EVALUATION OF COEFFICIENT OF CONSOLIDATION AND COMPRESSION INDEX OF KUANTAN CLAYEY SOIL STABILISED BY RECYCLED AND REUSED MATERIALS MIXED WITH PORTLAND CEMENT

CHUA PENG YANG

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Faculty of Civil Engineering and Earth Resources
UNIVERSITI MALAYSIA PAHANG

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ABSTRACT

This thesis presents the evaluation for the coefficient of consolidation and compression index of Kuantan soils using variable reused and recycled materials mixed with Portland cement. The objective of this thesis is to evaluate the change of compression index, void ratio, and coefficient of consolidation of Kuantan Clayey stabilized by recycle and reuse material mixed with Portland cement by using one-dimensional consolidation test and study the engineering properties of clay soil before and after undergoing one-dimensional consolidation test. This thesis describes the one-dimensional consolidation tests done to compute the changes of compressibility and justify the suitable amount of additives used. Crushed glass, shredded carpet fibres, fly ash, and shredded high density polyethylene plastic which are classified as recyle and reused materials were added into Kuantan clay soil and then mixed with Portland cement to study and evaluate the Kuantan clay in term of compressibility. In this thesis, the values of coefficient of consolidation and compression index soils were done using a One-dimensional consolidation test. The analysis of the test was performed semi-automatically using One-dimensional consolidation program from ELE International. After analysis by the system, the coefficient of consolidation and compression index of the samples obtained were employed as parameter to find the compressibility of Kuantan clay soil. From the results conducted, analysis of using fly ash blend is more conservative reading in coefficient of consolidation indicated better rate of consolidation. Still, soil sample added with crushed glass mixed with Portland cement performed better decrement in compression index indicated better performance in compressibility. The achieved results utilizing high density polyethylene and carpet fibres gave low performance in compressibility compared to crushed glass and fly ash. In conclusion, after comparing all the recycled and reused materials, crushed glass mixed with Portland cement is the most capable treatments to improve engineering properties of Kuantan clay. The results can also considerably reduce the cost of construction and materials to improve soils stability in Kuantan, Pahang.

ABSTRAK

Tesis ini membentangkan penilaian untuk pekali pengukuhan dan indeks mampatan tanah Kuantan menggunakan bahan-bahan yang boleh diguna dan dikitar semula dicampur dengan simen. Objektif projek ini adalah untuk menilai penukaran nilai pekali pengukuhan, nisbah lompang, dan indeks mampatan untuk tanah Kuantan distabilkan oleh bahan-bahan pengitar dan pengguna semula dicampuri dengan simen Portland dengan mengunakan ujian oedometer dan mengaji properti kejuruteraan sebelum dan selepas melaksanakan ujian konsolidasi satu dimensi. Thesis ini membincangkan ujian konsolidasi satu dimensi dan menghitung perubahan mampatan dan mengenalpasti jumlah kesesuaian bahan-bahan yang dicampuri dalam specimen tanah Kuantan. Kaca hancur, serat permaidani, abu terbang, dan bahan plastik polietilenayang diklasifikasikan sebagi bahan dikitar semula dan duguna semula telah ditambahkan ke dalam tanah liat Kuantan dan dicampuri dengan simen Portland untuk mengkaji kemampatan tanah tersebut. Dalam thesis ini, nilai-nilai pekali pengukuhan dan indeks mampatan tanah Kuantan telah dilakukan dikaji melalui ujian konsolidasi satu dimensi. Ujian ini telah dianalisasi melalui program ujian semi-automatik konsolidasi yang dikembangkan oleh ELE international. Selepas dianalisasi oleh system tersebut, nilai-nilai pekali pengukuhan dan indeks mampatan akan digunakan sebagai pembolehubah untuk mencari kemampatan tanah liat Kuantan. Daripada keputusan yang diperolehi, dengan menggunakan abu terbang menghasilkan keputusan yang lebih konservatif dalam pekali pengukuhan yang menunjukkan kadar pengukuhan tanah yang cepat. Selain itu, tanah sample kaca hancur yang ditambah dengan simen Portland memberi keputusan penurunan dalam indeks mampatan yang menunjukkan nilai kemampatan yang memuaskan. Walaubagaimanapun, keputusan yang diperolehi daripada kegunaan polietilena dan serat permaidani menunjukkan ciri mampatan yang tidak memuaskan dibandingkan dengan keputusan yang diperolehi menggunakan kaca hancur dan abu terbang. Secara kesimpulan, selepas membandingkan kesemua bahan-bahan mengitar semual dan mengguna semula, kaca hancur yang ditambah dengan simen Portland telah menunjukana bahawa ia adalah sesuai dijadikan rawatan yang menjanjikan dalam peningkatan properti kejuruteraan tanah liat Kuantan. Keputusan yang ketara juga boleh dipertimbangkan dalam pengurangan kos pembangunan dan bahan-bahan mentah dalam peningkatan kestabilan tanah di Kuantan, Pahang.

