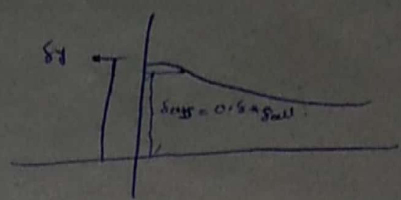
Chapter # 11

Columns

Pb # 1101 Select the lightest W shape that can be used as a column 7m long to support an axial load of 450 kN with a factor of safety 3. Assume (a) Both ends hinged & (b) One end fixed & other end hinged. Use $S_{pl} = 200\,MPa$ & $E = 200\,GPa$.

Solution:- When both ends hinged:-

$S_{assume} = 0.8 * S_{all}$ → (2).



First select short column whose $L/r = 0$

$$\boxed{F.S = 5/3}$$

& $$S_{all} = \left(1 - \frac{(L/r)^2}{2C_c^2}\right)\frac{S_{yp}}{F.S} \rightarrow (1).$$

$$C_c = \sqrt{\frac{2\pi^2 E}{S_{yp}}} \Rightarrow C_c = \sqrt{\frac{2*\pi^2*200\times10^3}{200}} = 140.42.$$

eq (1) ⇒ $$S_{all} = \left(1 - \frac{0}{2C_c}\right)\frac{200}{5/3} \Rightarrow \boxed{S_{al} = 120\,MPa}$$

eq (2) ⇒ $$S_{ass} = 0.8 \times 120 \Rightarrow \boxed{S_{ass} = 96\,MPa}$$

$P = S_{al} * A$.

$$450\times10^3 = 96\times10^6 * A \Rightarrow \cancel{A = 468.78}$$

$$\boxed{A = 4687.5\,mm^2}$$

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So select a W section whose area is Compatable with this area.

let select W250x39

$A = 4920\,mm^2$.

$r_{min} = 34.7\,mm$.

$$(L_e/r) = \frac{1 \times 7 \times 1000}{34.7}$$

$$\boxed{L_e/r = 201.7}$$

Now

$$C_c = \sqrt{\frac{2\pi^2 E}{S_{yp}}}$$

$$= \sqrt{\frac{2 \times 3.14 \times 200 \times 10^3}{200}}$$

$$\boxed{C_c = 79.246}$$

As $L_e/r > C_c$ so long Column.

use

$$S_{all} = \frac{12}{23} \frac{\pi^2 E}{(L_e/r)^2}$$

$$= \frac{12}{23} \times \frac{(3.14)^2 \times 200 \times 10^3}{(201.7)^2} \Rightarrow S_{all} = 25.28\,MPa$$

$P = S_{all} \times A$.

$P_{cal} = 25.28 \times 4920 \Rightarrow \boxed{P_{cal} = 124.4\,KN}$

As $P_{cal} < P_{given}$ so This section is inedequate.

let select

~~$W_{310}\times$~~

$W_{250}\times 73$.

$A = 9280\,mm^2$.

$r_{min} = 64.7\,mm$.

$$l_e/r = \frac{1\times 7000}{64.7}$$

$$\boxed{l_e/r = 108.2}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{S_{yp}}} = \sqrt{\frac{2\times(3.14)^2\times(200\times10^3)}{200}}$$

$C_c = 79.246$

As $l_e/r > C_c$ so long Column.

As;

$$S_{all} = \left(\frac{12}{23}\,\frac{\pi^2 E}{(l_e/r)^2}\right).$$

$$= \frac{12}{23} * \frac{(3.14)^2 * (200\times10^3)}{(108.2)^2}.$$

$S_{all} = 87.88\,MPa$

As;

$S_{all} = P/A$.

$P = S_{al} * A$.

$= 87.88 \times 9280$.

$$\boxed{P_{cal} = 815.5\,kN}$$

As $P_{cal} \geq P_{given}$. So

$W_{250}\times 73$ is our required Section.

As $A_{req} = 4687.5 mm^2$.

So let section W 360x64

$A = 8140 mm^2$.

$r_{min} = 48.1$

First find

$$l_e/r = \frac{0.7 \times 7 \times 1000}{48.1}$$

As hinged & fixed so $K = 0.7$.

$$l_e/r = 101.87 \longrightarrow (A)$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{pl}}}$$

$$= \sqrt{\frac{2(3.14)^2 \times 200 \times 10^3}{200}}$$

$$C_c = 140.4.$$

As $C_c > l_e/r$ So Short or Intermediate column.

Use;

$$\sigma_{al} = \left(1 - \frac{l_e/r}{2C_c^2}\right) \frac{\sigma_{yp}}{F.S} \longrightarrow (B).$$

$$F.S = 5/3 + 3/8 \left(\frac{(l_e/r)}{C_c}\right) - \frac{(l_e/r)^3}{8C_c^3}.$$

$$= 5/3 + \frac{3}{8} \frac{101.87}{140.4} - \frac{(101.87)^3}{8(140.4)^3}.$$

$$= 5/3 + 0.2721 - 0.0477.$$

$$\boxed{F.S = 1.89}$$

eq (B) ⇒

$$\sigma_{all} = \left(1 - \frac{101.87}{2(140.4)^2}\right)\left(\frac{200}{1.89}\right).$$

$$\boxed{\sigma_{al} = 105.54 MPa}$$

Pb # 1102

Given data:

· A = 50mm by 100mm.

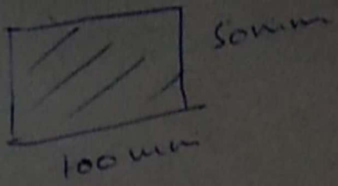
i) L = ?

E = 10 GPa.

σ_{pL} = 30 MPa.

(ii) F.S = 2

length = ?



Sol:- First To find length = ?

As we know

$$L_e/r = \sqrt{\frac{\pi^2 E}{\sigma_{pL}}} = \sqrt{\frac{(3.14)^2 (10\times10^3)}{30}}$$

$$\boxed{L_e/r = 57.33}$$

To find

$$r = \sqrt{I/A}$$

$$r = \sqrt{\frac{100\times50^3}{12\times100\times50}}$$

$$= \sqrt{\frac{50^2}{12}}$$

$$\boxed{r = 14.43\text{mm}}$$

$L_e = r\times57.33.$

$L_e = 14.43\times57.33.$

$L_e = 827.48$mm.

As Fixed ends,

so, $L_e = 1/2L$.

$1/2L = 827.48$m

$L = 1654.97$mm.

$$\boxed{L = 1.65 \text{ m}}$$

(b) Now to find P_{all}?

As $P_{cr} = \dfrac{\pi^2 EI}{(L_e)^2} \longrightarrow (A)$

$\cancel{P_{cr} = \dfrac{\pi^2 (10\times10^3)\, 50^2 \times 100}{(827.48)^2}}$

As $L = 2.5m.$

$L_e = \frac{1}{2} L = \frac{2.5}{2} = 1.25m.$

$\{ (A) \Rightarrow \quad P_{cr} = \dfrac{\pi^2 (10\times10^3)(50^3 \times 100)}{12\,(1.25)^2 \times 10^3}$

$P_{cr} = 65730.67\,N.$

As $P_{allowable} = \dfrac{P_{cr}}{2}.$

$= \dfrac{65730.67}{2} N.$

$P_{all} = 32865.33 N.$

or

$\boxed{P_{all} = 32.86 KN}$

Ans

Pb# 1103 Given data;

L = 6'

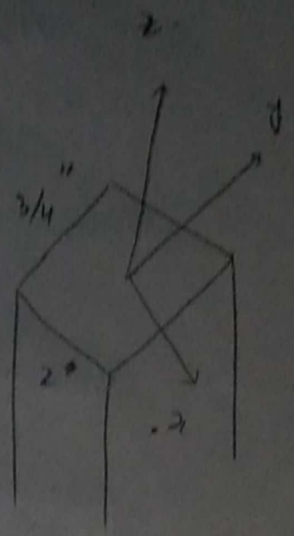
A = 3/4" * 2".

Act as hinged column about axis ⊥ to 2".
& act as fixed column about axis ⊥ to 3/4".

P_{safe} = ?

F.S = 2.

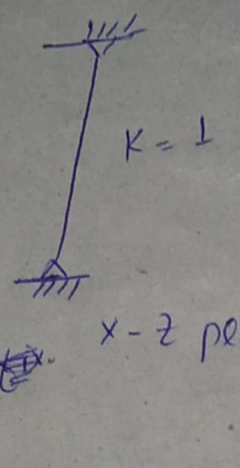
E = 10.3×10^6 psi



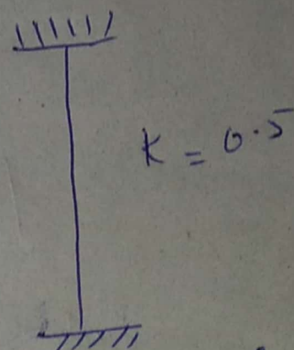
Sol:- As act as hinged column about axis ⊥ to 2"

So the buckling will not produce in y-plane it will act as hinged column in X-Z plane.

Similarly buckling will also reduce for fixed support In Y- axis. So buckling will produce in just Y-Z plane.



X-Z plane



Y-Z plane

The P_{cr} required to produce buckling in x-z plane is,

$$P_{cr} = \frac{\pi^2 E I}{(L_e)^2}$$

$$= \frac{\pi^2 \times 10.3 \times 10^6 \times \frac{(3/4)(2)^3}{12}}{(1 \times 6 \times 12)^2}$$

$P_{cr} = 9804\, lb.$

$$P_{all} = \frac{P_{cr}}{F.S} = \frac{9804\, lb.}{2}$$

$$\boxed{P_{all} = 4902\, lb}$$

For buckling produce in y-z plane.

$$P_{cr} = \frac{\pi^2 E I}{(L_e)^2}$$

$$= \frac{\pi^2 * 10.3 \times 10^6 * \frac{(2)(3/4)^3}{12}}{(0.5 \times 6 \times 12)^2}$$

$$\boxed{P_{cr} = 5515.2\, lb}$$

$$P_{al} = \frac{P_{cr}}{F.S} = \frac{5515.2\, lb.}{2}$$

$$\boxed{P_{al} = 2757.6\, lb}$$

for safest load select $\boxed{P = 2757.6\, lb}$ Ans

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Pb# 1104 :-

Given data ;

$P = 20$ Kips

$L = 16$ ft.

$E = 29 \times 10^6$ psi

For

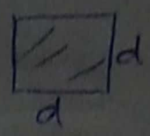
Rounded end

$K = 1$.

Solution -

To find length of each side

As square =



so;

Since;

$$P_{cr} = \frac{\pi^2 E I}{L_e^2}$$

$$I = P L_e^2 / \pi^2 E$$

$$d^4 = \frac{12 P_{cr} L_e^2}{\pi^2 E}$$

For square.

$$I = \frac{d(d)^3}{12} = \frac{d^4}{12}$$

$$d^4 = \frac{12 * 20 \times 10^3 * (10 \times 12)^2}{(3.14)^2 * (29 \times 10^6)}$$

$$d^4 = 12.08$$

$$d = (12.08)^{1/4}$$

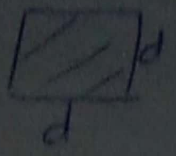
$$\boxed{d = 1.86''}$$

So each side of square is $1.86''$. Ans

Pb # 1105

Repeat Pb # 1104 For column made of wood for which $E = \cancel{29}\,1.6 \times 10^6$ psi.

Sol.



To find $d = ?$

As, $P_{cr} = \dfrac{\pi^2 E I}{L_e^2}$

$$I = \frac{P_{cr} L_e^2}{\pi^2 E}$$

Since for square $I = \dfrac{d(d)^3}{12}$

$$= \frac{d^4}{12}$$

$$\frac{d^4}{12} = \frac{P_{cr} L_e^2}{\pi^2 E}$$

$$d^4 = 12\,\frac{P_{cr} L_e^2}{\pi^2 E}$$

$$d^4 = \frac{12 \times 20 \times 10^3 (120)^2}{(3.14)^2 \times (1.6 \times 10^6)}$$

$$d^4 = 219.1$$

$$d = (219.1)^{1/4}$$

$$\boxed{d = 3.84''}$$ Ans
2

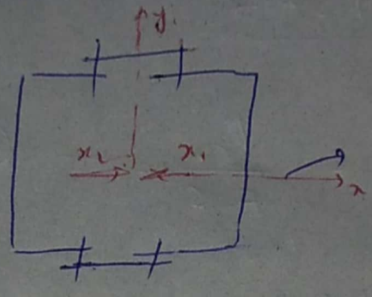
Pb# 1106:-

Two C310x45 channels are latticed together so they have equal moment of inertia about principal axis. Determine the minimum length of column having this section assuming pinned ends. E = 200 GPa and proportional limit of 240 MPa. What safe load will be column carry for length of 12 m with factor of safety of 2.5.

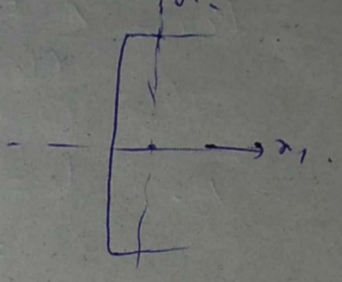
Solution:- Already solved!

Pb#1107:- Repeat Pb #1106 assuming that one end is fixed & other is hinged.

Solution:- As we have this case that $I_x = I_y$.



Square case.



As $I_{x_1} = 67.3 \times 10^6 \, mm^4$.

$A = 5690 \, mm^2$.

$I_{y_1} = 2.12 \times 10^6 \, mm^4$.

