Faculty of Engineering

DURABILITY EFFECT ON STABILIZED SUBGRADE SOIL

Noraida Binti Razali

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Project Supervisor

Date:

DURABILITY EFFECT ON STABILIZED SUBGRADE SOIL

NORAIDA BINTI RAZALI

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ABSTRACT

Soft clay soil can be categorized as a problematic soil as it has the low strength and high compressibility characteristics. In any highway construction on a soft clay soil, sub-grade soil stabilization is one of the important processes. Therefore, a careful design analysis should be taken for the purposes of any structure built on it. In Sarawak, problematic soils, namely peat, silt and soft clay are the major concern which is inadequate for sub-grade used in the construction of a pavement structure. The focus of this study was mainly the strength and durability of the silty clayey soil. The samples were collected from Kota Samarahan, Sarawak and admixed with cement, fly ash and rubberchip as an additive. The optimum mixture determine from the laboratory is then used as a recommendation for design guideline of sub-grade based on JKR Standard Specification for Road Works and the calculation are performed by using MathCad software. In this study, the stabilized clay specimens were prepared with 5% cement and various fly ash and rubber chips contents, of 5%, 10% and 15%, respectively. The specimens were cured for 7 and 28 days before subjected to Unconfined Compressive Strength (UCS) tests and California Bearing Ratio (CBR) tests. As observed, the stabilization improved the strength and stiffness of the soil properties significantly. However, the addition of 15% rubberchip shows a reduction in strength for both 7 and 28 days curing period. The optimum mixture which fulfilled the JKR Standard Specification was the mixture of 5% cement and 15% fly ash where the value of CBR is 82.6% while the UCS value is 941.69 kPa. However, the mixture of 5% cement and 10% rubberchip can also be used as an alternative to stabilize the sub-grade for low volume road as the CBR value is higher than 30% CBR required by JKR which is 64.66% while the UCS value was 771.77 kPa, respectively.

ABSTRAK

Tanah liat lembut boleh dikategorikan sebagai tanah yang bermasalah kerana mempunyai kekuatan yang rendah dan ciri-ciri kebolehmampatan yang tinggi. Penstabilan bagi tanah sub-gred adalah salah satu proses yang penting didalam pembinaan lebuh raya diatas tanah liat lembut. Oleh itu, langkah yang lebih teliti perlu diambil dalam analisis reka bentuk bagi pembinaan struktur yang dibina di atasnya. Di Sarawak, tanah bermasalah iaitu gambut, kelodak dan tanah liat lembut adalah merupakan masalah utama yang perlu diberi perhatian dimana kekuatan tanah tersebut adalah tidak mencukupi untuk menampung pembinaan struktur turapan diatas sub-gred. Fokus utama kajian ini adalah kekuatan dan ketahanan tanah liat yang berkelodak, yang diambil dari Kota Samarahan, Sarawak yang kemudiannya dicampur dengan simen, abu terbang dan cip getah sebagai bahan penstabilan. Campuran optimum yang terhasil kemudiannya digunakan sebagai garis panduan dalam mereka bentuk sub-gred berdasarkan Standard Spesifikasi JKR untuk Kerja Jalan dan pengiraan adalah dibuat menggunakan perisian MathCad. Dalam kajian ini, spesimen untuk penstabilan tanah liat telah disediakan dengan penambahan sebanyak 5% simen dengan jumlah abu terbang dan cip getah yang berbeza kandungannya iaitu 5%, 10% dan 15%. Spesimen tesebut kemudiannya diawet selama 7 dan 28 hari dan ujian Kekuatan Mampatan Tidak Terkurung (UCS) serta ujian Nisbah Galas California (CBR) dijalankan. Melalui pemerhatian, kekuatan dan kekakuan bagi tanah yang telah distabilkan telah menunjukkan peningkatan yang ketara. Walau bagaimanapun, penambahan 15% cip getah menunjukkan pengurangan kekuatan bagi campuran tersebut untuk kedua-dua tempoh pengawetan iaitu 7 dan 28 hari. Campuran optimum yang memenuhi Standard Spesifikasi JKR adalah campuran 5% simen dan 15% abu terbang di mana nilai CBR adalah 82.6% manakala nilai UCS pula adalah 941.69 kPa. Walau bagaimanapun, campuran simen 5% dan 10% cip getah juga boleh digunakan sebagai alternatif untuk menstabilkan sub-gred bagi jalan dengan jumlah trafik yang rendah dimana nilai CBR yang didapati adalah lebih tinggi daripada nilai yang dikehendaki oleh JKR iaitu 30% dimana nilai yang didapati daripada ujian adalah 64.66% manakala nilai UCS pula adalah 771.77 kPa.

