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ULTIMATE SHAFT RESISTANCE OF TENSION PILE IN GYPSEOUS SOILS

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

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بسم الله الرحمن الرحيم

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We certify that we have read the thesis entitled **(Ultimate Shaft Resistance of Tension Pile in Gypseous Soils)** and we have examined the student **(Heba Qasim Hussain)** 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.

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linguistic Amendment

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Dedication

To my father, who put me in the correct road
To my mother, the light of my eyes
To whose love flows in my veins, and my heart remembers them, the air that I breathe…my brothers and sister
To our honored teachers and professors who taught me letters of gold and words of jewel of the utmost and sweetest sentences in the whole knowledge. Who reworded me their knowledge simply and from their thoughts made a lighthouse which guides me through the knowledge and success path.

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Ultimate Shaft Resistance of Tension Pile in Gypseous Soils

By

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ABSTRACT

Deep foundation such as piles adopt in case of weak soil or when type of soil in the site not capable to resists the external loadings from superstructure or collapsible soil. Types of external loads that the pile can sustain such as compression, tension or lateral load reflects on the design of pile and on the real behavior of soil-structure interaction. Many piles designed to resists compression loads only but in specific places such piles subjected to tension load due to lateral external loads such as wind or earthquake loadings. Another place that the piles subjected to tensile load is in case of the piles distributed under the towers, in this case not only sustain loads but also make the towers more stable.

Many researchers investigated the behavior of piles embedded in sand or clay and subjected to axial and lateral loads, but little studies concerned on the behavior of pile in collapsible soils such as gypseous soil. This type of soil has capable to support the external load from superstructure in case of dry condition due to the existence of gypsum which strengthens the soil structure. Many problems appear when water flows through its particles due to the dissolution of gypsum inside the soil skeleton. This dissolution leads to form cavities in the soil structure and this causes many problems such as settlement, tilting, etc. for the structures.

The present study concerned on the behavior of shaft resistance of tension pile in gypseous soils in both dry and soaking conditions to examine the effect of presence of water in the gypseous soil on the ultimate shaft resistance of pile. Many parameters are taken into account such as amount

of gypsum content (30%, 46%, and 66%), the slenderness ratio of pile L/D (10, 15, 20, and 25), pile type (steel solid pile with circular and square cross sections, steel pipe piles with open and closed ends, H-pile, timber pile, and concrete pile), pile diameter (1cm, 1.5cm, and 2cm). Also the pile shape (circular, square, and rectangular) and effect of time (2hr, 4hr, 1day and 7day after installation of pile). The test results reveals and showed that the shaft resistance of pile increases with the increase of gypsum content. When the gypsum content increases from 30% to 46%, the increase in the shaft resistance about 18%, and when the gypsum content increases from 46% to 66%, the shaft resistance increased about 35%, at the dry condition. In the soaking case, the shaft resistance of pile in gypseous soil with 66% gypsum content is found to be greater than that of others soils of 46% and 30% by about, 40% and 77% respectively. The increase in the slenderness ratio of the pile (L/D) from 20 to 25 leads to increase in the ultimate shaft resistance of pile about 70% and 84% in dry and soaking conditions respectively. The shaft resistance of steel solid pile with circular section was more than that of other types of pile. The increase of pile diameter from 1.5cm to 2cm in dry case leads to the decrease in the ultimate shaft resistance reaches 25%. While in the soaking case, when the pile diameter increases from 1.5cm to 2cm, the increase in the shaft resistance reaches 71%. In addition, the results shows that the ultimate shaft resistance of pile with rectangular section is more than that for piles with square and circular sections about 39% and 63% respectively in a dry condition, and about 29% and 39% respectively in soaking condition. The increase of time between the installation of pile and its test leads to decrease in the pile shaft resistance in both dry and soaking cases. When time increases from 2hr to 4hr, the decreases in the resistance reaches 39% in a dry case, and 51% in a soaking case.

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LIST OF SYMBOLS

Symbol	Total Name
C	Cohesion of soil
$C.P.\%$	Collapse potential of gypseous soil
C_C	Coefficient of curvature
C_U	Coefficient of uniformity
D	Diameter of pile
D_{50}	Mean size of soil particles
D_{10}	Grain size at 10% passing
D_{30}	Grain size at 30% passing
D_{60}	Grain size at 60% passing
D_r	Relative density of soil
e	Void ratio
f_s	Unit shaft resistance
$f_{s\ ult}$	Ultimate unit shaft resistance
$G.C\%$	Gypsum content of soil%
G_S	Specific gravity
H	H-pile
K	Coefficient of lateral earth pressure
L	Embedded length of pile
L/D	Slenderness ratio of pile
P_α	Ultimate pullout resistance of inclined pile
P_o	Net ultimate pullout resistance of vertical pile
q_c	Cone penetration resistance
q_s	Side resistance of cone
Q_b	End bearing resistance
Q_s	Shaft resistance
S	Upward displacement of pile
S_1	Soil one with 30% gypsum content
S_2	Soil two with 46% gypsum content
S_3	Soil three with 66% gypsum content
S/D	Upward displacement of pile related to its diameter
t	Thickness of pile wall
$W.C\%$	Water content of soil
α	Batter angle of pile
δ_{cs}	Interface friction angle between pile and soil at critical state
δ	Interface friction angle between pile and soil
$Ø$	Angle of internal friction of soil
γ_d	Dry unit weight of soil

