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Study of Differential Length of Pile on carrying capacity of Model Square Piled Raft

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Abstract**—*****In the previous few decades research on piled raft foundation are rapid increases with technology. The main purpose of researches is economical and safe design. In this research study, examine the square raft model with the strategical arrangement of piles. In an experimental study of the model, there are six types of arrangement of model pile group and model piled raft examined on the homogeneous sandy soil. The effect of differential length of a pile on load-settlement characteristics, capacity of load bearing and the efficiency base on an ultimate load of the pile group and the piled raft are determined. Also, the reduction in settlement for pile raft is determined.***

Keywords— differential length of pile; piled raft; pile group; raft; model study of piled raft, long and short pile combination

I. INTRODUCTION

When excessive loads that come from the superstructures to the foundation at that time excessive settlements problem occurs also some time foundation soil having lower load bearing capacity so that to prevent problem like that we are used piled raft foundation.

The united system of pile and raft foundation is based on different design ideas which are classified as follow:

1) Settlement reducing pile concept: In this viewpoint, piles are only located to reduce the settlement and they are designed to work at limiting equilibrium, in other words, for the piles, the factor of safety against bearing capacity is taken as unity.

2) Piled raft concept: This viewpoint is one of the newly adopted concepts in which a significant portion of the total load is carried by the raft defiantly to the conventional design. In this concept piles are designed to work at 70-80% of the ultimate load capacity.

3) Differential settlement control: Placing piles under the raft advantageously and of course in a limited number will improve the ultimate load capacity of the foundation and decrease the settlement. In this pepar, emphasize will be given to all design ideas presented above.

In the present investigation, an attempt is made to study the behaviour of single pile, only raft, pile group and square piled raft using experimental studies. Additionally, an analytical procedure has been followed.

II. MATERIALS OF INVESTIGATION

A. *Soil property*

Clean and Dry sandy soil obtain from bahadurpur near sankheda district, Vadodara, Gujarat

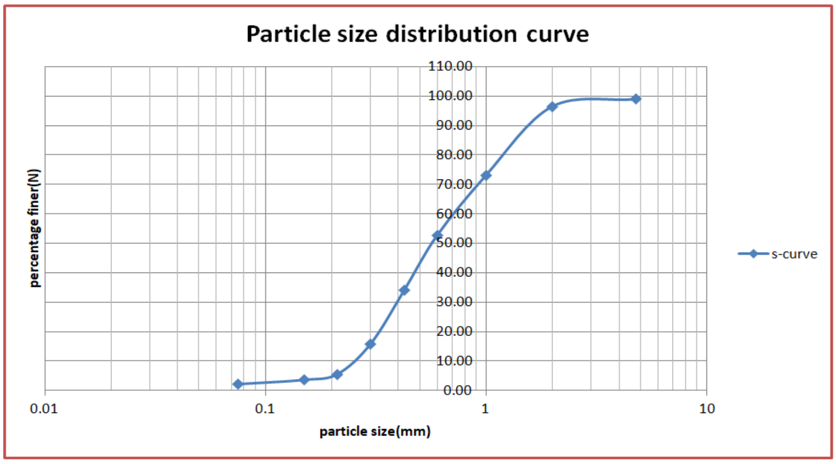


Fig.1 Grain size distribution curve of sandy soil

TABLE 1

Sr. No.	***Engineering properties of sand used for experiment***	
	Properties of Sand	***Value***
1	D_{10}, mm	0.32
2	D_{30}, mm	0.51
3	D_{60}, mm	0.71
4	Coefficient of Uniformity, C_u	2.22
5	Coefficient of Curvature, C_c	1.14
6	Fine Sand	19.00%
7	Medium Sand	74.10%
8	Coarse Sand	6.90%
9	IS Soil Classification	SP
10	Specific Gravity (G)	2.61
11	Experimental Density (γd)	1.733 g/cc
12	Maximum Density (γd max)	1.9 g/cc
13	Minimum Density (γd min)	1.47 g/cc
14	Relative Density (Rd)	66%
15	Angle of Internal Friction (ø)	36°
16	Angle of Soil-Pile Friction (δ) Mild Steel Pile	22°

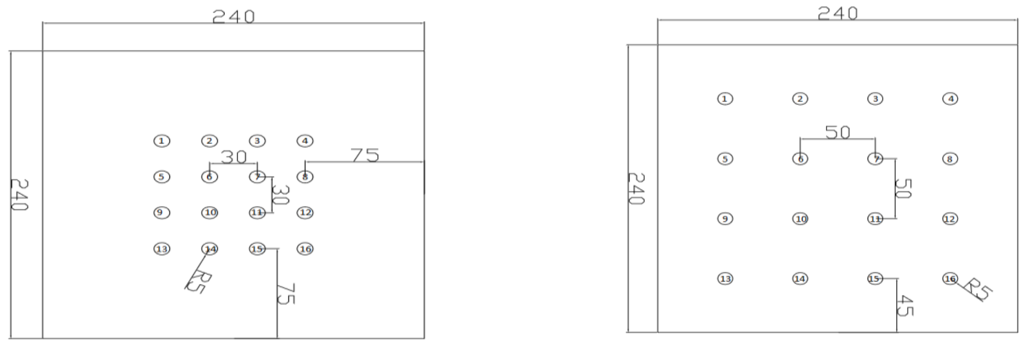
III. MODEL STUDY AND EXPERIMENTAL SET UP DETAIL

The laboratory tests are to be conducted for differential pile length in a group, pile spacing, square raft, pile arrangements using constant no. of piles. Here we are considering Pile diameter and size of raft are kept constant and settlements are measured under sustained increasing loading. The size of the tank is 1220mm x 1220mm x 1080mm. The size of the raft is 240 mm x 240 mm × 20 mm. The mild steel solid piles have dia. 10 mm. Pile lengths are 100mm, 250mm. No. of piles are 16. Pile spacing is 3d and 5d. (d = diameter of pile)

