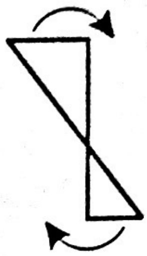
Final Revision on Columns

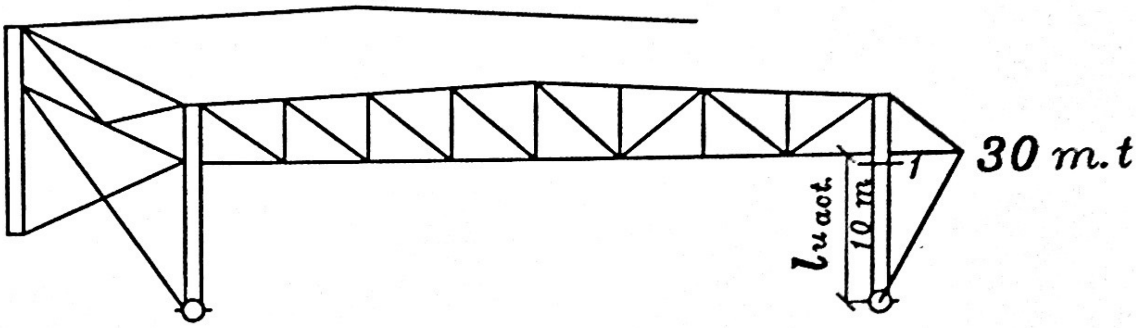
ملحوظة هامة

عند حساب الـ α فانها تحسب للطول الغير ممسوك من العمود $l_{unbraced}$

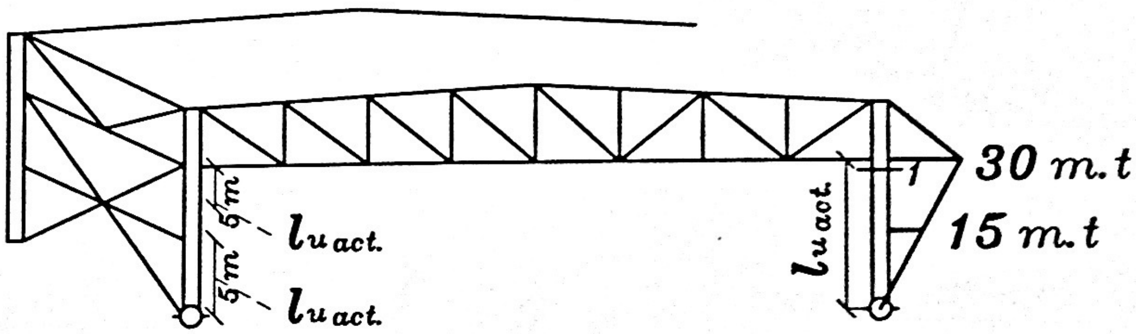
$\alpha = -Ve$



$\alpha = +Ve$



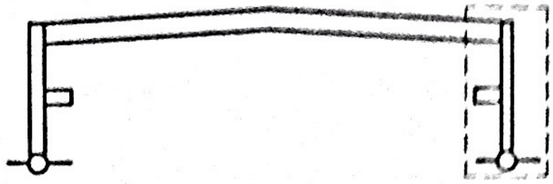
$$\alpha = \frac{\text{Smaller moment}}{\text{Bigger moment}} = \frac{0}{30} = 0$$

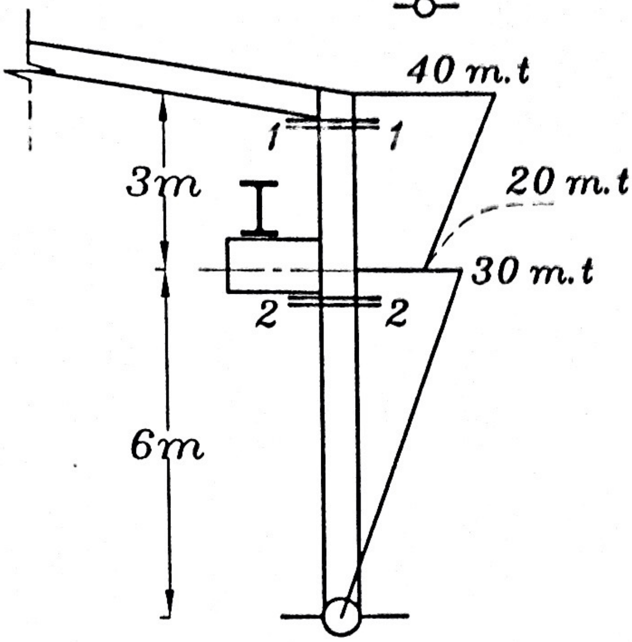


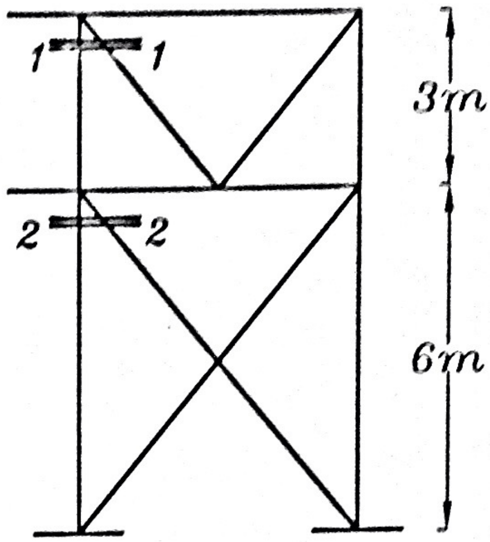
$$\alpha = \frac{\text{Smaller moment}}{\text{Bigger moment}} = -\frac{15}{30} = -0.5$$

و لم ندرس الجزء السفلى للعمود لان القطاع الذى سنقوم بتصميمه هو Section (1) وبالتالى ندرس الطول الغير ممسوك الموجود به Section (1)

EXAMPLE :

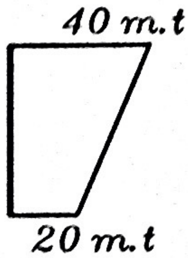






Section (1–1)

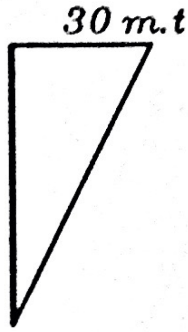
* $\alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = -\dfrac{20}{40} = -0.5$



* $l_{u_{act.}} = 300$ cm

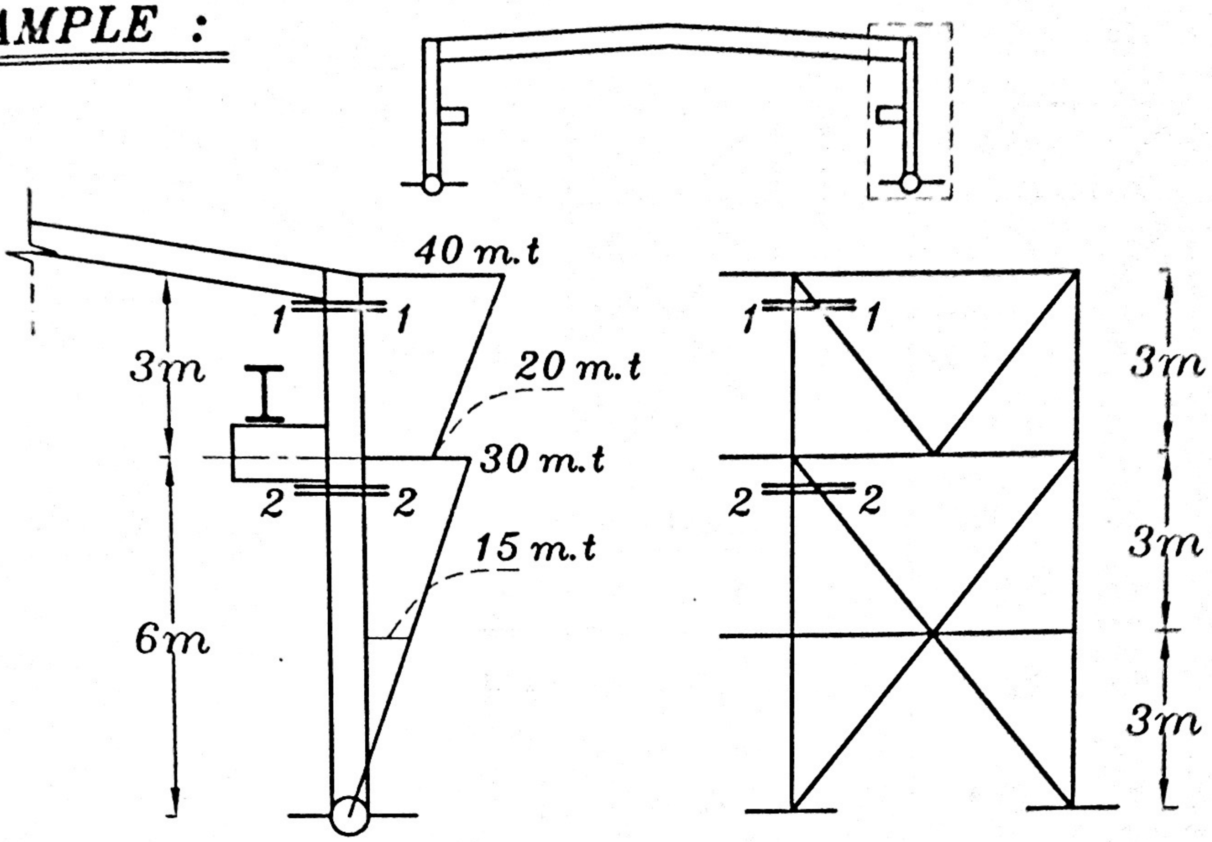
Section (2–2)

* $\alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = \dfrac{0}{30} = 0$



* $l_{u_{act.}} = 600$ cm

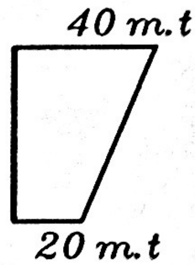
EXAMPLE :



Section (1-1)

* $\alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = -\dfrac{20}{40} = -0.5$

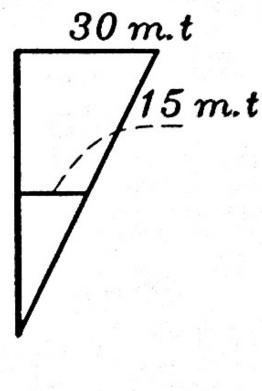
* $l_{u_{act.}} = 300 \text{ cm}$



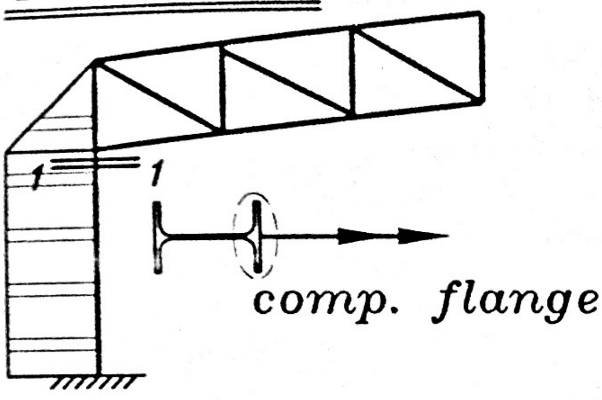
Section (2-2)

* $\alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = -\dfrac{15}{30} = -0.5$

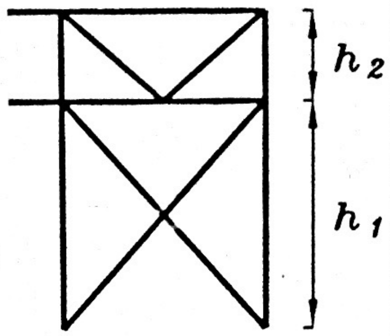
* $l_{u_{act.}} = 300 \text{ cm}$



EXAMPLE :



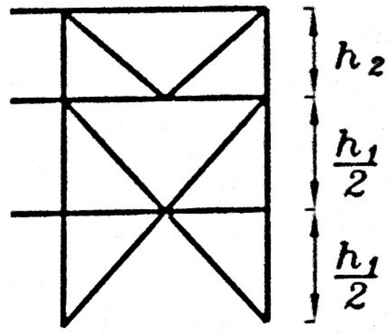
Elevation



Side View

Section 1

* $\alpha = -1$
* $l_{u_{act.}} = h_1$

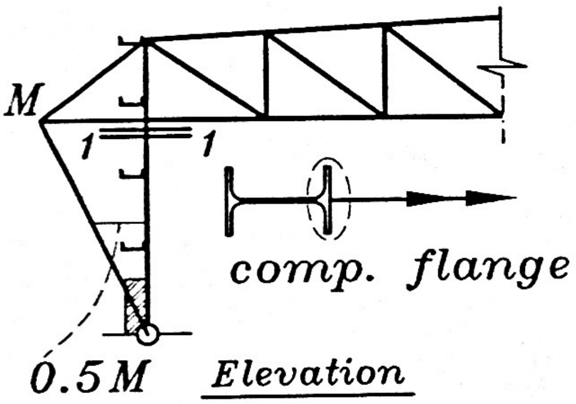


Side View

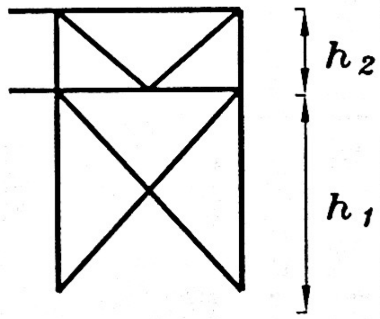
Section 1

* $\alpha = -1$
* $l_{u_{act.}} = \frac{h_1}{2}$

EXAMPLE :



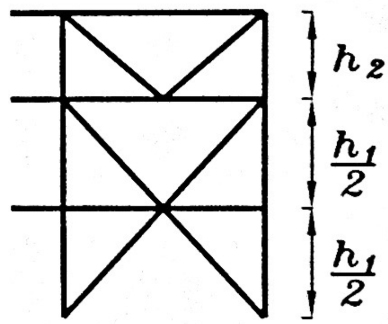
Elevation



Side View

Section 1

* $\alpha = 0$
* $l_{u_{act.}} = h_1$

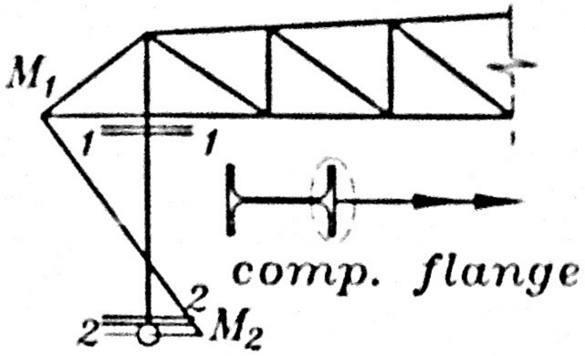


Side View

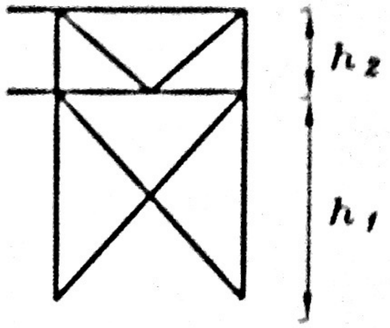
Section 1

* $\alpha = -\frac{0.5M}{M}$
* $l_{u_{act.}} = \frac{h_1}{2}$

EXAMPLE :

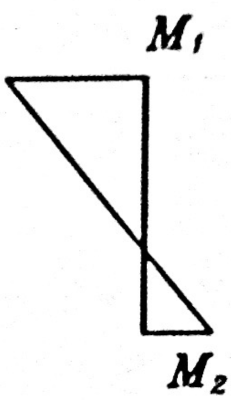


Elevation



Side View

Section 1

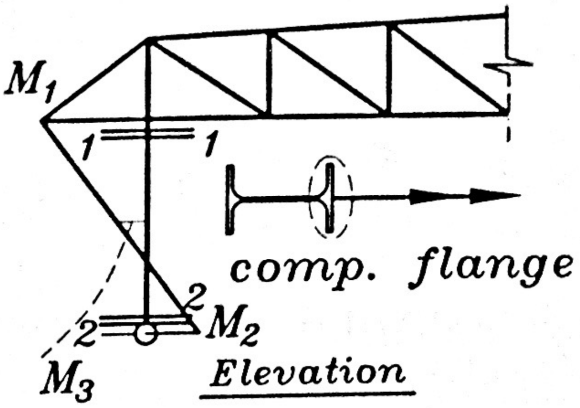


$* \ \alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = + \dfrac{M_2}{M_1}$

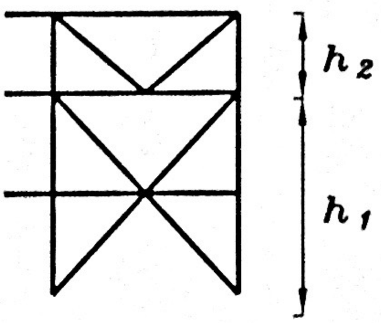
Section 2

$* \ \alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = + \dfrac{M_2}{M_1}$

EXAMPLE :

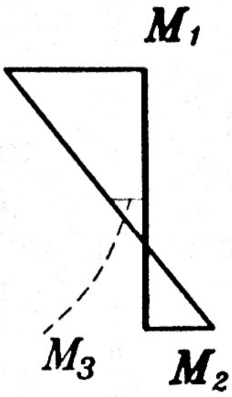


Elevation



Side View

Section 1



$* \ \alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = - \dfrac{M_3}{M_1}$

Section 2

$* \ \alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = \dfrac{M_3}{M_2}$

Built-up sections (I-Sections)

من الممكن أن نقوم بتصميم العمود بحيث يكون Built-up section (I-Sec.) و لتصميمه تكون نفس خطوات تصميم الـ Rolled (I-Sec.) و لكن مع بعض الاختلافات البسيطة .

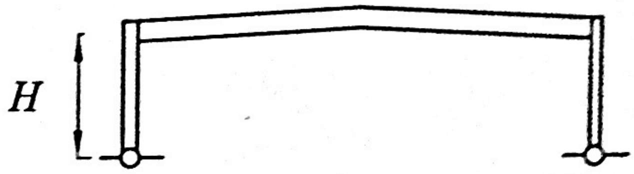
1) Suggest suitable bracing system

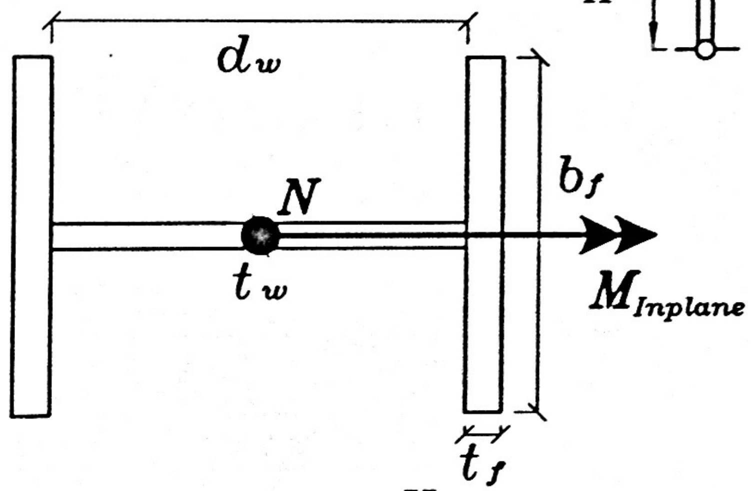
ومن الممكن أن يكون معطى

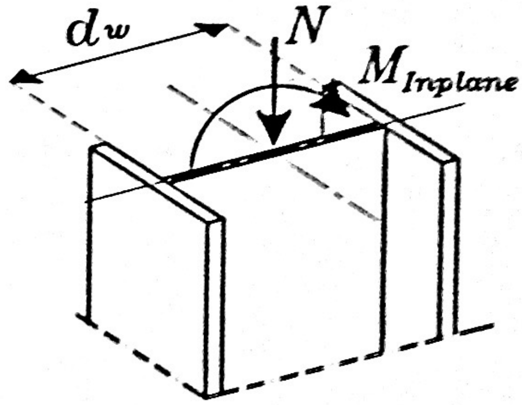
2) Calculate the straining actions

و تحسب حسب شكل العمود و الاحمال الموضوعة عليه .

3) Choice of section







* Assume $d_w = \dfrac{H}{12 \Rightarrow 15} \simeq 40 \Rightarrow 60\ cm$

حيث أن الـ H هى ارتفاع العمود

* Assume $t_w \geqslant 8\ mm$

* Force on one Flange $= C = \dfrac{N}{2} + \dfrac{M}{d}$

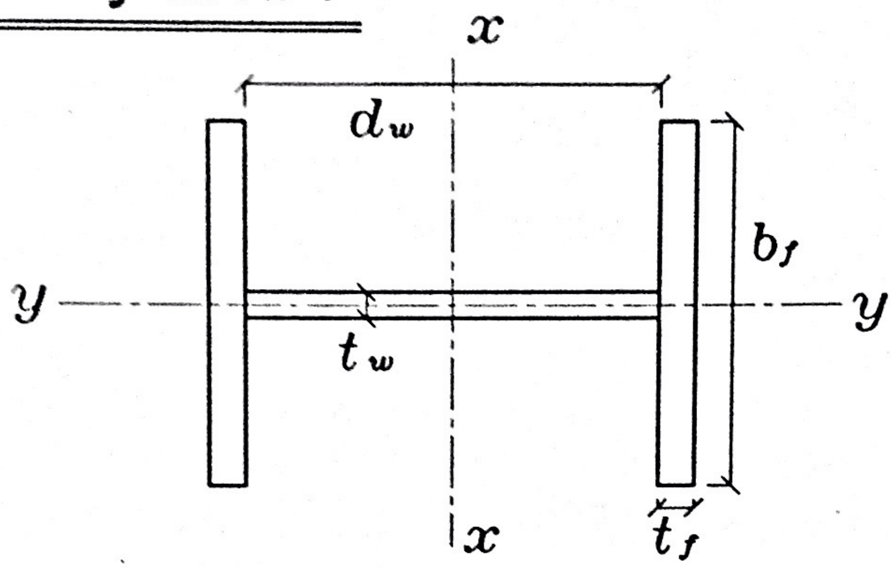
* Assume (allowable stress) $f = 1.00\ t\backslash cm^2$

$$f = \frac{Force\ (C)}{A_{One\ Flange}} \Rightarrow A_{\substack{One \\ Flange}} = \frac{Force\ (C)}{f} = \checkmark\ cm^2$$

$A_{One\ Flange} = b_f * t_f$

* Assume $b_f = (15 \Rightarrow 20)\, t_f$ $\quad b_f = \checkmark\ cm \quad t_f = \checkmark\ cm$

Properties of Area :



* $A = (2 * b_f * t_f) + (d_w * t_w) = \checkmark\ cm^2$
* $I_X = \dfrac{t_w * d_w^3}{12} + 2 * [\dfrac{b_f * t_f^3}{12} + b_f * t_f * (\dfrac{d_w}{2} + \dfrac{t_f}{2})] = \checkmark\ cm^4$
* $I_y = \dfrac{d_w * t_w^3}{12} + 2 * \dfrac{t_f * b_f^3}{12} = \checkmark\ cm^4$
* $r_x = \sqrt{\dfrac{I_x}{A}} = \checkmark\ cm$
* $r_y = \sqrt{\dfrac{I_y}{A}} = \checkmark\ cm$

4) Check Class of section

كما فى ال *Rolled sections* مع اختلاف فقط أن القيم التى نقارن بها فى ال *Flange* تؤخذ من الخانة الموجودة أمام ال *Welded* و ليس ال *Rolled* لان ال *Built-up section (I-Sec.)* تكون ملحومة .

