



Faculty of Engineering

**DETERMINATION OF OPTIMUM CONCENTRATION OF  
LIME SOLUTION FOR SOFT SOIL STABILIZATION**

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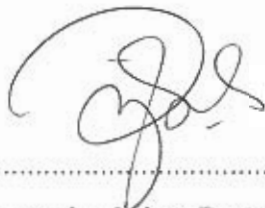
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DETERMINATION OF OPTIMUM CONCENTRATION OF LIME SOLUTION  
FOR SOFT SOIL STABILIZATION

**ABDUL HADI BIN ABDUL HALIK**

Thesis is Submitted to

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*To my beloved parents and family.*

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## ABSTRACT

Lime is an additive which commonly used to increase the soil strength and has been practiced many years back. The main objective of this research is to determine the optimum concentration of lime solution for soft soil stabilization. However, previous studies done shows lime will react effectively with certain proportion with respect to different types of soft soil been tested. This study is done in order to determine optimum concentration of lime solution for local clay stabilization. There are five different ratios in weight percentage are proposed for mixture, which are 0%, 3%, 5%, 7% and 9 %, and been cured for 0, 7, 14 and 21 days. The result indicates that the soil sample mixed with 7% lime and cured for 21 days gives the highest values of 417.80 kPa as the unconfined compression strength. Consequently, the optimum concentration of lime solution to stabilize the soil is 23.74 % of weight of water which is equivalent to 7% of dry lime. Generally, the optimum concentration of lime solution to stabilize local clay is 7% of dry lime.

## ABSTRAK

Kapur kering adalah sejenis agen pemangkin yang biasa digunakan bagi menambahkan kekuatan tanah dan telah lama dipraktikkan. Objektif utama kajian ini dijalankan ialah untuk mengenalpasti kepekatan optimum larutan kapur untuk penstabilan tanah. Walaubagaimanapun, kajian terdahulu menunjukkan kapur kering akan bertindakbalas dengan berkesan apabila digunakan dengan jumlah tertentu bergantung dengan jenis tanah yang digunakan untuk diuji. Kajian ini dijalankan bagi menentukan kepekatan optimum larutan kapur untuk penstabilan tanah tempatan. Lima nisbah yang berbeza (peratusan dalam berat) yang dicadangkan untuk campuran, iaitu 0%, 3%, 5%, 7% dan 9 % dan diawet untuk 0, 7, 14, dan 21 hari. Keputusan ujian menunjukkan sampel tanah yang dicampur dengan 7% kapur kering dan diawet selama 21 hari nilai Ujian Mampatan Tak Terkurung yang tertinggi iaitu 417.80 kPa. Justeru, kepekatan optimum larutan kapur yang digunakan untuk penstabilan tanah ialah 23.74 peratus daripada berat air bersamaan dengan 7% kapur kering. Biasanya, kepekatan optimum larutan kapur untuk penstabilan tanah tempatan ialah 7% kapur kering.

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## LIST OF NOMENCLATURES

$\mu\text{m}$	-	Micrometer
mm	-	millimeter
ml	-	milliliter
$\text{cm}^3$	-	Centimeter Cube
kg	-	Kilogram
CBR	-	California Bearing Ratio
N	-	Newton
d	-	Depth of Penetration
PI	-	Plasticity Index
LL	-	Liquid Limit
PL	-	Plastic Limit
PVC	-	Polyvinyl Chloride
UCS	-	Unconfined Compressive Strength



# CHAPTER 1

## INTRODUCTION

### 1.1 Background of Study

One of the common problems faced by engineers when commencing an engineering project is the geotechnical aspect. It is more challenging when it comes to problematic soil such as soft soil and peat soil. What is important is that the soil has to meet the engineering design required for the soil. If the soil is problematic, it is necessary to treat the soil by the mean of stabilization or compaction. Therefore, soil stabilization is one of important alternative before the construction process takes place. Lime is used in many field or sector such as water treatment, agriculture and sewer treatment. This study is carrying out to study the optimum concentration of lime for soft soil stabilization. We study the lime as the soil stabilizer and determine the optimum concentration of lime to stabilized soft soil so that the soil is fully stabilized in order to meet the engineering design required for the soil.

## **1.2 Problem Statement**

Soil stabilization with different additives such as lime, fly ash and cement has been practiced worldwide. However, previous studies indicated that optimum lime concentration used for soft soil stabilization is depending on the type of soil. This study will determine the optimum concentration of lime solution for Sarawak local clay with respect to its engineering properties.

