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Load carried by Piles in the Battered Piled Raft Foundation subjected to Vertical Loading

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Abstract—***Piled raft foundation provide more load carrying capacity and that to at a lesser settlement. When lateral load is acting or very heavy load is there on the building, battered piled raft foundation provide stability of the structure considerably. In battered piled raft foundation, materials can be saved compare to vertical piled raft foundation, as there is more optimization of the material. The practical work has been done to decide how much part of the load is carried by the piles in piled raft. From the experimental work it can be said that as the battered angle increases, up to certain limit, the load carried by the piles in piled raft also increases. Load carried by battered piles in piled raft foundation is also compared with two different configuration i.e. Diamond and Square.***

Keywords— Battered piled raft foundation, Battered angle of piles, Configuration of the battered piled raft, % load carried by the piles

I. INTRODUCTION

Foundation transfer the load of super-structure to the soil below. When more than half plan area is covered by footing the raft foundation can be used. The raft foundation can take the load of structure but due to soil condition the settlement criteria cannot be fulfilled. At that time foundation is made up of raft and pile which is known as piled raft foundation. Many tall buildings in the world are made on the piled raft foundation. It is assumed that the pile below the raft is only used for settlement reducer while raft take all the load. This is conventional approach, as per recent research the piles also take some amount of the load coming on the raft. If the piles in the piled raft foundation is inclined to the vertical what is the effect in the load carried by the piles is studied by the experimental work, presented herein.

For the experimental work raft is mild steel plate of 150mm X 150mm X 15mm, diameter of pile is 15mm and length of the pile is 150 mm. By this, length to diameter proportion kept 10. The bed on which tests are performed is maintained at relative density of 30%. Bed prepared is sand bed. Here piles are made of mortar (1:3) reinforced with threaded mild steel bar of 6mm diameter for real approach. Four numbers of Piles are connected to raft in two different pattern one is Square and other is diamond. The testsare performed for different degree of inclination which is shown in Table-1.

TABLE 1TEST TABLE

Sr. No.	Configuration	No. of piles	Angle of inclination
1	Only Raft	-	-
2	Square	4	0°, 5°, 7°, 14°,21°, 28°, 33° and 38°
3	Diamond	4	0°, 5°, 7°, 14°,21°, 28°, 33° and 38°

II. PROPERTIES OF SAND

Different initial test are done to know the properties of the material used to prepare the bed for test. Direct result is written for the test like sieve analysis, pycnometer bottle method and direct shear test.

TABLE 2 SAND PROPERTIES

Co-efficient of curvature (C_c)	**0.8041**
Co-efficient of uniformity(C_u)	**2.5600**
Specefic gravity(G_s)	**2.631**
Max. Density,γ_{max}	**1.83 g/cm^3**
Min. Density, γ_{min}	**1.624 g/cm^3**
Cohesion (C)	**0**
Angle of Internal Friction ϕ	**33°**

III. TEST PROGRAM

The graph is plotted for load versus settlement curve for raft only, vertical piled raft and battered piled raft. By knowing the ultimate load carried by the raft, load carried by the piles can be assumed. For this test, it should be seen that the there is no touching of pressure bulb to the test tank in which the model is placed for testing while the model is loaded. Thus tank dimension should be five times of the dimension of the model raft. The effect of the load applied should not reach up to the base of the tank so, the test tank height should be sufficient.Model piles are made of mortar (1:3) with maintained proportion of the cement and sand. It is strengthen by threaded bar of 6mm. The piles are casted such a way that this threaded bar remain in centre. Length of piles is 150mm and diameter is 15mm. Some portion of the bar is kept outside of the pile which is used as bolt for connecting it to raft with the help of nut. The hole is made in raft of 6mm for the vertical piles and for inclined piles the diameter of the holes is increased. After each test the angle of inclination is increased this way. The figure for square and diamond configuration is shown in Fig.1.

