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

AXIAL BEHAVIOR OF SCREW PILE IN SOFT CLAY OVERLAYING SAND LAYER

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

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August, 2019 **IRAQ** **Dhu al-Hijjah, 1440**

بسم الله الرحمن الرحيم

قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا

إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة

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I certify that's this thesis, entitled. "**Axial Behavior of Screw Pile in Soft Clay Overlaying Sand Layer**" was prepared by "**Omar Kareem Ali**" under my supervision in the University of Diyala in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

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Dedication

To …

God, The greatest truth in my life.

The first teacher of humankind prophet Muhammad "peace be upon him".

My father, the cause of my success, the amazing father, and the greatest professor I have ever had.

My mother, the light of my eyes, the greatest immolated person in my life.

My wife, who supported me in critical time.

My sister, brothers whose love flow in my veins.

My son, the hope of my life.

Our honorable teachers who taught and rewarded us their knowledge.

My close friends and everyone, who wishes me success in my life,

I dedicate this humble work.

Omar

Acknowledgment

"In the name of Allah, the most beneficent, the most merciful"

*First praise be to "**Allah**" who gave me the strength and health to work and en able me to finish this work.*

*I would like to express my sincere thanks to my supervisor **Assist . Prof. Dr. Hassan O. Abbas (Ph.D.)** for his valuable advice, guidance, constructive criticism, cooperation and giving generously of their expansive time when help was needed through out the preparation of this study. I am greatly indebted to him.*

Appreciation and thanks are also extended to the all staff of Civil engineering department, and the staff of Soil mechanics Laboratory.

Thanks are also due to all my friends, for their kindest help.

Finally, I would like to express my love and respect to my family, , no word can express my gratitude to them.

Omar Kareem Ali

August, 2019.

ABSTRACT

Axial Behavior of Screw Pile in Soft Clay Overlaying Sand Layer

By

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Supervisor

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The screw pile is a famous solution used in various engineering applications, which have relatively low capacity foundations offering stability against compression, overturning moment, uplift tension, and horizontal loads.

This study presents a series of model experiments conducted on single screw pile embedded in soft clay soil over laying a sandy soil under compressive loads. The effects of different parameters, such as screw pile length (L), number of helix plate, helix diameter (D_h), inter helix spacing (s) and screw pile settlement, are studied. Three different pile length (300, 350 and 400) mm, single and double helix and pile without helix, (1.5D, 3D and 4D) helix diameter, (30 and 50) mm spacing between helix plate are used in this study (where D is the diameter of the pile shaft). Also, buckling in screw pile is checked and a comparison between the measured and predicted compressive forces on the screw piles is investigated.

The results of the experiment showed that the screw piles settlement for piles embedded in soft clay soil overlaying a sandy soil layer decrease (59-182)% with increasing depth of embedment in the sandy layer L/D from 35 to 40, helix diameter and number of helix those provide anchorage against settlement. Deeper screw piles with higher L/D ratios showed compressive capacity (24-55) times greater than the shallower piles (screw pile embedded in soft clay). In addition, screw piles showed resistance to the applied compressive forces (9-16) times more than ordinary piles.

The compressive force increases with increasing diameters and number of helix plates. Furthermore, from this study, it is found that the screw piles with double helix principally failed by cylindrical surface occurred in the region between two helix plates. Another failure mode is individual bearing that occurred at double helix screw pile with spacing ratio (s/D_h) greater than 2 and at the base of screw piles, which has single helix plate. Comparing the predicted theoretical results with the actual measured load test results, it was found that the failure criterion (20% helix diameter) used to determine the ultimate compressive capacity was best suited for a valid comparison than other failure criteria (5%, 10% and 15%).

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LIST OF ABBREVIATIONS

Abbreviation	Total Name
ASTM	American Standard of Testing Measurements
B.S	British Standards Institution
CFA	Continuous Flight Auger Piles or Auger Cast Piles, are cast-in-place piles
CFEM	Canadian Foundations Engineering Manual
Cc	Compression Index
Cs	Swelling Index
C_u	Undrained Shear Strength
Cv	Coefficient of Consolidation
D	Pile Shaft Diameter
D_h	Helix Plate Diameter
e_o	Initial Void Ratio
FHWA	Federal Highway Administration
H	Thickness of Soft Clay Layer
H_{eff}	Effective Length of Pile
ISSMFE	International Society for Soil Mechanics and Foundation Engineering
Ic	Consistency Index
L	Pile Length
Ls	Thickness of Sandy Layer
P	Helix Pitch
Q_c	The Ultimate Compressive Capacity
q_u	Unconfined Compressive Strength
s	Inter Spacing between Helix

