An Experimental Study on Vertically Loaded Driven and Bored Piles

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Abstract— Deep foundation is a kind of foundation used when the soil near to the top surface is incapable of resisting the super structure load. Pile foundation is one type of deep foundation, where the piles are used to transfer the load coming from the super structure to the deeper depth safely. Piles are subjected to different types of loading viz… vertical load, horizontal load etc., and the capacity of the piles to carry load also depends on various factors like diameter of pile, depth or length of pile, material of the pile used etc. Present work consists of group of piles of four numbers placed in circular, square, triangular shape. The piles used in study are of same cross sectional area, spaced at 2.5d (diameter of pile), 3d, and 3.5d centre to centre. The group of piles embedded in soil of different density (dense, loose, loose over dense and dense over loose) are tested for vertical loading.
Key words: Driven and Bored Piles

I. INTRODUCTION

Deep foundation is used in the situations where the shallow depth of the soil is incapable of transmitting the load safely, in such cases depth of the foundation has to be increased so as to reach suitable soil stratum. A pile is a relatively smaller diameter shaft, which may be installed in the ground by different methods such as jacking, drilling and grouting, driving, screwing, drilling and placing, and post-grouting. Piles are usually installed in group for the foundation of structures. Piles are mainly of concrete, steel, wooden, composite material etc.., and all these materials have their own advantages. While installing the piles in group the method of installation, shape of the piles, pile spacing and many more parameters will contribute in the load bearing capacity of the piles.

Large structures supported on vertical piles groups which are mainly subjected to vertical load. Generally, the behaviour of group of piles is different from the single individual pile due to area of contact and interaction of neighbouring pile. It is worth of increasing experimental data on the behaviour of group pile under vertical load with different shapes, spacing, density, and installation methods. It is known that as the spacing between the groups of piles increase with increase of capacity to carry load up to a certain extent but simultaneously the cost of the pile cap is also a parameter which is to be considered.

In this experimental study, a group of wooden piles four in number of circular, square and triangle in cross section with same cross section area and constant length which are spaced at c/c distance of 2.5d, 3d, and 3.5d. These individual arrangements are investigated in different layered soil density. These test results are then compared for bored and driven pile groups. This work will leads to a thorough understanding of different variable parameter of the group pile foundation.

II. OBJECTIVE

The main objective of this investigation is to determine the effect of different shape of the piles, spacing of the piles, method of installation and different layered soil density on vertical load carrying capacity of piles. The following combinations are compared to achieve the main objective.

1) Shape of the pile: - circular, square and triangular.
2) Spacing of the piles: - 2.5d, 3d and 3.5d.
3) Density of soil: - homogeneous and layered soils.
4) Method of installation: - Bored and driven.

III. MATERIALS USED & METHODOLOGY

1) The model piles made of wood are square, circular and triangular in shape with cross sectional area of 3.142cm^2 are shown in Fig.1. The length of each pile is 30cm. The circular piles of diameter 2cm and square and triangular piles are of sides of 1.8cm and 2.7cm respectively. The piles are tapered at the bottom end for easy installation in to the soil media. Experiment is conducted for group of piles four in numbers.
2) The square pile cap of 13cm×13cm of 1cm thick MS plate is used in the present study and shown in the Fig.2. The holes are made on pile cap at 2.5d, 3.0d and 3.5d spacing of square pattern, circular groove is made at centre for placing of iron ball.
3) A rectangular rigid wooden box of dimension 60cm×60cm×60cm made up of 2cm thick ply wood is shown in Fig. 3. The test box is stiffened with battens at the middle and clamped on all corners to overcome the bulging effect.
4) The sand used in this study is of Ghataprabha River in Kaladagi as shown in Fig. 4. The engineering properties were determined in the laboratory. On the basis of test results the sand is defined as uniformly graded sand and the detailed properties are tabulated below in the TABLE I.

