**Problem 1)** Design economical built up column to carry 1100 KN using two channels back to back. The length of column is 5 mt. with both ends are held in position and only one end is restrained against rotation. Design a suitable **Lacing system** ? Take $f_y = 250\ Mpa$

**Answer :** Given ;

a) Length of member (clear) = 5.00 mt = $5.00 \times 10^3$ mm

Given case is **One End Fix And Other Is Hinge (case 02)**

$\therefore\ l_{eff} = KL = 0.8 \times 5 \times 10^3 = 4.00 \times 10^3$ mm

……………………………………………………… *IS 800-2007; pg. 45*

Let. $\lambda$ (slenderness ratio) = 70

For $f_y$=250; (compressive stress) $\sigma_{ac} = 152\ ^{N}/_{mm^2}$

……………………………………………………… *IS 800-2007; pg. 42*

Area Reqd. For the strut $(A_{Req}) = \frac{1100 \times 10^3}{152} = 7236.84\ mm^2$

Area of Each angle = $\frac{7236.84}{2} = 3618.42\ mm^2$

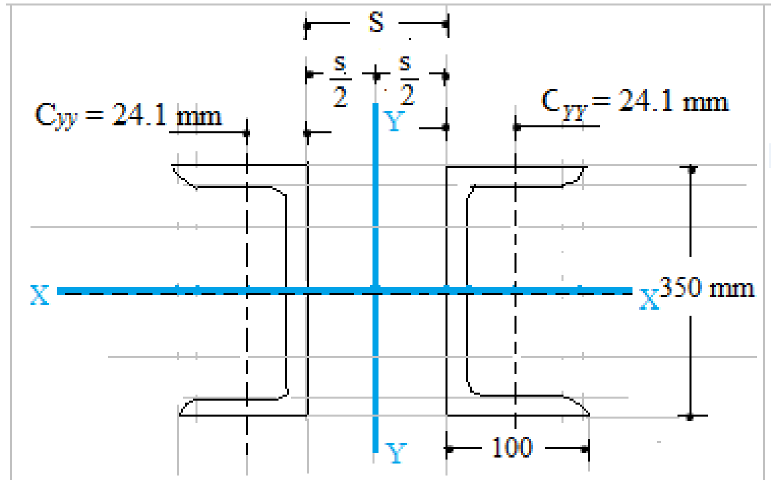
Refer the steel table and select rolled steel channel ISLC 350 @ 38.8 $\frac{kg}{m}$

For this channel ; A = 4947 $mm^2$; width (b) = 100 mm ;

$t_f$ = 12.5 mm ; $t_w$ = 7.4 mm; Center of gravity ; $C_{yy}$ = 24.1 mm ; guage distance ( $g^*$ ) = g = 60 mm ; $r_{xx} = 137.2\ mm$

$I_{xx} = 9312.6 \times 10^4\ mm^4$ , $I_{yy} = 394.6 \times 10^4\ mm^4$;

$r_{xx}$ = 137.2 mm , $r_{yy}$ = 28.2 mm




For economical Built up column ; We have

$I_{xx\ (whole\ s/c)} = I_{yy\ (whole\ s/c)}$

$\therefore\ \cancel{2}(I_{xx\ (self)}) = \{I_{yy\ (self)} + A\,(ht)^2\} \times \cancel{2}$

$9312.6 \times 10^4 = \{394.6 \times 10^4 + 4947\,(C_{yy} + \frac{S}{2})^2\}$

$\therefore$ S = 220.32 mm say 222 mm

***Step i) Actual L.C.C. Provided :***

$I_{xx\,(whole\ s/c)} = 2 \times 9312.6 \times 10 = 186.252 \times 10^6\ mm^4$

$I_{yy\,(whole\ s/c)} = \{ 394.6 \times 10^4 + 4947\ (C_{yy} + \frac{S}{2})^2 \} \times 2 = 188.47 \times 10^6\ mm^4$

$I_{xx\,(whole\ s/c)} < I_{yy\,(whole\ s/c)} \quad \therefore\ I_{min} = I_{xx\,(whole\ s/c)} = 186.252 \times 10^6$

$$r_{min} = \sqrt{\frac{I_{min}}{A_{gross}}} = \sqrt{\frac{186.252 \times 10^6}{2 \times 4947}} = 133.20\ mm$$

$$\text{Now, } (\lambda) = \frac{l_{eff}}{r_{min}} = \frac{4 \times 10^3}{133.20} = 30.03 \text{ say } 30$$

**Table 9(c) Design Compressive Stress, $f_{cd}$ (MPa) for Column Buckling Class c**

*IS 800-2007 ; Pg. 42;* (*Clause* 7.1.2.1)

| $(\lambda) = \frac{l_{eff}}{r_{min}} = KL/r$ ↓ | Yield Stress, $f_y$ (MPa) = 250 Mpa |
|---|---|
| 30.00 | 211 |

*Interpolation :*

$\{ \frac{(\quad - \quad)}{(\quad)} \times (\quad) \}$-

$\therefore\ (f_{cd}) = 211\ \frac{N}{mm^2}$

$\therefore$ Compressive strength $= f_{cd} \times A_{gross}$

$= 211 \times (2 \times 4947) = 2087.63\ KN$

$> 1100\ KN$ ; Safe

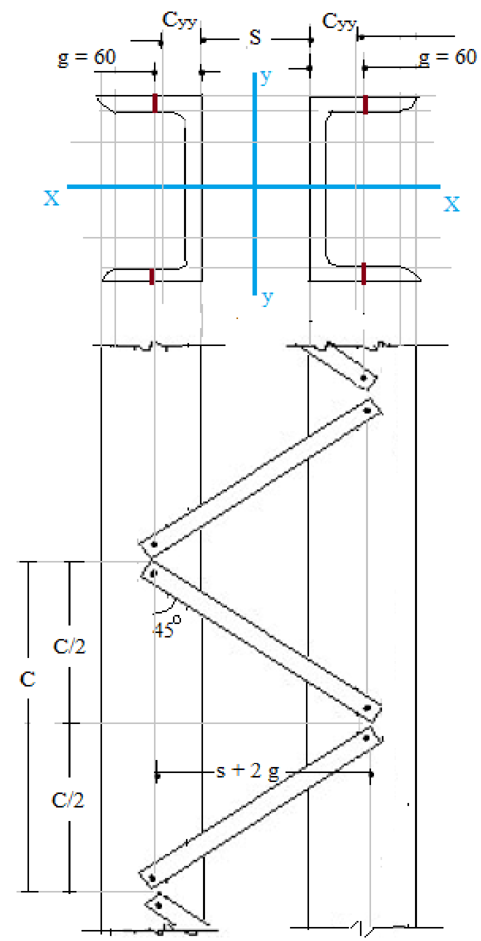
### *Step ii) Design Of Lacing :*

Let us provide single lacing system with bolted connection.

