COLD FORMED SECTION

* **Introduction:** The light gauge steel members are defined as structural me[mbers] cold formed to shapes in [rolled rolling machines] or [press brakes or bending brake operation] from carbon or low alloy steel sheets or strips or flats. The thickness of such members usually range from [0.378mm to about 6.35mm] even though steel plates as thick as 25.4 mm may be cold formed in to structural shape.

Cold rolling being used for (mass production) while press bra[kes] are used for [economical production] of small quantities of special shapes.

Cold formed section are used widely in structure subjec[ted] to [light or moderate loads or for members of short span length]. For such structures, the use of conventional hot rolled is often uneconomical bec[ause] the stress developed in smallest available shape may be very low. Furth[er] a variety of light gauge members can be formed in cold state with ease and material can be used in the most effective manner.

In order to provide very satisfactory [protection against corrosion in internal environment] zinc coating (galvanising) is applied.

Light gauge steel members are connected by (spot), (fillet), (plug or slot) weld or by screw, rivet, bolts etc.

Application of Cold formed Section:-
<1> In trucks and trailer bodies <2> In Railway Coaches <3> Building construction <4> Bridge Construction <5> Storage racks <6> Highway Pr[oducts] <7> Drainage Facility <8> Grain Bins <9> Transmission Tower <10> Car Bod[ies] <11> Floor Decks <12> Wall Panels.

Advantage of Cold formed Section:
<1> light in weight and easy to transport and erect <2> High strength and stiffness <3> Ease of prefabrication and mass production <4> Installed quickly <5> Economical in handeling <6> Any desired shape and leng[th] may be produced <7> All conventional fastenes (riveting, bolting, weld and adhesive) may be used for jointing <8> Pregalvanized or precoated with zinc metal to resistence for corroison.

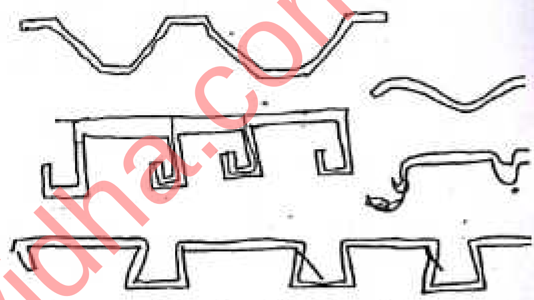
* **Various Types of Cold formed Section:** (1) Individual Structural Framin[g] member.
(2) Panel and Decks.

(1) **Individual Structural Framing Members:** The usual shapes of frami[ng] members are (channels), (zees), angles, hat sections, tees, I-section and tubular ... can carry sub-stantial load and are used as primary framing members in building...

commercial and industrial building up to two storeys in height and roof truss up to 15m span. Framing member are formed with light gauge structural steel sheets.
Thickness of framing members is usually 25 mm.

<2> Panels and Decks: Another category of cold formed sections, manufacture in panel sizes, used for roof and floor decks, sidings and walls. Stand roof decks are usually 58mm deep, with a rib spacing of 130mm and are used on spans b/w purlins up to 5m. Floor and roof panels are made to cover span from 3 to 10m. The thickness used generally range from 1.2 to 2.5mm and for standard roof deck.
Steel decks not only provide structural strength to carry loads but also provide a surface on which flooring, roofing or concrete fill may applied.


Framing Members

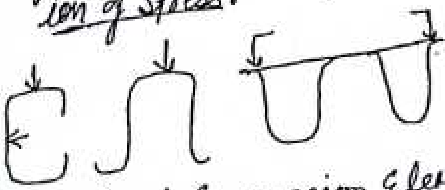

Panels & Decks.

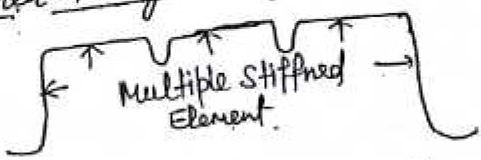
* Definitions:

<1> Stiffened Compression Element: When a flat compression element is stiffened on both ends or edges parallel to direction of stress by connected stiffners or by formed lips or flange offering a specified the ance to lateral deflection, then the element is known as stiffened compression element.