S_f	Spacing Ratio Factor
UCS	Unconfined Compressive Strength
Wc	Water Content
W_L	Liquid Limit
Wn	Natural Water Content
W_p	Plastic Limit
ϕ	Internal Friction Angle

CHAPTER ONE
INTRODUCTION

1.1 General

Soft clay soil covers large areas of Iraq, especially, in some central governorates and many southern governorates. Soft clay soils are recent alluvial deposits that are expected to have formed over the past 10,000 years, described by their featureless and flat ground surface.

Geological clays consist mainly of phyllosilicate minerals and contains variable amounts of water trapped in the mineral structure. Owing to their size and geometry of particles as well as water content, the clays are plastic and become hard, brittle and non–plastic when dried. Building heavy structures on soft clay soil is a very difficult task. The main problems associated with soft clay soils are low bearing capacity, settlements and stability problems.

Pile foundations are part of structure that carry and transfer the load of the superstructure to the bearing ground at a certain depth below the surface of the ground. Piles are long, slender elements that transfer the load through weak compressible layers or water into deeper soil or rock of high bearing capacity and less compressibility to avoid shallow soil of low bearing capacity, (Abeb and Smith, 2005). Pile foundations in more conventional civil engineering applications that have a wide range of types and sizes and materials used in practice.

1.2 Soft Clay Soil

In general, soft clay soils are recent alluvial sediments deposited by rivers, lakes, or seas. These soils of special nature are fine grained plastic soils with noticeable clay content and are characterized by low shear strength and high compressibility.

Usually, soft clay soils are so sensitive to the existence of water and illuminate a dramatic change in its performance if water content changes. In general, soft clay soils are stiff when dry and lose this characteristic when become more moisture. Leakage of sewer lines, floods, rains and non-evaporation due to buildings or pavement are the most common causes of increased moisture content in clayey soils (Firoozi et al., 2017).

The soils that have such characteristics causes several problems to geotechnical engineering associated with low bearing capacity, settlements and stability problems.

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 can be equal to or higher than its liquid limit or it can be defined as the normally or lightly over consolidated having a liquidity index of more than 0.5 and have an undrained shear strength. C_u which is usually less than 10 kPa according to Terzaghi, 1936 (as cited by Brand and Brenner, 1981).

Brand and Brenner, (1981) suggested that these type of soil could be identified by Cu less than 40 kPa. British Standard (B.S: C.P 8004: 1986), defined the soil is as soft when 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 (cited in 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 less than 25 kPa and soft if between 25 and 50 kPa (Terzaghi and Peck, 1967).

In fact, such soils cover middle part and most of the southern part of Iraq. Random surveys from various sites showed proven values for an undrained shear strength of less than 30 kPa in AL-Basrah governorate and less than 40 kPa in Missan and AL-Nasiriya governorates, and also reported high compression indices approximately 0.3 and clay fraction range between (50-70)%(Buringh, 1960).

Therefore, the high water table level in the basins of southern Iraq revealed weak and soft deposits (Abbawi, 2010). The textures of these soils formed of fine silty clay loams.

1.3 Screw pile

Many researches had carried out studies to find the appropriate type of piles for various geotechnical and structural conditions. First, the shape of the pile was a simple shaft, then it evolved over time to adopt complex shapes similar to those that are now used: Franki piles, Omega piles, Fundex piles, Drilled piles (CFA), Atlas piles and Screw piles etc., (Basu and Prezzi, 2005). With construction design challenges and ever-increasing demands for sustainable practices and cost-saving solutions, the construction industry is looking for foundations that offer efficient construction techniques, innovative pile configurations, and novel materials applications.

Owing to their many construction advantages, screw piles are gaining in popularity, especially in projects requiring quick installation and loading of the foundation (Fahmy and El Naggar, 2017). Screw piles called as screw anchors or helical piles, are structural, deep foundation elements used to give stability against compressive, tensile, and lateral loads (Abbase, 2017). Screw piles consist of a steel shaft either a solid square or circular pipe with one or more helix attached to it (Albusoda and Abbase, 2017). These deep foundation elements are screwed into the ground with hydraulic torque motors. Due to the pitch of the helical plate, these elements cause no damage and cause only minimal disturbances in the environment of the pile installation. On account of the relatively simple installation process compared to traditional deep foundations (eg drilling and bored piles) and increasing acceptance in the geotechnical industry, the popularity of screw piles has risen sharply in recent decades.

