

LOAD CARRYING CHARACTERISTICS OF PILE RAFT

FOUNDATION UPON DIFFERENT DENSITIES OF SOIL BED: A

EXPERIMENTAL STUDY

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ABSTRACT

The analysis and design of pile raft foundation is a complex problem due to interaction between various elements of pile raft foundation and soil. A lot of research is being carried out to simplify the analysis and design. In this study a series of experiments on sufficiently large model were conducted to observe the effect of soil density on load carrying capacity of pile raft foundation (PRF). Centre to centre pile spacing and pile length of piles were also taken as variable to investigate the optimum c/c pile spacing and to observe which type of pile (shorter or longer) is suitable in soil depending upon their relative compaction. It was observed that optimum c/c pile spacing is four times of pile diameter irrespective of the relative compaction of soil media. It was also found that relatively shorter piles are more suitable in denser medium soil. The load carrying capacity of pile raft foundation and its rate increases with the compaction level of soil media upto 78% relative density of soil and afterwards the rate of increase in load carrying capacity start decreasing.

Keywords: *Pile raft, rain fall technique, centric load, Relative density, Load carrying capacity*

INTRODUCTION

Research for cost cutting of a structure without compromising the safety of structures were being carried out since long back and is a continuous process. The concept of pile raft foundation was to reduce the cost, total as well as differential settlement in compressible soil. Polous and Devis [1] introduced the analysis of pile raft system, since then research on pile raft foundation to provide easy and handy approach of design or to bring more economy in construction cost is carried out till date. Different methods were proposed to design pile raft foundation system as compiled by Poulos [8] in TC 18 of ISSMGE. A variety of design methods from a simplified approach to very complex method involving various soil structure interaction the first approach is Simplified methods proposed by many researchers [1-7]. Most of the studies are based on Finite Element Methods [8-16] whereas few studies have been reported with small scale model in laboratory [17-20]. In present study, the effect of scale of compaction of sandy soil on load carrying capacity of pile raft foundation was

investigated. A series of experiments on a sufficiently large scale model were conducted in lab. Soil tank of 2.5x 5.0x 1.0m was filled with sand at different density by falling it from a height of 40,50,60 and 80mm. Tests were conducted by varying length of piles and their c/c spacing on sand bed of different densities. The behavior of pile raft under different density of soil were observed and it is found that load carrying capacity of pile raft foundation increases with increase in density of soil. The maximum rate of increase was found in the sand bed at a fall

of height of 60mm and if the height of fall further increased, the rate of increase in load carrying capacity decreased.

VARIABLES OF STUDY

The behavior of pile raft foundation (PRF) was studied by varying the parameters like length of piles, c/c pile spacing and density of sand bed. Dimension of raft (0.75mx0.75m area and 60.0mm thick), number of piles (9 no's) and diameter of piles were kept constant as 35mm. The variables of the study are represented in Table 1(a).

Table 1(a): Variables and Constants of study

Types of Piles	Size of Raft (mm)	Diameter of Piles (mm)	Pile length (mm)	c/c pile spacing (s/d)	Type of Loading
Wooden piles	750x750	35	300	2	Point Load at Centre of Raft
				4	
				6	
			450	2	
				4	
				6	
			759	2	
				4	
				6	

EXPERIMENTAL SETUP AND METHODOLOGY:

A soil tank of dimension 2.5x5.0x1.0m was fabricated in the college's heavy testing lab which was enclosed by concrete wall on three sides and with a thick fiber sheet on long side. The fiber wall was braced with flat steel strips in both the

direction to avoid bulging during loading the PRF. A systematic diagram was drawn in Figure 1. A course and dry sand was dropped from different heights in soil tank by rainfall technique to achieve uniform density of soil in tank. Properties of sand were determined as per IS code as shown in table 2.

