5. UNSYMMETRICAL BENDING

Symmetrical bending:-

The plane of loading (or) plane of bending is coincide. lie in a plane that contains centroidal axis of cross-section the bending is called "symmetric bending."

Unsymmetrical bending:-

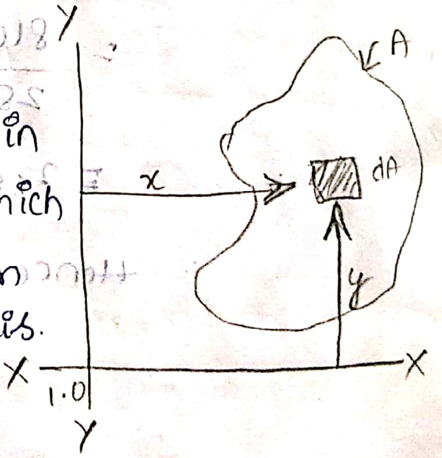
The plane of loading or bending does not lie in aplane that contains principle centroidal axis of cross-section the bending is called "unsymmetrical bending"

principle axis:-

If the two axis about which product of inertia becomes zero. The true axis are called "principle axis." The moment of inertia about principle axis is called "principle moment of inertia".

24/12/2020

Product of inertia:-



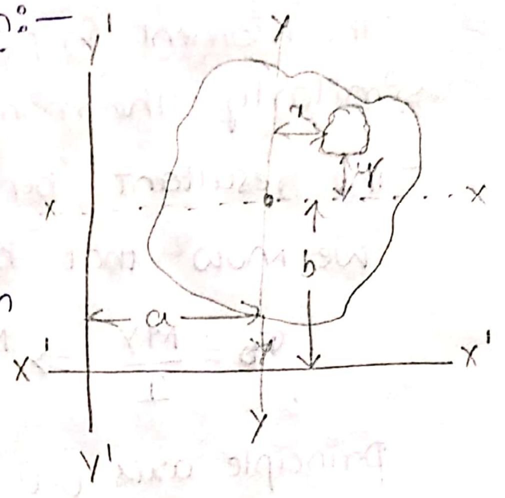
Consider a plane area 'A' in that elemental area 'dA' which is at a distance of 'x' from Y-Y axis, y from X-X axis respectively.

In that ~~the~~ $\Sigma xy.dA$ is defined as product of inertia of cross-section. Then it can be Mathematically written as

$$I_{xy} = \Sigma xy.dA = \int_0^A xy.dA.$$

parallel axis theorem:-

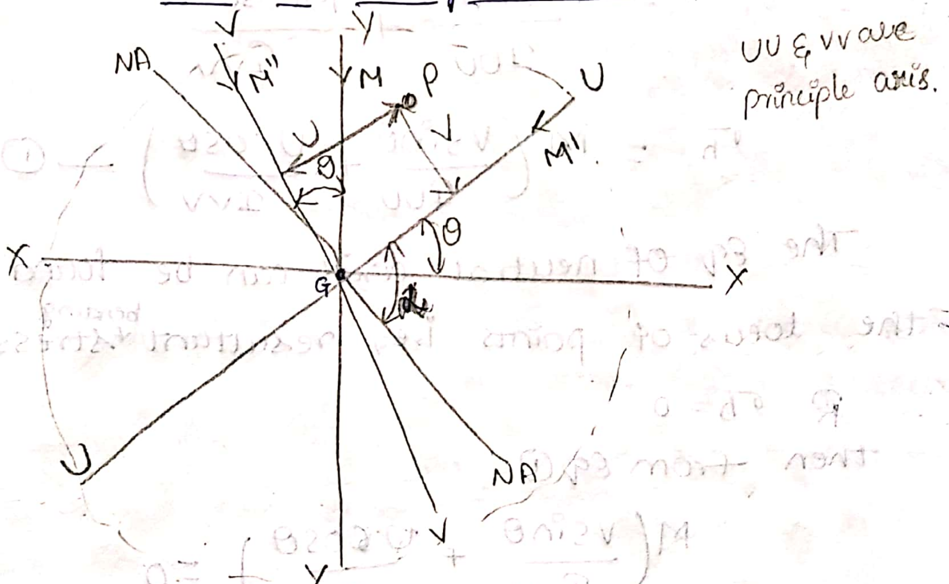
let x-x and y-y are centroidal axis x' and y' are co-ordinate axis. It is possible to transform the moment of inertia about co-ordinate axis.



∴ According to this theorem

$$Ix'y' = I_{xy} + A\,ab.$$

stresses due to unsymmetrical bending:-



'G' be the centroid of the section, x-x, y-y are co-ordinate axis passing through the center of gravity 'G'. Let NA be the Neutral axis. an angle 'θ' to xx-UU and V-V are principle axis. and y-y axis

Let us determine stress distribution over the diagram.

The moment 'M' in the plane Y-Y can be resolved into components in the plane of U-U and V-V principle axis.

The moment in plane U-U = $M' \overset{M(\cos 90 - \theta)}{=} M\sin\theta$.

