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Bridge Pile Foundation: Simulation and Analysis

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Abstract

The main objective of this study is to simulation and analysis of single pile and pile group for bridge pile foundation (case study). The project already exists at Baghuba City Center at AL-Mufrak Square named "Almujaser". Usually this huge structure has number of piles at its foundation part. Therefore this study deal with the FE simulation for the piles to estimate all expected problems that maybe occur at the foundation of this project. In addition this evaluation has included the layered soil system with three –dimension effect. It has been concluded that the pile with little change in resulted displacements are occurred due to different soil profile under each pile. The pile within group carries different capacity even if this difference is little. In addition the pile cap has improved in group capacity around 30%.

Keywords: bridge foundation, FEM, 3D soil profile, pile group, pile cap

1 Introduction

In order to design the foundation for a given structure, two main types of foundation are usually utilized depending on the state of loading and type of soil (i.e. shallow and deep foundation). For the case of very heavy structure constructed on a weak soil, deep foundation is always used, which is, in general, consists of a group of piles covered by cap.

The axial performance of single isolated pile subjected to axial load has been assessment by number of previous researches (i.e. Das 1999 Ismael 2002, Tosini 2010 and Abbas et al. 2012 Bourgeois et al. 2012) and usually common and not problematic. While the pile group assessment is more complex when compared with single isolated pile (Castelli and Maugeri 2002, Ismael 2002, McCabe ,Lehane 2006, Abbas et. al. 2010 and Jaeyeon Cho et. al. 2012).

Generally most of the previous studies take into account the surrounded soil as horizontal layers. While in fact the soil profile is usually not horizontal. Therefore this issue needs more studies to assess the effect of this issue on the pile group response. Thus, the main contribution that obtained from this research is simulating the soil layer as it is in the field.

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Therefore, the intention of this study is to evaluate the axial pile and pile group response in actual soil profile using three-dimensional finite element approach. Taking into account the influence of pile cap on the response of pile group.

2 Description of Case Study

This project is one of the important and vital projects in the region for several reasons, including its privileged location in the center of the province, which connects four sides with each other. In addition the service currently provided by the traffic of the road and its consequences for the future is also a number of factors, including: (a) increasing the capacity of the road, (b) reduce congestion momentum, and (c) reduce travel time for vehicles.

In other hand, this project in terms of aesthetic adds attendees view of the province in general. Either practice could evaluate the work of mega projects and very important in the region to work accuracy and quality of results in advanced stages of completion and reached by the project is currently

Add to this the "Almujaser" work of the foundations of a solid and strong (deep foundations), which is the subject of study of this project.Figure (1)showAlmujaser at Almufrak square site plan with both Aerial photographs and detailed sketch.

(a) (b)

Figure 1: Description of case study for Almujaser at Almufrak Sq., (a) Detailed sketch and (b) Aerial photograph

3 Data Collection for Case Study

Site visit were performed for case study taken from Al Mufrak Sq. project in Baqhuba city. The purpose for this visit was to collect the necessary data report, profile for this project. However the final aim was to use the finite element method to simulate this case study. In addition the aim of the visit was to evaluate the exist conditions in geotechnical issue for this huge project.

Soil properties are the first factor to determine the limitation of design foundation structure. In the site of Almujaser project, there are three bore hole with depth (30metere) has been made in different point at the site. The distribution of bore holes is shown in Figure (2). In addition the baseline soil parameters used for the analysis of axially loaded pile are illustrated in Tables 1(a, b and c).

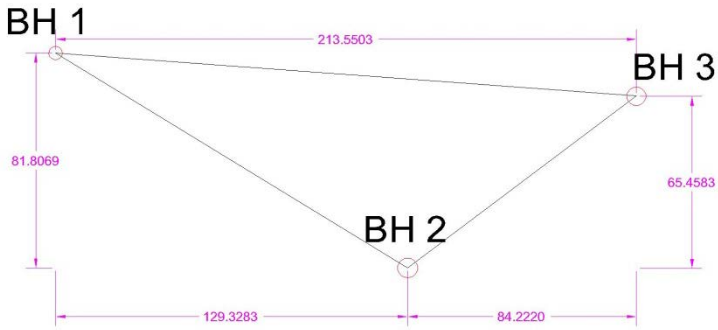


Figure 2: Boreholes distribution of Almujaser project

Table 1a: soil layers in Bore hole No.1 (BH1)

Type of soil l	Elev.	γ	E	v	c	φ
Brown sandy silt	1.5	16	13000	0.4	40	20
Brown clay sandy	7.5	15	11000	0.3	45	25
Brown clay silt	20	15.81	9000	0.32	75	28
Brown silt sand with amount of clay	30	14.84	50000	0.3	90	30