Inclination of lacing with vertical is $\nless 40$ and $\ngtr 70$

……………...............................................*cl 7.6.4* ; *IS 800-2007; pg. 50*

Let it be $\theta = 45^0$



$$\tan 45^0 = \frac{Opp}{adj} = \frac{S+2(g)}{C/2} = \frac{222+(2\times 60)}{C/2}$$

$\therefore$ Spacing ( c ) = 684 mm

***Step iii) Check for spacing as per IS 800-2007:***

$$\left(\frac{C}{r_{min}}\right) = \left(\frac{C}{r_{YY}}\right) = \frac{684}{28.2} = 24.25$$

$\ngtr$ *i)* 50 and

$\ngtr$ *i)* $0.7 \times (\lambda)_{group}$ = 0.7 x 30 = 21 ; Not safe

…………………………………………….*cl 7.6.5* ; *IS 800-2007; pg. 50*

Revise spacing ; $\therefore \left(\frac{C_{req}}{r_{min}}\right) = \left(\frac{C_{req}}{r_{YY}}\right) = \frac{C_{req}}{28.2} = 21$

$\therefore C_{req}$ = 28.2 x 21 = 592 mm ***and***

$$\left(\frac{C_{req}}{r_{min}}\right) = \left(\frac{C_{req}}{r_{YY}}\right) = \frac{C_{req}}{28.2} \ngtr 50$$

$\therefore \quad C_{req} = 28.2 \; x \; 50 = 1410 \;\; say \; 1000 \;\; mm$

$\therefore \quad C_{prov} = \;\; 1000 \;\; mm$

By mistake , I have taken $C_{req}$ = 576.70 mm in following calculations, you take 1000 mm

$$\tan \theta = \frac{Opp}{adj} = \frac{S+2(g)}{C/2} = \frac{222+(2\times 60)}{576.70/2} = \frac{342}{288} = 1.185$$

$\therefore$ Angle of Inclination ( $\theta$ ) $= tan^{-1}$ (1.185) = 50

$\therefore$ length of lacing ; Z = $\sqrt{(s+2g)^2 + {C/2}^2}$

$$= \sqrt{(342)^2 + (288)^2} = 447 \text{ mm}$$

***Step iii) Check for thickness as per IS 800-2007:***

*i)* $t \ngtr Z/40 = 447/40$ = 11.175 say 12 mm *(Single lacing)*

*i)* $t \ngtr Z/60$ *(Double lacing) ; Safe*

…………………………………………….*cl 7.6.3* ; *IS 800-2007; pg. 50*

***Step iv) Check for width of lacing as per IS 800-2007:***

$$b_{lacing} = 3 \times \varnothing_{bolt}$$

…………………………………………….*cl 7.6.2* ; *IS 800-2007; pg. 50*

Let us provide 20 mm Ø bolt of grade 4.6

$$\therefore b_{lacing} = 3 \times \varnothing_{bolt} = 3 \text{ x } 20 = 60 \text{ mm}$$

***Step v) Load / Force calculation as per IS 800-2007:***

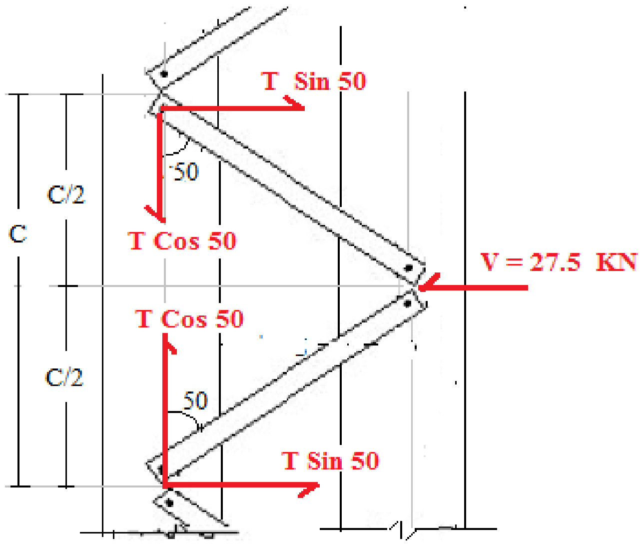
a) Transverse shear (v) = 2.5 % of Axial Load

$$= (2.5/100) \text{ x } 1100 = 27.5 \text{ KN}$$

b) Transverse shear In each lacing ;

Equating $\sum X = \sum Y$

2 T Sin 50 = 27.5……………………………..................Refer Fig.




$\therefore T = \left(\frac{27.5}{2}\right) \times \left(\frac{1}{\sin 50}\right) = 17.94$ KN

***Step v) Check For L.C.C. Of lacing bar :***

Properties ; b = 60 mm ; t = 12 mm ; Z = 447 mm

*a) In Compression ;*

We have ; $r_{min} = \sqrt{\frac{I}{A_{net}}} = \sqrt{\frac{\frac{b\ x\ t^3}{12}}{b\ x\ t}} = \frac{t}{\sqrt{12}} = \frac{12}{\sqrt{12}} = 3.46$ mm

$$\lambda = \frac{l_{eff}}{r_{min}} = \frac{Z}{r_{min}} = \frac{447}{3.46} = 129.19$$

**Table 9(c) Design Compressive Stress, $f_{cd}$ (MPa) for Column Buckling Class c**

*IS 800-2007 ; Pg. 42;* (*Clause* 7.1.2.1)

| $(\lambda) = \frac{l_{eff}}{r_{min}} = KL/r$ ↓ | Yield Stress, $f_y$ (MPa) = 250 Mpa |
|---|---|
| 120 | 83.7 |
| 129.19 | ??? |
| 130 | 74.3 |

*Interpolation :*

$\left\{\frac{(83.7 - 74.3)}{(130-120)} \times (129.19 - 120)\right\} - 83.7$

$\therefore (f_{cd}) = 75.06$

$\therefore$ Compressive strength $= f_{cd} \times A_{gross}$

75.06 x b x t = 75.06 x 60 x 12

= 54.04 KN

Here ; 54.0 KN > 17.94 KN ; Safe

*b) In Tension ;*

*i) Yielding Consideration :* $T_{dg} = 1/\gamma\ (A_g\ F_y)$

.............................................*IS 800-2007; cl. 6.2 ; pg. 32*

Where, $A_g$ = Gross Area Of bar S/c = ( 60 × 12) = 720 $mm^2$

$F_y$ = Yield Stress Of the bar = 250 $N/mm^2$

$\gamma$ = Partial Safety Factor for failure by Yielding = 1.10

...........................................*IS 800-2007 ; Table 5 ; pg. 30*

$\therefore T_{dg}$ = 163.636 KN > 17.94 KN ; Safe *ii)* *Rupture Consideration* : $T_{dn} = 1/\gamma\,(0.9\,A_n\,F_u)$

........................................... *IS 800-2007; cl. 6.3.1 ; pg. 32*

$\gamma$ = Partial Safety Factor for failure by Rupture = 1.25

.............................................*IS 800-2007 ; Table 5 ; pg. 30*

$A_n$ = Net effective area of the member = ((b) – ( n $d_o$ )) × t

Where , n = no. of Bolt Holes in weakest s/c = 1

Dia. Of Bolt Hole = $d_0$ = Ø + 2 = 20 + 2 = 22 mm

$A_n$ = (60 - 22) × 12 = 456 $mm^2$

Ultimate stress of laced bar material $F_u = F_{up}$ = 410 $N/mm^2$

$\therefore\ T_{dn}$ = 134.61 KN

$Since\ ;\ T_{dn} < T_{dg}$

$\therefore$ Design strength of bar in tension $T_{dn}$ = 134.61 KN

*c)* *Design Strength of bar in Shear* $(Double\ shear)\ (V_{ds})$;

$V_{ds} = \{\,1/\gamma\ [\frac{F_u}{\sqrt{3}}\,(n_n\,A_{nb})]\,\}$

.................................................*IS 800-2007; cl. 10.3.3 ; pg. 75*

Ultimate stress for bolt material $F_u = F_{ub}$ = 400 $N/mm^2$

$n_n$ = No. of shear planes with threads intercepting shear planes.

