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Seismic Analysis of Piled Raft Foundation on Soft Soil

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Abstract*— A piled raft foundation emerging as most efficient and economical foundation. The piled raft foundation is raft foundation with supported with piles where load bearing capacity is taken into consideration while designing. In present study 3 different pile arrangements are analyzed for Seismic Analysis In the current study, G+21 Tall building is considered for seismic analysis. Response Spectrum Analysis is performed on the SAP2000 software. The study is performed by using the Raft Foundation and 3 different Piled Raft Foundation and the results are compared in terms of base moment, displacement and base shear. The Raft and Piled Raft Foundation is designed by using IS2950-2008 and IS 2911-2010 and seismic analysis is done by IS1893:2016. It shows that the Base Moment is reduced by 66% in the Piled Raft Foundation than Raft Foundation, Base shear is reduced by 65% in Piled Raft Foundation than Raft Foundation and deflection of the structure with Piled Raft Foundation decreases compared with Raft only Foundation.

Index Terms*— Piled Raft Foundation, Raft Foundation, Response Spectrum Analysis, SAP2000.

I. INTRODUCTION

Piled raft foundations (PRF) are commonly utilized for large constructions and where soil is insufficient to prevent severe settlement. They are becoming a more popular alternative for high-rise buildings. Piled raft foundation can significantly reduce the differential settlement of a structure and enhance its serviceability.

In the piled raft foundation, the raft is attached to a group of piles and the structural load is conveyed through the combined action of the pile and the raft. Due to this combined action, the piled raft shows a complex mechanism by partial sharing of load through piles and the raft. Although the advantages of PRF over conventional pile group foundation are manifold, the prime benefit of this foundation derives from the load sharing by raft along with the piles. This leads to significant economical profit as the number of piles can be reduced without compromising the safety and serviceability aspects of the system.

Piled raft foundation system transfers the load by means of a complicated three-dimensional interaction among the constituent elements namely the pile, raft, and the soil. Unlike the traditionally designed pile group wherein the interaction is only between piles and the soil, in the case of piled raft there are four interactions namely raft and the soil, pile and the soil, raft and the pile and pile to pile. Further in the case of piled raft the pile group alone is not intended to ensure the safety of the system but it is the combined system of raft, pile and the soil ensures the safety of the structure.

As the load-bearing mechanism of PRF is complex in nature, significant amount of work has been carried out by several researchers to have a grasp on this subject.

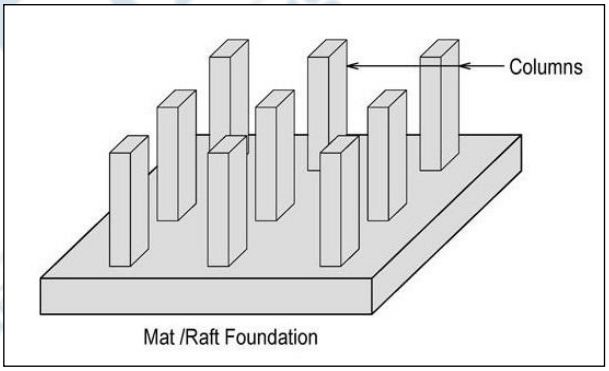

Figure 1. Raft Foundation

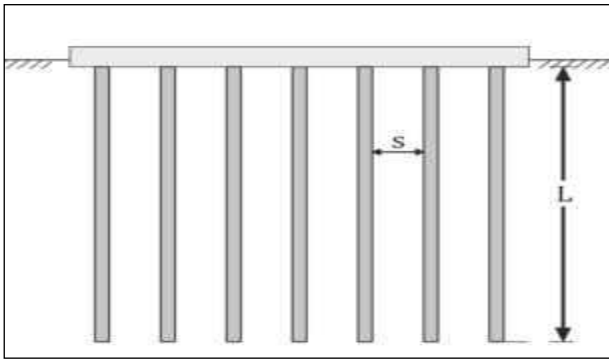

Figure 2. Piled Raft Foundation

II. PROPOSED STUDY

The current study focuses on the seismic behaviour of the Tall Building with raft foundation and piled raft foundation. The G+21 structure with raft and piled raft foundation is

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considered for the analysis provided under each column. The models are tested for Linear Dynamic Analysis (RSA) and results are obtained for Raft Foundation and Piled Raft Foundation.

III. Objectives of Proposed Work

- To design the Raft Foundation and Piled Raft Foundation using IS 2911-2010.
- To differentiate seismic behaviour of the structure with Raft Foundation and Piled Raft Foundation in terms of deflection, base moment and base shear.

IV. Methodology

- G+21 Tall Building model creation in Sap2000 Software.
- Define materials, section properties.
- Assign sections and loads on section.
- Determine Maximum Load on column.
- Design Raft and Piled Raft foundation by taking maximum load.
- Perform Response Spectrum Analysis on both structures.
- Compare results of structure with Raft Foundation and Piled Raft Foundation for Tall building.

