KUANTAN CLAY SUBGRADE STABILIZATION BY USING FLY ASH AS STABILIZER.

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Report submitted in partial requirement of the requirement
for the award of the degree of
Bachelor of Civil Engineering and Earth Resources.

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JUNE 2012

ABSTRACT

Roadways and highway have a high potential for large volume use of fly ash stabilized soils. The main objective of this study is the utilization of fly ash to improve the subgrades material in highway construction. The study conducts various content of fly ash to the sample of clay soil collected along Kuantan – Pekan road. Compaction test and California Bearing Ration (CBR) test were conducted in the laboratory to determine the optimum mixture design. The sample were set up by mixing soil samples with various content of fly ash at different water content in compaction test to obtain optimum dry unit weight and optimum water content. The optimum water content were used in CBR tests of mixture of soil sample-fly ash. The performance analysis of fly ash stabilized soil should be based on laboratory test such as engineering properties of soil, compaction test and CBR test. The strength gain in stabilization is depend on two factors which is fly ash content and water content. The variation content of fly ash were 3%, 6%, and 9% by total weight. From the test, the fly as stabilization increased the CBR values for the mixture tested and has the potential to offer an alternative for clay soil subgrades improvement of highway construction.

ABSTRAK

Jalan raya dan lebuhraya mempunyai potensi yang tinggi untuk pengunaan tanah yang stabil dengan menggunakan abu terbang. Objektif utama kajian iini adalah untuk mengkaji penggunaan abu terbang untuk memperbaiki bahan subgred dalam pembinaan lebuh raya. Kajian ini dijalankan ke atas pelbagai kandungan abu terbang terhadap sampel tanah liat yang diambil pada jalan Kuantan – Pekan. Ujian-ujian seperti ujian pemadatan dan California Bearing Ratio (CBR) telah dijalankan di makmal untuk menetukan reka bentuk campuran yang optimum. Sampel-sampel dihasilkan dengan mencampurkan tanah liat dengan pelbagai kandungan abu terbang pada kandungan air yang berlainan dalam ujian pemadatan untuk mendapatkan dry unit weight dan kandungan air yang optimum. Kandungan air optimum tersebut akan digunakan dalam ujian CBR ke atas campuran tanah liat bersama abu terbang. Analisis tentang prestasi tanah perlu berdasrkan ujian makmal seperti ujian sifat kejuruteraan tanah, ujian pemadatan dan ujian CBR. Kekuatan yang diperolehi semasa penstabilan tanah bergantung kepada dua factor iaitu kandungan abu terbang dan kandungan air. Variasi kandungan abu terbang yang digunakan adalah 3%, 6%, dan 9% oleh jumlah berat tanah. Hasil daripada ujian, penstabilan tanah dengan menggunakan abu terbang dapat meningkatkan nilai CBR dan mempunyai potensi sebagai alternatif untuk penambahbaikan subgred bagi pembinaan jalan raya dan lebuhraya.

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
CBR	California Bearing Ratio
OPC	Ordinary Portland Cement
CCPs	Coal Combustion Products
USCS	Unified Soil Classification System
BSCS	British Soil Classification System
FGD	Flue Gas Desulphurization
ASTM	American Standard Testing Method
LOI	Lost on Ignition
PCC	Portland Cement Concrete
LL	Liquid Limit
PL	Plastic Limit
PI	Plasticity Index

LIST OF SYMBOLS

%	Percentage
SiO_2	Silicate
Al_2O_3	Alumina
CaO	Calcium Oxide
SO_4	Sulfate
mm	Milimeter
kg	Kilograms

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

A soft sub grade in construction of roadways is one of the most frequent problems for highway construction in many parts of the world. In Pahang, Malaysia, these problems are also frequently encountered, especially at Kuantan-Pekan region. The usual approach when soft sub soil encountered is removes the soft soil, and replaces it with stronger materials likes crushed rock. The high cost of replacement causes highway contractors to explore alternative methods of highway construction on soft sub grades. One approach is to use chemical to stabilize the soft sub grade. Instead of using chemical product, recycled, reused material, Portland cement and lime or mixed of them are may offer more economical alternatives for a wide range application of soil stabilization. Soil stabilization using recycle and reused material besides to improve the engineering characteristics also performance of a soil and preservation with the goal of eliminating all environmental concerns is a serious matter (*Cabrera, J.G., and Woolley, G.R. 1994*). The engineering properties of some Kuantan Clay soils were high plasticity material, classified as A-7-6 by AASHTO Classification System (*Fauzi, A, et al., 2010*). Those engineering properties quality improved by adding Portland cement, fly ash and bottom ash as stabilizer in soil stabilization. Portland cement, fly ash and bottom ash soil stabilization increased the CBR values substantially and for addition of lime, this will contribute towards the improvement of soil workability but not to increase in CBR value (*Fauzi, A, et al., 2011*).