As symmetric about x-axis.

so; $I_x = 2 I_{x_1}$

$= 2(67.3 \times 10^6 \, mm^4)$

$$\boxed{I_x = I_y = 134.6 \times 10^6 \, mm^4}$$

To find slenderness ratio

i.e. $L_e/r = \sqrt{\frac{\pi^2 E}{f_{pl}}}$

$= \sqrt{\frac{(3.14)^2 * 200\times10^3}{240}}$

$L_e/r = 90.6.$

$L_e = 90.6 \times r$

$= 90.6 * \sqrt{\frac{I}{A}}$

$= 90.6 * \sqrt{\frac{134.6\times10^6}{5690 * 2}}$

$\boxed{L_e = 9.8 m}$

As; $P_{allowable} = \frac{P_{cr}}{F.S} \longrightarrow$ (A).

$P_{cr} = \frac{\pi^2 E I}{(L_e)^2}$.

As; $L_e = KL$.

$= 0.7 * 12 m$.

$= 8.4 m$.

As Fixed-hinged

$K = 0.7$.

$P_{cr} = \frac{(3.14)^2 * 200\times10^3 * 134.6\times10^6}{(8.4\times1000)^2}$

$\boxed{P_{cr} = 3761627.438 N}$

$P_{cr} = 3761.627 KN$

$\boxed{P_{cr} = 3761.6 KN}$

$\&$ (A) $\Rightarrow$ $P_{allowable} = \frac{P_{cr}}{2}$

$= \frac{3761.6}{2.5}$

$\boxed{P_{allowable} = 1504.64 KN}$

Pb #11108:-

Select the lightest W shape that will acts as column 8 m long with hinged end and support an axial load of 270 KN. F.O.S = 2.5. Assume that the proportional limit is 200 MPa & E = 200 GPa

Solution:- Given data

$l = 8m$.

Hinged ends.

$P_{all} = 270 KN$.

$\sigma_{PL} = 200 MPa$

$E = 200 GPa$

$F.O.S = 2.5$.

so; $P_{cr} = F.O.S * P_{allowable}$

$P_{cr} = 2.5 * 270$.

$\boxed{P_{cr} = 675 KN}$

As we know that;

$$P_{cr} = \frac{\pi^2 E I}{L^2}.$$

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As; $I = \frac{P_{cr} L_e^2}{\pi^2 E}$

$$I = \frac{675\times10^3 \times (8x)^2}{(3.14)^2 \times (200\times10^9)}$$

$$I = 2.19\times10^{-5}\,m^4 \Rightarrow 21.9\times10^{-6}\,m^4.$$

or $\boxed{I = 21.9\times10^{6}\,mm^4}$.

But we also know that;

$$L_e/r = \sqrt{\frac{\pi^2 E}{\sigma_{pL}}}$$

$$L_e/r = \sqrt{\frac{(3.14)^2\times(200\times10^3)}{200}}$$

$$\boxed{L_e/r = 99.29}$$

To find $r = ?$

As; $L_e/r = 99.29$

$r = \frac{L}{99.29}$

$r = \frac{(8 \times 1000 \times 1)}{99.29}$

$\boxed{r = 80.6 \text{ mm}}$

so the selection (selected) section has

$I \approx or > I_{cal}$

& $r_{cal} < r_{given}$

So To looking $W250 \times 67$ section the above two criteria are satisfied whose

$I = 22.2$ & $r = 51$ mm

So the lightest weight W section is $W250 \times 67$

Pb # 1109:- Select the lightest W-shape that will act as column 40' long with fixed ends and support an axial load of 150 kips with factor of safety of 2. Assume that proportional limit is 30ksi. Use $E = 29 \times 10^6$ psi. What set of criteria determines the section.

Sol:- As given $P_{all} = 150$ kips

As; $P_{cr} = F.O.S * P_{all}$

$= 2 * 150$ kips

$\boxed{P_{cr} = 300 \text{ kips}}$

Now first find $I = ?$

As $P_{cr} = \frac{\pi^2 E I}{l_e^2}$

$$I = \frac{P_{cr} \times l_e^2}{E \times \pi^2}$$

$$I = \frac{(300 \times 1000) \times (40 \times 0.5)^2}{29 \times 10^6 \times (3.14)^2}$$

$I = 0.6419\ ft^4$

$\boxed{I = 870.2.6 in^4}$ $\Rightarrow$ $\boxed{I = 8702.6\ in^4}$

Now check for $r = ?$

As; $l_e/r = \sqrt{\frac{\pi^2 E}{\rho pL}}$

$$l_e/r = \sqrt{\frac{(3.14)^2 (29 \times 10^6)}{(3 \times 1000)}}$$

$$\boxed{l_e/r = 308.7}$$

To find $r = ?$ $r = l_e/308.7 = (0.5 \times 40 \times 12)$

$$r = \frac{(20 \times 12)}{308.7} \Rightarrow \boxed{r = 0.78''}$$

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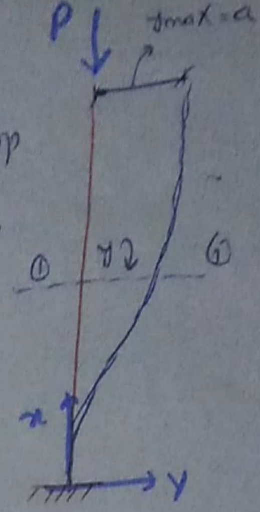
Concentrically loaded Column:-

Consider a column of length L on which load P is applied at top whose one end is fixed and other end is free as shown.

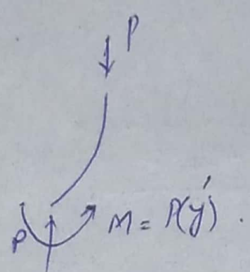


When the load on column become equal to critical load the column will deflect (buckle) as shown

The maximum buckling (deformation) is y_{max} as shown.

i.e $y_{max} = a$

Consider section ① – ① down area (portion).



where $y' = (a-y)$.

$$M = P(a-y)$$

From eqn of elastic curve.

$$EI \frac{dy^2}{dx^2} = M = P(a-y)$$

General solution of deflected shape of column.

$$y = A \sin k'x + B \cos k'x + a \longrightarrow ①$$

$$\text{where } k' = \sqrt{\frac{P}{EI}}$$

To find Value of A & B

apply boundry condition

$x = 0 ; y = 0$

eq ① ⇒ $0 = A(0) + B(1) + a$

$$\boxed{B = -a}$$

Similarly

when $x = 0$ $\frac{d}{dx} y = 0$.

$\frac{d}{dx} y = \frac{d}{dx}$ eq ① $= A \cos k'x + B(-\sin k'x)$

Apply condition.

$0 = A \Rightarrow \boxed{A = 0}$

eq ① ⇒ . Put values in ①

$y = -a \cos k'x + a \longrightarrow$ ②

We also know that

when $x = L$ $y = y_{max} = a$

eq ② ⇒ $y_{max} = a = -a \cos k'L + a$

$a = -a \cos k'L + a$

$-a\cos K'L = 0 \longrightarrow ①$

when $a = 0$, it means there is no buckling we not interest in that case

so, we consider

To satisfy eq ③ we will consider that,

$\cos K'L = 0.$

$\cos K'L = 0.$

$\cos(n\pi/2) = 0.$

i.e. $K'L = n\pi/2$

Since $K' = \sqrt{\frac{P}{EI}}$.

$\sqrt{\frac{P}{EI}}\,L = n\pi/2$

Taking square,

$\frac{PL^2}{EI} = \frac{n^2\pi^2}{4}.$

$$\boxed{P = \frac{n^2\pi^2 EI}{(2L)^2}}$$

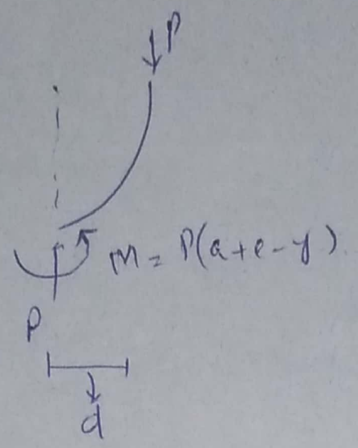
Since $L_e = 2L$.

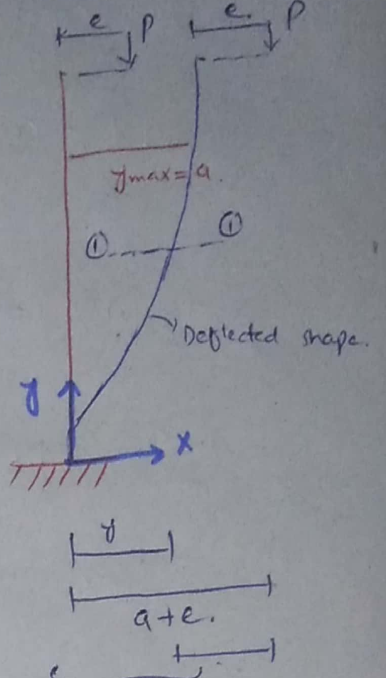
$$\boxed{P = \frac{n^2\pi^2 EI}{(L_e)^2}}$$

Eccentrically loaded Column:-

Consider a Column of length L whose one end is fixed and other is free. Let the load is applied at eccentricity "e". When $P = P_{cr}$ the column will bucked as shown.

Consider Section ① - ①





So $d = (a+e-y)$.

From eqn of elastic curve

$$EI \frac{d^2y}{dx^2} = M = P(a+e-y).$$

General solution of deflected shape of column is;

$$y = A \sin k'x + B \sin k'y + a + e \longrightarrow ①$$

where $k' = \sqrt{\frac{P}{EI}}$

Apply Initial (boundry) conditions.

when $x = 0$, $y = 0$.

eq ① ⟹ $0 = A(0) + B(1) + a + e$

$$\boxed{B = -a - e}$$

or $B = -(a+e)$.

When $x = 0$, $\frac{dy}{dx} = 0$.

$\frac{d}{dx}y = ?$

eq (1) $\Rightarrow$ $\frac{d}{dx}y = A\cos k'x - B\sin k'x$ ↳ (2)

$0 = A(1)$.

$$\boxed{A = 0}$$

eq (A) $\Rightarrow$

$y = -(a+e)\cos k'x + a + e \longrightarrow$ (3).

eq (3) gives buckled shape of deformed column.

When $x = L$, $y = y_{max} = a$.

$y = y_{max} = y = a = -(a+e)\cos k'\cancel{x}L + a + e$.

$\cancel{a} = -(a+e)\cos k'\cancel{x}L + \cancel{a} + e$

$0 = -(a+e)\cos k'L + e. \rightarrow$ (4)

$(a+e)\cos k'\cancel{x}L = e$.

Divide by $\cos k'L$.

$a+e = e/\cos k'L \Rightarrow a+e = \sec k'L\,(e)$ ↳ (5)

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eq (4) ⇒ $-a\cos k'L - e\cos k'L + e = 0$

$$a\cos k'L = -e\cos k'L + e = e - e\cos k'L$$

$$a\cos k'L = e(-\cos k'L + 1)$$

$$a\cos k'L = e(1 - \cos k'L)$$

Divide by $\cos k'L$.

$$a = e\left(\frac{1}{\cos k'L} - \frac{\cos k'L}{\cos k'L}\right)$$

$$a = e(\sec k'L - 1)$$

Since $y_{max} = a$.

$$y_{max} = a = e[\sec k'L - 1] \longrightarrow (6)$$

Eq (6) show equation of deflected column. which shows that deflection is max when either e is maximum or $[\sec k'L - 1]$ is max. As e is constant so we have possibility is;

∞ for max.

$$\sec k'L - 1 = \infty$$

$\therefore 1 + \infty = \infty$.

$$\sec k'L = 1 + \infty$$

$$\sec k'L = \infty$$

$$\sec(n\pi/2) = \infty.$$

$$\text{so,} \quad k'l = n\pi/2$$

$$\text{As } k' = \sqrt{\frac{P}{EI}}.$$

$$\sqrt{\frac{P}{EI}}\, l = n\pi/2.$$

$$\frac{P}{EI}\, l^2 = n^2\pi^2/2^2.$$

$$P = \frac{n^2\pi^2 EI}{(2L)^2}.$$

$$\therefore L_e = 2L.$$

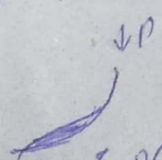
$$\boxed{P_{cr} = \frac{n^2\pi^2 EI}{L_e^2}}.$$

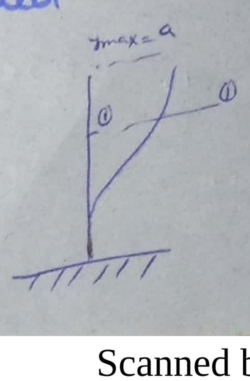
<u>**Result:-**</u> when the column is concentrically loaded or eccentrically it will buckled at same critical load.

→ The deformation in prevous case will be more than normal one.

Stresses for eccentrically loaded Columns:-

Consider eccentrically load column as shown





$$\text{TP: } M = P(a+e-y).$$

let assume compression +ve

$$\sigma_{max} = \frac{P}{A} + \frac{Mc}{I}$$

$$= \frac{P}{A} + \frac{M}{I/c}$$

$$= P/A + \frac{M}{S}$$

But; $M = Pe \sec k'L$.

$$\boxed{M = \frac{P}{A} + \frac{Pe \sec k'L}{S}} \rightarrow (A)$$

is called secant formula used for all kind of column whether short or long. also valid for eccentrically & concentrically loaded column.

For short column.

$L \rightarrow 0$.