= 2 (one bolt is passing from two lacing bars)

$A_{nb}$ = Net shear area of bolts at threads

$A_{nb} = 0.78\ to\ 0.80 \times \frac{\pi}{4} \times d^2$

$= 0.78\ to\ 0.80 \times \frac{\pi}{4} \times 20^2 = 251.32\ mm^2$

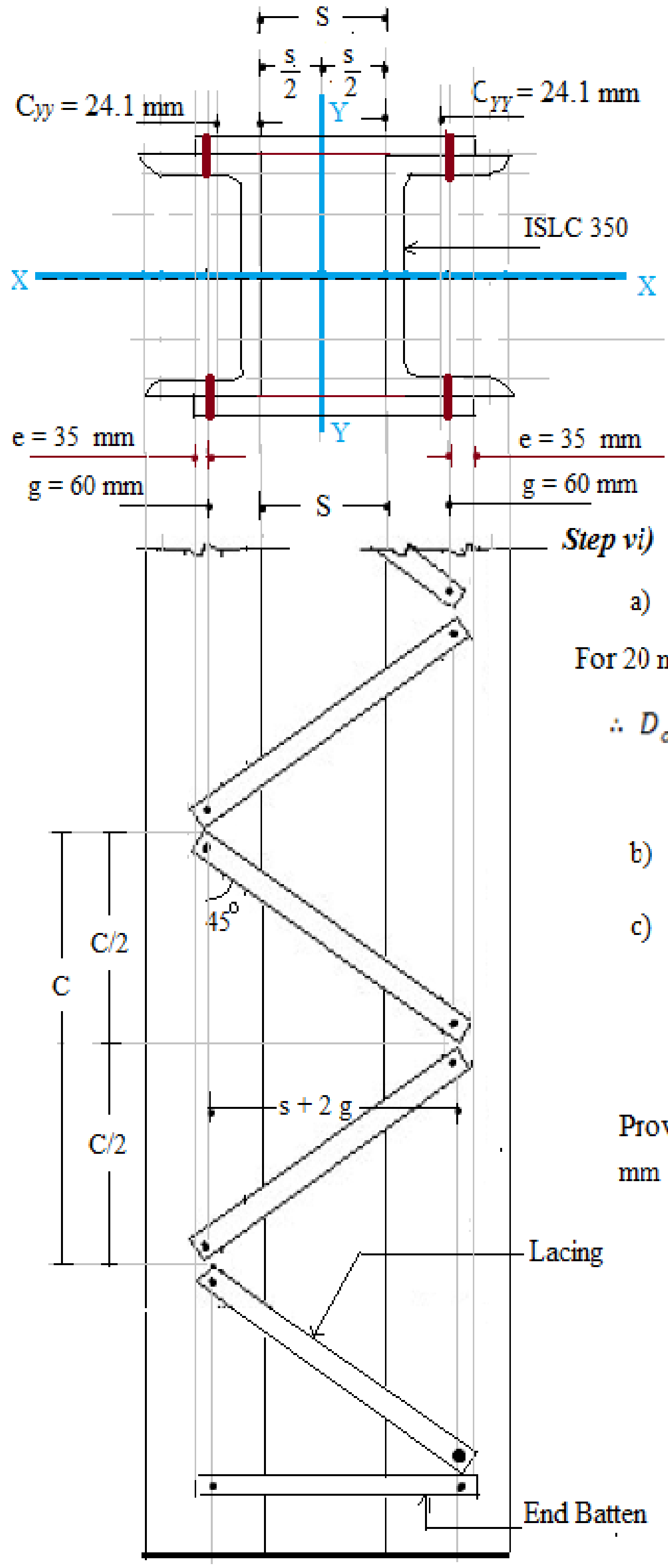
$\therefore\ V_{ds}$ = 92.865 KN

Since ; Compressive strength $< T_{dn} < V_{ds}$

$\therefore$ Design strength of lacing bar = **54.04 KN**

No. Of Bolts Required = $\frac{T}{\text{Design strength}}$

$= \frac{17.94 \times 10^3}{54.04 \times 10^3}$ = 0.33 say 01 No.




***Step vi) Design Of End Battens (Tie plate) :***

a) Effetive depth = d = S + 2(g) = 222 + 2 (60) = 342 mm

For 20 mm Ø bolt ; Edge distance = e = 1.5 × $d_0$ = 1.5 x 22 = 33

$\therefore D_{overall}$ = 342 + 2 (33) = 408 say 410 mm

$\not<$ (S + 2 (g)) = 342 mm ; Safe

b) Width $\not>$ S = 222 say 225 mm

c) Thickness of End Battens = $\frac{1}{50}$ x (S + 2g)

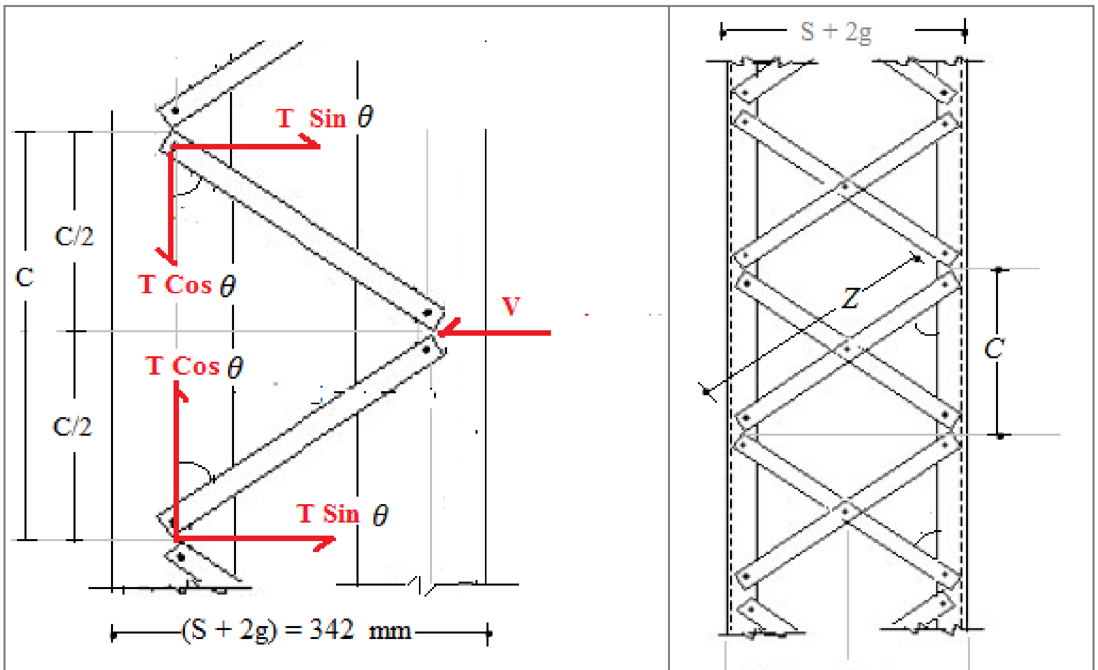
= $\frac{342}{50}$ = 6.84 say 8 mm

Provide end Battens of 410 x 225 x 8 mm connected using 20 mm Ø bolt.

