DESIGN OF STEEL STRUCTURES

BASIC LECTURES

ON

STRUCTURAL STEEL

FOR

FOURTH STAGE

IN CIVIL ENGINEERING COLLEGE

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BUILT UP COMPRESSION MEMBERS

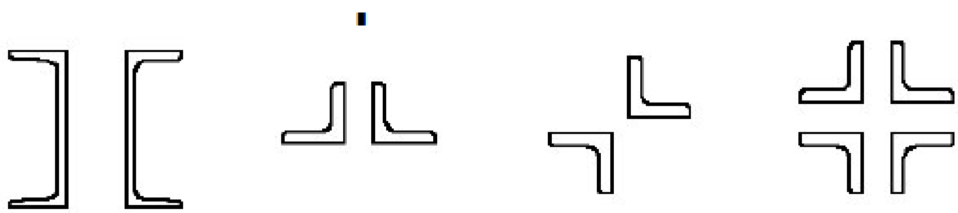
LECTURE # 05

BUILT UP COMPRESSION MEMBERS

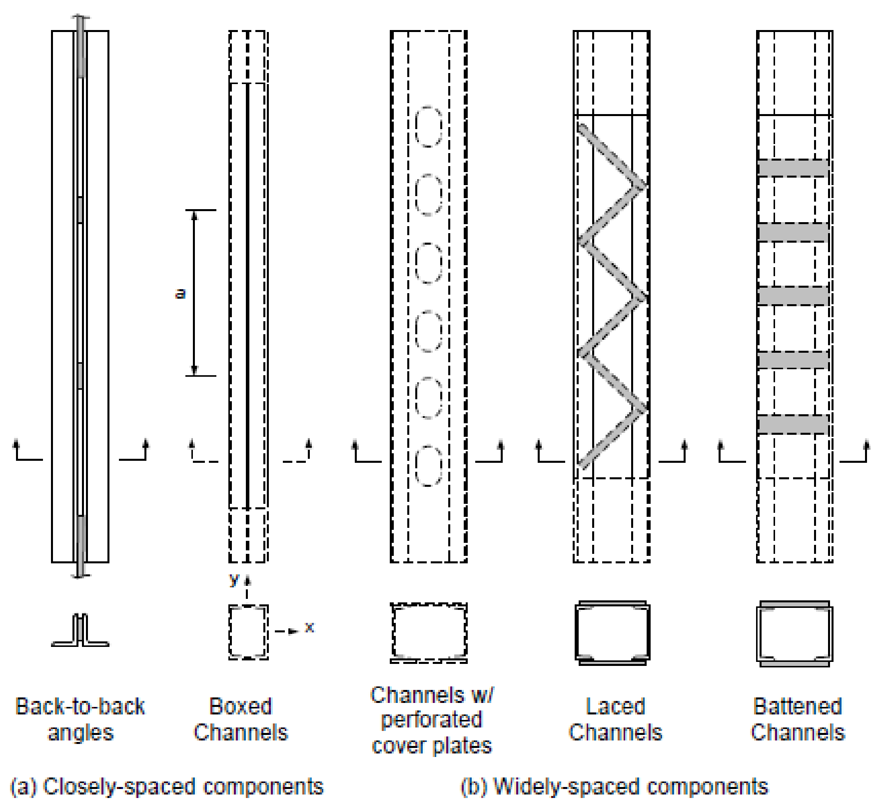
Part 16-1 / Pg. 32 / chapter E

<u>Introductions:</u>

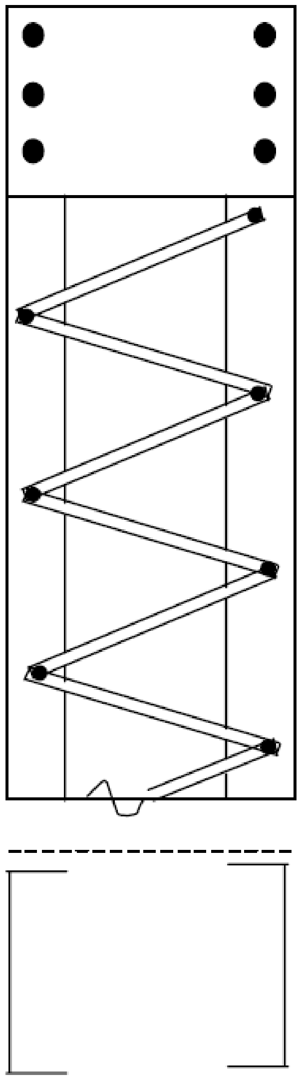
When compression members are required for large structures like bridges, it will be necessary to use built-up sections. They are particularly useful when loads are heavy and members are long (e.g. top chords of Bridge Trusses). So any members closely or widely spaced with two or more elements are called built up compression member as illustrated in figures below.