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LIST OF SYMBOLS

V	Volume
G_s	Specific Gravity
C_c	Compression Index
C_v	Coefficient of Consolidation
e_o	Initial Void Ratio
e	Void Ratio
LL	Liquid Limit
PI	Plasticity Index
PL	Plastic Limit
S_T	Total Settlement
S_C	Primary Consolidation Settlement
S_S	Secondary Consolidation Settlement
S_e	Elastic Settlement
W_s	Dry Weight of the Specimen
M_s	Dry Mass of the Specimen
Γ_w	Unit Weight of Water
Σ'	Effective Stress
P_w	Density of Water
H_v	Height of Void
H_s	Height of Soil

LIST OF ABBREVIATIONS

CaO	Calsium Oxide
SiO_2	Silicon Dioxide
Al_2O_3	Aluminium Oxide
Fe_2O_3	Iron (iii) Oxide
Si	Silicon
Fe	Iron
Mg	Magnesium
K	Potassium
Mn	Manganese
SPI	Society of Plastic Industry
AASTHO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
USDS	United States Department of Agriculture
USCS	Unconfined Soil Classification System
CF	Carpet Fibre
CG	Crushed Glass
FA	Fly Ash
HDPE	High Density Polyethylene
S2	Kuantan Clay located at Lepar Hilir
S24	Kuantan Clay located at Panching
1-D	One-Dimensional

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Kuantan Clay is one type of clayey soil situated in Kuantan, Pahang, Malaysia. Clay soil can be classified as a problematic soil. The low strength and high compressibility characteristic of the soil made the clayey soil is not favors in any kind of construction. The purpose of this research is to investigate the behavior of compression index, C_c and coefficient of consolidation, C_v when Kuantan Clay are mixed with additive such as fly ash, HDPE, crushed glass, and carpet fiber. Besides, this research needs to investigate engineering properties of Kuantan Clay when mixed additive mention above with Portland cement. The additives are made from reuse and recycle materials and used to stabilize Kuantan Clay and improve the engineering properties of Kuantan Clay for construction purpose. Consolidation is a process in which reduction in volume, V takes place by expulsion of water under long term of static loads. Compression index, C_c is an index developed by Terzaghi based on a test resulted from One-Dimensional Oedometer test (Terzaghi, 2006). The compression index can be used to predict the amount of consolidation of the soil. By obtaining the void ratio, e_o and effective pressure, σ', a graph of void ratio from oedometer test, e_o versus effective pressure, σ' can be plotted. The graph can be use to predict the compression index C_c in the Compressibility and settlement of clayey soil may alter by adding reuses and recycles materials. Furthermore, the coefficient of consolidation, C_v can be achieved by using square root time versus settlement method after the soil sample undergo consolidation test and used to determined the rate of consolidation of the soil.

1.2 PROBLEM STATEMENT

The rapid growth of construction development has lead to the insufficient of quality land for construction. This is the reason why the research on the clayey soil is more than necessary. The development in construction industry has minimized the preferred site of geotechnical quality for construction in Kuantan, Pahang. There are more development of infrastructure activity is now carried out in clayey soil and the construction sites have forced to carry out in compressible soils, especially for industrial structure and transportation project. Any development in construction industry will be affected by the occurrence of clayey soil.

High compressibility clayey soil has proved that it is increasing the difficulties in construction (Brandy & Weil, 1999). The construction taking places in clayed soil have increasingly lately. These have brought a lot of problematic issue toward the construction due to the low strength and high compressibility of the clayed soil. The not stable condition and settlement of clayey soil has become the major challenge toward the constructor. It is crucial for understanding the engineering properties of a clayey soil toward a structure built on it. In major clayey soil region, construction designs have to carry out carefully to avoid any failure of the structure due to clayey soil high compressibility and low shear strength condition. Foundation settlements are the most emergences problem happen in building construction. Many failure of construction structures throughout the world are due to the massive settlements of foundation. Therefore, it is important for us to understand, comprehend, and interpret problem related to this type of week soil. Consolidation of soils is an important engineering consideration.

