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Comparison of Isolated Pad Footing & Beam-Slab Isolated Footing based on Varying the Footing Size and Grade of Steel

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I. Introduction

Footings are the substructure of the building which is in direct contact with the soil. It is responsible for safely transferring the loads from the superstructure to the soil. It develops stability and hence prevents overturning of the building. Due to loads and soil pressure, footings are generally designed for bending moment (BM) and shear force (SF). In this paper the design has been completed in reference to IS 456:2000.

Isolated footings are designed when high soil bearing capacity is available at a shallow depth or the columns are far apart carrying very less load. In isolated pad footings (IPF), the lower portion of the footing is in tension. Beams are added to reduce the tension and hence reduce the overall depth of the slap. This reduction in the depth of slab helps in reduction of the concrete required.

Cost is a major factor in the construction industry. With the growing cost of raw materials attempts are made to reduce the raw materials used in a footing. Optimization of the design of footing is one technique employed in the industry for reducing the cost. [1] In this paper an attempt is made to reduce the quantity of material required in the foundation by the method of introduction of beams in an IPF.

Beam slab isolated footing (BSIF) is designed to analyze the materials required to enable safe transfer of loads from the superstructure to the substructure. Quantitative study has been carried out to analyze the steel and concrete requirement for Fe415 and Fe500 grade steel. An attempt has been made to analyze the values by varying the size of the footings for two grades of steel.

II. Methodology

While designing the rigid foundation, approach has been followed. According to this approach it is assumed that the foundation is rigid enough to bridge the non-uniformities of the upward pressure acting from the soil. Hence it is assumed that the pressure acts uniformly throughout the soil. In this type of footing the differential settlements are relatively low but the BM and SF acting on the foundation is high. [3]

All the calculations for this paper are done by preparation of Excel sheets. The Excel sheets were prepared in accordance to the limit state method mentioned in IS code 456:2000.

The upward pressure is assumed to be equal to the Soil bearing Capacity (SBC) for carrying out the analysis in this paper.

Throughout the paper certain parameters like M20 grade of concrete, column dimension as 300*300mm and SBC as 600kN/mm^2 have been kept constant. Calculations are carried out by varying the size of footing and grade of steel.

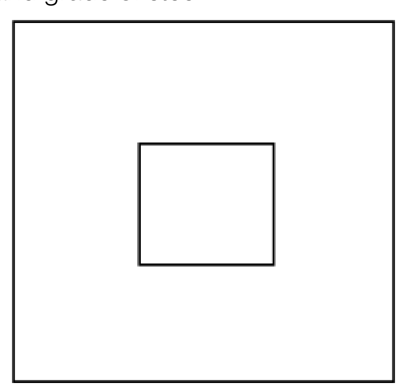

Figure 1: Isolated Pad Footing

a) Isolated Pad Footing

1. Depth Calculation

Depth is found out by performing the BM check, one-way shear check and two-way shear check. It is

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found that among the varying parameters, the depth of the footing is directly proportional to the size of the footing. Clear cover is taken as 50mm throughout the paper to avoid corrosion as per IS code 456:2000.

The BM for the critical section is located at the intersecting point of the column and the footing.

The minimum percentage of steel i.e. 0.12% for HYSD bars as per IS 456:2000 has been taken for calculation of depth for one-way shear. This process is carried out iteratively to ensure that design shear strength of concrete isgreater than or equal to nominal shear stress. For one way shear the critical section is located at a distance d (effective depth) from the face of the column as per IS code 456:2000.

The critical section for two-way shear is taken at distance .05 times the effective depth of the footing from the periphery of the column. The nominal value of two-way shear is equated to the Design value hence we attain the depth require. Two-way shear check is performed to ensure that the footing does not fail due to the punching action of the column.

Further the highest of the three values is taken as the effective depth for the footing. It is observed that for footings of size 1m to 1.5m, the depth obtained by one-way shear is taken as the effective depth of the footing while for footings of size greater than 1.5m the depth obtained from two-way shear check is governing for both the grades of steel.

