



RGPVNOTES.IN

Program : **B.Tech**

Subject Name: **Structural Design and Drawing (RCC-I)**

Subject Code: **CE-601**

Semester: **6th**



LIKE & FOLLOW US ON FACEBOOK

facebook.com/rgpvnotes.in

Unit – IV

Columns & Footings: Effective length of columns, Short and long columns- Square, Rectangular and Circular columns, Isolated and combined footings, Strap footing, Columns subjected to axial loads and bending moments (sections with no tension), Raft foundation

Introduction: A column is defined as a compression member, the effective length of which exceeds three times the least lateral dimension. Compression members, whose lengths do not exceed three times the least lateral dimension, may be made of plain concrete. A column forms a very important component of a structure. Columns support beams which in turn support walls and slabs. It should be realized that the failure of a column results in the collapse of the structure. The design of a column should therefore receive importance.

A column is a vertical structural member supporting axial compressive loads, with or without moments. The cross-sectional dimensions of a column are generally considerably less than its height. Columns support vertical loads from the floors and roof and transmit these loads to the foundations.

The more general terms compression members and members subjected to combined axial load and bending are sometimes used to refer to columns, walls, and members in concrete trusses or frames. These may be vertical, inclined, or horizontal. A column is a special case of a compression member that is vertical. Stability effects must be considered in the design of compression members.

Classification of columns

A column may be classified based on different criteria such as:

Based on shape

Rectangle

Square

Circular



Polygon

L type

T type

+ type

Based on slenderness ratio or height

Short column and Long column or Short and Slender Compression Members

A compression member may be considered as short when both the slenderness ratios namely 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 or long compression member.

The great majority of concrete columns are sufficiently stocky (short) that slenderness can be ignored. Such columns are referred to as short columns. Short column generally fails by crushing of concrete due to axial force. If the moments induced by slenderness effects weaken a column appreciably, it is referred to as a slender column or a long column. Long columns generally fail by bending effect than due to axial effect. Long column carry less load compared to long column.

Based on pattern of lateral reinforcement

Tied columns with ties as laterals

Columns with Spiral steel as laterals or spiral columns

Majority of columns in any buildings are tied columns. In a tied column the longitudinal bars are tied together with smaller bars at intervals up the column. Tied columns may be square, rectangular, L-shaped, circular, or any other required shape. Occasionally, when high strength and/or high ductility are required, the bars are placed in a circle, and the ties are replaced by a bar bent into a helix or spiral. Such

Structural Design & Drawing (RCC-1) (CE601)

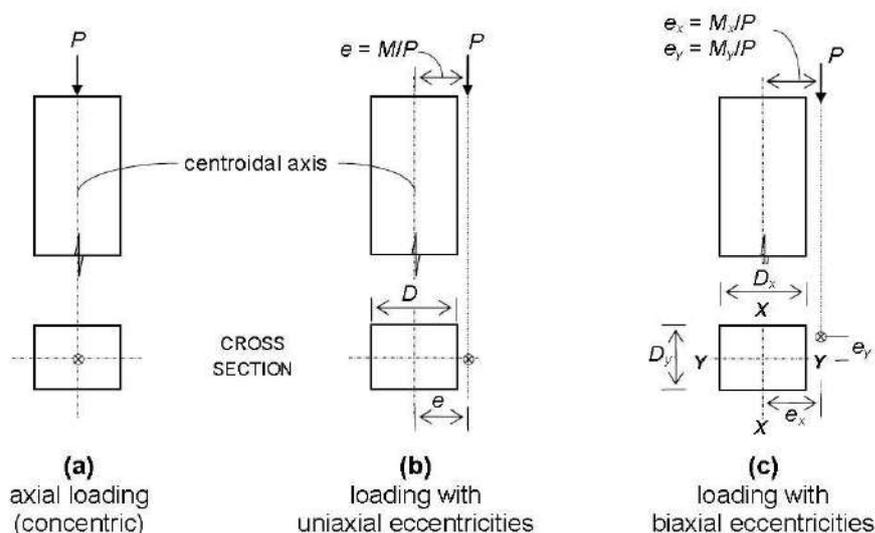
a column, called a spiral column. Spiral columns are generally circular, although square or polygonal shapes are sometimes used. The spiral acts to restrain the lateral expansion of the column core under high axial loads and, in doing so, delays the failure of the core, making the column more ductile. Spiral columns are used more extensively in seismic regions. If properly designed, spiral column carry 5% extra load at failure compared to similar tied column.