<2> Multiple Stiffned Element: An element that is stiffned b/w the or b/w a web and a stiffned edge by means of intermediate stiff parallel to direction of stress.

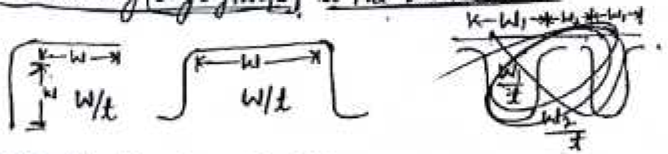
<3> Unstiffned Compression Element: Unstiffned compression element flat compression element stiffned at only one edge parellel to direction of stress.


Stiffned Compression Element (which Arrow)



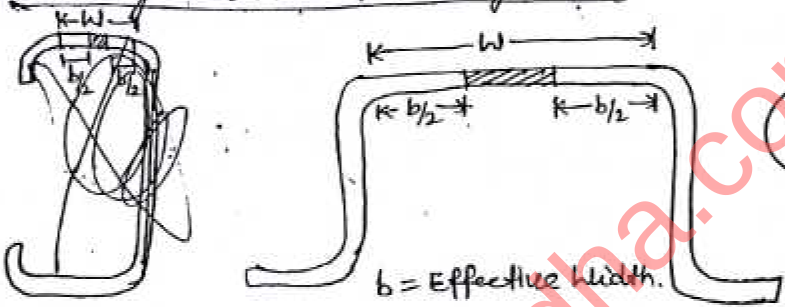

Unstiffned Compression

(4) Flat width ratio - It is the ratio of a single flat element of the flat width W exclusive of edge fillets to the thickness 't'.



<5> Effective Design Width :-

Effective design width of a flat element is a reduced width from design consideration. The portion of total width which is considered removed (to arrive at the effective design width) is located symmetrically about the center line of element.



* LOCAL BUCKLING OF PLATE ELEMENT :-

Most structural members, either hot or cold rolled, are composed of flat elements. These elements under compression may buckle locally out of their original planes. Local buckling of this element occurs before the general buckling. The effect of local buckling on the strength of entire member depend upon.

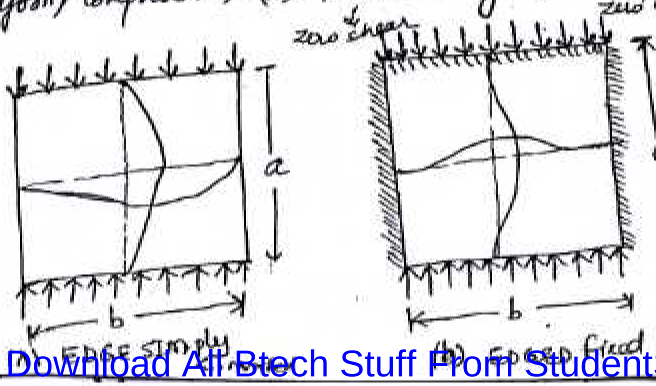
<i> location of buckled element <ii> Its buckling and post buckling strength

<iii> Type of Member.

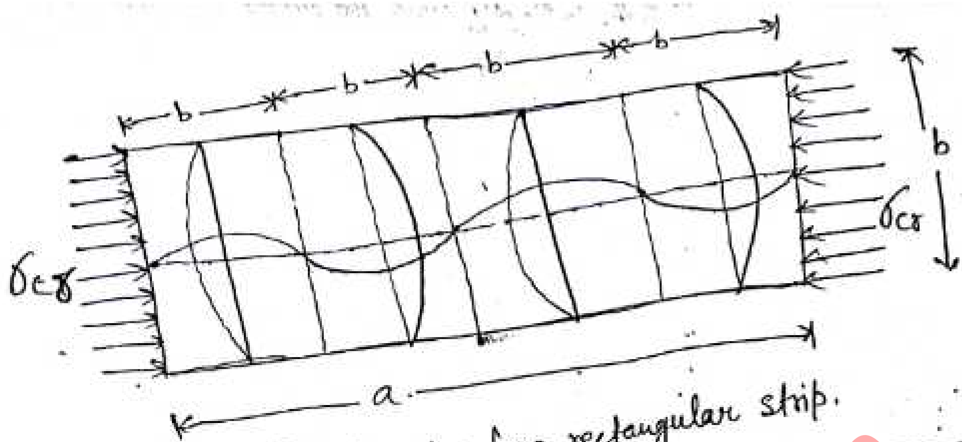
The theory of elastic buckling of ideal flate plate.