Highway subgrade may be defined as the supporting structure on which pavement and it is special under courses rest. Subgrades are commonly compacted before the construction of a pavement, and are sometimes stabilized by the addition of asphalt, soil cement, Portland cement or lime. It is the foundation of the pavement structure, on which the subbase is laid. Preparation of the subgrade for construction usually involves digging, in order to remove surface vegetation, topsoil and other unwanted material, and to create space for the upper layer of the pavement. This process is known as subgrade formation or reduction to level. The usual approach taken by contractors to soft subgrades stabilization is removes the soft soil, and replaces it with stronger materials likes crushed rock. The high cost of replacement caused highway contractors to assess alternative methods of highway construction on soft subgrades. One approach is to use chemical to stabilize the soft sub grade. Instead of using chemical product, fly ash is one of the products that offer more economical alternatives for a wide range of soil stabilization applications.

1.2 BACKGROUND OF STUDY

Nowadays, the use of recycled materials as subgrades stabilizers are gaining popularity and development because of increasingly stringent environmental legislation. Furthermore, there is significant research on many different materials used for subgrade stabilizers such as Ordinary Portland Cement (OPC), lime, Coal Combustion Products (CCPs), and many others material. For example, in United States, approximately 90% of the coal used is burned to produce electricity. The process results in the production of about 128.7 million of coal combustion products (CCPs) annually (*ACAA 2003*). Over 60 % of the coal combustion products (CCPs) will be send to landfill.

A large fraction of the coal ash of the total production is typically disposed of as a waste in utility disposal sites. Beneficial use of coal ash in construction projects requiring large material volumes, such as highway embankment construction, highway subgrades stabilizers offers an attractive alternative to disposal because substantial economic savings can be attained by the reduction of ash disposal costs and the conservation of natural soils and lands.

1.3 PROBLEM STATEMENT

Engineering properties of soil in Malaysia are different according to type of soil. Some soil will have different plastic limit, liquid limit, shear strength and others according to their type. The engineering properties of some Kuantan Clay soils were high plasticity material, classified as A-7-6 by AASHTO Classification System (*Fauzi, A, et al., 2010*). Those engineering properties quality improved by adding Portland cement, fly ash and bottom ash as stabilizer in soil stabilization. Portland cement, fly ash and bottom ash soil stabilization increased the CBR values substantially and for addition of lime, this will contribute towards the improvement of soil workability but not to increase in CBR value (*Fauzi, A, et al., 2011*).

In modern societies where very large quantities of industrial waste like fly ash is produced. It is very important to find uses for these waste products wherever possible. Therefore, fly ash can be used as stabilizer for road work especially for subgrade stabilization. The developed mixture of soil and fly ash must possess adequate strength and durability, should be easily compacted, and should be environmentally friendly. Roadways have a high potential for large volume use of the fly ash stabilized soils.

The two general methods of stabilization are mechanical and additive. The effectiveness of stabilization depends upon the ability to obtain uniformity in blending the various materials. Mixing in a stationary or travelling plant is preferred, however, other means of mixing, such as scarifies, plows, disks, graders, and rotary mixers, have been satisfactory. The method of soil stabilization is determined by the amount of stabilizing required and the conditions encountered on the project.

1.4 OBJECTIVES OF STUDY

The objectives of the study are:

i. To investigate the engineering properties of Kuantan stabilized soil.

ii. To demonstrate the stabilized of Kuantan Clay by using fly ash.

iii. To determine the optimum content of stabilizer those give the maximum strength.

