UNIT 14 AXIALLY LOADED COLUMNS

Structure

14.1 INTRODUCTION

A column supports the loads of super-structure and transfers them to a column or to the foundation below it. It is basically a compression member since loads are acting along its longitudinal axis. There may be bending moments due to wind, earthquake or accidental loads. Bending of a column is also due to monolithic construction and eccentricity of loads from super-structure. Being a compression member, its analysis and design becomes primarily a function of length to lateral dimension ratio (slenderness ratio). When length of a compression member is too short (*a pedestal*), its design and detailing differ from that of a column.

Therefore, *a column may be defined as a compression member for which the length to least dimension ratio is not less than three.*

In this unit, discussion shall be limited to types of column based on slenderness ratio and on eccentricity of loads. The detailing of *all* types of column and design of *axially loaded columns* will also be discussed and illustrated.

Objectives

After going through this unit, you should be able to know about the following:

- Types of column based on slenderness ratio,
- Types of column based on eccentricity of loads,
- Reinforcing and other detailing of a column, and
- Design of axially loaded columns.

14.2 TYPES OF COLUMN BASED ON SLENDERNESS RATIO

14.2.1 Types of Column

Strength of a column or of a compression member is the function of slenderness ratio, (SR) = *$\left(\frac{l_{ef}}{i_{min}}\right)$. The greater the value of SR, the lesser is the strength. To be more clear, the I.S. Code provides that permissible stresses in concrete (σ_{cbc}, σ_{cc} and τ_{bd}) and those for steel (σ_{st},σ_{sv} and σ_{sc}) shall be modified by multiplying coefficient (C_r) given by the following formula

$$C_r = 1.25 - \frac{l_{ef}}{160\, i_{min}} \qquad ...(14.1)$$

From the above equation, it is clear that if

$$SR = \left(\frac{l_{ef}}{i_{min}}\right) = 40\ ;\ C_r = 1$$

Based on above specifications, for strength evaluation, columns are classifed as of two types:

i) a *short column* for which $\frac{l_{ef}}{i_{min}} \leq 40$ i.e. $C_r = 1$, and

ii) a *long column* for which $\frac{l_{ef}}{i_{min}} > 40$ i.e. $C_r < 1$

Normally to simplify the evaluation of C_r, it is taken as follows :

$$C_r = 1.25 - \frac{l_{ef}}{48b} \qquad (14.2)$$

where b = least lateral dimension of column

In this case if $\frac{l_{ef}}{b} \leq 12$; $C_r = 1$

Therefore, a column, having $\frac{l_{ef}}{b} \leq 12$ i.e. $C_r = 1$, will be defined as a *short column* whereas a column having

$\frac{l_{ef}}{b} > 12$ i.e. $C_r < 1$ will be categorized as a *long column*.

14.2.2 Evaluation of Effective Length (l_{ef})

Unsupported length when multiplied by the ratio of effective length to unsupported length $\left(\frac{l_{ef}}{l}\right)$ gives effective length of a column. The unsupported length of a column depends on the type of construction and on end conditions if laterally supported by beams struts (Table 14.1).

* l_{ef} = Effective length of column

r_{min} = Minimum radius of gyration

Table 14.1: Unsupported Length, *l*, of a column

Type of Construction	Unsupported Length (*l*)
i) Flat Slab Construction	The least of clear distance between floor and lower extremity of the capital, drop panel or slab
ii) Beam & Slab Construction	Clear distance between the floor and underside of the shallower beam framing into the columns in each direction at the next higher floor level
iii) Columns restrained laterally by struts provided to be adeqate supports; two such struts shall meet the column approximately at the same level and the angle between vertical planes through the struts shall not vary more than 30^0 from a right angle	Clear distance between consecutive struts in each vertical plane
iv) Column restrained laterally by struts or beams with brackets used at the juction, provided the bracket width equals that of beam strut and is at least half that of column	Clear distance between the floor and the lower edge of the bracket

For *framed construction* the ratio, $\frac{l_{ef}}{l}$, for a column for different end conditions is obtained from Figures 14.1 & 14.2.

