Steel ثالثة
R /٢

12

Beam-Column
(C)
Combined Sections

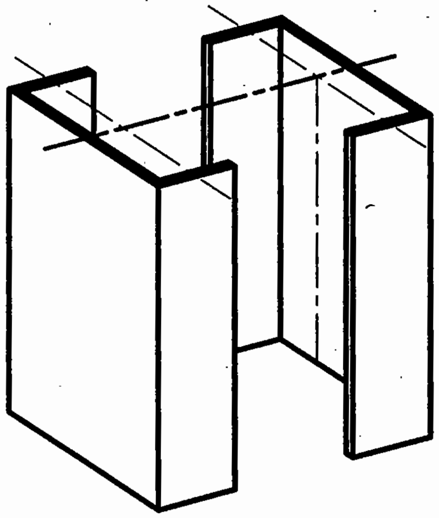
Combined Columns

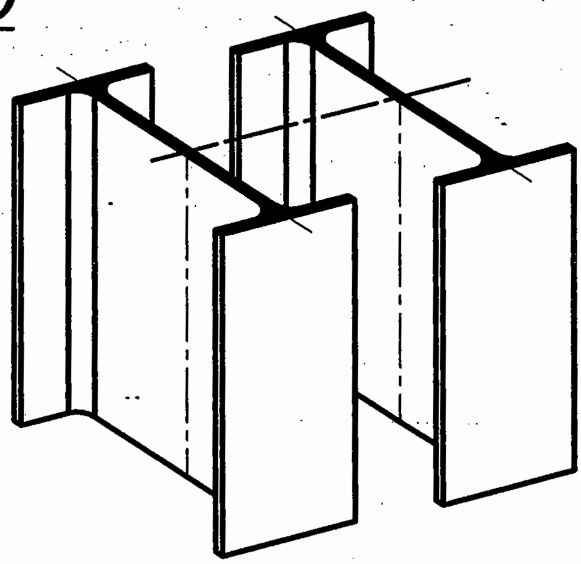
فى حالة الاحمال ذات القيم الكبيرة على الاعمدة أو فى حالة ما اذا كان الـ *Buckling Length* كبير فان الـ *Rolled sections* مثل الـ *I.P.E* و الـ *H.E.B* لا تستطيع تحمل هذا بمفردها و بالتالى نلجأ الى ما يسمى بالـ *Combined Columns* و هى استخدام قطاعين أو أكثر معا لتكوين قطاع نهائى قوى يستطيع تحمل القيم العالية للاحمال .

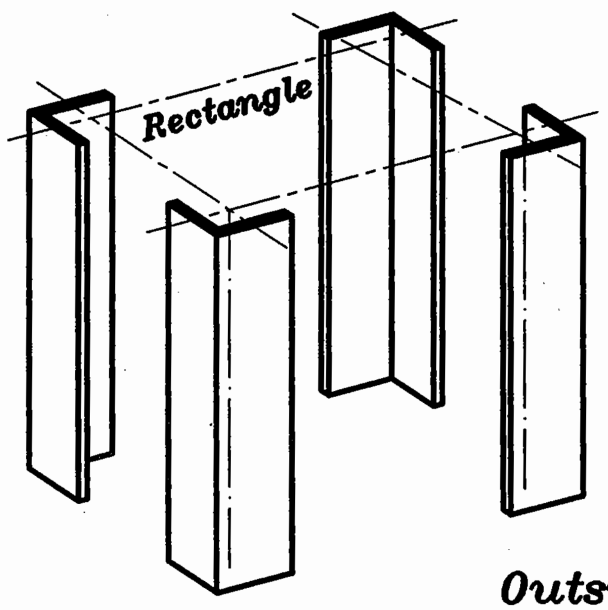
و من الممكن أن تكون قطاعات الـ *Combined Columns* كالتالى

1) Built-up sections

Combined of 2-Channels or 2-I-Sections or 4-angles (rectangular)







و تستخدم هذه القطاعات فى حالة ما اذا كانت قيم الـ N & $M_{Inplane}$ كبيرة .

و أيضا فى حالة ما اذا كان

$L_{b_{out}}$ is large $> 7 \Rightarrow 8m$

و أيضا فى حالة وجود $M_{Outside}$ بشرط الا تكون قيمته كبيرة

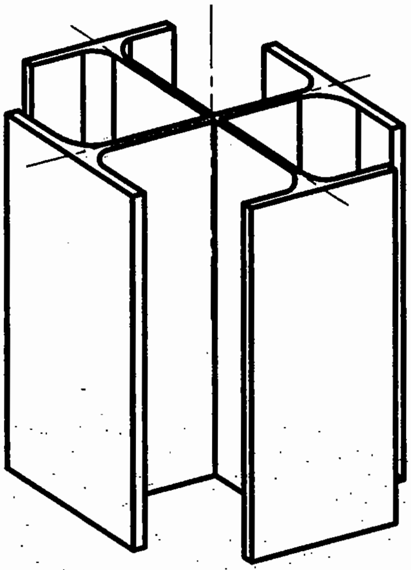
$$M_{Outside} < M_{Inplane}$$

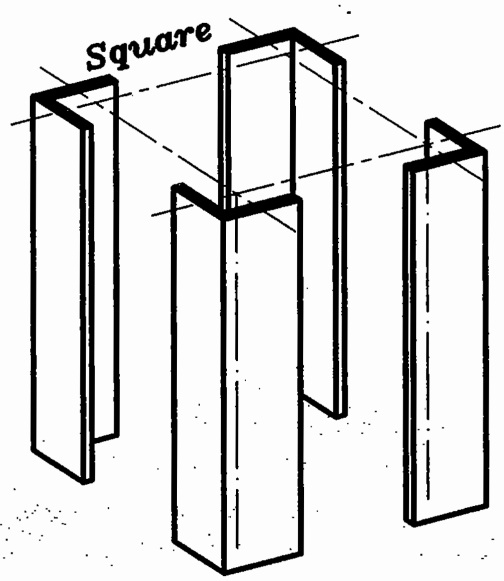
و ذلك لان *Inertia* هذا النوع من القطاعات كبيرة فى الـ *Inplane* و ضعيفة *Outside plane*

2) Built–up sections

Combined of <u>2–Cross I–Sections</u>

or <u>4–angles (Square)</u>





و تستخدم هذه القطاعات فى حالة وجود $M_{Inplane}$ & $M_{Outside}$

و تتستطيع تحمل قيم عالية للـ $M_{Outside}$

$\boxed{M_{Outside} \simeq M_{Inplane}}$

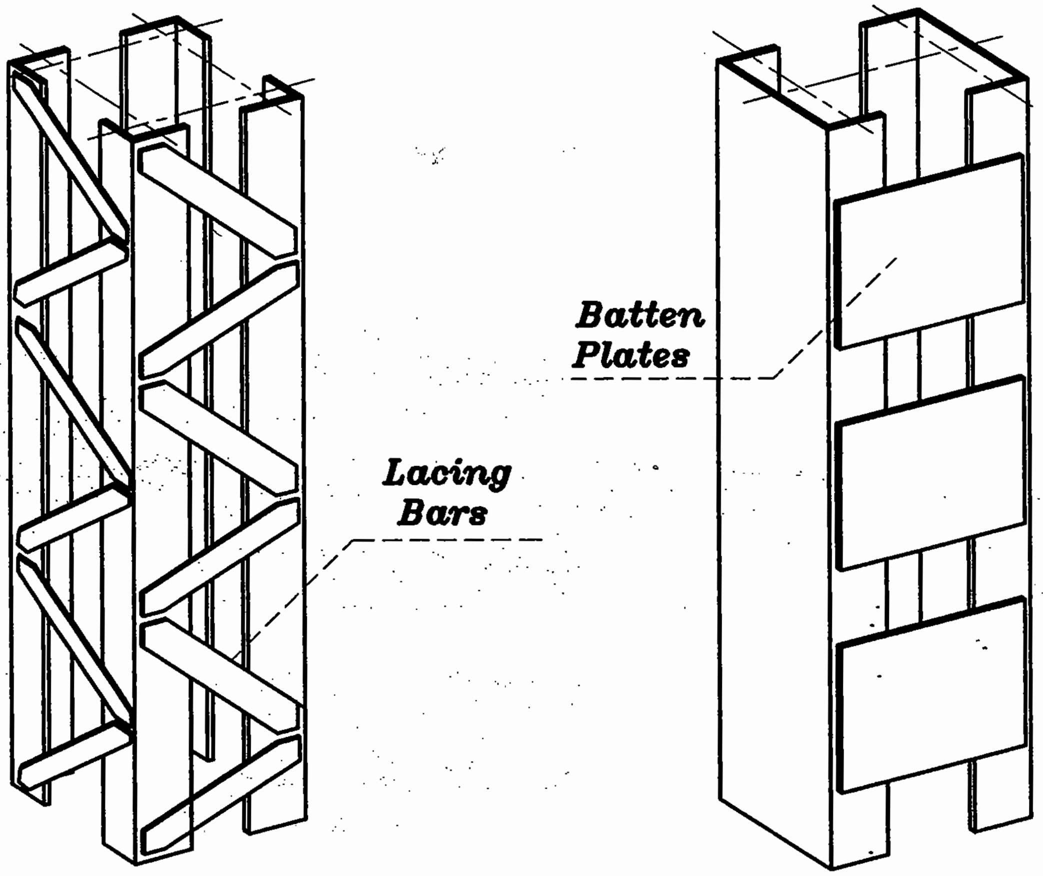
و ذلك لان *Inertia* هذا النوع من القطاعات

كبيرة فى الـ *Inplane* و كبيرة أيضا *Outside plane*

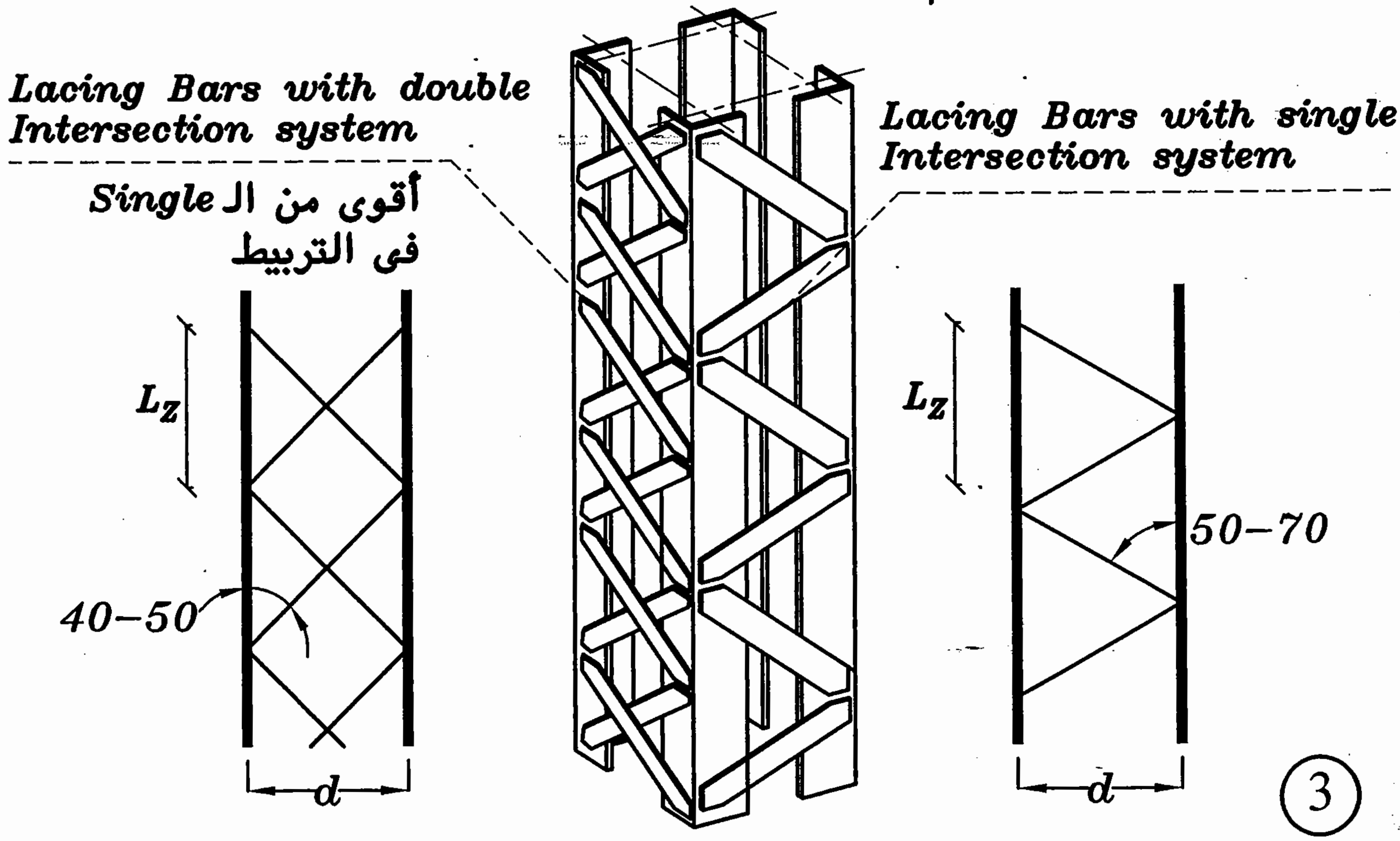
و أيضا فى حالة ما اذا كان

$L_{b_{out}}$ *is very large* >>> $7 \Rightarrow 8\,m$

و حتى نضمن أن يعمل القطاع المكون من مجموعة عناصر كأنه *One Unit*
نقوم بتربيط هذه العناصر معا باستخدام مجموعة من ال *Plates* تسمى
بال *Lacing Bars* أو بال *Batten Plates* و سيتم تصميمها فيما بعد



