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A Review on dynamic analysis and design of high-risestructure resting on pile raft foundation

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ABSTRACT

Recent earthquakes have demonstrated that structural damage caused by seismic behavior has a substantial impact on the foundation, ground, and superstructure. Since land is becoming less accessible due to rapid industrialization and urbanization, there is development in the vertical plane today, which has resulted in the formation of various tall structures. As a result, the structure is under more pressure. As a result, structures started to settle. In order to address the issue of tall constructions settling, several piles and rafts are used, and a brand-new type of foundation known as piled raft foundation is fast developing. In-depth analysis of the pile-and-raft foundation structure is provided in this work.

Keywords: Pile raft foundation, settlement, raft foundation, Structural Damage, Seismic Analysis

1. INTRODUCTION

The advantages of both shallow foundations (raft foundations) and deep foundations (pile foundations) are combined in a type of foundation known as a combined pile raft foundation (CPRF). The CPRF includes soil, piles, rafts, and occasionally a pad. The CPRF views the piles and raft as sharing the load with the soil, as opposed to the conventional foundation, which supports the load either by the piles or the rafts. The CPRF generally anticipates piles to reduce structure settlements and so enhance the soil's ability to provide foundation support. In order to facilitate cooperation between the rigid pile components and the subsoil, a loads move pad is occasionally added at the point where the piles and the raft meet.. In recent years, the pile raft foundation commonly used. This paper mainly focuses on review of literature based on pile raft foundation.

The shortage of land for future development has made the man to manufacture tall structures. These structures will give heavy axial and horizontal loads to the soils underneath their foundations. The load move system from the superstructure to the base is generally done by giving appropriate foundations. The foundation is the principal component of the structure where construction begins, however when it fails; it can cause numerous defects in the structure including failure or collapse of the structure. The fix of imperfection in the foundations is generally troublesome and expensive, so it is generally imperative to structure the foundation to maintain a strategic distance from such failure of the building.

There are various sorts of foundations to upgrade the load move system. Raft foundations are one among them to convey the load from the column and disperse the load in the entire base zone of the building. At the point when reasonable soil pressure is low, or the structural loads are overwhelming, the utilization of spread footings would cover more than one-half of regions and it might demonstrate progressively efficient to utilize raft foundation. The raft foundation can fulfill the bearing limit capacity however neglects to keep differential just as complete settlement beneath the most extreme permissible breaking point. Another option in contrast to the heavy load move is giving a deep foundation. Pile foundation might be embraced rather than a raft foundation where no firm bearing layers exist in any sensible depth and the loading is uneven. The waterfront district of India is found for the most part by delicate soil and pile foundation is embraced as the best answer to overcome the low bearing limit of delicate soils. Pile foundation is a deep foundation where the loads are taken to a more deep level. Some of the time lengths of the pile foundation will be huge to accomplish the load-bearing limit. The difficulties from raft or pile foundation alone can be abstained from utilizing the blend of both which is commonly known as the combined pile raft foundation (CPRF) framework. In the piled raft, the raft directly interfaces with soil and it is upheld by gathering of piles of different designs.

2. LITERATURE REVIEW

1. Riya T Johnson, Renjitha Mary Varghese, Jerin Joseph (2016), "Parametric study on the behavior of combined pile Raft foundation founded on multi-layered soil"

The purpose of the current study is to ascertain how pile rafts affect soil with many layers. The influence of pile diameter and spacing with altering raft thickness on settlement is included in the current parametric analysis. They take a look at three cases.

Case 1: In the first scenario, they examined the impact of raft thickness using a constant pile spacing of 4d (d=pile diameter), with a 0.6m pile diameter. In this instance, piled rafts with different raft thicknesses of 0.3, 0.4, 0.6, 0.8, and 1 m were modelled to determine the maximum and differential settlements under surface loads of 200 kN/m2 to 800 kN/m2 with a 200 kN/m increment.

