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INFLUENCE OF KENAF AND COIR FIBERS IN PROBLEMATIC SOIL FOR ROAD WORKS

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

INFLUENCE OF KENAF AND COIR FIBERS IN PROBLEMATIC SOIL FOR ROAD WORKS

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FALIL NISA BINTI ABDUL JALIL

December 2019

Chair : Nik Norsyahariati binti Nik Daud, PhD
Faculty : Engineering

Pavement construction on natural subgrade is most concern nowadays due to the variation of subgrade soil. The properties of existing subgrade soil play the important role in producing the best condition of road especially in rural area. The usual approach in solving weak soil is by remove and replaces the existing soil with any stronger materials, which is expensive. One of the economical ways to improve the soil properties is soil reinforcement using natural fibers. Use of natural fibers is advantageous due to their availability, cost effectiveness, favourable strength and environmental friendliness. This research was developed to study the influence of coir fiber and kenaf fiber in problematic soil in terms of road work purposes. First, the geotechnical properties of soil were studied to classify the soil type. Natural fibers were prepared in two conditions which are untreated sample and treated with 5% sodium hydroxide (NaOH) sample before mixing with soil. To confirm the alteration of morphology of the fibers, scanning electron microscope (SEM) test was performed. Furthermore, the mechanical properties of natural fiber-soil mixture were assessed. Direct shear test, consolidation test and California Bearing Ratio (CBR) test were carried out on original soil, untreated fiber- soil, and treated fiber-soil. The results revealed that the tensile strength of both fibers was increased after being treated with sodium hydroxide. The inclusion of untreated and treated fibers into soil has increased the optimum moisture content (OMC) and decreased the maximum dry density (MDD). The rate of consolidation for reinforced soil increased and resulting in lower value of rate of volume compressibility. The strength of soil was increased up to 48% when reinforced with untreated coir fiber. For soil reinforced kenaf fiber, the strength increased 29.6% with untreated kenaf fiber and 35.5% with treated kenaf fiber.

The results of CBR values for unsoaked and soaked condition were increases as the inclusion of fibers for all mixed samples. According to Arahan Teknik Jalan 5/85, the minimum requirement of CBR value for subgrade layer is 5% and all samples of soil reinforced coir fiber and kenaf fiber, achieve the minimum value. Overall, the properties of soil used have been identified and classified as organic clay with high plasticity. The inclusion of coir fiber and kenaf fiber improved the geotechnical properties of soil in terms of settlement behavior and shear strength. Natural fibers increased the CBR values up to 109% in unsoaked condition. In conclusion, all objectives have been satisfied and it can be said that natural fiber had influenced the properties of soil in terms of its shear strength, settlement and CBR values.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENGARUH SERAT KENAF DAN SERAT KELAPA DALAM TANAH BERMASALAH UNTK KERJA-KERJA JALAN

Oleh

FALIL NISA BINTI ABDUL JALIL

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Fakulti : Kejuruteraan

Pembinaan turapan jalan di atas tanah subgred asal menjadi perhatian pada masa kini disebabkan oleh variasi tanah sedia ada. Ciri-ciri tanah subgred sedia ada memainkan peranan penting dalam menghasilkan keadaaan jalan raya yang terbaik terutamanya di kawasan luar bandar. Pendekatan yang biasa dilakukan bagi menyelesaikan masalah tanah bermasalah adalah dengan membuang dan menggantikan dengan bahan yang lebih kuat namun kosnya agak tinggi. Salah satu cara yang lebih ekonomi untuk memperbaiki sifat tanah ialah dengan menggunakan serat semulajadi sebagai bahan tetulang di dalam tanah. Serat semulajadi digunakan secara meluas dalam aplikasi kejuruteraan dan industri berikutan lambakan bahan tersebut, keberkesanan dalam kos, kekuatan yang dikehendaki dan mesra alam. Kajian ini telah dibangunkan untuk mengkaji pengaruh serat kelapa dan serat kenaf di dalam tanah bermasalah dari segi kerja pembinaan jalan. Pertama, sifat-sifat geoteknikal tanah dikaji untuk mengklasifikasikan jenis tanah. Serat semulajadi disediakan dalam dua keadaan iaitu sampel yang tidak dirawat dan sampel yang dirawat dengan 5% sodium hidroksida (NaOH) sebelum dicampurkan dengan tanah. Untuk mengesahkan perubahan morfologi pada serat, ujian mikroskop pengimbasan elektron (SEM) telah dilakukan. Tambahan lagi, sifat-sifat mekanikal bagi campuran tanah dan serat semulajadi juga dinilai. Ujian ricih langsung, ujian pengukuhan, dan ujian nisbah galas California (CBR) dilakukan pada tanah asal, campuran tanah - serat tidak dirawat dan campuran tanah - serat yang dirawat. Keputusan menunjukkan bahawa kekuatan tegangan kedua-dua serat telah meningkat selepas dirawat dengan sodium hidroksida. Campuran serat yang tidak dirawat dan dirawat ke dalam tanah telah meningkatkan kandungan kelembapan optimum (OMC) dan mengurangkan ketumpatan kering maksimum (MDD). Kadar pengukuhan untuk tanah

