METALLIC STRUCTURES
STRN 302

AXIALLY LOADED COLUMNS

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TOPICS

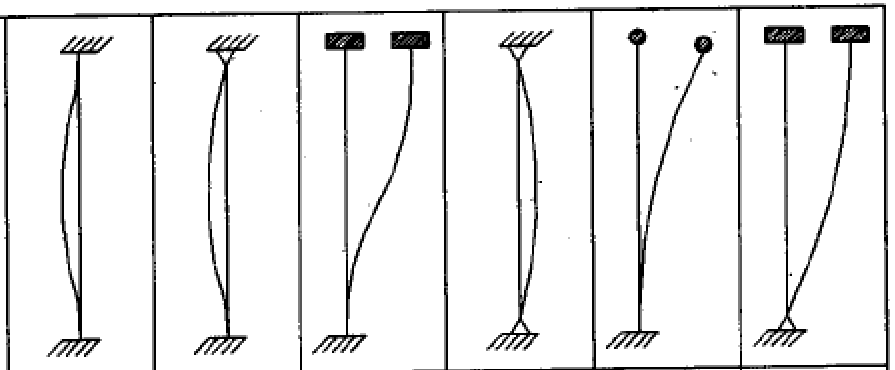
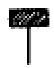
- INTRODUCTION
- BEHAVIOR OF AXIALLY LOADED COLUMN
- CROSS SECTION TYPES
- STIFFNESS LIMITATION
- BUCKLING OF OPEN COLUMN LATTICED COLUMN
- BUCKLING OF OPEN COLUMN BATTENED COLUMN
- DESIGN OF LACING BARS
- DESIGN OF BATTEN PLATES
- DESIGN STEPS
- EXAMPLES

INTRODUCTION

- Compression Members are those subjected to PURE COMPRESSION forces.
- They are not only used for trusses but they can be used as column.
- The columns can be either closed section or open section.

BEHAVIOR OF Axially Loaded Column

Table (4.3) Buckling Length Factor for Members with Well Defined End Conditions

BUCKLING MODE						
k	0.65	0.80	1.20	1.00	2.10	2.00
END CONDITIONS		ROTATION PREVENTED, TRANSLATION PREVENTED				
		ROTATION PERMITTED, TRANSLATION PREVENTED				
		ROTATION PREVENTED, TRANSLATION PERMITTED				
		ROTATION PERMITTED, TRANSLATION PERMITTED				

BEHAVIOR OF Axially Loaded Column

- Buckling length factor depends on:
  - End conditions

End Condition	Theoretical	Practical
Hinged-Hinged	1.0	1.0
Fixed-Fixed	0.5	0.65
Fixed-Hinged	0.7	0.8
Fixed-Free	2.0	2.1
Hinged-Guided	2.0	2.0
Fixed-Guided	1.0	1.2

  - Side-sway (prevented or permitted)

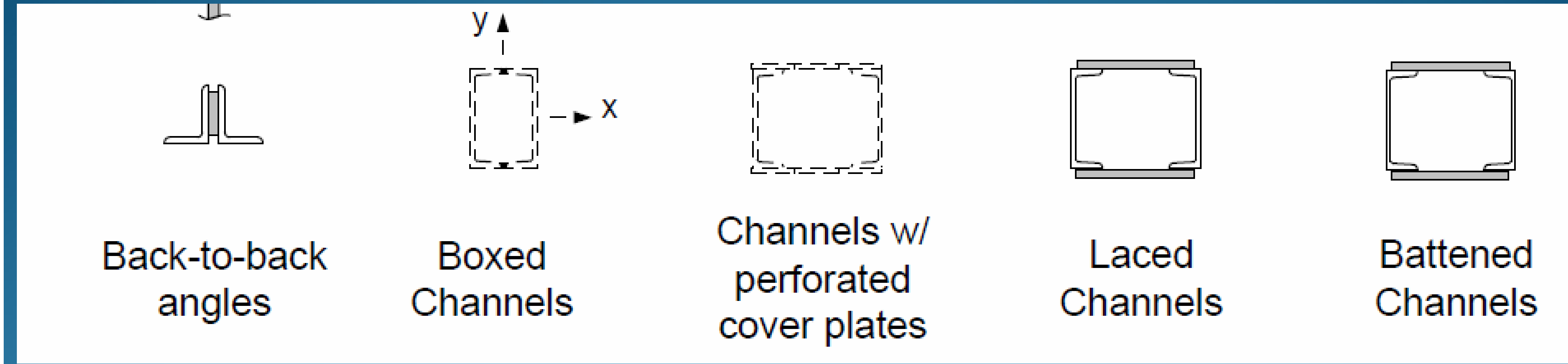
$$K \leq 1.0 \; (side - sway \;\; prevented)$$