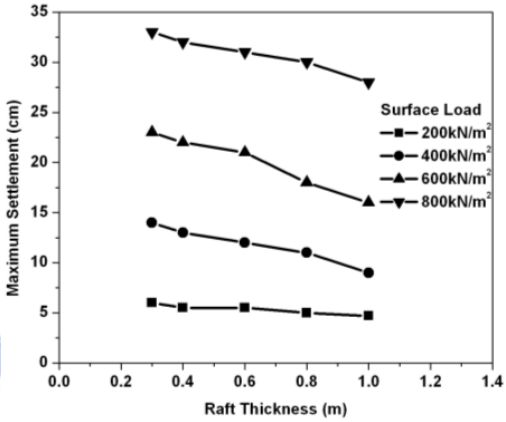


Fig 1 : varying raft thickness with maximum settlement

Case2: In this case different loads with raft thikness 0.8m was modeled by varying pile spacing as 3d, 4d, 5d, 6d, 7d. The same surface load increments and pile diameter was taken as that of Case 1.

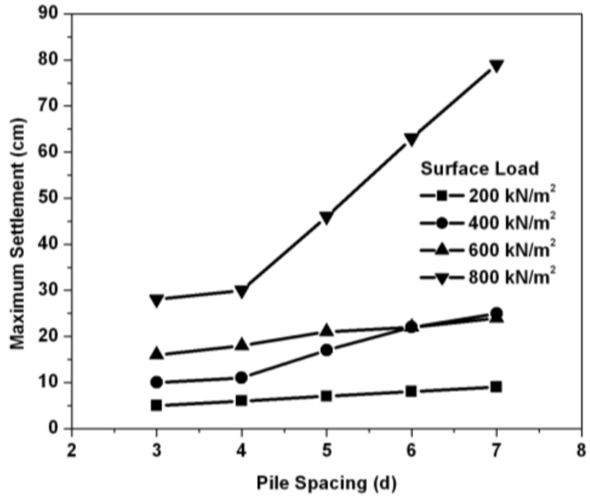


Fig.2: Varying pile spacing with maximum settlement

Case3: In case 3 pile diameter was vary with all same parameter which is consider in case1.

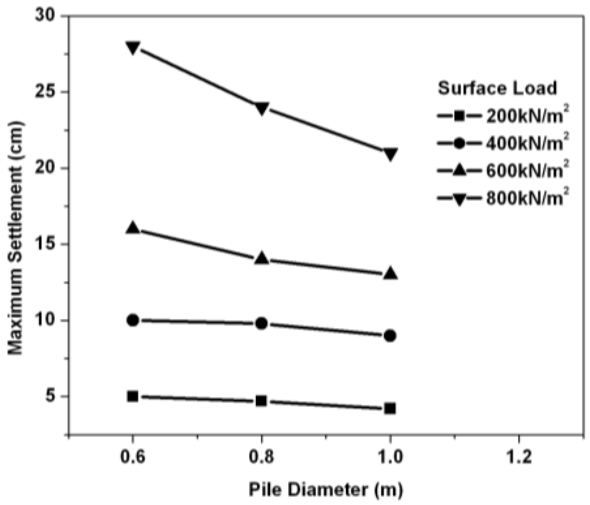


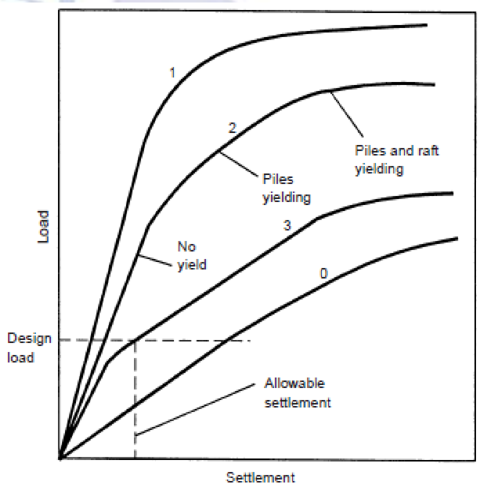
Fig 3: Varying pile diameter with maximum settlement

According to the results of the aforementioned study, i. raft foundations experience more settlement than pile raft foundations.
ii. Reducing total and differential settlements is largely unaffected by raft thickness.
iii. Additional helpful information regarding the behaviour of multi-layered soil was provided regarding the influence of pile diameter and pile spacing.

