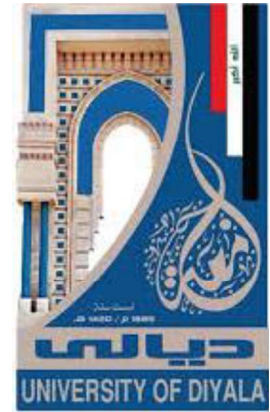


**Ministry of Higher Education
and Scientific Research
University of Diyala
College of Engineering**



**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
Aseel Kahlan Mahmood
(B.Sc. Civil Engineering, 1999)**

**Supervisor
Assist. Prof. Dr. Jasim M. Abbas**

September 2019

IRAQ

Muharram 1441

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا

إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ﴾

بِسْمِ اللَّهِ
الرَّحْمَنِ الرَّحِيمِ

(البقرة: ٣٢)

CERTIFICATION OF THE SUPERVISOR

I certify that this thesis entitled “**Lateral Dynamic Response of Group Piles Foundation Subjected to Axial and Lateral Load in Sandy Soil**” was prepared by “**Aseel Kahlan Mahmood**” was made my supervision in the University of Diyala in partial fulfillment of the requirements for the degree of master of science in civil engineering.

Signature:

Name: Assist. Prof. Dr. Jasim M. Abbas

(Supervisor)

Date: / /2020

COMMITTEE DECISION

We certify that we have read the thesis entitled (**Lateral Dynamic Response of Group Piles Foundation Subjected to Axial and Lateral Load in Sandy Soil**). We have examined the student (**Aseel Kahlan Mahmood**) 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**.

Examination Committee

Signature

1- Assist. Prof. Dr. Jasim M. Abbas (Supervisor)

2- Assist. Prof. Dr. Waad A. Zakaria (Member)

3-Assist. Prof. Dr. Qasim A. Al-janabi (Member).....

4-Prof. Dr. Mohammed A. Al-Neami (Chairman)

Prof. Dr. Khattab Saleem Abdul-Razzaq (Head of Department)

The thesis was ratified at the Council of College of Engineering / University of Diyala.

Signature.....

Name: Prof. Dr. Anees A.Khadom

Dean of College Engineering / University of Diyala

Date:

SCIENTIFIC AMENDMENT

I certify that this thesis entitled “**Lateral Dynamic Response of Group Piles Foundation Subjected to Axial and Lateral Load in Sandy Soil**” presented by “**Aseel Kahlan Mahmood**” has been evaluated scientifically; therefore, it is suitable for debate by examining committee.

Signature:-

Name: Assist. Prof. Dr. Mahmoud T.A. Al-Lamy

Title: Assistant Professor

Address: College of Engineering/ University of Baghdad

Date:

LINGUISTIC AMENDMENT

I certify that this thesis entitled “**Lateral Dynamic Response of Group Piles Foundation Subjected to Axial and Lateral Load in Sandy Soil**” presented by “**Aseel Kahlan Mahmood**” has been corrected linguistically; therefore, it is suitable for debate by examining committee.

Signature:-

Name: Assist.Prof.Shaqi K.Ismail (M.A.)

Title: Assistant Professor

Address: College of Education for Humanities / University of Diyala

Date:

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.

ASEEL KAHLAN

ACKNOWLEDGEMENTS

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.

Appreciation and thanks to the Dean and the staff the College of Engineering, University of Diyala and also the staff of Soil Laboratory and Road laboratory.

Very special thanks for Lec.Yassir Nashaat for his kindest help and thanks to all my colleagues, for their help.

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

ASEEL KAHLAN

ABSTRACT

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

By

Aseel Kahlan Mahmood

Supervisor by:

Assist. Prof.Dr. Jasim M. Abbas

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 ($D_r=70\%$) 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%).