$\sec 0 = 1$

Eq (A) $\Rightarrow$ $\boxed{M = \frac{P}{A} + \frac{Pe}{S}} \rightarrow (2)$

Eq (2) is used for analysis of short column.

Design of Column:-

As we have studied how to find the critical load corresponding for short, long & intermediate column & the corresponding stresses to critical load for those columns using physics or some imperical relation.

We also know how to find critical load for column whose one end is fixed at which load is applied ~~for~~ eccentrically or concentrically.

As in practically there are alot of uncertainity in placing load, strength of material etc.

For e.g. If In empirical method i.e to design a column load is applied at 2" from its centre but may be practically the load may applied at 2.2" or 2.3" which give uncertainity. & due to poor work manship.

→ So different design code take those uncertainity & are replaced or taken account by Factor of safety.

i. Structural stability research Council:- (SSRC).

For steel structures there is research council that develop their own empirical formula.

ii) American Institute of Steel Construction:-
(AISC)

iii_ Allowable stress design:-
(ASD)

These two are used to design column (steel)
→ Those columns that are used in building design.

To find allowable stress in Column:-

First we have to find slenderness ratio
i.e $(L/r) =$.

Now compare it with critical i.e "C_c"

If $(L/r) > C_c$ ∵ C_c is critical slenderness ratio.
Than used this formula.

∴ when $L/r > C_c$. (long column)

$$\boxed{\sigma_{all} = \frac{12}{23} \frac{\pi^2 E}{(Le/r)^2}}$$

∵ $12/23 =$ F.S.

∴ When $L/r < C_c$. (Short or Intermediate Column)

$$\boxed{\sigma_{allowable} = \left[1 - \frac{(Le/r)^2}{2C_c}\right] \frac{\sigma_{yp}}{F.o.S}}$$

Factor of safety:-

Factor of safety can vary & can be

Calculated as;

$$\boxed{F.O.S = \frac{5}{3} + \frac{3}{8}\frac{L_e/r}{C_c} - \frac{(L_e/r)^3}{8C_c^3}}$$

Critical slenderness ratio:-

$$\boxed{C_c = \sqrt{\frac{2\pi^2 E}{S_{yp}}}}$$

Note #
These all formulea for columns which are concentrically loaded & those are building structures (column) of steel.

(*) Design of Eccentrically load Column:-

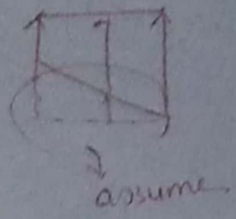
We have two approaches.

i) Maximum load approach:-

According to this approach effect of buckling deflection on moment arm is eliminated by limiting the maximum stresses to the allowable stresses computed from column formula.

$$S_{max} = \frac{P}{A} + \frac{M}{S} \longrightarrow ①$$

Then S_{max} will be compare with S_{axial} of material. We ignore the bending stresses for material.



(2) **Interaction formula:-**

In this case the axial stresses will be compared with axial strength of material & bending stresses (calculated) with bending stresses of material.

As max stresses is;

$$\delta_{max} = P/A$$

The area required to resist those stresses are

$$A_a = P/(\delta_a)_{max}.$$

If δ_B is max bendingig moment so the area required to resist those bending moment is;

$$A = \frac{M}{(\delta_B)_{max}\, r^2}.$$

Total area required will be;

$$A \geq A_a + A_B.$$

$$= P/(\delta_a)_{max} + M/(\delta_B)_{max} \times r^2.$$

Divide A (P by A)

$$= \frac{P/A}{(\delta_a)_{max}} + \frac{M/Ar^2}{\delta_{B}max} \leq 1.$$

$$= \frac{\delta a}{(\delta a)_{max}} + \frac{\delta_B}{(\delta_B)_{max}} \leq 1.$$

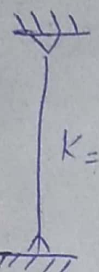
This AISC formule In which both axial & flexural stresses Contribute.

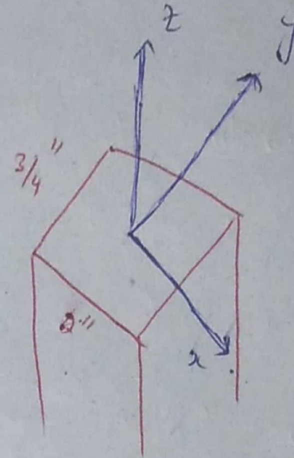
According to AISC.
when the axial stresses are equal or less than 15% of axial strength of material than we can use this Interaction formule
But if large so not used This formula.

Pb# 1103 An aluminum strut 6' long has a rectangular section 3/4" by 2". A bolt through each end secure the strut so that it acts a hinged column about an axis perpendicular to 2" dimension, and fixed end column about an axis perpendicular to 3/4". Determine the safe central load using a factor of safety of 2 & $E = 10.3 \times 10^6$ psi.

Solution:-

Consider the rectangular section of given dimension as shown.





For hinge column as buckling is restricted about y-axis.

So buckling can take place in x-z plane or about y-axis.

So to find safe load as;

$$P_{cr} = \frac{\pi^2 E I}{(L_e)^2}$$

$$P_{cr} = \frac{(3.14)^2 * 10.3 \times 10^6 * \frac{(3/4)(2)^3}{12}}{(1 \times 6 \times 12)^2}$$

$P_{cr} = 9804\ lb.$

$$P_{allow} = \frac{P_{cr}}{F.o.s}$$

$$= \frac{9804}{2} \Rightarrow \boxed{P_{allow} = 4902\ lb}$$

Similarly consider fixed ended column about an axis ⊥ to 3/4" which will prevent buckling about x-axis or buckling will take place in

* y-z plane

So; at this case.

$$P_{cr} = \frac{\pi^2 E I}{(L_e)^2} \qquad L_e = K * L.$$

$$= \frac{\pi^2 * 10.3 \times 10^6 * \frac{(3/4)^3 * 2}{12}}{(0.5 * 6 * 12)^2}$$

$$\boxed{P_{CR} = 5515.2\ lb}$$

$$P_{allowable} = \frac{P_{cr}}{2}.$$

$$= \frac{5515.2}{2}.$$

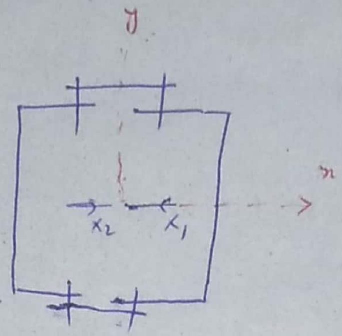
$$\boxed{P_{allowable} = 2757.6\ lb}$$

In order to prevent bucking in both ended consider $\boxed{P = 2757.6\ lb}$

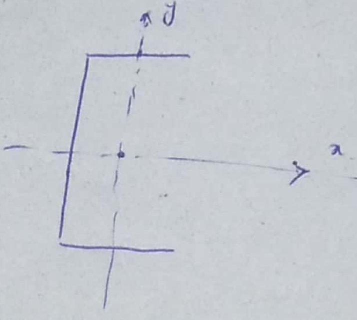
i.e safest value

Pb # 1106 Two $C_{310 \times 45}$ Channels are latticed together so that they have equal moment of inertia about P.A. Determine the minimum length of column having this section assuming pinned ends. E = 200GPa and proportional limit of 240MPa. What safe load column carry for a length of 12m with a factor of safety of 2.5?

Sol:- As two $C_{310 \times 45}$ channels are latticed together so that they have equal moment of inertia so if join them either in form of circle or square so this condition satisfy.



Consider one C section.



The properties of $C_{310 \times 45}$ section are.

$A = 5690 \ mm^2$

$I_{x_1} = 67.3 \times 10^6 \ mm^4$

$I_{y_1} = 2.12 \times 10^6 \ mm^4$

As given channel section is symmatric about X-axis so I_{xx} for both section when Combine can be written as;

$$I_x = 2I_{x_1}.$$

$$I_x = 2 \times 67.3 \times 10^6$$

$$I_x = 134.6 \times 10^6 mm^4.$$

As square section so,

$$\boxed{I_x = I_y = 134.6 \times 10^6 mm^4}$$ (given condition)

As we know that;

$$\delta_{cr} = \frac{\pi^2 E}{(l_e/r)^2}$$

$$l_e/r = \sqrt{\frac{\pi^2 E}{\delta_{cr}}}$$ Put $\delta_{cr} = \delta_{pl}$.

$$l_e/r = \sqrt{\frac{\pi^2 E}{\delta_{pl}}}$$ By putting values

$$l_e/r = \sqrt{\frac{\pi^2 \times 200 \times 10^3}{240}} \Rightarrow L_e/r = 90.6.$$

$$\therefore r = \sqrt{\frac{I}{A}}$$

$$l_e = r * 90.9$$

$$r = \sqrt{\frac{134.6 \times 10^6}{5690 \times 2}}.$$

As two channel section.

$$l_e = 90.6 * \sqrt{\frac{134.6 \times 10^6}{5690 * 2}}$$

$$\boxed{l_e = 9.8m}$$

so If $l_e > 9.8m$ it will consider long column.

If $l_e < 9.8m$ that will short or Interrmediate column.

To find $P_{allowable} = ?$

As $P_{allowable} = \frac{P_{cr}}{F.O.S}$ —— ①

As;

$$P_{cr} = \frac{\pi^2 E I}{(l_e)^2}$$

As $l_e = KL$
$= 1 * 12m$.

So;

$$P_{cr} = \frac{\pi^2 * 200 \times 10^3 * 134.6 \times 10^6}{(1 \times 12 \times 1000)^2}$$

$P_{cr} = 1843197.444$

Eq ① => $P_{allowable} = \frac{P_{cr}}{F.O.S}$

$$= \frac{1843197.444}{2.5}$$

$P_{allowable} = 737278.9N$.

or;

$$\boxed{P = 737.278 KN}$$

Ans.

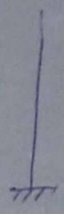
Pb# 1115 :- A $W_{14\times82}$ section is used as a column with an effective length of 30'. Use AISC specification. Compute the maximum load that can be easily applied. Use $\delta_{yp} = 50ksi$ & $E = 29\times10^6 psi$.

Solution:-

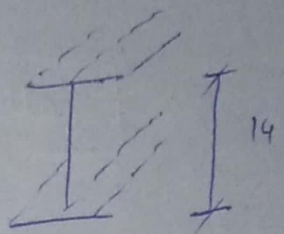
$P = ?$

As;

$$P = \frac{\pi^2 EI}{L_e^2} \longrightarrow ①$$



W- section



As other items are constant just P depend on I & I depend on "r". So consider that r which has smallest value.

So, $r = 2.45$ in.

First find $\frac{L_e}{r}$.

$$\frac{L_e}{r} = \frac{30\times12}{2.45} \Rightarrow \boxed{\frac{L_e}{r} = 145.16}$$

Now find critical slenderness ratio.

$$C_c = \sqrt{\frac{2\pi^2 E}{\delta_{yp}}} = \sqrt{\frac{2\pi^2 \times 29\times10^6}{50\times10^3}}$$

$$\boxed{C_c = 107}$$

As $L_e/r > C_c$ so this is long column

$\therefore$ to

$\delta al = P/A$

$P = \delta al * A \rightarrow$ (11).

$\delta all = \frac{12}{23} \frac{\pi^2 E}{(Le/r)^2}$ $\therefore Le/r = 145.16.$

$= \frac{12}{23} * \frac{(3.14)^2 * 29\times10^6}{(145.16)^2}$

$\boxed{\delta all = 7.09 ksi}$

Put in eq (11) $\Rightarrow$

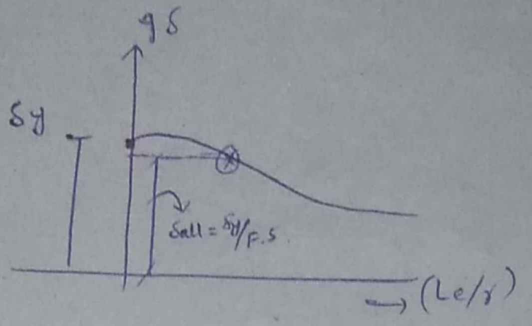
$P = \delta al * A$

$= 7.09 * 24.1$

$\boxed{P = 170.8 \text{ kips}}$ Ans

Pb #11.22:- Select the lightest W shape, according to AISC specification, that can be used as column to support an axial load of 420 kN on the effective length of 4m. Use AISC specification with $\delta_{yp} = 250 MPa$ & $E = 200 GPa$.

Solution:-



For short Column. Consider it to find allowable stress.

As $\delta assume = 0.8 * \delta all \rightarrow ①$.

As for short column from graph

$Le/r = 0$.

As for short column.

$$\delta all = \left[1 - \frac{(Le/r)^2}{2C_c^2}\right] \frac{\delta yp}{F.S} \rightarrow ①.$$

Find $\delta yp = ?$

$\delta yp = 250 MPa$ (Given)

$F.S = ?$ As $F.S = 5/3 + 3/8 \frac{Le/r}{C_c} - \frac{(Le/r)^3}{8C_c^3}$

By putting values.

$$F.S = 5/3 + 3/8 \frac{0}{C_c} - \frac{0}{8C_c}$$

$$\boxed{F.S = 5/3.}$$

A3

for short column.

$$\delta_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right) \frac{\delta_{yp}}{F.S}$$

$$= \left(1 - \frac{0}{2C_c^2}\right) \frac{250}{5/3}$$

$\because \delta_{yp} = 250MPa$ (given)

$$\delta_{all} = 150MPa.$$

$$\delta_{ass} = 0.8 * 150.$$

$$\boxed{\delta_{ass} = 120\ MPa}$$

As we have to find dimension;

i.e Area = ?

