



Faculty of Engineering

**ENGINEERING BEHAVIOR OF SOIL TREATED BY CHEMICAL
AND ELECTROKINETICS**

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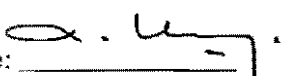
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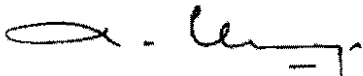
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**ENGINEERING BEHAVIOUR OF SOIL TREATED BY CHEMICAL AND
ELECTROKINETICS STABILIZATION**

LEE SHYUE LEONG

This project is submitted in partial fulfilment of the requirements for the Master of
Engineering
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“Dedicated to my beloved family...”

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ABSTRACT

Soft soil has the characteristics of high compressibility, low shear strength and low permeability. Research on soft soil stabilization was conducted to determine the strength development of treated soil. Chemical stabilization with lime and electrokinetic stabilization were used. Different lime contents were added to the soil for lime stabilization and electrokinetics-lime stabilization and the samples were tested after the curing period by using vane shear test equipment. Comparison of strength gained for both lime stabilization and electrokinetics-lime stabilization was conducted including the determination of optimum lime content required. The reason behind the strength gained for the treated soil is due to the pozzolanic reaction to produce calcium silicate hydrate (CSH) and calcium aluminium hydrate (CAH), which bind with the soil particles and increase the strength of the soil. The difference between lime stabilization and electrokinetics-lime stabilization is direct current is applied on the electrokinetics-lime stabilization for 1 hr at the voltage gradient of 34.96 V/m. The strength of lime stabilized soil increased by 16.43% for 7.5% to 12.5 % lime content. However, the strength of the elctrokinetics-lime stabilized soil decreased for 25.61% with increase in lime content from 7.5% to 12.5%. Hence, it can be concluded that lime stabilization is more effective than electrokinetics-lime stabilization in this research.

ABSTRAK

Tanah lembut mempunyai ciri-ciri kebolehmampatan yang tinggi, kekuatan ricih yang rendah, dan kebolehtelapan yang rendah. Penyelidikan penstabilan tanah lembut telah dijalankan untuk menentukan pembentukan kekuatan tanah yang dirawat. Penstabilan melalui kimia dan elektrokinetik dengan penambahan kapur adalah kaedah yang digunakan. Peratusan kapur yang berbeza dicampurkan ke dalam sampel tanah untuk penstabilan kimia dan penstabilan elektrokinetik dan akan diuji dengan menggunakan ujian ricih ram (vane shear test). Selain itu, perbandingan kekuatan tanah yang diperolehi bagi penstabilan kapur (lime stabilization) dan penstabilan elektrokinetik-kapur (electrokinetics-lime stabilization) telah dijalankan termasuk penentuan optimum kandungan kapur yang diperlukan. Sebab utama pembentukan kekuatan tanah lembut yang dirawat adalah disebabkan oleh tindak balas *pozzolanic* dengan menghasilkan kalsium silikat hidrat (calcium silicate hydrate, CSH) dan kalsium aluminium hidrat (calcium aluminium hydrate, CAH) yang menggabungkan dengan zarah tanah untuk meningkatkan kekuatan tanah. Perbezaan antara penstabilan kapur dan penstabilan elektrokinetik-kapur adalah penggunaan arus terus bagi penstabilan elektrokinetik-kapur selama 1 jam dengan keceruana voltan (voltage gradient) 34.96 V/m. Kekuatan penstabilan kapur meningkat sebanyak 16.43% daripada 7.5% kepada 12.5% kandungan kapur. Walau bagaimanapun, kekuatan penstabilan elektrokinetik-kapur telah menurun sebanyak 25.61% dengan peningkatan kandungan kapur daripada 7.5% kepada 12.5%. Oleh itu, kajian ini telah menunjukkan bahawa penstabilan kapur adalah lebih berkesan daripada penstabilan elektrokinetik-kapur.

