Ch-3 Bending moments and sheering force

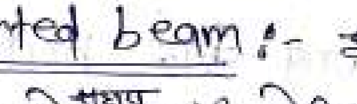
(1) Point Load :- एक बिंदु लोड या केन्द्रित भार वह होता है जिसे पॉइंट के मे कार्य करने के लिए माना जाता है। वास्तविक अभ्यास मे, भार के एक छोटे से क्षेत्र मे वितरित किया जाना चाहिए क्योंकि इस सतह तरह के छोटे चाकू - किनारे के संपर्क आमतौर पर न तो संभव है और न ही वाछनीय।

2) Distributed Load :- वितरित भार वह होता है जिसे किसी body के सतह पर कार्य करने के लिए जाना जाता है। वास्तविक में भार किसी सतह पर वितरित होता है।

Types of Beam

(1) Cantilever beam :- इस बिम का एक साइड फिक्स रहता है तथा दूसरा साइड फ्री रहता है जिसमे लोड भार लगता है।

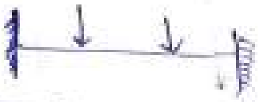
(2) Simply supported beam :- इस बिम के दोनो अंतिम छोर मे दो सपोर्ट रहता है लेकिन उसके बीच मे लगातार एया 3 और स्पोर्ट के लिए रहता है।



(3) Continous beam :- इस बिम मे दो स्पोर्ट के लिए होते हैं और उसके बाएँ एवं दाएँ मे स्पोर्ट के लिए रहता है।

(4) Overhanging beam :- एक ओवरहैंगिंग बीम वह है जिसमे समर्थन समाप्त नही होता है यानी कि एक या दोनो सिरो के समर्थन से परे है इसमे समर्थन से बिम आगे निकल जाता है।

⑤ **Fixed beam** :- एक निश्चित बीम वह है जिसका दोनों अंत कठोर खम्भे से सख या उसके अंदर समस्क दीवारों या स्तम्भो मे होता है।

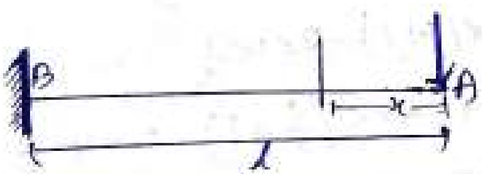


Shear Force :- ~~इसी तरह 'नकारात्मक' कतरन बल~~ । एक कतरनी बल दाहिने हाथ की ओर एक ऊपर की दिशा है। धारा या ऊपर की दिशा अनुभाग के बाई ओर या नीचे की दिशा मे नीचे की दिशा को सकारात्मक लिया जाएगा। इसी तरह नकारात्मक कतरन बल।

~~अरप का eft एक~~

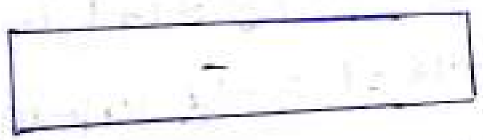
इसमे Right hand side से हल करता है। ↓(−) ↑(+)

Bending moment :-



S.F at $x = S_x = -W$

B.M. at $x = M_x = -Wx$



$x = 0$

$B.M = 0$

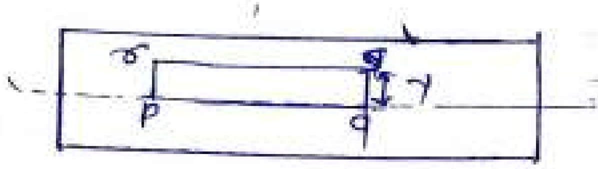
$x = l$

$B.M = Wl$

CHAPTER - 4 Bending Stresses in B

Imp

Bending eqn. → $\boxed{\frac{\sigma}{y} = \frac{M}{I} = \frac{E}{R}}$

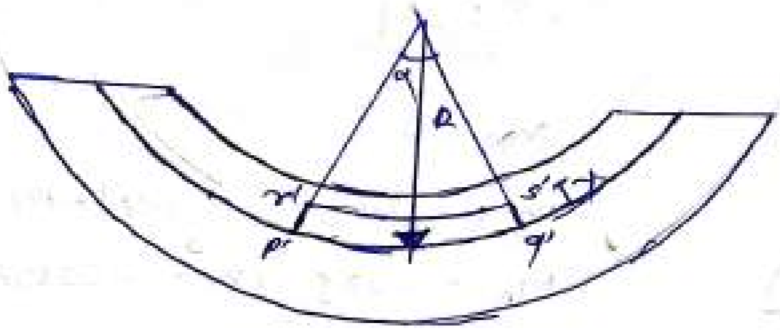


Before bending $rs = pq$

After Bending

$rs \neq r's'$

$pq = p'q'$



Strain = $\frac{\text{Change in length}}{\text{original length}}$ $r's' = (R-y)\alpha$; $p'q' = R\alpha$

$rs = pq = p'q' = R\alpha$

In $rs = \frac{rs - r's'}{rs}$

$= \frac{R\alpha - (R-y)\alpha}{R\alpha}$

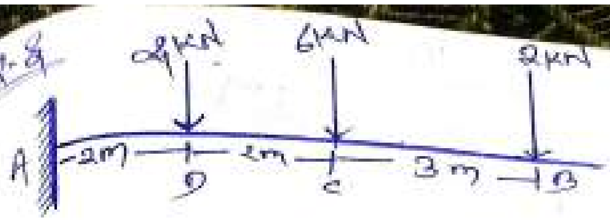
$= \frac{R\alpha - R\alpha + y\alpha}{R\alpha}$

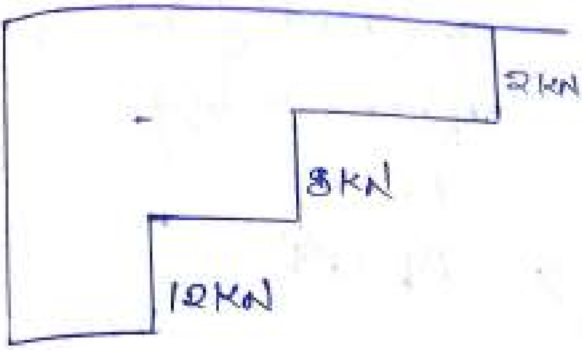
$= \frac{y\alpha}{R\alpha} = \frac{y}{R}$

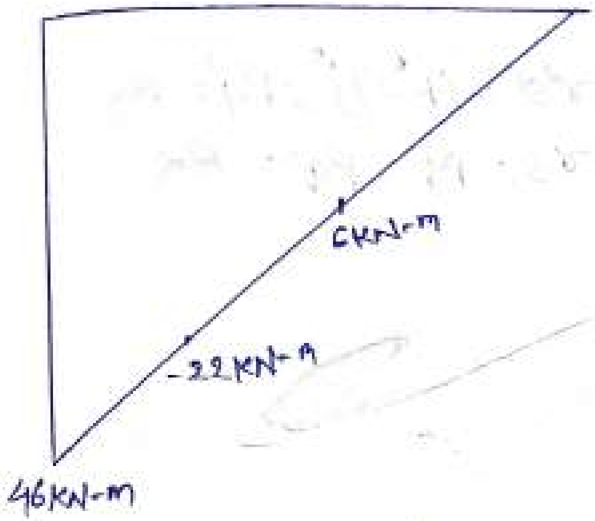
$$\boxed{\frac{\sigma}{E} = \frac{y}{R}}$$

$$\boxed{\frac{\sigma}{y} = \frac{E}{R}} \quad (1)$$

Q-8







S.F

$S_B = -2kN$

$S_C = -2-6 = -8kN$

$S_D = -2-6-4 = -12kN$

B.M

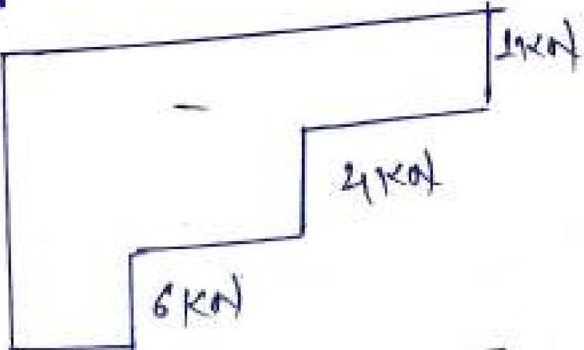
$M_B = 0$

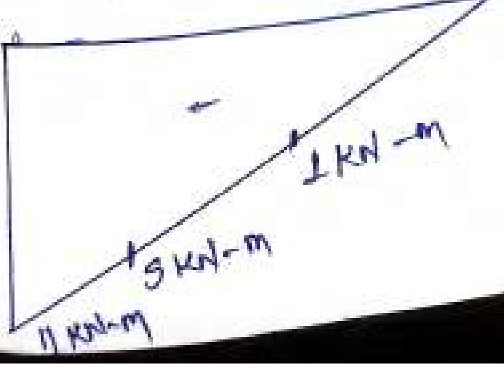
$M_C = -2\times3 = -6 kN\text{-}m$

$M_D = -2\times5 - 6\times2 = -22 kN\text{-}m$

$M_A = -2\times7 - 6\times4 - 4\times2 = -46 kN\text{-}m$

Q-9 :-





S.F

$S_B = -1kN$

$S_C = -1-3 = -4kN$

$S_D = -1-3-2 = -6kN$

B.M

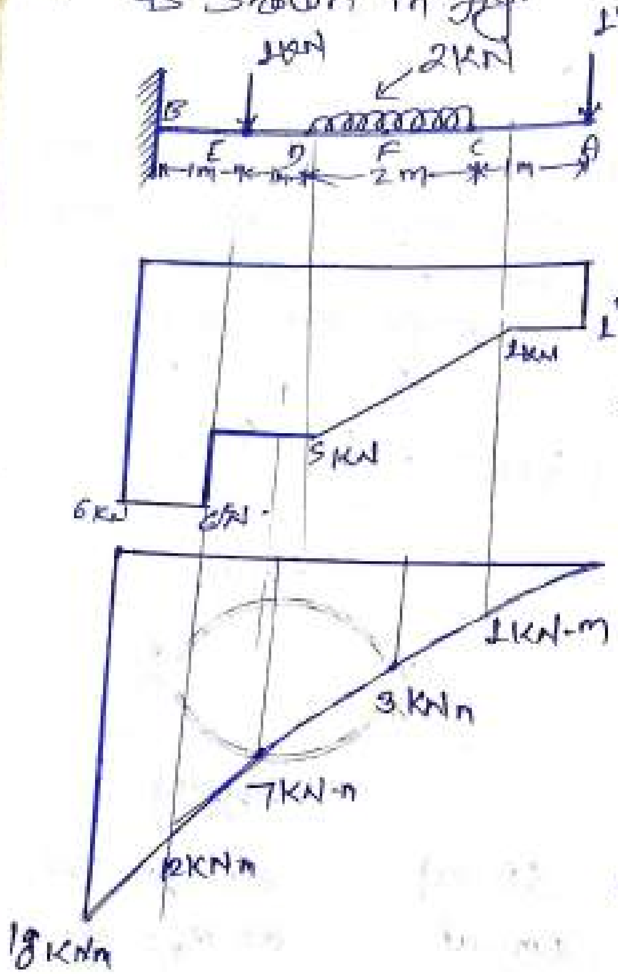
$M_D = 0$

$M_C = -1\times1 = -1 kN\text{-}m$

$M_D = -1\times2 - 3\times1 = -5 kN\text{-}m$

$M_A = -1\times3 - 3\times2 - 2\times1 = -11 kN\text{-}m$

Q→ Draw the S.F. and B.M diagrams for [illegible]
as shown in fig.



