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COMPARATIVE STUDY OF PILED RAFT FOUNDATION ON SAND

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Abstract: In civil engineering and construction, a piled raft foundation, also referred to as a raft with piles or a piled mat foundation, is one kind of foundation structure. It is frequently used to poor soil conditions, such as soft clay, loose sand, and extremely compressible soils. To increase load carrying capacity and settlement, the piled raft foundation combines the advantages of deep foundations and shallow raft foundations. It's crucial to keep in mind, nevertheless, that the design and building of PRF need for meticulous engineering study and consideration of site-specific factors, including soil conditions, structural loads, and foundation system behaviour. The study focuses on the PRF system's vertical load carrying capacity and settlement reduction under both eccentric and concentric stress on sand. To find out how different pile alignment and length affected the PRF's ultimate load, small-scale model tests are carried out. The study's findings suggest that the PRF system can minimize differential settlement and boost the raft's load bearing capacity by carefully placing the piles in optimized position. The study specifically aimed at how changing the pile's length to diameter (L/D) ratio affected their ability to support loads. The results of the research work indicate that strategical placing the piles in the PRF system improve the load bearing capacity and reduce the settlement.

***Keywords:* Piled raft foundation, cohesion less soil, Load improvement ratio**.

I. INTRODUCTION

A PRF consists of a large, stiff concrete slab(raft) that spreads the load from the structure over a wider area. This helps to reduce the stress on the soil below the foundation and control settlement. The loads from the structure are transferred to the raft. Piles are long slender structural elements made of concrete, steel or timber. They are designed to penetrate the weak soil layers and reach more stable and load bearing strata. The piles transfer a significant portion of the load to deeper, more competent soil layers, while the raft helps distribute the load evenly over a large area. This combination of load transfers a significant part of the load to deeper, more competent soil layers, while the raft helps to distribute the load evenly over a large area. This combination of load transfer techniques reduces the risk of excessive settlement and ensures the stability of the foundation. When raft (mat) foundations are supported by a piling group, they have been demonstrated to be capable of supporting extremely large loads. When estimating the contribution of both raft and piles to carrying the surcharge loads, the stiffness and strength of the soil linked elements in the system, in cases where isolated footings occupy more than 70% of the building area, raft foundations are employed. To enhance the load carrying capacity of the raft and reduce differential settlement, strategically positioned piles are utilized in the PRF system. This research aims to explore the effectiveness of piles in reducing settlement and improving the performance of the PRF, specifically in sand soil conditions. To investigate these aspects, small scale model experiments are conducted. The experiments involve varying length of pile and alignment to examine their effects on the ultimate load achieved by the piled raft foundation. Eslami et al. [1]: The exploration of three case studies using FE analysis to examine connected and disconnected PRF systems provides valuable thoughts into the influence of various design parameters on the behavior and performance of the foundation system. The mentioned parameters, including pile spacing, embedment length, pile configuration, and raft thickness, play a significant role in the design and effectiveness of the pile raft system. El-Garhy, B et al. [2]: The study focuses on the behaviour of settlements reducing piles related to raft dimensions. It suggests that increasing the firmness of the subsoil stratum can significantly reduce settlements and internal bending moments within the raft of non-connected piled raft systems. Gahlot et al. [3], focuses on the effect of varying pile lengths in pile raft foundations. It indicates that the layout and combination of piles play a key role in achieving desired settlement reduction, load sharing, a load carrying capability with the smallest possible number of piles in the design. Jaymin D Patil et al. [5]: The analysis examines the effect of pile numbers and raft thickness on load improvement ratio and settlement reduction in pile-raft foundations. The findings suggest the optimum design of PRFs to achieve the expected results and performance criteria such as load capacity and settlement control of piled raft foundations experimentally.

Experimental Program**:** The experimental program described aims to study the load-settlement behavior and load transfer process of a PRF system using various pile lengths and configurations. The program consists of twenty-five tests conducted in a laboratory setting. Table 1 shows the laboratory model test schedule for raft alone and raft foundations. Figure 1 depicts the pile configurations and measurements of a model raft of piled raft. The size of the model pile and raft were determined to ensure that there would be no stress concentration due to boundary conditions. To avoid the effect of a rigid soil tank foundation on pile behavior, the soil tank's height was two times higher than the pile length (Horikoshi & Randolph, 1999).

