STRENGTH OF SOFT CLAY REINFORCED WITH ENCAPSULATED BOTTOM ASH COLUMNS

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Penggunaan bahan semulajadi dan pengeluaran barang tersisa yang tidak terkawal telah memberi kesan yang teruk kepada bumi. Penggunaan abu bawah (bahan tersisa) yang tidak terkawal akan menyebabkan pencemaran kepada alam sekitar. Tiang berbutir menegak adalah satu teknik dimana mempunyai sifat-sifat penambahbaikan daya dukung, mengurangkan mendapan dan mempercepatkan pelesapan lebihan tekanan air liang dalam tanah lembut yang lemah. Kajian ini bertujuan untuk menyelidik tentang peranan tiang abu bawah dalam penambahbaikan kebolehmampatan dan kekuatan ricih tanah liat lembut kaolin dengan menggunakan model skala makmal. Ciri-ciri kekuatan ricih boleh didapati melalui nisbah penggantian kawasan, nisbah tinggi penembusan dan nisbah penggantian isipadu bagi tiang abu bawah. Sampel kaolin bertetulang telah diuji dengan menggunakan Ujikaji Mampatan Tak Terkurung (UCT) dan Tidak Disatukan Tak tersalir ujian-ujian tiga paksi (UU). Specimen yang digunakan adalah berukuran 50 mm diameter dan dengan ketinggian 100 mm. Menggunakan tiang abu bawah yang bertetulang dengan nisbah tinggi penembusan 0.6, 0.8 dan 1.0 dengan tiang yang berukuran 10 mm diameter dan 16 mm diameter, sampel tanpa tiang abu bawah adalah sampel yang dikawal. Peningkatan paling tinggi kekuatan ricih tiang abu bawah pada nisbah penggantian kawasan 4.00% dengan 10 mm diameter tiang adalah pada 0.8 dimana nisbah tinggi penembusan ialah 77.00%. Bagi nisbah penggantian kawasan 10.24% dengan 16 mm diameter tiang) adalah tertinggi pada 0.8 dengan nisbah tinggi penembusan ialah 71.48%. Sementara itu, peningkatan paling tinggi kekuatan ricih tiang abu bawah bagi nisbah penggantian kawasan 12.00% dengan 10 mm diameter tiang adalah 0.8 dengan nisbah tinggi penembusan ialah 75.63%, dan bagi nisbah penggantian kawasan 30.72% dengan 16 mm diameter tiang ialah juga pada 0.8 dengan nisbah tinggi penembusan ialah 56.41%. Peningkatan kekuatan ricih tiang abu bawah yang paling maksimum ialah pada 0.8 nisbah tinggi penembusan. Ujian Tidak Disatukan Tak tersalir (UU) menunjukkan peningkatan yang ketara di kejelekitan, c dengan 4.31% kepada 89.21% dan peningkatan bagi geseran, ϕ ialah dari 4.17% kepada 27.92%. Peningkatan tekanan deviasi berbanding dengan terikan paksi pada kegagalan bagi 70 kPa, 140 kPa dan 280 kPa tekanan sel telah direkodkan diantara 12.55% kepada 51.80%. Kesimpulannya, tiang abu bawah boleh meningkatkan kekuatan ricih dan kemampatan tanah liat lembut kaolin.

