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Study of Piled Raft Foundation

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***ABSTRACT*: In situations, where a raft foundation alone does not satisfy the design requirement, it may be possible to enhance the performance of the raft by the addition of piles. The use of a limited number of piles, may improve both the ultimate load carrying capacity, and the settlement and differential settlement. The analysis of piled raft is a complex problem. The present study is focused on the experimental investigation on performance of piled raft foundation on sand. Wooden rafts of different sizes with wooden piles (single or double) of three different diameters and lengths have been used. It is observed that the load carrying capacity increases considerably when the load is transferred to the soil through raft and pile combined while the settlement per unit load is quite less. The experimental results show that number of piles below the rafts and its locations play vital role in improving the load carrying capacity of the piled raft and settlement of the soil.**

Keywords: **Foundation shape; Load bearing capacity; Settlement; Soil base.**

NTRODUCTION

Pile draft foundation is combination of pile and raft foundation that covers the entire area beneath a structure and support all wall and columns. In situations, where a raft foundation alone does not satisfy the design requirement, it may be possible to enhance the performance of the raft by the addition of piles. The use of a limited number of piles, may improve both the ultimate load carrying capacity and the settlement performance of the raft. The Philosophy of using piles is as settlement reducers. Rafts supported on piles are being increasingly used for multi-storeyed buildings with basements in poor soils with high water table conditions.

The analysis of piled raft is a complex problem even more than that of a soil supported raft as too many parameters influence the behaviours of the system. Very little literature is available about the exact behaviour of piled raft foundations. The problem is to be understood by considering the composite behavior of the entire system e.g. superstructure, sub-structure, raft, piles and soil medium. These factors influence sharing of theload between piles and raft, between piles themselves and consequently the settlements, shears and moments in the raft. Most simple method followed is the conventional rigid approach, wherein the raft is assumed to be rigid. Some designers use the concept of beam on elastic foundation. As further improvement to this method, raft is taken as a plate supported on springs [1].

Design of raft as a reversed floor is dangerous. In 1988,designedraftormat[2]as rigid structures there bysoilpressure are computed in the case where the resultant of the forces coincide with the centre of the matarea.IS:2950(1981) discussed the design and construction of Raft Foundation [3] whereasIS:2911(1980)provides detail design and testing of piles [4].A plate on springs in which the raft

is represented by a plate and piles by springs are analyzed by different researchers [5, 6, 7]. Poulous (1994 a) analysed Piled raft foundation by applying numerical methods [8]. Poulos published a paper on piled-raft foundation but experimental investigation has not been made [9]. The Westend - 1 Tower is a 51-storey, 208 m high building in Frankfurt,Germany,has been described in details[10].The foundation for the tower consistsofpiledraftwith40piles,eachabout30 m long and 1.3 m in diameter. The central part of the raft is 4.5 m thick, decreasing to 3 m at the edges. Building is located on a thick deposit of relatively stiff Frankfurt clay.

The present study is focused on the experimental investigation on performance of piled raft foundation on sand. The piled-raft has been taken as rigid element and the response of the soil on application of the load has been observed and analysed. Wooden rafts of different sizes (217 mm x 270 mm), (105 mm x 108 mm),(166 mm x 171 mm), etc. with wooden piles (single or multiple) of three different diameters(30 mm, 40 mm, 50mm) and three lengths (300 mm, 450 mm and 600 mm) have been used for experimental study. Spacing between two piles has also been varied in case of two/three piles. The experimental study has revealed that piled-raft behaviour is somewhere between the pile foundation and raft foundation and the settlement response of the pile draft may be used quite effectively and economically for heavy loads in poor sub-soil conditions. When the load is taken by piles only under the raft, the settlement is quite faster with little load on the piled raft. It is also observed that the load carrying capacity increases considerably when the load is transferred to the soil through raft and pile combined while the settlement per unit load is quite less. In particular, the experimental results have shown that number of piles below the rafts and its locations play vital role in improving the load carrying capacity of the piled raft and the elastic settlement response of the soil.

