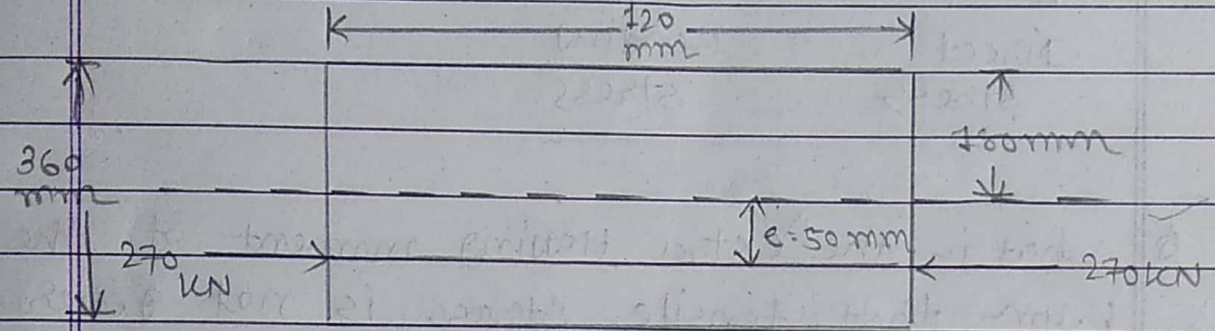
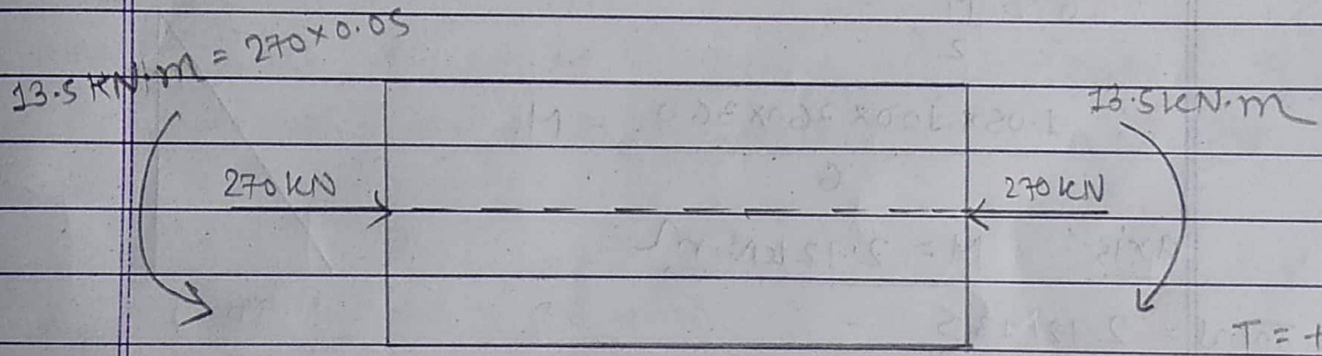
Unit:- 1

Direct and Bending stress (Combine stress)

Calculate over all stresses at top and bottom of the beam





T = +ve
C = −ve

(1) Direct stress $= \sigma_d = \frac{P}{A} = \frac{270 \times 10^3}{120 \times 360}$

$\Rightarrow 6.25 \ N/mm^2$

(2) Bending stress $= \sigma_b = \frac{M}{Z} = \frac{13.5 \times 10^6 \times 6}{120 \times 360 \times 360}$

$Z = \frac{I}{y} = \frac{bd^3/12}{d/2} = \frac{bd^2}{6}$

$= +5.20 \ N/mm^2$ (Top)

$-5.20 \ N/mm^2$ (bottom)

direct → compressive

σ_d → uniform

σ_b → depended about y.