2. Area of Steel Calculation

All the diameter values for steel are greater than or equal to 10mm and for stirrups they have been set to 8mm diameter or more. These values are taken to prevent corrosion of the bars. As the diameter of the bars decreases larger periphery of the bar is exposed to the atmosphere hence greater is the corrosion. Corrosion reduces the durability of the structure. The diameter of the bars is assumed by ensuring the minimum amount of steel required within the permissible limits.

The area of steel is carried out as per IS 456. This value is compared with the percentage of steel obtained after iteration from one-way shear. For all the sizes of footing the calculated are of steel is greater than minimum value. Hence the calculated value is taken as the area of steel for both the grades of steel.

The spacing is assumed to be the lesser of the value obtained by calculation, 3 times the effective depth value and 300.

For the calculation of development length (L_d) difference in the projected length of the footing is made with the value calculated by using the formula in IS 456:2000

3. Total Material required

Steel required is calculated by finding the number of bars and then multiplying it with the length and the weight per m of the bar.

Volume of concrete is obtained by finding the gross volume of concrete for the entire footing.

b) Beam Slab Isolated Square Footing

1. Depth calculation for Slab

The depth of the slab is calculated by taking half of the upward pressure while calculation of BM. This is done to ensure that the deflection occurring at the corners is equal for both length and breadth.

The deflection for cantilever slab is calculated by

$$\frac{WL_x^4}{8EI} = \frac{WL_y^4}{8EI} \qquad (1.1)$$

W is the uniformly distributed load acting on the cantilever slab (N/m)

L_x and L_y is the length of the cantilever slab in the x and y direction respectively (m)

E is the Young's Modulus for the given beam

I is the modulus of Elasticity for the given beam

Here L_x is equal to L_y. Hence, the upward pressure is divided by 2.

The depth check is performed for BM and one-way shear alone. The continuous beam prevents the additional punching action from the column.

It has been observed that the depth of the slab is governed by the one-way shear check for both the grades of steel. Depth calculation for one-way shear for BSIF is carried out in the same way as IPF.

2. Depth calculation for Beam

The depth for beam is calculated by carrying out BM check. The entire load from the slab is transferred to the beam while calculating the BM for the beam. The load is assumed to be distributed uniformly over the beam. Load from one slab is assumed to be distributed evenly on two beams.

3. Area of Steel Calculation

The area calculation for slab and the beam is carried out in the same manner as the IPF. In BSIF main reinforcement for the slab is provided in one direction. For the other direction, only minimum reinforcement is provided. This is done as a part of the tension is taken care by the insertion of beams in the BSIF.

Shear check has been performed for the beam and 8mm diameter 2 legged stirrups have been provided.

The diameter of the bar, spacing and the development Length (L_d) value for the slab is calculated in the same way as mentioned for the IPF.

4. Total Material required

The total amount of material required for the slab is calculated in the same way as the IPF.

For beam the volume of concrete is added for the extra depth of the beam. For main reinforcement, the steel required is calculated by adding the weight required in stirrups to the length times the no of bars in the beam.

III. Results and Discussion

a) Steel Quantity

In graph 1, as the size of footing increases the percentage reduction in the steel requirement for BSIF increases in comparison to the IPF for both Fe415 and Fe 500. The values for the steel requirement have been given in the table above.

This phenomenon is attributed to the provision of main reinforcement in both the direction for the IPF. While designing slab for the BSIF, main reinforcement is provided only in one direction with distribution bars in the other direction. This is done as the tension in the foundation is kept in check by the beam reinforcement.

It is observed that the percentage reduction in steel for BSIF in comparison to IPF is more for Fe 415 than for Fe 500. The graph is in congruence with the IS 456, which states that the area of steel calculated is inversely proportional to the strength of steel.

From table 1, it can be noted that the steel required for smaller size of BSIF is more than that required for IPF. This trend seems to reverse for footings of larger dimension.