The high compressibility clayey soil is one of the major problems which can lead to major settlement of foundation (Brandy & Weil, 1999). Water also could be the main agent that makes the soil become unstable especially with the high ability of the clayey soil to absorb water within its particles and difficult to release the water trap inside the particles due to low permeability of soil (Robert, 2009). The soils particles have high tendency to bond closely with one another make clayey soil become easily to be compress. Besides that, the stiffness of soil could easily be affected and this make the

soil become week in strength. Soil with weak strength, it cannot sustain high load on it and make the structure built on it become dangerous and more subjected to fail. Therefore, it is fundamental for the engineer to study this type of clayey soil and stabilize the clayey soil by using reuse and recycle materials.

Furthermore, increasing population and tremendous urbanization growth have increase the municipal wastes generate in Malaysia. The huge quantity of municipal solid waste, particular in Peninsular Malaysia, has increase from 16,200 tonnes a day in 2001 to 19,100 tonnes a day in 2005 on an average of 0.8kg/capital/day. Therefore the increasing of municipal solid waste has brought a lot of problems to the citizen and government of Malaysia. On the other hand, increment of solid waste will lead to pollution to the country. Therefore, in this research have been recommending to use recycle and reuse materials as the stabilizers (Zamali et al., 2009, p.2).

1.3 OBJECTIVE OF STUDY

The objectives of this study are as follows:

i. To evaluate the change of compression index and void ratio of Kuantan Clayey stabilized by recycle and reuse material mixed with Portland cement by using one-dimensional consolidation test.

ii. To evaluate the coefficient of consolidation of Kuantan Clayey stabilized by recycled and reused material mixed with Portland cement undergo one-dimensional consolidation test.

iii. To study the engineering properties of Kuantan Clay before and after stabilized by recycle and reused materials mixed with Portland cement.

iv. To determine the best proportion of recycled and reused material mixed with Portland cement in stabilizing Kuantan clay.

1.4 SCOPE OF STUDY

Portland cement is the major material to be used in this research to give effect on the clayey soil since Portland cement is significantly used in stabilization of soil in construction buildings or structure. The scope of study will cover the investigation of compression index of stabilized Kuantan clayey mixed with Portland cement. The objective of the study is to stabilize Kuantan clayey in order to allow construction of buildings on the clayey soil. This research will emphasize on compression index The lab testing will be conducted in compression index evaluation is One-Dimensional Consolidation Test. Soil preparation is done by drying the sample and breaking off lumps of hardened clay into finer particles and then sieving the dried sample with a 5mm sieve. Samples are then stabilized with some types of recycle and reuse material with mix of Portland cement and One-D consolidation test will be carried out to evaluate the compression index of clay.

The area of study for this study includes:

i. Investigate the needs of reuse and recycle to stabilize clayey soil.

ii. Compare the compressibility by referring to the compression index, C_c void ration, e_o, and coefficient of consolidation, C_v of soil after stabilization.

iii. Recommended the most economic and effective method to stabilized Kuantan soft clay.

1.5 BACKGROUND OF STUDY

The rapid growth of construction development has lead to the insufficient of quality soil for construction. Any development in construction industry will be affected by the occurrence of clayey soil. This is the reason why the research on the clayey soil is more than necessary. In this research, two areas within the Kuantan area have been chosen to be the investigation area for clayey soil. The soil sample will be tested in laboratory for further studies. The development in construction industry has minimized

the preferred site of geotechnical quality for construction in Kuantan, Pahang. There are more development of infrastructure activity is now carried out in clayey soil and the construction sites have forced to carry out in compressible soils, especially for industrial structure and transportation project. Therefore it is important for us to understand, comprehend, and interpret problem related to this type of week soil. Consolidation of soils is an important engineering consideration. Consolidation of soil is a process which involves decrease in water content of a saturated soil without replacement of water by air. Consolidation also known as a process in which reduction in volume takes place by expulsion of water under long term static loads. Consolidation of soil can be determined by many methods.

Compression index is one of the useful methods in determining the amount of settlement under additional loading through Oedometer test developed by Terzaghi from consolidation of soil. The oedometer test used to determine the compressibility of soil which is described using compression index, C_c, which is the slope of pressure-void ratio curve on a semi-log plot. Oedometer tests are performed by applying different loads to a soil sample and measuring the deformation response. The results from these tests are used to predict how a soil in the field will deform in response to a change in effective stress It is very important for a geotechnical research to know the compressibility of soil through this test. The compression index is used to predict the settlement of soil under additional load. Recycle and reused materials have been proposed acting as an additive to Kuantan Clay to improve the engineering properties of the Kuantan Clay.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Inadequate strength or inadequate compressibility resistance is a problem of soil in many form of construction such as buildings, airfields, tunnels, dams, roads, and trafficked area. A number of stabilization methods are being used to improve soil properties since ancient time. In present study, effect of various available stabilizing agent like Ordinary Portland cement, crushed glass, fly ash, and carpet fibre have been studies for strength improvement and stabilization of soil. Therefore it is important for us to study sources form journals, articles, books, and internet for literature review regarding our topic research.