Thickness of End Batten = $\frac{1}{50}$ x (S + 2g) ............................................ *IS 800-2007; cl. 7.7.2.3 ; pg. 51*

**Problem 2)** Design economical built up column to carry 1100 KN using two channels placed *toe to toe.* The length of column is 5 mt. with both ends are held in position and only one end is restrained against rotation. Design a suitable **Double Lacing system** ? Take $f_y = 250\ \ Mpa$

**Answer :**




*(a) Single Lacing*　　*(b) Double Lacing*

*(a) In single lacing*

$$\tan\ \theta = \frac{Opp}{adj} = \frac{S+2(g)}{C/_2}$$

$$= \frac{222+(2\times 60)}{1000/_2} = 0.684$$

$$(\theta) = tan^{-1}(0.684)$$

$$= 34.37 \text{ say } 35$$

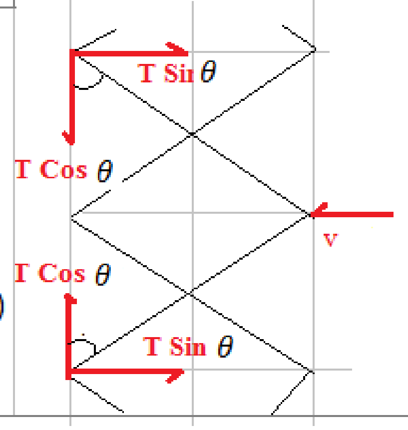
*(b) In Double Lacing ;*

$$\tan\ \theta = \frac{Opp}{adj} = \frac{S+2(g)}{C}$$

$$= \frac{222+(2\times 60)}{1000} = 0.342$$

$$(\theta) = tan^{-1}(0.342)$$

$$= 18.88 \text{ say } 20$$




**See the difference Of C (Spacing) in above cases and carry design steps as in Problem no.**

**Problem 3)** Design economical built up column to carry 1100 KN using two channels placed *toe to toe*. The length of column is 5 mt. with both ends are held in position and only one end is restrained against rotation. Design a suitable **Lacing system** ? Take $f_y = 250 \ \ Mpa$

**Answer** : Given ;

a) Length of member (clear) = 5.00 mt = 5.00 $\times \ 10^3$ mm

Given case is **One End Fix And Other Is Hinge (case 02)**

$\therefore \ l_{eff}$ = KL = 0.8$\times$ 5$\times$ $10^3$ = 4.00 $\times$ $10^3$ mm

……………………………………………………………… *IS 800-2007; pg. 45*

Let. $\boldsymbol{\lambda}$ (slenderness ratio) = 70

For $f_y$=250; (compressive stress) $\sigma_{ac}$ = 152 $N/mm^2$

……………………………………………………………… *IS 800-2007; pg. 42*

Area Reqd. For the strut ($A_{Req}$) = $\frac{1100 \times 10^3}{152}$ = 7236.84 $mm^2$

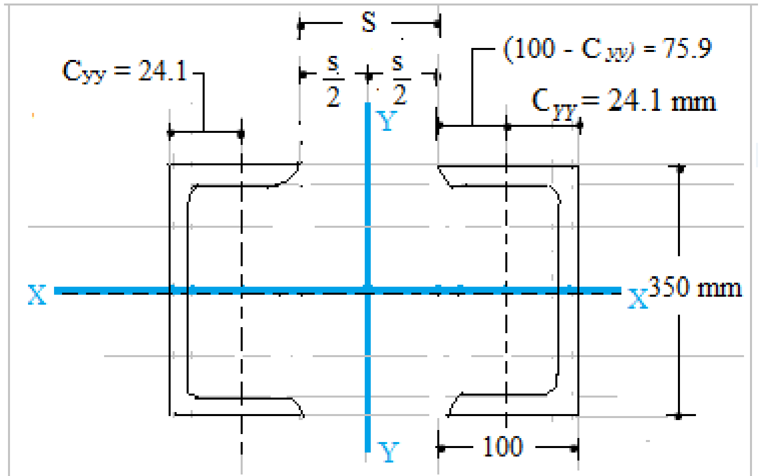
Area of Each angle = $\frac{7236.84}{2}$ = 3618.42 $mm^2$

Refer the steel table and select rolled steel channel ISLC 350 @ 38.8 $\frac{kg}{m}$

For this channel ; A = 4947 $mm^2$; width (b) = 100 mm ;

$t_f$= 12.5 mm ; $t_w$= 7.4 mm; Center of gravity ; $C_{yy}$ = 24.1 mm

; guage distance ( $g^*$ ) = g = 60 mm




For economical Built up column ; We have

$$I_{xx\,(whole\ s/c)} = I_{yy\,(whole\ s/c)}$$

$$\therefore \cancel{2}\,(I_{xx\,(self)}) = \left\{ I_{yy\,(self)} + A\,(h_t)^2 \right\} \times \cancel{2}$$

$$9312.6 \times 10^4 = \left\{ 394.6 \times 10^4 + 4947\,\left(75.9 + \frac{S}{2}\right)^2 \right\}$$

$$\therefore \quad S = 116.73 \text{ mm}$$

Say S = 117 mm

***Follow steps same as in Problem no. 01***

***Step i) Actual L.C.C. Provided :***

$$I_{xx\,(whole\ s/c)} = 2 \times 9312.6 \times 10 = 186.252 \times 10^6 \text{ mm}^4$$

$$I_{yy\,(whole\ s/c)} = \left\{ 394.6 \times 10^4 + 4947\,\left(C_{yy} + \frac{S}{2}\right)^2 \right\} \times 2 = 128.91 \times 10^6 \text{ mm}^4$$

$$I_{yy\,(whole\ s/c)} < I_{xx\,(whole\ s/c)} \quad \therefore \ I_{min} = I_{yy\,(whole\ s/c)} = 128.91 \times 10^6$$

$$r_{min} = \sqrt{\frac{I_{min}}{A_{gross}}} = \sqrt{\frac{128.91 \times 10^6}{2 \times 4947}} = 114.14 \text{ mm}$$

$$\text{Now},\ (\lambda) = \frac{l_{eff}}{r_{min}} = \frac{4 \times 10^3}{114.14} = 35$$

**Table 9(c) Design Compressive Stress, $f_{cd}$ (MPa) for Column Buckling Class c**

*IS 800-2007 ; Pg. 42;* (*Clause* 7.1.2.1)

| $(\lambda) = \frac{l_{eff}}{r_{min}} = KL/r$ ↓ | Yield Stress, $f_y$ (MPa) = 250 Mpa |
|---|---|
| 30 | 211 |
| 35 | ??? |
| 40 | 198 |

*Interpolation :*

$$\left\{ \frac{(211 - 198)}{(40 - 30)} \times (35 - 30) \right\} - 211$$

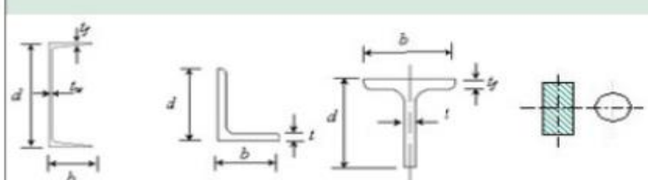
$$\therefore \ (f_{cd}) = 204.5 \ \frac{\text{N}}{\text{mm}^2}$$

$\therefore$ Compressive strength $= f_{cd} \times A_{gross}$

$= 204.5 \times (2 \times 4947) = 2023.32$ KN

$> 1100$ KN ; Safe

***IS 800 - 2007; Pg. 44; Table5.3 Buckling class of cross sections (Section 7.1.2.2)***

| Cross Section | Limits | Buckling about axis | Buckling Class |
|---|---|---|---|
| Channel, Angle, T and Solid Sections  | | Any | c |