Since $P_{all} = P/A$.

$$A = P/P_{all}.$$

$$= \frac{420 \times 10^3}{120 \times 10^6}.$$

$$A = 3.5 \times 10^{-3} m^2$$

$$\boxed{A = 3500\ mm^2}$$

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As; A = 3500mm

Now at end of book by looking properties of W section consider a section whose area is compatable with 3500mm².

let consider

W150x30

whose A = 3790mm²

& r_{min} = 38.3mm.

Now find L_e/r & C_c.

$$l_e/r = \frac{4\times10^3}{38.3} = 104.4.$$

$$C_c = \sqrt{\frac{2\pi^2E}{S_{yp}}} = \sqrt{\frac{2\pi^2 * 200\times10^3}{250\times10^{6}}} = 125.66.$$

As; $l_e/r < C_c$ So use short column formula

i.e

$$S_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right)\frac{S_{yp}}{F.S} \longrightarrow ①.$$

$$F.S = 5/3 + 3/8\frac{(l_e/r)^2}{C_c} - \frac{(l_e/r)^3}{8C_c^3}.$$

$$= 5/3 + 3/8\frac{(104.4)^2}{125.66} - \frac{(104.4)^3}{8(125.66)^3}.$$

$$\boxed{F.S = 1.91}$$

& ① =>. $S_{all} = \left(1 - \frac{(104.4)^2}{2(125.66)^2}\right)\frac{250}{} \Rightarrow \boxed{S_{all} = 85.67MPa}$

Since; $P = S_{all}*A = 85.67 * 3790 \Rightarrow \boxed{P = 324.689kN}$

$P_{cal} < P_{axial}$ so not this section.

So $W_{150 \times 30}$ is inadequate.

Consider $W_{200 \times 36}$ whose $A = 4580\ mm^2$ & $r_{min} = 40.8\ mm$

for this also find L_e/r & C_c.

$$L_e/r = \frac{40 \times 10^3}{40.8} = 98.04$$

$$C_c = \sqrt{\frac{2\pi^2 E}{S_{yp}}} = \sqrt{\frac{2\pi^2 (200 \times 10^3)}{250}}$$

$$C_c = 125.6$$

As $C_c > L_e/r$

so use short column formula;

$$S_{all} = \left(1 - \frac{(L_e/r)^2}{2C_c^2}\right)\frac{S_{yp}}{F.S} \longrightarrow (iii)$$

$$F.S = 5/3 + 3/8 \frac{(L_e/r)^2}{C_c} - \frac{(L_e/r)^3}{8C_c^3}$$

$$= 5/3 + 3/8 \frac{(98.04)^2}{125.6} - \frac{(98.04)^3}{8(125.6)^3}$$

$$\boxed{F.S = 1.90}$$

eq (iii) $\Rightarrow$ $S_{all} = \left(1 - \frac{(98.04)^2}{2(125.6)^2}\right)\frac{250}{1.90}$

$$\boxed{S_{all} = 91.53\ MPa}$$

$P = S_{all} \times A \Rightarrow 91.53 \times 4580.$

$\boxed{P = 419.2\ KN} \approx \boxed{420\ KN = P}$

So $W_{200 \times 36}$ is our required section whose $A = 4580\ mm^2$.

Pb# 1110 :-

Use AISC Specification.

$P_{allow} = ?$

Section = W360*122.

(a) Hinged ends. length of 9 m.

(b) Built in and unsupported length of 10m.

(c) Built in ends & length of 10m braced at midpoint.

(d) Use $\delta_{yp} = 380 MPa$ & $G = 200 GPa$.

Solution:- From property of W360*122.

$A = 15500 mm^2$

$r = 63 mm$

(a) For Hinged end of Length 9m.

So; $L_e/r = \frac{9 \times 1000 \times 1}{63}$

$$\boxed{L_e/r = 142.85}$$

$C_c = \sqrt{\frac{2\pi^2 E}{S_{yp}}} = \sqrt{\frac{2(3.14)^2(200 \times 10^3)}{380}}$

$C_c = 102.$

As $L_e/r > C_c$ So long Column & use

$\delta_{all} = \frac{12}{23} \frac{\pi^2 E}{(L_e/r)^2}$

$\delta_{all} = \frac{12}{23} \times \frac{(3.14)^2 \times 200 \times 10^3}{(142.85)^2}$

$$\boxed{\delta_{all} = 50.4 MPa}$$

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As; $P = \delta_{all} \times A$

$P = 50.4 * 15500.$

$\boxed{P = 781.2\ KN}$

(b) Built ends:-

As; for built end (fixed) $k = 1/2$

so;

$$l_e/r = \left(\frac{k * L}{r}\right) = \frac{0.5 * 10 \times 1000}{63.}$$

$\boxed{l_e/r = 79.36}$

And $C_c = \sqrt{\frac{2\pi^2 E}{\delta}} = 102$

As $C_c > l_e/r$ so Short or Intermediate Column.

So used

$$\delta_{all} = \left[1 - (l_e/r)^2/2C_c^2\right] \frac{\delta_{yp}}{F.S}$$

$$= \left[1 - \frac{(79.36)^2}{2(102)}\right] \frac{380}{F.S} \rightarrow 1$$

$$F.S = 5/3 + \frac{3\,l_e/r}{8C_c} - \frac{(l_e/r)^3}{8C_c^3}$$

$$= 5/3 + \frac{3(79.36)}{8(102)} - \frac{(79.36)^3}{8(102)^3}$$

$\boxed{F.S = 1.90}$

$\{ ① \Rightarrow$

$$\delta_{all} = \left[1 - \frac{(79.36)^2}{2(102)^2}\right] \frac{380}{1.9}$$

$$\delta_{all} = 139 \text{ MPa.}$$

Since; $P = \delta_{all} \times A$

$= 139 \text{ N/mm}^2 \times 15550 \text{ mm}^2$

$$\boxed{P = 2161.5 \text{ kN}}$$

ⓒ Built in of length 10m & braced at midpoint.

A: braced at mid point so the Column is behaving like hinged - fixed support of length 5m.

So; $\quad l_e/r = \frac{K \times L}{63} = \frac{0.7 \times 5 \times 1000}{63}$

$l_e/r = 55.6$

& $C_c = 102$

As $C_c > l_e/r$ so Short Column.

use $\delta_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right] \frac{S_{yp}}{F.S} \rightarrow ①$

$$F.S = 5/3 + \frac{3(l_e/r)}{8C_c} - \frac{(l_e/r)^3}{8C_c^3}$$

$$\boxed{F.S = 1.85}$$

$$S_{all} = \left(1 - \frac{(L_e/r)^2}{2C_c^2}\right)\frac{S_{yp}}{F.S}$$

$$= \left(1 - \frac{(55.6)^2}{2(102)^2}\right)\frac{380}{1.85}$$

$S_{all} = 175$ MPa

$P = S_{all} \times$ ~~175~~ Area

$= 175\ N/mm^2 \times 15500\ mm^2$

$\boxed{P = 2712.5\ kN}$ Ans ?

Pb # 1111 :-

Select W lightest shape.

$P = 90$ kips.

$L_e = 15'$.

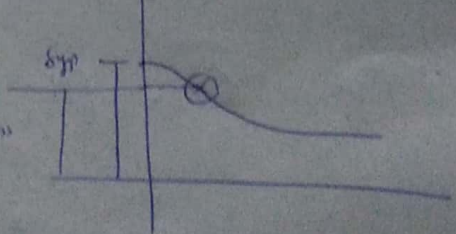
Use AISC specification

$S_{yp} = 36$ ksi

$E = 29 \times 10^6$ psi.

Sol:-

$S_{ass} = 0.8 \times S_{all} \rightarrow (1)$



To find $S_{all} = ?$

Consider $L_e/r = 0$

so, $F.S = 5/3$

$$f_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right)\frac{S_{yp}}{F.S}$$

$$= \left(1 - \frac{0}{2C_c^2}\right)\frac{36\times10^3}{5/3}.$$

$$f_{all} = 21.6\ ksi$$

$$f_{ass} = 0.8 * 21.6\ ksi.$$

$$f_{ass} = 17.28\ ksi$$

$$A = P/f_{ass} = \frac{90\times10^3}{17.28\times10^3}$$

$$\boxed{A = 5.21\ in^2}$$

So By trail method.

First try:-

Let select $W_6\times21$

$A = 6.16\ in^2$

$r_{min} = 1.26\ in$

To find l_e/r

$$= \frac{15\times12}{1.26} = 143.$$

$$C_c = \sqrt{\frac{2\pi^2E}{f_{yp}}} = \sqrt{\frac{2(3.14)^2(29\times10^6)}{36\times10^3}}$$

$$\boxed{C_c = 126}$$ A_3

As $l_e/r > C_c$ so long column

use

$$\sigma_{all} = \frac{12}{23} \frac{\pi^2 E}{(l_e/r)^2}$$

$$= \frac{12}{23} \times \frac{(3.14)^2 \times (29 \times 10^6)}{(143)^2}$$

$$\boxed{\sigma_{all} = 7.30\,ksi}$$

So; $P = \sigma_{all} \times A$

$= 7.30 \times 6.16$

$$\boxed{P = 45\,kips}$$

Since $P_{cal} < P_{given}$ so discard this column

Consider W5x28 section

$A = 8.25\,in^2$ & $r_{min} = 1.62"$

So; first $l_e/r = \frac{15 \times 12}{1.62} = 111.1$

& $C_c = 126$

Since $C_c > l_e/r$ so short & Intermediate Column use

$$S_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right] \frac{S_{yp}}{F.S} \rightarrow (A)$$

$$F.S = 5/3 + \frac{3}{8}\frac{l_e/r}{C_c} - \frac{(l_e/r)^3}{8C_c^3}$$

$$= 5/3 + 3/8 \frac{(111.1)}{126} - \frac{(111.1)^3}{8(126)}$$

$$F.S = 1.91$$

$$S_{all} = \left(1 - \frac{(111.1)^2}{2(126)^2}\right) \frac{36 \times 10^3}{1.91}$$

$$\boxed{S_{all} = 11.53 \text{ ksi}}$$

AS.

$$P = S_{all} * A.$$

$$= 11.53 * (8.25)$$

$$\boxed{P = 95.12 \text{ kips}}$$

~~as~~ given $P = 90$ kips.

So, $P_{cal} > P_{given}$

So consider $W_{8 \times 28}$ section.

Pb # 1112 :-

$L = 5m$

Built in ends.

a) If cross section is circular with radius 40mm.

(b) 50mm Square

Required $l_e/r = ?$

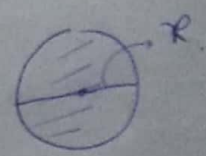
Solution:-

As buit in ends (fixed support)

so $K = 0.5$.

(a) For Circular Cross section of $R = 40mm$.

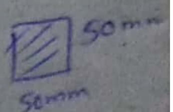
As; $\dfrac{l_e}{r} = \dfrac{K \times L}{r} = \dfrac{0.5 \times 5 \times 1000}{\sqrt{I/A}}$



$l_e/r = \dfrac{2500}{\sqrt{\dfrac{\pi R^4}{4\pi R^2}}}$

$= \dfrac{2500}{R/2} \Rightarrow \dfrac{5000}{R} = \dfrac{5000}{40}$

so, $\boxed{l_e/r = 125}$



(b) $l_e/r =$ For Square of 50mm.

$l_e/r = \dfrac{0.5 * 5 \times 1000}{\sqrt{\dfrac{50(50)^3}{12(50)(50)}}} = \dfrac{2500}{\sqrt{50^2/12}}$

$\boxed{l_e/r = 173.61}$ Ans.

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Pb # 1113 :-

Given data;

$L = 12'$,

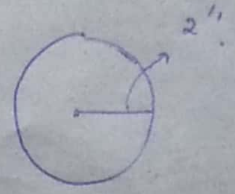
one fixed & other hinged

$K = 0.7$.

Find L/r

(a) Circular with radius 2" & (b) 2.5 in square

Sol: (a) For circular section.



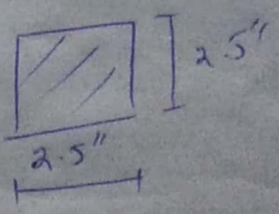
As $L/r = \frac{K \times L}{r} = \frac{0.7 \times 12}{\sqrt{I/A}}$

$= \frac{0.7 \times 12}{\sqrt{\frac{\pi r^4}{4 \pi r^2}}}$

$= \frac{0.7 \times 12 \times 12}{\sqrt{r^2/4}} = \frac{100.8}{r/2} = \frac{100.8}{2/2}$

$\boxed{L/r = 100.8}$

(b) For 2.5 in² Square



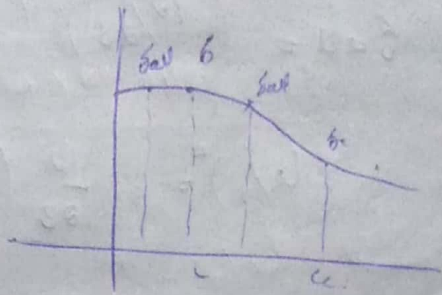
$L/r = \frac{KL}{r} = \frac{0.7 \times 12 \times 12}{\sqrt{I/A}}$

$= \frac{100.8}{\sqrt{\frac{b^4}{12 b^4}}} = \frac{100.8}{b} = \frac{100.8}{\sqrt{\frac{(2.5)^2}{12}}}$

$\boxed{L/r = 139.67}$ Ans

Pb #1114:- Determine the maximum length of a W250 x 167 section used as a hinged end column to support a load of 1600 kN. Use AISC specification with $\sigma_{yp} = 380$ MPa & $E = 200$ GPa.