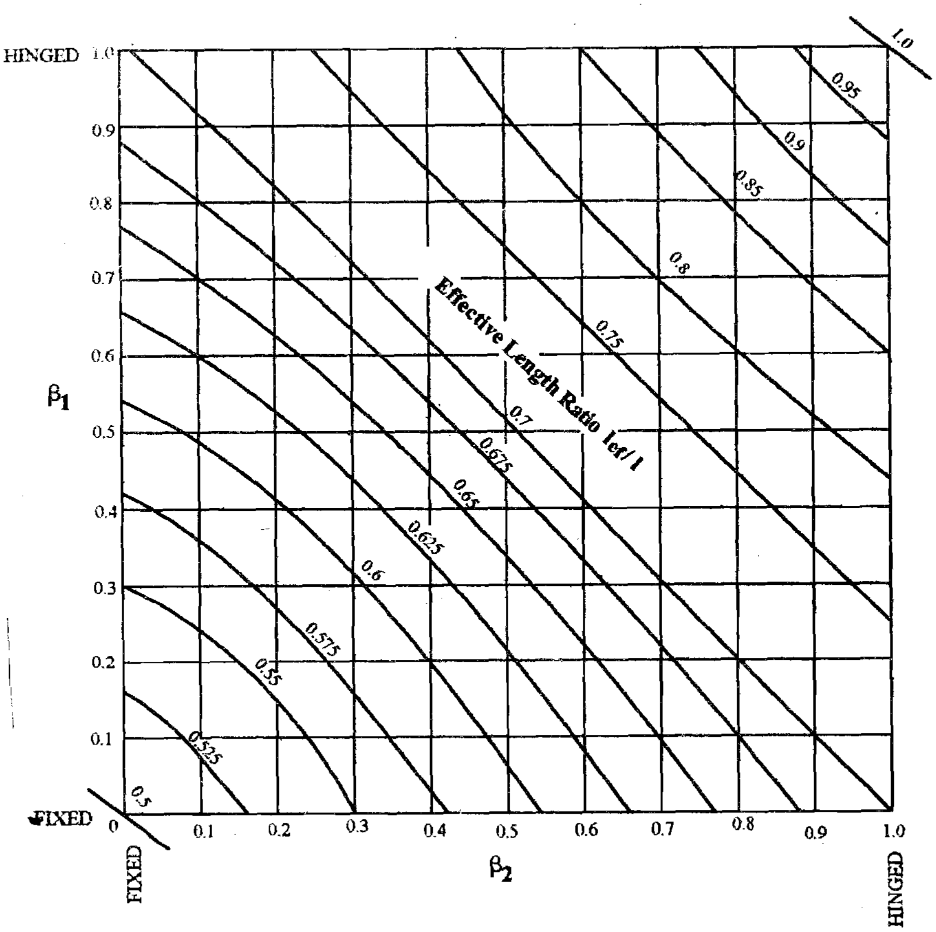


Figure 14.1: Effective Length Ratio (l_{ef}/l) for a Column in a Frame with no Sway

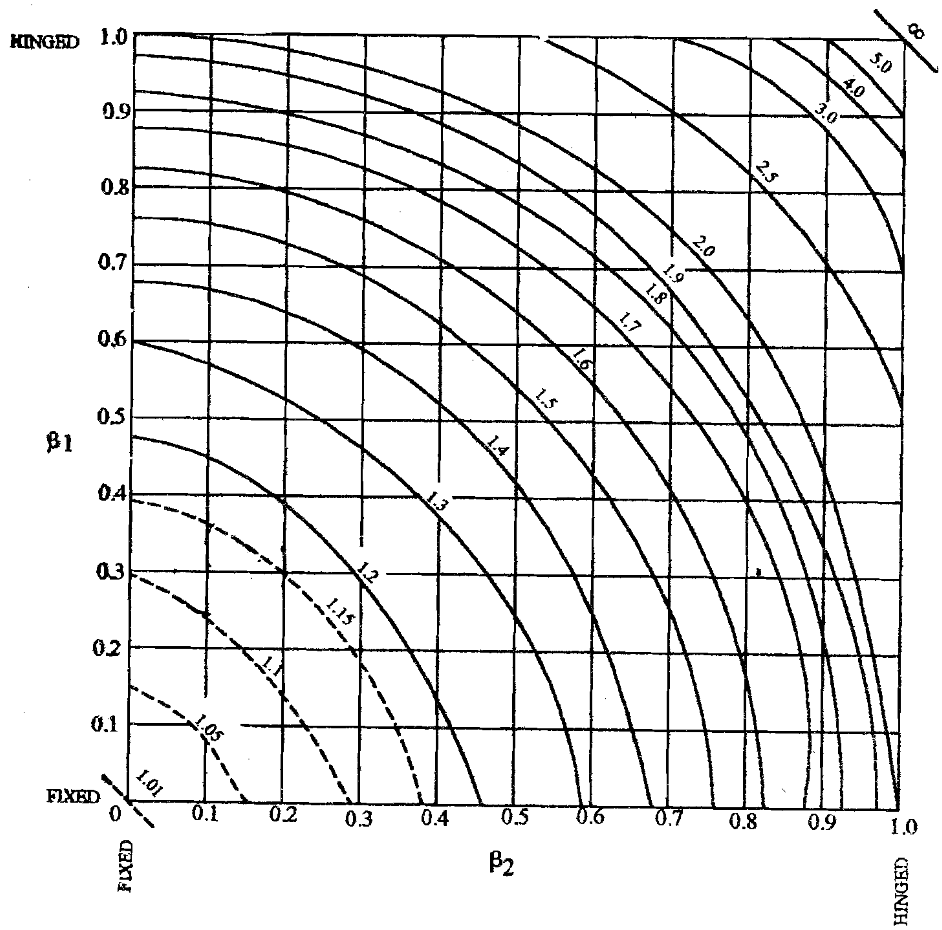


Figure 14.2: *Effective Length Ratio (l_{ef}/l) for a Column in a Frame without Restraint against Sway

In these Figures (14.1 & 14.2)

$$\beta_1 \,\&\, \beta_2 = \frac{\sum K_c}{\sum K_c + \sum K_b} \qquad \text{...(14.3)}$$

where,

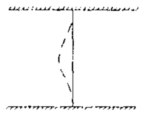
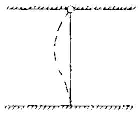
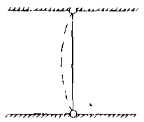
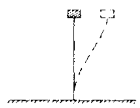
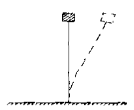
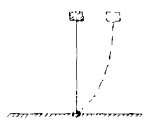
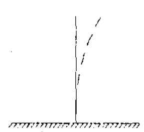
ΣK_c = summation of flexural stiffness of columns meeting at one of the ends of a column under consideration

ΣK_b = summation of flexural stiffness of all beams meeting at the above mentioned end of that column.

For *normal usage,* the effective length, l_{ef}, for different end conditions may also be assessed as given in Table 14.2.

* In this case it is recommended that the effective length ratio l_{ef}/l may not be taken to be less than 1.2.

