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

PERFORMANCE A PILE GROUP IN GYPSEOUS SOIL SUBJECTED TO AXIAL LOADING

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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January, 2019 A.D. IRAQ Jumada al-Awal, 1440 A.H.

بسم الله الرحمن الرحيم

(وَاتَّقُوا اللَّهَ صلے وَيُعَلِّمُكُمُ اللَّهُ قلے وَاللَّهُ
بِكُلِّ شَيْءٍ عَلِيمٌ)

صدق الله العظيم

سورة البقرة(٢٨٢)

Dedication

To my Father, who taught me the right path
To my mother, the light of my eyes
To My wife, who supported me in critical time
To My daughter and next baby, the hope of my life
To whom their love flow in my veins, and my heart remembers them, my brothers and sisters
To our teachers and professors who taught me the letters of gold. Who redefined my knowledge simply and from their ideas, made me a beacon to guide me through knowledge and the path of success.
Everyone, who wishes me success in my life
I dedicate this humble work.

Bilal

Acknowledgments

First, thanks are to Allah for every things, which guide 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. Safa Hussain Abid Awn and Assist. Prof. Dr. Hassan Obaid Abbas for whose valuable advice, constructive criticism, guidance, cooperation and giving their expansive time throughout the preparation of this work.

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

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

Bilal J. Noman Al-Mojamaei

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ABSTRACT

Performance A Pile Group In Gypseous Soil Subjected To Axial Loading

By

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As a matter of fact, the gypseous soil is usually considered as collapsible soil, such type of soil illustrates high resistance to settlement and high bearing capacity in its dry state, while it loses these characteristics when inundated and collapses excessively causes sudden decrease in volume of surrounding soil.

Deep foundation (piles) are one of the most common types used in collapsible soils which penetrating the weak soil layers till reached more hard ones (end bearing piles) or transfers loads depending on skin friction (floating piles). There are relatively few investigations on the response of single and group piles subjected to axial loadings in gypseous soil.

A series of 54 laboratory tests are performed to evaluate the behavior of single and group driven pile in case of floating pile (friction pile) with various pile spacing (2D, 4D and 6D), and different pattern of (triangular and sqaure) in two samples of gypseous soil of (S1= gypsum content of 60%, and S2= gypsum content of 30%) under axial load at two conditions (dry and soaked).

The results show that the group efficiency for 2D is less than one , whereas for 4D and 6D the group efficiency are more than one. In addition, the results show the spacing 4D is more efficiency in square and triangular pattern respectively in both dry and soaked states in S1 and S2. The triangle pattern is more efficiency than square. Additionally, there is a high reduction in bearing capacity of single and group pile embedded in gypseous soil due to soaking about 83% and 87% in S1 and S2 respectively. In practice, the driven pile is not recommended in gypseous soil.

