ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)
Vol 4, Issue 6, June 2019

Vertical and Lateral Load Behaviour of Piled Raft with Batter Piles

[1] Nimisha Baby, [2]Rubia Sulekha Basheer
[1] P.G. Student, Department of Civil Engineering, IES College of Engineering, Chitilapilly Trissur, India
[2] Assistant Professor, Department of Civil Engineering, IES College of Engineering, Chitilapilly Trissur, India

***Abstract:* - A piled raft foundation is a widely adopted concept in which the total load coming from the superstructure is partly shared by the raft through contact with soil and the remaining load is shared by piles through skin friction. Piled raft foundations are usually applied to support heavy structures such as high-rise buildings, bridges, wind-turbine towers and offshore structures, etc. When these structures are subjected to large horizontal loads caused by wind loads, water wave loads or earth quakes, a conventional approach to increase the horizontal resistance is the use of batter piles in addition to vertical piles. Experimental work was carried out in the laboratory on piled raft which consist of 9 piles, to investigate the vertical and lateral response of batter piled raft. Axial load test and lateral load test were conducted on piled raft with different batter angle for batter piles. Test were conducted on two relative densities (RD) such as 30% RD (loose condition) and 50% RD (medium dense condition). It is found from the experiments that batter piles have positive effects on the behaviours of the raft foundations such as increase of the load carrying capacity and decrease of the displacements caused by the vertical and lateral loading.**

Index Terms—Batter pile, Lateral load test , Piled raft, Plate load test

I. INTRODUCTION

Raft foundations are shallow foundations formed by a reinforced concrete slab of uniform thickness covering a wide area, often the entire footprint of a building. When a essential raft foundation does not provide adequate support, it can be enhanced by the addition of piles which is together known as piled raft foundation. Piled raft foundations are typically used for large structures and in situation where soil is not suitable to prevent excessive settlement. They are an increasingly popular choice for high rise buildings. When these structures are subjected to large horizontal loads caused by wind loads, water wave loads or earth quakes, a conventional approach to increase the horizontal resistance is the use of batter piles in addition to vertical piles. Batter piles are inclined piles which are driven at an angle to the vertical. These batter piles are very effective in carry lateral loads. Batter piles carry lateral forces mainly by axial compression and tension.

Applications of piled raft foundations to buildings are increasing in the world to reduce average and/or differential settlement, e.g. Harry et al. (2011), Baleshwar et al. (2011) and Alnuiam et al. (2013). Experimental studies as well as numerical analyses on piled raft foundation have been conducted, e.g. Matsumoto et al. (2004), Muhammed et al. (2013), Ghasemian et al. (2015). Number of studies on batter piles were reported, e.g. Mehul et al. (2011), Isam et al. (2012), Sadek et al. (2004) and Subramaniyan at al. (2016). However, the researches just only investigated the behaviours of pile group with batter piles or single batter pile and the behaviours of pile raft foundations having batter piles have not been fully understood

This research was carried out to investigate the vertical and lateral behaviour of batter piled raft having 9 piles with different batter angle for batter piles.

Fig. 1 Batter piles under bridge pier

II. MATERIALS USED

Locally collected clean river sand was used in all the experiments as a soil medium. A square raft model of sides 200mm x 200mm and with thickness 16mm was used in this study.This represents the behavior of foundation of a square raft of multi storied building. 9 piles are used in the piled raft. The model piles were circular hollow pile being hollow mild steel pipe having 18mm outer diameter and 1mm thickness. The tips of the piles were closed. The pile diameter was kept constant to represent pile diameter of 0.9m in the actual case.

The c/c distances between the piles at the top surface was 3.5D (=63 mm), where D is diameter of pile. The length of the pile tested were 288mm (L/D = 16), 324mm (L/D = 18) and 360mm (L/D = 20) where L is the length of pile.

