INVESTIGATION ON THE USE OF BOTTOM ASH AS ADDITIVE IN OPTIMIZING COST OF ROAD PAVEMENT STRUCTURE

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ABSTRACT

The main objective of this study is to find the relationship between the thickness of pavement with the percentage of bottom ash. The California Bearing Ratio (CBR) values are tested by adding 4% and 8% of bottom ash in pavement design as to determine thickness of the pavement using original sample and different percentage of additive. As the thickness of the pavement varies, the cost constructing the road pavement structure has been calculated for original, 4% and 8% of bottom ash. The CBR value of the sample increases from 4.40% to 8.71% as the percentage of bottom ash is increased by 4%. The addition of the original sample with 8% of bottom ash has increased the CBR value to 13.31. Overall, the addition of bottom ash to the original sample has increased the value of CBR thus decreasing the cost of constructing the road pavement structrure.

ABSTRAK

Tujuan utama kajian ini dijalankan adalah untuk mengetahui hubungan antara tebal struktur lapisan jalan dengan peratusan abu dasar. California Bearing Ratio (CBR) tersebut diuji dengan menambah 4% dan 8% daripada abu dasar dalam reka bentuk lapisan jalan raya bagi menentukan tebal lapisan jalan menggunakan sampel asli dan peratusan bahan tambah yang berbeza. Oleh kerana pelbagai tebal struktur lapisan jalan yang berbeza, kos untuk membina struktur lapisan jalan bagi penambahan 4% dan 8% bahan tambah telah dikira. Nilai CBR sample telah meningkat dari 4.40% ke 8.71% dengan penambahan 4% bahan tambah ke dalam sampel asli. Penambahan sebanyak 8% bahan tambah ke dalam sampel asli telah meningkatkan nilai CBR kepada 13.31. Kesimpulannya, penambahan abu dasar ke dalam sampel asli telah meningkatkan nilai CBR disamping mengurangkan kos pembinaan struktur jalan raya.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

All of civil engineering works such as the construction of highway or building structure do have a strong relationship with soil. It is important to ensure that the soil is strong enough to resist all of the structure build above it. The weakness and failure of soil may result in the structure from fail or collapse. Therefore, it is important to ensure that a proper soil investigation is done before a structure or a road been build. There are lots of types of soil which differ its soil properties from others. In order to have a very good knowledge on soil, sample need to be collected from the site and tested at laboratory in order to evaluate the properties of the soil sample. Besides, it is also necessary to do the in-situ test in order to get the overview of the sample in location.

For highway or pavement construction, California Bearing Ratio (CBR) test is one of the common tests used for determining the resistance of compacted soil to penetrate. This test was introduced by the California Division in Highways in 1930s which then been throughout the world. In designing the thickness of a pavement, CBR value is used. It is necessary to find the CBR value as it will affect the thickness of the pavement.

Nowadays, wastes from industries had increased through time. It is necessary to find solution on how we can benefit the use of this waste. Research by research has been done throughout the time. Some pozzolanic material has its own advantage which can help in improving the properties of soil for stabilizing purpose. An example of pozzolanic material which can be used in stabilizing soil purpose is bottom ash. This by product can be found easily and now been sell with low price as it is proven that some properties of the bottom ash can help in improving some aspect of engineering purpose.

Bottom ash is the slag that is deposited on the heat absorbing surfaces of the furnace and that subsequently falls into the furnace bottom. Based on this laboratory investigation, it is concluded that the properties of bottom ash compare favorably with conventional granular materials. It is obvious that utilization of such extensively produced by-products of the power industry as an economic highway material should be encouraged in the immediate future. It is recommended that the Indiana Department of Transportation proceed to schedule the construction of experimental sections of embankment and pavement using bottom ash (Wong Chee Ghun, 2009).

1.2 Problem Statement

In Malaysia, there are lack of site investigation been done as the budget is constraint. Site investigation does have cost very high as it will have to use expertise. High cost of the site investigation will also increase the total cost of the construction which make it not favorable to be done. Lack of site investigation for highway or pavement construction has results in the quality of work to be low. In this study, it is concern about determining the CBR value and the soil properties of a soil sample. CBR value of a soil sample is one of the most important parameter in pavement design as it can affect the thickness of the project. This study has been done due to lots of damage to the pavement which may be resulted from the subgrade. Jalan Sultan Abu Bakar in Kuantan had badly damaged which make the investigation been done. This study also concern about the properties of the soil which it can also affect the construction process.

1.3 Objective of Study

The objective of study is:

i. To find the relationship between thickness of pavement with the different percentage of bottom ash used

ii. To determine the cost of pavement construction for different thickness of pavement.