Table 2: Properties of sand

S.No.	Description ant Units	Value
1	Specific gravity	2.66
2	Uniformity coefficient Cu	2.59
3	Coefficient of curvature Cc	0.94
4	Classification of sand	poorly graded sand (SP)
5	Maximum dry unit weight(kN/m3)	18.35
6	Minimum dry unit weight(kN/m3)	12.46
7	Maximum void ratio	0.72
8	Minimum void ratio	0.42
9	Internal frictionAngle	35°
10	Coefficient of cohesion (kN/m2)	0.01
11	Poisson ratio	0.3

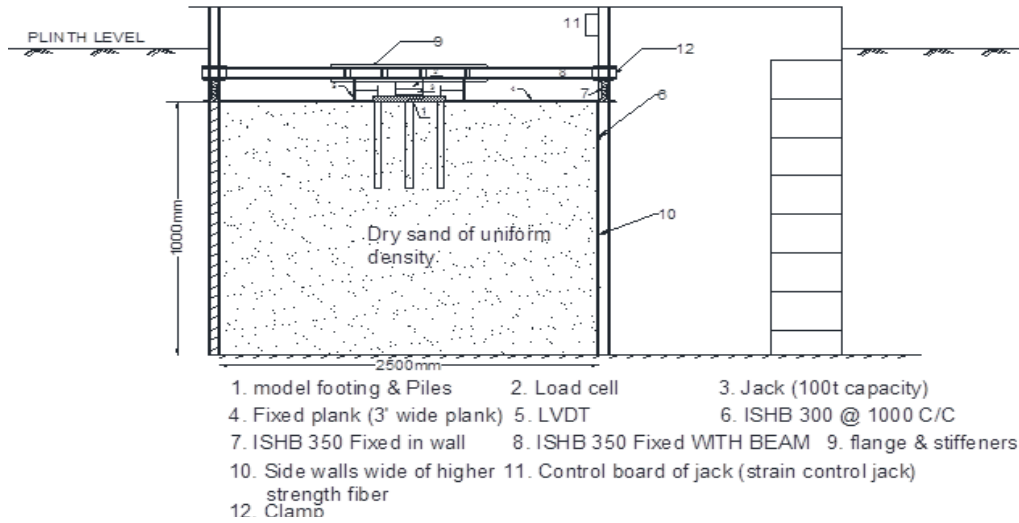


Fig. 1: Schematic view of loading arrangements used for experiment

A known volume canes were initially placed in tank so that density of sand may be verified after each fall. If the desired density of sand is achieved with 10% tolerance, further fall of sand was continued, otherwise sand was taken out and poured again till the desired density was achieved. Raft piles were inserted in sand. Sieve analysis of sand and density achieved with height of fall relation was

represented in Figure 2(a) and 2(b). Two LVDTs and load cell were placed at its position and connected to data acquisition device, finally to laptop. Initial setting were performed in laptop and a point load at the center of raft was applied with a constant strain at a rate of 2mm/minutes. Load and settlements were recorded and processed to convert it into load settlement curve.

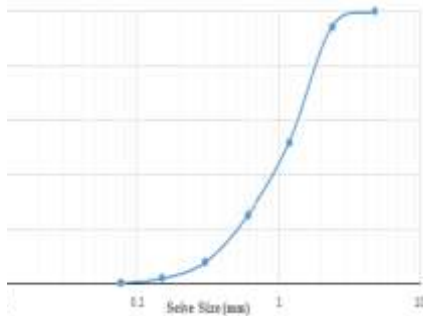


Fig.2(a) Sieve Analysis of sand

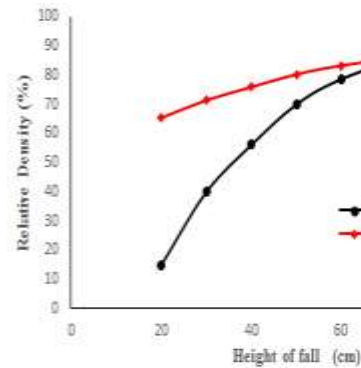


Fig.2(b) Density vs Height of fall and load cell provides values of Load

RESULT AND DISCUSSION

On the prepared sand beds, load was applied with hydraulic jack (100t capacity) at a strain rate of 2mm/minute, readings were recorded from LVDTs as settlements

corresponding to that settlement. These recorded readings were in .csv format and further processed to plot load settlement curves for each case.

