CHAPTER 1

INTRODUCTION

1.1 GENERAL

The concept in foundation design has always been tradition bound. Tall and heavily loaded structures such as office complex, shopping complex, residential apartments, large storage tanks, etc., are supported either on raft or on pile foundations. When both bearing capacity and settlement requirements are satisfied by the supporting soil mass which is near the ground, the obvious choice of the foundation system is the raft, otherwise pile foundation becomes the automatic choice. The main aim in introducing the pile foundation thus becomes twofold; one to provide sufficient safety against bearing failure, and another to eliminate the movement of the structure, otherwise called settlement of the structure. By convention even when adequate bearing capacity is available, if settlement poses a problem, piling is resorted to.

The traditional design of pile foundation is largely through empirical or semi empirical approaches. When the piles pass through particularly sandy strata, the pile design entirely depends on the observed N value and the parameters derived based on N value. In some cases, even dynamic formula is used and the piles are eventually terminated in the hard strata. The ultimate load on the pile is expected to be purely from the bearing and in many cases even the shaft friction is not accounted for, leaving this as an additional factor of safety.

When the piles pass through clayey strata, the ambiguities prevalent in taking the adhesion factor and computation of negative friction make the designer resort to a highly conservative design. This is mainly due to the complicated interactions between the constituents and the three
dimensional nature of the problem. The difficulties faced in sampling at site make the evaluation of in situ properties of the strata, a questionable issue. The above limitations have led to the permissible stress and deformation to be within the elastic limits.

By default, the design of piles and pile group are prepared in such a way that the entire structural load is taken by the piles and the load is transferred to the hard strata. The presence of the pile cap, or the raft as the case may be, and its contribution is completely ignored. Even when the cap or the raft is placed on a ground with a reasonable bearing capacity, its contribution in sharing the load is ignored. Even though this provides a very high overall safety factor, invariably the number of piles provided becomes more than what is required. The estimation of settlement in such cases becomes a routine, as it is going to be far less than the permissible value. This makes the foundation designers feel more confident although the design is uneconomical.

The geotechnical design of foundation has following three steps:

1. Estimation of bearing capacity of the soil.
2. Computation of settlement.
3. Evaluation of stress in the various components of the foundation element.

In the conventional approach of foundation design, the bearing capacity governs the design and the settlement is completely eliminated. Foundation design becomes economical when both the criteria of bearing capacity and settlement are satisfied in an optimum way. It will always be more economical when the settlement is controlled and brought to an acceptable limit rather than altogether eliminating it. This involves the computation of settlements and differential settlement more accurately and evaluation of the parameters required such as E_s of the soil with a reasonable level of reliability.
Considerable amount of work has been done on pile and pile group settlement over the last three decades by authors like Poulos from 1968, although most of the earlier part of work were with pile group having the cap not in contact with the ground. Simultaneously authors like Whitaker (1961) and Butterfield and Banerjee (1971) had established that the contribution of pile cap or the raft in sharing the load is significant. Subsequent attempts by Zeavert (1957) Burland et al (1977) had established the use of piles as settlement reducing elements with raft led to the generation of the concept of piled raft. In this case an optimum design of foundation is evolved with a simple raft, and piles installed below the raft to reduce the raft settlement.

1.2 BASIC CONCEPT

The basic concept in the piled raft make the piles behave more as settlement reducing elements than as load bearing members. In these cases the spacing of the piles can be larger resulting in the use of smaller number of piles. The piles are expected to undergo settlements, sufficient enough to generate their full capacity by friction.

The new concept of design is schematically shown in the Figure 1.1. Figure 1.1a indicates the contact pressure beneath a rigid raft, arrived based on the elastic solution. Figure 1.1 b shows a flexible raft with uniform contact pressure, but can undergo non-uniform settlement (i.e. differential settlement). By introduction of a small number of piles spread over the entire raft, or over a specific area of raft, where intensity of load is more and if the contact pressure can be converted to a uniform contact pressure with the overall settlement within the permissible limit; then the foundation design becomes economical.
It is to be noted here that settlement problem is not unique for clay alone, but is also applicable for sand. In the case of sand the permissible settlement is lesser than clay. Hence controlling of settlement in sand also gains paramount importance, particularly in the case of storage tanks and slender, but heavily loaded structures. The concept of introducing pile elements as settlement reducer is applicable for raft placed on sandy strata also when it undergoes larger settlement. One important aspect to be noted here is that installation of piles, particularly driven type compacts the sand and this aspect adds further fillup to the necessity of studying the interaction of pile-soil-raft in the sandy strata.
1.3 AIM AND SCOPE OF THE WORKS