TABLE OF CONTENT

Article	Topic	Page
ABSTRACT		VII
CONTENTS		IX
LIST OF FIGURES		XII
LIST OF PLATES		XVII
LIST OF TABLES		XVIII
LIST OF SYMBOLS		XIX
LIST OF ABBREVIATIONS		XXI
CHAPTER ONE	INTRODUCTION	
1.1	General Remark	1
1.2	Statement of the Problem	3
1.3	The Importance of Study	3
1.4	Aims of the Study	4
1.5	The Thesis Layout	4
CHAPTER TWO	LITERATURE REVIEW	
2.1	Introduction	6
2.2	Type of Loads	6
2.3	Types of Lateral Cyclic Loading	7
2.4	Failure Pattern of Pile and Transfer horizontal load Mechanism	7
2.5	Shape Factor	13
2.6	Behavior of Laterally Loaded Piles	15
2.7	Analytic Method for Laterally Loaded	16
2.7.1	Theoretical approach	16
2.8	Previous Studies of Lateral Cyclic Loading	17
2.9	Previous Studies of Piles Subjected to Combined Loads	18
2.10	Summary of This Chapter	21

CHAPTER THREE	EXPERIMENTAL WORK	
3.1	Introduction	22
3.2	Model of Pile and Pile Cap	22
3.2.1	Model of pile	22
3.2.2	Pile Cap	24
3.2.3	Configuration of Pile Group	27
3.3	Soil Material Used	28
3.4	Geotechnical Model Setup	30
3.4.1	Steel Container	30
3.4.2	Loading Frame	31
3.4.3	Device of Lateral Static Loading	32
3.4.4	Device of Lateral Cyclic Loading	33
3.4.4.1	Motor-Gear System	34
3.4.4.2	Controlling Electrical Circuit Part	35
3.4.5	Lined Variable Differential Transformer (LVDT)	36
3.4.6	Load Cell	38
3.5	Sand Deposit Preparation	38
3.6	Strain Gage Technique	41
3.6.1	General Description	41
3.6.2	Gage Length Selection	43
3.6.3	Install of Strain Gages	43
3.6.4	Strain Indicator (Data Achievement System)	44
3.6.5	Correction of Data Achievement System (Strain Indicator)	45
3.7	Carried out Two-Way Lateral Cyclical Loads	47
3.8	The Test Program	48
CHAPTER FOUR	RESULTS AND DISCUSSION	
4.1	General	50
4.2	Limitation of This Study	50
4.3	Pile Group Load Test under Static Loading	51
4.3.1	Prediction of Ultimate Axial Load Capacity	51
4.3.2	Prediction of Ultimate Lateral Load Capacity	54
4.4	Pile Group Load Test under Combined Axial and Cyclic Lateral Loading	57

4.4.1	Lateral Load-Displacement Response of Pile Group	58
4.4.1.1	Effect of Pile Spacing and configuration on Load-Displacement Behavior	58
4.4.1.2	Effect of Cyclic Load Ratio (CLR) on the Lateral Displacement of Pile Group Head	63
4.4.1.3	Effect of Number of Cycles of Loading on the Lateral Displacement of Pile Group Head	70
4.4.1.4	Influence of Cross Section pile on the Group Pile Lateral Response of pile group	75
4.4.2	Vertical Load - Displacement Response of Pile Group Cap	81
4.4.3	Bending Moment a Long Pile	89
CHAPTER FIVE	CONCLUSIONS AND RECOMMENDATIONS	
5.1	Conclusions	103
5.2	Recommendations for Future Works	104
	REFERENCES	105
	Appendix A	A-1
	Appendix B	B-1