## **1.3 Objective of Study**

The objectives of this study are to:

1. To determine the optimum concentration of lime solution for local soft soil stabilization.
2. To determine the factors influencing the strength development of lime-soil mixture.

## **1.4 Scope of Study**

This study is focused on the study of optimum lime solution to be used for Sarawak clay stabilization. The clay used in this study is collected from Simpang Tiga, Sarawak. The lime used in this study is quicklime which exists in form of powder. The proposed proportion to be used in this study is 0%, 3%, 5%, 7% and 9% to the mass of the soil. Result obtained from the unconfined compression strength test is analysed to identify the highest strength which represents the desired optimum lime solution for the soil sample.

## **1.5 Outline of Thesis**

1.1 Background of Study

1.2 Problem Statement

1.3 Objective of Study

1.4 Scope of Study

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Soil Improvement

In any engineering project, a lot of problems will occur in term of soil stability. It is standard to perform soil investigation before execute any engineering projects. The result of the soil investigation will be analyzed to acquire the information of the soil. If the bearing capacity of the soil is good, it is no problem then. If the soil is a problematic, then proper proccdures need to be done to solve the problem. The step taken to strengthen the soil is called soil improvement process.

It is rather almost than sometimes that engineer faced in problematic soil such as peat soil and soft soil. Soil improvement usually carried out by the mean of compaction or soil stabilization.

## 2.2 Soil Stabilization

Soil stabilization may be broadly defined as the alteration or preservation of one or more soil properties to improve the engineering characteristics and performance of a soil (Integrated Publishing, 2008).

Soil stabilization significantly changes the characteristics of a soil to produce long-term permanent strength and stability, particularly with respect to the action of water and frost (ARBAS, 2004).

Soil Stabilization is a century old method which is been used to treat soil. Stabilization can reduce the amount of surplus soil from earthworks operations and the associated tipping costs (Smith, 2005).

### 2.2.1 Mechanical Method

This method includes the removing of an original problematic soil and replaces it with a new desired type of soil or mixing the soil with soil from other source to achieve desired soil. Mechanical stabilization is accomplished by mixing or blending soils of two or more gradations to obtain a material meeting the required specification (Integrated Publishing, 2008). The process of mixing and blending may be done at the construction site, at central plant or at a borrow area (Integrated Publishing, 2008). After blended, the mixed soil is then spread and compacted.

Other mean in mechanical method include vibroflotation technique which rearrange loose sand and gravel particles into a denser state, vertical drain method which accelerate the consolidation settlement and shorten consolidation time,

geotextile technique which laying fabric into the soil layer to strengthened the soil layer.

### **2.2.2 Chemical Method**

Chemical soil stabilization is all about manipulation of water-soil relationship in order to reached desired soil condition. Chemical method is to modify the interaction of water-soil relationship by surface reaction to make the behavior of the soil with respect of the water as required in specification. There are many type of chemical stabilization method such as cement stabilization, bitumen stabilization and sodium silicate stabilization (Abdullah, 2006).

### **2.2.3 Additive Method**

This method requires the addition of manufactured commercial product which will improve the quality of the soil layer when added in proper quantity. Simple example of additives used to stabilize soil is portland cement, lime, lime-cement-fly ash, and bitumen. These additives may be used alone or in combination (Integrated Publishing, 2008).

The selection and determination of the percentage of additives depend upon the soil classification and the degree of improvement in soil quality desired . Generally, smaller amounts of additives are required to alter soil properties, such as gradation, workability, and plasticity, than to improve the strength and durability sufficiently to permit a thickness reduction design . After the additive has been



mixed with the soil, spreading and compacting are accomplished by conventional means (Integrated Publishing, 2008).

### **2.3 Lime**

The word “lime” is a generic term used to describe either quicklime or hydrated lime (Vorobieff, 2008). Lime is used to dry, temporarily modify or permanently stabilize soils. It is a new effective and economic mean for dealing with unstable soil by improving the strength and stiffness characteristics of clay soils. Lime is a very unique product and very popular in construction world because of its capability to provide several of benefits.