Table 1: Summary of the model tests on unpiled and piled rafts conducted for e =0 and e = 1 cm.

Test Explanation	Model Raft dimensions (mm xmmxmm)	L/D	S/D	No.of tests performed
Unpiled Raft	100x100x10			1
Raft +4 piles	100x100x10	5	5	1
	100x100x10	10		1
	100x100x10	15		1
	100x100x10	20		1
Raft+ 6 piles	100x100x10	5	4	1
	100x100x10	10		1
	100x100x10	15		1
	100x100x10	20		1
Raft + 9 piles	100x100x10	5	3	1
	100x100x10	10		1
	100x100x10	15		1
	100x100x10	20		1

The laboratory tests conducted on a dry sand sample as the foundation soil. Here are the properties listed in the table 2.

Table 2: Geotechnical properties of sand

Sl.No	Properties	Results
1	Specific Gravity(G)	2.62
2	Particle size distribution	
3	Percentage of Gravel size	0.8%
	Percentage of Sand size	99.20%
	Minimum Dry unit weight	14.9kN/m^3
4	Maximum dry unit weight	17.5 kN/m^3
5	Minimum void ratio	0.468
6	Maximum void ratio	0.725
7	Uniformity coefficient, Cu	3.15
8	Coefficient of curvature, Cc	1.22
9	Soil classification	SP

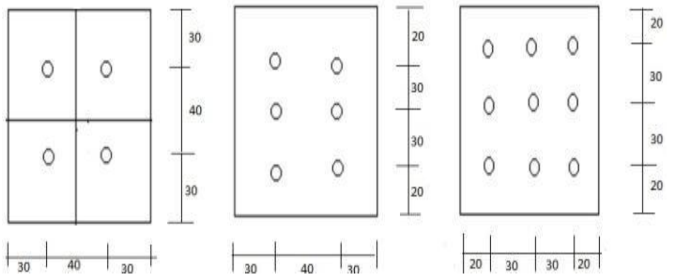

Figure 1: Arrangement of piles in piled raft foundation (unit: mm)

Figure 2: Piled raft arrangement for 4 number of piles

Figure 3: Piled raft arrangement for 6 number of piles

Figure 4: Piled raft arrangement for 9 number of piles

Mild Steel Piles: In the laboratory test conducted for the present study, mild steel piles with a diameter of 10 mm are used to fabricate the model piles. Specifically, pile lengths of 50 mm,100 mm,150 mm and 200 mm were employed, corresponding to slenderness ratios of 5, 10, 15, and 20, respectively

Figure 5: Model Steel Piles.

Experimental setup: In the experimental work, a circular test tank was utilized, which had a diameter of 500 mm and depth of 390 mm. The test tank provided a controlled environment for conducting the experiments on the piled raft foundation system.

Figure 6: Model test set up with connector, proving ring and dial gauges

Test procedure:

1. To achieve the desired density for the experiments, the rainfall method to pour the sand into the tank. The overall depth of the tank was divided into 50 mm intervals to facilitate control over the filling process.

   The sand pouring process was performed in 7 layers. Each layer of sand was poured incrementally, ensuring a uniform distribution and compaction within the tank.
2. In the experimental setup, the load was transferred to the model raft through a loading plate that was connected to the raft. To measure the vertical displacement of the raft during loading, three linear displacement transducers (LVDTs) were installed.
3. The load was conveyed to the model raft via a loading plate that was connected to the raft. Then, to measure vertical displacement, three LVDTs were installed.
4. The hydraulic jack is coupled to a Proving ring load cell with a 50 kN capacity. The model raft was loadedincrementally, and vertical settlement was measured at the conclusion of each load increment. The loadingrate was 0.1kN/min. The application of load is continued till the raft settlement is 25 mm.