Table 14.2: Effective Length of Compression Members

Degree of End Restraint of Compression Member	Symbol	Theoretical Value of Effective Length	Recommended Value of Effective Length
Effectively held in position and restrained against rotation at both ends		0.5 l	0.65 l
Effectively held in position at both ends, restrained against rotation at one end		0.7 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 at 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 at the other end		2.00 l	2.00 l

Note 1: The unsupported length (l) between end restraints shall not exceed 60 times the least lateral dimension of a column.

Note 2: In any given plane, if one end of a column is unrestrained, its unsupported length shall not exceed $\frac{100b^2}{D}$.

SAQ 1

i) Define a column.

ii) How unsupported length (l) and effective length (l_{ef}) of a column are defined and evaluated.

14.3 TYPES OF COLUMN BASED ON ECCENTRICITY OF LOADS

Rarely a column may be considered loaded with a concentric load. Even a column positioned at the centroidal axis of the super-structure, the gravity loads transferred to the column may be eccentric due to positioning of imposed loads, inaccuracies in construction, lateral loads, etc. Therefore, there cannot be any column designed as an axially loaded column (i.e. without eccentricity of loads or bending moments). To simplify the analysis, design and detailing procedures a column may be put into two categories based on the magnitude of eccentricity of loads due to bending moments, lateral loads or position of live loads on the super-structure as follows :

i) **Axially Loaded Columns :** A column is designed as an axially loaded column with the minimum eccentricity about any of its principal axis,

$$e_{min} \text{ which is greater of (i) } \left(\frac{l}{500}+\frac{b \text{ or } D}{300}\right) \text{ or (ii) 20 mm whichever is more} \quad ...(14.4)$$

This small eccentricity, though taken, will not cause tensile stress neither it will increase the maximum compressive stress to an extent necessitating its cognizance.

ii) **Eccentrically Loaded Columns :** A column having eccentricity greater than e_{min} (vide Eqn. 14.4) is designed as a column for combined axial load and bending (vide Unit 15).

14.4 REINFORCEMENT AND OTHER DETAILINGS

Direct load as well as bending moment in a column are resisted by concrete and steel together. While concrete resists compressive stress and the longitudinal reinforcement provided along the whole periphery are effective both in tension as well as in *compression. Transverse reinforcement in the form of lateral ties or helical reinforcement are provided to prevent the longitudinal reinforcement from buckling, to resist shear force due to bending and to confine the concrete for better ductile behaviour.

Protective cover to longitudinal as well as transverse reinforcement, development length at ends of longitudinal bars and splicing of longitudinal bars are appropriately provided.

14.4.1 Longitudinal Reinforcement

i) The minimum and the maximum reinforcement to be provided are 0.8% and 6% of the *gross* concrete cross-sectional area respectively.

However, the maximum reinforcement is normally limited to 4% if there is difficulty in placing concrete due to small concrete cross-sectional area, lapping of reinforcement etc.

ii) The evaluation of minimum longitudinal reinforcement shall be based upon the area of concrete *required* to resist the direct stress rather than the actural area provided.

iii) Minimum number of longitudinal bars shall be four for a rectangular column and 6 for a circular or for higher polygonal shapes.

iv) Minimum diameter of longitudinal bars shall not be less than 12 mm.

v) Spacing of longitudinal bars measured along periphery shall not exceed 300 mm.

* Provision of longitudinal reinforcement in compression reduces the creep in concrete as well as safeguards the column against reversal of bending moments.

14.4.2 Transverse Reinforcement

a) **Detailing of Lateral Ties**

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

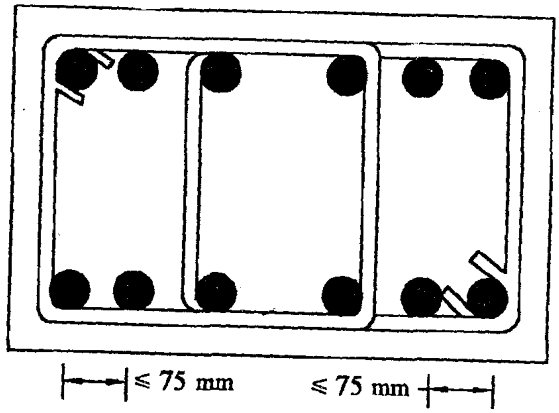


Figure 14.3: Transverse Reinforcement as per Section 14.4.3a(i)

ii) If the longitudinal bars spaced at a distance of not exceeding *48 ϕ_{tr} are effectively tied in two directions, additional longitudinal bars in between these bars need be tied in one direction by open ties (Figure 14.4).

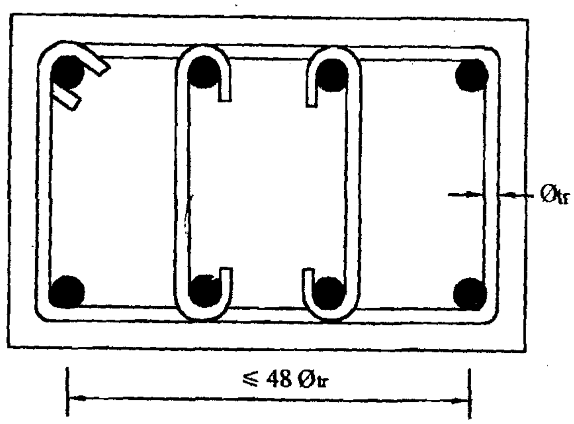


Figure 14.4: Transverse Reinforcement as per Section 14.4.3 a(ii)

iii) The *maximum pitch* of transverse reinforcement shall be the *least of* the following distances :

1) The least lateral dimension of the column,

2) 16 times the smallest diameter of the longitudinal bars, and

3) 48 times the diameter of the transverse reinforcement.

iv) Diameter of transverse reinforcement (ϕ_{tr}) shall not be less than 1/4th the largest diameter of the longitudinal bar nor less than 5 mm.

b) Helical reinforcement may be provided in place of lateral ties. All the required detailings shall be as for lateral ties except that such reinforcement shall be at regular formation with extra one and half turns of spiral bars at ends of the column.

