

**THE UNDRAINED SHEAR STRENGTH OF SOFT CLAY REINFORCED
WITH
SINGLE CERAMIC WASTE COLUMN**

MOHAMAD LAZIEM JAMEEL BIN MOHD SOFE

Faculty of Civil Engineering and Earth Resources

UNIVERSITY MALAYSIA PAHANG

Dedicated to my parents and my family



SUPERVISOR'S DECLARATION

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 in Bachelor of Civil Engineering.

(Supervisor's Signature)

Full Name :DR. MUZAMIR BIN HASAN

Position : SENIOR LECTURER

Date : 16. JUNE .2017

STUDENT'S DECLARATION

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 Universitiy Malaysia Pahang or any other institutions.

(Student's Signature)

Full Name : MOHAMAD LAZIEM JAMEEL BIN MOHD SOFE

ID Number : AA13165

Date : 16. JUNE. 2017

THE UNDRAINED SHEAR STRENGTH OF SOFT CLAY REINFORCED WITH
SINGLE CERAMIC WASTE COLUMN

MOHAMAD LAZIEM JAMEEL BIN MOHD SOFE

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

JUNE 2017

ACKNOWLEDGEMENTS

Alhamdulillah, all praises to Allah S.W.T., The Greatest and The Most Merciful for His guidance and blessing, because without it I cannot finished this research. I also wish to express my gratitude to my thesis's supervisor, Dr Muzamir Bin Hasan enthusiastic guidance, invaluable help, encouragement and patience for all aspect from this thesis progress. His numerous comments, criticisms and suggestion during the preparation of this project are gratefully praised. Mostly for his patience on any problem that occurred during the thesis is invaluable and appreciated.

I would like to thanks to all technicians that help me a lot in conducting the laboratory test in giving guidelines for laboratory work. Without them, it would be impossible for me to start and finished the thesis.

I also would like to thank to all my friends that gives supports and helping me for finishing the thesis. Their support and help always give motivation and energy for me to finish the thesis. Heartfelt acknowledgement is expressed to my family especially my parents. Without them guidance, support, encouragement and advises, I may never have overcome this long journey in my studies. When I felt down, their love will always give me strength to face all the problem and complication happened. I also would like to thank to people that direct or indirectly help me in finishing the thesis. Thank you very much.

TABLE OF CONTENT

DECLARATION	
TITLE PAGE	
ACKNOWLEDGEMENTS	ii
ABSTRAK	iv
ABSTRACT	v
TABLE OF CONTENT	vi
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF SYMBOLS	xv
LIST OF ABBREVIATIONS	xvii
CHAPTER 1 INTRODUCTION	1
1.1 BACKGROUND OF STUDY	1
1.2 PROBLEM STATEMENT	3
1.3 OBJECTIVE OF STUDY	4
1.4 SCOPE OF STUDY	4
1.5 SIGNIFICANCE OF STUDY	6
CHAPTER 2 LITERATURE REVIEW	7
2.1 SOFT CLAY	7
2.1.2 Undrained Shear Strength	9
2.2 CERAMIC WASTE	14
2.2.2 Chemical Properties of Ceramic waste	15

2.2.3	Particle Size Distribution	17
2.2.4	Permeability	19
2.2.5	Compressibility	19
2.2.6	Compaction	20
2.2.7	Stress Strain Behaviour	20
2.3	VERTICAL GRANULAR COLUMN	22
2.4	SMALL SCALE MODELLING	23
CHAPTER 3 METHODOLOGY		25
3.1	INTRODUCTION	25
3.2	SELECTION OF MATERIALS	27
3.3	SAMPLE COLLECTION	27
3.4	LABORATORY WORKS	28
3.5	DETERMINATION OF PHYSICAL AND MECHANICAL PROPERTIES OF MATERIALS	28
3.6	DETERMINATION OF PHYSICAL PROPERTIES OF SOFT CLAY	30
3.6.1	Hydrometer Test	30
3.6.2	Standard Compaction Test	31
3.6.3	Falling Head Permeability Test	31
3.6.4	Specific Gravity Test	32
3.6.5	Atterberg Limit Test	33
3.7	DETERMINATION OF PHYSICAL PROPERTIES OF CERAMIC WASTE	34
3.7.1	Dry Sieve Test	34
3.7.2	Specific Gravity Test	34
3.7.3	Standard Compaction Test	35
3.7.4	Constant Head Permeability Test	35

3.7.5	Direct Shear Test	36
3.7.6	Relative Density Test	36
3.7.7	One Dimensional Consolidation	37
3.8	REINFORCING KAOLIN WITH SINGLE BOTTOM ASH COLUMN	38
3.8.1	Kaolin Clay Sample	38
3.8.2	Ceramic Waste Column	41
3.8.3	Installation of Ceramic Waste Column	42
	CHAPTER 4 RESULTS AND DISCUSSION	44
4.1	INTRODUCTION	44
4.2	SUMMARY OF KAOLIN S300 AND CERAMIC WASTE	45
4.3	PHYSICAL PROPERTIES	47
4.3.1	Atterberg Limit Test	47
4.3.2	Specific Gravity	49
4.3.3	Particle Size Distribution	50
4.4	MECHANICAL PROPERTIES	52
4.4.1	Standard Proctor Compaction Test	52
4.4.2	Permeability	54
4.4.3	One Dimensional Consolidation	55
4.5	UNCONFINED COMPRESSION TEST	56
4.5.1	Stress-Strain Behaviour	56
4.5.2	The Effect of Column Penetration Ratio	61
4.5.3	The Effect of Height Over Diameter of Column	64
4.5.4	The Effect of Volume Penetration Ratio	67
	CHAPTER 5	70

