WALKWAY SUBGRADE STABILIZATION USING FLY ASH

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ABSTRACT

This thesis is about the walkway subgrade stabilization using fly ash. Fly ash has been used as an additive which can improve the stabilization of subgrade. The objective of this thesis is to conduct testing in order to ascertain the engineering properties of soil and to determine the optimum moisture content of fly ash that give maximum CBR value for 5%, 10% and 15% soil-fly ash mixture. The effectiveness towards the soil by using different percentages of fly ash which is 5%, 10% and 15% was tested. For this research, a few laboratory tests were carried out to determine the improvement in the soil stabilization by using fly ash. From the result of the experiment, it can be concluded that the CBR value increases when the percentage of fly ash used in the soil mixture increases. This shows that the increases in amount of fly ash increases the compression and shearing strength of the soil and hence makes the subgrade to be more stabilized.

ABSTRAK

Tesis ini adalah mengenai penstabilan subgred pejalan kaki dengan menggunakan *'fly ash'*. *'Fly ash'* telah digunakan sebagai bahan tambahan untuk meningkatkan penstabilan subgred. Objektif tesis ini adalah untuk mengetahui ciri-ciri tanah yang digunakan dan untuk menentukan kandungan lembapan optimum 'fly ash'yang memberikan nilai CBR yang maximum bagi 5%, 10% dan 15% campuran tanah dan 'fly ash'. Keberkesanan terhadap tanah telah dikaji dengan menggunakan kandungan 'fly ash' sebanyak 5%, 10% dan 15%. Dalam kajian ini, beberapa eksperimen telah dibuat untuk menentukan penstabilan tanah dengan menggunakan 'fly ash'. Melalui hasil daripada kajian, satu kesimpulan boleh dibuat iaitu nilai CBR meningkat apabila kandungan 'fly ash' dalam tanah juga meningkat. Ini menunjukkan yang peningkatan dalam kandungan 'fly ash' dapat menambahkan kemampatan dan kestabilan tanah dan ini secara tidak langsung menjadikan subgred lebih stabil.

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LIST OF SYMBOLS

AASHTO	- American Association of State Highway and Transportation Officials
ASTM	- American Society for Testing and Materials
CBR	- California Bearing Ratio
LL	- Liquid Limit
PL	- Plastic Limit
PI	- Plasticity Index
E	- Modulus

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Soil stabilization is the permanent physical and chemical alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a subgrade to support pavements and foundations. Soil stabilization involves the use of stabilizing agents in weak soils to improve its geotechnical properties such as compressibility, strength, permeability and durability. The components of stabilization technology include soils and or soil minerals and stabilizing agent or binders (Makusa, P.G., 2012).

Fly ash is a by-product from burning pulverized coal in electric power generating plants. During combustion, mineral impurities in the coal (clay, feldspar, quartz, and shale) fuse in suspension and float out of the combustion chamber with the exhaust gases. As the fused material rises, it cools and solidifies into spherical glassy particles called fly ash. The most-often-used specifications for fly ash are ASTM C 618 and AASHTO M 295.Two major classes of fly ash are specified based on their chemical composition resulting from the type of coal burned which are designated Class F and Class C. Class F is fly ash normally produced from burning anthracite or bituminous coal, and Class C is normally produced from the burning of subbituminous coal and lignite. Class C fly ash usually has cementitious properties in addition to pozzolanic properties due to free lime, whereas Class F is rarely cementitious when mixed with water alone (Ismail, N. K., Hussin, K., & Idris, M. S., 2007).

Fly ash has been used successfully in many projects to improve the strength characteristics of soils. Fly ash can be used to stabilize bases or subgrades, to stabilize backfill to reduce lateral earth pressures and to stabilize embankments to improve slope stability. Typical stabilized soil depths are 15 to 46 centimetres (6 to 18 inches). The primary reason fly ash is used in soil stabilization applications is to improve the compressive and shearing strength of soils. The compressive strength of fly ash treated soils is dependent on, in-place soil properties, delay time, moisture content at time of compaction and fly ash addition ratio (American Coal Ash Association, 2003).