The three most important cases are

<i> Uniform compression <ii> Pure Bending <iii> Pure Shear.



(Fig)
BUCKLING OF



Bukling of a long rectangular strip.

A rectangular plate with dimension $a \times b$ is shown, the material of plate is homogenous and isotropic (free from residual stress). The plate is perfectly plane and it is subjected to uniform compressive load along opposite edges. When compressive load is gradually increased, the plate will compressed uniformly untill the buckling stress is reached. When buckling stress is reached, the plate buckles in a single wave depending on boundry or edge condition and length to width (a/b) ratio. As a result of this redistribution of compressive stress occurs. When the load is further increased the entire plate buckles.

$\frac{\text{length}}{\text{width}} = \frac{a}{b}$ = aspect Ratio

Critical Elastic Buckling for first two Cases

$$f_{cr} = \sigma_{cr} = \frac{K_c \pi^2 E}{12(1-\mu^2)(b/t)^2} = f_y \quad (1)$$

$$\left(\frac{b}{t}\right)^2 = \frac{K_c \pi^2 E}{12(1-\mu^2) f_y} \quad (2)$$

Critical Elastic Buckling for third Case.

$$\tau_{cr} = \frac{K_c \pi^2 E}{12(1-\mu^2)(b/t)^2}$$

K_c = Buckling Cofficient depend on ratio of a/b.

E = Youngs Modulus of Elasticity $= 2 \times 10^5$

μ = Poisson Ratio

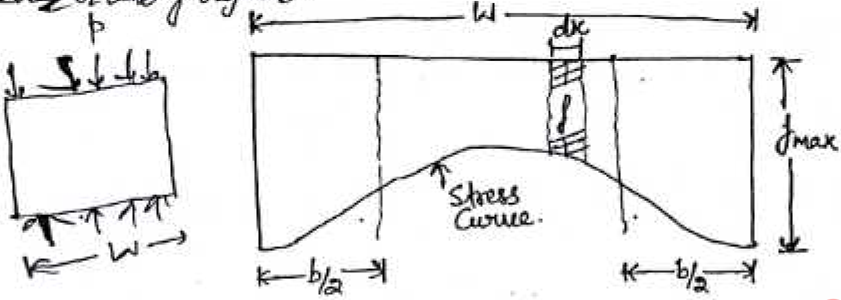
b = width of plate = effective width

a = length of plate

t = thickness of plate

* CONCEPT OF EFFECTIVE DESIGN WIDTH :-

Effective design width of a flat element is its reduced width from design consideration. The portion of total width which is considered req to arrive at effective design width is located symmetrically about center line of object.



$$\int_0^W f \cdot dx = f_{max} \cdot b$$

b = effective design width

The concept of effective design width is based on replacing the pl... across the width 'W', subjected to a varying stress distribution across the width 'W', in which the total load is carried by an equivalent width 'b', in which the edge stress a uniformly distributed stress equal to the edge stress $f_y = \frac{K\pi^2 E}{12(1-\mu^2)\left(\frac{b}{t}\right)^2}$

from concept of local buckling, eq ②

$$\left(\frac{b}{t}\right)^2 = \frac{K_c \pi^2 E}{12(1-\mu^2) f_y} \quad \text{—— ②'}$$

For simply supported plate, $K_c = 4$.

$$\left(\frac{b}{t}\right)^2 = \frac{4\pi^2 E}{3(1-\mu^2) f_y} = \frac{\pi^2 E}{3(1-\mu^2) f_y} \quad \text{—— ③}$$

$$\boxed{\frac{b}{t} = 1.9\sqrt{\frac{E}{f_y}}} \quad \text{—— ④}$$

[Taking $\mu = 0.$...

this equation is known as Von-Karman Equation.