Similarly the moment in plane V-V = $M'' = M\cos\theta$

The resultant bending stress at point 'p' is

We know that bending stress $\sigma_b = \frac{M}{Z}$ $\left(Z = \frac{I}{Y}\right)$

$$\sigma_b = \frac{MY}{I} \Rightarrow \frac{M(U+V)}{I} = \frac{M}{I_{UU}} \quad \frac{UV}{I_{UU}} + \frac{VU}{I_{VV}}$$

principle axis U-U corresponding moment = M'

$$\sigma_b = \frac{M'V}{I_{UU}} + \frac{M''U}{I_{VV}}$$

$$= \frac{M\sin\theta . V}{I_{UU}} + \frac{M\cos\theta . U}{I_{VV}}$$

$$\sigma_b = M\left(\frac{V\sin\theta}{I_{UU}} + \frac{U\cos\theta}{I_{VV}}\right) \quad \text{—} (1)$$

The Eq of neutral axis can be found by finding the locus of points i.e., resultant bending stress is 'zero'.

& $\sigma_b = 0$

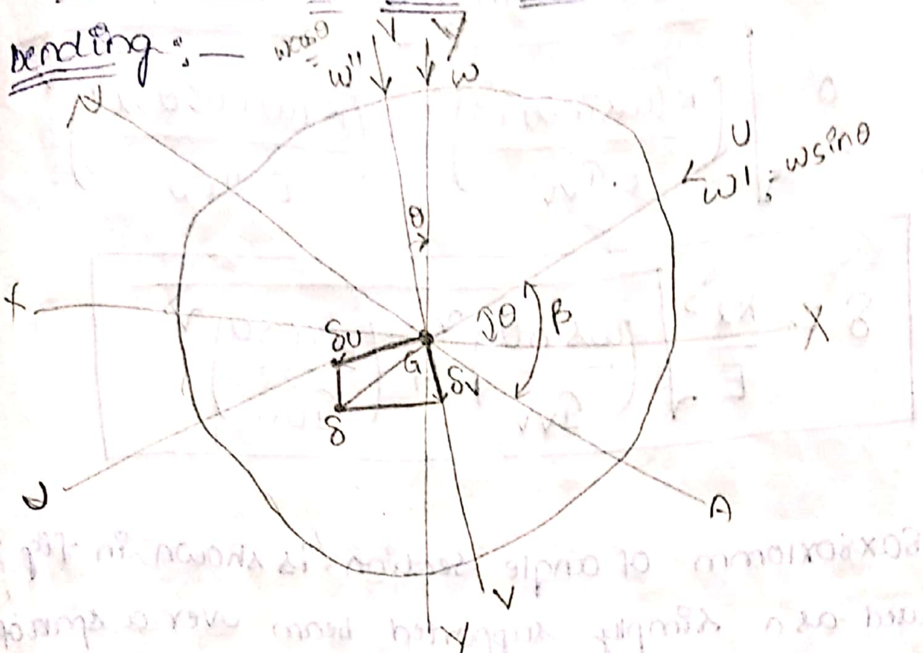
then from Eq (1)

$$M\left(\frac{V\sin\theta}{I_{UU}} + \frac{U\cos\theta}{I_{VV}}\right) = 0$$

$$\frac{V\sin\theta}{I_{UU}} + \frac{U\cos\theta}{I_{VV}} = 0$$

The max. stress will occurs at a point which is the greatest distance from the neutral axis.

Deflection of beams due to unsymmetrical bending :—



Let 'G' be the centroid of the section. X-X and Y-Y are co-ordinate axis which is passing through the center. U-U and V-V are principle axis inclined at an angle 'θ' with X-X and Y-Y axis.

Let 'w' be the load acting along line Y-Y on section of beam. The load 'w' can be resolved into two components along U-U = $w' = w\sin\theta$,

similarly along V-V = $w'' = w\cos\theta$

Let 'δ_U' be the deflection caused by the component of w' ($w\sin\theta$) along line 'GU' the bending occurs about V-V axis. similarly 'δ_V' deflection caused by the component of w'' ($w\cos\theta$) along line 'GV' the bending occurs about U-U axis.

The depending of the end conditions of the beam. The values of 'δ_U' and 'δ_V' are given by

$$\therefore \boxed{\delta_U = \frac{K(w\sin\theta)l^3}{E I_{VV}}}$$

$$\therefore \boxed{\delta_V = \frac{K(w\cos\theta)l^3}{E I_{UU}}}$$

'K' is constant depending upon end conditions of the beam and positions of load.

'l' = length of the beam

E = Young's modulus.