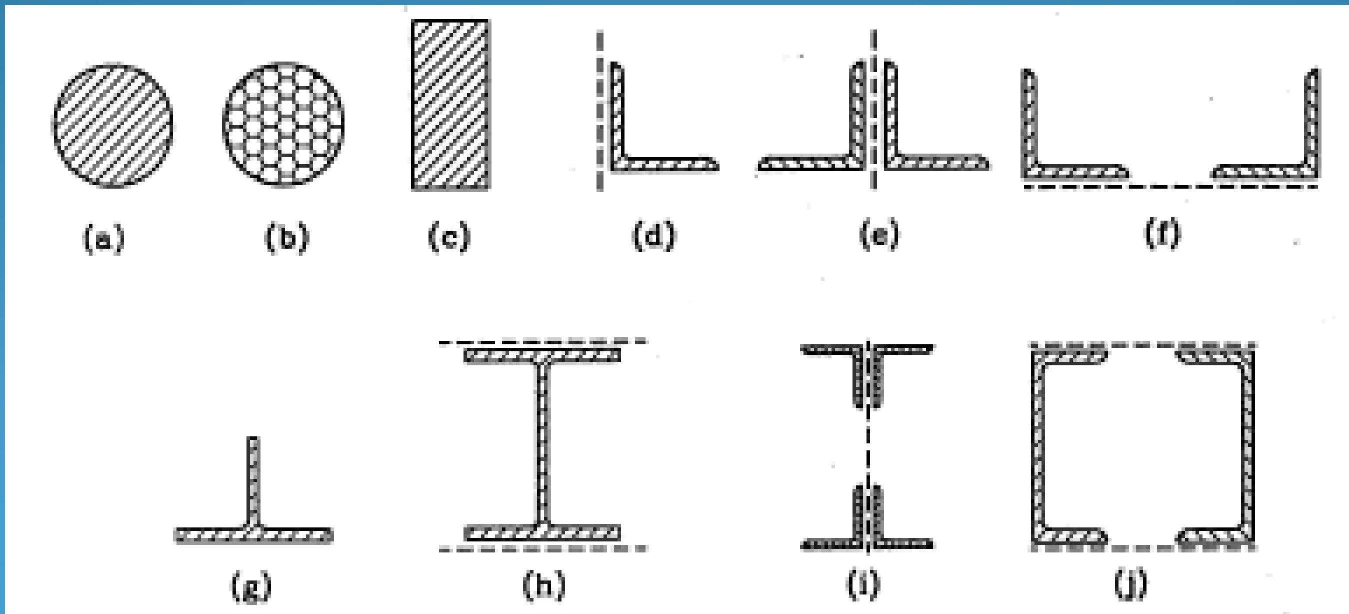
$$K \geq 1.0 \; (side - sway \;\; permitted)$$

BEHAVIOR OF Axially Loaded Column

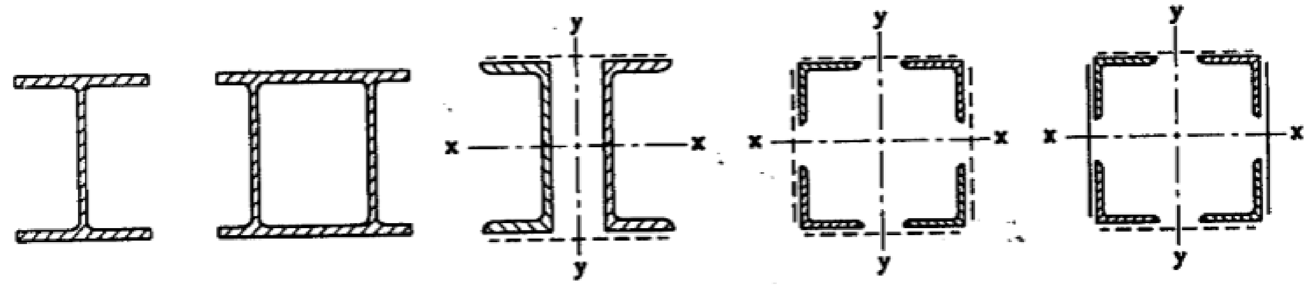
- Buckling length of any member needs to be evaluated in BOTH planes (in-plane and out-of plane)
- Buckling length about any Axis is the buckling length in the plane PERPENDICULAR to that axis.