(i) Analysis of Pile Raft with 300mm long pile and diameter 35mm

The load response curves for 300mm pile

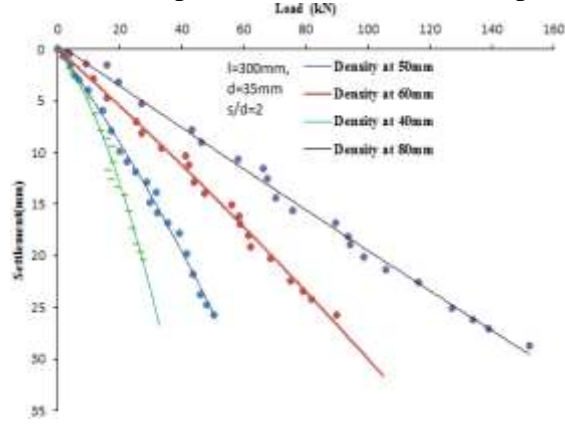


Fig.3(a) Load settlement response 300mm pile length at $s/d=2$

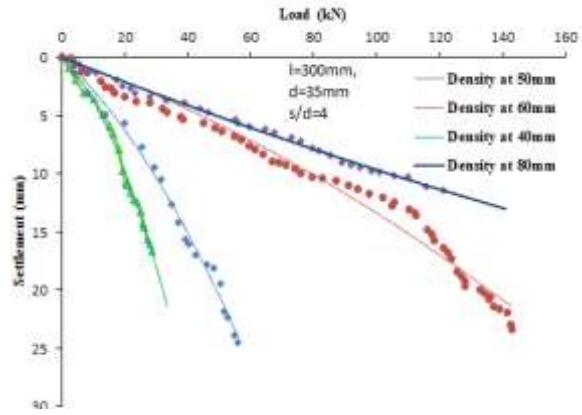


Fig.3(b) Load settlement response 300mm pile length at $s/d=4$

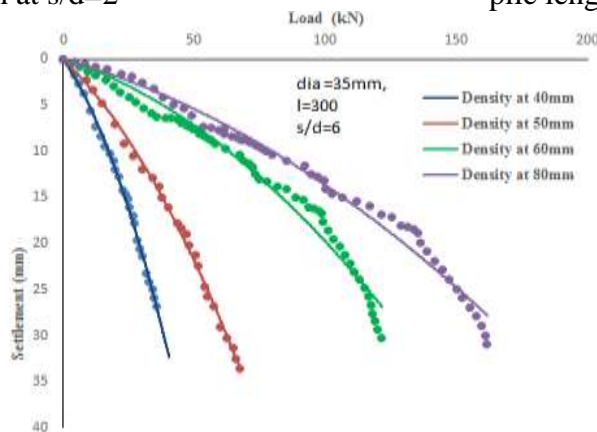


Fig.3(c) Load settlement response 300mm pile length at $s/d=6$

Load corresponding to 25mm settlement was considered as a load carrying capacity of pile raft foundation (PRF). From figure 3(a), the load observed were 33, 51, 86 and 132 kN at a density achieved by falling sand from a height of 40, 50, 60 and 80 cm respectively at $s/d=2$. The load carried by pile raft foundation were 38, 59, 161 and 190 kN at 40, 50, 60 and 80 cm height of fall when c/c pile spacing was kept at $4d$. For $s/d=6$, the load carried by pile raft were observed as 34, 56, 118 and 150 kN at a height of fall of 40, 50, 60 and 80 cm respectively as obtained from figure 3(c). These loads were divided by area of raft

length and 35mm diameters with c/c pile spacing 2, 4 and 6 are represented through Figures 3(a) to 3(c) respectively.

and bearing capacity of pile raft system were obtained. The bearing capacity of pile raft with 300mm long piles at $s/d=2, 4$ and 6 and for a height of fall of 40, 50, 60 and 80 cm were represented in Figure 4. From the figure 4, it was observed that Maximum Bearing capacity of PRF was achieved when piles were arranged with c/c spacing equal to four times the pile diameter irrespective of scale of soil compaction and if s/d was further increased to 6, bearing capacity of PRF decreased. It may be due to overlapping of stress bulb generated along the piles when piles are placed at lower spacing than $4d$

and soil at overlapped area was over stressed and failed at lower load.