The resultant deflection $\delta = \sqrt{\delta_u^2 + \delta_v^2}$

$$\delta = \sqrt{\left[\frac{K(w\sin\theta)l^3}{E.I_{vv}}\right]^2 + \left(\frac{K(w\cos\theta)l^3}{E.I_{uu}}\right)^2}$$

$$\therefore \boxed{\delta = \frac{Kl^3}{E}\sqrt{\left(\frac{w\sin\theta}{I_{vv}}\right)^2 + \left(\frac{w\cos\theta}{I_{uu}}\right)^2}}$$

29/2/2020

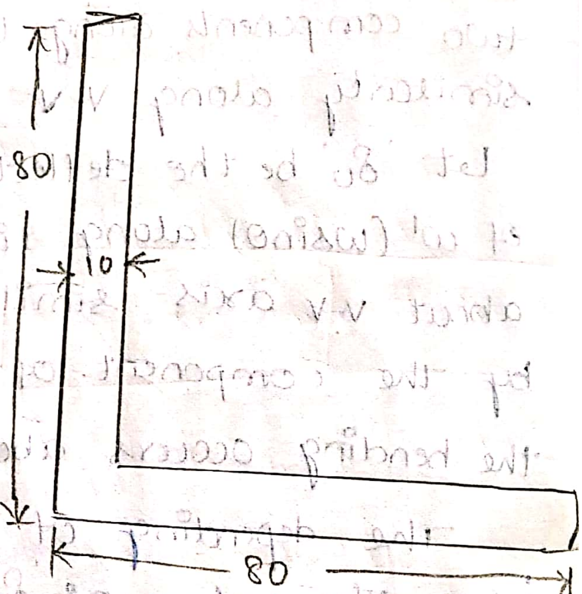
(1) A 80x80x10mm of angle section is shown in fig. It is used as a simply supported beam over a span of 2.4m. It carries a load of 400N along the line YG where 'G' is the centroid of the section. Calculate the (i) stress at points A, B and 'C' of the mid section of the beam. (ii) Deflection of the beam at the mid section and its direction with the load line. (iii) position of Neutral axis. Take $E = 200\ GN/m^2$

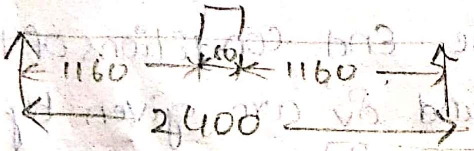
Sol:- Given data,

$l = 2.4m = 2400mm$

Simply supported beam of span 2.4m.

Load (W) = 400N.





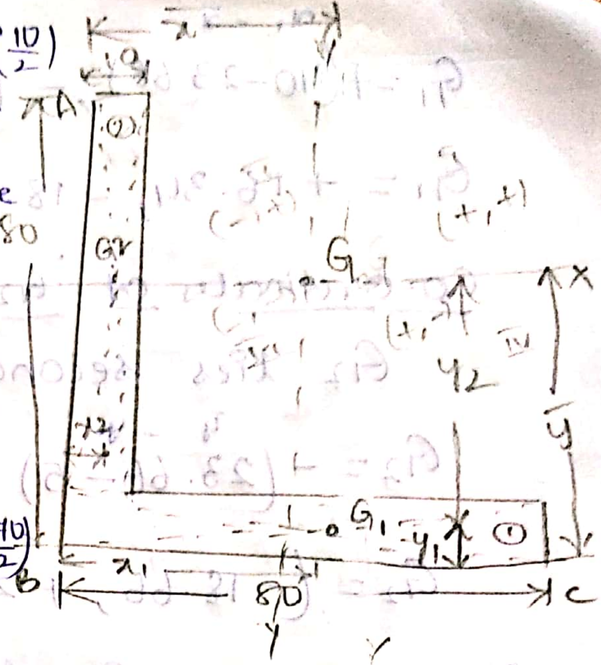
Simply supported beam point load at mid span

$B.M = \frac{Wl}{4} = \frac{400 \times 2400}{4} = 240\ KN.mm = 2.4 \times 10^5 N.mm$

$$\bar{x} = \frac{a_1x_1 + a_2x_2}{a_1 + a_2}$$

$$= \frac{(80\times10)\times\left(\frac{80}{2}\right) + (70\times10)\times\left(\frac{10}{2}\right)}{(80\times10)+(70\times10)}$$

x_1 = distance from G_1 to extreme End.



$\therefore \boxed{\bar{x} = 23.66\ mm}$

$$\bar{y} = \frac{a_1y_1 + a_2y_2}{a_1+a_2}$$

$$= \frac{(80\times10)\left(\frac{10}{2}\right) + (70\times10)\left(10+\frac{70}{2}\right)}{(80\times10)+(70\times10)}$$

$\therefore \boxed{\bar{y} = 23.66\ mm}$

The given section is Equal angle section.

$$I_{xx} = \left[\frac{bd_1^3}{12} + A_1(\bar{y}-y_1)^2\right] + \left[\frac{b_2d_2^3}{12} + A_2(\bar{y}-y_2)^2\right]$$

$$= \left[\frac{80\times10^3}{12} + (80\times10)\left(23.66-\frac{10}{2}\right)^2\right] + \left[\frac{10\times70^3}{12} + (70\times10)(23.66-45)^2\right]$$

$$= 285223.14 + 604610.25$$

$\therefore$ $I_{xx} = 889833.39\ mm^4 = 8.89\times10^5\ mm^4$

$$I_{yy} = \left[\frac{d_1b_1^3}{12} + A_1(\bar{y}-x_1)^2\right] + \left[\frac{d_2b_2^3}{12} + A_2(\bar{y}-x_2)^2\right]$$

$$= \left[\frac{10\times80^3}{12} + (80\times10)\left(23.66-\frac{80}{2}\right)^2\right] + \left[\frac{70\times10^3}{12} + (70\times10)(23.66-5)^2\right]$$

$$= 640263.14 + 249570.2$$

$\therefore \boxed{I_{yy} = 8.89\times10^5\ mm^4}$

Fix the Qudrants of G_1.