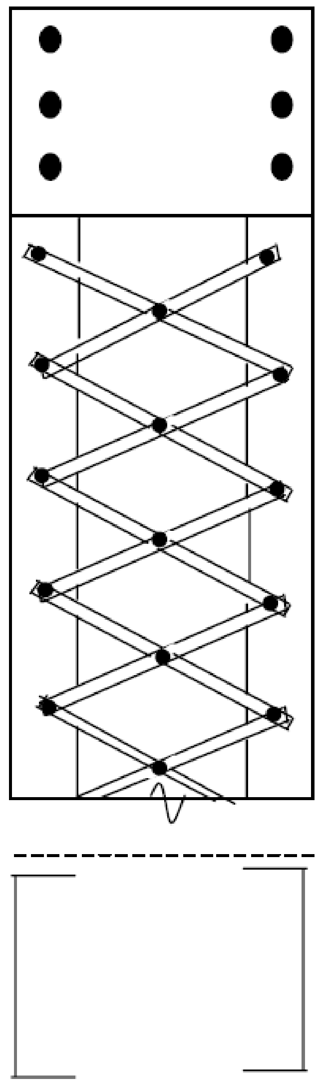
Some of closely spaced built up members



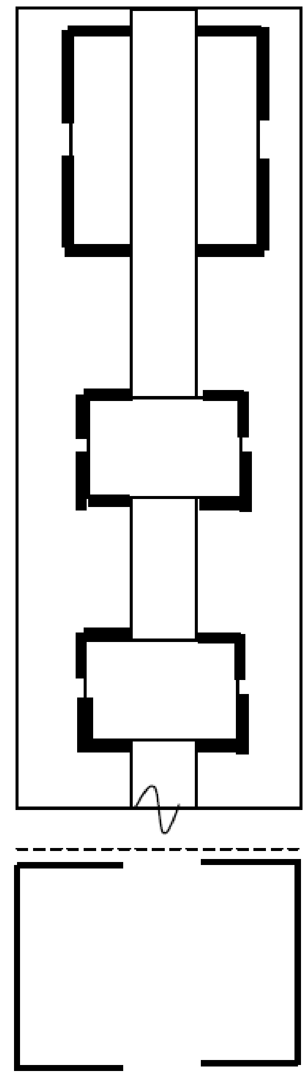
Types of built up compression members



(a) Single Lacing



(b) Double Lacing



(c) Battens

Limitations:

1- Mostly built up type are the latticed columns.
2- There are no tables for built-up shapes in the Manual, due to the number of possible geometries. This section makes suggestions as to how select built-up members to avoid slender elements, thereby making the analysis relatively straightforward.
3- The design of built-up shapes with slender elements can be tedious and time consuming, and it is recommended that standard rolled shapes be used, when possible.
4- The total strength is the summation of strength of elements. $P = \Sigma pi$

5- To select the section:

- Assume kL/ry = (50 -100).
- Then use table (4-22) to find Øc Fcr,
- Then calculate Areq = Pu / Øc Fcr.
- Then open AISC steel manual to select section with (Ag > Areq).

6- The design compressive strength, ØcPn, should be determined as follow:
Pn = nominal compressive strength based on the controlling buckling mode.

(LRFD)
Øc = 0.90

7- To prevent local buckling of unsupported lengths between the two constituent lattice points (or between two battens), the slenderness ratio:

$$\left(\frac{\mathrm{kl}}{\mathrm{r}}\right) of\ single\ element \leq \frac{3}{4}\left(\frac{kL}{r}\right) of\ whole\ built\ up\ member.$$

8- Lacing should be used to hold segments together & support lateral load.
If b\` ≤ 15" → single lacing & inclination with horizontal direction α is 30°
If b\` > 15" → double lacing & α is 45°
Where b\` is distance between connections.

[As in AISC –16.1 Sec E7 / page 39, the inclination of lacing bars to the axis of the member shall preferably be not less than 60◦ for single lacing and 45◦ for double lacing. When the distance between the lines of welds or fasteners in the flanges is more than 15 in., the lacing shall preferably be double or be made of angles].