Figure 7: Model Test setup for plain raft foundation

Effect of Pile length:

In the study, the effects length of pile and the number of piles on the behaviour of the PRF were investigated for both concentric loading and eccentric loading. Load settlement curves were generated to analyze the performance of the piled raft system under different configurations. The comparative analysis is made on the behaviour of piled raft foundation at concentric loading as well as eccentric loading.

Balakumar V et al., (2009): has observed and obtained the non– dimensional parameter "The Load improvement ratio" using the following formula.

Load Improvement Ratio:

Load Improvement Ratio, LIR =Where,

$$(Qpr-Qr)/Qpr$$

LIR =Load improvement ratio, Qr= Ultimate load of the raft,
Qpr = Ultimate load of the raft with pile,

Load settlement characteristics of group of Piled raft foundation on cohesionless soil under concentric and eccentric loading:

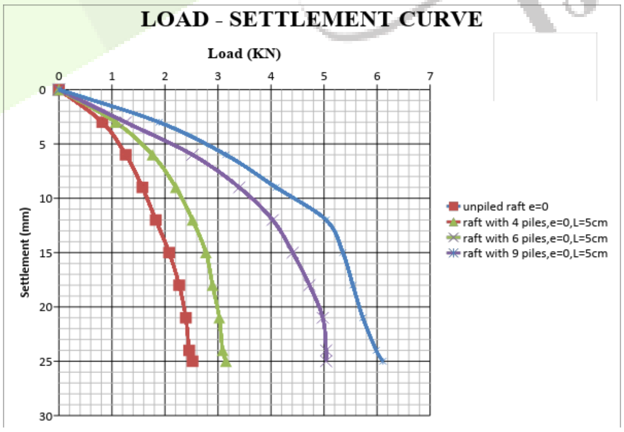

Figure 8: Load settlement curves of PRF (L/D=5).

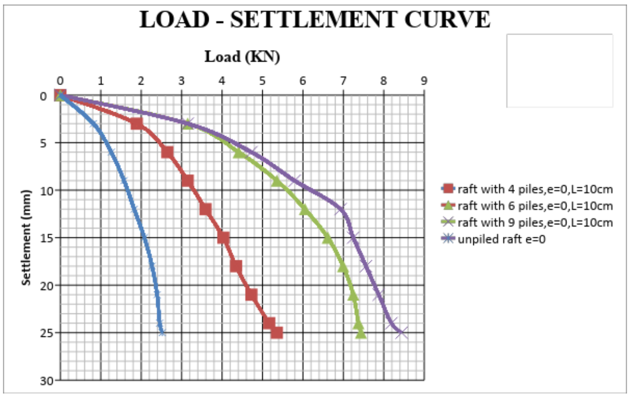

Figure 9: Load settlement curves of PRF (L/D=10).

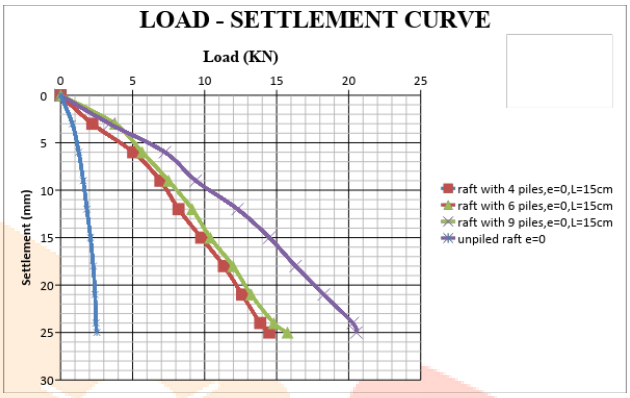

Figure 10: Load settlement curves of PRF (L/D=15).