1.4 Scope of Study

This study is done based on the specific scope in order to ensure the precision of the study area. Besides, it is also done in order to achieve the objective of the study. Therefore, its limit has been specific to specific scopes which are

a) Site Location

The location of the project site is limited for Indera Mahkota. The road which had been chosen is along Jalan Sultan Abu Bakar.

b) Scope of work

In this project, sample are taken from the site and tested at the laboratory in order to determine the engineering properties of the soil samples, laboratory testing such as particle size distribution, moisture content and atterberg limit will assessing the characteristic of the soil samples.

c) Material properties

Scope of study for the material properties is soil embankment sample.

d) Sampling

For sampling purpose, only the undisturbed sample is taken from the site before it is labeled.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A soil engineer must have similar knowledge relative to soils. The soil properties is complicated by the fact that many soils are quire complex in nature, both physically and chemically, and that soil deposits are likely to be extremely heterogenous in character. It must remember d that the properties of any given soil depend not only on its general type but also on its condition at the time when it is being examined. The solution of problems in soil engineering requires a detailed knowledge of the mechanical properties of soils which are, perhaps, among the most complex materials to be studied from this point of view. The present paper endeavors to present a reasonably comprehensive account of the relations governing the response of soils to applied forces. An introductory presentation of the aspects involved and their place within the general framework of the study of material properties is followed by a discussion of relevant methods used in describing and classifying soils. A separate section treats the important subject of soil water and the factors influencing its movement through the channel network of the soil skeleton (Richard *et al*, 2004).

2.2 Soil Classification

Soil classification is a way of systematically categorizing soils according to their probable engineering characteristics. The classification of a soil is based on its particle distribution and, if the soil is fine-grained, on its plasticity (LL and PI). The most widely used classification systems used in road engineering are the unified soil classification system, AASHTO classification and British Standard Classification. Soil classification should only be regarded as a means of obtaining a general idea of soil behaviour and it should never be used as a substitute for detailed investigation of soil properties (Richard *et al*, 2004).

2.3 AASHTO System

The AASHTO Soil Classification System was originally proposed by the Highway Research Board's Committee on Classification of Materials for subgrades and Granular Type Roads (1945). According to present form of this system, soils can be classified according to eight major groups, A-1 through A-8, based on their grain-size distribution, liquid limit and plasticity indices. Soils listed in groups A-1, A-2, and A-3 are coarse-grained materials, and those in groups A-4, A-5, A-6, and A-7 are fine-grained materials,. Peat, muck and other highly organic soils are classified under A-8. They are identified by visual inspection. The AASHTO classification system (for soil A-1 through A-7) is presented in Table 2.3.1. Note that group A-7 includes two types of soil. For the A-7-5 type, the plasticity index of the soil is less than or equal to the liquid limit minus 30. For the A-7-6 type, the plasticity index is greater than the liquid limit minus 30 (M.Das, 2003). Table 2.1 shows the specification of soil using AASHTO Classification System.

2.4 Atterberg Limits

The Atterberg Limits are basic measure of the nature of a fine-grained of the soil, the fine-grained of the soil may appear in four states; solid, semi-solid, plastic and liquid. In each state the consistency and behaviour of soil is different and thus so are its engineering properties. Thus, the boundary between each state can be defined based on a change in soil behaviour (Qotrunnada, 2010)

Smith (1981) states that as moisture removed from fine-grained soil it passes through a series of states, which are liquid, plastic, semi-solid and solid. The moisture contents of soil at the points where it passes from one stage to the next are known as the consistency limits. (Kamarudin, 2005) These limits are defined by Kamarudin (2005) as:

i. Liquid limit (LL) – the minimum moisture content at which the soil will flow under its own weight.

ii. Plastic limit (PL) – the minimum moisture content at which the soil can be rolled into a thread 3 mm diameter without breaking up.

iii. Shrinkage limit (SL) – the maximum moisture content at which further loss of moisture does not cause the decrease in the volume of soil.

Das (2003) mentions that when a clayey soils is mixed with an excessive amount of water, it may flow like a semi-liquid. If the soil is gradually dried, it will behave like plastic, semi-solid, or solid material, depending on the moisture content. The moisture content, in percent, at which the soil changes from liquid to plastic state defined as the liquid limit (LL).

2.5 Soil Engineering Properties

2.5.1 Moisture Content

The engineering properties of a soil, such as the strength and deformation characteristics depend to a very large degree on the amount of voids and water in the soil. The moisture content is defined as the mass of water contained the soil in a sample compared with the oven-dry mass of the sample. It is customarily expressed as a percentage, although the decimal fraction is used in most computation. (Robinson, Richard; Thagesen, Bent, 2004)

Water is an extremely important constituent of soils. The moisture content is defined as the weight of water contained in a given soil mass compared with the oven-dry-weight of the soil and is usually expressed as a percentage. In the laboratory, moisture content is usually "wet" soil sample and the "oven-dry" soil. (Wright, Paul H.; Dixon, K.;, 2004). All weights are recorded in grams and the following expression is used to determine the moisture content:

$$w(\%) = \frac{W1-W2}{W2} \quad \textbf{[Equation 1]}$$

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2.5.2 Specific Gravity

"Specific gravity" (G), as applied to soils, is the specific gravity of the dry soil particles or "solids". The specific gravity is frequently determined by the pycnometer method, the determination being relatively easy for a coarse-grained soil and more difficult for the finer soils. Values for the specific gravity refer to the ratio of the unit weight of water at some known temperature (usually 4^0C) and range numerically from 2.60 to 2.80. Values of the specific gravity outside the range of values given may occasionally be encountered in soils derived from parent materials that contained either unusually light or unusually heavy materials (Paul *et al,* 2004).