Fig. 2 Sand

Fig. 3 Steel Piled Raft

A. Properties of Sand

Table. I Index properties of sands

Parameters	Value
Specific Gravity	2.640
Effective size, D10 (mm)	0.21
D30 (mm)	0.520
D60 (mm)	0.900
Uniformity coefficient, Cu	4.28
Coefficient of curvature, Cc	1.43
Gradation of sand	SP
Maximum density (g/cc)	1.698
Minimum density (g/cc)	1.440
Sand density (30% RD) (g/cc)	1.508
Sand density (50% RD) (g/cc)	1.558
Angle of internal friction (30% RD) (degree)	39
Angle of internal friction (30% RD) (degree)	45

III. EXPERIMENTAL PROGRAMME

The vertical and lateral response of batter piled raft is investigated using a laboratory model experiments. Experiments were done in a test tank of size 1000 mm x 1000 mm x 600 mm, made up of steel sheet of thickness 5mm. Sand is filled in the tank in layers. Predetermined quantity of soil is filled in layers with a spacing of 50mm. Each layer was compacted to achieve the desired density. Pile raft is placed in desired embedment depth and continue the filling of sand till it reaches the top of the piled raft and level the top surface of sand bed.

The axial The load was applied by means of a hydraulic jack which was clamped to the reaction frame and its hose was connected to the lever system. The load was applied to the model piled raft by using reaction frame through the hydraulic jack and proving ring. A calibrated proving ring of capacity 100 kN and dial guage of 25 mm capacity with sensitivity of 0.01 mm are used for measuring loads and displacement respectively. The test was started by applying load using hand operated hydraulic jack. The pile was loaded at a constant loading rate until an ultimate bearing state was reached. Batter piled raft were fabricated with different batter angles 00,100, 200and 300

In lateral loading test, the load is applied through the pulley system. A dial gauge of 25 mm of sensitivity 0.01 mm was used to measure the lateral movement of the piled raft. The load was applied laterally through pulleys fixed on the left side of the tank through a steel wire attached to the hanger fixed at the centre of the raft. The load was applied incrementally and corresponding deflection from the dial gauge was noted. The loading was continued until the total horizontal displacement of piled raft reached 12 mm.

Fig. 4 Axial loading set up

Fig. 5 Lateral loading set up

IV. RESULTS AND DISCUSSIONS

A. Vertical Load Test Results

Axial load is applied at the top of the piled raft for obtaining vertical behavior of batter piled raft in sand. Batter angle of batter piled raft was changed 00, 100, 200 and 300 to obtain the effect of batter angle on vertical load capacity.

The advantages of the battered piled rafts over the vertical piled raft can be found in Fig.6 and Fig.7. By making inclination of piles one can get benefit of the material used to the fullest. The ultimate bearing capacity of the battered piled raft is much higher than that of the corresponding vertical piled raft, and the settlement of the battered piled raft is smaller than that of the corresponding vertical piled raft. Vertical load capacity of the battered piled raft increases as the batter angle increase up to 200 and then it decreases. Both the axial forces and bending moments in the piles of batter piled raft is larger than that of the piles in vertical piled raft. This may be the reason for increased bearing capacity and resistance of battered piled raft than that of vertical piled raft. When the batter angle increases, ultimate vertical load capacity of piled raft increases up to 17 % in both loose fill and medium dense fill conditions. The vertical displacement of the piled raft decreases up to 12% and 19% in loose fill and medium dense fill conditions respectively.

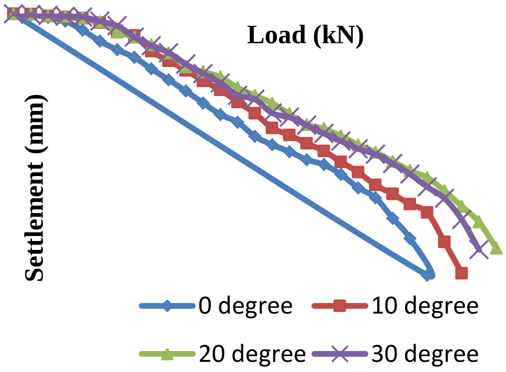

Fig. 6 Axial load-displacement graph of battered piled raft in loose sand fill

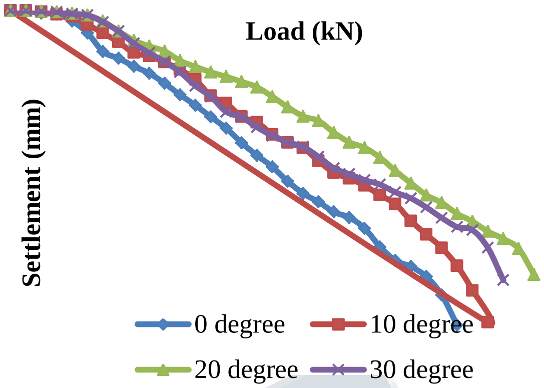

Fig. 7 Axial load-displacement graph of battered piled raft in medium dense sand fill

