Analysis of Physical Modeling of Cast -In-Situ Concrete Piled Raft

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Abstract:- Now days there is competition for constructing high rise buildings, the reason may be due to decreasing availability of land due rapid industrialization & urbanization. This has increased heavy load, complicated stress conditions and having limitation of bearing capacity of Soil. This results in settlement of high rise buildings. This leads to use of piled raft foundation. But the load bearing capacity of piles is not considered, they are used as settlement reducers only and load is carried by raft only. In another design method axial capacity of the piles to carry the structural load and bearing capacity of raft neglected. In both the design approach piled raft foundation becomes uneconomical. Now research is going on for considering the load bearing capacity of both pile and raft and developing detail analysis. In a pile raft foundation, pile-soil-raft interaction is complicated. Although several numerical studies have been carried out to analyze the behaviors of piled raft foundations, very few experimental studies are reported in the literature. The available laboratory studies mainly focus on piles made with steel or aluminum. The present study aims to study the behaviors of piled raft foundation, in the laboratory using physical model. The physical model is made up of Cast –in –place reinforced concrete piles and reinforced concrete raft are used for the tests. The test are conducted on single pile ,pile group, un-piled raft, free standing pile group and piled raft foundation. We examine the effects of numbers of piles, the interaction between different components of foundation and load sharing ratio of pile and raft. The results indicates that the ultimate bearing capacity of the pile raft foundation is considerably higher than that of free standing pile group with same number of piles .

Keywords: Pile, Piled Raft, Raft, model

1. Introduction: -

A piled raft foundation is not new approach and described by several authors including Zeevaert(1957), Davis and Poulos (1972), Hooper (1973). piles as settlement reducers have been discussed in past (Burland et al1997) in raft foundation. The structures based on the piled raft structures are also reported in the literature (H S W Chow, J C Small 2008). The piled raft is a foundation which acts as a composite structure consisting of three load bearing elements: piles, raft and subsoil (Reul and Randolph, 2004). Piled raft foundations are treated as combined foundations on raft and pile groups. It is getting well known as one of the most economical foundations among engineers. But still very few structures are constructed over this foundation. The reason for this may be partly because design code for piled raft foundations has not been established. The use of Pile Raft foundation is an effective way of minimizing both total differential settlements, of improving the bearing capacity of a shallow foundation and of reducing in an economic way the internal stress levels and bearing moments within a raft. The concept of pile raft combines the load-bearing elements of piles, raft and soil in a composite structure. The behavior of pied rafts is determined by complex soil structure interaction effects. There are no definite design strategies or standards available for reliable design and analysis of piled raft foundation. Although several numerical studies have been carried out to analyze the behaviors of piled raft foundations (Dung et al., 2010; Raut et al., 2014; Comodromos et al., 2016;

Alnuaim et al., 2017; Huang et al., 2017), . very few experimental studies are reported in the literature. The available laboratory studies mainly focus on piles made with steel or aluminum. But in field the piled raft is made up of concrete. So to stimulate the field situation, concrete is used for piled raft foundation. The present study aims to study the behaviors of piled raft foundation, in the laboratory using physical model. The physical model is made up of Cast –in –place reinforced concrete piles and reinforced concrete raft are used for the tests. Piled raft foundations utilize piled support for control of settlements with piles providing most of the stiffness at serviceability loads, and the raft element providing additional capacity at ultimate loading. Consequently, it is generally possible to reduce the required number of piles when the raft provides this additional capacity. In addition, the raft can provide redundancy to the piles, for example, if there are one or more defective or weaker piles, or if some of the piles encounter drastic conditions in the subsoil. Under such circumstances, the presence of the raft allows some measure of re-distribution of the load from the affected piles to those that are not affected, and thus reduces the potential influence of pile “weakness” on the foundation performance. Another feature of piled rafts, and one that is rarely if ever allowed for, is that the pressure applied from the raft on to the soil can increase the lateral stress between the underlying piles and the soil, and thus can increase the ultimate load capacity of a pile as compared to free-standing piles.