TABLE 2

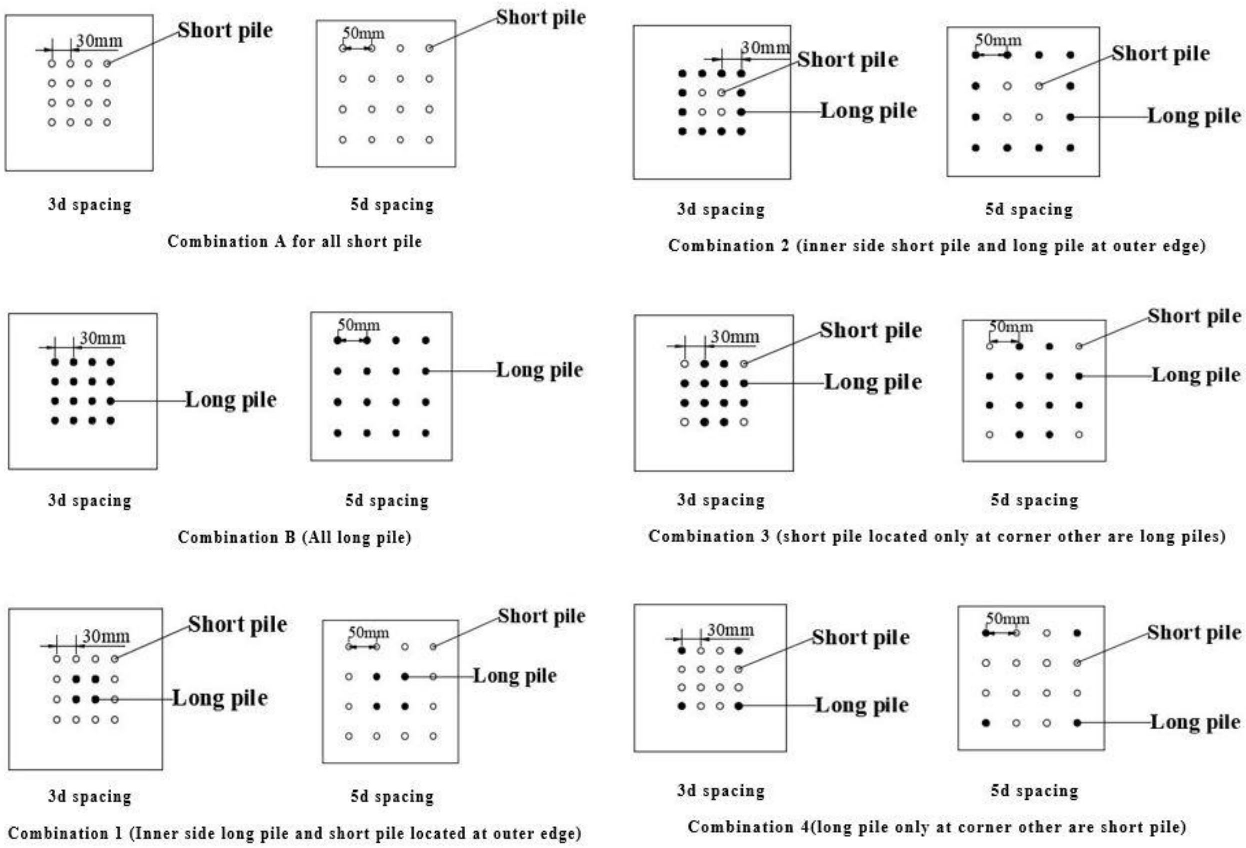
PARAMETER OF EXPERIMENTAL MODEL

Diameter of Piles (D) (mm)	10	
Total Length of Piles (L) (mm)	130,280	
Embedded Length of Piles (mm)	100,250	
L/d Ratio	Short pile	Long pile
	10	25
Spacing of piles	3d,5d	
Thickness of Raft (mm)	20	
Size of square raft (mm)	240×240	



3d spacing (All dimensions are in mm) 5d spacing (All dimension are in mm)

Fig.2 Design model of pile group and piled raft



(●Indicates long pile, ○Indicates short pile)

Fig 3 Different configurations of different combinations of piles in only pile group & piled raft

A. Single pile

Single pile of diameter 10mm and total length of long and short pile 130mm and 280mm with embedded length of 100mm and 250mm respectively were welded with pile cap of 20mm thickness and 50mm x 50mm size.

B. Pile groups (4x4)

Pile groups of identical pile with c/c distance of 3d (30mm) and 5d (50mm) were used for the investigation (shown in fig 2). Diameter of which were 16mm and embedded length of the piles were 24cm.

C. Model tank and test procedure

The size of the tank was 1220mm x 1220mm x 1080mm. Fig 4 show tank was filled in three layers of 20cm with vibration of 60sec, 90sec & 120s for respectively bottom, middle and top layer by small surface vibrator. All the tests are conducted at a relative density 66%. The center of the square tank is found out by plumb bob. Then piled raft is inserted into the sand using hammer and then checked that mechanical screw jack and raft are aligned with plumb bob in vertical line. Horizontal level of the raft is checked by spirit level. The dial gauges and the proving ring is placed such that the dial gauge gives displacement in the direction of load and in case of vertical eccentric loading, two dial gauges place at different end and at same distance from load of action are placed and average displacement is taken into consideration.

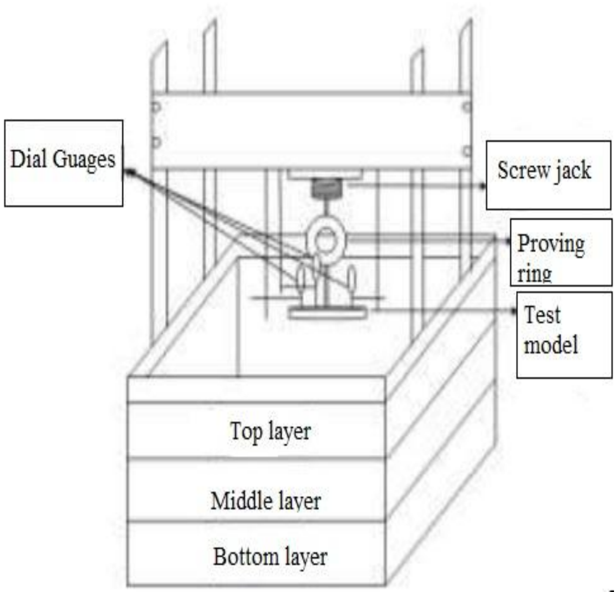


Fig 4 Model foundation test set and loading arrangement

IV. RESULT AND ANALYSIS

In present investigation the test was carried out on the single pile and pile group, raft and piled raft till ultimate load is reached, which subsequently shows decreasing proving ring reading accompanying with substantial increasing settlement reading. For vertical loading, IS 2911 (part – 4) suggests that, the initial load displacement curve is curvilinear from beginning with convex downward and after it become a straight. The failure load was taken to be that load at initial and final straight tangent intersection point in curve