**Problem 4)** Design economical built up column to carry 1100 KN using two channels back to back. The length of column is 5 mt. with both ends are held in position and only one end is restrained against rotation. Design a suitable **Battening system** ? Take $f_y = 250 \quad Mpa$

**Answer** : Given ;

a) Length of member (clear) = 5.00 mt = 5.00 $\times \ 10^3$ mm

Given case is **One End Fix And Other Is Hinge (case 02)**

$\therefore \ l_{eff}$ = KL = 0.8$\times$ 5$\times \ 10^3$ = 4.00 $\times \ 10^3$ mm

…………………………………………… *IS 800-2007; pg. 45*

Let. $\boldsymbol{\lambda}$ (slenderness ratio) = 70

For $f_y$=250; (compressive stress) $\sigma_{ac} = 152 \ {}^{N}/{}_{mm^2}$

…………………………………………… *IS 800-2007; pg. 42*

Area Reqd. For the strut ($A_{Req}$) = $\frac{1100 \times 10^3}{152}$ = 7236.84 mm$^2$

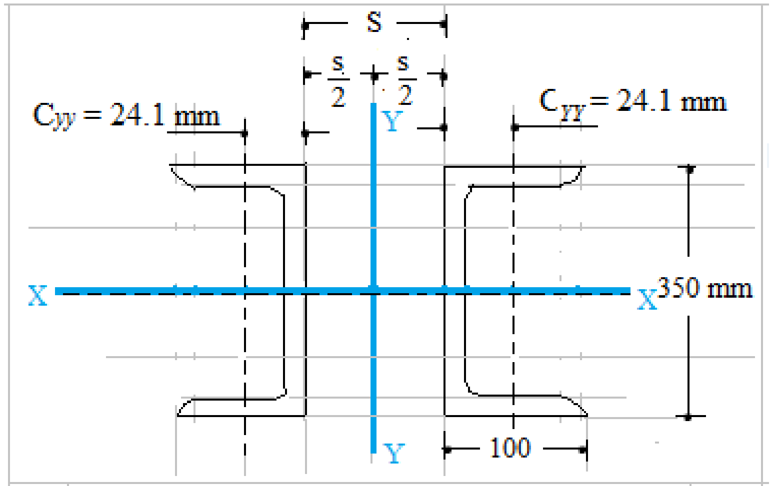
Area of Each angle = $\frac{7236.84}{2}$ = 3618.42 mm$^2$

Refer the steel table and select rolled steel channel ISLC 350 @ 38.8 $\frac{kg}{m}$

For this channel ; A = 4947 mm$^2$; width (b) = 100 mm ; $t_f$= 12.5 mm ; $t_w$= 7.4 mm; Center of gravity ; $C_{yy}$ = 24.1 mm ; guage distance ( $g^*$ ) = g = 60 mm

$I_{xx}$ = 9312.6 $\times \ 10^4$ mm$^4$ , $I_{yy}$ = 394.6 $\times \ 10^4$ mm$^4$;

$r_{xx}$ = 137.2 mm , $r_{yy}$ = 28.2 mm




For economical Built up column ; We have

$I_{xx\ (whole\ s/c)} = I_{yy\ (whole\ s/c)}$

$\therefore\ \cancel{2}\,(I_{xx\ (self)}) = \{I_{yy\ (self)} + A\,(h_t)^2\} \times \cancel{2}$

$9312.6 \times 10^4 = \{394.6 \times 10^4 + 4947\,(C_{yy} + \frac{S}{2})^2\}$

$\therefore\ S = 220.32$ mm say 222 mm

### *Step i) Actual L.C.C. Provided :*

$I_{xx\ (whole\ s/c)} = 2 \times 9312.6 \times 10 = 186.252 \times 10^6\ mm^4$

$I_{yy\ (whole\ s/c)} = \{394.6 \times 10^4 + 4947\,(C_{yy} + \frac{S}{2})^2\} \times 2 = 188.47 \times 10^6\ mm^4$

$I_{xx\ (whole\ s/c)} < I_{yy\ (whole\ s/c)}$ $\therefore\ I_{min} = I_{xx\ (whole\ s/c)} = 186.252 \times 10^6$

$$r_{min} = \sqrt{\frac{I_{min}}{A_{gross}}} = \sqrt{\frac{186.252 \times 10^6}{2 \times 4947}} = 133.20\ \text{mm}$$

$$\text{Now},\ (\lambda) = \frac{l_{eff}}{r_{min}} = \frac{4 \times 10^3}{133.20} = 30.03\ \text{say}\ 30$$

**Table 9(c) Design Compressive Stress, $f_{cd}$ (MPa) for Column Buckling Class c**

*IS 800-2007 ; Pg. 42; (Clause 7.1.2.1)*

| $(\lambda) = \frac{l_{eff}}{r_{min}} = KL/r$ ↓ | Yield Stress, $f_y$ (MPa) = 250 Mpa |
|---|---|
| 30.00 | 211 |

*Interpolation :*

$\{\frac{(\quad - \quad)}{(\quad)} \times (\quad)\}$-

$\therefore\ (f_{cd}) = 211\ \frac{N}{mm^2}$

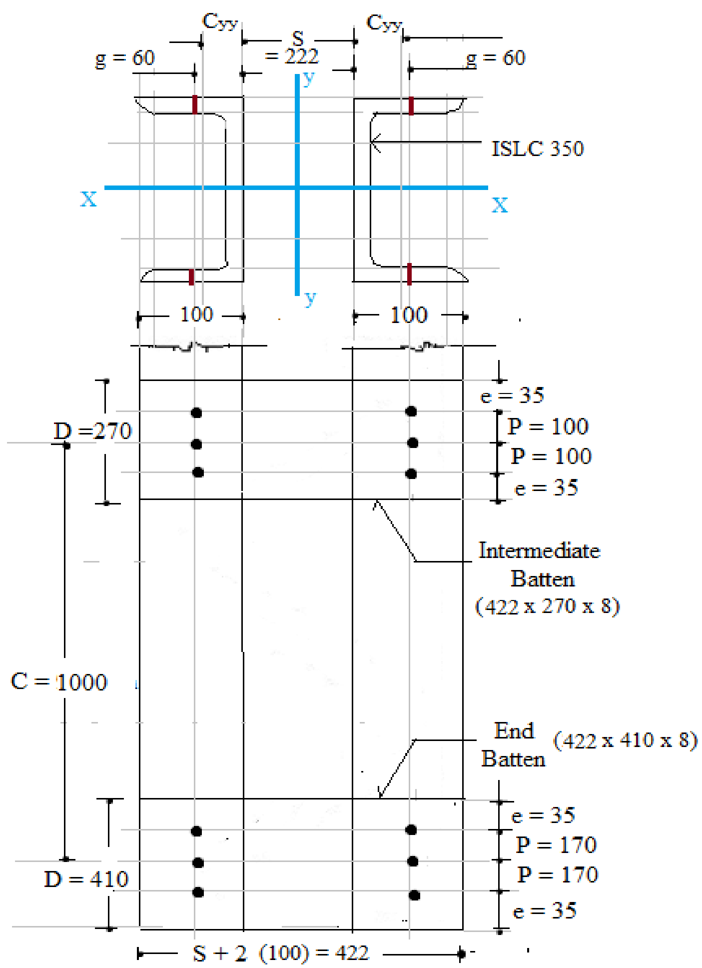
$\therefore$ Compressive strength $= f_{cd} \times A_{gross}$

$= 211 \times (2 \times 4947) = 2087.63$ KN

$> 1100$ KN ; Safe

### *Step ii) Design Of Battening :*

Let us provide single Battening system with bolted connection.