2. Nirmal John Joy, Hashifa Hassan (2014), "Study on Settlement Characteristics of Combined Pile Raft Foundation Founded on Sand with Various Arrangements of Piles "

According to studies, a combined pile raft foundation system performs better when piles are arranged permutatively rather than uniformly.Models and analyses of different pile-combination rafts were conducted. The most significant impact on drastically lowering maximum settlement and differential settlement is realised by putting high capacity piles in areas with the highest load concentration and strengthening the remainder of the raft with medium capacity piles.

3. Poulos, H. G. (2001). "Piled Raft Foundations: Design and Applications"
H.G.Poulos,



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Curve 0: Raft only (settlement excessive)
Curve 1: Raft with pile designed for conventional safety factor
Curve 2: Raft with piles designed for lower safety factor
Curve 3: Raft with piles designed for full utilization of capacity
Curve 0 represents the case where only raft is used as foundation leading to excessive settlement at design load.
Curve 1 shows conventional approach of design in which all the loads imposed on foundation from superstructure is considered to be taken only by piles.
Curve 2 lower safety factor is considered for design and as there are fewer number of piles are used, raft carries a considerable load.
Curve 3 represents the case in which piles are positioned in such a way to act as a settlement reducers. Even though there is more settlement at design load compared to first two cases, it is acceptable and method is economical.

4. Chaithra T P, Manogna H N (2015) "Dynamic Soil-Structure Interaction Analysis for Piled Raft Foundation"

Utilizing a linear time history approach, they conducted the inquiry to assess the seismic performance of the fifteen-story, reinforced concrete building with piled raft foundation. Various elements, including time, displacements, base, shear, and settlements, were compared. Study of the piled raft foundation behavior.

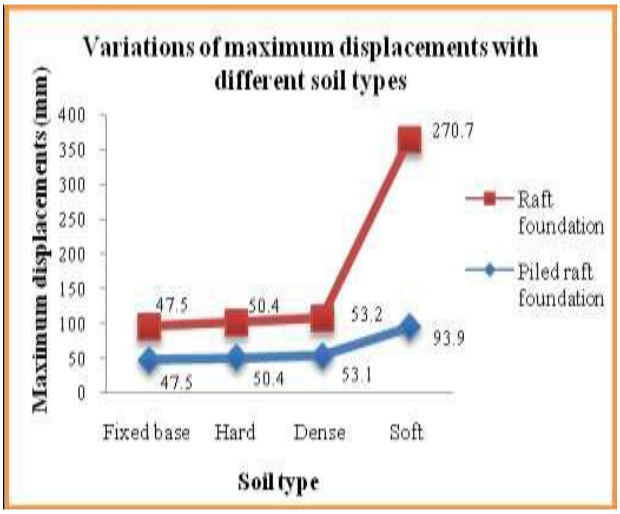

Fig 4: Variation of maximum displacements with soil

It is concluded that raft and piled raft foundations have virtually the same effects on the soil-structure interaction in hard and dense soil. Additionally, a raft foundation vibrates a building longer on soft soil than a piled foundation.By using a pile raft foundation rather than a raft foundation, displacement and settlement in soft soil are decreased.

5. A. K. Singh, A. N. Singh (2011)"Experimental study of piled raft foundation"

- The performance of a piled raft foundation on sand is the main topic of the current study's experimental examination. For experimental study, wooden rafts of various sizes have been employed with wooden piles (single or double) of three different diameters and lengths.
- They take into consideration four sets of stacked rafts.
- Set – I Length of Pile – 300 mm, Diameter of Pile – 30 mm Size of Raft – 270 mm x 217 mm L/d = 10
- Set – II Length of Pile – 600 mm, Diameter of Pile – 50 mm Size of Raft – 171 mm x 166 mm L/d = 12
- Set – III Length of Pile – 600 mm, Diameter of Pile – 50 mm Size of Raft – 380 mm x 121 mm L/d = 12
- Set – IV Length of Pile – 300 mm, Diameter of Pile – 50 mm Size of Raft – 380 mm x 121 mm L/d =

