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Analysis & Design of Pile Raft Foundation

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Abstract:
The use of piled raft foundations has become more popular in recent years, as the combined action of the raft and the piles can increase the bearing capacity, reduce settlement, and the piles can be arranged so as to reduce differential deflection in the raft. Piled raft foundation is a new concept in which the total load coming from the superstructure is partly shared by the raft through contact with soil and the remaining load is shared by piles through skin friction. A piled raft foundation is economical compared to the pile foundation. Because piles do not have to penetrate the full depth of clay layer but it can be terminated at higher elevations. Such piled raft foundation undergoes more settlement than the pile foundation and less settlement than the raft foundation. In this paper the study of different parameters like size of the raft, thickness of the raft, diameter of the piles, length of piles, configuration of piles stiffness of raft and piles etc., which affect the behaviour of piled raft foundation. And its interdependency is also reviewed for G + 14 storey building. This study is useful to decide the various parameters required in the design of piled raft foundation and suggest the suitable combination of Pile Raft Foundation..

***Keywords**: Compressible clay, settlement, deflection*

1. Introduction

The use of piled raft foundations has become more popular in recent years, as the combined action of the raft and the piles can increase the bearing capacity, reduce settlement, and the piles can be arranged so as to reduce differential deflection in the raft. Piled raft foundation is a new concept in which the total load coming from the superstructure is partly shared by the raft through contact with soil and the remaining load is shared by piles through skin friction. A piled raft foundation is economical compared to the pile foundation because piles in this case do not have to penetrate the full depth of clay layer but it can be terminated at higher elevations. Such piled raft foundation undergoes more settlement than the pile foundation and less settlement than the raft foundation. To support a heavy building on clay deposit the following three options are normally available .

- If the clay layer has very poor shear strength, the building is supported on load-bearing piles, transferring all loads to a deeper, competent layer. This of course is the most reliable solution, but the cost of piled foundations could be very high owing to the large pile length that is required.
- If the clay layer has adequate strength, the building can be supported on a raft foundation. Settlements can be high, but if the structure can functionally permit this, the raft can be provided for economy.
- When the clay layer has intermediate strength, alternative (b) may not be feasible, as the bearing capacity may not be adequate, or settlements may be excessive, which may also cause distresses to adjacent structures. Owing to the high cost of land in urban areas, the normal tendency is to utilize all the available plot area for building construction.

Therefore considerable deformation can be transferred to the foundations of adjacent structures, which may be old and weak. In such situations, where it becomes necessary to reduce settlements, a piled raft can be provided.

2. Literature Review

Historically, the pile raft analysis has its origin to the pile group analysis. The early work of Skempton (1953) and Meyerhof (1959) were empirical in nature and relates to the settlements of pile groups. The important work of Fraser and Wardle (1975), Poulos and Davis (1980), Randolph (2003), and Poulos (2006) are reviewed in relation to the pile group analysis, load transfer mechanism and other pertinent aspects related to the fundamentals of pile group analysis. The contributions from Tomlinson (1986), Coduto (1996), Poulos (1993) and Van Impe (1991) are also studied in relation to the equivalent raft methods of analysis. The contributions from Poulos (1993), and Clancy and Randolph (1993) are reviewed in relation to the equivalent pier methods of analysis in piled raft foundations. The rapid developments

In the numerical analysis of pile behaviour and piled raft foundations saw numerous. The more rigorous methods of piled raft analysis began with the contributions of Kuwabara (1989), and extended by Poulos (1993) with further contributions from Ta and Small (1996), Zhang and Small (2000), and Mendoca and Paiva (2003). Notably, Prakoso and Kulhawy (2001) used the PLAXIS software in the 2D analysis of piled raft foundations.

3. Notations

d = diameter of piles,t = thickness of raft,N= penetration number,W%= moisture content percentage,P I= plasticity index,L L = liquid limit,P L = Plastic limit

4. In Parameters to be Considered to Study the Behaviour of Piled Raft Foundation

Various researchers have examined some characteristics of behaviours of piled rafts and the effect of following factors on the behaviour:-

- The number of piles
- Pile spacing
- Diameter of piles
- Pile length
- Raft thickness
- Raft dimension ratio
- Applied load nature and applied load level Problem Statement

5. Methodology

For the present research work, a 14 storey building with piled raft foundation is selected and analysis of the behaviour for this structure in stratified soil deposits of the area of is carried out. For the analysis, finite element programme Etabs v9 & safe v12 is used. A generalized soil profile of above specified area and the geometrical properties of the building are shown in preceding sections.