A. Analysis of Square raft and single pile

Fig 5 load vs raft settlement for raft size 240 mm×240 mm and thickness 20 mm. Ultimate load of raft is 14750 N. Fig 6 shows the load vs pile head settlement for piles of diameter 10 mm and length of short and long pile are 130mm, and 280 mm. Short pile has a 75 N ultimate load and Long pile has a 300N ultimate load

Analysis of pile Group

B. Load settlement characteristics of pile group

Load-settlement characteristics of pile group Figure 7 and 8 shows the load vs settlement characteristics for the combinations A, B, 1 to 6 respectively of 3d and 5d spacing which consists of different configurations as per Figure 3, it is seen that combination B has a higher load carrying capacity compared to other combinations in 3d and 5d spacing because of the all long piles. In the other different configurations, combination 2 and 3 has a higher load carrying capacity compared to other combinations in 3d and 5d spacing respectively in pile group.

C. Bearing capacity analysis of pile group

Fig 9 shows the ultimate load of all combinations in 3d spacing. It is observed that combination B has a highest load carrying capacity and combination A has a least load carrying capacity,When comparing other combination with combination B,it is observed that reduction in load carrying capacity in combination 1,2,3,4,5 and 6 are 56.52%, 30.43%, 30.43%, 58.69%, 39.13% and 43.478% respectively.

Fig 10 shows the ultimate load of all combinations in 5d spacing. It can be observed that combination B has a highest load carrying capacity and combination A has a least load carrying capacity.When comparing other combinations with combination B, it is observed that reduction in load carrying capacity in combination 1,2,3,4,5 and 6 are 32.84%, 6.72%, 1.119%, 40.29%, 12.31% and 23.50% respectively.

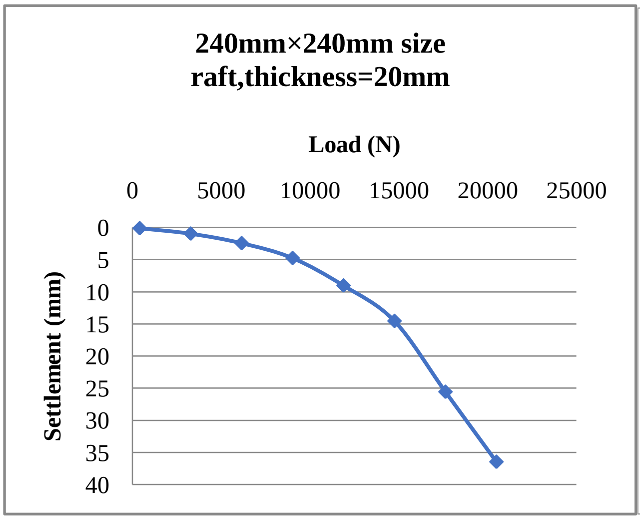


Fig 5 Load-Settlement characteristics of only raft

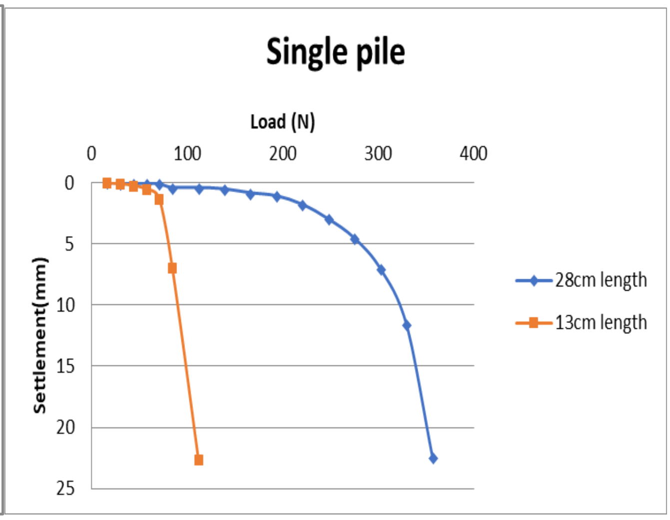
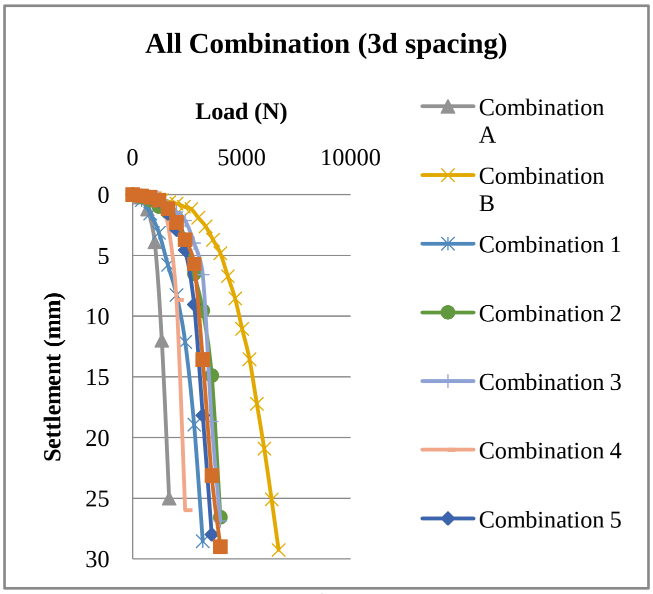