5) Check Compression

نقوم أولا بايجاد ال Buckling length

$l_{b\,in} = \checkmark$ cm $\qquad l_{b\,out} = \checkmark$ cm

$$\lambda_{in} = \frac{l_{b\,in}}{r_y} \ngtr 180 \qquad \lambda_{out} = \frac{l_{b\,out}}{r_x} \ngtr 180$$

و لعمل ال Check compression نوجد ال $\lambda_{max.}$

$$* \lambda_{max.} = \text{Bigger of} \begin{cases} \lambda_{Out} \\ \lambda_{in} \end{cases}$$

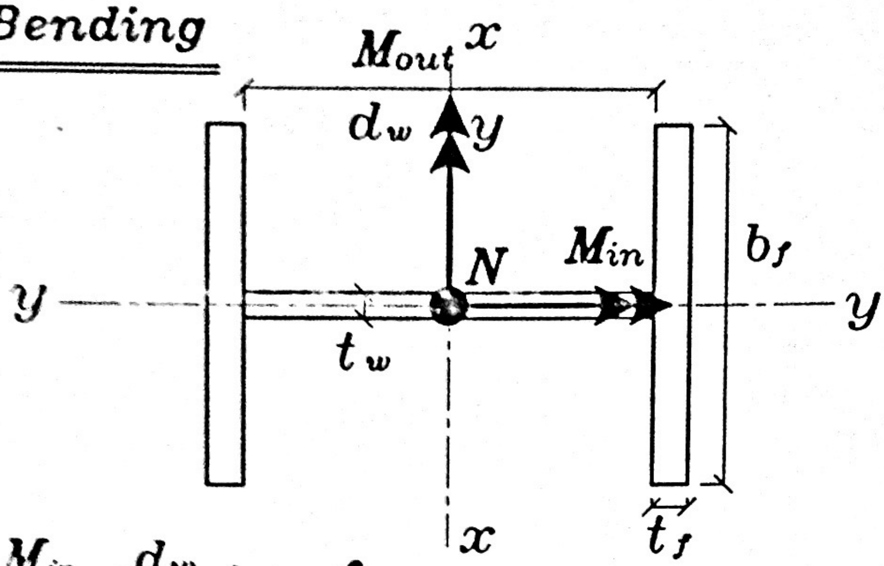
$$* F_C = \begin{cases} 1.4 - 6.5 * 10^{-5} \lambda^2_{max.} \quad St.37 & \lambda_{max.} \leqslant 100 \\ \dfrac{7500}{\lambda^2_{max.}} & \lambda_{max.} > 100 \end{cases}$$

$$* f_{ca} = \frac{N}{A}$$

For A_1 & A_2

* If $\dfrac{f_{ca}}{F_C} \leqslant 0.15 \Rightarrow A_1 = A_2 = 1$
* If $\dfrac{f_{ca}}{F_C} > 0.15 \Rightarrow A_{1\&2} = \dfrac{Cm\ x,y}{\left[1 - \frac{f_{ca}}{F_{E\ x,y}}\right]}$

6) Check Bending



$$f_{b(act.)_{in}} = \frac{M_{in}}{I_X}\left(\frac{d_w}{2}+t_f\right) = f_{bx}$$

$$f_{b(act.)_{out}} = \frac{M_{out}}{I_y}\left(\frac{b_f}{2}\right) = f_{by}$$

$$F_{bcx} = F_{bcy} = \begin{cases} 0.64F_y & \text{No LTB} \\ F_{LTB} & \text{If there is LTB} \end{cases}$$

7) Check the interaction equation

$$\boxed{\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{bCx}} * A_1 + \frac{f_{by\,(act.)}}{F_{bCy}} * A_2 < \begin{matrix} 1.0 & \text{Case A} \\ 1.2 & \text{Case B} \end{matrix}}$$

ملحوظة هامة

فى حالة وجود M_{out} يفضل زيادة عرض الـ Flanges عند عمل Choice للـ Section حتى يكون القطاع Safe .

فى حالة اذا كان العمود معرض ل Tension&Moment

نفس خطوات ال Compression&Moment مع بعض الفروق البسيطة

5) Check Tension

فى الخطوة الخامسة نعمل Check Tension بدلا من Check Comp.

نقوم أولا بايجاد ال Buckling length

* $l_{b\,in} = \checkmark\ cm$ $\qquad$ $l_{b\,out} = \checkmark\ cm$

* $\lambda_{in} = \dfrac{l_{b\,in}}{r_y} \not> 300$ $\qquad$ $\lambda_{out} = \dfrac{l_{b\,out}}{r_x} \not> 300$

* $F_t = 1.4\ t\backslash cm^2$

* $\dfrac{N}{A} \not> F_t$

6) Check Bending

$\dfrac{M_x}{S_x} \not> F_{bcx}$ $\qquad$ $\dfrac{M_y}{S_y} \not> F_{bcy}$

7) Check the interaction equation

$$\boxed{\frac{\frac{N}{A}}{1.4} + \frac{f_{bx\,(act.)}}{F_{bt}} * A_1 + \frac{f_{by\,(act.)}}{F_{bt}} * A_2 < \begin{matrix} 1.0 & \text{Case A} \\ 1.2 & \text{Case B} \end{matrix}}$$

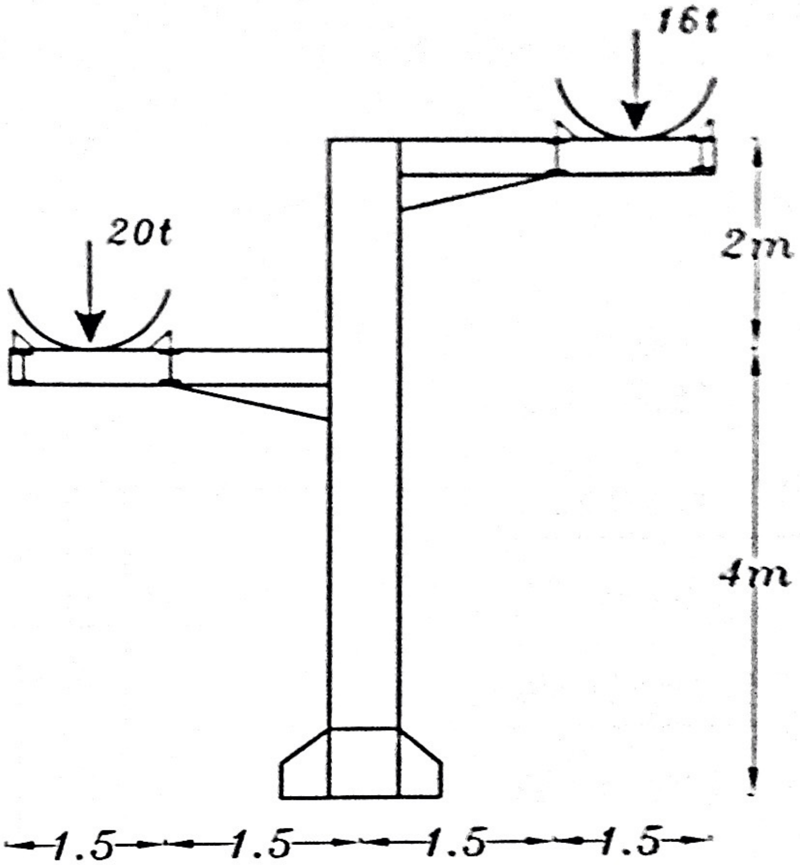
$$\boxed{\frac{-\frac{N}{A}}{1.4} + \frac{f_{bx\,(act.)}}{F_{bcx}} * A_1 + \frac{f_{by\,(act.)}}{F_{bcy}} * A_2 < \begin{matrix} 1.0 & \text{Case A} \\ 1.2 & \text{Case B} \end{matrix}}$$

$\Rightarrow A_1 = A_2 = 1 \Rightarrow$ لانه لا يوجد Compression

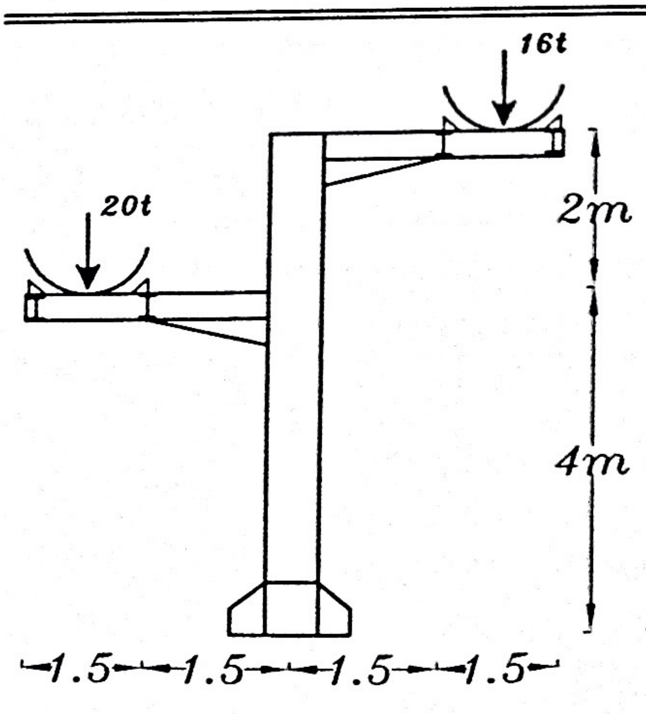
EXAMPLE :

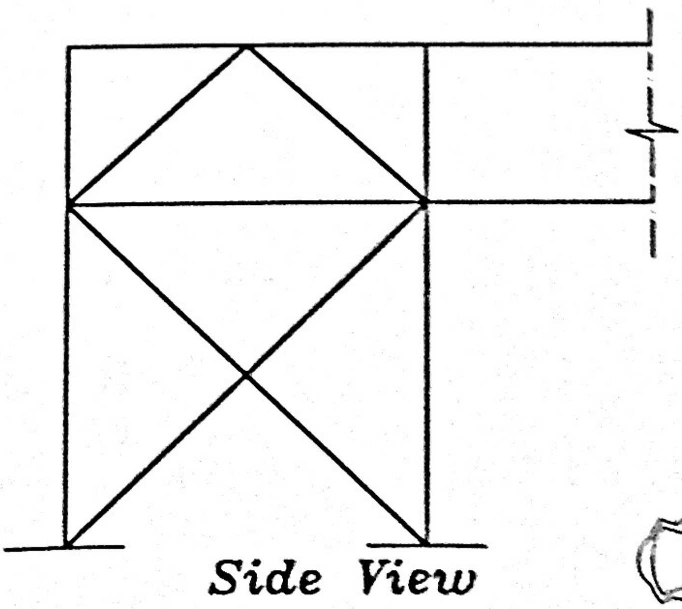
The figure shows an intermediate steel frame that supports pipe lines. The frames are spaced every 8.0 m.

- *Suggest suitable bracing system for the column (AB).*
- *Design a hot rolled I-Section for the column (AB).*



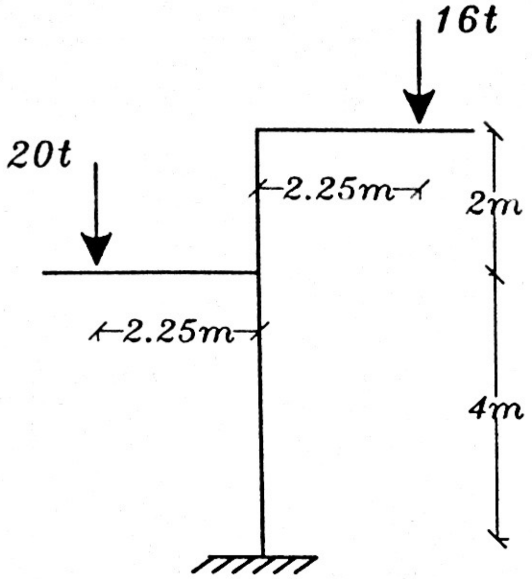
1) Suggest suitable bracing system

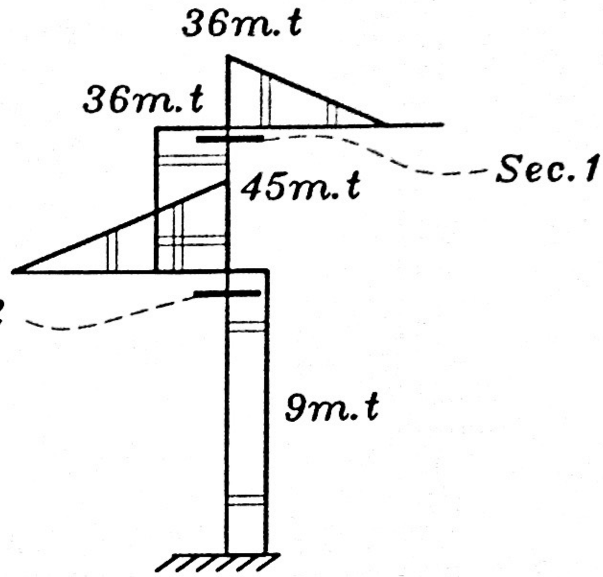




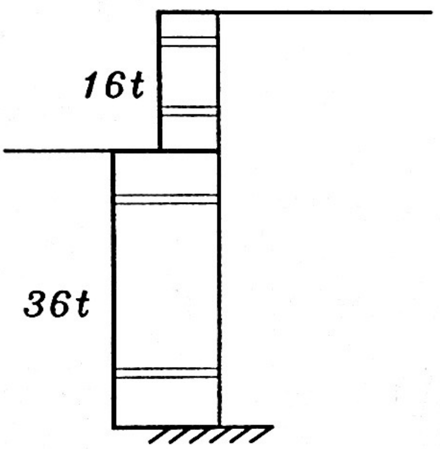
Side View

2) Calculate the straining actions





B.M.D



N.F.D

Section (1)

$N = 16\ t \qquad M_x = 36\ m.t$

Section (2)

$N = 36\ t \qquad M_x = 9\ m.t$

و بالتالى نصمم Section (1) ثم ذ Check
على Section (2)

Section (1)

3) Choice of section

* Assume (allowable stress) $f = 1.00\ t\backslash cm^2$

$$* \ S_x = \frac{M_x}{F} = \frac{36*100}{1.0} = 3600\ cm^3$$

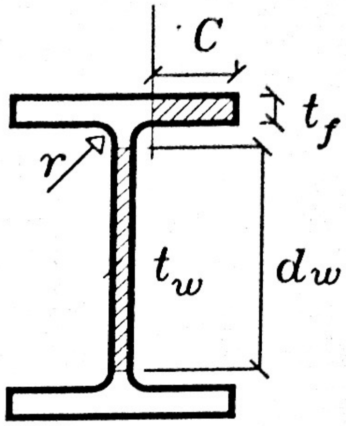
$\Rightarrow$ Choose **H.E.B 500**

اخترنا H.E.B لان ال S_x كبيرة و غير موجودة فى جداول ال I.P.E

4) Check Compactness

For flange

Subjected to compression



$d_w = 39$ cm   جداول $S_x = 4290\ cm^3$

$t_w = 1.45$ cm

$b_f = 30.0$ cm

$t_f = 2.80$ cm

$r = 2.7$ cm

$A = 239\ cm^2$

$$\frac{C}{t_f} = \frac{\frac{1}{2}(b_f - t_w - 2r)}{t_f} = \frac{\frac{1}{2}(30.0 - 1.45 - 2 * 2.7)}{2.80} = 4.13$$

$$\therefore \frac{C}{t_f} = 4.13 < \frac{16.9}{\sqrt{F_y}} = 10.9 \Longrightarrow \text{Compact Flange}$$

For Web

$$* \quad d_w * t_w * F_y = 39.0 * 1.45 * 2.4 = 135.7\,t > N = 16\,t$$

Web $\Longrightarrow$ Subjected to Bending

$$* \alpha = \frac{1}{2}\left[\frac{N}{d_w * t_w * F_y} + 1\right] = \frac{1}{2}\left[\frac{16}{135.7} + 1\right] = 0.560 > 0.5$$

$$\frac{d_w}{t_w} = \frac{39.0}{1.45} = 37.5 < \frac{699/\sqrt{F_y}}{13\alpha - 1} = 71.8 \Longrightarrow \text{Compact Web}$$

$\boxed{\therefore \text{The section is compact}}$

5) Check Compression

$l_{b\,in} = 2.1\ (6.0) = 12.60\ m$ $l_{b\,out} = 4.0\ m$

$r_x = 21.2$ cm $r_y = 7.27$ cm

* $\lambda_{\underset{x}{in}} = \dfrac{l_{b\,in}}{r_x} = \dfrac{1260}{21.2} = 59.4 < 180$

* $\lambda_{\underset{y}{out}} = \dfrac{l_{b\,out}}{r_y} = \dfrac{450}{7.27} = 55.0 < 180$

* $F_C = 1.4 - 6.5 * 10^{-5} \lambda^2_{max.}$
$= 1.4 - 6.5 * 10^{-5} * 59.4^2 = \boxed{1.17\ t \backslash cm^2}$

* $f_{Ca} = \dfrac{N}{A} = \dfrac{16}{239} = \boxed{0.066\ t \backslash cm^2}$

* $\dfrac{f_{Ca}}{F_C} = \dfrac{0.066}{1.17} = 0.057 < 0.15 \Rightarrow \boxed{A_1 = 1}$

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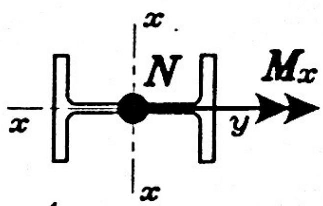
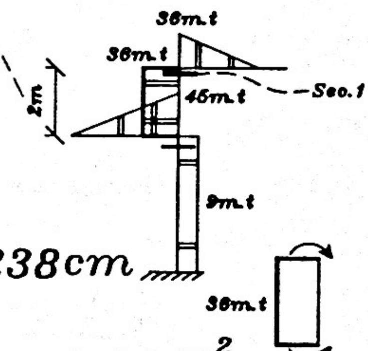
6) Check Bending



* $f_{b(act.)_x} = \dfrac{M_x}{S_x} = \dfrac{3600}{4290} = \boxed{0.839\ t \backslash cm^2}$

* $l_{u_{act.}} = 200\ cm$

$l_{u_{act.}}$ for sec.1



* $l_{u\,max.} = \begin{cases} \dfrac{20\ b_f}{\sqrt{f_y}} = \dfrac{20 * 30.0}{\sqrt{2.4}} = 387.3\ cm \\ \dfrac{1380 A_f}{d * F_y} C_b = \dfrac{1380 * 30 * 2.8}{39 * 2.4} * 1 = 1238 cm \end{cases}$

$\alpha = -\dfrac{36}{36} = -1.0 \Rightarrow * \ C_b = 1.75 + 1.05\ \alpha + 0.30\ \alpha^2$
$= 1.0$

$l_{u\,max.} = 387.3\ cm$

$l_{u_{act.}} < l_{u\,max.} \Rightarrow$ no LTB

* $F_{bcx} = 0.64 F_y = \boxed{1.536\ t \backslash cm^2}$

7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{bcx}} * A_1 + \cancel{\frac{f_{by\,(act.)}}{F_{bcy}}} * A_2 < 1.0$$

$$\frac{0.066}{1.17} + \frac{0.839}{1.536} * 1.0 = 0.60 < 1.0 \Longrightarrow \text{SAFE}$$

Section (2)

نبدأ من أول خطوة الـ Check compression

الـ λ_{in} و الـ λ_{out} لا تتغير لانها تحسب للعمود كله و ليس لجزء منه و بالتالى

الـ F_C لا تتغير عن Section (1)

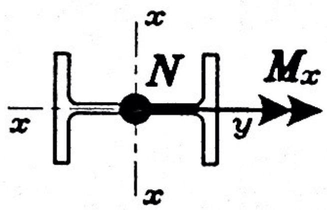
$$* F_C = \boxed{1.17\ t\backslash cm^2}$$

$$* f_{Ca} = \frac{N}{A} = \frac{36}{239} = \boxed{0.150\ t\backslash cm^2}$$

$$* \frac{f_{Ca}}{F_C} = \frac{0.150}{1.17} = 0.128 < 0.15 \Longrightarrow \boxed{A_1 = 1}$$

---

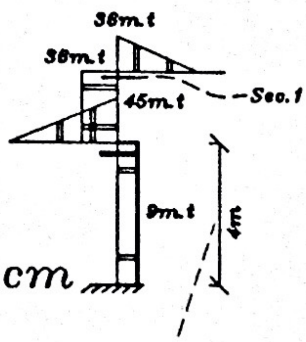
6) Check Bending



$$* f_{b(act.)x} = \frac{M_x}{S_x} = \frac{900}{4290} = \boxed{0.20\ \ t\backslash cm^2}$$

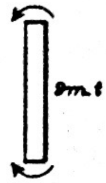
$$* l_{u\,act.} = 400\ cm$$

$$* l_{u\,max.} = \begin{cases} \dfrac{20\ b_f}{\sqrt{f_y}} = \dfrac{20 * 30.0}{\sqrt{2.4}} = 387.3\ cm \\[2ex] \dfrac{1380\,A_f}{d * F_y} C_b = \dfrac{1380 * 30 * 2.8}{39 * 2.4} * 1 = 1238 cm \end{cases}$$



$l_{u\,act.}$ for sec.2

$$\alpha = -\frac{9}{9} = -1.0 \Rightarrow * \; C_b = 1.75 + 1.05\,\alpha + 0.30\,\alpha^2$$
$$= 1.0$$



$$l_{u\,max.} = 387.3 \text{ cm}$$

$$l_{u\,act.} > l_{u\,max.} \Rightarrow \textbf{LTB Occurs}$$

$$* \; F_{ltb1} = \frac{800 * A_f}{l_u * d} C_b = \frac{800 * (30.0 * 2.80)}{250 * 27} * 1.0 = 3.36 \;\; t\backslash cm^2$$
$$\leqslant 0.58\, F_y = 1.4$$

$$F_{bcx} = F_{ltb} = \sqrt{(F_{ltb1})^2 + (F_{ltb2})^2} \leqslant 0.58\, F_y$$

$$F_{bcx} = \boxed{1.40 \;\; t\backslash cm^2}$$

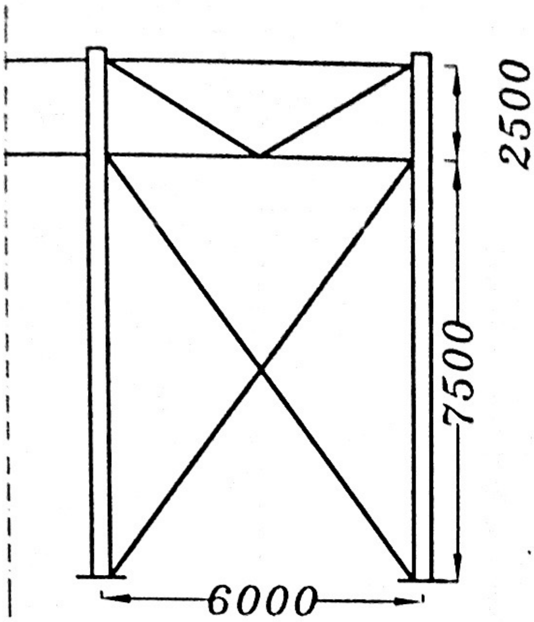
7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{bCx}} * A_1 + \cancel{\frac{f_{by\,(act.)}}{F_{bCy}}} * A_2 < 1.0$$

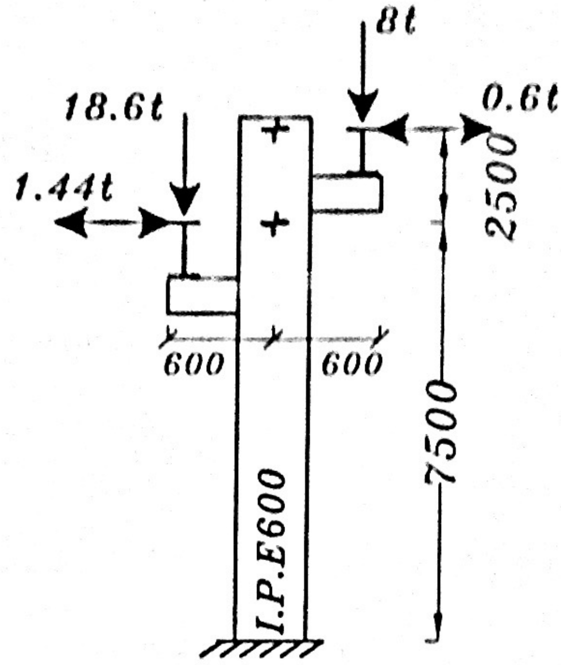
$$\frac{0.150}{1.17} + \frac{0.20}{1.40} * 1.0 = 0.27 < 1.0 \Rightarrow \textbf{SAFE}$$

$$\Rightarrow \textbf{Use H.E.B 400}$$

EXAMPLE :



Side View



Elevation

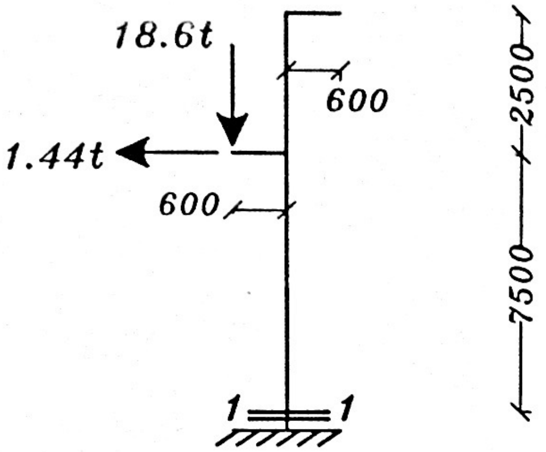
The figure shows a cantliver intermediate column of an
The figure shows a cantliver intermediate column of an
support the top crane girder at level (10.00m) only. an industrial crane girder will be added at level (7.50m). Find the value of the interaction equation for the column section given that:

$l_{u_{act.}} = 750$ cm $\qquad C_b = 1 \qquad C_{mx} = 0.85$

If the column section is unsafe, what would you propose to make the I.P.E section safe?. what would be the value of the interaction equation for this case.

لعمل حالة التحميل التى تعطى ال *maximum moment* نحمل ال *Crane* فى الناحية الاكبر .

Case of maximum Moment



Section (1)

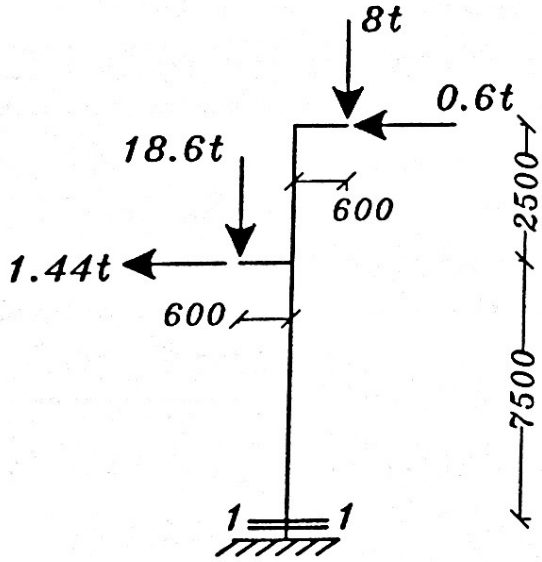
$$N = 18.6\ t$$

$$M_x = 18.6 * 0.6 + 1.44 * 7.5$$

$$= 21.6 \quad m.t$$

لعمل حالة التحميل التى تعطى ال *maximum Normal* نضع ال *Lateral shock* فى نفس الاتجاه الذى يعطى ال *maximum moment* نتيجة الاحمال الرأسية .

