Module – 5
Design of Columns and Footings

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5.1.1 Introduction

Compression members are structural elements primarily subjected to axial compressive forces and hence, their design is guided by considerations of strength and buckling. Examples of compression member pedestal, column, wall and strut.

5.1.2 Objective

To design the RCC rectangular and circular columns as per the codal provisions

5.1.3 Definitions

(a) Effective length: The vertical distance between the points of inflection of the compression member in the buckled configuration in a plane is termed as effective length l_e of that compression member in that plane. The effective length is different from the unsupported length l of the member, though it depends on the unsupported length and the type of end restraints. The relation between the effective and unsupported lengths of any compression member is $l_e = k\, l$ (1) Where k is the ratio of effective to the unsupported lengths. Clause 25.2 of IS 456 stipulates the effective lengths of compression members (vide Annex E of IS 456). This parameter is needed in classifying and designing the compression members.

(b) Pedestal: Pedestal is a vertical compression member whose effective length l_e does not exceed three times of its least horizontal dimension b (cl. 26.5.3.1h, Note). The other horizontal dimension D shall not exceed four times of b.

(c) Column: Column is a vertical compression member whose unsupported length l shall not exceed sixty times of b (least lateral dimension), if restrained at the two ends. Further, its unsupported length of a cantilever column shall not exceed $100b/D$, where D is the larger lateral dimension which is also restricted up to four times of b (vide cl. 25.3 of IS 456).

(d) Wall: Wall is a vertical compression member whose effective height H_{we} to thickness t (least lateral dimension) shall not exceed 30 (cl. 32.2.3 of IS 456). The larger horizontal dimension i.e., the length of the wall L is more than 4t.

5.1.4 Classification of Columns

Based on Types of Reinforcement

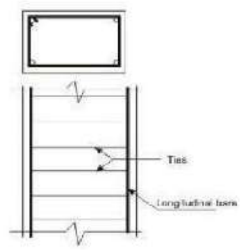


Figure 3.1(a) Tied Column

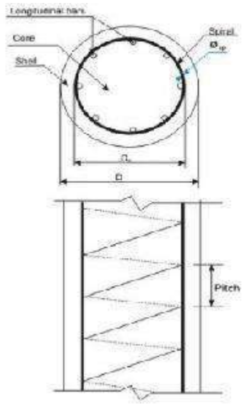


Figure 3.1(b) Column with helical reinforcement

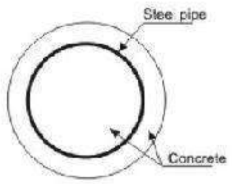


Figure 3.1(d) Composite column (steel pipe)

Figure 3.1 Tied, helically bound and composite columns

Based on the types of reinforcement, the reinforced concrete columns are classified into three groups:

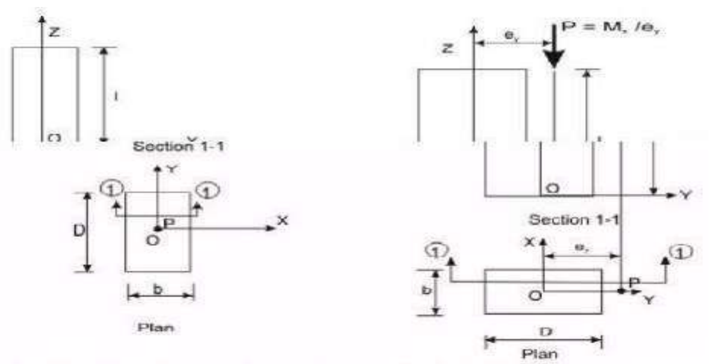
(i) Tied columns: The main longitudinal reinforcement bars are enclosed within closely spaced lateral ties (Fig.3.1a).