Based on type of loading

Axially loaded column or centrally or concentrically loaded column (P_u)

A column subjected to axial load and uniaxial bending ($P_u + M_{ux}$) or ($P + M_{uy}$)

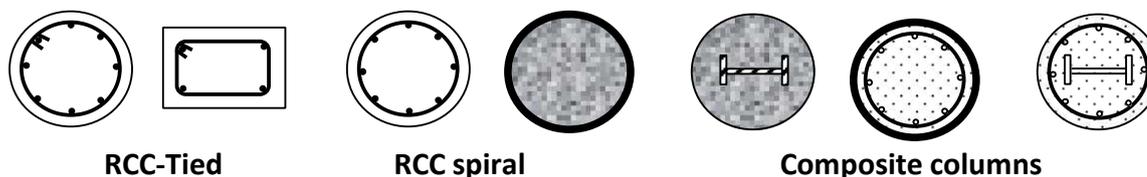
A column subjected to axial load and biaxial bending ($P_u + M_{ux} + M_{uy}$)



Different loading situations in columns

Based on materials

Timber, stone, masonry, RCC, PSC, Steel, aluminium, composite column



Behaviour of Tied and Spiral Columns

Figure shows a portion of the core of a spiral column. Under a compressive load, the concrete in this column shortens longitudinally under the stress and so, to satisfy Poisson's ratio, it expands laterally. In a spiral column, the lateral expansion of the concrete inside the spiral (referred to as the core) is restrained by the spiral. This stresses the spiral in tension. For equilibrium, the concrete is subjected to lateral compressive stresses. In a tied column in a non seismic region, the ties are spaced roughly the width of the column apart and, as a result, provide relatively little lateral restraint to the core. Outward pressure on the sides of the ties due to lateral expansion of the core merely bends them outward, developing an insignificant hoop-stress effect. Hence, normal ties have little effect on the strength of the core in a tied column. They do, however, act to reduce the unsupported length of the longitudinal bars, thus reducing the danger of buckling of those bars as the bar stress approaches yield. Load deflection diagrams for a tied column and a spiral column subjected to axial loads is shown in figure. The initial parts of these diagrams are similar. As the maximum load is reached, vertical cracks and crushing develop in the concrete shell outside the ties or spiral, and this concrete spalls off. When this occurs in a tied column, the capacity of the core that remains is less than the load on the column. The concrete core is crushed, and the reinforcement buckles outward between ties. This occurs suddenly, without warning,

Structural Design & Drawing (RCC-1) (CE601)

in a brittle manner. When the shell spalls off a spiral column, the column does not fail immediately because the strength of the core has been enhanced by the triaxial stresses resulting from the effect of the spiral reinforcement. As a result, the column can undergo large deformations, eventually reaching a second maximum load, when the spirals yield and the column finally collapses. Such a failure is much more ductile than that of a tied column and gives warning of the impending failure, along with possible load redistribution to other members. Due to this, spiral column carry little more load than the tied column to an extent of about 5%. Spiral columns are used when ductility is important or where high loads make it economical to utilize the extra strength. Both columns are in the same building and have undergone the same deformations. The tied column has failed completely, while the spiral column, although badly damaged, is still supporting a load. The very minimal ties were inadequate to confine the core concrete. Had the column ties been detailed according to ACI Code, the column will perform better as shown.

