Experimental Investigation on Behavior of Piled- Raft Foundation

Vedprakash C. Marlapalle[1], Dr. Ramachandra Hegde[2], Rohan Dasgupta[3], Wasim Shaikh[4]
Department of Civil Engineering
[1, 3, 4] AIKTC, New Panvel, Navi Mumbai.
[2] MPSTME, Vileparle, Mumbai.

Abstract-*In the piled-raft foundation systems the load is assumed to be shared between the piles and raft. Therefore, this improves the ultimate load capacity and reduces settlements in a very economic way as compared with the traditional foundation concepts. The use of strategically located piles improves the load capacity of raft and reduces the differential settlement. This research sheds some light on the philosophy of using piles as settlement reducer for raft foundation and also the behavior of pile length and alignment on the attained ultimate load are experimentally investigated. The experimental program includes the model test on unpiled raft, raft supported by single pile, (2x2), (3x3) and (4x4) pile groups. From the accomplished studies, it has been concluded that as the number of piles underneath the raft increases, load carrying capacity of foundation increases. Also, there is a negligible effect on load improvement ratio and settlement reduction ratio with increase in raft thickness and number of piles. The observed settlement values from Experimental study was compared with numerical modeling using PLAXIS-3D and found the results are in good agreement.*

Keywords- Piled-Raft, PLAXIS-3D, Ultimate Load, Foundation.

I. INTRODUCTION

Piled-Raft foundation is continuously being developed to achieve more economical foundation along with safety and serviceability of the structure. Piled-raft foundation has been applied to high-rise buildings all over the world and increasingly being recognized as economical foundation system. The concept of piled-Raft foundation was born out of the fact that any structure has a certain permissible settlement and the foundation system has to aim at reducing the settlement as close to the permissible value rather than eliminating the settlement completely. The piled-Raft foundation system provides a skilful geotechnical concept where in the applied load is transferred by means of a load sharing mechanism which is generated through a process of interaction between the pile, soil and Raft. They introduced factors reflecting the efficiency of interference for bearing capacity between footings.

In this research work, laboratory model tests were conducted on plain raft and piled raft with different configurations of piles supported on medium dense sand condition. The laboratory model tests were carried out on a model raft of size 150 mm x 150 mm and thickness 5mm. Tests were also conducted on model piled raft consisting of raft of same size and piles of 10 mm diameter and length 200, 300 & 400mm. eight different configurations of piles were used in this study viz; piles uniformly distributes over raft area, piles in central portion of raft, Using identical standard testing procedure, the model tests were conducted on a raft alone and piled raft with different configurations of piles. From the test results, the effects of configurations of piles, load sharing ratio and settlement reduction ratio was studied.

II. PEXPERIMENTAL PROGRAMME

The main purpose of experiment is to study the load sharing mechanism between the raft and piles as well as the load settlement behaviour of the piled raft foundation with different configurations.

For this purpose, a laboratory study was conducted on model piled raft with differing number of piles and configurations of piles. The materials used for the study, model raft and model piles are discussed in following section:

Properties of Material

- Sand dry density = 1.7gm/cc,
- Sp. Gravity = 2.69 , Cu = 2.15, Cc = 1.018
- D10 = 1, D30= 1.48, D60 = 2.15.
- Angle of internal friction $\Phi = 31^{\circ}$

Set-Up for Experimental Work

The apparatus consists of steel frame with a hydraulic jack, steel container, loading frame and accessories:

This test is carried out in a steel frame tank with dimensions of 85cm × 65cm and 65cm depth, bounded by Steel plate is 4 mm in thickness. The container is sufficiently

rigid and exhibited no lateral deformation during the preparation of the soil bed and during the application of loads. There is provision of small hole which is closed by a tap to provide different drainage condition and to vary the pore water pressure.

Loading Machine

The vertical load is applied on the model of piles, raft and piled raft. A digital indicator gauge is used for measuring the displacements of the piled raft model. The test results are saved by a digital Recorder.

Models of the Piled Raft

The pile models used as mild steel pile of length 20, 30 and 40 cm respectively and of 1 cm diameter. The embedment length ratio L/D= 20, 30 and 40 respectively. The spacing between piles is kept constant about 3 times the diameter of the pile. The model of raft used is a square steel plate of 15 ×15 cm and thickness is 5 mm.