TABLE OF CONTENTS

Subject **Page No.**

Acknowledgments

ABSTRACT .... **i**

TABLE OF CONTENTS .... **ii**

LIST OF TABLES .... **vi**

LIST OF FIGURES .... **vii**

LIST OF PLATES .... **x**

LIST OF SYMBOLS .... **xi**

LIST OF ABBREVIATIONS .... **xiii**

CHAPTER ONE **1**

INTRODUCTION **1**

1.1 General 1

1.2 Problems with Gypseous Soils 2

1.3 Objectives of Study 4

1.4 Thesis Layout 4

CHAPTER TWO **5**

REVIEW OF LITERATURE **5**

2.1 Introduction **5**

2.2 Gypseous Soils **6**

2.2.1 Definition of Gypseous Soils 6

2.2.2.1 Cementation 6

2.2.2.2 Solubility and Rate of Dissolution 7

2.3 Gypseous Soil Distribution in Iraq **7**

2.4 Collapsibility and Identification of Collapsing Soils of Gypseous Soils **8**

2.4.1 Collapse Mechanism 9

2.5 Effect of Soaking on Engineering Properties of Gypseous Soils. 10

2.5.1 Effect of Soaking on Collapsibility 11

2.6 Pile Foundation **13**

2.6.1 Calculating the Resistance of Piles to Compressive Loads 14

2.7 Negative Skin Friction **16**

2.8 Group Pile **19**

2.8.1 Group Action in Piles 19

2.8.2 Efficiency of pile Group 20

2.9 Behavior of Pile Foundations in Collapsible Soils **25**

2.10 Summary **30**
CHAPTER THREE **31**
EXPERIMENTAL WORK **31**
3.1 Introduction **31**
3.2 Gypseous Soil Site Description and Sampling **31**
3.3 Characterization of Gypseous Soil **32**
3.3.1 Physical Tests 32
3.3.1.1 Specific Gravity (Gs) 32
3.3.1.2 Grain Size Distribution 33
3.3.1.3 Atterberg Limits 33
3.3.1.4 Moisture Content, (ω) % 34
3.3.1.5 Compaction Test 36
3.3.1.6 Relative Density, (Dr %) 36
3.3.1.7 Identification of Gypsum Content (G.C %) 37
3.3.2 Chemical Tests 38
3.3.3 X -Ray Diffraction (XRD) Analysis 38
3.3.4 Engineering Tests 39
3.3.4.1 Single-Collapse Test 39
3.3.4.2 Direct Shear Test 41
3.4 Pile Model Tests and Properties **42**
3.4.1 Angle of Interface Friction (δ°) 43
3.5 Laboratory Model Tests **46**
3.5.1 Laboratory Model Box 46
3.5.2 Steel Frame 47
3.5.3 Loading Jack 48
3.5.4 Loading Control System 50
3.6 Model of Steel Piles Cap and Pile Group Configuration **51**
3.6.1 Model of Piles Cap 51
3.6.2 Group Configuration of Piles and Pattern 51
3.6.3 Holders of Group Piles 53
3.7 Soil Bed and Model Piles Preparations and Model Piles Installation **53**
3.7.1 Soil Bed Preparation 54
3.7.2 Installation of Model Group Piles 56
3.8 Test Procedure for Model Loading Test **57**
3.9 Testing Program **61**
3.10 Criteria for Pile Load Capacity **61**
3.11 Repeatability of Tests **63**

CHAPTER FOUR **64**
RESULTS AND DISCUSSIONS **64**
4.1 Introduction **64**
4.2 Selection Criteria for Ultimate Load Carrying Capacity 64
4.3 Effect of Direction of Inundation on Load-settlement Behavior 66
4.4 Observation of Negative Skin Friction Occurrence 66
4.5 Effect of Pile Spacing on Penetration Process of Model Driving Piles **69**
4.5.1 Effect of Pile Spacing on Penetration Resistance of Group Pile 69
4.5.2 Response of Single Pile with Last Pile Driven in Group 71
4.5.3 Effect of Pile Spacing on Uplift Soil Surface 72
4.6 Effect of L/D Ratio on Single Pile Load Tests **74**
4.6.1 Single Pile Load Tests for Different L/D Ratio without Soaking 74
4.6.2 Single Pile Load Tests for Different L/D Ratio at Soaked State 75
4.7 Effect of Pile Spacing and Group Configuration on the Load-Settlement Behavior **77**
4.7.1 Effect of Pile Spacing on the Load-Settlement Behavior at Dry State 77
4.7.2 Effect of Pile Spacing on the Load-Settlement Behavior at Soaked 79
4.8 Effect of Pile Spacing and Pattern on the Ultimate Load of Group Pile **82**
4.8.2 Effect of Pile Spacing and Pattern on the Ultimate Load at Soaked State .. 83
4.9 Effect of Pile Spacing and Pattern on the Group Efficiency **84**
4.9.1 Effect of Pile Spacing on the Group Efficiency at Dry State 85
4.9.2 Effect of Pile Spacing on the Group Efficiency at Soaked State 87
4.10 The Reduction of Ultimate Load Carrying Capacity for Single and Group Pile at Different Pile Spacing and Pattern 89
4.11 Effect of Pile Spacing and Pattern on Group Settlement Ratio **92**
4.12 Effect of Slenderness (L/D) Ratio on Load-Settlement Behavior of Group Pile **96**
4.12.1 Dry State 96
4.12.2 Soaked State 97
4.13 Effect of Gypsum Content on Ultimate Load Capacity of Single and Group Pile **99**
4.14 Effect of Group Configuration on the Load-Settlement Behavior **102**
CHAPTER FIVE **104**
CONCLUSIONS AND RECOMMENDATIONS **104**
5.1 Conclusions 104
5.2 Recommendations 105
- **REFERENCES** **106**

