Behavior of Battered Piled Raft Foundation under Verticle Load

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Abstract

The establishment of numerous tall structures including the tallest of the world Burj Khalifa is founded on Piled raft foundation. Piles utilized as a part of Piled raft foundation, are settlement reducers as well as load is also carried by them. In place of vertical piles if battered piles are utilized as a part of piled raft foundation, improvement in the load carrying capacity and reduction in the settlement may be observed. For different battered angles as well as different pile configurations, effect on load capacity as well as settlements has been studied for comparisons with the raft with normal vertical piles.

Keywords: *Battered Piled Raft Foundation, Ultimate load carrying capacity, Settlement improvement.*

INTRODUCTION

Raft foundation is utilized where the base covers over half the plan stretch. However, due to heavy loads, there are chances of higher settlements of the raft foundation, so by using piles under the raft will help in reducing the settlements. Thus piles act as settlement reducers as well as in load improvement. This kind of establishment is extremely famous as it is prudent and successful foundation system. The battered piles are normally utilized when there is more lateral load in the pile group.

To study effect of batted piles in piled raft foundation under vertical load, the experimental work has been conducted. A mild steel plate of 150mm X 150mm X 15mm as a model raft and piles with diameter of 15mm and length of 150 mm have been used so as to keep length to diameter ratio as 10. The sand bed on which tests are performed, relative density of 30% was maintained. Piles are comprised of cement mortar (1:3) reinforced with threaded mild steel bar of 6mm diameter for realistic approach. For diamond and square configurations, different battered angles as mentioned in the following table is used:-

Table – 1 Configurations and angle of inclination

Sr. No.	Description	No. of piles	Batter Angle
1	Only Raft	-	-
2	Piled Raft with Diamond configuration	4	0°, 5°, 7°, 14°,21°, 28°, 33° and 38°
3	Piled Raft with Square configuration	4	0°, 5°, 7°, 14°,21°, 28°, 33° and 38°

PROPERTIES OF SAND

The tests to determine properties of sand are performed as per IS 2720. Before utilizing sand it was washed and dried.

The figure given below is the distribution curve of the sand grains.
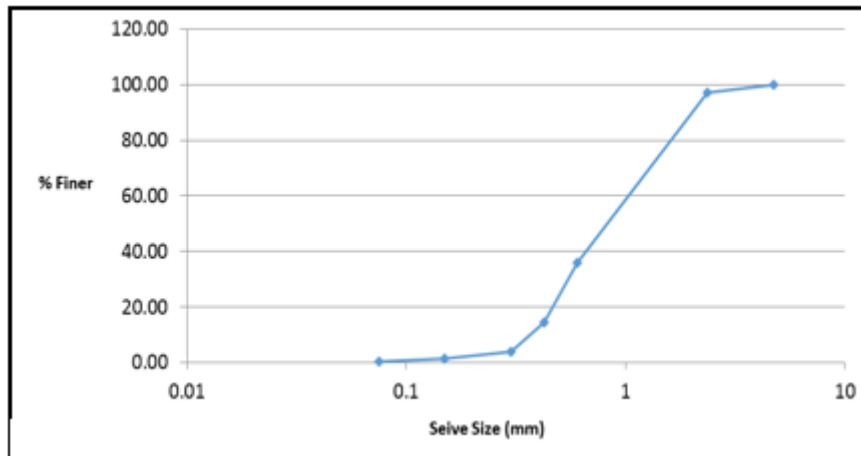
Fig. 1. *Particle size distribution curve*

Different properties of the sand are presented in Table – 2.

Table – 2 Sand properties

Coefficient of curvature (Cc)	0.80
Coefficient of uniformity(Cu)	2.56
Specefic gravity(G)	2.63
Max. Dry Density, γmax	1.83 g/cm3
Min. Dry Density, γmin	1.62 g/cm3
Cohesion (C)	0.0 kPa
Angle of Internal Friction ϕ	33°

*Further Subsequent Headings:* should me made run on with the text separated by a column.