bertetulang meningkat dan menyebabkan pengurangan kadar kebolehmampatan isipadu. Kekuatan tanah meningkat sebanyak 48% apabila diperkukuhkan dengan serat kelapa tidak dirawat. Bagi tanah diperkukuh dengan serat kenaf, kekuatan meningkat sebanyak 29.6% apabila diperkukuhkan dengan serat kenaf tidak dirawat dan 35.5% apabila diperkukuhkan dengan serat kenaf yang dirawat. Keputusan ujian nisbah galas California menunjukkan nilai CBR tanah dalam keadaan terendam dan tidak terendam meningkat dengan penambahan serat ke dalam tanah bagi semua sampel. Berdasarkan Arahan Teknik Jalan 5/85, nilai minimum bagi lapisan subgred yang menepati piawaian ialah 5% dan semua sampel tanah diperkukuh serat kelapa dan serat kenaf mencapai nilai tersebut. Secara keseluruhannya, ciri-ciri tanah yang digunakan telah dikenalpasti dan diklasifikasikan sebagai tanah liat organik dengan keplastikan yang tinggi. Penggunaan serat kelapa dan serat kenaf meningkatkan sifat geoteknikal tanah dari segi penyelesaian dan kekuatan ricih tanah. Serat semulajadi meningkatkan nilai CBR tanah sehingga 109% berbanding tanah asal dalam keadaan tidak terendam. Sebagai kesimpulan, semua objektif telah dicapai dan serat semulajadi terbukti mempengaruhi sifat tanah dari segi kekuatan ricih, enapan dan nilai CBR.

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Signature:
Name of Member of Supervisory Committee: Assoc. Prof. Dr Fauzan bin Mohd Jakarni

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LIST OF ABBREVIATIONS

μm	Micronmetre
BS	British Standard
c	Cohesion
C	Carbon
CBR	California Bearing Ratio
Cc	Coefficient of Curvature
CCL4	Carbon tetrachloride
CF	Coir fiber
CO2	Carbon dioxide
Cu	Coefficient of Uniformity
cv	Rate of consolidation
EDX	Energy dispersive X-ray spectrometer
GPa Gs	Gigapascal Specific Gravity
H2O2	Hydrogen peroxide
i.e.	Example
Ip	Plastic limit
K	Potassium
k	Permeability value
KF	Kenaf fiber
KMnO4	Potassium permanganate
kPa	Kilopascal
m	Metre
MDD	Maximum dry density
min	Minute

mm	Milimetre
MPa	Megapascal
mv	Rate of volume compressibility
Na	Sodium
NaOH	Sodium hydroxide
O	Oxygen
ø	Angle of friction
OMC	Optimum moisture content
PLA	Poly-lactic acid
Ref.	Reference
S	Soil
SCF	Soil with coir fiber
SEM	Scanning electron microscope
SKF	Soil with kenaf fiber
STCF	Soil with treated coir fiber
STKF	Soil with treated kenaf fiber
TCF	Treated coir fiber
TKF	Treated kenaf fiber
USCS	Unified Soil Classification System
UV	Ultraviolet
wL	Liquid limit
wP	Plastic limit

CHAPTER 1

INTRODUCTION

1.1 Background

Subgrade soil is the natural material which exists underneath a constructed road. Subgrade layer is very important as it will support the load that been transmitted into the pavement structure. However, this existing soil often having problems with the soil properties that associated with many geotechnical problems. Due to these problems, some of the pavements exhibited various types of deterioration in the form of rutting, cracking, formation of potholes and depression.

Tanjung Karang, Selangor is located near to the seaside, Straits of Malacca. One of the common areas in Tanjung Karang called Sawah Sempadan Irrigation Scheme consists of 24 blocks of paddy fields (GPS Coordinate: 3°25"35.0724", E 101°10"36.1704"). Based on the Geological Map of Peninsular Malaysia (1985) shown in Figure 1.1, this area is categorized as an unconsolidated deposit which composes of four elements. The elements are clay, silt, sand and peat with minor gravel of marine type (Azizan et al., 2015). This is supported by Mahyoub et al. (2017) who studied about the residues of herbicide at paddy area, the Sawah Sempadan soil is categorized as clay type soil.