Case of maximum Normal



Section (1)

$$N = 26.6\ t$$

$$M_x = 18.6 * 0.6 - 8 * 0.6 + 0.60 * 10 + 1.44 * 7.5$$

$$= 23.16\ m.t$$

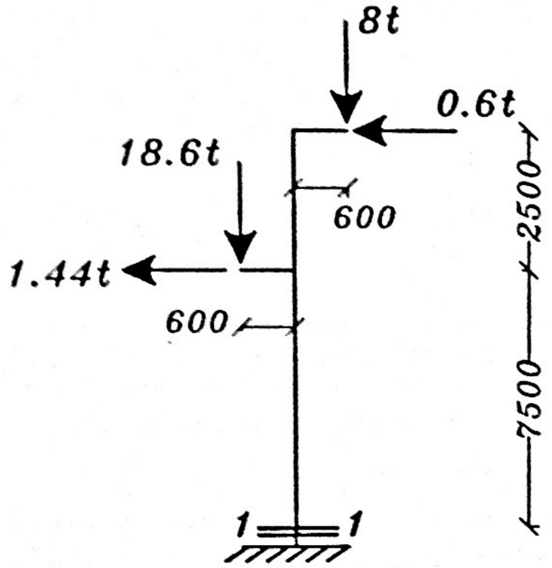
و هنا نجد أن ال *maximum Normal* و ال *maximum Moment* ينتجان من نفس الحالة و تكون هى ال *Critical*

1) Suggest suitable bracing system

لا نحتاج لانه معطى فى المسألة.

2) Calculate the straining actions

Case of maximum Normal Critical



Section (1)

$N = 26.6\ t$

$M_x = 18.6 * 0.6 - 8 * 0.6$
$+ 0.60 * 10 + 1.44 * 7.5$
$= 23.16\ m.t$

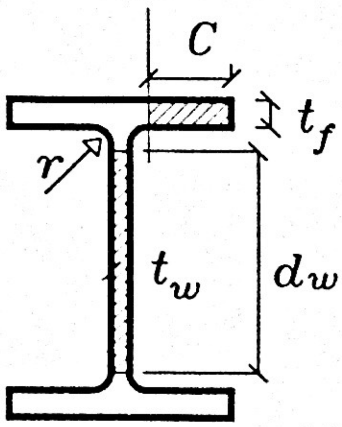
3) Choice of section

القطاع معطى فى المسألة أصلا .

4) Check Compactness

For flange Subjected to compression

$d_w = 51.4\ cm$ جداول $S_x = 3070\ cm^3$
$t_w = 1.20\ cm$
$b_f = 22.0\ cm$
$t_f = 1.90\ cm$
$r = 2.4\ cm$
$A = 156\ cm^2$



$$\frac{C}{t_f} = \frac{\frac{1}{2}(b_f - t_w - 2r)}{t_f} = \frac{\frac{1}{2}(22.0 - 1.20 - 2 * 2.4)}{1.80} = 4.44$$

$$\therefore \frac{C}{t_f} = 4.44 < \frac{16.9}{\sqrt{f_y}} = 10.9 \Longrightarrow \text{Compact Flange}$$

For Web

* $d_w * t_w * F_y = 22.0 * 1.20 * 2.4 = \mathbf{63.36\ t} > N = \mathbf{26.6\ t}$

Web $\Longrightarrow$ Subjected to Bending

* $\alpha = \frac{1}{2}\left[\frac{N}{d_w * t_w * F_y} + 1\right] = \frac{1}{2}\left[\frac{26.6}{63.36} + 1\right] = 0.710 > 0.5$

$$\frac{d_w}{t_w} = \frac{22.0}{1.20} = 18.3 < \frac{699/\sqrt{f_y}}{13\alpha - 1} = 54.8 \Longrightarrow \text{Compact Web}$$

$\boxed{\therefore \text{The section is compact}}$

5) Check Compression

$l_{b\,in} = 2.1\ (10) = 21.0\ m$ $\qquad$ $l_{b\,out} = 7.5\ m$

$r_x = 24.3\ cm$ $\qquad$ $r_y = 4.66\ cm$

* $\lambda_{in\,x} = \frac{l_{b\,in}}{r_x} = \frac{2100}{24.3} = 86.4 < 180$

* $\lambda_{out\,y} = \frac{l_{b\,out}}{r_y} = \frac{750}{4.66} = 160.94 < 180$

* $F_C = \frac{7500}{\lambda^2_{max.}} = \frac{7500}{114} = \boxed{0.289\ t\backslash cm^2}$

* $f_{Ca} = \frac{N}{A} = \frac{26.6}{239} = \boxed{0.170\ t\backslash cm^2}$

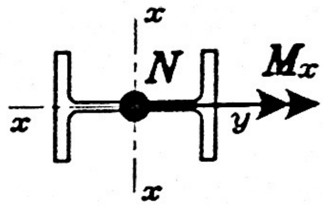
* $\frac{f_{Ca}}{F_C} = \frac{0.170}{0.289} = 0.607 > 0.15$

$$* \; F_{Ex} = \frac{7500}{\lambda_X^2} = \frac{7500}{86.42^2} = 1.004$$

Permitted to sway

$$A_1 = \frac{C_{mx}}{\left[1 - \frac{f_{ca}}{F_{Ex}}\right]} = \frac{0.85}{\left[1 - \frac{0.170}{1.004}\right]} = 1.02 \nless 1.0 \qquad \boxed{A_1 = 1.02}$$

6) Check Bending



$$* \; f_{b(act.)_x} = \frac{M_x}{S_x} = \frac{2316}{3070} = \boxed{0.754 \; t \backslash cm^2}$$

$$* \; l_{u_{act.}} = 750 \; cm$$

$$* \; l_{u\,max.} = \begin{cases} \dfrac{20 \, b_f}{\sqrt{f_y}} = \dfrac{20 * 22.0}{\sqrt{2.4}} = 284.1 \; cm \\[2ex] \dfrac{1380 \, A_f}{d * F_y} C_b \quad \text{لا نحتاج الى حسابه} \end{cases}$$

$$l_{u_{act.}} > l_{u\,max.} \Longrightarrow \text{LTB Occurs}$$

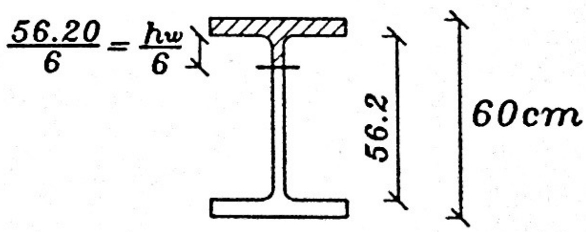
$$* \; C_b = 1.0 \Longrightarrow \text{Given}$$

$$* \; F_{ltb1} = \frac{800 * A_f}{l_u * d} C_b = \frac{800 * (22.0 * 1.80)}{750 * 60} * 1.0 = 0.74 \; t \backslash cm^2$$

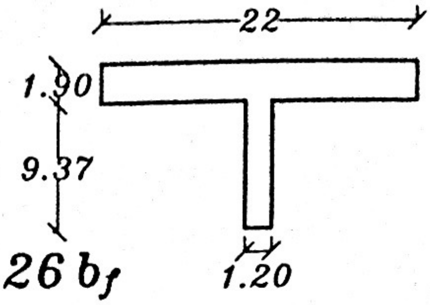
$$\leqslant 0.58 \; F_y = 1.4$$

و لحساب ال F_{ltb2} نحتاج الى حساب ال r_T لل T-Section المعرض لل Comp.

$$hw = 30 - 2 * 1.90 = 56.2 \quad cm$$



$$A_T = 22 * 1.90 + 9.37 * 1.20 = 53.04\ cm^2$$



$$I_Y = 1.90 * \frac{22^3}{12} = 1686\ cm^4$$

نهمل ال *Inertia* للweb لانها تكون صغيرة جدا

$$r_T = \sqrt{\frac{I_Y}{A_T}} = \sqrt{\frac{1686}{53.04}} = 5.72\ cm \simeq 0.26\ b_f$$

$$\frac{L_{U\,act.}}{r_T} = \frac{750}{5.72} = 131.1 \qquad 84\sqrt{\frac{C_b}{f_y}} = 84\sqrt{\frac{1.00}{2.4}} = 54.2$$

$$\frac{L_{U\,act.}}{r_T} > 84\sqrt{\frac{C_b}{f_y}} \Longrightarrow \text{not equation } 1$$

$$188\sqrt{\frac{C_b}{f_y}} = 188\sqrt{\frac{1.00}{2.4}} = 121.4$$

$$\frac{L_{U\,act.}}{r_T} < 188\sqrt{\frac{C_b}{f_y}} \Longrightarrow \text{not equation } 2$$

$$\frac{L_{U\,act.}}{r_T} > 188\sqrt{\frac{C_b}{f_y}} \Longrightarrow \text{Equation } 3$$

$$F_{ltb\,2} = \left(\frac{12000}{(l_u/r_T)^2}\right) * C_b$$

$$= \left(\frac{12000}{(126.9)^2}\right) * 1.0 = 0.698\ t\backslash cm^2 \leqslant 0.58\ F_y = 1.4$$

$$F_{bcx} = F_{ltb} = \sqrt{(F_{ltb1})^2 + (F_{ltb2})^2} = \sqrt{(0.740)^2 + (0.698)^2}$$

$$= \boxed{1.019t\backslash cm^2} \leqslant 0.58\ F_y = 1.4$$

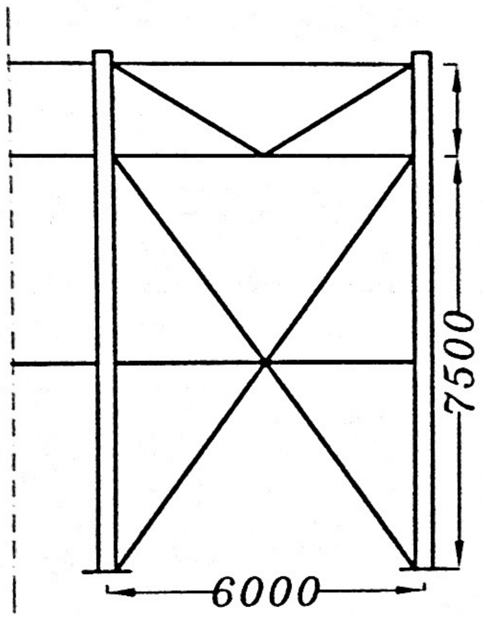
7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{bcx}} * A_1 + \cancel{\frac{f_{by\,(act.)}}{F_{bcy}}} * A_2 < 1.2$$

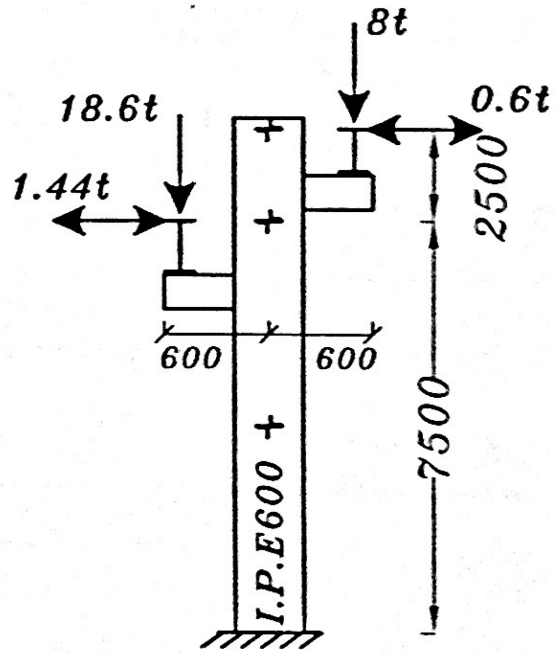
$$\frac{0.170}{0.289} + \frac{0.754}{1.019} * 1.02 = 1.36 > 1.20 \Rightarrow \text{UNSAFE}$$

Lateral shock

القطاع *Unsafe* و ذلك لان قيمة ال *allowable* فى ال *Bending* و ال *Comp.*
صغيرة و لزيادتها نحتاج الى تقليل ال $l_{u\,act.}$ و ال $l_{b\,out}$ و ذلك بوضع *Strut*
أى *Horizontal member* عند *Level (3750)*



Side View



Elevation

$l_{b\,out} = 375$ cm $\qquad l_{u\,act.} = 375$ cm

5) Check Compression

* $\lambda_{in_x} = \dfrac{l_{b\,in}}{r_x} = 86.4 < 180$ لم تتغير

* $\lambda_{out_y} = \dfrac{l_{b\,out}}{r_y} = \dfrac{375}{4.66} = 80.47 < 180$

* $F_C = 1.4 - 6.5 * 10^{-5} \lambda^2_{max.}$

  $= 1.4 - 6.5 * 10^{-5} * 86.40^2 = \boxed{0.914\ t\backslash cm^2}$

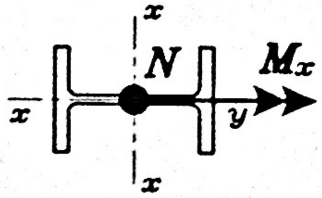
* $f_{Ca} = \dfrac{N}{A} = \dfrac{26.6}{239} = \boxed{0.170\ t\backslash cm^2}$

* $\dfrac{f_{Ca}}{F_C} = \dfrac{0.170}{0.914} = 0.186 > 0.15$

* $F_{Ex} = \dfrac{7500}{\lambda^2_X} = \dfrac{7500}{86.42^2} = 1.004$ Permitted to sway

$A_1 = \dfrac{C_{mx}}{[1 - \frac{f_{ca}}{F_{Ex}}]} = \dfrac{0.85}{[1 - \frac{0.170}{1.004}]} = 1.02 \nless 1.0$ $\boxed{A_1 = 1.02}$

6) Check Bending



* $f_{b(act.)_x} = \dfrac{M_x}{S_x} = \dfrac{2316}{3070} = \boxed{0.754\ t\backslash cm^2}$

* $l_{u_{act.}} = 375$ cm

* $l_{u\,max.} = \begin{cases} \dfrac{20\ b_f}{\sqrt{f_y}} = \dfrac{20 * 22.0}{\sqrt{2.4}} = 284.1 \text{ cm} \\ \dfrac{1380\,A_f}{d * F_y} C_b \text{ لا نحتاج الى حسابه} \end{cases}$

$l_{u_{act.}} > l_{u\,max.} \Rightarrow$ LTB Occurs

$C_b = 1.0 \Rightarrow$ Given

$$* \; F_{ltb1} = \frac{800 * A_f}{l_u * d} C_b = \frac{800 * (22.0 * 1.80)}{375 * 60} * 1.0 = 1.48 \; t\backslash cm^2$$

$$\leqslant 0.58 \; F_y = 1.4$$

$$F_{bcx} = F_{ltb} = \sqrt{(F_{ltb1})^2 + (F_{ltb2})^2} \leqslant 0.58 \; F_y$$

$$= \boxed{1.40 \; t\backslash cm^2}$$

---

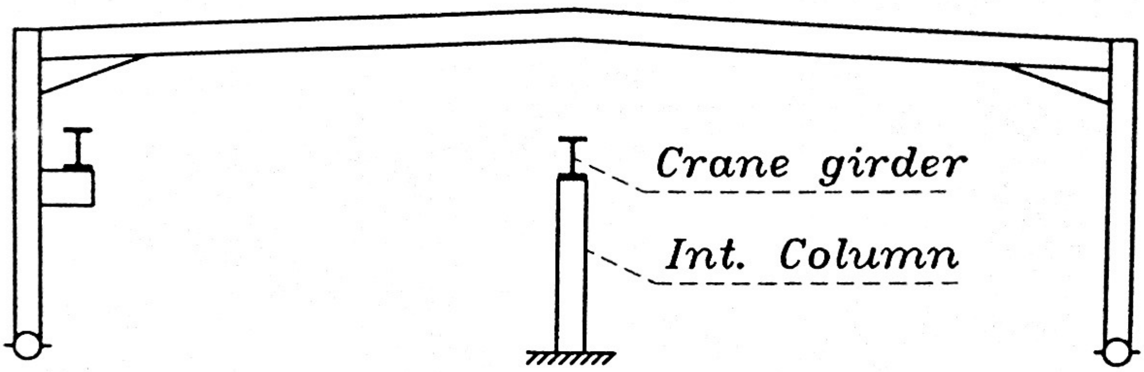
7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{bcx}} * A_1 + \cancel{\frac{f_{by\,(act.)}}{F_{bcy}}} * A_2 < 1.2$$

$$\frac{0.170}{0.914} + \frac{0.754}{1.40} * 1.02 = 0.74 > 1.20 \Rightarrow \text{SAFE}$$

Lateral shock

Intermediate Crane Column



و يستخدم الـ Int. Column ليحمل Crane girder و لذلك فانه يكون معرض لاحمال الـ Crane girder و هى الـ P_y و هى الاحمال الرأسية الناتجة من الـ Crane girder و الـ P_X و هى الـ Lateral Shock و الـ B و هى الـ Breaking force أى يتعرض لـ $P_y \& P_X \& B$.

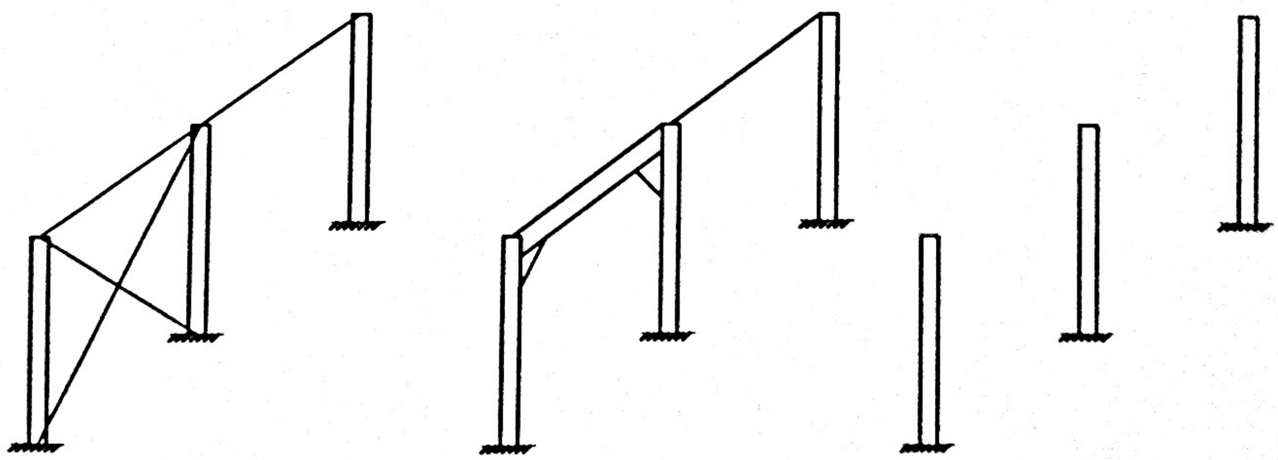
و يصمم هذا العمود كالتالى

For Inplane direction

دائما يكون Cantliver و يصمم على هذا الاساس .

For Out of plane direction

يكون حسب نوعية الـ Bracing المستخدم و يوجد لدينا ثلاثة طرق أو حلول



(a) (b) (C)

a) Using bracing system .

b) Using Portal frame bracing .

C) No bracing at all. و فى هذه الحالة يكون هذا العمود عبارة عن Cantliver فى ال out of plane direction

---

و لحل هذا العمود نحتاج أولا الى حساب أحمال ال Crane girder كما درسنا سابقا .

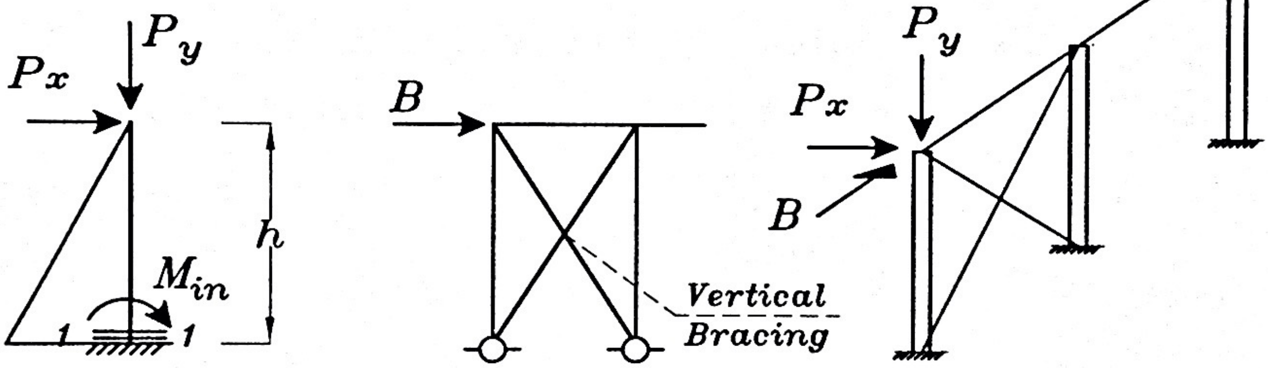
* $P_y = R_{D.L} + R_{L.L}\,(1+I)$

* $P_X = \frac{1}{10}\, R_{L.L}$

* $B = \frac{1}{7}$ Wheel loads

---

a) Using bracing system



Inside–plane outside–plane

ال Vertical Bracing هو الذى يقاوم ال Braking force و بالتالى لا نأخذها عند تصميم العمود و لذلك نصمم العمود على التالى

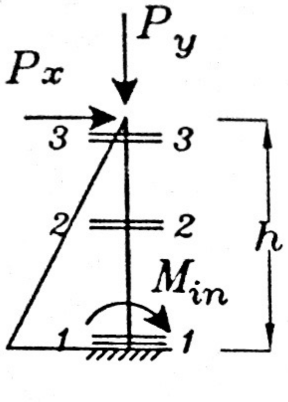
Section 1

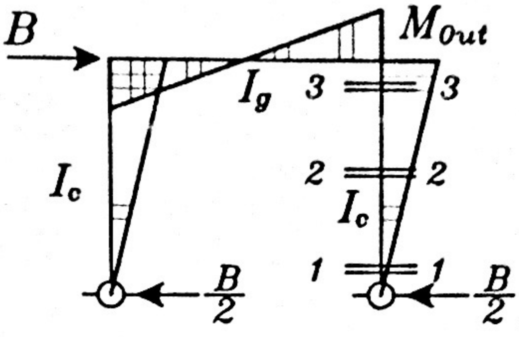
$M_{in} = \checkmark$ $M_{out} = Zero$ $N = P_y + 0.w_{column}$

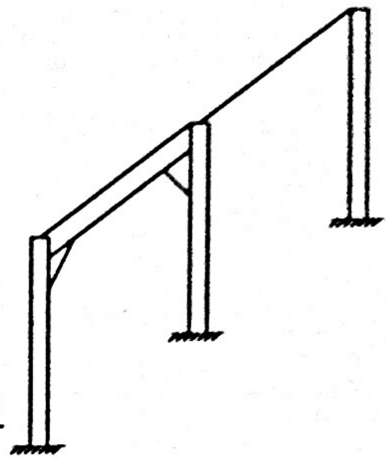
$l_{b\,in} = 2.1\ h$ $l_{b\,out} = h$

و لوجود M_{in} فقط نستخدم لهذا العمود قطاع I.P.E اذا لم يحدد لنا .