Sol:- Given data



$P = 1600$ kN.

As section is;

W250x167.

From properties table of

W250x167

$A = 21,300 \, mm^2$.

Now first step is to find σ.

As $\sigma = \frac{P}{A} = \frac{1600 \times 10^3 \, N}{2130 \, mm^2} \Rightarrow \boxed{\sigma = 75.11 \, MPa}$

Now find $C_c = ?$

As $C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2(200 \times 10^9)}{380 \times 10^6}}$

$\boxed{C_c = 101.87}$

to σ_c on basis of C_c

As; $\sigma = \frac{12}{23} \frac{\pi^2 E}{C_c^2}$

$\sigma = 12/23 \frac{(3.14)^2 (200 \times 10^9)}{(101.87)^2}$.

$\sigma_c = 10.05 MPa$

As $\sigma > \sigma_c$

So, use

$$\sigma_{all} = \left(12/23\right)\left(\frac{\pi^2 E}{(l_e/r)^2}\right)$$

$\because \sigma_{all} = \sigma.$

$$(l_e/r)^2 = \frac{12}{23}\left(\frac{\pi^2 E}{\sigma_{all}}\right).$$

$$= \frac{12}{23} \frac{(3.14)^2 (200 \times 10^9)}{75.11 \times 10^6}$$

$$l_e/r = \sqrt{13697.61}$$

$$l_e/r_{min} = 117$$

$$l_e = 117 \times r.$$

$r = 68.1 mm$

$$l_e = 117 \times 68.1.$$

$$l_e = 7967.7 mm$$

$$\boxed{l_e = 7.9 m}$$

As hinged end column so $k = 1$

or

$$L \times k = 7.9 m.$$

$$L \times 1 = 7.9 m.$$

$$\boxed{L = 7.9 m}$$ Ans

Pb # 1115 :- Given data

W14x82 section

$l_e = 30 ft.$

$\sigma_{yp} = 50 ksi$

$E = 29 \times 10^6 psi.$

Use AISC Specification Calculate $P = ?$

Sol:- As use AISC specification;

so;

$$l_e/r = \frac{30 \times 12}{2.48} \qquad r_{min} = 2.48''$$

$$\boxed{l_e/r = 145.2}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}}$$

$$= \sqrt{\frac{2(3.14)^2(29\times10^6)}{50\times10^3}}$$

$$\boxed{C_c = 106.94}$$

As $l_e/r > C_c$ so large column

Since;

$$\sigma_{all} = 12/23 \frac{\pi^2 E}{(l_e/r)^2}$$

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$$\delta_{all} = \frac{12}{23} \cdot \frac{\pi^2 E}{(L/r)^2}$$

$$= \frac{12}{23} * \frac{(3.14)^2 (29 \times 10^6)}{(145.2)^2}$$

$$\delta_{all} = 7075.83 psi$$

or

$$\boxed{\delta_{all} = 7.075 ksi}$$

To find $P_{safe} = ?$

As $\delta_{all} = P/A$

$A = 24.1 in^2$

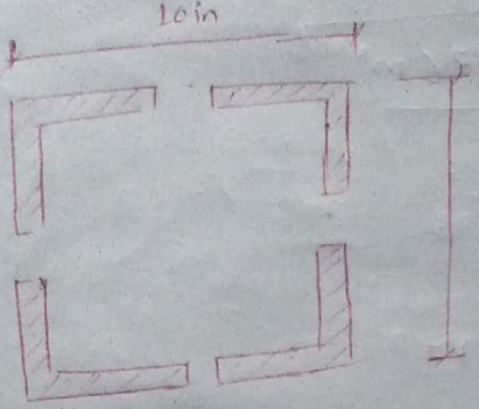
$$P_{safe} = \delta_{all} * A$$

$$= 7.075 * 24.1$$

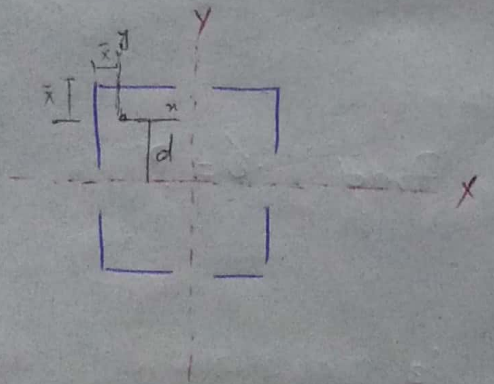
$$\boxed{P_{safe} = 170.5 \text{ kips}}$$ Ans

Pb # 1117:- Four $4 \times 4 \times \frac{1}{2}$ in angles are latticed together to form the column section shown in fig. Use AISC specification determine the maximum length at which a 200 kips load can be safely supported use $\sigma_{yp} = 60$ ksi & $E = 29 \times 10^6$ psi.

Figure:-



Solution:- First find geometrical moment of Inertia. Which can be calculated as;



$A = 3.75 \text{ in}^2$

As from property table we found Centroid is at $\bar{x} = 1.18"$, $I_x = 5.56 \text{ in}^4 = I_y$

Since (4)×(4)×1/2 both same so from both direction i.e $\bar{x} = \bar{y} = 1.8"$.

So, $I_x = (I_x + Ad^2) \times 4$ — As four L sections.

$I_x = \left(5.56 + 3.75(5 - 1.18)^2\right) \times 4$

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$$I_x = (556 + 54.7215) \times 4$$

$$\boxed{I_x = 241.126 \text{ in}^4}$$

Similarly

$$I_Y = (I_y + Ad^2) \times 4$$

$$\boxed{I_y = 241.126 \text{ in}^4}$$

As, $L_e/r = ?$

First find $r = ?$

$$r = \sqrt{I/A} = \sqrt{\frac{241.126}{3.75 \times 4}}$$

$$\boxed{r = 8.018 \text{ in}}$$

$L/r = ?$

First step is to find $\sigma = ?$

As $\sigma = P/A$

$$= \frac{200 \times 10^3}{4 \times 3.75}$$

$$\boxed{\sigma = 13.33 \text{ Ksi}}$$

Now find

$C_c = ?$

As $C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}}$

$$C_c = \sqrt{\frac{2(3.14)^2(29\times10^6)}{(60\times10^3)}}$$

$$\boxed{C_c = 97.62}$$

Now find "σ" on basis of C_c

As;

$$\sigma_{cc} = \frac{12}{23}\frac{\pi^2 E}{C_c^2}$$

$$= \frac{12}{23}\frac{(3.14)^2(29\times10^6)}{(97.62)^2}$$

$$\boxed{\sigma_{cc} = 15.65\,ksi}$$

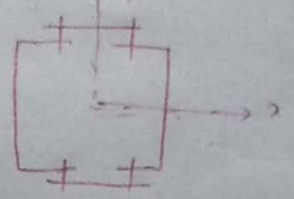
As $\sigma_{cc} > \sigma$. So now error & trail method.

Pb# 118 A steel column with effective length of 10m is fabricated from two C250X45 channels latticed together so that the section has equal moment of inertia about the principal axis. Determine the safe load P using AISC specification. Use $\sigma_{yp} = 380MPa$ & $E = 200GPa$.

Solution:-

Given that.

Figure:-



$L_e = 10m$

Section = C250x45.

$\sigma_{yp} = 380MPa$

$E = 200GPa$.

From the table, Properties of C250x45 are.

$A = 5670 mm^2$

$I_x = 42.8 \times 10^6 mm^4$.

$I_y = 1.6 \times 10^6 mm^4$.

$r_x = 86.9 mm$.

$r_y = 16.3mm$.

Note # For built up section radius of gyration should be found manually.

As,

$r_x = \sqrt{\frac{2I_x}{2A}}$ ⇒ For Combined Section.

$= \sqrt{\frac{2(42.8 \times 10^6)}{2(5670)}}$

$\boxed{r_x = 86.9 mm} = r_y$.

Now;

$$L/r_{min} = \frac{10 \times 100}{(86.9)^2}$$

$$\boxed{L/r = 115.1} = \boxed{57.54}$$

To find $C_c = ?$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2 (200 \times 10^9)}{(380 \times 10^6)}}$$

$$\boxed{C_c = 101.87}$$

$$\sigma_{all} = \left(1 - \frac{(L/r)^2}{2C_c^2}\right) \frac{\sigma_{yp}}{F.S} \rightarrow ①$$

$$F.S = 5/3 + \frac{3}{8} \frac{L/r}{C_c} - \frac{1}{8} \frac{(L/r)^3}{C_c^3}$$

$$= 5/3 + 0.2118 - 0.022525$$

$$\boxed{F.S = 1.86}$$

$$\sigma_{all} = \left(1 - \frac{(57.54)^2}{2(101.87)^2}\right) \frac{380 \times 10^6}{1.86}$$

$$\sigma_{all} = 171.71$$

$P =$

If $L/r > C_c$.

$$\sigma_{all} = \frac{12}{23} \frac{\pi^2 E}{(L/r)^2}$$

$$= \frac{12}{23} \frac{(3.14)^2 (200 \times 10^9)}{(115.1)^2}$$

$\sigma_{all} = 77.65$ MPa

$P_{all} = 77.65 \times 5670.$

$$\boxed{P_{all} = 440 \text{ kip.}}$$

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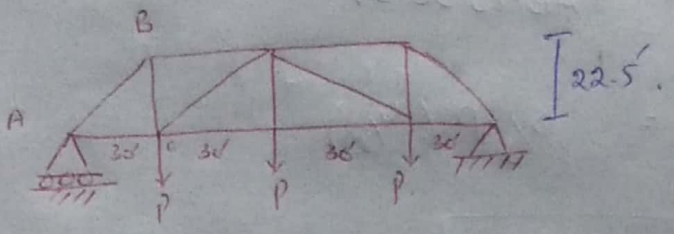
Pb # 1119 In the bridge truss as shown, the member AC is composed of two $C_{9\times20}$ channels latticed together so that equal moment of inertia about axis of symmetry. If safe load P on the truss is govern by strength of member AC. Compute P using AISC specification with $\sigma_{yp} = 36\,ksi$ & $E = 29\times10^{6}\,psi$.

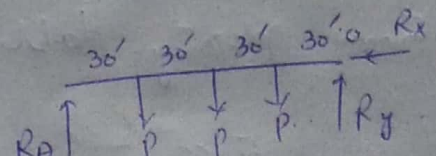
Figure:-



Solution:-

First step is to find reaction in member AC.

$$\sum M_A = 0$$



$$R_A \times 120 = P(90) + P(60) + P(30)$$

$$120\,R_A = 180P$$

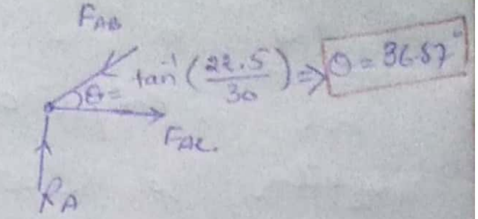
$$R_A = \frac{180}{120}P$$

$$\boxed{R_A = \tfrac{3}{2}P}$$

to find force in member AC using joint method

Draw FBD of joint A.

$\Sigma F_y = 0. \quad \uparrow + \quad \downarrow -.$



$F_{AB} \sin 36.87 = R_A.$

$$F_{AB} = \frac{3/2\ P}{3/5}$$

$$\boxed{F_{AB} = 5/2\ P.}$$

$\Sigma F_x = 0 \ (\xrightarrow{+} \ \xleftarrow{-})$

$$F_{AC} = F_{AB} \cos 36.87$$

$$= 5/2\ P\ (4/5)$$

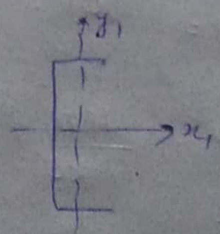
$$\boxed{F_{AC} = 2P.}$$

Now; Consider two C9x20 section.

From property table of C9x20.

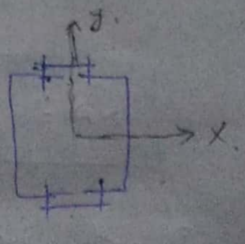
$A = 5.88\ in^2$, $I_{x_1} = 60.9\ in^4$, $I_{y_1} = 2.42\ in^4$.

$I_x = 2 \times I_{x_1}.$



$= 2 \times 60.9$

$$\boxed{I_x = 121.8\ in^4}$$



As square section

$$\boxed{I_x = I_y}$$

Now to find L/r.

$$L/r = \frac{K \times L}{r} = \frac{0.7 \times 30 \times 12}{\sqrt{I/A}} = \frac{252}{\sqrt{\frac{121.8}{5.88}}}$$

$$\boxed{L/r = 55.3688} \quad 78.3$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2 (29 \times 10^6)}{36 \times 10^3}}$$

$$\boxed{C_c = 126}$$

As $C_c > L/r$

$$\sigma_{all} = \left(1 - \frac{L/r}{2C_c^2}\right) \frac{\sigma_{yp}}{F.S} \longrightarrow (1)$$

$$F.S = 5/3 + 3/8 \frac{L/r}{C_c} - \frac{1}{8} \frac{(L/r)^3}{C_c^3}$$

$$= 5/3 + \overset{0.333}{0.1648} - 0.010667$$

$$\boxed{F.S = 1.8\cancel{7}} = 1.91$$

$$\sigma_{all} = \left(1 - \frac{(55.3688)^2}{2(126)^2}\right) \frac{36 \times 10^3}{1.82} \Rightarrow \sigma_{all} = 1909.81 \text{ Psi}$$

$$P = \sigma_{all} \times A = 1909 \times 5.88 = \underline{\underline{112.3 \text{ Kips}}}$$

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Pb# 1116:-

Section W310x52 (Hinged ends)

use AISC specification to find P = ?