APPENDIX A **1**
Ancillary Equipment A.1
1. Electronic Loading Cell A.1
2. Digital Weighting Indicator and Digital Dial Gauges A.1
3. Two Digital Dial Gauges. A.2
4. Timer A.2
1.Effect of Pile Spacing on Penetration Resistance of each pile A.2
2. Response of Single Pile Versus that of Last pile Driven in Group **A.7**
3. Effect of Slenderness Ratio on Load-Settlement of Group pile **A.8**
4. Effect of Pile Configuration on Load-Settlement Behavior of Group Pile **A.10**
5. Effect of Pile Spacing On Group Settlement Ratio **A.11**
6. Effect of pile spacing on group efficiency for different L/D ratio **A.12**
7. Criteria for Pile Load Tests **A.13**
7.1 Pile Load Test at Dry state in S1 .... A.13
7.2 Pile Load Test at Dry State in S2 .... A.13
7.2 Pile Load Test at Soaked State in S1 .... A.14
7.2 Pile Load Test at Soaked State in S2 .... A.15

LIST OF TABLES

NO.	Titles	Page No.
(2.1)	Classification of Gypseous Soil after Nashat, (1990).	6
(2.2)	The collapse potential severity problem, (Al-Obaidi, 2014).	9
(2.3)	Some of research's conclusion about the soaking effect on the collapsibility.	12
(2.4)	Summary of Some Researches about Test Data of Pile Group Efficiency.	23
(2.5)	Ultimate Pile Capacity in Soil at Natural Moisture and Wetted Condition, (Grigoryan, 1997).	26
(3.1)	Results of Physical Properties of Two Samples of soils.	35
(3.2)	Results of Chemical Properties of Two Samples.	39
(3.3)	Mineralogical Composition of Gypseous Soil by XRD Analysis.	39
(3.4)	The Collapse Potential Severity of Two Samples Used.	40
(3.5)	Results of Conventional Direct Shear Test of Two Samples.	42
(3.6)	Properties of model Steel pipe pile used.	43
(3.7)	Results of Interface Shear Test between Gypseous Soil and Steel pile.	44
(3.8)	Comparison between Results of Interface Shear Test between Gypseous Soil and Steel pile.	44
(4.1)	Summary of Ultimate Load Capacity (kN) for Single Pile Driven in Gypseous Soils for 4D Spacing at Dry and Soaked State	65
(4.2)	Summary of Effect of Pile Spacing and Pattern on Group efficiency at Dry State in S1 and S2.	87
(4.3)	Summary of Effect of Pile Spacing and Pattern on Group efficiency at Soaked State in S1 and S2.	89
(4.4)	The Reduction of Ultimate Bearing Capacity for the Single and Pile-Group.	90