K_c = Buckling Cofficient

E = Young's Modulus of elasticity

μ = Poisson's Ratio

Effective width of stiffned compression members without intermediate stiffner is given below :-

1 For Compression Element other than tubes :

(a) For load determination

for $\left(\frac{W}{t}\right)$ up to $\left(\frac{W}{t}\right)_{lim} = \frac{446}{\sqrt{f}}$

$$\boxed{b = W}$$

for $\left(\frac{W}{t}\right) > \left(\frac{W}{t}\right)_{lim}$,

$$\frac{b}{t} = \frac{658}{\sqrt{f}}\left(1 - \frac{145}{(W/t)\sqrt{f}}\right)$$

(b) For deflection Determination

for $\left(\frac{W}{t}\right)$ up to $\left(\frac{W}{t}\right)_{lim} = \frac{574}{\sqrt{f}}$

$$\boxed{b = W}$$

for $\left(\frac{W}{t}\right) > \left(\frac{W}{t}\right)_{lim}$,

$$\frac{b}{t} = \frac{842}{\sqrt{f}}\left(1 - \frac{186}{(W/t)\sqrt{f}}\right)$$

2 For Closed square and Rectangular Tubes

(a) For load determination

for $\left(\frac{W}{t}\right)$ up to $\left(\frac{W}{t}\right)_{lim} = \frac{478}{\sqrt{f}}$

$$\boxed{b = W}$$

for $\left(\frac{W}{t}\right) > \left(\frac{W}{t}\right)_{lim}$:- $\frac{b}{t} = \frac{658}{\sqrt{f}}\left(1 - \frac{130}{\left(\frac{W}{t}\right)\sqrt{f}}\right)$

(b) For deflection determination

for $\left(\frac{W}{t}\right)$ up to $\left(\frac{W}{t}\right)_{lim} = \frac{618}{\sqrt{f}}$

$$\boxed{b = W}$$

for $\left(\frac{W}{t}\right) > \left(\frac{W}{t}\right)_{lim}$:- $\frac{b}{t} = \frac{842}{\sqrt{f}}\left(1 - \frac{169}{(W/t)\sqrt{f}}\right)$

Compression Members

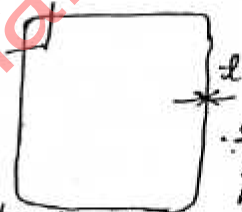
(1) **Column Strength :-** Column strength of thin plates is defined as the load carrying capacity of the members controlled by one or more combine of four types of failure (i) Crushing (ii) local buckling of thin plate element of section (iii) Overall or primary column buckling by lateral bending over the unsupported length of member (iv) Torsional buckling or twisting of section about a longitudinal axis

<2> **Form factor :- (Q)** It is the ratio of load at which a short length of member fails by local buckling ~~to the load at which a short leng of members fails by local buckling~~ to the load at which it would fall in simply yielding if local buckling is prevented.

<i> **Form factor for Member Composed Entirely Stiffned Element**

$$Q = \frac{\text{Effective designed area determined from effective width}}{\text{Total Area}}$$

$$Q_s = \frac{A_{ff}}{A}$$



Section with stiffned Member

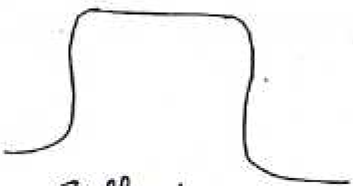
<ii> **Form factor For Member Composed of entirely Unstiffned Me**

$$Q_{un} = \frac{\text{Allowable Stress}}{\text{Basic design stress}} = \frac{f_c}{f_b} = \frac{f_c}{f}$$

$$f = f_b = \text{Basic design stress} = 0.6\, f_y$$

<iii> **Form factor for member composed of stiffned and unstiffned member :-**

$$Q = Q_s \cdot Q_{un} = \frac{A_{ff}}{A} \cdot \frac{f_c}{f}$$



Stiffend and Unstiffne M

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*- Allowable stress for shapes not Subjected to Torsional flexural
(3) Buckling :-

The average axial stress $\frac{P}{A}$, in compression members should not exceed the following values of allowab stress (f_{al})

(i) for $\frac{kL}{r} < \frac{C_c}{\sqrt{Q}}$:- $C_c = \sqrt{\frac{2\pi^2 E}{f_y}}$

$$f_{a1} = \frac{12}{23} Q f_y - \frac{3}{23} \frac{(Q f_y)^2}{\pi^2 E} \left(\frac{kL}{r}\right)^2$$

(ii) for $\frac{kL}{r} \geq \frac{C_c}{\sqrt{Q}}$:- $C_c = \sqrt{\frac{2\pi^2 E}{f_y}}$

$$f_{a1} = \frac{12\pi^2 E}{23\left(\frac{kL}{r}\right)^2}$$

Q = form factor.

f_{a1} = Allowable avg compression stress under concentrated loading

E = Modulus of Elasticity $= 2\times10^5$

k = effective length factor.

