

## Compression Members

A member of the structure subjected to Direct crushing is known as a compression member.

A compression member in an inclined position in a Framed structure is known as strut.

Important sections for the compression members

1. Angle section
2. Channel section
3. I - Section
4. Built-up section.

What is Slenderness ratio :-

Denoted by  $(\lambda)$ . It is defined as the ratio of effective height of a compression member to the least radius of gyration. Lower is Slenderness ratio greater is the strength of the compression member and Vice-versa.

There are two type of problem in compression members.

Type-1 :- To determine safe load for given compression member.

Step-1 :- Determine effective height of column for given end condition. From the code I.S. 800-2009

Step-2 :- Calculate moment of inertia of given section

about centroidal axis.

$$I_{xx} = ? , I_{yy} = ?$$

(Use steel tables if necessary)

Also calculate cross-sectional area of the given section

Step-3 :- Find out least radius of gyration

$$r_{\min} = \sqrt{\frac{I}{A}} \quad \text{mm}$$

where  $I$  = least of  $I_{xx}$  and  $I_{yy}$

Step-4 :- Calculate slenderness ratio

$$\lambda = \frac{L}{r_{\min}}$$

Step-5 :- From the table of I.S. code calculate safe compressive stress, corresponding to slenderness ratio.  
 $p_c = ?$

Step-6 :- Strength of compression member  $(P) = p_c \cdot A \quad \text{N}$   
This is also known as safe load.

Type-2 :- Design of compression member

Step-1 :- Assumed safe compressive stress =  $100 \text{ N/mm}^2$

Step-2 :- Gross area Required for compression member  
$$A = \frac{\text{Given load}}{100 (\text{Stress})} \text{ mm}^2$$

Calculate effective height of member as per given conditions.

Step-3 :- Corresponding to Gross area select a suitable section from steel table, keeping in mind that lesser  $\lambda$  more is strength.

Step-4 :- See  $r_{\min}$  of the selected section and find out  $\lambda = \frac{L}{r_{\min}}$

Step-5 :- Compute safe compressive stress corresponding to  $\lambda$  from the tables of I.S. Code 800 - 900.

Step-6 :- Load carried by selected section. This shall be more than given load. If load is less select another section.

Notes:- 1. If a compression member is welded or joint by two or more than two rows of rivets, consider effective length of member as  $0.85L$ . Where  $L$  = given length.  
$$L = 0.85L$$

2. If there is only one rivet row length remains same but safe compressive stress  $= 0.8 f_c$ . If angles are placed both sides of gusset plate, consider effective length  $= 0.7 l$ .

$$L = 0.7 l$$

3. If angles are placed on same sides of gusset plate then effective length  $= 0.85 l$   
 $\therefore L = 0.85 l$

4. For Design of members in compression  $\lambda$  shall not be more than 180.

IIIrd Type :- Design of built up compression members and lacing

Q:- A compression member consists of ISA  $80 \times 50 \times 6$ . It is connected by two rivets. Determine the strength of member.  $L_{\text{given}} = 2.65 \text{ m}$

Sol:- I - Effective length  $= 0.85 \times \text{given length}$   
 $L_{\text{eff}} = 2.2525 \text{ m}$

II - From Steel table  $k_{xx} = 2.54 \text{ cm}$   
 $k_{yy} = 1.39 \text{ cm}$   
 $r_{\text{mini}} = 1.39 \text{ cm} = 13.9 \text{ mm}$

III -  $\lambda = \frac{L}{r_{\text{mini}}} = \frac{2.2525 \times 1000}{13.9} = 162.0$

