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

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Abstract—The design of isolated footings is a fundamental aspect of foundation engineering, particularly for supporting individual columns in reinforced concrete structures. This paper outlines a systematic procedure for designing isolated footings in accordance with IS 456:2000, emphasizing critical steps such as load determination, soil bearing capacity assessment, and footing area calculation. The methodology includes selecting appropriate dimensions based on calculated areas, checking for settlement to ensure uniformity, and designing for flexure and shear to meet structural requirements. Reinforcement detailing is addressed to ensure adequate anchorage and compliance with minimum reinforcement standards. Additionally, the paper highlights the importance of verifying that the bearing pressure under the footing does not exceed the soil's safe bearing capacity. By following these guidelines, engineers can achieve stable and durable foundations that meet safety and performance criteria. This comprehensive approach not only enhances structural integrity but also contributes to sustainable construction practices by optimizing material use and minimizing risks associated with foundation failure. The findings serve as a valuable resource for civil engineers engaged in the design and analysis of shallow foundations for high-rise structures.

Index Terms— Isolated Footing, Foundation Design, Reinforced Concrete, Load Determination, Soil Bearing Capacity

I. INTRODUCTION

The design and analysis of shallow foundations for high-rise reinforced concrete structures is a critical aspect of civil engineering, particularly as urbanization accelerates and the demand for tall buildings increases. Shallow foundations, which are defined as those whose depth is equal to or less than their width, provide essential support for structures by transferring loads from the building to the underlying soil. This chapter aims to explore the various considerations involved in the analysis and design of shallow foundations specifically tailored for high-rise reinforced concrete constructions. Shallow foundations are typically employed for structures that do not exert excessive loads on the soil or when the soil has sufficient bearing capacity at shallow depths. These foundations are advantageous due to their relative simplicity in construction and lower costs compared to deep foundations. Common types of shallow foundations include spread footings, strip footings, and mat foundations. Each type serves distinct purposes based on the structural requirements and site conditions. The fundamental principle behind shallow foundation design is to ensure that the loads imposed by the structure are adequately supported by the soil without causing excessive settlement or failure. The design process involves determining the appropriate foundation type, size, and depth based on various factors including soil characteristics, load conditions, and environmental influences. A thorough soil investigation is paramount in the foundation design process. It involves drilling boreholes, collecting soil samples, and conducting in-situ tests such as Standard Penetration Tests (SPT) and Cone Penetration Tests (CPT). The results from these investigations provide critical data on soil stratigraphy, strength parameters, compressibility, and permeability. Understanding these properties allows engineers to assess the suitability of shallow foundations for high-rise structures. In particular, soil bearing capacity is a crucial factor that influences foundation design. The bearing capacity must be sufficient to support not only the dead loads (permanent/static loads) but also live loads (temporary/dynamic loads) that may occur during the building's lifespan. Additionally, factors such as wind loads and seismic forces must also be considered in high-rise buildings due to their significant impact on structural stability.

II. PROCEDURE FOR ISOLATED FOOTING DESIGN AS PER IS 456:2000

The design of isolated footings is a critical aspect of foundation engineering, particularly for structures that support individual columns. This procedure outlines the steps involved in designing an isolated footing according to the guidelines provided in IS 456:2000, which is the Indian Standard for the design and construction of reinforced concrete structures.

2.1 Determine the Loads on the Footing

The first step in the design process is to calculate the total loads that will be applied to the footing. This includes:

•Dead Load (DL): The weight of the structure itself, including walls, floors, and other permanent components.

•Live Load (LL): The variable loads that the structure will experience during its use, such as occupants and furniture.

•Other Loads: Any additional loads such as wind or seismic loads, if applicable.

P=DL+LL+ other loads P=DL+LL+ other loads

2.2 Soil Bearing Capacity Assessment

Conduct a soil investigation to determine the safe bearing capacity (SBC) of the soil at the site. This involves:

•Performing field tests such as Standard Penetration Test (SPT) or Cone Penetration Test (CPT).

•Analyzing laboratory test results to ascertain soil properties.

The SBC should be greater than the pressure exerted by the footing to ensure stability and prevent excessive settlement.

2.3 Calculate Required Footing Area

This calculation ensures that the pressure exerted by the footing does not exceed the allowable limits of the soil.

2.4 Select Footing Dimensions

Based on the calculated area, select appropriate dimensions for the footing. Common shapes include square, rectangular, or circular footings. The dimensions must also consider practical construction aspects and site constraints.

2.5 Check for Settlement

Estimate potential settlement due to loading conditions. Ensure that settlement is uniform across the footing to avoid structural damage. The allowable settlement should be checked against guidelines specified in IS 456:2000.

III. PROBLEM STATEMENT

The plot measures 28 meters in length and 22 meters in width, giving a total area of 616 square meters (28 x 22). This is the land on which the building is to be constructed. The FSI (Floor Space Index) is 2, which means the total allowable built-up area for the plot is double the plot area. Therefore, the maximum permissible built-up area would be 1,232 square meters (2 x 616). The building is planned to have G+5 floors, which means a ground floor (G) plus 5 additional floors. This configuration provides 6 levels in total. There are a total of 4 residential units in the building. Since there are 6 floors, the units will be distributed across these floors according to the design. The building consists of 1BHK (One Bedroom, Hall, Kitchen) apartments. This type of apartment typically includes a bedroom, a living room, a kitchen, and a bathroom. Each 1BHK apartment has a built-up area of 546 square feet (approximately 50.73 square meters). This space includes the living areas, bedroom, kitchen, bathroom, and any balconies. Details shown in table 1.

