ABSTRACT

Piled raft foundation is a fairly recent technique, in which the load is shared by its constituting elements namely the raft, piles and the supporting soil. This is yet to become a choice in the minds of designers because of the complexity involved in the analysis. The works reported in the literature are mostly on overconsolidated clay. Further its applicability to support moderately loaded buildings on sand and predominantly sandy soils are yet to be established. Keeping all the above in mind, a series of small scale 1g model test were conducted on piled raft founded on sand and the results were compared with three dimensional nonlinear analyses. Apart from model tests, a prototype piled raft foundation supporting a twelve storied structure was designed, constructed, and instrumented with settlement gauges and monitored during and after the construction.

In the case of small scale model studies, nearly 110 tests were carried out in all on the circular, square and strip piled raft. Test on the unpiled raft was also performed along with a series of tests on free standing pile group (pile group with cap/raft not in contact with soil). The load settlement behavior of the plain raft, free standing pile group and the piled raft were studied in detail under uniformly distributed load. From the results, the settlement reduction and load share between the raft and the pile group was obtained. It was found that the pile group of piled raft was exhibiting an elastic and work hardening behavior and was resisting a higher load than the free standing pile group. It was found that at a settlement of 2mm, which is 1% of the raft diameter (or width of the raft) used, the pile group starts losing its stiffness rapidly. In the case of piled raft while the settlement was same, the magnitude of frictional resistance of piles was much higher than free
standing pile group for a given settlement. This settlement has been termed as critical settlement and the magnitude of load taken, has been termed as limiting friction. All the tests were performed upto a settlement of 20mm, and the settlement reduction was arrived with reference to plain raft settlement.

It was found that the piled raft exhibited three phase behaviour. In the beginning the major part of the load was shared by the pile group. As the settlement increased the stiffness of the piled raft reduced and it was found that beyond a settlement level of 3% of the diameter / the width of the raft, the stiffness approached the magnitude of plain raft and at this stage the load shared by the pile group remained constant. This response of piled raft in sand is characterised as three phase behaviour and is termed as multi-linear strain hardening behaviour. The relative stiffness of the piledraft tested is higher than the raft stiffness irrespective of the pile parameters and densities of sand tested.

The parametric analyses carried out through 1g tests in this study established that the addition of even a smaller number of piles could reduce the raft settlement by an appreciable amount, though the load shared by them was small. It was found that an addition of piles of area ratio of 5.2% to the raft could produce a settlement reduction of 37% corresponding to 20mm settlement of the plain raft. It was also found that the load sharing behavior was depending upon the settlement. As the settlement increased the load sharing ratio decreased and for settlements more than 3% to 4% of the lateral dimension of the raft used, the magnitude of load sharing ratio, \( \alpha_{pr} \) remained constant. It was found that the number and length of the piles had a noticeable influence on the settlement reduction and load sharing behavior of the piled raft. Further, it was seen that increasing the pile length more than the L/B ratio (L = Length of pile and B = diameter or width of square raft) of 0.8 the contribution towards load sharing and settlement reduction is not appreciable.
However the length of pile of 1B is preferable for effective performance of the piled raft. Also the diameter to raft thickness ratio (d/t ratio) of unity will be ideal for obtaining a maximum settlement reduction and load sharing. It was also found that the performance of piled rafts were similar in all the three bed densities irrespective of their shapes.

The numerical analyses performed using ANSYS FEM Code showed a stiffer response when soil was treated as elastic material. The 3D nonlinear analyses with MISO material model for soil continuum predicted the behaviour closely with the 1g model tests. The head load and the tip load obtained from the numerical analysis indicated that the tip load was of the order of 10% of the applied load on the piled raft indicating the pile group functions purely as friction pile. The load sharing ratios obtained from the numerical analyses and the model tests agreed very closely.

Concurrently a twelve storied structure designed and supported on the piled raft was monitored over a period of 796 days including the post construction period of 436 days. The structure was supported on 93 piles of 500mm diameter having a length of 14m below the raft of 600mm thick founded in a deposit which is predominantly sand. The maximum settlement of the piled raft under the combination of structural load on completion and load on occupation of building (145kN/m²) was found to vary 9mm to 14mm at the location of settlement markers, which had showed that practically there was no differential settlement. From the settlements observed, the contact pressure below the raft was back computed using elastic theory for each stage of settlement; it was found that the load shared by the raft progressively increased to share 43% of the load at the end. The three dimensional linear analysis performed indicated that the contact pressure distribution below the raft was almost uniform. Also the pile head load and tip load distribution indicated that the piles behaved as friction piles which is one of the essential
requirements of the settlement reducing piles. Also it was found that the load sharing between the piles and the raft was of 62% and 38% respectively and is in close agreement with the values obtained from the observed settlements adopting elastic theory.

The entire study had established that the piled raft can perform satisfactorily in sand. The introduction of piles having a small ratio of area around 5% can produce a settlement reduction of 20% to 65% depending on the diameter and the length of pile adopted. The performance of piled raft was found to be almost similar in all the three bed densities. It was also found that length and diameter of the pile had more influence on the piled raft behaviour. The study on the prototype piled raft established that the piled raft with smaller diameter piles and relatively thinner raft is effective in supporting moderately loaded structure founded in predominantly sandy strata. In other words the study established the applicability of piled raft as foundation system in sandy soil to support moderately loaded structure.