Q:- grade of steel Fe-250 if not Given

$\lambda$	$f_c$
160	41
170	37
180	34

$$\text{diff} = 0.8$$

therefor compressive stress  $= 41 - 0.8 = 40.2 \text{ N/mm}^2$

$$A_{\text{sc}} = 746 \text{ cm}^2 \quad [\text{from table}]$$

$$= 74600 \text{ mm}^2$$

$$\begin{aligned} \text{Therefore strength of member} &= \text{stress} \times A_{\text{sc}} \\ &= 40.2 \times 746 \\ &= 29989.2 \text{ N} \\ &\Rightarrow 29.9 \text{ kN} \Rightarrow 30 \text{ kN} \end{aligned}$$

(b) member is joined by 1 rivet any eff. length  $= 2.65 \text{ m}$

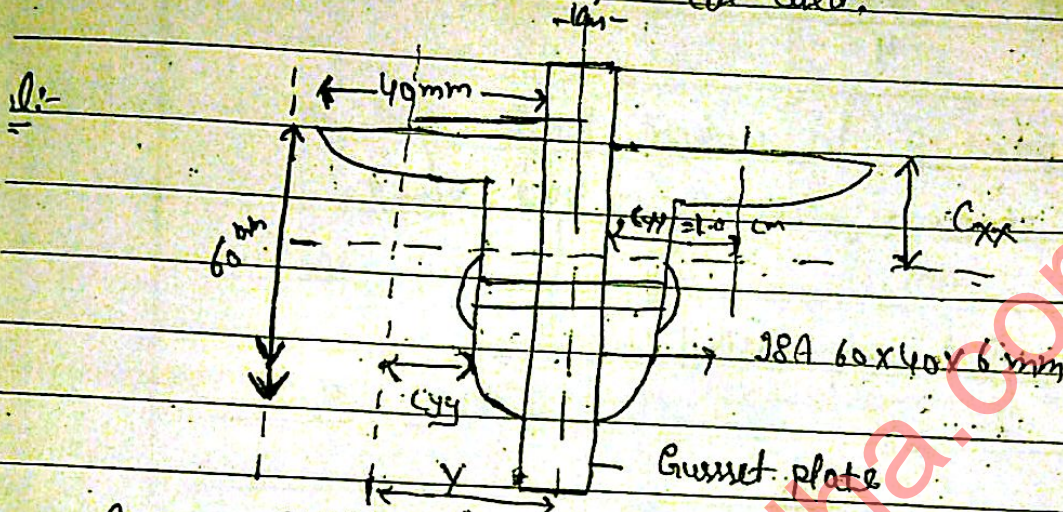
$$\lambda = \frac{L}{r_{\text{mini}}} = \frac{2.65 \times 1000}{13.9} = 190.65 \text{ say } 190$$

From tables

$\lambda$	$f_c$
190	30 $\text{N/mm}^2$ (from table)

In case of one rivet safe compressive stress  $= 0.8 f_c = 24 \text{ N/mm}^2$   
 therefor strength of member  $= 24 \times 746 = 17904 \text{ N} = 18 \text{ kN}$

Q :- A compression member consists of two ISA 60 x 40 x 6 mm with longer legs back to back on both sides of gusset plate 10 mm thick. Length of the member is 4 m. determine the safe load if two rivets are used.



$$\text{Area} = 5.65 \text{ cm}^2$$

$$C_{yy} = 1.00 \text{ cm}$$

$$I_{xx} = 19.9 \text{ cm}^4$$

$$I_{yy} = 7 \text{ cm}^4$$

$$\text{Area of angles} = 5.65 \times 2 = 11.2 = 11.3 \text{ cm}^2$$

$$I_{xx} \text{ for the given section} = 19.9 \times 2 = 39.8 \text{ cm}^4$$

$$I_{yy} = 7 \text{ cm}^4$$

$$I_{yy} = \left[ 7 + 5.65 (1.5)^2 \right] \times 2$$

$$= 39.425$$

$$r_{\min} = \sqrt{\frac{I}{A}} = \sqrt{\frac{39.425}{11.3}} = \sqrt{3.5} = 1.86 \text{ cm}$$