Fly ash has been used as fill, mixed into fertilizer, mixed as a percentage of cement and asphalt, and is a soil stabilization device. Stabilized bases and sub bases are mixtures of aggregates and binders, such as Portland cement, which increase the strength, bearing capacity, and durability of a pavement substructure. Because fly ash exhibits pozzolanic properties, it can and has been successfully used as part of the binder in stabilized base construction applications. When pozzolanic-type fly ash is used, an activator must be added to initiate the pozzolanic reaction. Self-cementing type C fly ash does not require an activator (Robert J. Glazewski., 2004).

1.2 Problem Statement

Walkway is an important medium used for walking by the pedestrians and bicycle riders. Defect on walkway is caused by the improper stabilization of the subgrade and also due to lack of compaction. The defect on walkway not only causes difficulties to the pedestrians and bicycle riders but also to the disabled people when they have to go on the road to move from one point to another.

To solve this problem, fly ash can be used as a subgrade stabilization material in order to avoid defects on the walkway surfaces. The usage of fly ash in subgrade stabilization can improve the compressive and shearing strength of walkway. Although fly ash had been identified as material which can increase the workability of cement concrete, however its application in improving the soil stabilization of road pavement is less proven. Study on road pavement however is time consuming and the result may not be convincing since there are many avoiding factors such as season and environmental factors.

Therefore, this study will test the application of fly ash as the subgrade stabilization material for walkway. The effectiveness of soil is determined by using different percentages of fly ash which is 5%, 10% and 15%. In this research, a location in Ipoh, Perak near the ST. Philomena School has been identified to have walkway with rough and crack surface.

Figure 1.1: Defect on walkway

1.3 Objectives of Study

The objectives of this study are;

i) To conduct testing in order to ascertain the engineering properties of soil.

ii) To determine the optimum moisture content of fly ash that give maximum CBR value for 5%, 10% and 15% soil-fly ash mixture.

1.4 Scope of Study

This research is carried out according to the scope of study that is specified. The scope focuses on the effectiveness towards the soil by using different percentages of fly ash which is 5%, 10% and 15%. Several laboratory tests will be carried out to determine the improvement in the soil stabilization by using fly ash.

The California Bearing Ratio (CBR) method is used to test the strength of the subgrade soil with different amount of fly ash. If the CBR value is increasing by adding the fly ash to the soil there is effectiveness in increasing the soil strength and vice versa. Proper soil condition could contribute to the development of pedestrians' awareness in the value of walking and the cultivation of norms in walkway usage which gradually helps reduce the use of the automobile. Analysis and interpretation of data will be carried out resulting from the lab testing that will be done.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss on the literature review which is related to the title of the research, "*Walkway Subgrade Stabilization Using Fly Ash*".

2.2 Properties of Soil

Soil is the earth material that can be disaggregated in water by gentle agitation. Soils consist of grains (mineral grains and rock fragments) with water and air in the voids between grains. The water and air contents are readily changed by changes in conditions and location. Soils can be perfectly dry, be fully saturated or be partly saturated. Although the size and shape of the solid (granular) content rarely changes at a given point, they can vary considerably from point to point. Soil bed should bear all generated stresses transmitted by shallows or piles. The soil often is weak and has no enough stability in heavy loading (Amin Esmaeil Ramaji, 2012).

Soil properties refer to the mineral fraction of the soil which is made up of proportion of sand, silt and clay sized particles. Light soil refers to a soil high in sand relative to clay, and heavy soils are made up largely of clay. The texture of soil is important because it controls the amount of water the soil can hold, workability of soil and the rate of water movement through the soil. The three profile types of texture are uniform, texture-contrast and gradational. When there are changes in water content, problems like swelling, dispersing and collapse occurs (Rezaei et al, 2012).