2. Equipment and Test Set Up

2.1 Loading Frame

All tests were carried out in the specially fabricated loading frame of cubical size as shown in figure 1. The loading frame consists of beam and column was fabricated by using box section of 60 mm x 60 mm. The loading frame is made up of steel box of size 60 mm x 60 mm and 1500 mm length. Bottom frame & top frame is made of four box sections of size 1500 mm. These top and bottom frame was connected by four boxes each at each corner of the frame at top & bottom. So there was a formation of cubical shape frame.

2.2 Soil Tank

For placing soil cubical specimen box of size 1500 mm x 1500 mm x 700 mm made up and open in upper side. The box is made up of mild steel sheet of 2 mm thick at bottom of loading frame of depth 700 mm. Soil tank was sufficiently larger than the zone of influence to avoid edge effect .

2.3 Loading Arrangement

Loading was done with the help of mechanical screw jack of capacity 25 kN. Loading was measured with the help of S-type load cell of capacity 25kN. The displacement was measured with the help of LVDT at corner of the foundation. The loading cell and the LVDT's are connected to the electronic display so that we can take the reading comfortably. The set up was fabricated and kept at Geotechnical laboratory. Mechanical screw jack is used for applying the loading to the model piled raft foundation. The Mechanical screw jack is manually operated and easy to handle. The s- shaped load cell is attached below the mechanical screw jack for measuring the load applied

2.4 Model Piles

In this laboratory model test cast-cast-in place board concrete piles are used. All these testing are done under equal conditions in order to investigate the behaviors of pile raft foundation. The main important aspect is to find the load sharing ratio of raft. The model piles used in the tests are concrete piles with a reinforcement of 3mm diameter mild steel and the pile length was, 50 cm. And the thickness of the concrete raft was 40mm so that the raft could behave as a rigid foundation. Generally, the contact pressure of the raft, stress and settlement of the pile depends on the relative stiffness of the components. Concrete piles of uniform circular section of 25 mm diameter and length of 400 mm, 500mm and 600 were used in the present investigation. To know the effect of change in material piles are made by RCC of M35 grad & using reinforcement of 3mm diameter. The arrangement shown in Figure 1

2.5 Model Raft (Pile Cap)

The size of the raft is 400 mm x 400mm was used in model tests. The size and thickness of the raft is kept constant. The thickness of the raft was chosen 40 mm (rigid raft).The raft is made up of concrete material raft made by RCC of M35 grad & using reinforcement of 3mm diameter as shown in Fig 1.

2.6 LVDT & Dial Gauge

To measure settlement, two linear variable displacement transducers (LVDT) having 50 mm range with 0.01 mm sensitivity used. They were placed at edges of the raft.

2.7 Electronic Display

Electronic display is required for the recording of the readings of load applied and the corresponding settlement. The digital electronic display is attached to the loading frame. One direct connection is done from load cell to the electronic display to read the load applied to the foundation. Another connection is done from LVDT to electronic display to record the settlement of the foundation.

2.8 Foundation Soil

The soil is collected from the site 40 km away from the geotechnical laboratory near village Kamptee site is shown in fig . 3.6 of clay type. Tests mentioned in table 1 are conducted to determine the properties of soil and results are tabulated as follows.

Table 3.1: Soil Properties

Sr. No.	Soil Properties	Results
1	Water Content	16.51 %
2	Specific Gravity (G)	2.32
3	Particle size Distribution	CH
4	Plastic Limit	23%
5	Liquid Limit	54%
6	Shrinkage Limit	12.87%
7	Optimum Moisture Content	16.51
8	Permeability	8. 11x 10-4cm/sec

2.9 Soil Bed Preparation

The technique of artificial consolidation of soft clay plays an important role in the process of achieving reproducible shear strength. The reliability of results would depend upon the uniformity of the foundation medium. With this consideration the soil was prepared in the laboratory to get similar shear strength and other properties of soil as follows.