$$\text{Eniron length} = 4 \text{ m}$$

$$\text{No. of rivets} = 2$$

$$\text{for 2 rivets eff. length} = 0.85 \times 4 = 3.4 \text{ m}$$

$$\lambda = \frac{8.4 \times 1000}{18.6} \Rightarrow 182.8 = 183 \text{ say}$$

From steel table

$\lambda$	$p_c$
180	33
190	30

$$\text{therefor } p_c = 33 - 0.9 = 32.1$$

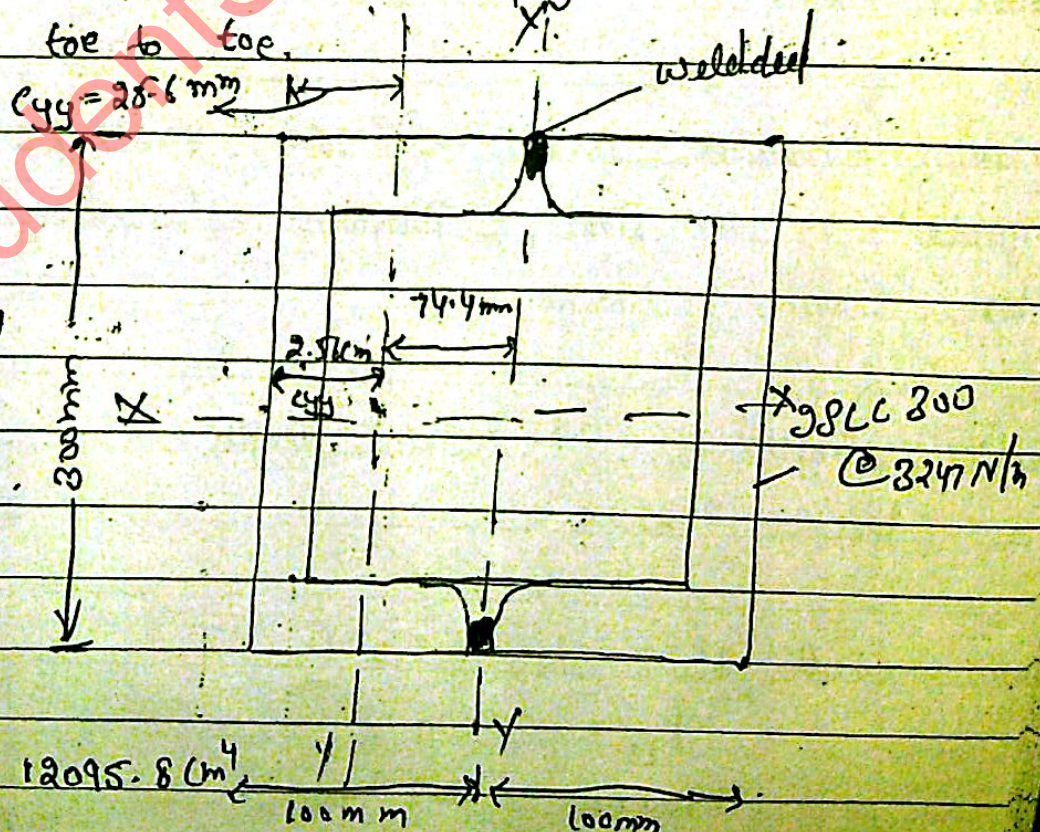
$$\begin{aligned} \text{Strength} &= \text{stress} \times \text{Area} \\ &= 32.1 \times 11.31 \times 100 \\ &= 36273 \text{ N} \\ &= 36.273 \text{ kN} \end{aligned}$$

Ques: Determine strength of C member consisting two channel section joining toe to toe.

$$\begin{aligned} I_{yy} &= 346 \text{ cm}^4 \\ I_{xx} &= 6047.9 \text{ cm}^4 \end{aligned}$$

$$C_{yy} = 2.56 \text{ cm}$$

$$\text{area} = 42.11 \text{ cm}^2$$



$$I_{xx} = 6047.9 \times 2 = 12095.8 \text{ cm}^4$$

$$I_{yy} = [346 + 42.11 \times 74.4^2] \times 2 = 8353.8 \text{ cm}^4$$

Area of the section =  $42.11 \times 2 = 84.22 \text{ cm}^2$

$$r_{\min} = \sqrt{\frac{I}{A}} = \sqrt{\frac{5368.8}{84.22}} = 8$$

Effective length of column is 4 m.