- Height – 44.40 m
- Building Plane – 21.33 x 14.25m
- Column Dimension - 230mm x 600mm
- Beam Dimension - 230mm x 600mm
- Length of piles – 28.50 m
- Diameter of piles - 1000 mm
- Thickness of raft - 1000 mm Soil Model.

The first layer varies from 1 to 09 m with blackish sitly plastic clay. The 1st layer is underlying by another layer from 7.50 m to 22.50 m with black medium to coarse sand with gravel. Under Black medium to coarse sand with gravel the Yellow high plastic with sand was found which varies from 22.50 m to 27 m .and the last layer from 27 m to 40 m was found of Black medium to coarse sand with gravel. The static water level is @ 9 m.

- Layer 1: 1 to 09 m with blackish silty plastic clay, with static water table 9 m below ground surface.
- Layer 2: 7.50 m to 22.50 m with black medium to coarse sand with gravel.
- Layer 3: Yellow high plastic with sand was found which varies from 22.50 m to 27 m.
- Layer 4: 27 m to 40 m of Black medium to coarse sand with gravel.

The generalized profile of the area is as shown below in fig. 1.

The main purpose of a parametric study is to investigate the piled raft performance under the changes of the geometry of the dimensions. Therefore, the numbers of cases are studied. It includes pile diameters, and raft thickness.

The combinations of cases are shown in the following fig. 2.

- Effect of Raft Thickness: - As shown in fig 4-6the study was carried out for different pile diameter with thickness of the raft. It was observed that maximum settlement of the raft decreases as the diameter of the pile increases. & with fig 7- 9 for all diameter of piles against the raft thickness the cost of Pile raft foundation is less for 1000 mm thick Raft.
- Effect of Pile Diameter: - As shown in fig 3 as per the analysis as the pile diameter increases, the settlement reduces. Whereas pile diameter 1000 mm gives minimum settlement for the axial load compares to 600 mm & 800 mm diameter Piles. The analysis is carried out for different pile diameters, 600mm, 800 mm and 1000 mm. Which shows fig 4-6 that the percentage of settlement variation is less under pile diameter of 1000 mm with raft thickness, compare with other diameter pile settlement.

6. Conclusion

- It has been observed that piled raft foundation concept has significant advantages in comparison to conventional foundation for some soft clay for high rise buildings.
- The ultimate bearing capacity of Piles will be increased as the Pile diameter increases.
- The settlement of Pile is reduced as the diameter of Pile increases.
- The percentage of settlement variation of Raft in various thicknesses is less under 1000mm diameter Pile.
- It is observed that the settlement value for all the thickness of Raft is very closely looped under 1000mm diameter pile.
- The quantity of raft steel required is reduced as the Raft thickness increased.
- The cost of Pile Raft foundation is observed less in 1000mm Raft thickness under all diameter of Pile.
- The suggested suitable section of Pile Raft foundation for the above shown building plan is 1000 mm thick Raft & 1000 mm diameter Pile.
- To reduce the differential settlement and moment the piles should be place strategically using some trial and error or using parametric study.

Depth (m)	IS classify -cation	Visual Soil Description	Field Test		SPT (N)	w (%)	Density (gm/cc)	Particle Size Analysis			Atterberg Limits			G	Shear Parameters	
			SPT	UDS			Dry	Gr	Sa	Sc	LL	PL	PI		C	Φ
A1.00 To 9.00 M	MI-CI	Blackish plastic silty clay	SPT	UDS	18	23.34	15.2	0	6	94	46	29	17	2.67	70 kpa	10
B7.50 To 22.50 M	SW-SM	Black medium to coarse sand with gravel	SPT	UDS	66	13.74	1S.4	6	88	6	NP	NP	NP	2.7	0	38
C21.00 To 28.50 M	MH	Yellow high plastic with sand	SPT	UDS	60	22.08	1S.6	1	4	95	66	45	23	2.67	100 kpa	10
D27.00 To 40.00 M	SW-GM	Black medium to coarse sand with gravel	SPT	UDS	>70	11.17	1.54	26	69	5	NP	NP	NP	2.7	0	40