2.2 CLAY SOIL

The term "clay" refers to a naturally occurring material composed primarily of fine-grained minerals, which is generally plastic at appropriate water contents and will harden with dried or fired. Although clay usually contains phyllosilicates, it may contain other materials that impart plasticity and harden when dried or fired. Associated phases in clay may include materials that do not impart plasticity and organic matter (Guggenheim, 1995). Clay soil has small air voids. Water retention is high creating poor drainage system. Clayey soil impedes the flow of water, meaning it absorbs water slowly and then retains it for a long time. Clay, referring to United Soil Classification System, is fine-grained soils with more than 50% by weight passing No.200 US standard sieve (0.075mm). Soft clay is defined as clay has shear strength below 25kPa (Brand & Brenner, 1981).

2.3 PORTLAND CEMENT

Cement is an adhesive substance that acts as a binder to bind particles or solid matter together into a compact whole (Hewlett, 1998, p.1). Portland cement is produced by mixing limestone and clay or other material that have similarity in term of bulk composition and sufficient reactivity by heating it to the temperature of 1450°C (Neville & Brooks, 1987, p.8).

A paste of Portland cement develops strength primarily by hydration of the di- and tri- calcium silicates it contains (Bye, 1999, p 2). Nevertheless, table 2.1 have summarised the chemical composition of Portland cement.

Table 2.1: Chemical composition of Portland cement

Mineral	Chemical Formula	Oxide Composition	Abbreviation
Tricalcium silicate (alite)	Ca_3SiO_5	$3CaO.SiO_2$	C3S
Dicalcium silicate (belite)	Ca_2SiO_4	$2CaO.SiO_2$	C2S
Tricalcium aluminate	$Ca_3Al_2O_4$	$3CaO.Al_2O_3$	C3A
Tetracalcium aluminoferrite	$Ca_4Al_nFe_{2-n}O_7$	$4CaO.Al_nFe_{2-n}O_3$	C4AF

Source: Taylor (1997)

Abbreviation notation: C = CaO, S = SiO_2, A = Al_2O_3, F = Fe_2O_3.

2.4 FLY ASH

Fly ash is the solid material carried away from the power plant boiler in the flue gas during coal combustion. Most fly ash particles are in the silt-sized range of 2-50 microns. The three major mineralogical matrices identified in fly ash are glass, mullite-quartz, and magnetic spinel. The major elemental constituents of fly ash are Si, Al, Fe, Ca, C, Mg, K, Na, S, Ti, P, and Mn. (El-mogazi et al., 1988).

2.5 CRUSHED GLASS

Glass is a significant solid waste produce by the daily activities in the society. Mostly glass is use as bottle, container for storing consumables or window. Glass is one of the unique wastes if compared to the others wastes because it can be fully recycle (Traeholt & Ling, 2010). Recycled glass particles are generally angular shaped and contain some flat and elongated particles (Disfani et al., 2011).

2.6 HIGH-DENSITY POLYETHYLENE (HDPE)

High-density polyethylene (HDPE) is a polyethylene thermoplastic made from petroleum. It is best known for its large strength to density ratio. The production of HDPE is plastic bottles, corrosion-resistant piping, and plastic lumber. HDPE is commonly recycled and has a SPI resin ID code of 2 for its recycling symbol. The mass-density can range from 0.93 to 0.97 g/cm^3. HDPE can be produce by chromium/silica catalysts, Ziegler-Natha catalysts, and chromium catalysts (Society of Plastic Industry, n.d).

2.7 SOIL CLASSIFICATION

Classification of clay soil can be done by first determine geotechnical characteristic of soil as discussed by Brand & Brenner (1981) are:

i. Moisture Content
ii. Liquid Limit
iii. Plastic Limit
iv. Plasticity Index
v. Shear Strength
vi. Pre- consolidation pressure with depth
vii. Characteristic of void ratio versus vertical stress

There are three common soil classification system are designed to allow an easy transition from field observations to basic predictions of soil engineering properties and

behaviours which are ASSHTO, USCS, and USDS classification. The AASHTO Soil Classification System was developed by the American Association of State Highway and Transportation Officials, and is used as a guide for the classification of soils and soil-aggregate mixtures for highway construction purposes. The soil classification system was first developed by Hogentogler and Terzaghi in 1929.