CROSS SECTION TYPES

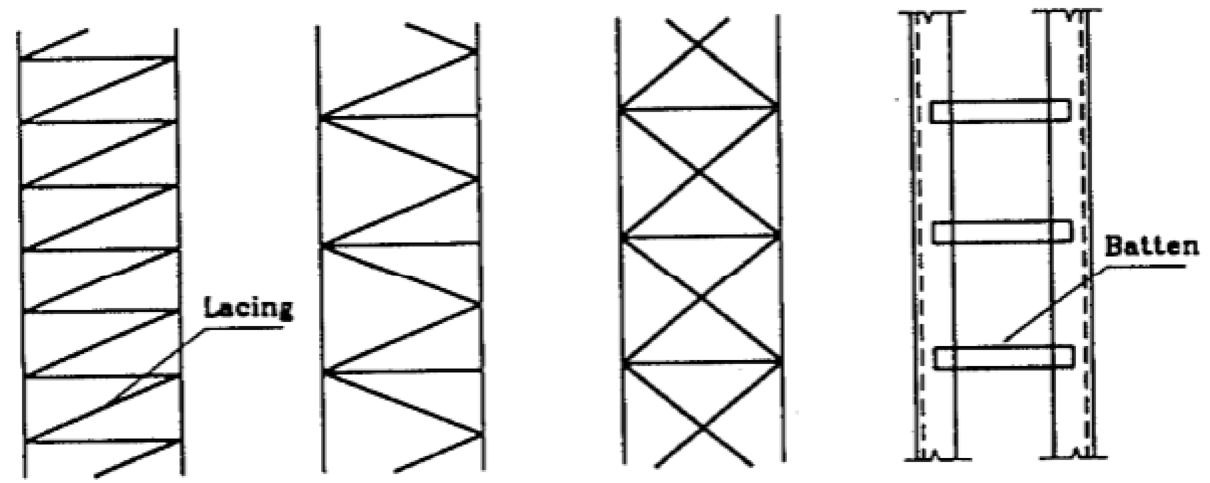




CROSS SECTION TYPES



(a) Rolled and Bult–up Section.



(b) Latticed and Batten Columns.

STIFFNESS LIMITATION

$$\left(\frac{KL}{i}\right)_{max} \leq 180 \qquad i = \sqrt{\frac{I}{A}}$$

Compute slenderness ratio in-plane and out of plane

Table(4.1) Maximum Slenderness Ratio for Compression Members

Member	λ_{max}
Buildings:	
Compression members	180
Bracing systems and secondary members	200
Bridges:	
Compression members in railway bridges	90
Compression members in roadway bridges	110
Bracing systems	140

Buckling of Open Column
Latticed Column

$$(L_y / i_y)_{corrected} = \sqrt{(L_y / i_y)^2 + (L_1 / i_1)^2}$$

where :

L_y = buckling length of the column w.r.t. y-y.

L_1 = buckling length of one rib (Fig. 3.23).

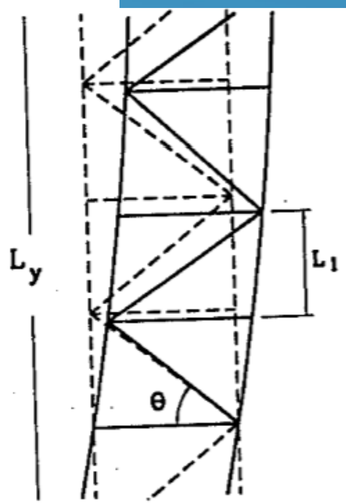
i_1 = least radius of gyration of the component part

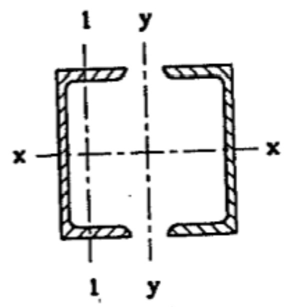
i_y = radius of gyration of the composit section.

Refer to examples 3.10, 3.11.