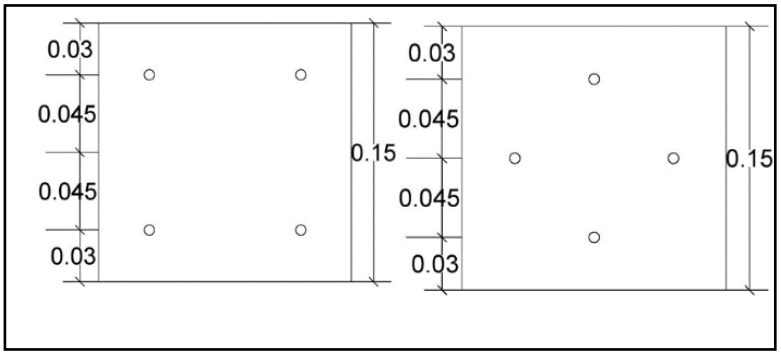

Fig. 1 Square and Diamond pattern (Dimensions are in meter)

IV. TEST SET-UP

The tank is made up from mild steel, having dimension 750mmX750mmX750mm. The loading frame comprises of one ISMB flat pillar supported by two vertical column. 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. The load is applied at the rate of 0.1 kN/min. 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 dial gauge.

A. TESTPROCEDURE

- Tank of 750 mm height is partitioned in 7 parts, each one is of 100 mm, and upper 50mm is not filled with sand. To keep up R_D = 30%, each part is packed with 91.34kg of the sand consistently.
- The piles are attached to raft at required battered angle through nuts and driven this entire model in the sand bed such a way that the raft is just touching the sand top. Model piled raft is shown in Fig.3.

Fig. 2 Test Performance

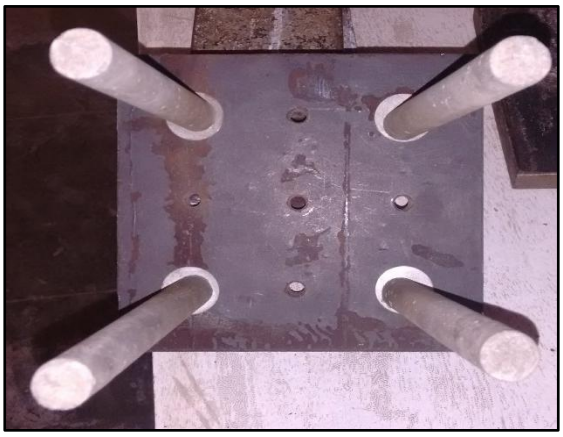

Fig. 3 Model battered piled raft

- To measure the settlement of piled raft model two linear variable differential transducers were placed diagonally at the two corners.
- Proving ring, with limit 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 approximately 2mm of the settlement. Proving ring is read simply after it gives stable reading. The arrangement is shown in Fig.2.
- Ultimate load limit of the model piled raft is taken as 10% of the raft width. This can be said by tangent intersection method after plotting the load versus settlement curve. Although readings are taken up to 20mm settlement for every one of the tests.

V. TEST RESULT AND DISCUSSION

By performing 17 numbers of test, it is said that piles (either vertical or inclined) under raft will take more load from the raft. Thus raft can have lesser bending moment and design accordingly.

Percentage load shared by piles at ultimate load is formulated by,

$$\%\ loadsharedbypiles = \frac{(Qu,pr - Qu,r)\times 100}{Qu,pr}\ \%$$

Where, $Q_{u,pr} = Ultimateloadcarryingcapacityofpiledraft$

$Q_{u,r} = Ultimateloadcarryingcapacityofraft$

TABLE 3 LOAD CARRIED BY PILES IN PILED RAFT

SR NO.	Description	Configuration	Pile Inclination	Load at 20mm settlement (kg)	Load Improvement (%)	Load carried by pile (%)
1	Raft	-	-	212.77	0	-
2	Piled Raft	Square	0	445.536	0.00	52.24
3			5	585.48	31.41	63.66
4			7.5	699.72	57.05	69.59
5			15	716.856	60.90	70.32
6			21	731.136	64.10	70.90
7			28	743.988	66.99	71.40
8			**33**	**755.412**	**69.55**	**71.83**
9			38	729.708	63.78	70.84
10	Piled Raft	Diamond	0	327.02	0.00	34.94
11			5	395.556	20.96	46.21
12			7.5	581.196	77.72	63.39
13			15	606.9	85.58	64.94
14			21	634.032	93.88	66.44
15			28	656.88	100.87	67.61
16			**33**	**662.592**	**102.62**	**67.89**
17			38	595.476	82.09	64.27