9- For slender ratio:
L/r ≤ 140 for single lacing with k = 1.0
L/r ≤ 200 for double lacing with k = 0.7

10- The load that these tying forces cause is generally assumed to cause a shearing force equal to 2% of axial load on the column. V = 2% P on each side.

11- Tie plates:

For end tie plate;

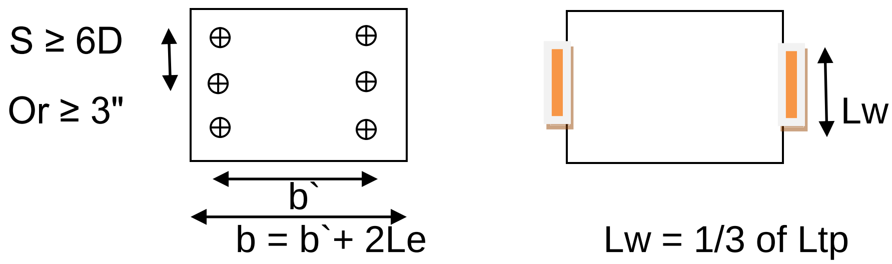
- The end tie plates shall have a length of not less than the distance between the lines of fasteners or welds connecting them to the components of the member. (Ltp ≥ b`).
- The thickness of tie plates shall be not less than one-fiftieth of the distance between lines of welds or fasteners connecting them to the segments of the members (ttp ≥ $1/50\ of\ b$`).

For intermediate tie plate;

- The intermediate tie plate shall have a length not less than one-half the distance between the lines of fasteners or welds connecting them to the components of the member.(Ltp ≥ $\frac{1}{2}$b`).
- The thickness of tie plates shall be not less than one-fiftieth of the distance between lines of welds or fasteners connecting them to the segments of the members (ttp ≥ $\frac{1}{50}\ of\ b$`).

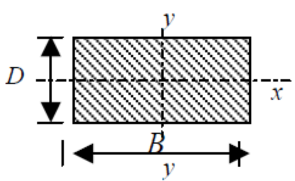
The width of tie plate in both end & intermediate plate shall be equal to distance between connectors with not less than minimum edge distance (wtp = b`+2(Le)).

Fastening of tie plate with main segments; the total welding on each line connecting a tie plate shall not be less than one-third the length of the plate. In bolted construction, the spacing in the direction of stress in tie plates shall be not more than six diameters and the tie plates shall be connected to each segment by at least three fasteners.

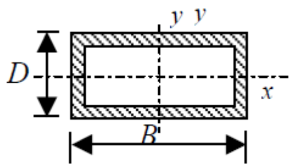


12 - From the following table, which include steel shapes as built up members, we can find the approximate radius of gyration depending on width of both directions.

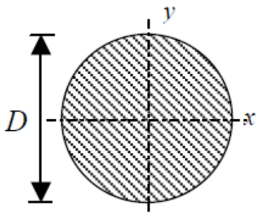
Table for calculating approximate radius of gyration (rx & ry)