S.F

$S_A = -1KN$

$S_D = -1-2\times2 = -5KN$

$S_E = -5-1 = -6KN$

$S_B = -6KN$

B.M

$M_A = 0$

$M_C = -1\times1 = -1KN/-m$

$M_D = -1\times(1+2)-2\times2\times\frac{2}{2} = -3-4 = -7$

$M_F = -1\times(1+1)-2\times1\times\frac{1}{2} = -2-1 = -3KN$

$M_E = -1\times4-2\times2\left(\frac{2}{2}+1\right) = -4-8 = -12KN$

$M_B = -1\times5-2\times2\left(\frac{2}{2}+1+1\right)-1\times1$

$= -5-12-1 = -18\ KN\text{-}m$

Q.2→

S.F) $S_A = 1KN$

$S_C = -2\times0 = 0KN$

$S_F = -2\times1 = -2KN$

$S_D = -2\times2 = -4KN$

$S_E = 1\times1 = -1KN$

$S_B = 1-2-1 = -4KN$

BM

$M_A = 0,\ M_C = 0$

$M_F = -2\times1\times\frac{1}{2} = -2KN$

$M_D = -2\times2\times\frac{2}{2} = 4KN\text{-}m$

$M_E = 2\times4 = 4KN\text{-}m$

$M_B = 1\times4-1\times2-1\times1$

$= -4-2-1$

$= -7$

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

$$I = \frac{bd^3}{12} = \frac{0.15 \times 0.25^3}{12}$$

$$= 0.0001953\ m^4$$

$$\frac{\sigma}{y} = \frac{M}{I}$$

$$\sigma = \frac{M}{I} \times y$$

$$= \frac{750 \times 10^3}{0.0001953} \times 0.125$$

$$= 4.8 \times 10^8\ N/m^2$$

$$\frac{M}{I} = \frac{E}{R}$$

$$R = \frac{M}{I} = E$$

$$= \frac{750 \times 10^3}{0.0001953} \times 200 \times 10^9$$

$R = 52.08$

$$\frac{M}{I} = \frac{\sigma_1}{y_1}$$

$y_1 = 0.0125\ m$
$b = 0.15\ m$
$d = 0.025\ m$

$$\sigma_1 = \frac{M}{I} \times y_1$$

$$= \frac{750 \times 10^3}{0.0001953} \times 0.06$$

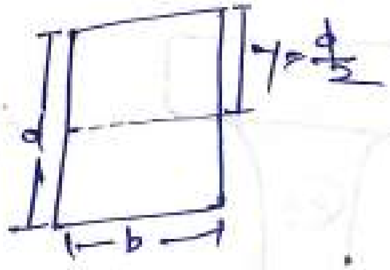
$$= 230.41 \times 10^6$$

Q.→ A simply supported timber beam of rectangular section carries 30 kN uniformly distributed load over a span of 3.5 m. If the depth of the beam is twice than width of the beam section and maximum stress is not exceed 7 MPa, find the dimension of the beam.

Sol:-

$$B.M = M_C = \text{load} \times \text{dis.} \times \frac{\text{dis.}}{2}$$

$$= w \times \frac{l}{2} \times \frac{l}{4}$$



$$M_{max} = \frac{wl^2}{8} \text{ or } \frac{wl}{8}$$

$$M = \frac{30 \times 3.5}{8}$$

$M = 13.5\ kN\text{-}m$

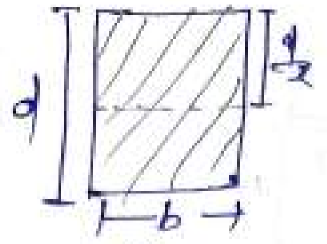
$M = 13.5 \times 10^3\ N\text{-}m$

$d = 2b$

$\sigma = 7\ MPa = 7 \times 10^6\ N/m^2$

1) Moment of Inertia

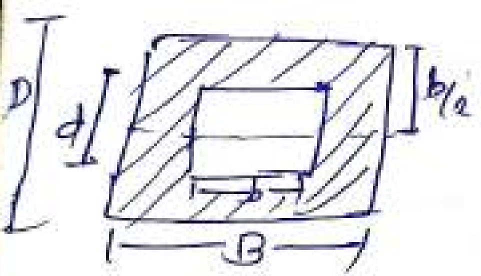
Solid Rectangular section , Solid circular section



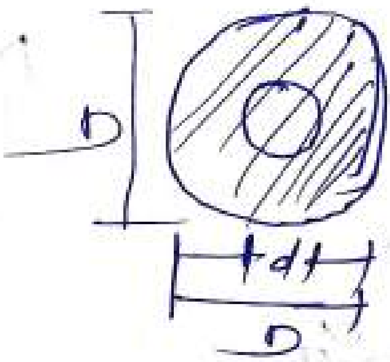
$I = \frac{bd^3}{12}$

$I = \frac{\pi d^4}{64}$

Hollow Rectangular section   Hollow Circular Section



$I = \frac{BD^3}{12} - \frac{bd^3}{12}$

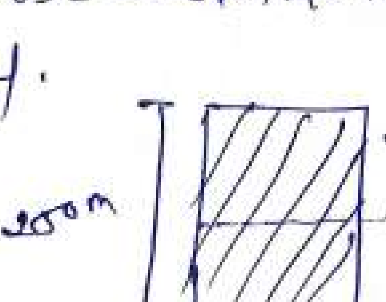


$I = \frac{\pi D^4}{64} - \frac{\pi d^4}{64}$

Q. A 200 mm (depth) x 150 mm (width) rectangular beam is subjected to maximum bending moment of 750 kN-m. Determine.

1) maximum stress
2) If $E = 200 GN/m^2$; find radius of curvature

Sol.



$y = \frac{200}{2} = 125$

$E = 200\ GN = 200 \times 10^9\ N/m$

$M = 750\ kN\text{-}m = 750 \times 10^3\ N/m$

$\sigma = max$

$R = ?$

$y_1 = 125 - 65$

$= 60$

$\therefore \sigma = \frac{E}{R} y$

force in elementary strip

$F = \frac{E}{R} \cdot y \cdot \delta a$

Bending movment

$= \text{force} \times \text{Distence}$

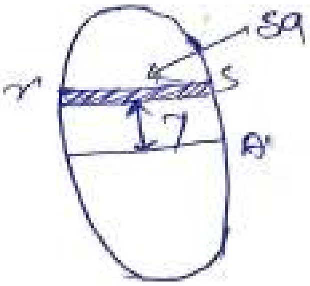
$= \frac{E}{R} \cdot y \cdot \delta a \cdot y$

$\Delta M_b = \frac{E}{R} \cdot y^2 \cdot \delta a$

$\sum \Delta M_b = \frac{E}{R} \sum y^2 \cdot \delta a$

$M = \frac{E}{R} \cdot I$

$\boxed{\frac{M}{I} = \frac{E}{R}}$ — ②



M.O.I = Distance^2 × Area

$I = \sum y^2 \cdot \delta a$

$M = \sum \Delta M_b$

समी ① व ② से

$\frac{M}{I} = \frac{E}{R}, \quad \frac{\sigma}{y} = \frac{E}{R}$

$\boxed{\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}}$ → Dirivation of Bending momen in equaction

M -

I -

σ - Stress

y - Natural axis of Distance

E - modulus of Elasticity

R - Radious of curvature.

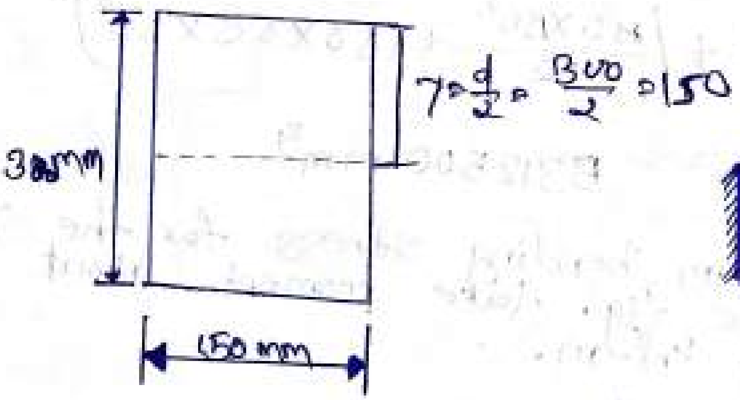
$$\sigma = \frac{M}{I} \times y$$

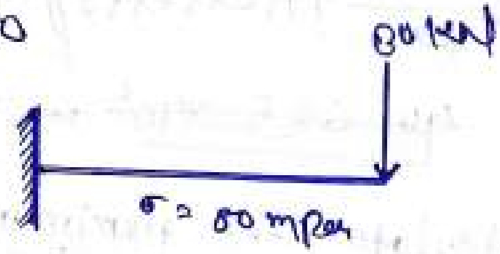
$$= \frac{3.4\times10^{3}}{0.531\times10^{-4}} \times 0.125$$

$$= 8.0037\times10^{6}\ N/m^2$$

Q.→ A Cantilever beam of rectangular Section 150 mm wide and 30 mm Deep. If the Cantilever is sujected to a point load of 30 kN at the free end and the bending stress is not to exceed 80 mpa. find the spen of the beam.