Firstly large lumps of oven–dried clay were broken and water was added. Water and soil were thoroughly mixed till the water content of the soil was nearly 55% to ensure complete saturation and hand shaken to eliminate air voids. Then, the soil was placed in the mild steel bin (tank) in three layers, each being 150 mm to 200mm in height and consolidated under the consolidation pressure. After placing the soil into the tank, a 50 –mm layer uniformly graded sand was placed on the top of the soil layer to serve as a pervious base for reducing the consolidation time. Between the sand and clay layer, a layer of jute was placed to prevent intermixing. Subsequently, covering the entire area of the test tank, a 5 mm thick perforated plate was placed on top of the sand layer. In order to reach the specified consolidation pressure, a high stack of dead weights were required to be placed over the clay layer. Consolidation period for the first two layers was set as 48 hours (2 days) for each layer and for the third layer it was set to 1days. Un-drained shear strength of the consolidated clay as measured by vane shear / unconfined compression test was found to be 8+- kPa. The optimum water content is maintained throughout test.

3.0 Load Settlement Behaviour Test Procedure

Depending on the number of piles in a group and centre to centre spacing between piles different pile configurations were identified. Consequently, following the consolidation of the clay bed, model piles of specified lengths were casted in the consolidated clay bed. Next, the model raft was placed over the piles. Finally, the horizontal alignment of the raft was checked using a sprit level. It was ensured that while performing tests on piled raft and individual raft, there was a full contact between the soil layer and the raft.

After the model set up is ready, the lever was placed over the piled raft for applying the load. To measure settlement, two linear variable displacement transducer (LVDT) having a 50-mm range with .01 mm sensitivity were used. They were placed diagonally opposite on the model raft to get average settlement at the centre of the raft. For determining the immediate settlement, loads were applied in gradual increment and settlement was recorded till there was no appreciable change in settlement for a particular load increment. Then the next load increment was applied. The tests were continued until the settlement was more than 10% of width of corresponding raft.

The working load were calculated by applying a factor of safety (F.S.) 2.5 and 1.5 to the ultimate load carrying capacity of the corresponding un-piled raft. The ultimate load carrying capacity was determined from the load settlement cure at an immediate settlement of 10 % of B (width of raft) as suggested by Cooke (1986). These findings have been recently confirmed by centrifuge tests (Conte et al. 2003), as well as field tests (Borel 2001). This dependent settlement behavior for a period of 48 hours, thereafter settlement ceases. During the experiment, soil deformation was monitored and the settlement reading were taken at regular time intervals until the relationship between settlement and the logarithm of time become horizontal. Same procedure was adopted for centrally located piles by keeping uniform spacing. In all the cases, the test was repeated to check their reproducibility.

4.0 Experimental Result and Discussion

As we have already seen that total 40 number of load settlement test and 45 time settlement tests has done and the results are presented in graphical forms and discussed.

The length of pile kept 400 mm is kept constant and the different combinations are tested to their ultimate capacity of raft and piles. Initially only raft model 200mm x 200mm is tested without piles. On the other hand only piles groups of 2 x 2, 3 x 3 and 4 x 4 are tested without raft. The raft is kept untouched to soil so that all the loads were taken by piles only. After this piled raft of above size and the different combinations of pile groups are tested and presented in Fig. 9.1.The sum of ultimate load bearing capacity of single raft and the ultimate load bearing capacity of 2 x 2 pile group must be nearly equal to the load bearing capacity of combined piled raft of same identities. But the ultimate load bearing capacity of combined piled raft is 2.75 % more than the addition of individual capacities of pile and the raft. Also the ultimate load bearing capacity of combined piled raft is 2.22 % more than the sum of ultimate load bearing capacity of single raft and the ultimate load bearing capacity of 3 x 3 pile groups. And the ultimate load bearing capacity of combined piled raft is 3.62 % more than the sum of ultimate load bearing capacity of single raft and the ultimate load bearing capacity of 4 x 4 pile groups. As we increase the number of pile 4 to 9 there is increase in capacity by 33%, and when we increase the pile number from 9 to 16 then there is increase in capacities by 24%. Also in case of combined piled raft foundation when we increase the number of piles from 4 to 9 the ultimate load bearing capacity of combined piled raft foundation increases by 17 % and for piles group 9 to 16 there is increase of 14 %.