(a) L = 10m (b) L = 14m

use $\sigma_{yp} = 250\,MPa$ & $E = 200\,GPa$.

Sol:- To find P.

$$L/r = \frac{L \times k}{r} = \frac{10 \times 1000}{39.3} = 254.45$$

use $r = r_{min}$.

from properties of W310x52.

$A = 6670\,mm^2$,

$I_x = 118 \times 10^6\,mm^4$, $I_y = 10.3 \times 10^6\,mm^4$,

$r_x = 133\,mm$, $r_y = 39.3\,mm$.

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2(200 \times 10^9)}{250 \times 10^6}}$$

$$\boxed{C_c = 125.6}$$

As $L/r > C_c$.

so long column.

$$\sigma_{all} = \left(\frac{12}{23}\frac{\pi^2 E}{(L/r)^2}\right) = \frac{12}{23}\frac{(3.14)^2(200 \times 10^9)}{(254.45)^2}$$

$$\boxed{\sigma_{all} = 15.89\,MPa}$$

$\therefore$ $P = \sigma_{all} \times A$

$= 15.89 \times 6670 \Rightarrow$ $\boxed{P = 105.98\,KN}$

For $L = 14m$

$$L/r = \frac{14 \times 1 \times 1000}{39.3} = 356.23.$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}}.$$

$$C_c = \sqrt{\frac{2(3.14)^2(200 \times 10^3)}{250 \times 10^6}}.$$

$$\boxed{C_c = 125.6}$$

$\therefore$ $L/r \geq C_c$ So Long Column.

Using $\sigma_{all} = \frac{12}{23} \frac{\pi^2 E}{(L/r)^2}.$

$$= \frac{12}{23} \times \frac{(3.14)^2(200 \times 10^9)}{(356.23)^2}.$$

$$\sigma_{all} = 8.11\ MPa$$

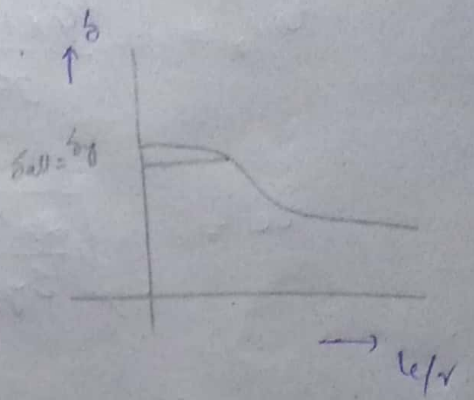
$P = \sigma_{all} \times A = 8.11 \times 6670.$

$\boxed{P = 54.093\,KN}$ Ans

Pb# 1122:- Select the lightest W that can be used as a column to support an axial load of P = 420 KN on an effective length of 4m. Use AISC specification with $\sigma_{yp} = 250$ MPa & E = 200 GPa.

Sol:- Given data:

$P = 420$ KN.
$l_e = 4$ m.
$\sigma_{yp} = 250$ MPa.
$E = 200$ GPa.



Required data
Lightest W shape = ?

$\sigma_{assume} = 0.8 \times \sigma_{all} \rightarrow$ (A).

Consider ~~long~~ short column

Since for ~~long~~ short column,

$l_e/r = 0$.

So, $F.S = 5/3 + 3/8 \frac{l_e/r}{C_c} - \frac{1}{8} \frac{(l_e/r)^3}{C_c^3}$.

So, $\boxed{F.S = 5/3}$

$\sigma_{all} < \sigma_{yp}$.

$\sigma_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right) \frac{\sigma_{yp}}{F.S}$.

$\sigma_{all} = \frac{250}{5/3}$

$\boxed{\sigma_{all} = 150 \text{ MPa}}$

eq (A) $\Rightarrow$ $\sigma_{ass} = \sigma_{all} \times 0.8$

$\sigma_{ass} = 0.8 \times 150$

$\boxed{\sigma_{ass} = 120\ MPa}$

To find area:-

As $\sigma_{all} = P/A$

$$A = \frac{P}{\sigma_{all}} = \frac{420 \times 10^3}{120 \times 10^6}$$

$\boxed{A = 3500\ mm^2}$

By checking to area of different section & compare with this calculated area;

let select W150×30 section whose area is

$A = 3790\ mm^2$

$r_{min} = 38.3\ mm$

So, $$\frac{le}{r} = \frac{4 \times 10^3}{38.3} = 104.4$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2 (200 \times 10^9)}{(250 \times 10^6)}}$$

$\boxed{C_c = 125.66}$

As $C_c > l_e/r$.

So short or intermediate column.

Using;

$$\sigma_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right)\frac{\sigma_{yp}}{F.S}$$

$$= \left(1 - \frac{(104.4)^2}{2(125.66)^2}\right)\frac{250\times10^6}{1.91}$$

$$\boxed{\sigma_{all} = 85.67\ MPa}$$

To find F.S.

$$F.S = 5/3 + 3/8\,\frac{l_e/r}{C_c} - 1/8\,\frac{(l_e/r)^3}{C_c^3}$$

$$F.S = 5/3 + 3/8\left(\frac{104.4}{125.66}\right) - 1/8\,\frac{(104.4)^3}{(125.66)^3}$$

$$\boxed{F.S = 1.91}$$

Now to find P.

As; $\sigma_{all} = P/A$

$P = \sigma_{all} \times A$

$= 85.67 \times 3790$

$P_{cal} = 324.67\ KN$

As $P_{cal} < P_{given}$ So this not

Compatable & W 150 × 30 is inedequate.

let select

$W200 \times 36$ section;

whose $A = 4580 mm^2$ & $r_{min} = 40.8 mm$.

So, $L_e/r = \frac{4 \times 1000}{40.8} = \boxed{L_e/r = 98.04}$

Since $\boxed{C_c = 125.66}$

As $L_e/r < C_c$. So short Column.

Using $\sigma_{all} = \left(1 - \frac{(L_e/r)^2}{2C_c^2}\right) \frac{\sigma_{yp}}{F.S} \rightarrow$ (B).

$F.S = 5/3 + 3/8 \frac{L_e/r}{C_c} - \frac{1}{8} \frac{(L_e/r)^3}{C_c^3}$.

By putting values.

$\boxed{F.S = 1.90}$

$\sigma_{all} = \left(1 - \frac{(98.04)^2}{2(125.66)^2}\right) \frac{250 \times 10^6}{1.9}$.

$\boxed{\sigma_{all} = 91.53 MPa}$

Using $P = \sigma_{all} \times A$.

$= 91.53 * 4580$.

$= 419.2 KN \approx 420 KN$

So select

$W200 \times 36$ section.

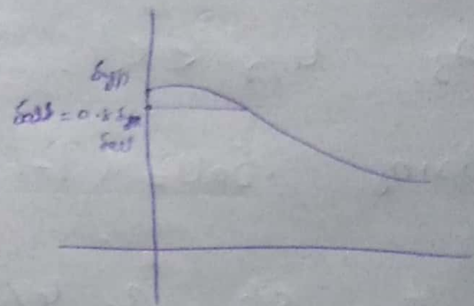
Pb # 1123:-

Select the lightest W shape that can be used as a column, according to AISC specification, to support an axial load of 700 kN on an effective length of 5.5m.

Assume $\sigma_{yp} = 250\,MPa$ & $E = 200\,GPa$.

Solution:-

Consider



$\sigma_{assume} = 0.8\ \sigma_{all} \rightarrow ①$

Consider short column

with $L_e/r = 0$.

As for short or intermediate column.

$$\sigma_{all} = \left(1 - \frac{(L_e/r)^2}{2C_c^2}\right)\frac{\sigma_{yp}}{F.S} \rightarrow ①$$

As

$$F.S = 5/3 + 3/8\,\cancel{\frac{L_e/r}{C_c}}^{\,0} - 1/8\,\cancel{\frac{(L_e/r)^3}{C_c^3}}^{\,0}.$$

$$\boxed{F.S = 5/3}$$

$$\sigma_{all} = \frac{250}{5/3}$$

$$\boxed{\sigma_{all} = 150\,MPa}$$

eq① ⇒ $\sigma_{ass} = 0.8 \times \sigma_{all}$

$= 0.8 \times 150$

$$\boxed{\sigma_{ass} = 120\,MPa}$$

To find area:-

As $\sigma_{all} = P/A$

$A = \cancel{\sigma_{all}} \; P/\sigma_{all}$

$$A = \frac{700 \times 10^3}{120 \times 10^6}$$

$$\boxed{A = 5833.33\,mm^2}$$

By comparing areas of different sections to get suitable section for P = 700 KN.

Let select W250x80.

with area = 10,200 mm² { $r_{min} = 65\,mm$.

$$l_e/r = \frac{5.5 \times 1000}{65} \Rightarrow \boxed{l_e/r = 84.61}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} \Rightarrow C_c = \sqrt{\frac{2(3.14)^2(200 \times 10^9)}{250 \times 10^6}}$$

$$\boxed{C_c = 125.6}$$

As $l_e/r < C_c$ so short or Intermediate Column.

use $$\sigma_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right)\frac{S_{yp}}{F.S} \rightarrow (B)$$

$$F.S = 5/3 + 3/8 \frac{l_e/r}{C_c} - 1/8 \frac{(l_e/r)^3}{C_c^3}.$$

$$F.S = 5/3 + 3/8 \frac{(84.61)}{(125.6)} - \frac{1}{8}\frac{(84.61)^3}{(125.6)^3}$$

$$= 5/3 + 0.2526 -$$

$$\boxed{F.S = 1.88}$$

$$\sigma_{all} = \left(1 - \frac{(84.61)^2}{2(125.6)^2}\right)\frac{250 \times 10^6}{1.88}$$

$$\sigma_{all} = 102.8 MPa$$

To find $P_{cal} = ?$

$$P_{cal} = \sigma_{all} \times A.$$

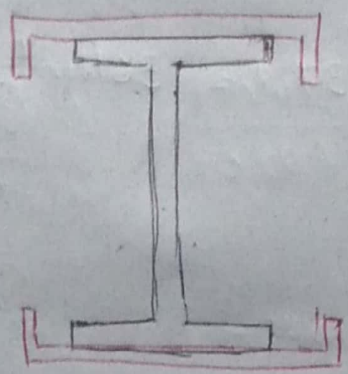
$$= 102.8 \times 10200$$

$$\boxed{P_{cal} = 1048.56 KN}$$

As $P_{cal} > P_{given}$, so this section can be used to support an axial load of 700 KN
So section is W250x80 Ans

Scanned by CamScanner

Pb # 1125 A hinged end steel column 30 ft long is fabricated from $W_{8\times31}$ section & two $C_{12\times30}$ channel section are arranged as shown. Determine the safe load using AISC specification with $\sigma_{yp} = 36$ Ksi & $E = 29\times10^6$ psi.



Properties of $W_{8\times31}$ section

$A = 9.13\ in^2$

Depth = 8 in

Thw = 0.285"

Fwidth = 7.995"

Fth = 0.435"

$I_x = 110\ in^4$

$I_y = 37.1\ in^4$

Properties of $C_{12\times30}$

$A = 8.82\ in^2$

Depth = 12"

Web thick = 0.510"

Fwidth = 3.170"

Fth = 0.501"

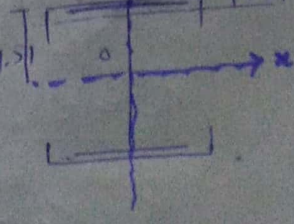
$I_x = 162\ in^4$

$I_y = 5.14\ in^4$

First find I_x & I_y about global axis.

$I_x = 2(I_y + Ad^2) + 1(I_x)$

$I_x = 2(5.14 + 8.82(4.51 - 0.67)^2)$
$+ 110$



$$\boxed{I_X = 350.39\ in^4}$$

To find I_Y

$$I_Y = 2(I_x)_{C12\times31} + 1[I_Y]_{W8\times31}$$

$$= 2[162] + 37.1 = 361.1\,in^4$$

$$\boxed{I_Y = 361.1\ in^4}$$

To find $l_e/r = ?$

First find $r = ?$

I should be I_{min},

$I_{min} = I_Y$

As $r = \sqrt{I/A} = \sqrt{\frac{I_{min}}{A}}$

$$r = \sqrt{\frac{361.1}{25.77}}$$

$A =$ Total area

$A = 2\times8.82 + 9.13$

$A = 25.77\,in^2$

$$\boxed{r = 3.67\ in}$$

$$l_e/r = \frac{30\times1\times12}{3.67} \Rightarrow \boxed{l_e/r = 98.1}$$

$C_c = ?$ As $C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}}$

$$C_c = \sqrt{\frac{2(3.14)^2(29\times10^6)}{36\times10^3}}$$

$C_c = 126.11$.

As $C_c > le/r$ so short or Intermediate column.

So; use

$$\sigma_{all} = \left(1 - \frac{(le/r)^2}{2C_c^2}\right)\frac{\sigma_{yp}}{F.S} \rightarrow (A)$$

$$F.S = 5/3 + 3/8 \frac{le/r}{C_c} - 1/8 \frac{(le/r)^3}{C_c^3}.$$

$$F.S = 5/3 + 3/8 \frac{(98.1)}{(126.11)} - \frac{1}{8}\frac{(98.1)^3}{(126.11)^3}$$

$$\boxed{F.S = 1.835}$$

eq (A) $\Rightarrow$

$$\sigma_{all} = \left(1 - \frac{(98.1)^2}{2(126.11)^2}\right)\frac{36 \times 10^3}{1.835}.$$

$$\boxed{\sigma_{all} = 13.683 ksi}$$

As $\sigma_{all} = P/A$.

