8. COLUMNS

WORKING STRESS METHOD

- Slenderness ratio (λ)

$$\lambda = \frac{\text{effective length}}{\text{least lateral dimension}}$$

if $\lambda > 12$ then the column is long.

- Load carrying capacity for short column

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

where, A_c = Area of concrete, $A_c = A - A_{sc}$

σ_{sc} = Stress in compression steel

σ_{cc} = Stress in concrete

A = Total area

A_{sc} = Area of compression steel

- Load carrying capacity for long column

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

where, C_r = Reduction factor

$$C_r = 1.25 - \frac{l_{eff}}{48B}$$

or

$$C_r = 1.25 - \frac{l_{eff}}{160\, i_{min}}$$

where, l_{eff} = Effective length of column

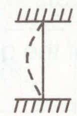
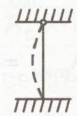
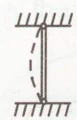
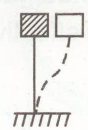
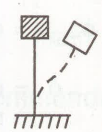
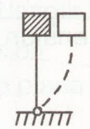
B = Least lateral dimension

i_{min} = Least radius of gyration and $i_{min} = \sqrt{\frac{I}{A}}$

where I = Moment of inertia and A = Cross-sectional area

- Effective length of column

Table. Effective Length of Compression Members

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
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
Effectively held in position and restrained against rotation in one end, and at the other partially restrained against rotation but not held in position		—	1.50 l
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

- **Column with helical reinforcement**

  Strength of the column is increased by 5%

  $$P = 1.05(\sigma_{sc} A_{sc} + \sigma_{cc} A_c) \rightarrow \text{For short column}$$

  $$P = 1.05 C_r(\sigma_{sc} A_{sc} + \sigma_{cc} A_c) \rightarrow \text{For long column}$$

> Helical reinforcement is provided only for circular columns.

- **Longitudinal reinforcement**
  - (a) Minimum area of steel = 0.8% of the gross area of column
  - (b) Maximum area of steel
    - (i) when bars are not lapped A_{max} = 6% of the gross area of column
    - (ii) when bars are lapped A_{max} = 4% of the gross area of 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)**

  $$\phi = \text{maximum}\begin{cases}\frac{1}{4}\cdot\phi_{main}\\ 6\text{ mm}\end{cases}$$

  where, ϕ_{main} = dia of mainbar

  ϕ = dia of bar for transverse reinforcement
- **Pitch (p)**

  $$\phi = \text{minimum}\begin{cases}\text{least lateral dimension}\\ 16\,\phi_{min}\\ 300\text{ mm}\end{cases}$$

  where, ϕ_{min} = minimum dia of bar
- **Helical reinforcement**
  - (i) Diameters of helical reinforcement is 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) $p \ngtr 75$ mm (b) $p \ngtr \frac{1}{6} d_c$ (c) $p \nless 3\,\phi_h$ (d) $p \nless 25$ mm

where, d_c = Core diameter = $d_g - 2 \times$ clear cover to helical reinforcement

A_G = Gross area = $\frac{\pi}{4}(d_g)^2$

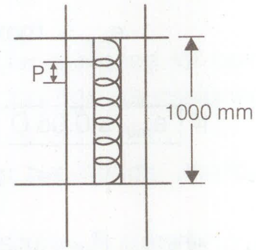
d_g = Gross diameter

V_h = Volume of helical reinforcement in unit length of column

ϕ_h = Diameter of steel bar forming the helix

$$V_h = \left(\frac{1000}{p}\right)(\pi d_h)\frac{\pi}{4}(\phi_h)^2$$

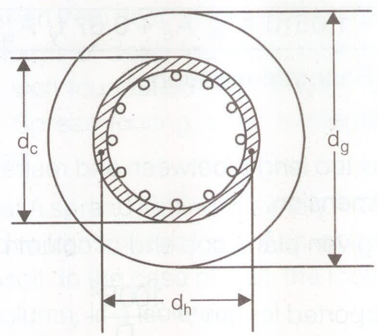
$$A_c = \frac{\pi}{4}(d_c)^2 \qquad V_c = A_c \times 1$$



d_h = centre to centre dia of helix

$= d_g - 2\text{ clear cover} - \phi_h$

ϕ_h = diameter of the steel bar forming the helix



- **Some others I.S recommendations**
  - (a) Slenderness limit
    - (i) Unsupported length between end restrains $\ngtr$ 60 times least lateral dimension.
    - (ii) If in any given plane one end of column is unrestrained than its unsupported length $\ngtr \frac{100B^2}{D}$.
  - (b) All column should be designed for a minimum eccentricity of

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

LIMIT STATE METHOD

1. Slenderness ratio (λ)

if $$\lambda = \frac{\text{effective length}}{\text{least lateral dimension}}$$

$$\lambda < 12 \rightarrow \text{Short column}$$

2. Eccentricity

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

If $e_{min} \leq 0.05\,D$ then it is a short axially loaded column.

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

where, P_u = axial load on the column

3. **Short axially loaded column with helical reinforcement**

$$P_u = 1.05(0.4\,f_{ck}\,A_c + 0.67\,f_y\,A_{sc})$$

4. **Some others I.S Recommendations**

   (a) Slenderness limit

   (i) Unsupported length between end restrains $\not>$ 60 times least lateral dimension.

   (ii) If in any given plane one end of column is unrestrained than its unsupported length $\not> \frac{100B^2}{D}$,

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

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

- **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 also used for member subjected to combined axial load and bi-axial bending and also used when $e > 0.05D$.