Specifications for covers and reinforcement in column

For a longitudinal reinforcing bar in a column nominal cover shall in any case not be less than 40 mm, or less than the diameter of such bar. In the case of columns of minimum dimension of 200 mm or under, whose reinforcing bars do not exceed 12 mm, a nominal cover of 25 mm may be used. For footings minimum cover shall be 50 mm.

Nominal Cover in mm to meet durability requirements based on exposure

Mild 20, Moderate 30, Severe 45, Very severe 50, Extreme 75

Nominal cover to meet specified period of fire resistance for all fire rating 0.5 to 4 hours is 40 mm for columns only

Effective length of compression member

Column or strut is a compression member, the effective length of which exceeds three times the least lateral dimension. For normal usage assuming idealized conditions, the effective length of in a given plane may be assessed on the basis of Table 28 of IS: 456-2000. Following terms are required.

Following are the end restraints:

Effectively held in position and restrained against rotation in both ends

Effectively held in position at both ends, restrained against rotation at one end

Effectively held in position at both ends, but not restrained against rotation

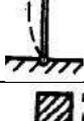
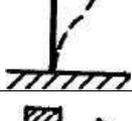
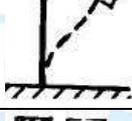
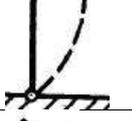
Effectively held in position and restrained against rotation at one end, and at the other restrained against rotation but not held in position

Effectively held in position and restrained against rotation in one end, and at the other partially restrained against rotation but not held in position

Effectively held in position at one end but not restrained against rotation, and at the other end restrained against rotation but not held in position

Effectively held in position and restrained against rotation at one end but not held in position nor restrained against rotation at the other end

Table. Effective length of compression member

Sl. No.	Degree of End Restraint of Compression Members	Figure	Theo. Value of Effective Length	Recon. Value of Effective Length
1	Effectively held in position and restrained against rotation in both ends		0.50 l	0.65l
2	Effectively held in position at both ends, restrained against rotation at one end		0.70 l	0.80l
3	Effectively held in position at both ends, but not restrained against rotation		1.0 l	1.0l
4	Effectively held in position and restrained against rotation at one end, and at the other restrained against rotation but not held in position		1.0 l	1.20l
5	Effectively held in position and restrained against rotation in one end, and at the other partially restrained against rotation but not held in position		-	1.5l
6	Effectively held in position at one end but not restrained against rotation, and at the other end restrained against rotation but not held in position		2.0 l	2.0l
7	Effectively held in position and restrained against rotation at one end but not held in position nor restrained against rotation at the other end		2.0 l	2.0l

Unsupported Length

The unsupported length, l , of a compression member shall be taken as the clear distance between end restraints (visible height of column). Exception to this is for flat slab construction, beam and slab construction, and columns restrained laterally by struts (Ref. IS: 456-2000),

Slenderness Limits for Columns

The unsupported length between end restraints shall not exceed 60 times the least lateral dimension of a column.

If in any given plane, one end of a column is unrestrained, its unsupported length, l , shall not exceed $100b^2/D$, where b = width of that cross-section, and D = depth of the cross-section measured in the plane under consideration.

Specifications as per IS: 456-2000**Longitudinal reinforcement**

The cross-sectional area of longitudinal reinforcement shall be not less than 0.8 percent nor more than 6 percent of the gross cross sectional area of the column.

NOTE - The use of 6 percent reinforcement may involve practical difficulties in placing and compacting of concrete; hence lower percentage is recommended. Where bars from the columns below have to be lapped with those in the column under consideration, the percentage of steel shall usually not exceed 4 percent.

In any column that has a larger cross-sectional area than that required to support the load, the minimum percentage of steel shall be based upon the area of concrete required to resist the direct stress and not upon the actual area.

The minimum number of longitudinal bars provided in a column shall be four in rectangular columns and six in circular columns.