و من الممكن عند استخدام ال *Lacing Bars* أن تكون أحد النوعين القادمين



DESIGN Of Columns

1) Suggest suitable bracing system

2) Calculate the straining actions $N \;\; M_x \; M_y$

3) Choice of section

4) Check class of section COPMACTNESS

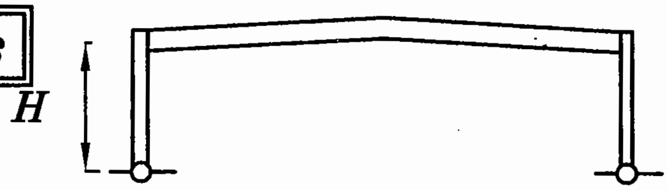
5) Check for compression

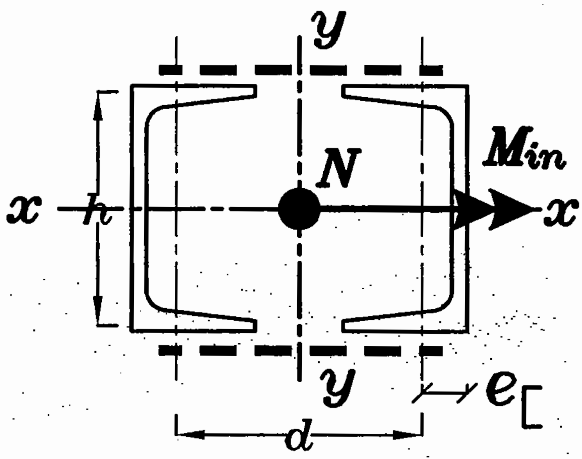
6) Check for bending

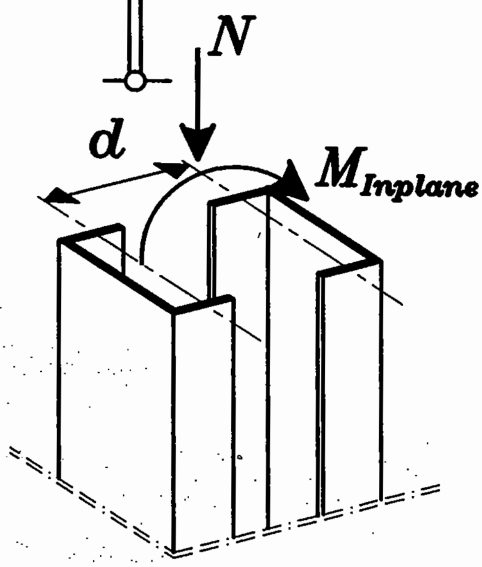
7) Check the interaction equation

Design of Built-up sections
(Combined Sections)

1) 2-Channels







3) Choice of section

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

حيث أن الـ H هى ارتفاع العمود

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

* Assume (allowable stress) $f = 1.00 \Rightarrow 1.30\ t \backslash cm^2$

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

و نقوم باختيار $Channel\ (UPN)$ من الجداول

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

و من الممكن تغيير المسافة (d) حتى يتحقق هذا الشرط.

In Case of $M_{Outside}$ & $M_{Inplane}$ & N

نعمل ال Choice of section على أساس ال N & $M_{Inplane}$ فقط و لكن نفرض ال (allowable stress) أقل لنحصل على قطاع ذو Area أكبر يستطيع تحمل ال N & $M_{Inplane}$ & $M_{Outside}$.

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

* Assume (allowable stress) $f = 0.50 \Rightarrow 0.70\ t\backslash cm^2$

$$f = \frac{Force\ (C)}{A_{One[}} \Longrightarrow A_{One[} = \frac{Force\ (C)}{f} = \checkmark\ cm^2$$

و بعد عمل ال Choice of section نقوم بحساب ال Properties of area للقطاع المُختار .

Properties of Area :

* $A_{[\,]} = 2\,A_{[}\quad cm^2$ * $I_{X[\,]} = 2\,I_{X[}\quad cm^4$

* $I_{Y[\,]} = 2\,[I_{Y[} + A_{[}\,(\frac{d}{2})^2]\quad cm^4$

$$r_{x[\,]} = \sqrt{\frac{I_{x[\,]}}{A_{[\,]}}} = \boxed{r_{x[}}\ cm \Longrightarrow From\ tables$$

$$r_{y[\,]} = \sqrt{\frac{I_{y[\,]}}{A_{[\,]}}} \simeq \boxed{(\frac{d}{2})}\ cm$$

فى حالة ال Channels فقط

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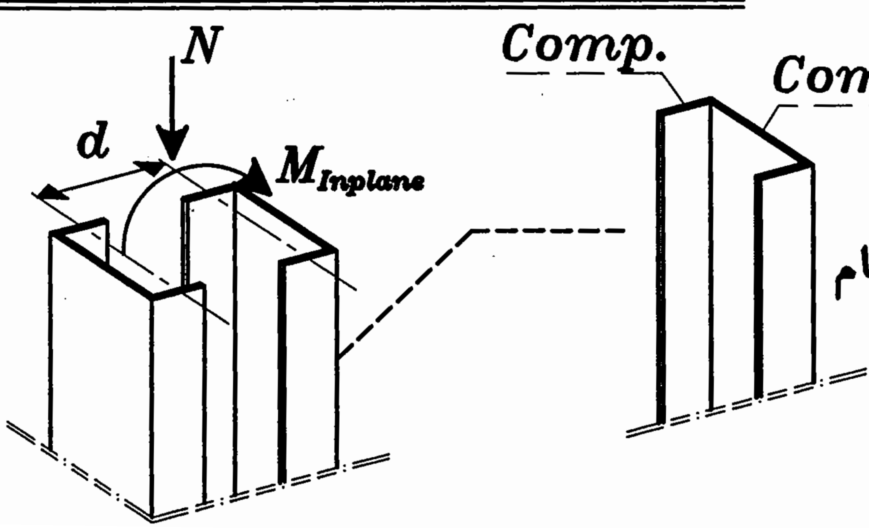
4) Check Class of section

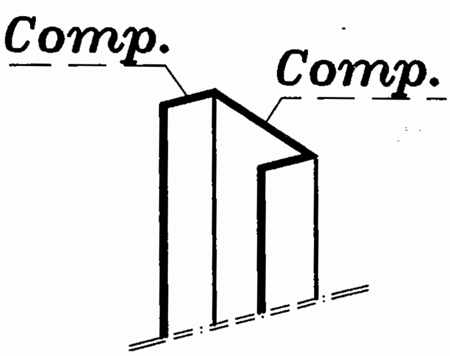


نتيجة لل N&M المؤثران على القطاع نجد أن الـChannel كلها معرضة لـ Compression و بالتالى للتأكد من أنها Non-Compact نقارن بالارقام التالية

القطاع غير متماثل حول محورين و بالتالى نعمل Check مباشرة أنه Non–Compact

* $\frac{C}{t_f} < \frac{23}{\sqrt{f_y}}$ ⟹ Flange subjected to comp. (Code page 11)

* $\frac{d_w}{t_w} < \frac{64}{\sqrt{f_y}}$ ⟹ Web subjected to comp. (Code page 9)



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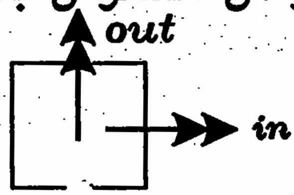
5) Check Compression

نقوم أولا بايجاد ال Buckling length

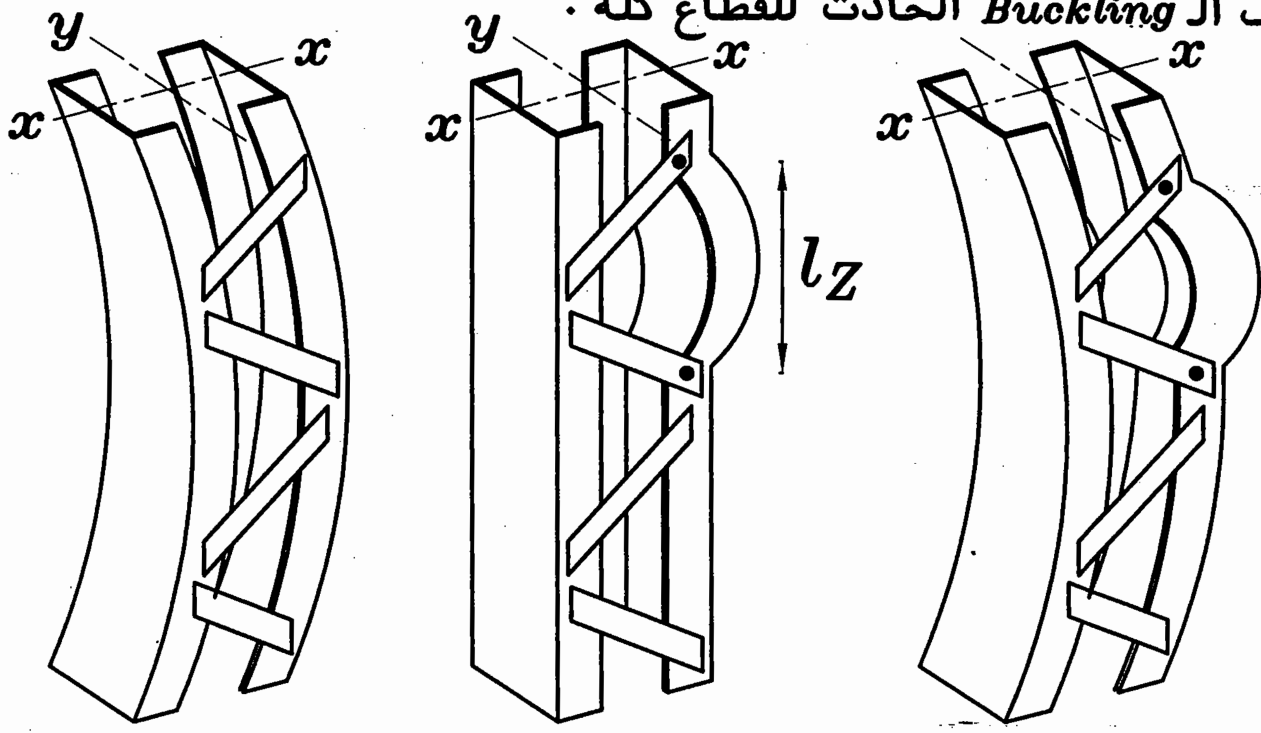
$l_{b\,in} = \checkmark\ cm$ $\qquad\qquad$ $l_{b\,out} = \checkmark\ cm$

و من المفترض بعد ذلك حساب ال λ_{out} & λ_{in} كالتالى

$$\lambda_{in} = \frac{l_{b\,in}}{r_{y\,\square}} \qquad \lambda_{out} = \frac{l_{b\,out}}{r_{x\,\square}}$$



و حيث أنه يوجد جزء من ال Channel غير ممسوك و هو الجزء الفاضى بين نقط تثبيت ال Lacing bars أو ال Batten plates فان هذا يؤدى الى حدوث Buckling لهذا الجزء ويسمى ال Local Buckling بخلاف ال Buckling الحادث للقطاع كله .



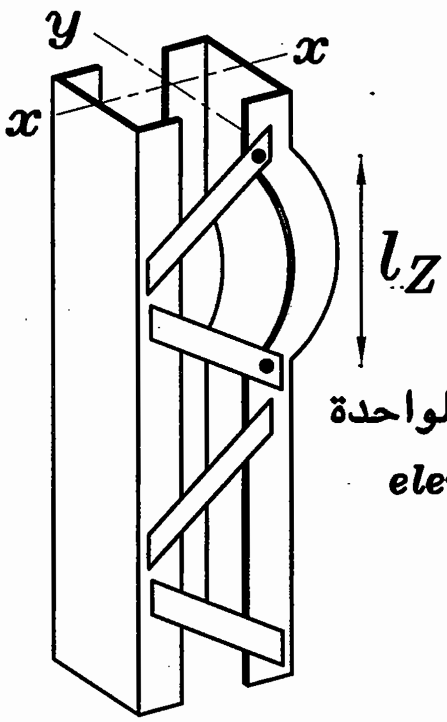
Global Buckling $\qquad$ **Local Buckling** $\qquad$ **Final Buckling**

و ال *Local Buckling* يحدث للـ *Channel* الواحدة حول المحور الضعيف لها
و هذا يؤدى الى زيادة ال *Global Buckling* للعمود كله حول المحور المماثل

و من الواضح أنه فى حالة هذا القطاع نجد أن ال *Local Buckling* يحدث
حول محور (y) للـ *Channel* و هو المحور الاضعف و يزيد من ال *Buckling*
حول نفس المحور و هو الـ *Inplane* و لا يؤثر على الـ *Buckling* فى الاتجاه
الاخر و بالتالى فان ال *Inplane Buckling* المحسوب لا يعتبر نهائى و لذلك
نسميه $\bar{\lambda}_{in}$ بينما ال *Out of plane Buckling* يعتبر نهائى فنسميه λ_{out}

$$\bar{\lambda}_{in} = \frac{l_{b\,in}}{r_{y_{[]}}} \qquad \lambda_{out} = \frac{l_{b\,out}}{r_{x_{[]}}} \not> 180$$