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CHAPTER 1

INTRODUCTION

1.1 General

Most of the civil engineering project is conducted on soils especially roads and highways. Therefore the stabilization of the soil is very important in constructions project to ensure that the project are carried out successfully either during the construction or after the project has been constructed in term to provide a stable sub-grade and a good working platform for the pavement construction.

In road and highway constructions, it is not only the pavement/ premix quality are taking into consideration, but the more important is the substructure below the pavement. The stability of the underlying soils needs serious attention to ensure that the pavement structures that has been construct can give long term performance and enhance the durability of the pavements. It is important to provide the optimum performance for the pavements because the pavement structures are significantly impacted by the direct loading from the traffic.

In other word, performances of the pavements are largely contributed by the performance of its foundation, which are the sub-grade and base layers. Therefore, foundations of pavements must provide a good engineering properties and strength such as shear strength, resistance to moisture; stability and the durability of the soils by stabilize the sub-grade and base layers.

Unfortunately, in Sarawak, some locations are frequently not sufficient to the project requirements due to the availability of the soft soil and it is clearly inadequate for the traffic loading demands. In order to meet such requirements, the sub-grade material requires a treatment to stabilize the soils in the specified area to provide a stable sub-grade and also a suitable working platform for the needs of the pavement construction.

The materials used for road construction in Sarawak are getting more expensive. However, pavement failures will occur if the materials used for the construction purposes are poor and inadequate in performance. Alternative methods that can be proposed are by stabilizing the local soil and improved its physical properties through soil treatment.

The treatment of the soils can be provided by two processes, either soil modification or soil stabilization. In this study, concentration has been made into local clayey soil only where the purpose of stabilize the sub-grade is to enhanced the strength development of the soft soil and also to determined the engineering properties. It is an effort to improve the engineering properties of the soft soils by modification. The method used in this study is by mixing the soil with additives such as cement, fly ash, and rubberchip at different proportions.

1.2 AIM AND OBJECTIVES OF THE STUDY

1.2.1 Aim of the study

The aim of the study is to investigate the durability and development of optimum strength effect on stabilization of the soft soil which are stabilized with different admixtures, namely cement, fly ash and rubberchip.

1.2.2 Objectives of the study

In order to achieve the above aims, the objectives are outlined as follows:

1. To design the mixture of the soft soils with designated amount of stabilizers used:
   - Cement
   - Fly ash and
   - Rubberchip
2. To determine the engineering properties of the control sample and the design mixture by performing several experiments such as:
   - Compaction Test by Standard Proctor Test
   - Unconfined Compressive Strength Test (UCS)
   - California Bearing Ratio Test (CBR)
3. To determine the development of strength of the stabilized soil at various admixtures.
4. To recommend the optimum design mix for the soft soils and the stabilizers use for stabilization of subgrade soil by comparing the shear strength development at various percentage of stabilized sample.
5. To recommend design guideline of subgrade based on JKR Standard of Specification for Road Work by using MathCad software.

1.3 SIGNIFICANCE OF STUDY

The work presented in this study is a contribution to the application of chemical stabilization techniques with different proportions of stabilizers for Sarawak soft clay especially in Kota Samarahan district. This study will help to provide information on which stabilizers are most effective for stabilizing the soft clayey soil and the result of this study can be used for the stabilization process. This report can also be used as a guide to select an appropriate stabilizer type and its amount based on soil properties and the desired strength. Other reasons that can put forward are that the use of local available materials will lead to lower costs in construction. The improvement in the characteristics of compacted soil, resulting from the addition of stabilizers like cement, fly ash and rubberchip will bring environmental and economic benefits.