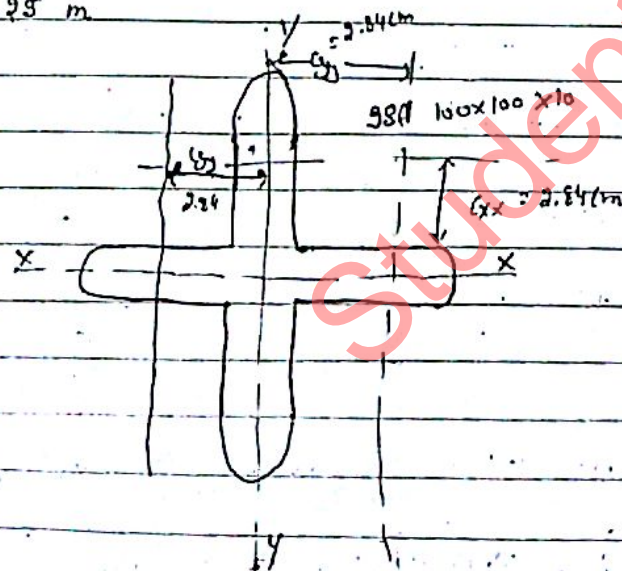
therefor  $\lambda = \frac{L}{r_{\min}} = \frac{400}{8} = 50 \text{ cm}$

From the table corresponding to  $\lambda$   
compressive stress  $p_c = 132 \text{ N/mm}^2$

therefor Strength of section = stress  $\times$  Area  
 $= 132 \times 84.22 = 1111704 \text{ N}$   
 $= 1111.7 \text{ kN}$

Num :- Determine Strength of a compression member which is built up for equal angle ISA  $100 \times 100 \times 10$  the angles are joined to form the shape of a cross. Use steel of grade  $f_c = 220$  effective length of = 6.25 m

Sol :-



From steel table ISA  $100 \times 100 \times 10$

area =  $19.03 \text{ cm}^2$ ,  $c_{yy} = 2.84 \text{ cm}$

$c_{xx} = 2.84 \text{ cm}$ ,  $I_{xx} = 177 \text{ cm}^4$

$I_{yy} = 177 \text{ cm}^4$

The properties are equal because equal angles  
Because angles are symmetrically placed therefor for  
the combine section  $I_{xx} = I_{yy}$

$$I_{xx} = I_{yy} = 4 \left[ 177 + 19.03 \times 2.84^2 \right] = 1322 \text{ cm}^4$$

