THE POTENTIAL OF CEMENT STABILIZATION IN SOFT SOIL

NUR DIYANA BINTI NORDIN
AA08009

A thesis submitted in fulfillment of the requirements for the award of
Bachelor of Civil Engineering

Faculty of Civil Engineering & Earth Resources
Universiti Malaysia Pahang

DECEMBER 2010

ABSTRACT

Soft soils often cause difficulties in construction operation with their low strength and low stiffness nature. However, the engineering properties of these soils can be enhanced by soil stabilization. This research was carried out to study the potential of cement (OPC) stabilization in soft soil around the area of Pekan, Pahang. The objectives of this research are firstly to determine engineering properties of soft soil. The soil was classified as clay with very high plasticity (CV), having liquid limit, plastic limit, plastic index and shrinkage limit of 72.0%, 31.36%, 40.64%, and 7.86% respectively, specific gravity was 2.51 and maximum dry unit weight and optimum moisture content of 14.45kN/m^3 and 20.0% respectively. Secondly, to compare the strength and characteristic of soft soil before and after treating with different range of cement concentration, ranging from 2% to 12% of weight of soil. Compaction test was applied to determine the maximum dry unit weight and the optimum moisture content of the soils. From this testing, the maximum dry unit weight was obtained for sample with 10% cement added. By compaction test with mixing water content of 40% the samples for triaxial test (Unconsolidated Undrained Test) were prepared and then cured in water for 0, 1, 7 and 28 days respectively to allow for investigation of the curing effect. The result showed the shear stress is increasing proportional to the cement ratio within curing period. The maximum shear stress was observed for samples with 10% cement added. Oedometer test was carried out to examine the relationship between void ratio and applied pressure to the soil sample. From this test, it showed that 4% and 6% of cement content in the soil were effective in decreasing the settlement of the originally weak soil or another word, increasing the applied pressure to the soil samples would decreases the void ratio of the soil samples. For overall, 10% of cement content shows the effective amount cement added in soft soil stabilization and the objective of this research was achieved.

ABSTRAK

Tanah lembut sering menyebabkan kesulitan dalam operasi pembinaan dengan kekuatan dan sifat kekerasan yang rendah. Namun sifat teknikal dari tanah dapat dipertingkatkan dengan penstabilan tanah. Penyelidikan ini dilakukan untuk mengkaji potensi simen (OPC) menstabilkan tanah lembut sekitar kawasan Pekan, Pahang. Tujuan dari penyelidikan ini adalah pertama untuk menentukan sifat kejuruteraan tanah lembut. Tanah diklasifikasikan sebagai tanah liat dengan keplastikan yang sangat tinggi (CV), mempunyai had cecair, had plastik, indek keplastikan dan had susut masing-masing adalah 72,0%, 31,36%, 40,64%, dan 7.86%, nilai graviti tentu adalah 2.51 dan berat unit kering yang maksimum dan kadar air optimum masing-masing adalah 14.45kN/m^3 and 20.0%. Kedua adalah untuk membandingkan kekuatan dan ciri-ciri tanah lembut sebelum dan selepas sampel tanah dicampurkan dengan kandungan simen yang berbeza bermula dari 2% hingga 12% daripada berat tanah. Ujian pemadatan digunakan untuk menentukan berat unit kering yang maksimum dan kadar air optimum dari tanah. Daripada ujian ini, berat unit kering yang maksimum diperolehi daripada sampel yang ditambah dengan 10% simen. Daripada ujian pemadatan dengan kadar air pencampuran 40%, sampel untuk ujian tiga paksi (ujian tak terkukuh tak tersalir) disediakan dan kemudiannya diawet dalam air selama 0, 1, 7 dan 28 hari untuk membolehkan kajian kesan daripada pengaruh awetan. Keputusan menunjukkan tegangan ricih meningkat setanding dengan nisbah simen dalam tempoh awetan. Tegangan ricih yang maksimum diperolehi untuk sampel dengan 10% kandungan simen. Ujian oedometer dilakukan untuk menguji hubungan antara nisbah lompang dan tekanan yang dikenakan keatas sampel tanah. Ujian ini menunjukkan bahawa 4% dan 6% adalah kandungan simen dalam tanah yang efektif dalam pengurangan pemendapan pada tanah yang awalnya lemah atau dalam erti kata lain, meningkatkan tekanan yang dikenakan keatas sampel tanah akan mengurangkan nisbah lompang sampel tanah. Untuk keseluruhan, 10% kandungan simen menunjukkan kadar yang paling efektif dalam penstabilan tanah lembut dan objektif penyelidikan ini tercapai.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