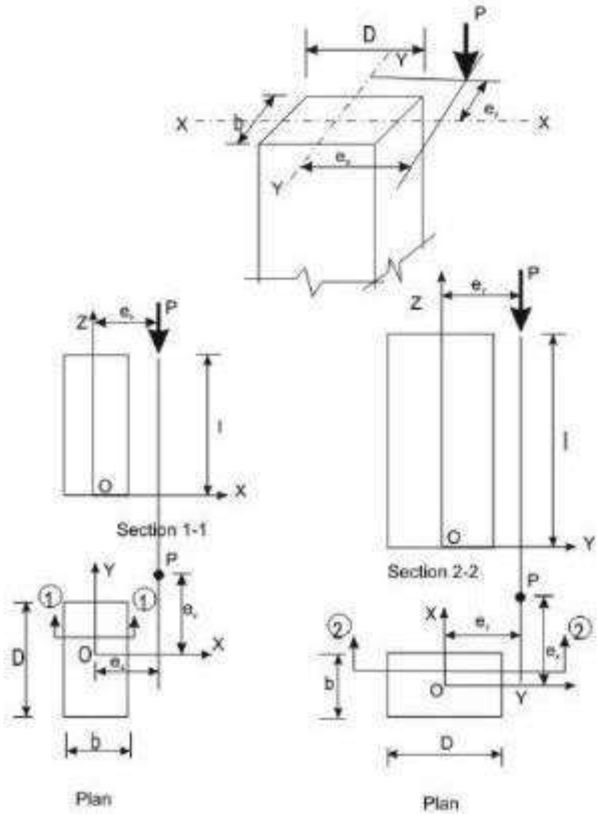
(ii) Columns with helical reinforcement: The main longitudinal reinforcement bars are enclosed within closely spaced and continuously wound spiral reinforcement. Circular and octagonal columns are mostly of this type (Fig. 3.1b).

(iii) Composite columns: The main longitudinal reinforcement of the composite columns consists of structural steel sections or pipes with or without longitudinal bars (Fig. 3.1c and d).

Out of the three types of columns, the tied columns are mostly common with different shapes of the cross-sections viz. square, rectangular etc. Helically bound columns are also used for circular or octagonal shapes of cross-sections.

Based on Loadings





Columns are classified into the three following types based on the loadings:
(i) Columns subjected to axial loads only (concentric), as shown in Fig. 3.2a.
(ii) Columns subjected to combined axial load and uniaxial bending, as shown in Fig. 3.2b.
(iii) Columns subjected to combined axial load and bi-axial bending, as shown in Fig. 3.2c.

Based on Slenderness Ratios

Columns are classified into the following two types based on the slenderness ratios:

(i) Short columns

(ii) Slender or long columns

The slenderness ratio of steel column is the ratio of its effective length l_e to its least radius of gyration *r*. In case of reinforced concrete column, however, IS 456 stipulates the slenderness ratio as the ratio of its effective length l_e to its least lateral dimension. As mentioned earlier in sec. 3.1(a), the effective length l_e is different from the unsupported length, the rectangular reinforced concrete column of cross-sectional dimensions *b* and *D* shall have two effective lengths in the two directions of *b* and *D*. Accordingly, the column may have the possibility of buckling depending on the two values of slenderness ratios as given below:

Slenderness ratio about the major axis = l_{ex}/D

Slenderness ratio about the minor axis = l_{ey}/b

Based on the discussion above, cl. 25.1.2 of IS 456 stipulates the following:

A compression member may be considered as short when both the slenderness ratios l_{ex}/D and l_{ey}/b are less than 12 where l_{ex} = effective length in respect of the major axis, D = depth in respect of the major axis, l_{ey}= effective length in respect of the minor axis, and b = width of the member. It shall otherwise be considered as a slender compression member.

Further, it is essential to avoid the mode 3 type of failure of columns so that all columns should have material failure (modes 1 and 2) only. Accordingly, cl. 25.3.1 of IS 456 stipulates the maximum unsupported length between two restraints of a column to sixty times its least lateral dimension. For cantilever columns, when one end of the column is unrestrained, the unsupported length is restricted to $100b/D$ where b and D are as defined earlier.

5.1.5 Longitudinal Reinforcement

The longitudinal reinforcing bars carry the compressive loads along with the concrete. Clause 26.5.3.1 stipulates the guidelines regarding the minimum and maximum amount, number of bars, minimum diameter of bars, spacing of bars etc. The following are the salient points:

(a) The minimum amount of steel should be at least 0.8 per cent of the gross cross-sectional area of the column required if for any reason the provided area is more than the required area.

(b) The maximum amount of steel should be 4 per cent of the gross cross-sectional area of the column so that it does not exceed 6 per cent when bars from column below have to be lapped with those in the column under consideration.

(c) Four and six are the minimum number of longitudinal bars in rectangular and circular columns, respectively.

(d) The diameter of the longitudinal bars should be at least 12 mm.

(e) Columns having helical reinforcement shall have at least six longitudinal bars within and in contact with the helical reinforcement. The bars shall be placed equidistant around its inner circumference.

(f) The bars shall be spaced not exceeding 300 mm along the periphery of the column.

