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College of Engineering

Stabilization Performance for Soft Clay Soil Improved by Metakaolin Based Geopolymer

A Thesis Submitted to the Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Geotechnical Engineering)

By

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

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I certify that this thesis entitled **"Stabilization Performance for Soft Clay Soil Improved by Metakaolin based Geopolymer"** was prepared by **"Shams Othman Abdulkareem"** under my supervision in the University of Diyala in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering (Geotechnical Engineering).

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Name: Prof. Dr. Jasim M. Abbas (Supervisor)

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We certify that we have read the thesis entitled **(Stabilization Performance for Soft Clay Soil Improved by Metakaolin based Geopolymer)** and we have examined the student **(Shams Othman Abdulkareem)** in its content and what is related with it, and in our opinion it is adequate as a thesis for the Degree of Master of Science in Civil Engineering (Geotechnical Engineering).

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Dedication

To my beloved parents,

To my dear sisters,

Who supported me all the way in my life to do the best,

Thank you for your love and encouragement,

Without you, I could not overcome the difficulties.

To All my teachers, my friends, and everyone who wished me success in my work.

I dedicated my humble work.

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Shams Othman Abdulkareem

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ABSTRACT

For many decades, soft clay soil has been stabilized using traditional soil stabilizers like cement and lime. These traditional stabilizers produce cementations productions that improve the strength characteristics and enhance other properties for soil. However, the consumed energy to produce the traditional soil stabilizers results in substantial amounts of dangerous greenhouse gases into the environment.

The Geopolymers have gained much attention as a sustainable alternative to conventional chemical additives. Geopolymers have high compressive strengths and can be prepared from many sources by employing waste materials or natural sources. Geopolymers as soil stabilizer have been reviewed by limited researchers, although most studies were conducted on several types of soil with other materials.

In this study, four percentages of Metakaolin-based Geopolymer were used (i.e. 8, 10, 12, and 14 % by dry weight of soil), and the total liquid of the activator ratio is 38 % by dry weight of soil. The prepared samples were firstly treated thermally for four hours at different temperature (i.e. 20 °C, 40 °C, 60 °C, and 80 °C). After that, samples were placed at room temperature for specific periods 1,3,7,14, and 28 days.

This study aimed to examine the effect of using the different percentages of Metakaolin on the mechanical strength of soft clay soil under different conditions. All treated samples were conducted mainly by the unconfined compressive strength test. In addition, assess the some geotechnical properties like specific gravity, liquid and plastic limit, and compaction properties for treated soil.

Finally, the microstructure and clay minerals of natural and treated soil were observed by scanning electron microscope and the X-ray powder diffraction respectively.

It can be concluded that, the results of unconfined compressive strength illustrated that the peak of unconfined compressive strength was recorded with addition of 10 % MK cured initially at 40 °C and completes for 14 days that giving 9.92 MPa. In addition, the results of specific gravity reduce from 2.72 to 2.3 as the Metakaolin content increased. Also, the maximum dry density decreased from 16.8 kN/m^3 to 15.5 kN/m^3 as Metakaolin content increased, while the optimum moisture content seems to increase from 18.4 % to 24.7 % with increase Metakaolin content. Moreover, the scanning electron microscope shows the formation of cementation compounds. In addition, the X-ray powder diffraction analyses confirm the chemical composition by the production of Sodium silicate and sodium aluminosilicate hydartes.

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LIST OF ABBREVAITIONS

Abbreviation	Term
ASTM	American Standard of Testing Measurements
MK	Metakaolin
OPC	Ordinary Portland Cement
AAS	Alkaline Activator Solution
UCS	Unconfined Compressive Strength
SEM	Scanning Electron Microscope
XRD	X – Ray Diffraction
USCS	Unified Soil Classification System
pH	Hydrogen Number
VS	Volumetric Shrinkage
Vo	Origin Volume of Specimen
Vf	Final Volume of Specimen
wc	Water Content
Gs	Specific Gravity
MDD	Maximum Dry Density
OMC	Optimum Moisture Content

