VOL. 13, NO. 6, MARCH 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ANALYSIS OF PILE-RAFT FOUNDATIONS NON- RESTED AND DIRECTLY RESTED ON SOIL

Elsamny M. Kassem[1], Abd EL Samee W. Nashaat[2] and Essa. Tasneem.A[1]
[1]Civil Engineering Department, Al-Azhar University, Cairo, Egypt
[2]Civil Engineering Department, Faculty of Engineering, Beni- Suef University, Beni- Suef, Egypt
E-Mail: waelnashat@eng.bsu.edu.eg

ABSTRACT

Piles are commonly connected using a raft to maintain group action and ensure overcoming any expected differential settlement. Although the raft is indirect contact with subsurface strata, conventional design system ignores the load transferred from raft to the soil due to this contact and encounter on the pile group bearing capacity and settlement. However, piled raft foundations that are not directly rested on soil such as the bases of the bridges and in case of settlement or scoured of soil underneath the raft do not take much attention. In the present study, the effect of group efficiency as well as the load distribution of the friction along the pile shaft the load transferred to the tip of the pile and load transferred to soil underneath pile cap in pile groups in cohesion less soil have been presented. The piles were tested in a setup under compressive axial loads. Load at pile tip and the strain along the piles as well as the pile head loads were measured simultaneously. Furthermore, the load under pile cap transferred directly through pile cap to soil has been measured. The program consisted of installing test piles in dense sand, placing piles in a soil chamber subjected to compressive axial load. However, three groups of testing were performed in axial compression. First group load test was carried out on single pile. Second group is four pile caps rested on soil. Third group is four pile caps non-rested on soil. The load capacity of the piles was established and the load distributions along pile walls were determined at various depths. In addition, the loads at pile tip and underneath the pile cap were measured by load cells. It was found that the group efficiency of pile groups cap of four pile rested on soil is more than that pile group cap of four pile non-rested on soil. The group efficiency was found to be ranging between 1.25 to 1.65. The load transferred to soil underneath pile cap was found to be 8 % from the ultimate load capacity. The settlement of pile groups for piles cap rested on soil is less than that for pile cap non-rested on soil. Finite element analysis gives values of settlement less than experimental test results. Fair agreement has been obtained between finite element analysis and experimental test results.

Keywords: pile group caps rested, pile group caps non-rested, rafted-pile, efficiency, settlement.

INTRODUCTION

Analysis of load shearing between rafted-pile and soil underneath pile raft is a complex task in geotechnical engineering. There is no simplified method prediction for load shearing between soil and rafted pile. Al-Mosawi *et al*. (2011) investigated the experimental behavior of piled raft system in sandy soil. A small scale "prototype" model was tested in a sand box with load applied to the system through a compression machine. Four configurations of piles were tested in the laboratory. In addition, rafts with different sizes were tested. The effects of pile diameter, pile length, and raft thickness on the load carried capacity of the piled raft system were included in the load-settlement presentation. It was found that the percentage of the load carried by piles to the total applied load of the groups with raft thickness of 5 mm, pile diameter of 9 mm, and pile length of 200mm was 28%, 38%, 56%, 79% respectively. The percentage of the load carried by piles increases with increasing number of piles.

El-Nahhas *et al.* (2012) used the sake of validating software to estimation of different input parameters needed for modeling of different pile group system. Pile load test was performed on ALZEY Bridge in Germany. The effect of pile position on the load transferred by the pile was studied. The effects of piles spacing and length to diameter ratio were studied. The capacity of selected piled rafts was examined. Abd Elsamee (2013) presented field pile load test data was analyzed to estimate the ultimate load for end bearing piles. Four pile load tests were performed on 600 mm diameters and 27 m lengths. Ultimate capacities of piles were determined according to different methods. It was concluded that the percentage of friction load carried by the shaft along the pile length was about 46% of total load while the percentage of load carried by the end bearing is 54% of total load.

Elsamny *et al.* (2017a) investigated the ultimate capacity, settlement and efficiency of pile groups in sandy soil. An experimental program was conducted to study the group efficiency. However, the experimental program consisted of testing single pile, pile groups of two, three and four piles in sand under axial compression load. The spacing between piles was kept three diameters of piles. The pile head loads, displacement, strains along the pile shaft were measured simultaneously. The obtained test results indicated that the ultimate capacity of single pile inside pile groups increases with increasing number of piles. However, the settlement of pile groups at the ultimate load was found to be more than that of the settlement of single pile. In addition, it was found that group efficiency of pile groups (2, 3 and 4 piles) increases with increasing number of piles. However, for number of piles in pile group more than four no significant increase has been obtained. In addition, the group efficiency was found to be ranging from 1.25 -1.47 as by using chin

ARPN Journal of Engineering and Applied Sciences

method (1970) for the determination of ultimate capacity of piles.

Elsamny *et al.* (2017b) investigated the load shearing between soil and pile raft cohesion-less soil. An experimental program was conducted to study the distribution of applying loads at the lower parts of founded soil as well as pile raft. However, the experimental program consisted of testing single pile, pile groups of two, three, four, five and six piles in sand under axial compression load. It was found that the percentage of the transferred load of single pile at pile tip = 13.5% from the ultimate capacity. Also for pile groups (2, 3, 4, 5 and 6 piles) it was found that the percentage of loads transferred to the soil underneath the pile caps = 0.88 to 1.10 % from the ultimate bearing capacity. In addition, for pile groups (2, 3, 4, 5 and 6 piles) it was found that the percentage of loads transferred to the soil at pile tip = 4.20 to 2.53 % and transferred to the soil by friction = 94.70 to 96.59 % from the ultimate bearing capacity.

Elsamny *et al.* (2017c) investigated theoretically and experimentally the settlement of single pile and pile groups. An experimental program was conducted to study the settlement of pile-raft. It was found that the settlement increases with increasing the number of piles. The values of settlement were obtained from theoretical calculations greater than the values those obtained from experimental program. As well as, the magnitude of settlement depends on the smallest width of the pile group without taking into consideration the geometry and the distribution of piles in plan.

EXPERIMENTAL PROGRAM

The experimental program was conducted to study effect of load shearing underneath the pile caps of pile groups and soil. The piles were tested in a setup under compressive axial loads. Load at pile tip, strains along the piles as well as the pile head loads were measured simultaneously. Furthermore, the load under pile cap transferred directly by pile cap to soil has been measured. The program consisted of installing test piles in dense sand, placing piles in a soil chamber subjected to compressive axial load. However, three groups of testing were performed in axial compression. First group load test was carried out on single pile. Second group was four pile caps rested on soil. Third group was four pile caps non-rested on soil. The test program carried out was as follows:

- Group (1) - Single pile.
- Group (2) - Group of four piles cap rested on soil.
- Group (3) - Group of four piles cap non-rested on soil.

Pile used materials

The followings are the concrete dimensions and reinforcement details of pile:

a. Graded sand has been used as fine aggregate.
b. Coarse aggregate used in the concrete mix is crushed stone.
c. Clean fresh water free from is used for mixing pile concrete.
d. Portland Cement BS EN 197-1-CEM 42.4N is used in concrete for the all experimental work.
e. Nominal cube strength was 2.10 kN/cm^2.

Reinforcement concrete details

A nine-precast concrete cylindrical piles of 0.15m diameter and 1.50m length were fabricated the details of which areas follows:

Group (1) - Single pile is shown in Figure-1.

Group (2) of four piles rested on soil having pile and head dimensions are shown in Figure-2.

Group (3) of four piles non-rested on soil are shown in Figure-3.

VOL. 13, NO. 6, MARCH 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

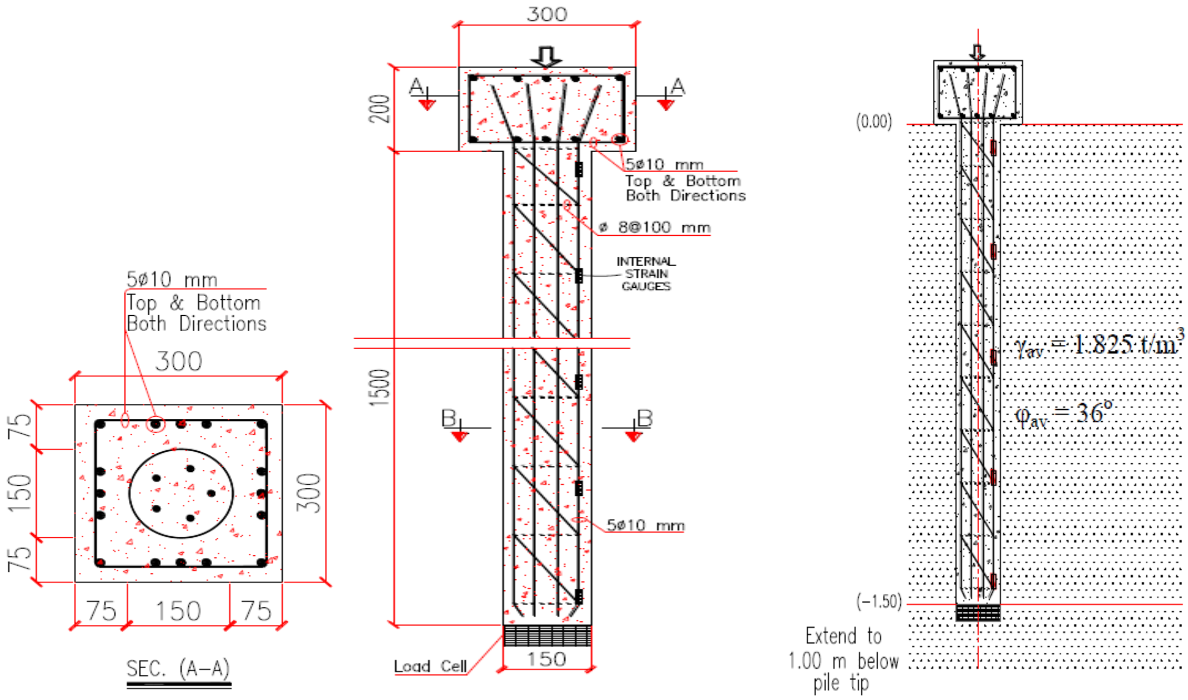


Figure-1. Reinforcement concrete dimension of group (1) – single pile.

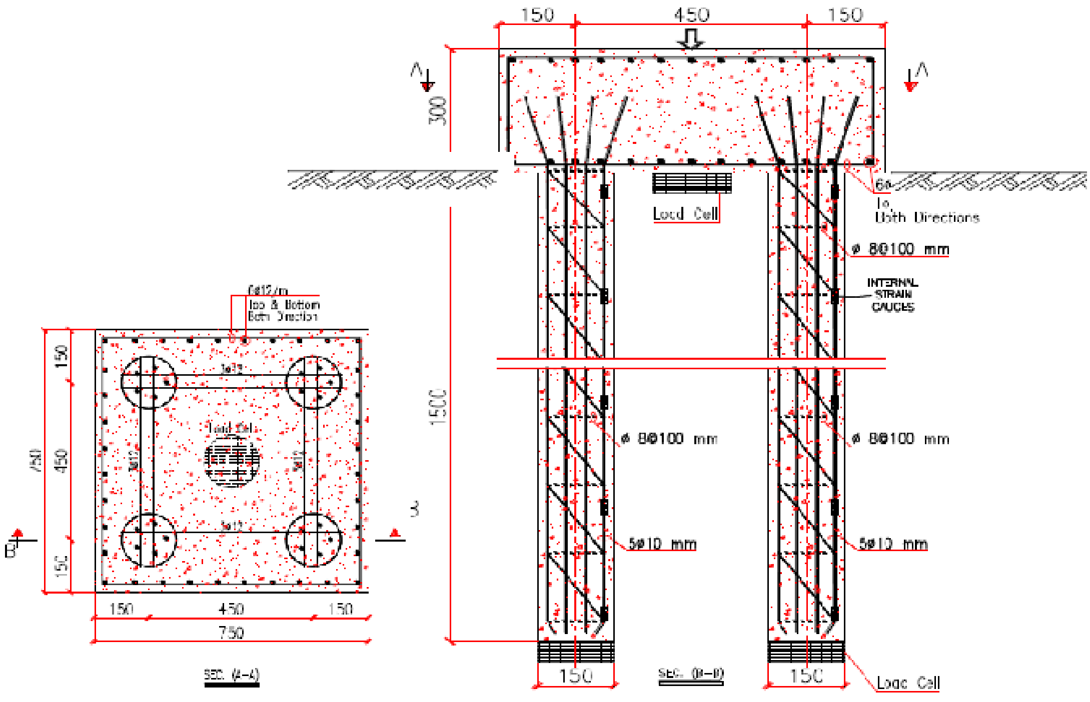


Figure-2. Reinforcement concrete dimension of group (2) – four piles cap rested on soil.