OPC	-	Ordinary Portland Cement
ASTM	-	American Society for Testing of Materials
BS	-	British Standard
LL	-	Liquid Limit
PL	-	Plastic Limit
SL	-	Shrinkage Limit
PI	-	Plasticity Index
CD	-	Consolidated-drained
CU	-	Consolidated-undrained
UU	-	Unconsolidated-undrained

LIST OF SYMBOLS

g	-	Gram
mm	-	Millimeter
m	-	Meter
cm	-	Centimeter
%	-	Percent
kPa	-	Kilo pascal
Gs	-	Specific gravity
L_0	-	Initial length
L_D	-	Oven-dried length
V	-	Volume
M	-	Mass
W	-	Weight
ρ	-	Density
γ_{wet}	-	Wet unit weight
γ_d	-	Dry unit weight
C	-	Undrained shear strength (mohr's circle)
Cu	-	Shear strength
e	-	Void ratio
ε	-	Strain
σ_3	-	Total and effective confining stress
σ_1	-	Total and effective axial stress at failure
ϕ	-	Angle of friction

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Research

The emergence of development in construction industry has minimized the preferred site of geotechnical quality for construction although these sites are known to reduce technical problems and thus the cost associated with their construction. By that, socio-economic and political considerations have forced the use of sites of lower quality and in particular, the site covered by compressible soils.

In developed country such as Malaysia, the chances to have good quality construction sites become rarer and it is necessary to choose sites that include compressible soils, especially for industrial structures and transportation projects. Therefore, the tasks to do constructions on these problematic soils have become a challenge for geotechnical engineers all over the world. The ground or soil condition is one of the important factors in foundation design. Before starting to design a foundation, a civil engineer must first obtain the required soil information from soil investigation carried out at the proposed site. Therefore, a civil engineer must have an adequate knowledge on the properties of soil and the soil testing.

Soils with characteristics of low strength and compressible exist all over the world. One of the most significant problems arises because of its characteristics that are difficulties in supporting loads on such foundation. The problem arises with low strength is that it leads to difficulties in guaranteeing the stability of the structure on this type of soil.

Therefore, the stabilization of soil is important to be done in the construction. The main purposes of soil stabilization are to modify the soil, expedite construction, and improve the strength and durability of the soil. Besides that, soil stabilization also can be defined as the modification or improvement of the characteristics of soil in order to enhance the engineering performance of the soil. For example, improve the density of soil, mixing the soil with additives to change the chemical and physical properties such as stiffness, compressibility, permeability, workability, lower the ground water level, and eliminate weak soil.

The term modification implies a minor change in the properties of a soil, while stabilization means that the engineering properties of the soil have been changed enough to allow field construction to take place. There are two primary methods of soil stabilization used today, mechanical and additives. The method of soil stabilization is determined by the amount of stabilizing required and the conditions encountered on the project. An accurate soil description and classification is essential to the selection of the correct materials and procedures. The most common improvements achieved through stabilization include better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and strength.

Mechanical stabilization is the process of altering soil properties by changing the gradation through mixing with other soils, densifying the soils using compaction efforts, or undercutting the existing soils and replacing them with granular material. The examples of mechanical method are soil replacement, vibroflotation, compaction and others.

In additive method, stabilization of soils to improve strength and durability properties often relies on cement, lime, fly ash, and asphalt emulsion. These materials are inexpensive, relatively easy to apply, and provide benefits to many different soil types. However, there are varieties of non-traditional soil stabilization/modification additives available from the commercial sector such as polymer emulsions, acids, lignin derivatives, enzymes, tree resin emulsions, and silicates. These additives may be in liquid or solid form and are often touted to be applicable for most soils. Previous research studies in this area have demonstrated that many soil additives have little to no benefit for silt and sandy soil types (Santoni et. al, 1787).

1.2 Problem Statement

Malaysia is a developing country located in South-East Asia. The demands for buildings, for commercial or residential use are high especially in Kuala Lumpur, the capital city of Malaysia. A building is designed to support the load applied to it safely. The ability of building to sustain the applied loads depends on the soil below the foundation of the building. The superstructure loads will be transferred to the underlying soil. Without a proper design and earthwork construction, problem such as cracking, settlement of building may occur and even to the extent, the whole building may collapse within its design life. Therefore, a proper earthwork required to maintain the safeness of a building.

Nowadays, many construction have face the problem of soil where the soil cannot reach the required specification such as bearing capacity of soft soil too weak to support superstructure above it. The existing soil at a construction site may not always be totally suitable for supporting structures such as buildings, bridges, highways, and dams. Due to that, the understanding and knowledge of engineering characteristics of soft soil are critical and should be understand by people related in this field. The selection of construction method on this formation is restricted by cost, duration of completion, and benefits. In this study, the type of soil will be focused on soft soil.

