Design of Columns

Design of columns means the designing of the dimensions of the various columns. Dimension includes fixing the shape and finding the length and width of the cross-section. Designing also means finding the reinforcing bars' diameters in the reinforced column's design. An essential factor to design columns is the Euler's theory of columns.

The design of columns depends on the columns' slenderness ratio and the load types on the columns. The column base is also designed considering these factors. Columns are mainly designed for compressive loads but can act in the pure axial direction or with the eccentric loading direction to the columns. Reinforced columns can be designed with working stress or limit state methods.

Different Materials for Designing Columns

A column is a structural member designed to transfer a load of superstructure to the below footings. It mainly takes compressive loads over it, whether it acts in the pure axial direction or has eccentricity to the axis of the column. Materials for the construction of the columns depend on the design load and other structural requirements.

Columns can be constructed with steel structures, timbers, concrete materials, etc. The selection of these materials is mainly based on their strength characteristics. For example, steel columns are preferred for high-strength and lightweight structures and timber columns are generally preferred for temporary structures.

Different Parameters of Design of Reinforced Column

Designing a reinforced column depends on the slenderness ratio, effective length, shape amount of external loads, eccentricity of loads, etc. These parameters are selected in such a way that it meets the suitable strength of the column and struts for which it is designed. Here a few parameters are discussed below.

Slenderness ratio (λ)

The slenderness ratio of the column is defined as the ratio of the effective length of the column to its least lateral dimension of the column. It depends on the type of column. The letter λ represents it.

For the short column, the value of $\lambda < 3$ and for the long column $\lambda > 12$.

The effective length of a column

The effective length of the column is the length that will be effective for the load resistance. The effective length of Compression Members can be represented below.

Degree of End Restraint of compression members	Symbol	Theoretical value of Effective Length	Recommended value of Effective Length
(i)	(ii)	(iii)	(iv)
Effectively held in position and restrained against rotation in both ends		0.50 *l*	0.65 *l*
Effectively held in position at both ends, restrained against rotation at one end		0.70 *l*	0.80 *l*
Effectively held in position at both ends, but not restrained against rotation		1.00 *l*	1.00 *l*

Degree of End Restraint of compression members	Symbol	Theoretical value of Effective Length	Recommended value of Effective Length
(i)	(ii)	(iii)	(iv)
Effectively held in position and restrained against rotation at one end, and at the other restrained against rotation but not held in position		1.00 *l*	1.20 *l*
Effective held in position and restrained against rotation in one end, and at the other partially restrained against rotation but not held in position		—	1.50 *l*

Degree of End Restraint of compression members	Symbol	Theoretical value of Effective Length	Recommended value of Effective Length
(i)	(ii)	(iii)	(iv)
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		2.00 *l*	2.00 *l*
Effectively held in position and restrained against rotation at one end but not held in position nor restrained against rotation at the other end.		2.00 *l*	2.00 *l*

Design of Column by Working Stress Method

Concrete columns are designed based on the working stress method or the principle of limit state methods. Earlier, the columns were designed based on the working stress method, but this method assumes that lesser amount of stress value at failure; hence it gives an uneconomical design. Here are a few points of column designing by working stress method explained.

Load carrying capacity for short column

$P = \sigma_{sc}A_{sc} + \sigma_{cc}A_{cc}$

Where

- A_C = Area of concrete, $A_C = A_g - A_{sc}$
- σ_{SC} ⇒ Stress in compression steel
- σ_{CC} ⇒ Stress in concrete
- A_g ⇒ Total gross cross-sectional area
- A_{SC} ⇒ Area of compression steel

Load carrying capacity for long column

$P = C_r(\sigma_{sc}A_{sc} + \sigma_{cc}A_{cc})$

where,

- C_r = Reduction factor
- $C_r = 1.25 - (l_{eff}/48B)$
- l_{eff} = Effective length of the column
- B = Least lateral dimension

