UNDRAINED SHEAR STRENGTH OF SOFT CLAY STABILISED WITH SILICA FUME AND EGGSHELL ASH

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Penggunaan wasap silika (SF) dan abu kulit telur (ESA) dalam penstabilan tanah dapat mengurangkan kesan negatif kepada alam sekitar secara berkesan, sementara itu bertindak sebagai penstabil alternatif kepada bahan tradisional yang mahal dan tidak mesra alam. Kajian ini bertujuan untuk menemui potensi SF dan digabungkan dengan ESA dalam menstabilkan kaolin lembut, dalam aspek pengedaran saiz zarah (PSD), graviti spesifik, had Atterberg, parameter pemadatan dan kekuatan ricih yang tidak bersaliran (USS). Perbandingan antara kaolin lembut yang sebelum stabil dan kaolin yang stabil dengan kandungan penstabil yang berbeza telah dinyatakan dalam kajian ini. Pada mulanya, 2 %, 4 % dan 6 % SF daripada berat tanah kering telah ditambah ke kaolin lembut dan kandungan optimum SF ditentukan berdasarkan USS. 3 %, 6 % dan 9 % ESA kemudiannya dimasukkan ke kaolin lembut yang telah digabungkan dengan kandungan optimum SF untuk menentukan keupayaannya dalam menstabilkan kaolin lembut dan kandungan optimum ESA yang menyebabkan peningkatan maksimum dalam USS. Kemasukan SF dengan ESA menyebabkan graviti spesifik yang lebih rendah, pengurangan kepekaan indeks (PI), penurunan ketumpatan kering maksimum (MDD), peningkatan kandungan kelembapan optimum (OMC), dan USS yang lebih tinggi daripada kaolin lembut yang sebelum stabil dan yang stabil dengan SF sahaja. Hasil ujian mampatan yang tidak terkandung (UCT) mendedahkan bahawa kandungan optimum penstabil adalah 6 % SF dan 6 % ESA, dengan penambahbaikan tertinggi sebanyak 68.8 % dalam USS. Ini menjelaskan kedua-dua SF dan ESA adalah penstabil tanah yang berpotensi.

ABSTRACT

The application of silica fume (SF) and eggshell ash (ESA) in soil stabilisation can effectively reduce the negative environmental impact, meanwhile, act as the alternative stabilisers to the costly and non eco-friendly traditional materials. This study discovers the potential of SF and in combination with ESA in stabilising the soft kaolin, in the aspects of particle size distribution (PSD), specific gravity, Atterberg limits, compaction parameters and undrained shear strength (USS). The comparison between the unstabilised soft kaolin and the stabilised kaolin with different stabilisers content is established in this study. Initially, 2 %, 4 % and 6 % SF by weight of dry soil were added to the soft kaolin and the optimum SF content was determined based on the USS. Then, 3 %, 6 % and 9 % of ESA was incorporated to the soft kaolin admixed with optimum SF content to define its ability in stabilising soft kaolin and the optimum ESA content that attributes to maximum improvement in USS. The inclusion of SF with ESA causes a considerably lower specific gravity, reduced plasticity index (PI), decreased maximum dry density (MDD), increased optimum moisture content (OMC), and higher USS than the unstabilised soft kaolin and those stabilised with SF alone. The result of unconfined compression test (UCT) reveals that the optimum stabilisers content is 6 % SF and 6 % ESA, with the greatest improvement of 68.8 % in USS. This elucidates both SF and ESA are the potential soil stabilisers.

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LIST OF SYMBOLS

$\rho_{d(max)}$	Maximum dry density
ρ_d	Dry density
$\emptyset$	Frictional angle
Ca^{2+}	Calcium ion
C_u	Undrained cohesion
G_s	Specific gravity
H_1	Head at beginning of permeation period
H_2	Head at end of permeation period
k	permeability
K	Potassium
K^+	Potassium ion
M	Mass of Soil
Mg^{2+}	Magnesium ion
M_s	Dry mass of soil
M_w	Mass of water
O^{2-}	Oxide ion
OH^-	Hydroxide ion
q_u	Unconfined compressive strength
S_u	Undrained shear strength
t	Permeation period
V	Volume of Soil
w	Moisture content
w_{opt}	Optimum moisture content
W_s	Dry weight of soil
W_w	Weight of water
σ_1	Major principal stress
σ_3	Minor principal stress
ρ	Density
ε	Axial strain

LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
Al_2O_3	Aluminion oxide
ASTM	American Society for Testing and Materials
BA	Bottom ash
BFS	Blast furnace slag
$Ca(OH)_2$	Hydrated lime; Calcium hydroxide
$CaCO_3$	Calcium carbonate
CaO	Calcium Oxide
CBR	California Bearing Ratio
CBR	California Bearing Ratio
CEC	Cation Exchange
CO_2	Carbon dioxide
CSH	Calcium silicate hydrate
ESA	Eggshell ash
GGBFS	Ground granulated blast furnace slag
LL	Liquid limit
MDD	Maximum dry density
OMC	Optimum moisture content
OPC	Ordinary Portland Cement
PI	Plasticity Index
PL	Plastic limit
POFA	Palm oil fuel ash
RHA	Rice husk ash
SF	Silica fume
SiO_2	Silica dioxide
SL	Shrinkage limit
UCS	Unconfined compression Strength
UCT	Unconfined Compression Test
UMP	Universiti Malaysia Pahang
USS	Undrained shear strength
USCS	Unified Soil Classification System

CHAPTER 1

INTRODUCTION

1.1 Introduction

Expansive soil is well known for its swell-shrink characteristics as it mainly consists of clay minerals and this often presents problems in civil engineering work (Negawo *et al.*, 2017). The geotechnical properties of the expansive soil vary when exposed to the fluctuations of water content. It shrinks upon drying and expands when wetting. This instability condition of the soil contributes to the formation of the significant hazard in construction such as causing enormous damage to the overlaying foundations and pavements. Thus, soil treatment should be carried out to enable the weak soil to be satisfactory for the construction.