6) Using Portal frame bracing







Inside−plane   outside−plane

* $assume\ I_c = 2\ I_g$

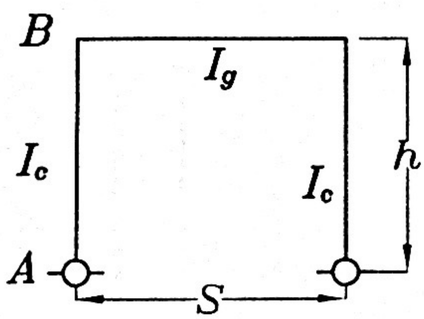
* $M_{Out} = \frac{B}{2} * h$

و نحتاج الى دراسة ثلاثة قطاعات Sec1&2&3 و لذلك سنقوم بتصميم القطاع اللى عليه أكبر moment و هو Sec1 ثم عمل Check على القطاعان الباقيان

Section 1

$M_{in} = \checkmark$ $M_{out} = Zero$ $N = P_y + O.w_{\ column}$

$l_{b\ in} = 2.1\ h$ $l_{b\ out} = K * h$ $G_B \& G_A$ نحسبه باستخدام ال



$G_A = 10$ حيث أن العمود ال Cantliver تكون قاعدته Fixed فى ال Inplane و Hinged فى ال Out of plane و هذا سوف ندرسه فى تصميم القواعد .

$$G_B = \frac{I_C / l_C}{I_g / l_g} = \frac{I_C / h}{I_g / S}$$

و نحصل على قيمة ال k من ال *Permitted to sway charts*

ثم نعمل *Check* على القطاعان الباقيان

Section 2

$$M_{in} = \frac{M_{in\ sec1}}{2} \qquad M_{out} = \frac{M_{out\ sec3}}{2} \qquad N = P_y + \frac{1}{2}\ O.w_{\ column}$$

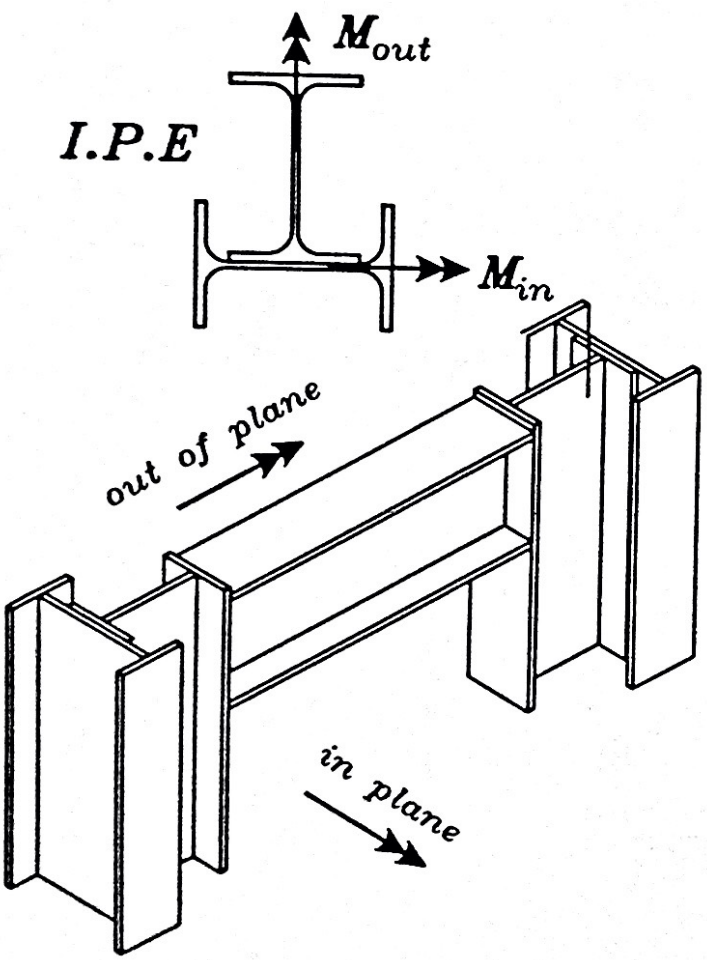
$l_{b\ in}$ & $l_{b\ out}$ مثل *Section 1* تماما

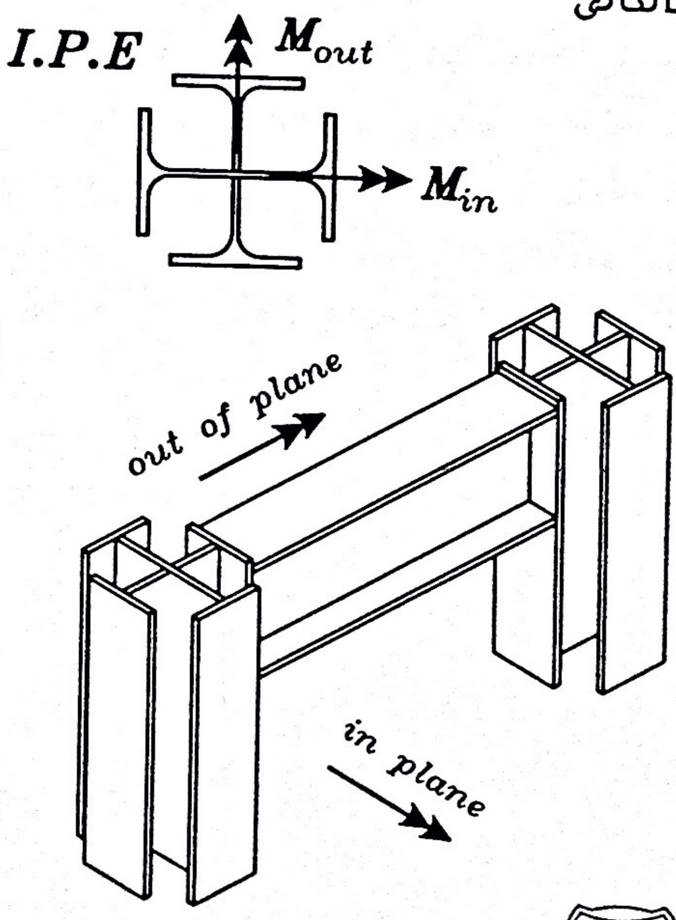
Section 3

$$M_{in} = Zero \qquad M_{out} = \checkmark \qquad N = P_y$$

$l_{b\ in}$ & $l_{b\ out}$ مثل *Section 1* تماما

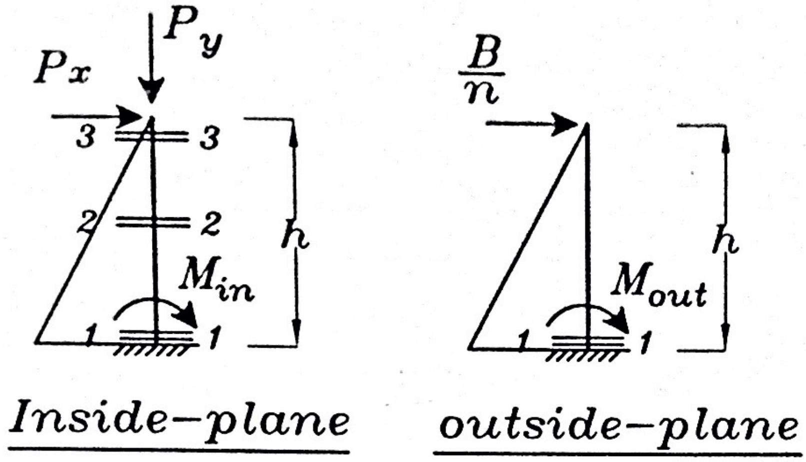
و لوجود M_{in} و M_{out} نستخدم *H.E.B* أو نستخدم *Combined section* كالتالى

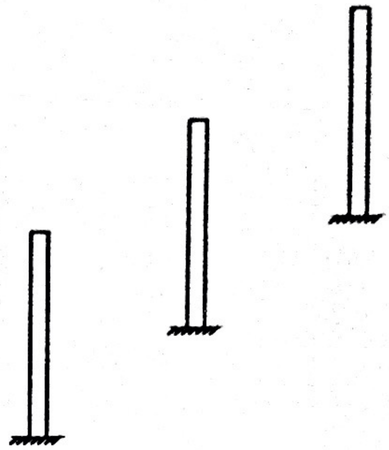




c) Using no bracing

و فى هذه الحالة يكون العمود Cantliver فى ال Inplane & Out of plane





Section 1

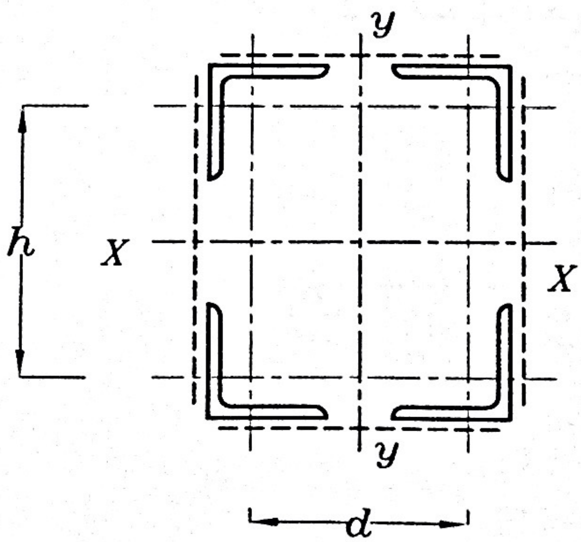
$M_{in} = \checkmark$ $\qquad M_{out} = \checkmark$ $\qquad N = P_y + 0.w_{column}$

$l_{b\,in} = 2.1\ h$ $\qquad l_{b\,out} = 2.1\ h$

و ال n هو عدد الاعمدة التى تقاوم ال Breaking force و اذا لم تعطى نأخذهم عمودين $n = 2$

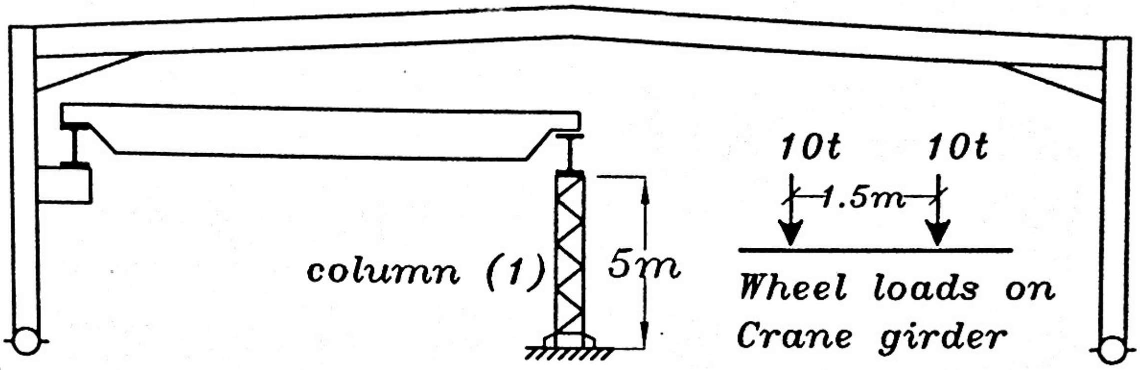
و نقوم بتصميم هذا القطاع على أنه عليه Double moment مع وضع ال Inertia الكبيرة فى اتجاه العزوم الكبيرة حتى تقاوم العزوم .

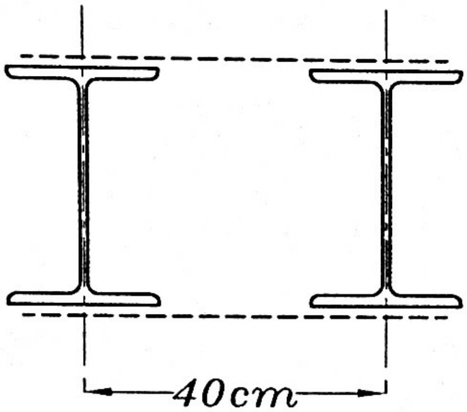
و يفضل هنا استخدام **4 angles** حتى نستطيع التحكم فى ال Inertia فى الاتجاهين .



EXAMPLE :

For the shown main system with spacing = 7.0m, it is required to design a built up section for column (1) using welded lacing bars. the column section is as shown.



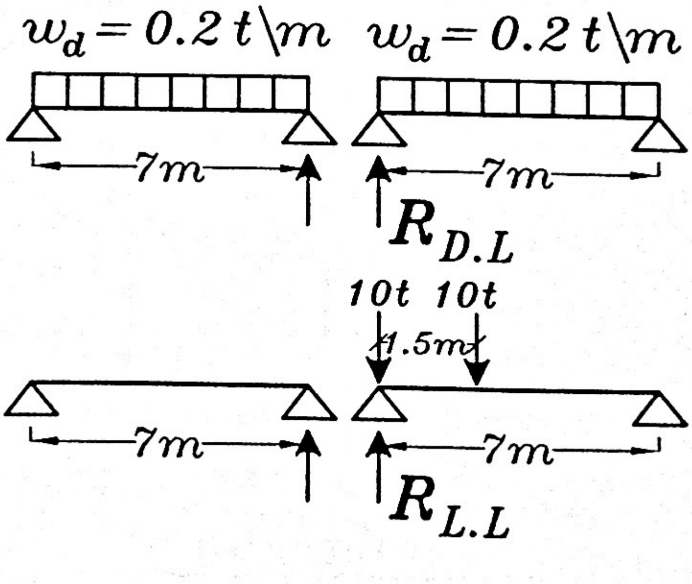


Column cross section

Suggest suitable bracing system .

Reactions from crane girder

Dead Load:



$$*R_{D.L} = w_d * \frac{S}{2} * 2$$

$$= 0.2 * \frac{7}{2} * 2 = 1.4\ t$$

Live Load:

$$*R_{L.L} = 10 + \left(10 * \frac{5.5}{7}\right)$$

$$= 17.86\ t$$

* Assume I = 25 %

* $P_y = R_{D.L} + R_{L.L}(1+I)$

$= 1.4 + 17.86\,(1+0.25) = \mathbf{22.32\,t}$

* $P_X = \frac{1}{10} R_{L.L}$ *Without Impact*

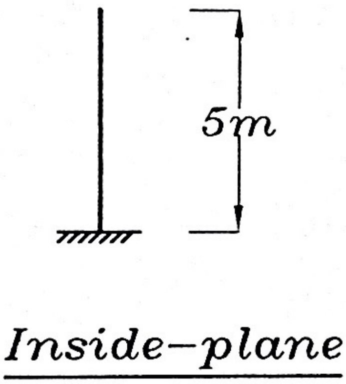
$= \frac{1}{10} * 17.86 = \mathbf{1.786\,t}$

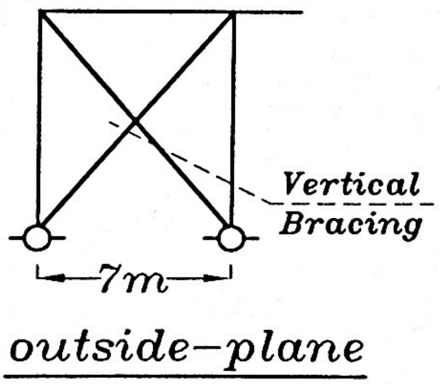
* B = Braking force $= \frac{\Sigma P}{7}$ *Without Impact*

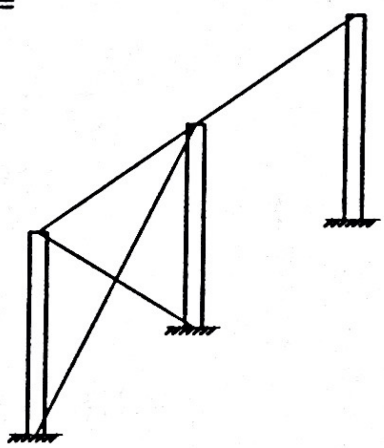
$= \frac{1}{7} * (10+10) = \mathbf{2.86\,t}$

---

1) Suggest suitable bracing system







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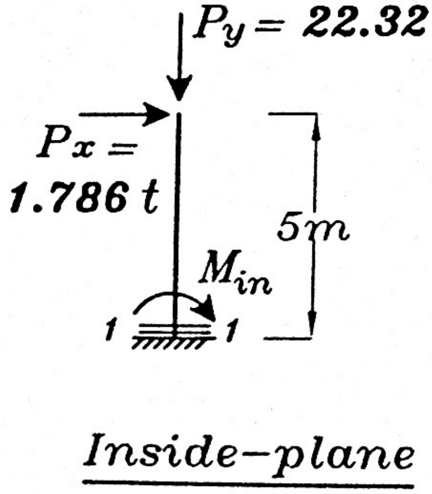
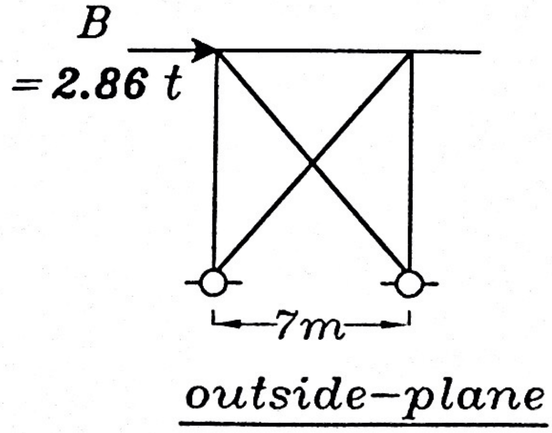
2) Calculate the straining actions





Section 1

assumed 0.1 t\m

* $N = P_y + 0.w_{column} = 22.32 + 0.10 * 5 = \mathbf{24.22}\ t$
* $Q = P_x = \mathbf{1.786}\ t$
* $M_{in} = 1.786 * 5 = \mathbf{8.93}\ m.t$
* $M_{out} = \mathbf{Zero}$

ال Vertical Bracing هو الذى يقاوم ال Braking force و بالتالى لا نأخذها عند تصميم العمود و لذلك نصمم العمود على التالى

---

3) Choice of section

* Assume $d = 40\ cm \Rightarrow$ given
* Force on one channel $= C = \dfrac{N}{2} + \dfrac{M}{d}$

$$= \frac{24.22}{2} + \frac{8.93}{0.4} = 34.4\ t$$

* Assume (allowable stress) $f = 1.20\ t\backslash cm^2$
* $A_{One\,I} = \dfrac{Force\ (C)}{f} = \dfrac{34.4}{1.2} = \mathbf{28.67}\ cm^2$

$\Rightarrow$ Choose **2 IPE 220**

و حتى يكون القطاع Economic يفضل أن تكون ال $d = (1.5 \Rightarrow 2.0)h$

$d = 40\ cm$ & $h = 22\ cm$ $\Rightarrow$ O.K

Properties of Area :

$d_w = 17.7\,cm$ جداول

$t_w = 0.59\,cm$

$b_f = 11.0\,cm$

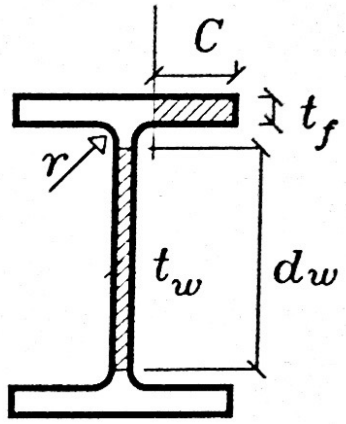
$t_f = 0.92\,cm$

$r = 1.50\,cm$

$A = 33.4\,cm^2$

$I_X = 2770 \quad cm^4$

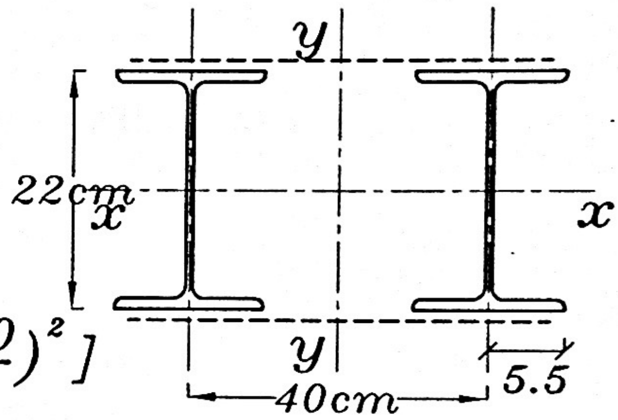
$I_Y = 205 \quad cm^4$



* $A_{II} = 2\,A_I = 2 * 33.4$
$= \mathbf{66.8} \quad cm^2$

* $I_{X_{II}} = 2\,[\,2770\,]$
$= \mathbf{5540} \quad cm^4$

* $I_{Y_{II}} = 2\,[205 + 33.4 * (\frac{40}{2})^2\,]$
$= \mathbf{27130}\ cm^4$



* $r_{X_{II}} = \sqrt{\dfrac{I_{x_{II}}}{A_{II}}} = \sqrt{\dfrac{5540}{66.8}} = 9.10 \quad cm$

* $r_{y_{II}} = \sqrt{\dfrac{I_{y_{II}}}{A_{II}}} = \sqrt{\dfrac{27130}{66.8}} = 20.15\ cm$

4) Check Compactness

For flange *Subjected to compression*

$$\frac{C}{t_f} = \frac{\frac{1}{2}(b_f - t_w - 2r)}{t_f} = \frac{\frac{1}{2}(11.0 - 0.59 - 2 * 1.5)}{0.92} = 4.03$$

$$\therefore \frac{C}{t_f} = 4.03 < \frac{16.9}{\sqrt{f_y}} = 10.9 \Longrightarrow \text{Compact Flange}$$

For Web Subjected to compression

$$\frac{d_w}{t_w} = \frac{17.7}{0.59} = 30 \quad < \quad \frac{58}{\sqrt{f_y}} = 37.4 \Longrightarrow \text{Compact Web}$$

$\boxed{\therefore \text{The section is compact}}$

5) Check Compression

$l_{b\,in} = 2.1\ (5.0) = 10.5\ m$ $\qquad$ $l_{b\,out} = 5.0\ m$

$r_x = 9.10\ cm$ $\qquad$ $r_y = 20.15\ cm$

$$* \ \bar{\lambda}_{in} = \frac{l_{b\,in}}{r_y} = \frac{1050}{20.15} = 52.11$$

$$* \ \lambda_{out} = \frac{l_{b\,out}}{r_x} = \frac{500}{9.10} = 54.9 < 180$$

$*$ assume $l_Z = d = 40\ cm \quad r_Z = r_{y_I}$

$$* \ \lambda_Z = \frac{l_Z}{r_Z} = \frac{40}{2.48} = 16.13 \not> 60$$

$$\not> \frac{2}{3}\lambda_{max.}\begin{cases}\overset{54.9}{\lambda_{Out}} \\ \bar{\lambda}_{in}\end{cases} = 36.3$$

$$* \ \lambda_{in} = \sqrt{\bar{\lambda}^2_{in} + (k\lambda_Z)^2}$$

assume batten plates

$$= \sqrt{52.1^2 + 1.25 * 16.13^2} = 54.5 \quad < 180$$

$$* \ F_C = 1.4 - 6.5 * 10^{-5}\lambda^2_{max.}$$
$$= 1.4 - 6.5 * 10^{-5} * 54.90^2 = \boxed{1.204\ t\backslash cm^2}$$

$$* \ f_{Ca} = \frac{N}{A} = \frac{24.22}{66.8} = \boxed{0.362\ t\backslash cm^2}$$

$$* \ \frac{f_{Ca}}{F_C} = \frac{0.362}{1.204} = 0.30 > 0.15$$

$$F_{Ey} = \frac{7500}{\lambda_y^2} = \frac{7500}{54.5^2} = 2.525$$

Permitted to sway

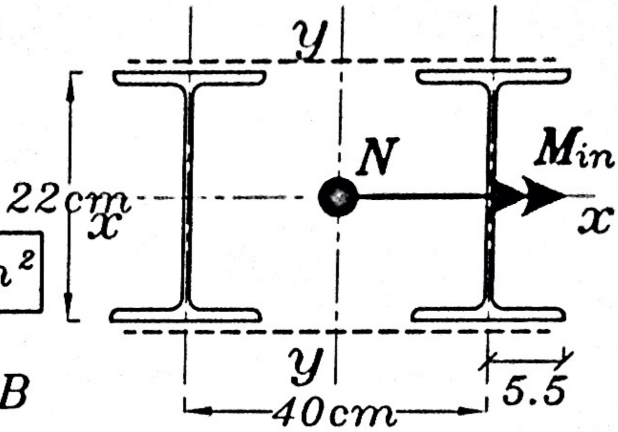
$$A_2 = \frac{C_{my}}{[1-\frac{f_{ca}}{F_{Ey}}]} = \frac{0.85}{[1-\frac{0.362}{2.525}]} = 0.99 \nless 1.0 \qquad \boxed{A_2 = 1}$$

---

6) Check Bending

$$f_{b(act.)_{in}} = \frac{M_{in}}{I_y}\left(\frac{d}{2}+\frac{b_f}{2}\right) = f_{by}$$

$$= \frac{893}{27130}\left(\frac{40}{2}+\frac{11}{2}\right) = \boxed{0.84\ t\backslash cm^2}$$



$F_{bcy} = 0.64\,F_y$ No LTB

لان ال I-Section يكون Compact

$$\boxed{F_{bcy} = 1.536\ t\backslash cm^2}$$

---

7) Check Interaction equation

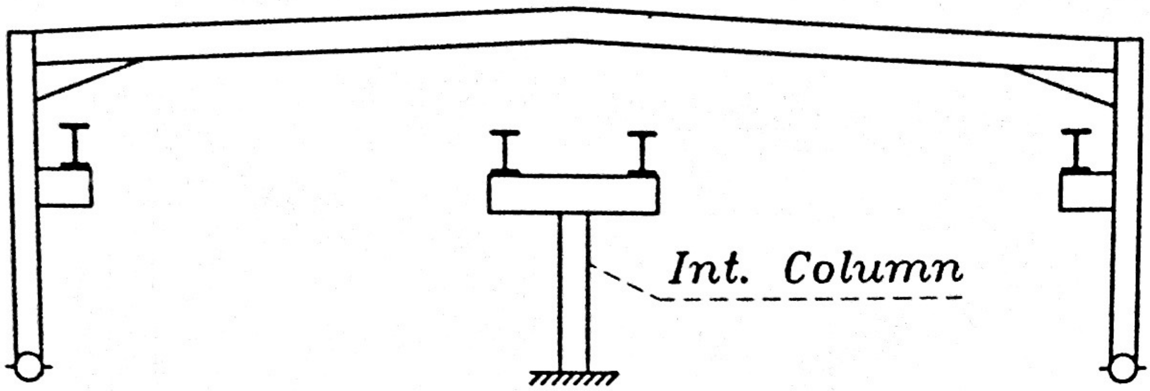
$$\frac{f_{ca}}{F_C} + \cancel{\frac{f_{bx\,(act.)}}{F_{bcx}}} * A_1 + \frac{f_{by\,(act.)}}{F_{bcy}} * A_2 < 1.20$$

$$\frac{0.362}{1.204} + \frac{0.84}{1.536} * 1.0 = 0.94$$

$< 1.2 \Rightarrow$ Case B (lateral shock)

$\Rightarrow$ **SAFE**

Intermediate Column Carries 2 cranes



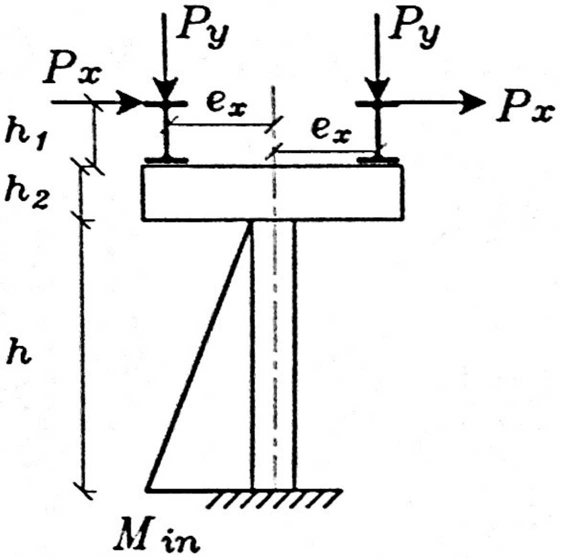
هذا العمود يحتاج الى حالتى تحميل عند دراسته

1) Two cranes are working.