LIST OF FIGURES

No.	Titles	Page No.
(2.1)	Regional Distribution of Gypseous Soils in Iraq, (After Barazanji, 1973)	7
(2.2)	Gypseous soils distribution in Iraq at depths (250-1500 mm) (After Al-Kaabi, 2007).	8
(2.3)	Typical structure of collapsible soil (after Clemence and Finbarr, 1981)	10
(2.4)	Structure of the Collapsible Soils. (Houston, et al., 1988).	10
(2.5)	a) SEM for Tikrit natural soil. b) SEM after short-term soaking. c) SEM after subjecting to single collapse test (Schanz and Karim, 2018).	12
(2.6)	Types of Pile Based on Method of Transferring Load (After Tomlinson, 2015).	13
(2.7)	(a) Soil Disturbance beneath Piled Foundations (Friction Pile), (After Tomlinson, 2015), (b) Pile Basement Soil Slap Plane (Bearing Capacity Theory), (After Meyerhof, 1961).	13
(2.8)	Proposed Chart for Estimation the (δ) Value, (After Aksoy et. al, 2016, 2018).	16
(2.9)	Mechanism of Load Transfer for Single Pile in Collapsible Soil (Near the Ground Surface) during Inundation, (After Kakoli, 2011)	18
(2.10)	Distribution of Drag Loads for Friction Pile and End- bearing (After Lee et al., 2002	18
(2.11)	Stresses Surrounding a Friction Pile and The Summing Effects of a Pile Group, (After Bowles, 1996).	20
(2.12)	Efficiency of Group Pile in Sand (Vesic, 1967), (After Murthy, 2007).	21
(2.13)	Surcharge (80 KPa), Negative Skin Friction and Soil Settlement with Time for CP = 4.2% (from Mashhour, 2009).	27
(2.14)	Time versus S/B% relationships (Zakaria, 2013).	28
(2.15)	Compression load versus settlement relationship of embedded pile in gypseous soil, (Al-Busoda and Al-Rubaye, 2015).	29
(2.16)	Compression load versus settlement relationship for, single pile, 3 piles, and 4 piles, a) dry case, b) soaked case (Abd-ullah, 2015)	29
(3.1)	Grain Size Distribution curve for gypseous soil.	34
(3.2)	The Results of Compaction Test for Two Samples Gypseous Soil Used.	36
(3.3)	Results of Single Oedometer Collapse Test for Two Samples of soil used.	41
(3.4)	Direct Shear Results for Gypseous Soil with Dry and Soaked.	42
(3.5)	Direct Shear Interface Results of Pile-soil at Dry and Soaked, for S1.	44

(3.6)	Direct Shear Interface Results of Pile-soil at Dry and Soaked, S2.	44
(3.7)	Boundary Condition of Model Box for Current Study.	47
(3.8)	Schematic Diagram of Manufactured Testing Equipment	49
(3.9)	Side View of Schematic Diagram of Manufactured Testing Equipment.	49
(3.10)	Model Piles Cap and Configuration of Group Piles.	52
(3.11)	The Grain Size Distribution Curve of Filter materials and (S1 &S2).	56
(3.12)	The Sequence of Driving Each Pile in Group for Both Pattern.	56
(3.13)	Soaking from Bottom and the Water Level Covers the Soil about 1cm.	60
(3.14)	Flow Chart of Testing Program	62
(3.15)	Repeatable tests for load-settlement for group pile at dry state in S1 (square pattern 4D)	63
(3.16)	Repeatable tests for load-settlement for group pile at soaked state in S1 (square pattern 2D)	63
(4.1)	Effect of Direction of Inundation on Load-Settlement Behavior in S1.	66
(4.2)	Movement of Soil Surface Uplift Responses after Group Pile Installation Ending at Dry State and Soaked in S1	68
(4.3)	Difference in Final Settlement of Pile head and the Settlement of Gypseous Soil for different pile Spacing.	68
(4.4)	Penetration Resistance for Each Pile of Group in S1.	70
(4.5)	Comparison of the Capacity of a Single Pile with Those of Last Pile Driven in Each Group.	72
(4.6)	Comparison between the Triangular Spacing and Square Spacing (after Gangatharan, 2014).	72
(4.7)	Sketch of Uplift Soil Surface Recording After Insertion The Group Piles.	73
(4.8)	Diagram of Soil Surface Uplift Responses after Group Pile Installation Ending in S1.	73
(4.9)	Load Test Behavior of Single Pile at Dry State for Different L/D Ratio	74
(4.10)	Ultimate Load Versus L/D Ratio For Single Pile at Dry and soaked State in S1(G.C30%) and S2(G.C60%).	75
(4.11)	Load Test Behavior of Single Pile at Soaked State for Different L/D Ratio	76
(4.12)	Ultimate Load Versus L/D ratio for single pile at Soaked State in S1 and S2.	76
(4.13)	Influence of Pile Spacing on Load-Settlement Behavior of Group Pile at Dry State,	78
(4.14)	Influence of Pile Spacing on Load-Settlement Behavior of Group Pile at Soaked State	80
(4.15)	The Relation Between Ultimate Load Versus (Spacing/Diameter) Ratio for Different Pattern at Dry State for S1 and S2,	83