TEST PROGRAM

Behavior of battered piled raft foundation has been studied experimentally from load versus settlement curves with different configurations and pile inclinations. For this 17 tests have been performed. Typical arrangement for diamond configuration has been shown in the fig. 2. Care ought to be taken that there is no stress globe in the tank limit so the tank used is 5 times the measurement of raft width. And in addition to maintain a strategic distance from the impact of rigid base, tank ought to be of adequate depth. The model raft was comprised of mild steel plate having a square shape. The measurement of raft is 150mm X 150mm X 15mm. The model piles were comprised of the mortar (1:3) strengthened with threaded bar of 6mm diameter. Pile length is 150mm and diameter is 15mm. Top head of each pile is associated with raft plate through nuts. After each test the inclination of pile is increased as shown in table 1.
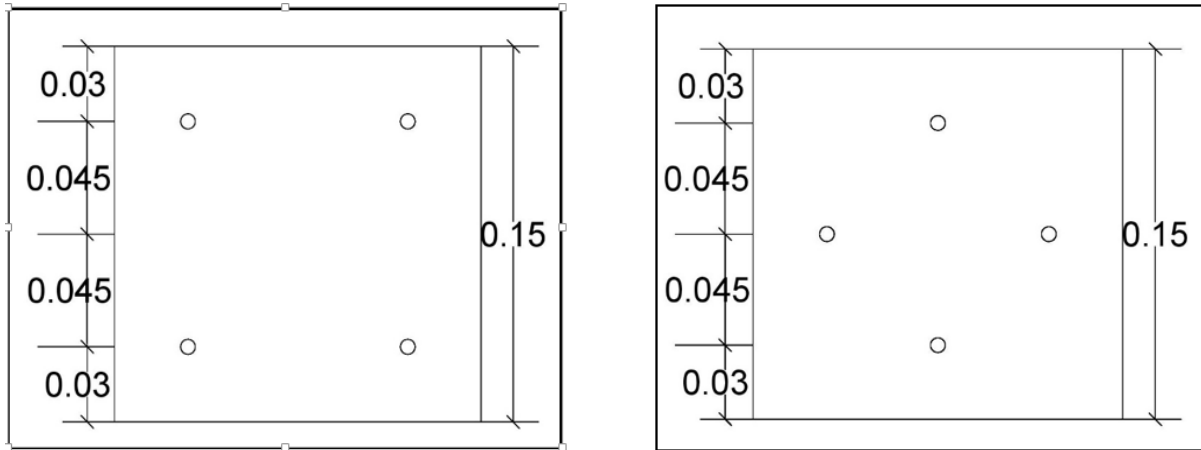
Fig. 2. Diamond and Square configuration (All dimension in mm)

For the visualization, the piled raft with battered angle of 5° is shown in Fig. 3
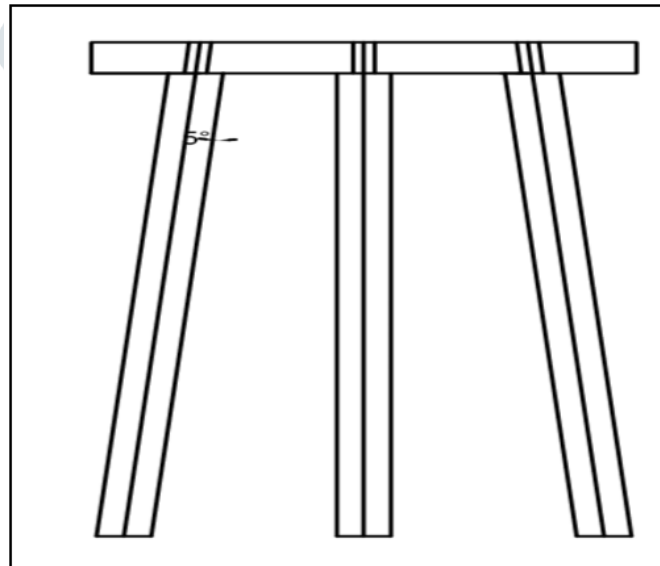
Fig. 3. Diamond and Square configuration (All dimension in mm)

TRIAL SET-UP

The tank is made up from mild steel, having measurement 750mmX750mmX750mm. The loading frame comprises of one ISMB flat pillar supported by two vertical part. The load applied to the piled raft by means of hydraulic jack. Demonstrating proving ring of 2 tons limit is settled at the lower end of the hydraulic jack. Two linear variable differential transducers of 0.01 mm exactness were set at two corners of the raft, opposite to each other. The normal settlement can be get from both of the perusing.