Fig 6 Load-Settlement characteristics of single pile



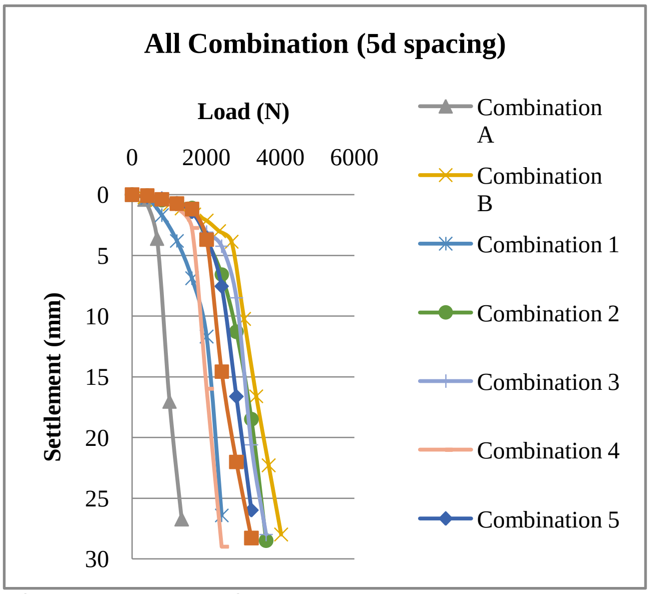
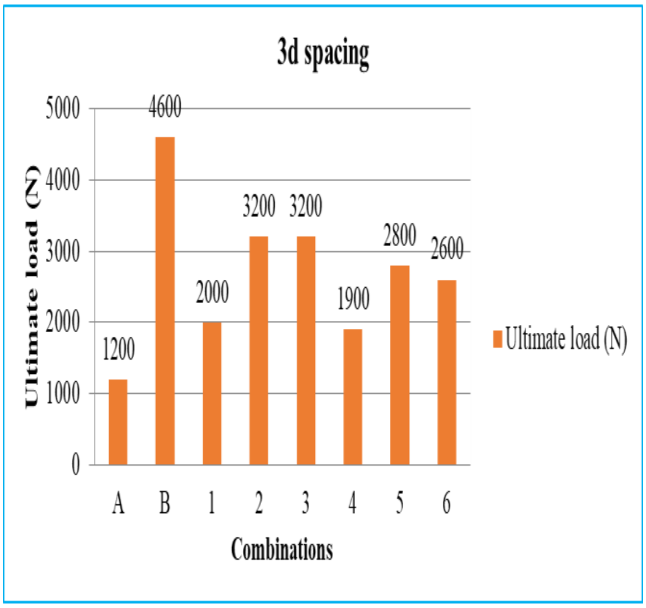


Fig 7 & Fig 8 Comparison of load-settlement characteristics of all combinations of pile group (3d spacing) & (5d spacing) (for combination refer fig 3)



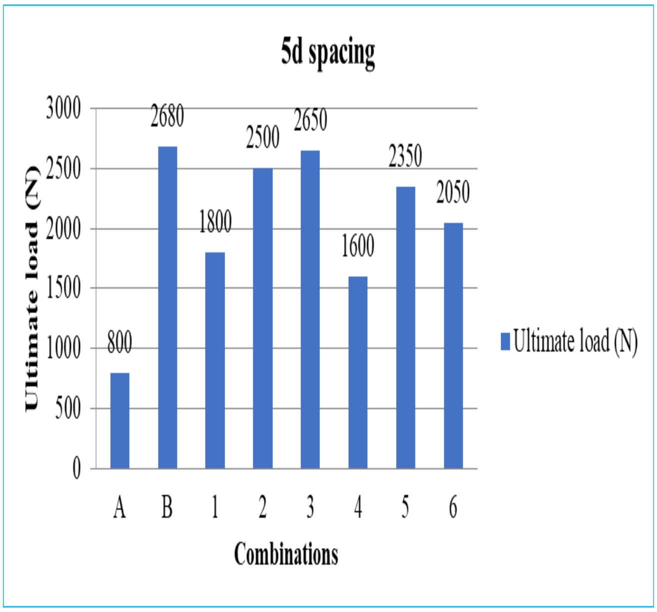


Fig 9 & Fig 10 Ultimate load of piled group all combinations (3d spacing) & (5d spacing)

D. Efficiency analysis of pile group

For combination A and B,

Efficiency of pile group = Qgu / (n × Qu)

For other combinations, two formulas are used.

Equation 1,

Efficiency of pile group = Qgu / ((n × Qu (short)) + (n × Qu (long)))

Equation 2,

Efficiency of pile group = Qgu / ((n% (short) × Qgu (short)) + (n% (long) × Qgu (long)))

Where,

Qgu = ultimate load of the pile group,

n = number of piles,

Qu = ultimate load of single pile,

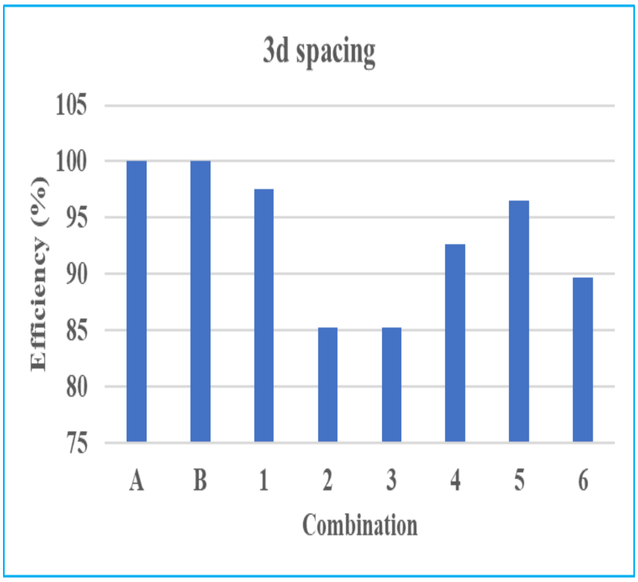
Qu (short) = ultimate load of single short pile,

Qu (long) = ultimate load of single long pile,

Qgu (short) = ultimate load of pile group having all short piles (combination A),

Qgu (long) = ultimate load of pile group having all long piles (combination B),

Fig 11 and Fig 12 shows the efficiency of the different combinations having 3dand 5d spacing by equation 1. It can be observed that combination 2 and 3 have the lesser efficiency. Fig 13 and Fig 14 shows the efficiency of the different combinations having 3d and 5d spacing by equation 2. For Efficiency of pile, If spacing between the piles is too close the zones of stress around the pile will overlap and the ultimate load of pile is less than the sum of individual pile capacities special in case of friction pile.



