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Analysis and Design of Pile Foundation for High Rise R.C.C. Structure

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***Abstract*—: This paper presents a detailed analysis of pile foundation design for a high-rise residential building. The structure, consisting of 20 floors and a ground floor, is designed with reinforced concrete piles to safely carry the loads from the superstructure. The study focuses on determining the appropriate pile sizes, reinforcement details, and vertical load capacity to ensure stability and safety. The building is located on a plot of 28x22 meters, with a Floor Space Index (FSI) of 2, allowing a total built-up area of 1232 square meters. The foundation design utilizes piles with diameters of 700 mm and 800 mm, embedded to a depth of 10 meters. The ultimate loads on the piles range from 4500 kN to 6500 kN, with corresponding safe vertical capacities of 3026.5 kN and 5506.92 kN, respectively. The paper provides a reinforcement schedule detailing the number and diameter of bars used in the piles to ensure sufficient load-bearing capacity. Additionally, the study includes the calculation of forces and moments from active earth pressure diagrams, emphasizing the importance of accurate pile design in mitigating lateral pressures. The findings contribute to the understanding of pile foundation design in high-rise buildings, ensuring that the structure can withstand vertical and lateral loads effectively.**

Index Terms: **Pile foundation, high-rise building, vertical load capacity, reinforcement scheduling, active earth pressure, foundation design, structural engineering, soil bearing capacity.**

I. INTRODUCTION

The foundation of a high-rise building is a critical component in ensuring the stability and safety of the entire structure. With the increasing demand for vertical construction in urban areas, especially in regions with soft soils or high-water tables, pile foundations have become an essential solution for providing deep and reliable support. Pile foundations are designed to transfer the loads of a building to stronger soil layers deep below the ground surface, where the bearing capacity is sufficient to support the structure’s weight and external loads. This paper focuses on the design and implementation of pile foundations for a 20-storey residential building, providing detailed insights into the pile design, vertical capacity, reinforcement scheduling, and load distribution.

The building’s structural design incorporates a high number of columns and beams, all of which require robust foundations to withstand both vertical and horizontal loads. Given the building's dimensions of 28x22 meters and an FSI of 2, the total built-up area of 1232 square meters necessitates a strong foundation system to support a significant load. The paper examines the calculation of active earth pressure and its impact on pile design, ensuring that the forces and moments generated by soil pressure are properly accounted for.

The reinforcement scheduling for the pile design is also crucial in providing the necessary strength to withstand the applied loads. The pile diameters vary between 700 mm and 800 mm, depending on the column groupings and the associated load. The number of piles provided is determined based on the ultimate load capacity required for each column, ensuring safety and long-term stability. Reinforcement in the form of high-strength steel bars of varying diameters is used to enhance the load-carrying capacity of the piles.

In this paper, the foundation design and calculations are integrated into the overall structural analysis, considering the lateral and vertical forces acting on the building. The use of piles as a foundation system is evaluated in light of the soil conditions, construction regulations, and safety standards for high-rise buildings. Through this comprehensive study, the paper aims to provide a clear methodology for pile foundation design, which can be used in similar urban construction projects.

II. DETAILS ANALYSIS OF THE PROJECTS

The general building layout details provide an overview of the proposed construction project. The plot has dimensions of 28 meters by 22 meters, covering a total area of 616 square meters. The Floor Space Index (FSI) for the project is 2, which allows the built-up area to be double the plot size, amounting to 1232 square meters. The building is designed as a high-rise structure comprising a ground floor and 20 upper floors (G+20). Each floor accommodates four residential units, making it a total of 80 units for the entire building. The apartments are all 1BHK type, each offering a carpet area of 546 square feet, making them compact and suitable for urban living. This design ensures optimal utilization of the plot area while meeting housing demands in a space-constrained urban environment.

The structural details of the proposed building provide critical information about its design and construction parameters. The building has a length of 19.14 meters and a width of 13.35 meters, with an overall height of 60 meters. The structural framework is designed using M30 grade concrete for durability and F500 grade steel for reinforcement, ensuring strength and stability. The columns are sized at 230 mm by 450 mm, while beams are 230 mm by 600 mm, providing adequate support for the structure.

The floors are constructed with slabs of 150 mm thickness, while the staircase slabs are slightly thicker at 200 mm to bear higher loads.

The building comprises 29 columns and 141 beams, reflecting a robust structural design to support the high-rise configuration. The dead load from wall construction is calculated at 11.60 kN/m², while the floor slabs contribute a dead load of 1.5 kN/m². The live load, representing the weight of occupants and furniture, is 2 kN/m² for the floor slabs. For the staircase, the design accounts for a dead load of 2 kN/m² and a live load of 4 kN/m². These details ensure the building is structurally sound and capable of safely accommodating both static and dynamic loads in compliance with engineering standards.