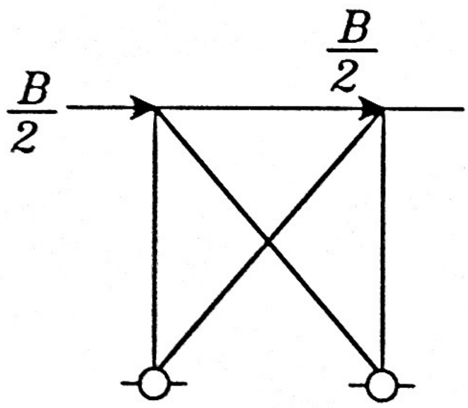
2) Only one crane is working.

Case (1)

Two cranes are working.



Inside–plane



outside–plane

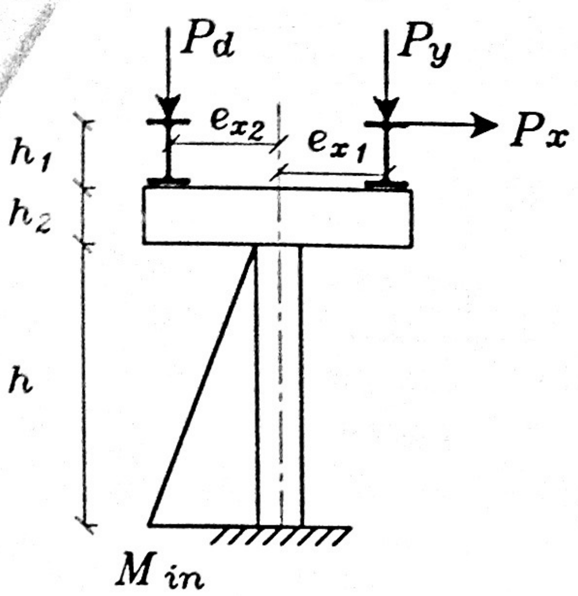
$$M_{in} = 2 * P_x * (h_1 + h_2 + h)$$

$$N = 2 * P_y + 0.w_{column}$$

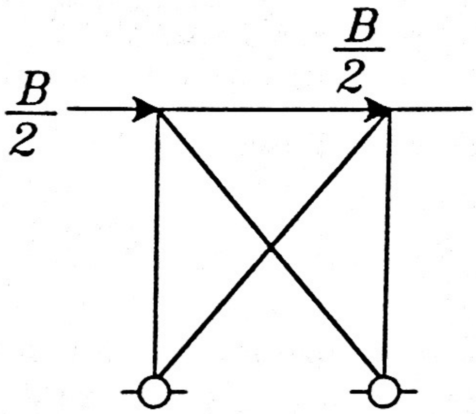
$$M_{out} = Zero$$

و من الممكن استخدام *Portal frame bracing* و فى هذه الحالة سينتج M_{out}

Case (2) Only one crane is working.



Inside–plane



outside–plane

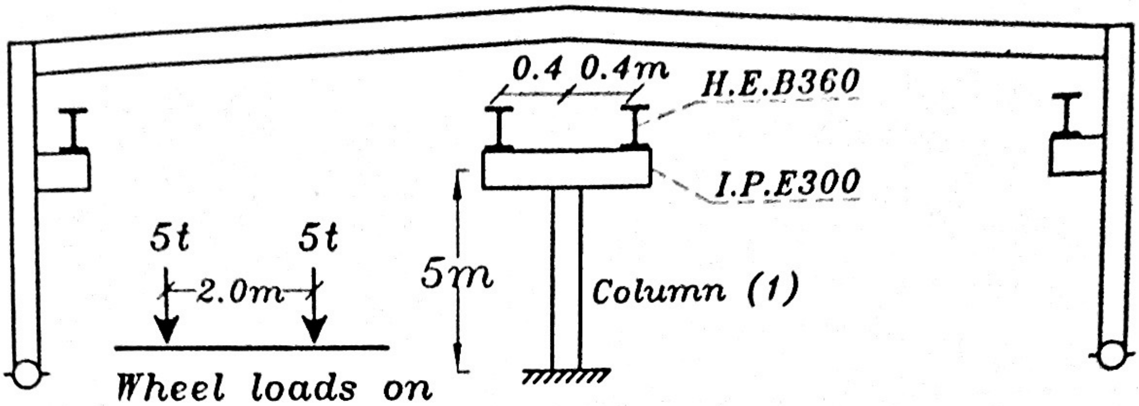
$$M_{in} = 2 * P_x * (h_1 + h_2 + h) + P_y * e_{x_1} - P_d * e_{x_2}$$

$$N = P_y + P_d + 0.w_{column}$$

$$M_{out} = Zero$$

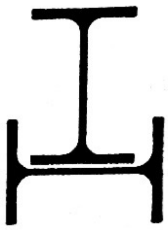
و من الممكن استخدام Portal frame bracing و فى هذه الحالة سينتج M_{out}

EXAMPLE :



For the shown main system with spacing = 6.0m, it is required to design column (1) for the following cases :

1)Design a B.U.S for column (1) if we use portal frame bracing outside plane,
(the column's section is as shown)



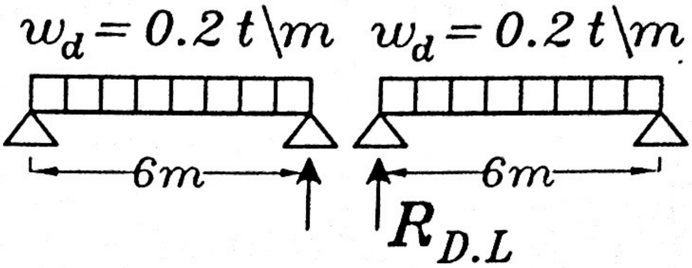
2)Design a combined column for column (1) using no bracing at all (cantliver), (which is better 4angles or 2channels).

Reactions from crane girder

Dead Load: من الجدول

$$*R_{D.L} = w_d * \frac{S}{2} * 2$$

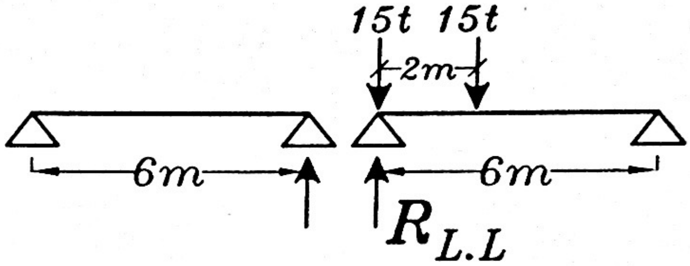
$$= 0.142 * \frac{6}{2} * 2 = 0.9\ t$$



Live Load:

$$*R_{D.L} = 15 + (15 * \frac{4}{6})$$

$$= 25\ t$$



* Assume $I = 25\ \%$

$$* \ P_y = R_{D.L} + R_{L.L}(1+I)$$

$$= 0.9 + 25.0\ \ (1 + 0.25) = \mathbf{32.15}\ t$$

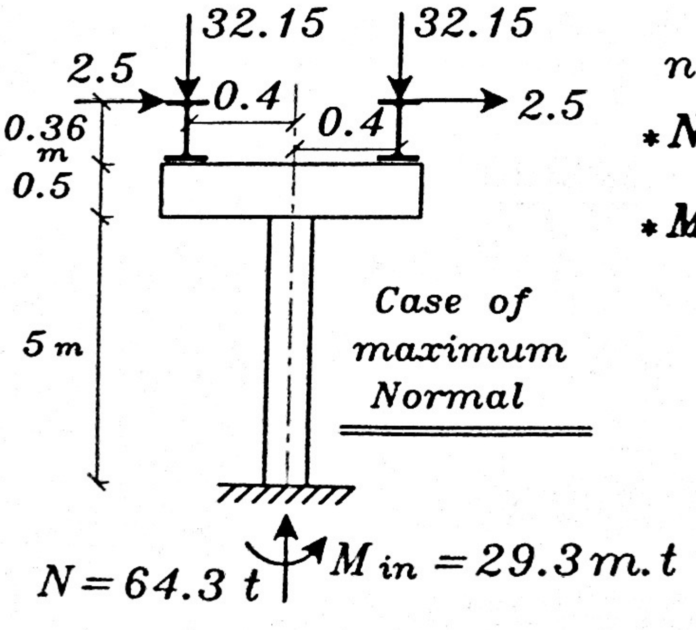
$$* \ P_X = \frac{1}{10} R_{L.L}$$ Without Impact

$$= \frac{1}{10} * 25.0 = \mathbf{2.50}\ \ t$$

$$* \ B = \text{Braking force} = \frac{\Sigma P}{7}$$ Without Impact

$$= \frac{1}{7} * (15 + 15) = \mathbf{4.30}\ t$$

Straining actions for inplane direction :



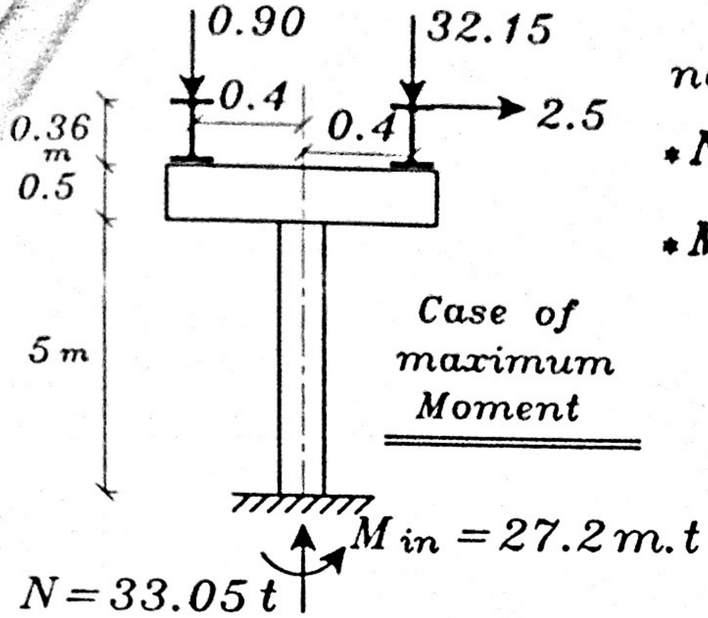
Case of maximum Normal

neglect o.w of column

$$*N = 2 * 32.15 = \mathbf{64.3}\ t$$

$$*M_{in} = 2 * 2.5 * (5 + 0.5 + 0.36)$$

$$= \mathbf{29.3}\ m.t$$



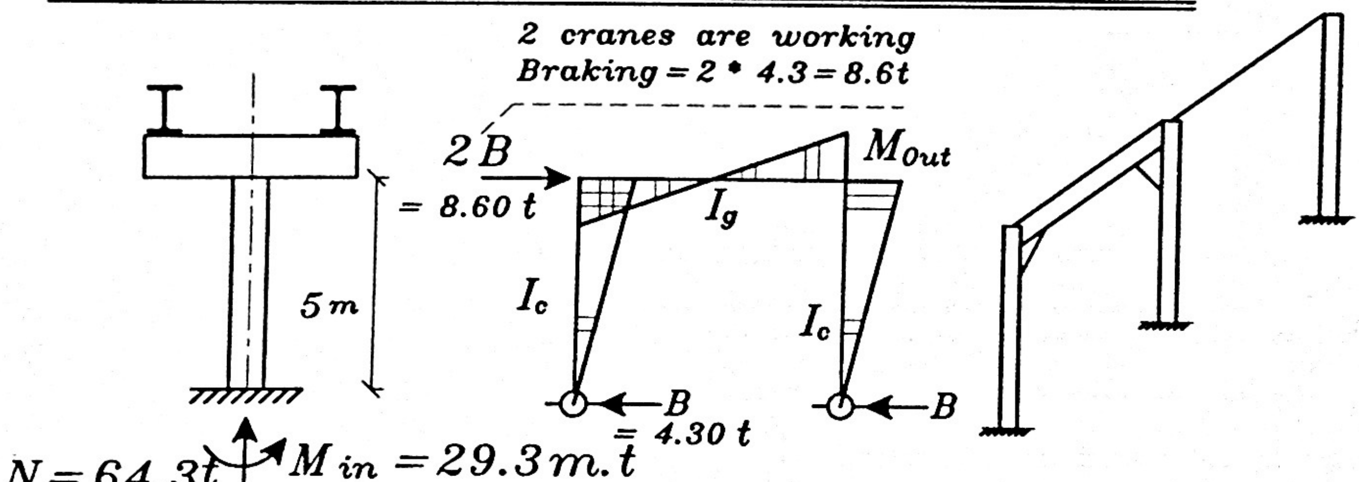
Case of maximum Moment

neglect o.w of column

* $N = 32.15 + 0.90 = \mathbf{33.05\, t}$
* $M_{in} = 2.5 * (5 + 0.5 + 0.36) + 32.15 * 0.4 - 0.90 * 0.4 = \mathbf{27.15\, m.t}$

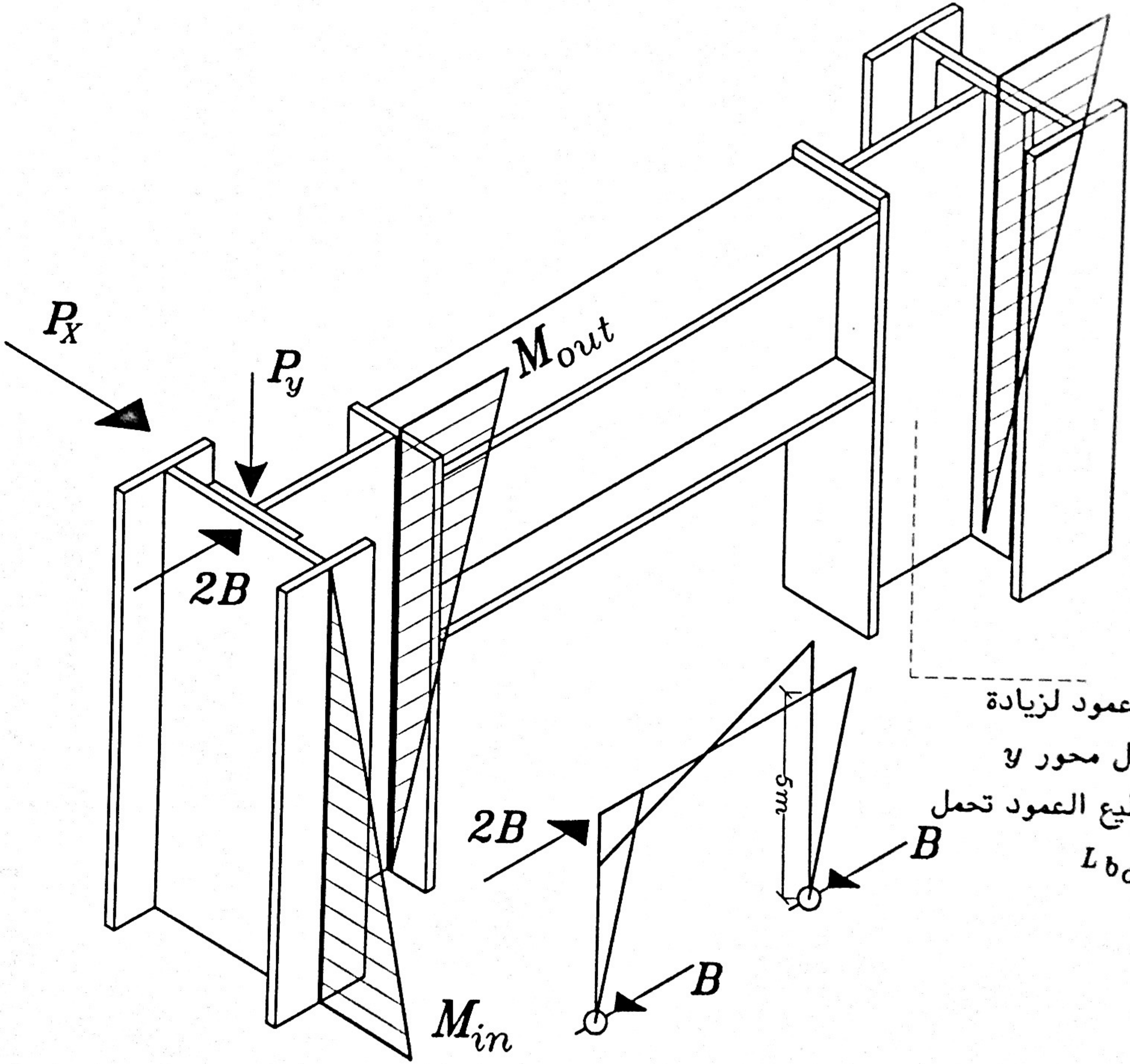
ال *Case of maximum Normal* تعطى أكبر *Normal* و أيضا فى هذه المسألة تعطى أكبر *Moment* و بالتالى فاننا ندرس هذه ال *Case* فقط.

1) Using portal frame bracing (outside plane)

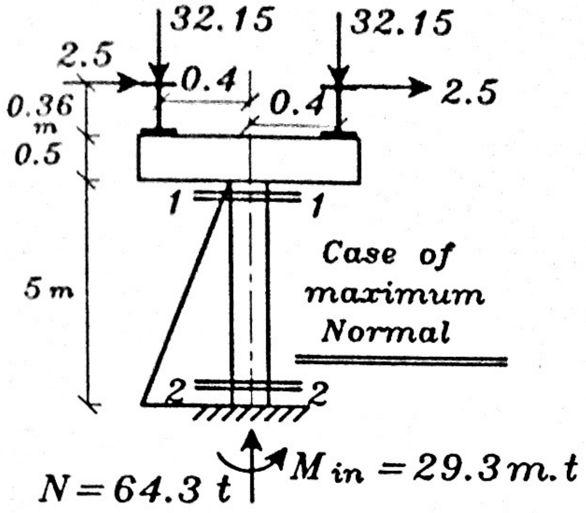


Inplane — outside-plane

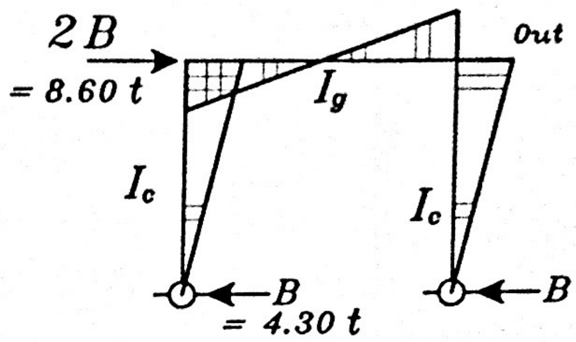
* assume $I_c = 2\, I_g$
* $M_{out} = 4.30 * (5) = \mathbf{21.5\, m.t}$



تم وضع هذا العمود لزيادة
ال $Inertia$ حول محور y
و بالتالى يستطيع العمود تحمل
ال M_y و ال $L_{b_{out}}$



Inplane



outside–plane

و نحتاج الى دراسة ثلاثة قطاعات و لكن سنكتفى بقطاعين فقط واحد فى بداية العمود و واحد فى نهايته .

Section (1–1)

$M_{in} = 29.3\ m.t$ $\qquad$ $N = 64.3\ t$ $\qquad$ $M_{out} = 0$

Section (2–2)

$M_{in} = 0$ $\qquad$ $N = 64.3\ t$ $\qquad$ $M_{out} = 21.5\ m.t$

و عند عمل الـ Choice of section نختار العمود اللى اتجاهه الطويل فى الـ Inplane لكى يقاوم الـ M_{in} و العمود اللي اتجاهه الطويل فى الـ Out plane لكى يقاوم الـ M_{out}

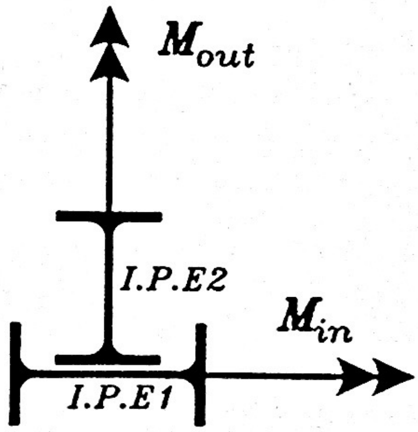
* Assume $f = 1.0\ t\backslash cm^2$

$$* \underset{I.P.E1}{S_x} = \frac{M_{in}}{f} = \frac{2930}{1.0} = 2930\ cm^3$$

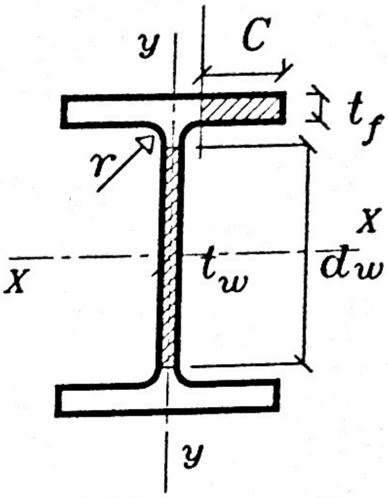
⇨ Choose **I.P.E 600**

$$* \underset{I.P.E2}{S_x} = \frac{M_{out}}{f} = \frac{2150}{1.0} = 2150\ cm^3$$

⇨ Choose **I.P.E 550**



Properties of Area :



I.P.E 600

$d_w = 51.4\,cm$ جداول

$t_w = 1.20\,cm$

$b_f = 22.0\,cm$

$t_f = 1.90\,cm$

$r = 2.40\,cm$

$A = 156\ cm^2$

$I_X = 92080\ cm^4$

$I_Y = 3390\ cm^4$

I.P.E 550

$d_w = 46.7\,cm$ جداول

$t_w = 1.11\,cm$

$b_f = 21.0\,cm$

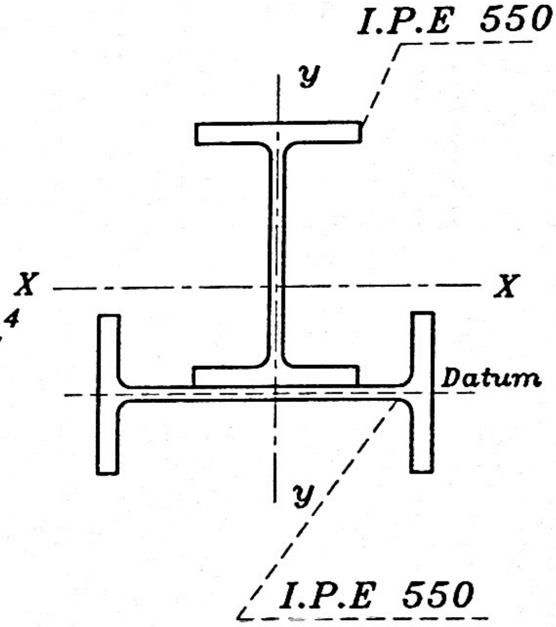
$t_f = 1.72\,cm$

$r = 2.40\,cm$

$A = 134\ cm^2$

$I_X = 67120\ cm^4$

$I_Y = 2670\ cm^4$



* $A = 134 + 156 = \mathbf{290}\ cm^2$

* $\underset{Inside}{I_Y} = I_{X_{I.P.E600}} + I_{y_{I.P.E550}}$

$= 92080 + 2670 = \mathbf{94750}\ cm^4$

* $\overline{y} = \dfrac{\Sigma Ay}{\Sigma A} = \dfrac{A_{I.P.E600} * 0 + A_{I.P.E550} * \frac{h}{2}}{\Sigma A}$

$= \dfrac{134 * \frac{55}{2}}{134 + 156} = \mathbf{12.7}\,cm$

* $\underset{outside}{I_X} = \left[I_{X_{I.P.E550}} + A_{I.P.E550}\left(\frac{55}{2} - 12.7\right)^2\right]$

$+ \left[I_{y_{I.P.E600}} + A_{I.P.E600}\left(\overline{y}\right)^2\right]$

$= \left[67120 + 134 * \left(\frac{55}{2} - 12.7\right)^2\right]$

$+ \left[3390 + 156 * (12.7)^2\right] = \mathbf{125023}\,cm^4$

$$\bullet\; r_{x\,\text{outside}} = \sqrt{\frac{I_x}{A}} = \sqrt{\frac{125023}{290}} = 20.7 \;\; cm$$

$$\bullet\; r_{y\,\text{Inside}} = \sqrt{\frac{I_y}{A}} = \sqrt{\frac{94750}{290}} = 18 \;\; cm$$

