INVESTIGATION ON THE USE OF FLY ASH AS ADDITIVE IN OPTIMIZING COST OF ROAD PAVEMENT STRUCTURE, CASE STUDY AT JALAN SULTAN ABU BAKAR, INDERA MAHKOTA KUANTAN

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A reported submitted in partial fulfillment of the requirements for the award of the degree of
Bachelor of Civil Engineering

Faculty of Civil Engineering & Earth Resources
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DECEMBER 2010

ABSTRACT

Fly ash stabilization is one of the methods of soil stabilization. It is used in many fields in the world, especially in highway engineering since many years ago for changing the soil characteristics so that the soil becomes more suitable for road construction. The main objective of this study is to determine the relationship between the thickness of pavement with the percentage of fly ash and to determine the cost of pavement construction for different thickness of pavement structure. Subgrade stabilization is usually been done with addition of lots of material such as Portland Cement, lime, and bottom ash. The California Bearing Ratio (CBR) values including the addition of 4% and 8% of fly ash had been used in pavement design to determine thickness of the pavement using original sample and different percentage of additive. As the thickness of the pavement varies, the cost of constructing the road pavement structure has been calculated to get the minimum cost by comparing between the cost calculated for original, 4% and 8% of fly ash. From the CBR test result, the CBR value of the sample increase from 4.40% to 4.49% with increasing the percentages of additive. Overall, the addition of fly ash to the original sample has increased the value of CBR thus decreasing the cost of constructing the road pavement structure.

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LIST OF ABBREVIATION

AASHTO	-	American Association of State Highway and Transportation Officials
ADT	-	Average daily traffic
ASTM	-	American Society for Testing and Materials
CBR	-	California Bearing Ratio
CD	-	Consolidated drained
CU	-	Consolidated undrained
CU’	-	Consolidated undrained with pore water pressure measurements
ef	-	equivalence factor
ESAL	-	Total Equivalent Standard Axle Load
JKR	-	Jabatan Kerja Raya
LL	-	Liquid limit
n	-	Design period (years)
$\square_{op}$	-	Optimum moisture content
Pc	-	Percentage of commercial vehicles
PI	-	Plastic index
PL	-	Plastic limit
r	-	Estimate the rate of annual traffic growth
SSA	-	Specific surface area
T_A	-	Equivalent thickness
UU	-	Unconsolidated undrained
V_c	-	The total number of commercial vehicles
V_o	-	The initial yearly commercial vehicle traffic
$\gamma_{d.max}$	-	Maximum dry density

CHAPTER 1

INTRODUCTION

1.1 Research Background

Determination of most physical and chemical soil properties needs laborious and time-consuming laboratory tests. For those reasons, it is economically justified to develop methods which are capable of estimating some of them based on knowledge of other, already identified properties. When assessing the soil properties, one generally assumes that input data need to be split into more homogeneous soil groups. Seybold et al. (2005) attempted to estimate the location exchange capacity from organic C content, clay and silt content, and soil pH, by linear regression models.

The effect of initial porosity and moisture content on mechanical properties of soils and weak rocks was discovered many years ago. It became clear (Schmertmann, 1955; Graham and Li, 1985; Holtz et al., 1986; Leroueil and Vaughan, 1990; Wesley, 1990; etc.) that material structure significantly affects its mechanical properties. It was reported (Bjerrum, 1967; Mitchell and Sitar, 1982; Vaughan, 1985, etc.) that the nature of structural bonds of cohesive soils is a function of their origin.

Basically, the engineering definition of the word soil is a very broad one. Soil might be defined as all the earth material, both organic and inorganic, that blankets the rocks crust of the earth. Practically all soils are products of disintegration of the rocks of the earth's crust. The disintegration or 'weathering' has brought about action of chemical and mechanical forces that have been exerted on the parent rock formation for countless ages. Included among these forces are those of wind, running water, freezing and thawing, chemical decomposition, glacial action, and many others. The basic of soil properties are steel, wood, and concrete. The soil properties include the moisture content, specific gravity, unit weight, unit weight, shearing resistance and many more. (American Association of State Highway and Transportation Officials, Washington, DC, 2001)

