A STUDY ON THE SHEAR STRENGTH BEHAVIOUR OF LATERITIC SOIL-DEOILED SPENT BLEACHING EARTH (DSBE) MIXTURES

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FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SABAH
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ABSTRACT

De-oiled Spent Bleaching Earth (DSBE) is the industrial waste originally from the edible oil refining process. In Malaysia, this palm oil waste literally dumps directly to the landfill that may cause severe pollutants to the environment. Despite the fact that DSBE is disposed of in landfills, which might cause environmental damage, it is recovered for use in the production of sustainable products. Lateritic soil, also known as problematic soil, is one type of soil that must be considered. This scenario, if not properly monitored, could cause significant damage to infrastructure and, consequently, have an impact on society. This study aims to propose DSBE as a soil stabilization material which also as an alternative to improve the strength behaviour of the lateritic soil. The DSBE content applied in this study are 25%, 50%, 75%, and 100% were mixed with the lateritic soil, in order to investigate whether or not the utilization of the material improved the engineering properties of the lateritic soil itself. To achieve the objectives of this study, the characteristics and index properties of lateritic soil-DSBE are reviewed. Several tests and experiments were conducted which are the sieve analysis, specific gravity, Atterberg limit, x-ray Diffraction (XRD) test, standard proctor compaction test and unconfined compression test. The results indicated that DSBE as stabilizer is able to significantly increase the unconfined compression strength and shear strength of lateritic soil. Thus, it was obtained that a soil sample of 75% lateritic soil, 25% DSBE has the highest compressive strength with lowest moisture content which are 92.65 kPa and 39.90%, respectively. Overall, this research also emphasizes the aspect of sustainability in the construction industry especially in Malaysia for the sake of the country's future economy and ecological system.

ABSTRAK

(KAJIAN MENGENAI TINGKAH LAKU KEKUATAN RICIH CAMPURAN TANAH LATERIT - DEOILED SPENT BLEACHING EARTH (DSBE)

De-oiled Spent Bleaching Earth (DSBE) ialah sisa industri yang asalnya daripada proses penapisan minyak makan. Di Malaysia, sisa minyak sawit ini dibuang terus ke tapak pelupusan sampah yang boleh menyebabkan pencemaran yang teruk kepada alam sekitar. Berdasarkan fakta tersebut, ia dicadangkan untuk digunakan dalam pengeluaran produk yang mampan. Tanah laterit boleh dikategorikan sebagai tanah bermasalah. Senario ini boleh membawa kepada kerosakan yang ketara kepada infrastruktur dan masyarakat. Kajian ini bertujuan untuk mencadangkan DSBE sebagai bahan penstabilan tanah yang juga sebagai alternatif untuk meningkatkan tingkah laku kekuatan tanah laterit. Kandungan DSBE yang digunakan dalam kajian ini ialah 25%, 50%, 75%, dan 100% dicampur dengan tanah laterit, untuk menyiasat sama ada penggunaan bahan tersebut meningkatkan sifat kejuruteraan tanah laterit itu sendiri atau tidak. Untuk mencapai objektif kajian ini, ciri-ciri dan sifat indeks tanah laterit-DSBE dikaji semula. Beberapa ujian dan eksperimen telah dijalankan iaitu analisis ayak, graviti tentu, had atterberg, ujian pembelauan sinar-x (XRD), ujian pemadatan proktor piawai dan ujian mampatan tidak terkurung. Keputusan menunjukkan bahawa DSBE sebagai penstabil mampu meningkatkan kekuatan mampatan tak terkurung dan kekuatan ricih tanah laterit dengan ketara. Oleh itu, didapati bahawa sampel tanah 75% tanah laterit, 25% DSBE mempunyai kekuatan mampatan tertinggi dengan kandungan lembapan terendah iaitu 92.65 kPa dan 39.90%, masing-masing. Secara keseluruhannya, penyelidikan ini turut menekankan aspek kelestarian dalam industri pembinaan khususnya di Malaysia demi ekonomi masa depan dan sistem ekologi negara.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