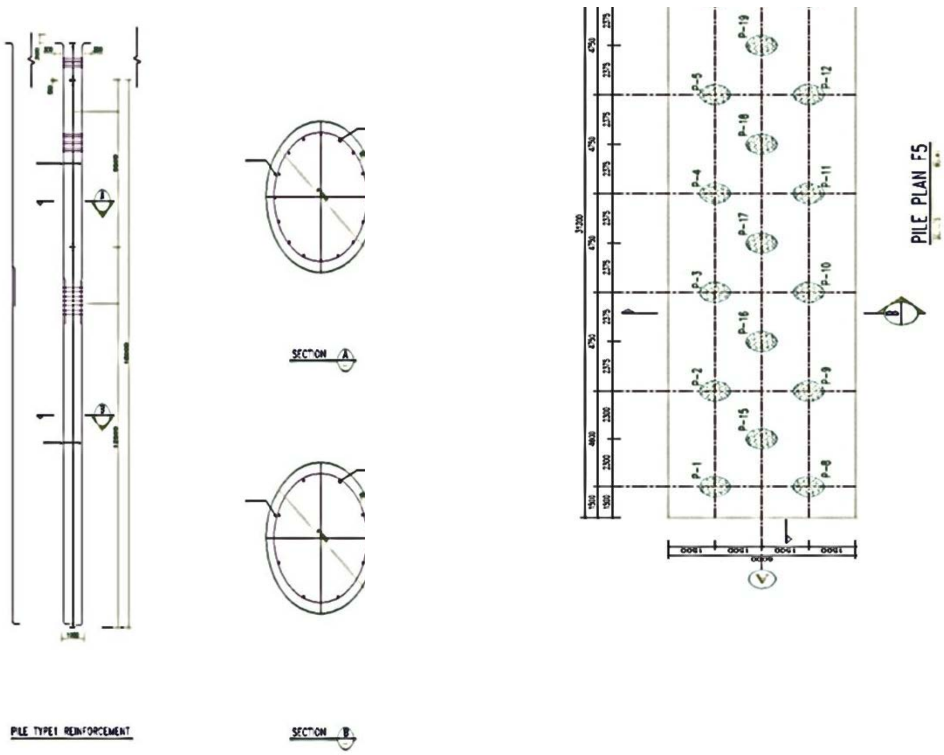
Table 1b: soil layers in Bore hole No.2 (BH2)

Type of soil 2	Elev.	γ	E	v	c	φ
Brown sandy silt with amount of clay and gravel	1	15.28	13000	0.4	55	20
Brown clay sandy silt	3	15	11000	0.3	53	25
Brown silt sandy with clay	5	15.4	9000	0.32	35	28
Brown clayey sand silt	7	14.84	50000	0.3	50	30
Brown clayey silt sand	20	14.5	5200	0.34	80	27
Brown silt sandy with clay	30	14.57	9200	0.31	70	30

Table 1c: soil layers in Bore hole No.3 (BH3)

Type of soil 2	Elev.	γ	E	v	c	φ
Brown sandy silt	1.5	16	13000	0.4	40	20
Brown clay sandy	7.5	15	11000	0.3	45	25
Brown clay silt	20	15.81	9000	0.32	75	28
Brown silt sand with amount of clay	30	14.84	50000	0.3	90	30

Pile is conceder the important member in heavy structure for its effort to transfer the applied loads from surface layer of soil to the strong stratum. The structural design of piles depend on the quantity of load and the type of soil profile for these limitations the designer decided to design pile under the bridge with diameter (1m) and (18m) depth. Figure (3) shows the pile section and plan section of pile foundation.



(a) (b)

Figure 3: Pile Foundation Description, (a) Pile section, (b) group configuration

4 Finite Element Modeling

For the investigation of the behavior of vertical piles and pile group under this project a three-dimensional (3-D) numerical model was used. The finite element program PLAXIS 3D was applied. Solid concrete piles with fixed embedded length were considered. One diameter has been selected.

One of the most important issues in geotechnical numerical modeling is the simulation of the soil profile as real using three dimensional action. An elasto-plastic material law with Mohr-Coulomb failure criterion has been used to describe the behavior of soil. The PLAXIS 3D can be simulate the concrete part and pile soil interface using linear elastic and 16-interface element, respectively.

The finite element mesh used in the simulation of deep foundation analysis is shown in Figure 4. The axial load is applied at the tip of the piles that is found at the ground surface in the x-direction. 3D view for the finite element mesh of single pile and surrounded soil mass is illustrated in Figure 4.