Figure 1: Generalized Profile used for analysis

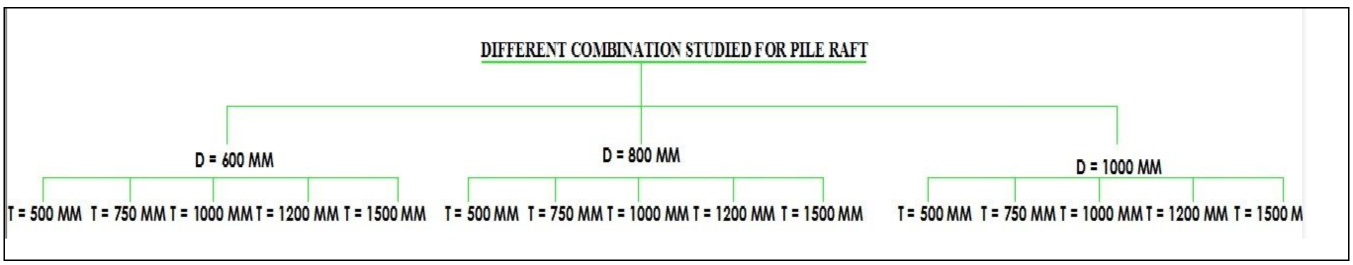
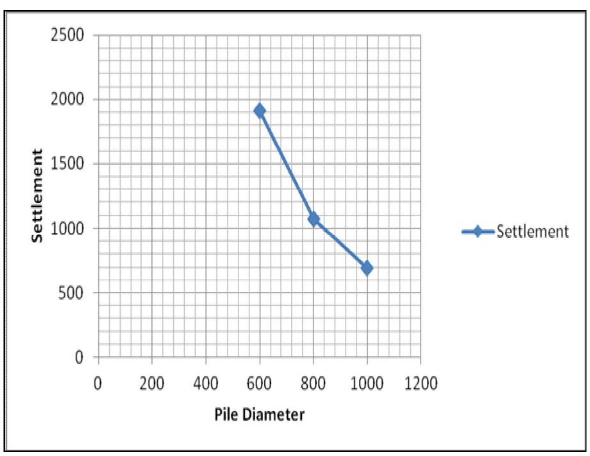


Figure 2: Different Combination studied for Analysis.



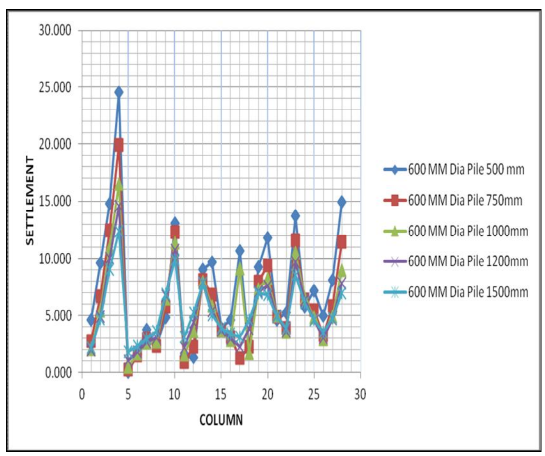
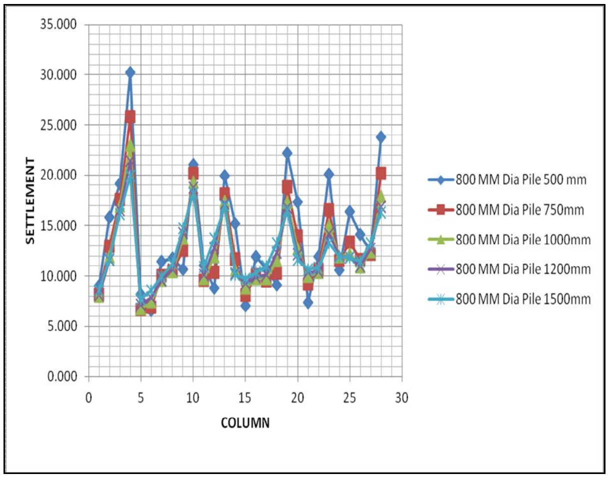


Figure 3: Graph of Settlement for Pile diameter
Figure 4: Graph of Raft Thickness for 600 mm Diameter Pile