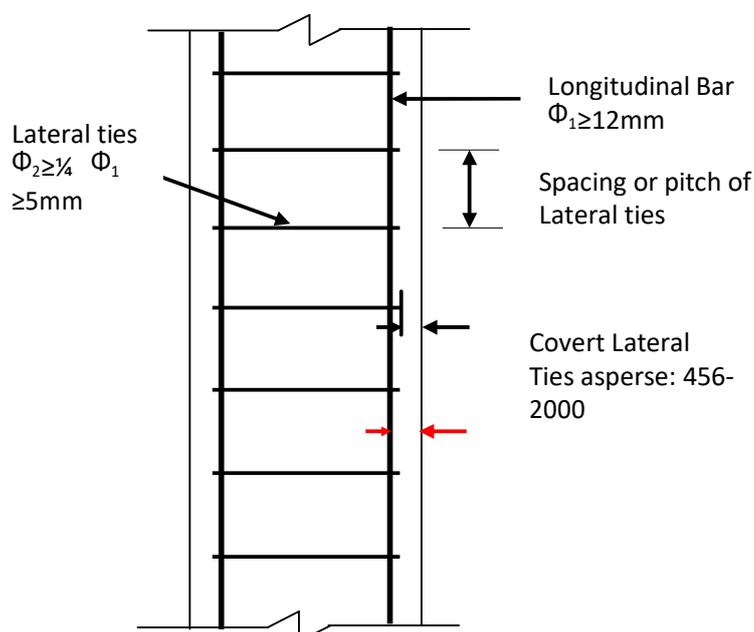
The bars shall not be less than 12 mm in diameter

A reinforced concrete column having helical reinforcement shall have at least six bars of longitudinal reinforcement within the helical reinforcement.

In a helically reinforced column, the longitudinal bars shall be in contact with the helical reinforcement and equidistant around its inner circumference.

Spacing of longitudinal bars measured along the periphery of the column shall not exceed 300 mm.

In case of pedestals in which the longitudinal reinforcement is not taken in account in strength calculations, nominal longitudinal reinforcement not less than 0.15 percent of the cross-sectional area shall be provided.



Transverse reinforcement

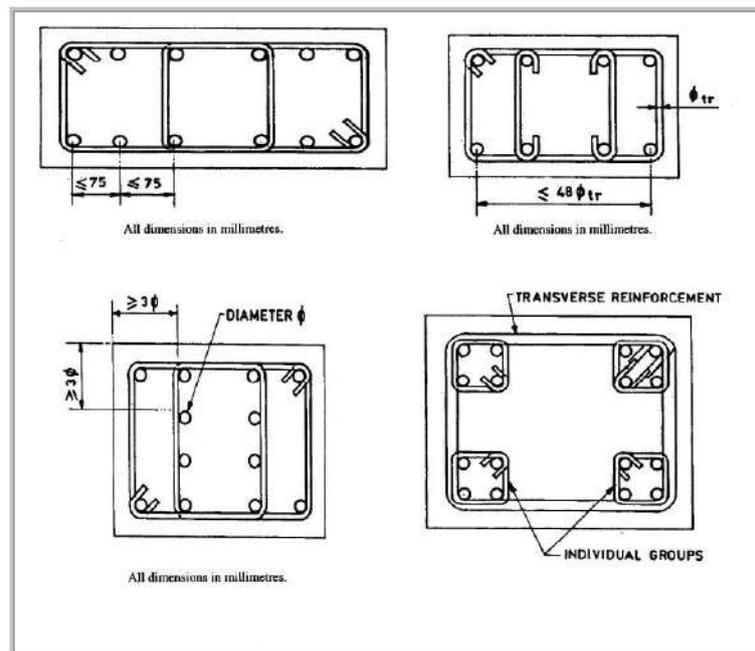
A reinforced concrete compression member shall have transverse or helical reinforcement so disposed that every longitudinal bar nearest to the compression face has effective lateral support against buckling.

The effective lateral support is given by transverse reinforcement either in the form of circular rings capable of taking up circumferential tension or by polygonal links (lateral ties) with internal angles not exceeding 135° . The ends of the transverse reinforcement shall be properly anchored.

Arrangement of transverse reinforcement

If the longitudinal bars are not spaced more than 75 mm on either side, transverse reinforcement need only to go round corner and alternate bars for the purpose of providing effective lateral supports (Ref. IS:456).