Fig. 1: Wooden Piles

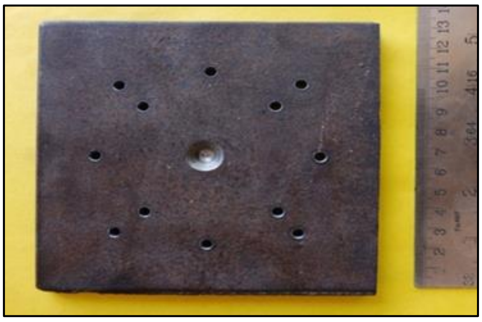

Fig. 2: Pile Cap

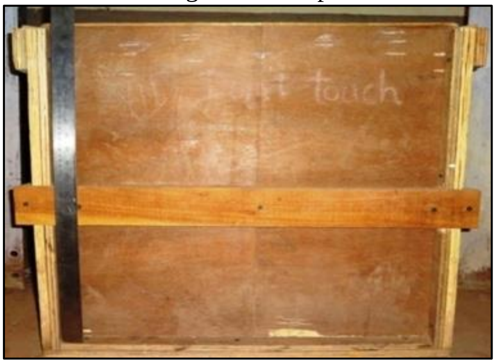

Fig. 3: Wooden Box

Fig. 4: River Sand

S.No	Properties	Symbol	Value
1	Specific Gravity	G	2.710
2	Effective Grain Size	D10	0.33 mm
3	Uniformity co-efficient	Cu	4.242
4	Co-efficient of curvature	Cc	0.832
5	Bulk Density Loose Dense	γ_{dmin} γ_{dmax}	16.28kN/m^3 19.04kN/m^3
6	Co-efficient of Internal friction 1)Loose 2) Dense	Ø	31 33
7	Relative Density	I	0.215 (for e=1) 0.397 (for e=0.91)

5) Loading frame: The dimension of frame as shown in the Fig.5 is adopted by keeping in mind that the test box of 60cm×60cm×60cm size with sufficient height to support loading arrangement as well as to change the position of loading whenever required. The frame is fixed on floor. The vertical compressive load is applied to pile cap through jack of 50kN capacity. Jack is fixed steel girder at centre and it is operated manually. The load transferred to the model through a proving ring of 20kN capacity, which is fixed on the head of jack. The proving ring of capacity of 20kN is used to measure the applied load and two dial gauges to measure the piled raft settlement. Each division in the proving ring was equivalent to 21.55N. The settlement is measured with two dial gauges of 0.01mm accuracy, having a 2.5cm plunger.

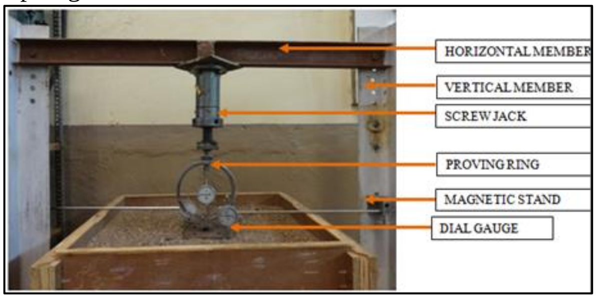

Fig. 5: Loading Frame

IV. Initial Set Up

The wooden box is kept below the loading frame so that the axis of loading should pass-through the centre of the test box. Sand is poured in to the box using sand poring technique, after complete filling of sand, piles are driven in to the sand medium then the pile cape is placed on the piles and the screws are tightened. Percussions are to be taken such that the axis of loading should pass through the centre of pile cap Proving ring of 20kN capacity is to be fitted to the jack then the iron ball is placed on the pile cap and proving ring is lowered such that the further lowering should show the deflections in the proving ring. Dial gauges are arranged in diagonal corners of pile cap using magnetic stands. The experimental setup is shown in the Fig. 6. Initial readings in the proving ring and the dial gauges are noted down before starting the actual experiment. The jack is rotated to apply the load then the corresponding readings in dial gauges are to be noted.

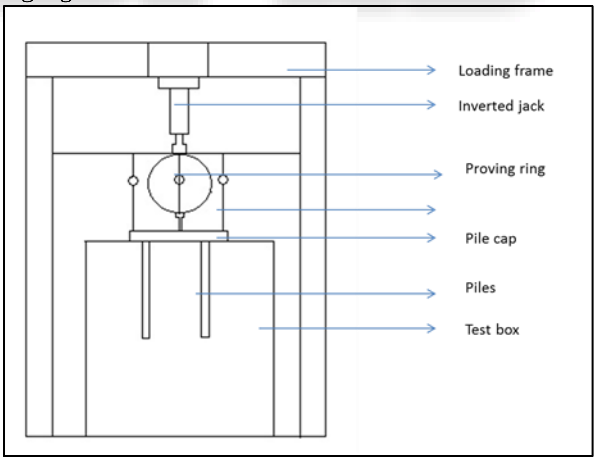

Fig. 6: Experimental Setup

V. Methodology

Initial set ups are to be done piles are to be kept in line with the axis of loading. Load is applied through the screw jack corresponding readings in proving ring and two dial gauges are to be recorded. The dial gauge reading adopted is the average of two readings. Load is applied till the settlement of 2.5cm is achieved, then the test is terminated, before commencing of next experiment the sand in the text box is completely emptied.