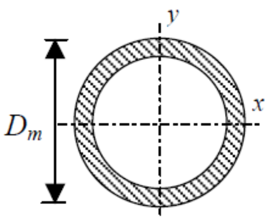
$r_x = 0.29\ D$
$r_y = 0.29\ B$



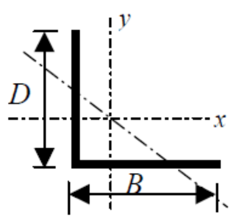
$r_x = 0.4\ D$
$D_m =$ mean D



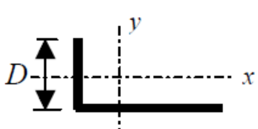
$r = 0.25\ D$



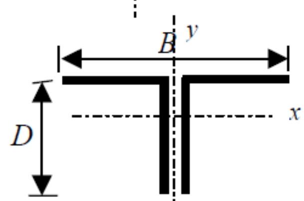
$r = 0.35\ D_m$



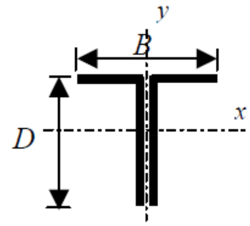
$r_x = r_y = 0.31\ D$
$r_z = 0.197\ D$



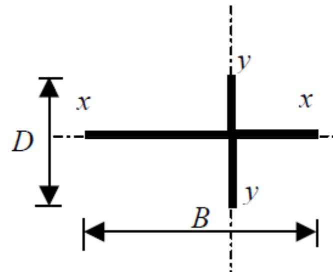
$r_x = 0.29\ D$
$r_y = 0.32\ B$



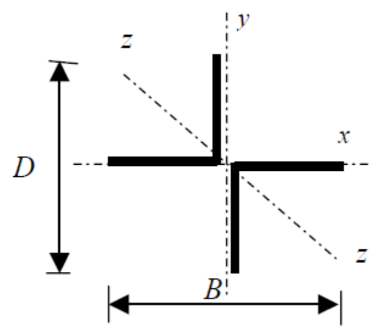
$r_3 = 0.18(D+B)/2$



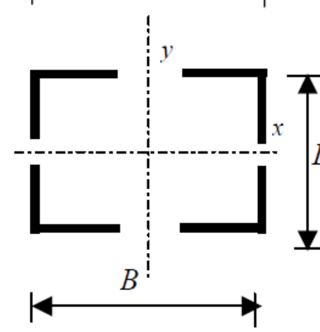
$r_x = 0.31\ D$
$r_y = 0.215\ B$
$= B\ (0.21+0.025)$



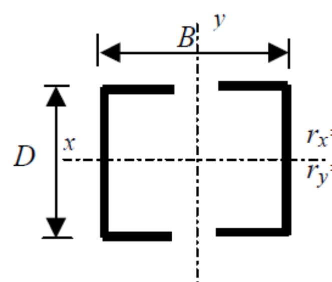
$r_x = 0.21\ D$
$r_y = 0.21\ B$
$r_z = 0.19\ D$