LIST OF FIGURES

No.	Title	Page
2.1	Type of cyclic loading (After Peng et al., 2011)	7
2.2	Modes of failures for piles under lateral loads embedded in cohesionless soil: (a) free head piles (b) fixed head for (Broms, 1964 modified after Poulos and Davis, 1980)	8
2.3	Ultimate behavior for cohesionless soil (Broms, 1964)	9
2.4	Diagram showing the gap formation around the pile group (Basack, 2009).	11
2.5	A diagram showing the basin-like depression formed around the pile group in sandy soil (Basack, 2009a).	12
2.6	Diagram showing the gap formation around the pile group in cohesive soil (Basack, 2009a).	12
2.7	Reduction in lateral pile resistance due to pile-pile interface (Rolline et al. 1998 and Ashour et al. 2004)	13
2.8	The difference in lateral resistance due to pile shape (After Reese and Van Impe, 2001)	14
2.9	The Complete form of the solution, cited by (Reese & Van Impe, 2001)	15
3.1	Stress-Strain curve for aluminum pipe	23
3.2	Schematic diagram illustrates piled cap details	25
3.3	Configuration of pile group .a)2x1,b)1x2,c)2x2	27
3.4	Sand grain size distribution curve	28
3.5	Soil strength parameters based on the direct shear test	29
3.6	Sketch showing the lateral loading device	33
3.7	Sketch showing the place of (LVDT) of the pile	37
3.8	Calibration of sand density	40
3.9	Strain gages	42
3.10	Sketch showing the location of strain gages along pile	43
3.11	Calibration of strain inductor	46
3.12	Two-Way lateral cyclic loading pattern that used in this tests.	47

3.13	Flow chart for testing program	49
4.1	Axial load versus settlement/diameter of pile for model group (1x2). a) Circular pile - b) Square pile	53
4.2	Axial load versus settlement/diameter of pile for model group (2x1). a) Circular pile - b) Square pile	53
4.3	Axial load versus settlement/diameter of pile for model group (2x2). a) Circular pile - b) Square pile	54
4.4	Load-Deflection curve for group pile model (1x2)a) Circular pile, b) Square pile	55
4.5	Load-Deflection curve for group pile model (2x1)a)Circular pile, b) Square pile	56
4.6	Load-Deflection curve for group pile model (2x2)a) Circular pile, b) Square pile	56
4.7	Load-Deflection curve at 100 cycle for group pile model (1x2) a) Circular pile, b) Square pile under pure and combined loads	60
4.8	Load-Deflection curve at 100 cycle for group pile model (2x1) a) Circular pile, b) Square pile under pure and combined loads	61
4.9	Load-Deflection curve at 100 cycle for group pile model (2x2) under pure and combined loads,a) Circular pile, b)Square pile	62
4.10	Effect of cyclic load ratio (CLR) on the pile group head lateral displacement of (1x2) model under pure cyclic load (Vertical load=0% Q_{all}) a) Circular pile, b) Square pile	64
4.11	Effect of cyclic load ratio (CLR) on the pile group head lateral displacement of (1x2) model under combined cyclic load (vertical load=100% Q_{all}) a) Circular pile, b) Square pile	65
4.12	Effect of cyclic load ratio (CLR) on the pile group head lateral displacement of (2x1) model under pure cyclic load (Vertical load=0% Q_{all}) a) Circular pile, b) Square pile	66
4.13	Effect of cyclic load ratio (CLR) on the pile group head lateral displacement of (2x1) model under combined cyclic load (Vertical load=100% Q_{all}) a) Circular pile, b) Square pile	67
4.14	Effect of cyclic load ratio (CLR) on the pile group head lateral displacement of (2x2) model under pure cyclic load (Vertical load=0% Q_{all}) a) Circular pile, b) Square pile	68