CO_2	-	Carbon Dioxide
SiO2	-	Silica Oxide
CaO	-	Calcium Oxide
Fe_2O_3	-	Iron (III) oxide
Mn_2O_3	-	Manganese (III) Oxide
SO^{3+}	-	Sulfur Trioxide
Fe^{3+}	-	Scanning Electron Microscopy
TiO_2	-	Titanium Dioxide
MgO	-	Magnesium Oxide
K_2O	-	Potassium Oxide
P_2O_5	-	Phosphorus Pentoxide
%	-	percentage
μm	-	Nanometer
mm	-	Milimetre

LIST OF ABBREVIATION

SBE	-	Spent Bleaching Earth
AASHTO	-	American Association of State Highway and Transportation Officials
ASTM	-	American Society for Testing and Materials
BS	-	British Standards
DSBE	-	De-oiled Spent Bleaching Earth
EPP	-	Eco Processed Pozzolans
GHG	-	Green House Gas
LAA	-	Los Angeles Abrasion
LL	-	Liquid Limit
MDD	-	Maximum Dry Density
OMC	-	Optimum Moisture Content
PI	-	Plasticity Index
PIPS	-	Centre of Instrumentation and Science Services
PL	-	Plastic Limit
POFA	-	Palm Oil Fuel Ash
PSBE	-	Processed Spent Bleaching Earth
SEM	-	Scanning Electron Microscopy
SL	-	Shrinkage Limit
UCS	-	Unconfined Compression Soil
USCS	-	Unified Soil Classification System
XRD	-	X ray Diffraction

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Civil engineering projects located in areas with weak soils are a common occurrence throughout the world. Traditionally, soil stabilization has involved removing the weak soil and replacing it with a stronger material. Due to the high cost of certain methods, researchers have looked for alternatives, one of which is the soil stabilization process.

Soil stabilization is a technique that was developed many years ago with the main objective of enabling soils to meet the requirements of specific engineering projects. (Kolias, S., *et al.*, 2005) Generally, when the soils on a site are insufficient or possess undesirable properties that make them unsuitable for use in geotechnical projects, they may require stabilization. In recent years, a variety of scientific techniques for soil stabilization have been introduced (Rogers *et al.*, 1997). Stabilization techniques generally utilize additives as cementing agents, such as cement, lime, or industrial by-products, and extensive research has been conducted on the stabilization of soils with various additives such as lime and cement (Basha *et al.,* 2005).

1.2 Definition

Stabilization of soils is described as chemical or physical treatments that increase or maintain a soil's stability or enhance its engineering properties. Compaction of soils is one means of stabilizing them. Compaction increases the soil's stiffness and strength properties while decreasing its permeability. Soil stabilization is the process of modifying or preserving one or more soil qualities in order to enhance a soil's engineering features and performance (Afrin, Habiba, 2017).

Soil stabilization is a process that involves the addition of a particular soil, a cementing substance, or other chemical components to a natural soil in order to enhance one or more of its features. Stabilization can be accomplished manually by mixing the natural soil and stabilizing material until they create a homogeneous mixture, or by adding stabilizing material to an undisturbed soil deposit and allowing it to penetrate via soil voids. (W. H. Perloff, 1976).

To attain appropriate engineering qualities, the majority of stabilization has been performed on soft soils (lateritic soil, silty, clayey peat, or organic soils). Sherwood claims that fine-grained granular materials are the easiest to stabilize due to their huge surface area in relation to particle diameter (Sherwood, P., 1993). Because of its flat and elongated particle shapes, it has a significant surface area in comparison to other soils. Stabilization of soil is the process of strengthening the shear strength characteristics of the soil and hence its bearing capacity. A soil that contains loose components can be stabilized with pozzolans materials by the use of a stabilizer. Stabilized soil materials are stronger, have a lower permeability, and are less compressible than natural soil (Keller Inc, 2011).

Water content, gradation, dry density, soil structure, and the normal effective stress acting on the failure plane are the key factors of compacted soil shear strength. It is not only the moulding water content that influences the shear strength, but any changes in moisture conditions after placement. Soil dry density is influenced by the amount of compaction exerted, the water content at which compaction is carried out and any subsequent density changes that may occur after initial compaction. It is the method of compaction and the water content that determines the structure of the soil. External pressure, such as overburden, and internal pressure, such as the apparent negative pore water pressure, exert stress on soil elements. For a subgrade, the overburden pressures are quite low, so the major contributor to the effective stress would be the internal pressure.