If such reinforcement is provided to increase the strength of column as well (vide Section 14.5) the maximum pitch of helical turns shall not be more than 75 mm, not more than one-sixth of the core diameter of the column, nor less than 25 mm, nor less than *three* times the diameter of helical bar.

14.4.3 Cover, Development Length and Splicing

a) Cover

i) For longitudinal reinforcing bars in a column, the clear cover shall not be normally

* ϕ_{tr} = diameter of transverse reinforcement

less than 40 mm nor less than diameter of such bar. Columns having least lateral dimension 200 mm or under and longitudinal bar of less than 12 mm diameter may have a clear cover of 25 mm.

ii) For transverse reinforcement the clear cover shall not be less than 15 mm.

b) Development Length (L_d)

Following specifications are applicable for development length for bars in compression :

i) The values of permissible bond stress (τ_{bd}) given in Table 8.2 in previous unit are increased by 25% for bars in compression.

ii) The anchorage length of straight bar in compression shall be equal to the development length of the bar in compression. The projected length of hook, bends and straight lengths beyond bends if provided for a bar in compression shall be considered for development length (Figure 5.8).

iii) Anchorage for lateral ties shall be deemed to have been provided when bar is bent through angle of 90^0 round bar of at least its own diameter and is continued beyond the end of the curve for a length of at least eight diameter, or when bent through an angle of 135^0 and is continued beyond the end of curve for a length of at least six times the bar diameter or when the bar is bent through an anle of 180^0 and is continued beyond the end of the curve for a length of at least four bar diameter.

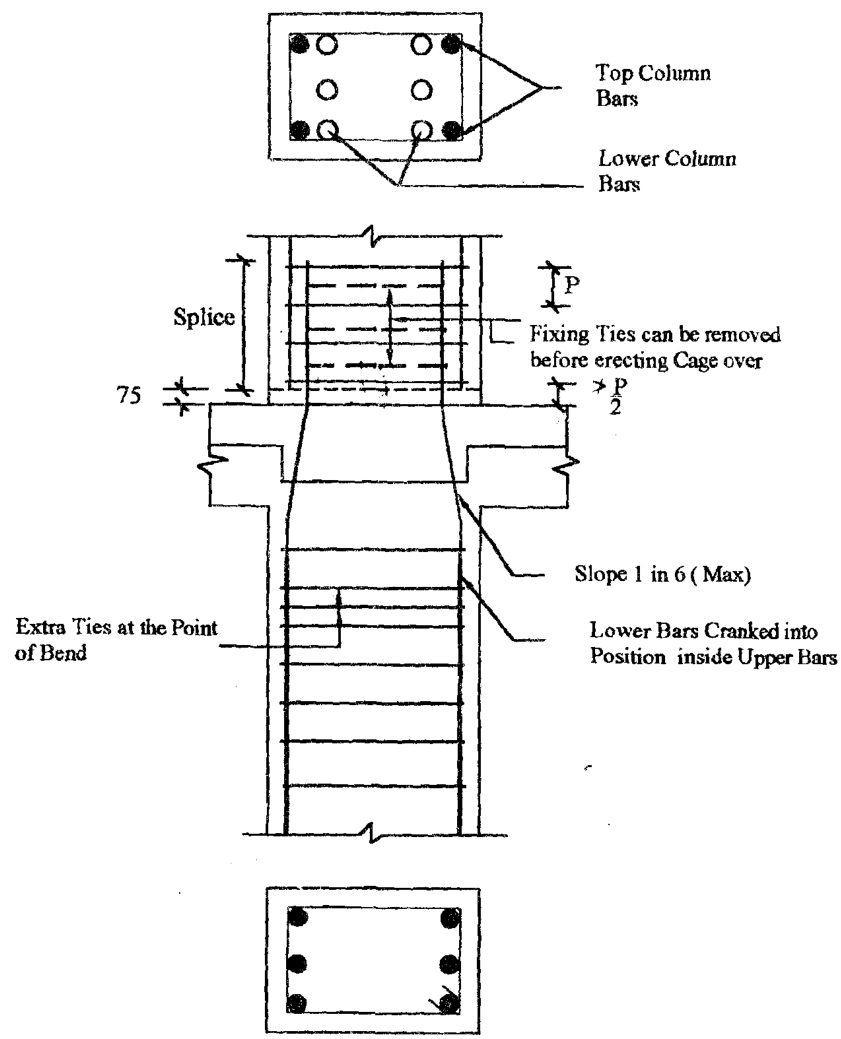


Figure 14.5: Splice with Lower Bars Cranked into Position inside Upper Bars (Intermediate Floor)

c) Splicing

Splicing shall be guided by the following specifications :

i) Lap length shall be equal to the development length in compression but not less than 24ϕ. When bars of two different diameters are to be spliced, the lap length shall be calculated on the basis of diameter of smaller bar.

ii) In columns where longitudinal bars are offset at a splice, the slope of the inclined portion of the bar shall not exceed 1 in 6 and the portion of the bar above and below the offset shall be parallel to the axis of the column. Additional lateral ties shall be provided at the bend to resist $1\frac{1}{2}$ times the horizontal component of normal stress in the inclined portion of the bar placed not more than 8ϕ length from the point of bend (Figure 14.5). For practical purpose, 3 closely spaced ties are usally used, one of which may be part of the regularly spaced tie plus two extra ties.

iii) For offset between column faces more than 75 mm, the longitudinal bars in the column below should be terminated at floor slab and separate dowels are use (Figure 14.6).

