EXPERIMENTAL STUDY ON RESILIENT MODULUS OF LIQUID SILICON DIOXIDE (SIO_2) STABILIZED SUBGRADE SOIL

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Dedicated to;

To my beloved parents,
Mr.Arumugam & Mrs.Saraswathy

To my best sisters,
Pathma & Keeli

To my supportive brothers and brother in law,
Sugunanathan, Saravanan and Kumar

For all the love, care and support… … … … …

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ABSTRACT

Village and estate roads have failed to function due to damage at earlier stage of construction and this required frequent maintenance. Weak sub-grade is the basic factor of exponential damage. In order to overcome this problem, many procedures have been developed to improve the physical behavior (strength or stiffness) of the sub grade soil. One of the procedures is to incorporate a wide range of stabilizing agent, additives or conditioners. Silicon dioxide (SiO_2) is a water based sodium silicate which is currently being patented on application by Probase Manufacturing Sdn.Bhd. to stabilize subgrade soils. The main objective of this research is to determine the resilient modulus of the liquid SiO_2 stabilized sub grade soil at number of state conditions (i.e. density, moisture content and amount of stabilizer). Repeated triaxial load test was carried out at Highway Engineering Laboratory, UTHM. The specimens were prepared with maximum (100%), 90% and 95% dry density, optimum moisture content, 3% dry of optimum and 3% wet of optimum, and the amount of stabilizer was 4%, 8% and 12% of dry density of the soil. The specimens were cured for 0, 7, 14 and 28 days to determine the effect of curing days on the stabilized soil. The resilient modulus data were used to identify the best fit equation with the data. However typical pavement system analyzed using KENLAYER for non-linear elastic layer for fine grained soil; the equation applicable is the bilinear equation. Analysis of Variance (ANOVA) has been carried out to evaluate the level of significance effect of the state conditions on the stabilized soil. It has been found that density affects the resilient modulus of fine grained materials; however the magnitude of this effect is smaller compared to effect of moisture conditions. The addition of liquid SiO_2 stabilizer improves the stiffness (resilient modulus) of the soil and consequently, the optimum concentration is found to be 4% for sub grade stabilization through this study.

ABSTRAK

Jalan-jalan kampung dan ladang gagal berfungsi selepas pembinaan disebabkan oleh kerosakkan pada peringkat awal, maka penyelenggaraan kerap dilakukan bagi mengatasi masalah ini. Lapisan subgrade yang lemah menjadi punca utama berlakunya kerosakan pada jalan raya. Bagi mengatasi masalah ini, pelbagai cara telah diperkenalkan, antaranya ialah aplikasi bahan penstabil, bahan tambah dan lain-lain lagi. Silicon dioksida (SiO_2) merupakan bahan penstabil dalam bentuk cecair yang kini digunakan dalam proses penstabilan lapisan subgrade jalanraya yang diperkenalkan oleh Probase Manufacturing Sdn.Bhd. Objektif utama kajian ini ialah mengkaji modulus ketahanan tanah subgrade yang telah distabilkan dengan penstabil SiO_2 pada beberapa keadaan (i.e. ketumpatan tanah, kandungan air dan jumlah penggunaan bahan penstabil) yang berlainan. Ujian repeated triaxial load telah dijalankan di Makmal Kejuruteraan Jalanraya, UTHM. Spesimen disediakan dengan ketumpatan maksimum (100%), 95%, 90%, kandungan air optimum, 3% kurang dari optimum, 3% lebih dari optimum, dan bahan penstabil sebanyak 4%, 8% dan 12% dari berat kering tanah. Kesemua spesimen telah diawet selama 0, 7, 14 dan 28 hari untuk mengkaji kesan tempoh pengawetan terhadap tanah yang telah distabilkan dengan SiO_2. Data modulus ketahanan digunakan untuk menentukan persamaan konstitutif yang mempunyai penyuaian terbaik dengan data tersebut. Sistem jalanraya dianalisis menggunakan KENLAYER untuk lapisan kenyal yang tidak linear untuk tanah subgrade, tetapi hanya persamaan bilinear diaplikasi dalam sistem KENLAYER bagi tanah subgrade. Analisis of Variance (ANOVA) telah dijalankan bagi mengkaji kepentingan beberapa keadaan (i.e.ketumpatan tanah, kandungan air dan jumlah penggunaan bahan penstabil)atas tanah yang telah distabil. Melalui kajian ini, didapati ketumpatan tanah mempunyai kesan yang kecil terhadap tanah yang telah distabilkan jika dibandingkan dengan kandungan air. Penstabilan dengan

bahan penstabil SiO_2 meningkatkan kekerasan (modulus ketahanan) tanah subgrade, dan kepekatan optimum yang dikenalpasti melalui kajian ini ialah sebanyak 4%.