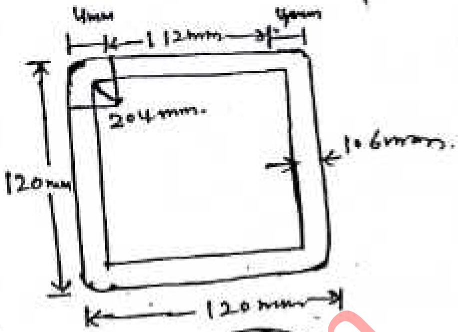
f_y = Yield point of steel.

r = radius of gyration.

P = total load.

A = full unreduced cross sectional area of the member

Que> Find Column Section Properties and allowable load for the column section shown. The effective length of column is 3 m. Take $f_y = 235\ N/mm^2$



Sol:

Radius of Corner, $R = 2.4 + 0.8$
$= 3.2\ mm.$

length of Corners $= 1.57R$
$= 1.57 \times 3.2$
$= 5.024\ mm.$

$C_{xx} = 0.637R = 0.637 \times 3.2$
$= 2.038\ mm.$

$L = 2 \times 112 + 2 \times 112 + 4 \times 5.024$

$\boxed{L = 468.1\ mm}$

$A = 468.1 \times 1.6 = 748.96\ mm^2$

$\boxed{A = 748.96\ mm^2}$

$$I_{xx} = 2 \times 112 \times (59.2)^2 + 2 \times \frac{(112)^3}{12} + 4 \times 5.024 \times (58.038)^2$$

$I_{xx} = 1086885.58\ mm^3$

But Actual $I_{xx} = 1086885.58 \times 1.6 = 1739016.92\ mm^4$

$\boxed{I_{xx} = 1739016.92\ mm^4}$

Radius of gyration, $r = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{1739016.92}{748.96}}$

$\boxed{r = 48.18\ mm = 4.8\ cm}$

Basic design stress, $f = 0.6 f_y = 0.6 \times 235$

$\boxed{f = 141\ N/mm^2}$

To calculate form factor effective width and effective area of the section will be required.

$$\left(\frac{w}{t}\right)_{lim} = \frac{478}{\sqrt{f}} = \frac{478}{\sqrt{141}} = 40.25$$

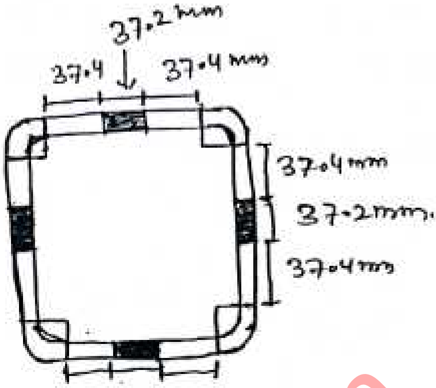
$$\frac{w}{t} = \frac{112}{1.6} = 70 > 40.25 \text{ or } \frac{w}{t} > \left(\frac{w}{t}\right)_{lim}$$

$$\frac{b}{t} = \frac{658}{\sqrt{f}}\left(1 - \frac{130}{\left(\frac{w}{t}\right)\sqrt{f}}\right) = \frac{658}{\sqrt{141}}\left(1 - \frac{130}{70 \times \sqrt{141}}\right)$$

$\frac{b}{t} = 46.75$

$b = 46.75 \times 1.6 = 74.8$ mm.

