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Analysis of Raft or Pile Foundation of any Building or Structure

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Abstract – High-rise structures may benefit from piled-raft foundations instead of standard pile or mat foundations. Pinned Rift Foundations are designed to be strong enough to hold the applied loads with an adequate factor of safety, while allowing for acceptable settlements at working load. Many studies have examined the behavior of pile raft foundations, including the impact of pile length, pile distance, pile arrangement, and cap thickness under static and dynamic loads that may be applied vertically or horizontally. Pile length combinations are examined in this study to determine how multi-story buildings respond to vertical loads. Soil settlements are assumed to be zero, and foundation settlements are calculated assuming a flexible structure. It is possible, however, that the structure's stiffness will limit any movement of its foundations, and even small differences in settlement would modify the structural elements' forces. This means that the actual behavior of a building is greatly altered by the interaction of the structure with its foundations and the soil medium underneath the foundations. Finite element software was used in this study to investigate the interaction between piles and soil structures. In ANSYS 11, This study discusses the importance of soil structure interaction in the performance of a structure, which has been proven to have a major impact.

Keywords – Raft, Pile Foundation, Building, Analysis;

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INTRODUCTION

Throughout the history of foundation design, there has always been an emphasis on tradition. A raft or a pile foundation is used to support tall and highly laden buildings such as office complexes, retail malls, residential flats, and enormous storage tanks. The raft is the obvious option of foundation system if the supporting soil mass is close to the ground and both bearing capacity and settling criteria are met. Otherwise, the pile foundation is the default choice. The fundamental purpose of adopting a pile foundation is therefore to give adequate protection against bearing failure and to eliminate the movement of the structure, otherwise known as settlement. Even if enough bearing capacity is present, piling is used if settling is an issue.

Piles are traditionally designed using empirical or semi-empirical methods. The design of the piles is fully dependent on the measured N value and the parameters obtained from N value when the piles travel through sandy layers. The piles are finally ended in the hard strata, even when using a dynamic formula. Even the shaft friction is not taken into consideration in many circumstances, leaving this as an extra element of safety for the pile's ultimate weight.

Clayey strata provide uncertainties in calculating adhesion factors and calculating negative friction, which necessitates a very cautious approach by the designer. This is mostly owing to the problem's three-dimensionality and the intricate relationships between its elements. Sample collection at the location is challenging, making the assessment of strata in situ characteristics a debatable issue. Limitations on stress and deformation have resulted in the elastic limits being met.

To begin with, the design of pilings and pile groups are developed such that the full structural load is transmitted to the hard stratum. The pile top, or the raft, as the case may be, is entirely neglected and its contribution is overlooked. An acceptable bearing capacity is not considered even if the cap or the raft is put on a solid surface. Even though this gives a very high overall safety factor, the number of heaps given inevitably exceeds what is needed. It becomes normal to estimate the settlement amount in these circumstances, since it is likely to be significantly less than the permitted amount. Although the design is unaffordable, the foundation designers feel more confidence.

There are three stages to geotechnical design of a foundation:

1. Preliminary assessment of soil strength.

2. Calculation of the settlement.

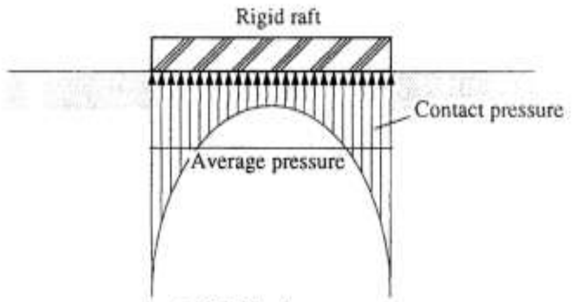
3. The foundation element's numerous components are evaluated for stress.

Settlement is fully avoided in the traditional method to foundation construction, which is governed by the design's bearing capacity. When both bearing capacity and settlement are optimally met, foundation design becomes cost-effective. It will always be more cost-effective to minimize the settlement rather than to completely eliminate it. Soil characteristics like Es may be evaluated with a decent degree of assurance and settlements and differential settlements can be calculated with better accuracy.

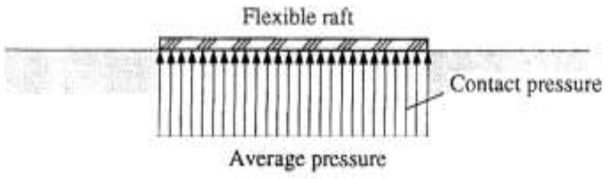
BASIC CONCEPT

Rather of being used as load-bearing parts, the piled raft's foundation is based on the idea that the pile's function more as settlement-reducing features. There is less need for individual heaps when the piles are spaced further apart. To produce their maximum potential, the piles are anticipated to settle enough.