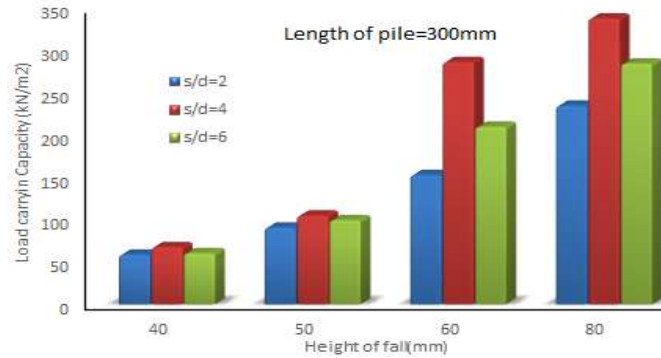


Fig.4 Bearing Capacity of PRF at different s/d and Height of fall

When pile spacing were increased to 4d, stress bulbs along piles got separated and hence no or very less interaction between piles to pile occurs and PRF system act as a block. If pile c/c spacing was further increased to 6d, No soil arching effect would develop soil between piles and hence lateral movement of soil was taken 4 and 6 are represented through Figure 5(a) to 5(c) respectively.

placed between piles and hence bearing capacity of PRF decreased.

(ii) Analysis of Pile Raft with pile length 450mm and diameter 35mm

The load response curves for 450mm pile length and 35mm diameters with c/c pile spacing 2,

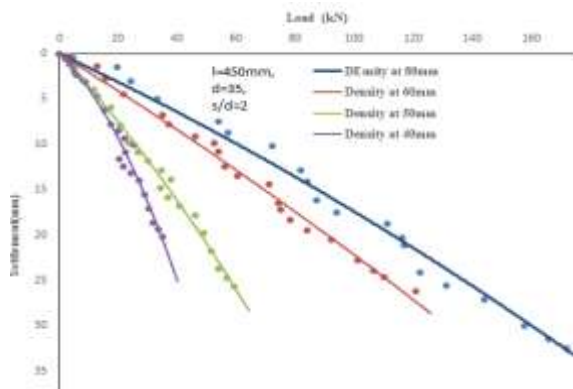


Fig.5(a) Load settlement response 300mm pile length at s/d=2

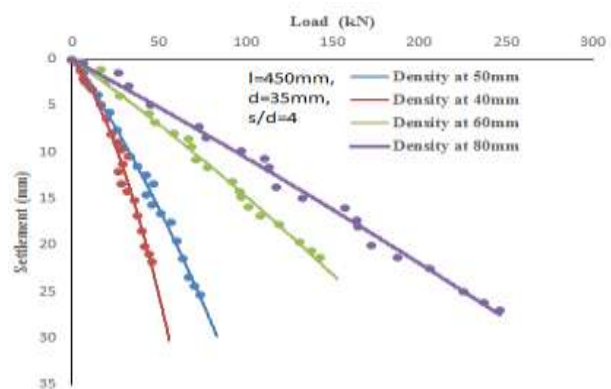


Fig.5(b) Load settlement response 300mm pile length at s/d=4

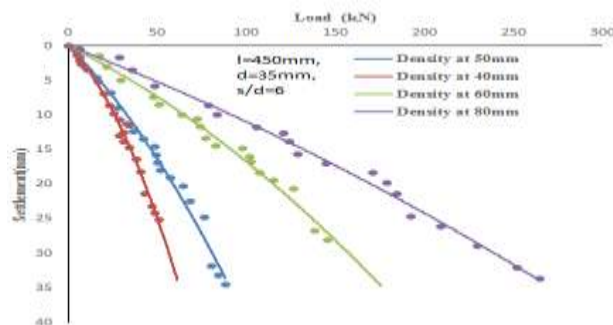


Fig.5(c) Load settlement response 300mm pile length at s/d=6
Load corresponding to 25mm settlement

was considered as a load carrying capacity of pile raft foundation (PRF). From figure 5(a), the load observed were 33, 51, 86 and