ANALYSISANDDESIGNOFPILED-RAFT

It is suggested that in a rational design process piled rafts involves three stages: (i) A preliminary stage to assess the feasibility of using a piled raft, and the required number of piles to satisfy designs requirements (ii) A second stage to assess where piles are required and the general characteristics of the piles and (iii) A final detailed design stage to obtain the optimums number, location and configuration of the piles, and to complete the detailed distribution of settlement, bending moments and shear in the raft, and the pile loads and moments.

EXPERIMENTAL PROGRAMME

The present investigation aims towards the behaviour of piled raft foundation. The main variable is the size of raft, length of piles, diameter of piles & spacing of piles. The investigation also covers the tests of single pile and multiple piledraft. The experimental study on the load-settlement behaviour of piles and piled rafts with varying no. of piles has been conducted.

Test Programme In the test programme,

different size of rafts such as (217 mm x 270 mm), (105 mm x 108 mm), (166 mm x 171 mm), (328 mm x 121 mm), (380 mm x 93 mm), (320 mm x 96mm), (380 mm x 121 mm) are used. The length of piles has been kept as 300 mm, 450 mm and 600 mm having different diameter 30 mm, 40 mm and 50 mm of each length. Size of wooden box was (860 mm x 710 mm) and depth of box was 835 mm remains same through out the test. Clearance between sand and raft surface has been varied as 6 mm, 14 mm, 20 mm, 26 mm, 28 mm, 30 mm, 35 mm, 40 mm and 50 mm during the tests.

Wooden Pile Mode

Single pile

Diameter of pile	Length of pile
d1 = 30 mm	L1 = 300 mm
	L2 = 450 mm
	L3 = 600 mm
d2 = 40 mm	L1 , L2 and L3
d3 = 50 mm	L1 , L2 and L3

Multiple piled-raft

Length of pile	Distance between two pile
L1 = 300 mm	d1 = 2d1, 3d1 and 4d1
	d2 = 2d2, 3d2 and 4d2
	d3 = 2d3, 3d3 and 4d3
L2 = 450 mm	d1 = 2d1, 3d1 and 4d1
	d2 = 2d2, 3d2 and 4d2
	d3 = 2d3, 3d3 and 4d3
L2 = 450 mm	d1 = 2d1, 3d1 and 4d1
	d2 = 2d2, 3d2 and 4d2
	d3=2d3,3d3 and 4d3

MATERIALS

Sand

Locally available Krishna River sand has been chosen as soil medium for the tests because it is easy to handle and is free from time effects. Test is conducted on sand of uniformly graded, having specific gravity, G = 2.64 and relative density, ID = 1.8.

EXPERIMENTALMETHOD

Placement of Sand

To get the desired density in all tests, sand was placed in the test tank by rain fall method. Height of fall of 400 mm was maintained in all the tests. An average density of 1.67 gm/cc is maintained in all the tests, the variation being marginal. Density was checked by weighing quantity of sand required to fill the tank.

Procedure

At first, sand layer was provided at the bottom of the tank by pouring sand from 400 mm height same as relative density. Then the pile with single pile having different length and different diameter and double pile having different length and different diameter and different spacing were placed in vertical position by little penetration into the sand to ensure proper seating of the pile and is held in position till the tank is filled up. Then the different size of raft was placed on piles. Two dial gauges of least count 0.01 mm were placed in two opposite sides on the piled raft for measuring the settlement at different loading increment as shown in Fig. 1. Load was applied with the help of screw-jack and was measured with a proving ring having calibration 1 div. = 0.1886 kg. Load was applied in increments and corresponding settlements readings were noted. With the help of the above tests the load settlement curves for the pile-raft were plotted.