G_1 lies fourth Quadrant $(+,-)$

$x_1 - \bar{x}$ $\quad$ $\bar{x} - x_2$

$G_1 = +(40-23.66), -(23.66-5)$

$G_1 = +16.34, -18.66$

<u>Co-ordinates of G_2</u>

G_2 lies second Quardrant $(-,+)$

$\bar{y} - y_1$ $\quad$ $y_2 - \bar{y}$

$G_2 = -(23.66-5), +(45-23.66)$

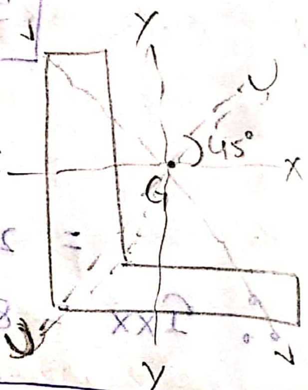
$G_2 = (-18.66, +21.34)$

Product of inertia (I_{xy}) = (Area of ① rectangle × multiplication of co-ordinates) + (Area of ② rectang × multiplication of co-ordinates)

$= (80\times10)\ 16.34\times(-18.66) + (70\times10)\times(-18.66)\times21.34$

$$\boxed{I_{xy} = -5.22\times10^5\ mm^4}$$

<u>Principle Moment of inertia</u> :-



Let U-U and V-V are principle axis.

∴ principle moment of inertia I_{UU}

$$\boxed{I_{UU} = \frac{1}{2}\left[I_{xx}+I_{yy}\right] + \frac{1}{2}\left[I_{xx}-I_{yy}\right]\cos 2\theta - I_{xy}\sin 2\theta}$$

$$= \frac{1}{2}\left[8.89\times10^5 + 8.89\times10^5\right) + \frac{1}{2}\left(8.89\times10^5 - 8.89\times10^5\right)\cos 2\times45° - \left(-5.22\times10^5\times\sin 2\times45°\right.$$

$$∴ \boxed{I_{UU} = 1411000 = 14.11\times10^5\ mm^4}$$

W.K.that M.I of principle axis = M.I of co-ordinate axis.

$I_{UU} + I_{VV} = I_{xx} + I_{yy}$

$I_{VV} = I_{xx} + I_{yy} - I_{UU}$

$= (8.89\times10^5) + (8.89\times10^5) - (14.11\times10^5)$

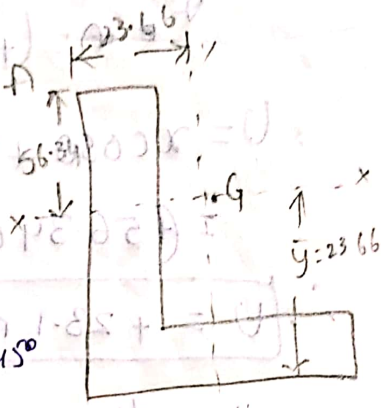
$\therefore \boxed{I_{VV} = 3.66\times10^5\ mm^4}$

(i) calculation of stresses at point 'A'

$B.M = M = 2.4\times10^5\ N.mm$

$M' = M\sin\theta = 2.4\times10^5 \times \sin 45° = 1.69\times10^5\ N.mm$

$M'' = M\cos\theta = 2.4\times10^5 \times \cos 45° = 1.69\times10^5\ N.mm$



~~stresses~~ co-ordinates at A.

$A = (-23.66), (+56.34)$

$U = x\cos\theta + y\sin\theta$

$= -23.66\cos45° + 56.34\sin45°$

$\therefore \boxed{U = 23.10\ mm}$

$V = \frac{du}{d\theta} = -x\sin\theta + y\cos\theta$

$= -(-23.66)\sin45° + 56.34\cos45°$

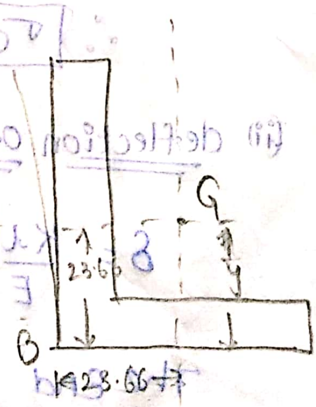
$\therefore \boxed{V = 56.56\ mm}$

$$\sigma_A = \frac{M'U}{I_{VV}} + \frac{M''V}{I_{UU}}$$

$$= \left(\frac{1.69\times10^5\times 23.1}{3.66\times10^5}\right) + \left(\frac{1.69\times10^5\times56.56}{14.11\times10^5}\right)$$