LIST OF ABBREVIATIONS

Abbreviation	Total Name
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
CPT	Cone Penetration Test
SPT	Standard Penetration Test
USCS	Unified Soil Classification System

Chapter One

Introduction

CHAPTER ONE

INTRODUCTION

1.1 General

One of the essential issues that the civil engineer should focus on is the type of soil, especially when such soil is one of the collapsible soils. Clemence and Finbarr (1981) distinction collapsible soils as any unsaturated soil that goes through large loss of volume and a radical rearrangement of particles upon wetting with or without extra loads.

Gypseous soil is considered a type of serious collapsible soils. Gypseous soils cover many regions of the world such as China, India, Australia, and Europe. They are also found in many Arab countries such as Bahrain, Iraq, Algeria, Syria, and Jordon. In Iraq it covers about 31.7% of the surface area with different gypsum content ranging from 10-70% according to (Ismail, 1994).

Gypseous soils are very strong to carry the structures loads when found on it. Problems occur in the structures constructed on that soil such as settlement, fissures, and tilting of the structures when wetted by water. The main cause for the mentioned problems was the dissolution of the gypsum content that related between the soil particles due to the presence of water. This dissolution led to cause sudden collapse, immediate settlement, and decrease in the strength of soil under the foundation of structures. Water can reach the soil particles either from the top such as rainfall, overflow, etc. or from the bottom through the rise in the level of the ground water (Noor, et al., 2013).

Many solutions were proposed to reduce the damages occurs for the structures constructed on/in gypseous soils like the improvement of the soil properties via using physical treatment, chemical treatment, or by using pile foundation. Up to date, a number of studies used piles to support structures constructed on collapsible soils to control settlement after the process of inundation for collapsible soils (Grigorian, 1997). The study of the behavior of tension piles in gypseous soil until now is limited and this point need to many studies. Therefore, this study focuses on this point.

1.2 Problems of Gypseous Soils

Many problems face the structures constructed on gypseous soils. That problem occurs in buildings like, Tikrit training center, Samarra tourist hotel, and Karbala elevated water tank this problem which occurs due to the soil collapse (Nashat, 1990; Razouki et al., 1994; Al-Mufty, 1997). On the other hand, many problems which occur beneath the foundation of the Mosul dam due to the cavities formed because of the gypsum dissolution (Nashat, 1990). In addition, problems occur in the roads of Samarra and Tikrit which were constructed on gypseous soils. Al-Neami (2000) revealed that at the College of Air Force, in its run ways, many cracks were noticed. Cracks and excessive settlement problems were also found in Al-Anbar University, Habbaniyah Tourist Village, and in the houses found in the Al-Ramadi city (Tawfeeq, 2009).

Hospitals of Tikrit, Balad, and Dijla also suffered from many problems due to the process of gypsum dissolution. Plate (1.1) explains failure of building constructed on gypseous soil, and plate (1.2) explains the failure of building constructed on gypseous soil in Iraq.