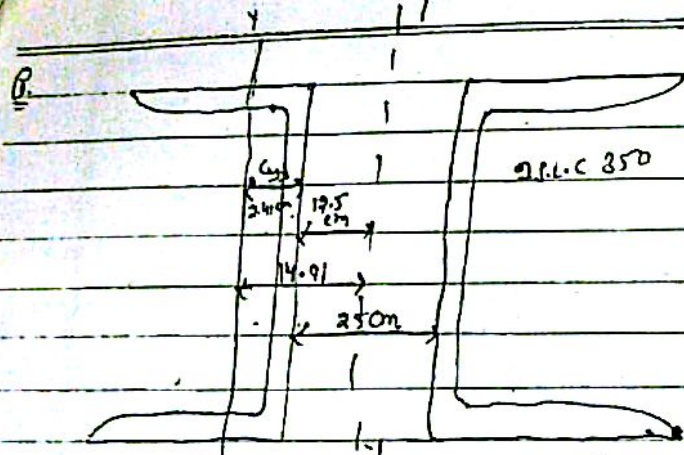
Effective length = 6.25 m = 625 cm

therefor  $\lambda = \frac{L}{r_{\min}} = \frac{625}{4.86} = 150$

$$r_{\min} = \sqrt{\frac{I}{A}} = \sqrt{\frac{1322}{19.03 \times 4}} = 4.86$$

for  $\lambda = 150$ , From table  $p_c = 45 \text{ N/mm}^2$

therefor strength of member =  $45 \times 1903 \times 4$   
 $= 342540 \text{ N}$   
 $= 342.54 \text{ kN}$



A compression member, made of double channel section. Determine strength of member when  $L_{eff} = 3m$  channel are back to back at a distance of 250 mm made of J.S.C 350.

sol: From Steel Table

$$Area = 4947 \text{ mm}^2, I_{xx} = 9812.6 \text{ cm}^4$$

$$I_{yy} = 894.6 \text{ cm}^4, C_{yy} = 2.41 \text{ cm}$$

$$I_{xx} = 9812.6 \times 2 = 19625.2 \text{ cm}^4$$

$$I_{yy} = [894.6 + 4947(14.91)^2] \times 2$$

$$I_{yy} = 22784.2 \text{ cm}^4$$

$$A = 4947 \times 2 = 9894 \text{ cm}^2$$

$$\sigma_{\min} = \sqrt{\frac{19625.2}{9894}} = 13.74$$

$$\lambda = \frac{300}{13.74} = 21.8$$

$$\lambda = \frac{p_c}{10} = \frac{148}{3} = 49.33$$

$$1 - 0.3 \times \frac{148}{3} = 0.54$$

$$p_c = 148 - 0.54 = 147.46$$

$$P = p_c A = 147.46 \times 9894$$

$$P = 145896 \text{ N} \quad \text{Ans}$$

Q. A column consists of 3 number I section as shown. Calculate safe load for column size of J.S.W.B 300.

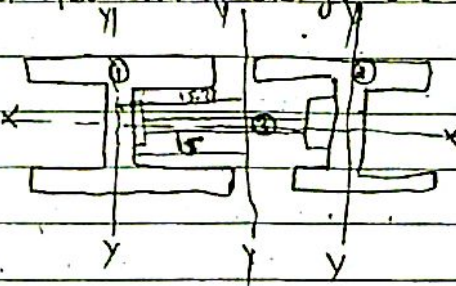
sol.

$$Area = 61.33 \text{ cm}^2$$

$$I_{xx} = 9821.6 \text{ cm}^4$$

$$I_{yy} = 990.1 \text{ cm}^4$$

$$\text{Web thickness} = 7.4 \text{ mm}$$



$$I_{xx} = 9821.6 \times 3 = 29464.8 \text{ cm}^4$$

$$I_{yy} = [990.1 + 61.33(15.37)^2] \times 3 + 9821.6$$

$$I_{yy} = 40778.6 \text{ cm}^4$$

$$A = 61.33 \times 3 = 183.99 \text{ cm}^2$$

$$\sigma_{\min} = \sqrt{\frac{I}{A}} = \sqrt{\frac{40778.6}{183.99}} = 10.58$$

$$\lambda = \frac{L}{r_{\min}} = \frac{400}{10.6} = 37.77$$

$\lambda$	$p_c$
80	145
40	139
10	6

$$1 \quad \text{---} \quad 0.6 \times 8 = 4.8$$

$$p_c = 145 - 4.8 = 140.2$$

$$P = 140.2 \times 183.99 \times 100 = 2579.53 \text{ N}$$

3. A column carries an axial load of 750 kN. length of column 4.25 m. It is fixed at one end and hinged at other end. design suitable section.