The load combinations for pile design are categorized based on the columns, their respective load ranges, and the design load requirements. For the first category, columns C-30, C-31, and C-32 experience loads ranging from 2871 kN to 4500 kN. These columns are designed to handle a maximum design load of 4500 kN, and there are a total of three columns in this group. Table 1 shows Load Combination for Pile Design.

Table 1: Load Combination for Pile Design

Sr No	Column No	Load Range kN	Load(kN)	Number of Column
1	C-30, C-32, C-31	2871 To 4500	4500	3
2	C-3, C-4, C-5, C-6, C-7, C- 8, C-10, C-11, C-13, C-14, C-15, C-16, C-17, C-18, C-19, C-20, C-21, C-22, C-24, C25, C-26, C-27, C-28, C-33, C-34, C-23	4500 To 6500	6500	26

In the second category, which includes columns C-3, C-4, C-5, C-6, C-7, C-8, C-10, C-11, C-13, C-14, C-15, C-16, C-17, C-18, C-19, C-20, C-21, C-22, C-24, C-25, C-26, C-27, C-28, C-33, C-34, and C-23, the load range is between 4500 kN and 6500 kN. These columns are designed to withstand a maximum design load of 6500 kN. This category comprises 26 columns in total. These load combinations are crucial for determining the appropriate pile capacity and ensuring the foundation is capable of supporting the superstructure's loads under various conditions.

III. FOUNDATION RECOMMENDATION AND DESIGNED FOR G+20 BUILDING

Table 2 shows calculation of forces and moment. The total force is 388 kN, with a total moment of 1225.67 kNm about the reference point. These calculations are essential for designing the retaining structure to withstand the forces generated by active earth pressure

For the first case, 800 mm diameter piles with a length of 10 meters embedded below the ground level are considered. These piles have a safe vertical capacity (Q) of 3671.28 kN each. The ultimate load on the corresponding column is 6500 kN, which necessitates the provision of two piles to safely distribute the load. In the second case, 700 mm diameter piles are used, also embedded 10 meters below ground level. While the table does not provide the exact safe vertical capacity of the 700 mm piles, they are designed to support a column with an ultimate load of 4500 kN. Similarly, two piles are provided for this load. Table 3 Shows Recommended vertical pile capacity.

The pile design ensures that the vertical capacities are sufficient to handle the loads transferred from the superstructure while maintaining stability and safety. Additional calculations for the 700 mm pile's safe vertical capacity can be performed based on soil properties and pile material specifications.

Table 2 calculation of forces and moment

Sr No	Forces (kN)	Lever arm distance (z)	Moment kNm
1	2.47 x 1 = 2.97	8.5 + $^1/_2$ = 89	26.73
2	$^1/_2$ x 4.95 x 1 = 2.475	8.5 + ($^1/_2$ x 1) = 8.83	21.85
3	1.5 x 7.44 = 11.16	7 + $^{1.5}/_2$ = 7.75	86.5
4	$^1/_2$ x (16.88-7.44) x 1.5 = 7.08	7 + $^1/_3$ x 1.5 = 7.5	53.1
5	1.5 x 16.88 = 25.32	5.5 + $^{1.5}/_2$ = 6.25	158.25
6	$^1/_2$ x (21.67 – 16.88) x 1.5 =3.592	5.5 + ($^1/_3$ x 1.5) = 6	21.55
7	5.5 x 16.77 = 92.23	$^{5.5}/_2$ = 2.75	253.63
8	$^1/_2$ X (23.37 – 16.77) x 5.5 =18.15	$^1/_3$ x 5.5 = 1.83	33.21
9	$^1/_2$ x 70 x 7 = 245	$^1/_3$ x 7 = 2.33	570.85

IV. RESULTS

The reinforcement scheduling for the piles supporting the columns is organized into two main groups. The first group includes columns C-30, C-31, and C-32, each supported by two piles of 700 mm diameter. The second group includes a total of 26 columns (C-3, C-4, C-5, C-6, C-7, C-8, C-10, C-11, C-13, C-14, C-15, C-16, C-17, C-18, C-19, C-20, C-21, C-22, C-24, C-25, C-26, C-27, C-28, C-33, C-34, and C-23). Each of these columns is supported by two piles of 800 mm diameter. These piles, also 10 meters in length, are designed to withstand an ultimate load of 6500 kN, with a safe vertical capacity of 5506.92 kN. Each pile is reinforced with 20 bars of 32 mm diameter, ensuring adequate support for the superstructure. This reinforcement schedule optimizes the pile foundation system for both safety and performance

These piles, with a length of 10 meters, are designed to handle an ultimate load of 4500 kN, providing a safe vertical capacity of 3026.5 kN. Each pile is reinforced with 25 bars of 32 mm diameter to ensure structural integrity. Table 3 Shows Reinforcement scheduling.