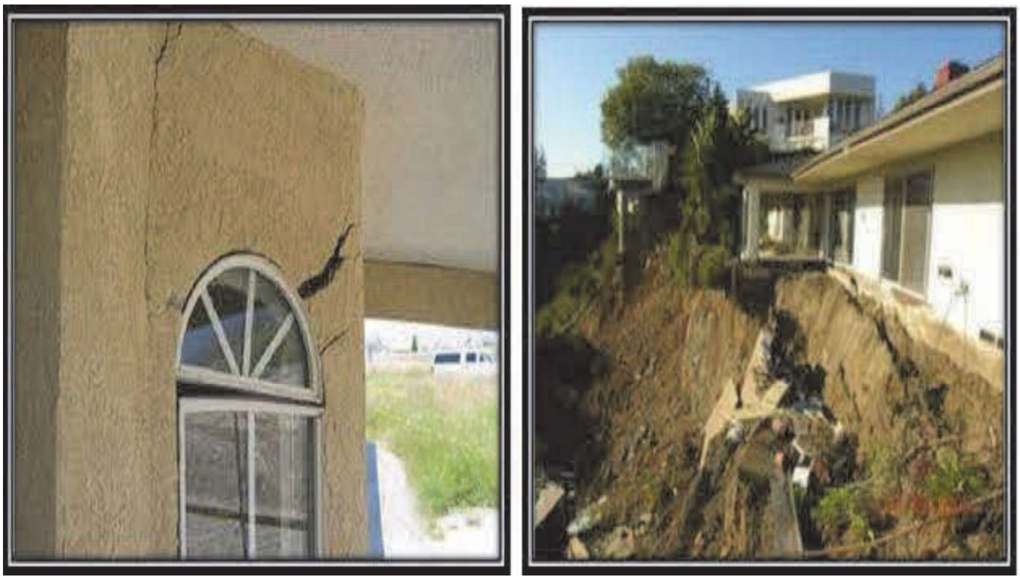

Plate 1.1 Structural failures of buildings which are constructed on gypseous soil (after Abid-Awn, 2010)

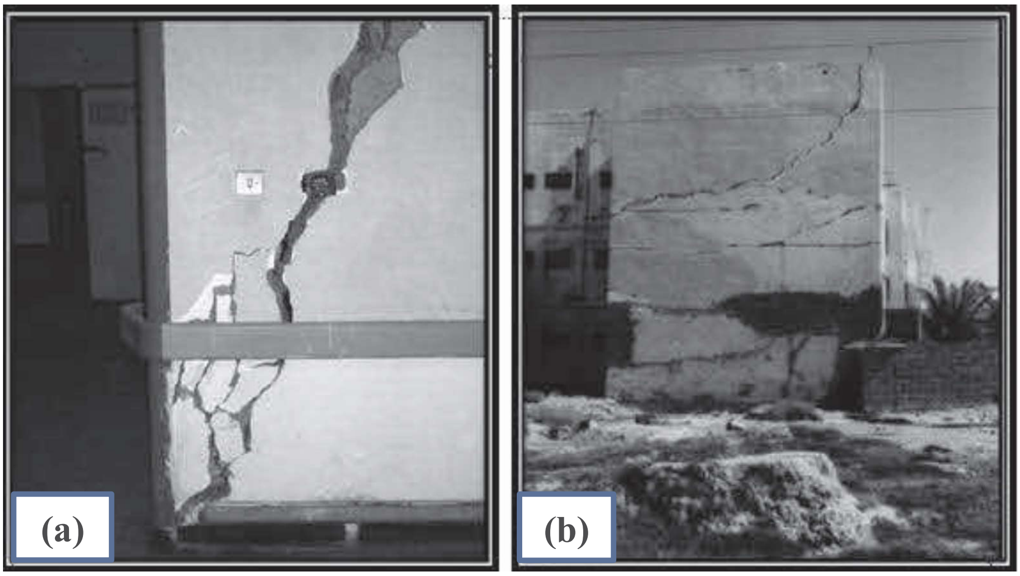

Plate 1.2 Failures of building constructed on gypseous soils: (a) wall cracks in Dijla Hospital in Tikrit; (b) failure of building in Al-Ramadi city (after Tawfeeq, 2009)

1.3 Purpose of Study

The behavior of tension pile installed in gypseous soil is yet not covered in a good way in Iraq. Therefore, this study focuses on finding the ultimate shaft resistance of tension pile when constructed in gypseous soil. The study was carried out by using a laboratory model constructed especially with loading frame for examining the soil- pile models. The main variables covered in this study are the gypsum content, G.C% (three percentages 30%, 46%, and 66% used to examine the influence of such problematic soil on pile behavior), slenderness ratios of pile L/D (L/D=10, 15, 20 and 25). Also type of piles (steel solid with both square and circular cross-sections, timber, concrete, pipe pile with both closed and open ends, H pile), effect of pile cross section (circular, square, and rectangular cross sections). As well as, effect of variation of pile diameter (D=1, 1.5, and 2cm), and effect of time (2hr, 4hr, 1day, and 7day from the installation of pile). All these variables are examined in two cases, when the soil-pile model is dry, and also examining the same model but after soaking it with water for 24 hours.

1.4 Thesis Layout

The construction of this thesis is based on five chapters; each one represents a specific part.

-*Chapter One* presents a general view of the thesis, purpose, scope of the study and some case studies for gypseous soil problems in Iraq.

-*Chapter Two* presents general information and literature review related to the subject of the study (about both piles and gypseous soils).

-*Chapter Three* presents the details of the laboratory tests of the model in addition to the properties of the soils and piles used, and description of the laboratory tests which conducted on the soils used in this study.

-*Chapter Four* presents the results of experimental works and discussion of results.

-*Chapter Five* presents conclusions which result from this study, as well as recommendations for future studies.