$P = \sigma_{all} \times A$

$P = 13.683 \times 10^3 * 26.77$.

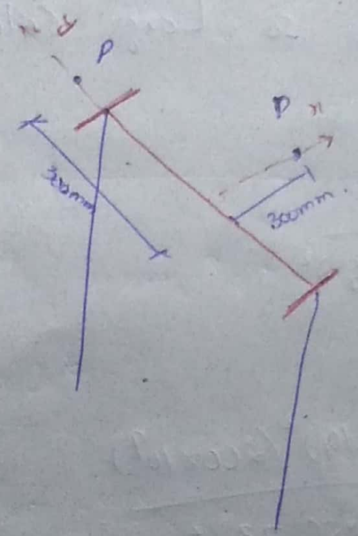
$\boxed{P = 366 Kips}$ Ans

Pb#11134:- A W360X122 Section is used as a column with an affective length of 10m. Determine the max load that can be carried at eccentricity of 300mm Should the load placed on X or Y axis?

Assume $\sigma_{yp} = 290MPa$ & $E = 200GPa$.

Solution:-

Figure.



As from properties table, of W360X122 section.

$A = 15500mm^2$

$d = 363mm$

$b_f = 257mm$

$I_x = 365 \times 10^6 mm^4$

$I_y = 61.5 \times 10^6 mm^4$

$r_x = 153mm$

$r_y = 63mm$

First find L_e/r_{min}

$$L_e/r = \frac{10 \times 1000}{63} = 158.73$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}}$$

$$= \sqrt{\frac{2(3.14)^2(200\times10^9)}{290\times10^6}}$$

$$C_c = 116.67$$

As $L_e/r > C_c$ so Long Column.

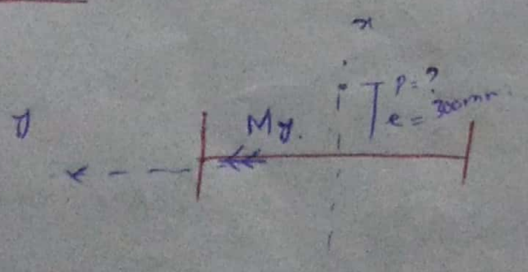
$$\sigma_{all} = \frac{12}{23}\;\frac{\pi^2 E}{\cancel{\sigma_y}\,(L_e/r)^2}$$

$$= \frac{12}{23}\times\frac{(3.14)^2(200\times10^9)}{(158.73)^2}$$

$$\boxed{\sigma_{all} = 40.8\ \text{MPa}}$$

Now we have two possibilities.

Case a:-



Using maximum stress approach.

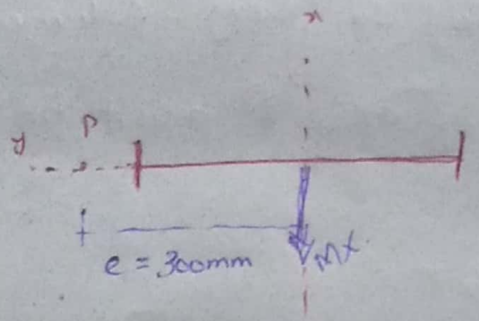
$$\sigma_a + \sigma_f \le \sigma_{all}$$

$$P/A + \frac{M_y c}{I_y} \le 40.87.$$

$$\frac{P}{15500} + \frac{P(300)(257/2)}{61.5 \times 10^6} = 40.87$$

$$\boxed{P = 59.117 \, kN}$$

Case #b



$$\delta_a + \delta_f \le \delta_{all}$$

$$\frac{P}{A} + \frac{M_x c}{I_x} \le 40.8$$

$$\frac{P}{15500} + \frac{P(300)(363/2)}{365 \times 10^6} = 40.8$$

$$\boxed{P = 191.25 \, kN}$$

So select the max safe load i.e $P = 191.25$ kN. which will apply on y-axis.

Pb#1139:- Given data.

Section = $C_{310 \times 45}$ (Hinged end Column).

$L = 2.2m$

$P = 50KN$.

$\sigma_{yp} = 380MPa$.

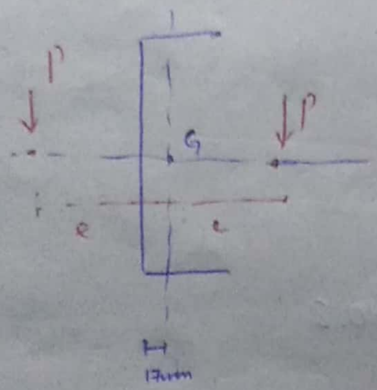
$\sigma_T = 140 MPa$

$E = 200GPa$.

On which side of axis P must be placed?

$e_{max} = ?$

Solution:-



From property of $C_{310 \times 45}$ section.

$A = 5690mm^2$

$I_x = 67.3 \times 10^6 mm^4$.

$I_y = 2.12 \times 10^6 mm^4$.

$r_x = 109mm$ $\quad r_y = 19.3mm$.

$\bar{x} = 17mm$. $\quad d = 305mm$ & $b_f = 80mm$.

As $\quad \frac{L}{r}_{min} = \frac{2.2 \times 1000 \times 1}{19.3} = 114$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}}$$

$$= \sqrt{\frac{2(3.14)^2(200\times10^9)}{380\times10^6}}$$

$$C_c = 101.87$$

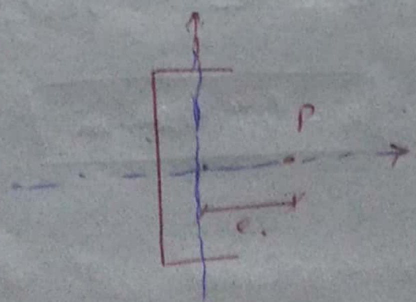
As $L_e/r > C_c$ so large column.

$$\sigma_{all} = \frac{12}{23}\frac{\pi^2 E}{(L_e/r)^2}$$

$$= \frac{12}{23}\frac{(3.14)^2(200\times10^9)}{(114)^2}$$

$$\boxed{\sigma_{all} = 79.16\,MPa}$$

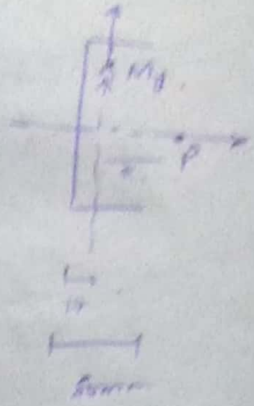
Case # 1
Consider the load applied on right side at distance E as shown.



Based on compression; use max. stress approach;

$$\sigma_a + \sigma_f \le \sigma_{all}$$

$$\frac{P}{A} + \frac{M_y\, c}{I_y} \le \sigma_{all}$$



$$\frac{50\times10^3}{5690} + \frac{50\times10^3 e\,(80-17)}{2.12\times10^6} = 79.24$$

$$\boxed{e = 47.42\,mm}$$

Based on Tension:

$$\sigma_a - \sigma_b \le \sigma_{all_T}$$

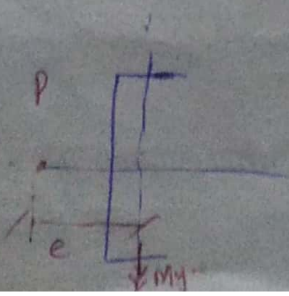
$$P/A - \frac{M_y\, c}{I_y} \le \sigma_T.$$

$$\frac{50\times10^3}{5690} - \frac{50\times10^3 e\,(17)}{2.12\times10^6} = -140$$

$$\boxed{e = 370.6\,mm}$$

So the max. safe value to prevent buckling & tensile failure is $\boxed{e = 47.42\,mm}$

Case #b let load is applied at ~~right~~ left



Based on compression

$$\sigma_a + \sigma_f \le \sigma_{all}$$

$$\frac{P}{A} + \frac{M_y c}{I_y} \le \sigma_{all}$$

$$\frac{50\times10^3}{5690} + \frac{50\times10^3 (e)(17)}{3.12\times10^6} = 79.24$$

$$\boxed{e = 175.72mm}$$

Based on tensile stresses.

$$\sigma_a - \sigma_f \le \sigma_T$$

$$P/A - \frac{M_y c}{I_y} \le \sigma_T$$

$$\frac{50\times10^3}{5690} - \frac{50\times10^3 (e)(80-17)}{2.12\times10^6} = -140$$

$$\boxed{e = 100mm}$$

Select the smallest $\boxed{e = 100mm}$

But In case (a) & case (b) we will Consider e_{max} which have largest e value

So Select $\boxed{e_{max} = 100mm}$ Ans

Pb #1136 :- Given data

Dimension = 2" by 3"

$L_e = 5'$

$e = 5"$ (from the weaker axis).

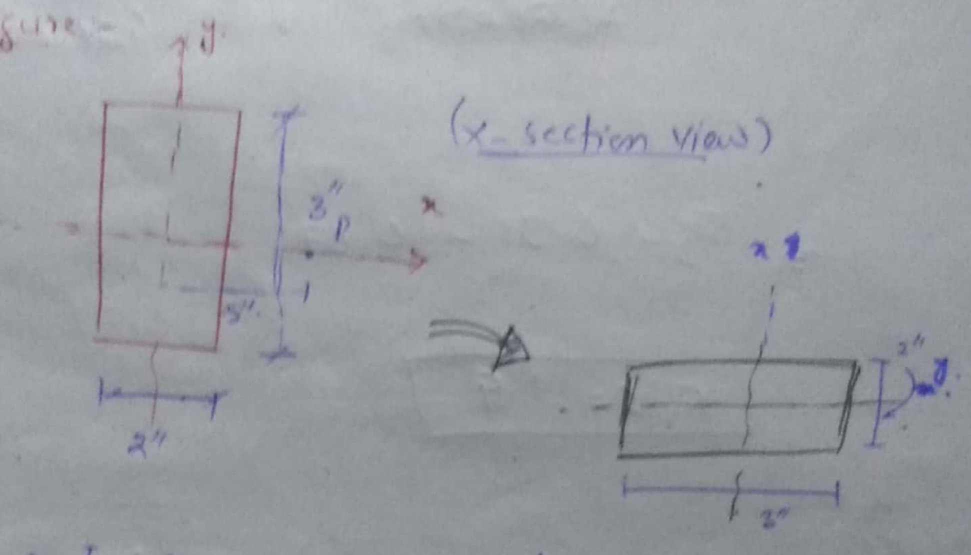
$\sigma_{yp} = 36$ ksi

$P_a = 11$ kips

$E = 29 \times 10^6$ psi

$P_e = ?$

Sol:- Figure:-



As $I_x > I_y$ so y-axis weaker axis

So from $$L_e/r = \frac{5 \times 12}{\sqrt{I/A}} = \frac{60}{\sqrt{\frac{3(2)^3}{12(2)(3)}}}$$

$$= \frac{60}{\sqrt{4/12}} = \frac{60}{0.577}$$

$$\boxed{L_e/r = 103.9}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2(29 \times 10^6)}{36 \times 10^3}}$$

$$\boxed{C_c = 126.035}$$

As $C_c > L_e/r$ so ~~Large~~ small Colum or Intermediate

So;

$$\sigma_{all} = \left(1 - \frac{(L_e/r)^2}{2C_c^2}\right)\frac{\sigma_{yp}}{F.S} \longrightarrow (1)$$

$$F.S = \frac{5}{3} + \frac{3(L_e/r)}{8\,C_c} - \frac{1}{8}\frac{(L_e/r)^3}{C_c^3}.$$

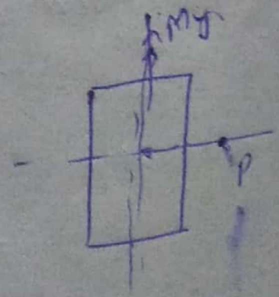
$$= \frac{5}{3} + \frac{3(103.9)}{8(126.035)} - \frac{1}{8}\left(\frac{(103.9)^3}{(126.035)^3}\right).$$

$$= \frac{5}{3} + 0.31 - 0.07$$

$$\boxed{F.S = 1.9}$$

$$\sigma_{all} = \left(1 - \frac{(103.9)^2}{2(126.035)^2}\right)\frac{36\times10^3}{1.9}$$

$$\boxed{\sigma_{all} = 12.51\ Ksi}$$



Using max. stress approach

$$\sigma_a + \sigma_f \leq \sigma_{all}$$

$$\frac{\Sigma P}{A} + \frac{M_y c}{I_y} = \sigma_{all}$$

$$\frac{P_e + 11}{2\times3} + \frac{P_e \times 5 \times (1) \times 12}{3(2)^3} = 12.51 \times 10^3$$

$$\frac{P_e + 11}{2 \times 3} + \frac{P_e \times 5 \times \cancel{2} \times \cancel{4}}{\cancel{2} \times \cancel{4} \times 2} = 12.51 \times 10^3$$

$$\frac{P_e + 11 + 3(P_e \times 5)}{6} = 12.51 \times 10^3$$

$$P_e + 11 + 15P_e = 75.06 \times 10^3$$

$$16P_e = 64.06$$

$$\boxed{P_e = 4000\ lb.}$$

Pb#113:- Given data.

$L = 5'$ (Fixed - Free).

Pb#1137:- Given data

$L = 8'$ (Fixed - Free end).

Sign whose c.G is 2" from axis of pipe.