If the longitudinal bars spaced at a distance of not exceeding 48 times the diameter of the tie are effectively tied in two directions, additional longitudinal bars in between these bars need to be tied in one direction by open ties (Ref. IS:456).



Pitch and diameter of lateral ties

1) Pitch-The pitch of transverse reinforcement shall be not more than the least of the following distances:

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.

2) 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.

Helical reinforcement

Structural Design & Drawing (RCC-1) (CE601)

1) Pitch-Helical reinforcement shall be of regular formation with the turns of the helix spaced evenly and its ends shall be anchored properly by providing one and a half extra turns of the spiral bar. Where an increased load on the column on the strength of the helical reinforcement is allowed for, the pitch of helical turns shall be not more than 7.5 mm, nor more than one sixth of the core diameter of the column, nor less than 25 mm, nor less than three times the diameter of the steel bar forming the helix.

LIMIT STATE OF COLLAPSE: COMPRESSION

Assumptions

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

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.

In addition the following assumptions of flexure are also required

Plane sections normal to the axis remain plane after bending.

The maximum strain in concrete at the outermost compression fibre is taken as 0.0035 in bending.

The relationship between the compressive stress distribution in concrete and the strain in concrete may be assumed to be rectangle, trapezoid, parabola or any other shape which results in prediction of strength in substantial agreement with the results of test.

An acceptable stress strain curve is given in IS: 456-200. For design purposes, the compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor γ of 1.5 shall be applied in addition to this.

The tensile strength of the concrete is ignored.

The stresses in the reinforcement are derived from representative stress-strain curve for the type of steel used. Typical curves are given in IS: 456-2000. For design purposes the partial safety factor equal to 1.15 shall be applied.

Minimum eccentricity

As per IS:456-2000, all columns shall be designed for minimum eccentricity, equal to the unsupported length of column/ 500 plus lateral dimensions/30, subject to a minimum of 20 mm. Where bi-axial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum about one axis at a time.

Short Axially Loaded Members in Compression

The member shall be designed by considering the assumptions given in 39.1 and the minimum eccentricity. When the minimum eccentricity as per 25.4 does not exceed 0.05 times the lateral dimension, the members may be designed by the following equation:

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

P_u = 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_s = area of longitudinal reinforcement for columns.

Compression Members with Helical Reinforcement

Structural Design & Drawing (RCC-1) (CE601)

The strength of compression members with helical reinforcement satisfying the requirement of IS: 456 shall be taken as 1.05 times the strength of similar member with lateral ties.

The ratio of the volume of helical reinforcement to the volume of the core shall not be less than

$$V_{hs} / V_c > 0.36 (A_g/A_c - 1) f_{ck}/f_y$$

A_g = gross area of the section,

A_c = area of the core of the helically reinforced column measured to the outside diameter of the helix,

f_{ck} = characteristic compressive strength of the concrete, and f_y = characteristic strength of the helical reinforcement but not exceeding 415 N/mm.

Members Subjected to Combined Axial Load and Uni-axial Bending

Use of Non-dimensional Interaction Diagrams as Design Aids

Design Charts (for Uniaxial Eccentric Compression) in SP-16

The design Charts (non-dimensional interaction curves) given in the Design Handbook, SP:16 cover the following three cases of symmetrically arranged reinforcement:

Rectangular sections with reinforcement distributed equally on two sides (Charts 27 – 38): the 'two sides' refer to the sides parallel to the axis of bending; there are no inner rows of bars, and each outer row has an area of 0.5A this includes the simple 4-bar configuration. s

Rectangular sections with reinforcement distributed equally on four sides (Charts 39 – 50): two outer rows (with area 0.3A each) and four inner rows (with area 0.1A each) s s

Have been considered in the calculations; however, the use of these Charts can be extended, without significant error, to cases of not less than two inner rows (with a minimum area 0.3A in each outer row).