(g) The amount of reinforcement for pedestal shall be at least 0.15 per cent of the cross sectional area provided.

5.1.6 Transverse Reinforcement

Transverse reinforcing bars are provided in forms of circular rings, polygonal links (lateral ties) with internal angles not exceeding 135^0 or helical reinforcement. The transverse reinforcing bars are provided to ensure that every longitudinal bar nearest to the compression face has effective lateral support against buckling. Clause 26.5.3.2 stipulates the guidelines of the arrangement of transverse reinforcement. The salient points are:

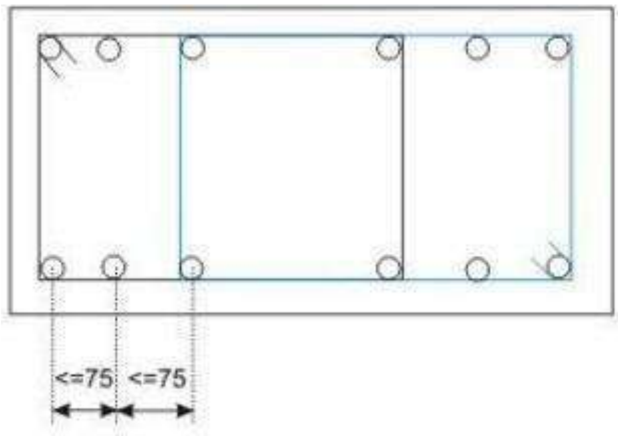


Figure 3.4 Lateral tie (Arrangement 1)

Pitch and Diameter of Lateral Ties

(a) Pitch: The maximum pitch of transverse reinforcement shall be the least of the following:

(i) The least lateral dimension of the compression members;

(ii) Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied; and

(iii) 300 mm.

(b) Diameter: The diameter of the polygonal links or lateral ties shall be not less than one fourth of the diameter of the largest longitudinal bar, and in no case less than 6 mm.

Assumptions in the Design of Compression Members by Limit State of Collapse The following are the assumptions in addition to given in 38.1 (a) to (e) for flexure for the design of compression members (cl. 39.1 of IS 456).

(i) The maximum compressive strain in concrete in axial compression is taken as 0.002.

(ii) The maximum compressive strain at the highly compressed extreme fibre in concrete subjected to axial compression and bending and when there is no tension on the section shall be 0.0035 minus 0.75 times the strain at the least compressed extreme fibre.

Minimum Eccentricity

In practical construction, columns are rarely truly concentric. Even a theoretical column loaded axially will have accidental eccentricity due to inaccuracy in construction or variation of materials etc. Accordingly, all axially loaded columns should be designed considering the minimum eccentricity as stipulated in cl. 25.4 of IS 456 and given below (Fig.3.2c)

$e_{x\,min} \geq$ greater of ($l/500 + D/30$) or 20 mm

$e_{y\,min} \geq$ greater of ($l/500 + b/30$) or 20 mm where l, D and b are the unsupported length, larger lateral dimension and least lateral dimension, respectively.

Governing Equation for Short Axially Loaded Tied Columns

Factored concentric load applied on short tied columns is resisted by concrete of area A_c and longitudinal steel of areas A_{sc} effectively held by lateral ties at intervals. Assuming the design strengths of concrete and steel are $0.4f_{ck}$ and $0.67f_y$, respectively, we can write

$P_u = 0.4f_{ck}A_c + 0.67f_yA_{sc}$

Where P_u = factored axial load on the member,

f_{ck} = characteristic compressive strength of the concrete,

A_c= area of concrete,

f_y = characteristic strength of the compression reinforcement, and

A_{sc}= area of longitudinal reinforcement for columns.

The above equation, given in cl. 39.3 of IS 456, has two unknowns Ac and A_{sc} to be determined from one equation. The equation is recast in terms of A_g, the gross area of concrete and p, the percentage of compression reinforcement employing

$A_{sc}= pA_g/100$

$A_c= A_g(1 – p/100)$

Accordingly, we can write

$P_u/A_g= 0.4f_{ck}+ (p/100) (0.67f_y– 0.4f_{ck}$

Equation 4 can be used for direct computation of A_g when P_u, f_{ck} and f_y are known by assuming p ranging from 0.8 to 4 as the minimum and maximum percentages of longitudinal reinforcement. Equation 10.4 also can be employed to determine A_g and p in a similar manner by assuming p.