### *Step iii) Check for spacing as per IS 800-2007:*

$\left(\frac{C}{r_{min}}\right) \ngtr$ *i)* 50 and

$\ngtr$ *ii)* $0.7 \times (\lambda)_{group} = 0.7 \times 30 = 21$ ; Not safe

……………………………………………*cl 7.6.5 ; IS 800-2007; pg. 50*

$$\therefore \left(\frac{C_{req}}{r_{min}}\right) = \left(\frac{C_{req}}{r_{YY}}\right) = \frac{C_{req}}{28.2} = 21$$

$\therefore C_{req} = 28.2 \times 21 = 592$ mm ***and***

$$\left(\frac{C_{req}}{r_{min}}\right) = \left(\frac{C_{req}}{r_{YY}}\right) = \frac{C_{req}}{28.2} \ngtr 50$$

$$\therefore \ C_{req} = 28.2 \ x \ 50 = 1410 \ \ say\ 1000\ mm$$

$$\therefore \ C_{prov} = \ 1000\ mm$$

$\therefore$ No. of Battens =

$$\frac{l_{eff}}{C} = \frac{4.00 \ \times 10^3}{1000} = 04 \ \text{No.}$$

***Step iv) Design Of End Battens (Tie plate) :***

a) Effetive depth = d = S + 2 (g) = 222 + 2 (60) = 342 mm

For 20 mm Ø bolt ; Edge distance = e = 1.5 × $d_0$ = 1.5 x 22 = 33 mm

$\therefore D_{overall}$ = 342 + 2 (33) = 408 say 410 mm

≮ (S + 2 (g)) = 342 mm ; Safe

b) Width ≯ S = 222 say 225 mm

c) Thickness of End Battens = $\frac{1}{50}$ x (S + 2g)

............................................... *IS 800-2007; cl. 7.7.2.3 ; pg. 51*

$= \frac{342}{50}$ = 6.84 say 8 mm

Provide end Battens of 410 x 225 x 8 mm connected using 20 mm Ø bolt.

***Step v) Design Of Intermediate Batten :***

a) Effetive depth = d = $\frac{3}{4}$ x ( S + ( 2 Cyy )) = $\frac{3}{4}$ x 270.2 = 202.65 mm

For 20 mm Ø bolt ; Edge distance = e = 1.5 × $d_0$ = 1.5 x 22 = 33 mm

$\therefore D_{overall}$ = 202.65 + 2 (33) = 268.6 say 270 mm

b) Width ≯ S = 222 say 225 mm

c) Thickness of Intermediate batten = $\frac{1}{50}$ ( S + 2g )

=

............................................... *IS 800-2007; cl. 7.7.2.3 ; pg. 51*

$= \frac{342}{50}$ = 6.84 say 8 mm

***Step vi) Load / Force calculation as per IS 800-2007:***

a) Transverse shear (v) = 2.5 % of Axial Load

$= (2.5/100)$ x 1100 = 27.5 KN

b) Longitudinal shear ( $V_1$ )

$$(V_1) = \frac{V \times C}{N \times S} = \frac{27.5 \times 10^3 \times 1000}{2 \times 342} = 40.20 \text{ KN}$$

Where N = No. of parallel planes of battens = 2

c) Moment (M) ;

$$(M) = \frac{V \times C}{2 \times N} = \frac{27.5 \times 10^3 \times 1000}{2 \times 2} = 6875 \text{ KN}$$

………….......................cl. 7.7.2.1; *IS 800-2007; pg. 51*

***Step vii) Check For Stresses as per IS 800-2007:***

***a) End Batten :***

***i)*** **:** Shear stress ;

$$\frac{V1}{d \times t} = \frac{40.20 \times 10^3}{342 \times 8} = 14.70 \ N/mm^2$$

$$\not> \frac{f_y}{\sqrt{3} \times \gamma} = \frac{250}{\sqrt{3} \times 1.10} = 131.2 \ N/mm^2 \text{ ; Safe}$$

***ii)*** **:** Bending Stress ;

We have ; $\frac{M}{I} = \frac{\sigma}{y} \quad \therefore \ \sigma = \frac{M \ x \ y}{I} = \frac{M \ x \ d}{2 \ x \ \frac{t \ x \ d^3}{12}} = \frac{6 \ x \ M}{t \ x \ d^2}$

$$= \frac{6 \ x \ 6875 \ x \ 10^3}{8 \ x \ 342^2} = 44.08 \quad {}^{N}/_{mm^2}$$

➢ $\frac{F_y}{\gamma} = \frac{250}{1.1} = 227.27 \quad {}^{N}/_{mm^2}$ ; Safe

***b) Intermediate Batten :***

***i)*** **:** Shear stress ;

$\frac{V1}{d \ x \ t} = \frac{40.20 \ x \ 10^3}{202.62 \ x \ 8} = 24.80 \quad {}^{N}/_{mm^2}$

➢ $\frac{f_y}{\sqrt{3} \ x \ \gamma} = \frac{250}{\sqrt{3} \ x \ 1.10} = 131.2 \quad {}^{N}/_{mm^2}$ ; Safe

***ii)*** **:** Bending Stress ;

We have ; $\frac{M}{I} = \frac{\sigma}{y} \quad \therefore \ \sigma = \frac{M \ x \ y}{I} = \frac{M \ x \ d}{2 \ x \ \frac{t \ x \ d^3}{12}} = \frac{6 \ x \ M}{t \ x \ d^2}$

$$= \frac{6 \ x \ 6875 \ x \ 10^3}{8 \ x \ 202.65^2} = 125.55 \quad {}^{N}/_{mm^2}$$

➢ $\frac{F_y}{\gamma} = \frac{250}{1.1} = 227.27 \quad {}^{N}/_{mm^2}$ ; Safe

***Step viii) Design Of Connections :***

Let us provide 20 mm Ø bolt of grade 4.6

*a) Design Strength of bolt in Shear* $(Double\ shear)\ (V_{ds})$;

$V_{ds} = \{ 1/\gamma \ [\frac{F_u}{\sqrt{3}} (n_n \ A_{nb})] \}$

.........................................*IS 800-2007; cl. 10.3.3 ; pg. 75*

Ultimate stress for bolt material $F_u = F_{ub} = 400 \quad {}^{N}/_{mm^2}$

$n_n$ = No. of shear planes with threads intercepting shear planes.