$r_x = 0.32\ D$
$r_y = 0.21\ B$
$= B\ (0.19 + 0.025$



$r_x = 0.42D$
$r_y = 0.42B$



$r_x = 0.36\ D$
$r_y = 0.45\ B$

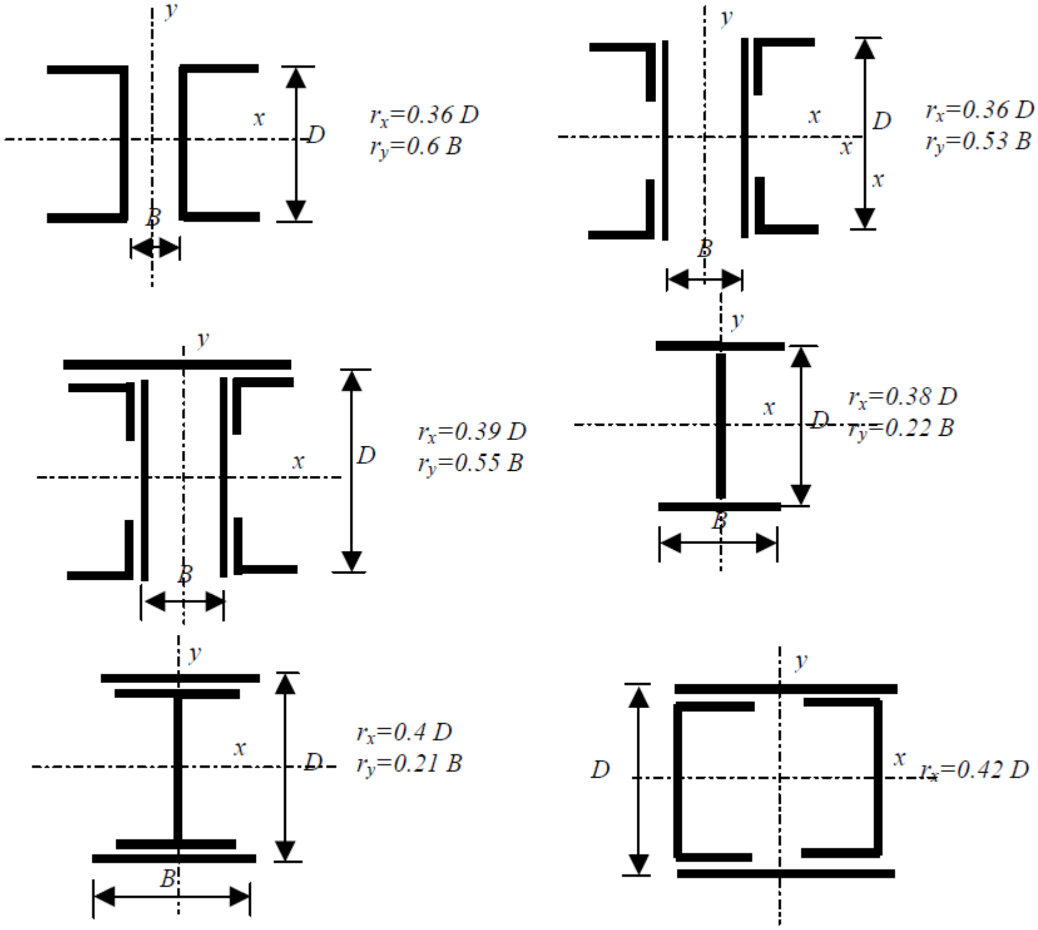


TABLE J3.4
Minimum Edge Distance,[a] in., from Center of Standard Hole[b] to Edge of Connected Part

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.

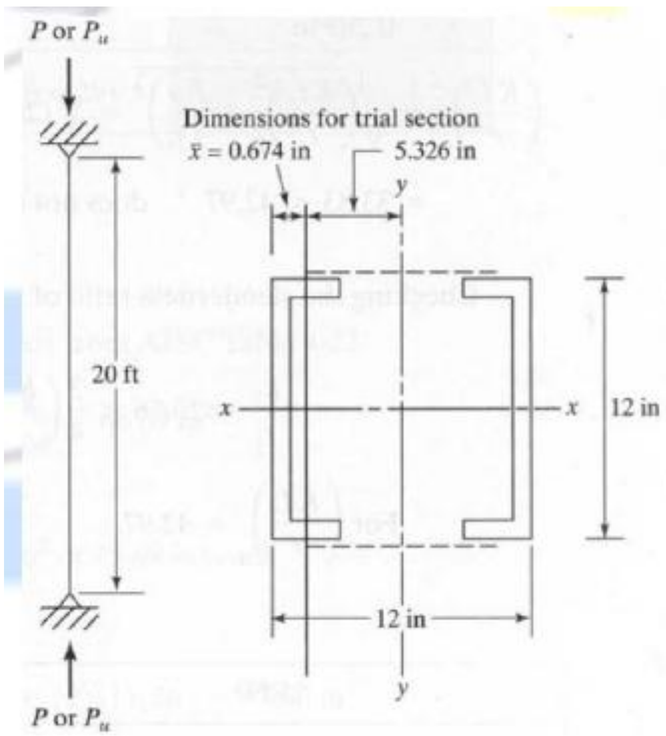
[b] For oversized or slotted holes, see Table J3.5.

[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.

EX: Design 20ft built up column consists of pair of 12-in standard Channels face to face using A572G50 steel. Subjected to P_D= 100 kips & P_L= 300 kips. Assume boundary conditions of column is hinged in both ends.

Solution:



1- Sp, Dim, & Properties:

steel	Fy	Fu	P_D	P_L	Ky = kx	L
A572G50	50	65	100	300	1.0	20

2- Loading:

LRFD
Pu=1.2(100) + 1.6(300) = 600kips

3- Assume $\frac{kLy}{ry} = 50,$ So (from AISC **Table 4-22**) → read ØcFcr = 37.5 ksi

4- Areq = $\frac{Pu}{\emptyset Fcr} = \frac{600}{37.5} = 16.0\ in^2$

5- Select channel of Ag > Areq from tables 1-5 / page 1.34

sec	Ag	d	tw	bf	tf	Ix	rx	Iy	ry	ẋ
C12x30	8.81			`		162	4.29	5.12	0.762	0.674

6- Properties of built up section:

Ixb = 2 (Ix) = 2 x 162 = 324 in^4

Iyb = 2 [Iy + Ag x $(\frac{12}{2} - 0.674)^2$] = 510 in^4

$$rx = \sqrt{\frac{324}{2x8.81}} = 4.29\ in$$

$$ry = \sqrt{\frac{510}{2x8.81}} = 5.1 in$$

Least value control → rx = 4.29 in

So go to table 4 – 22 / page 4-319 with $\frac{kL}{rx} = \frac{1x20}{4.29}\ x\ 12 = 56$, read ØcFcr= 35.8 ksi