Peat soils and organic soils are rich in water content of up to about 2000%, high porosity and high organic content. The consistency of peat soil can vary from muddy to fibrous, and in most cases, the deposit is shallow, but in worst cases, it can extend to several meters below the surface (Pousette et al., 1999; Cortellazzo and Cola., 1999; Ahnberg and Holm., 1999). Organic soils have high exchange capacity, it can hinder the hydration process by retaining the calcium ions liberated during the hydration of calcium silicate and calcium aluminate in the cement to satisfy the exchange capacity. In such soils, successful stabilization has to depend on the proper selection of binder and amount of binder added (Hebib and Farrell., 1999; Lahtinen and Jyrava., 1999, Ahnberg et al., 2003).

2.3 Stabilization of Soil

Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two (Sherwood, 1993). The simplest stabilization processes are compaction and drainage. The other process is by improving gradation of particle size and further improvement can be achieved by adding binders to the weak soils (Rogers et al, 1996).

The stabilized soil materials have a higher strength, lower permeability and lower compressibility than the native soil. The chief properties of soil which are of interest to engineers are volume stability, strength, compressibility, permeability and durability (Ingles and Metcalf, 1972; Sherwood, 1993; EuroSoilStab, 2002). Laboratory tests will help to assess the effectiveness of stabilized materials in the field. Results from the laboratory tests, will enhance the knowledge on the choice of binders and amounts (EuroSoilStab, 2002).

In order to obtain the desirable engineering properties of the soil, the soil improvement method is carried out in soft soils (silty, clayey peat or organic soils). The fine- grained granular materials are easiest to stabilize due to the large surface area in relation to their particle diameter. A clay soil compared to others has a large surface area due to flat and elongated particle shapes. On the other hand, silty materials can be sensitive to small change in moisture and, therefore, may prove difficult during stabilization (Sherwood, 1993). In such soils, successful stabilization has to depend on the proper selection of binder and amount of binder added (Hebib and Farrell, 1999; Lahtinen and Jyrävä, 1999, Åhnberg et al, 2003).

2.3.1 Mechanical Stabilization

Mechanical stabilization is the simplest method of soil stabilisation. The process involves improving the subgrades of low bearing capacity by changing its gradation. Two or more types of natural soils are mixed to obtain a composite material which is superior to any of its components (S.Trivedi, Nair & Iyyunni, 2013). Mechanical stabilization is accomplished by mixing or blending soils of two or more gradations to obtain a material meeting the required specification. The soil blending may take place at the construction site, a central plant, or a borrow area. The blended material is then spread and compacted to required densities by conventional means (Guyer, 2011). Soil stabilization is attained by physical process where the physical nature of native soil particles is changed by induced vibration, compaction or by incorporating other physical properties such as barriers and nailing (Makusa, P.G., 2012).

2.3.2 Chemical Stabilization

Soil stabilization depends mainly on chemical reactions between stabilizer (cementitious material) and soil minerals (pozzolanic materials) to achieve the desired effect. Through soil stabilization, unbound materials can be stabilized with cementitious materials (cement, lime, fly ash, bitumen or combination of these). The selection of type and determination of the percentage of additive to be used is dependent upon the soil classification and the degree of improvement in soil quality desired (Guyer, 2011).

Cement Stabilization can be done by mixing pulverised soil and Portland cement with water after which compacting the mix gives a strong material. A well graded soil requires about 5% cement, whereas poorly graded; uniform sand may require about 9% cement. Lime Stabilization involves addition of lime to the soil for stabilisation of the soil. It is mostly useful for clayey soils. When lime reacts with soil, there is exchange of cations in the absorbed water layer and a decrease in plasticity of the soil occurs. The amount of lime required for stabilisation varies between 2 to 10% of the soil. Bituminous Stabilisation is generally done with asphalt as binder. As asphalts are normally too viscous to be used directly, these are used as cut-back with some solvent, such as gasoline. The amount of bitumen required generally varies between 4 to 7% by weight (S.Trivedi, Nair & Iyyunni, 2013).

2.4 Fly Ash

Fly ash is a by-product of coal fired electric power generation facilities; it has little cementitious properties compared to lime and cement. Most of the fly ashes belong to secondary binders; these binders cannot produce the desired effect on their own. However, in the presence of a small amount of activator, it can react chemically to form cementitious compound that contributes to improved strength of soft soil. Fly ashes are readily available, cheaper and environmental friendly. There are two main classes of fly ashes; class C and class F (Bhuvaneshwari et al, 2005, FM 5-410).

