COMPRESSIVE STRENGTH BEHAVIOR OF TREATED MARINE CLAY USING ORDINARY PORTLAND CEMENT AND BLAST FURNACE SLAG

KUAN SIEW FUNG

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To my beloved mother and father

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ABSTRACT

Soft marine clay often treated as a problematic soil with undesirable properties of low bearing capacity, high compressibility and low hydraulic conductivity. In many suggested ground improvement works, mixing of additional binders to the marine clay can increase the strength of the soft marine clay. This research will be focused on the effects of compressive strength of the marine treated clay using ordinary Portland cement (OPC) and ground-granulated blast furnace slag (GGBFS) by conducting laboratory testing of unconfined compressive strength (UCS) with different curing time. The preliminary tests on the physical and chemical properties of the marine clay was carried out to have a better understanding on the suitability and properties of the marine clay. The marine clay used in this research is collected from Jimah, Port Dickson in Negeri Sembilan, Malaysia. The samples were tested after a curing period of 7, 14, 28 and 56 days based on two (2) different design mix of slag cement proportion of 0:100 and 70:30. Total of 8%, 11% and 14% binder content to the total weight of samples with water cement ratio of 1.0 were added. From the study, it can be concluded that the strength of the treated marine clay increased with increasing amount of binder content and duration of the curing time. Sample with slag cement proportion of 70:30 have lower strength at early stage but reach higher UCS at later stage when compared with sample with slag cement proportion of 0:100 due to strong pozzolanic reaction of GGBFS. The investigation has shown that GGBFS is a strong bind product that can be used to improve UCS.

ABSTRAK

Tanah lempung marin lembut sering dianggap sebagai tanah yang bermasalah dengan ciri-ciri keupayaan galas kebolehmampatan dan kekonduksian hidraulik yang rendah. Dalam kebanyakan projek cadangan pembaikan tanah, campuran pengikat digunakan untuk menambah kekuatan tanah lempung marin. Kajian ini akan fokus kepada kesan kekuatan mampatan tanah lempung marin dengan campuran Portland Simen Biasa (OPC) dan sanga relau (GGBFS)untuk menjalankan ujian makmal ekuatan mampatan tak terkurung (UCS). Ujian awal mengenai sifat-sifat fizikal dan kimia tanah lempung marin juga dijalankan untuk mengetahui kesesuaian dan sifat-sifat tanah lempung marin. Tanah lempung marin yang digunakan dalam kajian ini dikumpul dari Mukim Jimah, Port Dickson di Negeri Sembilan, Malaysia. Sampel diuji selepas tempoh 7, 14, 28 dan 56 hari berdasarkan dua campuran yang berbeza iaitu sanga simen bahagian 0:100 dan 70:30. Sebanyak 8%, 11% dan 14% kandungan simen dengan jumlah berat sampel telah ditambah. Dalam kajian ini, dapat disimpulkan bahawa kekuatan tanah lempung marin ynag dirawat dapat ditingkatkan dengan tempoh masa yang meningkat. Keputusan kajian ini menunjukkan bahawa GGBFS mempunyai kekuatan mampatan yang rendah pada peringkat awal tetapi mencapai kekuatan mampatan yang lebih tinggi pada peringkat kemudian jika dibandingkan dengan sampel dengan sanga simen bahagian 0:100 disebabkan oleh proses pozzolanic yang kuat oleh GGBFS. Kajian ini menunjukkan bahawa GGBFS adalah produk pengikat yang kuat dan boleh digunakan untuk meningkatkan kekuatan mampatan.

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LIST OF ABBREVIATIONS

Al	Aluminum
ASSHTO	American Association of State Highway and Transportation Officials
ASTM	American Testing Manual
BS	British Standard
Ca	Calcium
D	Number of day
F	Floride
Fe	Felium
GGBFS	Ground-granulated blast furnace slag
K	Potassium
MC	Marine clay
Mg	Magnesium
Na	Sodium
O	Oxygen
OPC	Ordinary Portland Cement
S	Sulphur
Si	Silicate
Su	Undrained shear strength
UCS	Unconfined Compressive Strength
USCS	Unified Soil Classification System
W	Moisture content

LIST OF SYMBOLS

m_{binder}	binder content
w_N	natural water content in unstabilised soil
ρ_{soil}	bulk density of unstabilised soil
ɣ	Unit Weight
G_c	Specific gravity of Binder
G_S	Specific gravity of Clay
G_S	Specific gravity
γ_w	Unit Weight of Water
I_p	Plasticity Index
V_a	Volume of air Void
V_c	Volume of Binder
V_S	Volume of Clay
V_w	Volume of Water
w	Natural Moisture Content
Wc	Weight of binder

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Marine clay normally deposited along the coastal line of east and west part of Peninsular Malaysia. It represents the fine grained soft soil which the hydrous silicate aluminum molecules microcrystalline and arranged repetitiously to produce sheet-like structure. The mineralogical composition of marine clay consists of three main groups of clay minerals which are kaolinites, illites and montmorillonites with some non-clay minerals of feldspars and quartz (Basack & Purkayastha, 2009). This cohesive soil has higher moisture content than the liquid limit, thus displaying low bearing capacity, low permeability and high compressibility in term of engineering properties for construction (Vipulanandan et al., 2007).