Fig. 1 Pile Load Test Setup

RESULTS AND DISCUSSION

The test results and the behaviour of load with settlement have been presented in the graphical form. For raft size (270 mm x 217 mm) and single pile of 30 mm diameter of length 300 mm shows 30 mm settlement of foundation on less than 25 Kg load (Fig. 2) and the settlement from 30 mm to 42 mm for the load variation of 25 Kg to 236.71 Kg. Hence the ultimate load carrying capacity of piled-raft is 0.0024 Kg/mm2 (2.34 t/m2). For raft size (328 mm x 121 mm), double pile of 50 mm diameter, length 600 mm and distance between two pile is 3d (150 mm), shows 8 mm settlement on less than 350 Kg load whereas settlement from 8 mm to 34 mm for the load variation of 350 Kg to 578.24 Kg (Fig. 3), hence the ultimate load carrying capacity of the soil in this case of piled raft system is 0.0125 Kg/mm2. For same length of pile, load carrying capacity of piled raft increases from 75 kg to 140 kg for same settlement of 35 mm when diameter of pile increases from 30 mm to 50 mm. Similarly, Load carrying capacity increases from 50 kg to 125 kg for same settlement of 30 mm when length of pile increases from 300 mm to 600 mm keeping constant pile diameter 40 mm. Load carrying capacity of piled raft foundation increases from 200 kg to 235 kg if pile spacing increases from 2d to 3d for 25 mm settlement. Same trend has been also observed from different set of piles Load carrying capacity of piled raft model for single pile is 140 kg and it is 225 kg for piled raft with double pile of same diameter and length but spacing is 3d for 25 mm settlement. Hence, load carrying capacity of piled raft increases rapidly with increase in no. of piles under raft for proper spacing. It is observed that for load of 150 kg, settlement is 28 mm for single piled raft, where as it is reduced to 16 mm for double piled raft of same diameter and same length of pile. Therefore, it can be concluded that settlement can be effectively control by providing of greater number of piles under the raft.

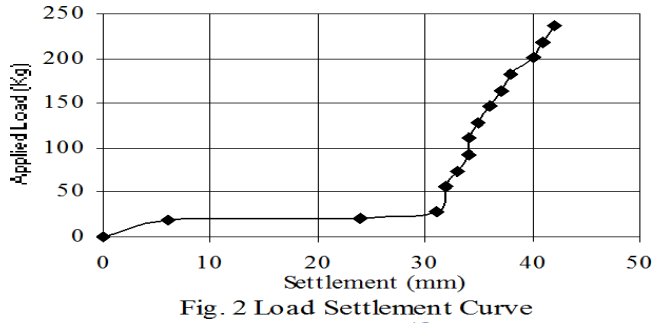

Fig. 2 Load Settlement Curve

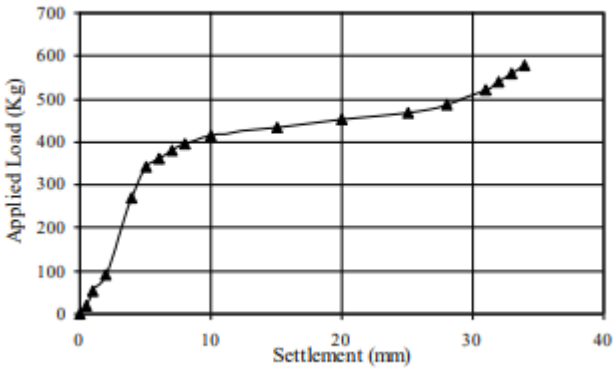

Fig. 3 Load Settlement Curve

CONCLUSIONS

On the basis of the experimental findings on the behaviour of soil under piled raft foundation model, the following conclusions are drawn:

(i) When the load is taken by piles only under the raft, the settlement is quite faster with little load on the piled raft.

(ii) The load carrying capacity increases considerably when the load is transferred to the soil through raft and pile combined while the settlement per unit load is quite less.

(iii) In case of piled raft with single pile, the settlement per unit load is more with decrease in the l/d ratio, (higher is the diameter compared to the length of the pile) more effective is the piled raft foundation.

(iv) More is the size of the raft less is the settlement per unit load.

(v) In case of two piles supporting the piled raft, rate of settlement per unit load is quite low, implies that the performance of the foundation improves considerably. In future,

simple method of design of piled-raft foundations may be developed based on graphical charts generated through laboratory and field experiments. More exhaustive study can be made on various size of rafts, number of piles, shape and size of piles and different types of soils.

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