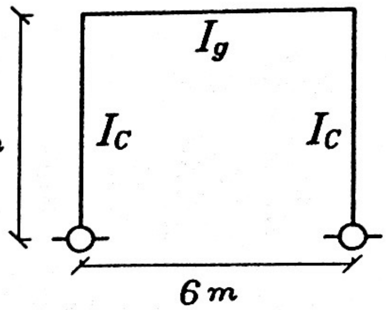
4) Check Compactness

assume that the section is compact

5) Check Compression

$l_{b\,in} = 2.1 \;\; (5.0) = 10.5\, m$ $\qquad l_{b\,out} \Rightarrow Frame \Rightarrow G_A \,\&\, G_B$

$\bullet$ assume $I_c = 2\, I_g$



$$G_A = 10$$

$$G_B = \frac{I_c/l_c}{I_g/l_g} = \frac{2I_g/5}{I_g/6} = 2.4$$

$\bullet$ From charts permitted to sway

$\boxed{k = 2.2}$ $\qquad l_{b\,out} = 2.2 * 5 = 11 m$

$r_x = 20.7 \;\; cm$ $\qquad r_y = 18 \;\; cm$

$$\bullet\; \lambda_{in} = \frac{l_{b\,in}}{r_y} = \frac{1050}{18.0} = 58.33 < 180$$

$$\bullet\; \lambda_{out} = \frac{l_{b\,out}}{r_x} = \frac{1100}{20.7} = 53.14 < 180$$

$$\bullet\; F_C = 1.4 - \;\; 6.5 * 10^{-5} \lambda^2_{max.}$$
$$= 1.4 - \;\; 6.5 * 10^{-5} * 58.33^2 = \boxed{1.18 \;\;\; t\backslash cm^2}$$

$$\bullet\; f_{Ca} = \frac{N}{A} = \frac{64.30}{290} = \boxed{0.22 \;\; t\backslash cm^2}$$

* $\dfrac{f_{Ca}}{F_C} = \dfrac{0.22}{1.18} = 0.19 > 0.15$

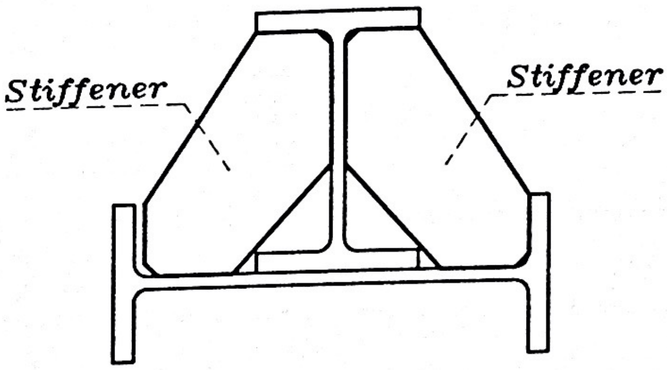
* $F_{Ey} = \dfrac{7500}{\lambda_y^2} = \dfrac{7500}{58.3^2} = 2.2$

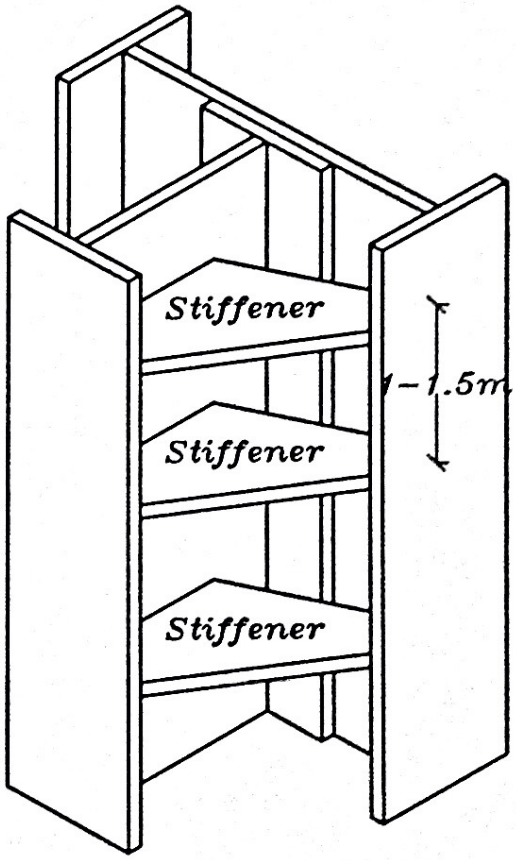
Permitted to sway

$$A_2 = \frac{C_{my}}{\left[1-\frac{f_{ca}}{F_{Ey}}\right]} = \frac{0.85}{\left[1-\frac{0.22}{2.20}\right]} = \mathbf{0.94} \not< 1.0 \qquad \boxed{A_2 = 1}$$

6) Check Bending

نستخدم Stiffener فى العمود كل مسافة $1.5m \Rightarrow 1.0m$ لكي يجعل ال $l_{u\ act.}$
صغيرة و بالتالى يمنع ال LTB

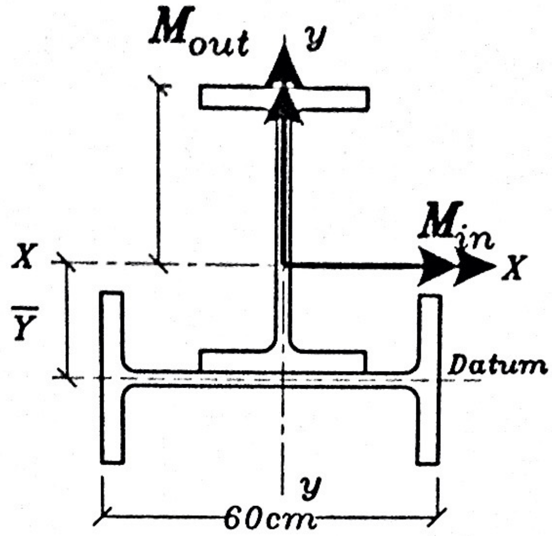




* $l_{u\,act.} = 100$ cm

* $l_{u\,max.} = \begin{cases} \dfrac{20\ b_f}{\sqrt{f_y}} = \dfrac{20 * 22.0}{\sqrt{2.4}} = 284 \text{ cm} \\ \dfrac{1380\, A_f}{d * F_y}\, C_b \end{cases}$

$l_{u\,act.} > l_{u\,max.} \Rightarrow$ NO LTB



$$f_{b(act.)in} = \frac{M_{in}}{I_y}\left(\frac{30}{2}\right) = f_{by}$$

$$= \frac{2930}{94750}\left(\frac{30}{2}\right) = \boxed{0.93\ t\backslash cm^2}$$

Section (1–1)

$M_{in} = 29.3\ m.t$

$N = 64.3\ t$

$M_{out} = 0$

$F_{bcy} = \underline{0.64\,F_y}$ No LTB

Compact لان ال I–Section يكون

$$\boxed{F_{bcy} = 1.536\ t\backslash cm^2}$$

7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \cancel{\frac{f_{bx\,(act.)}}{F_{bCx}}} * A_1 + \frac{f_{by\,(act.)}}{F_{bCy}} * A_2 < 1.0$$

$$\frac{0.22}{1.18} + \frac{0.93}{1.536} * 1.0 = 0.84$$

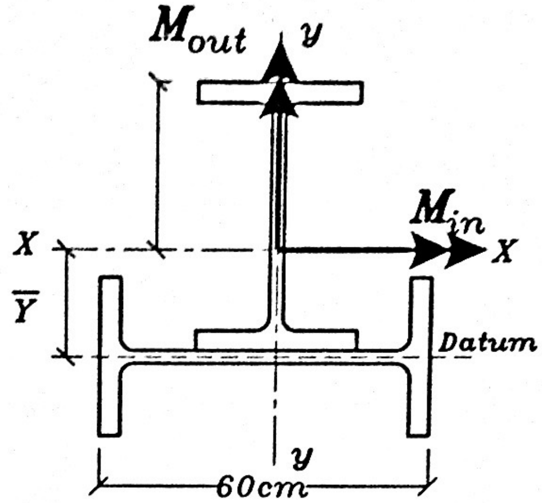
$< 1.2 \Rightarrow$ Case B (lateral shock)

$\Rightarrow$ SAFE

Check on section (2-2)

$M_{in} = 0$ $\qquad N = 64.3\,t$ $\qquad M_{out} = 21.5\ m.t$

الخمسة خطوات الاولى ثابتة و التغيير يكون من أول الـ Check bending



$$f_{b(act.)out} = \frac{M_{out}}{I_y}\left(55 + \frac{1.2}{2} - \overline{Y}\right) = f_{bx}$$

$$= \frac{2150}{125023}\left(55 + \frac{1.2}{2} - 12.7\right) = \boxed{0.74\ t\backslash cm^2}$$

$$* \quad F_{Ex} = \frac{7500}{\lambda_X^2} = \frac{7500}{53.1^2} = 2.65$$

Permitted to sway

$$A_2 = \frac{C_{my}}{\left[1 - \frac{f_{ca}}{F_{Ey}}\right]} = \frac{0.85}{\left[1 - \frac{0.22}{2.65}\right]} = 0.93 \not< 1.0 \qquad \boxed{A_1 = 1}$$

$$F_{bcx} = \underline{0.64\,F_y} \qquad \text{No LTB}$$

لان الـ I-Section يكون Compact

$$\boxed{F_{bcx} = 1.536\ t\backslash cm^2}$$

7) Check Interaction equation

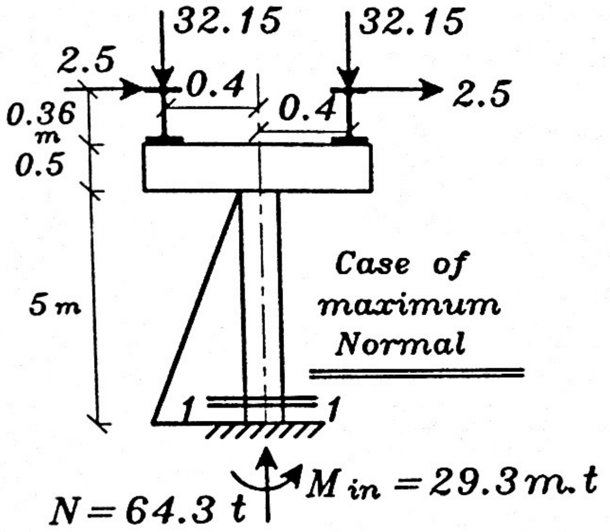
$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{bcx}} * A_1 + \cancel{\frac{f_{by\,(act.)}}{F_{bcy}}} * A_2 < 1.2$$

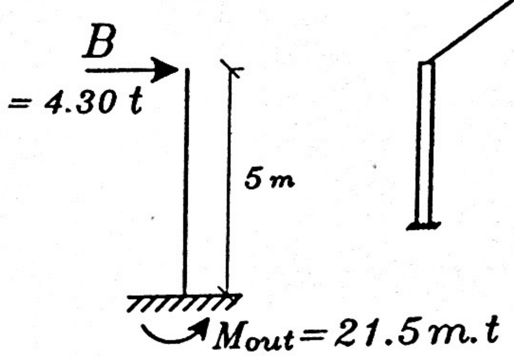
$$\frac{0.22}{1.18} + \frac{0.74}{1.536} * 1.0 = 0.70$$

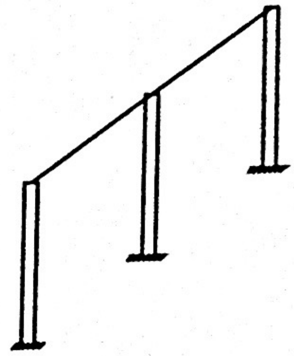
$< 1.2 \Rightarrow$ Case B (lateral shock)

$\Rightarrow$ **SAFE**

2) Using no bracing system (outside plane) (cantliver)







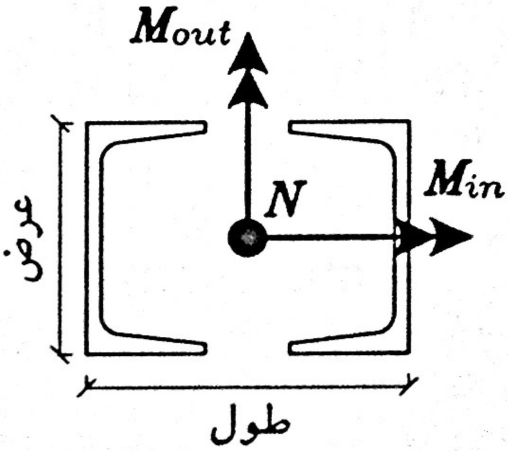
Inplane　　　　outside-plane

و بفرض أن ال braking force تتوزع على عمودين فقط فان العمود الواحد يحمل $\frac{2B}{2}$ أى يحمل B

Section (1-1)

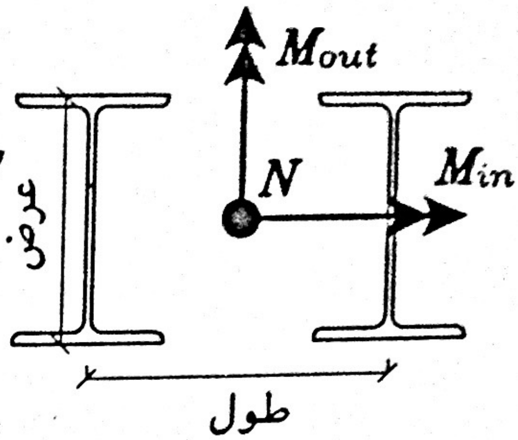
$M_{in} = 29.3\ m.t$　　　$N = 64.3\ t$　　　$M_{out} = 21.5\ m.t$

و عند اختيار قطاع Combined ليقاوم ال M_{in} و ال M_{out} نجد التالى

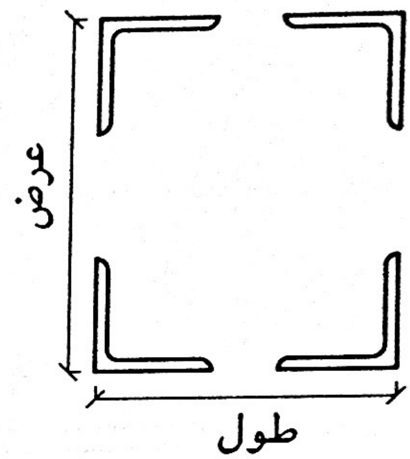


هذا القطاع قطاع محدد لان عرض العمود لا يزيد عن 40cm و ذلك لان أكبر Channel موجودة هى U.P.N400 و لذلك لا يفضل استخدامه فى حالة ال double moment

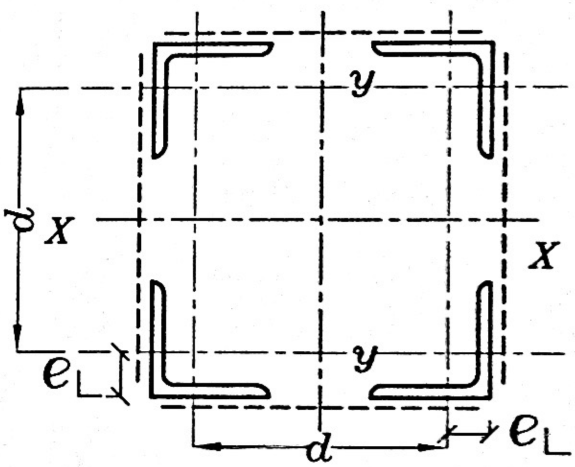
هذا القطاع قطاع أقوى و لكن أقصى عرض لا يزيد عن $60cm$ و لذلك مثل السابق لا يفضل استخدامه فى حالة الـ *double moment*



هذا القطاع قطاع مناسب جدا حيث من الممكن التحكم فى طوله و عرضه كما نريد و يفضل استخدامه فى هذه المسألة حيث أن العمود معرض لـ *double moment* كما أن الـ *Buckling length* كبير فى الاتجاهين



3) Choice of section



* *Assume* $d = \dfrac{500}{12 \Rightarrow 15} = 40\ cm$

* *Force on one angle*

$$= C = \frac{N}{4} + \frac{M}{2d}$$

$$= \frac{64.3}{4} + \frac{29.30}{2 * 0.4} = \mathbf{52.7}\ t$$

* *Assume (allowable stress)* $f = 1.0\ t \backslash cm^2$

* $A_{One\ L} = \dfrac{Force\ (C)}{f} = \dfrac{52.7}{1.0} = \mathbf{52.7}\ cm^2$

قيمة كبيرة جدا لذلك نلجأ الى زيادة الـ d

Assume $d = 70\ cm$

* Force on one angle

$$= C = \frac{N}{4} + \frac{M}{2d}$$

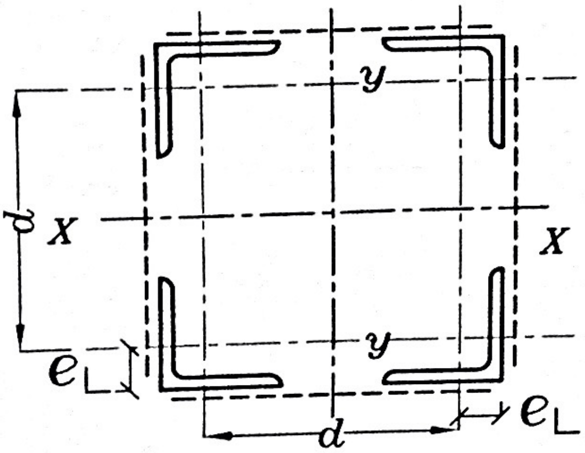
$$= \frac{64.3}{4} + \frac{29.30}{2 * 0.7} = \mathbf{37.0\,t}$$

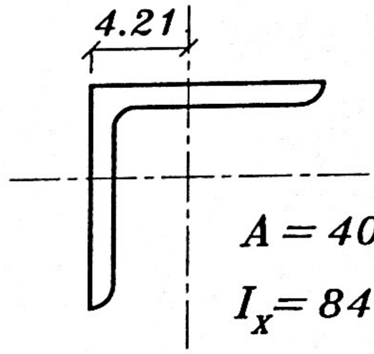
* Assume (allowable stress) $f = 1.0\ t\backslash cm^2$

* $A_{One\ L} = \frac{Force\ (C)}{f} = \frac{37.0}{1.0} = \mathbf{37.0\ cm^2}$

$\Rightarrow$ Choose **4 L 150x150x14**

Properties of Area :





$A = 40.3\ cm^2$

$I_X = 845\ cm^4$

$I_Y = 845\ cm^4$

* $A_{\square} = 4\,A_L = 4 * 40.3 = \mathbf{161.2}\ cm^2$

* $I_{X\,\square} = 4\,[I_{X_L} + A_L\,(\frac{h}{2})^2] = I_{Y\,\square}$

$$= 4\,[845 + 40.3\,(\frac{70}{2})^2] = \mathbf{200850}\ cm^4$$

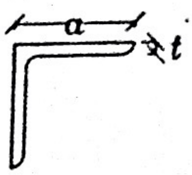
* $r_{x\,\square} = \sqrt{\frac{I_{x\,\square}}{A_{\square}}} = \sqrt{\frac{200850}{161.2}} = 35.29\ cm \simeq (\frac{d}{2}) = 35\ cm$

$= r_{y\,\square}$

4) Check Compactness

Flange subjected to comp.

$$* \; \frac{C}{t_f} = \frac{a}{t} = \frac{15}{1.4} = 10.7 < \frac{23}{\sqrt{f_y}} = 14.8$$



$\therefore$ **The section is Non-compact**

5) Check Compression

$$l_{b\,in} = 2.1 \; (5.0) = 10.5\,m = l_{b\,out}$$

$$r_x = 35.29\ cm = r_y$$

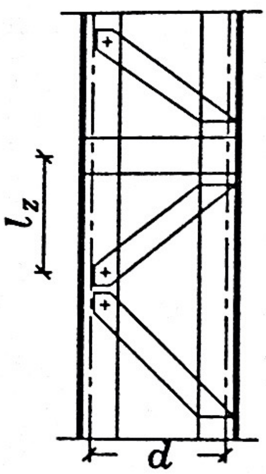
$$* \; \lambda_{in} = \frac{l_{b\,in}}{r_y} = \frac{1050}{35.29} = 29.7 = \lambda_{out}$$

$* \;$ assume $l_Z = 70\ cm \qquad r_Z = r_{vL} = 2.94\ cm$

$$* \; \lambda_Z = \frac{l_Z}{r_Z} = \frac{70}{2.94} = 23.8$$

$$\not> 60$$

$$\not> \frac{2}{3} \overset{38.1}{\lambda_{max.}} \begin{cases} \lambda_{Out} \\ \lambda_{in} \end{cases} = 25.4$$



$$* \; \lambda_{in} = \sqrt{\lambda_{in}^2 + (k\lambda_Z)^2} = \lambda_{out}$$

$$= \sqrt{29.70^2 + \overset{\text{Lacing Bars}}{1.00} * 23.8^2} = 38.1 \quad < 180$$

$$* \; F_C = 1.4 - 6.5 * 10^{-5} \lambda_{max.}^2$$

$$= 1.4 - 6.5 * 10^{-5} * 38.10^2 = \boxed{1.305\, t \backslash cm^2}$$

$$f_{ca} = \frac{N}{A} = \frac{64.3}{161.2} = \boxed{0.390\, t \backslash cm^2}$$

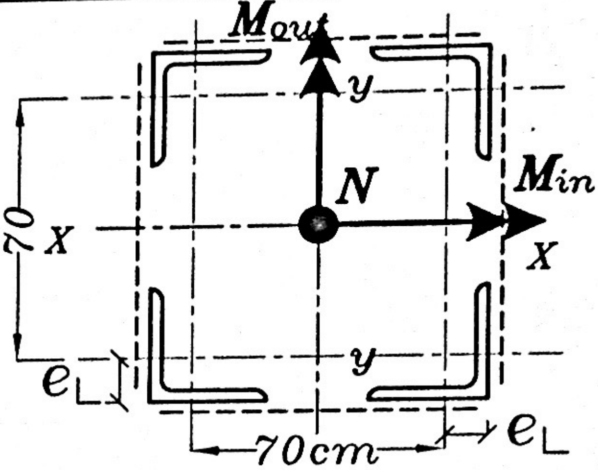
- $\dfrac{f_{ca}}{F_C} = \dfrac{0.390}{1.305} = 0.29 \quad > 0.15$

- $F_{Ex,y} = \dfrac{7500}{\lambda^2_{x,y}} = \dfrac{7500}{38.1^2} = 5.16$

$$A_{1,2} = \frac{Cm_{x,y}}{\left[1 - \frac{f_{ca}}{F_{Ex,y}}\right]} = \frac{\overset{\text{Permitted to sway}}{0.85}}{\left[1 - \frac{0.390}{5.16}\right]} = 0.96 \not< 1.0 \qquad \boxed{A_1 = 1}$$

$$\boxed{A_2 = 1}$$

6) Check Bending



$$f_{b(act.)in} = \frac{M_{in}}{I_y}\left(\frac{d}{2} + e_L\right) = f_{by}$$

$$= \frac{2930}{200850}\left(\frac{70}{2} + 4.21\right) = \boxed{0.57\, t \backslash cm^2}$$

$$f_{b(act.)out} = \frac{M_{out}}{I_y}\left(\frac{d}{2} + e_L\right) = f_{bx}$$

$$= \frac{2150}{200850}\left(\frac{70}{2} + 4.21\right) = \boxed{0.42\, t \backslash cm^2}$$

$F_{bcy} = \underline{0.58\, F_y}$ No LTB

Non–Compact تكون angle لان ال

$$\boxed{F_{bcy} = 1.40\, t \backslash cm^2}$$

$$\boxed{F_{bcx} = 1.40\, t \backslash cm^2}$$

7) Check Interaction equation

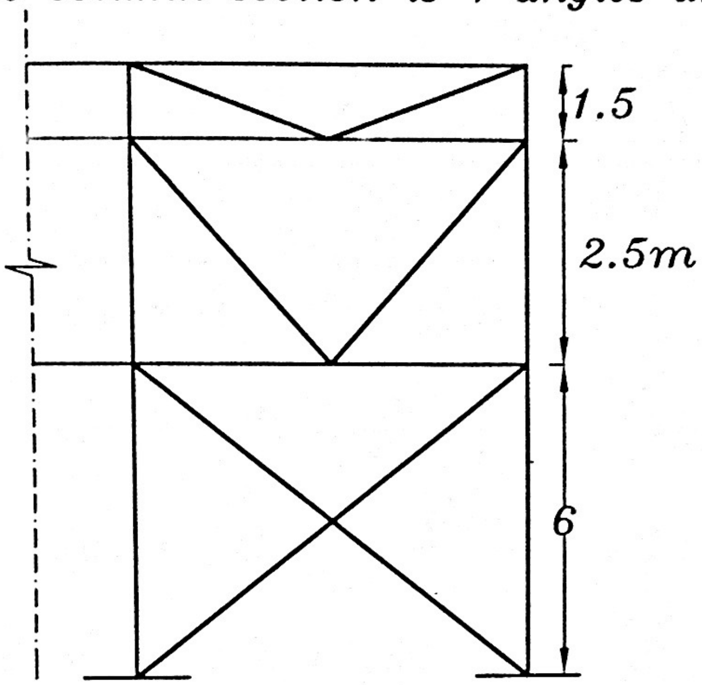
$$\frac{f_{ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{b_{cx}}} * A_1 + \frac{f_{by\,(act.)}}{F_{b_{cy}}} * A_2 < 1.2$$

$$\frac{0.390}{1.305} + \frac{0.570}{1.40} * 1.0 + \frac{0.42}{1.40} * 1.0$$

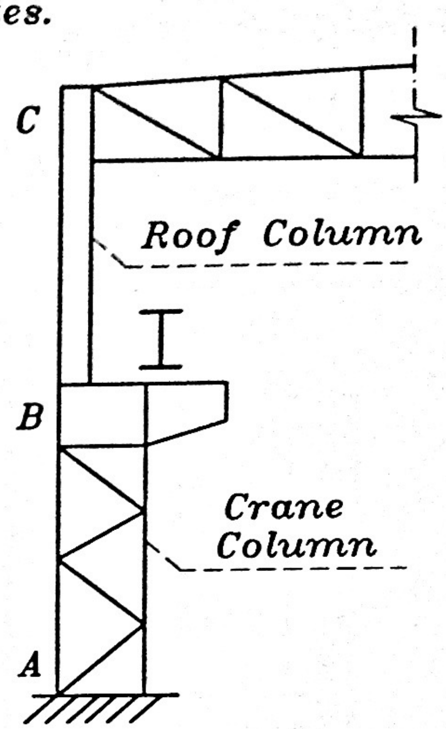
$$= 0.99 < 1.2 \Rightarrow \text{SAFE}$$

EXAMPLE :

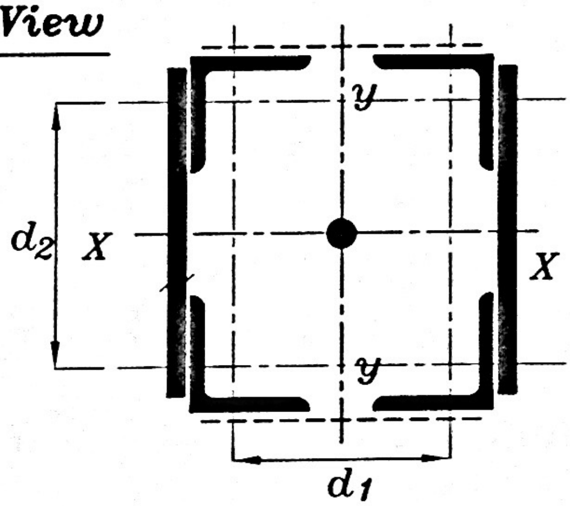
Design the shown crane column AB (N=40t , M=30m.t)
The column section is 4 angles and 2 plates.