The engineering and environmental properties of soft marine clay can be dramatically improved through ground improvement method of soil mixing with ordinary Portland cement (OPC) and furnace slag. Ordinary Portland Cement (OPC) is a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, and usually containing one or more of the forms of calcium sulfate as an intergranular condition (ASTM C-150, 2005).

Furnace slag is the byproduct of the steel industry that is naturally cementitious and is often used as a cement replacement material in concrete. It consists of silt and clay-sized, non-cohesive particles with relatively low specific gravity ranging from 2.2 to 2.7. For the specific gravity of OPC is typically over 3.1 (ASSHTO M295, 2011).

1.2 Research Background

With rapid urbanization and fast growing in construction and infrastructure, the expansion of human population led to more utilization of soft ground on coastal area for further project development and construction. However, in geotechnical perspective, soft marine clay layers are weak and often treated as a problematic soil with undesirable properties as it imposes restrictions on the design and performance of site work. Bearing capacity failure occurs normally due to the reduction in strength and stiffness of the soil which led to consolidation and undergo excessive vertical settlement and lateral deformation which damage the construction building and foundation.

As marine clay is unfavorable in designing of engineering structures, many geotechnical engineers used different methods to improve the soft soil strength. One of the common practice is either by removing the whole marine clay and replace it with suitable soil or increase the bearing capacity by transferring the load through it stronger stratum layer below. Some engineers re-design the building or structures foundation used to accommodate the prevailing difficulties of soft soil However, all these methods are very cost effective as the depth that needed to be considered and the quantities that concerning are small. Thus, the problem of economically construct and maintain of the soft ground within limited right way is a continue concern as this can be very difficult and expensive engineering problem to resolve.

1.3 Problem Statement

Marine clay is one of the problematic soil that exist along the coastal line of West Malaysia. Several problems are faced when dealing with the soft clay from soil characterization, stability of structures and ground improvement solution. Due to it complex geological histories, thus the stress-strain-strength behavior of the soft clay is very complicated. As it exhibits high potential of shrinkage during dry periods and swell during wet periods, it causes a lot of geotechnical issues on construction. Low shear strength and high compressibility of the soft clay causes low bearing capacity which led to the settlement of structures and subsequently causing failure of the foundation.

In many suggested ground improvement works, mixing of additional binders to the marine clay can increase the strength of the soft marine clay. In designing of foundation and structures, it is desirable to know the amount of binders needed for the improvement of soft ground before implementing the treatment process. It is necessary to provide information based on treated local soft marine clay as it will provide better understanding on the most suitable binders to be used for achieve required maximum strength. Thus, trial mix in laboratory is carry out in order to achieve the expected strength needed in the mix. Unconfined compressive strength of treated marine clay is easily related with the type and amount of binders to reach desired strength.

1.4 Objectives

The aims of this research are to improve the strength soft marine clay by mixing of OPC and furnace slag at various percentage and curing period based on laboratory

experimental works and physical model tests. The objectives of this research are as follows:

a) To determine the physical and mechanical properties of untreated marine clay.

b) To determine the unconfined compressive strength of treated marine clay using ordinary Portland cement and ground-granulated blast furnace slag.

c) To compare the effect of addition of Ordinary Portland Cement and ground granulated blast furnace slag on the improvement of compressive strength of treated marine clay with different curing time.

1.5 Scope of Research

This research will be focuses on the effects of compressive strength of the marine treated clay using OPC and GGBFS by conducting laboratory testing of unconfined compressive strength (UCS) at constant rate of strain to determine the maximum strength with slag cement proportion of 0:100 and 70:30. The preliminary tests on the physical and chemical properties of the marine clay is carried out to have a better understanding on the suitability and properties of the marine clay. The marine clay used in this research is collected from Mukim Jimah, Port Dickson in Negeri Sembilan, Malaysia. The samples are tested after a curing period of 7, 14, 28 and 56 days based on four (3) different design mix of 8%, 11% and 14% binder content to the total weight of samples.

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