Soft soil is chosen as a sample in this study because of their low strength and high compressibility. Usually, due to sedimentary process on different environments, both physical and engineering properties (namely void ratio, water content, grain size distribution, compressibility, permeability, and strength) show a significant variation. Further, they exhibit high compressibility (including an important secondary consolidation), reduced strength, low permeability and compactness, and consequently low quality for construction.

The problem of settlement is significant when dealing with structure such as roads, housing and embankment constructions on soft soil. Due to the characteristic of soft soil, the structure may settle excessively both due to high compressibility and low shear strength. The settlement may take a long time depending on the ability of the soil to dissipate the excess prop induced by the construction. Structures built on soft soil are subject to settlement and some settlement is often inevitable, depending on the circumstances, and tolerable. For example, small uniform settlement of a building throughout the floor area might be tolerable, whereas non-uniform settlement of the same building might not be.

Clay soils can be classified as a soft soil. Some clay soils undergo slow volume changes that occur independently of loading and are attributable to swelling or shrinkage. These volume changes can give rise to ground movements that can also cause damage to structures. Low rise buildings are particularly vulnerable to such ground movements since they generally do not have sufficient weight or strength to resist.

In certain cases, the soft soil failed to support the foundation of the structure. In this case, the softer layers are found under the intermediate layers. The presence of intermediate hard layers makes it difficult to penetrate the soil using driven or jacking piles. It may results in the piles being falsely terminated on top of the intermediate layer. Consequently, the high building loads are transferred to the softer layers which underlain the intermediate hard layers. This wills leads to building settlement as the loads are not properly transferred to the actual founding level.

This study was conducted in Pekan, Pahang. The soft soil sample was taken near to the river mouth of Sungai Pahang. Figure 1.1 shows the location map of Pekan, Pahang.

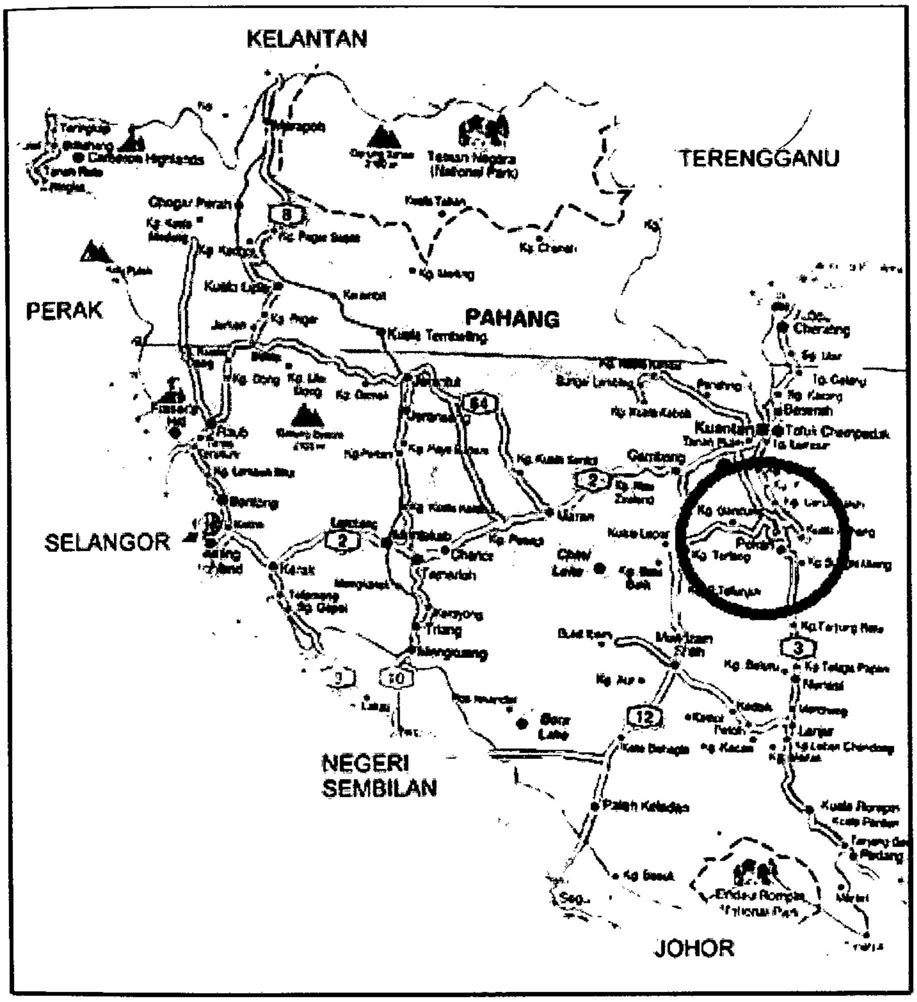

Figure 1.1: The location map of Pekan, Pahang

1.3 Research Objectives

The objectives of the project are:

1. To determine engineering properties of soft soil.
2. To compare the strength and characteristic of soft soil before and after treating with different concentration of cement and curing periods.
3. To determine the effectiveness of cement in soft soil.