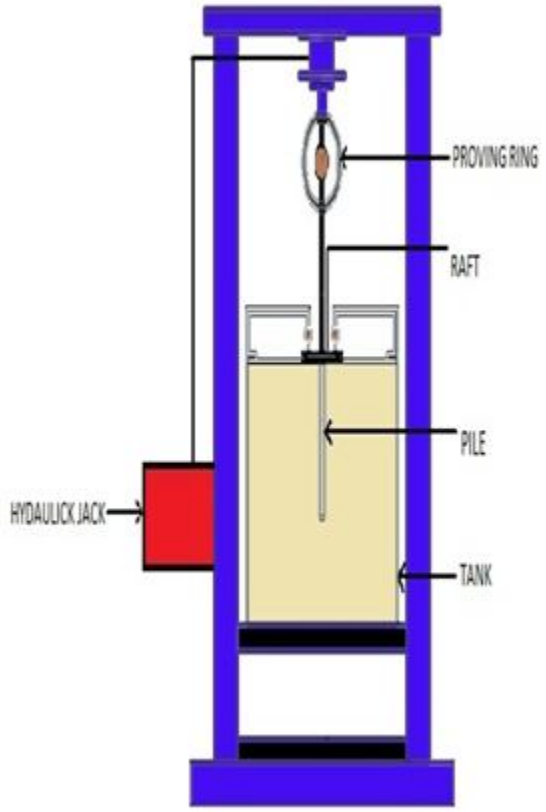

Fig. 1 Schematic diagram of Loading Frame used in Experimental Investigations

Table 1. Experimental Configuration Used in Piled-Raft Foundation

Study Cases	Raft Model Size in mm	No. of Piles
Unpiled- Raft	150x150x5	----
Raft+1 Pile	150x150x5	1
Raft+2 Pile	150x150x5	2
Raft+3 Pile	150x150x5	3
Raft+4 Pile	150x150x5	4
Raft+6 Pile	150x150x5	6
Raft+9 Pile	150x150x5	9
Raft+12 Pile	150x150x5	12
Raft+16 Pile	150x150x5	16

III. TEST PROCEDURE

The detailed test procedure adopted for experimental investigation is explained below:

Preparation of Sand Bed

Sand was poured in tank by rainfall method, In order to achieve required density in all the tests. The total height of the tank was divided into intervals of 50 mm. The tank was filled with sand up to a depth of 400 mm by using the sand rainfall technique. In the present investigation the height of fall was selected as 30 cm in rainfall technique and the corresponding relative density was maintained at 40 %. After completely filling the tank with the sand to the required level, the bed was levelled and checked using spirit level. Preparation of sand bed was then continued till the full depth of sand bed. The top surface of sand bed was then levelled and then model raft was kept over the sand bed, with the pile passing through the holes made in the raft. The piles were then fixed to the raft by bolts so that piles and raft acted as a monolithic structure.

Model Plate Load Test

After the preparation of sand bed along with piled raft the load was applied on the raft in increments of one-tenth of estimated ultimate bearing capacity and the settlements were recorded. Each load increment was kept constant till the rate of settlement became less than 0.02 mm/min. The next increment of load was then applied and the settlement was measured. The test was continued till the failure of foundation or until settlement reached to 10 % of width of raft i.e. 15 mm.

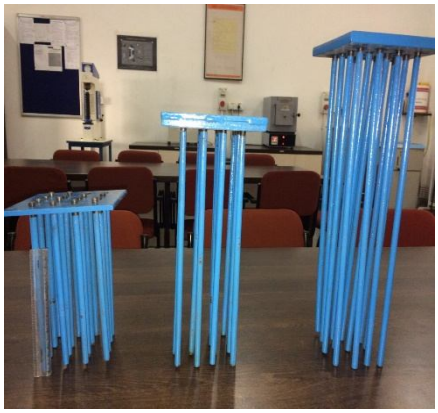

Fig 2. Photograph Showing Piled-Raft Model

Fig 3. Photograph Showing loading on Piled –Raft Foundation

The experimental results obtained from laboratory tests are analyzed and discussed in this section. The load was applied incrementally until reaching failure. Each load increment was maintained at a constant value until the raft settlement had stabilized. Table 2 shows the load-settlement behavior of unpiled raft and raft with 1,2,3,4,6,9,12 and 16 piles for raft size 150 mm x 150 mm x 5 mm thickness. It can be noted that, when number of piles increases, the bearing capacity of piled raft increases.