Table 1: Steel Requirement

Side (m)	Fe 415			Fe 500		
	IPF	BSIF	% Reduction	IPF	BSIF	% Reduction
1	12.2	16	-31.1	12.4	15.8	-27.4
1.5	34.5	49.6	-43.8	30	43.3	-44.3
2	91.1	113.4	-24.5	72.6	97.6	-34.4
2.5	174.7	212.9	-21.9	145	183.3	-26.4
3	314.7	354.1	-12.5	257.5	306.5	-19
3.5	504.4	552.2	-9.5	415	472.2	-13.8
4	751	801.1	-6.7	630	689.3	-9.4
4.5	1085.1	1128.4	-4	888.9	977.7	-10
5	1522.6	1518.7	0.3	1226.8	1309.6	-6.7
5.5	2079.6	1984.4	4.6	1704.6	1727.8	-1.4
6	2677.2	2550.6	4.7	2182.5	2205.6	-1.1

All Values are in kg

b) Concrete Quantity

In graph 2, it is observed that with the increase in the size of the footing, the difference in the percentage reduction of the required concrete in BSIF increases in comparison to IPF. The values for the concrete requirement and the percentage reduction have been given in the table above. From the table it can be observed that the volume of concrete required for BSIF is less than that required for IPF. The decrease in the depth of the slab for BSISF in comparison to IPF is the reason for the observed trend. For BSIF the load is transferred to the beams from the slabs hence reducing the depth of the footing.

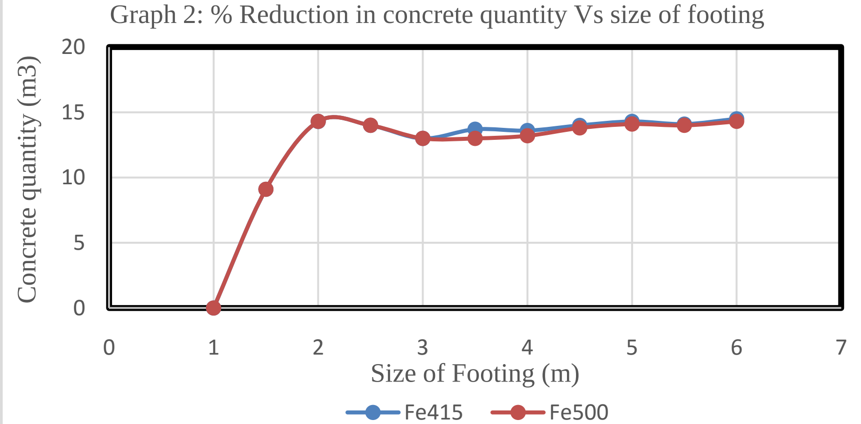
A sudden increase in the percentage reduction of concrete in BSIF in comparison to IPF for footing of length 1m to 1.5m length is observed. This sudden increase is due to the provision of minimum depth for the footing (150mm). The depth calculated is less than. 15mm hence in both the cases the concrete required is same for 1m footing.

The depth value for BM varies with the strength of steel. This accredits to the fact that the depth calculated by BM is inversely proportional to x_{umax}/d value, which is inversely proportional to the strength of steel as per the IS 456, where d is the effective depth of the footing and x_{umax} is the maximum depth of the numeral axis. When the depth attained by the BM governs the calculation, there is a deviation between the graph for the two steel values.

Table 2: Concrete Requirement

Side (m)	Fe 415			Fe 500		
	IPF	BSIF	% Reduction	IPF	BSIF	% Reduction
1	0.3	0.3	0	0.3	0.3	0
1.5	1.1	1	9.1	1.1	1	9.1
2	2.8	2.4	14.3	2.8	2.4	14.3
2.5	5.7	4.9	14	5.7	4.9	14
3	10	8.7	13	10	8.7	13
3.5	16.1	13.9	13.7	16.1	14	13
4	24.3	21	13.6	24.3	21.1	13.2
4.5	34.9	30	14	34.9	30.1	13.8
5	48.3	41.4	14.3	48.3	41.5	14.1
5.5	64.4	55.3	14.1	64.4	55.4	14
6	84.1	71.9	14.5	84.1	72.1	14.3

All Values are in m



Graph 2: % Reduction in concrete quantity Vs size of footing

c) *Weight by Volume Ratio*

In graph 3, it is observed that with the increase in the size of the footing the percentage reduction in the weight by volume ratio for the BSIF in comparison follows a similar trend like the percentage reduction for the steel. This is ascribed to the fact that the percentage reduction in the steel is minimal in comparison to the percentage reduction in the concrete.