132 kN at a density achieved by falling sand from a height of 40, 50, 60 and 80 cm respectively at $s/d=2$. The load carried by pile raft foundation were 38, 59, 161 and 190 kN at 40, 50, 60 and 80 cm height of fall when c/c pile spacing was kept at 4d. For $s/d=6$, the load carried by pile raft were observed as 34, 56, 118 and 150kN at a height of fall of 40, 50, 60 and 80 cm respectively as obtained from figure 5(c). These loads were divided by area of raft and bearing capacity of pile raft system were obtained. The bearing capacity of pile raft with 300mm long piles at $s/d=2, 4$ and 6 and for a height of fall of 40, 50, 60 and 80 cm were represented in Figure 6. From the figure 6, it was observed that Maximum Bearing capacity of PRF was achieved when piles were arranged with

c/c spacing equal to four times the pile diameter irrespective of scale of soil compaction and if s/d was further increased to 6, bearing capacity of PRF was decreased. It may be due to overlapping of stress bulb generated along the piles when piles are placed at lower spacing than 4d and soil at overlapped area was over stressed and failed at lower load. When pile spacing were increased to 4d, stress bulbs along piles got separated and hence no or very less interaction between pile to pile occurs and PRF system acts as a block. If pile c/c spacing was further increased to 6d, No soil arching effect would develop soil between piles and hence lateral movement of soil was taken placed between piles and hence bearing capacity of PRF decreased.

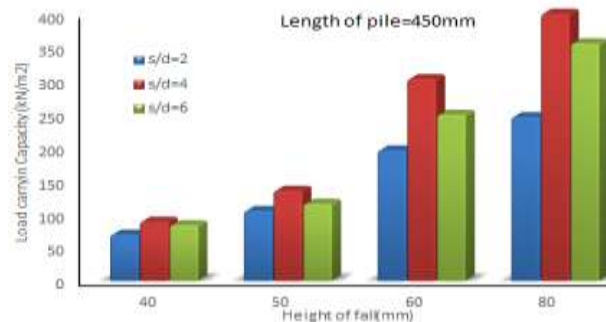


Fig.6. Bearing Capacity of PRF at different s/d and Height of fall

(iii) Analysis of Pile Raft with pile length 750mm and diameter 35mm

The load response curves for 450mm pile length and 35mm diameters with c/c pile spacing 2,4 and 6 are represented through Figures 7(a) to 7(c) respectively. Load corresponding to 25mm settlement was considered as a load carrying capacity of pile raft foundation. From figure 7(a), the load observed were 50, 80, 165 and 240 kN at a density achieved by falling sand from a height of 40, 50, 60 and 80 cm respectively at $s/d=2$. The load carried by pile raft foundation were 96, 140, 280 and 375 kN at 40, 50, 60 and 80 cm height of fall when c/c pile spacing was kept at 4d.

For $s/d=6$, the load carried by pile raft were observed as 85, 125, 242 and 305kN at a height of fall of 40, 50, 60 and 80 cm respectively as obtained from figure 7(c). These load were divided by area of raft and bearing capacity of pile raft system were obtained. The bearing capacity of pile raft with 750mm long piles at $s/d=2, 4$ and 6 and for a height of fall of 40, 50, 60 and 80 cm were represented in Figure 8. From the figure 8, it was observed that Maximum Bearing capacity of PRF was achieved when piles were arranged with c/c spacing equal to four times the pile diameter irrespective of scale of soil compaction and if s/d was further

increased to 6, bearing capacity of PRF decreased.

It may be due to overlapping of stress bulb generated along the piles when piles are placed at lower spacing than 4d and soil at overlapped area was over stressed and failed at lower load. When pile spacing were increased to 4d, stress bulbs along piles got separated and hence no or very

less interaction between piles to pile occurs and PRF system acts as a block. If pile c/c spacing was further increased to 6d, No soil arching effect would develop soil between piles and hence lateral movement of soil was taken placed between piles and hence bearing capacity of PRF decreased.