$= 10.66 + 6.77$

$\therefore \boxed{\sigma_A = 17.43\ N/mm^2}$



$B = (-23.66), (-23.66)$

$U = x\cos\theta + y\sin\theta$

$= (-23.66\cos45°) + (-23.66\sin45°)$

$\therefore \boxed{U = -33.46mm}$

$V = \frac{du}{d\theta} = -x\sin\theta + y\cos\theta$

$= -(-23.66\sin45°) + (-23.66\cos45°)$

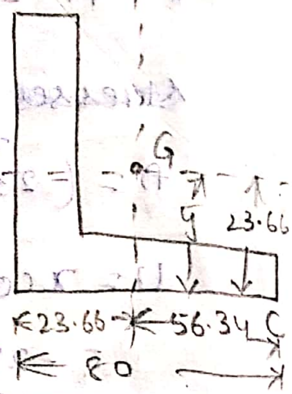
$\boxed{V = 0}$

$$\sigma_B = \frac{M'U}{I_{VV}} + \frac{M''V}{I_{UU}}$$

$$= \frac{1.69\times10^5 \times (-33.46)}{3.66\times10^5} + \frac{1.69\times10^5\times 0}{14.11\times10^5}$$

$$\therefore \boxed{\sigma_B = -15.45\ N/mm^2}$$

σ_C $C = (+56.34), (23.66)$



$$U = x\cos\theta + y\sin\theta$$

$$= (+56.34\cos45^\circ) + (-23.66\sin45^\circ)$$

$$\therefore \boxed{U = +23.1\ mm}$$

$$V = \frac{du}{d\theta} = -x\sin\theta + y\cos\theta$$

$$= -56.34\sin45^\circ + (-23.66\cos45^\circ)$$

$$\therefore \boxed{V = -56.56\ mm}$$

$$\sigma_C = \frac{M'U}{I_{VV}} + \frac{M''V}{I_{UU}}$$

$$= \frac{1.69\times10^5 \times 23.1}{3.66\times10^5} + \frac{1.69\times10^5\times(-56.56)}{14.11\times10^5}$$

$$= \cancel{-5.040\ N/mm^2}\ 10.66 + (-6.74)$$

$$\therefore \boxed{\sigma_C = 3.88\ N/mm^2}$$

(ii) deflection of the beam :-

$$\delta = \frac{Kl^3 W}{E}\sqrt{\left(\frac{\sin\theta}{I_{VV}}\right)^2 + \left(\frac{\cos\theta}{I_{UU}}\right)^2}$$

The End condition is simply supported $K = \frac{1}{48}$

$W = 400N$, $l = 2400mm$, $E = 200\ GN/m^2$

$I_{UU} = 14.12\times10^5\ mm^4$, $I_{VV} = 3.66\times10^5\ mm^4$ $= 200\times10^9\ N/m^2$

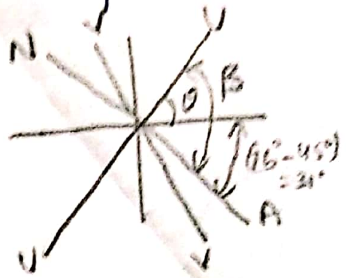
$\theta = 45^\circ$ $= 200\times10^3\ N/mm^2$

$$\delta = \frac{1}{48} \times \frac{2400^3}{200 \times 10^3} \times 400 \sqrt{\left(\frac{\sin 45^\circ}{3.66 \times 10^5}\right)^2 + \left(\frac{\cos 45^\circ}{14.12 \times 10^5}\right)^2}$$

$$= 576000 \sqrt{3.98 \times 10^{-12}}$$

$$\therefore \boxed{\delta = 1.14\,mm}$$

(iii) Let θ = Angle b/w co-ordinate axis to principle axis, β = Angle b/w Neutral axis to principle axis



$$\tan\beta = \frac{I_{UU}}{I_{VV}} \cdot \tan\theta.$$

$$= \frac{14.12 \times 10^5}{3.468 \times 10^5} \times \tan 45^\circ$$

$\tan\beta = 4.08057 \Rightarrow \beta = \tan^{-1}(3.857)$.

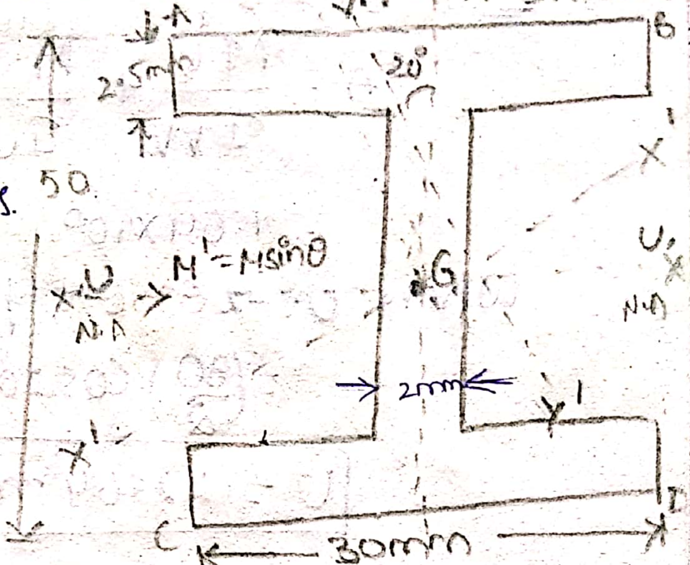
$\therefore \beta = 76^\circ 28'$

Position of Neutral axis

The Neutral axis is perpendicular to line of deflection angle. $(90^\circ - \text{deflection angle})$

$= 90^\circ - 31^\circ = 59^\circ$

① A cantilever of I-section 2.4m long is subjected to a load of 200N at the free end. Determine the resulting stress at corners A & B on the fixed section of cantilever.