Screw piles differ from conventional piles in that they are usually made of high strength steel consisting of helices fixed to the shaft at spaced intervals and having a pointed tip to allow for better installation in the ground, (Arup Geotechnics, 2005). There are various dimensions of screw piles that are specific to certain conditions, among which, shaft and helical plate diameters, helix pitches, spacing between helical plates and embedment depths are differential points. The screw piles were initially used primarily as anchors, and therefore focused on tensile loads such as transmission tower sand buried pipelines. However, their use has been extended to structures that are subject to compressive, tension and lateral loading, (Livneh and El-Naggar, 2008). The screw pile system is not suitable for the foundation in gravely or stiff soil because the helix plates may be damage in installation process.

1.4 Importance of the Study

Over the last few decades, there have been unrelenting efforts to understand and solve engineering problems in soft soils. Various methods can be used to minimize the effects of soft soil damage. These include soil replacement, physical and chemical treatment and use of special techniques. The application of these methods remains for a long time. However, many of them have certain limitations and can be very expensive. To address these shortcomings, an attempt to develop a simple, effective, easy-to-install and low cost alternative foundation system, this study presents a simple foundation method in the name of screw piles as a reliable solution for suppressing problems caused by soft soils.

In this study, the behavior of screw piles in soft clay soils has focused predominantly on the behavior of screw piles loaded in axial compression with varying embedment depth, number and diameter of helix plate, helical plate spacing ratio, s/D_h, and pile length, L, as defined in Figure. (1.1)

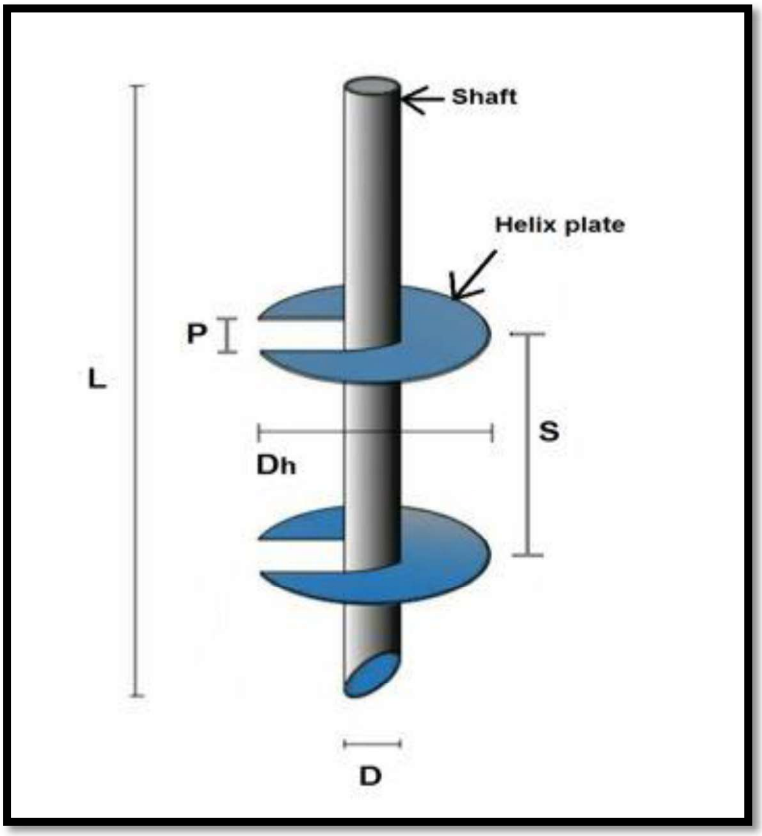

Figure. 1.1 The geometry of a screw pile

1.5 Statement of the Problem

Soft clay soil covers vast areas of the central and southern governorates of Iraq. In most soils of these areas, the shear strength parameters (i.e. cohesion (c) and internal friction angle (ϕ)) vary with depth, as shown in Figure (1.2). Low cohesion values appear for soil samples with depth. That can be attributed to the particle size of the soil at which the clay with water content approaches to the liquid limit than the plastic limit. However, values are increasing with internal friction with depth. This is mainly due to the increase in coarse grains (Sand content) (Al-Taie, 2015).