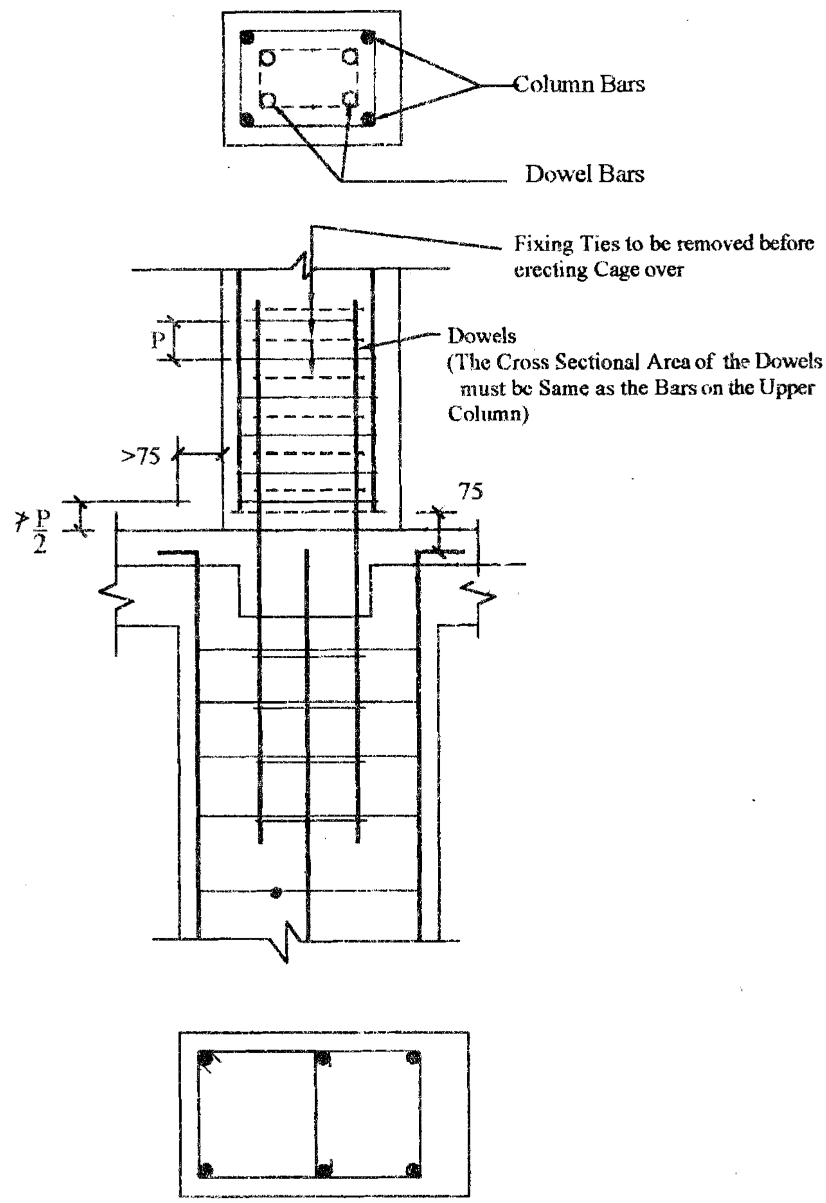


Figure 14.6: Splicing at the Floor Level when the Relative Displacement of Column Faces is more than 75 mm

SAQ 2

i) Why longitudinal reinforcements are provided preferably on all the faces of a column?

ii) Why lateral reinforcement is essential in a column?

iii) What extra detailing is taken care of if an increased load on column on the strength of helical reinforcement is allowed?

iv) Sketch splicing for a column.

14.5 DESIGN OF AXIALLY LOADED COLUMNS

14.5.1 Permissible Loads

a) An axially loaded column may be a short or a long (slender) column depending upon its slenderness ratio (SR) as explained in section 14.2. The permissible load on a short column *with lateral ties* is given by the following equation :

$$P = \sigma_{cc} A_c + \sigma_{sc} A_{sc} \qquad \text{... (14.5)}$$

where, σ_{cc} = permissible stress in direct compression

A_c = cross-sectional area of concrete excluding reinforcing steel and any finishing material.

σ_{sc} = permissible compressive stress for longitudinal reinforcement

A_{sc} = cross-sectioanl area of longitudinal reinforcement

b) The permissible load for a short column *with helical reinforcement* shall be *1.05 times the permissible load* given by Equation 14.5 provided

i) $$\frac{\text{Volume helical reinforcement}}{\text{Volume of core of column}} < 0.36\left(\frac{A_g}{A_c} - 1\right)\frac{f_{ck}}{f_y}$$

where, A_g = gross area of the section

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

f_y = characteristic strength of the helical reinforcement but not exceeding 415 N/mm^2

ii) The conditions for pitch of helical spiral given in Section 14.4.3b are complied with.

14.5.2 Construction and Use of Interactive Curves for Axially Loaded Short Columns

Equation 14.5, $P = \sigma_{cc} A_c + \sigma_{sc} A_{sc}$, may be written as

$$P = \sigma_{cc}\left(A_g - \frac{p_t A_g}{100}\right) + \sigma_{sc}\frac{p_t A_g}{100}$$

or $$P = A_g\left\{\sigma_{cc}\left(1 - \frac{p_t}{100}\right) + \sigma_{sc}\frac{p_t}{100}\right\} \qquad \text{...(14.6)}$$

or $$\frac{P}{A_g} = \sigma_{cc} + \frac{p_t}{100}(\sigma_{sc} - \sigma_{cc}) \qquad \text{...(14.7)}$$

where, A_g = gross cross-sectional area of column, and

p_t = %age of longitudinal reinforcement w.r.t. A_g i.e. $p_t = \frac{100 A_{sc}}{A_g}$

For *known* grade of steel, Figure 14.7(a) ($\frac{p_t}{A_g} \sim P$ curves) for different gross cross-sectional area (A_g) and Figure 14.7(b) ($\frac{P}{A_g} \sim P_t$ curves) for different grades of concrete and for a *particular grade of steel have been plotted according to Equations 14.6 and 14.7 respectively.