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%	-	Percent
et al.	-	And other people
i.e.	-	In other words
UTHM	-	Universiti Tun Hussein Onn Malaysia
FKAAS		Fakulti Kejuruteraan Awam dan Alam Sekitar
km		kilometer
OMC		Optimum Moisture Content
JKR		Jabatan Kerja Raya
LVDT		linear variable differential transformer
LTPP		Long Term Pavement Protocol
UTM		Universal Testing Machine
ANOVA		Analysis of Variance
Mr		Resilient Modulus
σ_1		major principal stress or maximum axial stress
σ_2		minor principal stress
σ_3		confining pressure
σ_d		deviator stress
ε_R		recoverable (resilient) axial strain
kPa		kilo Pascal
k_1, k_2, k_3 and k_4		model parameter
R^2		regression coefficient
Pa		atmospheric pressure (100kPa)
PR		Poisson Ratio
E		Elastic Modulus
ε_v		Compressive Strain

ε_t		Tensile Strain
N_d		Allowable number of load repetitions to limit Permanent deformation
CBR		California Bearing Ratio
BS		British Standard
SiO_2		Silicon Dioxide
NaO_2		Sodium Oxide
Na		Natrium
Mg		Magnesium
Ca^+	-	Calcium ion
K^+	-	Potassium ion
Al_2O_3	-	Alumina
Fe_2O_3	-	Iron Oxide
Na_2O	-	Sodium Oxide
TiO_2	-	Titanium Oxide
CaO	-	Calcium Oxide

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CHAPTER I

INTRODUCTION

1.1 Introduction

Village roads and estate roads were vital components in the national road system. This road system has functioned as the source of transportation to transfer agricultural products from the farm or estates to the urban areas, where it is processed and sold. These road networks were important transportation mode and are regarded as an essential source for the development of rural areas.

According to Yoder (1995), "in most cases, the roads are used more than its capacity. This is due to lack of systematic and comprehensive maintenance. As the damage occurs at a very early stage, it affects the functionality of the village and estate roads. The damage occurs at faster rate whenever high numbers of heavy vehicles use the road frequently. The repercussion is that the roads do not function to the maximum years it was designed to last."

One of the basic factor which results in exponential damage is weak sub-grade. This sub-grade is not properly compacted during the construction and constantly soaked in water. Water is sump on the road due to lack of drainage and lower road level compared to the shoulders. The wearing course is the surface exposed to vehicle load while bitumen functions as the adhesive. Both the wearing course and bitumen become weaker when it's constantly exposed to water. This results in deformation of the sub-grade at a very early stage (Man, 2005).

The design of flexible pavement is a process where the thickness of each structural layer is determined as a structural unit which can sustain vehicular load to its maximum capacity. The most important element in the design of pavement is the selection of materials for wearing course, base, subbase, subgrade and the thickness of each layer. In the structural design aspect, there are three types of village and estate roads as shown in Figure 1.1.

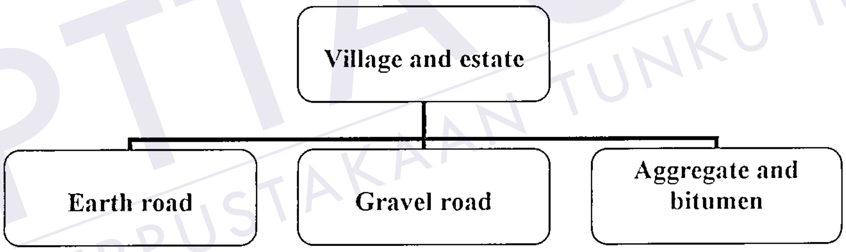

Figure 1.1: Types of village and estate road (Man, 2005).

Earth road does not have wearing course. Earth road is not designed. The performance of earth roads depends on the road section, characteristics of material used and type of drainage system provided. Earth road have low traffic flow, hence it is important to make sure that it is not damaged or closed, because the closure of the road will cause loss to the road users (Robert, 1998).

Gravel road is a type of road where the top of the road consists of gravel which enables the movement of vehicles particularly during rain at minimal construction cost. The gravel layer also minimizes or slows down the damage to the village road. The biggest problem with gravel road is that it has sections which deforms particularly at wheel-tracks. If the traffic volume increase, the damage to the gravel road will be faster because of the volume at the surface level will decrease once load is applied. Generally, gravel roads which experiences high traffic volume is upgraded by constructing bituminous road (JKR, 1998).

Subgrade is used to define the natural foundation or fill which directly receives the loads from the pavement. Basically most of village and estate roads consist of a sub-grade layer and wearing surface layer of bitumen mixed with aggregate in accordance to the recommendation by Public Works Department (Jabatan Kerja Raya, (JKR)). Village and estate roads are classified as flexible pavement because the bitumen used in the construction of these roads is the same materials used for flexible pavement designed and build by JKR. The difference is on the number of layers only where village and estate roads have two layers i.e. sub-grade and wearing course where else other category roads have four layers i.e. sub-grade, base, sub-base and wearing course as shown in Figure 1.2.