The Unified Soil Classification System (USCS) is a soil classification system used in geotechnical field to illustrate the texture and grain size of soil. The USCS has three major classification groups listed as follow:

i. coarse-grained soils (sands and gravels)
ii. fine-grained soils (silts and clays)
iii. highly organic soils (referred as peat)

Another approach is UDCS Soil Classification System. USDA Soil Taxonomy developed by United States Department of Agriculture and the National Cooperative Soil Survey provides classification system for soil type according to several parameters and in several levels such as order, suborder, great group, subgroup, and family (Evett et al., 2007).

Table 2.2: Soil type based on particle sizes

Soil Type	**Particle Sizes (mm)**		
	British Standard (BS 5930:1999)	**ASTM (D2487)**	**USCS**
Boulders	>200	>300	>300
Cobbles	60-200	75-300	75-300
Gravel	2-60	4.75-75	4.75-75
Sand	0.063-2	0.075-4.75	0.075-4.75
Silt	0.002-0.063	0.005-0.075	0.005-0.075
Clay	<0.002	<0.005	<0.005

2.7.1 Water Content

The water content measurement in clayey soil in this research will be using gravimetric water content (GWC) measurement method. Water content, w is measure from the ratio of mass of water to mass of dry soil for gravimetric water content (Campbell, n.d.). The technique uses for gravimetric water content are as follows:

i. Sample the clayey soil for measure
ii. Weight on precision balance (wet weight)
iii. Dry at 105°C for 24 hours
iv. Weight on precision balance (dry weight)

$$\text{Moisture content (\%)} = \frac{\text{Mass of Water}}{\text{Mass of oven-dried soil}} \text{x } 100 \qquad (2.1)$$

2.7.2 Plastic Limit

The plastic limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dry soil, at the boundary between the plastic and semisolid states of consistency. It is the moisture content at which a soil will just begin to crumble when rolled into a thread ⅛ in. (3 mm) in diameter using a ground glass plate or other acceptable surface (Geotechnical Engineering Bureau, 2007).

2.7.3 Liquid Limit

The liquid limit (LL) is the water content at which a soil changes from plastic to liquid behaviour. The liquid limit of soil is the water content corresponding to the arbitrary limit between liquid and plastic state of consistency of a soil. It is define as the minimum water content at which the soil still in liquid state but have a small shearing strength to resist the flow of the soil.

Liquid limit could be measure by using Casagrande cup (Casagrande, 1932). The liquid limit of a soil also can be determined by using cone penetrometer test. The references standard for cone penetrometer test in determine liquid limit is B.S 1377:

PART 2: 1990: clause 4.3 & 4.5. For penetrometer test, liquid limit is generally mixing soil to consistency just wet and dry of the liquid for determining the liquid limit by interpolating between four point (Clayton & Juke, 1978). Liquid limit of soil is determined when 30^{o} of cone penetrate 80g of soil at exactly 20mm in 5 second.

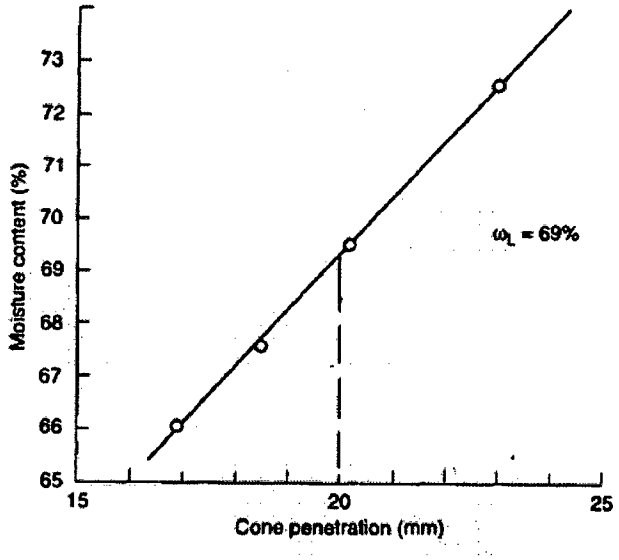

Figure 2.3: Moisture content (%) versus cone penetration (mm)

2.7.4 Plasticity Index

Plastic Index, I_P is a measure of the plasticity of soil. The plasticity index is the size of range of water content where soil exhibit plastic properties. The I_P is the difference between liquid limit (LL) and plastic limit (PL). Soil with a higher I_P tends to declare as clay. Soil with a lower I_P tends to become silt. It shows that a higher I_P has greater compressible and volume change in soil. The plasticity is one of the most useful ways to describe a clayey soil.