V. CONCLUSION

In conclusion, the design and implementation of pile foundations for high-rise buildings require careful consideration of various factors, including soil conditions, load-bearing capacity, reinforcement details, and safety requirements. This study has provided a thorough analysis of pile foundation design for a 20-storey residential building, incorporating the calculation of forces and moments, the determination of pile diameters and vertical capacities, and a detailed reinforcement schedule. The building, with its substantial vertical load, requires piles with diameters of 700 mm and 800 mm, with safe vertical capacities ranging from 3026.5 kN to 5506.92 kN, depending on the column group.

The reinforcement schedule ensures that the piles are adequately reinforced with high-strength steel bars to support the imposed loads, with the use of 32 mm diameter bars in varying numbers based on the load distribution. The analysis of active earth pressure and its effect on pile design is essential in ensuring that the foundation can withstand lateral pressures as well as vertical loads. By using piles embedded 10 meters below the ground surface, the foundation is designed to distribute the loads safely and effectively to deeper, stronger soil layers.

The findings from this study contribute to the field of foundation engineering by providing a comprehensive approach to pile design in high-rise buildings. The methodology presented can be applied to similar projects, ensuring that the foundations of large urban buildings are both safe and efficient.

Table 3. Reinforcement scheduling

No.	Column	No of column (No)	Dia of Pile (mm)	No of Pile	Ultim ate load on Pile (kN)	Vertical Capacity of Pile (kN)	R/f dia ϕ (mm)	No of R/f	Leng th of Pile (m)
1	C-30, C-32, C-31	03	700	02	4500	3026.5	32	25	10
2	C-3, C-4, C-5, C-6, C-7, C-8, C-10, C-11, C-13, C-14, C-15, C-16, C-17, C-18, C-19, C-20, C21, C-22, C-24, C25, C-26, C-27, C-28, C-33, C-34, C-23	26	800	02	6500	5506.92	32	20	10

REFERENCE

[1] Bowles, J. E. (2012). Foundation analysis and design (5th ed.). McGraw-Hill.
[2] Das, B. M. (2013). Principles of foundation engineering (8th ed.). Cengage Learning.
[3] Tomlinson, M. J., & Woodward, J. (2008). Pile design and construction practice (5th ed.). CRC Press.
[4] Uysal, M., & Yıldırım, M. B. (2011). "A study on the axial load capacity of bored piles in clayey soils." Journal of Geotechnical and Geoenvironmental Engineering, 137(2), 222-229. https://doi.org/10.1061/(ASCE)GT.1943-5606.0000460
[5] Reese, L. C., & Van Impe, W. F. (2011). Single piles and pile groups under lateral loading (2nd ed.). CRC Press.
[6] Poulos, H. G., & Davis, E. H. (1980). Pile foundation analysis and design. Wiley-Interscience.
[7] Sharma, R. S., & Joshi, S. (2014). "Analysis of pile foundation under lateral load." International Journal of Civil Engineering and Technology, 5(1), 98-107.
[8] Mollah, M. H., & Kazi, A. S. (2016). "Design and construction of pile foundations for high-rise buildings in soft soil." Geotechnical Engineering Journal, 47(2), 152-161. https://doi.org/10.1109/GEOJ.2016.011122
[9] Abdel-Rahman, A. A., & Elsharouny, M. H. (2015). "Reinforced concrete pile design: Analysis of load distribution and bending moments." International Journal of Civil Engineering Research, 6(3), 345-352.
[10] Kumar, S., & Rao, P. S. (2012). "Optimization of pile diameter for high-rise buildings on soft soil." Journal of Structural Engineering, 39(4), 1121-1133.
[11] Zhang, L., & Yin, Z. (2013). "Numerical modeling of pile behavior under lateral loading." International Journal of Geomechanics, 13(5), 576-585. https://doi.org/10.1061/(ASCE)GM.1943-5622.0000259
[12] Mohamad, R. A., & Ismail, M. Z. (2017). "Impact of pile cap dimensions on the performance of pile foundations." Proceedings of the 12th International Conference on Geotechnical Engineering, 92-98.