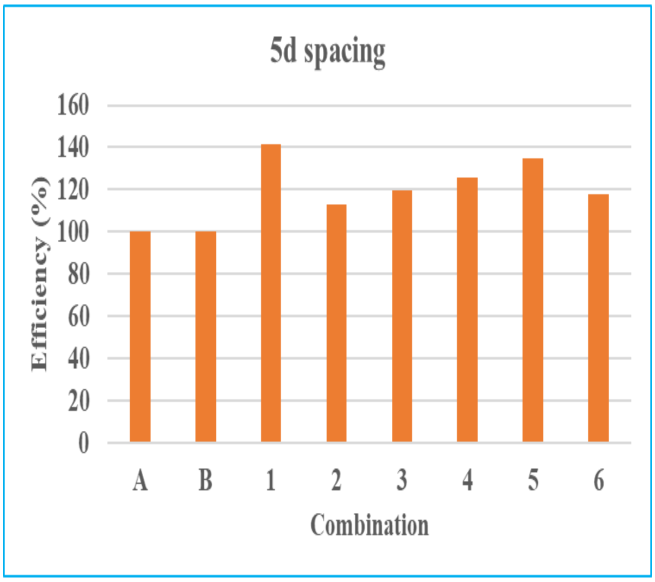
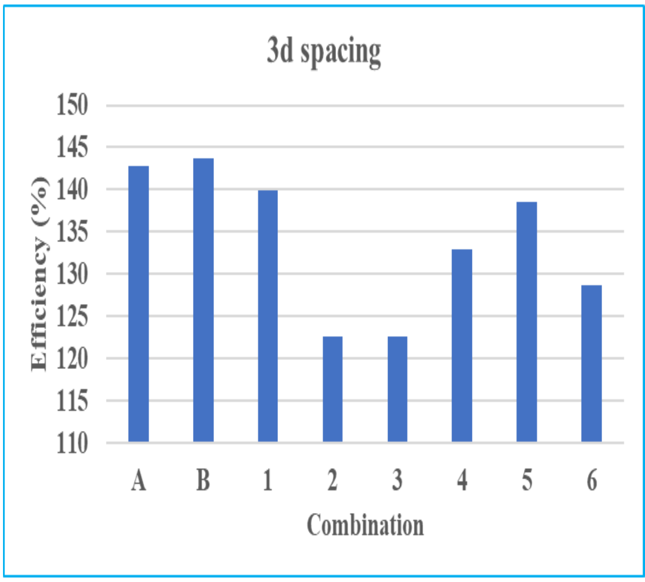


Fig 11 & Fig 12 Effect of combination on the efficiency of pile group (3d spacing) & (5d spacing) by Equation 1



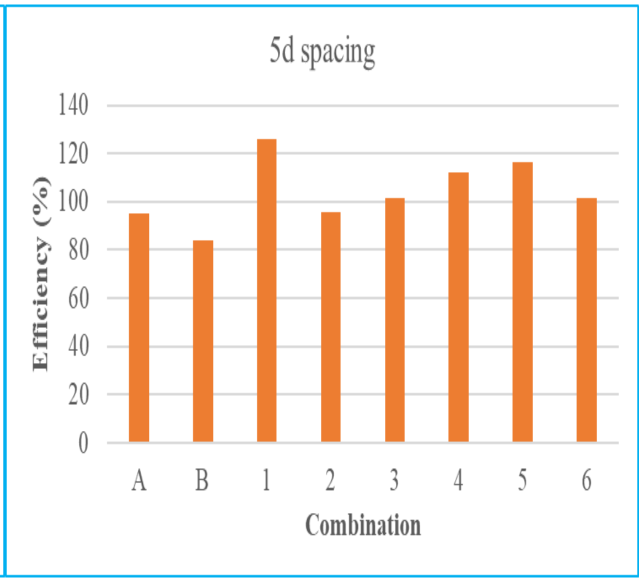


Fig 13 & Fig 14 Effect of combination on the efficiency of pile group (3d spacing) & (5d spacing) by Equation 2

Analysis of piled raft

E. Load-settlement characteristics of piled raft

Fig 15 and Fig 16 shows comparison of load vs settlement characteristics of all combinations having 3d and 5d spacing respectively. combinations B has a higher load carrying capacity compare to other combinations in 3d and 5d spacing in piled raft.

F. Bearing capacity analysis of piled raft

Figure 17 shows the ultimate load of all combinations in 3d spacing. It can be observed that combination B has a highest load carrying capacity and combination A has a least load carrying capacity. When comparing other combinations to combination B, Reduction in load carrying capacity in combination A, 1, 2, 3, 4, 5 and 6 is 20%, 15.217%, 2.437%, 3.04%, 17.39%, 12.82% and 7.826% respectively.

Figure 18 shows the ultimate load of all combinations in 5d spacing. It can be observed that combination B has a highest load carrying capacity and combination A has a least load carrying capacity. When comparing other combinations to combination B, Reduction in load carrying capacity in combination A,1, 2, 3, 4, 5 and 6 is 25.09%, 20.727%, 8.36%, 7.27%, 22.181%, 20% and 16.363% respectively.

G. Efficiency analysis of piled raft

Efficiency of piled raft = Qpru / (Qru + Qpgu),

Where,

Qpru = ultimate load of piled raft,

Qru = ultimate load of raft alone,

Qpgu =ultimate load of pile group.

Fig 19 and Fig 20 shows the combinations vs efficiency of various combinations having pile diameter 10 mm, Differential lengths 10 cm and 25 cm in all the combinations 1, 2, 3, 4, 5 and 6 having 3d and 5d spacing.

H. Settlement reduction in pile raft

The settlement of only raft is determined at different point levels equal to Qu/8, Qu/4, Qu/3, Qu/2 (where Qu = ultimate load of raft) from load-settlement characteristics of raft and at the same load level the settlement data are obtained for piled raft.