Therefore ØcPn = Ag x ØcFcr = 2 x 8.81 x 35.8 = 630 kips > Pu = 600 kips O.K

7- Check width thickness ratio:

d	tw	bf	tf	k
12	0.51	3.17	0.5	$1\frac{1}{8}$

Go to table 4- 1 / page B4-1 case 3 & 14

For Flange $\frac{bf}{tf} = \frac{3.17}{0.5} = 6.34 < 0.56\sqrt{\frac{29000}{50}} = 13.49$ O.K

For web $\frac{h}{tw} = \frac{12-2(1.125)}{0.51} = 19.12 < 1.49\sqrt{\frac{29000}{50}} = 35.88$ O.K

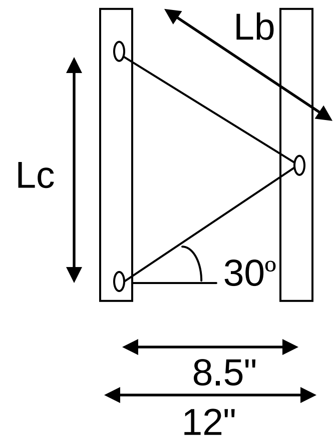
So use 2C12x30 as main segments of built up column

8- Design lacing bar:

b’= b – 2g = 12 – 2 x 1.75 = 8.5" < 15" so use single lacing with $\alpha = 60^o$ with member axis.

Length of lacing Lb= 8.5 / cos 30^o = 9.8"

Length between opposite connection in channel = Lc = 2 [8.5 x tan 30^o] = 9.8"



Check slenderness of channel between connections:

L / r = 9.8 / 0.762 = 12.9 < $\frac{3}{4}\ x\ \frac{kL}{rb} = \frac{3}{4}\ x\ \frac{1x20x12}{4.29} = \frac{3}{4}\ x\ 55.94 = 42 \quad O.K$

Force in lacing bar:

Shear V\`= 2% Pu = 0.02 x 631 = 12.62kips

$$\frac{1}{2}\ x\ V = \frac{1}{2}\ x\ 12.62 = 6.31\ kips\ on\ each\ opposite\ side$$

Compression force in lacing bar

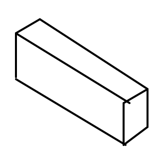
$$\frac{P`}{V`} = \frac{9.8}{8.5}\ so\ \ \frac{9.8}{8.5}\ x\ 6.31\ =\ 7.28\ kips$$

Properties of lacing flat bar:

$$I = \frac{1}{12}\ b`t`^3 \ldots\ldots let\ A` = b`t` \ldots\ldots r = \sqrt{\frac{I}{A`}} = \sqrt{\frac{\frac{1}{12}b`t`^3}{b`t`}} = 0.289\ t`$$

Design of lacing bar:

$$\text{Let } \left(\frac{L}{r}\right)\text{max} = 140 \ \ldots.\frac{9.8}{0.289t`} = 140 \ldots \text{ so t` } = 0.242 \text{ say } \frac{1}{4}"$$



$\therefore \frac{L}{r} = \frac{9.8}{0.289\ x\ 0.25} = 136 < 140 \ldots\ldots O.K \ldots now\ go\ to\ table\ 4-22 \quad read\ that\ ØcFcr$

$= 12.2ksi \ldots therefore\ \text{A`req} = \frac{\text{P`}}{\text{ØcFcr}} = \frac{7.28}{12.2}$

$= 0.596\ , so\ \text{b`} = \frac{\text{A`}}{\text{t`}} = \frac{0.596}{0.25} = 2.39 say\ 2.5"$

So total lacing bar length Lb` = 9.8 + 2(Le). For bolt diameter of 3/4" min Le = 1.25"

Lb` = 9.8 + 2 (1.25) = 12.3 say 12.5"

Therefore, use lacing flat bar size (1/4 x 2.5 x 12.5" length).

9- Design of end & intermediate tie plate:

For length use Ltp = b’ = 8.5"

For thickness use ttp = (1/50) b’ = 0.17"

For width use wtp = b’ + 2 (Le) = 8.5 + 2 (1.25) = 11" say = b = 12"

Use tie plate of (3/16 x 8.5 x 12")

Note: the intermediate tie plate shall have length Ltp= $\frac{1}{2}\ b` = 4.25"$

Other dimensions are same as for end tie plate.

THANKS FOR LISTENING, READING & UNDERSTANDING