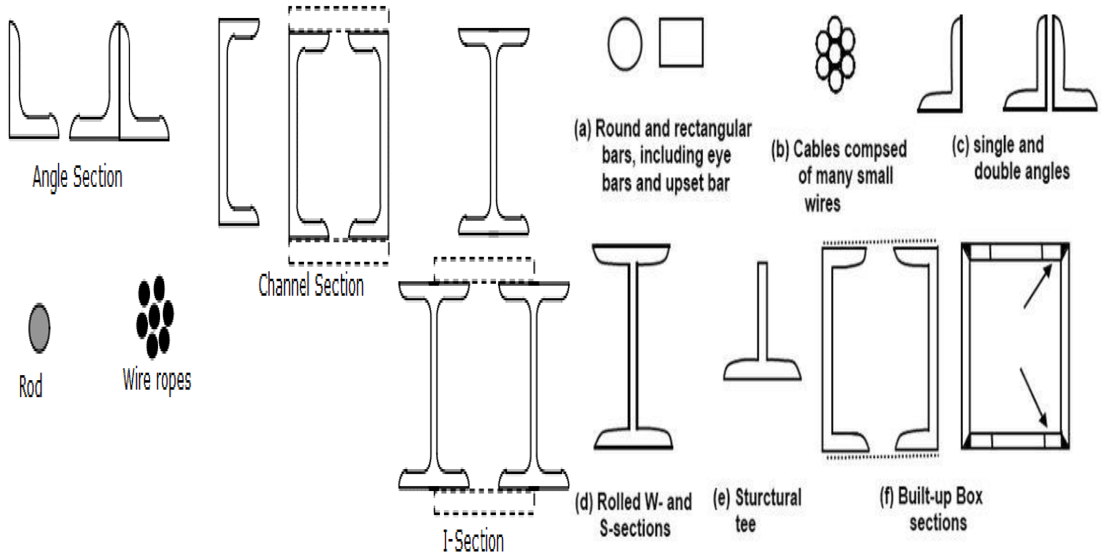
Built up section for tension members

Built up section are members made up by a fabricator from two or more standard sections as shown in the Fig. below



BUILT UP TENSION MEMBERS

Built up tension members: are structural members subjected to axial tension load, built up tension members used when:

- Tensile load capacity is not sufficient
- Slenderness ratio (l/r) does not satisfy (does not provide sufficiently rigidity)
- Required large stiffness, when there is combined effect from bending and tension
- Required large stiffness, when there is combined effect from bending and tension
- Unusual connection detail
- Esthetic control

AISC limitation for built up tension members

- They are tension members consist of 2 or more single members in separate or continuous contact with each other
- Components of a built-up tension member should be connected at frequent intervals to ensure that they act together, that faying surfaces intended to be in contact stay in contact, that excessive vibration of relatively thin parts does not occur, and that moisture will not penetrate between faying surfaces and cause corrosion
- For tension member built of separate elements, the elements should be connected by plates or other steel shapes in interval that the slenderness ratio of individual shape not exceed 300
- Provisions for lacing and tie plates, perforated cover plates, and fasteners, except those provisions intended specifically for compression members, are the same as for built-up compression members

Summary and Limitation and requirements for built up tension members

1-Find the allowable tensile load

LRFD Method	ASD Method
- Depending on the yielding strength $\theta Pn = \theta \sum Agx\ Fy$ where: θ= 0.9 $\sum Ag$ =summation of gross area for segments parts for built up section Fy =Minimum yielding stress	- Depending on the yielding strength $\frac{Pn}{\Omega} = \frac{\sum Agx\ Fy}{\Omega}$ where: Ω= 1.67 $\sum Ag$ =summation of gross area for segments parts for built up section Fy= Minimum yielding stress
- Depending on the rupture g strength $\theta Pn = \theta \sum Aex\ Fu$ where: θ= 0.75 $\sum Ae$ =summation of effective net area for segments parts for built up section $Ae = UxAn$ Where U= shear lag factor An= minimum net area $An = Ag\text{-} t\sum \left(Diam.\ of\ bolt + \frac{1}{8}\right) + t\sum \frac{s^2}{4g}$ $An = Ag\text{-} t\sum \left(Diam.\ of\ hole \frac{1}{16}\right) + t\sum \frac{s^2}{4g}$ Fu =Minimum tensile stress	- Depending on the rupture g strength $\frac{Pn}{\Omega} = \frac{\sum Aex\ Fu}{\Omega}$ where: Ω= 2 $\sum Ae$ =summation of effective net area for segments parts for built up section $Ae = UxAn$ Where U= shear lag factor An= minimum net area $An = Ag\text{-} t\sum \left(Diam.\ of\ bolt + \frac{1}{8}\right) + t\sum \frac{s^2}{4g}$ $An = Ag\text{-} t\sum \left(Diam.\ of\ hole \frac{1}{16}\right) + t\sum \frac{s^2}{4g}$ Fu =Minimum tensile stress
θPn yielding θPn Rupture } Choose minimum value	$\frac{Pn}{\Omega}$ yielding $\frac{Pn}{\Omega}$ Rupture } Choose minimum value