5.1.7 Introduction To Footing

Design of isolated column footing

The superstructure is placed on the top of the foundation structure, designated as substructure as they are placed below the ground level. The elements of the superstructure transfer the loads and moments to its adjacent element below it and finally all loads and moments come to the foundation structure, which in turn, transfers them to the underlying soil or rock. Thus, the foundation structure effectively supports the superstructure. However, all types of soil get compressed significantly and cause the structure to settle. Accordingly, the major requirements of the design of foundation structures are the two as given below,

1. Foundation structures should be able to sustain the applied loads, moments, forces and induced reactions without exceeding the safe bearing capacity of the soil.

2. The settlement of the structure should be as uniform as possible and it should be within the tolerable limits. It is well known from the structural analysis that differential settlement of

avoiding the differential settlement is considered as more important than maintaining uniform overall settlement of the structure.

Types of Foundation Structures

1. Shallow Foundation

Shallow foundations are used when the soil has sufficient strength within a short depth below the ground level. They need sufficient plan area to transfer the heavy loads to the base soil. These heavy loads are sustained by the reinforced concrete columns or walls (either of bricks or reinforced concrete) of much less areas of cross-section due to high strength of bricks or reinforced concrete when compared to that of soil. The strength of the soil, expressed as the safe bearing capacity of the soil is normally supplied by the geotechnical experts to the structural engineer. Shallow foundations are also designated as footings. The different types of shallow foundations or footings are discussed below.

(i) Plain concrete pedestal footings

(ii) Isolated footings

(iii) Combined footings

(iv) Strap footings

(v) Strip foundation or wall footings

(vi) Raft or mat foundation

(vii) Deep foundations

As mentioned earlier, the shallow foundations need more plan areas due to the low strength of soil compared to that of masonry or reinforced concrete. However, shallow foundations are selected when the soil has moderately good strength, except the raft foundation which is good in poor condition of soil also. Raft foundations are under the category of shallow foundation as they have comparatively shallow depth than that of deep foundation. It is worth mentioning that the depth of raft foundation is much larger than those of other types of shallow foundations.

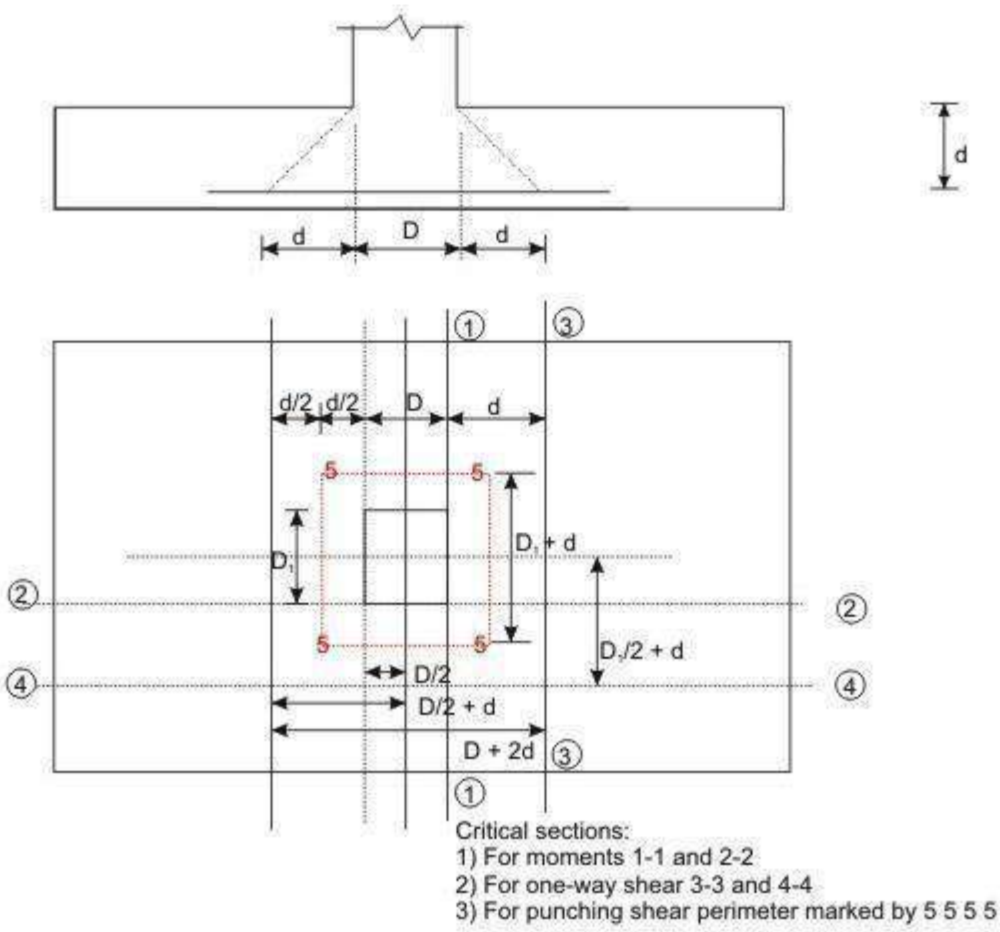
However, for poor condition of soil near to the surface, the bearing capacity is very less and foundation needed in such situation is the pile foundation. Piles are, in fact, small diameter columns which are driven or cast into the ground by suitable means. Precast piles are driven and cast-in-situ are cast. These piles support the structure by the skin friction between the pile surface and the surrounding soil and end bearing force, if such resistance is available to provide the bearing force. Accordingly, they are designated as frictional and end bearing piles. They are normally provided in a group with a pile cap at the top through which the loads of the superstructure are transferred to the piles.