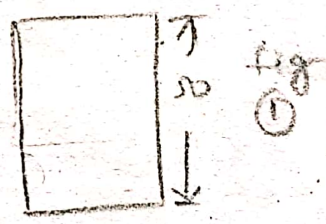


→ let X'-X' and Y'-Y' are co-ordinate axis.

** X-X and Y-Y (or) U-U and V-V are principle axis.

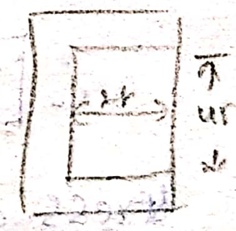
Let us Assume I-section is a symmetrical section then moment of inertia of principle axis

$$I_{xx} = I_{UU} = \frac{BD^3}{12} - \frac{bd^3}{12}$$



$$= \frac{30\times50^3}{12} - \frac{28\times45^3}{12}$$

$$= 99875\,mm^4$$

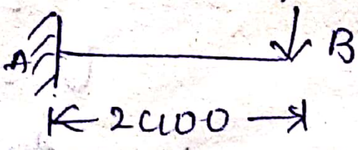


$$I_{yy} = I_{VV} = 2\left(\frac{2.5\times30^3}{12}\right) + \frac{45\times2^3}{12}$$

$$= 11280\,mm^4$$

Given support beam is cantilever the I-section acts at freend.

Cantilever beam with point load at freeend.



$B.M = Wl$

$= 200\times2400$

$= 480000\,N.mm$

$M' = M\sin\theta = 480000 \times \sin 20^\circ = 1.64\times10^5$ N.m

$M'' = M\cos\theta = 480000 \times \cos 20^\circ = 4.51\times10^5$ N.m

Stress at a 'A' — 4^{th} Quadrant $(-,+)$

$$\sigma_A = \frac{M'U}{I_{VV}} + \frac{M''V}{I_{UU}}$$

where $U = -x\cos\theta + y\sin\theta$

$$= -\left(\frac{30}{2}\right)\cos 20^\circ + \left(\frac{50}{2}\right)\sin 20^\circ$$

$\therefore \boxed{U = \cancel{22.64}\ mm}$ -5.54 mm

$$V = \frac{du}{d\theta} = -(-x\sin\theta) + y\cos\theta$$

$$= +\left(\frac{30}{2}\sin 20^\circ\right) + \left(\frac{50}{2}\cos 20^\circ\right)$$

$$= 18.362\,mm$$

$$\sigma_A = \frac{1.64\times10^5 \times -5.54}{11280} + \frac{4.51\times10^5 \times 18.3}{99875}$$

$\therefore \boxed{\sigma_A = 49.2\cdot28\ N/mm^2}$

Stress at a 'B' :- at 1^{st} Quadrant $(+,+)$

$$\sigma_B = \frac{M'U}{I_{VV}} + \frac{M''V}{I_{UU}}$$

where, $U = x\cos\theta + y\sin\theta$

$$= 15\times\cos 20^\circ + 25\sin 20^\circ$$

$$U = 22.64\,mm.$$

$$V = \frac{du}{d\theta} = -x\sin\theta + y\cos\theta$$

$$= -\left(\frac{30}{2}\sin 20^\circ\right) + 25\cos 20^\circ$$

$V_B = 18.36mm$

$$\sigma_B = \frac{1.64 \times 10^5 \times 22.64}{11280} + \frac{18.36 \times 4.51 \times 10^5}{99875}$$

$$\therefore \boxed{\sigma_B = 412.07 \, N/mm^2}$$

Stress at 'C'

3rd Quardrant (-,-)