4.15	Effect of cyclic load ratio (CLR) on the pile group head lateral displacement of (2x2) model under combined cyclic load (Vertical load=100%Q _{all}) a) Circular pile, b) Square pile	69
4.16	Effect of number of cycles on load- lateral displacement curve of (1x2) group piles model (S/D=3) under pure and combined load a) circular pile - b) square pile	72
4.17	Effect of number of cycles on load- lateral displacement curve of (2x1) group piles model (S/D=3) under pure and combined load a) circular pile - b) square pile	73
4.18	Effect of number of cycles on load- lateral displacement curve of (2x2) group piles model (S/D=3) under pure and combined load a) circular pile - b) square pile	74
4.19	Comparison of lateral displacement to diameter of (i.e. Square and Circular) pile in-group model (1x2) under combined cyclic load a) Axial load =0%Q _{all} . b) Axial load =100% Q _{all} .	76
4.20	Comparison of lateral displacement to diameter of (i.e. Square and Circular) pile in-group model (2x1) under combined cyclic load a) Axial load =0%Q _{all} . b) Axial load =100% Q _{all} .	77
4.21	Comparison of lateral displacement to diameter of (i.e. Square and Circular) pile in-group model (2x2) under combined cyclic load a) axial load =0%Q _{all} , b) axial load =100% Q _{all} .	78
4.22	Variation of vertical displacement (upward) with number of cycles of (1x2) group model(S/D=3) under vertical load = 0% Q _{all} . a) Circular pile, b) Square pile	82
4.23	Variation of vertical displacement (upward) with number of cycles of (2x1) group model(S/D=3) under vertical load = 0% Q _{all} . a) Circular pile, b) Square pile	82
4.24	Variation of vertical displacement (upward) with number of cycles of (2x2) group model(S/D=3) under vertical load = 0% Q _{all} . a) Circular pile, b) Square pile	83
4.25	Variation of vertical displacement (settlement) with number of cycles of (1x2) group model(S/D=3) under vertical load = 100% Q _{all} . a) Circular pile, b) Square pile	83

4.26	Variation of vertical displacement (settlement) with number of cycles of (2x1) group model(S/D=3) under vertical load = 100% Q _{all} . a) Circular pile, b) Square pile	84
4.27	Variation of vertical displacement (settlement) with number of cycles of (2x2) group model(S/D=3) under vertical load = 100% Q _{all} . a) Circular pile, b) Square pile	84
4.28	Variation of vertical displacement (upward) with S/D under pure cyclic load (V = 0% Q _{all} .) for group model a) 1x2 b) 2x1 c) (2x2)	85
4.29	Variation of vertical displacement (settlement) with S/D under combined cyclic load (V = 100% Q _{all} .) for group model a) 1x2 b) 2x1 c) (2x2)	86
4.30	Comparison of vertical displacement (upward) with configuration of piles, (1x2) and (2x1) model. a)Circular pile, b) Square pile	87
4.31	Comparison of vertical displacement (settlement) with configuration of piles, (1x2) and (2x1) model a) Circular pile, b) Square pile.	88
4.32	The variation of moment with depth for leading row (2x2) group circular pile model under combined vertical load =0% Q _{all} . a)CLR 40% =152 N,b) CLR 60% = 228 N, c) CLR 80% = 304N	93
4.33	The variation of moment with depth for rear row (2x2) group circular pile model under combined vertical load =0% Q _{all} . a)CLR 40% =152 N ,b) CLR 60% = 228 N, c) CLR 80% = 304N	94
4.34	The variation of moment with depth for leading row (2x2) group circular pile model under combined vertical load =100% Q _{all} . a)CLR 40% =152 N,b) CLR 60% = 228 N, c) CLR 80% = 304N	95
4.35	The variation of moment with depth for rear row (2x2) group circular pile model under combined vertical load =100% Q _{all} . a)CLR 40% =152 N,b) CLR 60% = 228 N, c) CLR 80% = 304N	96
4.36	Bending moment comparison for leading and rear row (2x1) group circular pile model under pure and combined load at 100 cycle. a)CLR 40% =67 N,b) CLR 60% = 114 N, c) CLR 80% = 152 N.	97
4.37	Bending moment comparison for leading and rear row (2x1) group square pile model under pure and combined load at 100 cycle. a)CLR 40% =67 N,b) CLR	98