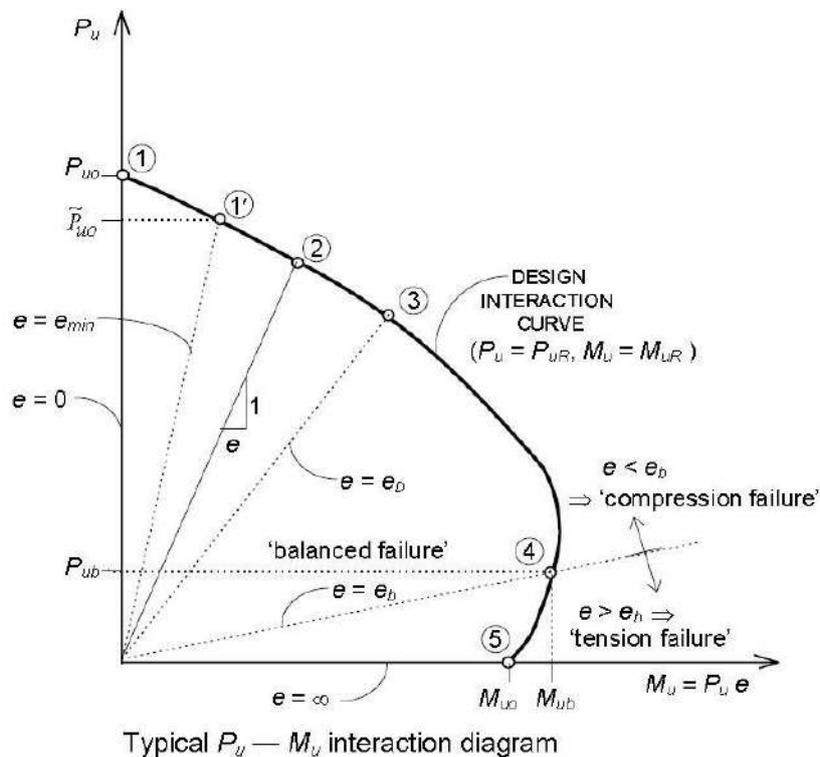
Circular column sections (Charts 51 – 62): the Charts are applicable for circular sections with at least six bars (of equal diameter) uniformly spaced circumferentially.

Corresponding to each of the above three cases, there are as many as 12 Charts available covering the 3 grades of steel (Fe 250, Fe 415, Fe 500), with 4 values of d^1/D ratio for each grade (namely 0.05, .0.10, 0.15, 0.20). For intermediate values of d^1/D , linear interpolation may be done. Each of the 12 Charts of SP-16 covers a family of non-dimensional design interaction curves with p/f values ranging from 0.0 to 0.26. ck

From this, percentage of steel (p) can be found. Find the area of steel and provide the required number of bars with proper arrangement of steel as shown in the chart.

Typical interaction curve

Structural Design & Drawing (RCC-1) (CE601)

**Salient Points on the Interaction Curve**

The salient points, marked 1 to 5 on the interaction curve correspond to the failure strain profiles, marked 1 to 5 in the above figure.

The point 1 in figure corresponds to the condition of axial loading with $e = 0$. For this case of 'pure' axial compression.

The point 1' in figure corresponds to the condition of axial loading with the mandatory minimum eccentricity e prescribed by the Code. Min

The point 3 in figure corresponds to the condition $x = D$, i.e., $e = e$. For $e < e$, the Entire section is under compression and the neutral axis is located outside the section ($x > D$), with $0.002 < \epsilon < 0.0035$. For $e > e$, the NA is located within the section $u < D$ ($x < D$) and $\epsilon = 0.0035$ at the 'highly compressed edge'. u cu

Procedure for using of Non-dimensional Interaction Diagrams as Design Aids to find steel

Given:

Size of column, Grade of concrete, Grade of steel (otherwise assume suitably)

Factored load and Factored moment

Assume arrangement of reinforcement: On two sides or on four sides

Assume moment due to minimum eccentricity to be less than the actual moment

Assume suitable axis of bending based on the given moment (xx or yy)