Piles are very useful in marshy land where other types of foundation are impossible to construct. The length of the pile which is driven into the ground depends on the availability of hard soil/rock or the actual load test. Another advantage of the pile foundations is that they can resist uplift also in the same manner as they take the compression forces just by the skin friction in the opposite direction.

However, driving of pile is not an easy job and needs equipment and specially trained persons or agencies. Moreover, one has to select pile foundation in such a situation where the adjacent buildings are not likely to be damaged due to the driving of piles. The choice of driven or bored piles, in this regard, is critical.

Exhaustive designs of all types of foundations mentioned above are beyond the scope of this course. Accordingly, this module is restricted to the design of some of the shallow footings, frequently used for normal low rise buildings only.

Isolated Footing



Design Considerations

(a) Minimum nominal cover (cl. 26.4.2.2 of IS 456)

The minimum nominal cover for the footings should be more than that of other structural elements of the superstructure as the footings are in direct contact with the soil. Clause 26.4.2.2 of IS 456 prescribes a minimum cover of 50 mm for footings. However, the actual cover may be even more depending on the presence of harmful chemicals or minerals, water table etc.

(b) Thickness at the edge of footings (cls. 34.1.2 and 34.1.3 of IS 456)

The minimum thickness at the edge of reinforced and plain concrete footings shall be at least 150 mm for footings on soils and at least 300 mm above the top of piles for footings on piles, as per the stipulation in cl.34.1.2 of IS 456.

For plain concrete pedestals, the angle α (see Fig.11.28.1) between the plane passing through the bottom edge of the pedestal and the corresponding junction edge of the column with pedestal and the horizontal plane shall be determined from the following expression (cl.34.1.3 of IS 456)

$$\tan\alpha \leq 0.9\{(100 q_a / f_{ck}) + 1\}^{0.5}$$

where q_a = calculated maximum bearing pressure at the base of pedestal in N/mm^2, and

2

(c) Bending moments (cl. 34.2 of IS 456)

1. It may be necessary to compute the bending moment at several sections of the footing depending on the type of footing, nature of loads and the distribution of pressure at the base of the footing. However, bending moment at any section shall be determined taking all forces acting over the entire area on one side of the section of the footing, which is obtained by passing a vertical plane at that section extending across the footing (cl.34.2.3.1 of IS 456).
2. The critical section of maximum bending moment for the purpose of designing an isolated concrete footing which supports a column, pedestal or wall shall be:

(i) at the face of the column, pedestal or wall for footing supporting a concrete column, pedestal or reinforced concrete wall, and

(ii) halfway between the centre-line and the edge of the wall, for footing under masonry wall. This is stipulated in cl.34.2.3.2 of IS 456.

The maximum moment at the critical section shall be determined as mentioned in 1 above. For round or octagonal concrete column or pedestal, the face of the column or pedestal shall be taken as the side of a square inscribed within the perimeter of the round or octagonal column or pedestal (see cl.34.2.2 of IS 456 and Figs.11.28.13a and b).