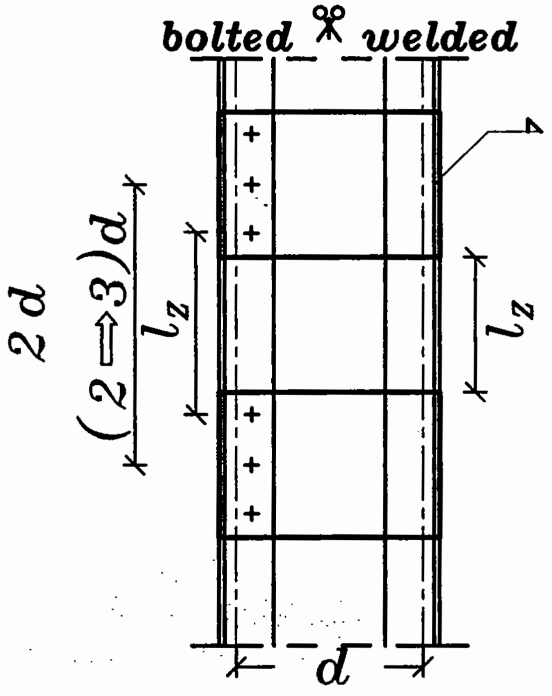
Local Buckling



$$\lambda_Z = \frac{l_Z}{r_Z} \not> 60$$

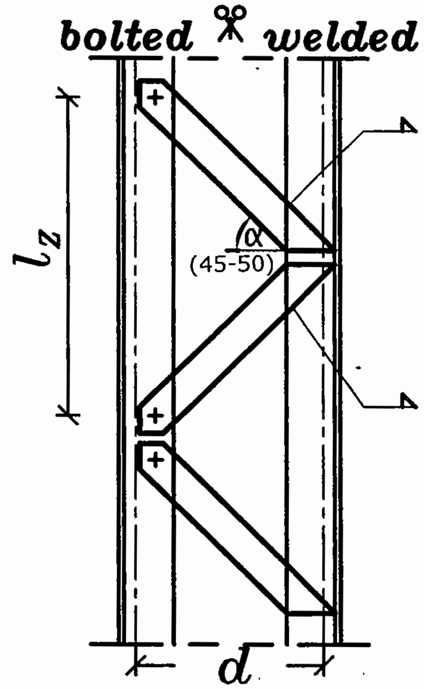
$$\not> \frac{2}{3}\lambda_{max.}\begin{cases}\lambda_{out} \\ \lambda_{in}\end{cases}$$

حيث ال l_Z هو الطول الغير ممسوك من الـ*Channel*الواحدة
و ال r_Z هو الـ *min. radius of gyration* لـ *element*
و احد من الـ *elements* المكونة للعمود .
و فى حالة ال *Channel* تكون ال $r_Z = r_{y_{[}}$
و هى موجودة فى الجداول .



Batten plates

$l_Z \simeq 80 \Rightarrow 100$ cm



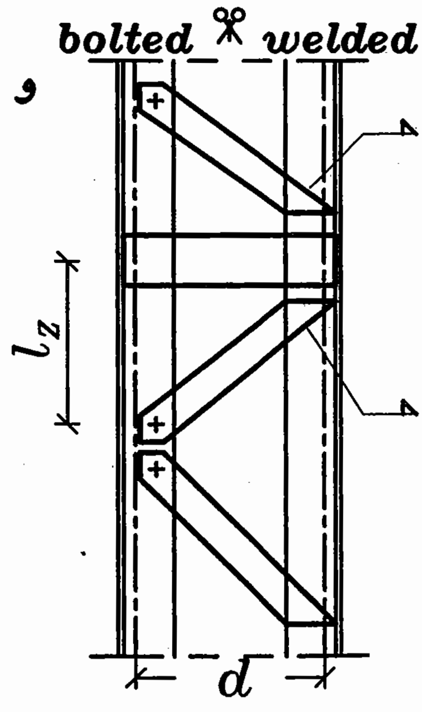
lacing bars

$\alpha \simeq 45^\circ$

$l_Z \simeq 2\,d$

و فى حالة λ_Z كانت *Unsafe* فنحتاج الى تقليل الـ l_Z و ذلك بتقليل المسافة الـ*Batten Plates* فى حالة استخدامها أو اضافة *Horizontal member* فى حالة استخدام الـ *Lacing Bars*

و فى هذه الحالة يكون $l_Z \simeq d$



lacing bars

و بالتالى فى النهاية نحسب ال λ_{in} من المعادلة التالية

$$\boxed{\lambda_{in} = \sqrt{\bar{\lambda}_{in}^{2} + (k\lambda_{Z})^{2}} \not> 180}$$

Where

* $k = 1.00 \Rightarrow$ For lacing bars

  $1.25 \Rightarrow$ For Batten plates

* $\bar{\lambda}_{in} = \dfrac{l_{b\,in}}{r_{y\,[]}}$ * $\lambda_{Z} = \dfrac{l_Z}{r_Z} \not> 60$

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

و تكون ال λ_{out} كما حسبناها سابقا

$$\boxed{\lambda_{out} = \frac{l_{b\,out}}{r_{x\,[]}} \not> 180}$$

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

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

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

* $f_{Ca} = \dfrac{N}{A}$

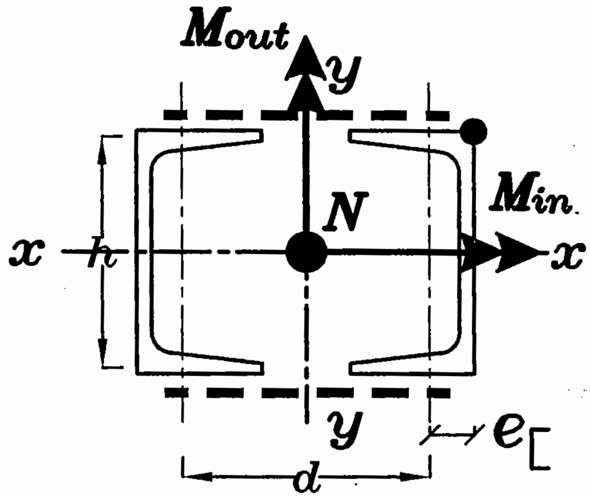
For A_1 & A_2

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

6) Check Bending

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

$$f_{b(act.)_{out}} = \frac{M_{out}}{I_X}\left(\frac{h}{2}\right) = f_{bx}$$



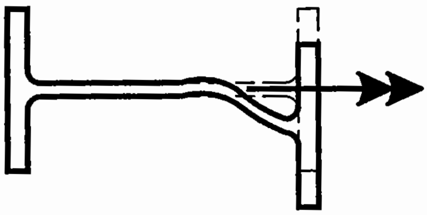
$F_{bcx} = F_{bcy} = \underline{0.58\, F_y}$ No LTB

لان الـ Channel تكون Non-Compact

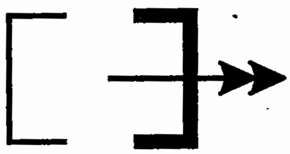
فى كل أنواع الـ Combined cloumns لا يوجد LTB نظرا لان القطاع كله معرض لـCompression و ليس جزء منه بالاضافة الى كبره

7) Check the interaction equation

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



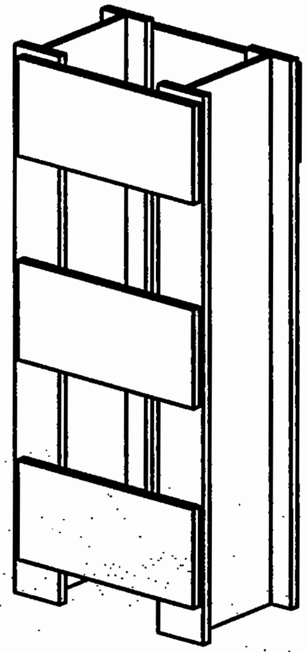
NO LTB

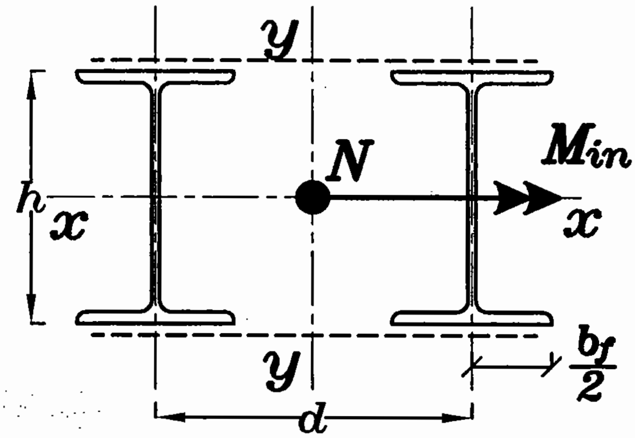


الـ Flange و جزء من الـ Web
فقط هما المعرضان لـ Compression
و بالتالى يحدث LTB لهما

الـ Channel كلها معرضة
لـ Compression و ليس
جزء منها

2) 2–I–Sections





نفس طريقة ال *Design* مع بعض الاختلافات البسيطة
و هى كالتالى

3) Choice of section

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

حيث أن ال H هى ارتفاع العمود

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

* *Assume (allowable stress)* $f = 1.00 \Rightarrow 1.30\ t\backslash cm^2$

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

و نقوم باختيار *(I.P.E)* or *(H.E.B)* من الجداول

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

و من الممكن تغيير المسافة *(d)* حتى يتحقق هذا الشرط.

4) Check Class of section

Flange subjected to comp. (Code page 11)

* $\frac{C}{t_f} < \frac{16.9}{\sqrt{f_y}} \Longrightarrow$ Compact

* $\frac{16.9}{\sqrt{f_y}} < \frac{C}{t_f} < \frac{23}{\sqrt{f_y}} \Longrightarrow$ Non-Compact

Web subjected to comp. (Code page 9)

* $\frac{d_w}{t_w} < \frac{58}{\sqrt{f_y}} \Longrightarrow$ Compact

* $\frac{58}{\sqrt{f_y}} < \frac{d_w}{t_w} < \frac{64}{\sqrt{f_y}} \Longrightarrow$ Non-Compact

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5) Check Compression

$$\boxed{\lambda_{in} = \sqrt{\bar{\lambda}_{in}^{2} + (k\,\lambda_Z)^2} \ngtr 180} \qquad \boxed{\lambda_{out} = \frac{l_{b\,out}}{r_{x_I}} \ngtr 180}$$

Where

* $k = 1.00 \Longrightarrow$ For lacing bars

  $1.25 \Longrightarrow$ For Batten plates

$r_Z = r_{y_I}$

حول المحور الاضعف

* $\bar{\lambda}_{in} = \frac{l_{b\,in}}{r_{y_I}}$

* $\lambda_Z = \frac{l_Z}{r_Z} \ngtr 60$

  $\ngtr \frac{2}{3}\lambda_{max.} \begin{cases} \lambda_{out} \\ \lambda_{in} \end{cases}$

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

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

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

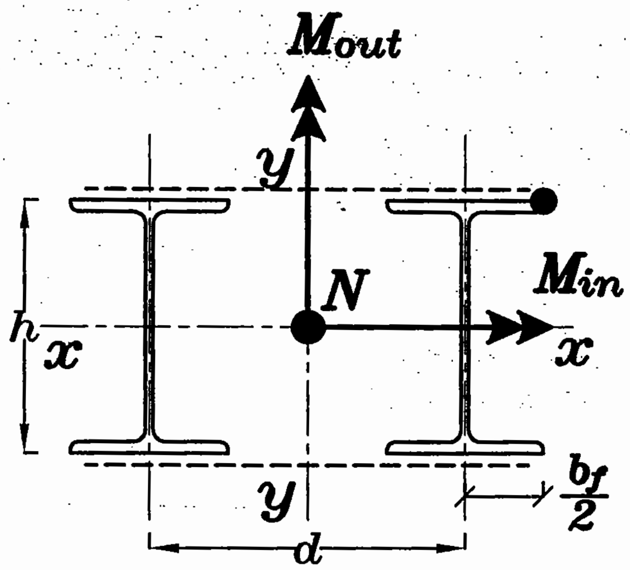
For A_1 & A_2

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

6) Check Bending

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

$$f_{b(act.)_{out}} = \frac{M_{out}}{I_X}\left(\frac{h}{2}\right) = f_{bx}$$



$F_{bcx} = 0.64 F_y$

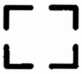
$F_{bcy} = 0.72 F_y$ No LTB

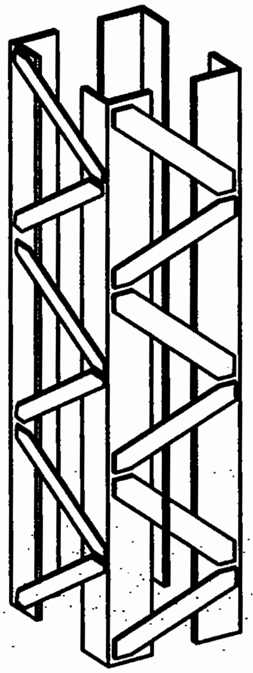
لان ال I-Section يكون Compact

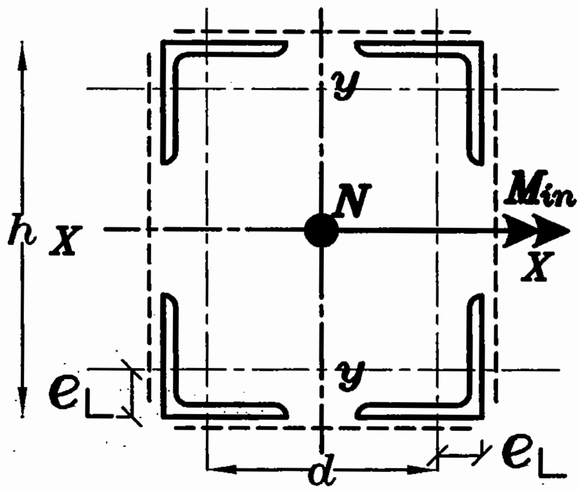
فى كل أنواع ال Combined cloumns لا يوجد LTB نظرا لان القطاع كله معرض لـCompression و ليس جزء منه بالاضافة الى كبره