Sol:- Step-1 Assume safe compressive stress = 100 N/mm<sup>2</sup>  
 Gross Area =  $\frac{\text{Given load}}{\text{Safe comp. stress}} = \frac{750 \times 1000}{100} = 7500 \text{ mm}^2$

$$\text{I S L B 450} \quad \text{Area} = 83.14$$

$$r_{yy} = 8.2 \text{ cm}$$

$$\text{I S M B 400} \quad \text{Area} = 78.46$$

$$r_{\min} = 2.82$$

$$\text{I S H B 300} \quad \text{Area} = 74.85$$

$$r_{\min} = 5.41$$

$$\text{I S H B 300} \quad \text{Area} = 80.25$$

$$r_{\min} = 5.29$$

As per I.S code

$$\begin{aligned} \text{Effective length} &= 0.8l \\ &= 0.8 \times 4.25 \\ &= 3.4 \text{ m.} \end{aligned}$$

Adopt I.S.H.B. 300 having Area = 74.85 cm<sup>2</sup> and  $r_{\min} = 5.41$

$$\lambda = \frac{L}{r_{\min}} = \frac{340}{5.41} = 62.85$$

$\lambda$	$p_c$
60	122
70	112
10	10

$$1 \quad \text{---} \quad 1 \times 2.85 = 2.85$$

$$p_c = 122 - 2.85 = 119.15$$

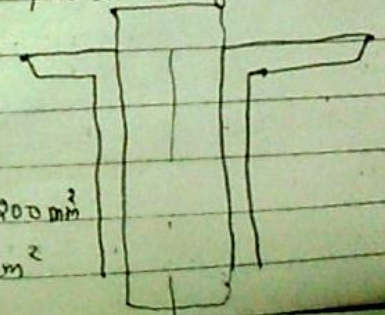
$$\begin{aligned} \text{Strength of member} &= \sigma_{\text{stress}} \times \text{Area} \\ &= 119.15 \times 74.85 = 891.83 \text{ kN} \end{aligned}$$

Section is safe.

Num:- A compression member eff. length 8m. load of 120 kN. It consists two angle both sides of gusset plate. Design the section.

Sol:- Assume thickness of gusset plate 10 mm.

$$\begin{aligned} \text{Gross Area} &= \frac{120 \times 1000}{100} = 1200 \text{ mm}^2 \\ &= 12 \text{ cm}^2 \end{aligned}$$



Double angle ISA 65x45x6

$$A_{eq} = 12.50$$

$$r_{xx} = 2.04, r_{yy} = 2.06$$

$$\text{Length} = 3\text{m}, r_{\min} = 2.04$$

$$\lambda = \frac{L}{r_{\min}} = \frac{3 \times 100}{2.04} = 147$$

$\lambda$	$p_c$
140	51
150	45
160	40
170	36
180	33
190	30
200	28
210	26
220	24
230	22
240	20
250	18
260	16
270	14
280	12
290	10
300	8
310	6
320	4
330	2
340	1
350	0
360	0
370	0
380	0
390	0
400	0
410	0
420	0
430	0
440	0
450	0
460	0
470	0
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790	0
800	0
810	0
820	0
830	0
840	0
850	0
860	0
870	0
880	0
890	0
900	0
910	0
920	0
930	0
940	0
950	0
960	0
970	0
980	0
990	0
1000	0

$$\text{Strength of member} = 46.8 \times 1250 = 58500$$

$$58.5 \text{ kN}$$

less than 120 unsafe.