ARPN Journal of Engineering and Applied Sciences

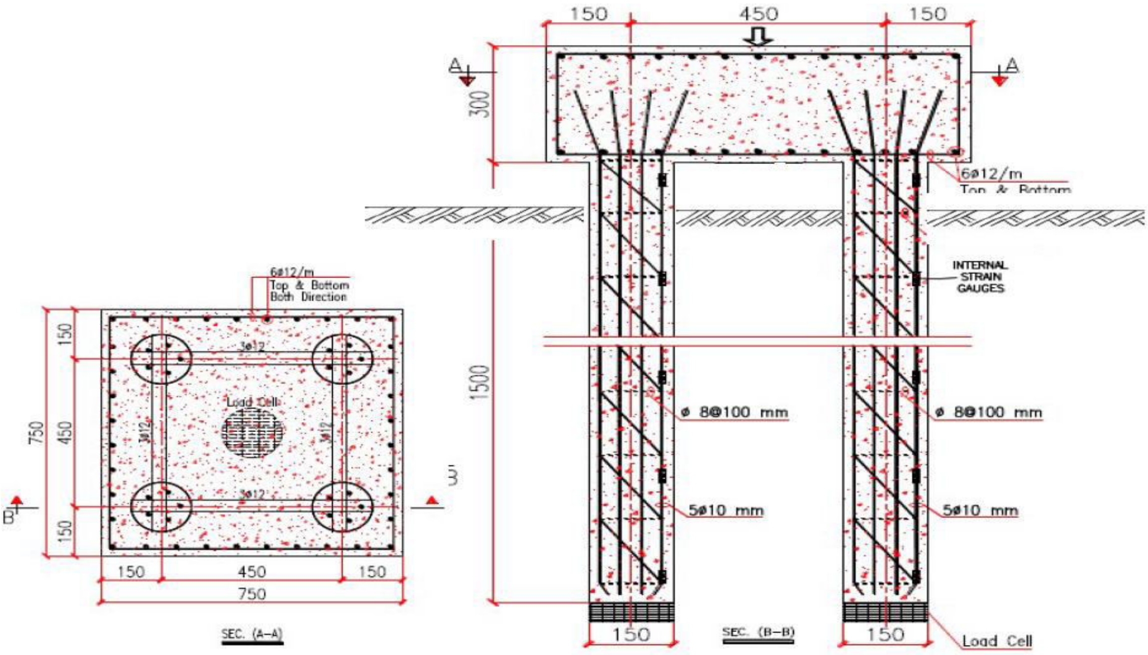


Figure-3. Reinforcement concrete dimension of group (3) – four piles cap non-rested on soil.

Strain gauges

The strain gauges were used on the longitudinal steel reinforcement for internal measurements as shown in Figure-4. The strain gauges used were manufactured by TOKYO SOKKI KENKYUJO CO. LYD. The type used was PFL-30-11-3L, which has a resistance of 120.4 ± 0.5nd % Ohms at 11 ºC, and a gauge factor of 2.13 ± 1.0%. The strain gauges' wires, extending to ground level, were connected to a strain indicator. The instrumentation was carried out to determine the axial load transfer along the piles during the testes.

Figure-4. Strain gauges mounted on the longitudinal steel reinforcement of pile.

ARPN Journal of Engineering and Applied Sciences

Piles casting

All cylindrical piles were casted in tubes (forms) are shown in Figures (5) and (6). A mechanical vibrator was used, and all cylindrical piles were cured.

Figure-5. Tubes (forms) cylindrical piles.

Figure-6. Piles casting.

Ultimate capacity of pile

Before execution of piles, estimation of pile load capacity is done by theoretical formula. The theoretical pile capacities have been calculated by using Egyptian code (2001) for single pile. The calculated theoretical ultimate capacity of single pile Q_u=30 KN .and the calculated theoretical ultimate capacity of four pile rested on soil, non-rested on soil Q_u=120KN.

Testing of pile

Three pile load tests were performed according to Egyptian code. Pile groups were tested as shown in Table-1.

Table-1. Tested piles groups.

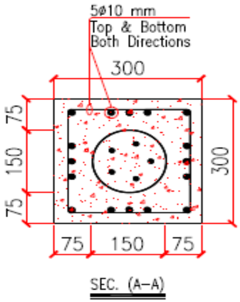
Test No.	**Theoretical ultimate load** (kN)	**Test load** (kN)	**Pile diameter** (m)	**Pile length** (m)	**No. of pile**
Group (1) Single pile	30	1.50*30=45	0.150	1.50	1
Group (2)Four piles cap rested on soil	120	1.75*120=210	0.150	1.50	4
Group (3)Four piles cap non-rested on soil	120	1.75*120=210	0.150	1.50	4

In this present study three pile load tests were performed. The reaction load was performed by a system of jacking bearing against dead load of a loading frame. Loading frame was manufactured to resist the expected maximum loads that might occur during the test as shown in Figure-7. A hydraulic jack system comprising a 100 kN jack, was used in the test as shown in Figure-8. The load was measured at underneath the pile caps and the tip of pile by an 800 kN load cells connected to the data acquisition system as shown in Figures (9) and (10). In the present study all of three groups were loaded in twelve increments according to Egyptian code (2001). Settlement of the piles was measured by dial gauges. Each load increment was maintained till settlement rate was observed less than 0.25 mm per hour. However, load cells were placed at the tip of piles and underneath the pile caps to measure the transferred load to soil. In addition, strains readings along pile shaft were recorded. Tables (2) and (3) show the load increments in the test.

ARPN Journal of Engineering and Applied Sciences

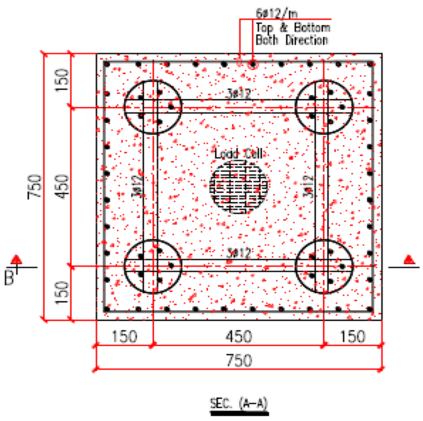
www.arpnjournals.com

Table-2. Increment of load and interval time for group (1) according to Egyptian code.



	Load %	Time	Load (kN)
Loading	25	1.00 hr	7.50
	50	1.00 hr	15.00
	75	1.00 hr	22.50
	100	3.00 hrs	30.00
	125	3.00 hrs	37.50
	150	12.00 hrs	45.00
Unloading	Load %	Time	Load (kN)
	125	15 min.	37.50
	100	15 min.	30.00
	75	15 min.	22.50
	50	15 min.	15.00
	25	15 min.	7.50
	0	4.00 hrs	0.00

Table-3. Increment of load and interval time for groups (2) and (3) according to Egyptian code.



	Load %	Time	Load (kN)
Loading	25	1.00 hr	30.00
	50	1.00 hr	60.00
	75	1.00 hr	90.00
	100	3.00 hrs	120.00
	125	3.00 hrs	150.00
	150	12.00 hrs	180.00
Unloading	Load %	Time	Load (kN)
	125	15 min.	150.00
	100	15 min.	120.00
	75	15 min.	90.00
	50	15 min.	60.00
	25	15 min.	30.00
	0	4.00 hrs	0.00

Figure-7. Loading frame.

Figure-8. Loading jack.

ARPN Journal of Engineering and Applied Sciences

Figure-9. The load cell.

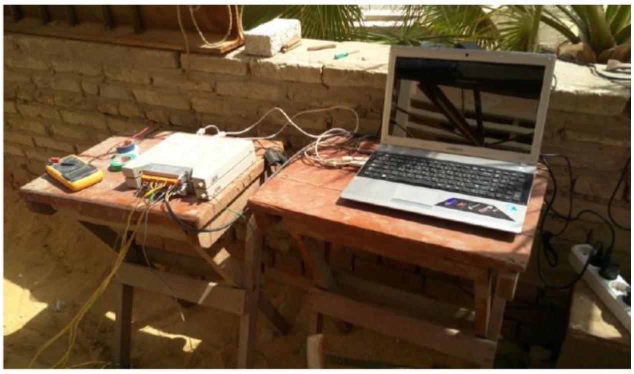


Figure-10. Data acquisition system.

Pile load test of group (1) - Single pile

The total embedment depth of the pile was 1.50 m after filling compacted layers with 15cm of sand in soil chamber using mechanical compactor as shown in Figure-11. However, the vertical displacements of the pile cap were measured by four dial gauges with accuracy of 0.001 cm as shown in Figure-12.

Figure-11. Tested pile for group (1) - single pile after placing compacted sand soil around pile.

Figure-12. Dial gauges' setup for group (1) - (single pile).

Pile load test of group (2) - Four piles group rested on soil

The piles were embedded in the compacted layers of sand such that the total embedment depth of the pile was 1.50 m after filling the soil chamber with 15cm of sand using mechanical compactor as shown in Figure-13. However, the vertical displacements of the pile cap were measured by six dial gauges with accuracy of 0.001 cm as shown in Figure-14.

Figure-13. Tested pile for group (2) - four piles cap rested on soil after placing compacted sand soil around piles.

Figure-14. Dial gauges' setup for group (2) - group of four piles cap rested on soil and Loading jack.

Pile load test of group (3) - Four piles group non-rested on soil

The piles were embedded in the compacted layers of sand such that the total embedment depth of the pile was 1.50 m after filling the soil chamber with 15cm using mechanical compactor as shown in Figure-15. Moreover, the vertical displacements of the pile cap were measured by dial six gauges with accuracy of 0.001 cm as shown in Figure-16.

Figure-15. Tested pile for group (3) - four piles cap non-rested on soil after placing compacted soil around piles.

Figure-16. Dial gauges' setup for group (3) - four piles cap non-rested on soil and loading jack.

Determination of ultimate capacity of piled-raft

Determination the ultimate pile load capacity

Determination the ultimate pile load capacity has been done by using Modified Chin Method (1970) and Tangent (Egyptian Code, 2001) - tangent Method (U.S. Army Corps Engineers, 1991) as follow:

Excremental results for group (1) - single pile

The ultimate load capacity for single pile was determined by the slope modified chin method and the tangent-tangent method from load settlement readings at the point of intersection of the initial and final tangents of the load settlement curve. This point is marked in Figure-17 for single pile by a vertical arrow at a load of 28.0 KN. However, the ultimate capacity was determined for single pile group (1) by using Modified Chin Method (1970) as shown in Figure-18.