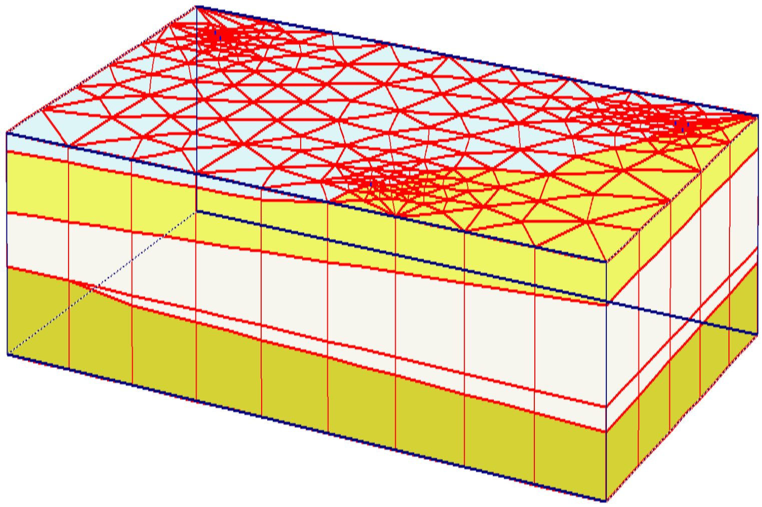


Figure 4: Three dimension finite element mesh of single pile and surrounded soil mass

5 Numerical Modeling Results

This part is includes the study of axial pile foundation response (i.e. axial pile settlement and soil pressure) under pure axial load. The stat of load was carry out similar to the exist case study and depend on the design load. The following sections included both the result of single isolated pile as well as the group of pile with details.

5.1 Analysis of Single Isolated Pile

Figure 5 shows plan and profile views of an idealized prototype of vertical pile with diameter, D and length L. It is assumed that the pile head is within the ground surface elevation. The surrounded soil is assumed as homogenous. The pile studied is free-headed pile type.

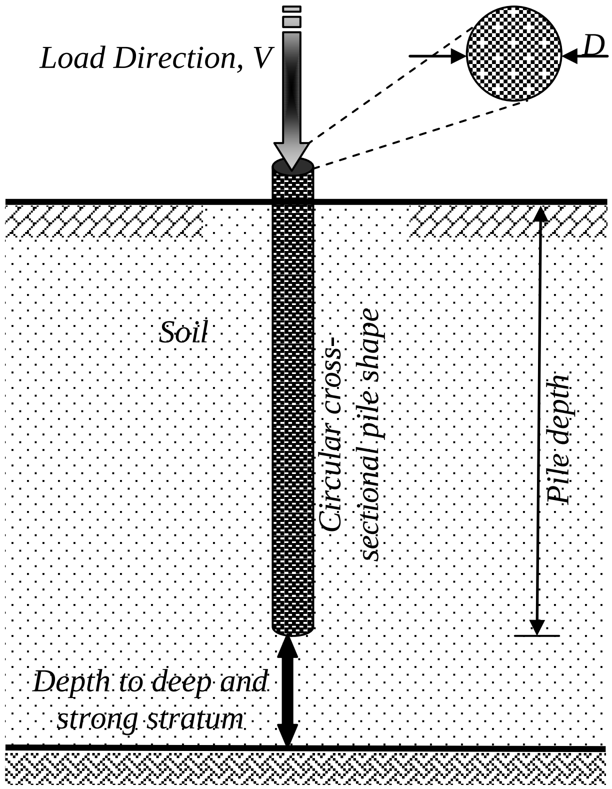


Figure 5: Profile views of free-headed and fixed-headed pile

5.1.1 Load Settlement Analysis

The load settlement analysis for single pile is important to evaluate the performance of single pile. This performance gives indication of pile group behavior. Therefore to understand the group behavior should firstly understand the single pile behavior.

Figure (6) shows the maximum settlement of all 6 piles that it was tested in the field. It can be shown the little differences in the measures settlement between these pile and this occurred due to different soil profile under each pile and this is what this research need to prove.

In addition the load settlement curves for these piles are illustrated in Figure (7). It can be seem that the pile behave for all case same with little differences as described previously.