1.5 SCOPE OF STUDY

In this project samples are collect along Kuantan-Pekan highway. Laboratory testing will be held to obtain the required parameters. Testing program include test of engineering properties of original soil, engineering properties of stabilized soil (such as Sieve Analysis, Atterberg Limit, and Specific Gravity), compaction test which is Standard Proctor Test, and California Bearing Ratio test (CBR). The testing procedure is following the AASHTO Standard or British Standard or Malaysian Standard. Qualitative method are using in analyze the data and supporting by computer. The proportions of the fly ash introduced in the soil sample are 3%, 6%, and 9%.

1.6 SIGNIFICANT OF STUDY

The study will serve at the good application of highway and geotechnical engineering theories into practice by giving the opportunity for the student to conduct site investigation, to carry out laboratory testing for the analysis of the sample, to determine performance of fly ash as stabilizers in highway subgrades. The data collected can then be forwarded to the owner/contractor of the project for their consideration and this will also serve as one of the community service from University Malaysia Pahang.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will present about the theoretical part of the research. This chapter also present some of the researches that have been conducted which related to the research.

2.2 PHYSICAL PROPERTIES OF SOIL

Soil is consisting largely of mineral matter formed by the disintegration or decomposition of variety of rock either from igneous rock, sedimentary rock or metamorphic rock. The disintegration to soil may be caused by the action of water, ice, frost, or temperature changes, or by plant or animal life. In most instance, soils are blends or mixture of particles of many sizes, shapes, and parents materials. Different types of soils exhibit diverse behaviour and physical properties.

2.3 SOIL CLASSIFICATION

Basically, soil may be separated into three board categories; cohesionless, cohesive, and organic soil. These three terms always has been use widely by engineer to distinguish between the different types of soils. In term of grain size, soil can also be separated by two categorize which is course-grained soil and fined-grained soil.

In order to be able to describe, in general, a specific soil without listing value of its many soil parameter, it would be convenience to have some kind of generalized classification system. Some soil classification system is available at present i.e. Unified Soil Classification System (USCS), Association of State Highways and Transportation Officials (ASSHTO), and British Soil Classification System (BSCS). For highway work, the ASSHTO soil classification system is widely been used.

In the case of most cohesionless soils, distribution of grain size can be determined by sieve analysis. Generally, it is a screening process in which coarse fraction of soil are separated by means of series of U.S Standard Sieves Number.

Table 2.1 : Soil Classification Based On Grain Size.

Types	Agency	USCS	AASHTO
Coarse-Grained	Gravel	Coarsed : 75 - 19.00mm (3 in. - ¾ in. Sieves) Fine : 19 - 4.74mm (¾ in. – No. 10 sieves)	75 – 2.00mm (3 in. – No. 10 sieves)
	Coarse Sand	4.74 - 2.00mm (No. 4 - N0.10 sieves)	2.00 – 0.425mm (No. 10 – No. 40 sieves)
	Medium Sand	2.00 - 0.425mm (No. 10 – No. 40 sieves)	
	Fined Sand	0.425 – 0.075mm (No. 40 – No. 200 sieves)	0.425 – 0.075mm (No. 40 – No. 200 sieves)
Fine-	Silt	Fines < 0.075mm	0.075 – 0.002mm

Grained	Clay	(silt or clay)	< 0.002mm

In the case of cohesive soil, the distribution of grain size cannot be determined by sieve analysis because the particles of soil are too small. The particles sizes may be determined by the hydrometer method, which is a process for indirectly observing the settling velocities of the particles in soil water mixture. However, this test is more complicated and difficult to conduct. Another technique for analyzing cohesive soils is by use of atterberg limit.

2.4 SOIL STABILIZATION

In constructing of Civil Engineering Project especially in highway, airport, dam, slope stability project often met bad condition of soil such as loose sand, soft clay, highly organic deposit or dumped heterogeneous material. That condition forced the engineer to do alternative solution to avoid construction failure and increase of cost. One of the solutions is to improve the characteristics at site and make soil capable of carrying load and to increase the shear strength decrease the compressibility of the soil. Soil Stabilization was one of the well known methods in ground improvement. Clay soil can be stabilized by addition small percentage of stabilizer such as coal combustion products such as fly ash and bottom ash, Portland cement, lime, asphalt or other chemical agent. The objective of the soil stabilization is improving engineering properties quality and in increases the soil strength.

The two general methods of stabilization are mechanical and chemical stabilization. The effectiveness of stabilization depends on the ability to obtain the uniform in blending various materials. Mixing in a stationary or travelling plant is prefer. However, other types of mixing such as scarifies, plows, disks, graders, and rotary mixers, have been satisfactory (*Muyad, 2007*). 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.