= 2 (one bolt is passing from two Battening bars)

$A_{nb}$ = Net shear area of bolts at threads

$A_{nb} = 0.78 \ to \ 0.80 \times \frac{\pi}{4} \times d^2$

$= 0.78 \ to \ 0.80 \times \frac{\pi}{4} \times 20^2 = 251.32 \ mm^2$

$\therefore \ V_{ds}$ = 92.865 KN

∴ **Strength Of bolt =** $V_{ds}$ = 92.865 KN

No. Of Bolts Required = $\frac{V_1}{\text{Design strength}} = \frac{40.20}{92.865}$

= 0.432 say 03

***Step ix) Design for Bolts against***

***A) End Batten :***

***i) :*** Longitudinal (Vertical) shear :

$$\frac{V1}{no.of\ bolts} = \frac{40.20\ x\ 10^3}{03} = 13.4\ \text{KN}$$

***ii) :*** Horizontal shear due to moment ;

For 20 mm Ø bolts ;

$d_0$ = diameter of Bolt Hole = Ø + 2 = 20 + 2 = 22 mm

Edge Distance = e = 1.5 × $d_0$ = 1.5 x 22 = 33 say 35 mm

$$\text{Pitch} = \frac{d_{overall-2\,(e)}}{2} = \frac{410-2\,(35)}{2} = 170\ \text{mm}$$

$$\therefore\ \text{Horizontal shear} = \frac{M}{\sum Pitch^2} \times (Pitch)$$

$$= \frac{6875\ x\ 10^3}{2(170^2+170^2)} \times (170) = 10.110\ \text{KN}$$

$$\text{Resultant} = \sqrt{13.4^2 + 10.11^2} = 16.78\ \text{KN} < V_{ds} = 92.865\ \text{KN}$$

∴ Safe

***B) Intermediate Batten :***

***i) :*** Longitudinal (Vertical) shear :

$$\frac{V1}{no.of\ bolts} = \frac{40.20\ x\ 10^3}{03} = 13.4\ \text{KN}$$

***ii) :*** Horizontal shear due to moment ;

For 20 mm Ø bolts ;

$d_0$ = diameter of Bolt Hole = Ø + 2 = 20 + 2 = 22 mm

Edge Distance = e = 1.5 × $d_0$ = 1.5 x 22 = 33 say 35 mm

$$Pitch = \frac{d_{overall-2\,(e)}}{2} = \frac{270-2\,(35)}{2} = 100\ \text{mm}$$

$$\therefore\ \text{Horizontal shear} = \frac{M}{\sum Pitch^2} \times (Pitch)$$

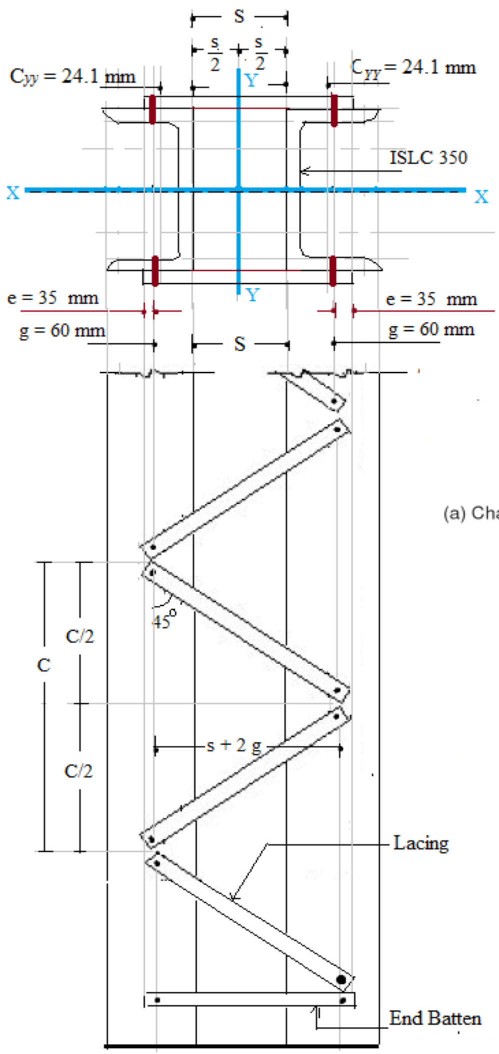
$$= \frac{6875\ x\ 10^3}{2(100^2+100^2)} \times (100) = 17.187\ \text{KN}$$

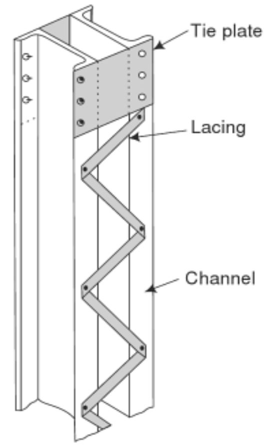
$$\text{Resultant} = \sqrt{13.4^2 + 17.187^2} = 21.80\ \text{KN} < V_{ds} = 92.865\ \text{KN}$$

∴ Safe

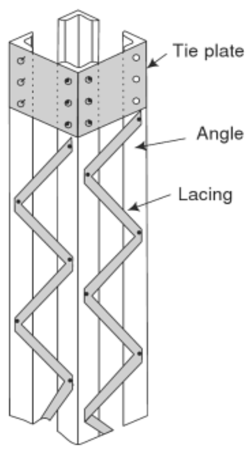
SEE FIGURE

# Sheet NO. 02 ( Lacing & Battening ) 8.

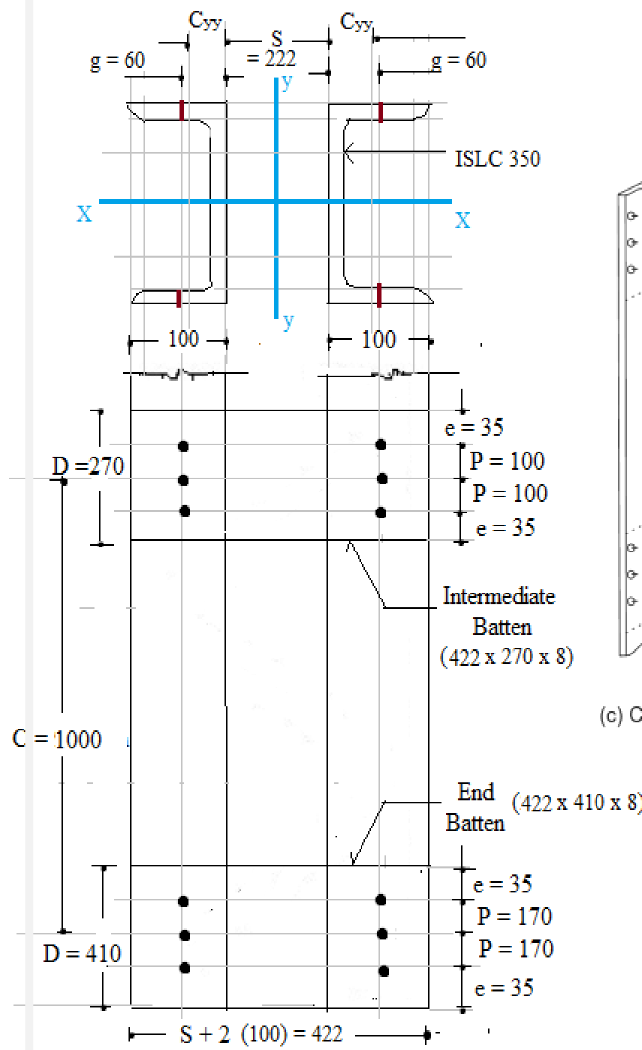


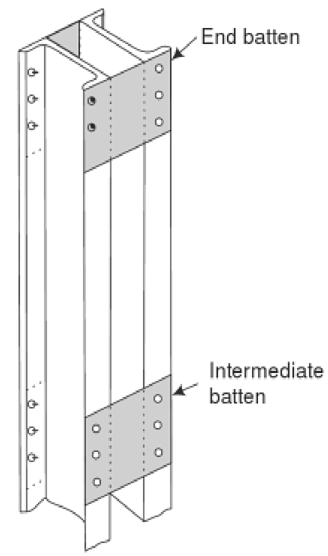




(a) Channels face-to-face connected by single lacing




(b) Angles connected by single lacing (shown on two faces only)




