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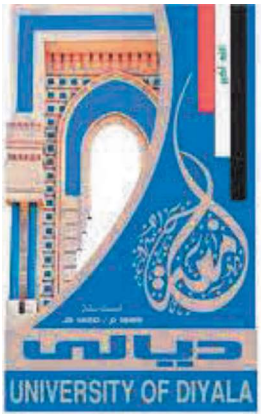

A Laboratory Study for a Single Pile Subjected to Vertical and Horizontal forces

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

Qasim Ibrahim Hussain

BSC. Civil Engineering, 2000

Supervisors by

Ass. Prof. Dr. Jasim Mohammed Abbas

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بسم الله الرحمن الرحيم

قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

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Dedication

To …

*My **late** father, who was the cause of my success*

*My **late** mother, the sight of my eyes.*

My wife, who supported me.

My brothers and sister whose love flow in my veins.

Our honorable teachers who taught and rewarded us their knowledge.

Everyone, who wishes me success in my life

I dedicate this humble work.

QASIM

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*Thanks are to **Allah** for all things which led me into the light during the critical time.*

*I would especially like to express my deep appreciation and sincere gratitude to my supervisor, **Assist. Prof. Dr. JASIM M. ABBAS** for his supervision and his valuable guidance and assistance throughout the preparation of this work.*

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*My thanks to the **head** and **the staff** of Civil Engineering Department, University of Diyala and also **the staff of Road laboratory and soil Laboratory**.*

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Special thanks are also to my family for their support through the study and project intervals.

Qasim Ibrahem

ABSTRACT

A LABORATORY STUDY FOR A SINGLE PILE SUBJECTED TO VERTICAL AND HORIZONTAL FORCES

By

Qasim Ibrahem Hussain

Supervisor by:

Assist. Prof. Dr. Jasim M. Abbas

ABSTRACT

In fact, the pile foundation usually carries the applied load as combined from axial and lateral load at the same time. Many previous studies dealt only with the effect of pure lateral load in the analysis of pile foundation. While few studies covered the behavior of piles under combination load. These few studies were usually done out of the laboratory. They generally used another technique like finite element or analytical methods. Therefore, this issue needs more laboratory studies for assessing the performance of pile foundation under different load combinations.

Consequently, the main objectives of this study are to model a single pile in a laboratory when subjected to different load combinations, and with different slenderness ratios, pile materials, pile cross sectional areas, and finally with three relative soil densities. The applied axial load is divided into six stages (i.e. 0%, 20%, 40%, 60%, 80% and 100% from the allowable pile capacity). While the lateral load is divided into five stages (i.e. 20%, 40%, 60%, 80% and 100% of the lateral load). In addition, the other parameters taken into account are the pile slenderness ratio (i.e. 25, 30, 35, 40 and 45), pile materials (i.e. aluminum and steel), pile cross-section (i.e. square and circle) and soil relative densities (i.e. 30%, 50% and 70%). In this study, the soil is prepared using raining technique, while the loads are applied directly on the tip of the piles.

Based on the results, it can be seen that in most cases the lateral deformation of the pile under pure lateral load was larger compared with a case that included combined loads for different soil densities. The reduction in the displacement reaches for example to 57%, while in specific cases like L/D=45 (in case of aluminum pole), the axial load increases the lateral pile displacement and this value reaches to about 42%. This means that the application of axial load clearly affects the lateral pile performance.

In addition, the lateral capacity of a square pile section is more than that of circular pile section for different soil densities and different materials. The increase of pile capacities reacts to 47% for L/D=25 and 58% for L/D=45. It can also be seen that the increase of axial loads produces lead to excess in the amounts of bending moment in most cases.

Finally, this study develops the p-y relationship for both the pile displacement and lateral soil opposition. The pile displacement and the soil behavior appears as nonlinear in all cases which is usually close to the actual performance and can be used directly for the analysis and design of pile foundation.