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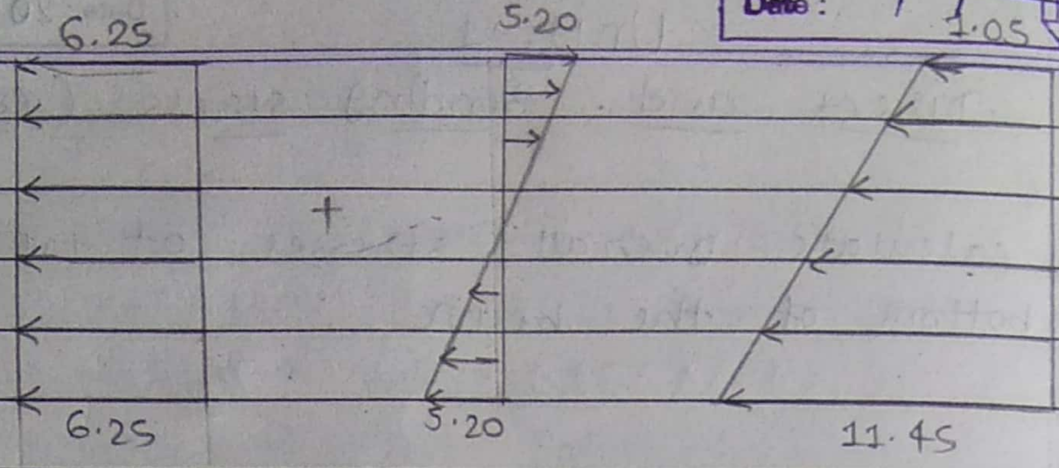


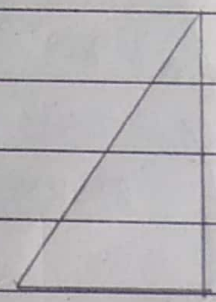
Direct stress

Bending stress

* What is the extra Hogging moment of the beam that tensile stress is not generated

$$\sigma = \frac{M}{z}$$

$$\therefore \frac{1.05 \times 120 \times 360 \times 360}{6} = M$$



Hogging

axis ∴ $M = 2.72$ kN.m

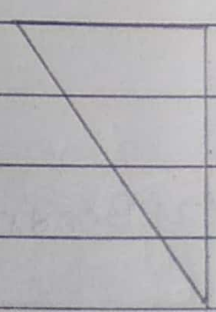
Total $= 2.72 + 13.5$
$= 16.22$

* What is the extra total sagging moment (tensile stress)

$$\sigma = \frac{M}{z}$$

$$\therefore M = \frac{11.45 \times 120 \times 360 \times 360}{6}$$

$\therefore M = 27.6$ kN.m



Sagging

Total $= 27.6$ kN.m

Axial force → direct stress

diagram is stress vs depth

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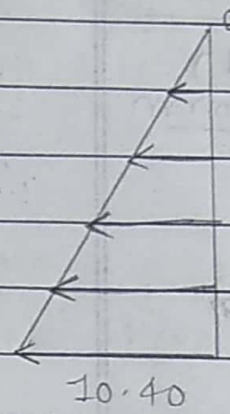
* what is the value of external axial force (Tensile force) which is applied such that section is not subjected to tensile stress -

→ direct stress $\sigma_d = \frac{P}{A}$



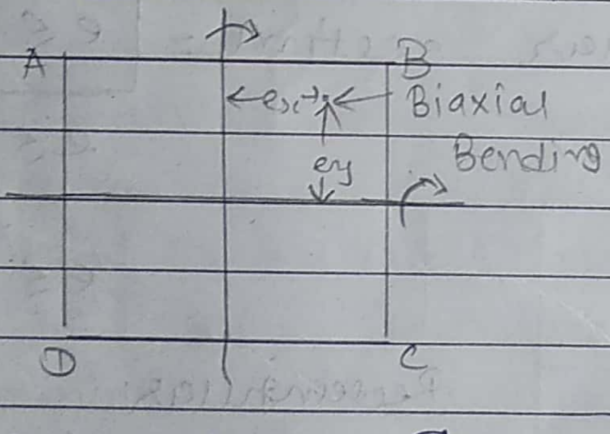
$\therefore 1.05 = \frac{P}{120 \times 360}$