$d_{out} = 4.5''$

$Area = 3.174\ in^2$

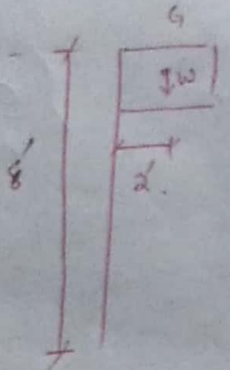
$I = 7.233\ in^4$

$\sigma_{yp} = 50\ Ksi$

$E = 29 \times 10^6\ psi.$

$W = ?$

Figure:-



Solution:- Since;

$$L/r = \frac{8 \times 2 \times 12}{\sqrt{\frac{7.233}{3.174}}} \Rightarrow \boxed{L/r = 127.2}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2(29 \times 10^6)}{50 \times 10^3}}.$$

$$\boxed{C_c = 106.94}$$

As $L/r > C_c$ so long Column.

Since; $\sigma_{all} = \frac{12}{23} \frac{\pi^2 E}{(L/r)^2}$

$$= \frac{12}{23} \frac{(3.14)^2 (29\times10^6)}{(127.2)^2}$$

$$\boxed{\sigma_{all} = 9220.12 \text{ Psi}}$$

Using max. stress approach.

$$\sigma_a + \sigma_f \le \sigma_{all}$$

$$\because \sigma_f = \frac{Mc}{I}$$

$$W = P/A + \frac{w(2\times12)\times(\frac{4.5}{2})}{7.233} \le 9.22 \text{ ksi}$$

$$\sigma_f = \frac{P\times d(c)}{I}$$

$$\frac{d}{2} = c = \frac{4.5}{2}$$

$$\frac{w}{3.174} + 7.465w \le 9.22$$

$$0.31501W + 7.465w = 9.22\times10^3$$

$$7.78w = 9.22\times10^3$$

$$\boxed{w = 1185.1 \text{ Lb}}$$

or

$$\boxed{W = 1.185 \text{ Kips}}$$ Ans

Pb # 1138 :- Given data

Section = W360×134 = W360×134.

$l_e = 6m$

$P_a = 260 KN$

$P_e = 220 KN$ (applied on minor axis).

$e_{max} = ?$, $\sigma_{yp} = 250 MPa$ & $E = 200 GPa$.

Solution:- From the property of W360×134.

$A = 17100 mm^2$.

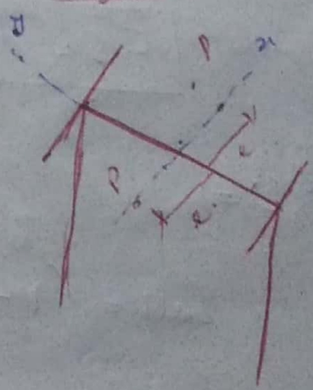
$d = 356 mm$.

$b_f = 369 mm$.

$r_x = 156$

$r_y = 94 mm$.

Figure



Frist find $l_e/r_{min} = ?$

$$l_e/r_{min} = \frac{6 \times 1000}{94}$$

$$\boxed{l_e/r = 63.83}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2(200\times10^9)}{250\times10^6}}$$

$$\boxed{C_c = 125.6}$$

As $C_c > l_e/r$ so Short or Intermediate column.

$$\sigma_{all} = \left(1 - \frac{(l_e/r)^2}{2C_c^2}\right)\frac{\sigma_{yp}}{F.S} \longrightarrow (1)$$

$$F.S = 5/3 + \frac{3(l_e/r)}{8\,C_c} - \frac{(l_e/r)^3}{8\,C_c^3}$$

$$= 5/3 + \frac{3}{8}\,\frac{(63.83)}{125.6} - \frac{(63.83)^3}{8(125.6)^3}$$

$$= 5/3 + 0.19 - 0.0164$$

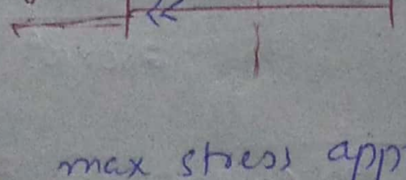
$$\boxed{F.S = 1.84}$$

in (1) =>

$$\sigma_{all} = \left(1 - \frac{(63.83)^2}{2(125.6)^2}\right)\frac{250}{1.84}$$

$$\sigma_{all} = 118.32\ MPa.$$

Case a



Using max stress approach

$$\sigma_a + \sigma_f \leq \sigma_{all}$$

$$\Sigma P/A + \frac{M_y c}{I_y} < \sigma_{all}$$

$$\frac{(260+220)\times 10^3}{17100} + \frac{\cancel{260}^{220} \times 10^3 \times e\,(369/2)}{415\times 10^6} = 118.32$$

$$28.07\,\text{MPa} + 0.097e = 118.32$$

$$0.097e = 90.25$$

$$e = \frac{90.25}{0.097}$$

$$\boxed{e = 930.4\,\text{mm}}$$ Ans 2

Pb# 1139:- Given data

Section $C_{310\times 45}$ (Hinged end column).

Already solved!

Pb

Pb# 1141 :- Given data

Section W14x90.

$L = 30'$.

$P_a = 65$ Kips

$P_e = 90$ Kips (acting on Y-axis),

$e_{max} = ?$

Using max. stress approach & AISC specification

$\sigma_{yp} = 50$ Ksi & $E = 29\times10^6$ psi.

Sol:- From the property table, the $W_{14}\times90$ has;

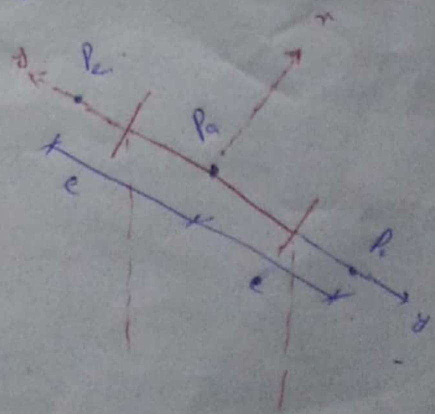
$A = 26.5\ in^2$

$d = 14.02$ in

$d_f = 14.520''$

$I_x = 999\ in^4$ $\quad$ $I_y = 362\ in^4$.

$r_x = 6.14$ in, $\quad$ $r_y = 3.70$ in.



Using AISC Specification

$$L/r_{min} = \frac{30\times12\times1}{3.70}$$

$$\boxed{L/r_{min} = 97.3}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}}$$

$$= \sqrt{\frac{2(3.14)^2(29\times10^6)}{50\times10^3}}$$

$$\boxed{C_c = 106.9}$$

As $C_c > L_e/r$ so short or Intermediate

Column.

$$\sigma_{all} = \left(1 - \frac{(L_e/r)^2}{2C_c^2}\right)\frac{S_{yp}}{F.S} \longrightarrow (1)$$

$$F.S = 5/3 + \frac{3}{8}\frac{(L_e/r)}{C_c} - \frac{(L_e/r)^3}{8C_c^3}$$

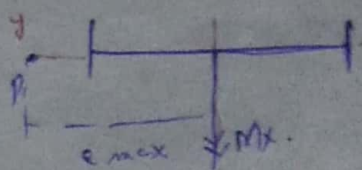
$$= 5/3 + 3/8\,\frac{(97.3)}{106.9} - \frac{(97.3)^3}{8(106.9)^3}$$

$$= 5/3 + 0.341 - 0.09425$$

$$\boxed{F.S = 1.9}$$

in (1) $\Rightarrow$ $$\sigma_{all} = \left(1 - \frac{(97.3)^2}{2(106.9)^2}\right)\frac{50\times10^3}{1.9}$$

$$\boxed{\sigma_{all} = 15.415\ ksi}$$



Using max stress approach.

$$\sigma_a + \sigma_f \le \sigma_{all}$$

$$\cancel{P_e + P/A} \quad \frac{\Sigma P}{A} + \frac{M_x c}{I_x} = \sigma_{all}$$

$$\frac{(65+90)\times10^{3}}{26.5} + \frac{90\times10^{3}\times e\times\left(\frac{14.02}{2}\right)}{999} = 15.415\times10^{3}$$

$$5.85\times10^{3} + 631.53e = 15.415\times10^{3}$$

$$631.53e = 9.565\times10^{3}$$

$$\boxed{e = 15.14\text{ in}}\ \text{Ans}$$

Pb #1139 A C310×45 channel is used as a hinged end column 2.2 m long. How far off centre can a load of 50 kN be placed on X-axis. Assume $\sigma_{yp} = 380$ MPa, & tensile stress to be limited to 140 MPa. On which side of Y axis must the load be placed? use E = 200 GPa

Given data.

$L = 2.2\,m$

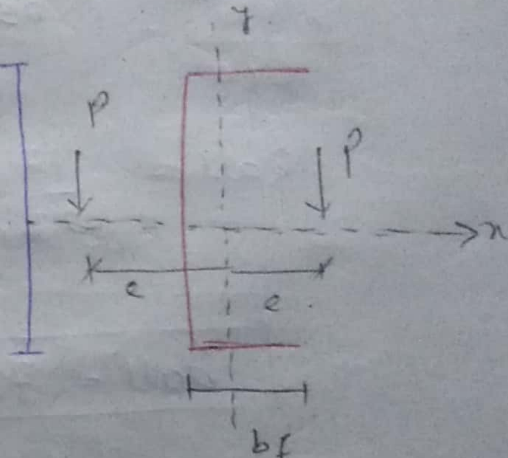
Hinged end, $K = 1$

$P = 50\,kN$

$\sigma_{yp} = 380\,MPa$

$\sigma_T = 140\,MPa$

Figure



Required data

$e_{max} = ?$

From property table of C310×45 section.

$A = 5690\,mm^2$, $I_x = 67.3 \times 10^6\,mm^4$, $I_y = 2.12 \times 10^6\,mm^4$

$r_x = 109\,mm$, $r_y = 19.3\,mm$ $\bar{x} = 17\,mm$.

$d = 305\,mm$. $b_f = 80\,mm$.

Solution:-

First find $L_e/r = ?$

$$L_e/r = \frac{2.2 \times 1000 \times 1}{19.3}$$

$$\boxed{L_e/r = 114}$$

$$C_c = \sqrt{\frac{2\pi^2 E}{\sigma_{yp}}} = \sqrt{\frac{2(3.14)^2(200\times10^9)}{(380\times10^6)}}$$

$$\boxed{C_c = 101.87}$$

as

$L_e/r > C_c$ long Column.

Use

$$\sigma_{all} = \frac{12}{23}\frac{\pi^2 E}{(L_e/r)^2}$$

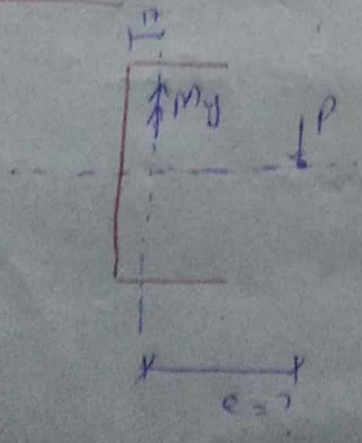
$$\sigma_{all} = \frac{12}{23}\frac{(3.14)^2(200\times10^9)}{(114)^2}$$

$$\boxed{\sigma_{all} = 79.18\ MPa}$$

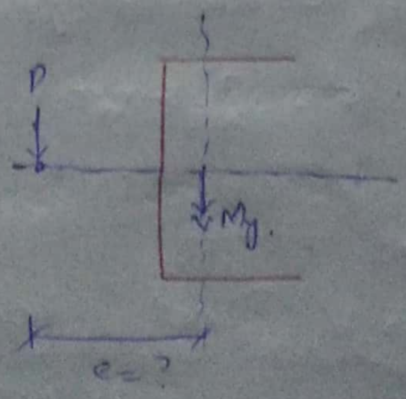
Using Max. stress approach.

Two Cases

Case # 1



Case # 02



Consider Case # 1

Based on Compression:-

Consider Compression side

$\sigma_a + \sigma_f \le \sigma_{all}$

$$P/A + \frac{M_y \times c}{I_y} \le 79.24$$

$$\frac{56\times10^3}{5690} + \frac{50\times10^3\times(e)(80-17)}{2.12\times10^6} = 79.24$$

$$\boxed{e = 47.42\,mm}$$

Based on tension side:-

$\sigma_a - \sigma_f \le \sigma_{all_T}$

$$P/A - \frac{M_y \times c}{I_y} < -140$$

$$\frac{56\times10^3}{5690} - \frac{50\times10^3(e)(17)}{2.12\times10^6} = -140$$

$$\boxed{e = 370.6\,mm}$$

Consider the smallest value of e to prevent buckling & tension failure so

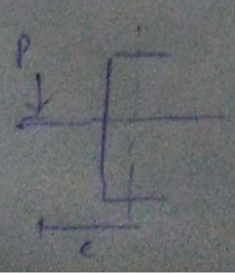
$\boxed{e = 47.42\,mm}$

Case#02 Load applied on left side

Based on compression:-

$\sigma_a + \sigma_f \le \sigma_{all}$

$P/A + M_y(c)/I_y = \sigma_{all}$.



$$\frac{50\times10^3}{5690} + \frac{50\times10^3(e)(17)}{2.12\times10^6} = 79.24.$$

$$\boxed{e = 175.72\,mm}$$

On tension side:-

$\sigma_a - \sigma_f < -140.$

$$\frac{50\times10^3}{5690} - \frac{(50\times10^3)e(63)}{2.12\times10^3} \le -140$$

$$\boxed{e = 100\,mm}$$

Here In these case Consider the smallest value i.e $\boxed{e = 100mm}$

But for
max safe e :-
Consider $\boxed{e = 100mm}$.

Max. eccentricity is e = 100mm & the load should applied on left of Y-axis.