Sol:





$b = 150\ mm = 150\times10^{-3}\ m$

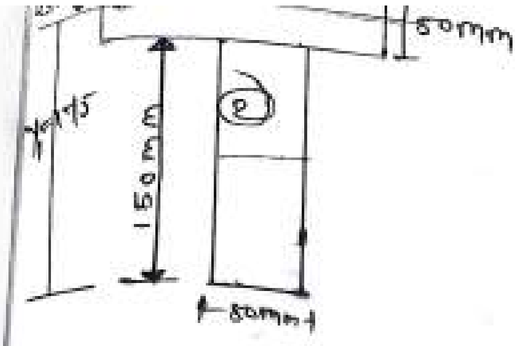
$d = 300\ mm = 300\times10^{-3}\ m$

$\sigma = 50\times10^{-6}\ pa$

सूत्र $\left\{\frac{M}{I} = \frac{\sigma}{y}\right\}$

$$I = \frac{bd^3}{12} = \frac{(150\times10^{-3})\times(300\times10^{-3})^3}{12}$$

$$I = 3.375\times10^{-4}\ m$$



$A_1 = 150 \times 50 \ mm^2$

$y_1 = 175 = \frac{150}{2} = 75 = 175 mm^2$

$A_2 = 150 \times 50 \ mm^2$

$y_2 = \frac{150}{2} = 75 mm$

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2} = \frac{150 \times 50 \times 175 + 150 \times 50 \times 75}{150 \times 50 + 150 \times 50} = 125 \ mm$$

$$I = \left(\frac{b_1 d_1^3}{12} A_1 h_1^2\right) + \left(\frac{b_2 d_2^3}{12} A_2 h_2^2\right)$$

$h_1 = (175 - 125) = 50$

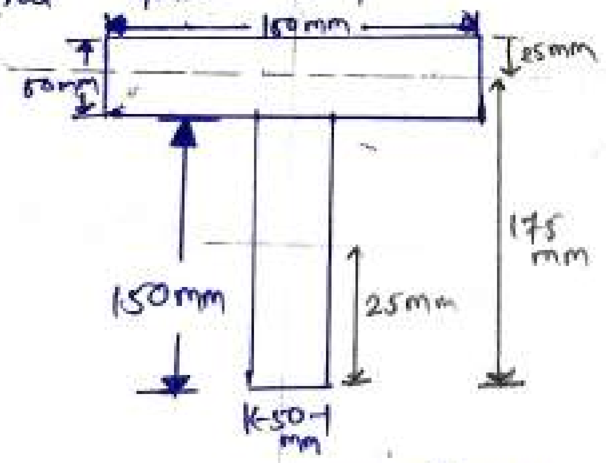
$h_2 = (125 - 75) = 50$

$$= \left(\frac{150 \times 50^3}{12} + 150 \times 50 \times 50^2\right) + \left(\frac{150 \times 50^3}{12} + 150 \times 50 \times 50^2\right)$$

$$= \cancel{40.625 \times 10^6 \ mm^4} = 5312500 \ mm^4$$

2019 N02

Q.→ Calculate the maximum bending stress for the T-section given below in the fig. take moment about Netural axis = 3.4 KN-m.



Sol:- $M = 3.4 \ KN\text{-}m = 3.4 \times 10^3 \ \cancel{K}N/m$

$I = 5312500 \ mm^4 = 5312500 \times 10^{-12} \ m^4 = 0.531 \times 10^{-4} \ m^4$

$y = \bar{y} = 125 \ mm = 0.125 \ m$

$$\left\{\frac{M}{I} = \frac{\sigma}{y}\right\}$$

∴ Solid rectangular section is

$$I = \frac{bd^3}{12} = \frac{b\times(2b)^3}{12} = \frac{8b^3}{12} = \frac{2b^3}{3}$$

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\frac{13.5\times10^3}{2b^{\cancel{3}2}/3} = \frac{7\times10^6}{\cancel{b}}$$

$$\Rightarrow b^2 = \frac{13.5\times10^3\times3}{7\times10^6}$$

$b^2 = 5.785\times10^{-3}$ m

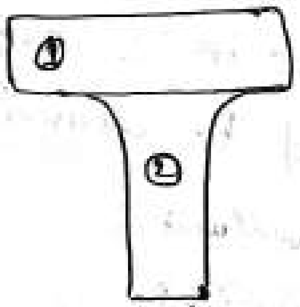
$b = 0.00578$ m

$d = 2b$

$d = 2\times0.00578$

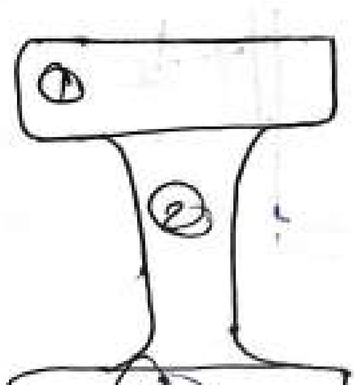
$d = 0.01156$ m

T-Section and I-Section



$$\bar{y} = \frac{A_1y_1 + A_2y_2}{A_1+A_2}$$

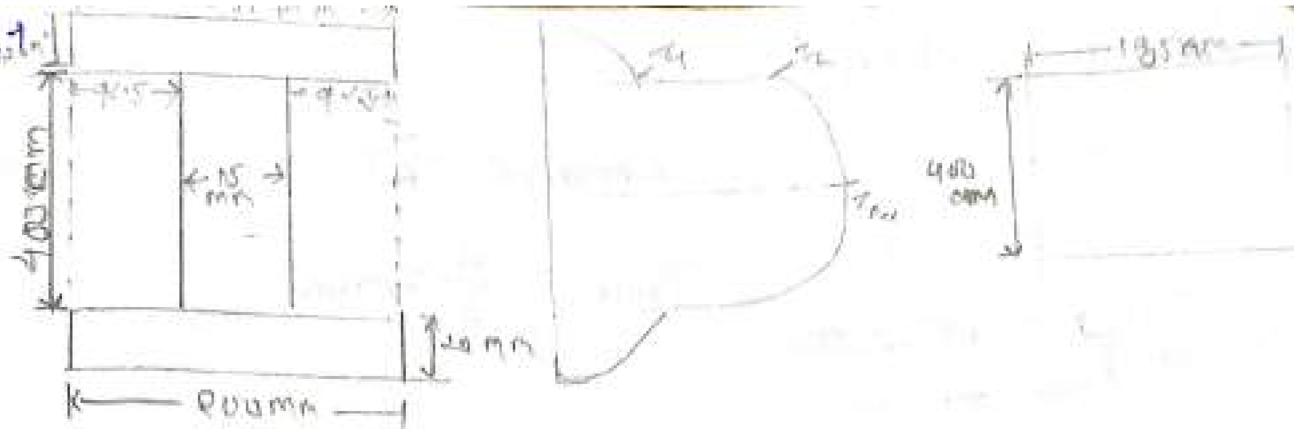
$$I = \left(\frac{b_1d_1^3}{12} A_1y_1^2\right) + \left(\frac{b_2d_2^3}{12} A_2y_2^2\right)$$



$$\bar{y} = \frac{A_1y_1 + A_2y_2 + A_3y_3}{A_1+A_2+A_3}$$

$$I = \left(\frac{b_1d_1^3}{12} A_1y_1^2\right) + \left(\frac{b_2d_2^3}{12} A_2y_2^2\right) + \left(\frac{b_3d_3^3}{12} A_2y_2^2\right)$$

Sol.:



$$I = \frac{BD^3}{12} - \frac{bd^3}{12} = \frac{200 \times 440^3}{12} - \frac{185 \times 400^3}{12} = 433066666.67 \ \text{m}^4$$

$$\tau_1 = \frac{150}{8 \times 433066666.67}(0.44^2 - 0.4^2) = 1.454741379 \times 10^{-9} \ \text{kN/m}^2$$

$$\tau_2 = \tau_1 \frac{B}{b} = 1.454741379 \times 10^{-9} \times \frac{0.2}{0.185} = 1.572693383 \times 10^{-9} \ \text{kN/m}^2$$

$$\tau_3 = \frac{150}{8 \times 433066666.6 \times 10^{-12} \times 0.15} \times (0.2(0.44^2 - 0.4^2) + 0.015 \times 0.4^2)$$

$$= 2632.891 \ \text{kN/m}^2$$

Q.→ A laminated wooden beam 10 cm wide and 15 cm deep is made up of three 5×10 cm wide planks glued together to resist the longitudinal shear. The beam is simply supported over a span of 2 m. If the glued joint is 0.45 MN/m². Find the safe concentrated load that the beam may carry at its centre.