ARPN Journal of Engineering and Applied Sciences

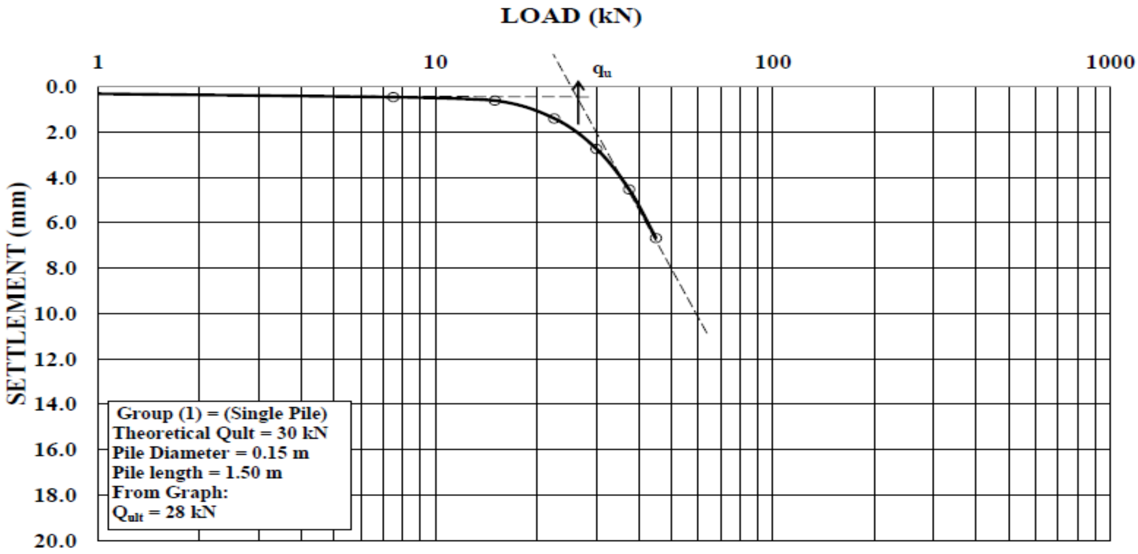


Figure-17. Determination the ultimate load by tangent method, (U.S. Army Corps Engineers, 1991) for (group (1) - single pile).

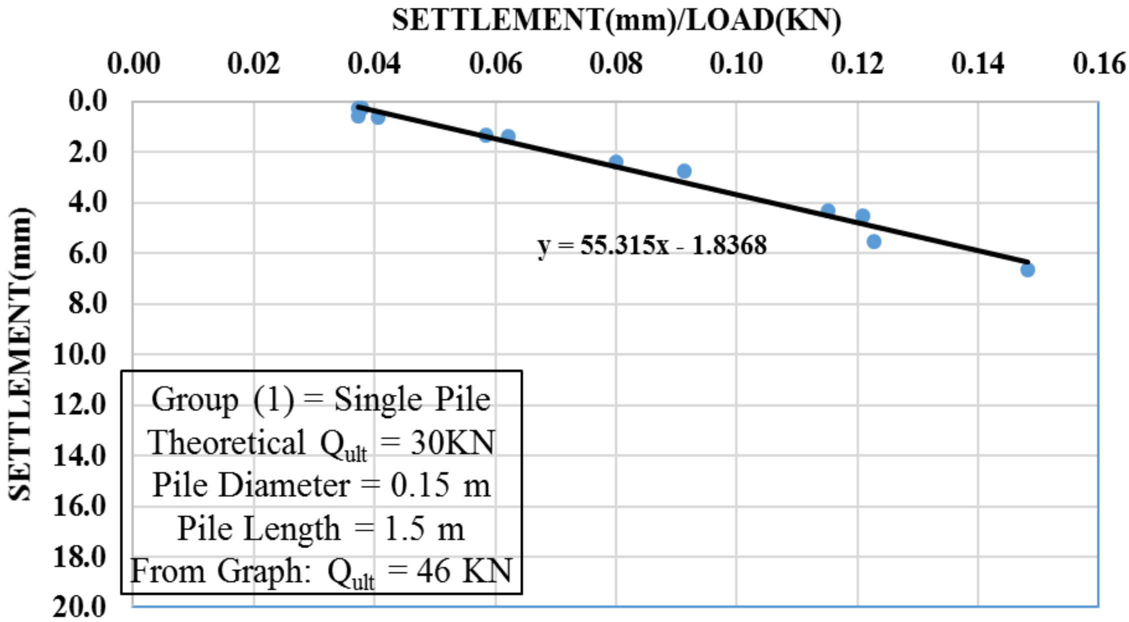


Figure-18. Determining the ultimate capacity by modified chin for group (1) - single pile.

Experimental results for group (2) - four piles group rested on soil

The ultimate load capacity for group (2) - four piles group cap rested on soil was determined by the slope modified chin method and the tangent-tangent as shown in Figure-19. However, the ultimate capacity was determined for group (2) - four piles group cap rested on soil by using Modified Chin Method (1970) by using Modified Chin Method (1970) as shown in Figure-20.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

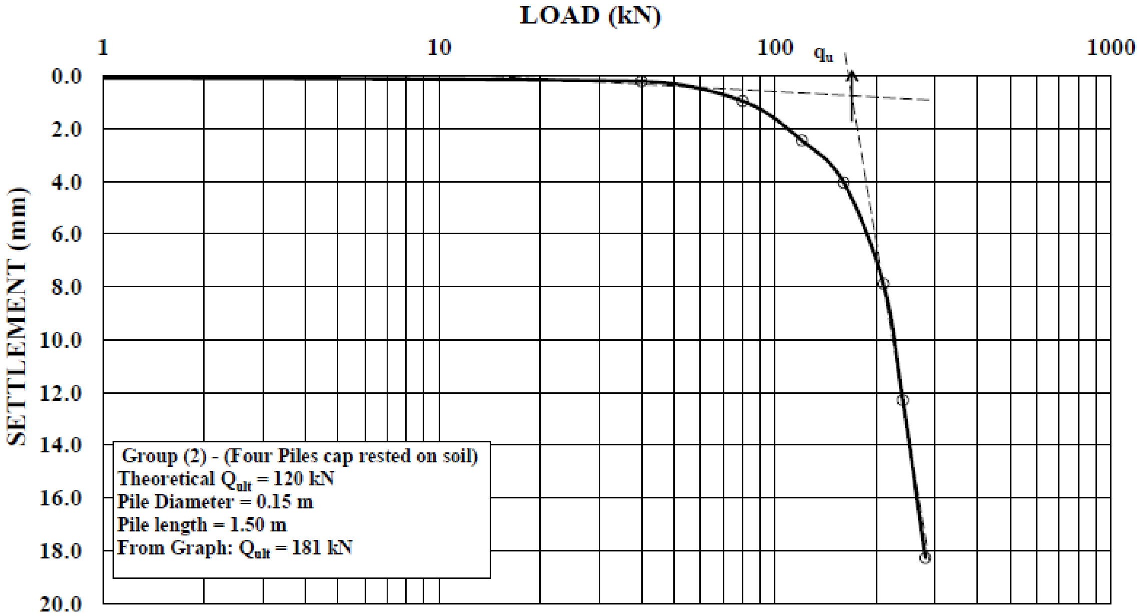


Figure-19. Determination the ultimate load by tangent method, (U.S. Army Corps Engineers, 1991) for (group (2)) - four piles cap rested on soil).

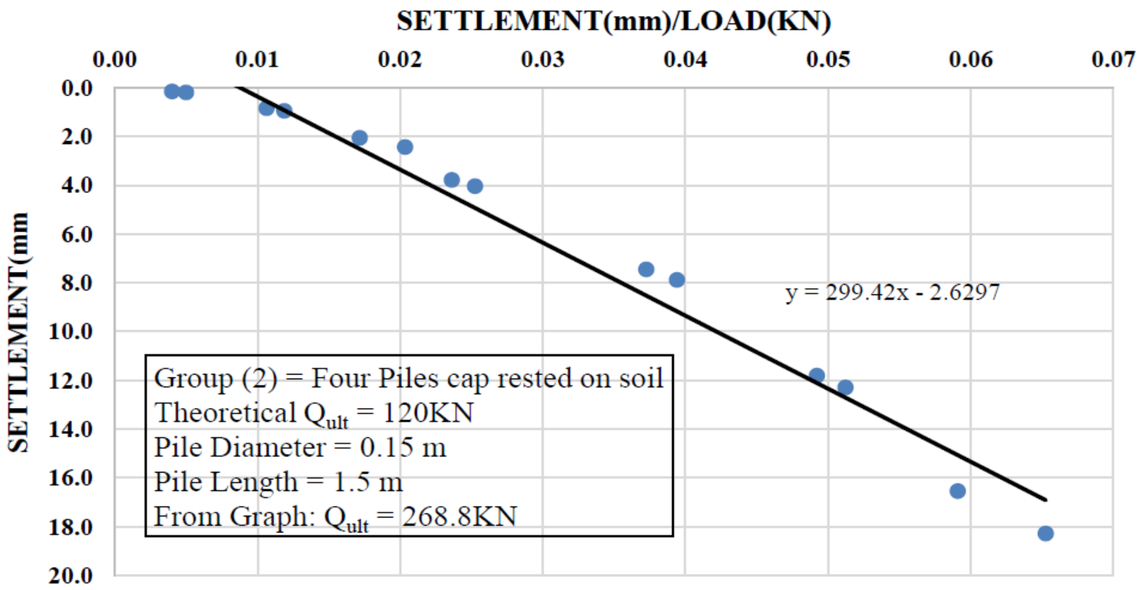


Figure-20. Determining the ultimate capacity by modified chin for (group (2)) - four piles cap rested on soil).

Experimental results for group (3) - four piles group non-rested on soil

The ultimate load capacity for group (3) - four piles group cap non-rested on soil was determined by the slope modified chin method and the tangent-tangent as shown in Figure-21. However, the ultimate capacity was determined for group (2) -four piles group cap non-rested on soil by using Modified Chin Method (1970) by using Modified Chin Method (1970) as shown in Figure-22. The ultimate load for single pile calculated in this study was determined by different theoretical approaches. The values of ultimate capacities and ultimate capacities of single pile and single pile inside groups from different methods are listed in Table-4.

VOL. 13, NO. 6, MARCH 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-4. Ultimate capacities and ultimate capacities of single pile and single pile inside groups by theoretical methods and experimental methods.

Group	Ultimate load (Q_{ult}) from theoretical Methods (kN)	Ultimate load (Q_{ult}) from pile load test (kN)		Ultimate capacities of single pile and single pile inside groups (Q_{ult}) from pile load test (kN)	
	Egyptian code (2001)	Tangent method (1991)	Modified chin method (1970)	Tangent-tangent method (1991)	Modified chin method (1970)
Single pile	30.00	28.00	46.00	28.00	46.00
Four piles cap rested	120.00	181.00	268.80	45.25	67.20
Four piles cap non-rested	120.00	142.00	211.65	35.50	52.75

A comparison between ultimate capacities of piles for single pile group (1) and single pile inside groups (2) and (3) from tangent - tangent Method is shown in Figures (23) and (24). A comparison between ultimate capacities of piles for single pile group (1) and single pile inside groups (2) and (3) from Modified Chin method as shown in Figures (25) and (26).