In the construction and maintenance of transportation facilities, geomaterials like soil and rocks must be stabilized through chemical and mechanical processes. Chemical stabilization includes the use of chemicals and emulsion as compaction aids to soil as binders and water repellents and ultimately modifying the behaviour of soil. It is also includes deep mixing and grouting. Chemical stabilization can aid in dust control on roads and highway, especially unpaved roads, in water erosion control, and in fixation and leaching control of waste and recycled materials (*Graves and Smith, 1988*).

Mechanical stabilization includes compaction, and fibrous and other non biodegradable reinforcement of geomaterials to improves strength. In applying these techniques, it is necessary to ensure the properties of stabilized materials and their mixture as applicable for use in the design of foundation, embankments, shoulders, subgrades, bases and surface courses.

However, as technology advance and economic condition change, many more chemical agents will be introduced into subgrade to improve their compactability, durability, and strength. At the same time, more performance testing will be held to prove the effectiveness of these stabilization agents. In addition, there are chemicals being use today in the petrochemical industry whose use in soils is as yet unexplored. Application of recycled and waste products has improve chemical and mechanical stabilization techniques. Such waste materials as crushed old asphalt pavement, copper and zinc slag, paper mill sludge, and rubber tire chips (*Osipov and Dilimonov, 2002*).

Past research has shown that the strength and load bearing capacity of subgrade and base course materials can be improve through the inclusion of non-biodegradable reinforcing materials such as fibres, geotextiles, geogrids, and geocomposites. Use of these materials can improve the performance and durability of future highway and may reduce the cost of construction. Since many of the traditional materials design criteria are empirical and inappropriate, increased emphasis is likely to be placed on the development of mechanistic evaluation test and technique for stabilized materials (*Chaddock, 1996*).

2.5 SOIL STABILIZATION BY USING ADMIXTURE

The important engineering properties of soil can be economically improves by using admixture or stabilizer. The admixture or stabilizer used includes lime, Portland cement, asphalt, coal combustion products which are fly ash, bottom ash, boiler slag, and flue gas, polymers, salt (Sodium Chloride) and others. The procedure of soil stabilization involves the mixing of admixture with the soil with appropriate quantity which changes its soil properties and then applying adequate degree of compaction to the stabilized soil. This soil stabilization method is applicable for soils in the base course of roads, airfield pavements, shallow foundation and other else.

2.6 COAL COMBUSTION PRODUCTS (CCPs)

CCPs are the solid materials that not use during the combustion of coal. There are four types of CCPs which are fly ash, bottom ash, boiler slag and flue gas desulphurization (FGD) material. The amount and types of CCPs material produced depend on the type of boiler, the source of the coal, and the type of emissions controls installed. Modern interests in the use of coal ash as a building material started in Europe after World War II. By the 1950s and 1960s, power plants were collecting their fly ash and identify a number of beneficial uses such as a pozzolanic admixture in concrete and for soil improvement (*Mateos, 1964; Joshi et al. 1975*). Fly ash is the most CCPs material generated and beneficially recycled. Currently, fly ash and bottom ash are the most widely used CCPs materials in highway construction.

2.7 FLY ASH

Fly ash is one of the solid material generated in combustion, and consist of fine particles that rise with the flue gases. The quantity of fly ash generated per year worldwide was expected to exceed 100 million tons by the year 2000 (*Sridharan et al. 1996*). As the time fly by, there will more than 100 million tons of fly ash generated till now. Fly ash consists of silt-sized particles which are generally spherical, normally ranging in size from 10 to 100 micron. These small particle, which are finer than Portland cement or lime, improve the fluidity and workability of fresh concrete. The properties of this industrial solid waste mainly depend on coal quality and combustion technique (*Cabrera and Woolly, 1994*). Fineness is one of the important properties contributing to the pozzolanic reactivity of fly ash. The presence of SiO2 and Al2O3 in amorphous form in fly ash contribute towards its pozzolanic property.

McCallister and Petry (1991) showed in laboratory testing that stabilisation with an small amount of lime could prodice improvements in soil behaviour that is not permanent. Laboratory research by Parsons and Milburn (2003a) showed some evidence that the plasticity of fly ash stabilised soils can also revert to native levels with leaching. However, Ferguson and Zey (1992) found that fly ash stabilised soils performed well in the field after a period of two years.