$\boxed{b = 74.8 \text{ mm}}$



$A_{eff} = 749 - 4 \times 37.2 \times 1.6$

$\boxed{A_{eff} = 510.92 \text{ mm}^2}$

Form factor, $Q = \frac{A_{eff}}{A} = \frac{510.92}{749}$

$\boxed{Q = 0.682}$

$$C_c = \sqrt{\frac{2\pi^2 E}{f_y}} = \sqrt{\frac{2\pi^2 \times 2 \times 10^5}{235}} = 129.61$$

$$\frac{C_c}{\sqrt{Q}} = \frac{129.61}{\sqrt{0.682}} = 157$$

$$\frac{kl}{r} = \frac{3 \times 100}{4.8} = 62.5$$

$$\frac{kl}{r} < \frac{C_c}{\sqrt{Q}}$$

$$f_{a1} = \frac{12}{23} Q f_y - \frac{3}{23} \frac{(Q f_y)^2}{\pi^2 E} \left(\frac{kL}{r}\right)^2$$

$$= \frac{12}{23} \times 0.682 \times 235 - \frac{3}{23} \frac{(0.682 \times 235)^2}{\pi^2 \times 2 \times 10^5} \times (62.5)^2$$

$$= 76.99 \text{ N/mm}^2$$

Allowable load $= f_a \times A = 76.99 \times 749$

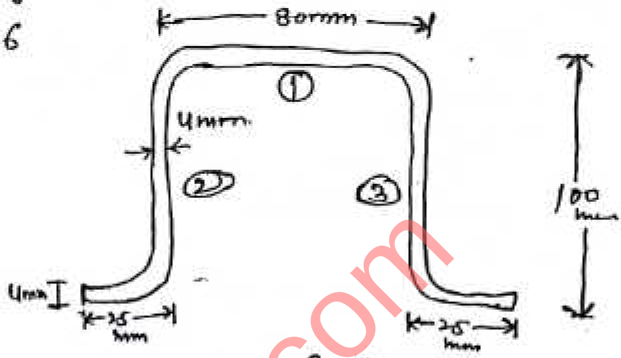
$= 57662$ N

$= 57.66$ kN.

Que> A hat of 100mm × 80 mm × 4 mm section with a 25 mm lip is to be used as concentrically loaded column of 3.1 m effective length. Determine the allowable load. Take $f_y = 235\ N/mm^2$

Sol: Basic design stress $f = 0.6 f_y = 0.6 \times 235 = 141\ N/mm^2$

$$\left(\frac{w}{t}\right)_{lim} = \frac{446}{\sqrt{f}} = \frac{446}{\sqrt{141}} = 37.6$$



$$\frac{w_1}{t} = \frac{72}{4} = 18 < 37.6$$

$$\frac{w_2}{t} = \frac{92}{4} = 23 < 37.6$$

Since $\frac{w}{t}$ ratio for both flange and web is less than $\left(\frac{w}{t}\right)_{lim}$, full width be effective.

$\boxed{b = w}$ and $\boxed{Q = 1}$

From IS code, relevant properties of section.

$A = 1180\ mm^2$ $C_y = 45.1\ mm$.

$I_{xx} = 152 \times 10^4\ mm^4$, $I_{yy} = 161 \times 10^4\ mm^4$

$r_{xx} = 35.8\ mm$, $r_{yy} = 36.9\ mm$.

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Now, $$\frac{kl}{r_{xx}} = \frac{3.1 \times 1000}{35.8} = 86.6$$

$$C_c = \sqrt{\frac{2\pi^2 E}{f_y}} = \sqrt{\frac{2\pi^2 \times 2 \times 10^5}{235}} = 129.61$$

$$\frac{C_c}{\sqrt{Q}} = \frac{129.61}{\sqrt{1}} = 129.61$$

$\frac{kl}{r} < \frac{C_c}{\sqrt{Q}}$, ∴ $$f_{a1} = \frac{12}{23} Q f_y - \frac{3}{23} \frac{(Q f_y)^2}{\pi^2 E} \left(\frac{kl}{r}\right)^2$$

$$f_{a1} = \frac{12}{23} \times 1 \times 235 - \frac{3}{23} \frac{(235)^2 (1)^2}{\pi^2 \times 2 \times 10^5} (86.6)^2$$