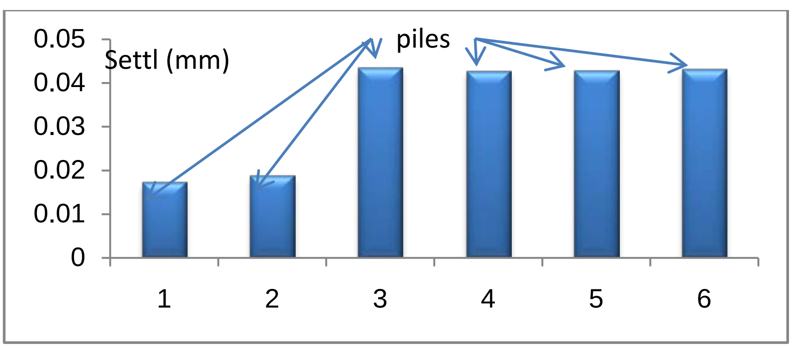
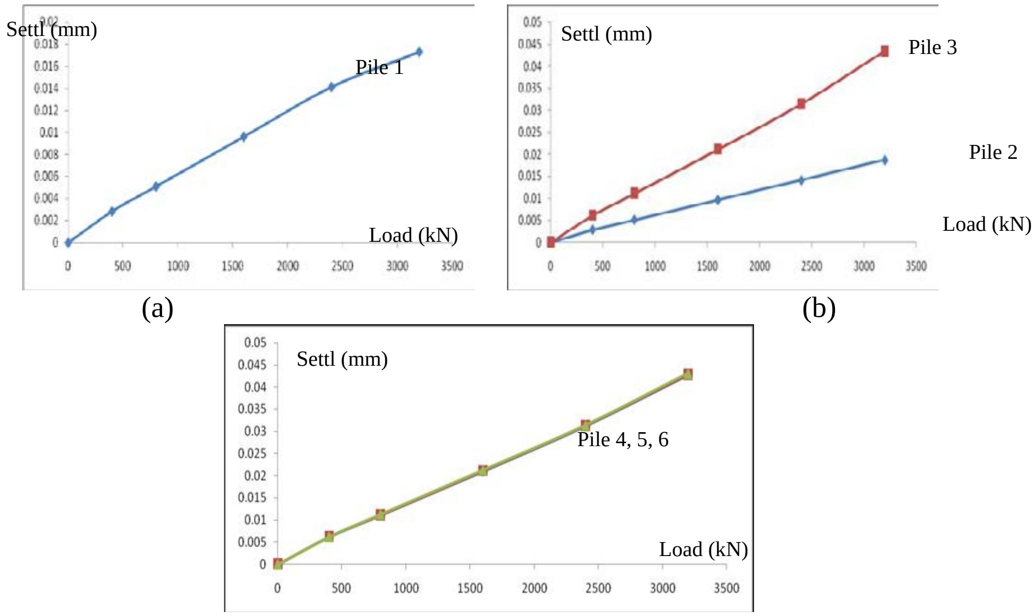


Figure 6: the maximum settlement of all 6 piles



(a) (b)

(c)

Figure 7: load settlement curves

5.1.2 Load Pressure Analysis

The load pressure analysis is one of the key for analysis of pile foundation. The important of the study the pressure that generated under the pile is come from the risk if the soil around the pile fails.

Figure (8) shows the maximum pressure occurred under these three piles. In addition Figure (9) shows the load pressure curves for all studied piles.

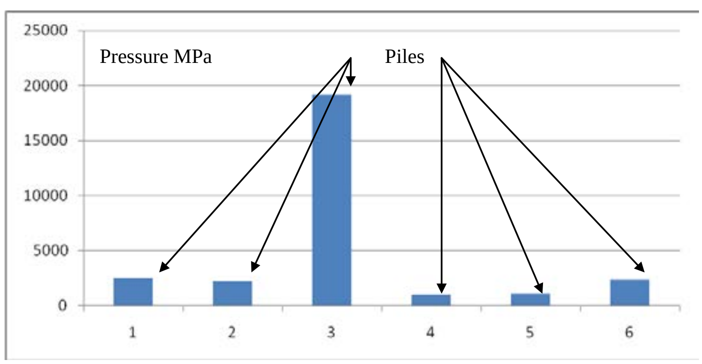
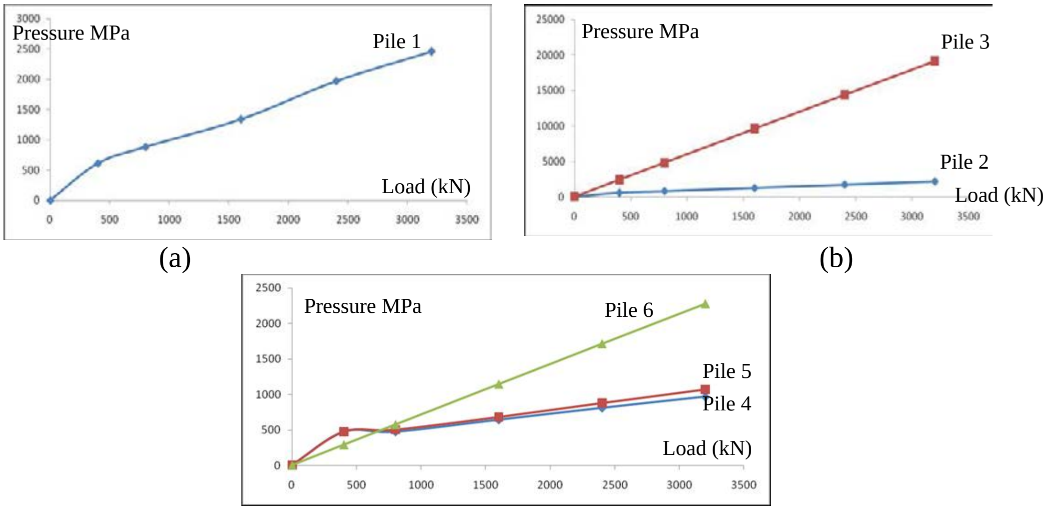