Soil stabilisation is a process of altering the geotechnical characteristics of weak soil in order to enhance its soil properties in terms of strength, volume stability, permeability, compressibility, and durability. The stabilisation of soil can be attained by blending and mixing the weak soil with other soil or stabilising additives (Afrin, 2017). Through soil stabilisation, the weak soil will become sustainable for carrying the structural load from construction as the stabilised soil has better strength, lower permeability, reduced compressibility, and increased durability. Soil stabilisation can be either carried out in-situ or ex-situ.

There are two types of soil stabilisation techniques, namely mechanical stabilisation and chemical stabilisation. Mechanical stabilisation is achieved by modifying soil gradation by mixing with the other soil of different gradations. A dense mix is then formed through compaction. Chemical stabilisation is the technique that stabilised the weak soil by using stabilising admixture such as cement, slag, lime, chemical additives, fly ash, rice husk ash, bituminous materials, waste products and some more (Afrin, 2017). Cation exchange process and pozzolanic reaction among soil and the added stabiliser in chemical stabilisation contribute to the improvement in soil strength.

1.2 Problem Statement

Clay soil is one of the troublesome soil that presents low soil strength, high compressibility and less durability due to its softness and expansive characteristics. This problematic soil possesses problems in many structures and highway construction. A settlement is elucidated as deformation of soil due to the applied load and it is the most common problem that the civil engineers have to deal with for the construction over soft clay. In the international context, Pisa Leaning Tower in Italy is the famous building that illustrates the uneven settlement of soft clay foundation soil. This tower had experienced consolidation settlement and tilted 3.97 ° toward the south. Several engineering remediations were carried out in order to stop further leaning. In the Malaysia context, Leaning Tower at Teluk Intan, Ipoh represents another soft soil problem. The lean was triggered by the differential settlement of the tower foundation (Huat, 2005). Thus, the method for stabilising soft clay soil is significance for the construction over such problematic soil as when the availability of good soil that suitable for construction is decreasing.

Chicken eggshells are the domestic waste produced in by hatcheries, household, and food industry. The generation of the wasted eggshell is massive in quantity. The Star Online (Lee, 2011) reported that 20 million eggs were consuming by Malaysian per day. As stated by Food and Agriculture Organization of United Nations, Malaysians egg consumption per capita in the year 2013 was 14.0 kg and Malaysia was the 14^{th} out of 139 countries in terms of egg consumption (FAOSTAT, 2013). A survey conducted in 1997 showed that 26.6 % of the eggshell waste were being used as compost, 26.3 % were disposed of as waste, 21.1 % as a feed ingredient and 15.8 % with other use (Schumacher *et al*., 2002). Improper waste chicken eggshells handling method brings tremendous environmental impact such as smelly by-products when the waste egg attached on shell get rotten, consequently causing the spread of viruses and bacteria, groundwater pollution by leachate, unpleasant aesthetic view, and so on.

1.3 Objectives

This study is to study the performance of soft kaolin stabilised by the silica fume (SF) with eggshell ash (ESA). Therefore, the objectives of this present study are as follow:

1. To determine the basic engineering properties of kaolin, SF, and ESA.

2. To determine the basic engineering properties of kaolin stabilised with SF and ESA.

3. To evaluate the optimum percentage of SF and ESA corresponding to the maximum undrained shear strength.

1.4 Scope of Research

The key motive of this research is to examine the ability of SF combined with ESA in soft clay soil stabilisation. Kaolin S300 is used as the soil sample while the densified SF and ESA are the stabilisers in this research. The ESA is generated from the raw chicken eggshells collected from cafeterias at Universiti Malaysia Pahang. Calcination process of eggshell was carried out through the furnace at 800 °C as this is the decomposition temperature of calcium carbonate ($CaCO_3$) to calcium oxide (CaO) and the ESA gained is in white colour with a little grey (Tangboriboon and Sirivat, 2012). Numerous tests were performed to find out the basic engineering properties of these materials.

Various percentages SF (2 %, 4 %, and 6 %) and of ESA (3 %, 6 %, and 9 %) were added to Kaolin S300 in this research to acquire the optimum content of the additives that the stabilised soil manage to achieve its maximum shear strength. The shear strength property of the kaolin clay was determined through Unconfined Compression Test (UCT). The maximum shear stress at failure was then later determined through Mohr's Circle.

The basic engineering characteristics of kaolin, ESA and SF are carried out through the following laboratory tests:

1. Sieve Analysis

2. Hydrometer Test

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