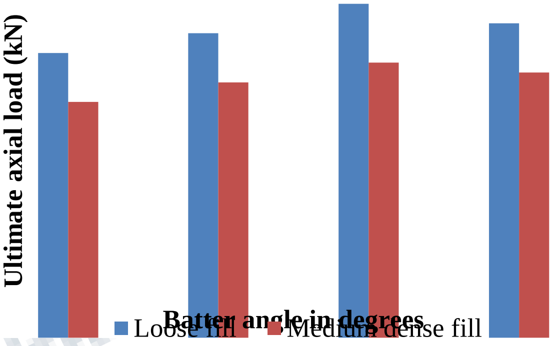

Fig. 8 Ultimate axial load capacity variation battered piled raft in loose and medium dense fill

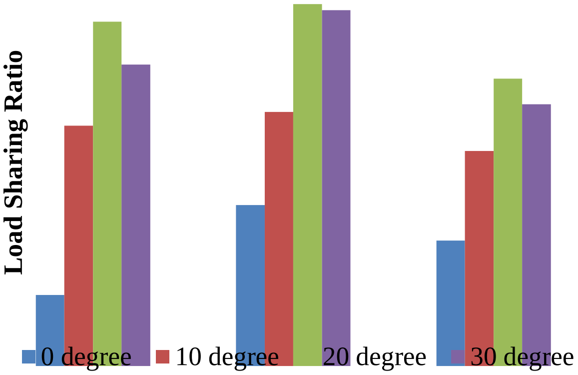

Fig. 9 Load sharing ratio for battered piled raft

Ultimate axial load capacity battered piled raft increases with increse in sand density as shown in Fig. 8. The load sharing ratio at corresponding settlement is given by equation 1:

$$\alpha PR = (P_{PR}-P_R)/P_{PR} \qquad \text{Eq.1}$$

Where αPR= load sharing ratio, P_{PR} = load carried by piled raft, P_R = load carried by raft

The load sharing behaviour of the pile group of piled raft on vertical loading is presented in the form of bar chart in Fig. 9. Load sharing ratio at 4mm settlement is found to be more than load sharing ratio at 2mm and 6mm. Piled raft with 200 degree battered piles have higher load sharing ratio than other battered piled raft.

B. Lateral Load Test Results

Lateral load capacity of battered piled raft increases as the batter angle increases up to 200, and then decreases in both loose fill and medium dense fill conditions as shown in Fig. 10 and Fig. 11. Reduction of overlapping of shear zones in the surrounding soil of each pile is the main reason for relatively higher lateral load resistance of batteres piled raft when compared to the vertical piled raft. As the batter angle increases, lateral load capacity is also increases. This is due to linear increase of distance between two piles with pile length towards the bottom. Horizontal component of axial resistance can take some amount of lateral force. So as the batter angle increases, horizontal component of axial resistance and also lateral capacity of batered piled raft increases. When the batter angle increases the lateral load capacity of piled raft increases upto 50% and 56% in loose fill and medium dense fill conditions. Ultimate lateral load capacityof battered piled raft increases with increse in sand density as shown in Fig. 12.