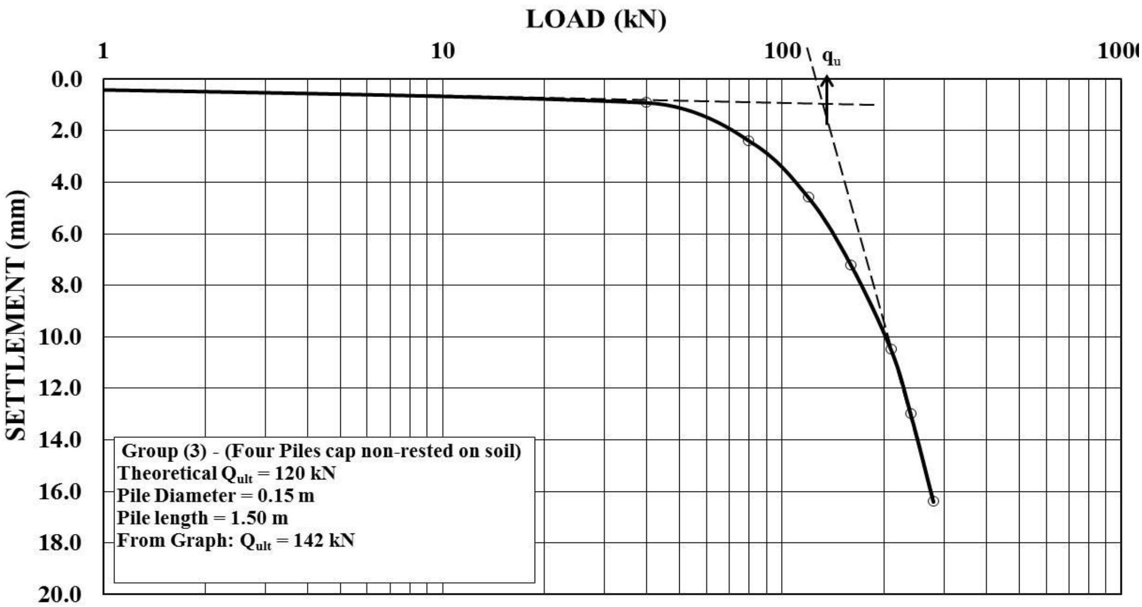


Figure-21. Determination the ultimate load by tangent method, (U.S. Army Corps Engineers, 1991) for (group (3)) - four piles cap non-rested on soil).

ARPN Journal of Engineering and Applied Sciences

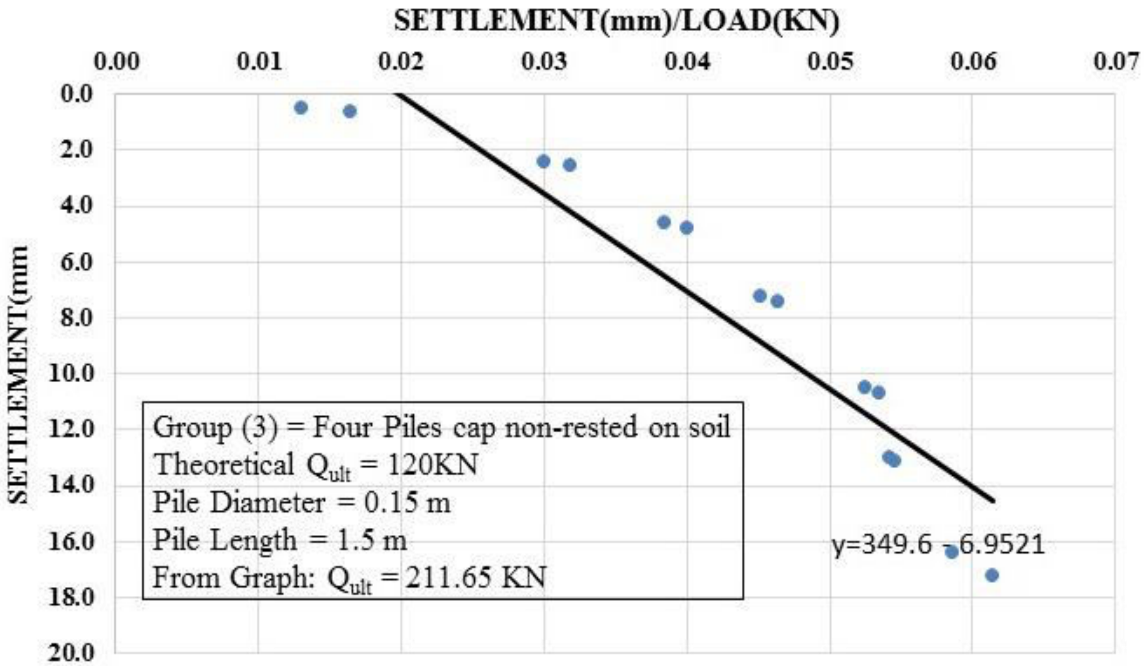


Figure-22. Determining the ultimate capacity by modified chin for (group (3)) - four piles cap non-rested on soil).

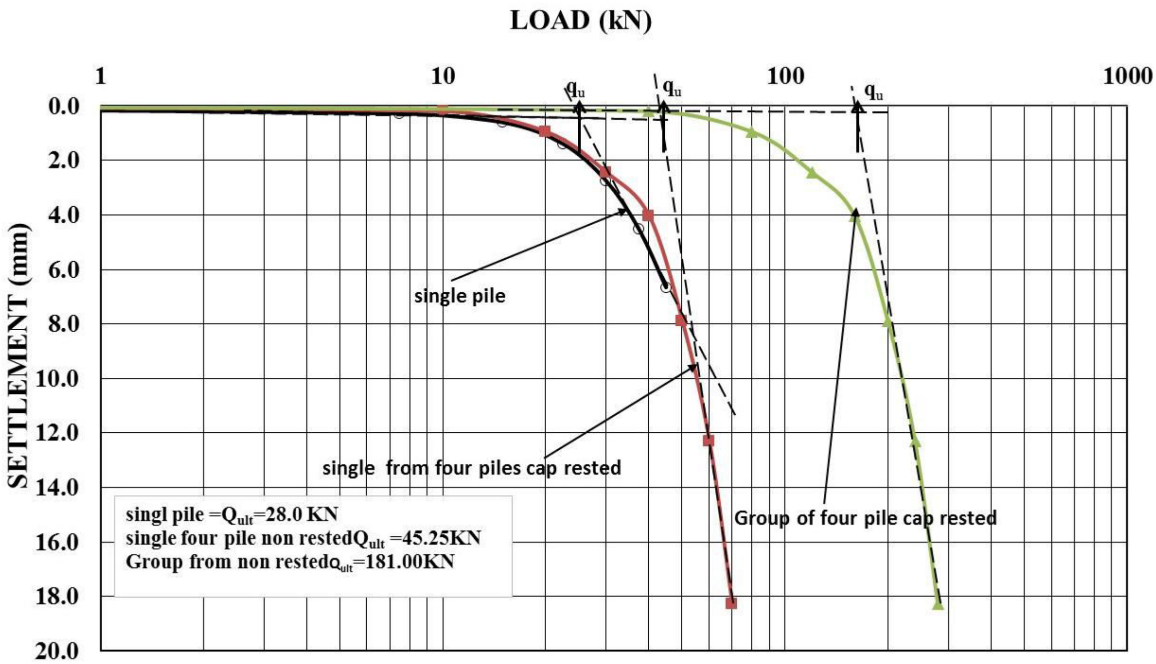


Figure-23. Comparison between ultimate capacities of piles for single pile group (1) and single pile inside groups group (2) - four piles cap rested on soil from tangent - tangent Method.

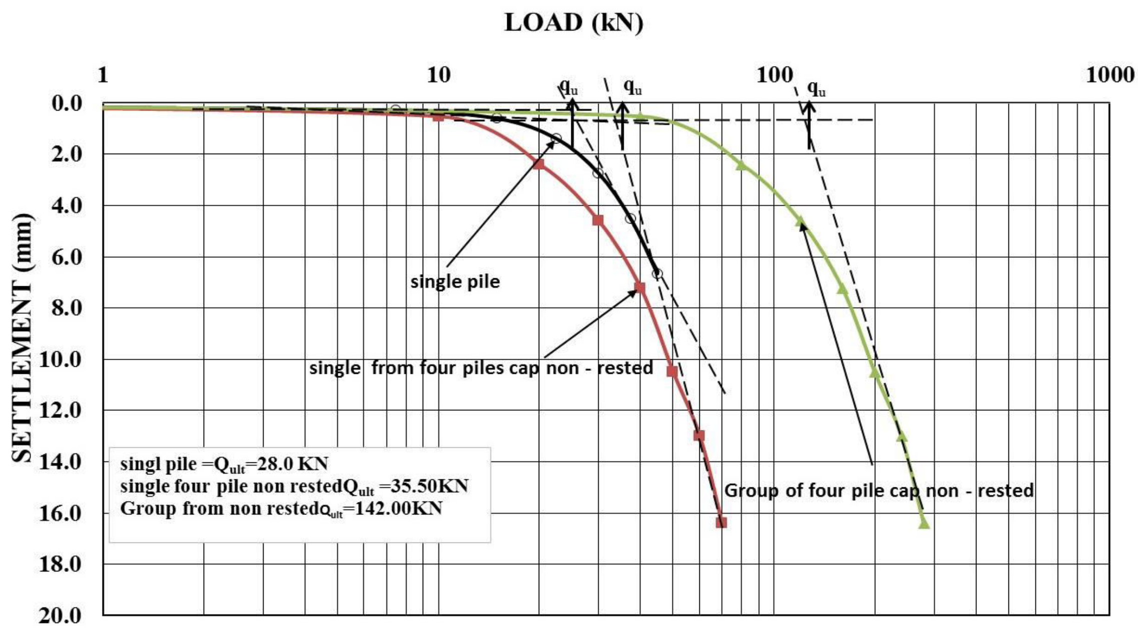


Figure-24. Comparison between ultimate capacities of piles for single pile group (1) and single pile inside groups group (2) - four piles cap non-rested on soil from tangent - tangent Method.