Chapter One

Introduction

1.1 General

In Iraq and several countries, soft soils cover large areas of the ground surface that result in problematic behaviors especially when constructed upon. According to that, this type of soils are challenging for geotechnical engineers because of their low compressive strength, high compressibility, shrink and swell behaviors even under low loads might be caused displacements **(Sargent et al., 2013; Consoli et al., 2015).** Construction projects and highways and railways on soft soils may experience problems and hazards, therefore, this soil requires special construction measures to avoid or reduce the damage to a certain extent **(Kempfert and Gebreselassie, 2006).**

Geotechnical properties of such soils are improved by various methods including mechanical stabilization and chemical stabilization **(Sherwood, 1993).** These techniques can improve the properties of the soils by treating them in situ. These techniques include densifying treatment such as compaction, preloading, bonding of soil particles such as grouting, chemical stabilization, and the use of reinforcing soil improvement such as stone columns, geotextiles, and geogrid.

One of the methods for improving weak soil is to replace it with suitable soil. The high cost for this method has led to identify alternative methods, and soil stabilization with different admixtures one of these methods. In general, the term "soil stabilization" goes back about 5,000 years **(Firoozi et al., 2017).**

Chemical stabilization technique of soft soil has been increased significantly in latest decades ago due to new construction site, Also this technique will be important for many of the geotechnical engineering applications **(Ismaiel, 2006).** In recent several of years, alternative materials commonly referred to as Geopolymers have received much attention as a sustainable alternative to other materials. It has been considered innovative, sustainable, eco-friendly as a result of their low-cost and their low carbon emissions. Therefore these materials are used to improve the properties of weak soil such as strength and durability, and other characteristics. Hence, use of Geopolymer which is an eco-friendly product may be considered as a green solution **(Zhang et al., 2013)**.

1.2 Importance of the Study

Improvement of ground soil is an essential role in Civil engineering as well as it affects in cost and life of people, therefore it is necessary to use new material considered an eco-friendly and low cost for study the feasibility of these materials.

1.3 Problem Statement of the Study

In general, several materials were used to improve soft soil like cement and lime but these material considered unfavorable for example the Portland cement generate 8% of cumulative emissions **(Andrew, 2018).** Therefore, the problem at hand is improving the unconfined compressive strength and enhance some geotechnical properties of soft clay soil. The applied improvement technique is stabilization of soil by using Metakaolin to achieve the required results.

1.4 Objectives of the Study

The objective of this thesis is to study the feasibility of Metakaoiln based Geopolymer for soft clay soil stabilization, by increasing their strength and enhance their geotechnical properties for the study. In addition, this study aims to investigate the effect of the MK-based Geopolymer on the strength of soil samples treated by a specific percentage of stabilizers on soil samples treated under different temperatures cured by different periods.

1.5 Scope of the Study

The scope of this study is to evaluate the laboratory performance of soft clay soil with the various addition of Metakaolin based Geopolymer. In the present study, there were limitations on;

- Evaluate the unconfined compressive strength; in addition, illustrate the stress-strain relationship for all treated specimens.
- Evaluate the volumetric shrinkage, pH soil, and remaining moisture content for all treated specimens.
- Examine some geotechnical properties such as specific gravity, Atterberg limits, and compaction test for the specific group treated by specific conditions.
- Analyze scanning electron microscope (SEM) and x-ray diffraction (XRD) for the specific group treated by specific conditions.

1.6 Thesis Organization

The thesis work is organized into five chapters as follows:

Chapter one: This chapter presents a brief introduction and importance, also includes the aim of this study.

Chapter two: Presents the previous study regarding the influence of additives included MK- based Geopolymer in stabilization soft soil.

Chapter three: Presents full details of the experimental work including laboratory tests and chemical tests for natural and treated soil.

Chapter four: Is devoted to the results, analysis, and discussion of the test results.

Chapter five: Include the main conclusions provide for this study as well as the recommendations for future work.