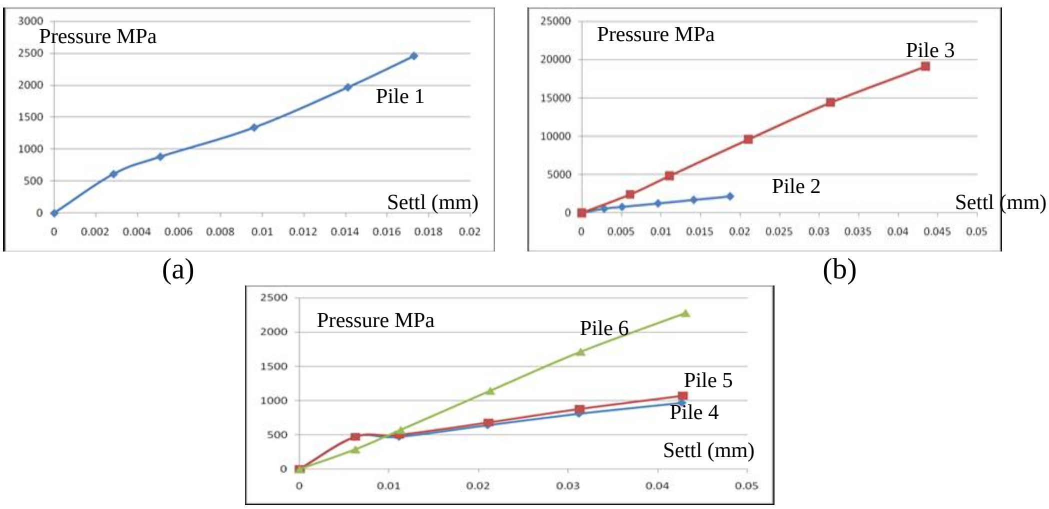
Figure 8: The maximum pressure



(a) (b)
(c)
Figure 9: load Pressure curves

5.1.3 P-Delta Analysis

For the design of pile foundation the p-delta curves is usually used to understand the behavior of pile as both axial displacement and the corresponding pressure. Figure (10) show these curves for all studied piles.



(a) (b)
(c)
Figure 10: P-Delta Analysis

5.2 Analysis of Pile Group

Figure 11 shows 3D views of an idealized prototype of pile group with vertical pile diameter, D, length L and group dimensions (L_{Gr} x W_{Gr}). It is assumed that the pile head is within the ground surface elevation. The surrounded soil is assumed to be homogenous. This study included both piles with and without pile cap. In the case of capped group, the pile cap assumed to be a rigid, therefore every pile carry equal amount of load. In this, it

is assumed that no pile cap resistance is present on the applied load (i.e. only distributing the loads to the piles head). While in other case, the piles and cap are working together as usual case. This part helps to understanding the performance of pile group in two actual cases.
The analysis of piles within group is included only seven piles. These piles represent good samples for these 20 piles. The first samples represent the side row of piles as shown in Figure (3). This row actually contains the piles between (P1-P7) and (P8-P14). The second row represents the middle piles row with piles between (P15-P20). Therefore the selected samples are (P1, P2, P3 and P4) from side row and (P15, P16 and P17) from middle row.