2-Find the slenderness ratio for built up section

Find $I_{x\text{-}x}$, $I_{y\text{-}y}$, for single segment and h1, h_2, d_1, d_2

Where:

$I_{x\text{-}x}$, $I_{y\text{-}y}$: moment of inertia about X and Y axis (in^4) respectively

h_1, h_2: outside dimensions for built up section (in)

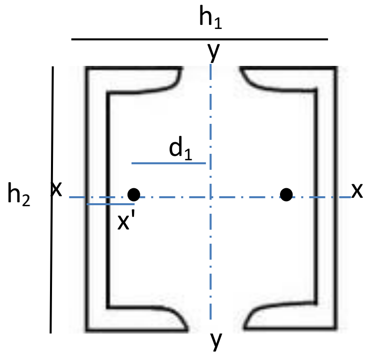
d_1, d_2: distance from the centroid of segment to the centroid of built up section (in)

$I_{(x\text{-}x)}$ group=$\sum$I x-x for segment + $(A.d_2)^2$

$I_{(y\text{-}y)}$ group =$\sum$I y-y for segment+ $(A.d_1)^2$

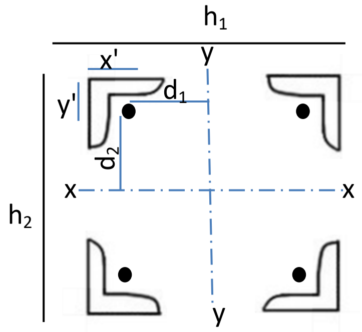
For example

A double channel at dimension ($h_1 x h_2$)



$I_{(x-x)}$ group=$\sum I_{x-x}$ for segment + A. $(d_2)^2$)
$I_{(x-x)}$ group=2. (I_{x-x} for segment + 0)
$I_{(x-x)}$ group= 2. (I_{x-x} for segment)
$I_{(y-y)}$ group =$\sum I_{y-y}$ for segment+ A.$(d_1)^2$
$I_{(y-y)}$ group =2. (I_{y-y} for segment+ (A. $(h_1 - x')^2$

For four angles at dimension ($h_1 x h_2$)



$I_{(x-x)}$ group=$\sum$I x-x for segment + A. $(d_2)^2$
$I_{(x-x)}$ group= 4. (I x-x for segment + A. $(\frac{h2}{2} - y')^2$))
$I_{(y-y)}$ group =$\sum$I y-y for segment+ A.$(d_1)^2$
$I_{(y-y)}$ group =4. (I x-x for segment + A. $(\frac{h1}{2} - x')^2$)

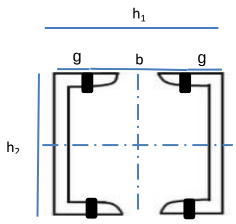
$I_{(x-x)}$ group
$I_{(x-x)}$ group } Use min. value I_{min}

(r_{min}) group $= \sqrt{\frac{Imin}{\sum Ag}}$

$(\frac{L}{rmin})_{group} \leq 300$ OK

3- Design of the tie plate

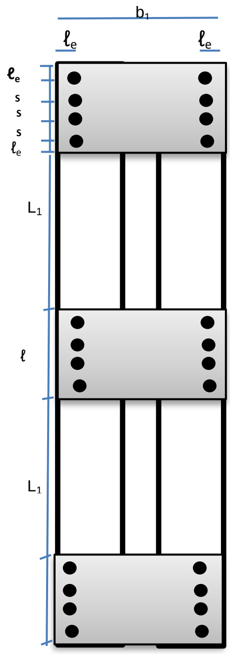
a- find the distance between centers to center of connectors (b)



b= h- 2 g
g=distance from external edge of section to the center of bolt diam.