$$\sigma_C = \frac{M'U}{I_{VV}} + \frac{M''V}{I_{UU}}$$

$$U = -x\cos\theta - y\sin\theta$$

$$= -15\cos 20^\circ - 25\sin 20^\circ$$

$$= -22.64 \, mm$$

$$V = \frac{du}{d\theta} = -(x\sin\theta) - y\cos\theta$$

$$= 15 \times \sin 20^\circ - 25 \times \cos 20^\circ$$

$$= -18.36 mm$$

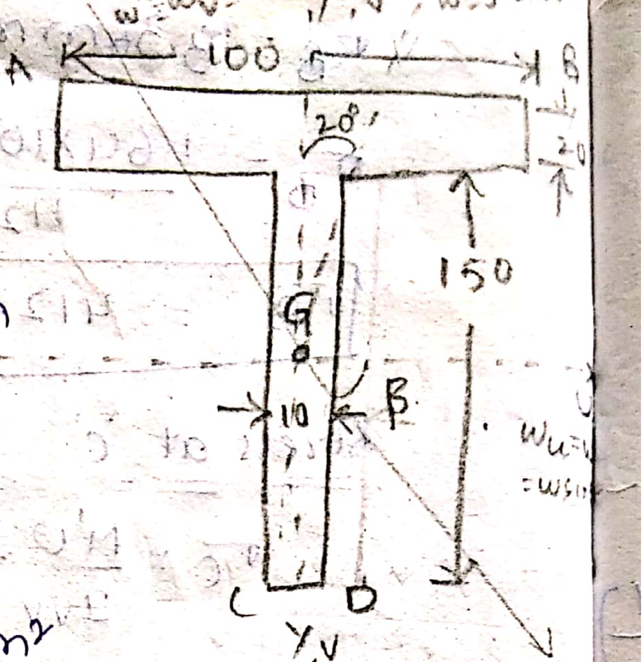
$$\sigma_C = \frac{1.64 \times 10^5 \times -22.64}{11280} + \frac{4.51 \times 10^5 \times -18.36}{99875}$$

$$= -329.163 - 82.90$$

$$\therefore \boxed{\sigma_C = -412.07 \, N/mm^2}$$

(2) A beam of 'T' section of flange dimension is 100mm x 20mm, web dimension is 150mm x 10mm, is 2.5m length and is simply support-ed at it's ends. It carries a load of 3.2 kN. inclined at 20° to the vertical and passing through the centroid of the section. Take $E = 200 \, GN/m^2$. Calculate (i) the max. Tensile stress and compressive stress. (ii) Deflection due to load (iii) position due to principle axis.

— Given data,



The principle axis are

X-X = U-U , Y-Y = V-V.

Then $l = 2.5m = 2500mm$

$W = 3.2KN.$

$\theta = 20°$

$E = 200\ GN/m^2$

$= 200 \times 10^3\ N/mm^2$

for simply supported beam with point load $B.M = \frac{Wl}{4} = \frac{3200 \times 2500}{4} = 20 \times 10^5\ N.mm$

$\bar{x} = \frac{a_1x_1 + a_2x_2}{a_1 + a_2} = \frac{(150 \times 10) \times \frac{100}{2} + (100 \times 20) \times \frac{100}{2}}{(150 \times 10) + (100 \times 20)}$

$\therefore \boxed{\bar{x} = 50\ mm}$

$\bar{y} = \frac{a_1y_1 + a_2y_2}{a_1 + a_2} = \frac{(150 \times 10) \times \frac{150}{2} + (100 \times 20) \times 150 + \frac{20}{2}}{(150 \times 10) + (100 \times 20)}$

$\therefore \boxed{\bar{y} = 123.57\ mm}$ from bottom.

$\therefore \boxed{\bar{y} = 170 - 123.5 = 46.5\ mm}$ from top

5/3/2020

$I_{xx} = \frac{bd^3}{12} + A \times (\bar{y} - y_1)^2 + \frac{bd^3}{12} + A\ (\bar{y} - y_2)^2$

$= \frac{100 \times 20^3}{12} + (100 \times 20)\left(46.5 - \frac{20}{2}\right)^2 + \frac{10 \times 150^3}{12} + (10 \times 150)\left(46.5 - 20 + \frac{150}{2}\right)^2$

$= 27.31 \times 10^5 + 63.4 \times 10^5$

$I_{xx} = 90.7 \times 10^5\ mm^4$

$$I_{yy} = \frac{db^3}{12} + A(\bar{x}-x_1)^2 + \frac{db^3}{12} + A(\bar{x}-x_2)^2$$

$$= \frac{20\times100^3}{12} + (20\times100)(50-50)^2 + \frac{150\times10^3}{12} + (150\times10)(50-50)^2$$

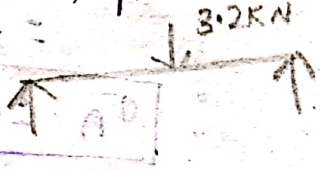
$$\therefore \boxed{I_{yy} = 16.79\times10^5\ mm^4}$$

Components of (ω)

$\omega' = \omega\sin\theta = 3.2\times10^3 \times \sin20^\circ = 1094.46N$

$\omega'' = \omega\cos\theta = 3.2\times10^3 \times \cos20^\circ = 3007.01N.$

for simply supported beam with point load.



$$B.M = \frac{\omega l}{4} = \frac{3.2\times2500}{4}$$

$= 2000$ kN.mm

In ω consists of two components. i.e., ω' and ω''

$$M' = \frac{\omega' l}{4} = \frac{1094.46\times2500}{4} = 684.03\times10^3 N.mm$$

$$M'' = \frac{\omega'' l}{4} = \frac{3007.01\times2500}{4} = 1.87\times10^6 N.mm$$

M' will cause max. compressive stress at B & D. M'' will cause max. tensile stress at C & D. ~~A~~.

$\therefore$ Maximum tensile stress.