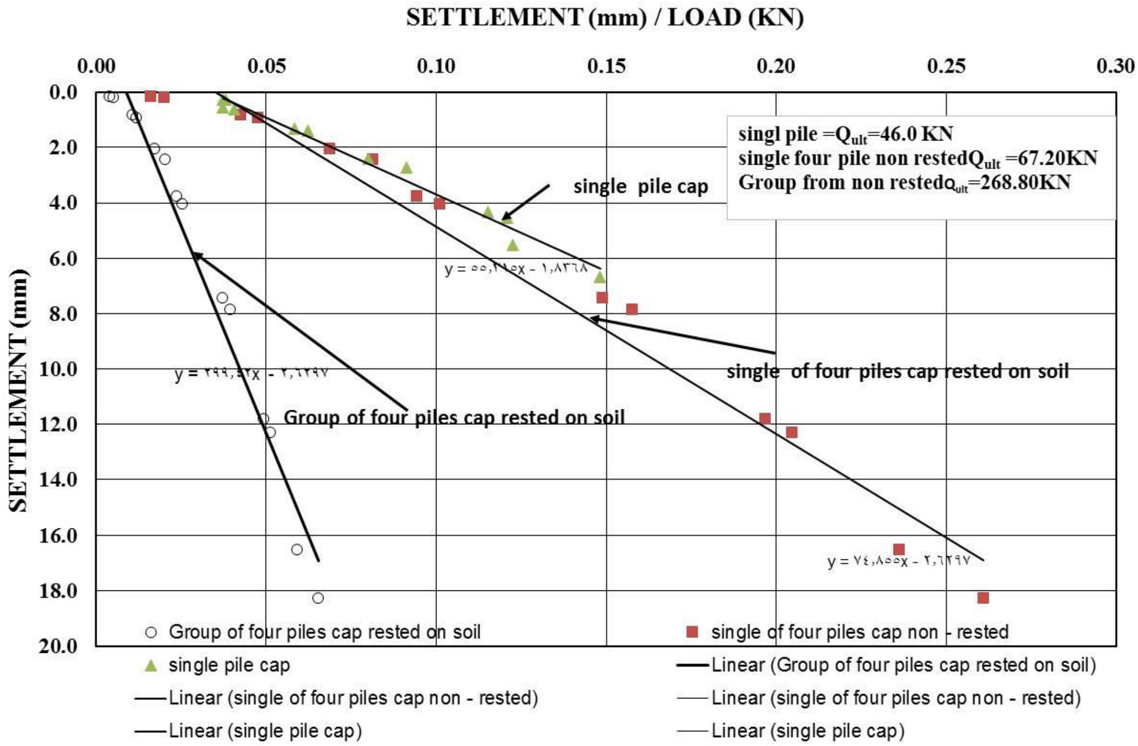


Figure-25. Comparison between ultimate capacities of piles for single pile group (1) and single pile inside groups group (2) - four piles cap rested on soil from Modified chin method.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

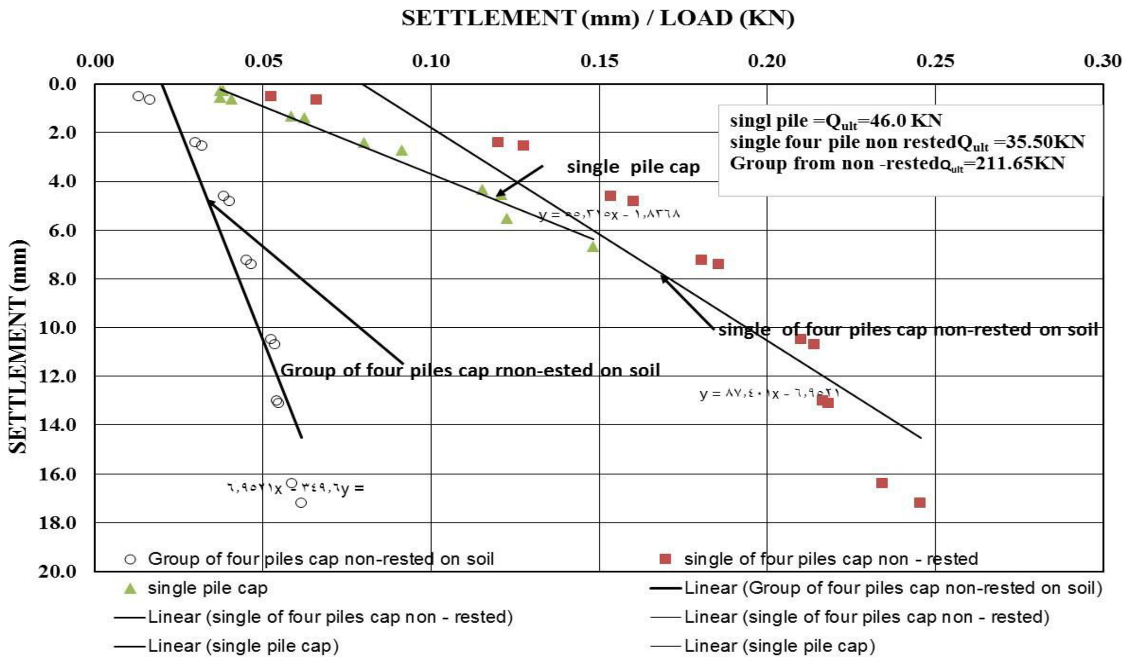


Figure-26. Comparison between ultimate capacities of piles for single pile group (1) and single pile inside groups group (2) - four piles group cap non-rested on soil from Modified chin method.

Distributions of load at pile tip

The pile axial load from strain gauges reading at various depths for group (1) - single pile and group (2) - group of four piles cap rested on soil as wellasgroup (3) - group of four piles cap non-rested on soilare listed in Table-6.

Table-5. Distribution of load (friction) along the pile shaft at ultimate capacities obtained from tangent-tangent Method and Modified chin method (1970).

Depth (%)	Load (KN)					
	Group (1) - single pile		Group(2) - four piles cap rested		Group(3) - four piles cap non-rested	
	Tangent method	Modified Chin method	Tangent method	Modified Chin method	Tangent method	Modified Chin method
0	28.00	45.00	45.50	67.20	35.50	52.75
25	23.40	39.00	34.28	50.40	25.32	42.13
50	16.59	26.00	21.42	31.49	16.83	28.35
75	9.31	14.90	13.03	18.70	9.13	16.9
100	3.77	1.75	1.90	1.37	2.62	7.10

Figures (27) to (29) illustrate the relationship between test load at pile tip and along pile shaft measured by load cell as percentage of pile head load for group (1) - single pile, group (2) - four pilescap rested and group (3) - four pilescap non- rested. The distribution of loads around piles shaft (friction) at ultimate capacities obtained from tangent-tangent method and Modified chin method (1970) are shown in Figures (30) and (31). The values of transferred load to soil underneath pile caps and at tip of pile as percentage of ultimate load measured from load cell are listed in Table-7.

VOL. 13, NO. 6, MARCH 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table-6. The percentage of load transferred to soil underneath pile cap, at pile tip and around pile shaft (friction) as percentage of ultimate load of single pile and pile groups (2) and (3) obtained from tangent-tangent Method.

Group	Transferred loads as (%) of load at head of pile to soil at ultimate loads			Q_{ult} (KN)
	Around pile (friction) %	Underneath pile cap %	At pile Tip %	
Single pile	85.00	0.00	15.00	28.00
Four piles cap rested	88.27	7.98	3.75	181.00
Four pilescap non-rested	95.67	0.00	4.33	142.50

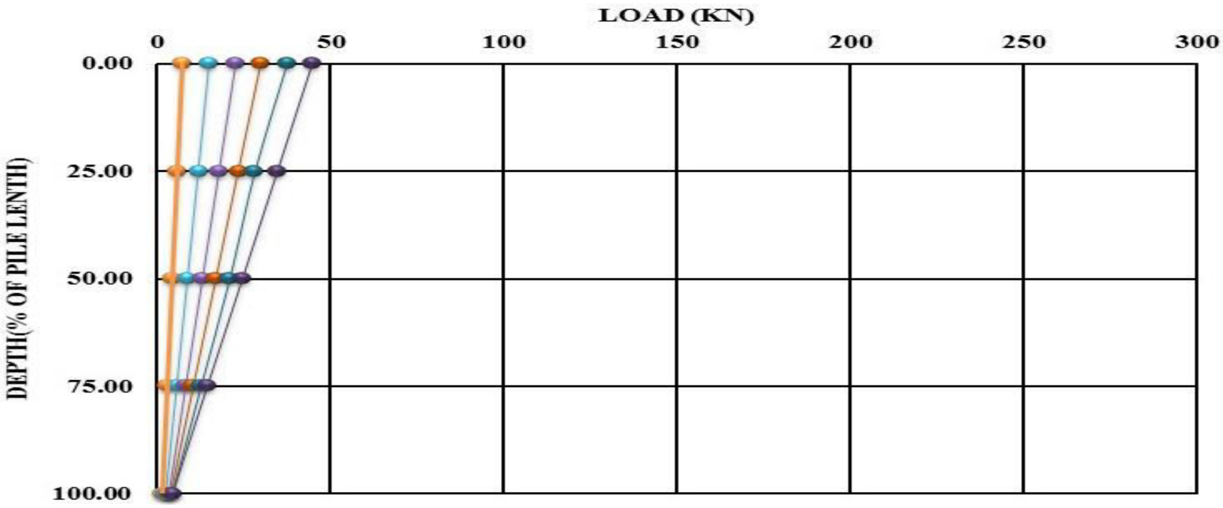


Figure-27. Distribution of load at pile tip from load cell and along pile shaft measured from strain gauges (group (1) - single pile).

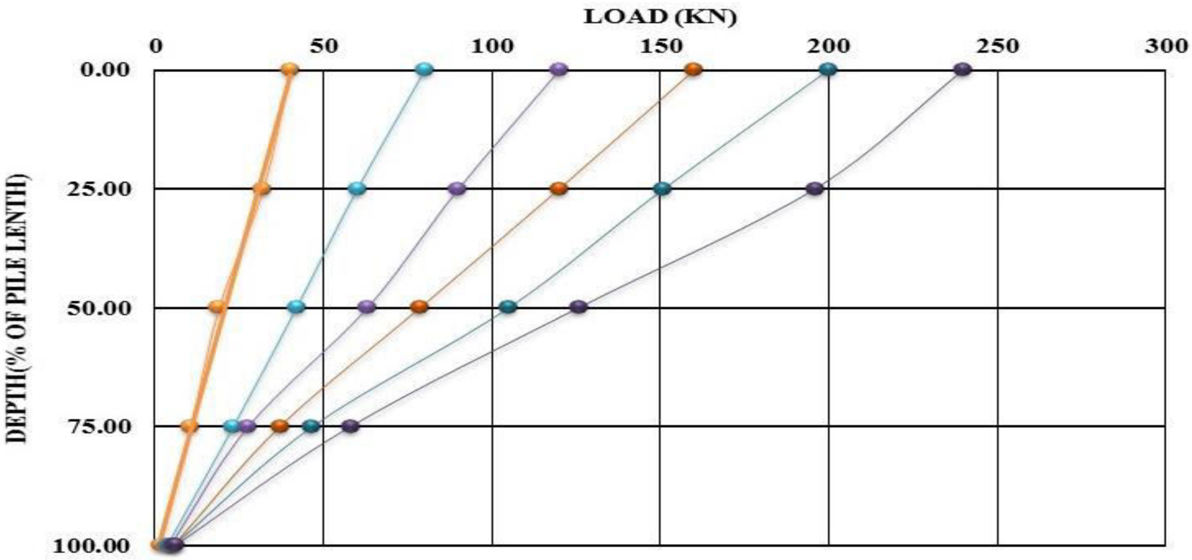


Figure-28. Distribution of load at pile tip from load cell and along pile shaft measured from strain gauges (group (2) - four pilescap rested on soil).

VOL. 13, NO. 6, MARCH 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

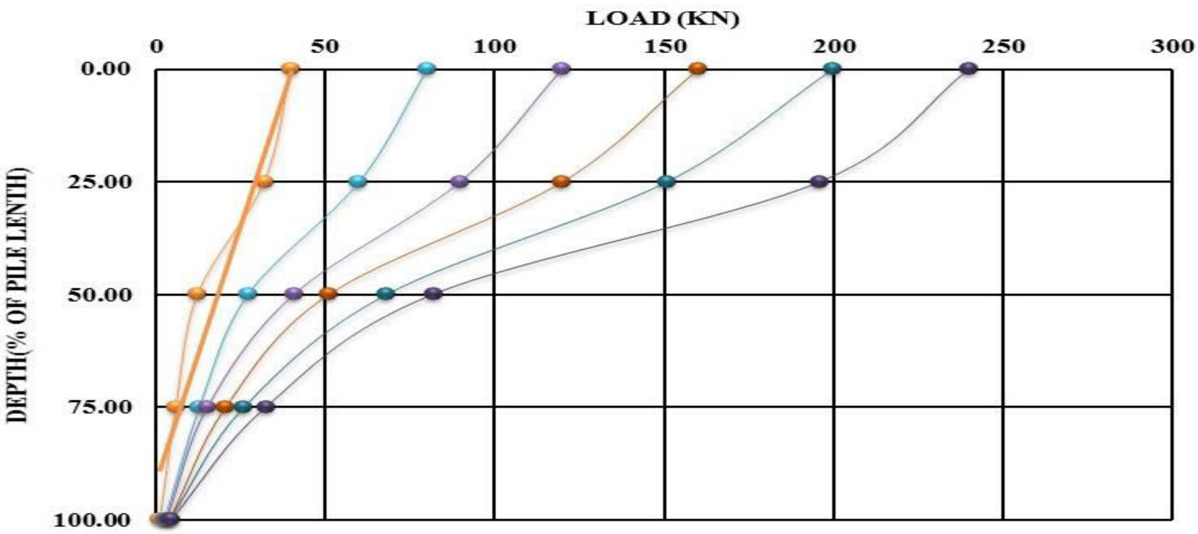


Figure-29. Distribution of load at pile tip from load cell and along pile shaft measured from strain gauges (group (3) - four pilescap non - rested on soil).