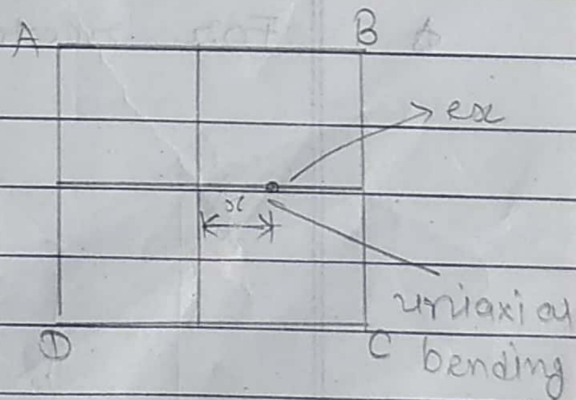
$\therefore \boxed{P = 45.36 \text{ kN}}$

* column

(1) Axial force → Buckling
Axial force → Bulging } Length of column

C+, T−





$A = \sigma_d + \sigma_{bx} - \sigma_{by}$

$B = \sigma_d + \sigma_{bx} + \sigma_{by}$

$C = \sigma_d - \sigma_{bx} + \sigma_{by}$

$D = \sigma_d - \sigma_{bx} - \sigma_{by}$

$A = \sigma_d - \sigma_b$ → Critical

$B = \sigma_d + \sigma_b$

$C = \sigma_d + \sigma_b$

$D = \sigma_d - \sigma_b$ → Critical

$\sigma_{bx} = \frac{M_x}{Z} = \frac{P e_y}{Z}$ $\sigma_{by} = \frac{M_y}{Z} = \frac{P e_x}{Z}$

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uniaxial :→ centroid axis

$\downarrow$ eccentrically some distance

Mea $\sigma_d \geq \sigma_b$ No tension condition

σ_b (maximum) $\sigma_d - \sigma_b \geq 0$

(σ_d) uniform $\therefore \frac{P}{A} - \frac{P.e}{Z} \geq 0$

$$\therefore \frac{P}{A} \geq \frac{P.e}{Z}$$

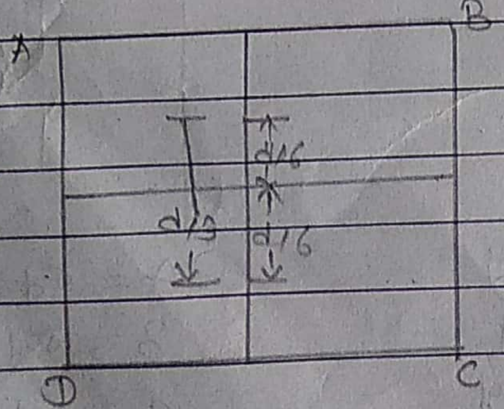
$$\therefore e \leq \frac{Z}{A}$$

"Justify that eccentricity of the force acting at section should be less or equal to ratio of section Modulus ~~to~~ Area of the section."

For rectangular section = $\boxed{e \leq \frac{Z}{A}}$

$$e \leq \frac{\frac{bd^2}{6}}{bd}$$

$$e \leq b/6$$



Rectangular

$\frac{b}{6} + \frac{b}{6} = \frac{b}{3}$ or

$\frac{d}{6} + \frac{d}{6} = d/3.$

force should be acting at middle their part that so member is in compression.

Note:→ σ_b is depended about y so σ_b is not uniform.
→ σ_d is uniform

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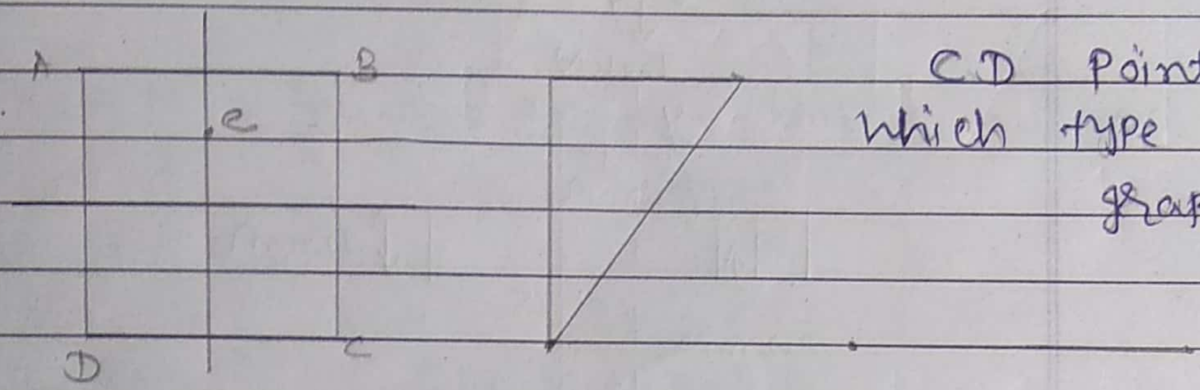
d/3 f (Maximum)