1.4 Scope of Study

The term of soft soils had been used in this study to describe soils that have a high moisture content, approaching that of the liquid limit and have a high sensitivity. Soil samples from various locations in Pekan, Pahang were collected. Undisturbed and disturbed soil sample was taken and brought to the laboratory for classified and to be investigated for use in soil cement. The soil samples were chosen to represent plasticity index is less than about 25 and clay fraction (passing No. 200 sieve) are less than about 40 percent.

Ordinary Portland Cement (OPC) was used in this research. Portland cement had proven to be a very good method of base stabilization by decrease the liquid limit and increase the plasticity index and workability of soft soil.

For soils classification, soils included size of particle, specific gravity, and water content. In soil classification tests, there are three laboratory testing were carried out that are Particle size distribution test, Atterberg limits test, and Specific gravity test. Each testing was conducted with three samples of soil to get the average results.

The main testing was carried out to compare the strength and characteristic of soft soil before and after treating with different concentration of cement. The testing were Standard Proctor test, Triaxial test (Unconsolidated Undrained test), and Oedometer test. There were seven different ratios (0%, 2%, 4%, 6%, 8%, 10%, and 12%) of cement content were mixed with the soft soil to make soil samples. Cement ratio is ratio of the weight of cement to the weight of soil sample.

Standard proctor test was applied to determine the maximum dry unit weight and the optimum moisture content of the soils. Triaxial Test was conducted to determine shear strength parameters and to allow for investigation of the curing effect. Triaxial specimens were about 38mm in diameter and 76mm long was used and the testing was tested after curing period of 0, 1, 7 and 28 days. Lastly, odometer test was conducted to determine the consolidation characteristics of soil for low permeability.

1.5 Significant of Study

Many studies and researches had been carried out. Demonstrating cement stabilized soil has a significant enhancement in strength and other soil engineering properties. With this research, tests are carried to investigate whether the sets of tested cement stabilized has enough strength to withstand the increasing load. It provides a reference for the behavior of compressive strength on cement stabilized soft soil under different amount of cement contents.

Soil stabilization with cement has been successfully applied in engineering construction. Applications of this method have recently been further expanded. The more common uses today are for stream bank protection, grade control (drop) structures, and pond liners. Soil cement has been proven in all of these uses to be cost effective, aesthetically pleasing, performance and time tested. Other uses for soil cement are retaining walls, streets, shoulders, airports, parking and storage areas.

As the soil cement is placed and compacted, the cement hydrates and the mix becomes a structural slab-like material. After construction and curing, soil cement is hardly affected by water or the freeze thaw cycle, therefore does not pump under construction traffic or rut during spring thaws, and can bridge over soft sub grade.

Treatment of soils offers technical, economic, ecological and environmental advantages. For technical advantage, treatment with cement allows production and use of homogeneous, long-lasting and stable materials with mechanical characteristics. In addition, these materials are characterised by great stiffness and excellent fatigue strength. They show good performance in hot weather, with no deformation or rutting, and good performance on exposure to freeze-thaw cycles due to the stiffness of the material.

For economic advantage, field recycling is a significant savings factor as this reduces to a minimum stripping cuts, landfill, provision of aggregates and thus the cost of their transport. The absence of transport of aggregates and of cuts to the landfill contributes to preserving the road network in the vicinity of the building site.

CHAPTER 2

LITERATURE REVIEW

2.1 Soft soil

Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical, and mineralogical characteristics (Birkeland,1999).

Soft soils can be considered as near-normally consolidated clays, clayey silts and peat. The special features of these materials are their high degree of compressibility. But in the same time soft soil has a high sensitivity and low strength compared to another types of soil and the most important problem related to building on soft soil is settlement which is relatively large and takes long time to complete.

Usually, due to sedimentary process on different environments, both physical and engineering properties such as void ratio, water content, grain size distribution, compressibility, permeability and strength are show a significant variation. Further, they exhibit high compressibility (including an important secondary consolidation), reduced strength, low permeability and compactness, and consequently low quality for construction.

Due to the rapid increase in population and associated development activities taking place, especially in the congested coastal areas, construction activities have become concentrated in low-lying marshy areas, which are comprised of highly compressible weak organic and peaty soils of varying thickness (Indraratna et al., 1992). The entire coastal belt is dotted with very soft clays up to significant depths. These soft clay deposits have very low bearing capacity and excessive settlement characteristics, affecting major infrastructure including buildings, roads, and rail tracks (Johnson, 1970). Figure 2.1 shows the Peninsular Malaysia soil coverage in terms of Great Soil Groups