Try Double angle ISA 80x50x8

$$A_{eq} = 19.56 \text{ cm}^2, r_{xx} = 2.52, r_{yy} = 2.22$$

$$r_{\min} = 2.22$$

$$\lambda = \frac{800}{2.22} = 360.36$$

$\lambda$	$p_c$
130	57
140	51
150	45
160	40
170	36
180	33
190	30
200	28
210	26
220	24
230	22
240	20
250	18
260	16
270	14
280	12
290	10
300	8
310	6
320	4
330	2
340	1
350	0
360	0
370	0
380	0
390	0
400	0
410	0
420	0
430	0
440	0
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880	0
890	0
900	0
910	0
920	0
930	0
940	0
950	0
960	0
970	0
980	0
990	0
1000	0

$$0.6 \times 4.5 = 2.7$$

$$p_c = 57 - 2.7 = 54.3$$

$$\text{Strength} = 54.3 \times 19.56 = 1066 \text{ kN}$$

Take ISA 100x65x6

$$A_{eq} = 19.10$$

$$r_{\min} = 2.70$$

$$\lambda = \frac{800}{2.70} = 296.3$$

$\lambda$	$p_c$
110	72

$$\text{Strength of member} = 72 \times 19.10 = 1375.2 \text{ kN}$$

This is safe section.

Num:- Design a compression member consisting of equal angle section subjected to a load of 105 kN. Length of column is 2.5 m. Use more than one rivet at each end.

Sol:- Step-1 Gross Area =  $\frac{105 \times 1000}{100} = 1050 = 10.5 \text{ cm}^2$

$$\text{Take ISA 65x65x6, } A_{eq} = 14.98$$

$$r_{\min} = 1.98$$

$$\lambda = \frac{2500}{1.98} = 1263.13$$

$\lambda$	$p_c$
100	80
110	72
120	64
130	57
140	51
150	45
160	40
170	36
180	33
190	30
200	28
210	26
220	24
230	22
240	20
250	18
260	16
270	14
280	12
290	10
300	8
310	6
320	4
330	2
340	1
350	0
360	0
370	0
380	0
390	0
400	0
410	0
420	0
430	0
440	0
450	0
460	0
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830	0
840	0
850	0
860	0
870	0
880	0
890	0
900	0
910	0
920	0
930	0
940	0
950	0
960	0
970	0
980	0
990	0
1000	0

$$80 - 5.6 = 74.4$$

$$\text{Strength of member} = 74.4 \times 14.88 = 110 \text{ kN}$$

Section is safe.  $105 < 110$

Ques:- A compression member effective length 10 m. Support load 1000 kN. design the column limiting of two channel back to back at full load section.

Use  $F-250$

Sol:- Step-I Gross Area  $\propto \frac{\text{Load}}{\text{Stress}}$

$$= \frac{1000 \times 1000}{100} = 10000 \text{ mm}^2 \quad X -$$

therefor gross area for each channel  $= 50 \text{ cm}^2$

Try 2 S.L.C 250

$$\text{Weight} = 380.6 \text{ N/m}$$

$$\text{area} = 49.47 \text{ cm}^2, \quad r_{xx} = 13.72 \text{ cm}$$

$$\lambda = \frac{10 \times 1000}{13.72} = 73$$

$\lambda$	$p_c$
70	112
80	101
10	11

$$p_c = 112 - 0.3 = 108.7$$

$$\text{Strength of member} = 108.7 \times (49.47 \times 2) \times 100 = 1068.5$$

$$1000 < 1068.5 \quad \text{Design is safe}$$

$F_y 250$

$$P = 1000 \text{ kN}$$

$$L = 10 \text{ m}$$

$$r_{yy} = 2.41 \text{ cm}, \quad r_{xx} = 13.72 \text{ cm}$$

Because back to back of channels is not known therefor consider  $r_{xx}$  as  $r_{\min}$

$$\lambda = \frac{L}{r_{\min}} = 73 \quad \text{By last section}$$

$$\text{Strength of material} = 1068.5 \approx 1075 \text{ kN}$$

To find distance b/w channel let  $\alpha_x = \alpha_y = 0.66$

$$137.2 = 0.66$$

$$b = 228.6 \text{ u } 230 = 23 \text{ cm}$$

$$I_{yy} = 894.6 \text{ cm}^4$$

$$I_{yy} = \{894.6 + 49.47 [13.91]^2\} \times 2$$

$$I_{yy} = 19933 \text{ cm}^4$$

$$r_{yy} = \sqrt{\frac{I}{A}} = \sqrt{\frac{19933}{49.47 \times 2}} = 14.19$$

Hence  $r_{xx}$  is  $r_{\min}$

therefor section is safe.