Side View



Elevation



Proposed section

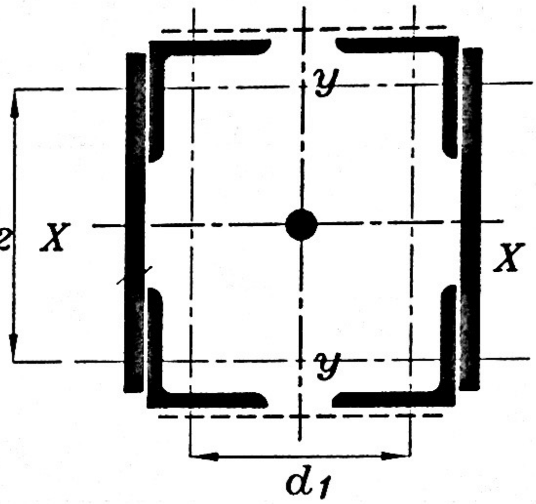
1) Suggest suitable bracing system

لا نحتاج لانه معطى فى المسألة.

2) Calculate the straining actions

$N = 40\,t \qquad M_{in} = 30\,m.t$

3) Choice of section



* Assume $d_1 = \dfrac{600}{12 \Rightarrow 15} = 40\ cm$

* Assume $d_2 = \dfrac{d_1}{1.5 \Rightarrow 2} = 25\ cm$

* Force on one side

$$= C = \frac{N}{2} + \frac{M}{d}$$

$$= \frac{40}{2} + \frac{30}{0.4} = 95\ t$$

* Assume (allowable stress) $f = 1.20\ t \backslash cm^2$

* $A_{One\ side} = \dfrac{Force\ (C)}{f} = \dfrac{95.0}{1.2} = 79\ cm^2$

و نقوم بفرض أبعاد الـ Plate حيث نفرض السمك $t = 10 \Rightarrow 12\ mm$

* Assume $t_P = 10\ mm \qquad h_P = 25\ cm$

و المفروض أن الطول الحقيقى للـ Plate هو $h_P = 25 + 2\,e_L$ و لكننا لا نعرف أبعاد الـ angles .

* $A_{One\ angle} = \dfrac{A_{One\ side} - \overset{\simeq h*t}{A_{Plate}}}{2} = \dfrac{79 - (25 * 1)}{2} = 27\ cm^2$

و لكن مساحة الـ angles كبيرة و من الممكن تقليلها بزيادة قيمة الـ d_1

* Assume $d_1 = 50\ cm \qquad d_2 = 30\ cm$

$*$ Force on one side

$$= C = \frac{N}{2} + \frac{M}{d}$$

$$= \frac{40}{2} + \frac{30}{0.5} = 80\ t$$

$$* \ A_{One\ side} = \frac{Force\ (C)}{f} = \frac{80.0}{1.2} = 66.7\ cm^2$$

$*$ Assume $t_p = 15$ mm $\quad h_p = 30$ mm

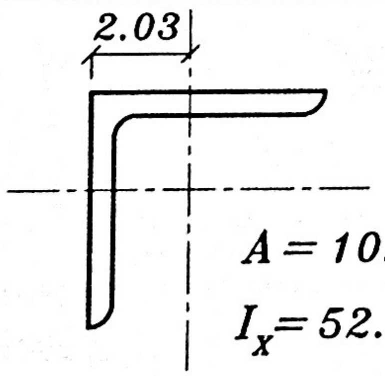
$$* \ A_{One\ angle} = \frac{A_{One\ side} - \overset{\simeq h*t}{A_{Plate}}}{2} = \frac{66.7-(30*1.5)}{2}$$

$$= 10.85\ cm^2$$

$\Rightarrow$ Choose **2 L 75x75x7**

$$h_p = 25 + 2\,e_{L} = 25 + 2*2.03 = 34\ cm$$

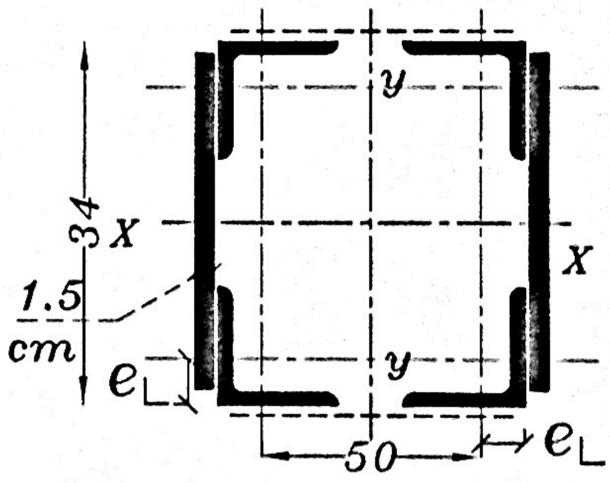
Properties of Area :



$A = 10.1\ cm^2$

$I_X = 52.4\ cm^4$

$I_Y = 52.4\ cm^4$



$$* \ A_{Plate} \simeq h*t$$

$$\simeq 34*1.5 = 51\ cm^2$$

$$* \ A_{[\,]} = 4\,A_{L} + 2\,A_{Plate} \quad cm^2$$

$$= 4*52.4 + 2*51 = 142.4\ cm^2$$

$$* \; I_{Y[\,]} = 4\left[I_{Y_L} + A_L\left(\frac{d}{2}\right)^2\right] + 2\left[\frac{h * t^3}{12} + A_{Plate} * \left(\frac{d}{2} + e_L + \frac{t}{2}\right)^2\right]$$

$$= 4\left[52.4 + 10.1\left(\frac{50}{2}\right)^2\right] + 2\left[\frac{34 * 1.5^3}{12} + 51 * \left(\frac{50}{2} + 2.03 + \frac{1.5}{2}\right)^2\right] = \mathbf{104176}\ cm^2$$

$$* \; I_{X[\,]} = 4\left[I_{X_L} + A_L\left(\frac{d_2}{2}\right)^2\right] + 2\left[\frac{t * h^3}{12}\right]$$

$$= 4\left[52.4 + 10.1\left(\frac{30}{2}\right)^2\right] + 2\left[\frac{1.5 * 34^3}{12}\right]$$

$$= \mathbf{19126}\ cm^2$$

$$* \; r_{x[\,]} = \sqrt{\frac{I_{x[\,]}}{A_{[\,]}}} = \sqrt{\frac{19126}{142.4}} = 11.6\ cm$$

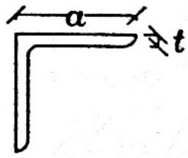
$$* \; r_{y[\,]} = \sqrt{\frac{I_{y[\,]}}{A_{[\,]}}} = \sqrt{\frac{104176}{142.4}} = 27.0\ cm$$

---

4) Check Compactness

Flange subjected to comp.

$$* \; \frac{C}{t_f} = \frac{a}{t} = \frac{7.5}{0.7} = \mathbf{10.7} < \frac{23}{\sqrt{f_y}} = \mathbf{14.8}$$



∴ The section is Non-compact

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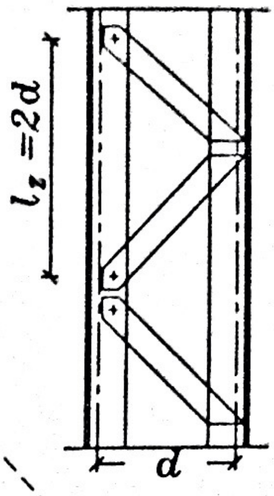
5) Check Compression

$l_{b\,in} = 1.5\ (6.0) = 9.0\ m$ $\qquad$ $l_{b\,out} = 6.0\ m$

$r_x = 11.6\ cm$ $\qquad$ $r_y = 27.0\ cm$

$$* \; \lambda'_{in} = \frac{l_{b\,in}}{r_y} = \frac{900}{27.0} = \mathbf{33.3}$$

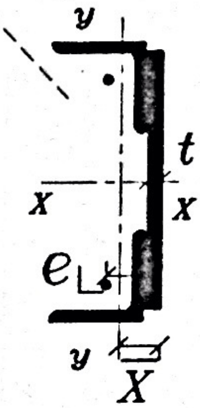
$$* \lambda_{out} = \frac{l_{b\,out}}{r_y} = \frac{600}{11.6} = \mathbf{51.7} < \mathbf{180}$$



* *assume using lacing bars with angle 45*

$$l_Z = 2 * 50 = \mathbf{100}\,cm \qquad r_Z = r_{y\,[}$$

نتعامل مع هذا الشكل كأنه *Channel* و بالتالى يكون ال *min. radius of gyration* هو ال r_y لهذا الشكل و بالتالى نضطر الى حسابها .



$$* A_{Plate} \simeq h * t = \mathbf{51}\ cm^2$$

$$* A_{]} = 2\,A_L + A_{Plate} = 2 * 10.1 + 51 = \mathbf{71.2}\,cm^2$$

$$* \overline{X} = \frac{2\,A_L * (e_L + t) + A_{Plate} * \frac{t}{2}}{A_{]}}$$

$$= \frac{2 * 10.1 * (2.03 + 1.5) + 51 * 0.75}{71.2} = \mathbf{1.54}\,cm$$

$$* I_{Y\,[\,]} = 2\left[I_{Y_L} + A_L\left(e_L + t - \overline{X}\right)^2\right] + 2\left[\frac{h * t^3}{12} + A_{Plate} * \left(\overline{X} - \frac{t}{2}\right)^2\right]$$

$$= 2\left[52.4 + 10.1\left(2.03 + 1.5 - 1.54\right)^2\right] + \left[\frac{34 * 1.5^3}{12} + 51 * \left(2.03 - \frac{1.5}{2}\right)^2\right] = \mathbf{226.19}\ cm^2$$

$$* r_{y\,[\,]} = \sqrt{\frac{I_{y\,[\,]}}{A_{[\,]}}} = \sqrt{\frac{226.19}{71.20}} = 1.78\ cm$$

$$* \lambda_Z = \frac{l_Z}{r_Z} = \frac{100}{1.78} = 56.5 \not> \mathbf{60}$$

$$\not> \frac{2}{3}\overset{65.3}{\lambda_{max.}}\begin{cases}\lambda_{out} \\ \lambda_{in}\end{cases} = 43.5$$

$$* \ \lambda_{in} = \sqrt{\lambda_{in}^{2} + (k\lambda_Z)^2} =$$

$$= \sqrt{33.30^2 + \overbrace{1.00}^{\text{Lacing Bars}} * 65.2^2} = 65.3 \quad < 180$$

$$\lambda_Z > \frac{2}{3}\lambda_{max.} = \frac{2}{3} * 65.3 = 43.5 \Rightarrow Unsafe$$

نحتاج الى اضافة Horizontal member للـ Lacing bars حتى تقل

الـ l_Z و بالتالى تقل الـ λ_Z

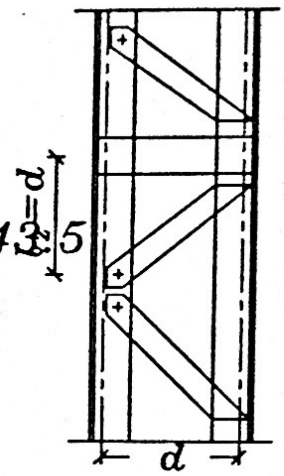
$$l_Z = 50 \ cm$$

$$* \ \lambda_Z = \frac{l_Z}{r_Z} = \frac{50}{1.78} = 28.1$$

$$\not> 60$$

$$\not> \frac{2}{3}\lambda_{max.} \begin{cases} \overset{51.7}{\lambda_{Out}} \\ \lambda_{in} \end{cases} 34.5$$

$= 43.5$



$$* \ \lambda_{in} = \sqrt{\lambda_{in}^{2} + (k\lambda_Z)^2} =$$

$$= \sqrt{33.30^2 + \overbrace{1.00}^{\text{Lacing Bars}} * 28.1^2} = 43.6 \quad < 180$$

$$* F_C = 1.4 - 6.5 * 10^{-5} \lambda^2_{max.}$$

$$= 1.4 - 6.5 * 10^{-5} * 51.7^2 = \boxed{1.230 \, t\backslash cm^2}$$

$$* f_{Ca} = \frac{N}{A} = \frac{40}{142.2} = \boxed{0.280 \, t\backslash cm^2}$$

$$* \frac{f_{Ca}}{F_C} = \frac{0.280}{1.230} = 0.23 \quad > 0.15$$

$$* F_{Ey} = \frac{7500}{\lambda_y^2} = \frac{7500}{43.6^2} = 3.94$$

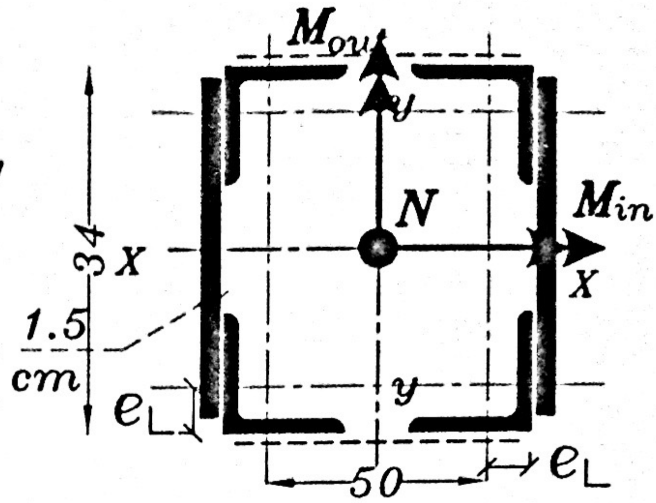
$$A_2 = \frac{C_{my}}{[1 - \frac{f_{ca}}{F_{Ey}}]} = \frac{\overset{\text{Permitted to sway}}{0.85}}{[1 - \frac{0.280}{3.94}]} = 0.82 \not< 1.0 \qquad \boxed{A_2 = 1}$$

6) Check Bending

$$f_{b(act.)_{in}} = \frac{M_{in}}{I_y}\left(\frac{d}{2} + e_L + t_p\right) = f_{by}$$

$$= \frac{3000}{104176}\left(\frac{50}{2} + 4.21 + 1.5\right)$$

$$= \boxed{0.82\ t\backslash cm^2}$$



$F_{bcy} = 0.58\, F_y$ No LTB

Non-Compact تكون angle لان ال

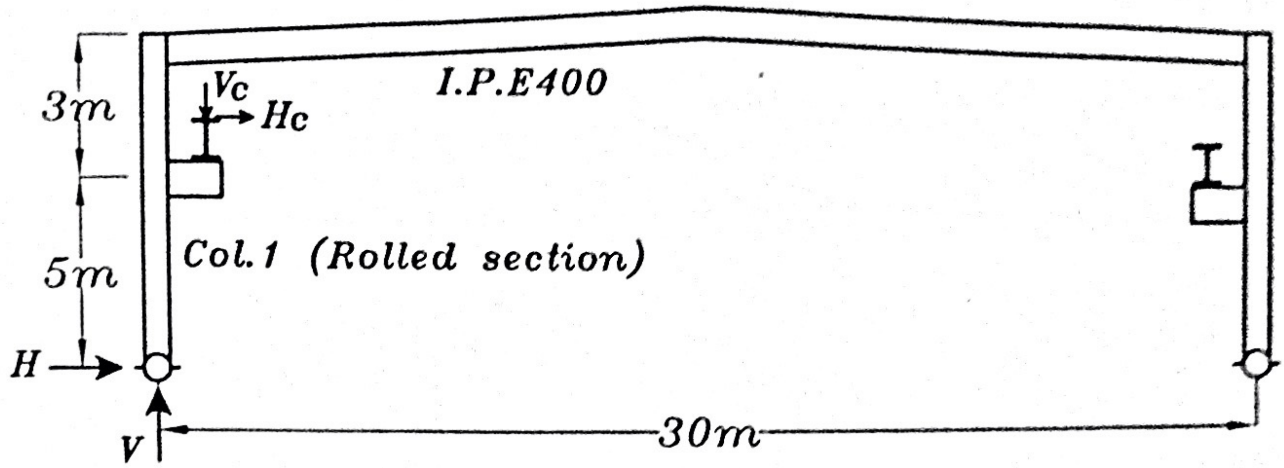
$$\boxed{F_{bcy} = 1.40\ t\backslash cm^2}$$

7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \cancel{\frac{f_{bx\,(act)}}{F_{bcx}}} * A_1 + \frac{f_{by\,(act.)}}{F_{bcy}} * A_2 < 1.0$$

$$\frac{0.280}{1.230} + \frac{0.82}{1.40} * 1.0 = 0.82 < 1.0 \Rightarrow \text{SAFE}$$

EXAMPLE :



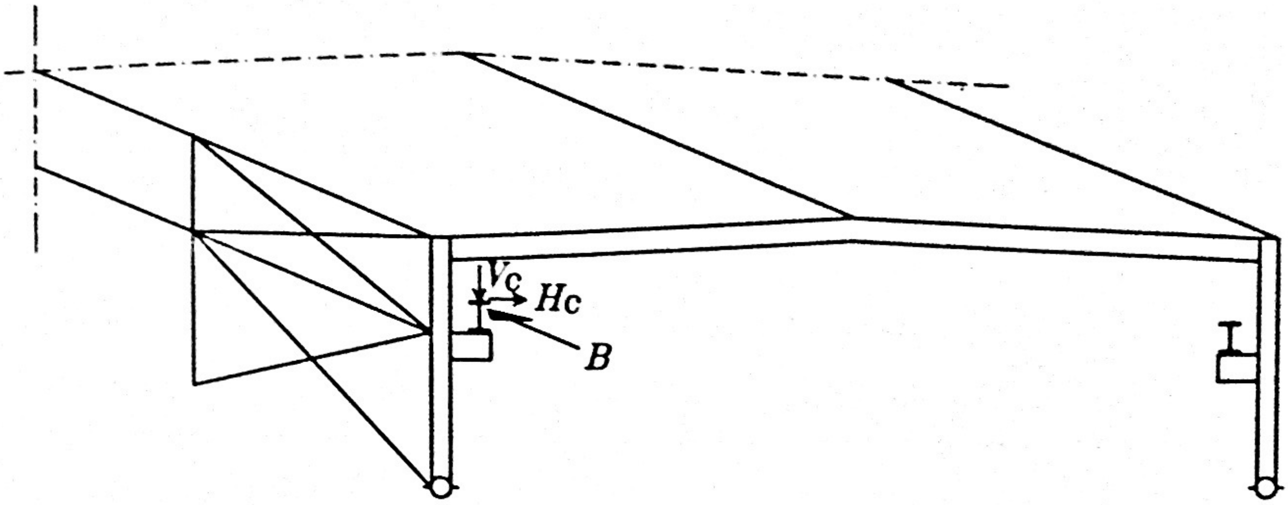
The given figure shows the main structural system of an industrial building . It is required to :
Design column (1) in the following cases:

a) Using horizontal member at the level of crane girder .
b) Without using horizontal member at the level of the crane girder.

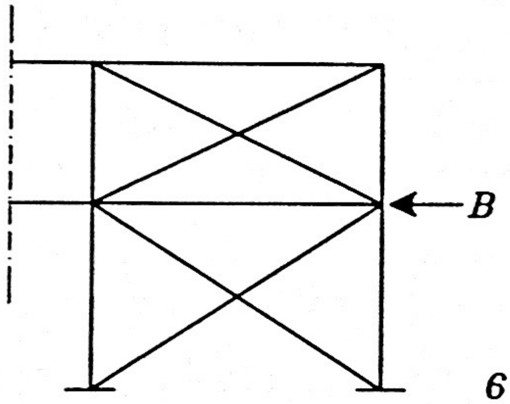
Data :

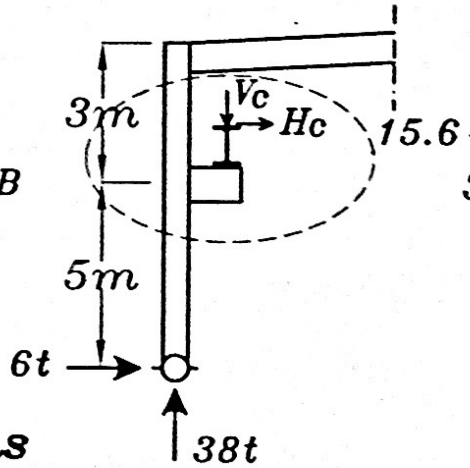
* Brackets are I.P.E 500
* Crane girder is H.E.B 360
* Distance between centerline of crane girder and centerline of column is 40 cm.
* Assume braking force is to be carried by 2 columns.
* $H = 6\ t$ * $V = 38\ t$
* $H_C = 2.5\ t$ * $V_C = 32.15\ t$
* Crane girder wheel loads are 15t each and spaced 2m.

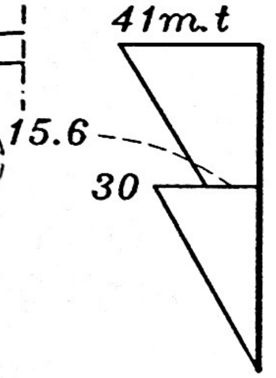
a) Using horizontal member at the level of crane girder .



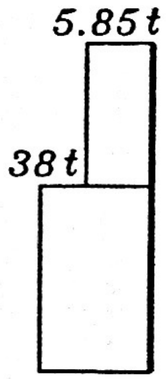
الـ Horizontal member الموجود فى الـ Bracing system فى نفس مستوى الـ Crane girder هو الذى يقاوم الـ Braking force و بالتالى فان العمود لا يتأثر بها و بالتالى لا يوجد M_{out} على العمود .







N.F.D.



B.M.D

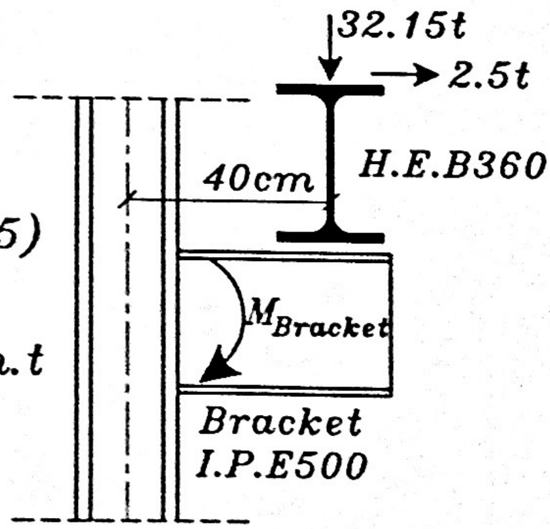
Straining actions

* $N_{Below\ crane} = \mathbf{38\ t}$
* $N_{Above\ crane} = 38 - 32.15 = \mathbf{5.85t}$
* $M_{Just\ below\ bracket} = 6 * 5 = \mathbf{30\ m.t}$
* $M_{Bracket} = 32.14 * 0.4 + 2.5 * (0.36 + 0.25)$

  $= \mathbf{14.4\ m.t}$
* $M_{Just\ above\ bracket} = 30 - 14.4 = \mathbf{15.6\ m.t}$
* $M_{Upper} = 6 * 8 - 32.15 * 0.4$

  $+ 2.5 * (3.0 - 0.25 - 0.36)$

  $= \mathbf{41\ m.t}$



Section (1-1)

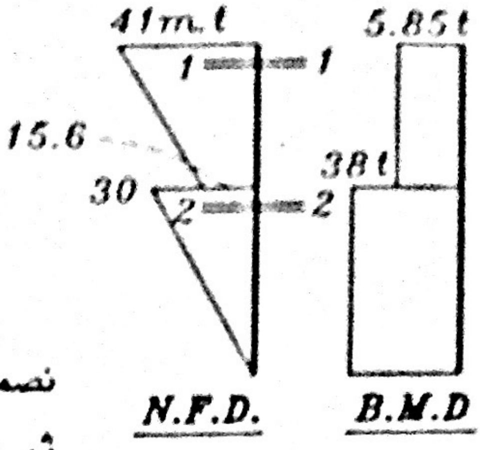
$N = 5.85\ t$ $\qquad M_{in} = 41\ m.t$

Section (2-2)

$N = 38\ t$ $\qquad M_{in} = 30\ m.t$

نصمم Section (1) لانه عليه ال moment الاكبر

ثم نعمل Check على Section (2)



Section (1-1)

1) Suggest suitable bracing system

لا نحتاج لانه معطى فى المسألة.