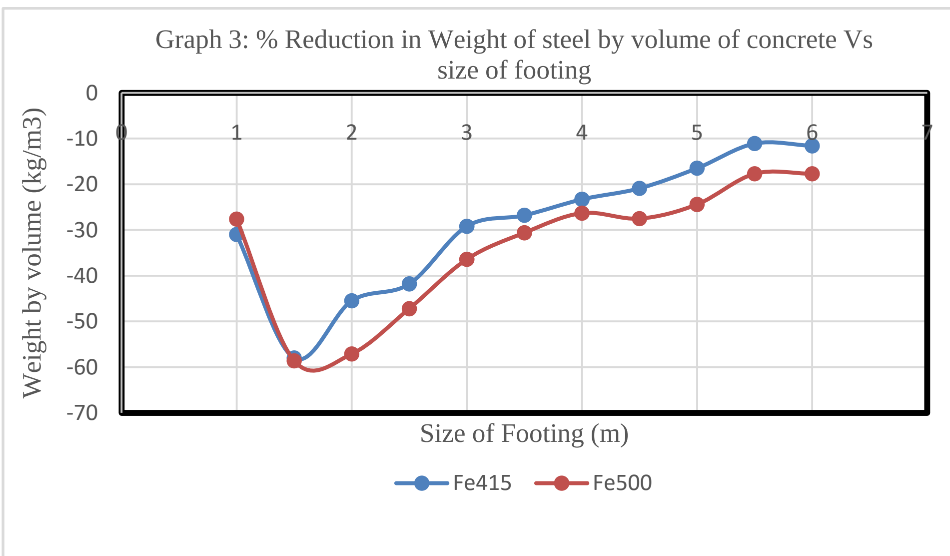
The table indicates that more weight by volume for IPF is less than that for BFIS, which indicates that less steel in kg is required per m^3 of concrete.

For Fe415 the percentage reduction in the weight by volume ratio is more than that observed in Fe500. This is because the percentage reduction in steel is much greater in Fe 415 in comparison to Fe500 whereas the difference in percentage reduction in concrete for the two steel values is negligible.

The percentage reduction of weight by volume decreases sharply from footing of size 1m to 1.5m and then increases. The abrupt fall in the percentage reduction is due to the sudden decrease in the concrete quantity for BSIF for footing of size 1.5m from footing of size 1m.

Table 3: Weight By Volume

Side (m)	Fe 415			Fe 500		
	IPF	BSIF	% Reduction	IPF	BSIF	% Reduction
1	40.7	53.3	-31	41.3	52.7	-27.6
1.5	31.4	49.6	-58	27.3	43.3	-58.6
2	32.5	47.3	-45.5	25.9	40.7	-57.1
2.5	30.6	43.4	-41.8	25.4	37.4	-47.2
3	31.5	40.7	-29.2	25.8	35.2	-36.4
3.5	31.3	39.7	-26.8	25.8	33.7	-30.6
4	30.9	38.1	-23.3	25.9	32.7	-26.3
4.5	31.1	37.6	-20.9	25.5	32.5	-27.5
5	31.5	36.7	-16.5	25.4	31.6	-24.4
5.5	32.3	35.9	-11.1	26.5	31.2	-17.7
6	31.8	35.5	-11.6	26	30.6	-17.7



All values are in Kg/m^3

IV. Conclusion

From the analysis performed on different graphs the following inferences can be drawn

1. For BSIF in comparison to IPF, as the size of footing increases from 1m to 6m the percentage reduction in steel increases from -31.1% to 4.7% for F1415 and -17.4% to -1.1% for Fe500.
2. For BSIF in comparison to IPF, as the size of footing increase from 1m to 6m the percentage reduction in concrete increases from 0% to 14.5% for Fe415 and 0% to 14.3% for Fe500.
3. For BSIF in comparison to IPF, as the size of footing increases from 1m to 6m the percentage reduction in weight by volume increases from -31% to -11.6% for F1415 and -27.6% to -17.7% for Fe500
4. It is safe to conclude that BSIF can be designed for footings of larger size with lower steel strength to reduce the material required. This conclusion is made taking size of the columns as 300mm, M15 grade of concrete and SBC of 600MPa.

Further research should be carried out on cost incurred for the skill labor and various other parameters like soil medium, column dimension while designing.

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