5.1	INTRODUCTION	70
5.2	CONCLUSION	70
	REFERENCES	73
	APPENDIX B SAMPLE APPENDIX 2	Error! Bookmark not defined.

LIST OF TABLE

Table 2.1: Physical Properties of Soil Sample.....	9
Table 2.2: Undrained strength classification of clay.....	10
Table 2.3: Effect of area replacement ratio on undrained shear strength.....	11
Table 2.4: Classification by particle size.....	17
Table 2.5: Classification of soil according to permeability value.....	19
Table 3.1: Test standard and methods of laboratory testing for materials.....	29
Table 3.2: Density of various dimensions of bottom ash columns installed in kaolin Specimens.....	43
Table 4.1: Summary for properties of Kaolin Clay.....	45
Table 4.2: Summary of properties of ceramic waste.....	46
Table 4.3: Comparison of ceramic waste with bottom ash specific gravity values.....	49
Table 4.4: Comparison of ceramic waste with bottom ash Permeability test.....	54
Table 4.5: Maximum deviator stress and axial strain values at different height penetration ratio.....	57
Table 4.6: Results of Unconfined Compression Test (UCT).....	59
Table 4.7: Improvement shear strength.....	60
Table 4.8: Correlations and R ² value.....	69

LIST OF FIGURES

Figure no.	Title	Page
2.1	Column arrangement	12
2.2	Deviator stress at failure for various column penetration ratio	13
2.3	Effect of ratio of column height to diameter	13
2.4	Classification of ceramic wastes by type and production process	14
2.5	Pozzolanic properties	15
2.6	The influence mineral in clay	16
2.7	Ceramic sample based on waste sludge	16
2.8	The influence of various oxidation reduction condition	16
2.9	Particles size distribution	18
2.10	Particles size of ceramic waste	18
2.11	Stress-strain response under uniform undrained loading for singular column	21
2.12	Installation Vertical Column	22
2.13	Photograph of sample of small scale modelling	23
2.14	Photograph of enlarged consolidation cells in operation	24
3.1	Flowchart of Project Methodology	26

3.2	Guocera Tiles Sdn. Bhd	28
3.3	Kaolin (M) Sdn. Bhd.	28
3.4	Hydrometer test	30
3.5	Standard Compaction Procedure	31
3.6	Specific Gravity equipment	32
3.7	Atterberg liquid limit equipment	33
3.8	Constant Head Permeability test	35
3.9	One Dimensional Consolidation test	37
3.10	Position of clay samples	38
3.11	Apparatus for the preparation of soft homogenous kaolin specimens	39
3.12	Kaolin mixed with water poured into the mould	39
3.13	Customized mould set for 50 mm diameter and 100 mm height specimen	39
3.14	Hole was drilled using 10 mm and 16 mm diameter drill bit	40
3.15	Detail column arrangement for 10mm	41
3.16	Detail column arrangement for 13mm	41
3.17	Hole was drilled using 10 mm and 16 mm diameter drill bits	42
4.1	Graph of penetration versus moisture content	47

4.2	Plasticity Chart (ASTM D2487)	48
4.3	AASHTO soil classification table (ASTM D3282)	50
4.4	Particle size distribution of kaolin	51
4.5	Particle size distribution of ceramic waste	51
4.6	Graph of compaction of kaolin	52
4.7	Graph of void ratio versus applied pressure	55
4.8	Deviator stress versus axial strain at failure of ceramic waste column at different penetration ratio	57
4.9	Height of penetration ratio versus Shear Strength	58
4.10	Shear strength versus height of penetration ratio	61
4.11	Improvement shear strength versus height of penetration ratio	62
4.12	Graph correlation of shear strength versus height of penetration ratio	63
4.13	Graph correlation of improvement shear strength versus height of penetration ratio	63
4.14	Shear strength versus height over diameter of column	64
4.15	Improvement shear strength versus height over diameter of column	65
4.16	Graph correlation of shear strength versus height over diameter of column	66
4.17	Graph correlation of improvement shear strength versus height over diameter of column	66

4.18	Shear strength versus volume penetration ratio	67
4.19	Improvement shear strength versus volume penetration ratio	67
4.20	Graph correlation of shear strength versus volume penetration ratio	68
4.21	Graph correlation of improvement shear strength versus volume penetration ratio	69

LIST OF SYMBOLS

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

CWC	Ceramic Waste Column
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
UU	Unconsolidated Undrained Test