Sol.:
$$I = \frac{bd^3}{12}$$

$$I = \frac{0.1 \times 0.15^3}{12}$$

$$I = 2.8125 \times 10^{-5} \ \text{m}^4$$

$$0.45 \times 10^6 = \frac{W}{2} \frac{(0.10 \times 0.05)}{2.8125 \times 10^{-5} \times 0.1}(0.025 + 0.025)$$

$$= 10125 \ \text{N}$$

$$\tau = \frac{SA_1\bar{y}_1}{Ib} + \frac{SA_2\bar{y}_2}{Ib}$$

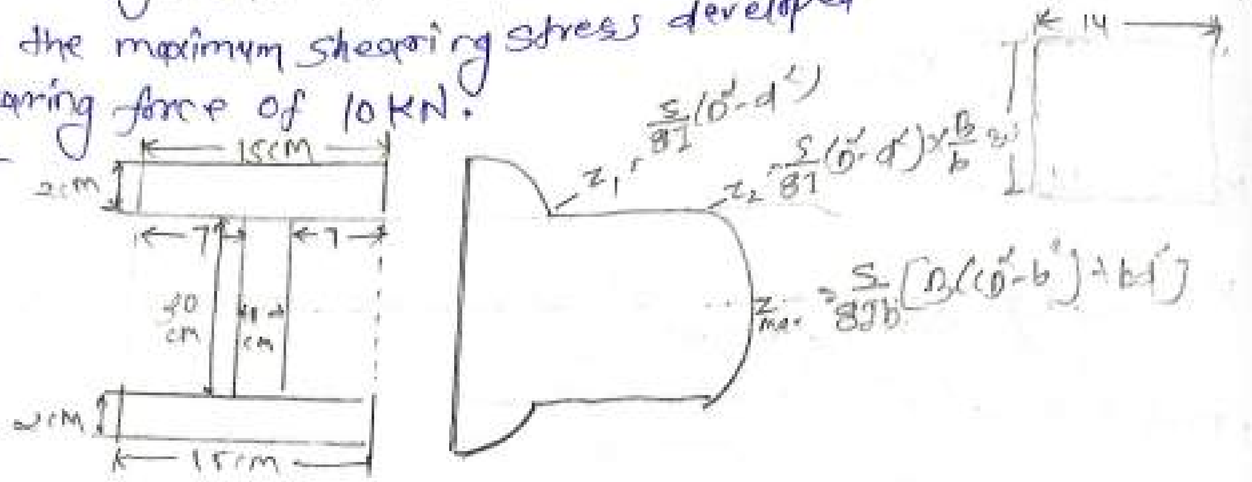
$$= \frac{S}{Ib}(A_1\bar{y}_1 + A_2\bar{y}_2)$$

Q.) An I section, with rectangular ends, has the following dimensions:-

Flange : 15cm × 2cm , web : 30cm × 1cm

Find the maximum shearing stress developed in the beam for a shearing force of 10 KN.

Sol:-



$$I = \frac{BD^3}{12} - \frac{bd^3}{12} \Rightarrow \frac{15\times34^3}{12} - \frac{14\times30^3}{12} \Rightarrow 17630cm^4 = 17630\times10^{-8}m^4$$

$S = 10KN$ $D = 34cm = 0.34m$

$I = 17630\times10^{-8}$ $B = 15cm = 0.15m$

$\bar{y} = 17cm$ $b = 1cm = 0.01m$

$d = 30cm = 0.3m$

$$\tau_1 = \frac{S}{8I}(D^2-d^2) = \frac{10}{8\times17630\times10^{-8}}(0.34^2-0.3^2) = 181.509 \ KN/m^2$$

$$\tau_2 = \tau_1\times\frac{B}{b} = 181.509\times\frac{0.15}{0.1} = 2917.16 \ KN/m$$

$$\tau_{max} = \frac{S}{8Ib}[B(D^2-d^2)+bd^2] = \frac{10}{8\times17630\times10^{-8}\times0.01}[0.15(0.34^2-0.3^2)+0.1\times0.3^2]$$

$$= 3960 \ KN/m^2$$

Q.→ An I-section having flange 200mm × 20mm and web 400 mm × 10mm is used as beam. If this section it is subjected to a shear force of 50 KN, find the shear stress in the beam and show and the variation of shear stress across the section.

अब सूत्र $\frac{M}{I} = \frac{\sigma}{y}$ से

$$M = \frac{\sigma}{y} \times I$$

$$= \frac{50 \times 10^6}{150} \times 3.375 \times 10^{-4}$$

$$M = 112.5$$

$$M = \text{load} \times \text{Distance}$$

$$112.5 = 30 \times l$$

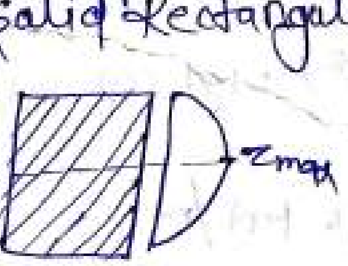
$$l = \frac{112.5}{30 \times 10^3}$$

$$\cancel{l = 3.75\ m^4}$$

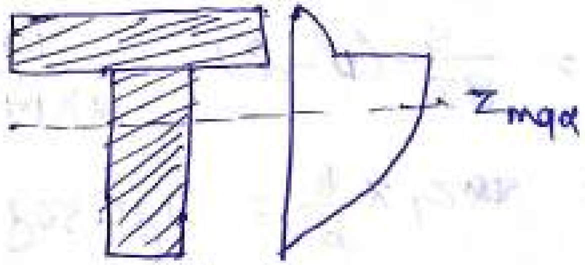
$$l = 3.75 \times 10^{-3}\ m^4$$

SHEAR STRESS DISTRIBUTION

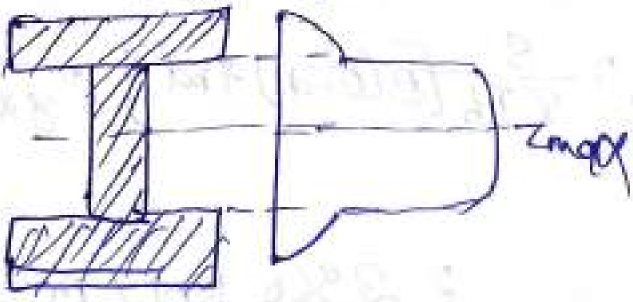
1) Solid Rectangular Section:-



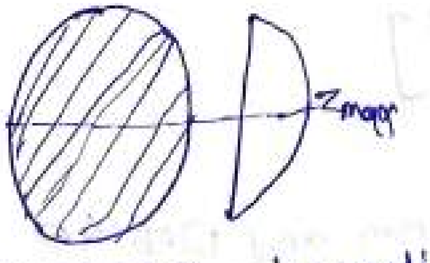
(4) T-section.



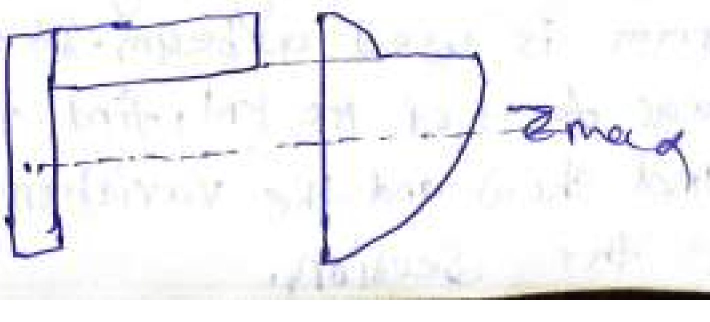
(5)



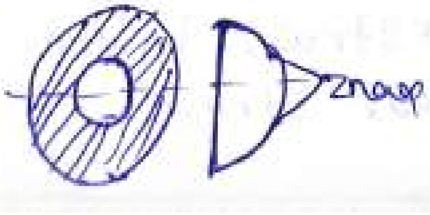
2) Solid Circular section:-



(6) L-section



3) Hollow Circular section:-



$$\tau_{max} = \frac{100 \times 6.6015625 \times 10^{-4}}{0.0001134 \times 0.05} = 11642.96\ kN/m^2$$

Shear stress in the flange at the junction of flange and web.

$$= \frac{100 \times 0.2 \times (0.0375 + 0.025)}{0.0001134 \times 0.2} = 2755\ kN/m^2$$

Shear stress in the web at the junction of flange and web.

$$\tau_2 = \frac{SA\bar{y}}{Ib}$$

$$\tau_2 = \frac{100 \times 0.2 \times 0.05 \times (0.0375 + 0.025)}{0.0001134 \times 0.05}$$

$$= 11023\ kN/m^2$$

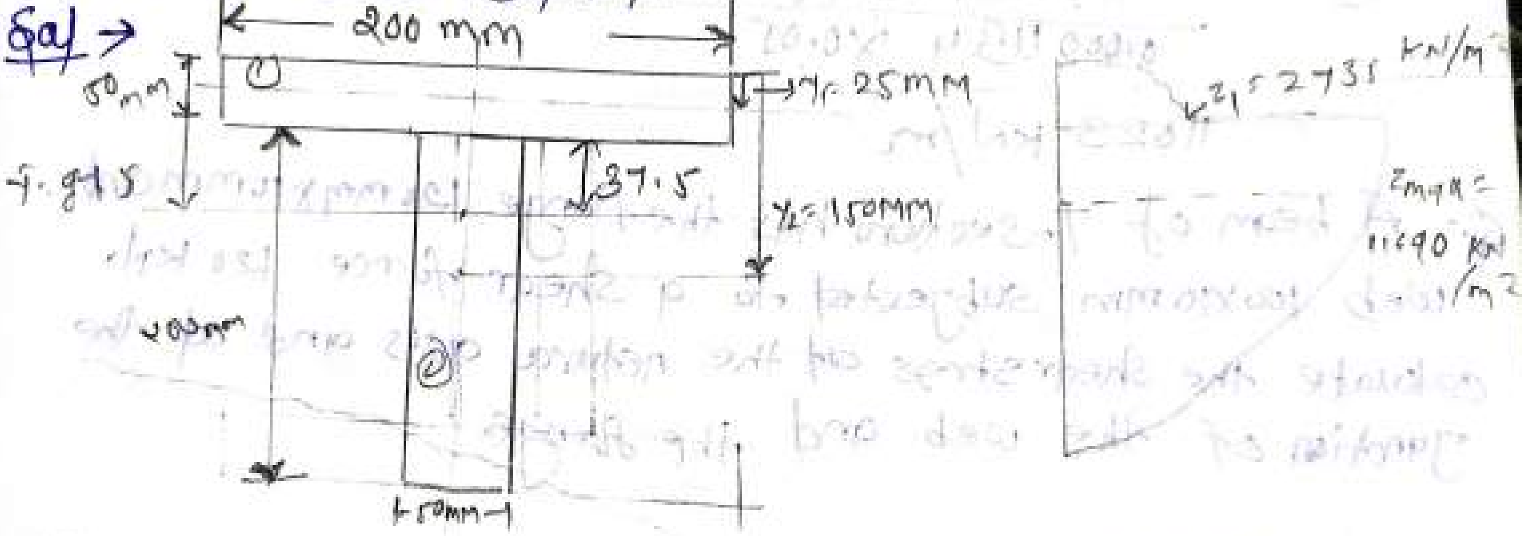
Q. A beam of T-section has the flange 120 mm × 10 mm and web 100 × 10 mm subjected to a shear force 120 kN. Calculate the shear stress at the neutral axis and at the junction of the web and the flange.