b- Find the width of a tie plate (b_1)

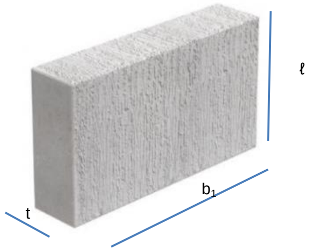
b_1= minimum width of a tie plate
ℓe = minimum edge distance from table (J3-4) P.P 107 (M2)
b_1= b+ 2.ℓe ≤ outside dimension ($h_1$or h_2)



c- Find minimum length of a tie plate ℓ = $\frac{2}{3}$ b ≥ (n-1) S + 2.ℓe

d- Find minimum thickness of a tie plate = $\frac{1}{50}$ b

e- Find the distance between of a tie plate (L_1)



$L_1 \leq \frac{300xrminfor\ single\ segments}{12}$

Use **tie plate ($txb_1xℓ$)@L_1**

Sect. J3.]   BOLTS AND THREADED PARTS   107

TABLE J3.4
Minimum Edge Distance,[a] in., from Center of Standard Hole[b] to Edge of Connected Part

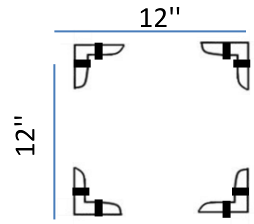
Bolt Diameter (in.)	At Sheared Edges	At Rolled Edges of Plates, Shapes or Bars, or Thermally Cut Edges [c]
1/2	7/8	3/4
5/8	1 1/8	7/8
3/4	1 1/4	1
7/8	1 1/2 [d]	1 1/8
1	1 3/4 [d]	1 1/4
1 1/8	2	1 1/2
1 1/4	2 1/4	1 5/8
Over 1 1/4	1 3/4 × d	1 1/4 × d

[a] Lesser edge distances are permitted to be used provided provisions of Section J3.10, as appropriate, are satisfied.
[b] For oversized or slotted holes, see Table J3.5.
[c] All edge distances in this column are permitted to be reduced 1/8 in. when the hole is at a point where *required strength* does not exceed 25 percent of the maximum strength in the element.
[d] These are permitted to be 1 1/4 in. at the ends of *beam connection angles* and shear end plates.

Example

For 40 ft. built up tension member consist of four angles(4L4x4x1/2) useA36 steel material use LRFD method to determine:-

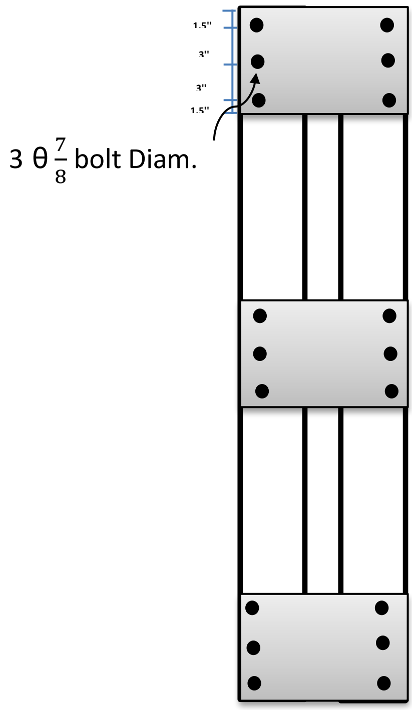
1-allowable tensile design capacity
2-check the slenderness ratio
3-design the tie plate dimension



Solution

Steel	fy	fu
A36	36	58

Section	Ag	x'=y'	$I_{x-x}=I_{y-y}$	rz
L 4x4x1/2	3.75	1.18	5.52	0.776



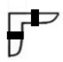
1-Allowable tensile design capacity

a-Depending on the(gross area) yielding strength -

θPn=θ∑Agx Fy
=0.9x4x3.75x36 =486 kips

b- Depending on the rupture g strength

θPn=θ∑Aex Fu
=0.75 ∑Aex Fu
U= 1 (connection in two legs)



An=Ag- t∑(Diam. of bolt+1/8)+t∑s^2/4g
An=3.75- 1/2x2x (7/8+1/8) +0
=2.75 in^2
Ae=UAn
=1x 2.75=2. 75 in^2
θPn=0.75x4x2.75= 478.5 kips

Allowable tensile design capacity= 478.5 kips

2-Check the slenderness ratio

$I_{(x-x)} = I_{(y-y)}$, x'=y' (equal legs)