(4.16)	The Relation Between Ultimate Load Versus (Spacing/Diameter) for Different Pattern at Soaked State,	84
(4.17)	The Relation Between Efficiency Versus (Spacing/Diameter) for Different Pattern at Dry State,	86
(4.18)	Ideal Stresses Surrounding Friction Pile and The Summing Effects of a Pile Group for Different Spacing,	88
(4.19)	The Relation Between Efficiency Versus (Spacing/Diameter) for Different Pattern at Soaked State,	89
(4.20)	Response of Single Pile and Individual Piles of Pile Groups (Triangular and Square Pattern) in S1.	94
(4.21)	Group Settlement Ratio versus Spacing/Diameter Relationship,	95
(4.22)	Pile Group Settlement Ratio versus Individual Load Pile in pile Group at Different Loading level for Square and Triangular Pattern in S1.	95
(4.23)	Load Versus Settlement for Different L/D Ratio at Dry State of 4D spacing in S1.	96
(4.24)	Ultimate Load Versus L/D Ratio for Different Pattern at Dry State for 4D spacing,	97
(4.25)	Load Versus Settlement for Different L/D Ratio at Soaked State of 4D spacing in S1,	98
(4.26)	Ultimate Load Versus L/D Ratio for Different Pattern at Soaked State for 4D spacing	98
(4.27)	Ultimate Load of Single Pile versus L/D Ratio for Different Gypsum Content,	99
(4.28)	Ultimate Load for Group piles Versus (Spacing/Diameter) for Different Gypsum Content and Pattern,	101
(4.29)	Load-Settlement Behavior for Pile Group System of Single, 3 Piles and 4Piles in S1	103
(4.30)	Ultimate Load versus Pile Group Configuration at Soaked State in S1.	103

LIST OF PLATES

No.	Titles	Page No.
(1.1)	Employees Work at Strengthening the Mosul Dam in Northern of Iraq Due to Failure of Gypseous Soil Under Construction.	4
(1.2)	Failure of Buildings That are Built on Gypseous Soil (After Abid-Awn, 2010).	4
(3.1)	Map Image of Tikrit and Study Area with Two Samples Locations	32
(3.2)	Piles Used in Model Tests.	42
(3.3)	Systematic Procedure for Preparation of Samples for Direct Shear Test.	45
(3.4)	Steel Box. a) General View, b) Top View	47
(3.5)	Manufactured Testing Equipment, a) An Arrangement of the Sliding Piston and Manual Jack, b) An Overview.	48
(3.6)	An Arrangement of Load Cell, Digital Indicator and Digital Dial Gauges During Test.	50
(3.7)	An Arrangement of Dial Gauge for Soil Settlement Reading.	51
(3.8)	Model Piles Cap Used in Current Study.	52
(3.9)	Manufactured Steel Holder for Different Configuration.	53
(3.10)	Preparing the Soil Bed by Using Vibration Hammer and Leveling.	54
(3.11)	Preparing the Filter Material in the Base of Model Box.	55
(3.12)	Group Pile Settlement Reading by Digital Dial Gauges and Reading Loads from Load Cell Indicators.	57
(3.13)	Steps of Installation of Model box and Group Piles.	58
(3.14)	Piles Covered by Gypsum on Tip after Pile Testing in Soaked Case.	60
(3.15)	Piles Covered by Gypsum on Tip after Pile Testing in Dry Case.	60
(3.16)	Soaking Process.	61
(4.1)	Clarity of Gypsum Particles between The Soil and Group Pile Surface at Different Depth	81
(4.2)	Close Up Image of Soil-Pile Interface of a Model Driven Pile in Gypseous Soil.	92