$\tau_{mean} = \frac{S}{A} = \frac{10}{7.92989 \times 10^{-3}} = 1261.24 \ kN/m^2$

$\tau_{max} = \frac{4}{3} \times \tau_{mean} = \frac{4}{3} \times 1261.24 = 1681.656 \ kN/m^2$

Q.→ A T-section is subjected to a vertical shear force of 100 KN. Calculate the shear stress at the neutral axis and at the juction of the web and flange. Moment of inertia about the horizontal neutral axis is 0.0001134 m⁴.

Sol →



$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2} = \frac{(200 \times 50) \times 25 + (200 \times 50) \times 150}{(200 \times 50) + (200 \times 50)} = 87.5 \ mm$

Shear stress at netural axis

$\tau_{max} = \frac{S A\bar{y}}{Ib}$

$A\bar{y} = (200 \times 50) \times 62.5 + (37.5 \times 50) \times 18.75$ $\quad \frac{37.5}{2}$

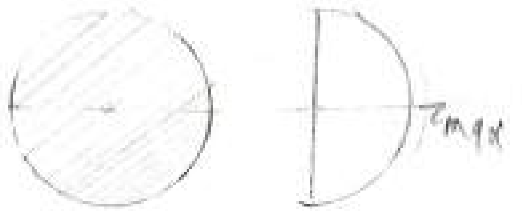
$A\bar{y} = 663156.25 \ mm^3$

$= 6.6315625 \times 10^{-4} \ m^3$

Circular section :-

$$\tau_{mean} = \frac{S}{A}$$

$$\tau_{max} = \frac{4}{3}\tau_{mean}$$



Q.→ A Circular beam 150mm diameter is subjected to a shear force of 7 kN. Calcute the value of maxim shear stress and sketch variation of shear stress along the depth of the beam.

Sol :- $d = 150\,mm = 0.15\,m$
$S = 7\,kN$

$A = \frac{\pi}{4} \times d^2$
$= 0.01767\,m^2$

$\tau_{mean} = \frac{S}{A} = \frac{7}{0.01767} = 396.151\,kN/m^2$

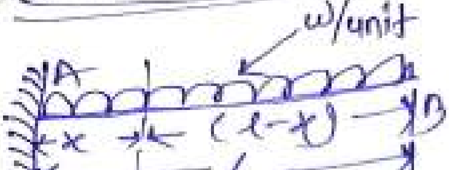
$\tau_{max} = \frac{4}{3} \times 396.151 = 528.201\,kN/m^2$

Q.→ The Circular beam of 100.5 mm diameter is subjected to a shear forces of 10 kN. Calculate the value of mean and maximum shear stress and sketch the variation of the shear stress along the depth of the beam.

Sol→ $D = 100.5\,mm \rightarrow 0.1005\,m$
$S = 10\,kN$

$A = \frac{\pi}{4} d^2$
$= \frac{\pi}{4}(0.1005)^2 = 7.92869 \times 10^{-3}\,m^2$

Cantilever beam udial load



$$M = -\omega \cdot (l-x) \cdot \frac{(l-x)}{2}$$

$$M = -\omega \frac{(l-x)^2}{2}$$

$$EI \frac{d^2y}{dx^2} = \frac{-\omega (l-x)^2}{2}$$

on Integrating

$$\int EI \frac{d^2y}{dx^2} = \int -\frac{\omega (l-x)^2}{2}$$

$$EI \frac{dy}{dx} = \omega \frac{(l-x)^3}{6} + C_1 \quad \text{—(1)}$$

At Point A

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

$$C_1 = \frac{-\omega l^3}{6}$$

$$EI \frac{dy}{dx} = \omega \frac{(l-x)^3}{6} + \left(\frac{\omega l^3}{6}\right) \quad \text{—(2)}$$

At point B

$$x = l$$

$$EI \cdot \frac{dy}{dx} = 0 - \frac{\omega l^3}{6}$$

$$\frac{dy}{dx} = \frac{-\omega l^3}{6EI}$$

$$\boxed{\theta_B = \frac{-\omega l^3}{6EI}}$$

Slope at Point B $x = l$

$$EI\frac{dy}{dx} = -\omega\left(l.l - \frac{l^2}{2}\right)$$

$$EI\frac{dy}{dx} = -\omega\left(l^2 - \frac{l^2}{2}\right)$$

$$EI\frac{dy}{dx} = \frac{-\omega l^2}{2}$$

<u>Duble Intergation Method</u> :-

$$\theta_B = \frac{dy}{dx} = -\frac{\omega l^2}{2}$$

$$\boxed{\theta_B = \frac{-\omega l^2}{2}}$$

$$EI\frac{dy}{dx} = -\omega\left(lx - \frac{x^2}{2}\right)$$

on intrigating

$$\int EI\frac{dy}{dx} = \int -\omega\left(lx - \frac{x^2}{2}\right)$$

$$EI.y = -\omega\left(\frac{lx^2}{2} - \frac{x^3}{6}\right) + c_2 \quad (3)$$

At point A

$x = 0$, $y = 0$

$0 = c_2$

$$EI.y = -\omega\left(\frac{lx^2}{2} - \frac{x^3}{6}\right)$$

Deflection of point B

$$EI.y = -\omega\left(\frac{l^3}{2} - \frac{l^3}{6}\right)$$

$$\boxed{y = -\frac{\omega l^3}{3EI}}$$

Sol.

Chapter - 4 Deflection of beam

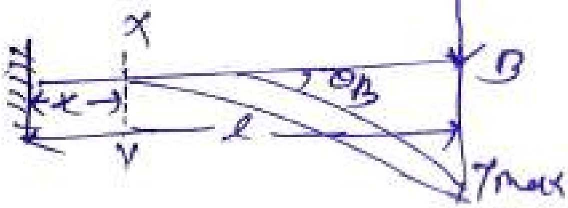
Sloop and deflaction

Relation between Radius of curvature, slope and Deflection -

formula → $\boxed{M = EI \frac{d^2y}{dx^2}}$ → Derivation is No syllebus.

slope = $\frac{dy}{dx}$, Deflection = dx

Cintilever beam :-



$M = -\omega(l-x)$

$EI \frac{d^2y}{dx} = -\omega(l-x)$

on Intregating

$\int EI \frac{d^2y}{dx^2} = \int -\omega(l-x)$

$EI \frac{dy}{dx} = -\omega(lx - \frac{x^2}{2}) C_1$ — (1)

At point A

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

on putting value of $x = 0$ and $\frac{dy}{dx} = 0$

$0 = C_1$

$EI \frac{dy}{dx} = -\omega(lx - \frac{x^2}{2})$ -- (2)

Slope at point C

$x = \frac{l}{2}$, $y_c = \frac{dy}{dx}$

$EI\, y_c = \frac{w(\frac{l}{2})^2}{4} - \frac{wl^2}{16}$

$y_c = 0$

Slope at A

$x = 0$

$EI\, y_A = -\frac{wl^2}{16}$

$\boxed{y_A = -\frac{wl^2}{16EI}}$

$\int EI \frac{dy}{dx} = \int \frac{wx^2}{4} - \frac{wl^2}{16}$

$EI y = \frac{wx^3}{12} - \frac{wl^2}{16}x + C_2$

$x = 0, y = 0, C_2 = 0$

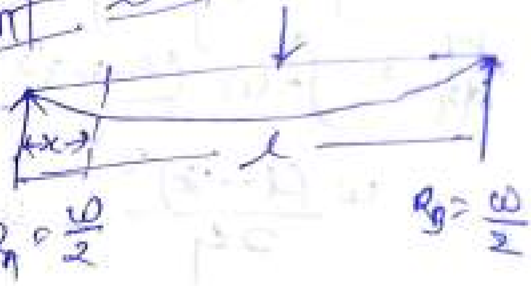
$EI y = \frac{wx^3}{12} - \frac{wl^2}{16}x$

$y_c = \frac{w(\frac{l}{2})^3}{12} - \frac{wl^2}{16} \cdot (\frac{l}{2})$

$= \frac{wl^3}{96} - \frac{wl^3}{32} = -\frac{wl^3}{48}$

$\boxed{y_c = -\frac{wl^3}{48EI}}$

Simply supported beam :- Point load



$$M = \frac{w}{2}(l-x) - w\left(\frac{l}{2} - x\right)$$

$$= \cancel{\frac{wl}{2}} - \frac{wx}{2} - \cancel{\frac{wl}{2}} + wx)$$

$$= -\frac{wx}{2} + wx$$

$$EI\frac{d^2y}{dx^2} = \frac{wx}{2} + wx = \frac{wx}{2}$$

on Integrating

$$\int EI\frac{d^2y}{dx^2} = \int \frac{wx}{2} + wx$$

$$EI\frac{dy}{dx} = \frac{w}{2}\cdot\frac{x^2}{2}$$

$$EI\frac{dy}{dx} = \frac{wx^2}{4} + C_1 \quad \text{—(1)}$$

At point C

$$x = \frac{l}{2}, \quad \frac{dy}{dx} = 0$$

$$0 = \frac{w\left(\frac{l}{2}\right)^2}{4} + C_1$$

$$C_1 = -\frac{wl^2}{16}$$

$$EI\frac{dy}{dx} = \frac{wx^2}{4} - \frac{wl^2}{16} \quad \text{—(2)}$$

on Intergating eq. 2.

$$\int EI \frac{dy}{dx} = \int -\omega \frac{(l-x)^3}{6} - \frac{\omega l^3}{6})$$

$$EI \cdot y = \omega \frac{(l-x)^2}{24} - \frac{\omega l^3}{6} \cdot x + C_2 \quad (3)$$

At point A

$x = 0$, $y = 0$

$$0 = \frac{-\omega l^4}{24} + C_2$$

$$C_2 = \frac{\omega l^4}{24}$$

$$EI \cdot y = \frac{-\omega l(l-x)^4}{24} - \frac{\omega l^3}{6} x + \frac{\omega l^4}{24}$$

Deflection at point B

$x = l$

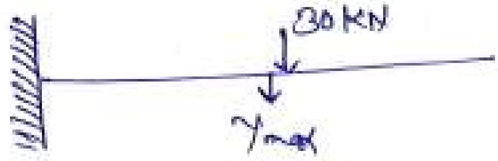
$$EI \cdot y = 0 - \frac{\omega l^4}{6} + \frac{\omega l^4}{24}$$

$$EI \cdot y = \frac{-\omega l^4}{8}$$

$$\boxed{y_B = -\frac{\omega l^4}{8EI}}$$ Deflection on point B.