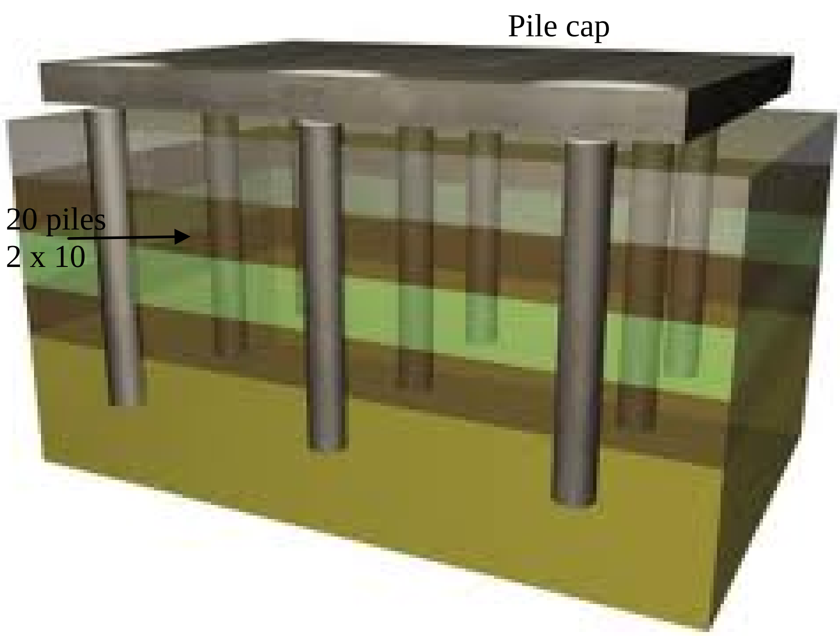


Figure 11: Pile group configurations used in this study

5.2.1 Load Settlement Analysis

Figure (12) shows the maximum settlement of all 7 piles that represent the case study. In case piles without cap, it can be shown the settlement of piles closed to the center is little more than the settlement measures for piles far from center. This is possibly because of pile to pile action as well as the pile closed to center carry more load even the cap can equally distribute the external load.
In addition the load settlement curves for these piles are illustrated in Figure (13) in case of pile cap action. It can be seemed that the differences been more compared with previous case and this because of pile cap action. Also it can be seem that the piles with cap can carry around 30% compare with piles without cap. This help to improve understandings about the capacity of pile group when assume the cap contact with ground.

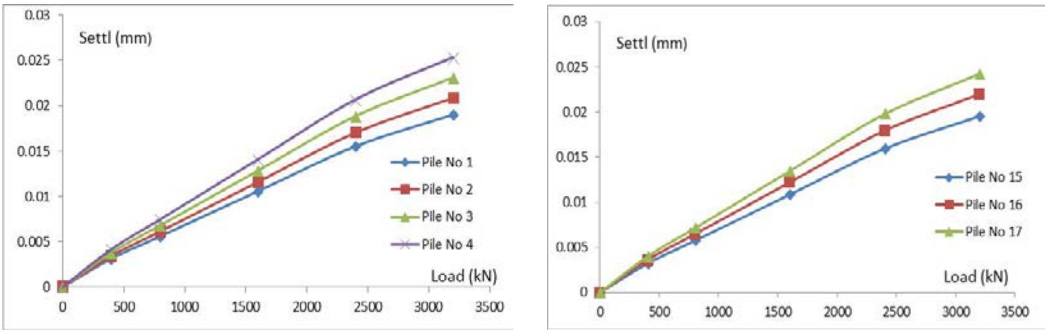


Figure 12: Load Settlement Curves for Pile Group (without pile cap effect)

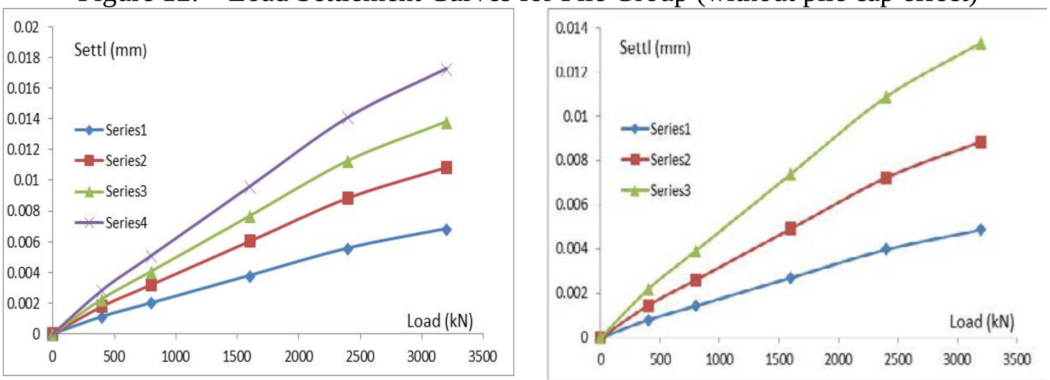


Figure 13: Load Settlement Curves for Pile Group (with pile cap effect)

5.2.2 Load Pressure Analysis

Usually the pressure assessment of single pile is different with those measured from pile group. This is due to pile to pile action as well as the cap action. Therefore it is important to compare between the existences cases to improve understanding for this issue and then proposed the assumptions.