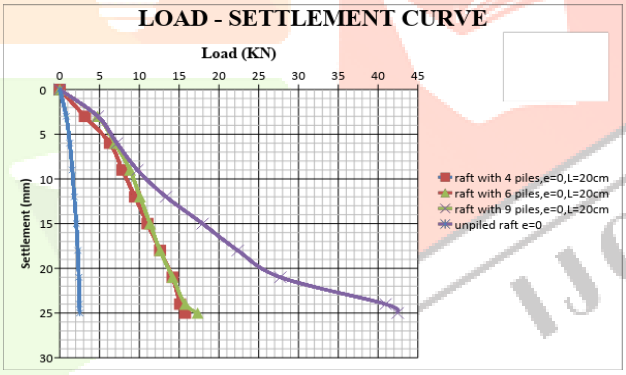

Figure 11: Load settlement curves of PRF (L/D=20)

By comparing the load settlement curves of the plain raft and the piled raft, it is clear that the addition of small number of piles connected to the raft enhances the improvement in carrying load of the foundation system. The load versus settlement curves demonstrates that the firmness of the combined system (piled raft) helps in improving the bearing capacity and significant reduction in settlement compared to the plain raft at a maximum settlement of 25 mm. This suggests that the piles primarily act as settlement reducers rather than solely carrying the load especially at higher settlements.

Effect of eccentricity: The Pile raft foundation are subjected to eccentricity of e =1 cm in X direction and the test results are plotted as follows.

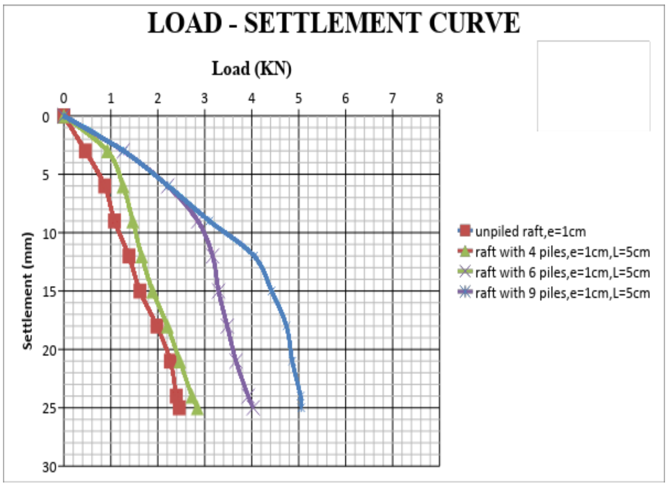

Figure 12: Load versus Settlement of PRF at e/B = 0.1 (Pile length=50 mm).

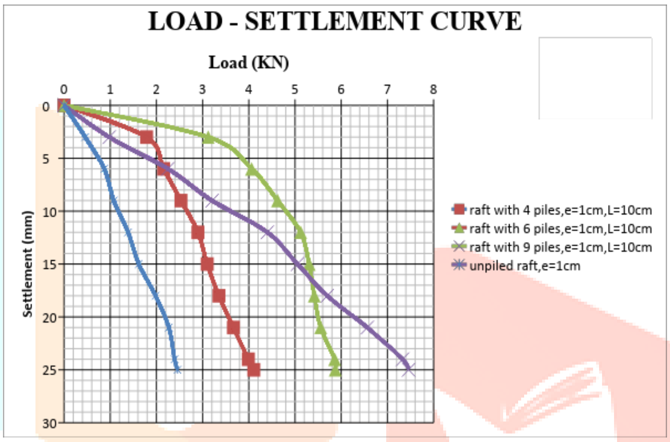

Figure 13: Load versus Settlement of piled raft at e/B = 0.1 (Pile length=100 mm).

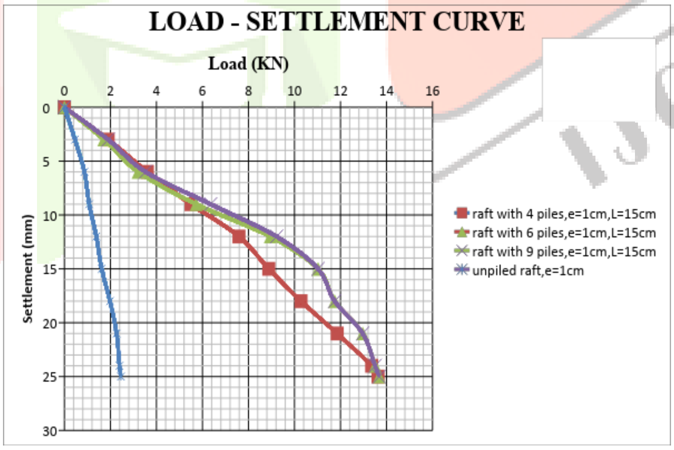

Figure 14: Load versus Settlement of piled raft at e/B = 0.1 (Pile length=150 mm).