% settlement reduction = $S_r – S_{pr} /(S_r)$

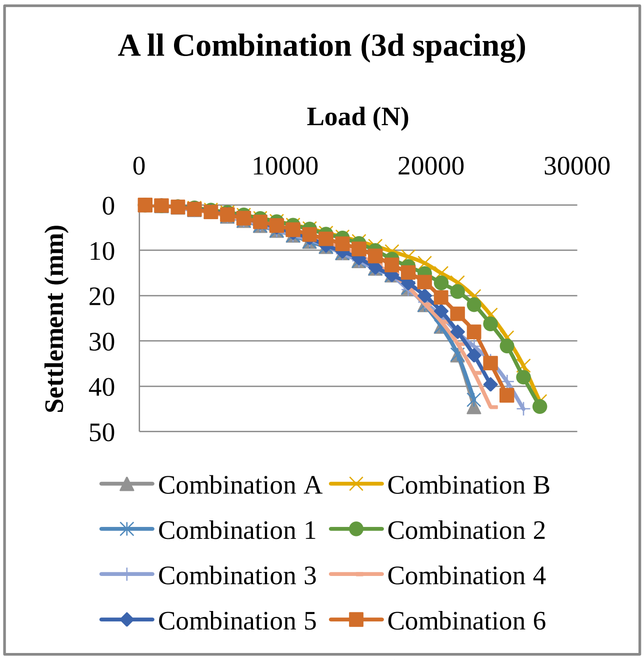
Where,

S_r = Settlement of raft only

S_{pr} = Settlement of piled raft

Fig 21 and Fig 22 shows the load (Q/Qu) vs Settlement reduction (%) of all combination 1, 2, 3, 4, 5 and 6 having 3d and 5d spacing.

I. Comparison of load-settlement characteristics of only pile,only raft, (pile group + only raft) and piled raft



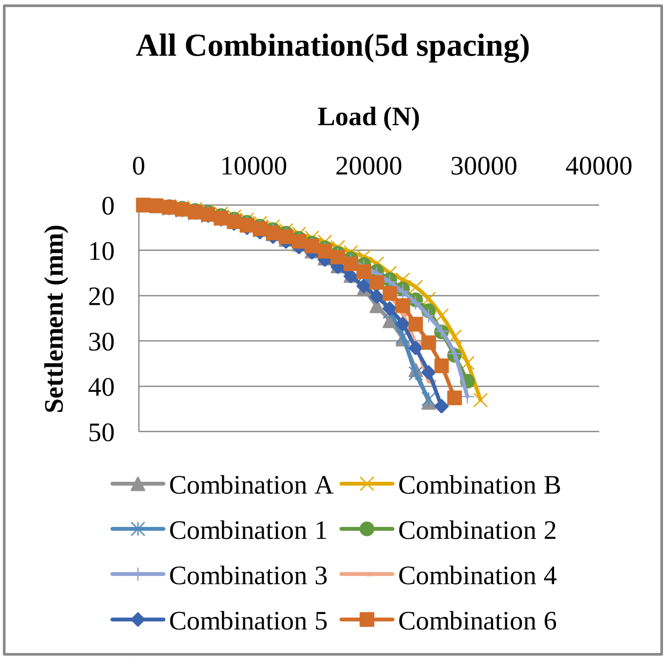
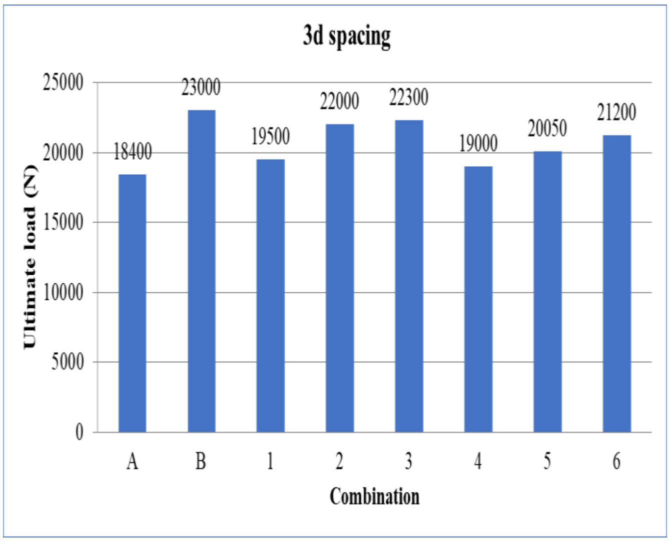


Fig 15 & Fig 16 Comparison of Load-settlement characteristics of piled raft all combinations (3d spacing) & (5d spacing)



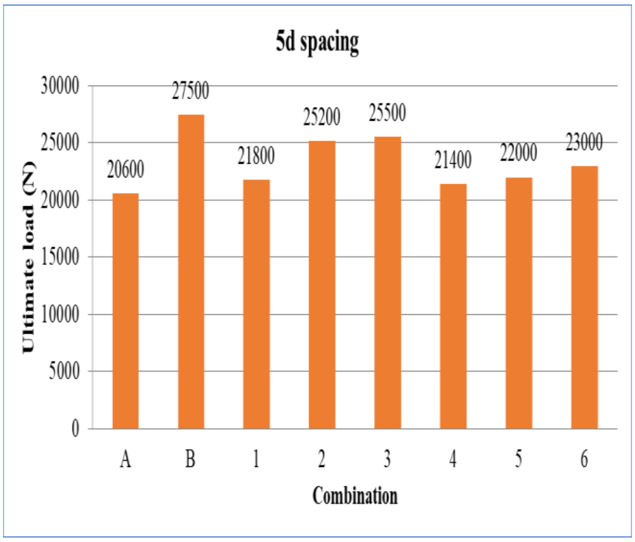
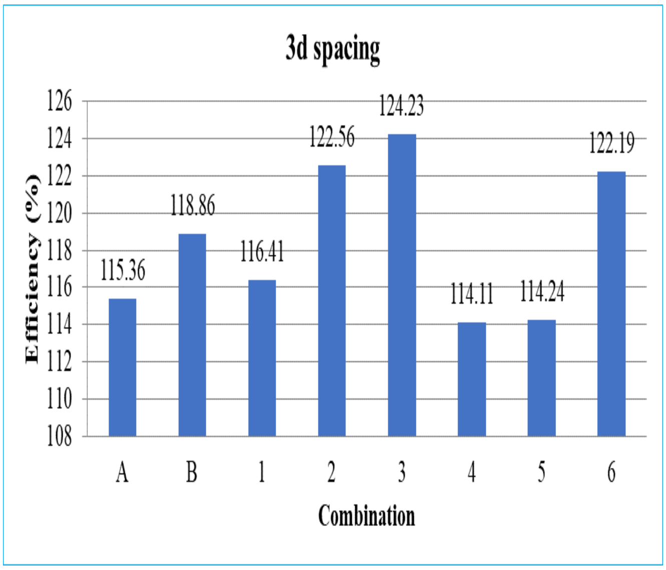