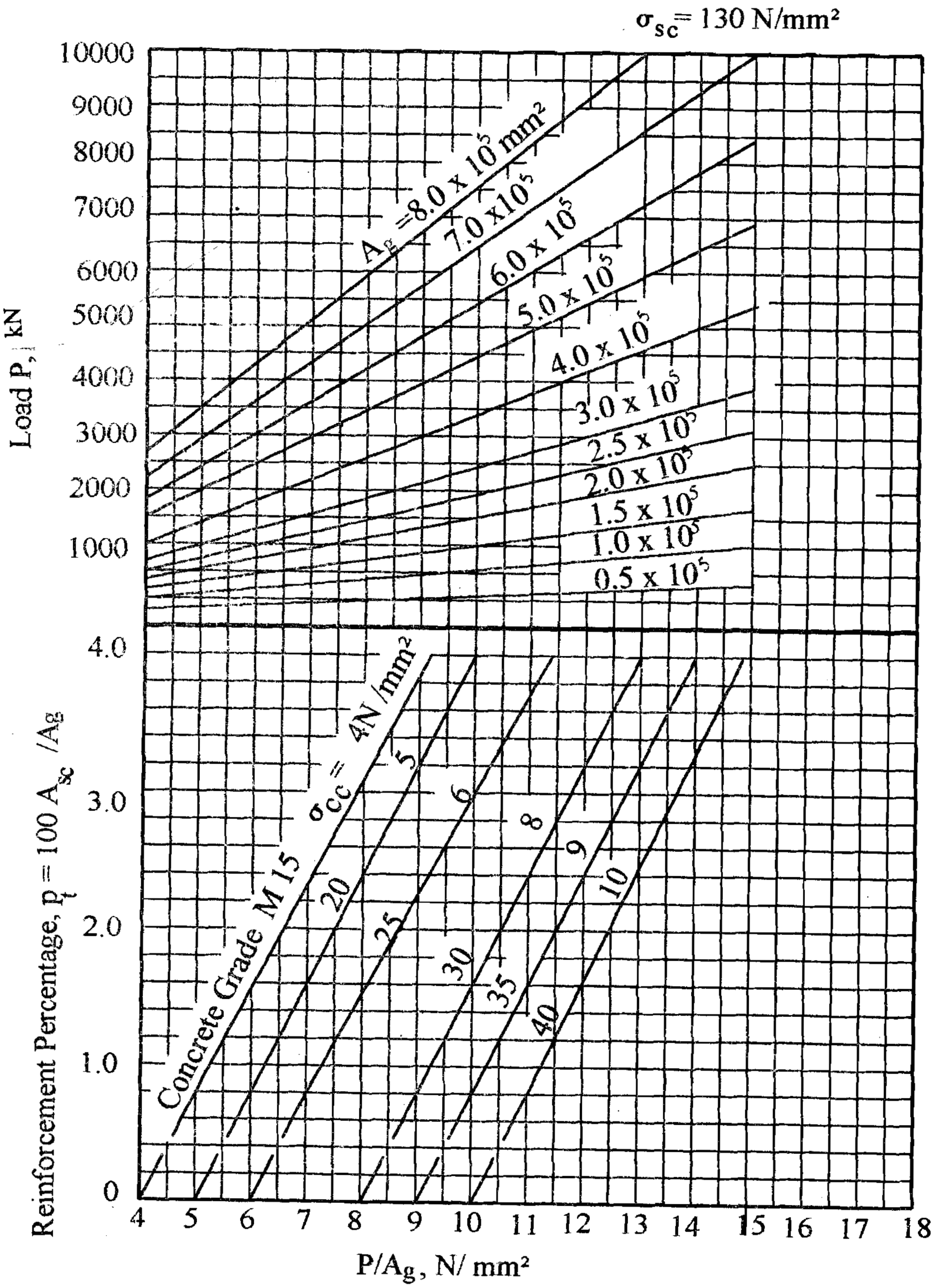


Figure 14.7: Interactive Curves for Axially Loaded Short Columns for σ_{sc} = 130 N/mm²

* Here Figure 14.7 has been drawn for σ_{sc} = 130 N/mm²

To design a column for design load P and known strength of concrete and steel, gross cross-sectional area of concrete is assumed. A horizonal line is drawn from design load P to cut the curve for A_g on Figure 14.7(a). From that point a vertical line is dropped to cut the curve of known grade of concrete in Figure 14.7(b), and from there a horizontal line to meet at p_t-axis to determine A_{sc}.

Similarly, if, for a known cross-sectional area and strengths of steel and concrete the permissible load P is to be determined, then from known p_t point on p_t-axis in Figure 14.7(b), a horizontal line is drawn to cut the curve for known strength of concrete. From there a vertical line cut a curve for known A_g in Figure 14.7(a) and a horizontal line from there indicates the permissible load P on the column.

14.5.3 Types of Problem

There may be two types of problem :

i) To design a column for a given load and known strengths of concrete and steel, and

ii) To determine permissible load for known cross-sectional area and strengths of concrete and steel.

Both types of problem have been exemplified to illustrate analytical and graphical methods of solutions.

Example 14.1

Using Interactive Curves (Figure 14. 7) design a short column for an axial load of 1500 kN. Use M 20 concrete and Fe 250 steel. Check the design analytically.