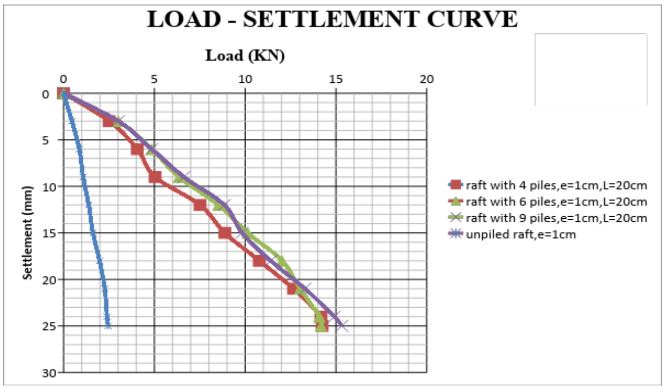

Figure 15: Load versus Settlement of piled raft at e/B = 0.1 (Pile length=200 mm).

Table 1: Load Shared by Plain Raft and Piled Raft with L/D ratio=5 (constant)

Description	Load taken by plain raft	raft with piles		
Number of piles		4	6	9
Load (kN)	2.52	3.15	5.04	6.1
LIR (%)		20	50	58.75

Table 2: Load Shared by Plain Raft and Piled Raft with L/D ratio=10 (constant)

Description	Load taken by plain raft	raft with piles		
Number of piles		4	6	9
Load (kN)	2.52	5.35	7.43	8.44
LIR (%)		52.89	66.08	70.12

Table 3: Load Shared by Plain Raft and Piled Raft with L/D ratio=15 (constant)

Description	Load taken By plain raft	raft with piles		
Number of piles		4	6	9
Load (kN)	2.52	14.49	15.75	20.54
LIR (%)		82.60	84.0	87.73

Table 4: Load Shared by Plain Raft and Piled Raft with L/D ratio=20 (constant)

Description	Load taken by plain raft	raft with piles		
Number of piles		4	6	9
Load (kN)	2.52	15.75	17.33	42.46
LIR (%)		84	85.45	94.06

Effect of concentricity of e = 1 cm on Plain raft and piled raft for different configurations

Table 5: Load Shared by Plain Raft and Piled Raft with eccentric loading for L/D =5 at eccentricity =1cm.

Description	Load taken by Plain Raft	raft with piles		
Number of piles		4	6	9
Load (kN)	2.46	2.84	4.03	5.05
LIR (%)		13.38	38.95	51.28

Table 6: Load Shared by Plain Raft and Piled Raft with eccentric loading for L/D =10 at eccentricity =1cm.

Description	Load taken by plain Raft	raft with piles		
Number of piles		4	6	9
Load (KN)	2.46	4.11	5.87	7.46
LIR (%)		40.14	58.09	67.02

Table 7: Load Shared by plain Raft and Piled Raft with eccentric loading for L/D =15 at eccentricity =1cm.

Description	Load taken by plain Raft	raft with piles		
Number of piles		4	6	9
Load (kN)	2.46	13.63	13.68	13.68
LIR (%)		81.95	82.01	82.01

Table 8: Load Shared by plain Raft and Piled Raft with eccentric loading for L/D =20 at eccentricity =1cm.