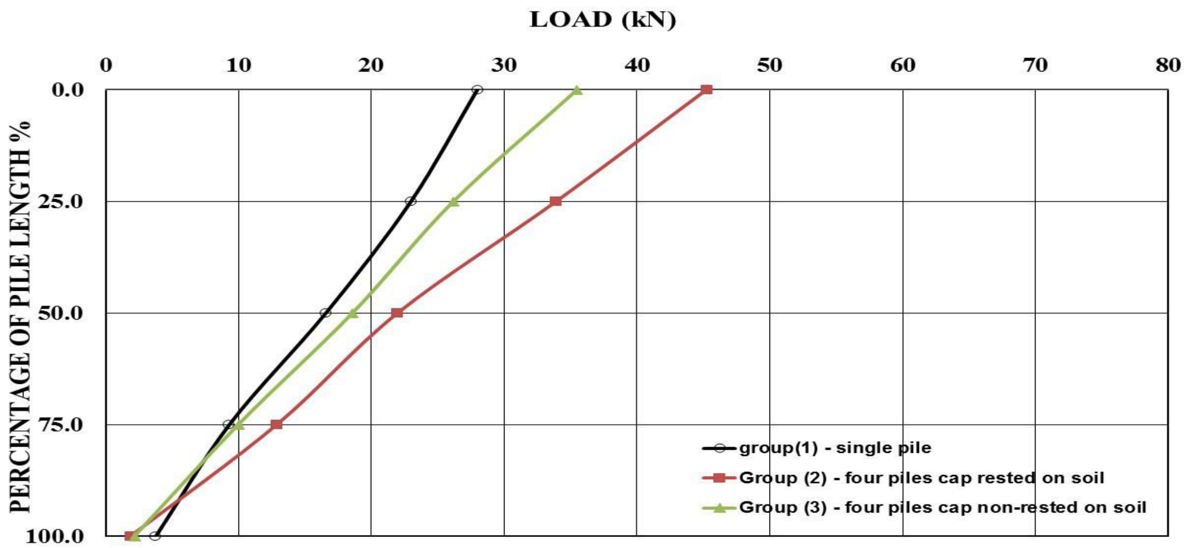


Figure-30. Distribution of loads around pile shaft (friction) at ultimate capacity obtained from tangent-tangent method.

VOL. 13, NO. 6, MARCH 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

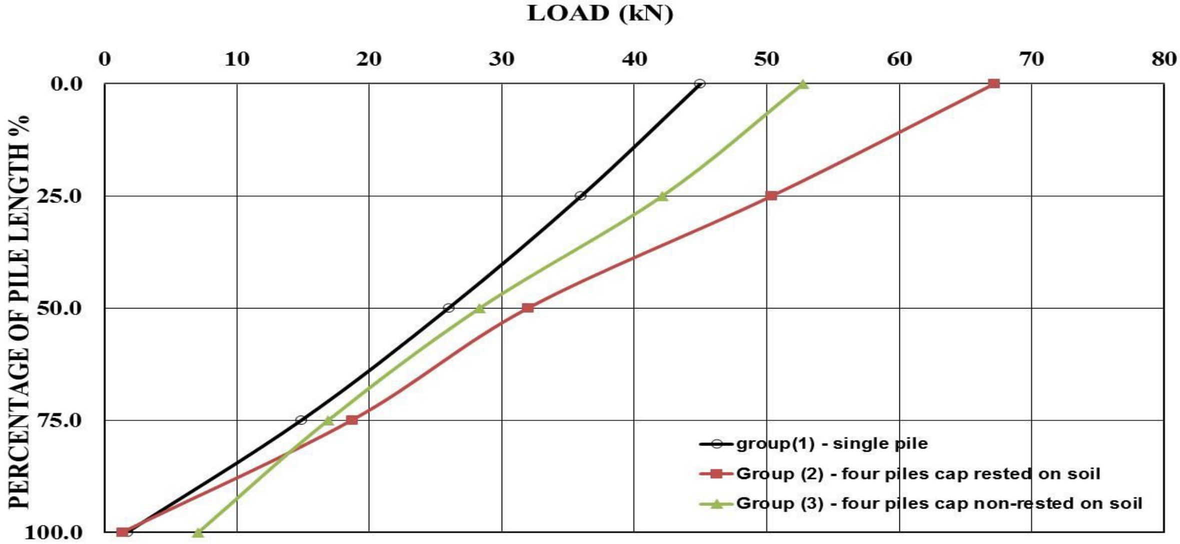


Figure-31. Distribution of loads around piles shaft (friction) at ultimate capacities obtained from Modified chin method (1970).

RESULTS AND DISCUSSIONS

Theoretical group efficiency

Murthy (2008) presented the spacing of pile is usually predetermined by practical and economical condition. The factor η_g is called group efficiency which depends on parameters such as type of soil in which the piles are embedded; method of installation of piles i.e. either driven or cast- in - situ piles, and spacing of piles. The Converse- Labarre formula is one of the most widely group efficiency equations which is expressed as:

$$\eta_g = 1 - \theta \frac{(n-1)\,m + (m-1)\,n}{90\,m\,n}$$

Where:

η_g = Group efficiency;
θ = $\tan^{-1}$ (D/S) in degrees;
D = Pile diameter (m).
S = Pile spacing (m).
n = Number of piles in a row.
m = Number of pile rows.

In the present study the theoretical group efficiency has been calculated ηg = 0.80.

Experimental group efficiency

The pile group efficiencies at ultimate capacities were determined as shown in Table (8). The relationship between pile group efficiency and number of piles is shown in Figure-32.

Table-7. Groups efficiency from values of Ultimate capacities based on result of tangent-tangent Method and Modified chin method (1970).

Group	Groups efficiency from values of ultimate capacities of single pile and single pile inside groups (kN)				
	Theoretical group efficiency (Murthy, 2008)	tangent-tangent Method		Modified chin method (1970)	
	η_g	Q_{ult}	Efficiency	Q_{ult}	Efficiency
Group (1) - single pile	---	28.00	---	46.00	---
Group (2) - four pile cap rested	0.80	45.25	1.60	67.20	1.43
Group (3) - four pile cap non -rested	0.80	35.50	1.25	52.75	1.13

ARPN Journal of Engineering and Applied Sciences

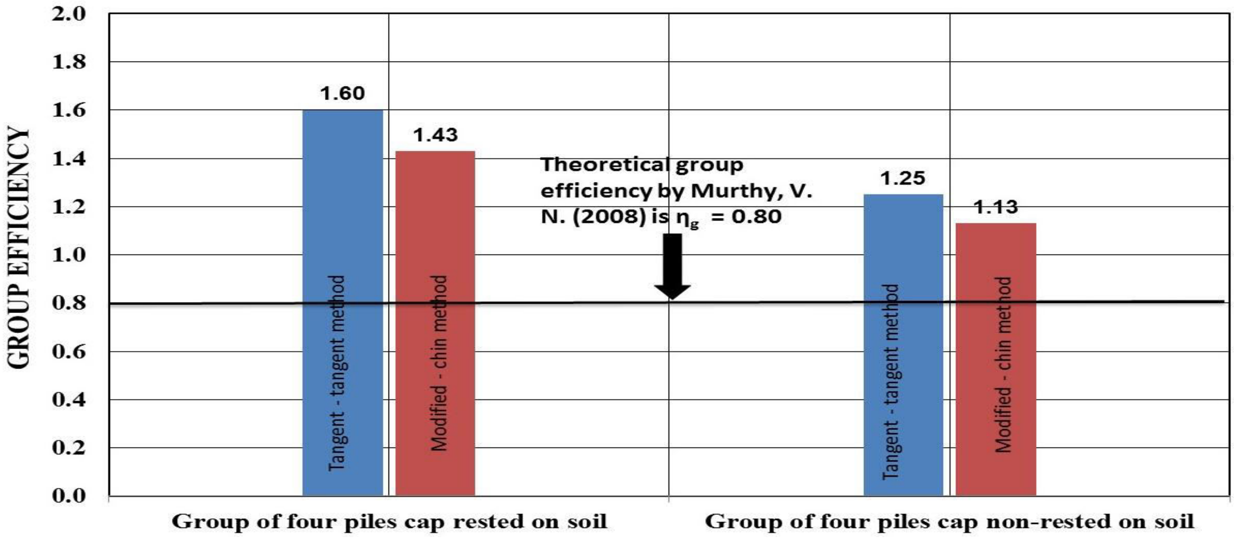


Figure-32. The relationship between pile group efficiency and number of piles based on results of tangent-tangent Method and Modified chin method (1970).

The group efficiency was found to be ranging from 1.43 to 1.60 for group (2) - four piles cap rested on soil by using tangent - tangent Method (1991) and Modified chin method (1970). However, the group efficiency was found to be ranging from 1.13 to 1.25 for group (3) - four piles cap non-rested on soil by using tangent - tangent Method (1991) and Modified chin method (1970). Thus, I tis concluded that the group efficiency of piles groups for piles cap rested on soil is more than that for piles cap non-rested on soil.

Settlement of the pile groups

The Egyptian Code of Practice (ECOP) introduce the elastic equations for calculating the pile settlement at certain load, which was also, introduced by Braja M. Das in the book named principles of foundation engineering. In the present study a comparison and relationships between number of piles and settlement for single pile group (1) and single inside pile group (2) - four piles cap rested as well as group (3) - four piles cap non-rested obtained from loading tests from tangent - tangent Method (1991) and Modified chin method (1970) are shown in Table-9 and Figure-33.

Table-8. Settlement at ultimate capacities of single pile and pile groups rested and non-rested based on the results of tangent-tangent Method and Modified chin method.