Test Procedure

- Tank of 750 mm height is partitioned in 7 parts each of 100 mm. To maintain RD = 30%, each part is packed with 91.34kg of the sand consistently and top 50mm segment isn't filled.
- The piles are joined to raft at required level of inclination through nuts and driven this entire form in the sand bed such a way that the raft is touching the sand top.
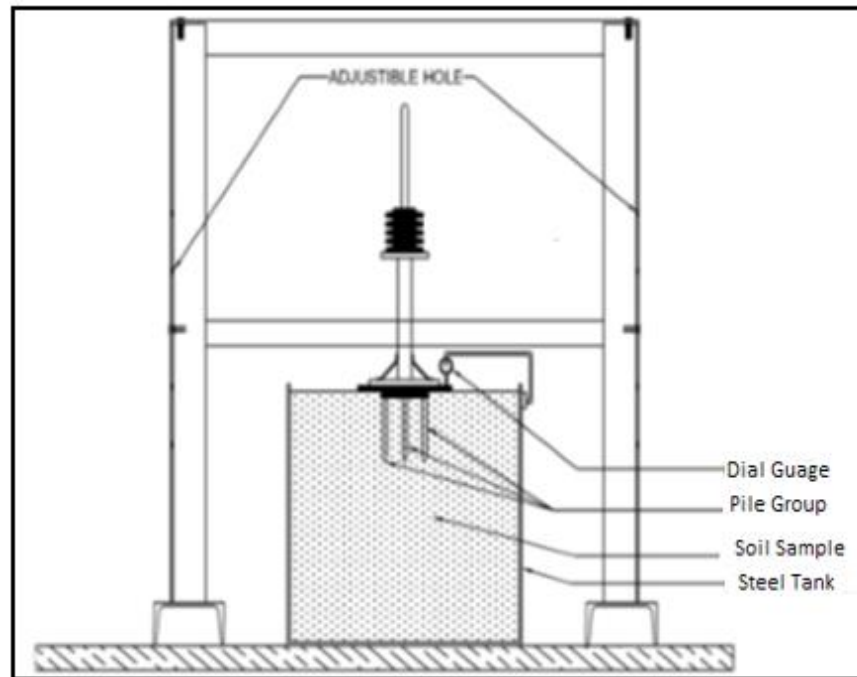
Fig. 4. Set up of test

- To measure the vertical settlement two linear variable differential transducers were set at the two diagonally opposite corners.
- Proving ring, with capacity of 2 tons, is associated with the hydraulic jack to gauge load. The load is applied from the handle mounted on the water driven jack. The load is applied such a way that in one minute the increment in load isn't more than 0.1KN.
- The reading of the proving ring is taken after each 2mm of the relocation. Proving ring examination is taken simply after it gives stable reading.
- Ultimate load limit of the model piled raft is taken as 10% of the raft width. In spite of the fact that readings are taken up to 20mm settlement for every one of the tests.

TEST RESULT AND DISCUSSION

By performing 17 numbers of test, it is observed that piles (either vertical or inclined) under raft will decrease the settlement.

Effect of inclination on settlement is very noticeable. By this enhanced results can be drawn as far as settlement and load carrying capacity is concerned.

Table - 3 shows improvement in load capacity for inclined piles at fixed settlement with respect to only raft and vertical pile of same length and same configuration. The load capacity is compared at 20mm of settlement.

Here, Load improvement ratio is obtained by comparing vertical piled raft with all the battered piled raft models.

As appeared in table there is improvement in the load carrying capacity of the piled raft as the inclination of the piles is increased. This applies for both the setups, diamond and square. From the table, it can be seen that at 33° inclination of each pile in pile group, most extreme load conveying limit is achieved. After 33° of inclination, there is decrement in the limit of the pile group with respect to increase in the inclination.