Fig 17 & Fig 18 Ultimate load of piled raft all combinations (3d spacing) & (5d spacing)



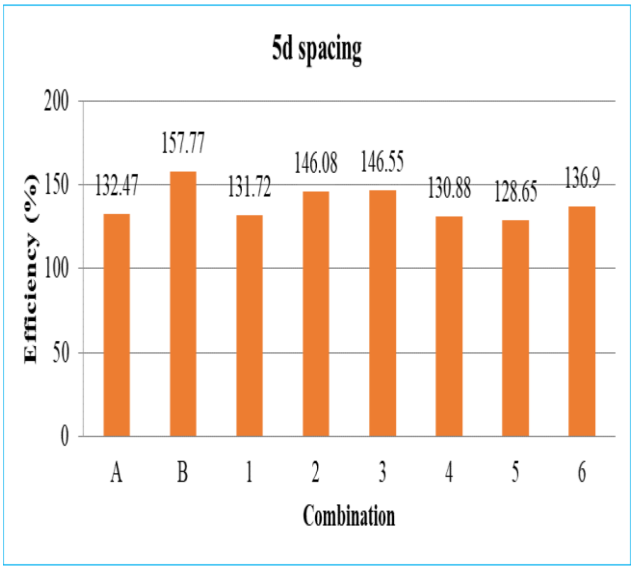
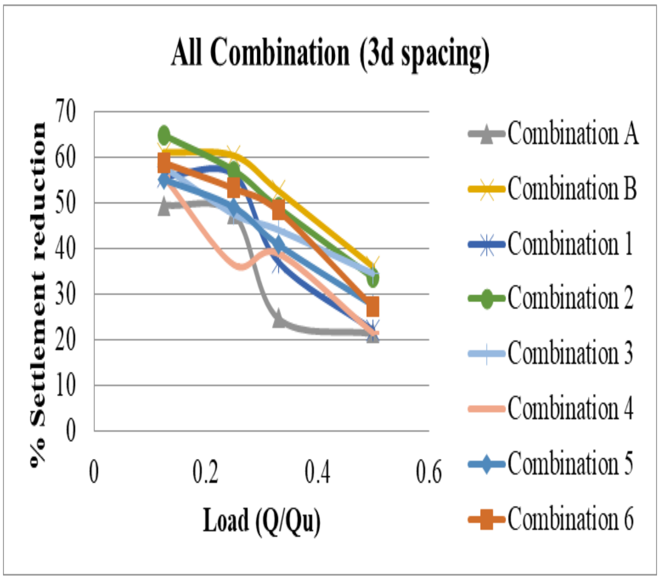


Fig 19 & Fig 20 Effect of combinations on the efficiency of piled raft (3d spacing) & (5d spacing)



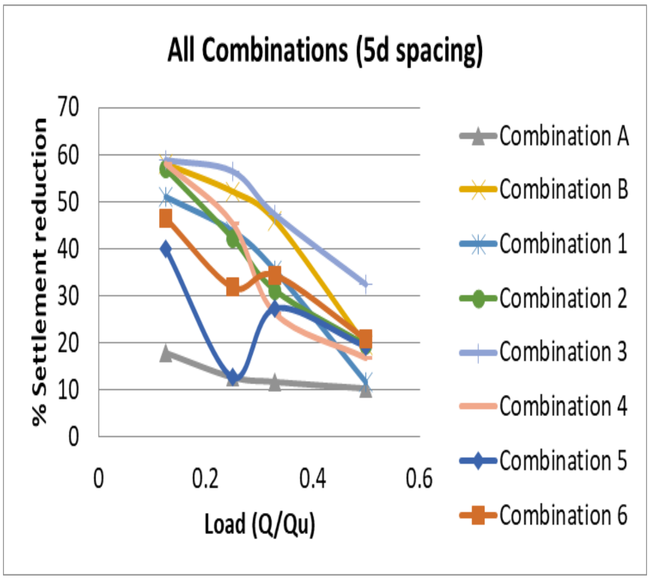


Fig 21 & Fig 22 Settlement reduuction of all combination 3d spacing &5d spacing

Comparison of load-settlement characteristics of {only pile, raft, (pile group + raft}) and piled raft

TABLE 3

IMPROVEMENT IN LOAD CARRYING CAPACITY (%)

Combination	3d spacing(%)	5d spacing(%)
A	14.82	31.84
B	17.04	55.10
1	16.41	31.72
2	22.56	46.096
3	24.23	46.551
4	14.11	30.888
5	14.24	28.654
6	22.19	36.904