Stabilization is used to improve the physical properties when inferior soils, gravel, crushed stones, ashes; slag etc. are used for road and aerodrome pavement construction. Mechanical stabilization is achieved by blending with suitably grade materials. In chemical stabilization, rigidity is imparted and the attraction of clay soils for water reduced by the formation of cementitious products in reactions between chemicals, lime and cement and soil mineralogical component. There are guides for determining the suitability for soils for stabilization without recourse to testing and decision to stabilize is usually based on the strengths developed when trial soil-stabilizing agent mixtures are compacted, aged and tested in unconfined compression or by the C.B.R. method; tensile strength determination, triaxial shear tests or durability tests are advocated by some investigator. *(J.B. Croft, 1968).*

Laboratory soil compatibility tests involve compaction in standardized ways at various moisture contents and plotting the relationship between dry density of solid particles (or unit weight) and moisture content. The moisture content at which compacted soil reaches the maximum dry density of solid particles is called optimum water content w_{opt}. The most common methods, which are applied for determining compaction parameters of fine-grained soils, are dynamic methods. The values, ρ_d max and w_{opt}, are obtained by Proctor's method (called the Standard Proctor test), with compaction energy corresponding to field compaction conditions by lightweight soil compactors, and the modified AASHTO method (also called the Modified Proctor test) with energy corresponding to field compaction by heavy compactors. (*Journal of Hazardous Materials* 151 (2008) 481–489)

The CBR design method for flexible airfield pavements was modified in 1971, on the basis of full-scale tests. A new load repetition factor and Equivalent Single Wheel Load computation scheme were introduced and implemented in the modified CBR design method. In the present paper, the method is extended to flexible highway pavements. The effect of loading conditions (which are different in highway and airfield pavements), is verified using AASHO Road Test results. The load repetition factor is then adjusted for the heavy traffic range. Pavement thicknesses obtained with the extended CBR design method are compared with those obtained with the current CBR method for highways, AASHO Road Test, SHELL and the British Roate Note 29. It is found that the extended CBR design method leads to: (1) A substantial reduction of pavement thickness as compared to the current CBR method; (2) A slightly thicker pavement in the light and medium traffic range and a slightly thinner pavement for heavy traffic as compared to other design methods. Design curves are presented for different subgrade CBR values. *(Ahmad S Simonovic, S P, 1985)*

1.2 Problem Statement

Road environment factor is one of the main factors that contributing the accident cases in Malaysia. Based on my observation Jalan Sultan Abu Bakar, Indera Mahkota, Kuantan roadway area, the road condition was very bad and not satisfactory. There is too much damage along the way road.

Poor maintenance of road such as potholes, water ponding debris on the road edges, settlement, pavement cracking, wrong road designing, drainage system, and low maintenances of construction works can cause the increasing number of accident.

The poor condition of road could probably cause by the unstable subgrade. The engineering properties of subgrade need to be taken into consideration as it influence the ability of subgrade to resist force or loading from the upper surface layer.

Generally in Kuantan, there are many types of soft soil. The soft soil is not suitable for construction work because their strength is not strong enough to cover and prevent the loading from upper surface to the subgrade soil. In any road in the world, especially in Malaysia at Kuantan, Pahang, the base layer is the critical part that should be obtains their strength so that there are not have any problems to the users.

Surfacing course of a road is the most expensive part of maintenance of a road. In order to avoid the surfacing course from damage easily, a good compaction for obtaining optimum moisture content (OMC) should be done. OMC of a soil would influence the percentage value of California Bearing Ratio (CBR). For this case study, it would come from a lower percentage value of CBR.

In other words, we must make sure that the soil under the road must be strong and available to use and if the soil is not full fill of criteria of the JKR road, we must upgrade the soil with some method to make sure the soil is safe to be use as road base.

1.3 Objective of Study

The objectives of study are:

i. To find the relationship between thickness of pavement with the different percentage of fly ash used.
ii. To determine the cost of pavement structure for different thickness of pavement

1.4 Scope of project

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:

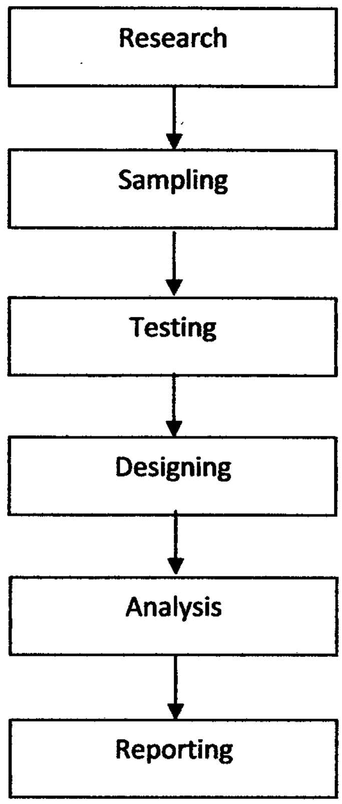

Figure 1.1: The flow chat for scope of work

i. Research

The research covers along 2 kilometers Jalan Abu Bakar, Indera Mahkota, Kuantan. Several sites which involved in soil embankment are visited.

ii. Sampling

Various type of soil is taken such as laterite, clay and etc.

iii. Testing

The sample is going test in field and laboratory to determine the engineering properties of soil and the optimum content of cement.

iv. Designing

The road will design according to the CBR value and the additive of the cement content in the subgrade and base.

v. Analysis

The sample will be analyzed base to the result and data

vi. Reporting

The conclusion base on the objective.

CHAPTER 2

LITERATURE REVIEW

2.1 Soil Properties

Soil properties are determined by field examination of the soils and by laboratory index testing of some benchmark soils. Established standard procedures are followed. During the survey, many shallow borings are made and examined to identify and classify the soils and to delineate them on the soil maps. Samples are taken from some typical profiles and tested in the laboratory to determine grain-size distribution, plasticity, and compaction characteristics. Estimates of soil properties are based on field examinations, on laboratory tests of samples from the survey area, and on laboratory tests of samples of similar soils in nearby areas. Tests verify field observations; verify properties that cannot be estimated accurately by field observation, and help to characterize key soils. *(Paul H. Wright, and Karen K.Dixon 2004)*

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 *(Monden, 1960)*

2.1.1 Moisture Content

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 determined by selecting s small representative sample soil and determining the weight of the 'wet' soil sample and the 'oven-dry' soil. If the void spaces in soil are completely filled with water, the soil is said to be saturated. The moisture content of soil may be than 100 percent or more, as might be the case in a saturated clay, muck, or peak soil. Water in soils may be present in its normal liquid form. As when filling or partly filling the voids of sand mass, or it may be present in the form of adsorbed water existing as films surrounding the separate soil particles, as in the case of the water remaining in dried clay mass. The water films existing in the latter case may have properties sharply differing from those exhibited by water in its normal form. Properties of fine-grained soils are greatly dependent on the properties and behavior of the absorbed water films. (Paul H. Wright, and Karen K.Dixon 2004). All weight is recorded in grams and the following expression is used to determine the moisture content:

$$w(\%) = \frac{W1 - W2}{W2}$$

2.1.2 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 soil particles to the unit weight of water at some known temperature (usually 4°C) 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 minerals. *(Paul H. Wright, and Karen K.Dixon, 2004)*

2.1.3 Unit Weight

The unit weight of soil is the weight of the soil mass per unit of volume and is expressed in pounds per cubic foot (kilograms per cubic 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 H.Wright and Karen K.Dixon, 2004). The wet unit weight, dry unit weight and moisture content are related by the following expression:

$$dry\ unit\ weight = wet\ unit\ weight \frac{100}{(100 + w\%)}$$

2.1.4 Shearing Resistance

Failures that occur in soil masses as a result of the action of highway loads are principally shear failures. Therefore, the factors that go to make up the shearing resistance within soil masses is commonly attributed to the existence of soil are importance. Shearing resistance within soil masses is commonly attributed to the existence of internal friction and cohesion.

A simplified explanation of these properties is most easily accomplished by consideration of two extremely different types of soils: first a cohesion less sand and second, highly cohesive clay in which the internal friction is assumed to be negligible. The shearing strength of most fine-grained soils decreases when their moisture content is increased and is frequently sharply reduced when their natural structure is destroyed. The interpretation of the factors influencing the shearing strength of cohesive soils is probably the most complex problem in soil mechanics, and no comprehensive explanation. Factors of importance include density, water content, and loss of strength with remolding, drainage conditions of the clay mass subjected to stress, variation of cohesion with pressure, and variation in the angle of internal friction. Paul H. Wright, and Karen K.Dixon, 2004 has simplified the explanation which these properties is most easily accomplished by consideration of two extremely different types of soils which is a cohesionless sand and a highly cohesive clay in which the internal friction is assumed to be negligible.