Table 1: General Building Layout Details

Plan Dimension	28 x 22mts.
FSI	2
Number of floors	G+5
Number of units	4
Type Apartment	1BHK
Area of Each Apartments	546 Sqft

IV. LOAD COMBINATIONS

Table 2 provides information about the load combinations used for designing the footings of columns in a structure. The key details for each entry include the column numbers, the range of loads experienced by the columns, the design load considered for the footing design, and the total number of columns. The group 1 consists of columns C-4, C-5, C-6, C-8, C-11, C-23, C-30, C-31, C-32, C-33, and C-34, making up a total of 11 columns. The columns in this group experience a range of loads from 736 kN to 1500 kN. For the purpose of footing design, the load is standardized to 1500 kN. This means that the foundation is designed to handle a maximum load of 1500 kN, ensuring safety and stability for all columns within this load range. The total number of columns in this group is 11, indicating the structural design's requirement to accommodate the specified loads for these columns.

Group 2 includes C-3, C-7, C-10, C-13, C-14, C-15, C-16, C-17, C-18, C-19, C-20, C-21, and C-22, totaling 18 columns. The load range for these columns is between 1500 kN and 2500 kN. The design load used for footing design is set at 2500 kN. The total number of columns in this group is 18, which indicates a significant portion of the building's load distribution.

V. RESULTS

The structural analysis of the columns provides the following results for the two groups of columns in the study:

The analysis of the column groups reveals a design strategy that accommodates varying load requirements by adjusting column dimensions and reinforcement details. The first group, comprising columns C-4, C-5, C-6, C-8, C-11, C-23, C-30, C-31, C-32, C-33, and C-34, is designed to carry a load of 540 kN. These columns have a diameter of 1500 mm, a depth of 400 mm, and an effective cover of 50 mm. The longitudinal reinforcement consists of 20 mm diameter bars spaced at 190 mm intervals, providing a total steel area (Ast) of 1647.59 mm². The columns are placed over a span of 2.2 m in length and 1.2 m in width. The second group, which includes columns C-3, C-7, C-10, 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, and C-28, is designed to support a higher load of 720 kN.

These columns are larger, with a diameter of 2500 mm and a depth of 550 mm, while maintaining the same effective cover of 50 mm for durability and reinforcement protection. The reinforcement in this group uses 20 mm diameter bars spaced at 130 mm intervals, resulting in a total steel area (Ast) of 2263.49 mm². The columns span a length of 2.8 m and a width of 1.5 m. The differences in column design between the groups reflect the need to support different load levels, with larger dimensions and more closely spaced reinforcement for the higher load group, enhancing structural capacity and stiffness. Table 3 shows details of reinforcement calculation.

Table 2 Load Combinations for Footing Design

Sr No	Column No	Load (kN)	Design Load (kN)	Number of Column
1	C-4, C-5, C-6, C-8, C-11,C-23,C-30,C-31 ,C-32,C33,C34	736 TO 1500	1500	11
2	C-3,C-7, C-10, C-13, C-14, C-15,C-16,C-17,C-18, C-19,C-20,C-21,C-22,	1500 TO 2500	2500	18

Table 3 Reinforcement Calculation Details

Sr No	Column No.	Load kN	d mm	D mm	Eff. cover	Φ mm	Spacing	Ast mm^2	Length (L)	Width (B)
1	C-4, C-5, C-6, C-8, C-11,C-23,C-30,C-31 ,C-32,C33,C34	1500	400	450	50	12	200	540 along length	2.2	1.2
						20	190	1647.59 along Width		
2	C-3,C-7, C-10, C-13, C-14, C-15,C-					12	150	720		

	16,C-17,C-18, C-19,C-20,C-21,C-22, C-24,C25,C-26,C-27,C-28	2500	550	600	50			along length	2.8	1.5
						20	130	2263.49 along width		

Maintaining a consistent effective cover across all columns ensures adequate durability. The results suggest that the columns are well-designed to meet structural requirements, with reinforcement details optimized for strength and stability under various loading conditions.

VI. CONCLUSION

a. The column design effectively accommodates varying load requirements, with larger column dimensions and increased reinforcement provided for higher load-carrying capacities, ensuring structural safety.
b. Maintaining a consistent effective cover of 50 mm across all columns enhances the durability and protection of the reinforcement, contributing to the overall longevity of the structure.
c. The closer spacing of reinforcement bars in columns subjected to higher loads improves structural stiffness and load-bearing capacity, demonstrating an optimized approach to reinforcement detailing.
d. In 1st combination of load, there are 11 columns which carries 1500kN load and footing size provided (2.2x1.2x0.45m) with 5 bars of 12mmϕ bar @ 200mm centre to centre along length and 6 bars of 20mmϕ bar @ 190mm centre to centre along width.
e. In 2nd combination of load, there are 18 columns which carries 2500kN load and footing size is provided (2.8x1.5x0.60m) with 7 bars of 12mmϕ bar @ 150mm centre to centre along length and 8 bars of 20mmϕ bar @ 130mm centre to centre along width.

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