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IMPROVEMENT OF SOME SOFT CLAY SOIL PROPERTIES USING GEOPOLYMER MATERIALS

A THESIS SUBMITTED TO THE COUNCIL OF COLLEGE OF ENGINEERING,
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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

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Dedication

To …

God,The greatest truth in my life.

My father spirit, the nice memory of my life

My mother, the sight of my eyes.

My wife, who supported me.

Our honorable teachers who taught and rewarded us their knowledge.

Everyone, who wishes me success in my life,

I dedicate this humble work.

Abdalla

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Abdalla Mohamed Shihab

IMPROVEMENT OF SOME SOFT CLAY SOIL PROPERTIES BY GEOPLYMER MATERIALS

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ABSTRUCT

In general, soil improvement by admixtures or simply (soil stabilization) is a common cost effective way to treat soft clay soils and overcome its undesirable behavior. In this way, this field have seen increasingly many attempts for finding the suitable soil admixtures.

The Geopolymers are innovative materials that illustrate good properties which were argued to overcome the other usual soil admixtures shortcomings. In order to develop the knowledge about the Geopolymer – soft clay strength and the consequent geotechnical performance, an experimental program was introduced, moreover, a considerable concern was conducted throughout this program to the temperature effects which can vary the properties of the resulting Geopolymers to a great extent.

The experimental program consists of main two parts to make a preliminary assessment of soft soil with this new admixture. The first part included the temperature effects on the mechanical strength of Geopolymer – soft clay mix that characterized by the unconfined compressive strength as well as the ductility and the stiffness that represented by failure strain and Young's modulus, respectively. While in the second part, some heated conditions was devoted to investigate some geotechnical properties like specific gravity, liquid and plastic limit, compaction characteristics and California bearing ratio. The microstructure of the treated soil was observed by the scanning electron microscope and the mineralogical changes

were detected by the X-ray powder diffraction using specific heating conditions. The percentage of source material used are 8, 10, 12, and 14 % by dry weight and the total liquid is 38 % which corresponds 4.75, 3.8, 3.167 and 2.714 liquid over fly ash used.

The experimental results showed that the optimum liquid over fly ash ratio with respect to peak unconfined compressive strength is 3.8 when the reported degree of improvement factor about 20.1. Ductility and stiffness were also enhanced considerably with degree of improvement of 3.5 and 8.7 respectively. It can be concluded also that the optimum temperature can vary according to the source material percent and nature.

The specific gravity and the maximum dry density decreased as the fly ash content increased whereas the optimum moisture content increased. The scanning electron microscope test illustrated the formation of the Geopolymer gel and the X-ray powder diffraction analyses confirms the chemical composition of this gel represented by the potassium alominosilicat hydrate and sodium alominosilicat hydrate.

TABLE OF CONTENTS

CHAPTER TWO	LITERATURE REVIEW	
2.1	Introduction	7
2.2	Methods of Improving Soft Clay Properties	7
2.3	Admixtures Soil Improvement	9
2.4	Admixtures Soil Improvement Agents	10
2.4.1	Cement	10
2.4.2	Lime	12
2.4.3	Fly Ash	14
2.4.4	Silica Fume	15
2.4.5	Rice Husk Ash	16
2.4.6	Sugarcane Straw Ash	17
2.4.7	Tire Ash	19
2.5	Geoplymers Definition, Features and Motivation	19
2.5.1	Geopolymerization Process	20
2.5.2	Materials of Geopolymers	21
2.5.2.1	Fly Ash	21
2.5.2.2	Sodium Hydroxide NaOH	22
2.5.2.3	Sodium Silicate Na_2SiO_3	22
2.6	Applying Heat in Geopolymers	22

TABLE OF FIGURES

TABLE OF PLATES

TABLE OF ABBREVIATIONS

Abbreviation	Total name
ASTM	American Standard of Testing Measurements
CaO	Calcium Oxide
CBR	California Bearing Ratio
CSH	Calcium Silicate Hydrate
C_u	Undrained Shear Strength
EDS	Energy Dispersive Spectrotropy
FTIR	Fourier Transform Infrared Spectroscopy
KASH	Potassium Alominosilicate Hydrate
NASH	Sodium Alominosilicate Hydrate
OPC	Ordinary Portland Cement
SEM	Scanning Electron Microscope
UCS	Unconfined Compressive Strength
XRD	X – Ray Powder Diffraction

CHAPTER ONE

INTRODUCTION

1.1 General

In fact, soil improvement refers to any general action that can be done to the soil in order to enhance / control the general behavoir and / or some desired soil properties. Usually, this goal can be achieved by following common trends, for the first glance, the soil can be modified without any addition of any other materials, or some certain materials can be used to treat the problematic soils or inclusions can be provided to play the role of reinforcement agent. on the other hand, soil stabilization can be defined as a frequent and economic method to improve the properties of soil by using admixtures which is involving blending soil with suitable type of materials to render some of the target soil properties less sensitive to fluctuation or simply “stable”. There are no clear differentiations between soil stabilization and improvement because of the overlap between the applications which dictates to use this two terms interchangeably (Murthy, 2007 and Nickolson, 2015).

Furthermore, this method can be considered as an effective technique as it results in non-water soluble soil matrix. However, admixtures like ordinary Portland cement (OPC) , lime and high calcium fly ash and bitumen are widely used and examined to do this function (Swain 2015).

Geopolymers are binding gels that result from the alkali activated aluminisilicate sources which is excelled to be a suitable alternative to Portland cement as a primary binder, in this study, it is tries to investigate the effectiveness of using fly ash based geoplymers to treat soft clay soils.