d/6 farthest fiber of the centroidal axis.

Note:→ Value of eccentricity within d/6 value then not induce the tension but induced the compression.



CD Point which type graph

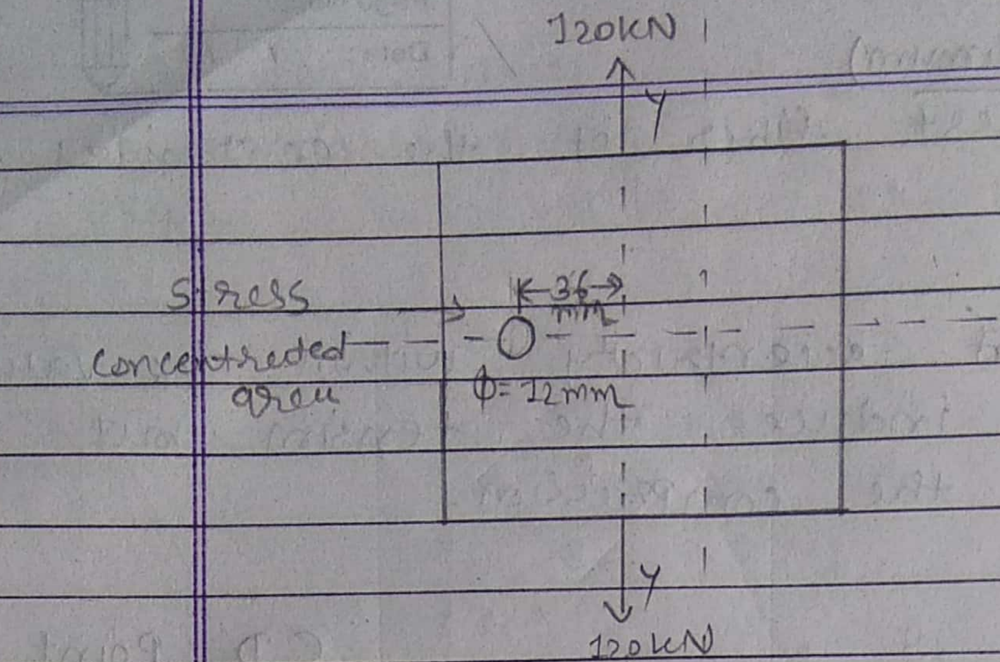
A flat bar is subjected to an axial pull of 120 kN as shown in figure. The bar is punched with a hall of 12 mm Diameter such that distance between center of the hall and centroidal axis (y-y axis) of the solid section is 36 mm. Calculate maximum and minimum stresses at the weakest section. or plot stress Distribution diagram or tentative