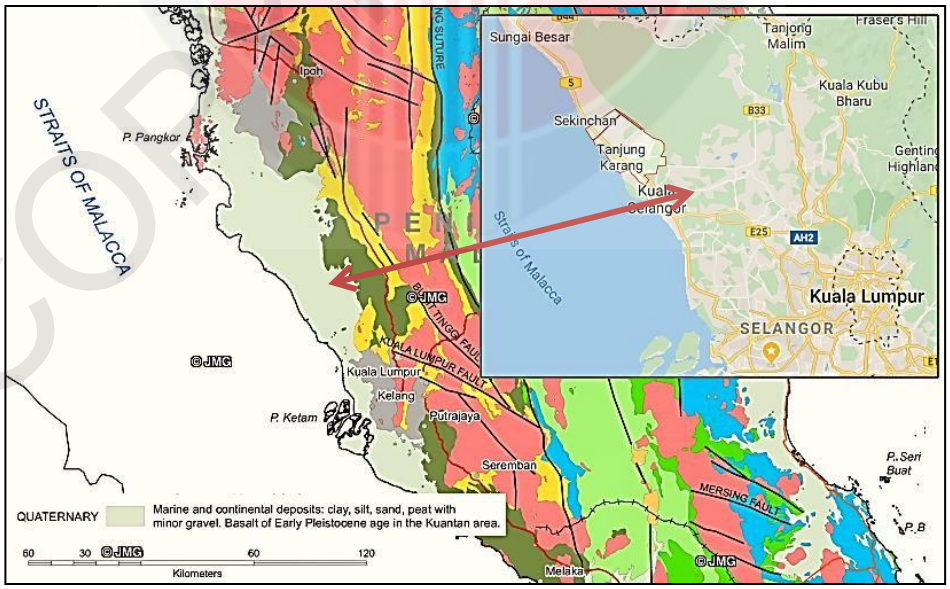

Figure 1.1: Geological Map of Tanjung Karang, Selangor

Study on soil sample in Tanjung Karang was conducted and the particle size distribution of soil shows a high content of clay for about 66% (Yulnafatmawita et al., 2018; Shaidatul Azdawiyah et al., 2010). This type of soil is very prone to have problems on road constructed over this soil.

One of the cases happened in Malaysia due to soft soil issues was Bentong Lipis Road. This project was facing a road settlement problem because of the nature of the subgrade soil is clayey soil. The road was built on the clayey soil without proper treatment, thus, consolidation was taking place. Due to this, maintenance cost was higher than the original construction cost of the project (Teh et al., 2017).

The usual approach in solving weak subgrade soil is to remove the soil and replace it with stronger material of crushed rock, yet it is very expensive. This has become major concern among engineers and researchers and there is a need to study the economical way on improving geotechnical properties of subgrade soil. One possible solution is soil reinforcement using natural fiber and waste material. Use of natural fiber is advantageous as it is cheap and locally available.

Soil reinforcement involves the incorporation of certain materials with some desired properties into soils which lack those properties. It can be defines as a technique to improve engineering characteristics of soil such as its stability, bearing capacity and to reduce soil settlement. There are several soil reinforcement methods, including root piles, stone columns, soil nailing and reinforced soils.

Reinforced soil is a composite mixture consists of existing subgrade soil with reinforcing materials such fibrous materials. The idea of reinforcing soils using fibers has been widely studied for a long time (Otoko, 2014; Dutta et. al., 2012; Ekinci & Ferreira, 2012; Baley et. al., 2006; Bledzki & Gassan, 1999).

The mechanical properties of fiber reinforced soil have been investigated by various researchers. A number of triaxial tests, unconfined compression tests, California bearing ratio (CBR) tests, direct shear tests, tensile strength tests and flexural strength tests have been conducted by several researchers in the last few decades (Maurya, 2016; Singh & Mittal, 2014; Singh & Bagra, 2013; Freilich et.al., 2010; Chauhan et.al., 2008; Bledzki & Gassan, 1999).

In this study, the application of using distributed natural fibers which are coir fiber and kenaf fiber as reinforcement material in subgrade soil is investigated. The properties of subgrade soil will be determined to classify the problems of the soil. The natural fibers are prepared in two conditions which is untreated and treated with sodium hydroxide before mixing with soil. Soil-fibers mixture

will be tested according to the standard to assess the geotechnical properties of soil.

1.2 Problem Statements

There are three problem statements appear in this study. First, at present, natural fibers are too abundant due to high demand in food industry and increasing of housing area that lead to clearance of plantation area. Waste from plant such as kenaf and coconut need proper management to avoid negative impact to the environment. Other than being used in products such as floor mat and rope, natural fibers are getting lot of attention among researchers to be used as a reinforcement material to the problematic soil. Natural fibers provide an economic option and a major step forward in the direction of sustainable development.

