وزارة التعليم العالي والبحث العلمي
جامعــة ديــالى
كليـة الهندســـة

# دراسة مختبرية لتصرف اساس مربع فوق تربة انتفاخية مرصوصة محسنة باستخدام الرماد المتطاير كمادة جيوبولمرية

رسالة مقدمـــة إلى مجلس كليـــة الهندســـة / جامعـــة ديالى

وهي جزء من متطلبات نيل درجة الماجستير في علوم الهندســـة المدنيـــة

تقدمت بها الطالبة

نور عبدالرحمن عبدالله

بكالوريوس هندسة مدنية/2013

باشراف

أ.د. جاسم محمد عباس

1444هـ/ ذو القعدة 2023م/حزيران

Ministry of Higher Education
and Scientific Research
University of Diyala
College of Engineering

# EXPERIMENTAL STUDY OF SQUARE FOOTING BEHAVIOR OVER TREATED COMPACTED EXPANSIVE SOIL USING FLY-ASH 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**

**BY**

**Noor Abdulrhman Abdullah**

**(B.Sc. Civil Engineering, 2013)**

**Supervised by**

**Prof. Dr. Jasim M. Abbas**

**June 2023** **Dhul -Qidah 1444**

# Chapter One

# Introduction

## 1.1 General

The expansive soil covers wide areas of the world as shown in Figure 1.1, especially in arid and semi-arid regions **(Mishra et al., 200□; Nelson et al., 201□)**. In Iraq, expansive soil covers a sizable portion of the north and middle regions, as shown in Figure 1.2 **(Al-□ubaisy, 2010)**. These soils are essentially residual soils that were left behind at the site of their creation after the chemical decomposition of rocks like basalt and trap. Moreover, the weathering of igneous rocks and the cooling of lava following a volcanic eruption are responsible for the formation of various types of soils. Although these soils are rich in alumina, iron, and lime, they are deficient in phosphorus, nitrogen, and organic matter **(Parhi, 2014).**

This type of soil contains water-absorbing expanding clay minerals like smectite; the more of these minerals a soil has, the higher its swell potential, and the more water it can hold. Because of this, these soils expand when they are wet, increasing in volume, and shrink when they are dry **(Punthutaecha et al.,200□)**.

Expansive soil is one of the more problematic soils that damages a variety of civil engineering buildings. Expansive soils behave differently than typical soils. Due to expansive soil swelling and shrinkage behavior, problems may arise causing damage in construction projects, especially for lightweight structures such as lifting buildings, cracks in walls and ceilings, and damage to pipelines, sidewalks, and walkways **(Nelson et al., 1□□□Das, 201□)**. There are plenty of amendments and treatments to improve these soils and make them suitable for such engineering projects, and soil stabilization technology has been developed in recent decades **(□olias et al., 200□).** Mechanical and chemical techniques are the methods usually used to stabilize the expansive soil. Mechanical methods such as surcharge loading, compaction control, and pre-wetting. Chemical additives such as lime, cement, chlorides, and polymers, these additives act as binders that alter soil structure and restrict swelling.

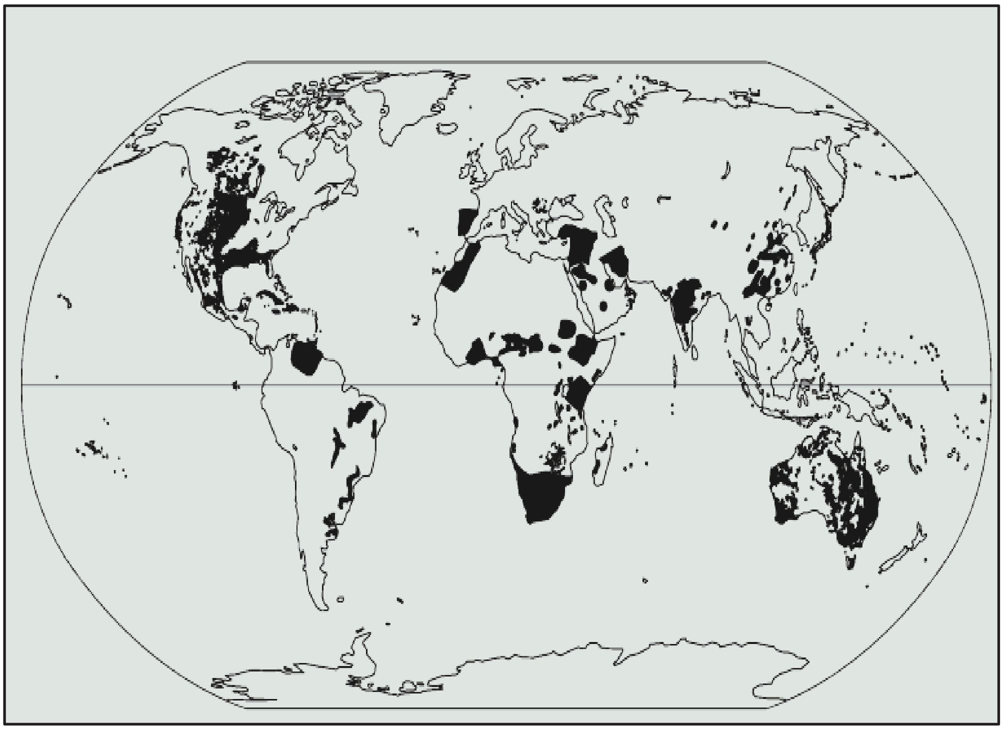

**Figure 1.1**□Distribution of expansive soils in different regions of the world **(Nelson et al., 201□).**

## 1.2 Importance of the study

Improving the problematic soil, including expansive soil, is important in geotechnical engineering, as the problems of this soil affect not only the cost but also affect people's lives. It is necessary to find the best ways, environmentally friendly and economical materials that limit the problems of this soil such as geopolymers, instead of costly traditional methods.