In this study there are two methods of installations, i) driven, ii) bored. In driven pile the piles are driven or pushed in the sand gradually. In bored pile, in this mode of installation initially the sand is poured to mid height of the test box then the hollow pipes of cross sectional area 2 times of pile cross sectional area are made to stand in position by some arrangements then remaining sand is poured in the box then the pipes are removed without disturbing the surrounding medium, then the load is applied. Conduction of experiment is shown in the Fig.7.

Fig. 7: Conduction of Experiment

VI. RESULTS & ANALYSIS

Experimental data obtained are tabulated in excel format, graphs are plotted for different combinations with load as X-axis and settlement as Y-axis, following figures represents the pattern of settlement verses load applied on piles and double tangent method which is used to calculate ultimate load bearing capacity of piles.

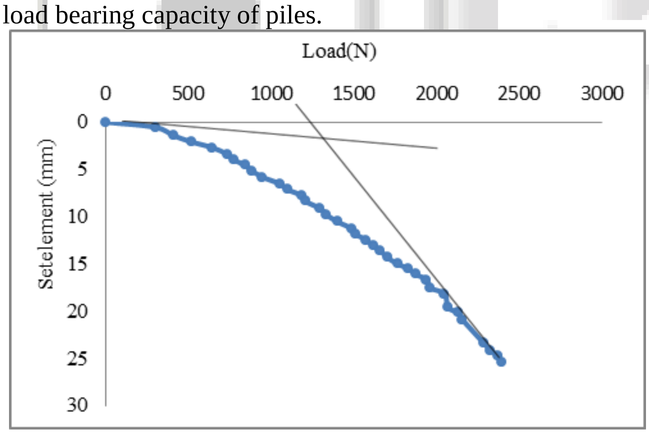

Fig. 8: Shows Square piles with spacing 2.5D under density of 16.28 kN/m^3

The following table represents the ultimate load caring capacity of the piles under different combinations.

BORED		ULTIMATE LOAD (N)			
Shape	Spacing	16.28 kN/m^3	19.04 kN/m^3	16.28/19.04 kN/m^3	19.04/16.28 kN/m^3
Circular	2.5d	720	900	850	800
	3.0d	790	950	900	820
	3.5d	850	1090	1000	900
Square	2.5d	1100	1220	1150	1120
	3d	1150	1320	1280	1200
	3.5d	1200	1380	1300	1250
Triangular	2.5d	650	820	780	700
	3d	680	900	880	800
	3.5d	750	1040	950	850

Table 2: Ultimate Load Carrying Capacity Of Bored Piles

DRIVEN		ULTIMATE LOAD (N)			
Shape	Spacing	16.28 kN/m^3	19.04 kN/m^3	16.28/19.04 kN/m^3	19.04/16.28 kN/m^3
Circular	2.5d	1300	1480	1420	1350
	3d	1380	1600	1500	1420
	3.5d	1450	1750	1700	1620
Square	2.5d	1350	1600	1480	1400
	3d	1480	1800	1700	1550
	3.5d	1550	1980	1820	1650
Triangular	2.5d	1680	1880	1750	1720
	3d	1780	2020	1950	1880
	3.5d	1910	2280	2150	1950

Table 3: Ultimate Load Carrying Capacity Of Driven Piles

1) Shape comparison: for the combination of 2.5d spacing of piles, homogeneous soil density of 16.28kN/m^3 and piles were bored in the soil medium, circular piles bares an ultimate load of 720N, square shaped piles carry an ultimate load of 1100N and triangular piles carry an ultimate load of 650N.
2) Spacing comparison: For the piles of circular shape, bored in the homogeneous soil medium of density 16.28kN/m^3 when spaced at 2.5d centre to centre carries an ultimate load of 720N, at 3d spacing carries 790N and at 3.5d spacing carries 850N load.
3) Density of soil comparison: Bored piles of circular shape, spaced at 2.5d centre to centre when bored in to homogeneous soil of density 16.24kN/m^3 bares an ultimate load of 720N, similarly for homogeneous soil density of 19.04kN/m^3 carries 900N, and layered soil with 16.28 kN/m^3 on top 19.04 kN/m^3 at bottom bares 850N and for layered soil with 19.04 kN/m^3 on top 16.28 kN/m^3 bares a load of 800N.
4) Method of installation: Piles of circular shape spaced at 2.5d centre to centre, in the homogeneous soil medium of density 16.24kN/m^3 when bored in to soil medium carries a load of 720N and when driven in to soil medium carries a load of 1300N.