Q→ A steel Cantilever of span 2.5M Carries a point load of 30KN of its free ends the moment of inertia of the Contilever beam is 9900 cm^4. find the maximum deflection of beam at the free end. ~~deflection~~ Take E = 210 GN/m^2.

Sol →



$I = 9900\ cm^4 = 9900 \times 10^{-8}\ m^4$

$E = 210 GN/m^2 = 210 \times 10^9\ N/m^2$

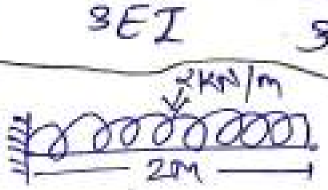
$\omega = 30 KN = 30 \times 10^3\ N$

$l = 2.5 m$

$$\text{slope } \theta_B = -\frac{wl^2}{2EI} = \frac{30\times10^3 \times (2.5)^2}{2\times 210\times10^9 \times 9900\times10^{-8}} = -4.509\times10^{-3}\ \underline{\text{raidan}}$$

$$Y_{max} = -\frac{wl^3}{3EI} = \frac{30\times10^3\times(2.5)^3}{3\times210\times10^9\times9900\times10^{-8}} = -7.516\times10^{-3}\ M$$

Q.→



100 mm wide
240 mm deep
$E = 210 GN/m^2$
$\theta_B = ?$
$Y_{max} = ?$

$$I = \frac{bd^3}{12}$$

$$= \frac{0.1\times0.24^3}{12}$$

$= 1.152\times10^{-4}$

On Integrating eqn - ②

$$EI.y = \frac{wlx^3}{12} - \frac{wx^4}{24} - \frac{wl^3}{24}x + C_2 \quad - ③$$

At point A

$x=0,\ y=0$

$0 = 0-0-0+C_2$

$C_2 = 0$

$$EI.y = \frac{wlx^3}{12} - \frac{wx^4}{24} - \frac{wl^3}{24}.x \quad - ④$$

At point A

$y_A = 0$

At point C

$x = \frac{l}{2}$

eqn (4) $x = \frac{l}{2}$

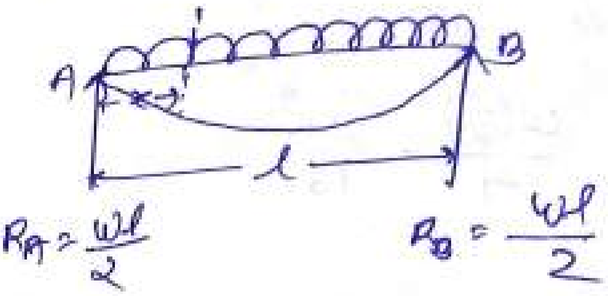
$$EIy = \frac{wl^4}{96} - \frac{wl^4}{384} - \frac{wl^4}{48}$$

$$EIy = \frac{-5wl^4}{384}$$

$$\boxed{y_c = \frac{-5wl^4}{384EI}}$$

Simply supported beam (udl load)

$M = \frac{wl}{2}x - wx \cdot \frac{x}{2}$



$M = \frac{wl}{2}x - \frac{wx^2}{2}$

$EI\frac{d^2y}{dx^2} = \frac{wl}{2}x - \frac{wx^2}{2}$

On Integrating

$EI\frac{dy}{dx} = \frac{wl}{4}x^2 - \frac{wx^3}{6} + C_1$ — ①

At point c

$x = \frac{l}{2}, \frac{dy}{dx} = 0$

$0 = \frac{wl^3}{16} - \frac{wl^3}{48} + C_1$

$C_1 = \frac{wl^3}{48} - \frac{wl^3}{16}$

$C_1 = -\frac{wl^3}{24}$

$EI\frac{dy}{dx} = \frac{wlx^2}{4} - \frac{wx^3}{6} - \frac{wl^3}{24}$ — ②

Slope At point A

$x = 0$

$EI\frac{dy}{dx} = -\frac{wl^3}{24}$

$\boxed{\theta_A = -\frac{wl^3}{24EI}}$

$\frac{dy}{dx} = \frac{wl^3}{24EI}$

Safe compressive load:

$$S.c.l = \frac{\text{Criping load}}{\text{F.O.S (force of safety)}}$$

Q.7 A solid round bar 60mm in diameter in diameter and 2.5 m long is used as a strut, one end of the strut is fixed, while the other end is hinged. Find the safe compressive load for this strut, using Euler's formula. Assume $E = 200 \, GN/m^2$ and factor of safety 3.

Sol:- $P_c = \dfrac{\pi^2 E I}{l_e^2}$

$E = 200 GN/m^2 = 200 \times 10^9 \, N/m^2$

$D = 60 \, mm = 0.6 \, m$

$l = 2.5 \, m$

one end fixed and other end is hinged -

$$l_e = \frac{l}{\sqrt{2}} = \frac{2.5}{\sqrt{2}} = 1.768 \, m$$

$$I = \frac{\pi}{64} \times d^{2^2}$$

$$= \frac{\pi}{64} \times 0.6^{2^4} = 6361 \times 10^{-7}$$

$$P_c = \frac{\pi^2 \times 200 \times 10^9 \times 6361 \times 10^{-7}}{1.768^2} = 401.7 \times 10^3 \, N$$

$$S.c.l = \frac{\text{Criping load}}{f.o.S} = \frac{401.7 \times 10^3}{3} = 133.9 \times 10^3 \, N.$$

Defination of the following:-

1) Calumn

2) Strud

3) Slenderness ratio (k) $= \dfrac{\text{unsupported length}}{\text{min. radius of gyraction}}$

Chapter 07 column / strut

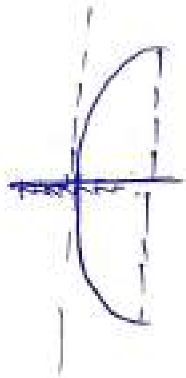
① Both and Hinged or pin :

$\boxed{l_e = l}$

Euler's formula -

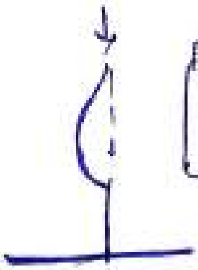
$$P_c = \frac{\pi^2 E I}{l_e^2}$$

2) one end fix in other end free -



$\boxed{l_e = 2l}$

3) one end fix in other end pin joint :-



$\boxed{l_e = \frac{l}{\sqrt{2}}}$

4) Both ends are fixed

$\boxed{l_e = \frac{l}{2}}$

$$\theta_B = \frac{-wl^3}{6EI} = -\frac{2\times10^3\times2^3}{6\times210\times10^9\times1152\times10^{-4}} = -1.102\times10^{-4}\ \text{radian}$$

$$y_{max} = \frac{-wl^4}{8EI} = -\frac{2\times10^3\times2^4}{8\times210\times10^9\times1152\times10^{-4}} = -1.653\times10^{-4}\ m$$

Q.→ A 250mm long cantilever of rectangular section 48mm and 35mm deep carries a uniformaly distributed load. calculate the value of load w. If maximum deflection 1mm Take $E = 70\ GN/m^2$.

Sol.→

$$I = \frac{bd^3}{12} = \frac{0.048\times0.035^3}{12} = 1.86624\times10^{-7}\ m^3$$

$$0.001 = \frac{-w\times250\times10^3}{8\times70\times10^9\times1.86624\times10^{-7}}$$

$$w = 2.3921\times10^{-3}$$

5000 cm^2

CHAPTER - 8

$$\frac{T}{I_p} = \frac{\tau}{R} = \frac{C\theta}{l}$$

T = Torque = $\tau \cdot \frac{\pi}{16} D^3$ (N-m)

I_p = Polar moment of Ineritia = $\frac{\pi}{32} d^4$

τ = shear stress

C = shear modulus

θ = Angle of twist

R = Radious

Power, $P = \frac{2\pi N T}{60}$ T = mean or avrage torque, N = speed R.P.M.

Hollow Circular Shaft.

$$T = \tau \cdot \frac{\pi}{16}\left(\frac{D^4 - d^4}{D}\right) \quad \text{max} = T$$

$$I_p = \frac{\pi}{32}(D^4 - d^4)$$

Q. - A Hollow shaft is to transmit 300 kW at 80 r.p.m. If the shear stress is not to exceed 60 MN/m² and internal diameter is 0.6 the external diameter find the Internal & external diameter assuming that the maximum torque is 1.4 times the mean.

$$I = \frac{\pi}{64}(D^4 - d^4)$$

$$= \frac{\pi}{64}(0.2^4 - 0.16^4)$$

$$= 4.637 \times 10^{-5}$$

$$A = \frac{\pi}{4}(D^2 - d^2)$$

$$= \frac{\pi}{4}(0.2^2 - 0.16^2)$$

$$= 0.11030973355$$

$$K = \sqrt{\frac{I}{A}} = \sqrt{\frac{4.637 \times 10^{-5}}{0.11030973355}} = 0.0205027276$$

4) Buckling load

5) Classification of load

I) short column → जब length $l < 8d$ से कम से या $K < 32$

II) medium size column → इसका length 8 से 30 गुना होता है व K 32 से 120 के बीच होगा।

III) long column – $l > 30d$, $K > 120$

Rankine's formula :-

$$P_R = \frac{\sigma_c \times A}{1 + a\left(\frac{l_e}{K}\right)^2} \quad \left\{ \because a = \frac{\sigma_c}{\pi^2 E} \right\}$$

σ_c = Compressive stress

l_e = equivalent length / effective length

K = radious of gyration $\boxed{K = \sqrt{\frac{I}{A}}}$

Q.- A hollow C.I column whose outside dia. is 200 mm has a thickness 20 mm. It is 4.5 m long and is fixed at both ends. Calculate the safe load by using Rankine's formula

Take $\sigma_c = 550 \, MN/m^2$, $a = \frac{1}{1600}$

Sol.