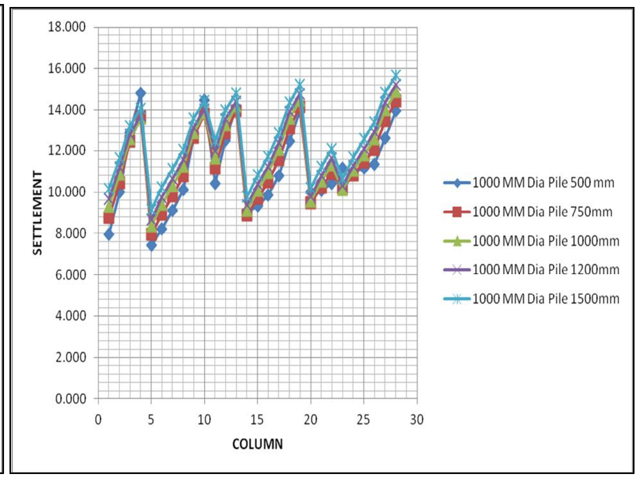
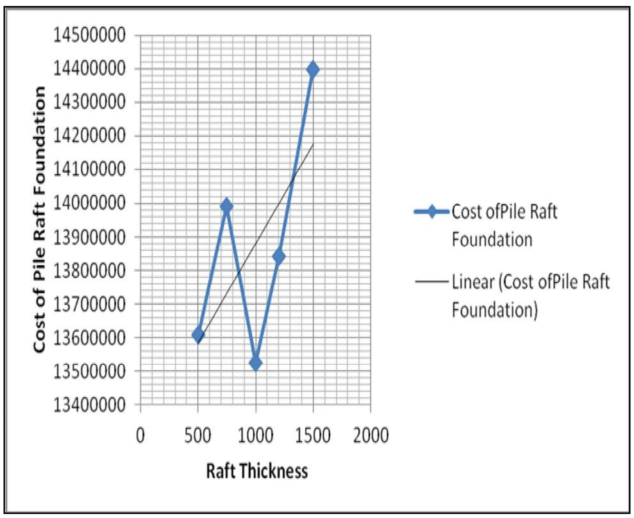


Figure 5: Graph of Raft Thickness for 800 mm Diameter Pile
Figure 6: Graph of Raft Thickness for 1000 mm Diameter Pile



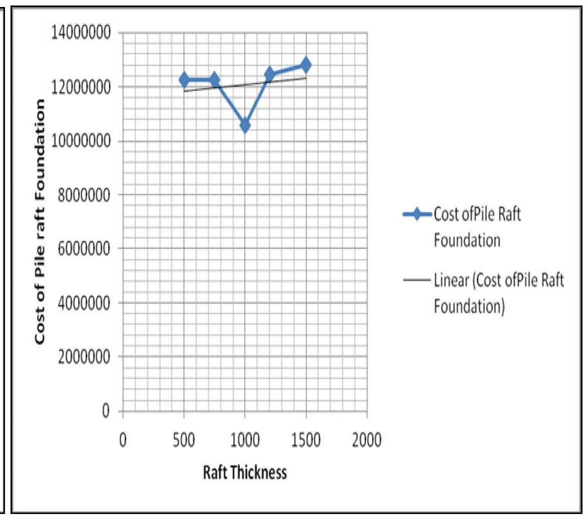


Figure 7: Graph of Cost of Pile Raft Foundation under 600 mm Diameter Pile against Raft thickness
Figure 8: Graph of cost of Pile Raft Foundation under 800 mm Diameter Pile against Raft thickness

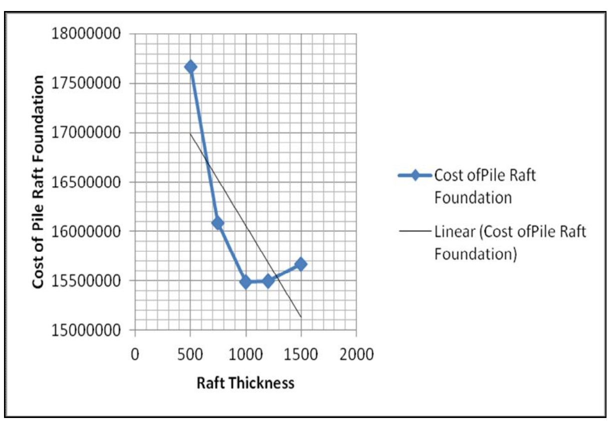


Figure 9: Graph of Cost of Pile Raft Foundation under 1000 mm Diameter Pile against Raft thickness

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