Q

A compression member 4.75 m long, effective is subjected to axial load of 2000 kN. This member has 4 equal angle symmetrically placed in a square of area 400 mm x 400 mm

sol:- Use fy = 250

when four angle symmetrically placed then approximate

$$r_{\min} = 0.4b$$

where b = size of square

$$\text{So } r_{\min} = 0.4 \times 400 = 160 \text{ mm}$$

$$\lambda = \frac{L}{r_{\min}} = \frac{4.75 \times 1000}{160} = 29.68$$

$\lambda$	$p_c$
20	148
30	145
10	3

$$1 \quad \quad \quad 0.3 \times 29.68 = 2.904$$

$$148 - 2.904 = 145.096$$

$$p_c = 145 \text{ N/mm}^2$$

$$\text{Gross area} = \frac{2000 \times 1000}{145} = 13793 \text{ mm}^2$$

$$\text{for each angle Gross area} = \frac{13793 \text{ mm}^2}{4} = 3448 \text{ mm}^2$$

$$= 34.48 \text{ cm}^2$$

From steel table choose J.B.A 150 x 150 x 12

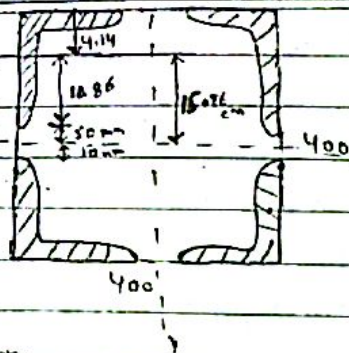
$$\text{area} = 34.59 \text{ cm}^2$$

$$c_{xx} = 4.14 \text{ cm}$$

It is a symmetrical section so  $I_{xx} = I_{yy}$

$$I_{xx} = [735.4 + 34.59 \times (15.81)^2] \times 4$$

$$I_{xx} = 87744.6 \text{ cm}^4$$



$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{37444.6}{84.4574}} = 16.5$$

$$\lambda = \frac{475}{16.5} = 28.8$$

$\lambda$	$p_c$
20	148
30	145
10	3

$$0.3 \times 28.8 = 2.64$$

$$p_c = 148 - 2.64 = 145.36 \text{ N/mm}^2$$

$$\text{Strength of member} = 145.36 \times 34.59 \times 100$$

$$P = 2001 \text{ kN} > 2000 \text{ kN}$$

So section is safe.



A compression member of  $L_{eff} = 8.5 \text{ m}$  load 850 kN channel are placed back to back at suitable spacing. Also calculate spacing of channel

Sol:-

$$\text{Gross Area} = \frac{850 \times 1000}{145} = 8500 \text{ cm}^2$$

$$\text{Gross section} = 42.5 \text{ cm}^2$$

$$\text{J.B.C 300 Area} = 42.11$$

$$r_{yy} = 11.98$$

$$\lambda = \frac{850}{11.98} = 71$$

$$\lambda = 70 \quad p_c = 112$$

$$p_c = 112.98$$

$$\text{Strength of member} = 112.98 \times 42.11 \times 100 \times 2 = 934 \text{ kN}$$

Section is safe.

$$r_{xx} = 0.6b$$

$$b = \frac{11.98}{0.6} = 19.6 \leq 20 \text{ cm or } 200 \text{ mm}$$

$$I_{yy} = [346 + 42.11 (12.87^2)] \times 2$$

$$I_{yy} = 18956 \text{ cm}^4$$

$$r_{yy} = \sqrt{\frac{18956}{42.11 \times 2}} = 12.87 \text{ cm}$$

$$r_{xx} = 11.98$$

So  $r_{xx}$  is min. so Section is safe.