1.3 Background of Study

Soft soil modification to enhance their engineering qualities is a well-known and commonly utilized technique. Stabilization reduces the flexibility of soil, making it more workable and improving its compressive strength and load-bearing qualities. These enhancements are the consequence of a series of chemical reactions occurring in the presence of a stabilizer.

Spent Bleaching Earth is a solid waste product formed as a by-product of the edible oil refining process on a global scale. Bleaching Earth that has been used is often disposed of in landfills or trash dumps. Due to the increasing expense of disposal and the potential for environmental hazard, it is desirable to extract oil efficiently and economically utilizing a Solvent Extraction method prior to properly disposing of Spent Bleaching Earth in accordance with environmental standards. SBE is a by-product of the bleaching earth refining process used in the manufacture of edible oils. Globally, it is estimated that around 600,000 million tonnes of bleaching earths are needed to produce approximately 60 million tonnes of oil (Loh S K , Cheng, S. F., May C and Ngan, M, 2006). Globally, between 1 and 2 million tonnes of SBE were produced in 2014, containing 25-40% oil and other impurities. It commonly ends up in landfills, having a negative effect on the environment and posing health risks.

1.4 Problem Statement

Laterite soils are occasionally associated with geotechnical problems such as road deformation, erosion, settlement, dam seepage, slope instability, leachate permeation through hydraulic barriers, and many more. Numerous soil improvement techniques were being applied to overcome these problems, including mixing the laterite soil with cements, limes, bitumen, chemicals, pozzolans, etc. These additives may not be locally available and cheap, and could significantly increase the cost of construction. Likewise, in many cases, these stabilizing agents are not environmentally friendly.

The conditions, qualities, and attributes of the laterite soils in east Malaysia are crucial in evaluating their suitability for use in building as well as their behaviour and effects on the local environment. Due to a loss in strength brought on by water seepage, laterite soils have been implicated in both the failure of slopes and as a building material (Alayaki, 2012). Where it is abundant, a soil study is required to measure and collect this information for use now or in the future when planning.

Each year, crude palm oil refineries generate around 2 million tonnes of spent bleaching earth (SBE) (A. Beshara and C. R. Cheeseman, 2014). Malaysia is well-known for its abundant palm oil fruit production. Bleaching earth is used during the pre-treatment stage of degumming and bleaching crude palm oil to produce refined palm oil. SBE is a by-product of the refining of crude palm oil. SBE from refineries is commonly disposed of in Malaysian landfills (Loh S K , Cheng, S. F., May C and Ngan, M, 2006). Additionally, it can be utilized as a fuel in boilers, and anhydrous clay can be used in the manufacture of cement. Due to anaerobic degradation, SBE disposal in landfills has the potential to affect greenhouse gas (GHG) emissions (Raihana Farahiyah, 2019). Additionally, SBE poses a fire hazard during spontaneous combustion due to the pyrogenic nature of the unsaturated fatty acids in the residual oils. Frequently, waste is disposed of in landfills without being pre-treated. Due to the high oil content of Spent Bleaching Earth, its disposal may pose environmental problems, as it is flammable and can contaminate groundwater.

Creating DSBE as a soil binder also has the advantage of eliminating SBE waste from being disposed of in landfills, which contributes to greenhouse gas emissions. There have been no studies in Malaysia that have used it on laterite or soft soil. The primary purpose of this research is to look into the application of DSBE as a lateritic soil stabilizer. This work is crucial for promoting the numerous applications of DSBE, which are not limited to producing bio-fertilizer, cement replacement and many more.