Benefit of using lime such as drying with lime of wet soils, lime modification and lime stabilization can minimizes weather-related construction delays, chemically transform clay soil into friable, workable and compactable material, and creates long term chemical changes in unstable clay soil to create strong but flexible, permanent structural layers in pavement systems and other foundations respectively (National Lime Association, 2005).

Sometimes the term “lime” is used to describe agricultural lime which is generally finely ground limestone, a useful soil amendment but not chemically enough to lead to soil stabilization. “Lime” is also sometimes used to describe byproduct of the lime manufacturing process (such as lime kiln dust), which, although they contain some reactive lime, generally have fraction of the oxide or hydroxide content of the manufactured product (ARBAS, 2006).

### 2.3.1 Lime Stabilization

Lime stabilization is a method adopted to treat unsuitable soil and contaminated soil in order to improve strength and stiffness properties of road foundations, reduce the swell-shrink potential of expansive soils and improve soft clay properties by surface mixing of lime and soil (Abdullah, 2006).

Lime stabilization dates back to Roman times and can be used for a wide variety of modern day applications (Smith, 2005). One example of Roman usage of lime in construction is the stretches of the Appian Way in Rome which now still sit on lime stabilized soils two millennia old. Lime stabilization is now seen as a “win-win” solution, saving time and money as well as being more environmentally friendly. Its environmental benefits are so marked that it is likely to be used on an expanding scale (Wheeler, 2004).

Lime and water when added together in proper quantity will quickly increase the pH value above 10.5, which enables the clay particles to break down. The reaction of calcium from lime with silica and alumina will form calcium silicate hydrates and calcium aluminates hydrates. These two compounds form the matrix that contributes to the strength of the soil-stabilized soil layers. The soil then transformed from its highly expansive, undesirable natural state to a more granular, relatively impermeable material that can be compacted into a layer with significant load bearing capacity (National Lime Association, 2005).

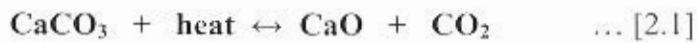
Soil stabilization by lime takes place when lime in the form of calcium oxide and calcium hydroxide mix with the soil and the compaction of the mixture at the

optimum water content. Lime and clay reaction occur in two ways, namely long term reaction and short term reaction.

### 2.3.2 Types of Lime

According to the Webster and precise definition, lime can be refer to quicklime (calcium oxide) or hydrated lime (calcium hydroxide), which is burned forms of limestone (calcium carbonate). It is a strong alkaline base (Ng, 2005).

Limestone is a sedimentary rock composed principally of calcite (Calcium Carbonate -  $\text{CaCO}_3$ ). Crushed to varying sizes it is used as landscaping spalls, roadbase, aggregates, screenings, foundry flux or toppings (Unimin, 2008). Limestone is heated at 1250 C in kiln to yield quicklime and at the same time drove off the carbon dioxide.



Bulk quicklime is more dense than hydrated lime and it's greater effectiveness per unit weight can offer comparative economy (Unimin, 2008). Quicklime's ability to form alkaline solutions / suspensions in water is a key to its being able to modify certain soils in such a way that the end result is a benefit to road engineers (Vorobieff, 2008).

Hydrated lime is produced by reacting quicklime with sufficient water to form a dry white powder with the evolution of steam. It is less caustic than quicklime but it still requires some care in handling (Unimin, 2008).



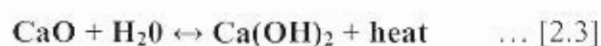
The hydration process releases significant amount of heat. It has lower available lime content than quicklime so it is more suited to drier soils but it may be less economical and in urban areas there may be a dust problem (Ng, 2005).

### 2.3.3 Mechanism of Lime Stabilization

Three mainly reactions which give a major strength gain of lime treated clay are dehydration of soil, ion exchange and flocculation, and pozzolanic reaction. There are two types of reaction in which above mentioned reaction consist in; short term reactions (hydration and flocculation) and long term reactions (cementation and carbonation).

#### 2.3.3.1 Hydration

Quicklime when mixed with clay will release a great amount of heat despite forming calcium hydroxide. Calcium oxide will react to pore water in the soil and cause immediate drop in the water content of the soil because the water is being used up in the hydration process.



It is very important to make sure the water content is adequate for the reaction to complete and to complete the slacking of quicklime. During the reaction, when hydrated lime is formed, it will dissociate in the water and dissolve the  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  from the clay particles. This will also increase the electrolytic concentration and the pH of the pore water (Abdullah, 2006).