Fly ash is classified according to the type of coal from which the ash was derived. Class C fly ash is derived from the burning of lignite or sub-bituminous coal and is often referred to as “high lime” ash because it contains a high percentage of lime. Class C fly ash is self-reactive or cementitious in the presence of water, in addition to being pozzolanic. Class F fly ash is derived from the burning of anthracite or bituminous coal and is sometimes referred to as “low lime” ash. It requires the addition of lime to form a pozzolanic reaction (Guyer, 2011).

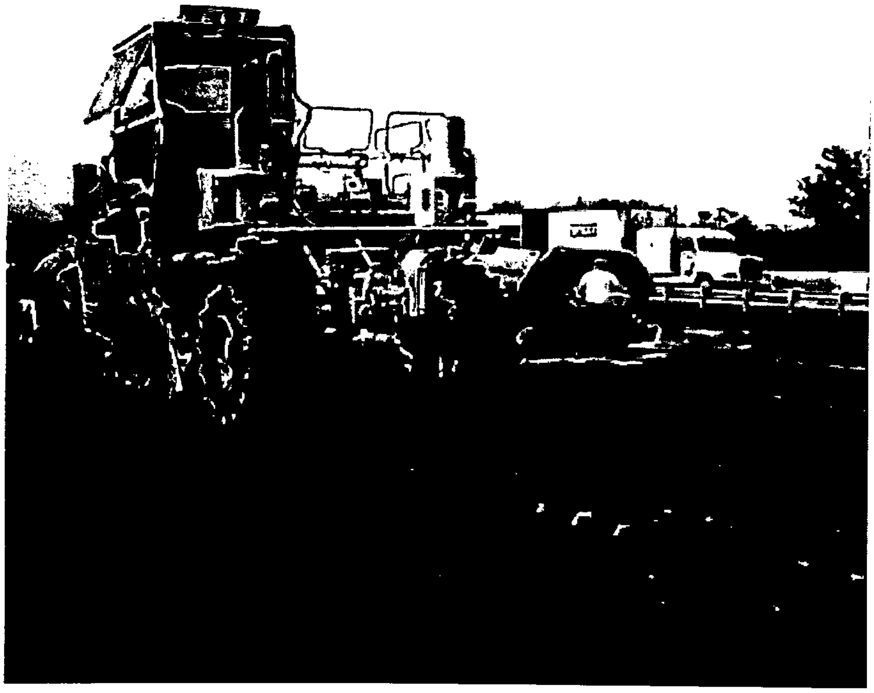

Figure 2.1: A road reclaimer mixes soil with moist conditioned fly ash (Beeghly, 2003)

2.4.1 Components of Fly Ash

Fly ash consists of fine, powdery particles that are predominantly spherical in shape, either solid or hollow, and mostly glassy, or amorphous in nature. The carbonaceous material in fly ash is composed of angular particles. The particle size distribution of most bituminous coal fly ashes is generally similar to that o f a sit, less than a 0.075 mm or No. 200 sieve. The specific gravity of fly ash usually ranges from 2.1 to 3.0, while its specific surface area may range from 170 to 1000 m^2 /kg. The colour of fly ash can vary from tan to grey to black, depending on the amount of unburned carbon in the ash. The lighter the colour, the lower the carbon content (Robert J. Glazewski., 2004).

Class C ashes are generally derived from sub-bituminous coals and consist primarily of calcium alumina sulphate glass, as well as quartz, tri calcium aluminate, and free lime (CaO). Class C ash is also referred to as high calcium fly ash because it typically contains more than 20 percent CaO. Class F ashes are typically derived from bituminous and anthracite coals and consist primarily of an alumina silicate glass, with quartz and magnetite also present. Class F, or low calcium fly ash has less than 10 percent CaO (American Coal Ash Association, 2003).