Figure (14) shows the maximum pressure occurred for case of piles without cap. In addition Figure (15) shows the load pressure curves for piles with cap action. It can seem that the little change in maximum pressure occurred between the piles. This issue is logic because the piles work near as single piles. This due to the spacing closed to 4-5D, but still the group action is affect because it is difficult to neglect its influence anymore.

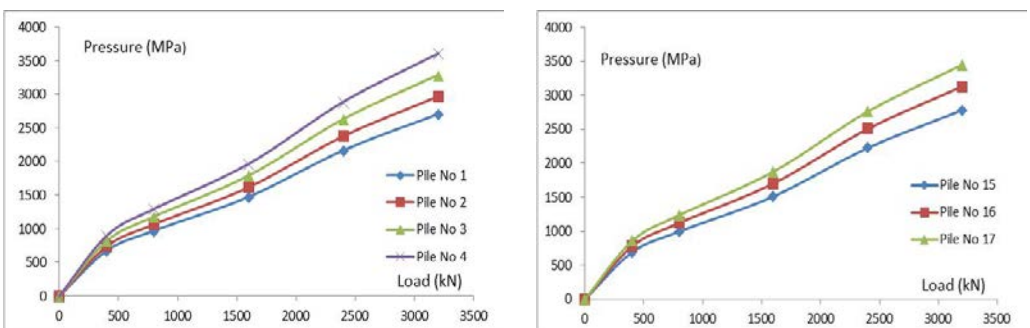


Figure 14: Load Pressure Curves for Pile Group (without pile cap effect)

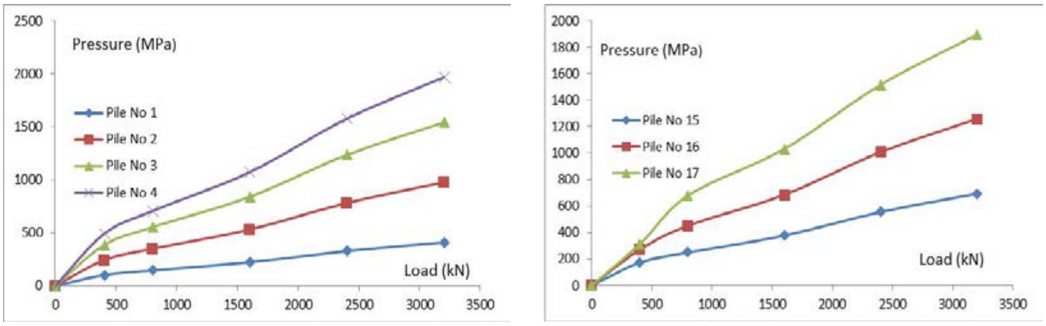


Figure 15: Load Pressure Curves for Pile Group (with pile cap effect)

5.2.2 P-Delta Analysis

For the design of pile foundation the p-delta curves is usually used to understand the behavior of pile as both axial displacement and the corresponding pressure. Figure (16) and Figure (17) shows these curves for all studied piles. It can seem that little change appeared in this behavior in case of piles without cap. This is due to the piles work as single with little effect of group action. While the piles with cap can see more change due to cap action and increase of croup action.

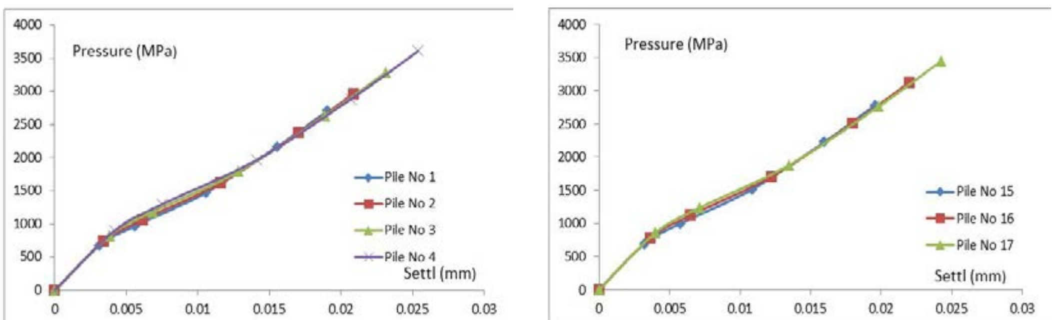


Figure 16: P-Delta Curves for Pile Group (without pile cap effect)