$L_1/i_1 < 60$

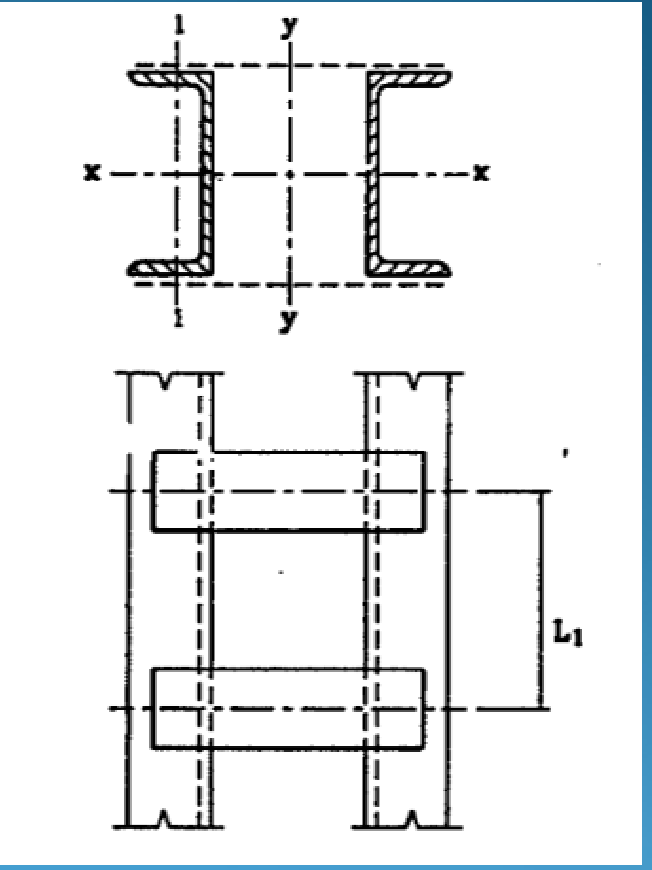
$L_1/i_1 < 2/3$ L/i of the member



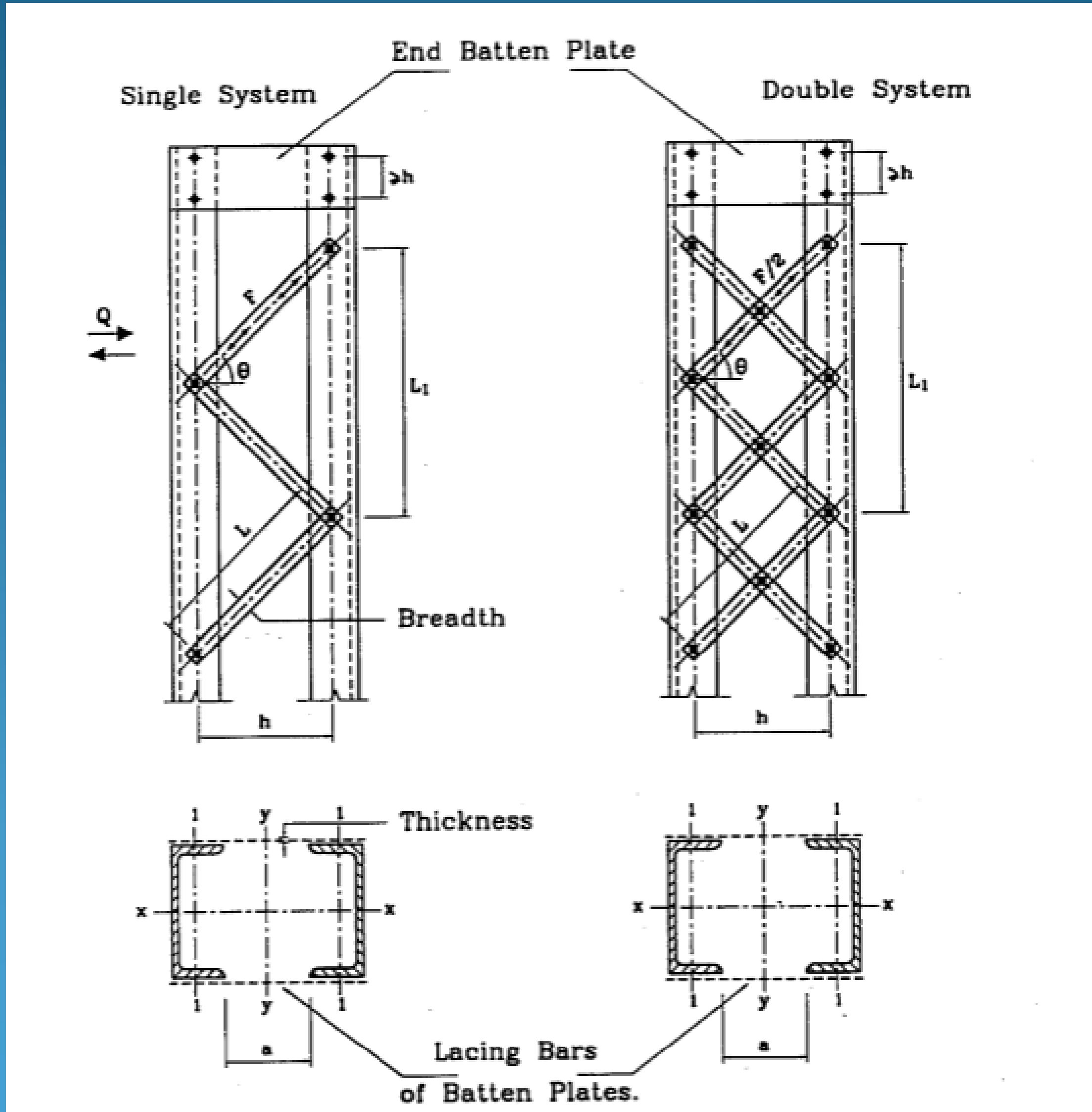


Buckling of Open Column
Battened Column

$$(L_y/i_y)_{corrected} = \sqrt{(L_y/i_y)^2 + (1.25\ L_1/i_1)^2}$$



Design of Lacing Bars



Design of Lacing Bars

a) Design Forces

$F = \pm 0.02 P / \cos \Theta$ for single system

For double system use half of the force.