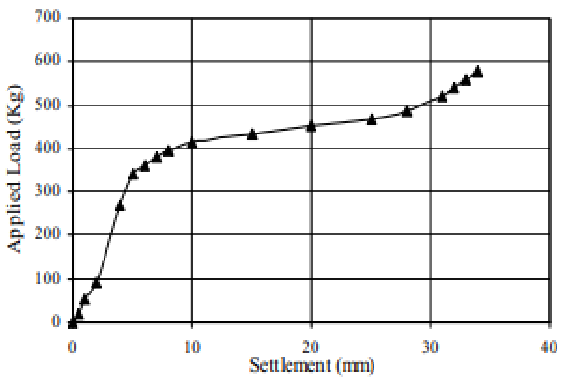

Fig 5: settlement curve for set I

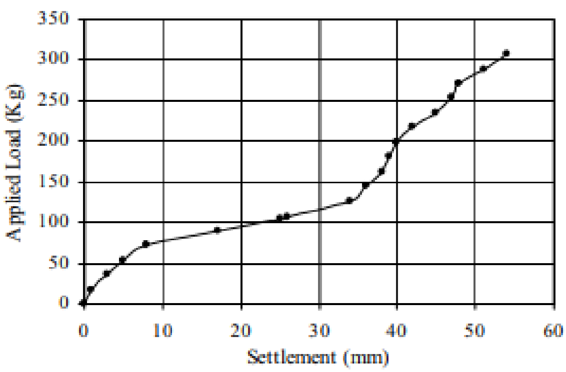

Fig 6: settlement curve for set II

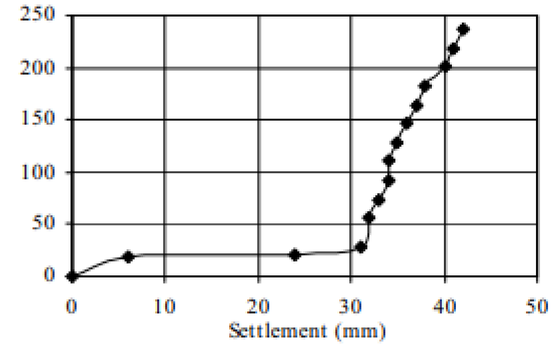

Fig 7: settlement curve for set III

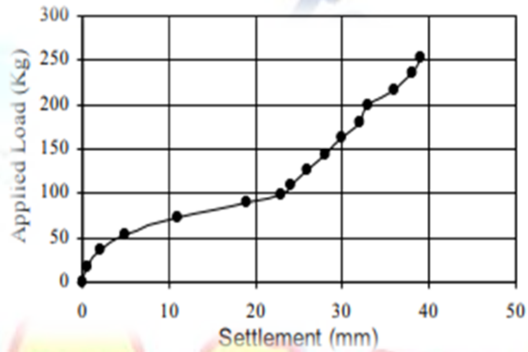

Fig 8: settlement curve for set IV

They draw the following conclusions from the aforementioned study:

i. Settlement occurs rather quickly with little weight on the piled raft when the load is only supported by piles underneath the raft.

ii. When a load is delivered to the soil using a raft and pile together, the load carrying capacity increases significantly while the settlement per unit load decreases.

iii. The piled raft foundation is more successful when there is only one pile present since the settlement per unit load increases when the l/d ratio decreases (the diameter of the pile is larger than its length).

iv. The settlement per unit load decreases as raft size increases. Rate the likelihood of two piles supporting the piled raft.

6. NingombamThoiba Singh, Baleshwar Singh (2008), Interaction Analysis for Piled Rafts in Cohesive Soils"

The findings of a finite element study for piled rafts in cohesive soils are presented in this research. According to the study, reducing overall settlement does not generally benefit from increased raft thickness. It is better to limit the number of piles so that they reach their maximum capacity before the raft. It's not always better for the behaviour of the stacked raft foundation to increase raft thickness for maximum settlement. The centre pile in the piled raft bears the heaviest weight, followed by the edge pile and the corner pile, which bears the lightest weight. The piles are effective at reducing total settlement because they reach their maximum capacity earlier than the raft.