Solution

Cross-sectional area

For an *assumed* gross rectangular cross-sectional area, $A_g = 2 \times 10^5$ mm² ($b \times D = 400 \times 500$); and the design load,

P = 1500 kN (Figure 14.7a), $\left(p_t = \dfrac{100 A_{sc}}{A_g} \right)$ = 2.2 for the given grade of concrete M 20 has been marked on Figure 14.7b.

$$\therefore \quad A_{sc} = \frac{p_t \times A_g}{100} = \frac{2.2 \times 2 \times 10^5}{100} = 440 \text{ mm}^2$$

Hence provided 10ϕ25 (A_{sc} = 4909 mm²) as longitudinal reinforcement

Lateral Ties

The diameter of lateral tie (ϕ_{tr}) shall not be less than

$\dfrac{\text{Diameter of long.bar}}{4} = \dfrac{25}{4} = 6.125$ or 5 mm and spacing of lateral ties shall not exceed

i) $16\,\phi = 16 \times 25 = 400$, and

ii) $48\,\phi_{tr} = 48 \times 8 = 384$

Hence provided lateral ties of ϕ8 @ 380 c/c

The details have been shown in Figure 14.8.

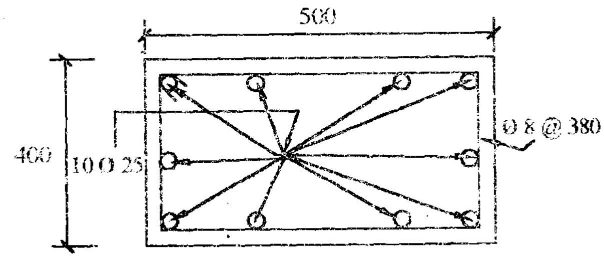


Figure 14.8: Cross-section of the Designed Column

Analytical Check

The permissible load P for a cross-sectional area $A_g = b \times D = 400 \times 500$, percentage of steel area $p_t = \frac{100 A_s}{A_g} = 2.2$, $\sigma_{cc} = 5$ N/mm² and $\sigma_{sc} = 130$ N/mm² may be evaluated as

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

$$= \sigma_{cc}\left(A_g - \frac{p_t \times A_g}{100}\right) + \sigma_{sc}\frac{p_t \times A_g}{100}$$

$$= 5\left(400 \times 500 - \frac{2.2 \times 400 \times 500}{100}\right) + \frac{130 \times 2.2 \times 400 \times 500}{100}$$

= 1550 kN ≈ 1500 kN Hence O.K.

Example 14.2

A column of unsupported length 4.5m and cross-sectional area 250 × 250 is reinforced with 4#16. Determine permissible load if

a) both ends are effectively held in position but not restrained against rotation.

b) one end is effectively held in position and restrained against rotation, but the other end is neither held in position nor restrained against rotation.

Use M 15 concrete and Fe 415 steel.

Solution

Permissible load *assuming* the column to be short one

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

$$= \sigma_{cc}(A_g - A_{sc}) + \sigma_{sc} A_{sc}$$

$$= 4\,(250 \times 250 - 4 \times \frac{\pi}{4} \times 16^2) + 130 \times 4 \times \frac{\pi}{4} \times 16^2$$

$$= 351.34 \text{ kN}$$

Slenderness Ratio

Unsupported length, $l = 4.5$ m

for the given end conditions

$l_{ef} = 1.0 \times l = 4.5$ m (vide Table 14 .2)

Slenderness Ratio, $SR = \frac{l_{ef}}{b} = \frac{4500}{250} = 18 > 12$

∴ i.e. the column is *slender* one.

∴ Reduction coefficient, $C_r = 1.25 - \frac{l_{ef}}{48b}$ (vide Eq. 14.2)

$$= 1.25 - \frac{4500}{48 \times 250}$$
$$= 0.875$$

∴ *Permissible Load*

$P = C_r P' = 0.875 \times 351.34 =$ **307.42 kN Ans**

Check from Interactive Curves (Figure 14.7)

For $\sigma_{sc} = 130\ N/mm^2$; $A_g = 250 \times 250 = 62500\ mm^2$;

$$A_{sc} = 4 \times \frac{\pi}{4} \times 16^2 \left(\text{i.e. } p_t = \frac{100 \times 4 \times \frac{\pi}{4} \times 16^2}{250 \times 250} = 1.29 \right)$$

$$\frac{P'}{A_g} = 5.6 \text{ or } P' = 5.6 \times 62500 = 350 \text{ kN}$$

∴ $P = C_r P' = 0.875 \times 350 =$ **306.25 kN ≈ 307.42 kN** Hence O.K.

b) As its one and is unsupported , $l < \frac{100b^2}{D}$ (vide Table 14.2 Note 2)

$$\frac{100b^2}{D} = \frac{100 \times 250^2}{250} = 25000 \text{ mm} = 25 \text{ m} > 4.5 \text{ m} \text{ Hence O.K.}$$

For the given end conditions

$l_{ef} = 2l = 2 \times 4.5 = 9\text{m} < 60b\ (= 60 \times 250 = 15\text{m})$. vide Table 14.2 Note 1

$$\therefore SR = \frac{l_{ef}}{b} = \frac{9000}{250} = 36 > 12$$

As one of its end is supported,

∴ Strength Reduction (*SR*) Factor

$$C_r = 1.25 - \frac{l_{ef}}{48b} = 1.25 - \frac{9000}{48 \times 250} = 0.5$$

Permissible load *as short columns*

$P' = 351.34$ as calculated in 9a)

∴ $P = C_r P' = 0.5 \times 351.34 =$ **175.67 kN Ans**

Example 14.3

Determine permissible load for a R.C. circular column of 400 mm diameter reinforced with 6#25 main reinforcement. The lateral reinforcement is in the form of helical spiral of #8 of pitch 55 mm c/c. Use M 20 concrete and Fe 415 steel.