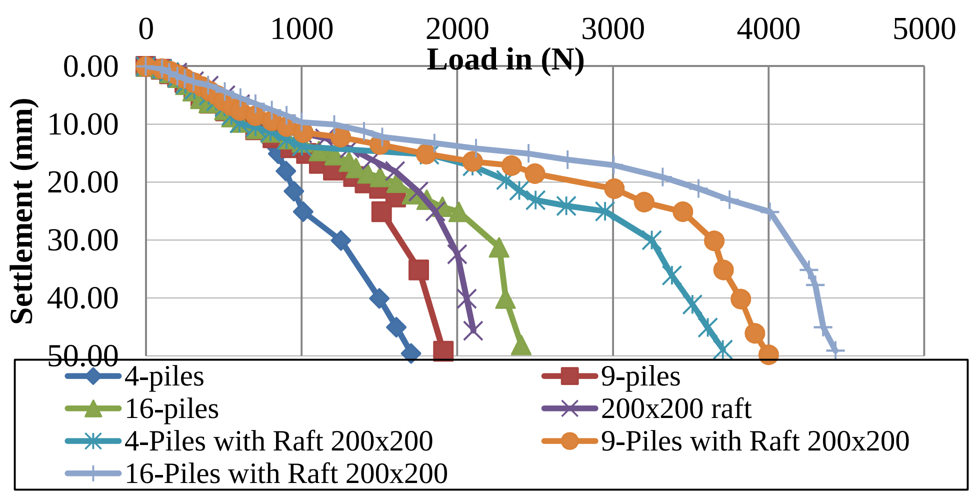
The size of the raft is changed to 300mm x 300 mm and different pile combinations are tested for the same pile length of 400 mm. As the size of the raft get increases the ultimate load bearing capacity of raft increases more than double. The same combination of piles groups of 2 x 2, 3 x 3 and 4 x 4 are tested combined with raft and then individual raft tested. There is no need to test pile groups individually as we have already tested and same values can be used here. The ultimate load bearing capacity of combined piled raft is 1.50 % more than the addition of individual capacities of pile and the raft. Also the ultimate load bearing capacity of combined piled raft is 1.11 % more than the sum of ultimate load bearing capacity of single raft and the ultimate load bearing capacity of 3 x 3 pile groups. And the ultimate load bearing capacity of combined piled raft is 1.11 % more than the sum of ultimate load bearing capacity of single raft and the ultimate load bearing capacity of 4 x 4 pile groups.

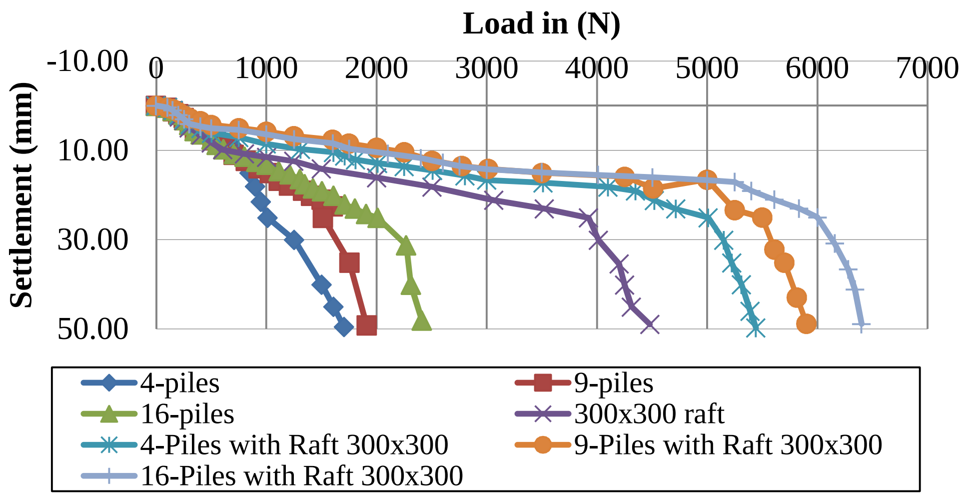
The size of the raft is changed to 400mm x 400 mm and different pile combinations are tested for the same pile length of 400 mm. As the size of the raft get increases the ultimate load bearing capacity of raft increases by 78%. The same combination of piles groups of 2 x 2, 3 x 3 and 4 x 4 are tested combined with raft and then individual raft tested. There is no need to test pile groups individually as we have already tested and same values can be used here. The ultimate load bearing capacity of combined piled raft is 1.3 % more than the addition of individual capacities of pile and the raft. Also the ultimate load bearing capacity of combined piled raft is 5.5 % more than the sum of ultimate load bearing capacity of single raft and the ultimate load bearing capacity of 3 x 3 pile groups. And the ultimate load bearing capacity of combined piled raft is 9.03 % more than the sum of ultimate load bearing capacity of single raft and the ultimate load bearing capacity of 4 x 4 pile groups.

