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LATERAL DYNAMIC RESPONSE OF GROUP PILES FOUNDATION SUBJECTED TO AXIAL AND LATERAL LOAD IN SANDY SOIL

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

﴿قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ﴾

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DEDICATION

To …

My father, who was the cause of my success

My mother, the sight of my eyes.

My husband, who supported me.

My sons 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.

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ABSTRACT

LATERAL DYNAMIC RESPONSE OF GROUP PILES FOUNDATION SUBJECTED TO AXIAL AND LATERAL LOAD IN SANDY SOIL

By

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Supervisor by:

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ABSTRACT

In the current era, the most regions of the world are subjected to seismic loads that result periodic (cyclic) lateral forces. There are also regular loads resulting from wind and marine waves, which act on offshore structures. Therefore, it is important to take influence of these forces and add to the loading effect, which mainly includes of the vertical load that generally results from the self-weight of the structures.

The main aim of this study is to investigate the influence of the vertical load and pile shape on the behavior of piles group embedded in sandy soil under lateral cyclic loads by applying lateral cyclic regular loading system on the top of group piles (1 × 2, 2 × 1 and 2 × 2) which simulates the wave movements in the nature.

The effect of a number of variables is studied, and their influence on the behavior of group piles (piles spacing S/D = 3, 5, 7 and 9, cyclic load ratio, number of load cycles, shape of pile and configuration of piles). This study is conducting a series of tests with 48 samples instill in dry sandy soil which have relative density (Dr=70%) by using (Raining Technique) under frequency of (0.2 Hz.).

According to the results, the presence of the allowable vertical load has a positive effect on the behavior of cyclically loaded groups. By other mean, this is caused reduction in lateral displacement and bending moment along the pile in a group by approximately (60%) and (50%) respectively.

On the lateral pile group response under cyclic loads, the spacing piles in-group (1 × 2) has no significant effect on the lateral displacement. Nevertheless, it is observed with the group model (2 × 1) and (2 × 2) where the lateral displacement increased with decrease pile spacing.

In addition, the shape of the pile in group has clear effect on the group response to cyclical loads a rounded of (25-30%).

Finally, the maximum bending occurs at the first upper of the embedded length of the pile (1/4) L. It is also noted that the piles in the leading row take a larger share of the load than rear row a rounded by (18%).

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LIST OF SYMBOLS

Total Name Symbol	Term
c	Cohesion
Cu	Coefficient of uniformity
Cc	Coefficient of Curvature
D	Pile diameter
D_{50}	Mean size of soil particles
D_{10}	Effective size at 10% passing
D_{30}	Grain size at 30% passing
D_{60}	Grain size at 60% passing
Dr	Relative density of soil
Es	Soil Modulus
EI	Stiffness of pile section
E	Modulus of elasticity
e	Eccentricity of load
$e_{max.}$	Maximum void ratio of soil
$e_{min.}$	Minimum void ratio of soil
f	Frequency
Gs	Specific gravity
H	Lateral load applied on the pile head
HZ	Hertz
I	Moment of inertia
L	Embedded length of pile
L/D	Slenderness ratio of pile
M	Bending moment
p	The soil pressure per unit length of the pile
pt	Lateral load applied at or above ground level
V	Vertical load
$Q_{all.}$	Allowable vertical load
$Q_{ult.}$	Ultimate vertical load
r	Outside radius of the pipe

x	Segment length of the pile
yg	Deflection at ground level
y	Pile deflection
γ	Unit weight of soil
γd	Initial dry unit weight of soil
ε	Measured strain
Ø	Angle of internal friction
Qb	End bearing (base) resistance of pile
Qs	Skin friction (shaft) resistance of pile
qb	Ultimate bearing capacity at pile base
qs	Ultimate skin friction of pile shaft
Ab	Area of pile base
As	Perimeter area of the pile shaft
q'	Effective vertical stress at pile base
Nq	Bearing capacity factor for pile foundation
σ_{av}	Average vertical effective stress in a given layer
K	Lateral earth pressure coefficient
δ	Angle of soil-pile friction (in degree)

LIST OF ABBREVIATION

Abbreviation	Term
API	American Petroleum Institute
ASTM	American Society For Testing and Materials
CLR	Ratio of magnitude of cyclic lateral load to static ultimate lateral capacity of the pile
LVDT	Linear Variable Differential Transformer
SSI	Soil-structure interaction
PLC	Programmable Logic Controller

CHAPTER ONE
INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1 General Remarks

Deep foundations involving driven or drilled-in piers and piles usually undergo the transmission perpendicular structural load from soft soils to stiff and deep bearing layers. Furthermore, these foundations can also be subjected to transitory or cyclical horizontal loads rising from earthquake, waves, impacts, wind, blasts, or instrument loading.