**Figure 1.2** The location of the expansive soils in the regions of Iraq **(after, Al-ubaisy, 2010)**

### 1.3 Problem of The Study

Generally, the presence of water in the expansive soil is the main problem, as the soil swells and the strength and hardness of the soil decrease dramatically as the moisture content increases beyond the optimum water content. The swelling or shrinkage property of the soil is a function of the moisture content of the site. The expansive soil's swelling is of great importance, it can cause damage to lightweight buildings on/in the soil.

For example, in Iraq, in regions where soils have a high potential for swelling, several problems occurred in roads and buildings especially, including in the city of Mosul. In this case, two-story residential building cracks appeared on its walls due to swelling of the soil as shown in Figure 1.3a. In addition, in the city of Ramadi, the same problem appeared as shown in Figure 1.3b. In order to reduce or avoid these problems, soil stabilization has become necessary, as the soil is treated in various ways, including chemical stabilizers with traditional materials such as lime, cement, and others.

Research over the past years has indicated that these materials work well, but some of these additives are undesirable for several reasons, including the production of ettringite, which causes expansion and some of them cause gaseous emissions. Therefore, the studies have tended in the past few years to use other alternatives with fewer defects and better performance, such as geopolymer.

On the other side. given the currently limited knowledge in the literature on the use of a small-scale lab model of shallow foundation on expansive soil. This needs to be assessed the behavior of the foundation on expansive soils before and after treatment of these soils with class F fly ash-based geopolymer and alkaline solutions.

As Geopolymer materials are economical as well as environmentally friendly because they encourage the use of industrial waste and reduce carbon dioxide emissions, geopolymer soil mixtures also have high compressive strength, sufficient hardness, and enhanced durability. Thus the use of this material needs more tests to assess if it can be a new generation of soil improvement

(a) (b)

**Figure 1.3**: The appearance of cracks in the buildings in a) Mosul city, b) Ramadi city

## 1.4 Objectives of The Study

The following topics are covered in this study: -

1. Investigate the effect of adding fly ash-based geopolymer material in different percentages on the mechanical and physical characteristics of the expansive soil (i.e., compaction characteristics, Atterberg limit, unconfined compressive strength, swelling pressure, free swelling).
2. Studying the behavior of the foundation on the expansive soil by a laboratory small-scale model before and after treating the soil under and around the foundation.
3. Study the method of loading during laboratory small-scale tests that include the loading applied after or before the swelling occurs.

**1. Layout of the Thesis**

This research work's contents are presented in five chapters.

**Chapter One**: This chapter provides a general introduction to expansive soils and their problems also the purpose of this study.

**Chapter T o**: This chapter provides a review of the properties of expansive soils, the factors affecting them, and the materials used for soil improvement

**Chapter Three**: This chapter covers test equipment, steps for performing mechanical and physical tests on fly ash-based geopolymer-treated soils, materials used, and their chemical and physical properties.

**Chapter Four**: This chapter contains a presentation of the test findings and their discussions.

**Chapter Five**: includes an overview of the study's findings and conclusions, as well as any necessary future recommendations.

# ABSTRACT

The aim of this study is to evaluate the effect of geopolymer on the properties of the expansive soil. This study included two parts. In the first part, five percentages of geopolymer were selected (0.5,1,2,4, and 6%) from the weight of the dry soil. It was found that percentages 2,4, and 6 % geopolymer gave the best improvement in terms of free swelling and decreased more than 90%. In this case, the soil changed classification from a high to a very low expansion potential. Based on this, it was selected 2% to conduct tests in the second part. Also, swelling pressure decreased from 230 kPa to (25, 10, and 7 kPa) at (2, 4, and 6%) GP.

In addition, the unconfined compressive strength was tested during the curing period (0, 3, and 7 days) where the optimal percentage of geopolymer was 4%, which gave the highest improvement rate, which reached 733% at a curing period of 7 days.

In the second part, a small-scale laboratory model with dimensions of (450 x 450 x 500) mm was proposed to find out the behavior of lightweight buildings over expansive soils. The experiments were carried out in two cases when the foundation loaded before/after saturated soil. These tests were conducted before and after treating the soil in the form of three layers (2, 3, and 4 cm), starting from the surface of the clay soil, i.e. (10, 15, and 20%) of the total thickness of the expansive clay layer of 20 cm. It can be concluded that the soil has changed from high to low expansion potential at the free soil surface.

While the soil under the foundation has changed from a high to a very low expansion potential when treating 15 and 20 % of the thickness clay layer. In addition, the Geopolymer had an effect on the bearing capacity of the soil,

as it improved by 72% when treating 20 % of the clay layer. Accordingly, it can be noted that the Geopolymer material can be used as an environmentally friendly material for soil stabilization.