$= 95.24\ N/mm^2$

Allowable load $= f_a \times A$

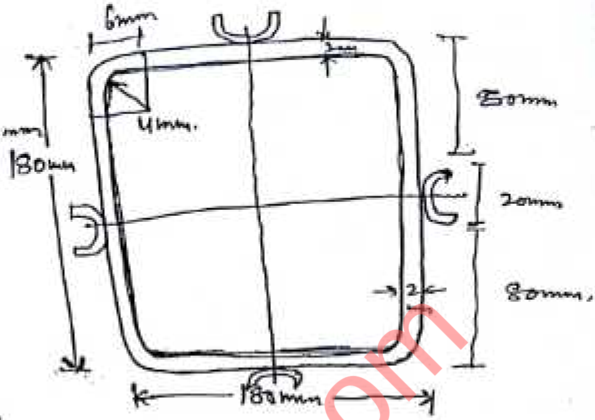
$= 95.24 \times 1180 = 112383\ N = 112.4\ kN$

Que) A square box of 180mm × 180mm × 2mm section is to be used as a column of 4m effective length. It stiffned on all four sides; find maximum load it can carry. Design also stiffners. Take $f_y = 235\ N/mm^2$

Sol Radius of Corner $R = 4 + 1 = 5$ mm.

length of Corner $= 1.57 R$

$= 1.57 \times 5 = 7.85$ mm



$C_{xx} = 0.637 R$

$= 0.637 \times 7.85$

$= 3.185$ mm.

$L = 2 \times 168 + 2 \times 166 + 4 \times 7.85$

$= 703.4$ mm.

$A = 703.4 \times 2 = 1406.8$ mm.

$$I_{xx} = 2 \times 168 \times 89^2 + 2 \times \frac{168^3}{12} + 4 \times 7.85 \times 87.185^2 =$$

$I_{xx} = 3511397.6\ mm^3$.

Actual $I_{xx} = 3511397.6 \times 2 = 7022795.22\ mm^4$.

$$r = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{7022795.22}{1406.8}} = 70.65\ mm$$

$r = 70.65\ mm \simeq 7.1\ cm$.

$$\left(\frac{w}{t}\right)_{lim} = \frac{478}{\sqrt{f}} = \frac{478}{\sqrt{141}} = 40.25$$

$$\boxed{\frac{w}{t} = \frac{172}{2} = 86 > 40.25}$$

$$\frac{b}{t} = \frac{658}{\sqrt{f}}\left(1 - \frac{130}{\left(\frac{w}{t}\right)\sqrt{f}}\right)$$

$$= \frac{658}{\sqrt{141}}\left[1 - \frac{130}{86\sqrt{141}}\right] = 48.36$$

when flat width ratio of sub element of a multipled stiffned element exceed 60, the effective design width is reduced and is given by

$$\frac{b_e}{t} = \frac{b}{t} - 0.10\left(\frac{w}{t} - 60\right)$$

$$\frac{b_e}{t} = 48.36 - 0.10 \times (86-60) = 45.76$$

$$b_e = 45.76 \times 2t = 45.76 \times 2 = 91.52\,mm$$

$$A_{eff} = 1406.8 - 4 \times (168 - 91.52) \times 2 = 794.96\,mm^2$$

$$Q = \frac{A_{eff}}{A} = \frac{794.96}{1406.8} = 0.565$$

$$C_c = \sqrt{\frac{2\pi^2 E}{f_y}} = \sqrt{\frac{2\pi^2 \times 2 \times 10^5}{235}} = 129.61$$

$$\left(\frac{l}{r}\right)_{lim} = \frac{C_c}{\sqrt{Q}} = \frac{129.61}{\sqrt{0.565}}$$

$$\text{Actual } \frac{kl}{r} = \frac{4 \times 100}{7.1} = 56.34 < 172.43.$$

$$f_{a1} = \frac{12}{23}(Qf_y)^2 - \frac{3}{23}\frac{(Qf_y)^2}{\pi^2 E} \cdot \left(\frac{kl}{r}\right)^2$$

$$= \frac{12}{23}(0.565 \times 235)^2 - \frac{3}{23}\frac{(0.565 \times 235)^2}{\pi^2 \times 2 \times 10^5}(56.34)^2$$