Solution

The permissible load P' will be first determined for a short column with lateral ties. If the specification for increased load (vide Section 14.4.3(b) and 14.5.1(b)) of helical reinforcement will be complied with, the permissible load,

$$P = 1.05\,P'$$

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

$$= \sigma_{cc} (A_g - A_{sc}) + \sigma_{sc} A_{sc}$$

$$= 5\left(\frac{\pi}{4} \times 400^2 - 6 \times \frac{\pi}{4} \times 25^2\right) + 190 \times 6 \times \frac{\pi}{4} \times 25^2$$

$$= 1173.189 \text{ kN}$$

The helical reinforcement provided is of the following specifications :

i) Pitch, p (@55 c/c) is less than 75 mm and is also less than 1/6th of core diameter,

$\left(= \frac{400 - 80 + 16)}{6} = 56\right)$. It is more than 25 mm and $3\phi_{tr}$ (= 3 × 8 = 24)

ii) The diameter $\phi_{tr} > \frac{\phi}{4}\left(\frac{25}{4} = 6.25\right)$ and is also greater than 5 mm.

iii) $\dfrac{\text{Volume of helical reinforcement / m}}{\text{Volume of the core of the column / m}}$

$$= \frac{\frac{1000}{55} \times \pi(400 - 2 \times 40 + 8) \times \frac{\pi}{4} \times 8^2}{1000 \times \frac{\pi}{4} \times (400 - 2 \times 40 + 2 \times 8)^2} = 0.0106$$

$$0.36\left(\frac{A_g}{A_c} - 1\right)\frac{f_{ck}}{f_y}$$

$$= 0.36\left(\frac{\frac{\pi}{4} \times 400^2}{\frac{\pi}{4}(400 - 2 \times 40 + 2 \times 8)^2} - 1\right) \times \frac{20}{415}$$

$$= 0.0072 < 0.0106$$

Since the specifications of helical spiral complies with those for increased load, therefore,

$$P = 1.05\,P'$$

$$= 1.05 \times 1173.189 = \mathbf{1231.848 \text{ kN}} \text{ Ans}$$

The details have been shown in Figure 14.9.

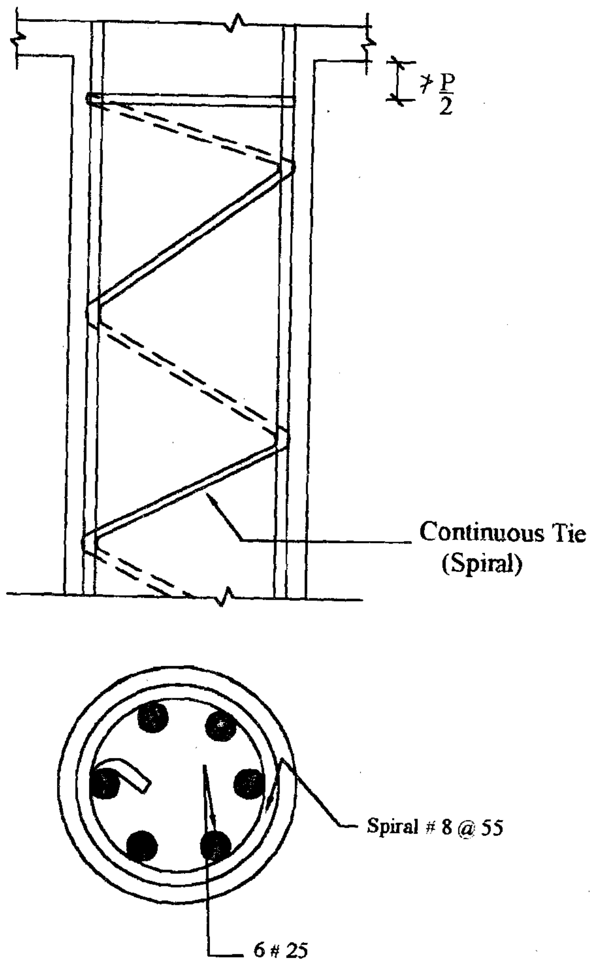


Figure 14.9: Circular Column

SAQ 3

i) Design a rectangular R.C. column of load carrying capacity, 1050 kN using M 20 concrete and Fe 250 steel.

ii) Determine permissible load for a 4 m long rectangular R.C. column of size 250 × 350 mm reinforced with 4#20 and adequate lateral ties if

   a) its both ends are effectively held in position and restrained against rotation.

   b) its both ends are effectively held in position, but restrained against rotation at one end.

14.6 SUMMARY

A column is predominantly a compression member hence its analysis, design and detailings are quite different from that of a beam. Buckling of column under compression and eccentricity of loads, therefore, play major role in deciding the type of a column for analysis and design purposes. Lateral reinforcement in the form of stirrups are provided, not only to resist shear due to lateral loads or bending moment, but also to confine concrete against bursting due to compression and to provide lateral support to longitudinal steel against buckling. Sometimes lateral ties are also provided in the form of helical spiral, which if provided *adequately* as specified in Section 14.4.3(b) and 14.5.1(b), shares longitudinal loads as well.

14.7 ANSWERS TO SAQs

SAQ 1

i) Refer Text 14.1

ii) Refer Text 14.2

SAQ 2

i) Refer Text 14.4.1

ii) Refer Text 14.4.1

iii) Refer Text 14.4.3

iv) Refer Figure 14.4.4(c)

SAQ 3

i) Refer Example 14.1

ii) Refer Example 14.2