1.4 SCOPE OF WORK

The study is focused on clayey soil with bearing capacity around 20kPa to 25kPa. The method used for stabilization of the soil is by chemical and fibre treatment which is by using ordinary Portland cement, class F fly ash and rubberchip mixture. The study was conducted at lower percentage of cement which is 5% for every mixture in order to get a minimum usage of cement for the design mixture. For every stabilizer, there are three concentrations for each; and three tests in order to obtained the engineering properties for each mixture. The tests that are conducted in this study, namely Compaction Tests by Standard Proctor, Unconfined Compressive Strength (UCS) Tests and California Bearing Ratio (CBR) Tests.

1.5 OUTLINE OF THE REPORT

This report consists of five chapters. Chapter 1 presents an introduction and explains the scope of the present study. Chapter 2 discuss about the results of literature review that focused on the stabilization of the soft soils and the stabilizer used. In Chapter 3 covers the methodology of the study, such as the characteristics of the materials, preparation of specimens and testing procedures used in this study. All the results were being presented in Chapter 4 while Chapter 5 focuses in the design guidelines of pavement using JKR Standard Specification for Road Work. All the calculations are performed using the MathCad software. Chapter 6 summarises the results, findings, and the achievement of the objectives as well as recommendations for the future works.

CHAPTER 2

LITERATURE REVIEW

2.1 General

This section presents the literature review from the published works which are relevant to the research topic and serve as background for the stabilization of soft soil with various admixtures.

2.2 Materials

Followings are the materials used throughout the study:

2.2.1 Clay

The AASHTO (M 145) soil classification system differentiates the type of soils, based on particle size and the Atterberg limits. The soil is considered either a silt or clay if 35% or more of the mass of the soil is smaller than 75 μm in diameter (Little and Nair, 2009).

Clay is the soil passing through a No. 200 (75 μm) sieve where the particle size range is lower than 0.002mm (Dunn et. al, 1980) that can be made to exhibit plasticity within a range of water contents and exhibits considerable strength when air dry. Clay is also classified as a fine grained soil, with a plasticity index equal to or greater than 4 and the plot of plasticity index versus liquid limit falls on or above the “A” line (see Figure 1).

While, in wet condition and subject to any loading, clay soil has high compressibility as it has particle size less than 0.002 mm. It is therefore inappropriate to build structure on clayey soil and it has to be stabilized first to achieve higher strength for supporting the structure built on it. When saturated, clay subgrade may provide inadequate support regarding to the loads transfer on it.

Silt is the soil passing through a No. 200 (75 µm) sieve where the particle size range is between 0.002 to 0.0075mm (Dunn et. al, 1980) that is non-plastic or very slightly plastic and that exhibits little or no strength when air dry. It is also a fine-grained soil with the plasticity index less than 4, and the plot of plasticity index versus liquid limit falls below the “A” line (see Figure 2.1).