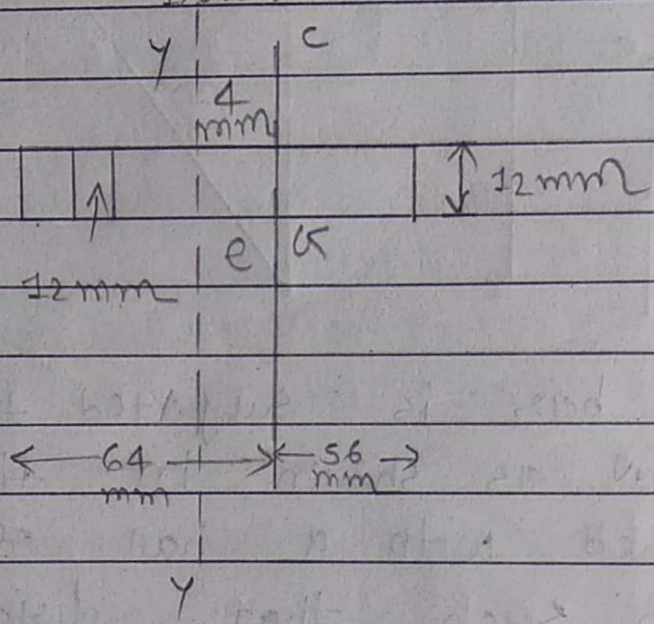
→ b = 120

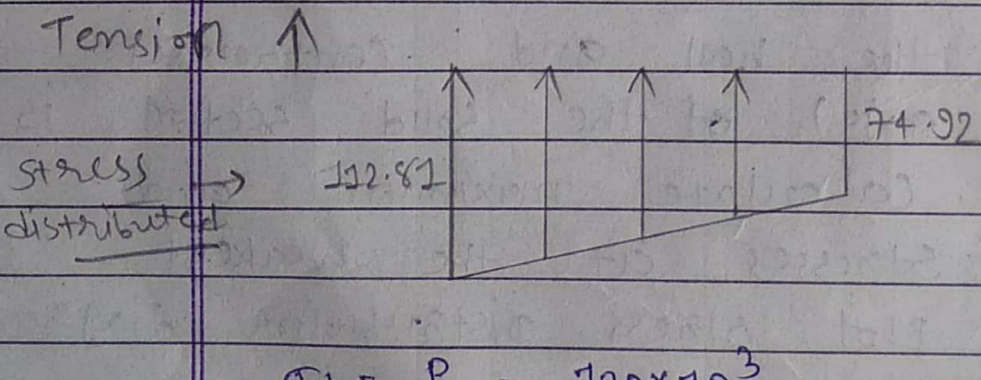
Pull stress

T +
C −

Pull stress
T +
C -







$$\sigma_d = \frac{P}{A} = \frac{120\times10^3}{(120\times12)-144} = \frac{120\times10^3}{1296} = 92.59\ N/mm^2$$

$$\sigma_b = \frac{M}{Z} = \frac{P_e}{I}\cdot y_c = \cancel{120}\times\cancel{10^3}\times$$

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$$\bar{x} = \frac{A_1 x_1 - A_2 x_2}{A_1 - A_2}$$

$$= \frac{1440(0) - (12\times12)(36)}{1440 - 144} = \underline{4\,mm}$$

Ans.

$$\sigma_{bc} = \frac{M}{2} = \frac{P_c}{I} \cdot y_c = \frac{120\times10^3 \times 4 \times 56}{1.52\times10^6} = 17.68\ N/mm^2$$

$$\sigma_{bt} = \frac{M}{2} = \frac{P_t}{I} \cdot y_t = \frac{120\times10^3 \times 4 \times 64}{1.52\times10^6} = 20.21\ N/mm^3$$

→ $I_{yy} = \frac{bd^3}{12} - \left[\left(\frac{bd^3}{12}\right)_h + Ah^2\right]$

$$= \frac{12\times(120)^3}{12} - \left[\frac{12\times(12)^3}{12} + (12\times12)(36)^2\right]$$