1.2 Soft Clay Soil

Usually, soft clay soils are very sensitive to the presence of water and illustrate a dramatic changes in its performance if water conent varies. In general, soft clay soils are stiff when dry and loss this property when become more wet. Leakage of sewer lines, floods, rains and lack of evaporation due to buildings or pavements are the poupular reasons of increasing mositure content in clayey soils (Firoozi et al., 2017). The consequent undesirable behavior of such soils causes considerable problems like fracture and cracking in pavements as shown in Plate 1.1

Plate 1.1 Failure of flexible pavement due to weak underlying soils (www.dailycivil.com)

In fact, the construction of buildings, highways and other structures may be dictated to be done over such type of soils, at the first sight, these soils have to be avoided as much as possible due to its inadequacy to be foundation ground because of its low bearing capacity. However, It is believed that there are some factors which must be taken into account when the decision of soft soil improvement are subjected to discussion like the degree of stabilization required, site conditions and cost effectiveness (Ibrahim et al., 2014).

As a matter of fact, There is no clear definition for the term "soft soil", usually, it can be can be identified by high water content (40-60) % (Broms, 1990) which may equal or higher than its liquid limit or it can be defined as the normally or lightly over consolidated which have liquidity index greater than 0.5 and possess un drained shear strength c_u usually less than 10 kPa according to Terzaghi, 1936 (as cited by Brand Brenner, 1981). In addition, as suggested by Brand and Brenner, 1981, such type of soil can be identified by c_u less than 40 kPa.

British Standard (B.S: C.P 8004: 1986), defined a soil as soft if its C_u ranged between 20 to 40 kPa while the term very soft referred to soil with $c_u < 20$ kPa.

Kamon and Bergado, 1991 (as cited by Bergado et al., 1996) stated that for clayey soils, the softness of the ground can be assessed by its c_u, or by its unconfined compression strength (UCS), soft soils are considered very soft when UCS is less than 25 kPa and soft if between 25 and 50 kPa (Terzaghi and Peck, 1967).

In fact, the presence of soft clays in Iraq are concentrated in central and southern parts (Al Jubouri, 2013), C_u to about 30 kPa was reported in Basrah and 40 kPa or less in Maysan and Dhi Qar governorates. Random surveys show that compression indeces are of approximately 0.3 and clay fraction between 50 % and 70 % (Buringh, 1960). Therefore, high water table level in the Iraqi southern basins revealed poor soft deposits (Abbawi,2010). Textures of those soils consist of fine silty clay loams.

1.3 Geopolymers

The reaction of the materials which have alominisilicate such as red mud, fly ash, meta kaolin and rice husk ash by alkaline solutions produces binding gels called Geopolymers (Davidovits, 1988). These innovative materials appears to be promising alternatives to the OPC and other common soil stabilizers due to its good mechanical properties and sustainable nature.

Additionally, Geopolymers can be used in numbers of field applications likes precast units, pavement, bricks …..etc (Aldred and Day, 2012). Generally Geopolymer gel has a technical advantageous over the traditional cement common binding gels like high mechanical strength development, ability to gain strength rapidly, high chemical resistance, sulfate attack and cost effectiveness.

Many source material can be used as alominosilicate source such as fly ash, meta kaolin, rise husk ash, slag …..etc.

1.4 Problem Statement

Actually, the industry of OPC emits 10% of carbon dioxide around the world (Khedary et al. 2005), furthermore, when lime and high calcium fly ash and/or calcium based additives are used, the formation of ettringate and thaumasite is possible due to the sulfate attack (Firoozi et al., 2017) which dictates strength loss with respect to its long term performance. Bitumen has many problems including deterioration with age, drying and failure due to repeated load.

It is evident that there is a considerable lack of information about soil – Geopolymer applications (Singhi et al., 2016) which motivates to develop this field by scientific research programs.

1.5 Importance of the Study

In many flexible and rigid pavements surface layers failure records, it can be recognized that the subgrade and or other bottom layers failure is the main source of such hazard.

In this way, using admixtures in road ways layers design is very usefull for many purposes like cost savings in materials used through reduction in the thickness required for each layer, reducing mainainance and enhancing the deterioration rate of the upper pavment layer. For that reason, it is needed to seek for new admixtures that can play the desired role and overcome the shortcomings of the common stabilizers.

Therefore, this study tries to improve the knowledge about the soil Geopolymers application through an experimental program.

1.6 Objectives of This Study

The basic aim of this study is to investigate the effect of using fly ash based Geopolymer as an admixture on soft clay mechanical strength and some relevant geotechnical properties taking into account some of the most important key elements that govern the production of Geopolymers gels.

In order to achieve the basic aim of this study, the experimental program is divided into two general main parts:

- ***Part one:*** comprises a parametric study to understand the effect of temperature on soil - Geopolymer mix in term of mechanical strength.
- ***Part two:*** comprises an investigation to the effect of Geopolymer on some geotechnical properties using certain soil

-Geoppolymer conditions concluded in part one.

1.7 Thesis Layout

The general layout of this study consists of five chapters as explained below:

Chapter one: Presents a brief introduction of the problem and geopolymers demonstrating the importance, aim and objectives of the study.

Chapter Two: Presents a background depending on the literature re view of the recent studies.

Chapter Three: Presents the experimental works describing the laboratory testing and chemical analysis covered in this study.

Chapter Four: Shows the presentation of results recorded in this study and a brief discussion.

Chapter Five: Contains the conclusions and recommendations based on testing results.