$$= 65.57\,N/mm^2$$

$$\text{Allowable load} = f_a \times A$$

$$= 65.57 \times 1406.8$$

$$= 92243.8\,N$$

$$= 92.24\,kN$$

For stiffneris,

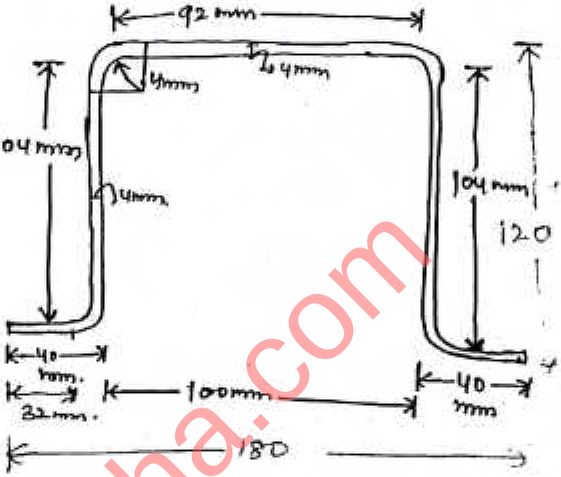
$$I_{min} = 1.83\,t^4 \sqrt{\left(\frac{w}{t}\right)^2 - \frac{27590}{f_y}}$$

$$= 1.83 \times 2^4 \sqrt{(86)^2 - \frac{27590}{235}}$$

$$= 2498\,mm^4.$$

Que) A top chord member of a roof truss is of hat section. It is subjected to a compression of 132.5 kN and a moment of 1636 kNm. Check the safety of the section if $f_y = 210 N/mm^2$ and length of member is 1.70m.

Sol:



Basic Design Stress $= 0.6 f_y$

$f = 0.6 \times 210 = 125 N/mm^2$

$\left(\frac{W}{t}\right)_{lim} = \frac{446}{\sqrt{f}} = \frac{446}{\sqrt{125}} = 40.58$

$\frac{W_1}{t} = \frac{92}{4} = 23$

$\frac{W_2}{t} = \frac{104}{4} = 26$

$$\frac{W_1}{t}, \frac{W_2}{t} < \left(\frac{W}{t}\right)_{lim}$$

Hence, all elements are fully effective (i.e $b = w$) and $Q = 1$

Linear Property

$L = 2 \times 32 + 2 \times 104 + 92 + 4 \times (9.42) = 401.68$ mm.

$A = ~~406~~ \; 401.68 \times 4 = 1607 \; mm^2$

Radius of Corner $(R) = 4 + 2 = 6$mm.

length of Corner $= 1.57 \times R = 1.57 \times 6 = 9.42$ mm

$C_{xx} = 0.637 R = 0.637 \times 6 = 3.822 = 3.822$ mm.

$I_{xx} = 92 \times 54^2 + 2 \times \frac{104^3}{12} + 2 \times 104 \times 4^2 + 2 \times 32 \times (62)^2$
$+ 2 \times 9.42 \times (51.822)^2 + 2 \times 9.42 \times (59.822)^2$

$I_{xx} = 823.11 \times 10^3 \; mm^3$

Actual $I_{xx} = 823.11 \times 10^3 \times 4 = 329.24 \times 10^4 \; mm^4$

$$r_{xx} = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{329.24 \times 10^4}{1607}} = 45.26 \text{ mm.}$$

$$\frac{kl}{r} = \frac{1.7 \times 100}{45.26} = 37.6$$

$$\frac{C_c}{\sqrt{Q}} = \sqrt{\frac{2\pi^2 E}{f_y}} = \sqrt{\frac{2 \times 2 \times 10^5 \times \pi^2}{210}}$$

$$= 2\pi \sqrt{\frac{(10)^8}{21 \times 10}} = 129.1$$

$$f_{a1} = \frac{12}{23}(Qf_y) - \frac{3}{23}\frac{(Qf_y)^2}{\pi^2 E}\left(\frac{kl}{r}\right)^2$$

$$= \frac{12}{23}(1 \times 210) - \frac{3}{23}\frac{(210)^2}{\pi^2 \times 2 \times 10^5} \times (37.6)^2$$

$$f_{a1} = 117.45 \text{ N/mm}^2$$

$$f_e' = \frac{12}{23}\frac{\pi^2 E}{\left(\frac{kl}{r}\right)^2} = \frac{12}{23} \times \frac{\pi^2 \times 2 \times 10^5}{(37.6)^2}$$

$$\boxed{f_e' = 728.46 \text{ N/mm}^2}$$

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