7.MeisamRabiei (2009)"Parametric study for piled raft foundation"

This research considers the effects of a number of parametric variables, including pile configuration, pile number, pile length, and raft thickness. It has been discovered that as raft thickness, pile number, and pile length decrease, so does the maximum bending moment in the raft. With increased raft thickness and uniformly increased pile length, central and differential settling is reduced. Additionally, it has been discovered that the design of a pile raft depends heavily on pile configuration.

8.R. R. Chaudhari, Dr. K. N. Kadam (2013), "Effect Of Piled Raft Design On High-Rise Building Considering Soil-Structure Interaction"

Under vertical or horizontal static and dynamic loads, the influence of pile length, pile distance, pile arrangement, and cap thickness is studied. The effect of pile length configurations on multi-story building behaviour under vertical loading is assessed in the current work. It comes to the conclusion that for all soil types, the maximum moments for the V-shape and U-shape models are lower than those for the other models. Therefore, the V-shape and U-shape models are the best choice for pile length in terms of moments and concrete volume.Additionally, it has been discovered that the ideal pile configuration depends on the soil. The ideal arrangement varies from soil to soil.

9. Shivanand Mali, Baleshwar Singh (2018), "Behavior of large piled raft foundation on different soil profiles for different loadings and different pile raft configurations"

Among them are Baleshwar Singh, To understand the settlement, load-sharing, bending moment, and shear force behaviour of large piled rafts, founded on homogeneous soil profile and varying soil profile for different load configurations and different piled raft configurations, as well as the effect of pile spacing and the number of piles, the present study uses a 3D numerical model. The study's findings indicate that for soil profiles that vary from homogenous to variable, average settlement falls significantly with pile spacing and is reported to be less for uniform piled raft structures. As opposed to homogenous soil profiles and uniformly distributed loads, it is seen to be greater for variable soil profiles and corresponding point loads.

10. J.M. Raut, Dr. S.R.Khadeshwa , Dr. S.P.Bajad , Dr. M.S.Kadu(2014) "Simplified design method for piled raft foundation"

The Poulos-Davis-Randolph (PDR) design process for piled rafts shows this to be the case, however employing a straightforward stiffness formula causes settlement to rise, the opposite of what is really seen in practise. The length of the pile increases the piled-raft's load carrying capacity. Up to a certain point, the length of the pile lessens the settlement of the pile raft; after that point, additional length increases are ineffective at reducing settlement. The load carrying capacity of a piled raft rises as the diameter of the pile grows generally, however this only lowers settlement up to a certain diameter after which additional increases in diameter have little effect.

3. CONCLUSION ON ABOVE REVIEW PAPER

The pile cap is utilised above the pile foundation as a pile cap, and in this foundation, the pile is used as a settlement reducer, as can be seen from the aforementioned pile raft case studies. Based on each component's capability, the raft and pile in a pile raft foundation distribute the weight concurrently. varying types of soil and soil structures have varying effects on the behaviour of pile raft foundations. Pile raft foundation utilisation is particularly cost-effective. It is possible to reduce the quantity, length, and diameter of piles by taking the raft's bearing capacity into consideration.The greatest option for a tall building with significant loads was a combination pile raft.

4. GAPS IN LITERATURES

The gaps and issues that have not yet been studied following analysis of numerous national and international research articles on the pile raft foundation are listed below;

1. Starting with previous research and continuing today, numerous studies have conducted experimental studies of the behaviour of mixed pile raft foundations for various soil types, soil structures, pile spacing, and pile diameters, as well as their behaviour for structure settlement.
2. Only experimental investigations are used to examine the pile raft foundation. No research has been done using the building's exact plan.
3. Nowadays, if plot area is limited, we can study the building for the use of pile raft foundation by using new software. Additionally, to assess the bearing capacity of the soil on site and design a pile raft foundation for the actual building plan.
4. In the literature review mentioned above, it was noted that the foundation's settlement behavior was the only factor that was examined.

5. OVERVIEW OF THIS PROJECT

The primary objective of this study is to compare the behaviour of the two types of raft foundations. Consider G+15 RC building with SBC of 135kn/m2 for the study. STAAD Pro software will be used to analyse the structure. On the study and design of the aforementioned high-rise structure resting on a simple raft foundation and a pile raft foundation, an attempt will be made to compare various parameters. As per IS code and building design as per Indian Standard standards, several load combinations are applied to the structure.