Group	**Settlement** (mm)	
	tangent-tangent Method	**Modified Chin method** (1970)
Group (1) - single pile	2.00	6.17
Group (2) - four piles cap rested	4.25	13.96
Group (3) - four piles cap non -rested	6.15	16.65

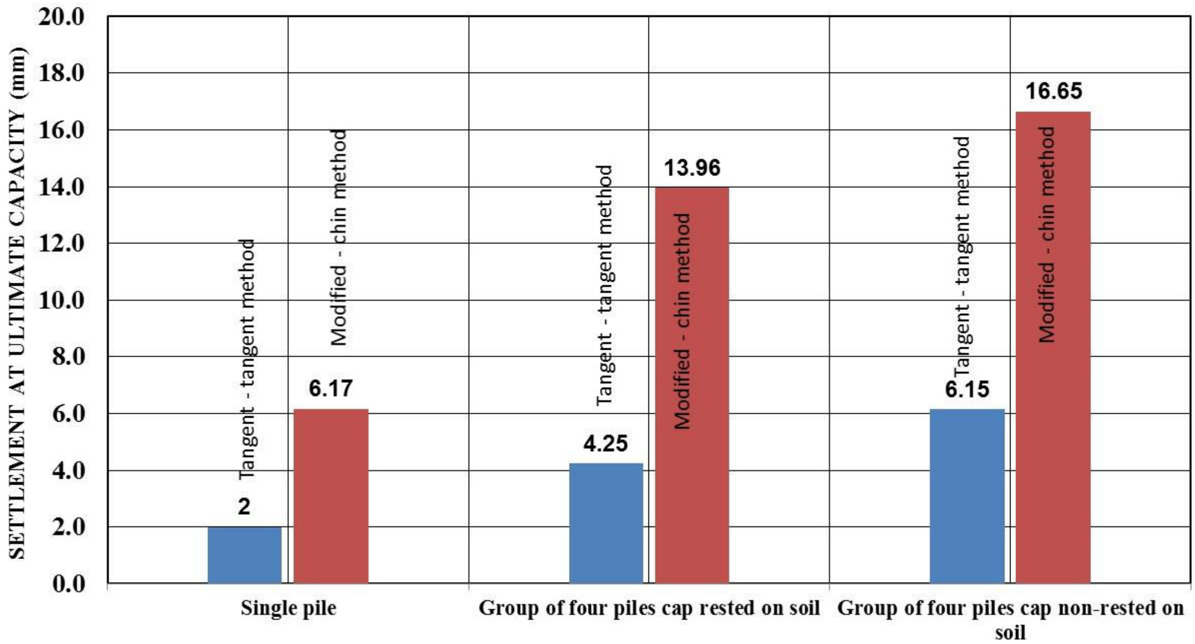


Figure-33. Comparison between settlement for single pile group (1) and single inside pile group (2) - four piles group cap rested as well as group (3) - four piles group cap non-rested obtained from loading tests by from tangent - tangent Method (1991) and Modified chin method (1970).

The settlement at the obtained ultimate capacities from tangent - tangent Method was found to be less that the obtained from Modified chin method. It was found also that the settlement of piles groups for pilescap rested on soil is more than that pilescap non-rested on soil.

Analysis of finite element

In the present study finite element analysis was used for single pile and pile groups. The analysis is done by using 3D Plaxis program in which the soil is simulated by a semi-infinite element isotropic homogeneous elastic material. A model with a fixed yield surface as perfectly-plastic is assumed. The stress states are assumed purely elastic. The Mohr-Coulomb model requires a total of five parameters, and can be obtained from basic tests on soil samples. These parameters with their standard units are listed below:

E: Young's modulus [kN/m^2] = $20x10^6 kN/m^2$- ν: Poisson's ratio [-] = 0.2-
Φ: Friction angle [°] = 36° - c: Cohesion [kN/m^2] = 0 - α: Dilatancy angle [°] =6.

Using this model of soil, the stress relationship of soil is linear and elastic.

Figure-34 shows 3D deformed mesh for group (1) - group of single pile. Figure-35 shows vertical displacement for group (1) - group of single pile. Figure-36 shows 3D deformed mesh for group (2) - group of four piles cap rested on soil. Figure-37 shows vertical displacement for group (2) - group of four piles cap rested on soil. Figure-38 Total displacement for group (2) - group of four pile cap rested on soil. Figure-39 shows 3D deformed mesh for group (3) - group of four piles cap non-rested on soil. Figure-40 shows vertical displacement for group (3) - group of four piles cap non-rested on soil. Figure-41 Total displacement for group (3) - group of four pile cap non-rested on soil.

In the present study a comparison and relationships between number of piles and settlement for single pile group (1) and single inside pile group (2) - four piles cap rested as well as group (3) - four piles cap non-rested obtained from loading tests from tangent - tangent Method (1991) and Modified chin method (1970) and finite element analysis are shown in Table-10. Fair agreement was found between the values that obtained from both experimental results and by using finite element analysis.

Table-9. Settlement at ultimate capacities of single pile and pile groups rested and non-rested based on the results of tangent-tangent Method and Modified chin method and by using finite element analysis.

Group	**Settlement** (mm)		
	Finite element analysis	**Tangent-tangent Method**	**Modified chin Method** (1970)
Group (1) - single pile	1.85	2.00	6.17
Group (2) - four piles cap rested	3.13	4.25	13.96
Group (3) - four piles cap non - rested	4.01	6.15	16.65

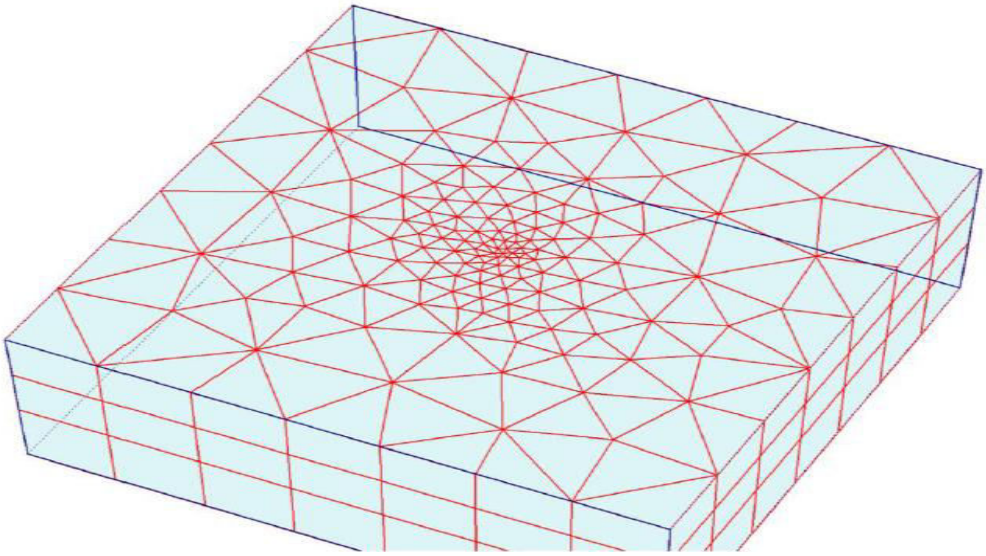


Figure-34. 3D deformed mesh for group (1) - group of single pile.

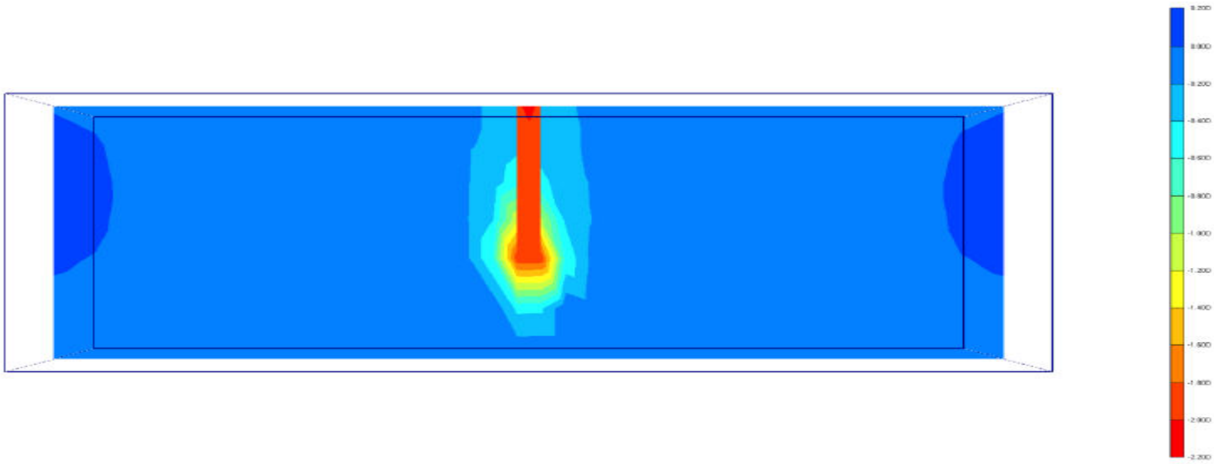


Figure-35. Vertical displacement for group (1) - group of single pile.

ARPN Journal of Engineering and Applied Sciences

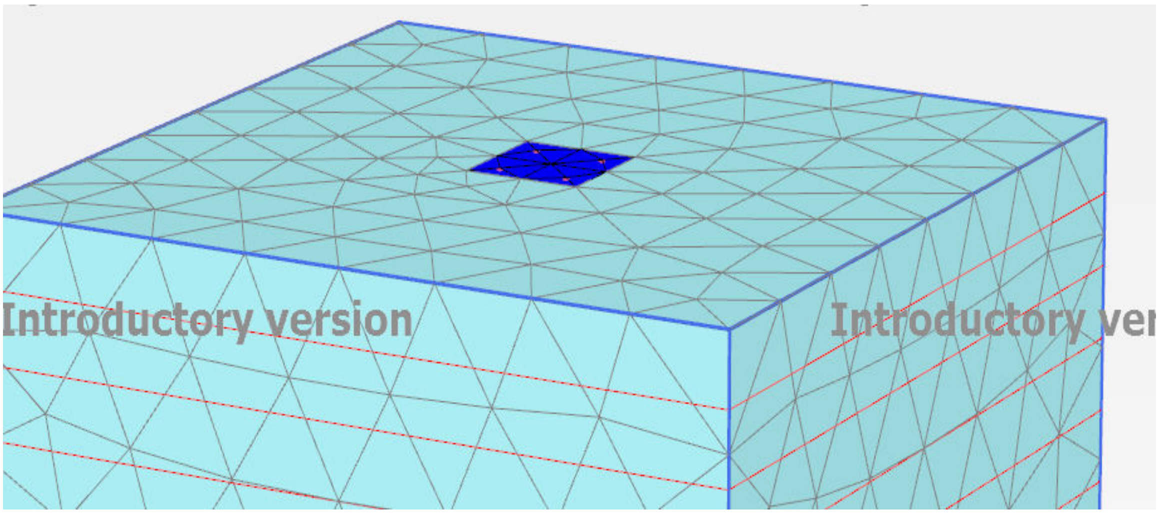


Figure-36. 3D deformed mesh for group (2) - group of four pile rested on soil.

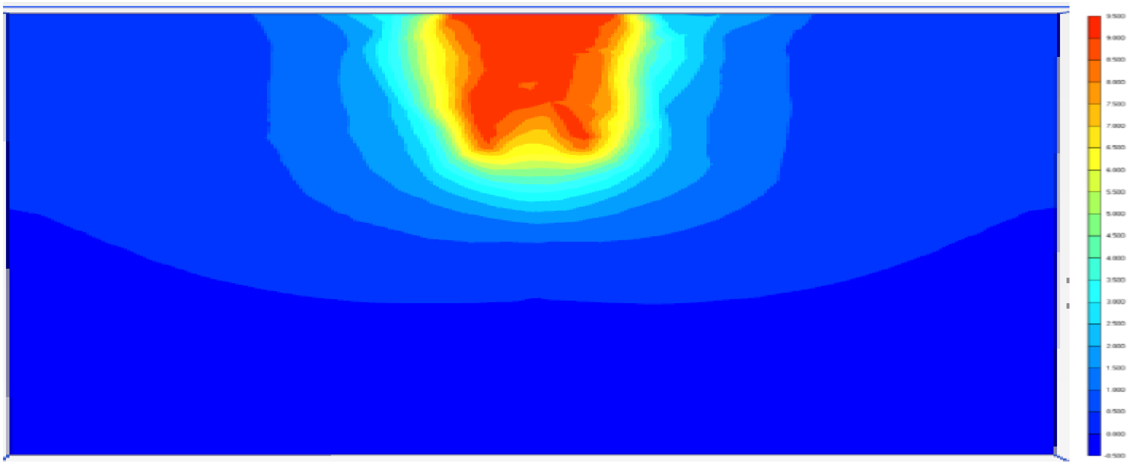


Figure-37. Vertical displacement for group (2) - group of four pile cap rested on soil.