LIST OF SYMBOLS

Symbol	Meaning
Ap	Area of cross-sectional of pile.
AS	Surface area of (skin) shaft pile.
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
D10	Grain size at 10% passing
D30	Grain size at 30% passing
D50	Mean size of soil particles
D60	Grain size at 60% passing
Dr	Relative density of soil
e	Void ratio
e_o	initial void ratio
G.C%	Gypsum content of soil%
Gs	Specific gravity
Ho	Initial height of the specimen.
Ic	Magnitude of collapse determined at 200 kPa.
i	Hydraulic gradient
K	Coefficient of lateral earth pressure
Ks1	Earth pressure coefficient of corresponding layer.
L	Embedded length of pile
L/D	Slenderness ratio of pile
N γ,Nq	factors for bearing capacity
NP	Neutral plane
Ø	Angle of internal friction of soil
P	Load on pile
PD	effective overburden pressure
PD1	Effective overburden pressure of corresponding layer.
Qb	End bearing resistance
Qgu	Ultimate load of the group pile
Qs	Shaft resistance
r	Radial distance
Rd	Reduction percent in ultimate load
S	Spacing between pile
S/D	Spacing between pile / diameter of pie
S1	Soil one with 30% gypsum content
S2	Soil two with 66% gypsum content
SM	Silty sand

SP	Sand poorly graded
t	Thickness of pile wall
Uz	Upward displacement of pile
W105oC	Weight of sample that oven dried at (105oC)
W45oC	Weight of sample that oven dried at (45oC)
Wc %	Water content of soil
γ_d	Dry unit weight of soil
δ	Interface friction angle between pile and soil
Δe	void ratio changing in upon wetting
Δe	The difference between the initial void ratio of specimen and the final void ratio resulting from soaked.
ΔHe	The difference between the initial height of specimen and the final height resulting from soaked.
χ	Gypsum content %
η	Group efficiency

LIST OF ABBREVIATIONS

Abbreviation	Meaning
ASCE	American Society of Civil Engineering
ASTM	American Society for Testing and Materials
CPT	Cone Penetration Test
DOT	Double oedometer test
LCD	liquid crystal display
NCCLR	National Center for Construction Laboratory and Research
NSF	Negative skin friction
O.M.C	Optimum Moisture Content
PSF	Positive skin friction
SEM	Scanning electron microscope
SOD	Single oedometer test
SPT	Standard Penetration Test
T.S.S.	Total soluble salts
UPS	Uninterruptible Power Supply
USCS	Unified Soil Classification System
XRD	X -Ray Diffraction

Chapter One

Introduction

CHAPTER ONE

INTRODUCTION

1.1 General

The gypseous soil is classified as one of the collapsible soils, which is defined as any unsaturated soil that undergoes a radical re-orientation of particles resulting large loss in volume of soil mass when soaked with or without additional loads (Clemence and Finbarr, 1981). It is found in open area concentrated mainly in the arid and semi-arid regions of the world in Asia, South Asia (Iraq, Syria, Jordan, and Yemen), North Africa, and North America. Gypsum mineral deposits in shape of ($CaSO_4.2H_2O$) hydrated calcium sulfate or anhydrate ($CaSO_4$) with intermediate solubility (≈ 2.6 g/l at 25ºC). These soils occupy approximately 1.5 % of the total area of the world, (FAO, 1990). It covers more than (31%) of the surface area in Iraq with different percentage of gypsum ranging from 10% to 70% (Ismail, 1994). In addition, Al- Saoudi, et al. (2013) show that the gypseous soils cover about 20 to 30 % of total area of Iraq which is concentrated mainly in the southern parts and extending to the west desert, also it found in middle toward north of Iraq.

The gypseous soils are generally stiff in case of dry, it shows high bearing capacity, very low compressibility. In contrast, it shows high reduction of volume, bearing capacity and sudden change in compressibility in case of any change in moisture content. In addition, the high reduction is due to the dissolution of the gypsum content in soil mass and loss the bonds between particles of soil, (Dudley, 1970; Clemence and Finbarr, 1981; Al-Saoudi, et al., 2013).