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LIST OF SYMBOLS

Symbol	Total Name
C	Soil cohesion
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_{max}	Maximum void ratio of soil
e_{min}	Minimum void ratio of soil
Gs	Specific gravity
K	Coefficient of lateral earth pressure
L	Embedded length of pile
L/D	Slenderness ratio of pile
M_m	Maximum bending moment within a pile
p	Soil resistance
Q_b	End bearing resistance
Q_s	Shaft resistance
q_c	Cone penetration resistance
y	Pile deflection
z_o	Depth of slip initiated from mudline (pile-base)
z_1	Depth of slip initiated from mudline (pile-base)
z_m	Depth of maximum bending moment
z_r	Depth of rotation point
δ	Interface friction angle between pile and soil
$Ø$	Angle of internal friction of soil
γ	Unit weight of soil
β	Pile characteristic
AL	Aluminum
ST	Steel
D	Circular
SQ	Square
V	Ultimate load

LIST OF ABBREVIATION

Abbrev.	Total Name
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
CPT	Cone Penetration Test
DNV	Det Norske Veritas
USCS	Unified Soil Classification System

Chapter One

CHAPTER ONE

INTRODUCTION

1.1 General Remarks

In general, pile foundation is considered as one of the most important types of deep foundation, which is used when the soil under buildings in the certain site is weak and also when the shallow foundation cannot be used (Karthigeyan et al. 2007). In this case, piles are usually used to transfer the external loads (from any sources of loading) to the deep layers of soil stratum which has adequate amount of bearing capacity.

In fact, piles are always subjected to different types of load, such as, vertical, lateral, earthquake, moment, etc., probably more than one type of load at the same time. Accordingly, the studies for such cases of loading should be improved to protect the structures from any catastrophic failures due to these loads.

A number of the previous studies took into account the axial pile performance by using different methods (such as. FEM, laboratory program and field test). On the other hand, other studies took into consideration the lateral pile behavior. In many cases, the piles were subjected to lateral loads in addition to axial load in the same time.

Bridge foundation, towers, offshore structures present cases of piles when subjected to lateral load (Abbas et al., 2008b).

Many experimental and theoretical investigations have been performed on vertical single pile by many of researchers. Matlock and Reese (1960) presented general solutions for vertical pile subjected to lateral load. Davisson (1960) evaluated the influence of the presence of vertical loads as well as lateral loads in terms of non-dimensional parameters. Whereas Broms (1964 a and b) and Poulos and Davis (1980) presented different approaches to solve the problems of piles when subjected to lateral load. The method of Broms depended on the

use of limiting amounts of soil resistance, while the second method (Poulos and Davis) depended on theory of elasticity. The p-y curves concept was developed by Reese et al. (1974, 1975) and Matlock (1970) to solve problems of piles subjected to lateral load (Murthy, 2007).

In brief, the researchers focused on studying the behavior of pile when subjected to either pure axial load or pure lateral load, while in fact the piles were subjected to both axial and lateral loads in the same time, and certainly such cases represented one of the complicated cases of the soil-structure interface in the site, so such cases required to a very accurate study.

1.2 Importance of the Study

In most building failure records, it can be seen that the failure of foundation is a usual source of this kind of hazard. At the same time, the research organizations lead to cover all expected factors that may cause the failure of the civil engineering project in order to save the human being as well as money. Plate (1.1) shows the failure of building foundation as a type of the important of pile studies to save the building form failure in future.

Therefore, this study works inside this field to improve the knowledge about the performance of pile foundation under deferent load combinations.

Plate 1.1 Failure of structure due to lateral load which result from earthquake

1.3 Statement of the Problem

From the literature, there are number of studies concerning the lateral pile response under pure lateral load with limited variables such as soil type, load intensity, slenderness ratio and pile cross section through laboratory program. While, there are few results about this type of problem in the case of pile subjected to simultaneous axial and lateral load, therefore this issue needs more studies to cover this effect on the lateral pile performance.

1.4 Objectives of Study

The major aims of this study are to investigate:

1. The influence of axial load on the lateral response of piles.

2. The influence of relative density (D_r) on the lateral pile response.

3. The effect of slenderness ratio (L/D) on the response of laterally loaded pile.

4. The effect of cross-sectional shape of pile on the lateral pile response.

5. The effect of pile materials on the lateral pile response.

1.5 The Thesis Layout

The general layout of this study consists from five chapters as explained below: ***Chapter One*** introduces general the subject of the study and it's the purpose. ***Chapter Two*** covers the previous literature related to this study. ***Chapter Three*** presents a general description of the laboratory works, required to perform the purpose of this study. In addition, it describes all the details of the pile models and soil used in this study and other details of the work. ***Chapter Four*** presents the discussion of the results resulted from the experimental works in the laboratory. ***Chapter Five*** introduces the conclusions which are based on the results of tests and also presents recommendations for the future works.