Description	Load taken by Plain Raft	Raft with piles		
Number of piles		4	6	9
Load (kN)	2.46	14.24	14.19	15.32
LIR (%)		82.67	82.55	83.92

CONCLUSIONS:

The findings are the outcome of a small-scale laboratory model test conducted on sand to investigate load-settlement behavior and load distribution between the raft and piles. The following conclusions are drawn from the tests:

1) The findings indicate that the LIR increases by 20 percent to 94 percent when the length of the piles increased from 50 mm to 200 mm compared to an plain raft. This recommends that longer piles contribute significantly to increase the load carrying capacity of the piled raft system.
2) The greater the number of piles below the raft leads to an increment in the load bearing of the raft. It can be understood that as the length to L/D ratio increases. This implies that longer piles relative to their diameter, contribute more effectively to sharing the load with the raft.
3) The research findings demonstrate a significant improvement in laod carrying capacity with an increase in the slenderness ratio of the piles. The increase in slenderness ratio contributes to a linear improvement in the load bearing ratio of the system.
4) The number and length of piles have a substantial impact on settlement reduction. The addition of

piles to the raft increases the stiffness of the soil, thereby reducing settlements. The increased stiffness and load sharing capacity provided by the piles contribute to a more stable and resilient foundation system, leading to significant settlement reduction compared to an plain raft.

5) Based on the present study, it can be concluded that increasing the number of piles in a piled raft foundation leads to increase in the load bearing capacity. Specifically for eccentric loading with a pile length of 50 mm, introducing 4,6, and 9 piles to a plain raft resulted in load improvement ratio of 13.38%, 38.95% and 51.28% respectively, compared to the load carrying capacity of the plain raft al one. This demonstrates that the presence of additional piles significantly enhances the load bearing capability of the piled raft system, particularly in eccentric loading conditions.
6) The load carrying capacity of piled raft increases as the number of piles increases beneath the raft with increase in length of pile up to 150 mm length whereas with further increase in length of pile to200mm, the Load improvement ratio have not shownmuch improvement in LIR.
7) There is significant increase in load carrying capacityof piled raft system for eccentric loading with e/B ratio equals to 0.1(e/B =0.1) when compared to eccentric loading with e/B equals to 0.15.
8) Also, it can be inferred that in weak soils instead of designing piles for a longer length, with load taken entirely by piles, it leads to uneconomical design. It is economical to design the piled – raft system with optimal pile length as it carries maximum load and decreases the settlements and hence the length of piles can be decreased.

REFERENCES

[1] Eslami, “Study on optimized piled-raft foundations (PRF) performance with connected and non connected pile-three case histories” International Journal of Civil Engineering, Volume 10, No.2, June 2012.

[2] El-Garhy, B., Galil, A.A., Abdel-Fattah A.A., Raia,”. Behavior of Raft on Settlement Reducing Piles: Experimental Model Study”, Journal of Rock Mechanics and Geotechnical Engineering, Vol.5, pp389–399 (2013).

[3] Gahlot, “Effect of Varying Length and Diameter of Pile in Pile Raft Foundation”. International Journal of Emerging Technology and Advanced Engineering. Volume 5, Issue 8, August 2015.

[4] H G Poulos, “Methods of analysis of piled raft foundation” (International society of soil mechanics and geotechnical engineering, July 2011.

[5] Jaymin D Patil, “An experimental investigation on behavior of piled raft foundation”. INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES. Volume 5 No 2, November 2014.

[6] Sven kabbenhoft et al., (2014): Bearing Capacity of Strip Footings in Cohesionless Soil Subject to Eccentric and Inclined Loads. DOI: 10.1061/(ASCE)GM.1943-5622.0000332. © 2014 American Society of Civil Engineers.

[7] Ganesh R et al., (2016): Bearing Capacity of Shallow Strip Foundations in Sand under Eccentric and Oblique Loads. International Journal of geomechanics 17(4):06016028 DOI: 10.1061/(ASCE)GM.1943-5622.0000799. © 2016.

[8] George G et al., (1983): Ultimate Pile Capacity For Eccentric Inclined Load. J Geotech. Engineering., 1983, 109(3): 408-423.

[9] Mustafa EL Sawwaf et al., (2010): Experimental Study of Eccentrically Loaded raft With Connected and Unconnected Short piles. Journal of Geotechnical and Geoenvironmental Engineering ASCE, DOI: 10.1061/(ASCE)GT:1943-5606.000