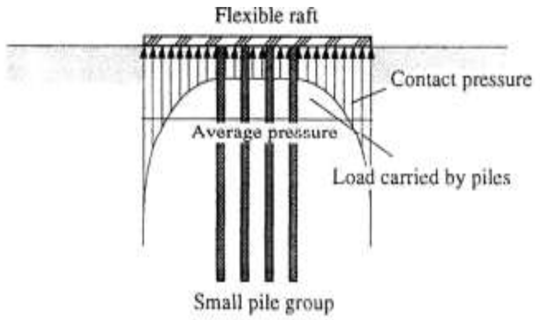
Figure 1 depicts a schematic representation of the new design paradigm. An elastic solution to the problem of the contact pressure is shown in Figure 1a. Despite having consistent contact pressure, the settling of the flexible raft shown in Figure 1b may be uneven (i.e., differential settlement). Pile foundation design becomes more cost-effective by using modest numbers of piles to cover a large amount of land, or to focus on an area of land that experiences a high level of stress. If this stress is evenly distributed, the total settlement is kept within acceptable limits.



(a) Rigid raft



(b) (Fully) flexible raft



(c) Flexible raft with small central pile group

Figure 1: General concept of piled raft

Clay and sand both have a settling issue, and it's important to point this up. Sand has a lower permitted settling than clay. Controlling settling in sand, especially in the case of storage tanks and thin, but strongly laden structures, is thus of fundamental significance. In the case of a raft built on sandy strata, the notion of incorporating piling pieces as a settlement reducer is valid even when the settlement is bigger. For example, if you're going to use driven type piling in a sandy area, you'll notice that it'll make it more essential to examine the pile-soil-raft interaction there.

REVIEW OF LITERATURE

Sunesra Shakir et. al. (2020) Commercially accepted structural software "SAFE-12.3.2" is used in the suggested Project Analysis of Raft and Piled Raft Foundations. Noida, Delhi, is the location of this G+22-story residential structure. High-rise buildings are becoming more common owing to the development in industry and urbanization as well as rising construction costs, making raft foundations less popular among architects. To put it another way, the enormous load, intricate stress and soil limitations have resulted from this. As a consequence, buildings begin to sink. A novel style of foundation known as a combination piled raft foundation is rapidly gaining popularity as a solution to high-rise structures' settling issues. With the combined action of the pile and raft, the superimposed load is transmitted to soil and helps settlement reduction in medium-rise structures. The total settling of the structure is reduced by using a combination of rafts and piles. According to IS CODE 1904:1986, the goal of this project was to decrease settlement and soil bearing pressure within the permitted range.

Elsamny et al [(2017)] pile groups on sandy soil for their ultimate capacity, settling, and efficiency. The group's efficiency was studied in an experiment. However, the experimental program was limited to evaluating single heaps, pile groups of two, three, and four piles in sand under axial compression loads. The piles were spaced apart by three pile diameters. It was possible to simultaneously measure the pile head loads, displacement, and strains along the pile's axis. According to test results, a single pile's ultimate capacity increases as the number of piles in the group increases. However, it was discovered that the settling of pile groups was greater than the settlement of a single pile under the ultimate load. Additional findings show that pile groups of two, three, and four heaps are more efficient than groupings of two, three, and four piles, respectively. However, when the number of piles in a pile group is greater than four, there is no significant improvement. Using chin's approach (1970) for determining the ultimate capacity of piles, group efficiency was found to range from 1.25-1.47.

Jayarajan P, Kouzer KM. (2015) Pinned-raft foundations are still designed using plate-and-spring-based structural analysis systems, which are still used by design engineers. There are no soil-pile interactions taken into account when the piles are treated as simple spring components with their stiffness determined for a single isolated pile. Additionally, Winkler springs are often used to mimic the raft's interactions with the soil and pile. Such programs will lead to substantial underestimation of settlement and erroneous predictions of raft bending moments and pile loads if they do not take into account the interactions involved in the stacked raft system.

It is necessary to calculate the relative proportions of raft and pile load and the influence of the piles on total settlements and differential settlement in a CPRF. Combined pile and raft foundations may be studied using both simple techniques and finite element analysis in the early analysis stage of this work. Analysis processes are shown using an example problem from the Poulos-Davis-Randolph (PDR) approach and PLAXIS, a finite element program that offers an effective computational environment to represent the complex interactions between numerous foundation components.

El-Nahhas et al. (2012) utilized for the purpose of testing software to estimate the various input parameters required for modelling different pile group systems. Tests were carried out on the ALZEY Bridge in Germany. The influence of the pile's location on the amount of weight it can bear was examined. Pile spacing and the length to diameter ratio were examined. Each of these piles was tested for it carrying capacity. To estimate the ultimate load for end bearing piles, Abd Elsamee (2013) used field pile load test data. The 600 mm diameter and 27 m length piles were subjected to four load tests. Various approaches were used to calculate the final capacity of piles. The end bearing was found to carry 54 percent of the entire load, while the shaft was found to carry 46 percent of the total load.