(c) Channels back-to-back connected by battens

**Problem 5)** Design economical built up column to carry 2000 KN using Four angles. The length of column is 6.4 mt. with both ends are held in position and one end is restrained against rotation. Design a suitable **Lacing / Battening also** ? Take $f_y = 250 \ \ Mpa$ *[Summer 2013 ]*

**Answer :** Given ;

a) Length of member (clear) = 6.4 mt = 6.4 $\times$ $10^3$ mm

Given case is **One End Fix And Other Is Hinge (case 02)**

$\therefore$ $l_{eff}$ = KL = 0.8$\times$ 5$\times$ $10^3$ = 5.12 $\times$ $10^3$ mm

……………........................................... *IS 800-2007; pg. 45*

Let. $\lambda$ (slenderness ratio) = 70

For $f_y$=250; (compressive stress) $\sigma_{ac}$ = 152 $^N/_{mm^2}$

……………......................... *IS 800-2007; pg. 42 ( See table )*

Area Reqd. For the strut

$(A_{Req}) = \frac{2000 \times 10^3}{152}$ = 13.57 X $10^3$ $mm^2$

Area reqd. of Each angle = $\frac{13.57 \text{ X } 10^3}{4}$ = 3289.47 mm$^2$

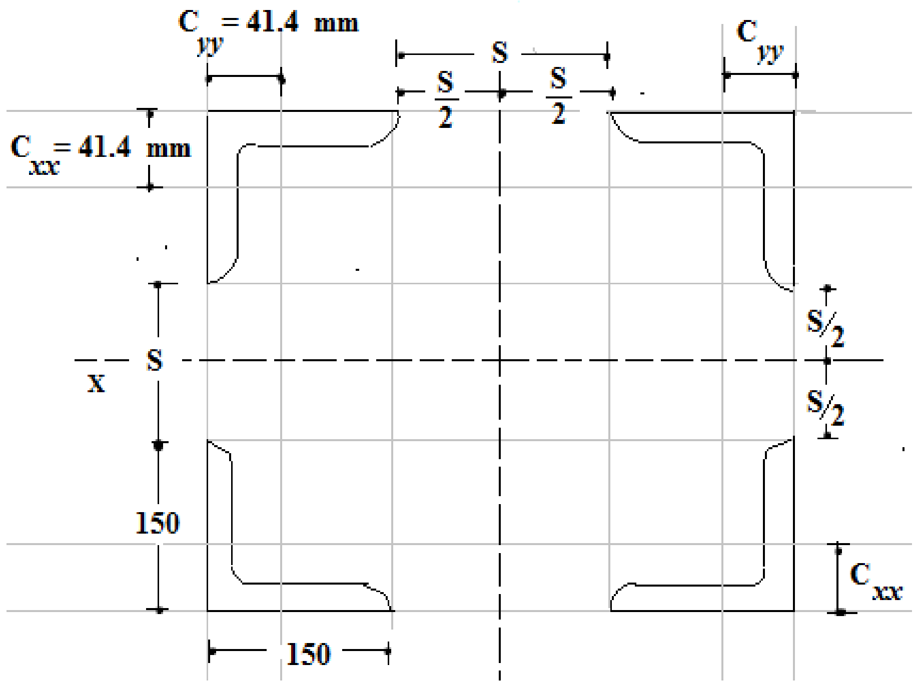
**Note : Always select Equal angle s/c for easy calculations**

Refer the steel table and select rolled steel equal angle such that $A_{prov} > A_{req}$ thus selecting ISA 150 x 150 x 12

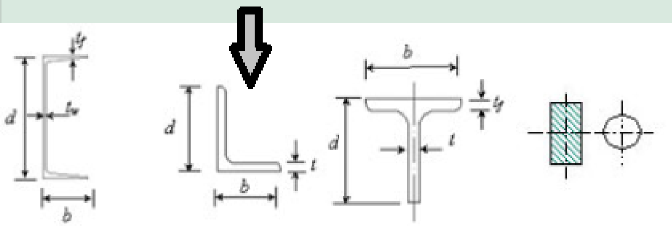
For this Angle ; Area = 3459 mm$^2$; width (b) = 150 mm ;

Center of gravity ; $C_{yy}$= $C_{XX}$ = 41.4 mm

Here, Area = 3459 > 3289.47 mm$^2$



*IS 800 - 2007; Pg. 44; Table5.3 Buckling class of cross sections (Section 7.1.2.2)*

| Cross Section | Limits | Buckling about axis | Buckling Class |
|---|---|---|---|
| Channel, Angle, T and Solid Sections  | | Any | c |

( λ ) **Table 9(c) Design Compressive Stress, $f_{cd}$ (MPa) for Column Buckling Class c** (*Clause* 7.1.2.1) ; Pg. 42 ; IS 800 - 2007

| $KL/r$ ↓ | Yield Stress, $f_y$ (MPa) = 250 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 200 | 210 | 220 | 230 | 240 | 250 | 260 | 280 | 300 | 320 | 340 | 360 | 380 | 400 |
| 10 | 182 | 191 | 200 | 209 | 218 | | 236 | 255 | 273 | 291 | 309 | 327 | 345 | 364 |
| 20 | 182 | 190 | 199 | 207 | 216 | | 233 | 250 | 266 | 283 | 299 | 316 | 332 | 348 |
| 30 | 172 | 180 | 188 | 196 | 204 | | 219 | 234 | 249 | 264 | 278 | 293 | 307 | 321 |
| 40 | 163 | 170 | 177 | 184 | 191 | | 205 | 218 | 231 | 244 | 256 | 268 | 280 | 292 |
| 50 | 153 | 159 | 165 | 172 | 178 | | 189 | 201 | 212 | 222 | 232 | 242 | 252 | 261 |
| 60 | 142 | 148 | 153 | 158 | 163 | | 173 | 182 | 191 | 199 | 207 | 215 | 222 | 228 |
| 70 | | | | | | 152 | 156 | 163 | 170 | 176 | 182 | 187 | 192 | 197 |
| 80 | 120 | 123 | 127 | 130 | 133 | 136 | 139 | 145 | 149 | 154 | 158 | 162 | 165 | 169 |

M. I. ; $I_{xx} = I_{yy} = 735.4 \times 10^4$ mm$^4$;

Radius Of Gyration ; $r_{xx} = r_{yy} = 46.1$ mm

We have ; $\lambda = \frac{l_{eff}}{r_{min}}$ ; $70 = \frac{5.12 \times 10^3}{r_{min}}$

$$r_{min} = 73.142 \text{ mm}$$

Again We have ; $r_{min} = \sqrt{\frac{I_{min}}{A}}$ $\therefore$ $I_{min} = A \, x \, r_{min}{}^2$

$\therefore$ $I_{min}$ = (4 x 3459) x $73.142^2 = 74.01 \times 10^6 \, mm^4$

Now, Finding actual M. I. of the S/C And Comparing With $I_{min} = 74.01 \times 10^6 \, mm^4$ ; We will get spacing (S)

$\therefore$ $74.01 \times 10^6 = 4 \, [\, I_{xx(self)} + \text{Area}\,(distance^2)\,]$

$74.01 \times 10^6 = 4\,[\,735.4 \times 10^4 + 3459\,(\frac{S}{2} + (150 - 41.4))^2]$

Find S = spacing and carry steps in lacing and battening