b) Angle of Inclination

For single lacing Angle Θ 50-70 degree

For double Lacing Angle Θ 40-50 degree

c) Type of Cross-Section

Mostly flat bars

Sometimes angle and channels

Design of Lacing Bars

d) Thickness and Breaddth Limitations

t > l/50

t = thickness of lacing and l is its length

L = distance between innermost weld lines or bolts

b > 3 Φ

b = width of lacing and Φ is bolt hole diameter.

Design of Lacing Bars

e) Slenderness Ratio

$L/i < 140$

L = length of lacing for single lacing

L = 0.7 L length of lacing for double lacing

L_1 / i_1 of column component < L/i of column (max value)

This is to prevent local buckling.

Design of Lacing Bars

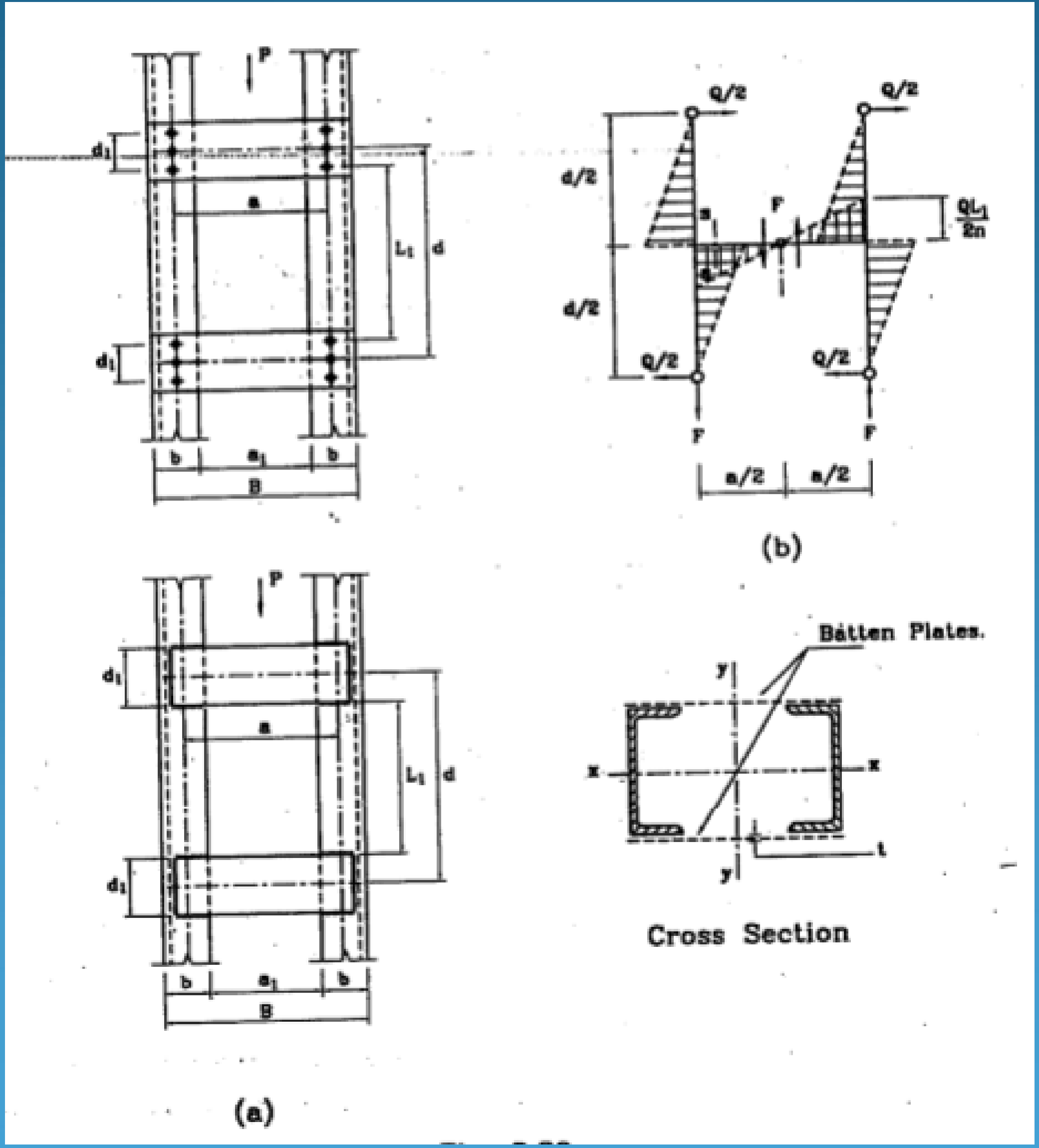
f) Batten Plates

To be provided at ends of lacing system and at any lacing member interruption with other member