Anuj Chandiwala. (2010) “Fem Modelling for Piled Raft Foundation in Sand Anuj Chandiwala”. The use of stacked rafts as a foundation to lessen overall and differential settlements has grown in recent years. Use of piles of various sizes may enhance the foundation's performance when a piled raft is exposed to uneven loads. The behavior of stacked rafts has been studied extensively in the past. Research on non-identical pile rafts has been largely ignored in favor of pile rafts supported by identical piles. An 18 MIDAS GTS computer program based on the finite layer and finite element techniques is used to investigate the stacked raft's performance in this article. In order to analyses the layered soil system, the finite layer approach is used. The raft and piles are analyzed using the finite element technique. The whole interplay between the raft, piles, and so on that is critical to the behavior of stacked rafts is taken into account in the study. The stacked raft foundation has four main sorts of interactions. A significant factor is the way the heaps interact with one another. An investigation of two-dimensional (2D) finite element analysis of raft foundations on sandy soils. For the 8mx8m and 15mx15m rafts, the normalized settlement parameter (IR) varied from 1.03-1.17mm and 0.66-0.83mm, respectively, for the un-piled raft. Using a stacked raft, the maximum settlements for a raft of 0, 25, 40, 80, 1, 50, and 3.0 m thickness are 66 mm for each. Design charts based on the findings of these investigations may be put to good use in engineering practice.

FINITE ELEMENT ANALYSIS

As part of the parametric analysis, several soil types are used to examine the impact of different pile length configurations on the building's performance. Figure 2 depicts the building's layout with the piles in place. The pile raft system with structure is modelled and analyzed using a simplified 2D finite element method. Section A-A, a strip, was chosen because of this. One pile is supported beneath each column of the four bay G+11 story G+11 frame, which has been modelled and evaluated in numerous circumstances, such as adjusting the raft thickness and diameter, as well as the soil types. There is a 41-meter depth of soil and a 63-meter horizontal dimension in the study. Table 1 lists the dimensions of the beams and columns, as well as the other material properties that were considered.

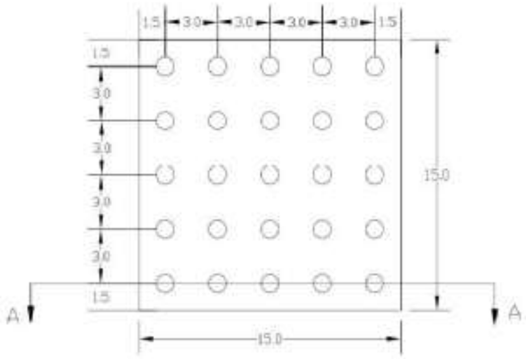


Fig.2: The building's layout, as well as its piles. “All dimension is in m”

TABLE 1: Beam, column, raft, pile, and soil material and geometric qualities

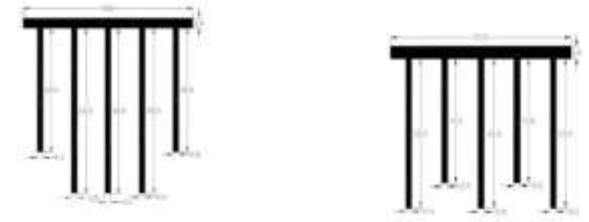
Sr.no.	Structure	Component	Details
1.	Frame	Storey height	3 m
		Bay width	3 m
		Beam size	0.35 m x 0.60 m
		Column size	0.35 m x 0.80 m
2.	Pile	Diameter	Varying
		Length	Varying
3.	Concrete	Young's modulus	2.4 x 10¹⁰N/m²
		Poisson's ratio	0.15
		Density	25000 N/m³
4.	Clay	Young's modulus	16.5 x 10⁶ N/m²
		Poisson's ratio	0.45
		Density	16.4 x 10³N/m³
5.	Stiff clay	Young's modulus	60x10⁶/m²
		Poisson's ratio	0.35
		Density	20.0 x 10³ N/m³
6.	Silty sand	Young's modulus	205 x 10⁶ N/m²
		Poisson's ratio	0.30
		Density	21.0 x 10³ N/m³

RESULTS AND DISCUSSIONS

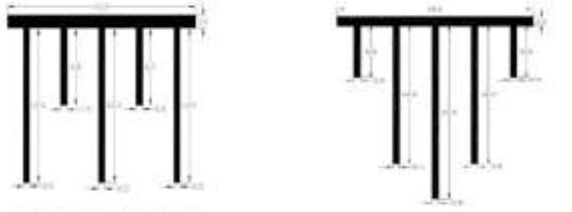
Rafter thickness is 1m and pile diameter is 500mm for the various lengths of piles studied. Diverse pile lengths, soils, and structures are used in various groupings. Combinations of equal length, U-type, zig-zag, V-type, and T-shape type are taken into consideration. Analyses are carried out utilizing a variety of models shown in Figure 3. The numerous models with differing pile lengths and raft designs are illustrated below.