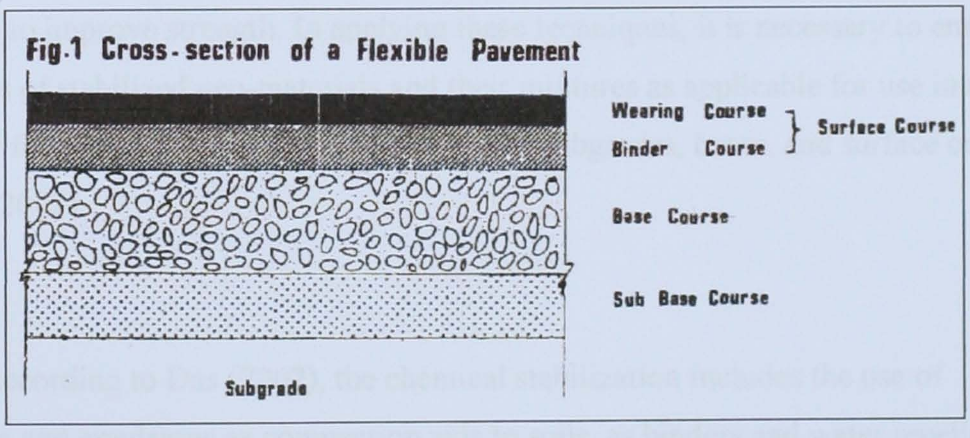

Figure 1.2: Typical flexible pavement layers (Arahan Teknik Jalan 5/85, JKR)

Flexible pavement is so called because it allows a small amount of vertical movement of the road structure under load. The main purpose of the road structure is to reduce the stress or pressure due to wheel load to a certain value that the structure can support. The intensity of the static and dynamic stress is greatest at the surface of the road and spreads in a pyramidal shape through out the depth of the structure. The load is reduced with the increasing of the load spreading. The stress is low enough for the subgrade to support it without distortion or damage (Davies, 2004).

Pavement engineers have long time recognized long term benefits in increasing the strength and durability of pavement subgrade soil by mixing additives during the reconstruction or new construction. Many procedures have been developed to improve the physical behaviour of subgrade soil by incorporating a wide range of stabilizing agents, additives or conditioners. Stabilization is a process of blending and mixing materials with a soil to improve certain properties of the soil. There are two types of stabilization that being applied in order to improve the soil and its strength, which was mechanical and chemical stabilization (Gorantla, 2005).

Stabilization without additives may be 'mechanical'- rearrangement of particles through compaction or addition or removal of soil particles. Mechanical stabilization includes compaction, and fibrous and other non-biodegradable reinforcement of geo-materials to improve strength. In applying these techniques, it is necessary to ensure the properties of stabilized geo-materials and their mixtures as applicable for use in the design of foundations, embankments, shoulders, subgrades, bases, and surface courses (Sankar, 2003).

According to Das (2002), the chemical stabilization includes the use of chemicals and emulsions as compaction aids to soils, as binders and water repellents, and as a means of modifying the behavior of clay. Chemical stabilization can aid in dust control on roads and highways particularly on unpaved roads. It also aids in water erosion control and leaching control of waste and recycled materials.

In the selection of a stabilizer, the factors that must be considered are the type of soil to be stabilized, the purpose for which the stabilized layer will be used, the required strength and durability of the stabilized layer to support the loadings, and the cost and environmental conditions. Soil stabilizing agents such as cement, fly ash, lime, salt, or rice husk ash are used to improve the handling and engineering characteristics of soils for civil engineering purposes (Sahruzi. 2000).

1.1.1 Cement stabilization

Cement can be used either to modify and improve the quality of the soil or to transform the soil into a cemented mass with increased strength and durability. The soil-cement stabilization has been used for many years because of the significant improvement in soil properties that may be achieved as a result of cement treatment. Stabilization of soils and aggregates with asphalt differs greatly from cement and lime stabilization. The basic mechanism involved in asphalt stabilization of fine-grained soils is a waterproofing phenomenon. Soil particles or soil agglomerates are coated with asphalt that prevents or slows the penetration of water which could normally result in a decrease in soil strength (Dallas et.al, 2001).

1.1.2 Lime stabilization

Generally, lime treated fine grained soils exhibit decreased plasticity which improves the strength of the soil. It also exhibits improved workability and reduced volume change characteristics of the stabilized soil. It should be emphasized that the properties of soil lime mixtures are dependent on many variables. Soil type, lime type, lime percentage and curing conditions (time, temperature, and moisture) are the most important. Stabilization occurs when the proper amount of lime is added to a reactive soil. Stabilization differs from modification in that a significant level of long-term strength gain is developed through a long-term pozzolanic reaction. This pozzolanic reaction is the formation of calcium silicate hydrates and calcium aluminate hydrates as the calcium from the lime reacts with the aluminates and silicates solubilized from the clay mineral surface. This reaction can begin quickly and is responsible for some of the effects of modification (soil stabilization for pavement) (Eddie, 2004).

1.1.3 Other stabilization material

The sodium ions present in salt stabilization react with clay particles, giving greater dispersions of some clay. This makes it possible to obtain desired compaction with less effort. It provides a strong bond between soil particles. After curing and recrystallization of the un-reacted salt within the void has taken place, a firm, stable layer is formed, increasing the strength and load bearing capacity. Salt has considerable use in stabilizing the surface of dirt roads with low traffic volume (Eddie, 2004).

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