. End batten plate length > distance between center line of main column components.

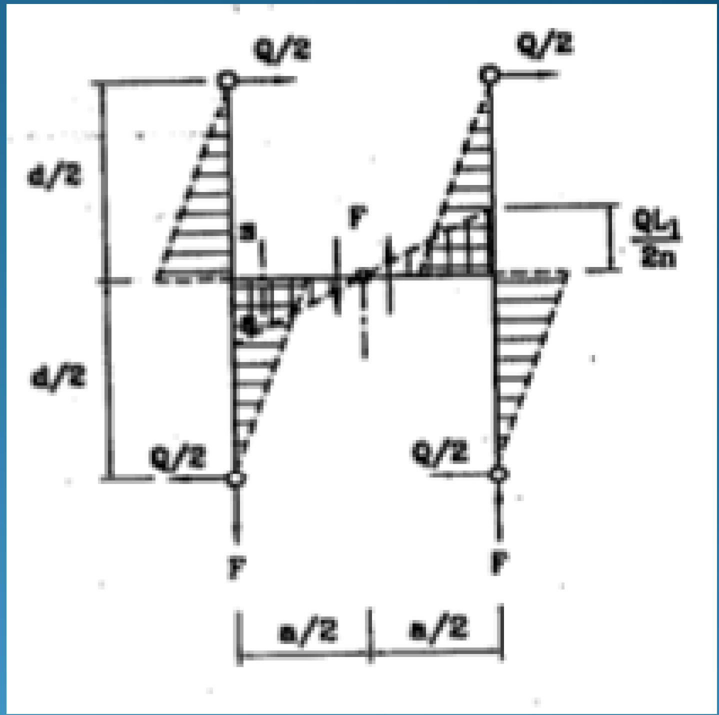
Intermediate batten plate length > 0.7 distance between center line of main column components

Design of Batten Plates



Design of Batten Plates

a) Straining Actions



$Q = 0.02\ P$

$F = Q\ d/n\ a$

$Ms = Q\ s\ /\ 2\ n$

n = number of batten plates = 2

d = distance center to center between batten plates

a = distance between bolt gage lines of bolts or weld lines.

Design of Batten Plates

b) Dimensions of Batten Plates

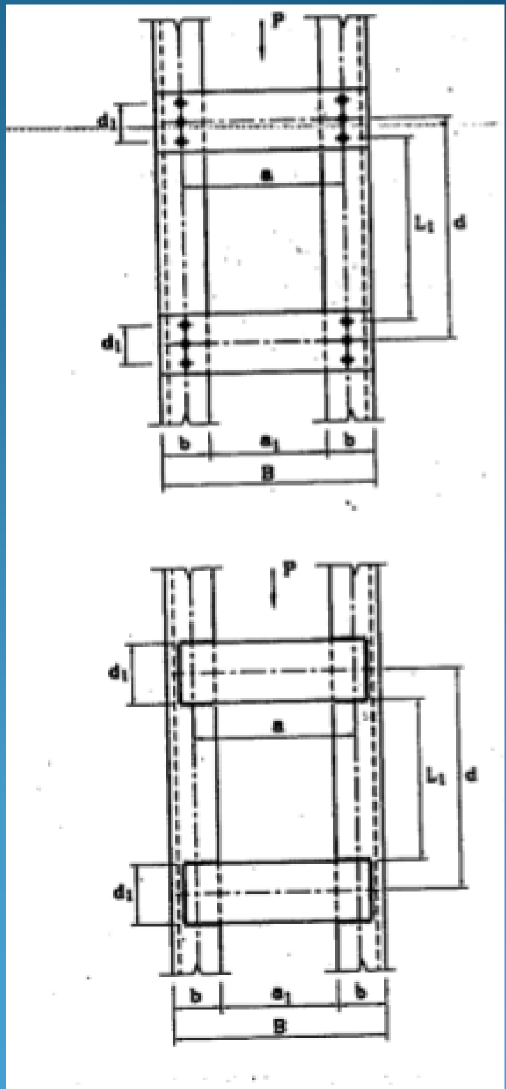
$d_1 \geq a$ for end battens

$d_1 \geq \frac{3}{4} a$ for intermediate battens

$d_1 \geq 2b$

a_1 is chosen such that L_x/i_x and L_y/i_y are, as much as possible, of equal value. Thus B can be determined.