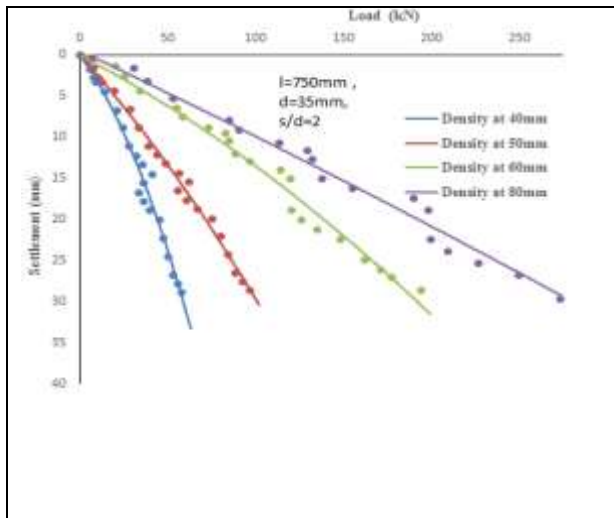


Fig.7(a) Load settlement response 300mm pile length at s/d=2

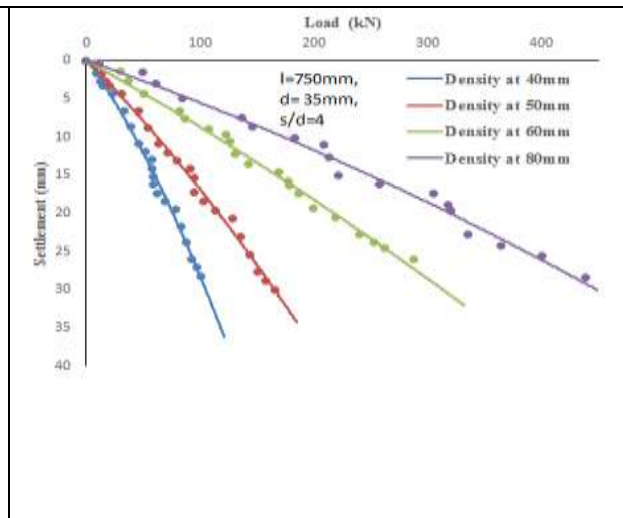


Fig.7(b) Load settlement response 300mm pile length at s/d=4

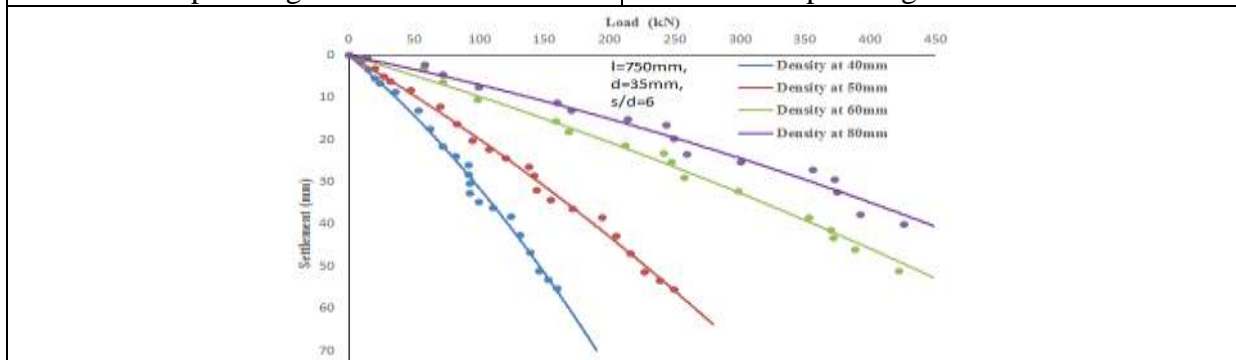


Fig.7(c) Load settlement response 300mm pile length at s/d=6

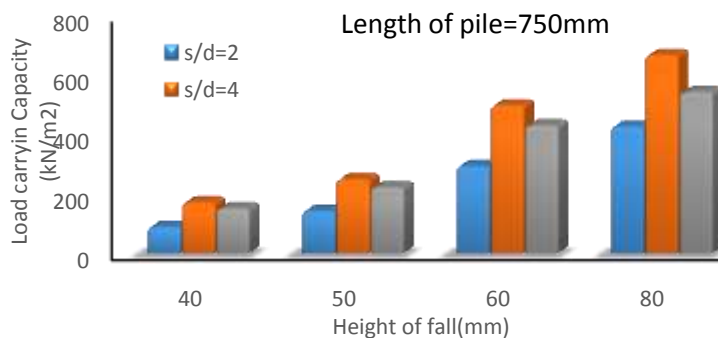


Fig.8. Bearing Capacity of PRF at different s/d and Height of fall

(iv) Effect of length and scale of density on bearing capacity

From the experiments performed on the sand bed of various densities, a relation between density (height of fall) and load carrying capacity for different lengths of piles were plotted and represented in figures 9(a) and 9(b). Figure 9 shows that load carrying capacity of pile raft foundation increased very rapidly at the rate of 173%, 123% and 100% for pile raft with piles length of 300, 450 and 750mm respectively w.r.t. respect to the load carrying capacity when pile raft was tested on the sand bed of relative density 67.8% (when sand was dropped from a height of 50mm) and 78.68% (when sand was

dropped from a height of 60mm). If the load carrying capacity of pile raft in sand bed of 78.68% relative density and 90% relative density sand bed, the increase in load carrying capacity are 18%, 32% and 34% for pile raft with piles of 300, 450 and 750mm respectively. It was also observed that the increase in load carrying capacity for smaller piles are much more than that of larger piles. For 300mm long piles load carrying capacity increases by 173%, for 450mm long piles it increases by 123% and for 750mm long piles load carrying capacity increases by 100%. Hence in denser medium smaller piles are more economical that larger piles.