V. Example Building and Design of Foundation

In the current study the 22-storey building with Raft and Piled Raft Foundation is considered for the seismic analysis. The Raft and Piled Raft is designed as per the IS 2911-2010 for the tall building located in a Seismic zone IV. Plan and 3D view of the building is shown in figure 3. Height of storey is 3 m. Average size of the column is 450mm x 450mm and size of beam is 300mm x 450mm. The thickness of the slab is 180mm. Raft Size is 34m x 17.5 m and thickness of raft is 1200mm. The grade of concrete is M35 and Fe500 steel is used.

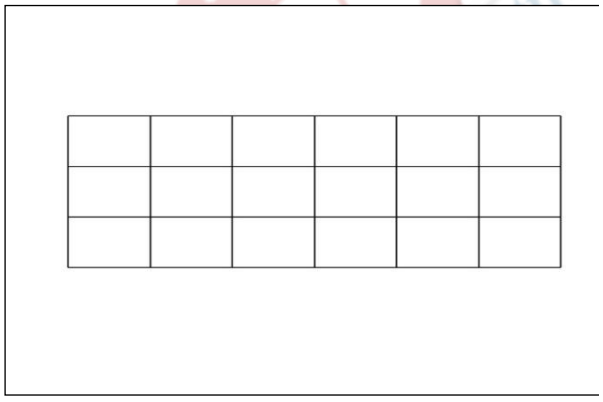

Figure 3- Plan of Building

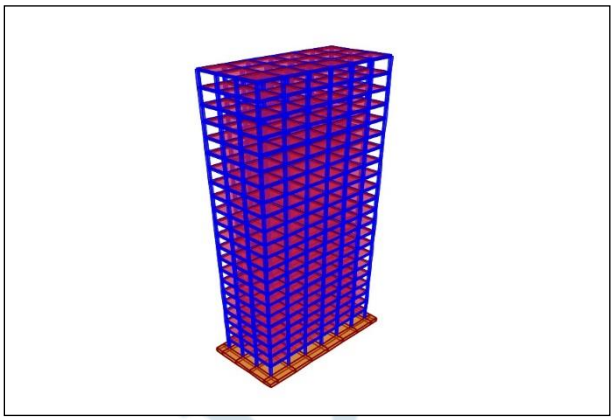

Figure 4- 3D view of Building

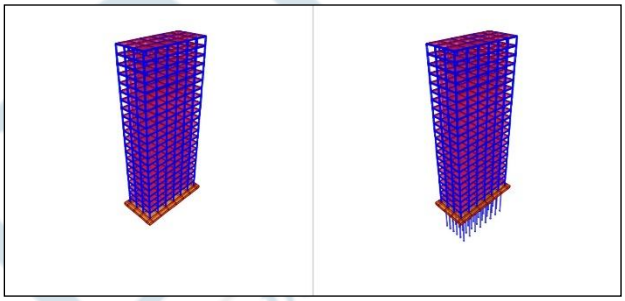

Figure 5- Raft and Piled Raft Foundation

The following equations estimate various design parameters for this model.

- Pile is designed as a column. Column is designed as short or long column depending on slenderness ratio.
- Column is designed for minimum eccentricity. And minimum eccentricity is given by,

$$e_{min} \geq \frac{l}{300} + \frac{D}{30}$$

Where,

l = Unsupported length of column in mm

D = Lateral dimension of column in the direction under consideration in mm.

- The column is checked for Design load.
  a) Ultimate load capacity: The maximum load which a pile can carry before failure, i.e., when the soil fails by shear as evidence from the load settlement curve or the pile fails as a structure member.
  b) Load carrying capacity of piled- Static formula (IS: 2911:2010, Part 1, Section2, clause 6.3.2)

(i) For cohesive soil:

$$Q_u = A_p N_c C_p + \Sigma_{i=1}^{n} \alpha_i c_i$$

where,

Q_u, = Ultimate bearing capacity of pile in cohesive soil.

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(kN/m^2)

Nc= Bearing capacity factor, usually taken as 9

Cp = Average cohesion of soil at pile toe (kN/m^2)

αi = Adhesion factor for ith layer depending on the consistency of soil

ci = Average cohesion for ith layer (kN/m^2)

Ap= Surface area of pile stem in the ith layer (m^2)

- The minimum factor of safety on static formula should be taken 2.5. Design load <Safe load.
- Structural Design of Pile Foundation is done on the following basic

$\frac{P_u}{f_{ck}D^2}$ and $\frac{M_u}{f_{ck}D^2}$

percentage of steel for longitudinal reinforcement is calculated from the chart in SP: 16

where,

Mu = Factored moment.

