physical Properties of Bottom Ash	33
	3.6.1 Dry Sieve Test	33
	3.6.2 Specific Gravity Test	33
	3.6.3 Standard Compaction Test	34
	3.6.4 Constant Head Permeability Test	34
	3.6.5 Direct Shear Test	35
	3.6.6 Relative Density Test	35
3.7	Reinforcing Kaolin with Single Bottom Ash Column	36
	3.7.1 Kaolin Clay Samples	36
	3.7.2 Bottom Ash Sample	37
	3.7.3 Installation of Bottom Ash Column	38
	3.7.4 Unconfined Compression Test	39

CHAPTER 4 RESULT AND DISCUSSION

4.1	Introduction	40
4.2	Summary of Kaolin, Bottom Ash and Geotextile	41
4.3	Physical Properties	44
	4.3.1 Atterberg Limit Test	44

	4.3.2	Specific Gravity	45
	4.3.3	Particle Size Distribution	47
4.4		Mechanical Properties	49
	4.4.1	Standard Proctor Compaction Test	49
	4.4.2	Permeability	50
	4.4.3	Direct Shear Strength	51
4.5		Unconfined Compression Test	52
	4.5.1	Stress-Strain Behavior	52
	4.5.2	Undrained Shear Strength	54
	4.5.3	The Effect of Column Penetration Ratio	57
	4.5.4	The Effect of Height Over Diameter of Column	60
	4.5.5	The Effect of Volume of Bottom ash Column	63
CHAPTER 5		CONCLUSION AND RECOMMENDATION	
5.1		Introduction	66
5.2		Conclusion	66
5.3		Recommendation	68
REFERENCES			69
APPENDIX			
A		Specific Gravity Test	72
B		Atterberg Limit Test Result	74
C		Compaction Test Result	76
D		Falling Head Test Result	78
E		Constant Head Test Result	79
F		Hydrometer Test Result	80
G		Sieve Analysis Test Result	81

LIST OF TABLE

Table No.	Title	Page
2.1	Classification types of soil (Brand and Brenner, 1981)	8
2.2	Physical properties of Batu Pahat soft clay (Chan and Ibrahim, 2008; Robani and Chan, 2009; Ho and Chan, 2011)	9
2.3	Undrained strength classification of clay (Raymond, 1997)	10
2.4	Chemical properties of bottom ash (Siddique, 2012)	13
2.5	Classification by particle size (Head, 1992)	14
2.6	Comparison of bottom ash specific gravity values	16
2.7	Result of direct shear test of bottom ash	19
3.1	Test standard and methods of laboratory testing for materials	29
4.1	Summary for properties of Kaolin Clay	41
4.2	Summary for properties of Tanjung Bin Bottom Ash	42
4.3	Summary for properties of Polyester Non-woven Geotextile Needle punched (MTS 130)	43
4.4	Comparison of bottom ash specific gravity values	46
4.5	Maximum deviator stress and axial strain values at different height penetration ratio	53
4.6	Results of Unconfined Compression Test (UCT)	55
4.7	Improvement shear strength	56
4.8	Correlations and R ² value	65

LIST OF FIGURES

Figure No.	Title	Page
2.1	Graphical representation of grain size curve (Abdul Hameed, 2012)	15
2.2	Bottom ash applications as a percentage of total reused (American Coal Ash Association, 2006)	20
2.3	Geotextile fabric	21
2.4	Stone column installation (Menard Group USA, 2015)	23
2.5	Sketch of enlarged consolidation cell (Gniel and Bouazza, 2009)	24
2.6	Photograph of enlarged consolidation cells in operation (Gniel and Bouazza, 2009)	25
3.1	Flowchart of Project Methodology	27
3.2	Detail Column Arrangement	37
3.3	Installation of bottom ash column	38
3.4	Sample testing using Unconfined Compression Test (UCT) machine	39
4.1	Graph of penetration versus moisture content	44
4.2	Plasticity Chart (ASTM D2487)	45
4.3	Particle size distribution of kaolin	48
4.4	Particle size distribution of bottom ash	48
4.5	Graph of compaction of kaolin	49
4.6	Graph of compaction of bottom ash	50
4.7	Graph of shear stress versus normal stress	52
4.8	Deviator stress versus axial strain at failure of bottom ash column at different penetration ratio	54
4.9	Shear strength versus height of penetration ratio	57
4.10	Improvement shear strength versus height of penetration ratio	58

4.11	Graph correlation of shear strength versus height of penetration ratio	59
4.12	Graph correlation of improvement shear strength versus height of penetration ratio	59
4.13	Shear strength versus height over diameter of column	60
4.14	Improvement shear strength versus height over diameter of column	61
4.15	Graph correlation of shear strength versus height over diameter of column	62
4.16	Graph correlation of improvement shear strength versus height over diameter of column	62
4.17	Shear strength versus volume penetration ratio	63
4.18	Improvement shear strength versus volume penetration ratio	63
4.19	Graph correlation of shear strength versus volume penetration ratio	64
4.20	Graph correlation of improvement shear strength versus volume penetration ratio	65

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
D_r	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 kebolehampatan 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 a 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 coarse, porous, glassy, granular, greyish and incombustible materials that are collected from the bottom of furnaces that burned coal. 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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