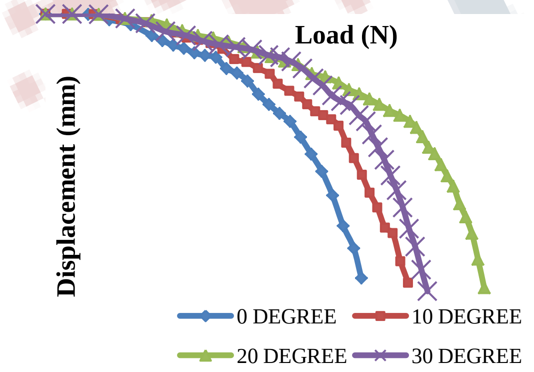

Fig. 10 Lateral load-displacement graph of battered piled raft in loose sand fill

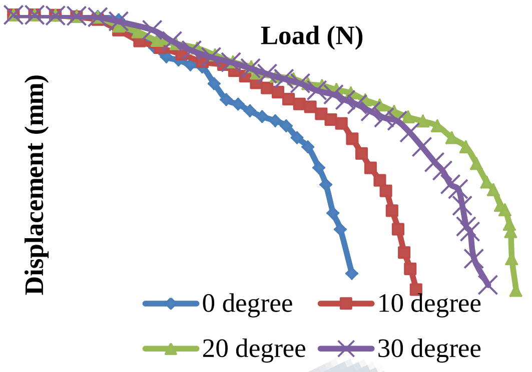

Fig. 11 Lateral load-displacement graph of battered piled raft in medium dense sand fill

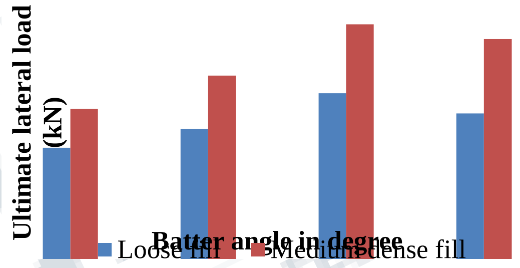

Fig. 12 Ultimate lateral load capacity variation battered piled raft in loose and medium dense fill

CONCLUSION

Battered piled raft configuration has greater vertical load capacity than vertical piled raft configuration in loose fill and medium dense fill soil conditions

Ultimate vertical load capacity of battered piled raft in both loose fill and medium dense fill conditions increases up to 200 and then decreases.

Load sharing ratio at all settlement is found to be more for battered piled raft than vertical piled raft.

Lateral load capacity of battered piled raft increases with increasing batter angle up to 200 and then decreases in both loose fill and medium dense fill soil conditions.

Lateral load capacity of batter piled raft is about 1.5 times the vertical piled raft.

REFERENCES

[1] Ahmed and Hari, “3D modeling of piled raft foundation subjected to vertical loading.” ResearchGate. Vol 3, 2016.

[2] A. Alnuiam , H. Naggar and M.H Naggar, “Performance of Piled-Raft System under Axial Load.” Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical

Engineering, Paris, 2013.

[3] Anh-Tuan Vu, Tatsunori Matsumoto, "Behaviour of pile groups and piled raft foundation models having batter piles." ReasearchGate;Vol. 2, pp 27-40, 2016.

[4] Baleshwar Singh and T.S. Ningombam, "Influence of Piles on Load settlement Behaviour of Raft Foundation." International Journal of Engineering Science and Technology: Vol 3, 2011.

[5] L. Ghasemian , B. M. Panjalizadeh, B. Heidarpour , Ekramirad and Hosseinnezhad, "Dimensional Optimization of Piled Raft Foundation."Research Journal of Recent Sciences; Vol: 4, 2015

[6] G. Harry and C. John, " Piled Raft Fundations for Tall Buildings" ResearchGate: Vol:42, 2011.

[7] Hamada, T. Suchiya ,Tanikawa and Yamashit, "Lateral Loading Tests on Piled Rafts and Simplified Method to Evaluate Sectional Forces of Piles" Geotechnical Engineering Journal of the SEAGS & AGSSEA: Vol:46, 2015

[8] .Jaymin, A. Sandeep, Vasanwala, Chandresh, H. Solanki, " An experimental investigation on behavior of piled raft foundation" International Journal of Geomatics and Geosciences : Vol.5, 2014

[9] H. Kenichi, M. Tansunori and F. Hideki, " Perfomance of Piled Raft Foundtions Subjected to Static Horizontal Loads." International Journal of Physical Modelling in Geotechnics; Vol:2, 2003

[10] M. Krishna and S. Neelima, "Load Carrying Capacity of Laterally Loaded Batter Piles." Indian Geotechnical Conference GeoNEst, 2017.