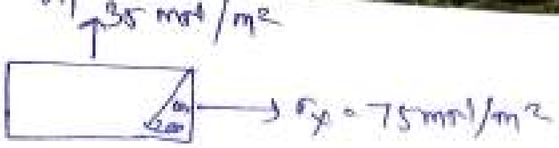
$\sigma_c = 550 \, MN/m^2 = 550 \times 10^6 \, N/m^2$

$D = 200 \, mm = 0.2 \, m$

$t = 20 \, mm = 0.02 \, m$

inner diameter = $D - 2t = 200 - 40 = 160 = 0.16 \, m$

Sol →



$$\sigma_n = \frac{\sigma_x+\sigma_y}{2} + \frac{\sigma_x-\sigma_y}{2}\cos 2\theta$$

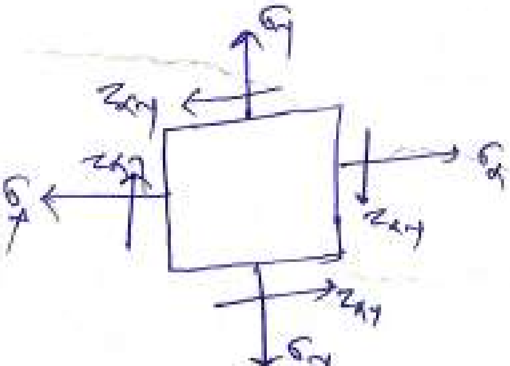
$$= \frac{75+35}{2} + \frac{75-35}{2}\cos 40^\circ = \overset{70.32}{\cancel{70.85}} \text{ mN/m}^2$$

$$\tau = \frac{\sigma_x-\sigma_y}{2}\sin 2\theta$$

$$= \frac{75-35}{2}\sin 40 = 12.85 \text{ mN/m}^2$$

$$\sigma_R = \sqrt{\sigma_n^2+\tau^2} = \sqrt{(70.32)^2+(12.85)^2} = 71.48 \text{ mN/m}^2$$

$$\tan\phi = \frac{\tau}{\sigma_n} = \frac{12.85}{70.32} = 0.1828, \quad \phi = 10^\circ 21' \text{ (Ans)}$$

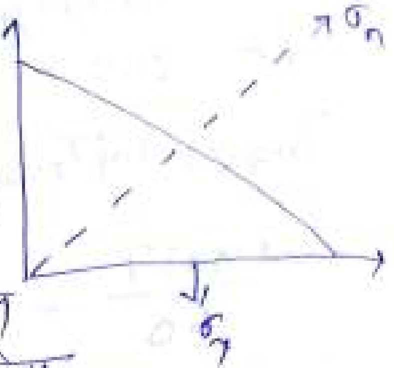


① major principal stress.

$$\sigma_1 = \sigma_{max} = \frac{\sigma_x+\sigma_y}{2} + \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

② minor principal stress

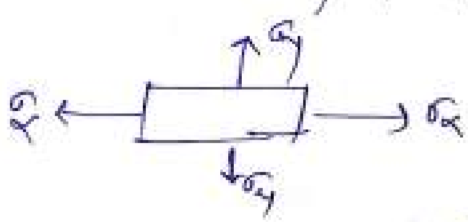
$$\sigma_2 = \sigma_{min} = \frac{\sigma_x+\sigma_y}{2} - \sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2 + \tau_{xy}^2}$$



Q.- What is principle stress?

Ans → किसी बिंदु पर कार्यरत अधिकतम और न्यूनतम सामान्य प्रतिबल होते है। जब किसी वस्तु पर बल लगाया जाता है, तो इसके अंदर विभिन्न दिशाओं में प्रतिबल उत्पन्न होते है। प्रिंसिपल स्ट्रेस वे दिशाएँ होती है जहाँ केवल सामान्य प्रतिबल होते है और कोई भी अपरूपण प्रतिबल नहीं होता है।

Two mutually perpendicular direct stress-



1) normal stress $= \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta$

2) shear stress or tangential stress $(\tau) = \frac{\sigma_x - \sigma_y}{2} \sin 2\theta$

3) $\tau_{max} = \frac{\sigma_x - \sigma_y}{2}$

4) Resultant stress $(\sigma_r) = \sqrt{\sigma_n^2 + \tau^2}$

5) $\tan\phi = \frac{\tau}{\sigma_n}$

Q.→ The principle stress at a point across two perpendicular plane are 78 MN/m^2 (tensile) and 35 MN/m^2 (tensile). find the normal stress tangential stress and resultant stress and its obliquity on a plane at 20° with the major principal plane.

Sol → $P = 300\ kW = 300 \times 10^3\ W$

$N = 80\ r.p.m$

$\tau = 60\ MN/m^2 = 60 \times 10^6\ N/m^2$

$d = 0.6\ D$

$T_{max} = 1.4\ T_{mean}$

$$P = \frac{2\pi N T}{60} = 300 \times 10^3 = \frac{2\pi \times 80 \times T}{60}$$

$$T = T_{avg.} = 35809\ N\text{-}m$$

$$T_{max} = 1.4 \times 35809 = 50132\ N\text{-}m$$

$$T_{max} = \tau \cdot \frac{\pi}{16}\left(\frac{D^4 - d^4}{D}\right)$$

$$50132 = 60 \times 10^6 \times \frac{\pi}{16}\left(\frac{D^4 - (0.6D)^4}{D}\right)$$

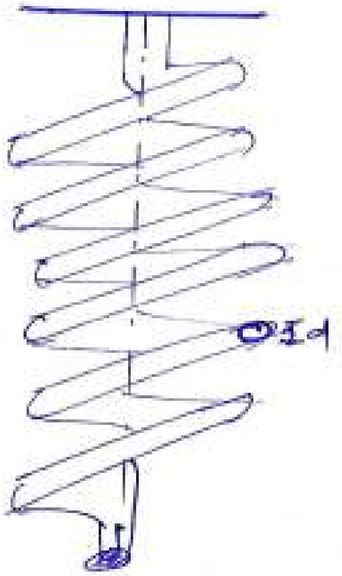
$$50132 = 60 \times 10^6 \times \frac{\pi}{16} D^3 (1 - 0.6^4)$$

$$D = 0.169\ m$$

$$d = 0.6 \times 0.169 = 0.102\ m$$

SPRING Chr 6

The close - COILED HELICAL SPRINGS:-



R - Radius of coil

d = diameter of the wire of the coil

δ = Deflection of coil under the load W

C = modulus of rigidity

n = numbers of coil or turns

θ = Angle of twist

l - Length of wire $= 2\pi Rn$

τ = shear stress, and

I_p = Polar moment of inertia $= \frac{\pi}{32} d^4$

$$\frac{T}{I_p} = \frac{C\theta}{l} = \frac{\tau}{R}$$

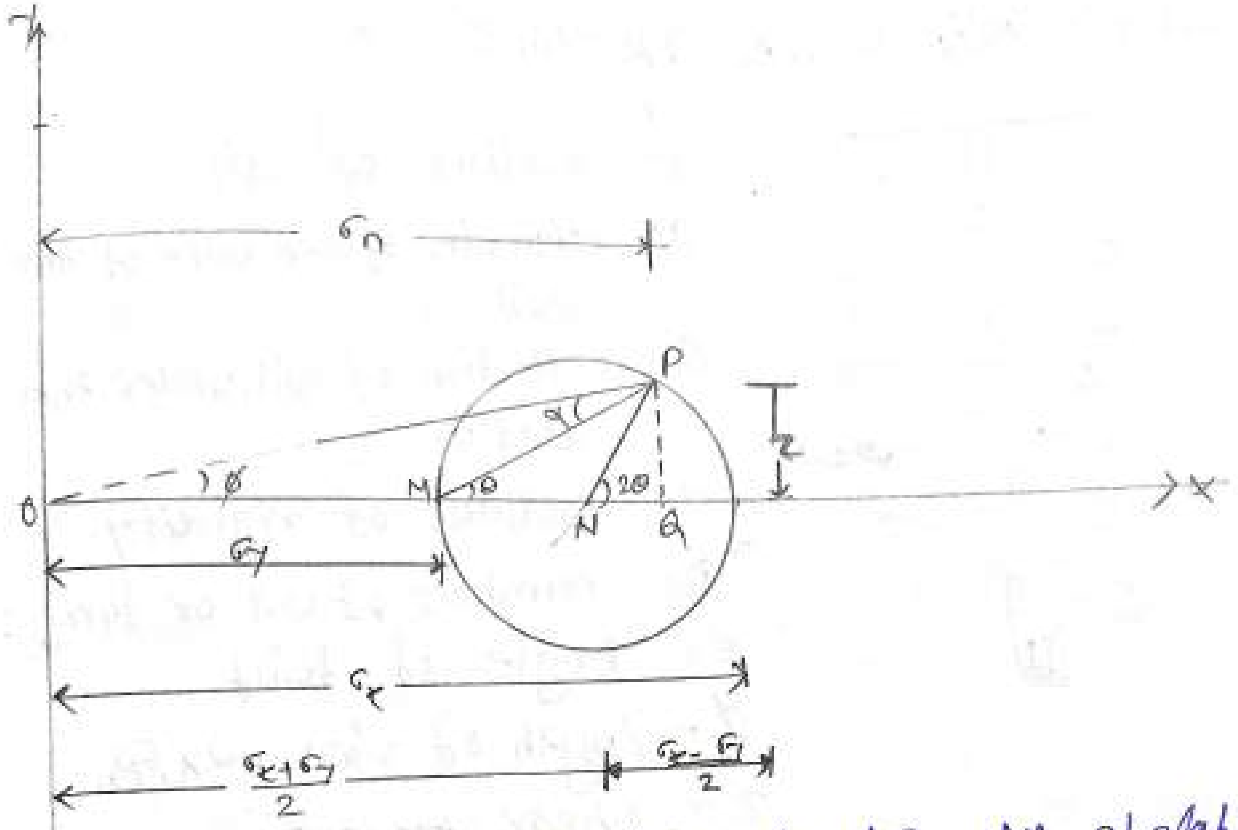
(1) shear stress $\tau = \frac{16WR}{\pi d^3}$

(2) Deflection $(\delta) = \frac{64WR^3n}{Cd^4}$

3) Stiffness $(K) = \frac{W}{\delta}$

4) Energy store by the spring $U = \frac{1}{2} W\delta$ (N-m) J

Mohr's Circle Construction for "Like Stresses".