Assuming suitable diameter of longitudinal bars and suitable nominal cover

Find d^1/D from effective cover d^1

Find non dimensional parameters $P_u/f_{ck}bD$ and $M_u/f_{ck}bD^2$

Referring to appropriate chart from S-16, find p/f_{ck} and hence the percentage of reinforcement, p

Find steel from, $A_s = p bD/100$

Provide proper number and arrangement for steel

Design suitable transverse steel

Provide neat sketch

Structural Design & Drawing (RCC-1) (CE601)

Members Subjected to Combined Axial Load and Biaxial Bending

The resistance of a member subjected to axial force and biaxial bending shall be obtained on the basis of assumptions given in IS: 456 with neutral axis so chosen as to satisfy the equilibrium of load and moments about two axes. Alternatively such members may be designed by the following equation:

$$\left[\frac{M_{ux}}{M_{ux1}} \right] \alpha_n + \left[\frac{M_{uy}}{M_{uy1}} \right] \alpha_n \leq 1, \text{ where}$$

M_{ux} and M_y = moments about x and y axes due to design loads,

M_{ux1} and M_{y1} = maximum uni-axial moment capacity for an axial load of P_u bending about x and y axes respectively, and α_n is related to P_u / P_{uz} , where $P_{uz} = 0.45 f_{ck} .A_c + 0.75 f_y A_{sc}$

For values of $P_u / P_{uz} = 0.2$ to 0.8 , the values of α_n vary linearly from 1.0 to 2.0 . For values less than 0.2 and greater than 0.8 , it is taken as 1 and 2 respectively

NOTE -The design of member subject to combined axial load and uniaxial bending will involve lengthy calculation by trial and error. In order to overcome these difficulties interaction diagrams may be used. These have been prepared and published by BIS in SP:16 titled Design aids for reinforced concrete Corresponding minimum eccentricities as per IS: 456-2000

Assume a trial section for the column (square, rectangle or circular).

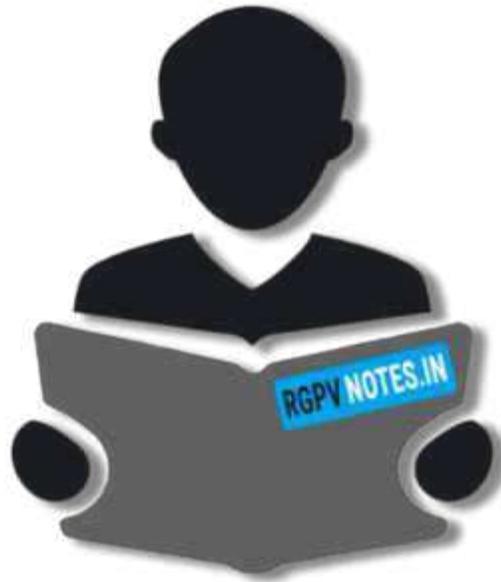
Determine M_x and M_y , corresponding to the given P (using appropriate curve from $M_x - P$ and $M_y - P$ SP-16 design aids)

Ensure that M_x and M_y are significantly greater than M_{ux} and M_{y1} respectively; $M_x > M_{ux}$ and $M_y > M_{y1}$. Otherwise, suitably redesign the section.

Determine P_n and hence α_n

Check the adequacy of the section using interaction equation. If necessary, redesign the section and check again.

Slender Compression Members: The design of slender compression members shall be based on the forces and the moments determined from an analysis of the structure, including the effect of deflections on moments and forces. When the effects of deflections are not taken into account in the analysis, additional moment given in 39.7.1 shall be taken into account in the appropriate direction.



RGPVNOTES.IN

We hope you find these notes useful.

You can get previous year question papers at
<https://qp.rgpvnotes.in> .

If you have any queries or you want to submit your
study notes please write us at
rgpvnotes.in@gmail.com



LIKE & FOLLOW US ON FACEBOOK
facebook.com/rgpvnotes.in