Due to the large lack of information concerning the use of screw pile in such a profile and the difficulty of implementation and high costs of other treatment methods, in addition to the need for the country to fast and efficient and inexpensive solutions to address damage to buildings due to earthquakes and explosions, which may be provided by the use of this type of piles characterized by Fast and easy installation, Versatility, low cost and high efficiency, it was necessary to simulate the development of this field through scientific research programs.

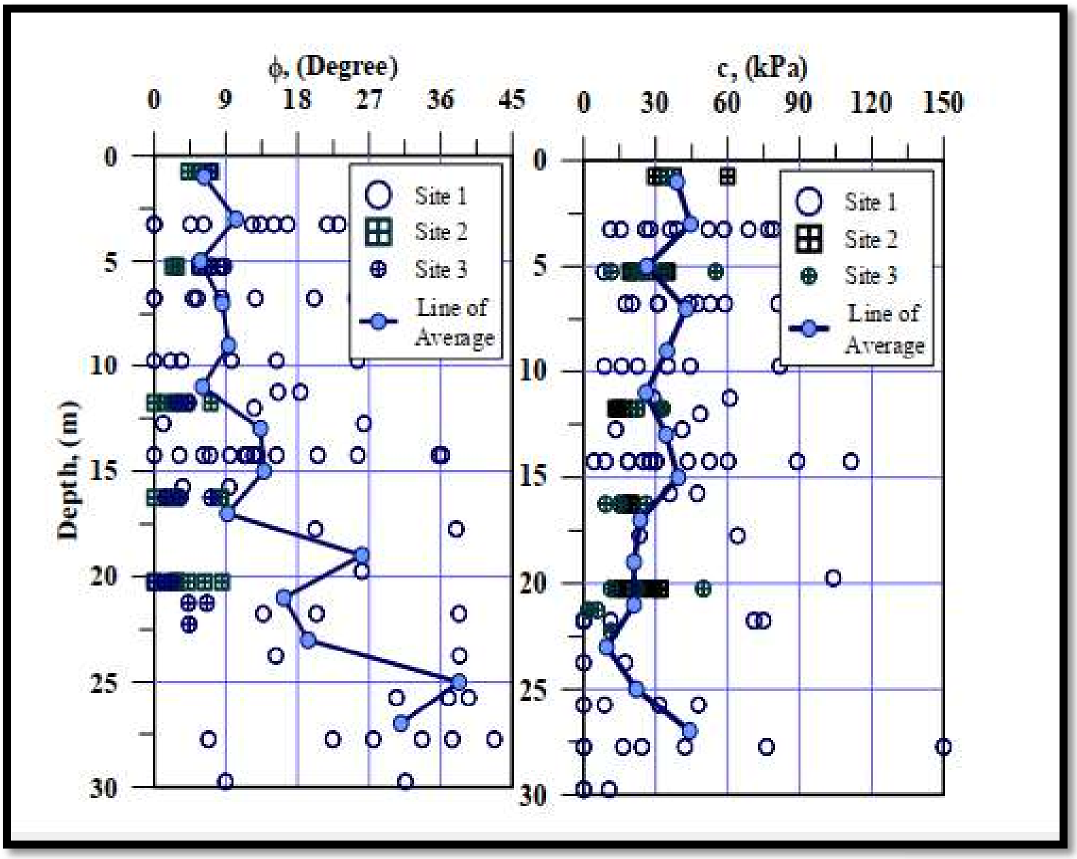

Fig. 1.2 Variation of the results of the direct shear tests of the soil of Basra (after Al-Taie, 2015).

1.6 Objectives of This Study

Due to limited knowledge currently available in the literature about using screw piles in soft clay, the present study is an attempt to understand and demonstrate the behavior of screw piles in soft soils.

In this study, the following aspects are covered:

- ***One:*** The behavior of screw piles embedded in soft clay soil overlaying sandy soil under compression force.

- ***Two:*** The effect of helix diameter, number of helix, spacing between helix and pile length on the capacity of screw pile are investigated**.**

1.7 Thesis outline

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

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

Chapter Two: A detailed literature review of soft soil and screw piles.

Chapter Three: Presents the experimental work, modeling, properties of material used, screw pile installation and testing program procedure.

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.