Cohesionless sand,

$$Sr = \sigma \tan \Phi$$

Highly Cohesive Soil,

$$Sr = \sigma \tan \Phi + C$$

2.1.5 Other Soil Properties

Several other soil properties, including those listed and briefly defined here, may influence the behavior of soil masses and affect the performance of highways subgrades and structure foundations.

Permeability is the property of a soil mass that permits water to flow through it under the action of gravity of some gravity or some other applied force. Capillarity is the property that permits water to be drawn from a free water surface through the action of surface tension and independent of the force of gravity. Shrinkage of a soil mass is a reduction in volume that occurs when the moisture content is reduced from that existing when it is partially saturated or fully saturated. Swelling is term used to describe the expansion in volume of soil mss that accompanies an increase in the moisture content. Compressibility is the property of a soil that permits it to consolidate under the action of an applied compressive load. Elasticity is the property of a soil that permits it to return to its original dimensions after the removal of an applied load. The resilient modulus also represents the elasticity property of a soil and is more commonly used in pavement design. *(Paul H. Wright and Karen K.Dixon, 2004)*

2.2 Properties of the Soil Significant to Stabilization

For soil to provide the required level of performance as a walling material the process of stabilization must improve or impart new properties to the soil. The aims of stabilization are to:

a) increase the wet strength of the soil

b) provide adequate cohesion
c) increase volume stability
d) increase durability, resistance to erosion and frost attack
e) lower permeability

These aims cannot be achieved economically in all soils and therefore the limits of suitability have to be defined. While this may indicate that not all the significant properties soil have been identified there is sufficient evidence to establish the major characteristic of the soil for successful stabilization. By the nature of the soil it uses as a construction material is dependent upon its physical, chemical and biological characteristics. These are normally identified by carrying out classification tests. Those significant to the selection of soil for stabilization recognized. *(A.J. Bryan, 1988)*

a) Textural classification test. The fill classification to B.S. 1377:1975 is appropriate although others such as the American Standards are often used. Most authorities recommend procedures for developing countries with simplified tests for the clay and silt fractions generally taken together as fines. However, the role of the clay is of such significance that this expedient may not be appropriate in all circumstances. Sedimentation to identify the clay content may be necessary for both soil suitability and materials specification decisions.

b) Plasticity or Atterberg limits. The determination of liquid and plastic limit to B.S. 1377:1975 or other approved standards and the calculation of the plasticity index are required.

c) The clay mineralogy and cation exchange potential. Clay mineralogy can be identified by technique such as X-Ray Diffraction or Differential Thermal Analysis. IF important to the stabilizing process cation exchange capacity can also be measured. However, soils including montmorillionites or other active clays can be identified from the activity of the soil calculated from textural and plasticity data. The data clay content and the activity can be then related to the expansive characteristics of the soil.

d) The linear shrinkage. This is not used in all studies but is an indicator that may determine the quantity of cement and therefore the economics of the mix. The procedure is B.S. 1377:1975 is for a small scale test performed only with the fine material. Alcock reported in a United Nations report to have suggested the use of a larger scale test on the whole soil to determine the fly ash required. This test is possibly more realistic and may offer more information since it is more direct test as it uses the whole soil.

2.2.1 Limits to the Suitability of Soil for Fly Ash Stabilization

A number of researchers have suggested limits of soil suitability for walling purpose for projects in the developing countries based on laboratory and field tests. However, most do not consider frost resistance as a significant criterion.

Their recommendations do, however, represent an initial indication of suitability for stabilization by cement. A summary of the recommendation is given in Table 2. Although there is not complete agreement and the basis for the testing is not consistent, certain trends can be identified. There is requirement for a small amount of clay but an upper limit is also necessary to limit shrinkage to ensure effective stabilization. Plasticity is required as a complementary measure to the limit of the clay content and plasticity will allow the identification of the more active or expansive clay minerals. *(A.J. Bryan, 1988)*

The textural characteristics of suitable soil must also be defined by distribution of the larger particles of silts, sand and fine gravel. In this respect the abstracted information in Table 1 is less explicit. All agree, however, that a distribution of particles of particles to achieve a dense packing is required so a predominance of one size particle will produce an inferior stabilized material. In some cases the other criteria suggested in Table