This research also emphasizes the aspect of sustainability in the construction industry especially in Malaysia. Sustainable practices can influence a country's future economy and ecological. For example, in this context, the DSBE materials may contribute to GHG emission during their extraction, processing, manufacture, maintenance, and disposal. In addition, DSBE may be possible to be commercial as the established stabilizer. Sustainability is the ability to meet current requirements without compromising future needs. That is, sustainability is a method of action whose effects can be perpetuated. Construction is one of the most destructive industries to the environment. So sustainable building methods are vital. Sustainable building practices are more eco-friendly. Sustaining this industry's economy and environmental goals will benefit both.

1.5 Objectives of Study

The objectives of this study are:

a) To characterize the index properties of lateritic soil.
b) To characterize the physical properties of lateritic soil.
c) To identify the mineral composition of the DSBE.
d) To assess the effect of DSBE dosage on the compaction properties of lateritic soil.
e) To investigate the effect of DSBE dosage on soil strength development behaviour through compression.

1.6 Scope of Study

The scope of work included all necessary and relevant work as well as important data in order to meet the study's goals. Lateritic soil samples were collected in the Labuan area, and DSBE waste from a palm oil factory in Lahad Datu, Sabah.

Lateritic soil and DSBE samples will be characterized and analysed in terms of their index and physical properties. Particle size analysis, specific gravity, and the Atterberg limit test are among the tests that will be performed.

The study aims to assess the strength behaviour of lateritic soil and DSBE mixtures. Therefore, the effect of DSBE dosage on the compaction and strength properties of lateritic soil is being studied. The DSBE dosages used were 0%, 25%, 50%, 75% and 100% of the soil replacement, respectively. The standard proctor compaction test is conducted to determine the optimum water content and maximum dry density of the soil and mixtures. The shear strength properties of soil (untreated) and treated mixtures were analysed using the unconfined compressive strength (UCS) test. The effect of dosages DSBE on soil strength development behaviour with respect to the percentage of DSBE dosage used in this study was also investigated.

The code of practice used for this test will be based on the BS1377 Methods of Test for Soils for Civil Engineering Purposes and ASTM D698. The physical and mechanical properties tests will be carried out at the Faculty of Engineering's Geotechnical Laboratory.

1.7 Significance of Study

Laterites have been observed to exhibit property changes even during construction. Therefore, proper laterite soil selection is critical at times depending on the type of engineering application. The primary goal of this research, which is to evaluate the properties of lateritic soil and DSBE, is expected to be met. In addition, the impact of various DSBE dosages (25%, 50%, 75%, and 100%) on the compaction and strength properties of lateritic soil will be examined. The goal of this study is to find the most effective method for improving lateritic soil behaviour and characteristics that can be used in the construction industry. Furthermore, the purpose of this research is to assess the trend of DSBE addition to soil samples. As a result, it is critical to emphasise the role of DSBE in construction and to promote its use as an alternative stabiliser in the industrial environment.

In general, engineering applications such as embankments, road construction, foundations, dams, and stabilisation methods for road bases necessitate the determination of soil classification. In this regard, determining other soil parameters or properties prior to execution is critical for any engineering application. It helps to have a general understanding of the soil and its behaviour. Researchers use data from basic engineering geological properties to plan for any such applications.

1.8 Thesis Outline

An overview for every chapter discussed in this thesis is in this segment.

Chapter 1 is for the introduction part, which is made up of several sub-unit, which are background study, problem statement, objectives of study, the scope of the study, expected result and the significance of the study.

Chapter 2 primarily the literature review for the lateritic soil and de-oiled Spent Bleaching Earth (DSBE). This chapter summarises previous studies on lateritic soils and DSBE, discussing its origin, production, types, classes, behaviour, and qualities. The review sources included in this chapter are drawn from a variety of past studies conducted by various researchers, as evidenced by their high indexing consistency and recognition as appropriate references.

The methodology section of Chapter 3 delves into the details of this study. It covers the procedures used, sample preparation techniques, and mechanical testing procedures for everyone. Additionally, this chapter covered the apparatus' implementation, specification, and limitations.

Chapter 4 is providing and presenting the information of the result from the conducted experiments, data collection, data analysis of each experiment, and the justification of the data to be discussed.

Finally, Chapter 5 outlines the research's conclusion and highlights the research's key findings and conclusions from the analysis. This chapter concludes with an additional recommendation for future study endeavours.