A column with helical reinforcement

In the case of helical reinforcement, the column strength is increased by 5%

$P = 1.05(\sigma_{sc}A_{sc} + \sigma_{cc}A_{cc})$ for short column

$P = 1.05\ C_r(\sigma_{sc}A_{sc} + \sigma_{cc}A_{cc})$ for long column

Longitudinal reinforcement

(a) **Minimum area of steel** = 0.8% of the gross area of the column

(b) **Maximum area of steel**

(i) When bars are not lapped A_{max} = 6% of the gross area of the column

(ii) When bars are lapped A_{max} = 4% of the gross area of the column

Minimum number of bars for reinforcement

For rectangular column 4

For circular column 6

Minimum diameter of bar ⇒ 12 mm

Maximum distance between longitudinal bar ⇒ 300 mm

Pedestal

It is a short length whose effective length is not more than 3 times of least lateral dimension.

Transverse reinforcement (Ties)

$\varphi = \max\{\frac{1}{4}\varphi_{min} \text{ and } 6 \text{ mm}\}$

where Φ_{min} = Minimum dia of the main longitudinal bar

φ = dia of the bar for transverse reinforcement

Pitch (p)

$\varphi = \min\{\text{Least lateral dimension, } 16\,\varphi_{min} \text{ and } 300 \text{ mm}\}$

where φ_{min} = minimum dia of the main longitudinal bar

Helical reinforcement

(i) Diameters of helical reinforcement are selected such that

$$0.36\left[\frac{A_g}{A_C}-1\right]\frac{f_{ck}}{f_y} \le \frac{V_h}{V_C}$$

(ii) Pitch of helical reinforcement (p)

(a) $p \le 75$ mm

(b) $p \le (1/6)^{th}\, d_c$

(c) $p \ge 3\,\varphi_h$

(d) $p \ge 25$ mm

where,

- d_c = Core diameter = $d_g - 2 \times$ clear cover to helical reinforcement
- A_G = Gross area = $\Pi(d_g)^2/4$
- d_g = Gross diameter

- V_h = Volume of helical reinforcement in a unit length of the column
- φ_h = Diameter of steel bar forming the helix
- d_h = centre to centre dia of the helix ⇒ d_g – 2 clear cover - φ_h
- φ_h = diameter of the steel bar forming the helix

Some other IS recommendations

(a) Slenderness limit

(i) Unsupported length between end restrains < 60 times least lateral dimension.

(ii) If in any given plane, one end of the column is unrestrained, then its unsupported length <100 B^2/D

(b) All columns should be designed for a minimum eccentricity of

$$e_{\min} = \text{maximum}\begin{cases} \dfrac{l}{500} + \dfrac{'B'or'D'}{30} \\ 20\ mm \end{cases}$$

Design of Column by Limit State Method

The design of columns by limit state method is carried out based on the IS 456. This design uses the material's ultimate strength at its failure point; hence, it gives an economical design to the structure. The ultimate load on columns is calculated based on the following expression.

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

For the column having helical reinforcement, the strength of the column is increased by 5%. Hence it will be ⇒ $P_u = 1.05(0.4f_{ck}A_c + 0.67f_yA_{sc})$

IS 456 Recommendations

(a) Slenderness limit

(i) Unsupported length between end restrains <60 times least lateral dimension.

(ii) If in any given plane, one end of the column is unrestrained, then its unsupported length <100 B^2/D

(b) All columns should be designed for a minimum eccentricity of

$$e_{min} = \text{maximum} \begin{cases} \dfrac{1}{500} + \dfrac{B}{30} \\ 20\text{ mm} \end{cases}$$

Concentrically Loaded Columns

Where e = 0, i.e., the column is truly axially loaded.

$P_u = 0.45 f_{ck} A_c + 0.75 f_y A_{sc}$

This formula is used for members subjected to combined axial load and bi-axial bending when e > 0.05 D.