2.7.1 Fly Ash Class C

Fly ash is divided into two categories based on the chemical composition: Class C and Class F (*ASTM C618-03 2003*). Class C fly ash is derived from subbituminous and lignite coal and contains more than 20 percent calcium oxide (CaO) and 1 to 3 percent free lime. That making Class C fly ash self-cementing. In the presence of water, Class C fly ash will harden and gain strength over time. Unlike Class F, self-cementing Class C fly ash does not need an activator. This is because alkali and sulfate (SO_4) contents are generally higher in Class C fly ashes.

2.7.2 Fly Ash Class F

Class F fly ash is got from bituminous and anthracite coal and contains less than 10 percent CaO and no free lime (*USDOT, 1998*). It is also not self-cementing. With the pozzolanic properties, Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. In addition, the addition of a chemical activator such as sodium silicate to a Class F ash can lead to the formation of a geopolymer.

Loss On Ignition (LOI) is a measurement of the unburned carbon that remain in the ash and is considered the most critical characteristic of fly ash as far as its suitability for use as an additive in concrete. High LOI values can causing air problems in fresh concrete and it will affecting durability of the concrete. For this reason, current ODOT specifications restrict the LOI to 3% (*ODOT 2003*).

2.8 BENEFICIAL USE OF CCPs IN HIGHWAY ENGINEERING

Currently, typical highway engineering CCPs applications include: the use of fly ash in Portland cement concrete (PCC), and fly ash and/or bottom ash in soil and road base stabilization, flowable fills, grouts, structural fill and asphalt filler.

2.8.1 CCPs Application in Subgrade Stabilization

The modification of soil properties by chemical, thermal, mechanical and other means to meet specific engineering requirements is known as soil stabilization (*Ingles and Metcalf, 1972*). Various organic and inorganic materials have been investigated as stabilization agents for subgrade soils. Lime or cement has been traditionally used alone to improve subgrade soil (*Diamond et al. 1965; Druss 2003*). Studies and some recent practice have shown that Class C fly ash and Class F-lime product blends can be used in numerous geotechnical applications common in highway construction including enhancing strength properties, stabilizing embankments, controlling shrink swell properties of expansive soils and reducing soil moisture contents (*Chu et al 1955; Ferguson, 1993; Çokça, 2001*) . When appropriately designed and constructed, lime-fly ash stabilization can offer cost savings by reducing material costs by up to 50% as compared to Portland cement stabilization (*Beeghly, 2003*).

The primary reason fly ash is used in soil stabilization applications is to improve the compressive and shearing strength, and resilient modulus of subgrade soil. The results from a previous laboratory study on Class F ash conducted at The Ohio State University (*Lee, 2003*) show that the lime-fly ash-stabilized soils had lower liquid limits, higher unconfined compressive strengths compared to the control soils which is the untreated soils. The Engineering properties and strength properties of Kuantan clay and Kuantan clay stabilized with stabilizer have to utilized to improve the road structure quality, decrease thickness and decrease cost of construction in Kuantan state significantly (*Fauzi et al. 2011*)

2.9 BENEFITS OF FLY ASH STABILIZATION

There are a lot of benefits of using fly ash as the medium for soil stabilization. The primary benefits of using fly ash for soil stabilization are :

i. Environmental incentives, because materials used does not have to be wasted;
ii. Cost saving, because fly ash is typically cheaper than cement and lime;
iii. Availability, because fly ash sources are distributed geographically across state.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter discuss about the methodology of the research. The study is to come up to investigate the engineering properties of Kuantan stabilized soil, to demonstrate the stabilized of Kuantan Clay by using fly ash, and to determine the optimum content of stabilizer those give the maximum strength.

For this study, data from testing and physical properties of soil were collected from a number of journals. Among the physical properties of soil test collected were particle size distribution, atterberg limit, density and moisture content. These soil data were obtained from the soil investigation. The laboratory test were conducted to solidify the hypothesis.

From this research, the expected results are utilization of engineering properties of soil and stabilized of soil by using fly ash by Civil Engieer, basic engineering data for developing research in ground stabilization, and optimum content of stabilizers for subgrade stabilization. To get those expected result, there will be methods to follow. The study will be implemented in stages as shown in Figure 3.1.