7) Check the interaction equation

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

3) 4-Angles 





3) Choice of section

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

حيث أن ال H هى ارتفاع العمود

* Force on one angle $= C = \dfrac{N}{4} + \dfrac{M}{2d}$

* Assume (allowable stress) $f = 1.00 \Rightarrow 1.30\ t\backslash cm^2$

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

و نقوم باختيار $angle$ من الجداول

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

فى حالة وجود $M_{Inplane}$ فقط و يفضل أن تكون $d \simeq h$ فى حالة وجود

$M_{Inplane}$ و $M_{Outside}$

Properties of Area :

$$* \; A_{\square} = 4\,A_{\llcorner} \quad cm^2$$

$$* \; I_{Y\,\square} = 4\left[I_{Y\llcorner} + A_{\llcorner}\left(\frac{d}{2}\right)^2\right] \quad cm^4$$

$$* \; I_{X\,\square} = 4\left[I_{X\llcorner} + A_{\llcorner}\left(\frac{h}{2} - e_{\llcorner}\right)^2\right] \quad cm^4$$

$$r_{x\,\square} = \sqrt{\frac{I_{x\,\square}}{A_{\square}}} \simeq \boxed{\frac{h}{2} - e_{\llcorner}} \quad cm$$

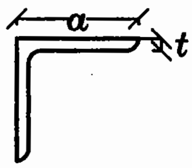
$$r_{y\,\square} = \sqrt{\frac{I_{y\,\square}}{A_{\square}}} \simeq \boxed{\left(\frac{d}{2}\right)} \quad cm$$

---

4) Check Class of section

القطاع غير متماثل حول محورين و بالتالى نعمل *Check* مباشرة أنه *Non–Compact*

$$* \; \frac{C}{t_f} = \frac{a}{t} < \frac{23}{\sqrt{f_y}} \Longrightarrow$$ *Flange subjected to comp. (Code page 11)*



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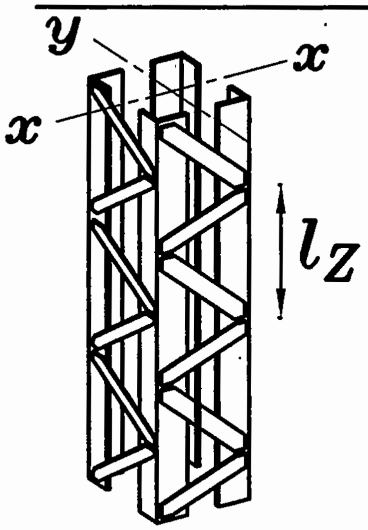
5) Check Compression

Local Buckling



$$\lambda_Z = \frac{l_Z}{r_Z} \ngtr 60$$

$$\ngtr \frac{2}{3}\lambda_{max.}\begin{cases}\lambda_{Out} \\ \lambda_{in}\end{cases}$$

حيث ال l_Z هو الطول الغير ممسوك من العمود

و ال r_Z هو ال *min. radius of gyration* ل *element*

و احد من ال *elements* المكونة للعمود .

و فى حالة ال $angles$ تكون ال $r_Z = r_{VL}$ و هى موجودة فى الجداول .
و لان ال $Local\ Buckling$ يحدث حول محور v لذلك فانه يؤثر على
ال $Global\ Buckling$ فى اتجاه ال $Inplane$ و ال $Outside\ Plane$

$$\boxed{\lambda_{in} = \sqrt{\bar{\lambda}_{in}^{2} + (k\,\lambda_Z)^2} \ngtr 180}$$

$$\boxed{\lambda_{out} = \sqrt{\bar{\lambda}_{out}^{2} + (k\,\lambda_Z)^2} \ngtr 180}$$

Where

* $k = 1.00 \Rightarrow$ For lacing bars

  $1.25 \Rightarrow$ For Batten plates

$r_Z = r_{VL}$

حول المحور الاضعف

* $\bar{\lambda}_{in} = \dfrac{l_{b\,in}}{r_{y\,[\;]}}$

* $\lambda_Z = \dfrac{l_Z}{r_Z} \ngtr 60$

  $\ngtr \dfrac{2}{3}\lambda_{max.}\begin{cases}\lambda_{Out}\\ \lambda_{in}\end{cases}$

* $\bar{\lambda}_{out} = \dfrac{l_{b\,out}}{r_{x\,[\;]}}$

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

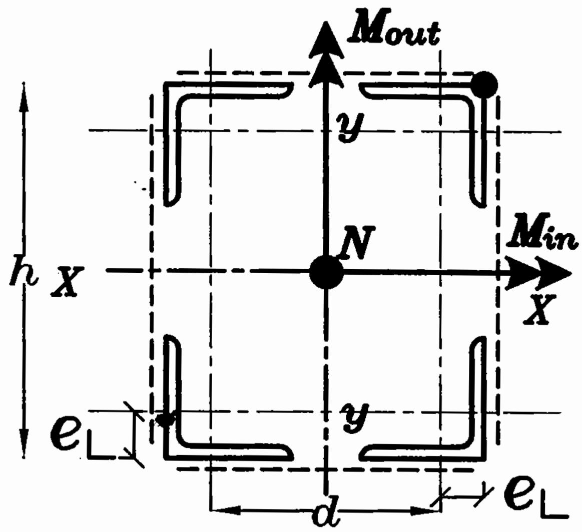
* $F_C = \begin{cases}1.4 - 6.5 * 10^{-5}\lambda^2_{max.} & St.37 \quad \lambda_{max.} \leq 100\\[2ex] \dfrac{7500}{\lambda^2_{max.}} & \lambda_{max.} > 100\end{cases}$

* $f_{Ca} = \dfrac{N}{A}$

For A_1 & A_2

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

6) Check Bending



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

$$f_{b(act.)_{out}} = \frac{M_{out}}{I_X}\left(\frac{h}{2}\right) = f_{bx}$$

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

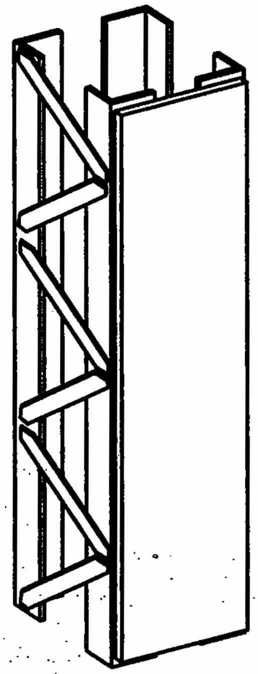
لان ال angle تكون Non-Compact

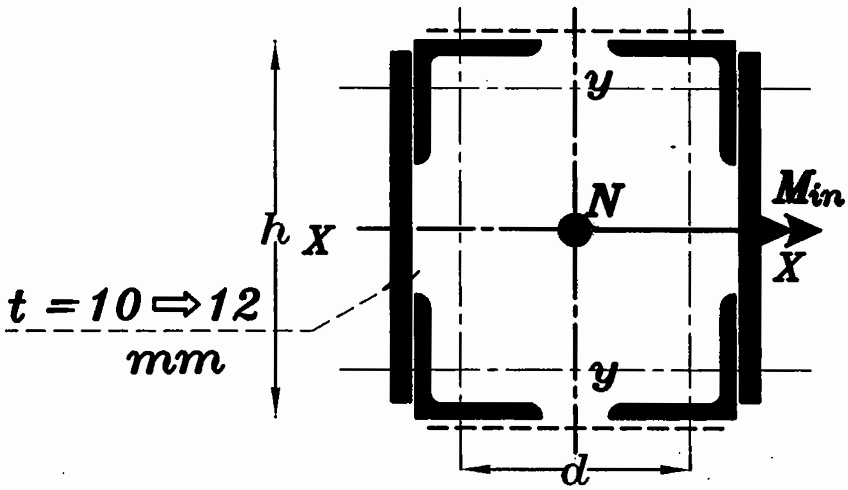
فى كل أنواع ال Combined cloumns لا يوجد LTB نظرا لان القطاع كله معرض لـCompression و ليس جزء منه بالاضافة الى كبره

7) Check the interaction equation

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

4) 4–Angles with Plate





3) Choice of section

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

حيث أن الـ H هى ارتفاع العمود

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

* Assume (allowable stress) $f = 1.00 \Rightarrow 1.30\ t\backslash cm^2$

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

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

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

فى حالة وجود $M_{Inplane}$ فقط و يفضل أن تكون $d \simeq h$ فى حالة وجود

$M_{Inplane}$ و $M_{Outside}$

و بعد فرض أبعاد الـ Plate من الممكن الحصول على مساحة الـ angle

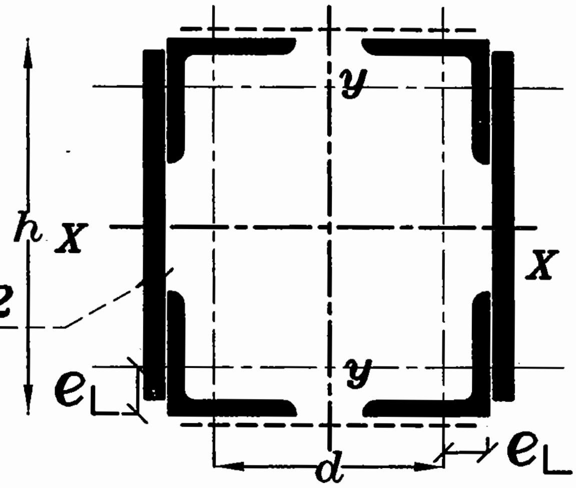
$$A_{One\ angle} = \frac{A_{One\ side} - \overbrace{A_{Plate}}^{\simeq h*t}}{2} = \checkmark\ cm^2$$

و نقوم باختيار angle من الجداول

Properties of Area :

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

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



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

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

* $r_{x[\,]} = \sqrt{\dfrac{I_{x[\,]}}{A_{[\,]}}}$

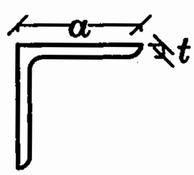
* $r_{y[\,]} = \sqrt{\dfrac{I_{y[\,]}}{A_{[\,]}}}$

---

4) Check Class of section

القطاع غير متماثل حول محورين و بالتالى نعمل Check مباشرة أنه
Non-Compact

* $\frac{C}{t_f} = \frac{a}{t} < \frac{23}{\sqrt{f_y}}$ ⇨ Flange subjected to comp. (Code page 11)



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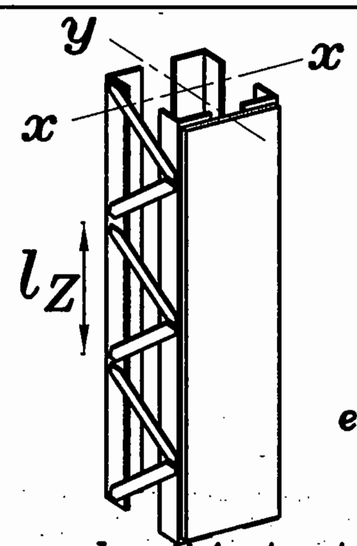
5) Check Compression

Local Buckling



$$\lambda_Z = \frac{l_Z}{r_Z} \not> 60$$

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

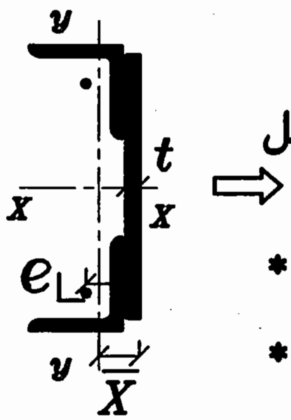
حيث ال l_Z هو الطول الغير ممسوك من العمود

و ال r_Z هو ال min. radius of gyration لل element

و احد من ال elements المكونة للعمود .

و لكن هنا لا يحدث Local Buckling لل angle على حدا و انما لل 2-angles

بال Plate الذى يربطهم كأن هذا الشكل عبارة عن Channel



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 .

* $A_{Plate} \simeq h * t$
* $A_{]} = 2A_L + A_{Plate} \quad cm^2$
* $\bar{X} = \dfrac{2A_L*(e_L+t) + A_{Plate}*\frac{t}{2}}{A_{]}} \quad cm$
* $I_{Y[\,]} = 2[I_{Y_L} + A_L(e_L + t - \bar{X})^2] + 2[\dfrac{h*t^3}{12} + A_{Plate}*(\bar{X} - \dfrac{t}{2})^2] \; cm^4$
* $r_{y[\,]} = \sqrt{\dfrac{I_{y[\,]}}{A_{[\,]}}}$

$$\boxed{\lambda_{in} = \sqrt{\bar{\lambda}_{in}^{2} + (k\,\lambda_Z)^2} \ngtr 180}$$

$$\boxed{\lambda_{out} = \frac{l_{b\,out}}{r_{x\,[\,]}} \ngtr 180}$$

Where

* $k = 1.00 \Rightarrow$ For lacing bars

$\quad\ 1.25 \Rightarrow$ For Batten plates

$r_Z = r_{y\,]}$ حول المحور الاضعف

* $\bar{\lambda}_{in} = \dfrac{l_{b\,in}}{r_{y\,[\,]}}$

* $\lambda_Z = \dfrac{l_Z}{r_Z} \ngtr 60$

$$\ngtr \frac{2}{3}\lambda_{max.} \begin{cases} \lambda_{Out} \\ \lambda_{in} \end{cases}$$