***Table – 3** Load improvement*

| SR NO.	Raft or Piled Raft	Configuration	Pile Inclination	Load at 20mm settlement (kg)	Load Improvement (%)
1	Raft	-	-	212.77	-
2	Piled Raft	Square	0°	445.53	0.00
3			5°	585.48	31.41
4			7.5°	699.72	57.05
5			15°	716.85	60.90
6			21°	731.13	64.10
7			28°	743.98	66.99
8			33°	755.41	69.55
9			38°	729.70	63.78
10	Piled Raft	Diamond	0°	327.02	0.00
11			5°	395.55	20.96
12			7.5°	581.19	77.72
13			15°	606.90	85.58
14			21°	634.03	93.88
15			28°	656.88	100.87
16			33°	662.59	102.62
17			38°	595.47	82.09
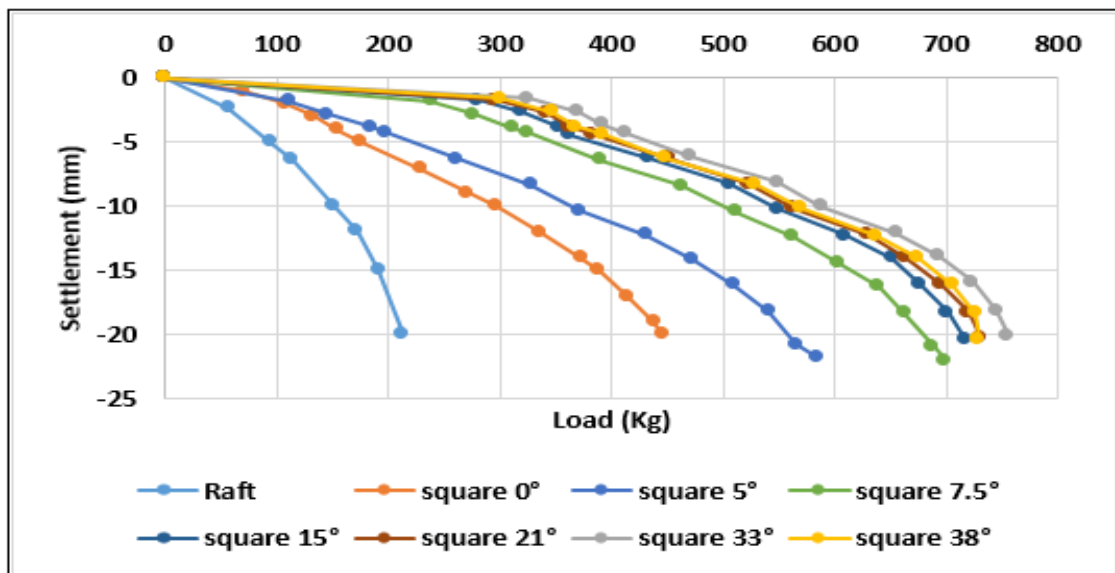
***Fig. 5.** Graph for Square configuration with min. and max. Degree of inclination*
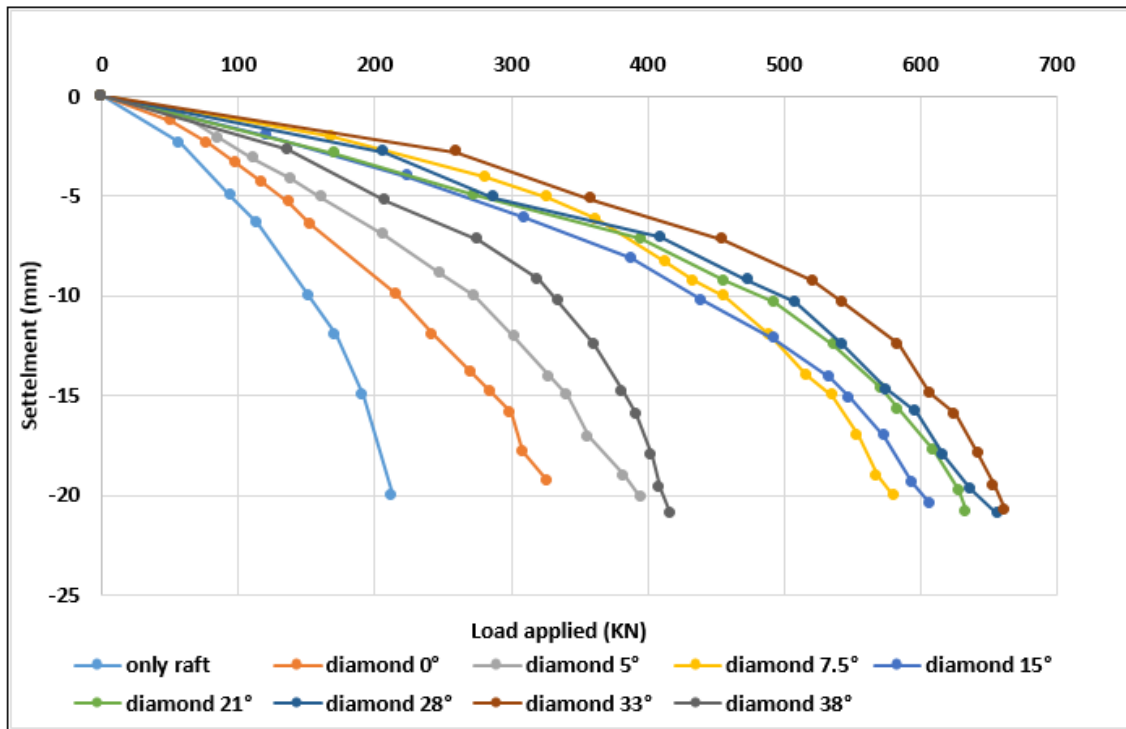
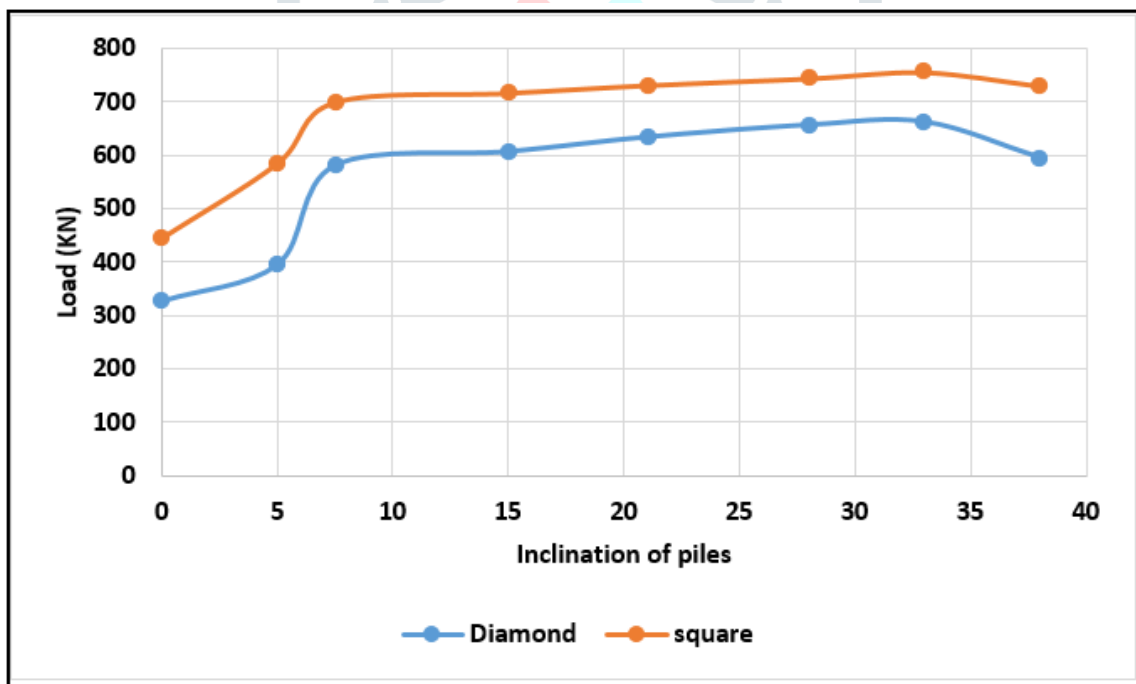***Fig. 6.*** *Graph for Diamond configuration with min. and max. Degree of inclination*

Fig. 7. *Chart for comparison of diamond and square configuration*

To picture this conduct the diverse chart is plotted for square and diamond course of action based on the performed experiment.

Configuration Effect

From fig.7, it can be observed that for all the inclination angles, the square arrangement gives enhanced outcomes than the diamond arrangement.

It gives at least 20% more load taking limit than the diamond arrangement for all the battered angle.

CONCLUSIONS

After performing the laboratory tests at various inclinations and for two configurations, conclusions can be drawn as mentioned below:-

- In the piled raft foundation, the piles can be used as settlement reducers which is conventional approach but they can also be used for increasing the load carrying capacity.
- From two selected configurations, square configuration has shown higher load carrying capacity compared to the diamond configuration.
- Degree of inclination of the piles is observed to play important role in improving the load carrying capacity of the piled raft foundation. For square configuration, 57.05% improvement could be observed at 7.5° inclination compared to the vertical piles.
- However increase in the load capacity with respect to the increase in the inclination could be observed up to 33° only. After this, further increase in inclination has shown decrease in the capacity. That is the optimum angle of inclination should be determined to take the maximum benefit.
- Effect of inclination of piles could be observed on settlements also. With increase in inclination, reduction in settlements could be observed up to 33°.

ACKNOWLEDGEMENT

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