A. Material Properties

M-25 grade of concrete and Fe-415 grade of reinforced steel are used for all the concrete frame models is used in this study. Elastic material properties of these materials are taken as per Indian Standard IS 456 (2000) and IS 800:2007

The short-term modulus of elasticity (Ec) of concrete is taken as: Ec = $5000\sqrt{Fck}$

B. Building Description

The building is G+15 storey building and is made of reinforced Concrete (RC) Special Moment resisting frames (SMRF). It is located in seismic zone II. The lateral loads to be applied on the buildings are based on the Indian standards. Earthquake analysis performs on model.

Table 1: Model data

Basement to Ground Floor	4.15 m
Ground Floor to First Floor	4.5 m
Floor to Floor height	3.00 m (each)
Seismic zone	zone II
Safe bearing capacity	135 kN/ m2

Earthquake Analysis

As Nagpur is in Zone II, earthquake detailing is carried as per IS: 13920-2016. However, complete 3 dimensional analysis has been carried out using **dynamic method (Spectrum Analysis)** as per IS1893 Part I : 2016 by taking following data.

- Zone factor Z = 0.10
- Response Reduction factor = 3 (IS1893 Part I:2016 Table 9)
- Importance factor = 1.2 (Occupancy more than 200 Person as per IS1893 Part I:2016)
- Soil Type = Hard Soil (Type I)
- Depth of foundation = Up to Basement Lvl (1.15m from G.L.)
- Structure Type = 1(RCC)

The load combinations that were considered as per IS 1893 : 2016

1. DL+LL
2. DL + 1.5 LL
3. 1.5[DL + EQX]
4. 1.5[DL - EQX]
5. 1.5[DL + EQZ]
6. 1.5[DL - EQZ]
7. 0.9DL + 1.5EQX
8. 0.9DL - 1.5EQX
9. 0.9DL + 1.5EQZ
10. 0.9DL - 1.5EQZ
11. 1.2[DL + LL + EQX]
12. 1.2[DL + LL – EQX]
13. 1.2[DL + LL + EQZ]
14. 1.2[DL + LL - EQZ]

C. Modeling

The structure will be modeled using STAAD pro. Software. various load combinations were applied to the model. After doing a building analysis, STAAD foundation transfers all loads. Isolated footing was first examined. then analyze and design the raft and pile raft foundation. These three foundations' behaviors are contrasted. Studying stresses, settling, and bending moment behavior.

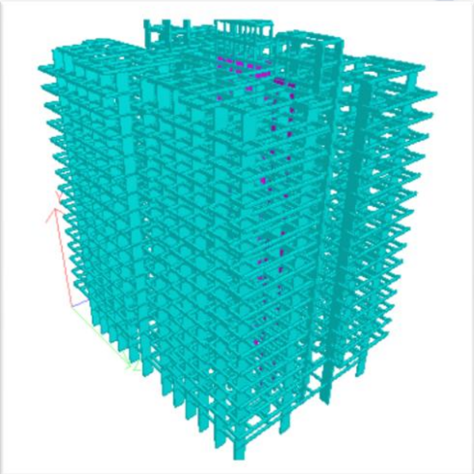

Fig. 9 : Sample Model of G+15 Building

D. Manual calculations

All foundation manually calculated. Design concepts of pile raft foundation explain in detail. All manual results compare with software results.

E. Methodology

The proposed work is planned to be carried out in the following manner

1. Model of G+15 RC building analyzed and design using software STAAD Pro.
2. Firstly isolated footing design using software. Manually also calculated.
3. After the footing raft foundation design for above mention building. Raft foundation design and analyzed using software.
4. Similarly Piled raft foundation analyzed and design.
5. All software results compare with manual calculation.

F. Expected results from project

1. The best foundation for the aforementioned structures will be determined by the results.
2. Parameters like stresses, settlement, displacement, etc. will be obtained from the outcome.
3. Using the aforementioned parameter, we shall contrast the behaviour of raft and pile raft foundations.
4. By comparing pile raft and raft foundations, we can determine which is the best and most appropriate foundation for the aforementioned structures.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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