$I_{group} = \sum I$ *for segment* $+ (A.(d_2)^2)$

$= 4\,(5.52 + 3.75\,(\frac{12}{2} - 1.18)^2) = 370.0566\ In^4$

$r_{min} = \sqrt{\frac{Imin}{\sum Ag}} = \sqrt{\frac{370.566}{4x3.75}} = 4.97\ in$

$$\frac{L}{rmin} = \frac{40x12}{4.97} = 96.58 < 300 \quad \text{OK}$$

3-Design of the tie plate dimension

a- find the distance between centers to center of connectors (b)

g=2.5 (table P.P (1-46) M1

b= h- 2g= 12- 2x2.5 =7 in

b- Find the width of a tie plate (b_1)

ℓe = minimum edge distance from table (J3-4) P.P 107 (M_2)

θ= 7/8 ⟶ ℓe = 1.5 in

$b_1 = 7 + 2x1.5 = 10 \leq 12$ OK

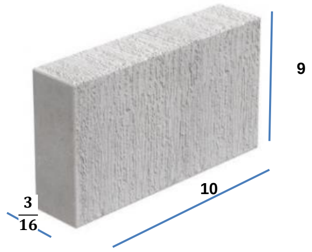
c- Find minimum length of a tie plate ℓ = $\frac{2}{3}$ b ≥ (n-1) S + 2.ℓ_e

$\ell = \frac{2}{3}\,x\,7 = 4.66 < (3-1)\,x3 + 2x1.5 = 9$

Use ℓ = 9 in

d- Find minimum thickness of a tie plate = $\frac{1}{50}$ b

$t = \frac{1}{50}x7 = 0.14x\frac{16}{16} = \frac{2.24}{16} = \frac{3}{16}$



e- Find the distance between of a tie plate (L_1)

$L_1 \leq \frac{300xrmin\text{for single segments}}{12}$ (r_z=0.766)

$L_1 \leq \frac{300x0.776}{12}$ =19.4 ft.

Use 18.875 ft.

Use tie plate ($\frac{3}{16}$x 10 x 9)@18.875 ft.

Workable Gages in Angle Legs, in.														
Leg	8	7	6	5	4	3½	3	2½	2	1¾	1½	1⅜	1¼	1
g	4½	4	3½	3	2½	2	1¾	1⅜	1⅛	1	7/8	7/8	3/4	5/8
g_1	3	2½	2¼	2										
g_2	3	3	2½	1¾										

Note: Other gages are permitted to suit specific requirements subject to clearances and edge distance limitations

Homework

1 -resolve the above example by use ASD

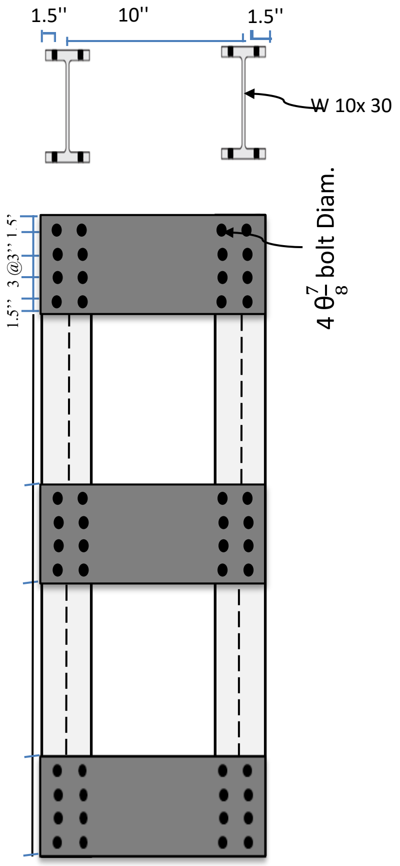
Example

For 70 ft. built up tension member consist of (2W10x30) useA992 steel material use LRFD method to determine:-

1-Allowable tensile design capacity

2-Check the slenderness ratio

3- Design the tie plate dimension



Solution

Steel	fy	fu
A992	50	65

Section	Ag	d'	b_f	t_f	r_x	I_{x-x}	r_y	I_{y-y}
W10x 30	8.84	10.5	5.81	0.510	4.38	170	1.37	16.7

	x'=y'
WT5x15	1.10

1-allowable tensile design capacity

a- Depending on the yielding strength

$\theta Pn = \theta \sum A_g \times F_y$

$= 0.9x2x\ 8.84x50 = 795.6$ kips

b- Depending on the rupture g strength

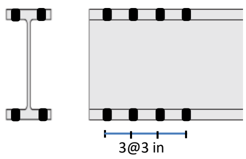
$\theta Pn = \theta \sum Aex\ Fu$

$= 0.75 \sum Aex\ 65$

U= 0.85
- W shape
- Connection in flange
- No. of bolt>3 in each line
- bf $< \frac{2}{3}$ d
- 5.81<7