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LIST OF ABBREVIATIONS

CSH	Calcium Silicate Hydrates
CAH	Calcium Aluminate Hydrate
H ⁺	Hydrogen
OH ⁻	Hydroxide
CaO	Lime
CaCO ₃	Limestone
CaO	Calcium Oxide
Ca[OH] ₂	Calcium Hydroxide
Ca ²⁺	Calcium Ions
Fe ²⁺	Ferrous Ions
Al ₂ (SO ₄) ₃	Aluminum Sulfate
H ₃ PO ₄	Phosphoric Acid
CEC	Cation Exchange Capacities
EC	Electro-Conductivity

CHAPTER 1

INTRODUCTION

1.1 Overview

Soft soil is a problematic soil due to its characteristics of high compressibility, low shear strength and low permeability (Gan, & Tan, 2003; Said & Taib, 2009). Any infrastructure built on the soft soil cannot be supported due to its characteristic. The common construction problems on soft soil are low bearing capacity, excessive post construction settlement and instability on excavation and embankment forming (Gan, & Tan, 2003). There are few common construction methods which can be applied on soft soil such as soft soil replacement; installation of prefabricated vertical drains (PVD) for pore water dissipation; and installation of stone column or sand compaction piles to increase the bearing capacity of subsoil. However, the application of these methods would cause an increase in construction cost and construction time and also constrained by the technical feasibility (Gan, & Tan, 2003).

In this research, chemical stabilization and electrokinetics stabilization are the methods used for the soft soil stabilization purpose. The chemical substance which is lime is

used for chemical stabilization and the treated soil was also applied for electrokinetics treatment.

In terms of chemical reaction of lime with soil, flocculation and pozzolanic reactions are the main chemical reactions (Jacques et. al., 1996). These chemical reactions produced secondary products which bind together with the soil particles and crystallize. The bonding between the soil and the secondary products becomes stronger because the process of crystallizing is a time dependent process. Hence, the strength of the soil is increased day by day (Grim, 1962; Little, 1995; Kok & Khairul, 2001).

Electrokinetics treatment is still considered a new method and is being investigated for soil treatment (Nasim et. al., 2012). This type of treatment is performed by passing the electric current through the soil from anode to cathode. The process consists of several phenomena which are electrolysis, electro-osmosis, electromigration and electrophoresis (Morefield et. al., 2004). Moreover, this method can be used with or without the addition of chemical stabilizers which is fed at the anode or at the cathode, depending on the ions to be transferred into the soil, such as calcium chloride aluminium, aluminium sulphate and phosphoric acid (Kamarudin et. al., 2006).

Redox reaction occurs at the anode and cathode of the electrode when the electric current is applied. Oxidation and reduction occur at anode and cathode, respectively which produce hydrogen (H^+) ions at anode and hydroxide (OH^-) ions at cathode. The migration of

positive and negative charge respectively affects the pH of the soil, such as the alkalinity and acidity of the soil will change (Barker et. al., 2004).

In this research, chemical treatment and electrokinetics treatment were conducted and to measure the effectiveness of these methods, vane shear test was conducted.

1.2 Statement of Need

Chemical stabilization and electrokinetic stabilization are useful methods for soil stabilization. Both methods can be used to increase the strength of the problematic soil (Grim, 1962). For example, the progress of a construction on soft soil site will be delayed due to the high water content which reduces the shear strength of the soil and increases the compression of the soil (Phani Kumar et. al., 2001; TenCate, 2010). So, with the application of these methods, the problem can be solved. Moreover, lime is also used in the construction area of highway, railroads and airport construction to improve roadbeds and bearing layers. So, the railway tracks and other can be constructed using local soils and at a low cost (Brandl, 1981; Lhoist Group, 2010).

Besides this, problematic local soil of a construction site can be used after proper soil treatment either with lime stabilization or electrokinetics stabilization. In lime stabilization, the chemical reaction of soil with lime will produce silicate gel which binds with the soil particles to increase the strength of the soil. In the meantime, the compressibility of the soil is

reduced due to the reduction of the water content (Brandl, 1981; Lhoist Group, 2010). In electrokinetics treatment, with the application of direct current through anode and cathode to soil, soil strengthening occurs. The water content of the soil is reduced due to the heat produced, as well as by the chemical reaction of soil with lime that also requires water content (Morefield et. al., 2004). Hence, replacement of the problematic soil is not required and the local soil of the site can be used, which directly leads to the reduction of construction cost.