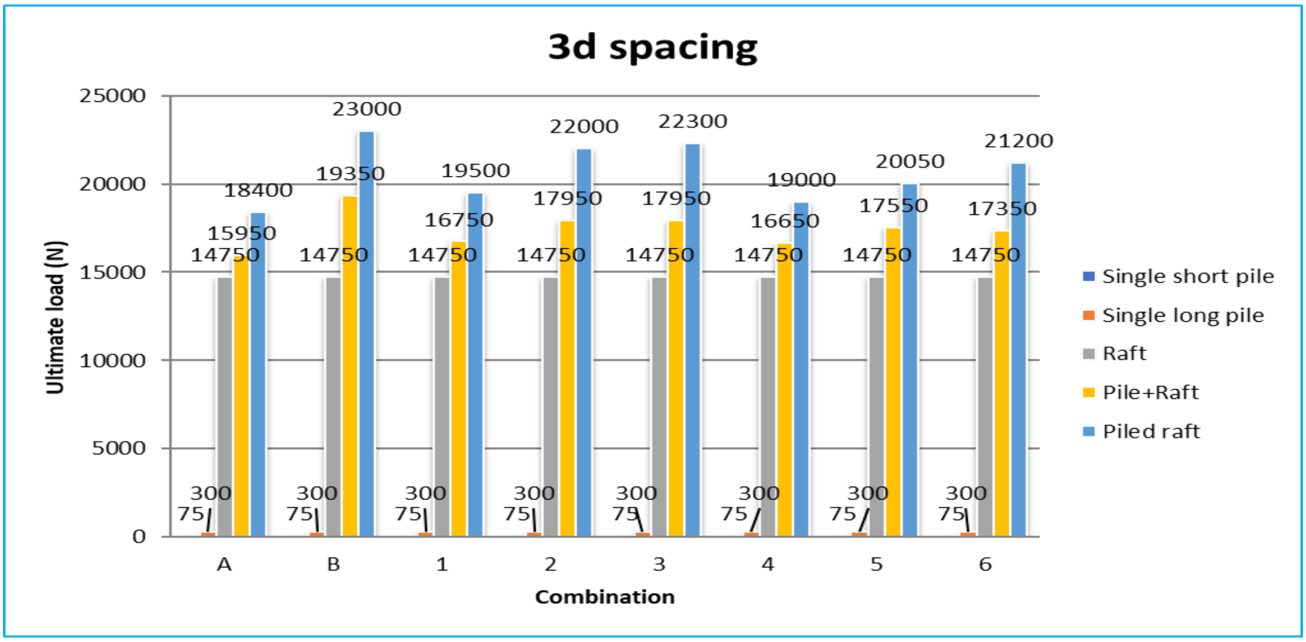


Fig 23 Comparison of load-settlement characteristics of only pile, raft, (pile group + raft) and piled raft (3d spacing)

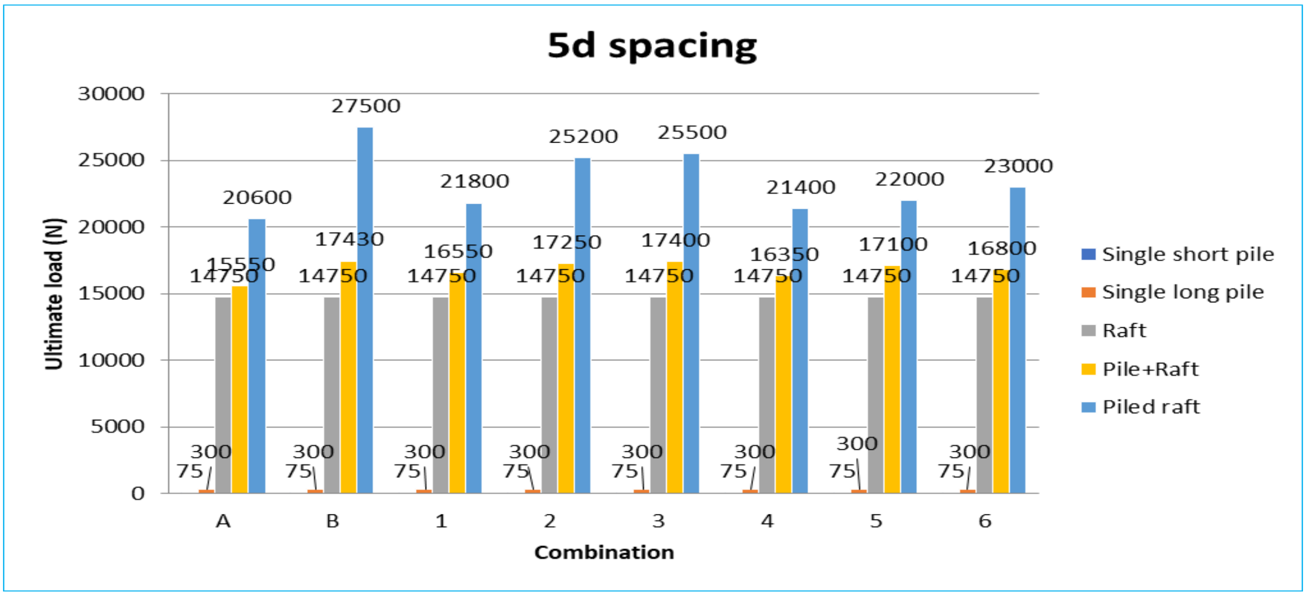


Fig 24 Comparison of load-settlement characteristics of only pile, raft, (pile group + raft) and piled raft (5d spacing)

V. Conclusions

A. Conclusion from Single pile

As the length of pile increases load carrying capacity increase and settlement decreases

B. Conclusion from Pile group

As the spacing of pile increases in pile group the load carrying capacity decrease and settlement increase. As the number of short piles increase the load carrying capacity decrease and settlement increase (combination 1 and 2). With same numbers of long and short piles in pile group the arrangement of combination 1 give better result than combination 4. With spacing 3d between the piles the arrangement of combination 2 and 3 give almost similar result but with 5d spacing combination 3 gives better results. With same numbers of long and short piles in pile group arrangement of combination 5 give better result than combination 6.

C. Conclusion from Piled raft

As the length of pile increases the load carrying capacity increase and settlement decrease (combination A and B). As the spacing of pile increases in pile raft the load carrying capacity increase and settlement decrease. As the number of short piles increase the load carrying capacity decrease and settlement increase (combination 1 and 2). With same numbers of long and short piles in piled raft the arrangement of combination 1 give better result than combination 4. With same number of long and short piles in piled the arrangement of combination 3 give better result than combination 2 with both 3d and 5d spacing. With same numbers of long and short piles in pile raft the arrangement of combination 6 give better result than combination 5. Load ratio (Q/Qu) vs % settlement reduction characteristics is curvilinear in nature. As the number of long piles increases, higher the settlement reduction is observed. Square Piled raft of all the combinations have more load carrying capacity and less settlement than the single pile, only raft and pile group. Ultimate load of the all the combinations of piled raft are more than that of the ultimate load of summation of pile group and only raft due to interaction between pile and raft. Piled raft has much higher load carrying capacity due to block action of a pile group in it.

VI. References

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