$U = 1 - \frac{x'}{l}$

$U = 1 - \frac{1.10}{9} = 0.877$



Use U=0.877

$An = Ag - t\sum(\text{Diam. of bolt} + 1/8) + t\sum S^2/4g$

$An = 8.84 - 0.51x4x\,(7/8+1/8) + 0$

$= 6.8\ in^2$

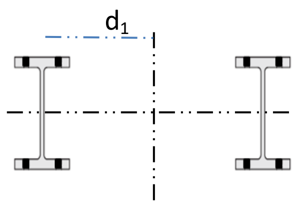
Ae=UAn

$= 0.877x\ 6.8 = 5.968\ in^2$

$\theta Pn = 0.75x2x5.963x65 = 581.96$ kips control

Allowable tensile design capacity= 581.96 kips

2-Check the slenderness ratio



$I_{(x\text{-}x)\ group} = \sum I_{x\text{-}x} + A.d_2^2 \qquad d_2 = 0$

$= 2(170 + 8.84 \times (0)) = 340\ In^4$ control

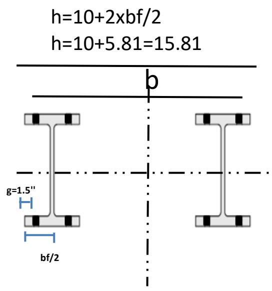
$I_{(y\text{-}y)\ group} = \sum I_{y\text{-}y} + (A.d_1^2) \qquad d_1 = \frac{10}{2} = 5\ in$

$= 2(16.7 + 8.841x(5)^2)) = 475.4\ In^4$

$r_{min} = \sqrt{\frac{Imin}{\sum Ag}} = \sqrt{\frac{340}{2x8.84}} = 4.385\ in$

$$\frac{L}{rmin} = \frac{70x12}{4.385} = 191.56 < 300 \quad \text{OK}$$

3-Design the tie plate dimensions



a- find the distance between centers to center of connectors (b)
distance from edge=1.5 in

b= 10+ 2 $(\frac{bf}{2} - g)$ = 10+ 2 x $(\frac{5.81}{2} - 1.5)$ =12.81 in

b- Find the width of a tie plate (b_1)

ℓe = minimum edge distance from table (J3-4) P.P 107 (M_2)

θ= 7/8 ⟶ ℓe = 1.5 in

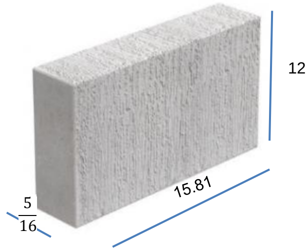
b_1 = 12.81+ 2x1.5 =15.81 = h OK

c- Find minimum length of a tie plate ℓ = $\frac{2}{3}$ b ≥ (n-1) S + 2.ℓ_e

ℓ = $\frac{2}{3}\, x$ 12.81 = 8.54 < (4-1) x3 + 2x1.5=12

Use ℓ = 12 in

d- Find minimum thickness of a tie plate = $\frac{1}{50}$ b



t = $\frac{1}{50}$x12.81 =0.2562= $\frac{0.2562x16}{16} = \frac{4.0992}{16} = \frac{5}{16}$

e- Find the distance between of a tie plate (L_1) , (ry=1.37)

$L_1 \le \frac{300xrmin \text{ for single segments}}{12}$

$L_1 \le \frac{300x1.37}{12}$ =34.25 ft

Use 33.5 ft

Use tie plate ($\frac{5}{16}$x15.81x12)@33.5ft

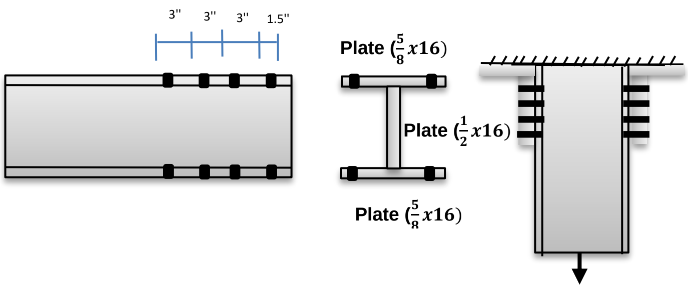
Example

For 50 ft built up tension member consist of three plates as shown below connected by 8 θ $\frac{7}{8}$ bolt diam. @ spacing 3''center to center In each plate flange, useA36 steel material and use LRFD method to determine:-