Similarly for all other possible combinations the experiments are conducted, compared and plotted in to a graph then tabulated. The following are some figures which represents the comparison of different combinations.

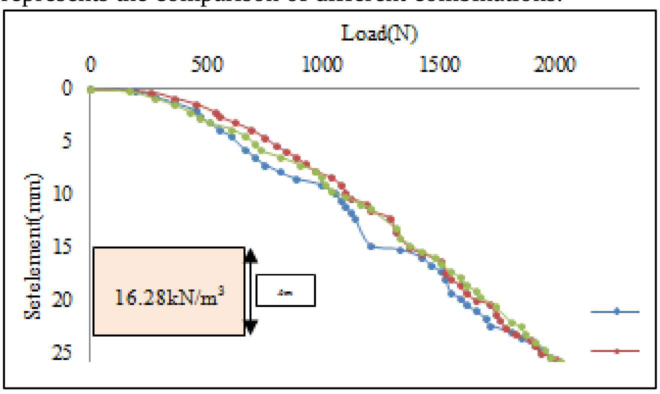

Fig. 9: Shows Load vs. Settlement of Circular piles at different spacing of density 16.28kN/m^3

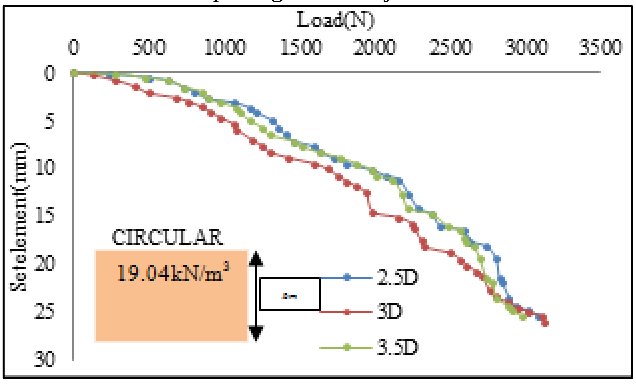

Fig. 10: Shows Load vs. Settlement of Circular piles at different spacing of density 19.04kN/m3.

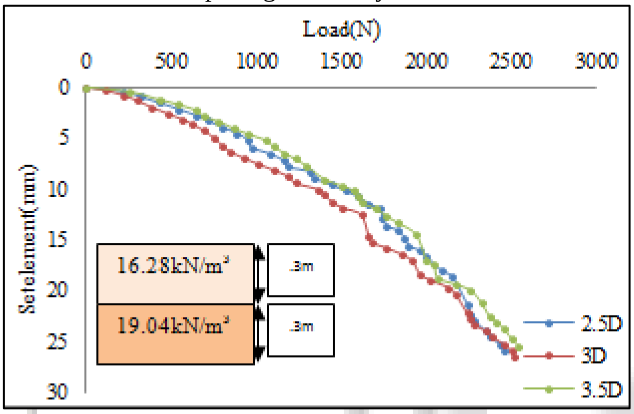

Fig. 11: Shows Load vs. Settlement of Circular piles at different spacing of density 16.28kN/m^3 over 19.04 kN/m^3.

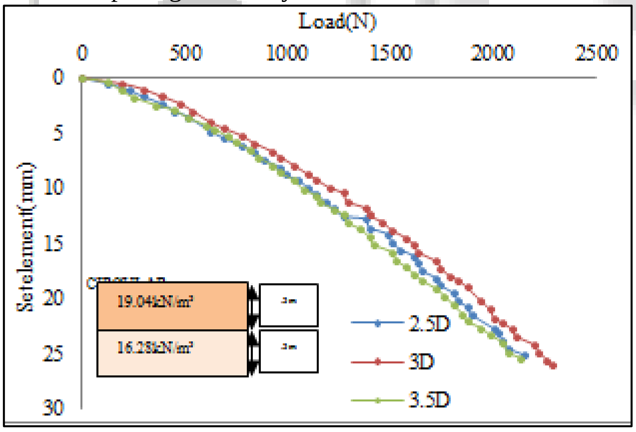

Fig. 12: Shows Load vs. Settlement of Circular piles at different spacing of density 19.04kN/m^3 over 16.28kN/m^3.