ABSTRACT

The uncontrollable usage of non-renewable natural resources and production of waste gives severe impact on the earth. The uncontrollable usage of bottom ash (waste material) can cause pollution to the environment. The vertical granular columns has the properties to improve the bearing capacity, reduce the settlement, and accelerate the dissipation of excess pore water pressure of the weak soil. The aim of this research is to investigate the role of single and group encapsulated bottom ash columns in improving the shear strength of the soft reconstituted kaolin clay by using the laboratory scale model. The shear strength characteristic can be obtained by determining the effect of area replacement ratio, height penetration ratio, and volume replacement ratio on single and group of encapsulated bottom ash columns. The reinforced kaolin samples were tested under Unconfined Compression Test (UCT) and Unconsolidated Undrained Triaxial Test (UU). The specimen used were 50 mm in diameter and 100 mm in height. Using the encapsulated bottom ash column reinforcement of 0.6, 0.8, and 1.0 height penetrating ratio with 10 and 16 mm diameters columns while the specimen without any reinforcement was referred as the controlled samples. The highest improvement of shear strength of the single encapsulated bottom ash column on area replacement ratio of 4.00 % at 10 mm diameter columns is at 0.8 height penetration ratio with 77.00% while for area replacement ratio of 10.24% at 16 mm diameter columns is also at 0.8 height penetration ratio with 71.48%. Meanwhile, the highest improvement of shear strength of the group encapsulated bottom ash column on area replacement ratio of 12.00 % at 10 mm diameter columns is at 0.8 height penetration ratio with 75.63% while for area replacement ratio of 30.72% at 16 mm diameter columns is also at 0.8 height penetration ratio with 56.41%. The maximum improvement of shear strength was at 0.8 height penetrating ratio for both single and group encapsulated bottom ash columns. UU testing showed the significant improvement on cohesion which was recorded to be from 4.31% to 89.21%, and the improvement of friction angle, φ was from 4.17% to 27.92%. The improvement of deviator stress versus axial strain at failure of 70 kPa, 140 kPa, and 280 kPa for cell pressure were recorded to be at between 12.55%–51.80%. In conclusion, the installation of single and group encapsulated bottom ash columns can improve the shear strength and the compressibility of the soft reconstituted kaolin clay.

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LIST OF SYMBOLS

A_c	Area of bottom ash column
A_s	Area of kaolin clay sample
α	Alpha
β	Beta
c	Cohesion
cm	Centimetre
C_c	Compression index
C_v	Coefficient of consolidation
C_u	Undrained cohesion
D_c	Diameter of bottom ash column
D_r	Relative density
G_s	Specific gravity
GWh	Gigawatt hour
H_c	Height of bottom ash column
H_s	Height of kaolin clay sample
k	Permeability
g/m^3	Gram per cubic metre
kg	Kilogram
kN	Kilo Newton
kN/m^2	Kilo Newton per square metre
kN/m^3	Kilo Newton per cubic metre
kPa	Kilo Pascal
L	Length of the column
D	Diameter of the column
d	Particle of size granular material
Mg	Mega Gram
MN	Mega Newton
MW	Mega Watt
m^2	Square metre
t_f	Time to failure
MPa	Megapascal
m/s	Metre per second
mm	Milimetre
μm	Micrometre
e	Void ratio
s	Shear strength

S_u	Undrained shear strength
v	Specific volume
V_c	Volume of bottom ash column
V_s	Volume of kaolin clay sample
w	Moisture content
w_{opt}	Optimum moisture content
ρ_d	Dry density
$\rho_{d(max)}$	Maximum dry density
γ	Gamma
γ	Unit weight
γ_{min}	Minimum unit weight
γ_{max}	Maximum unit weight
ϕ	Friction angle
ϕ'	Effective friction angle
ϕ^{o}	Angle of internal friction
%	Percent
^{o}	Degree
℃	Degree celcius
σ	Total normal stress
σ'	Effective normal stress
σ_{ef}	Effective stress
w_L	Liquid limit
w_P	Plastic limit
I_p	Plasticity index
q	Deviator stress

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACAA	American Coal Ash Association
ASTM	American Society for Testing and Material
BA	Bottom Ash
BS	British Standard
CCP	Coal Combustion Product
CD	Consolidated Drained
CU	Consolidated Undrained
CL	Clay Low plasticity
LL	Liquid Limit
ML	Silt Low plasticity
MH	Silt High plasticity
CH	Clay High plasticity
GDS	Geotechnical Digital System
GT	Gas Turbine
OH	Organic High plasticity
PI	Plasticity Index
PL	Plastic Limit
Pt	Peat
SEM	Scanning Electron Microscope
SL	Shrinkage Limit
ST	Steam Turbine
UCT	Unconfined Compression Test
US	United States
USCS	Unified Soil Classification System
UU	Unconsolidated Undrained

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