(d) Shear force (cl. 31.6 and 34.2.4 of IS 456)

Footing slabs shall be checked in one-way or two-way shears depending on the nature of bending. If the slab bends primarily in one-way, the footing slab shall be checked in one-way vertical shear. On the other hand, when the bending is primarily two-way, the footing slab shall be checked in two-way shear or punching shear. The respective critical sections and design shear strengths are given below:

1. One-way shear (cl. 34.2.4 of IS 456)

(i) One-way shear has to be checked across the full width of the base slab on a vertical section located from the face of the column, pedestal or wall at a distance equal to effective depth of the footing slab in case of footing slab on soil, and

(ii) half the effective depth of the footing slab if the footing slab is on piles.

The design shear strength of concrete without shear reinforcement is given in Table 19 of cl.40.2 of IS 456.

2. Two-way or punching shear (cls.31.6 and 34.2.4)

Two-way or punching shear shall be checked around the column on a perimeter half the effective depth of the footing slab away from the face of the column or pedestal.

The permissible shear stress, when shear reinforcement is not provided, shall not exceed $k_s \tau_c$, where $k_s = (0.5 + c\beta)$, but not greater than one, $c\beta$ being the ratio of short side to long side of the column, and $\tau_c = 0.25(f_{ck})^{1/2}$ in limit state method of design, as stipulated in cl.31.6.3 of IS 456.

(f) Tensile reinforcement (cl.34.3 of IS 456)

The distribution of the total tensile reinforcement, calculated in accordance with the moment at critical sections, as specified in part (c) of this section, shall be done as given below for one-way and two-way footing slabs separately.

(i) In one-way reinforced footing slabs like wall footings, the reinforcement shall be distributed uniformly across the full width of the footing i.e., perpendicular to the direction of wall. Nominal distribution reinforcement shall be provided as per cl. 34.5 of IS 456 along the length of the wall to take care of the secondary moment, differential settlement, shrinkage and temperature effects.

(i) In two-way reinforced square footing slabs, the reinforcement extending in each direction shall be distributed uniformly across the full width/length of the footing.

(**i**) In two-way reinforced rectangular footing slabs, the reinforcement in the long direction shall be distributed uniformly across the full width of the footing slab. In the short direction, a central band equal to the width of the footing shall be marked along the length of the footing, where the portion of the reinforcement shall be determined as given in the equation below. This portion of the reinforcement shall be distributed across the central band:

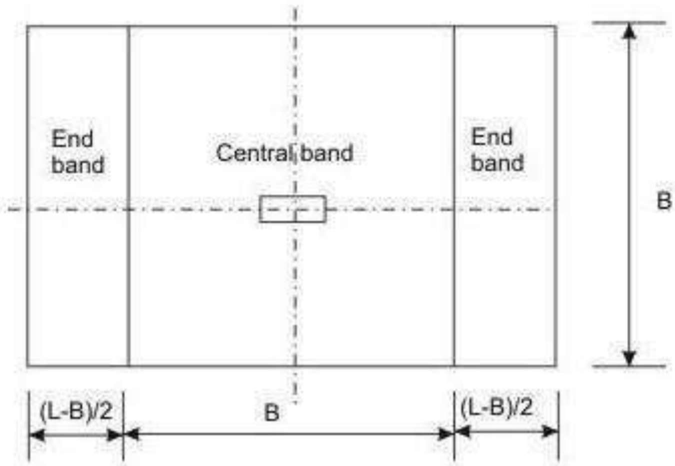


Figure 3.10 Bands for reinforcement in rectangular footing Reinforcement

in the central band = {2/(β+1)} (Total reinforcement in the short direction)
Where β is the ratio of longer dimension to shorter dimension of the footing slab (Fig.3.10).

Each of the two end bands shall be provided with half of the remaining reinforcement, distributed uniformly across the respective end band.

(g) Transfer of load at the base of column (cl.34.4 of IS 456)

All forces and moments acting at the base of the column must be transferred to the pedestal, if any, and then from the base of the pedestal to the footing, (or directly from the base of the column to the footing if there is no pedestal) by compression in concrete and steel and tension in steel. Compression forces are transferred through direct bearing while tension forces are transferred through developed reinforcement. The permissible bearing stresses on full area of concrete shall be taken as given below from cl.34.4 of IS 456:

$\sigma_{br} = 0.25 f_{ck}$, in working stress method, and

$\sigma_{br} = 0.45 f_{ck}$, in limit state method

The stress of concrete is taken as $0.45 f_{ck}$ while designing the column. Since the area of footing is much larger, this bearing stress of concrete in column may be increased considering the dispersion of the concentrated load of column to footing. Accordingly, the permissible bearing stress of concrete in footing is given by (cl.34.4 of IS 456):

$$\sigma_{br} = 0.45 f_{ck} (A_1/A_2)^{1/2}$$

with a condition that

$$(A_1/A_2)^{1/2} \quad 2.0 \ (11.8) \le 2$$

where A_1 = maximum supporting area of footing for bearing which is geometrically similar to and concentric with the loaded area A_2.