2.5.3 Unit Weight

The unit weight of a soil is the weight of the soil mass per unit of volume and is expressed in pounds per cubic foot (kilograms percubic meter. As commonly used in highway engineering, the term wet unit weight refers to the unit weight of a soil mass having a moisture content that is anything different from zero, whereas dry unit weight refers to the unit weight of the soil mass in an oven-dry condition (Paul *et al,* 2004). The wet unit weight, dry unit weight and moisture content are related by the following expression:

$$\text{dry unit weight} = \text{wet unit weight}\frac{100}{(100+w\%)}$$ **[Equation 2]**

2.5.4 Shearing Resistance

Shearing resistance within soil masses is commonly attributed to the existence of "internal friction" and "cohesion". Paul (2004) has simplified the explanation which these properties is most easily accomplished by consideration of two extremely different types of soils which is cohesionless sand and highly cohesive clay in which the internal friction is assumed to be negligible.

Cohesionless sand

$$Sr = \sigma \tan \Phi \quad \textbf{[Equation 3]}$$

Highly Cohesive Soil

$$Sr = \sigma \tan \Phi + C \quad \textbf{[Equation 4]}$$

2.6 Compaction

If a small amount of water is added to soil that is then subjected to compaction by a given amount of energy, the soil will be compacted to a certain unit weight. If the moisture content the same soil is gradually increased and the compaction is done in the same way, the dry unit weight of the compaction will gradually increased. This is because the water behaves as a lubricant between the soil states. The increase in dry unit weight with the increase of the moisture content for a given soil will reach a limiting value beyond which further addition of water to the soil will results in reduction of dry unit weight (M.Das, 2003).

Compaction is the oldest and most common method for soil stabilization, at first being accomplished automatically as herd animals followed the same trails some of which are followed by the routes of modern highways (Richard *et al*, 2007).

Compaction has some obvious benefits. A compacted soil is harder, and can support some weight and shed water better than the same soil that has not been compacted. The extensive road system of the Roman Empire consisted attempted to compact soil with elephants, which not very efficient because elephants prefer to step in the same tracks. The modern version of the elephant walk is a "sheepsfoot roller" that emulates tracking by feet or hoofs, but does so randomly (Richard *et al*, 2007). A suitable compacting devices should be used in ensuring that the subgrade of a road could be compacted in proper way to avoid it from failed.

Compaction specification not only intended to control future volume changes of a soil, they also may be intended to increase the soil strength. It sometimes is assumed that higher density means higher strength. But this trend is trumped by the moisture content, compacting on the dry side of the OMC may leave the soil such that it can collapse under its own weight when wet with water, or too vigorous compaction on the wet side can shear and remould the soil (Richard *et al*, 2007).

Most of compacted soil is used in embankments for roads, highways or earth dams. In these applications, soil in the embankments not only should resist volume changes, it must have sufficient shearing strength that side slopes are stable and do not develop landslides (Richard *et al*, 2007). There are important in ensuring the road embankment is constructed properly in order to avoid the subgrade to fail in resisting load from traffic.

Compacted soil should be strong enough to support the upper structures which are subbase, base, and surface course. The strength of the compacted soil should be determined as it can be used in designing a good road. A strong compacted soil should have support structures beside minimize settlement that not only can affect the integrity of the structure but also that of connecting the utility line, a broken gas or water line or sewer that slopes the wrong way is more than just an inconvenience (Richard *et al*, 2007).

The soil compaction is not always harmful. Sometimes it is beneficial, for instance to increase the contact area between roots and soil particles to increase nutrient and water uptake. This can be achieved by using 'press wheels' or tractor wheels with low ground pressure. In order to be able to distinguish the needed compaction from the harmful, Gupta and Allmaras (1987) proposed the term excessive compaction (Alfredo *et al* 2004).

2.7 Standard Proctor Test

Proctor whose has designed this test had recognized that moisture content is a major variable influencing compaction, and therefore devised a test that isolates the role of moisture content by holding other variables constant. Compaction was accomplishes in the laboratory by ramming a soil into a standardized steel mould by using a standardized amount of energy, and it was discovered that there is an optimum moisture content that gives the highest density for a given compaction effort. If a soil is too dry more energy is required to attain a particular density, and it is too wet, no amount of energy will compact it to the same density. The optimum moister content is designated by OMC (Richard *et al,* 2007).