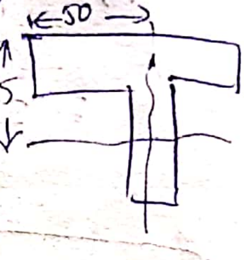
$$\sigma_A = \frac{M'U}{I_{VV}} + \frac{M''V}{I_{UU}}$$

~~$= 684.03\times10^3\times$~~

'A' lies 2nd Quardrant $(-,+)$ $\therefore$ $-50, +46.5$.

$U = x\cos\theta + y\sin\theta$

$= -50\cos 20^\circ + 46.5 \times \sin 20^\circ$



$= -31.08\ mm$

$V = \dfrac{du}{d\theta} = -x\sin\theta + y\cos\theta$

$= -(-50\sin 20^\circ + 46.5\cos 20^\circ)$

$= 60.79\ mm$

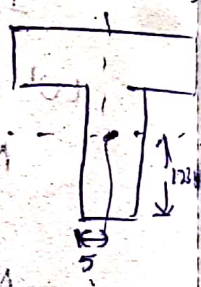
$$\sigma_A = \left(\frac{684.03\times10^3 \times (-31.08)}{16.79\times10^5}\right) + \left(\frac{1.87\times10^6 \times 60.79}{90.7\times10^5}\right)$$

$= -12.66 + 12.53$

$\therefore \boxed{\sigma_A = -0.12\ N/mm^2}$

σ_C lies in 3rd Quardrant $(-,-) = (-5, -123.6)$

$U = x\cos\theta + y\sin\theta$



$= -5\cos 20^\circ + (-123.6 \times \sin 20^\circ)$

$= -46.97\ mm$

$V = -x\sin\theta + y\cos\theta$

$= -(-5\sin 20^\circ) + (-123.6 \times \cos 20^\circ)$

$= -114.4\ mm$

$$\sigma_C = \left(\frac{684.03\times10^3 \times (-46.97)}{16.79\times10^5}\right) + \left(\frac{1.87\times10^6 \times (-114.4)}{90.7\times10^5}\right)$$

$= -19.13 + (-23.5)$

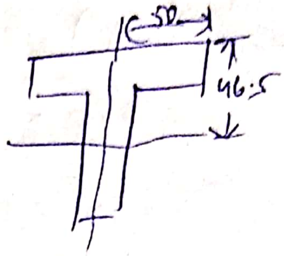
$\therefore \boxed{\sigma_C = -42.7\ N/mm^2}$

'B' lies 1st Quadrant $(+,+)$ $(50, 46.5)$

$U = x\cos\theta + y\sin\theta$

$= 50\times\cos 20^\circ + 46.5\times\sin 20^\circ$

$= 62.88\,mm$



$V = -x\sin\theta + y\cos\theta$

$= -50\sin 20^\circ + 46.5\times\cos 20^\circ$

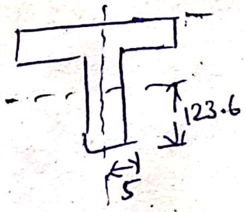
$= 26.59\,mm$

$$\sigma_B = \left(\frac{684.03\times10^3\times(62.88)}{16.79\times10^5}\right) + \left(\frac{1.87\times10^6\times 26.59}{90.7\times10^5}\right)$$

$= 25.61 + 5.48$

$\therefore \boxed{\sigma_B = 31.092\ N/mm^2}$

'D' lies in 4th Quadrant $(+,-)$ $(+5, -123.6)$



$U = x\cos\theta + y\sin\theta$

$= 5\cos 20^\circ + (-123.6\sin 20^\circ)$

$= -37.5\ mm$

$V = -x\sin\theta + y\cos\theta$

$= -5\sin 20^\circ + (-123.6\cos 20^\circ)$

$= -117.85\,mm$

$$\sigma_D = \frac{684.03\times10^3\times(-37.5)}{16.79\times10^5} + \frac{1.87\times10^6\times(-117.85)}{90.7\times10^5}$$

$= -15.27 + (-24.29)$

$\therefore \boxed{\sigma_D = -39.56\ N/mm^2}$

(ii) Deflection of beam

$$\delta = \frac{Kwl^3}{E}\sqrt{\left(\frac{\sin\theta}{I_{vv}}\right)^2 + \left(\frac{\cos\theta}{I_{uu}}\right)^2}$$

'K' is constant for S.S Beam $\left(\frac{1}{48}\right)$

$$= \frac{1}{48} \times \frac{3.2\times10^3 \times 2500^3}{200\times10^3}\sqrt{\left(\frac{\sin 20^\circ}{16.79\times10^5}\right)^2 + \left(\frac{\cos 20^\circ}{90.7\times10^5}\right)^2}$$

$$= 5.20\times10^6 \times 2.28\times10^{-7}$$

$$\therefore \boxed{\delta = 1.18\,mm}$$

(iii) Position of Neutral axis

$$\tan\beta = \frac{I_{uu}}{I_{vv}} \cdot \tan\theta$$

$$= \frac{90.7\times10^5}{16.79\times10^5} \times \tan 20^\circ$$

$$= \tan^{-1}(1.966)$$

$$\therefore \boxed{\beta = 63^\circ 2'}$$