A_2 = loaded area at the base of the column.

The above clause further stipulates that in sloped or stepped footings, A_1 may be taken as the area of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for its upper base, the area actually loaded and having side slope of one vertical to two horizontal.

If the permissible bearing stress on concrete in column or in footing is exceeded, reinforcement shall be provided for developing the excess force (cl.34.4.1 of IS 456), either by extending the longitudinal bars of columns into the footing (cl.34.4.2 of IS 456) or by providing dowels as stipulated in cl.34.4.3 of IS 456 and given below:

(i) Sufficient development length of the reinforcement shall be provided to transfer the compression or tension to the supporting member in accordance with cl.26.2 of IS 456, when transfer of force is accomplished by reinforcement of column (cl.34.4.2 of IS 456).

(i) Minimum area of extended longitudinal bars or dowels shall be 0.5 per cent of the cross-sectional area of the supported column or pedestal (cl.34.4.3 of IS 456).

(i) A minimum of four bars shall be provided (cl.34.4.3 of IS 456).

(iv) The diameter of dowels shall not exceed the diameter of column bars by more than 3 mm.

(v) Column bars of diameter larger than 36 mm, in compression only can be doweled at the footings with bars of smaller size of the necessary area. The dowel shall extend into the column, a distance equal to the development length of the column bar and into the footing, a distance equal to the development length of the dowel, as stipulated in cl.34.4.4 of IS 456.

(h) Nominal reinforcement (cl. 34.5 of IS 456)

Clause 34.5.1 of IS 456 stipulates the minimum reinforcement and spacing of the bars in footing slabs as per the requirements of solid slab (cls.26.5.2.1 and 26.3.3b(2) of IS 456, respectively).

5.1.8 Numerical Problem

Design the reinforcement in a column of size 400 mm x 600 mm subjected to an axial load of 2000 kN under service dead load and live load. The column has an unsupported length of 4.0 m and effectively held in position and restrained against rotation in both ends. Use M 25 concrete and Fe 415 steel.

Solution

Step 1: To check if the column is short or slender

Given l = 4000 mm, b = 400 mm and D = 600 mm. Table 28 of IS 456 = $l_{ex} = l_{ey} = 0.65(l)$ = 2600 mm. So, we have

$l_{ex}/D = 2600/600 = 4.33 < 12$

$l_{ey}/b = 2600/400 = 6.5 < 12$

Hence, it is a short column.

Step 2: Minimum eccentricity

$e_{x\,min}$ = Greater of ($l_{ex}/500 + D/30$) and 20 mm = 25.2 mm

$e_{y\,min}$ = Greater of ($l_{ey}/500 + b/30$) and 20 mm = 20 mm

$0.05\,D = 0.05(600) = 30$ mm > 25.2 mm (= $e_{x\,min}$)

$0.05\,b = 0.05(400) = 20$ mm = 20 mm (= $e_{y\,min}$)

Hence, the equation given in cl.39.3 of IS 456 (Eq.(1)) is applicable for the design here.

Step 3: Area of steel

Fro Eq.10.4, we have

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$

$$3000(10^3) = 0.4(25)\{(400)(600) - A_{sc}\} + 0.67(415) A_{sc}$$

which gives,

$$A_{sc} = 2238.39 \text{ mm}^2$$

Provide 6-20 mm diameter and 2-16 mm diameter rods giving 2287 mm^2 (> 2238.39 mm^2) and p = 0.953 per cent, which is more than minimum percentage of 0.8 and less than maximum percentage of 4.0. Hence, o.k.

Step 4: Lateral ties

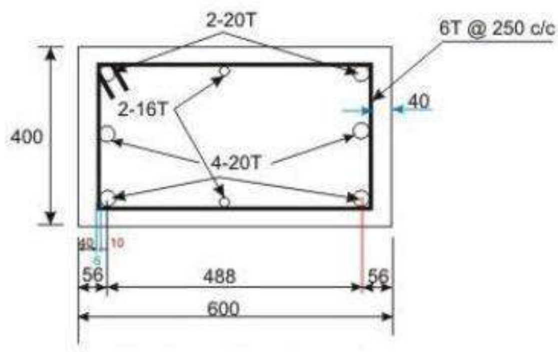
The diameter of transverse reinforcement (lateral ties) is determined from cl.26.5.3.2 C-2 of IS 456 as not less than (i) θ/4 and (ii) 6 mm. Here, θ = largest bar diameter used as longitudinal reinforcement = 20 mm. So, the diameter of bars used as lateral ties = 6 mm.