t > 1/50 of the distance between bolts or weld lines



DESIGN STEPS

- Determine
  - DF (Compression Force), Load Case (I or II)
  - Member location, Length (L_g), Bolted or Welded
- Determine $L_{in\ plane}$ and $L_{out\ of\ plane}$
- Choose section type (B.F.I.B., S.I.B. , Built-up)

- **<u>Approximate Design</u>**
- Get $f_{av.}$ based on Design force.
- Get $A_{approx.}$ = Force/ $f_{av.}$
- get minimum i_x and i_y to satisfy stiffness condition l_x/i_x and $l_y/i_y < 180$

DESIGN STEPS

- Determine
  - DF (Compression Force), Load Case (I or II)
  - Member location, Length (L_g), Bolted or Welded
- Determine $L_{in\ plane}$ and $L_{out\ of\ plane}$
- Choose section type (B.F.I.B., S.I.B. , Built-up)

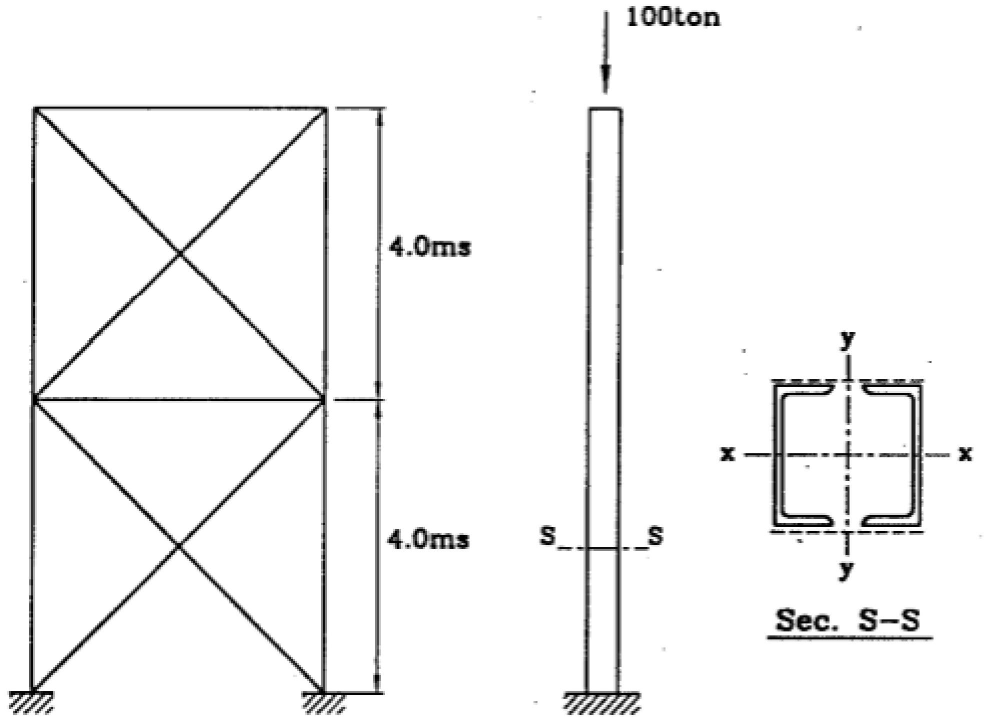
- **Approximate Design**
- Get $f_{av.}$ based on Design force.
- Get $A_{approx.} = Force/\ f_{av.}$
- get minimum i_x and i_y to satisfy stiffness condition l_x/i_x and $l_y/i_y < 180$

DESIGN STEPS

- Chose the section
- Calculate allowable compressive stresses , F_c based on the maximum of l_x/i_x and l_y/i_y
- Calculate actual stress f_c = Force/ A
- Check that $f_c < F_c$.
- Design the lacing or batten plates if open section.

EXAMPLES

Example (3.11): Column with Opened Section from One Side:



Design a column to carry conc. load of 100 tons (Case I), using an opened section composed of 2 channels. The column has the shown transversal bracing system.