Pu = Factored axial load

d' = Clear cover

D = diameter of pile

As per IS: 2911:2012 (Part-2), the minimum area of longitudinal reinforcement is 0.4% of sectional area calculated based on outside diameter.

- IS: 456:2000, clause26.5.3 states that
  - Minimum diameter of longitudinal reinforcement should not be less than 12mm.
  - Spacing of longitudinal bars measured along the periphery of pile should not exceed300mm.
  - Diameter of lateral tie should not less than one fourth of the diameter of longitudinal bar and in no case less than 6mm.
  - Clear cover to all main reinforcement in pile shaft should not less than 50mm.
  - The minimum diameter of the links should not less than 6mm and minimum spacing should not be less than 150mm.

Table 1 shows the properties of the Piled Raft Foundation,

Table 1- Properties of Piled Raft Foundation

Model no	No of piles		Spacing of pile(m)		Diameter of pile (m)	Length of Pile(m)
	X direction	Y direction	X direction	Y direction		
9x5	9	5	3.40	2.91	0.75	15
8x6	8	6	3.78	2.50	0.75	15
10x5	10	5	3.09	2.91	0.75	15

VI. RESULTS

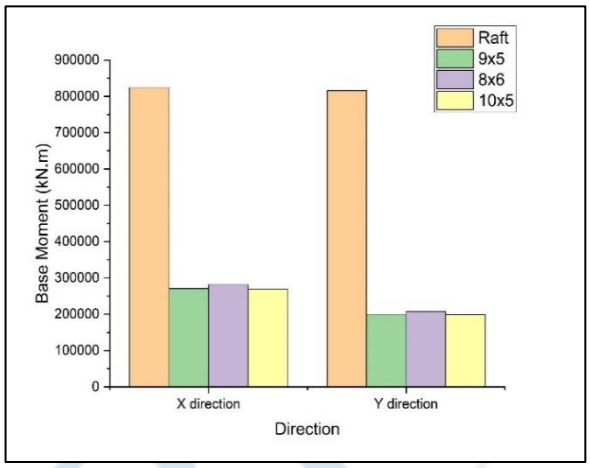

Figure 6- Base Moment

As shown in Figure 6, base moment is reduced by 66% for Piled Raft Foundation in X direction and 75% in Y direction.

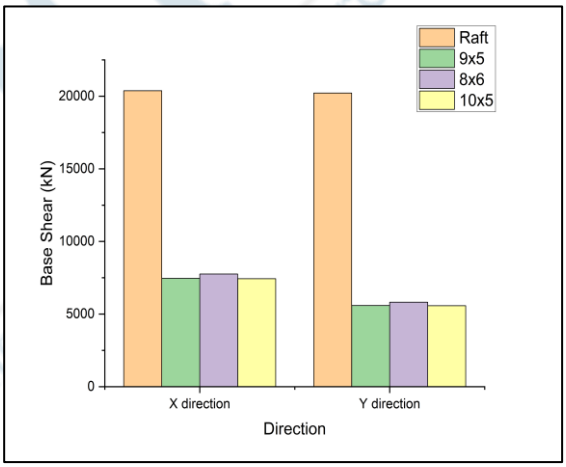

Figure 7- Base Shear

As shown in Figure 7, base shear is reduced for Piled Raft Foundation.

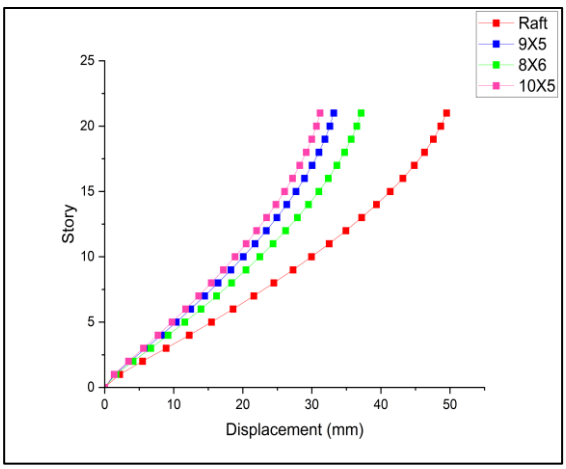

Figure 8- Deflection

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As shown in Figure 8, deflection is reduced for Piled Raft Foundation than Raft Foundation.

VII. CONCLUSION

From the result, Base reaction in X-direction is reduced by 65% for structure with Piled Raft foundation and it is reduced by 71% for Piled Raft Foundation in Y-direction. Maximum deflection for structure with Raft Foundation is 56.105mm and 42.078mm for Piled Raft Structure (8x6) is less than the 264 mm (H/250), it shows that the structure with Piled Raft Foundation is safe for seismic load than structure with Raft Foundation only.

By considering the above values it states that combined Piled Raft Foundation is effective for damage reduction of the structure but not completely stop the earthquake damage. It gives stability to the structure and enhances serviceability of the structure.

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