Compared with the electrokinetics, conventional methods are well applied but are expensive, time consuming, and may be difficult to implement in some existing structures. On the other hand, electrokinetics can minimize the disturbance of the surface while treating the building foundation, roads, railway or pipelines by improving the engineering characteristics of subsurface soils such as increase shear strength and reduce compressibility (Kamaruddin et. al., 2011; Nasim et. al., 2012).

Geotechnical Engineering Ltd (2012) in United Kingdom used electrokinetics to stabilize a 15 m high slope with the average angle of 45°. After the soil treatment, the anodes were converted to soil nails to provide additional long-term stability-grouted in a centralized re-bar, then capped with a galvanized face plate. Thus, electrokinetics stabilization also brings some extra benefit to the soil stabilization by transferring the anode into soil nail.

Hence, a study of lime stabilization and electrokinetics stabilization can be carried out to increase the knowledge of soil stabilization by using these methods with the soil in Malaysia.

1.3 Problem Statement

Soft soil is a problematic soil with the high compressibility, low shear strength, low permeability, and large settlement. Any infrastructure built on the soft soil cannot be supported due to low bearing capacity of the soil. The conventional methods such as soil replacement can be used. However, conventional methods is time consuming and expensive. So, alternative methods are required, which the construction time and construction cost can be reduced.

From the published work, lime stabilization and electrokinetic stabilization have shown to solve the soft soil problem by increasing the strength of the treated soil. In overseas, these methods are applied in construction site. For example in Augusta, Georgia, reconstruction and widening a portion of interstate 20 (I-20) road was carried out. Lime stabilization for subgrade of the pavement was proposed but not replacement of the weak subgrade. By using lime stabilization, the California bearing ratio (CBR) value increased from 3 (untreated) to 28 (treated). The treated soil continued to gain strength and achieved a CBR value of 66 after 7 days of moist curing at 40 °C. Compared with soil replacement of 6

inch with graded aggregate base, lime stabilization is more cost effective with the potential saving of 30 % - 40 % (Webb, 2007).

At Kent, United Kingdom, electrokinetic stabilization was applied on stabilization the road embankment with the slope height of 15 m and average angle of 45°. With the application of direct current, electrical potential was created and caused the water to move from anode to cathode. The difference of electrical potential across the slope promoted the water to be drained away via cathodes and lead to consolidation of the slope materials. The advantages of this method are the trees on the slope was protected, traffic management measure was not required and cost saving approximately 38% compared with conventional methods. After the treatment, anodes were converted into soil nail to provide additional long term stabilization. Cathodes were left in place to provide ongoing passive drainage and as additional reinforcement of the embankment (Grotechnical Engineering Ltd, 2012).

By performing the study, the effectiveness of the lime stabilization and electrokinetic stabilization can be determined. Comparison between the strength gained of the treated soil by both stabilizing methods can be measured, and to identified which stabilization methods is less time consuming and cheaper.

1.4 Objective

The main purpose of the research is to determine the strength gained of the treated soil by lime stabilization and electrokinetics-lime stabilization. After the soil was treated with these two methods, the soil was tested with vane shear test to determine the strength development of the treated soil. Moreover, through the result analysis, comparison of strength gained for both methods can be performed, including the determination of optimum lime content. Hence, the objectives of this research are outline as follow:

- I. To determine the amount of lime needed in lime stabilization and electrokinetics-lime stabilization.
- II. To determine the strength development after lime stabilization and electrokinetics-lime stabilization.
- III. To compare the strength of lime stabilization and electrokinetics-lime stabilization.

1.5 Scope of Study

In this research, Atterberg Limit, sieve analysis, vane shear test, specific gravity, moisture content and Proctor test were conducted before proceed to the mix design for the