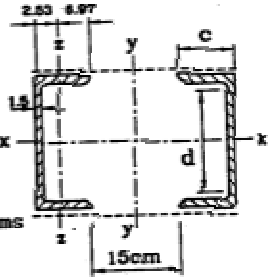
EXAMPLES

Buckling Length:

$l_x = 400$ cms $\quad l_y = 2x800 = 1600$ cms

$l_x / i_x \le 180 \quad \therefore \; i_x \ge 2.22$ cms

$l_y / i_y \le 180 \quad \therefore \; i_y \ge 8.89$ cms



Area Required: $f_{av.} = 0.95$ t/cm^2

$$A_{2[} = \frac{100}{2 \times 0.95} = 52.632 \text{ cm}^2$$

Try 2 [s' No. (28) $t_w = 1.0$cms, $t_f = 1.5$cms

c = 9.5 cms

c/t = 9.5/1.5 = 6.33 < 14.8

(Table 3.2) O.K.

$d_w = 28 - 2x1.5 - 2x1.5 = 22$ cms

$d_w/t_w = 22/1.0 = 22 < 41.3$

(Table 3.2) O.K.

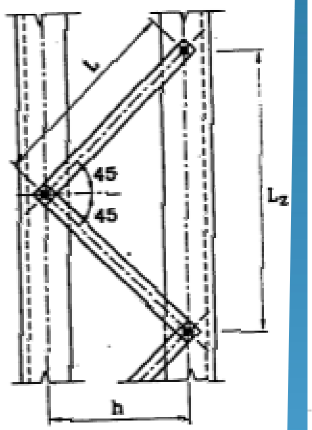
$$I_y = 2\left[399 + 53.30(14.47)^2\right]$$

$= 23118.004$ cm^4

$i_y = 14.726$ cms, $i_x = 10.855$ cms

$$l_x / i_x = \frac{400}{10.855} = 36.849$$

$$l_y / i_y = \frac{1600}{14.726} = 108.65$$



L_z=2x23=46.0 cm

$$l_z = 2\left[15 + (9.50 - 1.50)\right] = 46.0 \text{ cms}$$

$i_z = \sqrt{\frac{399}{53.30}} = 2.736$ cms $\quad \therefore \; l_z / i_z = 16.812 < 60$ (O.K.)

& < (2/3)x36.849 (O.K.)

$$l_y / i_y)_{corrected} = \sqrt{(108.65)^2 + (16.812)^2} = 109.943$$

$$F_c = \frac{7500}{(109.94)^2} = 0.6205 \text{ t/cm}^2$$

$f_c = \frac{100}{2 \times 53.30} = 0.938$ t/cm^2 $\quad \therefore$ (Unsafe)

Try 2 [s' No. (35)

$$I_y = 2\left[570 + 77.30\,(15.1)^2\right] = 36390.35 \text{ cm}^4$$

$$i_y = \sqrt{\frac{36390.35}{2 \times 77.30}} = 15.342 \text{ cms}$$

$l_y / i_y = 104.287$

$$l_z = 2\left[15 + (10 - 1.40)\right] = 47.20 \text{ cms}$$

$i_z = 2.715$ cms $\qquad l_z / i_z = 17.382$

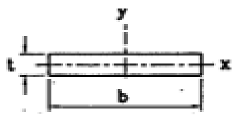
$$\frac{l_y}{i_y})_{corrected} = \sqrt{(17.382)^2 + (104.29)^2} = 105.73$$

$$F_c = \frac{7500}{(105.73)^2} = 0.671 \text{ t/cm}^2$$

$f_c = \frac{100}{2 \times 77.30} = 0.647$ t/cm^2 (Safe and economic)

Design of Lattice Bars:

$$D.F. = \pm \frac{0.02 \times 100}{2 \cos 45^\circ} = \pm 1.40 \text{ tons}$$



$$l = \left[15 + (10 - 1.6)\right]\sqrt{2} = 33.09 \text{ cms}$$

$t \ge \frac{33.09}{50} \ge 0.662$ cm $\qquad$ take t = 0.80 cm

$b \ge 3\,\phi \ge 3 \times 1.60$ cm $\qquad$ take b = 5.0 cms

EXAMPLES

$$I_x = \frac{(0.8)^3 \times 5.0}{12} = 0.213 \text{ cm}^4 , \quad i_x = 0.231$$

$$\therefore\ l_x / i_x = \frac{33.09}{0.231} = 143.283 \cong 140 \text{ (o.k)}$$

$$F_c = \frac{7500}{(143.28)^2} = 0.365 \text{ t/cm}^2 , \quad f_c = \frac{1.40}{5.0 \times 0.80} = 0.35 \text{ t/cm}^2$$

(Safe)

Check as Tension Member:

$$A_{net} = \left[5.0 - (1.6 + 0.2)\right] 0.8 = 2.56 \text{ cm}^2$$

$$f_t = \frac{1.40}{2.56} = 0.547 \text{ t/cm}^2 < 1.40 \quad \text{(Safe)}$$