Deep foundation (piles) are one of the most common types used in collapsible soils. A full scale is carried out of pile load test in collapsible soil, the result show that there is a high reduction in ultimate bearing capacity of piles due to inundation the soil by water, (Gregoryan, 1997); (Fernandes and Cintra, 1997).

The experimental studies which are concerned to investigate the performance of piles in gypseous soil show there is a high reduction in bearing capacity and high settlement of piles when inundated after 24 hours, whereas, in case of dry there is a high bearing capacity of piles, (Albusoda and Al-Rubaye ,2015; Abd-ullah, 2015). Some time, the settlement of gypseous soil is faster than of pile, which is developed the skin friction along the pile shaft acts downward, is called negative skin friction (NSF), (Kakoli, 2011); (Noor et al, 2013); (Mashhour, 2016); (Mashhour and Hanna, 2016).

Actually, there is a considerable lack of information can be recognized through the literature regarding the response of single and group piles subjected to axial loadings in gypseous soil, most of the previous studies where dealt the issue of end bearing piles. During the current study, behavior of driven pile group in gypseous soil (friction pile) is studied in detailed.

1.2 Problems with Gypseous Soils

There is a structural risk in the presence of gypsum content under the foundations of structures in practice, especially when environmental fluctuations in the case of water saturation, mainly in dissolution of gypsum when these soils are wetted, soaked or leached by water. However, these problems usually have been led to cracks, tilting and collapse of the structure, like Mosul dam (Nashat, 1990).

Moreover, failure of different structures constructed on gypseous soils in other locations are recorded such as Samarra tourist hotel, Tikrit training center, Tikrit water storage tank, Kerbala elevated water tank, Dujail communication center and Habbaniyah tourist village, (Nashat, 1990; Razouki et al., 1994; Al-Mufty, 1997). As shown in plates (1.1) and (1.2).

Furthermore, many cracks are noticed in runways of College of Air Force (Al-Neami, 2000). In addition, there a various problems of construction that regard to gypseous soils, such as: collapse, tilting, cracks and leaching, (Mahdi, 2004). Additionally, cracks and excessive settlement problems are also found in Habbaniyah Tourist Village, Al-Anbar University and some houses found in the Al-Ramadi city (Tawfeeq, 2009).

Finally, damages produce via gypseous soils have been observed in numerous regions in the world in addition to Iraq, such as Arabian countries, Russia, Chine, USA, and Spain. The construction of buildings, railways, channels, bridges and roads in gypseous soils has been related with collapse problems. The problem appears when water table or rainfall fluctuates and or infiltrates into gypseous soils, (Al-Saoudi et al, 2013).

Plate (1.1) Employees Work at Strengthening the Mosul Dam in Northern of Iraq Due to Failure of Gypseous Soil under Construction (Internet source, Alghad Press,2016).

Plate (1.2) Failure of Buildings That are Built on Gypseous Soil (After Abid-Awn, 2010)

1.3 Objectives of Study

The basic objectives that are established to get the aim of this study are as the following:

1. Investigating the effect of pile spacing on penetration process of group driven pile.
2. Investigating the effect of pile spacing on group efficiency and the ultimate load.
3. Investigating the effect of pattern (Triangular & Square) on group efficiency and ultimate load.
4. Investigating the reduction in bearing capacity of single and group pile.

1.4 Thesis Layout

The contents of this study work are presented in five chapters as follows:

Chapter one presents a general introduction to collapsible (gypseous) soil, distribution, problems of gypseous soil and uses of piles in these soils. chapter two shows a review of literature and properties of gypseous soils, collapse potential and general introduction to pile, mode of load transferring in pile, group action in piles, and the definitions of drag load and down drag. In addition, previous studies related to piles constructed in collapsible soils are reviewed. Moreover, chapter three, it presents the full details of experimental work that contains conventional classification tests and model loading tests on pile bearing capacity determination. The model loading tests are carried out on floating in soaked and dry conditions. Chapter four, it presents the results of the tests and their discussions. Finally, chapter five includes the main points concluded from this work and recommendations for future studies are presented.