The recent developments in the numerical techniques and application softwares have facilitated the study on the complex soil-structure interaction problems such as piled raft foundations. Real interactions can be considered with some of the advanced techniques similar to what had been developed by Clancy (1993). Studies have also been conducted on small scale models and centrifuge models and the outcome had provided a lot of information on the behavior of piled raft pertaining to load-settlement and load sharing behavior. Field observations of the performance of piled raft are on the rise. In spite of all the above, the piled raft is yet to become an alternate choice among the practising geotechnical engineers. Further, most of the studies reported are in clay, its suitability on sand needs to be studied in detail to establish that this system can be adopted in all types of soil. Also the use of piled raft for moderately loaded structure with relatively smaller dia piles and thinner raft placed on an actual site conditions need to be studied. The utility of a commonly available software in generating the numerical model by validating the model with the data need to be established.

The present scope of the work is aimed at establishing the applicability of piled raft on granular soil and the effect of various parameters relating to pile, raft and the supporting strata on the overall settlement reduction and load sharing behavior of piled raft. In order to achieve this, a series of small scale 1g model tests were planned and conducted on circular, square and rectangular shaped piled raft with loose, medium dense and dense sand beds. The performance of piled raft was analysed using ANSYS finite element code with MISO (Multi-linear ISO tropic hardening) nonlinear material model and verified the results of numerical analyses with experiments. Simultaneously a twelve storied building was designed with piled raft as supporting system and was constructed; the settlement was monitored for a period of 796 days, 360 days of construction period and 436 days after construction. The monitoring was done for a period of nearly 2 months after occupation. Through the study of these results the applicability
of the piled raft with smaller diameter piles and thinner raft supporting a moderately loaded building has been examined. The behavior has been studied adopting the ANSYS, FEA code and linear material model (elastic behaviour) to bring out its suitability for modelling real size piled raft under working load in layered strata. The results in the form of contact pressure and load sharing are studied to establish the performance of piled raft for a moderately loaded building.

The results of all the three studies are compiled to understand the behaviour of piled raft in sand and also to that a simple concept such as equivalent pier theory can be used for the design of piled raft.

1.4  THESIS COMPOSITION

The present thesis consists of the following seven chapters:

Chapter one presents basic concept of piled raft along with aim and scope of the proposed research.

The work done so far and the present level of understanding on the behaviour of piled raft has been presented in the Chapter 2. The review has been presented under three heads namely: (i) Small scale model studies (ii) Observational study on the proto type piled raft, and (iii) Numerical modelling or Numerical models. The limitations of the above works have been indicated to establish the need of the present study.

The details of the experimental set up and other facilities developed for conducting 1g test on models are discussed in Chapter 3. The procedure for bed preparation and installation of model piles and raft are outlined and the test adopted producers are explained.

In the Chapter 4, the results obtained from the small scale model tests are presented in the form of load-settlement curves and discussed by comparing with the plain raft behaviour. The settlement reduction achieved
by the introduction of piles is presented for various cases; also the load shared
behaviour of the raft and the piles are presented. The load transfer mechanism
is discussed and the effect of various parameters relating to pile, raft and the
bed on load sharing and settlement reduction are brought out in this chapter.

Chapter 5 presents the details on ANSYS FEM code used in this
study to numerically model the tests conducted on the laboratory models of
piled raft foundation. Typical results of linear and nonlinear analyses are
presented and validated with the experimental results. Results of numerical
studies are analysed further and the load shared by the piles of the piled raft
for various settlement are compared with the load taken by the raft.

Chapter 6 presents the field study performed by the observations
made on an instrumented piled raft supporting a twelve storied structure. The
settlements observed are used to compute the load taken by the raft. The
results of the study conducted on the numerical model are used to establish
the contact pressure at various sections and the load shared by the raft and the
pile group.

The conclusions drawn in this study based on tests on lab models,
numerical analyses and field test results; and the scope for further study are
presented in the Chapter 7.