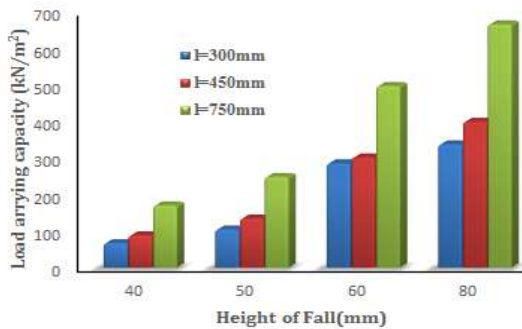


Fig.9(a) Bearing Capacity of PRF at different s/d and Height of fall

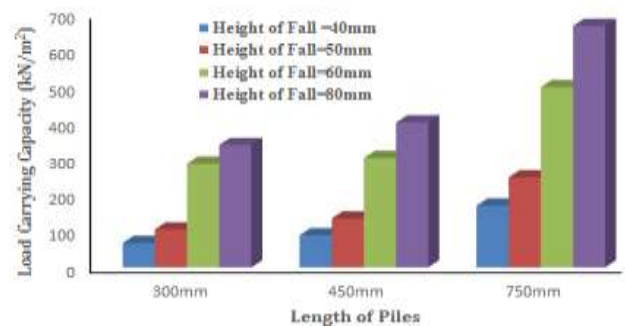


Fig.9(b) Bearing Capacity of PRF at different s/d and Height of fall

CONCLUSION

A series of experiments were performed by varying length and the density of sand bed. Number of piles and diameter of piles are kept constant. The results were represented in terms of load settlement curves. From the study, following conclusion may be drawn:

1 The density of sand of sand bed increases as the height of fall of sand increases upto a height and afterwards the density became constant as velocity of

sand particles achieved terminal velocity and this height depends upon the size of sand particle.

2 The optimum c/c pile spacing is four times the diameters of pile (4d) irrespective of relative density of sand bed

and length of piles used in pile raft foundation.

3 The load carrying capacity of pile raft increases with the increase in the

relative density of sand bed. The rate of increase of load carrying capacity also increases with the increase of density of sand bed. Maximum load carrying capacity was observed on the bed of 78% relative density and it decreases for denser sand.

4 Pile raft foundation with the shorter piles shows a tremendous increase in load carrying capacity thus it is more economical.

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