1-Allowable tensile design capacity

2-Check the slenderness ratio

Steel	fy	fu
A36	36	58



Section

Plate ($\frac{5}{8}x16$)

Plate ($\frac{1}{2}x16$)

1-Allowable tensile design capacity

a- Depending on the yielding strength

θPn= θ∑ Ag x Fy

=0.9x (2x ($\frac{5}{8}x16$)+ ($\frac{1}{2}x16$))x36 =907.2 kips b- Depending on the rupture g strength

θPn=θ∑ Ae x Fu

=0.75 ∑Ae x 58

An=Ag- t∑(Diam. of bolt+1/8)+t∑S2/4g

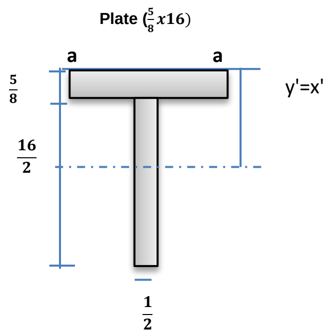
An=(2x($\frac{5}{8}x16$)+ ($\frac{1}{2}x16$)) $-$ $\frac{5}{8}$x4x (7/8+1/8) +0

=25.5 in^2

U= $1-\frac{x'}{l}$

Y'=x'= $\frac{\sum M@a-a}{\sum Ag}$

$=\frac{\left(\frac{5}{8}x16\,x\frac{5}{2x8}\right)+\left(\frac{1}{2}\ x\,8\,x(\frac{8}{2}+(\frac{5}{8})\right)}{(\frac{5}{8}x16+\frac{1}{2}x8\ )}$



X' =1.544

x'= $1-\frac{1.544}{9}$ =0.828

Ae=UAn

=0.828x 25.5=21.11 in^2

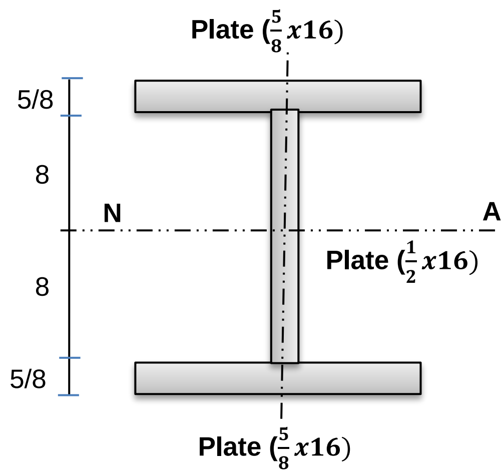
θPn=0.75x21.11x 58= 918.28 kips   control

Allowable tensile design capacity= 907 kips

2- Check the slenderness ratio

I (x-x) group=∑I x-x + (A.d 2)

$= 2\left(\frac{(\frac{5}{8})^3\ x\ 16}{12} + \left(\frac{5}{8}\right)x16\,x\left(8+\frac{5}{2x8}\right)^2\right) + \frac{16^3\ x\ \frac{1}{2}}{12}$



=1553.27 in^4

I (y-y) group=∑I y-y + (A.d2)

$= 2x\left(\frac{\left(\frac{5}{8}\right)x\,16^3}{12}\right) + \frac{16\ x\left(\frac{1}{2}\right)3}{12}$

= 427 in^4 controls

$r_{min}=\sqrt{\frac{427}{28}}$ $= 3.905\ in$

$\frac{L}{rmin}=\frac{50x12}{3.905}=153.65<300$ **the slenderness ratio is OK**

Homework

For 80 ft. built up tension member consist of (2MC 12x50) useA36 steel material by $4\ \theta \frac{7}{8}$ bolt diam. @ spacing 3''center to center In each flange use LRFD method to determine:-

1-Allowable tensile design capacity

2-Check the slenderness ratio

3- Design the tie plate if g = bf/2

4- Determine the number of tie plate, which it be used if slenderness ratio of component is not exceed 200