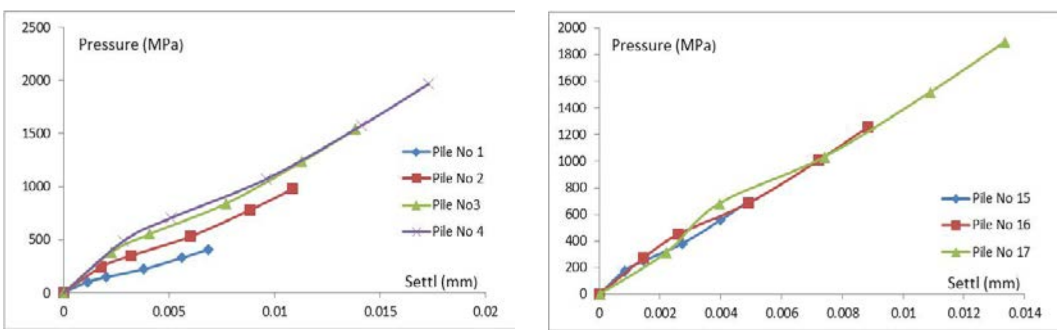


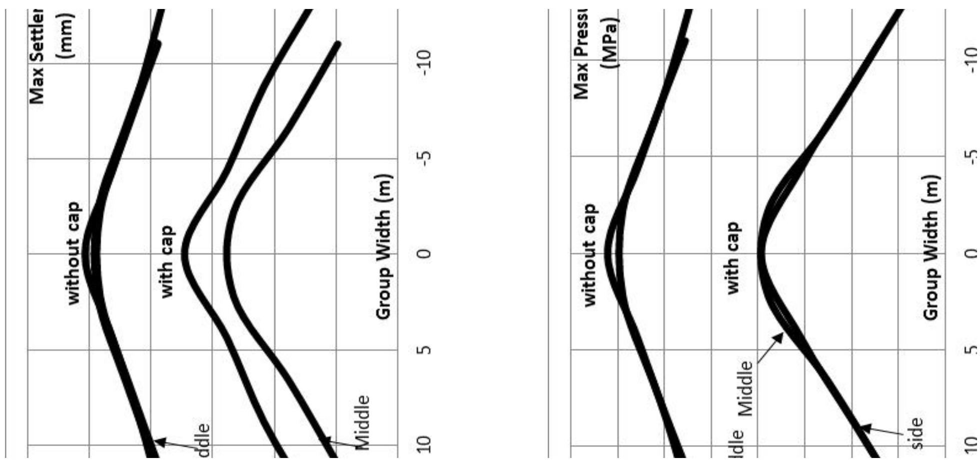
Figure 17: P-Delta Curves for Pile Group (with pile cap effect)

6 Maximum Settlement and Pressure Distribution along Group Width

This part of the study is very important part because it can shows the real pile response. In this part, the center line of pile cap take as (0) at the exact middle of cap. In this part the maximum settlement as well as the maximum pressure has been taken along the pile cap.

Figure (18a) shows the maximum settlement distribution along pile cap. It can seem that the maximum settlement occurred at the center line of pile cap for both case (i.e. without and with pile cap). This is logically because the pile in the middle is usually carrying more load even the cap can distribute equal amount of loading for all piles. In addition it is due to group action. It can be observed that the piles without cap have little differences compared with pile with cap.

This also can seem in the case of maximum pressure; the piles in the middle part carry more pressure compared with piles closed to edge. Figure (18b) shows the maximum pressure distribution along pile cap.



(a) (b)

Figure 18: Maximum Settlement and Pressure Distribution along Group Width, (a) Maximum Settlement and (b) Maximum Pressure

7 Conclusion

This part is concludes the research with main findings from the assessment of lateral pile and pile group responses subjected to axial and load. The followings are conclusions obtained from this investigation:

1. The axial displacement and pressure is influence by the magnitude of loading. The pile with little change occurred due to different soil profile under each pile.
2. Due to group action, the piles have more change in the response compared with the pile without this action. In addition, the piles with cap can carry around 30% compare with piles without cap.
3. The maximum settlement occurred at the center line of pile cap for both case (i.e. without and with pile cap). Smoothly decreased to the lowest values when measured closed to the pile group edge.

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