4.38	Influence S/D ratio on bending moment profile for (2x1) group circular pile model, CLR=80% a) leading row, b) rear row (under pure cyclic load), c) leading row, d) rear row (under combined cyclic load)	99
4.39	Influence S/D ratio on bending moment profile for (2x1) group square pile model, CLR=80% a) leading row, b) rear row (under pure cyclic load), c) leading row, d) rear row (under combined cyclic load)	100
4.40	Influence cross sectional shape on bending moment profile for (2x1) group pile model, CLR=80%, a) $V=0\% Q_{all}$. b) $V=100\% Q_{all}$.	101
4.41	Influence configuration of piles on bending moment profile under pure and combined load at CLR=80% a) circular pile in-group, b) square pile in-group	102

LIST OF PLATES

No.	Title	Page
3.1	Model piles used in the present study.(a) Shape of pile (b) Tensile test	23
3.2	Models piles cap.	26
3.3	Loading frame	31
3.4	Static loading device	32
3.5	Cyclic loading device	34
3.6	Motor-Gear system	35
3.7	Parts of controller circuit	36
3.8	The linear variable differential transformer (LVDT) and data logger	37
3.9	Load cell	38
3.10	Cans location individual density	40
3.11	Raining technique	41
3.12	Strain gauges, SB tape and compatible adhesive type (CN).	42
3.13	Bonding and Coating: a)-Applying CN-E Adhesive.b) Applying strain and constant pressure (c) Covering with SB tape.	44
3.14	Strain indicator	45
3.15	Device to calibrate the strain gage	46
4.1	Generate a deformation (a) CLR =40% (b) CLR=60%	70

LIST OF TABLES

No.	Title	Page
3.1	Mechanical properties of aluminum piles used in this study	24
3.2	Summary of test results for sand	29
3.3	Strain gauge specifications	42

LIST OF SYMBOLS

Total Name Symbol	Term
<i>c</i>	Cohesion
<i>Cu</i>	Coefficient of uniformity
<i>Cc</i>	Coefficient of Curvature
<i>D</i>	Pile diameter
<i>D₅₀</i>	Mean size of soil particles
<i>D₁₀</i>	Effective size at 10% passing
<i>D₃₀</i>	Grain size at 30% passing
<i>D₆₀</i>	Grain size at 60% passing
<i>Dr</i>	Relative density of soil
<i>Es</i>	Soil Modulus
<i>EI</i>	Stiffness of pile section
<i>E</i>	Modulus of elasticity
<i>e</i>	Eccentricity of load
<i>e_{max.}</i>	Maximum void ratio of soil
<i>e_{min.}</i>	Minimum void ratio of soil
<i>f</i>	Frequency
<i>Gs</i>	Specific gravity
<i>H</i>	Lateral load applied on the pile head
<i>HZ</i>	Hertz
<i>I</i>	Moment of inertia
<i>L</i>	Embedded length of pile
<i>L/D</i>	Slenderness ratio of pile
<i>M</i>	Bending moment
<i>p</i>	The soil pressure per unit length of the pile
<i>pt</i>	Lateral load applied at or above ground level
<i>V</i>	Vertical load
<i>Q_{all.}</i>	Allowable vertical load
<i>Q_{ult.}</i>	Ultimate vertical load
<i>r</i>	Outside radius of the pipe

x	Segment length of the pile
y_g	Deflection at ground level
y	Pile deflection
γ	Unit weight of soil
γ_d	Initial dry unit weight of soil
ϵ	Measured strain
ϕ	Angle of internal friction
Q_b	End bearing (base) resistance of pile
Q_s	Skin friction (shaft) resistance of pile
q_b	Ultimate bearing capacity at pile base
q_s	Ultimate skin friction of pile shaft
A_b	Area of pile base
A_s	Perimeter area of the pile shaft
q'	Effective vertical stress at pile base
N_q	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 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.