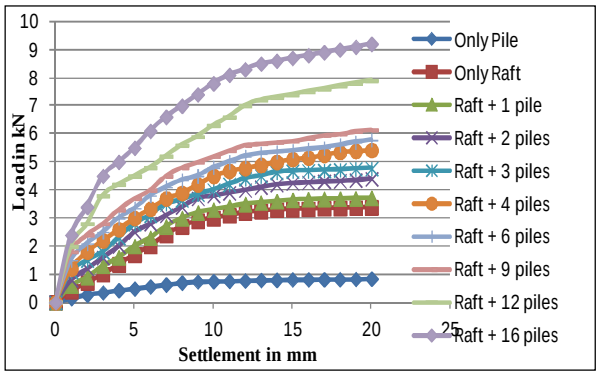

Fig. 4 Settlement Vs Load Curve for Pile length 200mm, Raft Size 150x150x5mm

IV. TESTS RESULTS AND DISCUSSION

Table 2. Settlement to Load results for Raft Size 150mm x 150mm x 5mm, Pile Length = 200mm, Dia. = 10mm

Settlement (mm)	Only Pile (kN)	Only Raft (kN)	Raft + 1 pile (kN)	Raft + 2 piles (kN)	Raft + 3 piles (kN)	Raft + 4 piles (kN)	Raft + 6 piles (kN)	Raft + 9 piles (kN)	Raft + 12 piles (kN)	Raft + 16 piles (kN)
0	0	0	0	0	0	0	0	0	0	0
1	0.15	0.4	0.6	0.8	1.1	1.2	1.5	1.8	2	2.4
2	0.28	0.7	0.9	1.2	1.5	1.8	2.1	2.4	2.8	3.4
3	0.35	1	1.3	1.6	1.8	2.2	2.5	2.8	3.8	4.5
4	0.43	1.35	1.6	2	2.3	2.6	3	3.3	4.2	5
5	0.49	1.7	2	2.5	2.8	3	3.35	3.7	4.5	5.5
6	0.56	2	2.3	2.8	3.1	3.33	3.8	4	4.8	6.1
7	0.63	2.4	2.7	3.1	3.5	3.7	4.1	4.5	5.2	6.6
8	0.7	2.7	3	3.4	3.65	3.89	4.35	4.8	5.6	7
9	0.74	2.9	3.2	3.7	3.85	4.2	4.5	5	5.9	7.4
10	0.75	3	3.3	3.8	4	4.5	4.8	5.2	6.3	7.8
11	0.76	3.1	3.4	3.9	4.2	4.68	5	5.4	6.6	8.1
12	0.78	3.2	3.5	4	4.4	4.78	5.2	5.6	7	8.3
13	0.79	3.25	3.55	4.1	4.5	4.89	5.3	5.65	7.2	8.5
14	0.8	3.3	3.6	4.2	4.63	5	5.35	5.7	7.3	8.6
15	0.81	3.32	3.65	4.25	4.67	5.1	5.4	5.75	7.4	8.7
16	0.81	3.33	3.67	4.27	4.68	5.15	5.45	5.85	7.5	8.8

17	0.82	3.35	3.68	4.3	4.7	5.25	5.5	5.95	7.6	8.9
18	0.82	3.36	3.69	4.32	4.72	5.35	5.6	6	7.7	9
19	0.83	3.37	3.7	4.35	4.75	5.39	5.7	6.1	7.8	9.1
20	0.84	3.38	3.72	4.4	4.77	5.42	5.78	6.15	7.9	9.2

V.CONCLUSION

The paper has presented load test results on model piled raft in sand soil to investigate the load-settlement behavior and load sharing between the piles and raft. From the results of this study, the following conclusions can be drawn:

1. For the piled-Raft models, the total carrying capacity of the model increased with increasing the number of piles in the group.
2. The change in configuration of piles over the raft areahas a significant effect on the ultimate bearing capacityofpiled raft foundation.
3. At 10 mmsettlements, the load improvement ratioincreases as the number of settlement reducing pilesincreases.
4. The efficiency of piled- Raft foundation system in reducing settlement is minimal beyond a 12 number of piles.