(b) E2 – All length of pile - 16 m

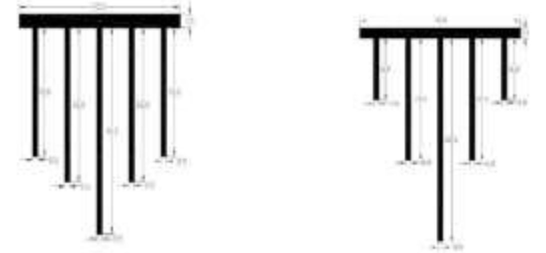
(c) Z1 – Alternate 16 m and 12 m pile length


(e) U3 - Exterior and interior pile length 12 m and 16 m respectively

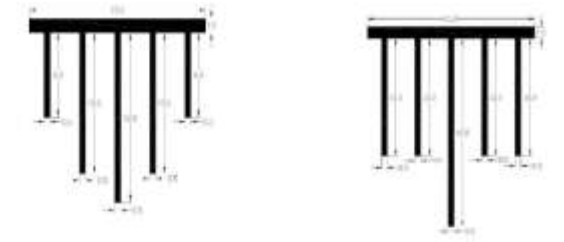
(f) Z2 - Alternate 12 m and 10 m pile length


(g) Z3 - Alternate 12 m and 6 m pile length

(j) V3 – Exterior – 6 m, interior - 16 m and middle pile length - 20 m


(h) V1 – Exterior – 10 m, interior - 12 m and middle pile length – 16 m

(k) V4 – Exterior - 6 m, interior - 12 m and middle pile length - 20 m


(i) V2 - Exterior - 6 m, interior – 10 m and middle pile length - 12 m

(l) T1 – Middle pile length – 16 m and other pile length - 10 m

Fig.3: Models with a variety of pile lengths are used.

All 12 models of various pile configurations were subjected to a finite element analysis using the ANSYS 11 program. To discover the most economical pile length for a given amount of concrete, the results of the research are plotted against several models.

Soft clay is observed to have higher maximum moment values than silty sand and stiff clay. V-shape and U-shape models also have lower maximum moment values than the other models for all soil types. Because of this, the combination of pile length in terms of both moment and concrete amount is best achieved by using the V-shape and U-shape models. The optimal pile design seems to be soil-dependent as well. From one soil to the next, the optimal arrangement will be different.

The greatest displacements in soft clay are greater than in silty sand. Furthermore, it can be observed that the values of displacements for all models are close to the same for all kinds of soils. In terms of moments and displacements, the V-shape, U-shape, and T-shape models provide the best results. As a result, Fig.4 shows the total pile length for each V-shape, U-shape, and T-shape configuration of pile length.

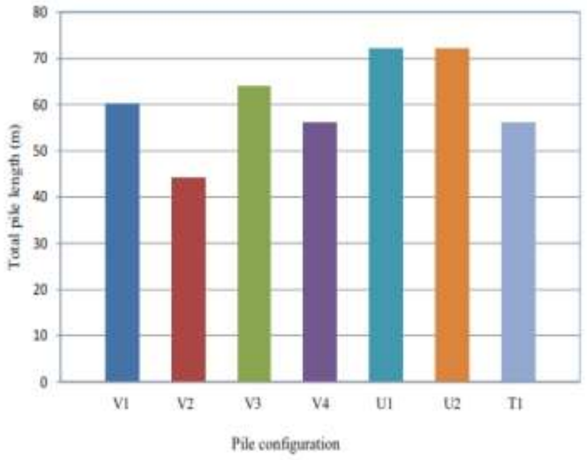


Fig.4: Total pile length for pile configurations in V, U, and T shapes

CONCLUSIONS

Soft clay's maximum moments are substantially bigger than silty sand's and stiff clay's maximum moments in every circumstance. V-shape and U-shape models have lower maximum moment values than other models for all soil types. There is no better combination of piling length in terms of both moment and concrete amount than the V and U-shaped variants. The optimal pile design seems to be soil-dependent as well. Soil-to-soil, the ideal setup varies.

Under the right geotechnical circumstances, piling raft foundations may offer cost-effective foundation solutions. For this reason, the final load capacity and settling requirements must be taken into account while designing the raft, and the essential issue is to determine what the ideal pile length configurations are for the raft in order to meet all of these criteria. The foundation designer may utilize some of the findings in this article to help them come up with a logical response to this issue.

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