The pitch of lateral ties, as per cl.26.5.3.2 C-1 of IS 456, should be not more than the least of

(i) The least lateral dimension of the column = 400 mm

(ii) Sixteen times the smallest diameter of longitudinal reinforcement bar to be tied = 16(16) = 256 mm

iii) 300 mm



Reinforcement Detailing

Design an isolated footing of uniform thickness of a RC column bearing a vertical load of 600 KN and having a base of size 500x500 mm. the safe bearing capacity of soil may be taken as 120 KN/m2. Use M20 concrete and Fe 415 steel.

Solution

<u>Size of footing</u>

W=600 KN;

Self weight of footing @ 10% =60 KN

Total load =660 KN

Size of footing = 660/120 = 5.5 m^2

Since square footing , B= $\sqrt{5.5}$ =2.345 m2

Provide a square footing = 2.4mx 2.4m

Net upward pressure , p_0= 600/(2.4x2.4) = 104.17 KN/m^2

<u>Design of section</u>

The maximum BM acts at the face of column

$$M = p_o \frac{B}{8}(B-b)^2 = 112.8\ KN-m$$

Mu = 1.5M =169.2 KN-m

Therefore d = 160 mm; D = 160+60 = 220mm

<u>Depth on the basis of one-way shear</u>

For a one way shear, critical section is located at a distance _d' from the face of the column where shear force V is given by

$V = p_o B\{0.5(B - b) - d\} = 104.17x2.4\{0.5x(2.4 - 0.5) - 0.001d\}$

Vu = 1.5V

$$\tau_c = \frac{V_u}{bd} = \frac{375012(0.95 - 0.001d)}{2400d}$$

From table B.5.2.1.1 of IS 456:2000 k=1.16 for D = 220mm.

Also for under-reinforced section with p_t = 0.3% for M20 concrete, τ_c =0.384 N/mm^2.

Hence design shear stress = kτ_c =0.445 N/mm^2

From which we get d= 246.7 $\simeq$ 250 mm

<u>Depth for two way shear</u>

Take d greater one of the two i.e. 250mm. for two-way shear, the section lies at d/2 from the column face all round. The width bo of the section = b+d = 750mm

Shear force around the section

$F = p_o[B^2 - b^2]_o = 541.42\ KN$

Fu=1.5F

$$\tau_v = \frac{F_u}{4b_o d} = \frac{812.13x10^6}{4x750x250} = 1.083\ N/mm^2$$

Permissible shear stress = $k_s\tau_c$

Where $k_s = (0.5 + \beta_c) = (0.5 + 1)$ with a maximum value 1. ks=1

$\tau_c = 0.25\sqrt{f_{ck}}$ =1.118 N/mm2

Permissible shear stress= 1.118 N/mm2

Hence safe.

Hence d=250 mm, using 60 mm as effective cover and keeping D=330 mm, effective depth = 330-60= 270 mm in one direction and other direction d=270- 12 =258 mm.

Calculation of reinforcement

A_{st}= 1944 mm^2

So provide 12 mm @ 125 c/c in each direction.

Development length

L_d=564 mm

Provide 60 mm side cover, length of bars available =0.5[B-b]-60=890 mm

>L_d So safe.

Transfer of load at column base

A2= 500x500 = 250000 mm^2

A1=[500+2(2x330)]= 3312400

mm^2

$\sqrt{\frac{A_1}{A_2}}$ = 3.64

Taking $\sqrt{\frac{A_1}{A_2}}$ =2

Hence permissible bearing stress = 18

KN/m^2 Actual bearing stress = 3.6 N/mm^2

Hence safe.

5.1.9 Outcome

1. Able to design the RCC columns

5.1.10 Assignment questions

Design the reinforcement to be provided in the short column is subjected to P_u= 2000 kN,

M_{ux}= 130 kNm (about the major principal axis) and M_{uy}= 120 kNm (about the minor principal axis). The unsupported length of the column is 3.2 m, width b = 400 mm and depth D = 500 mm. Use M 25 and Fe 415 for the design.

5.1.11 Future Study

https://nptel.ac.in/courses/105105105/