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

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

* $f_{Ca} = \dfrac{N}{A}$

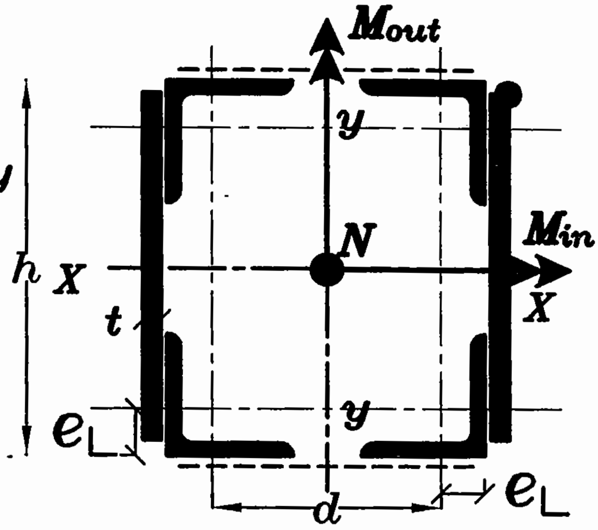
For A_1 & A_2

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

6) Check Bending

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

$$f_{b(act.)_{out}} = \frac{M_{out}}{I_X}\left(\frac{h}{2}\right) = f_{bx}$$



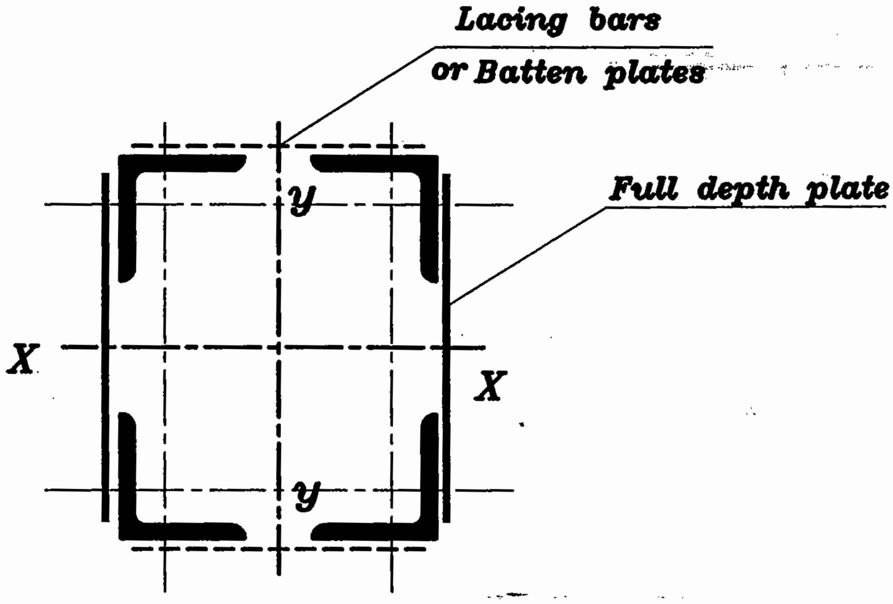
$F_{bcx} = F_{bcy} = \underline{0.58\,F_y}$ No LTB

لان ال angle تكون Non-Compact

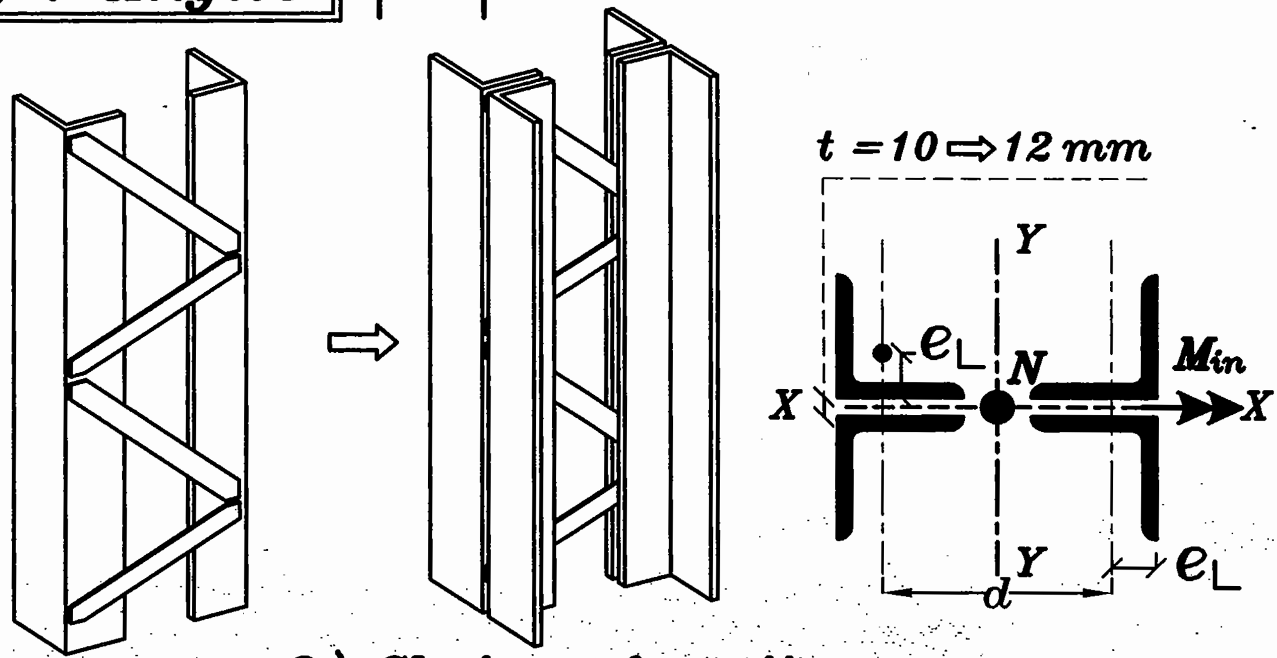
فى كل أنواع ال Combined cloumns لا يوجد LTB نظرا لان القطاع كله معرض لـCompression و ليس جزء منه بالاضافة الى كبره

7) Check the interaction equation

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



5) 4-Angles



3) Choice of section

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

حيث أن ال H هى ارتفاع العمود

* Force on one angle $= C = \dfrac{N}{4} + \dfrac{M}{2d}$

* Assume (allowable stress) $f = 1.00 \Rightarrow 1.30\ t \backslash cm^2$

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

و نقوم باختيار $angle$ من الجداول

Properties of Area :

* $A_{\vdash\dashv} = 4\, A_{\llcorner} \quad cm^2$

* $I_{Y_{\vdash\dashv}} = 4\,[\, I_{Y_{\llcorner}} + A_{\llcorner}\, (\frac{d}{2})^2 \,] \quad cm^4$

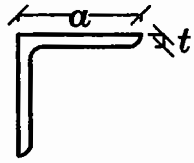
* $I_{X_{\vdash\dashv}} = 4\,[\, I_{X_{\llcorner}} + A_{\llcorner}\, (\frac{t}{2} - e_{\llcorner})^2 \,] \quad cm^4$

* $r_{x_{\vdash\dashv}} = \sqrt{\dfrac{Ix_{\vdash\dashv}}{A_{\vdash\dashv}}}$ * $r_{y_{\vdash\dashv}} = \sqrt{\dfrac{Iy_{\vdash\dashv}}{A_{\vdash\dashv}}}$

4) Check Class of section

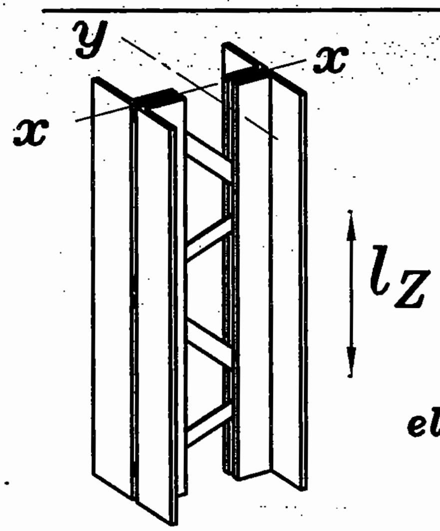
القطاع غير متماثل حول محورين و بالتالى نعمل Check مباشرة أنه
Non-Compact

$* \quad \frac{C}{t_f} = \frac{a}{t} < \frac{23}{\sqrt{f_y}}$ ⇨ Flange subjected to comp.
(Code page 11)



5) Check Compression

Local Buckling



$$\lambda_Z = \frac{l_Z}{r_Z} \not> 60$$

$$\not> \frac{2}{3} \lambda_{max.} \begin{cases} \bar{\lambda}_{out} \\ \bar{\lambda}_{in} \end{cases}$$

حيث ال l_Z هو الطول الغير ممسوك من العمود

و ال r_Z هو ال min. radius of gyration ل element

و احد من ال elements المكونة للعمود .

و فى حالة ال angles تكون ال $r_Z = r_{vL}$ و هى موجودة فى الجداول .

و لان ال Local Buckling يحدث حول محور v لذلك فانه يؤثر على

ال Global Buckling فى اتجاه ال Inplane و ال Outside Plane

$$\boxed{\lambda_{in} = \sqrt{\bar{\lambda}_{in}^2 + (k \lambda_Z)^2} \not> 180}$$

$$\boxed{\lambda_{out} = \sqrt{\bar{\lambda}_{out}^2 + (k \lambda_Z)^2} \not> 180}$$

Where

$* \, k = 1.00$ ⇨ For lacing bars

1.25 ⇨ For Batten plates

$$r_Z = r_{v\llcorner}$$

حول المحور الاضعف

$$* \ \bar{\lambda}_{in} = \frac{l_{b\,in}}{r_{y\,\vdash\dashv}} \qquad * \ \lambda_Z = \frac{l_Z}{r_Z} \ \ngtr \ 60$$

$$* \ \bar{\lambda}_{out} = \frac{l_{b\,out}}{r_{y\,\vdash\dashv}} \qquad \ngtr \ \frac{2}{3}\lambda_{max.}\begin{cases}\lambda_{out}\\ \lambda_{in}\end{cases}$$

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

$$* \ F_C = \begin{cases} 1.4 - 6.5 * 10^{-6}\lambda^2_{max.} & St.37 \quad \lambda_{max.} \leqslant 100 \\ \dfrac{7500}{\lambda^2_{max.}} & \lambda_{max.} > 100 \end{cases}$$

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

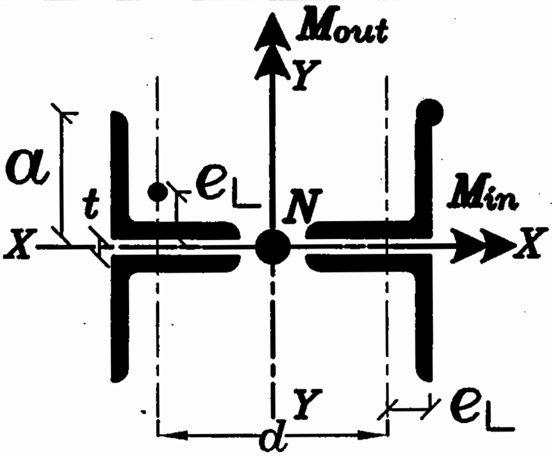
For A_1 & A_2

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

6) Check Bending

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

$$f_{b(act.)out} = \frac{M_{out}}{I_x}\left(\frac{t}{2} + a\right) = f_{bx}$$



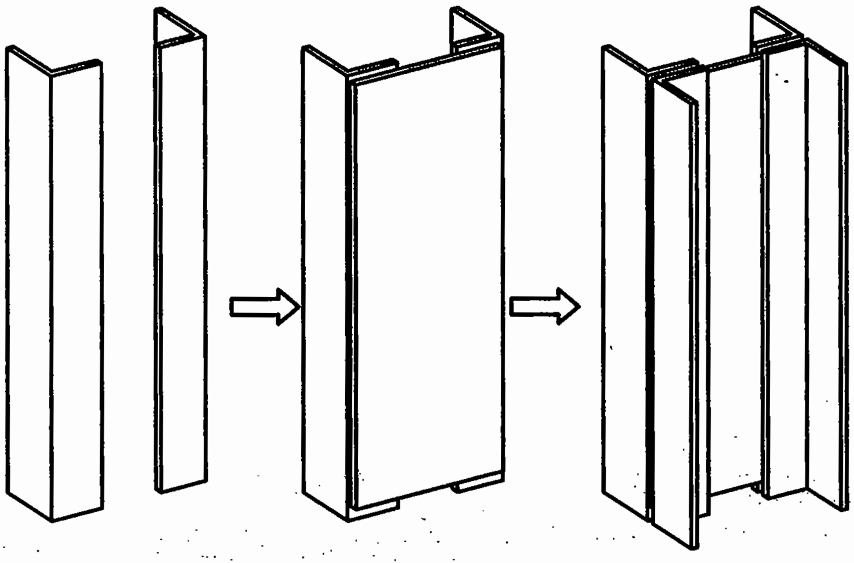
$F_{bcx} = F_{bcy} = \underline{0.58\, F_y}$ No LTB

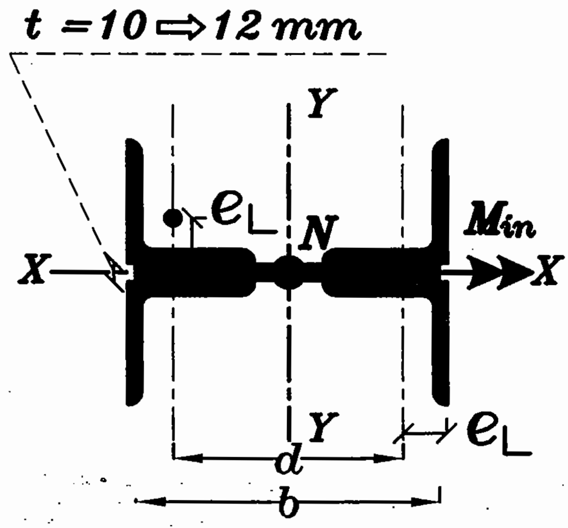
Non–Compact تكون angle لان ال

7) Check the interaction equation

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

5) 4-Angles with plate





3) Choice of section

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

حيث أن الـ H هى ارتفاع العمود

* Force on one angle $= C = \dfrac{N}{4} + \dfrac{M}{2d}$

من الممكن اهمال الـ Plate عند حساب الـForce على الـangles و لكن نزود قليلا الـ (allowable stress)