2) Calculate the straining actions

$N = 5.85\ t$ $\qquad M_{in} = 41\ m.t$

3) Choice of section

* Assume (allowable stress) $f = 1.00\ t\backslash cm^2$

$$* \ S_x = \frac{M_x}{F} = \frac{41*100}{1.0} = 4100\ cm^3$$

أكبر I.P.E فى الجداول $S_x = 3070\ cm^3$ لذلك نختار H.E.B

⇒ Choose **H.E.B 500**

4) Check Compactness

For flange Subjected to compression

$d_w = 39.0\ cm$ جداول $S_x = 4290\ cm^3$

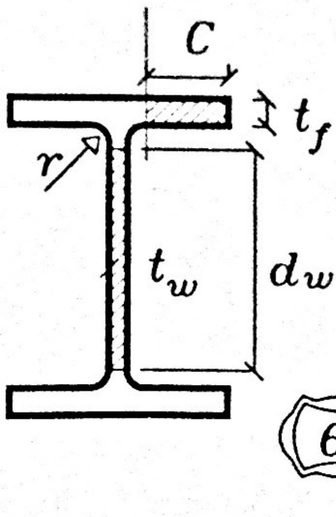
$t_w = 1.45\ cm$ $\qquad I_x = 107200\ cm^4$

$b_f = 30.0\ cm$

$t_f = 2.80\ cm$

$r = 2.7\ cm$

$A = 239\ cm^2$



$$\frac{C}{t_f} = \frac{\frac{1}{2}(b_f - t_w - 2r)}{t_f} = \frac{\frac{1}{2}(30.0 - 1.45 - 2 * 2.7)}{2.8} = 4.13$$

$$\therefore \frac{C}{t_f} = 4.13 < \frac{16.9}{\sqrt{F_y}} = 10.9 \Longrightarrow \text{Compact Flange}$$

For Web

* $d_w * t_w * F_y = 39.0 * 1.45 * 2.4 = 135.7\ t > N = 5.85\ t$

Web $\Longrightarrow$ Subjected to Bending

* $\alpha = \frac{1}{2}[\frac{N}{d_w * t_w * F_y} + 1] = \frac{1}{2}[\frac{5.85}{135.7} + 1] = 0.52 \quad > 0.5$

$$\frac{d_w}{t_w} = \frac{39.0}{1.45} = 26.8 < \frac{699/\sqrt{F_y}}{13\alpha - 1} = 78.3 \Longrightarrow \text{Compact Web}$$

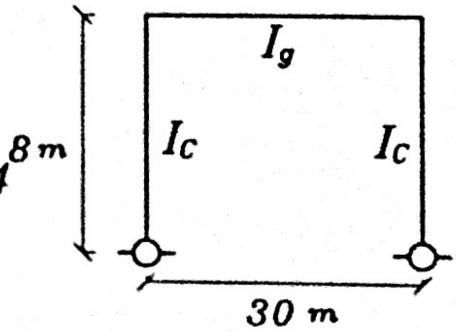
$\boxed{\therefore \text{The section is compact}}$

5) Check Compression

$l_{b\,in} \Rightarrow$ Frame $\Rightarrow G_A \& G_B$

$G_A = 10$ (Hinged base)

$$G_B = \frac{I_c / l_c}{I_g / l_g} = \frac{107200 / 8}{23130 / 30} = 17.4$$



* From charts permitted to sway

$\boxed{k = 3.8}$ $\quad l_{b\,in} = 3.8 * 8 = 30.4\ m$

$l_{b\,out} = 5.0\ m$

$r_x = 21.2 \ cm \qquad\qquad r_y = 7.27 \ cm$

* $\lambda_{\substack{in \\ x}} = \dfrac{l_{b\,in}}{r_x} = \dfrac{3040}{21.2} = 143.4 < 180$

* $\lambda_{\substack{out \\ y}} = \dfrac{l_{b\,out}}{r_y} = \dfrac{500}{7.27} = 68.8 < 180$

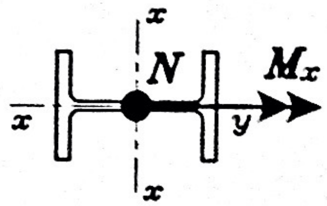
* $F_C = \dfrac{7500}{\lambda^2_{max.}} = \dfrac{7500}{143.4} = \boxed{0.360 \ t\backslash cm^2}$

* $f_{Ca} = \dfrac{N}{A} = \dfrac{5.85}{239} = \boxed{0.024 \ t\backslash cm^2}$

* $\dfrac{f_{Ca}}{F_C} = \dfrac{0.024}{0.360} = 0.06 \ > 0.15 \qquad \boxed{A_1 = 1.00}$

---

6) Check Bending

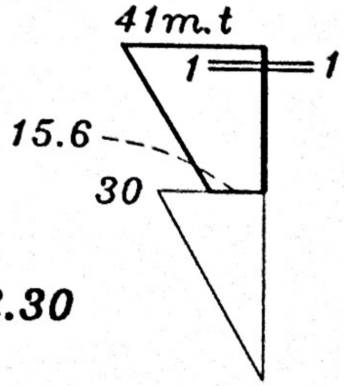


* $f_{b(act.)_x} = \dfrac{M_x}{S_x} = \dfrac{4100}{4290} = \boxed{0.955 \ t\backslash cm^2}$

* $l_{u_{act.}} = 500 \ cm$

* $l_{u\,max.} = \begin{cases} \dfrac{20 \ b_f}{\sqrt{f_y}} = \dfrac{20 * 30.0}{\sqrt{2.4}} = 387.3 \ cm \\ \dfrac{1380 A_f}{d * F_y} C_b \end{cases}$ لا نحتاج الى حسابه

$l_{u_{act.}} > l_{u\,max.} \Rightarrow$ **LTB Occurs**



* $\alpha = \dfrac{\text{Smaller moment}}{\text{Bigger moment}} = -\dfrac{15.6}{41} = -0.38$

* $C_b = 1.75 + 1.05 \ \alpha + 0.30 \ \alpha^2 = 1.39 < 2.30$

* $F_{ltb1} = \frac{800 * A_f}{l_u * d} C_b = \frac{800 * (30.0 * 2.80)}{500 * 55} * 1.39 = 3.73 \ t\backslash cm^2$
$\nless 0.58 \ F_y = 1.4$

* $F_{bcx} = F_{ltb} = \sqrt{(F_{ltb1})^2 + (F_{ltb2})^2} \nleq 0.58 \ F_y = 1.4$

$$\boxed{F_{bcx} = 1.40 \ t\backslash cm^2}$$

---

7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{bcx}} * A_1 + \cancel{\frac{f_{by\,(act.)}}{F_{bcy}}} * A_2 < 1.0$$

$$\frac{0.024}{0.360} + \frac{0.955}{1.40} * 1.0 = 0.74 < 1.2 \Rightarrow SAFE$$

Lateral shock

Section (2-2)

$N = 38 \ t$ $\qquad$ $M_{in} = 30 \ m.t$

Check Comp. الاربعة خطوات الاولى ثابتة و التغيير يكون من أول الـ

5) Check Compression

الـ λ_{in} و الـ λ_{out} و الـ Fc ثابتين و لكن الـ Normal تغير

* $F_C = \boxed{0.360 \ t\backslash cm^2}$

* $f_{Ca} = \frac{N}{A} = \frac{38}{239} = \boxed{0.159 \ t\backslash cm^2}$

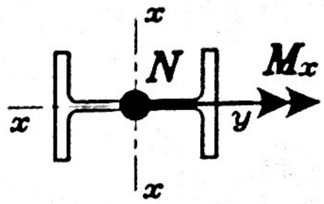
* $\frac{f_{Ca}}{F_C} = \frac{0.159}{0.360} = 0.44 > 0.15$

$$* \; F_{Ex} = \frac{7500}{\lambda_x^2} = \frac{7500}{143.4^2} = 0.36$$

Permitted to sway

$$A_1 = \frac{C_{mx}}{[1-\frac{f_{ca}}{F_{Ey}}]} = \frac{0.85}{[1-\frac{0.159}{0.36}]} = 1.52 \nless 1.0 \qquad \boxed{A_1 = 1.52}$$

6) Check Bending

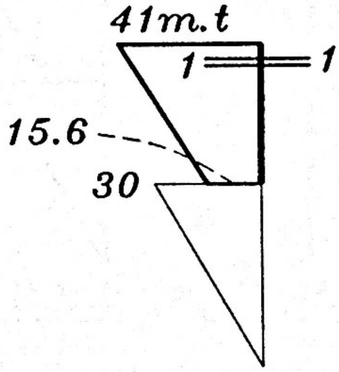


$$* \; f_{b(act.)x} = \frac{M_x}{S_x} = \frac{3000}{4290} = \boxed{0.699 \; t\backslash cm^2}$$

$$* \; l_{u\,act.} = 500 \text{ cm}$$

$$* \; l_{u\,max.} = \begin{cases} \dfrac{20\, b_f}{\sqrt{f_y}} = \dfrac{20 * 30.0}{\sqrt{2.4}} = 387.3 \text{ cm} \\ \dfrac{1380\, A_f}{d * F_y} C_b \quad \text{لا نحتاج الى حسابه} \end{cases}$$

$$l_{u\,act.} > l_{u\,max.} \Rightarrow \text{LTB Occurs}$$



$$* \; \alpha = \frac{\text{Smaller moment}}{\text{Bigger moment}} = \frac{0}{30} = 0$$

$$* \; C_b = 1.75 + 1.05\,\alpha + 0.30\,\alpha^2 = 1.75$$

$$F_{bcx} = F_{ltb} \qquad \boxed{F_{bcx} = 1.40 \; t\backslash cm^2}$$

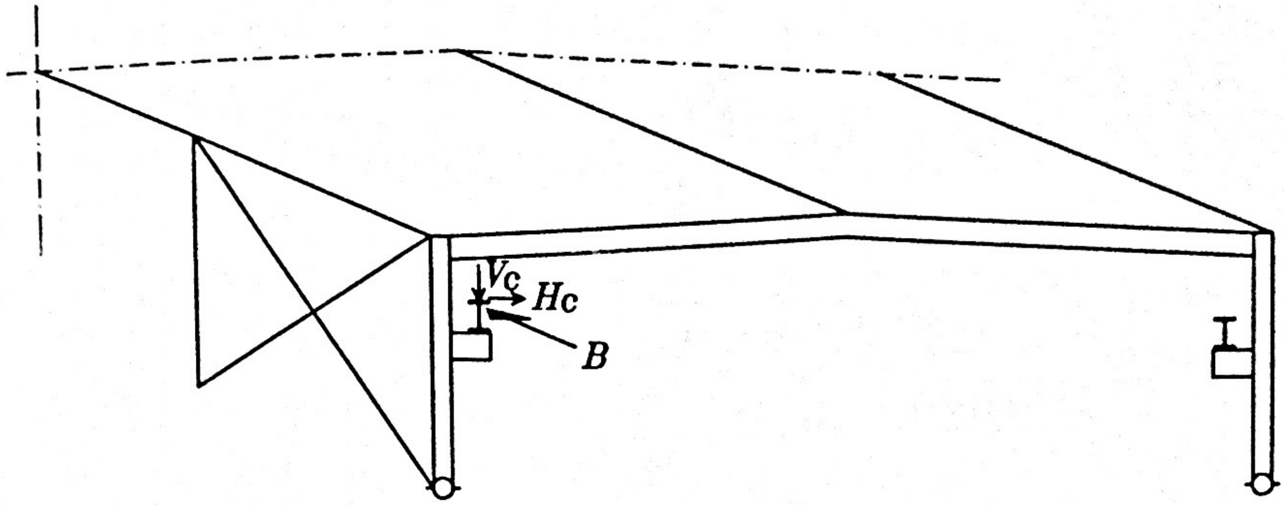
7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{bcx}} * A_1 + \cancel{\frac{f_{by\,(act.)}}{F_{bcy}}} * A_2 < 1.20$$

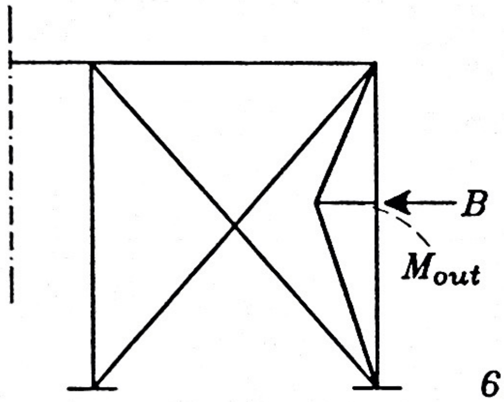
$$\frac{0.159}{0.360} + \frac{0.699}{1.40} * 1.52 = 1.2005 \simeq 1.2 \Rightarrow \text{SAFE}$$

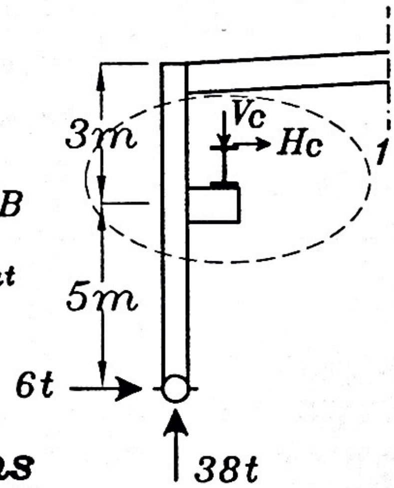
Lateral shock

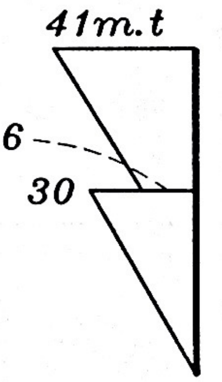
b) Without using horizontal member at the level of the crane



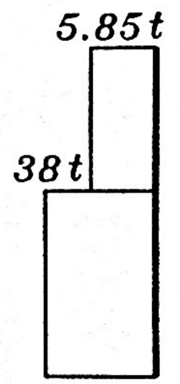
لا يوجد Horizontal member فى ال Bracing system فى نفس مستوى ال Crane girder ولذلك فان ال Braking force يتحملها العمود و بالتالى تسبب به M_{out} .







B.M.D



N.F.D.

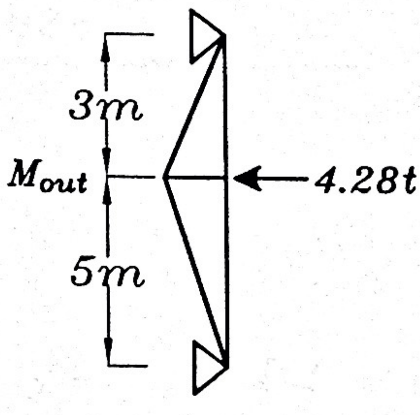
Straining actions

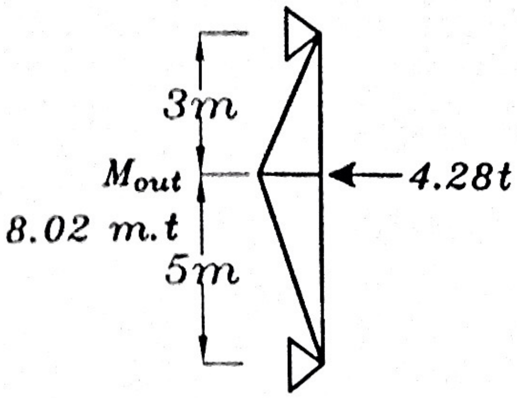
* B = Braking force $= \frac{\Sigma P}{7}$ Without Impact

$$= \frac{1}{7} * (15 + 15) = \mathbf{4.28}\ t$$

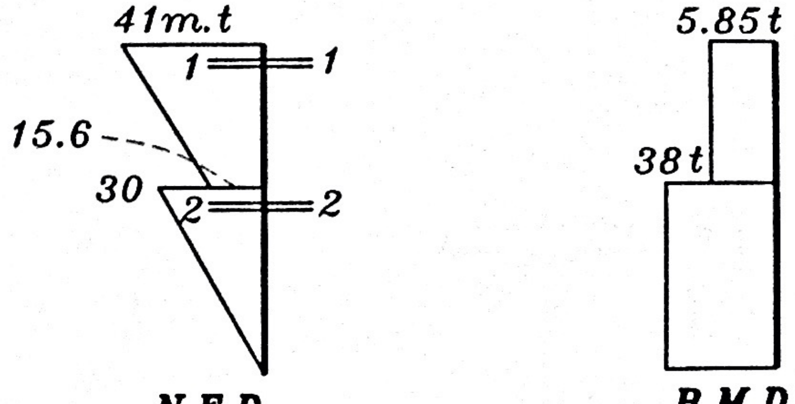
* $M_{out} = \mathbf{8.02}\ m.t$

كل الStraining actions فى ال Inplane direction مثل الحالة السابقة .





Out of plane



N.F.D. **B.M.D**

Inplane

Section (1–1)

$N = 5.85\ t$ $\quad M_{in} = 41\ m.t$ $\quad M_{out} = 0\ m.t$

Section (2–2)

$N = 38\ t$ $\quad M_{in} = 30\ m.t$ $\quad M_{out} = 8.02\ m.t$

نصمم Section (2) لانه عليه ال Double moment

ثم نعمل Check على Section (1)

Section (2–2)

1) Suggest suitable bracing system

لا نحتاج لانه معطى فى المسألة.

2) Calculate the straining actions

$N = 38\ t$ $\quad M_{in} = 30\ m.t$ $\quad M_{out} = 8.02\ m.t$

3) Choice of section

* Assume (allowable stress) $f = 0.50\ t \backslash cm^2$

* $$S_x = \frac{M_x}{f} = \frac{30*100}{0.50} = 6000\ cm^3$$

أكبر I.P.E فى الجداول $S_x = 3070\ cm^3$ لذلك نختار H.E.B

$\Rightarrow$ Choose **H.E.B 650**

4) Check Compactness

For flange Subjected to compression

$d_w = 53.4\ cm$ جداول $S_x = 6480\ cm^3$

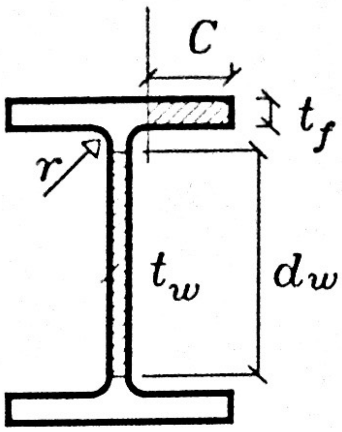
$t_w = 1.55\ cm$ $I_x = 210600\ cm^4$

$b_f = 30.0\ cm$ $S_y = 932\ cm^3$

$t_f = 3.0\ cm$ $I_y = 13980\ cm^4$

$r = 2.7\ cm$

$A = 286\ cm^2$



$$\frac{C}{t_f} = \frac{\frac{1}{2}(b_f - t_w - 2r)}{t_f} = \frac{\frac{1}{2}(30.0 - 1.55 - 2 * 2.7)}{3.0} = 3.84$$

$$\therefore \frac{C}{t_f} = 3.84 < \frac{16.9}{\sqrt{f_y}} = 10.9 \Longrightarrow \text{Compact Flange}$$

For Web

$$* \quad d_w * t_w * F_y = 53.4 * 1.55 * 2.4 = 198.6\ t > N = 38.0\ t$$

Web $\Longrightarrow$ Subjected to Bending

$$* \alpha = \frac{1}{2}\left[\frac{N}{d_w * t_w * F_y} + 1\right] = \frac{1}{2}\left[\frac{38.0}{198.6} + 1\right] = 0.59 > 0.5$$

$$\frac{dw}{t_w} = \frac{53.4}{1.55} = 34.4 < \frac{699/\sqrt{f_y}}{13\alpha - 1} = 67.7 \Longrightarrow \text{Compact Web}$$

$\boxed{\therefore \text{The section is compact}}$

5) Check Compression

$l_{b\,in} = 3.8 * 8 = 30.4\ m$ مثل الحالة السابقة تماما

$l_{b\,out} = 8.0\ m$

$$r_x = 27.1\ cm \qquad\qquad r_y = 6.99\ cm$$

$$* \ \lambda_{\substack{in \\ x}} = \frac{l_{b\,in}}{r_x} = \frac{3040}{27.1} = \mathbf{112.2} < 180$$

$$* \ \lambda_{\substack{out \\ y}} = \frac{l_{b\,out}}{r_y} = \frac{800}{6.99} = \mathbf{114} < 180$$

$$* \ F_C = \frac{7500}{\lambda^2_{max.}} = \frac{7500}{114} = \boxed{0.57 \ t\backslash cm^2}$$

$$* \ f_{Ca} = \frac{N}{A} = \frac{38.0}{286} = \boxed{0.132\ t\backslash cm^2}$$

$$* \ \frac{f_{Ca}}{F_C} = \frac{0.132}{0.570} = 0.230 > 0.15 \qquad \boxed{A_1 = 1.00}$$

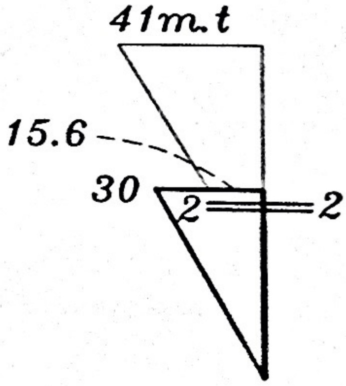
$$* \ F_{Ex} = \frac{7500}{\lambda^2_x} = \frac{7500}{112.2^2} = 0.60$$

Permitted to sway

$$A_1 = \frac{Cmx}{[1 - \frac{f_{ca}}{F_{Ey}}]} = \frac{0.85}{[1 - \frac{0.132}{0.60}]} = \mathbf{1.09} \not< 1.0 \qquad \boxed{A_1 = 1.09}$$

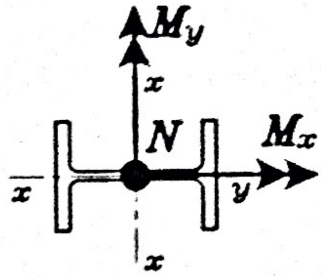
$$* \ F_{Ey} = \frac{7500}{\lambda^2_y} = \frac{7500}{114.0^2} = 0.58$$

$$* \ Cmy = 1.0 \Longrightarrow$$ Prevented from sway with lateral loads (braking force)



$$A_2 = \frac{Cmy}{[1 - \frac{f_{ca}}{F_{Ey}}]} = \frac{1.0}{[1 - \frac{0.132}{0.58}]} = \mathbf{1.30} \not< 1.0 \qquad \boxed{A_2 = 1.30}$$

6) Check Bending



* $f_{b(act.)_x} = \dfrac{M_x}{S_x} = \dfrac{3000}{6480} = \boxed{0.460\ t\backslash cm^2}$

* $f_{b(act.)_y} = \dfrac{M_y}{S_y} = \dfrac{802}{932} = \boxed{0.80\ \ t\backslash cm^2}$

* $l_{u_{act.}} = 800\ cm$

* $l_{u\ max.} = \begin{cases} \dfrac{20\ b_f}{\sqrt{f_y}} = \dfrac{20 * 30.0}{\sqrt{2.4}} = 387.3\ cm \\ \dfrac{1380\,A_f}{d * F_y} C_b \end{cases}$ لا نحتاج الى حسابه

* $C_b = 1.75 + 1.05\ \alpha + 0.30\ \alpha^2$

نفرض ان ال $C_b = 1.0$ لان قيم العزوم غير ثابتة على الطول الغير ممسوك

* $F_{ltb1} = \dfrac{800 * A_f}{l_u * d} C_b = \dfrac{800 * (30.0\ \ * 3.0\ )}{800 * 65} * 1.75 = 1.39\ \ t\backslash cm^2$

$\leqslant 0.58\ F_y = 1.4$

* $F_{bcx} = F_{ltb} = \sqrt{(F_{ltb1})^2 + (F_{ltb2})^2} \leqslant 0.58\ F_y = 1.4$

$$\boxed{F_{bcx} = F_{ltb} = 1.40\ t\backslash cm^2}$$

$$\boxed{F_{bcy} = 1.40\ t\backslash cm^2}$$

7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{b_{Cx}}} * A_1 + \frac{f_{by\,(act.)}}{F_{b_{Cy}}} * A_2 < 1.2$$

$$\frac{0.132}{0.570} + \frac{0.460}{1.40} * 1.09 + \frac{0.840}{1.40} * 1.30$$

$$= 1.37 > 1.2 \Rightarrow \text{UNSAFE}$$

Lateral shock

$\Rightarrow$ **TRY HEB 700**

ثم نقوم بعمل Check على Section (1−1)

Section (1−1)

$N = 5.85\ t$ $\qquad M_{in} = 41\ m.t$ $\qquad M_{out} = 0\ \ m.t$

$l_{b\,in} = 3.8 * 8 = 30.4\ m$

$l_{b\,out} = 8.0\ m$

$l_{U_{act}} = 8.0\ m$