load, Area, Inclination Angle An abelable

1) Normal stress = $\sigma_n = \frac{P}{A}\cos^2\theta$

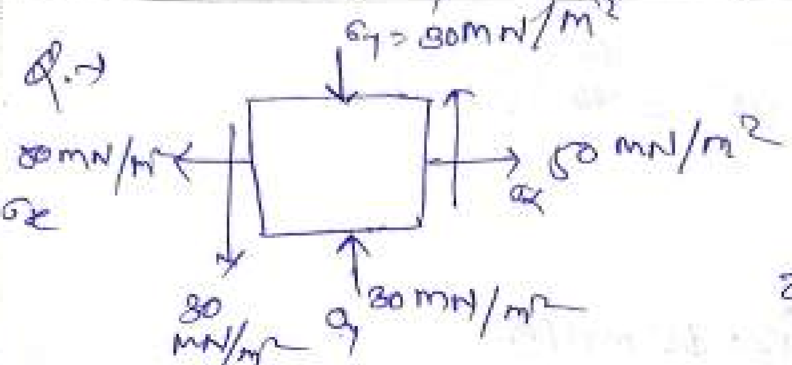
2) maximum shear stress $\tau_{max} = \frac{P}{2A}$

3) $\tau = \frac{P}{A}\cos\theta\sin\theta$

(3) $\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$

(4) $\tan 2\theta = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$

Q.→



$\sigma_x = 50 mN/m^2$

$\sigma_y = -30 mN/m^2$

$\tau_{xy} = 30 mN/m^2$

(1) major principle stress

$\sigma_1 = \frac{50+(-30)}{2} + \sqrt{\left(\frac{50+30}{2}\right)^2 + 30^2} = 60$

(2) minor principle stress-

$\sigma_2 = \frac{50+(-30)}{2} - \sqrt{\left(\frac{50+30}{2}\right)^2 + 30^2} = -40$

3) $\tau_{max} = \frac{60+40}{2} = 50$

4) $\tan 2\theta = \frac{2\times 30}{50+30} = \frac{60}{80} = \frac{3}{4}$

$\tan 2\theta = \frac{3}{4}$

$2\theta = \tan^{-1}\frac{3}{4}$

$2\theta = 36.87$

$\theta = \frac{36.87}{2}$

$\theta = 18.435$

$W = 200N$; $C = 80\ GN/m^2$

Deflection of the spring

$$\delta = \frac{64WR^3 n}{Cd^4}, \quad \delta = \frac{64 \times 200 \times (0.06)^3 \times 10}{80 \times 10^9 \times (0.01)^4}$$

$= 0.03456\,m = 34.56\,mm$

Stiffness of the spring K:-

$$K = \frac{W}{\delta}, \quad K = \frac{200}{34.56} = 5.79\ N/mm$$

maximum shear stress τ:-

$$\tau = \frac{16WR}{\pi d^3} = \tau = \frac{16 \times 200 \times 0.06}{\pi \times (0.01)^3} =$$

$= 61.11 \times 10^6\ N/m^2$

$= 61.11\ MN/m^2$

Strain energy stored U:-

$$U = \frac{1}{2} \cdot W \cdot \delta, \quad = \frac{1}{2} \times 200 \times 0.03456$$

$= 3.456\ N/m$

Q.) A closed coiled spring is made of 10 mm diameter wire. It has 10 coils. The mean coil diameter is 80mm If it is loaded by 200N axial load, find the following:
(1) stress induced in the spring wire (3) stiffness of spring
(2) Axial deflection of the spring (4) The strain energy in spring
Take $G = 0.84 \times 10^5\ N/m^2$.

Sol. $d = 10\,mm$
$n = 10$
$D = 80\,mm$
$W = 200\,N$

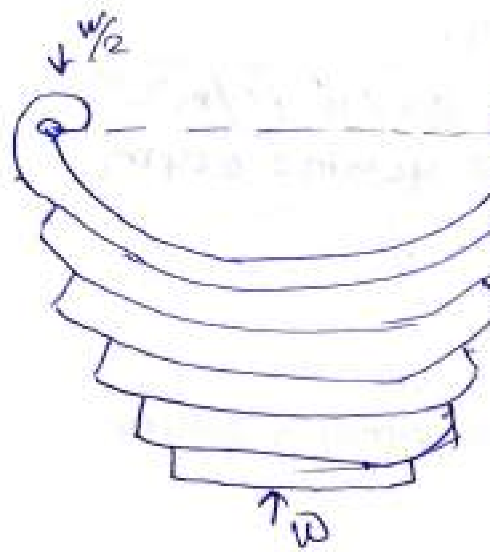
1) stress induced in the spring wire $\tau = \frac{8WD}{\pi d^3}$

$$= \frac{8 \times 200 \times 80}{\pi \times 10^3}$$

$= 40.76\ N/mm^2$

Laminated spring : -

leaf spring, semi-elliptical spring, carrige spring.



(1) $\sigma_b = \frac{3wl}{2Nbt^2}$

N = Number of plate

b = width

t = thickness

(2) Radius of curvature

$$\frac{\sigma_b}{y} = \frac{E}{R}$$

(3) central deflection

$$\delta = \frac{3wl^3}{8ENbt^3}$$

Moment of each plates

$$m = \frac{wl}{4N}$$

Nov-Dec 2022

Ex: - A close-coiled helical spring is made out of 10 mm diameter steel rod. The coil consists of 10 complete turns with a mean diameter of 120 mm. The spring carries an axial pull of 200N. find the maximum shear stress induced in the section of the rod. If C = 80 GN/m². Find the deflection in the spring. the stiffeness and strain energy in the spring.

Solution :-
$d = 10mm = 0.01 m$

$n = 10$

$R = \frac{120}{2} = 60mm = 0.06 m$

Q.9 A closed coil helical spring is made of 12mm diameter steel wire wound on a 120mm diameter mandrel. If here are 10 active coils what is spring constent? Take $C = 82 GN/m^2$. what force must be applied to the spring to elongate it by 40mm.

Sol.

$d = 12\ mm = 0.0120\ m$

$D = 120\ mm$

$R = 60\ mm = 0.06\ m$

$n = 10$

$K = ?$

$C = 82 \times 10^9\ N/m^2$

$\delta = 40\ mm = 0.04\ m$

$W = ?$

Elongation of the spring $\delta = 40\ mm = 0.04\ m$

Spring Constent:-

we know that

spring constant = stiffness of spring (K)

$$K = \frac{W}{\delta} = \frac{Cd^4}{64 R^3 n} = \frac{82 \times 10^9 \times (0.012)^4}{64 \times \left[\frac{0.12}{2}\right]^3 \times 10}$$

$$K = 12300\ N/m$$

force to be applied to the spring, W:-

$$\frac{W}{\delta} = 12300 \text{ or } \frac{W}{0.04} = 12300$$

$W = 492\ N$ Ans

$$P = \frac{3WL}{2nbt^2}, \quad n = \frac{3WL}{2Pbt^2}$$

$$= \frac{3 \times 4 \times 10^3 \times 1}{2 \times 40 \times 0.09 \times 0.015^2} = 9.877.$$

30×10^6

$= \cancel{29.629629.63}$

विक्षेप $$\delta = \frac{3WL^3}{8nEbt^3} = \frac{3 \times 4 \times 10^3 \times (1)^3}{8 \times 10 \times 2 \times 10^{11} \times 0.09 \times (0.015)^3}$$

April-May 2024

$$= 2.469 \times 10^{-3} \text{ m}.$$

Q.→ A laminated spring 1 m long is made up of plates each 90mm wide and 15 mm thick of the bending stress in a plate is limited to 30MN/m². How many plate are required to enable the spring to carry a central point load 3.5 KN? If E = 200GN/m², what is the deflection under the load?

Sol→ $L = 1\text{m}$

$b = 90\text{mm} = 0.09 \text{ m}$

$t = 15\text{mm} = 0.015 \text{ m}$

$W = 3.5\text{kN} = 35000 \text{ N}$

$= 3.5 \times 10^3 \text{ N}$

$P = 30\text{MN/m}^2 = 30 \times 10^6 \text{ N/m}^2$ $\qquad P = \frac{3WL}{2nbt^2}$

$E = 200\text{GN/m}^2 = 200 \times 10^9 \text{ N/m}^2$

$$n = \frac{3WL}{2Pbt^2} = \frac{3 \times 3.5 \times 10^3 \times 1}{2 \times 30 \times 10^6 \times 0.09 \times (0.015)^2} = 8.642$$

विक्षेप

$$\delta = \frac{3WL^3}{8nEbt^3} = \frac{3 \times 3.5 \times 10^3 \times (1)^3}{8 \times 8.6419 \times 30 \times 10^6 \times 0.09 \times (0.015)^3} = 16.669 \text{ m}$$

$$f_2 = \frac{W}{A} = \frac{4W}{\pi d^2} = \frac{4 \times 200}{\pi \times (10)^2} = 2.55 \ N/mm^2$$

$$f_s = f_1 + f_2$$
$$= 40.76 + 2.55 = 43.31 \ N/mm^2$$

ii) Axial deflection of the spring

$$\delta = \frac{8WD^3 n}{Cd^4} = \frac{8 \times 200 \times (80)^3 \times 10}{0.84 \times 10^5 \times (10)^4}$$

$$\delta = 9.752 \ mm$$

iii) stiffness of spring → $S = \frac{W}{\delta} = \frac{200}{9.752} = 20.5 \ N/mm$

iv) The strain energy stored in spring →

$$E = \frac{1}{2} W\delta$$
$$= \frac{1}{2} \times 200 \times 9.752$$
$$= 975.2 \ N\text{-}mm$$
$$E = 0.9752 \ J \quad \text{Ans}$$

Q= A leaf spring 1m long is made up of plates each 90 mm wide and 15 mm thick. The bending stress in the spring is limited to 30Mpa. How many plates are required to enable the spring to carry a central load of 4kN. Also calculate the deflection under the load. TAKE $E = 2 \times 10^5$ mpa.

Sol → $L = 1$
$b = 90 \ mm = 0.09 \ m$
$t = 15 \ mm = 0.015 \ m$
$W = 4kN = 4 \times 10^3 \ N$
$P = 30 \ mp = 30 \times 10^6 \ Pa$
$E = 2 \times 10^5 = 2 \times 10^4$