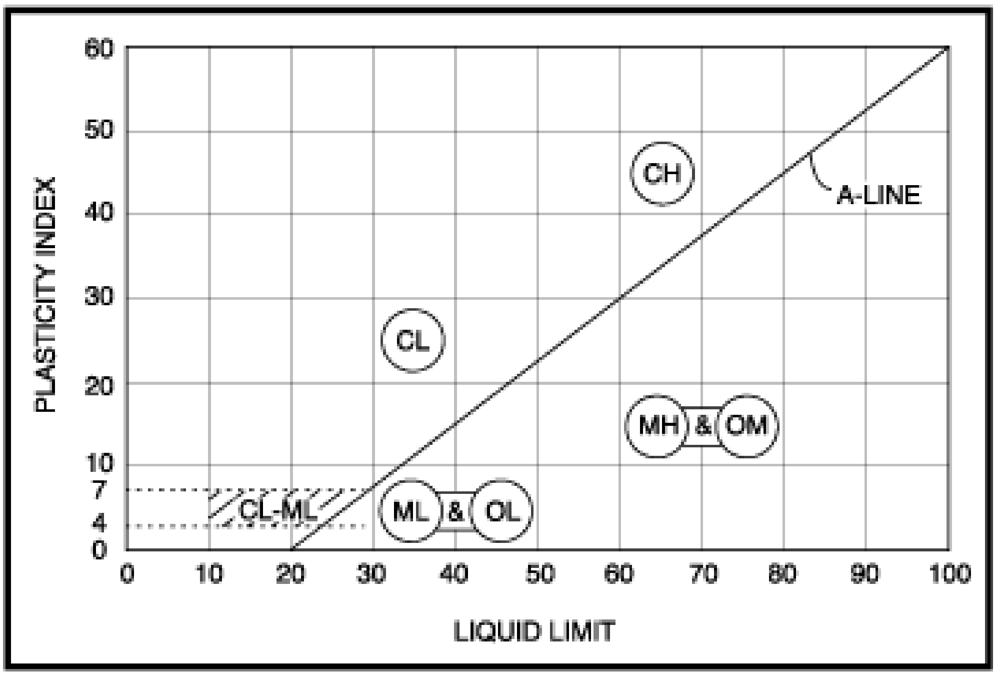

Figure 2.1: Plasticity chart

2.2.2 Cement

Portland cement is a manufactured material and has been used widely as a soil stabilizer. Portland cement was first developed in the early to mid-1800s (Mindes et. al, 2003; Parson et. al, 2003) and basically it is a compound containing calcium, silica, alumina, and iron that hydrate to form cementitious product (Little & Nair, 2009; TxDot, 2005). The mixture of Portland cement and soil has increasingly used in recent years in order to stabilize soils especially for the construction of highways (Dunn et. al, 1980).

Parker (2008); PCA, (1995); Terrel et al. (1979) stated that cement stabilization mechanisms are well documented in the literature. There are two basic reactions occurs in cement stabilization which are hydration reactions and pozzolanic reactions. Hydration reactions will occur when water is combined with cement, and this will gain the strength of the cement-treated material as well as the pozzolanic reactions that contribute to the strength of a specimen (Parker, 2008).

A guideline for Modification and Stabilization of Soils from Texas Department of Transportation also agreed with the statement where they stated that cement which contains calcium, silica, alumina, and iron compounds will resulting into new compound when combined with water, which will lead to enhance the strength-producing properties due to hydration. When it is mixed with soil, the particle compounds bounds together and the mixture increases in strength and moisture resistance.

Trivedi et. al (2013) also stated in her study that mixing weak soil with Portland cement and water will gives a strong material. It is pointed in various research that Portland cement has successfully used in stabilizing the fine grained silt and clay soils with a certain concentrations to achieve some engineering properties (Little & Nair, 2009; Trivedi et. al, 2013). Based on the Table 1 from Veisi et. al. (2010), it shows that the cement requirements for clay soil is 7 % of the dry weight while for silty soil the amount of cement required is 9%.

Some experimental work also done by Veisi et. al (2010) and they come out with findings that consist of typical cement contents for moisture-density and durability test. The typical range of the cement for various type of clayey and silty soil are also shown in Table 2 where for silty clay (AASHTO soil classification as A-5), the typical range of cement required by weight is 8% to 13 % while for clay soil (A-6 and A-7), it is around 9% to 16% by weight of the cement. With unconfined compressive strength and durability tests performed on the specimens as shown in Table 3, the study shows the strength development for soil-cement mixture where the strength achieve for 7 day soaked compressive strength of silty soil are around 250 psi to 500 psi while for 28 day soaked, the strength are a bit higher with the value of 300 psi to 900 psi. On the other hand, compressive strength development for 7 day soaked clay soil-cement mixture are 200 psi to 400 psi and for 28 day soaked compressive strength shows that it can reach 250 psi to 600 psi of the strength.

However, Office of Geotechnical Engineering, Indianapolis argued of the cement quantities in their report published on 2008 as they come out with suggestion of the required cement quantity as 4% to 6% from the dry mass of the soil. Also from their research, they stated that ”strength gain of 100 psi (700 kPa) for a soil-cement mixture over the natural soil shall be considered adequate for cement stabilization with 4% cement by dry weight of the soils”.

A study by Munfakh and Wyllie (2000) has stated that both the strength and the permeability of the treated soils are influenced by the quantity of cement in the ground which in turn will influenced the controlled volumes of the cement mixture with water and also the additives. The statement also agreed by Little and Nair (2009), where according to them,