* Assume (allowable stress) $f = 1.20 \Rightarrow 1.40\ t \backslash cm^2$

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

و نقوم باختيار angle من الجداول

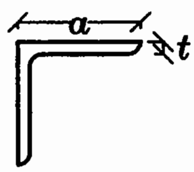
Properties of Area :

* $b = d + 2\,e_{\llcorner}$
* $A_{Plate} \simeq b * t$
* $A_{\vdash\dashv} = 4\,A_{\llcorner} + A_{Plate} \quad cm^2$
* $I_{Y_{\vdash\dashv}} = 4\,[\,I_{Y_{\llcorner}} + A_{\llcorner}\,(\frac{d}{2})^2\,] + [\,\frac{t * b^3}{12}\,] \quad cm^4$
* $I_{X_{\vdash\dashv}} = 4\,[\,I_{X_{\llcorner}} + A_{\llcorner}\,(\frac{t}{2} - e_{\llcorner})^2\,] + [\,\frac{b * t^3}{12}\,] \quad cm^4$
* $r_{x_{\vdash\dashv}} = \sqrt{\frac{I_{x\vdash\dashv}}{A_{\vdash\dashv}}}$ * $r_{y_{\vdash\dashv}} = \sqrt{\frac{I_{y\vdash\dashv}}{A_{\vdash\dashv}}}$

4) Check Class of section

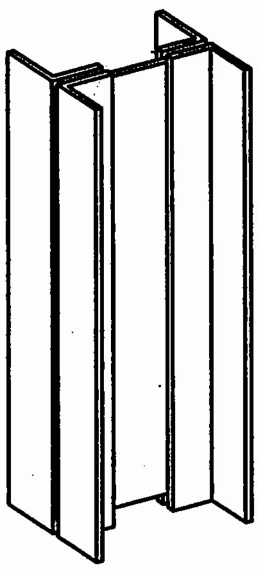
القطاع غير متماثل حول محورين و بالتالى نعمل Check مباشرة أنه
Non-Compact

* $\frac{C}{t_f} = \frac{a}{t} < \frac{23}{\sqrt{f_y}} \Longrightarrow$ Flange subjected to comp. (Code page 11)



5) Check Compression

Local Buckling



لا يوجد Local Buckling و ذلك لان الـ Plate موجود بكامل طول العمود و بالتالى لا يوجد جزء فى العمود غير ممسوك نخاف فيه من حدوث الـ Local Buckling وبالتالى الـ Global Buckling لا يزيد فى هذا النوع .

* $\lambda_{in} = \frac{l_{b\,in}}{r_{y_{\vdash\dashv}}}$

* $\lambda_{out} = \frac{l_{b\,out}}{r_{x_{\vdash\dashv}}}$

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

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

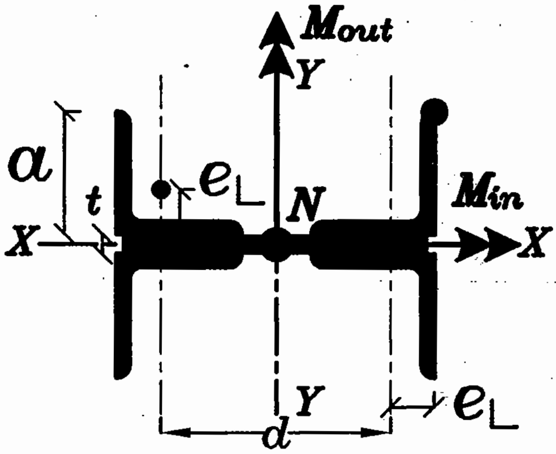
$$* f_{Ca} = \frac{N}{A}$$

For A_1 & A_2

$$* \text{ If } \frac{f_{ca}}{F_c} \leqslant 0.15 \Rightarrow A_1 = A_2 = 1$$

$$* \text{ If } \frac{f_{ca}}{F_c} > 0.15 \Rightarrow A_{1\&2} = \frac{Cm_{x,y}}{\left[1 - \frac{f_{ca}}{F_{E\,x,y}}\right]}$$

6) Check Bending



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

$$f_{b(act.)_{out}} = \frac{M_{out}}{I_X}\left(\frac{t}{2} + a\right) = f_{bx}$$

$$F_{bcx} = F_{bcy} = \underline{0.58 F_y} \qquad \text{No LTB}$$

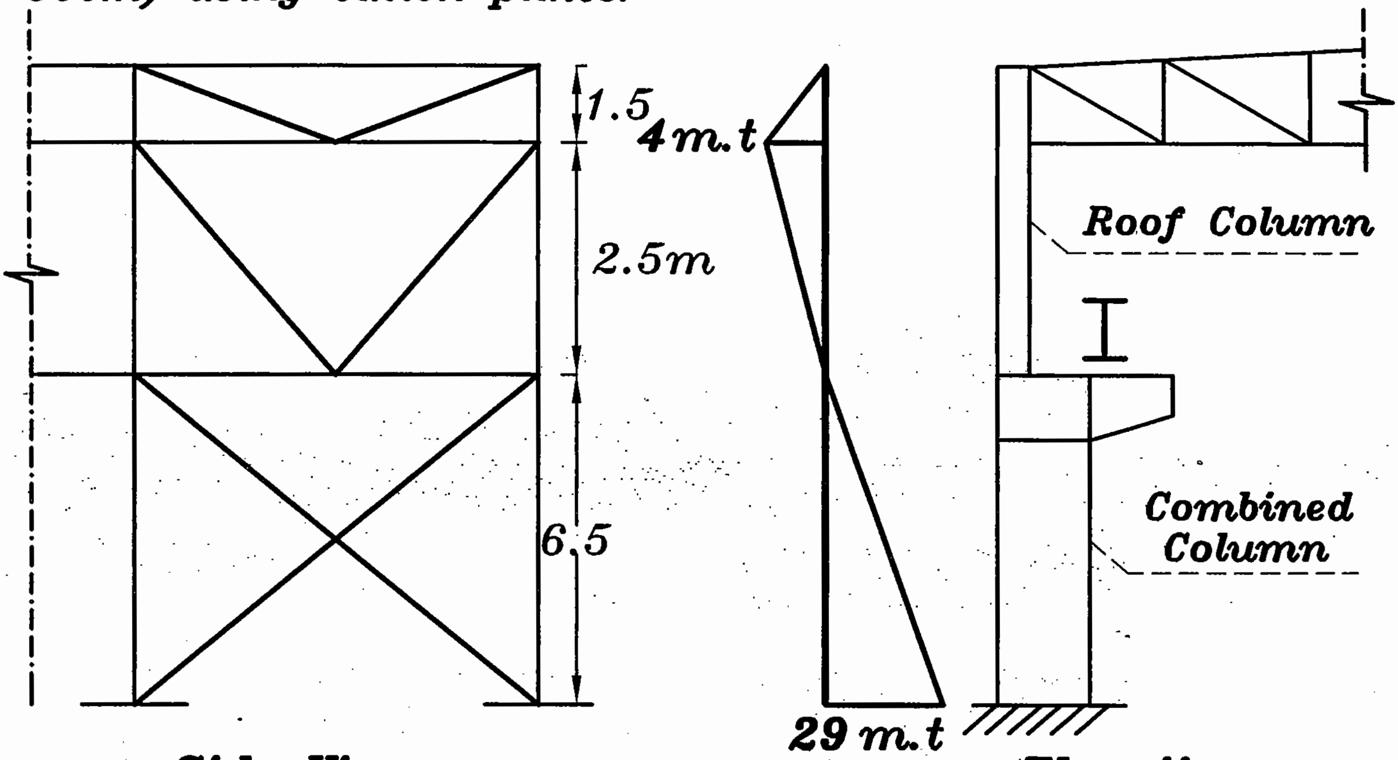
لأن ال angle تكون Non–Compact

7) Check the interaction equation

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

EXAMPLE :

Design the shown roof column (N=7.0t , M=4m.t) and design the combined column (N=25t , M=29m.t) (2 channels spaced by 50cm) using batten plates.



Side View

Elevation

Roof Column :

1) Suggest suitable bracing system

لا نحتاج لانه معطى فى المسألة.

2) Calculate the straining actions

$N = 7\ t \qquad M_x = 4\ m.t$

3) Choice of section

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

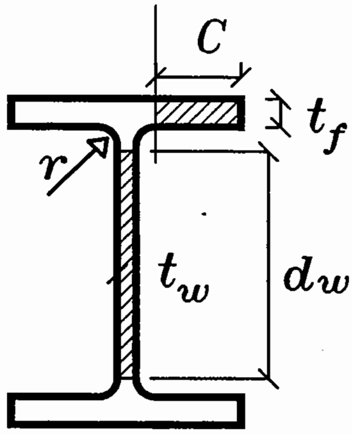
$$* \ S_x = \frac{M_x}{F} = \frac{4 * 100}{1.0} = 400\ cm^3$$

$\Rightarrow$ Choose I.P.E 270

4) Check Compactness

For flange

Subjected to compression



$d_w = 22.9\,cm$ جداول

$t_w = 0.66\,cm$

$b_f = 13.5\,cm$

$t_f = 1.02\,cm$

$r = 1.5\,cm$

$$\frac{C}{t_f} = \frac{\frac{1}{2}(b_f - t_w - 2r)}{t_f} = \frac{\frac{1}{2}(13.5 - 1.02 - 2*1.5)}{1.02} = 4.64$$

$$\therefore \frac{C}{t_f} = 4.64 < \frac{16.9}{\sqrt{f_y}} = 10.9 \Longrightarrow \text{Compact Flange}$$

For Web

$$* \quad d_w * t_w * F_y = 22.9 * 0.66 * 2.4 = 36.2\,t > N = 7\,t$$

Web $\Longrightarrow$ Subjected to Bending

$$* \, \alpha = \frac{1}{2}\left[\frac{N}{d_w * t_w * F_y} + 1\right] = \frac{1}{2}\left[\frac{7}{36.2} + 1\right] = 0.896 > 0.5$$

$$\frac{d_w}{t_w} = \frac{22.9}{0.71} = 34.7 < \frac{699/\sqrt{f_y}}{13\alpha - 1} = 66.8 \Longrightarrow \text{Compact Web}$$

$\therefore$ The section is compact

5) Check Compression

$l_{b\,in} = 1.5\ (2.5 + \frac{1.5}{2}) = 4.875\,m$ $\qquad$ $l_{b\,out} = 2.5\,m$

$r_x = 11.7\,cm$ $\qquad$ $r_y = 3.02\,cm$

$$* \lambda_{\substack{in \\ x}} = \frac{l_{b\,in}}{r_x} = \frac{487.5}{11.7} = 43.5 < 180$$

$$* \lambda_{\substack{out \\ y}} = \frac{l_{b\,out}}{r_y} = \frac{250}{3.02} = 82.7 < 180$$

$$* F_C = 1.4 - 6.5 * 10^{-5} \lambda^2_{max.}$$
$$= 1.4 - 6.5 * 10^{-5} * 82.7^2 = \boxed{0.95\ t \backslash cm^2}$$

$$* f_{Ca} = \frac{N}{A} = \frac{7}{45.9} = \boxed{0.153\ t \backslash cm^2}$$

$$* \frac{f_{Ca}}{F_C} = \frac{0.153}{0.95} = 0.16 > 0.15$$

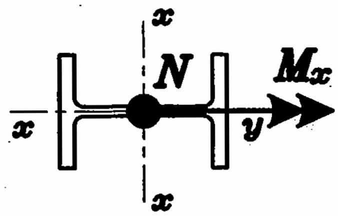
$$* F_{Ex} = \frac{7500}{\lambda_X^2} = \frac{7500}{43.5^2} = 3.96$$

Permitted to sway

$$A_1 = \frac{C_{mx}}{\left[1 - \frac{f_{ca}}{F_{Ex}}\right]} = \frac{0.85}{\left[1 - \frac{0.153}{3.96}\right]} = 0.88 \not< 1.0 \qquad \boxed{A_1 = 1}$$

---

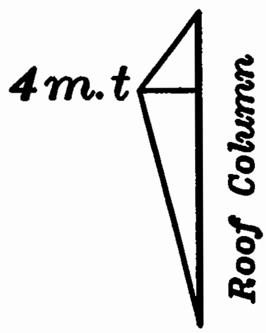
6) Check Bending



$$* f_{b(act.)_x} = \frac{M_x}{S_x} = \frac{400}{429} = \boxed{0.932\ t \backslash cm^2}$$

$$* l_{u\,act.} = 250\ cm$$

$$* l_{u\,max.} = \begin{cases} \frac{20\,b_f}{\sqrt{f_y}} = \frac{20 * 13.5}{\sqrt{2.4}} = 174.3\ cm \\ \frac{1380\,A_f}{d * F_y} C_b \quad \text{لا نحتاج الى حسابه} \end{cases}$$



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

$$* C_b = 1.75 + 1.05\,\alpha + 0.30\,\alpha^2 = 1.75 \qquad \alpha = \frac{0}{4} = 0$$

$$* \; F_{ltb1} = \frac{800 * A_f}{l_u * d} C_b = \frac{800 * (13.05 * 1.02)}{250 * 27} * 1.75 = 2.85 \quad t\backslash cm^2$$

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

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

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

7) Check Interaction equation

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

$$\frac{0.153}{0.95} + \frac{0.932}{1.40} * 1.0 = 0.83 < 1.0 \Rightarrow \text{SAFE}$$

Combined Column :

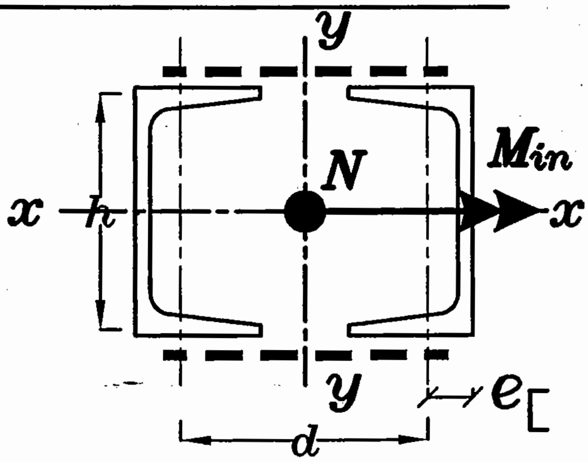
1) Suggest suitable bracing system

لا نحتاج لانه معطى فى المسألة.