For several years, groups of piles have been commonly used for supporting constructions such as highway bridges, waterfront structures and dams. For the past two decades, group-pile foundations have also been applied to offshore platforms. These structures frequently are an endangered to major horizontal forces and actions that need perfect identification of the issues which affecting on the behavior of pile foundations. Unconservative study can product in extreme pile-head deflection and rotation, stressful the superstructure and lead to uneconomical foundations (Sabry 2002).

The geometric constraints in foundations place in danger to high lateral loads often need the piles to be driven narrowly spaced in a group. Lateral loads are in the rate of 10–20% of the axial load in location of onshore structures. Whereas this rate may be above of 30% in case of offshore constructions (Rao et al.1998). Therefore the amount of horizontal displacement due to lateral force overhead the allowable can be caused wide loss to engineering structure (Bartlett and Youd, 1995).

The rigidity of individually pile in the group is affected by stresses of adjacent piles (shadow effect). This phenomenon happens due to reaction in the soil; this leads to fail the soil surrounding the piles and decreases ultimate lateral capacity of group pile (Ashour et al. 2004).

In spite of the importance of static loads in design of deep foundation, the dynamic loads indicate a chief challenge in the design because of extra forces, which apply on the foundation due to dynamic loading that includes axial and lateral loads (Moss et al.1998).

The cyclic load (periodic load) is one of the simple forms of dynamic loads, which in turn have a degree of uniformity in frequency and magnitude (Das 2010) .Therefore, the investigation of pile group response to such cyclic stresses of pile foundations is very important in geotechnical engineers and design of the structures. This is, in a particular, the real for the pile foundations of offshore structure.

1.2 Statement of the Problem

Many previous studies have mainly investigated only the effect of cyclical loading on the behavior of piles in sandy soils without axial load. Only a small number of load tests outcomes are obtainable to illustrate the distribution of loads in pile group (e.g. Meimon et al. 1986; Brown et al. 1987; Brown et al. 1988; Ruesta and Townsend 1997; Rollins et al. 1998; and Rollins et al. 2006). Therefore, a few data is obtainable of dynamic reaction on pile foundations. This is mainly because of the large number of changeable in soil and piles, these lead to important difficulties in guiding the test.

As a result, the effect of cyclical vertical loads on the behavior of piles group is very slight facts and not fully thoughtful at nowadays to guide the engineer in the design of closely spacing piles group. Therefore, the work informed in this study is an extension of this on- going studies but will be different about the previous works by using axial and two way lateral cyclic loading in the tests. This is applied on the modeling of group piles, with different spacing piles, different cyclical load ratio and two shape of piles. These variables give details which of these reduced the effect of cyclic loads.

1.3 The Importance of Study

The design and analysis of pile foundations of highway structures are very critical and depend on the lateral load capacity of piles. In spite of reliable performances have been developed for surmise the lateral capability under static loads of piles, there are minor facts to guide engineers in the design of group pile foundation under dynamic load. Therefore, the study of the effect of vertical load on the behavior of pile group under cyclical load is very important to increase the database of the performance of pile foundations in geotechnical engineering requirements, increase the safety of buildings and reduce the cost and human losses.

1.4 Aims of the Study

The current study aims as follows:

1. To studying the effect of axial load and piles shape on the performance of piles group foundation under cyclic loads.
2. To study the effect of number of cycles under combined loads with different cyclic load ratio on the horizontal and vertical movements for pile group models.
3. Evaluating the difference of bending moment along pile shaft under combined loading.
4. Identifying the best configuration of piles in-group under pure and combined loading.
5. To study the effect of pile spacing on lateral displacement of pile groups under pure and combined loading.

1.5 The Thesis Layout

The study scope has been distributed into five chapters and two appendices. A brief summary of each chapter is illustrated in the consequent passages:

Chapter one: This chapter displays a general idea about group of piles foundation subjected to cyclic and combined loading, aims, and the scope of this study.

Chapter two: This chapter reviews present literature, including of both practical and theoretical workings along with field investigations and some of the analytical procedures to study the horizontal loading of piles foundations.

Chapter three: presents the practical setup and approach, including of a demonstration of the soil classification and group piles. It is also presenting detailed explanation of the typical models of pile-soil erection with the technique that used to analysis the dynamic reaction of group pile when embedded in dry sand.

Chapter four: Introduces the outcomes of the practical system model and their discussions. Studies the responses of group pile pattern under pure and combined cyclic loading. The practical system on the group pile model is also showed the effects of cross sectional shape and configuration on the dynamic reaction of group piles.

Chapter five: presents the conclusions gained after test results of the research; furthermore the recommendations for outlook.

Finally, extra results for the different parameters discussed and explanation of experimental effort by pictures are illustrated in Appendixes A and B.