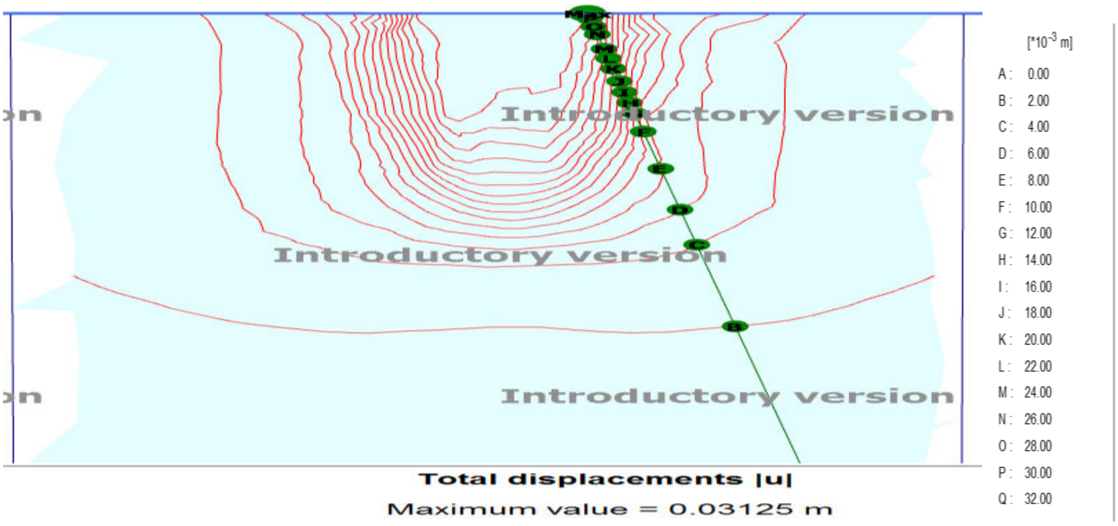


Figure-38. Total displacement for group (2) - group of four pile cap rested on soil.

VOL. 13, NO. 6, MARCH 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

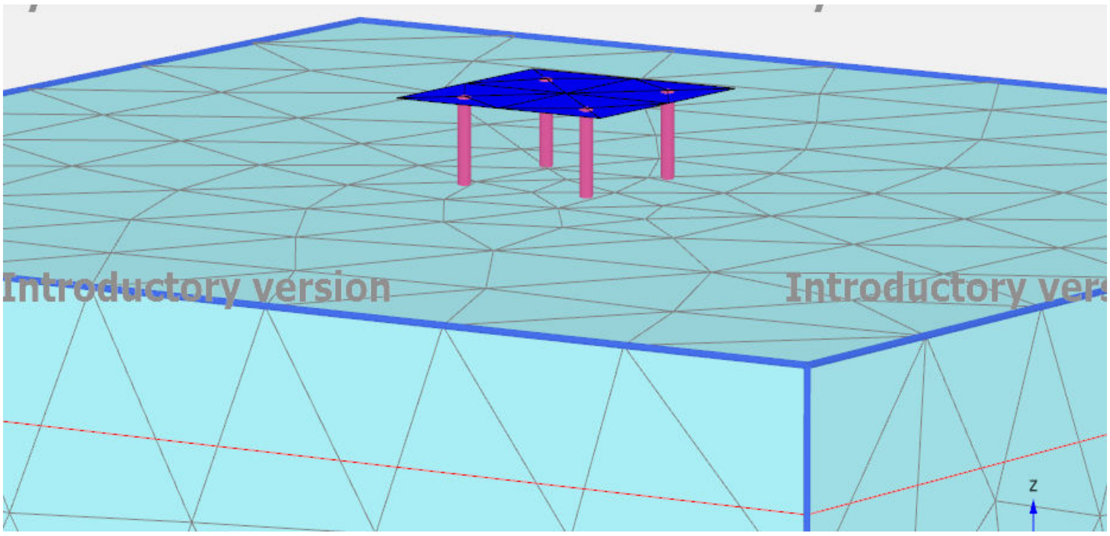


Figure-39. 3D deformed mesh for group (3) - group of four piles cap non-rested on soil.

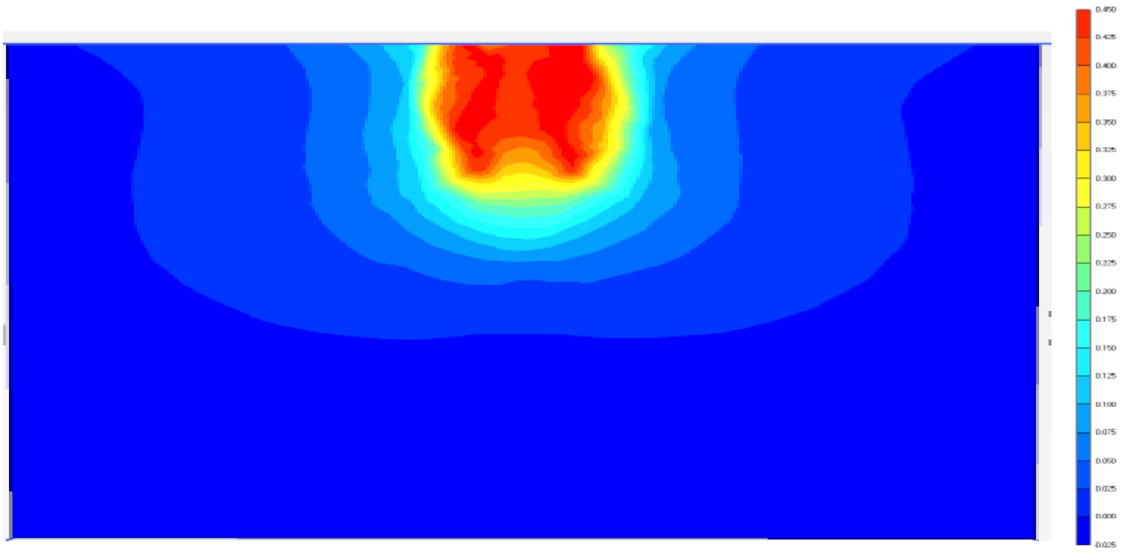


Figure-40. Vertical displacement for group (3) - group of four pile cap non-rested on soil.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

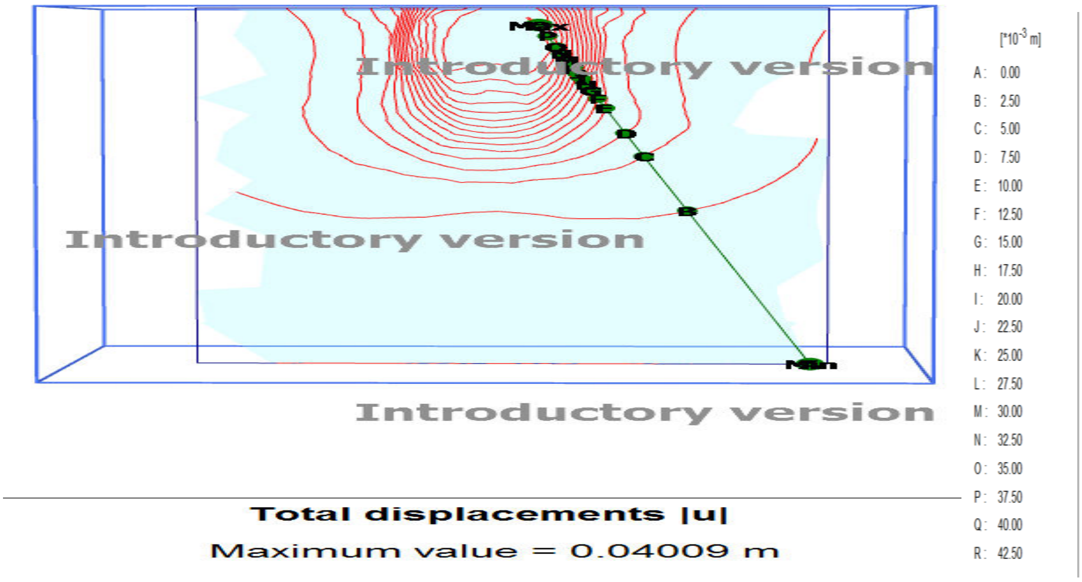


Figure-41. Total displacement for group (3) - group of four pile cap non-rested on soil.

CONCLUSIONS

From the present study, the following conclusions are obtained:

a) The group efficiency of pile groups for pilescap rested on soil is more than that for pilescap non-rested on soil.

b) The group efficiency was found to be ranging from 1.43 to 1.60 for four piles cap rested on soil and was found to be ranging from 1.13 to 1.25 for four piles cap non-rested on soil.

c) The load transferred to soil underneath pile cap rested on soil was found to be 7.98% from the ultimate load capacity. However, the load transferred to soil by friction was found to be 88.27% from the ultimate load capacity. In addition, the load transferred to soil at pile tip was found to be 3.75% from the ultimate load capacity.

d) The settlement of pile groups for pile cap rested on soil is less than that for pile cap non-rested on soil.

e) Finite element analysis gives values of settlement less than experimental test results.

f) Fair agreement has been obtained between finite element analysis and experimental test results.

REFERENCES

Abd Elsamee W. N. 2013. New Method for Prediction Pile Capacity Executed by Continuous Flight Auger (CFA). Engineering. 5(4): 344-354.

AL-Mossalmy Y. M., EL-Nahhas F.M, Essawy. A. S. 2006. Innovative Use of Piled Raft Foundation Optimize the Design of High-Rise Buildings. M.Sc. Thesis, department of structural engineering, faculty of engineering, Ain shams university, Egypt.

Mosawi M.J., Fattah M. Y., Al-zayadi A.A.O. 2011. Experimental Observation on the Behavior of aPiled Raft foundation. M.Sc. Thesis, department of structural engineering, faculty of engineering, Ain shams university, Egypt.

El-Nahhas F. M., El-Mossallamy Y. M., Arafat H. M., Al-kadi O. A. 2012. Performed of Pile Raft System. M.Sc. Thesis, department of structural engineering, faculty of engineering, Ain shams University, Egypt.

Egyptian Code. 2001. Soil Mechanics and Foundation Organization, Cairo, Egypt.

Elsamny M. K., Ibrahim M. A., Gad S. A., Abd-Mageed M. F. 2017a. Experimental Study on Pile Groups Settlement and Efficiency in Cohesionless Soil. International Journal of Engineering Research & Technology. 6(5): 967-976.

Elsamny M. K., Ibrahim M. A. Gad S. A., Abd-Mageed M. F. 2017b. Experimental Investigation on Load Shearing of Soil around Piles and Underneath Raft on Pile Groups. International Journal of Research in Engineering and Technology. 6(7): 26-40.

Elsamny M. K., Ibrahim M. A., Gad S. A., Abd-Mageed M. F. 2017c. Analysis of Pile - Raft Settlement. International Journal of Scientific& Engineering Research. 8(5): 34-43.

Meyerhof G. G. 1976. Bearing Capacity and Settlement of Pile Foundations. JGED, ASCE, Vol. 102, GT 3.

Murthy V. N. S. 2008.Principle and practices of soil mechanics and foundation engineering. Text Book, Marcel Dekker, Inc. 270 Madison Avenue. New York, 10016.