2) Calculate the straining actions

$N = 25\,t \qquad M_x = 29 \; m.t$

3) Choice of section



$* \text{ Assume } \quad d = \dfrac{650}{12 \Rightarrow 15} = 50 \text{ cm}$

$*$ Force on one channel

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

$$= \frac{25}{2} + \frac{29}{0.5} = 70.5 \; t$$

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

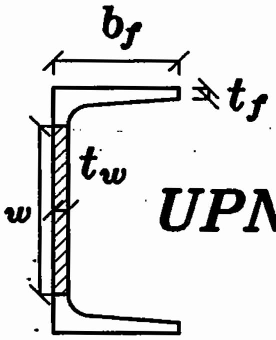
* $A_{One[} = \dfrac{Force\ (C)}{f} = \dfrac{70.5}{1.2} = 58.75\ cm^2$

$\Rightarrow$ Choose 2 UPN 300

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

$d = 50\ cm$ & $h = 30\ cm$ $\Rightarrow$ O.K

Properties of Area :



UPN 300

$b_f = 10\ cm$ $\quad I_X = 803\ cm^4$

$A = 58.8\ cm^2$ $\quad I_Y = 49.5\ cm^4$

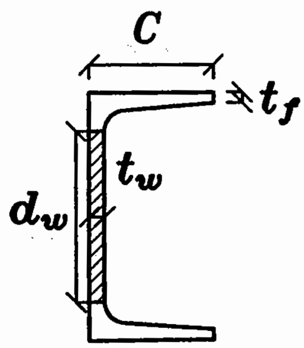
* $A_{[\,]} = 2\,A_{[} = 2 * 58.8 = 117.6\ cm^2$

* $r_{x[\,]} = \sqrt{\dfrac{I_{x[\,]}}{A_{[\,]}}} = r_{x[} = 11.7\ cm$

* $I_{Y[\,]} = 2\,[\,49.5 + 58.8 * (\dfrac{50}{2})^2\,] = 74490\ cm^4$

* $r_{y[\,]} = \sqrt{\dfrac{I_{y[\,]}}{A_{[\,]}}} = \sqrt{\dfrac{74490}{117.6}} = 25.17\ cm \simeq (\dfrac{d}{2}) = 25\ cm$

4) Check Compactness



$d_w = 23.2\ cm$ $\quad C = 10.0\ cm$ $\quad A = 10.0\ cm$

$t_w = 1.0\ cm$ $\quad t_f = 1.6\ cm$

For flange Subjected to compression

$$\frac{C}{t_f} = \frac{10}{1.6} = 6.25 < \frac{23}{\sqrt{f_y}} = 14.8 \Longrightarrow \text{Non-Compact Flange}$$

For Web Subjected to compression

$$\frac{dw}{t_w} = \frac{23.2}{1.0} = 23.2 < \frac{64}{\sqrt{f_y}} = 41.3 \Longrightarrow \text{Non-Compact Web}$$

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

5) Check Compression

$l_{b\,in} = 1.5\ (6.5) = 9.75\ m$ $\quad l_{b\,out} = 6.5\ m$

$r_x = 11.7\ cm$ $\quad r_y = 25.17\ cm$

$$* \; \lambda_{in} = \frac{l_{b\,in}}{r_y} = \frac{975}{25.17} = 38.7$$

$$* \; \lambda_{out} = \frac{l_{b\,out}}{r_x} = \frac{650}{11.7} = 55.5 < 180$$

$*$ assume $l_Z = 100\ cm$ $\quad r_Z = r_{y\,[}$

$$* \; \lambda_Z = \frac{l_Z}{r_Z} = \frac{100}{2.9} = 34.5 \ngtr 60$$

$$\ngtr \frac{2}{3} \lambda_{max.} \begin{cases} \lambda_{out} \\ \lambda_{in} \;\; 57.94 \end{cases} = 38.62$$

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

assume batten plates

$$= \sqrt{38.7^2 + 1.25 * 34.5^2} = 57.94 < 180$$

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

$$= 1.4 - 6.5 * 10^{-5} * 57.94^2 = \boxed{1.18\ t\backslash cm^2}$$

$$* f_{Ca} = \frac{N}{A} = \frac{25}{117.6} = \boxed{0.213\, t \backslash cm^2}$$

$$* \frac{f_{Ca}}{F_C} = \frac{0.213}{1.18} = 0.18 > 0.15$$

$$* F_{Ey} = \frac{7500}{\lambda_y^2} = \frac{7500}{57.94^2} = 2.23$$

Permitted to sway

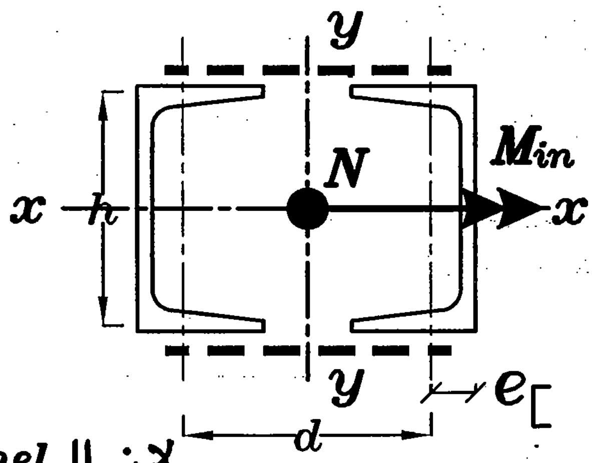
$$A_2 = \frac{C_{my}}{[1-\frac{f_{ca}}{F_{Ey}}]} = \frac{0.85}{[1-\frac{0.213}{2.23}]} = 0.94 \not< 1.0 \qquad \boxed{A_2 = 1}$$

---

6) Check Bending

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

$$= \frac{2900}{74490}\left(\frac{50}{2} + 2.7\right) = \boxed{1.08\, t \backslash cm^2}$$



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

لان ال Channel تكون Non–Compact

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

---

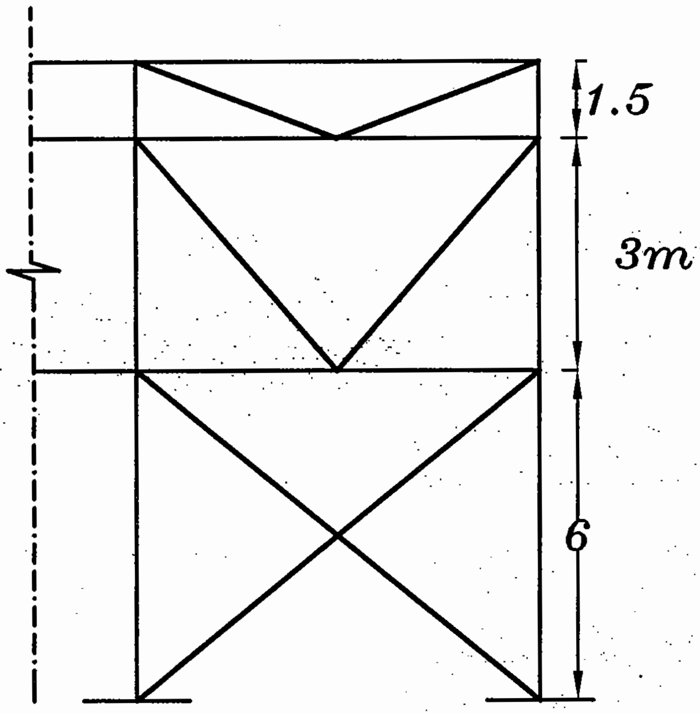
7) Check Interaction equation

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

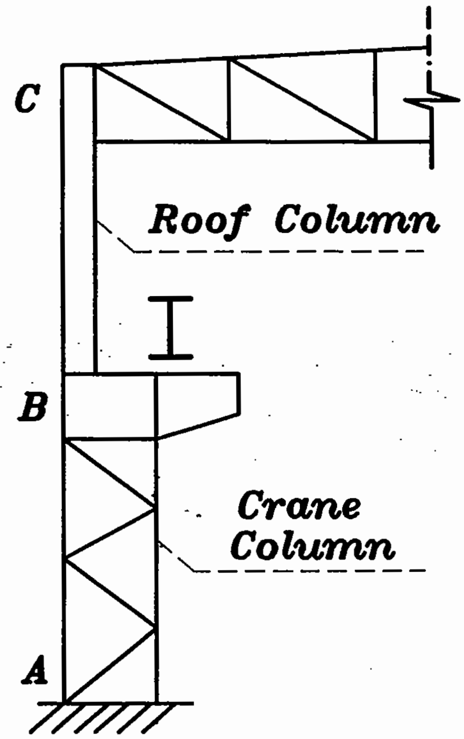
$$\frac{0.213}{1.18} + \frac{1.08}{1.40} * 1.0 = 0.95 < 1.0 \Rightarrow \textbf{SAFE}$$

EXAMPLE :

Design the shown crane column AB (N=30t , M=30m.t)
The column section is 4 angles spaced 70 cm in the direction of truss and 40 cm in the direction perpendicular to truss using lacing bars .



Side View



Elevation

1)Suggest suitable bracing system

لا نحتاج لانه معطى فى المسألة.

2) Calculate the straining actions

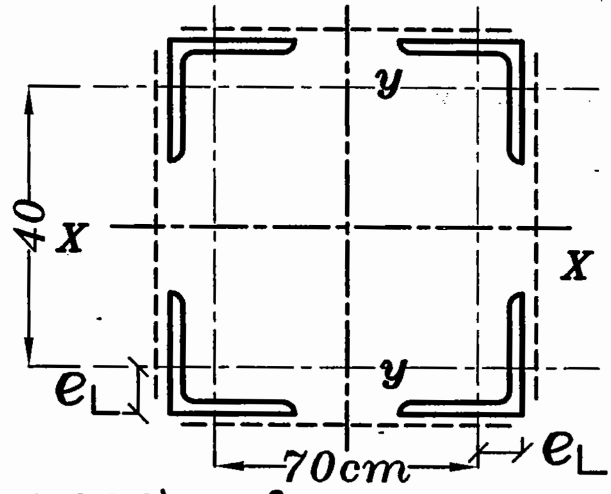
$N = 30t \qquad M_{in} = 30 m.t$

3) Choice of section

* Force on one angle

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

$$= \frac{30}{4} + \frac{30}{2*0.7} = 28.9\,t$$



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

* $A_{One\,\llcorner} = \frac{Force\ (C)}{f} = \frac{28.9}{1.2} = 24.1\ cm^2$

$\Rightarrow$ Choose 4 L 120x120x12

الابعاد الـ $h\&d$ معطيان و بالتالى لا يمكن التحكم بهما و لذلك نستخدمهما كما هما .

Properties of Area :

* $A_{\boxed{}} = 4\,A_{\llcorner} = 4 * 27.5 = 110 cm^2$

* $I_{X\,\boxed{}} = 4\,[\,I_{X\llcorner} + A_{\llcorner}\,(\frac{h}{2})^2\,]$

$$= 4\,[368 + 27.5\,(\frac{40}{2})^2\,] = 45472\ cm^4$$

* $I_{Y\,\boxed{}} = 4\,[\,I_{Y\llcorner} + A_{\llcorner}\,(\frac{d}{2})^2\,]$

$$= 4\,[\,368 + 27.5\,(\frac{70}{2})^2\,] = 136222\ cm^4$$

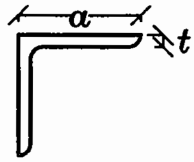
* $r_{x\,\boxed{}} = \sqrt{\frac{Ix_{\boxed{}}}{A_{\boxed{}}}} = \sqrt{\frac{45472}{110}} = 20.33 cm \simeq (\frac{h}{2}) = 20\ cm$

* $r_{y\,\boxed{}} = \sqrt{\frac{Iy_{\boxed{}}}{A_{\boxed{}}}} = \sqrt{\frac{136222}{110}} = 35.2\ cm \simeq (\frac{d}{2}) = 35\ cm$

4) Check Compactness

Flange subjected to comp.

$$* \quad \frac{C}{t_f} = \frac{a}{t} = \frac{12}{1.2} = 10 < \frac{23}{\sqrt{f_y}} = 14.8$$



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

5) Check Compression

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

$r_x = 20.33\ cm$ $\qquad$ $r_y = 35.2\ cm$

$$* \quad \bar{\lambda}_{in} = \frac{l_{b\,in}}{r_y} = \frac{900}{35.2} = 25.56$$

$$* \quad \bar{\lambda}_{out} = \frac{l_{b\,out}}{r_x} = \frac{600}{20.33} = 29.5$$

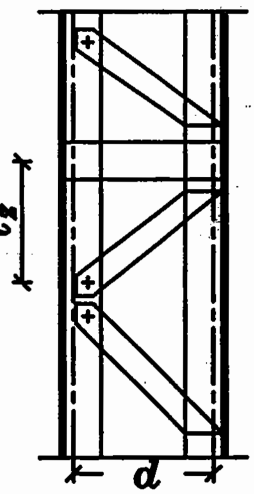
* assume $l_Z = 60\ cm$ $\qquad$ $r_Z = r_{v\,L} = 2.35\ cm$

$$* \quad \lambda_Z = \frac{l_Z}{r_Z} = \frac{60}{2.35} = 25.5$$

$$\not> 60$$

$$43.47$$

$$\not> \frac{2}{3}\lambda_{max.}\begin{cases}\lambda_{out} \\ \lambda_{in}\end{cases} = 28.98$$