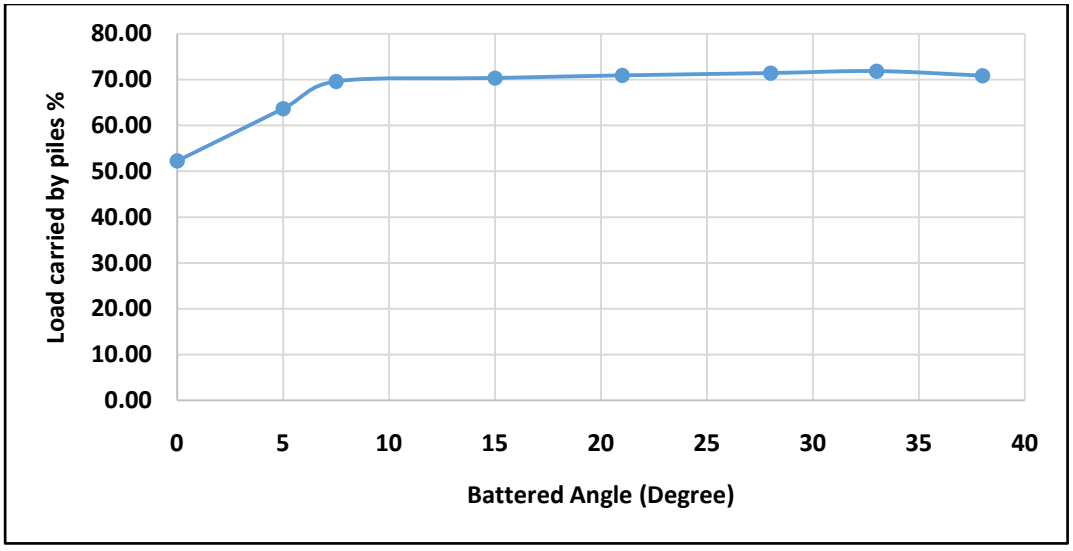

Fig. 4 Graph for load carried by piles in square pattern

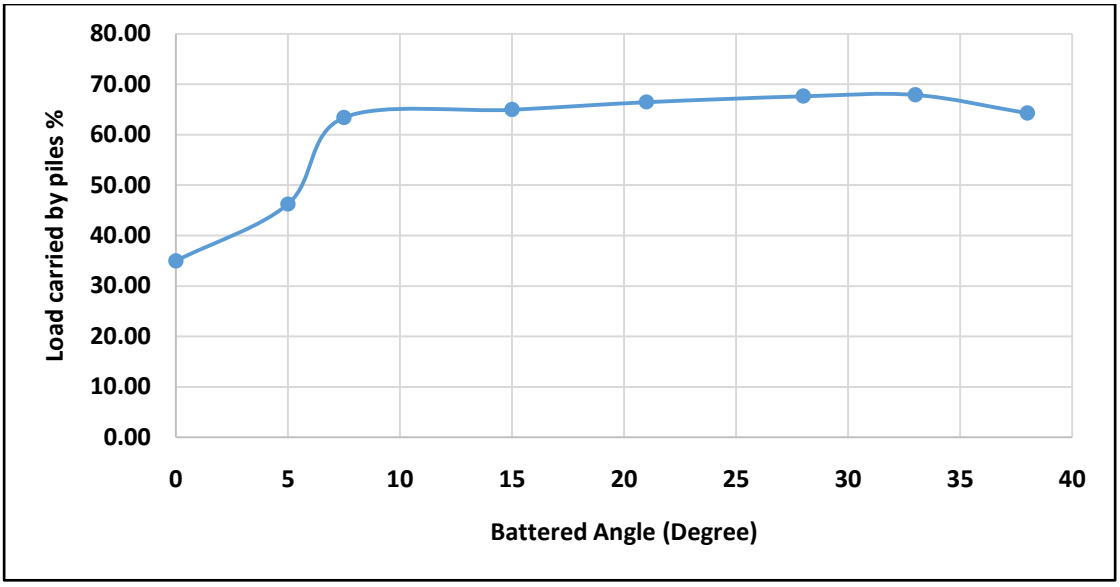

Fig. 5 Graph for load carried by piles in diamond pattern

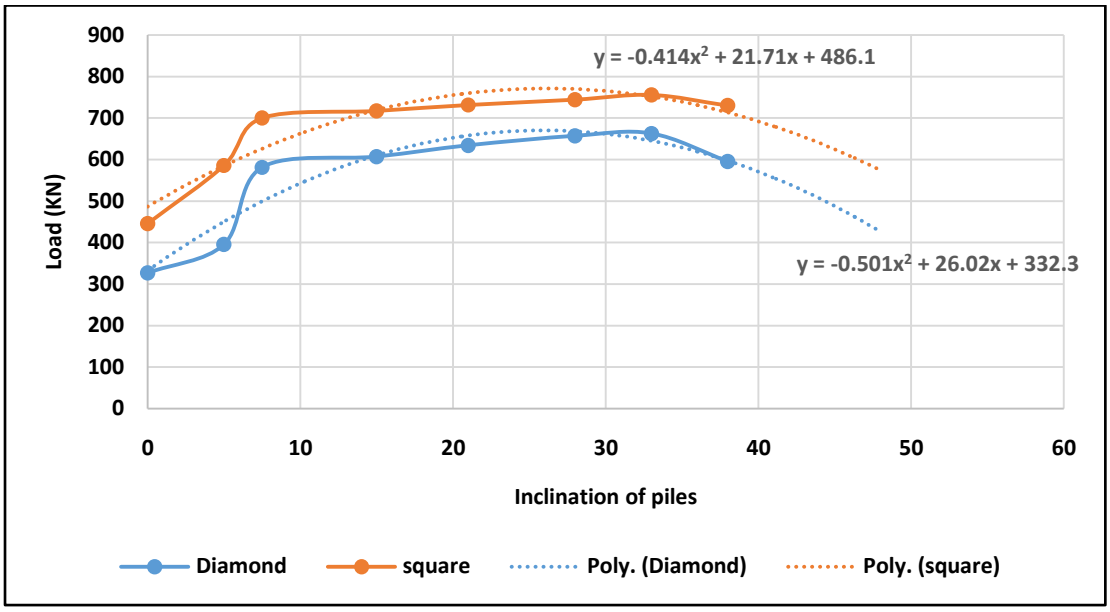

Fig. 6 Prediction for ultimate load carried by the piled raft at different battered angle

Thus from the Table-3, load carried by piles in battered piled raft foundation is more compare to the vertical piles. By making inclination of piles one can get benefit of the material used to the fullest. From Fig. 4 and Fig.5 it can be observed that the load carried by piles in square pattern is more compared to the diamond pattern. Maximum load carried by inclined piles at 33° of inclination.

From Fig.6 load carrying capacity of the piled raft is decided. From trade line (dotted) it can be seen that load carrying capacity cannot be increased after 33° of inclination of piles. So, it can be said that piles take more load at 33° of inclination.

VI. CONCLUSION

1. Square pattern for the piled raft foundation gives more advantage in the load carried by piles.
2. Maximum load carried by piles for particular pattern is at particular degree of battered angle.
3. After 33° of inclination, the load carried by piles is decreasing.

VII. ACKNOWLEDGEMENT

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