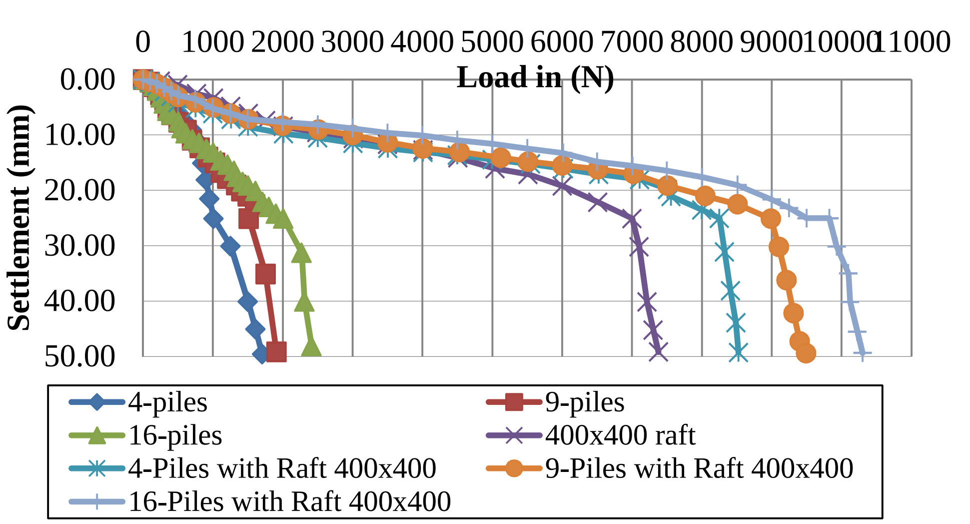
The above described testing for the piled raft is repeated for the length of pile of 500mm and 600 mm with different sizes of raft 200mm x 200mm , 300mm x 300mm, 400mm x 400mm with the different pile groups of 2 x 2, 3 x 3 and 4 x 4 pile groups. The load – settlement nature of these testing are shown in the graphs.

In this study main objective was to calculate load bearing ratio of piled raft foundation. Experimentally we cannot determine the load taken by piles and load taken by raft separately in combine raft foundation. So we first determined the load taken by raft only up to failure. And then load carried by piled raft foundation up to a failure point. This total load taken by combine piled raft foundation minus load taken by raft gives us the load carried by piles.

Fig.1 Actual Test Set-up







5.0 CONCLUSIONS

1) The use of piled raft foundation plays very important role in reducing maximum as well as differential settlements. Also the use of piled raft foundation reduces the considerable number of piles or the length of pile as compared to the fully piled foundation Due to this piled raft foundation becomes economical and saves time as compared to piled foundation.

2) Load carrying capacity of piled raft foundation is always more than the addition of individual load carrying capacity of pile and raft. The increase in the capacity is due to combined action of both pile and raft foundation and the consolidation increases due to piles.
3) The load distribution of the piled raft foundation depends on contact surface area with soil of raft as well as piles. The surface area ratio of 1.25 to 1.6 is more suitable for perfectly piled raft foundation. This ratio indicates that due to different load resisting mechanism of raft & pile i.e. pile resist load by skin friction and raft by bearing action.
4) It is observed that load sharing ratio of piled raft foundation depends on stiffness of pile and raft. While designing piled raft foundation depending upon situations we can adjust load sharing of piled & raft, by changing the stiffness (dimension) of the piles as well as raft. If we increase the thickness & dimension of raft we can reduce the number of piles in piled raft foundation.

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