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

$$= \sqrt{25.56^2 + \overbrace{1.00 * 25.5^2}^{\text{Lacing Bars}}} = 40.9 \quad < 180$$

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

$$= \sqrt{29.5^2 + \overbrace{1.00 * 25.5^2}^{\text{Lacing Bars}}} = 43.47 \quad < 180$$

$$*F_C = 1.4 - 6.5 * 10^{-5} \lambda^2_{max.}$$
$$= 1.4 - 6.5 * 10^{-5} * 43.47^2 = \boxed{1.28\ t\backslash cm^2}$$

$$*f_{Ca} = \frac{N}{A} = \frac{30}{110} = \boxed{0.272\ t\backslash cm^2}$$

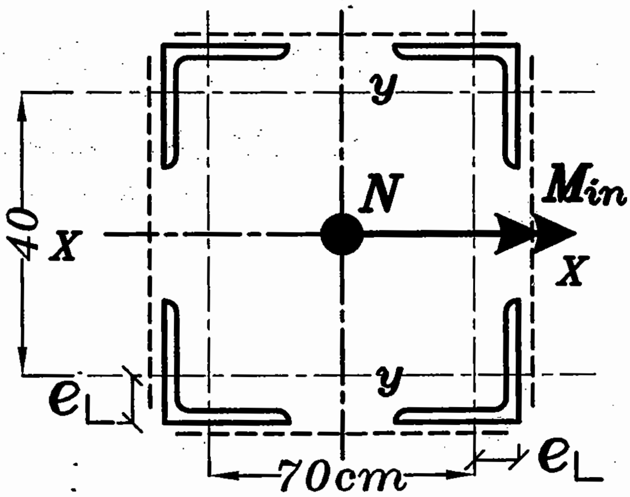
$$*\frac{f_{Ca}}{F_C} = \frac{0.272}{1.28} = 0.219 > 0.15$$

$$*\ F_{Ey} = \frac{7500}{\lambda_y^2} = \frac{7500}{40.9^2} = 4.68$$

Permitted to sway

$$A_2 = \frac{C_{my}}{[1 - \frac{f_{ca}}{F_{Ey}}]} = \frac{0.85}{[1 - \frac{0.219}{4.68}]} = 0.90 \nless 1.0 \qquad \boxed{A_2 = 1}$$

6) Check Bending



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

$$= \frac{3000}{136222}\left(\frac{70}{2} + 3.4\right) = \boxed{0.85\ t\backslash cm^2}$$

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

Non–Compact لان ال angle تكون

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

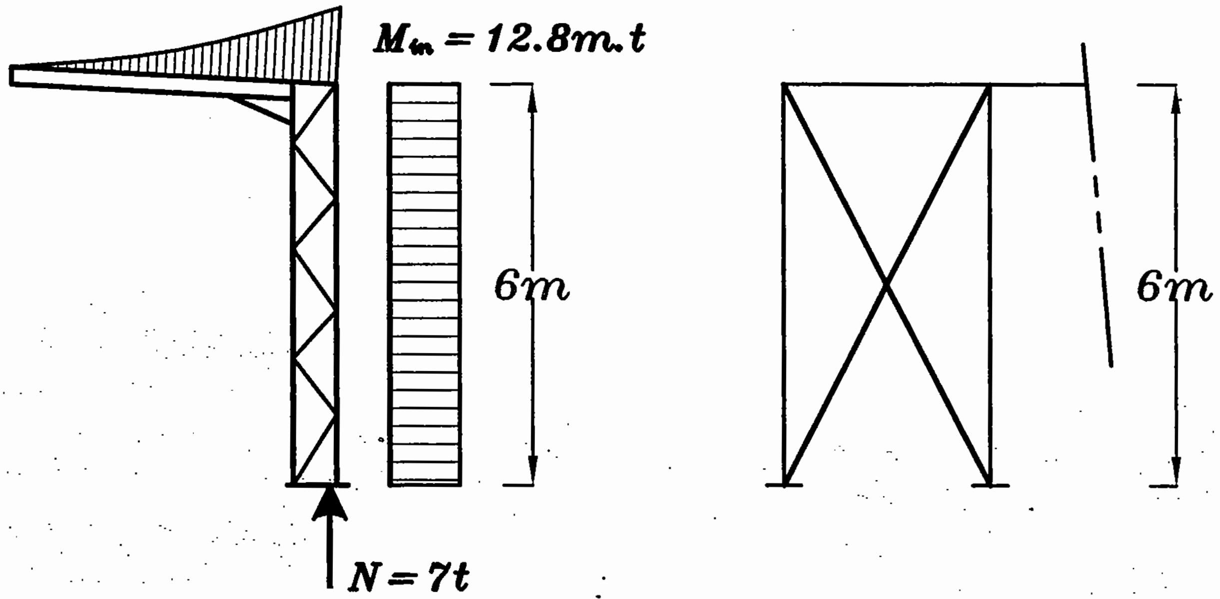
7) Check Interaction equation

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

$$\frac{0.272}{1.28} + \frac{0.845}{1.40} * 1.0 = 0.82 < 1.0 \Rightarrow \textit{SAFE}$$

EXAMPLE :

Design the shown column with the shown straining actions in addition to $M_{out} = 4 m.t$ using 2–I–Sections connected with batten plates .



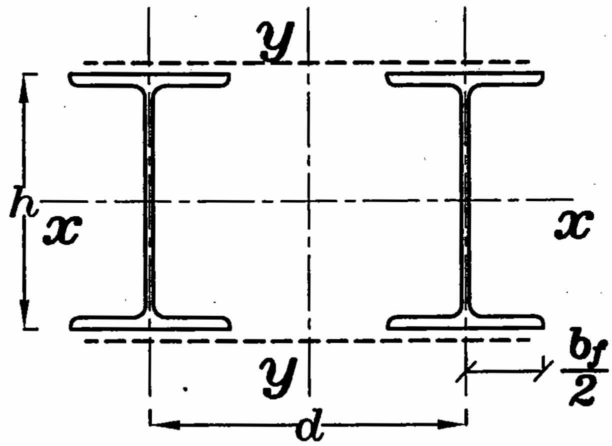
1) Suggest suitable bracing system

لا نحتاج لانه معطى فى المسألة.

2) Calculate the straining actions

$N = 7t$ $\quad$ $M_{in} = 12.8\ m.t$ $\quad$ $M_{out} = 4\ m.t$

3) Choice of section



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

* Force on one I–Section

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

$$= \frac{7}{2} + \frac{12.8}{0.4} = 35.5\ t$$

* Assume (allowable stress) $f = 0.50\ t\backslash cm^2$ لوجود M_{in} & M_{out}

$$*A_{One[} = \frac{Force\ (C)}{f} = \frac{35.5}{0.50} = 71\ cm^2$$

$\Rightarrow$ Choose **2 IPE 360**

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

$d = 40\ cm$ & $h = 36\ cm$ $\Rightarrow$ O.K

و لذلك من الممكن زيادة الـ d حتى تحقق هذا الشرط و فى هذه الحالة ستقل الـ h و لكننا لن نفعل هذا هنا لاننا نريد أيضا أن تكون الـ h كبيرة لوجود M_{in} & M_{out}.

Properties of Area :

$d_w = 29.9\ cm$ جداول

$t_w = 0.80\ cm$

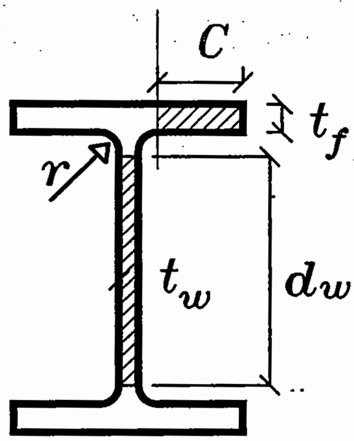
$b_f = 17.0\ cm$

$t_f = 1.27\ cm$

$A = 72.7\ cm^2$

$I_X = 16270\ cm^4$

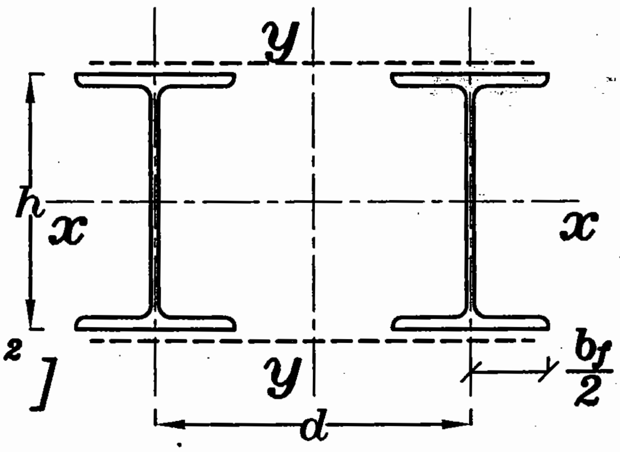
$I_Y = 1040\ cm^4$



$$*A_{II} = 2A_I = 2*72.2 = 145.4\ cm^2$$

$$*I_{X_{II}} = 2[16270] = 32540\ cm^4$$

$$*I_{Y_{II}} = 2\left[1040 + 72.7*\left(\frac{40}{2}\right)^2\right] = 60240\ cm^4$$



$$*r_{X_{II}} = \sqrt{\frac{Ix_{II}}{A_{II}}} = \sqrt{\frac{32540}{145.4}} = 14.96\ cm$$

$$*r_{y_{II}} = \sqrt{\frac{Iy_{II}}{A_{II}}} = \sqrt{\frac{60240}{145.4}} = 20.35\ cm$$

4) Check Compactness

For flange Subjected to compression

$$\frac{C}{t_f} = \frac{\frac{1}{2}(b_f - t_w - 2r)}{t_f} = \frac{\frac{1}{2}(17.0 - 0.80 - 2*1.8)}{1.27} = 5.0$$

$$\therefore \frac{C}{t_f} = 5.0 \quad < \quad \frac{16.9}{\sqrt{f_y}} = 10.9 \Longrightarrow \text{Compact Flange}$$

For Web Subjected to compression

$$\frac{d_w}{t_w} = \frac{29.9}{0.80} = 34.7 < \frac{58}{\sqrt{f_y}} = 37.4 \Longrightarrow \text{Compact Web}$$

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

5) Check Compression

$l_{b\,in} = 2.1\ (6.0) = 12.6\ m$ $\qquad$ $l_{b\,out} = 6.0\ m$

$r_x = 14.96\ cm$ $\qquad$ $r_y = 20.35\ cm$

$$* \ \bar{\lambda}_{in} = \frac{l_{b\,in}}{r_y} = \frac{1260}{20.35} = 61.9$$

$$* \ \lambda_{out} = \frac{l_{b\,out}}{r_x} = \frac{600}{14.96} = 40 < 180$$

$*$ assume $l_Z = 100\ cm$ $\qquad$ $r_Z = r_{y_I}$

$$* \ \lambda_Z = \frac{l_Z}{r_Z} = \frac{100}{3.79} = 26.4 \ngtr 60$$

$$\ngtr \frac{2}{3}\lambda_{max.}\begin{cases}\lambda_{out} \\ \bar{\lambda}_{in}\end{cases} = 41.3$$

61.9

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

assume batten plates

$$= \sqrt{61.9^2 + 1.25 * 26.4^2} = 70.0 \quad < 180$$

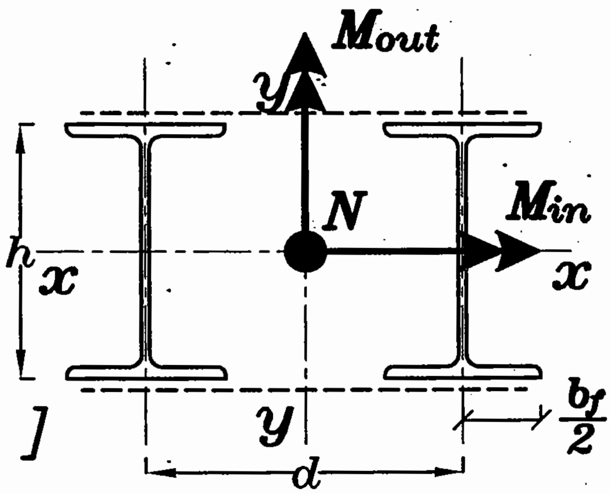
$$* F_C = 1.4 - 6.5 * 10^{-5} \lambda^2_{max.}$$

$$= 1.4 - 6.5 * 10^{-5} * 70.0^2 = \boxed{1.08 \ t\backslash cm^2}$$

$$* f_{Ca} = \frac{N}{A} = \frac{7}{145.4} = \boxed{0.05 \ t\backslash cm^2}$$

$$* \frac{f_{Ca}}{F_C} = \frac{0.05}{1.08} = 0.05 < 0.15 \qquad \boxed{A_1 = 1} \qquad \boxed{A_2 = 1}$$

6) Check Bending



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

$$= \frac{1280}{60240}\left(\frac{40}{2} + \frac{17}{2}\right) = \boxed{0.60 \ t\backslash cm^2}$$

$$f_{b(act.)_{out}} = \frac{M_{out}}{I_X}\left(\frac{h}{2}\right) = f_{bx}$$

$$= \frac{400}{32540}\left(\frac{36}{2}\right) = \boxed{0.22 \ t\backslash cm^2}$$

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

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

7) Check Interaction equation

$$\frac{f_{Ca}}{F_C} + \frac{f_{bx\,(act.)}}{F_{b_{Cx}}} * A_1 + \frac{f_{by\,(act.)}}{F_{b_{Cy}}} * A_2 < 1.0$$

$$\frac{0.05}{1.08} + \frac{0.60}{1.536} * 1.0 + \frac{0.22}{1.536} * 1.0 = 0.64$$

$$< 1.0$$

$\Rightarrow$ SAFE but waste

Try to use IPE300