REFERENCES

[1] Bajad S.P., Sahu R.B., (2008), an experimental study on the behavior of vertically loaded piled raft on soft clay, The 12th Intl. Conf. of International Association for Computer Methods and Advances in Geomechanics (IACMAG), pp 84–90.

[2] Basuony El-Garhy, Ahmed Abdel Galil, Abdel-Fattah Youssef, Mohamed Abo Raia Behavior of raft on settlement reducing piles: Experimental model study Journal of Rock Mechanics and Geotechnical Engineering 5 (2013) 389–399

[3] Burland J.B., Broms B.B., and de Mello, V.F.B., (1977), Behavior of foundations and structures, Proc.9 ICSMFE, Tokyo 2, pp 495-546.

[4] Burland JB. Piles as settlement reducers. In: The 8th Italian Conference on Soil Mechanics; 1995.

[5] Clancy P., and Randolph, M.F.,(1993),An approximate analysis procedure for piled raft foundations, International Journal of Numerical and Analytical Methods in Geomechanics, 17(12),pp 849–869.

[6] EI-Garhy B., Galil A.A., Youssef A.F., Raia M.A.,(2013),Behavior of raft on settlement reducing piles: Experimental model study, Journal of Rock Mechanics and Geotechnical Engineering, pp 389–399.

[7] E.Y. N Oh, Q. M. Bui, C. Surarak, R. Adamec and A. S. Balasurbamaniam Parametric Study on Piled Raft Foundation in Sand Using Numerical Modeling.

[8] Fioravante V, Giretti D, Jamiolkowski M. Physical modeling of raft on settlement reducing piles. In: In: From Research to Practice in Geotechnical Engineering. Reston; 2008. p. 206–39.

[9] Horikoshi K., and Randolph M.F., (1996), Centrifuge modeling of piled raft foundation on clay, Geotechnique, 46(4), pp 741–752.

[10] J. Patil, Vasanwala S A, and Solanki C H Investigation of The Behavior of Piled Raft In Sand: An Experimental Study. ISSN 2319 – 6009 www.ijscer.com Vol. 4, No. 1, February 2015.

[11] Katzenbach, R., Arslan, U., Moormann, C., and Reul, O., ‘‘Piled Raft Foundation -Interaction between Piles and Raft’’ Proc., Int. Conf. on Soil- Structure Interaction in Urban Civil Engineering, Darmstadt Geotechnics, 2, pp. 279-296, Darmstadt University of Technology, Darmstadt, Germany, 1998

[12] Lee S.H., and Chung C.K.,(2005),An experimental study of the interaction of vertical loaded pile groups in sand, Canadian Geotechnical Journal, vol 42, pp 1485-1493.

[13] AL-Qaissy,Hussein H. Karim, Mudhafar K. Hameedi Behavior of Experimental Model of Piled Raft Foundations on Clayey Soils 1st International Conference for Geotechnical Engineering and Transportation ICGTE in2415/4/2013

[14] Mandolini A. and Viggiani C.,“ Settlement of Piled Foundations” Geotechnique, Vol. 47, pp.791-816, 1997.

[15] Phung DL. Piled raft – a cost-effective foundation method for high-rises. Geotechnical Engineering Journal of the SEAGS&AGSSEA 2010;41(3):1–12.

[16] P. Garg, H. Singh, J. N. Jha Optimization of Piled-Raft Foundation https://www.researchgate.net/publication/236015109.

[17] R. S. Bisht, B. Singh, Study on Behavior of Piled Raft Foundation by Numerical Modeling. SAITM Research Symposium on Engineering Advancements (SAITM – RSEA 2012).

[18] Randolph MF. Design methods for pile groups and piled rafts. In: Proc. 13th Intl. Conf. on Soil Mechanics and Foundation Engineering; 1994. p. 61–82.

[19] S. W. Thakare , P. Dhawale Performance of Piled Raft Foundation on Sand Bed, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 6, June 2016.

[20] S. F Ibrahim, H. F.Hasan, Amjad I. Fadhil Evaluation of Bearing Capacity For Model Piles Driven In Sandy Soil, Journal of Engineering and Development, Vol. 18, No.3, May 2014, ISSN 1813- 7822.

[21] Sanctis LD, Mandolini A, Russo G, Viggiani C. Some remarks on the optimum design of piled rafts. In: In: Deep Foundations 2002: An International Perspective on Theory, Design, Construction and Performance. Orlando: ASCE; 2002. p. 405–2