Second, the subgrade soil generally consists of various locally available soil materials that sometimes might be soft and wet that cannot have enough strength to support the pavement loading. Road construction on soft soil may have difficulty because of the very low bearing capacity. For this type of soil, proper treatment such as stabilizing agents and adding materials as reinforcement to the soil might be needed in order to make the subgrade workable for overlying layers in road construction.

Third, the oldest way in reinforcing the weak soil was by placing the wooden piles to distribute the load brought by the structure to more resistant soil area. Some of the old methods were ineffective and hard to apply. Thus, insertion of short fibers into soil is gaining attention as one of the new methods to increase the soil strength properties. Use of coir fiber in soil have been widely studied and the results from previous researches showed that inclusion of coir fiber improved the moisture-density relation, the shear strength, the unconfined compression strength and the bearing capacity of laterite soil and expansive soil (Dutta et al., 2012; Gaurav et al., 2018; Lekha et al., 2015; Parag & Dhatrak, 2013; Singh & Mittal, 2014). But for kenaf fiber, research on this type of fiber as filler in soil matrix is still in an early stage and results on kenaf fiber reinforced soil are very limited.

Natural fibers have a hydrophilic nature and the surface of the natural fiber has dirt and other substances that may affect the bonding strength between fiber and soil. Therefore, one of the ways to remove all the substance is by alkali treatment. Some of the studies (Andiç-Çakir et al., 2014; Edeerozey et al., 2007; Gu, 2009; Valadez-Gonzalez et al., 1999) found that surface fiber treatment can improve the bonding between fiber and soil particle.

In this case, it is important to investigate the influence of agricultural waste materials in subgrade soil for road works. This study is needed to investigate

the compatibility of these natural fibers in soil from paddy area and the suitability of alkali treatment with natural fiber used and the effects of treated fibers into the reinforced soil.

1.3 Research Objectives

The aim of this project is to study the effectiveness of natural fiber as reinforcing material to the soil. The objectives can be summarized as follows:

1. To determine the physical properties of studied soil.
2. To investigate the strength properties of soil mixed with kenaf and coir fibers.
3. To evaluate the influence of untreated and treated natural fiber inclusion in soil behavior (settlement, strength and bearing capacity).

1.4 Scope and Limitation of Research

The scope of work in this study involves conducting laboratory work to produce soil-fiber mixture of 1% of fibers by weight of soil with two different types of natural fibers. Sample of soil mixed with untreated fiber and treated fiber will be prepared. The natural fibers are treated with chemical solution to treat the fiber surface. Sample of soil mixed with untreated fiber and treated fiber will be prepared. The specimen will be tested according to the BS 1377 (1990) to obtain the geotechnical properties of those soil mixtures in terms of compressive strength, CBR value, settlement and hydraulic conductivity.

There are some notable limitations in this research. There is lack of previous studies on kenaf fiber as a reinforce material to soil, but kenaf fibers are great in reinforcing cement, thermoplastic, thermoset and rubber. On the other hand, coir fiber was extensively studied on the performance of fiber-soil mixture and this research was done to study the compatibility with the subgrade soil used. Therefore, the literatures that have similar aim are being referred to.

1.5 Thesis Outline

This report includes a total of five chapters. Chapter One is an introduction part that presents the problem statement, objective and scope of this study. Reviews on previous studies performed by various researchers are briefly summarized in Chapter Two. Chapter Three deals with the properties of the materials used and adopted methodology to accomplish the objectives of the project. Results and discussions of all laboratory tests performed and findings from the tests were explained in Chapter Four. Finally, Chapter Five presents the conclusion derived throughout the work and some recommendations based on the experiences during study period.

BIODATA OF STUDENT

Falil Nisa bt Abdul Jalil was born in Perak on 31st October, 1990. She is a master‟s student in Civil Engineering under the supervision of Dr. Nik Norsyahariati Nik Daud. Her interest is in geotechnical engineering and environmental engineering. She got her Bachelor Degree in Civil Engineering from Universiti Putra Malaysia, Malaysia. Her final year project was about the usage of natural fiber in soil reinforcement. Currently, she‟s continuing her study in master degree (by research) at the same university and focusing more on the usage and development of new process of natural fiber to reinforce clay soil as a subgrade purposes. Until now, she has published four papers related to her study and looking forward to share her experience with others.

LIST OF PUBLICATIONS

Daud, N. N. N., Jalil, F. N. A., Sadiq, M. A., and Azmi, J. A. (2016). Influence of Agricultural Wastes on Shear Strength Properties of Soil. *MATEC Web of Conferences*, 47, 1-7.

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