Table 2.1: Sample oxide analysis of fly ash (American Coal Ash Association, 2003)

Compounds	Fly Ash Class F	Fly Ash Class C
SiO_2	55	40
Al_2O_3	26	17
Fe_2O_3	7	6
CaO (Lime)	9	24
MgO	2	5
SO_3	1	3

2.4.2 Specifications for Fly Ash

The most-often-used specifications for fly ash are ASTM C 618 and AASHTO M 295.Two major classes of fly ash are specified in ASTM C 618 on the basis of their chemical composition resulting from the type of coal burned; these are designated Class F and Class C. Class F is fly ash normally produced from burning anthracite or bituminous coal, and Class C is normally produced from the burning of subbituminous coal and lignite. Class C fly ash usually has cementitious properties in addition to pozzolanic properties due to free lime, whereas Class F is rarely cementitious when mixed with water alone (Ismail, N. K., Hussin, K., & Idris, M. S., 2007). There are also wide differences in characteristics within each class. Despite the reference in ASTM C 618 to the classes of coal from which Class F and Class C fly ashes are derived, there was no requirement that a given class of fly ash must come from a specific type of coal. For example, Class F ash can be produced from coals that are not bituminous and bituminous coals can produce ash that is not Class F (Halstead, 1986).

2.4.3 Characteristics of Fly Ash

The morphology of the fly ash particles is studied using Cambridge Stereo scan 200. Examination under the scanning electron microscope showed that the samples had the usual fly ash morphology and were composed of mostly small, spherical particles. Fig. 2 shows SEM micrograph of the cenospheres particle. It can be noticed that the fly ash sample consists of almost regular spherical (cenospheres) particles ranging 2 um to 14 um in diameter. Fig. 2 shows micrograph of cenospheres particle. Usually, fly ash composed of mostly small and spherical particles (Swamy and Lambert, 1981).

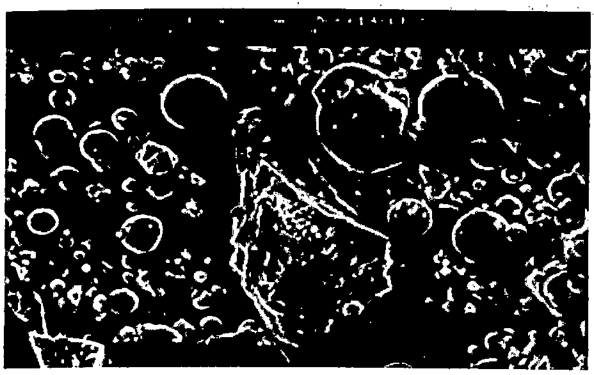

Figure 2.2: SEM micrograph for the cenospheres particle 2.20kx (Ismail, N. K., Hussin, K., & Idris, M. S., 2007)

2.4.4 Quality of Fly Ash

In addition to being handled in a dry, conditioned, or wet form, fly ash is also sometimes classified according to the type of coal from which the ash was derived. The principal components of bituminous coal fly ash are silica, alumina, iron oxide, and calcium, with varying amounts of carbon, as measured by the loss on ignition (LOI), which is a measurement of the amount of unburned carbon remaining in the fly ash. LOI is one of the most significant chemical properties of fly ash, especially as an indicator of suitability for use as a cement replacement in concrete (Robert J. Glazewski., 2004).

LOI is a measurement of unburned carbon (coal) remaining in the ash and is a critical characteristic of fly ash, especially for concrete applications. High carbon levels, the type of carbon (activated), the interaction of soluble ions in fly ash, and the variability of carbon content can result in significant air-entrainment problems in fresh concrete and can adversely affect the durability of concrete. AASHTO and ASTM specify limits for LOI. However, some state transportation departments will specify a lower level for LOI. Carbon can also be removed from fly ash. Some fly ash uses are not affected by the LOI. Filler in asphalt, flowable fill, and structural fills can accept fly ash with elevated carbon contents (American Coal Ash Association, 2003).

Fineness of fly ash is most closely related to the operating condition of the coal crushers and the grinding ability of the coal itself. For fly ash use in concrete