5) Considering all parameters: Every possible combination are compared, the results are represented in percentages by considering the piles of circular shape spaced at 2.5d centre to centre are driven in a homogeneous soil of density 16.28kN/m^3 as base (100%) Ultimate Bearing Capacity. The following table represents the percentage of ultimate bearing capacity.

INCRESE OF Q_U (%)				
DENSITY 16.28kN/m^3	SPACING	CIRCULAR	SQUARE	TRIANGULAR
DRIVEN	2.5d	100	103.85	129.23
	3.0d	106.15	113.85	137.00
	3.5d	111.50	119.20	147.00
BORED	2.5d	100	153.00	91.00*
	3.0d	109.72	160.00	94.44*
	3.5d	118.05	166.67	104.20*

Table 4: Shows Increase of QU in % W.R.T Density 16.28kn/M3 for Spacing 2.5d of Circular Piles.

INCRESE OF Q_U (%)				
DENSITY 19.04kN/m^3	SPACING	CIRCULAR	SQUARE	TRIANGULAR
DRIVEN	2.5d	113.84	123.00	145.00
	3.0d	123.00	138.40	155.30
	3.5d	134.60	152.30	175.40
BORED	2.5d	125.00	169.44	114.00*
	3.0d	132.00	183.33	125.00*
	3.5d	151.40	192.00	144.44*

Table 5: Shows Increase of Q_U in % W.R.T Density 16.28kn/M^3 for Spacing 2.5d of Circular Piles.

INCRESE OF Q_U (%)				
DENSITY 16.28/19.04kN/m^3	SPACING	CIRCULAR	SQUARE	TRIANGULAR
DRIVEN	2.5	109.23	113.84	134.60
	3.0	115.40	131.00	150.00
	3.5	131.00	140.00	165.40
BORED	2.5	118.05	160.00	97.22*
	3.0	125.00	177.70	122.22*
	3.5	139.00	180.50	132.00*

TABLE VII
SHOWS INCREASE OF Q_U IN % W.R.T DENSITY 16.28KN/M^3 FOR SPACING 2.5d OF CIRCULAR PILES.

INCRESE OF Q_U (%)				
DENSITY 19.04/16.28kN/m^3	SPACING	CIRCULAR	SQUARE	TRIANGULAR
DRIVEN	2.5	103.84	107.70	132.30
	3.0	109.23	119.23	144.60
	3.5	124.60	127.00	150.00
BORED	2.5	118.05	160.00	97.22*
	3.0	125.00	177.70	122.22*
	3.5	139.00	180.50	132.00*

Table 6: Shows Increase of Q_U in % W.R.T Density 16.28kn/M^3 for Spacing 2.5d of Circular Piles.

*in the bored method of installation, The disturbance of surrounding soil media of circular and square piles is constant and it is of the order 0.82 times the area of c/a of piles. Whereas for triangular piles the disturbance of surrounding soil media of piles of order 1.179 times the area of c/a of piles.

VII. Conclusion

For the framed combinations the results are obtained and with all possible combinations the results were compared. Whereas the shapes of the bored piles were not compared as the surrounding soil media disturbance was unable to keep constant for all different shapes.

1) The increase in the density of soil leads to the increase in load carrying capacity of group of piles both in driven and bored method of installation.
2) The triangular piles have more load carrying capacity in driven piles compared to circular & square piles and square piles have more load carrying capacity in both driven and bored piles.
3) The increase in the spacing of piles increases the load carrying capacity of group of piles both in driven and bored.
4) Load carrying capacity of piles in loose over dense medium is higher compared to dense over loose condition in both bored and driven piles.
5) The load carrying capacity of driven piles is greater than bored piles in all conditions.
6) Triangular piles of driven at 3.5d spacing in dense soil medium is the best combination which carries the maximum load compare to all conditions.
7) In case of bored piles disturbance in surrounding soil medium is a very important factor.

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