$$= 1728000 - 1728 - 186624$$

$I_{yy} = 1.54\times10^6\ mm^4$

$I_{CG} = I_{yy} - Ah^2$

$= 1.54\times10^6 - 1296(4)^2$

$I_{CG} = 1.52\times10^6\ mm^4$

→ $\sigma_{max} = \sigma_d(T) + \sigma_b(T)$

$= 92.6 + 20.21$

$\sigma_{max} = 112.81$

$\sigma_{min} = \sigma_d(T) - \sigma_b(C)$

$= 92.6 - 17.68$

$\sigma_{min} = 74.92$

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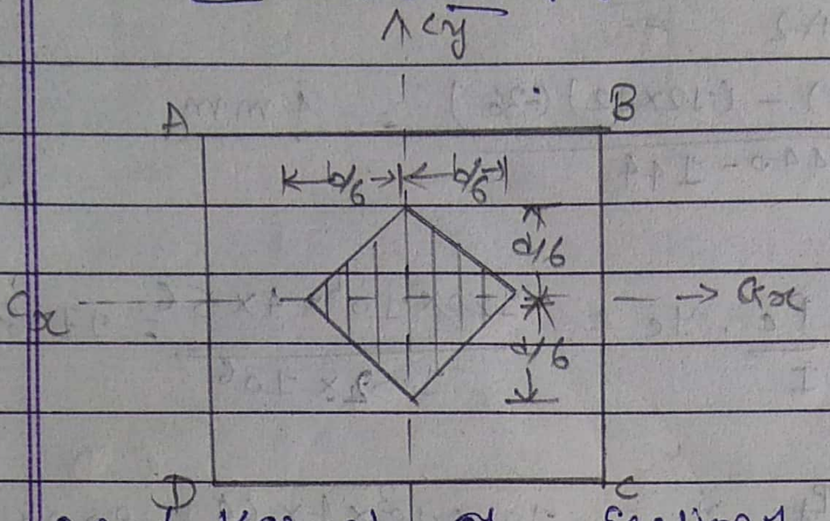
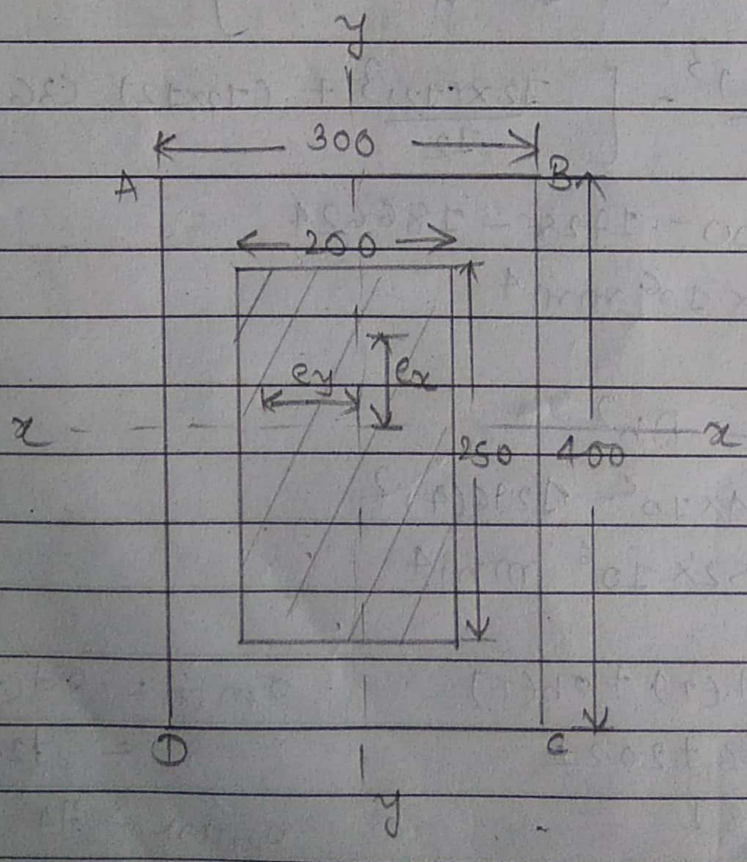
Biaxial Bending :-



Core / Kernel of Section :-

The Region within the section where if force is applied the section would remain under the compressive stress only.



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$$z_x = \frac{I_{xx}}{y} = \frac{\frac{BD^3}{12} - \frac{bd^3}{12}}{D/2}$$

$$= \frac{BD^3 - bd^3}{6D}$$

$$z_y = \frac{I_{yy}}{y} = \frac{DB^3 - db^3}{6B}$$

$$Z_x = \frac{300 \times (400)^3 - (200)(250)^3}{6 \times 400} = \frac{BD^3 - bd^3}{6D}$$

$$= \frac{1.92 \times 10^{10} - 3.125 \times 10^9}{2400}$$

$$= 6.697 \times 10^6 \text{ mm}^3$$

→ $$z_y = \frac{DB^3 - db^3}{6B}$$

$$= \frac{400 \times (300)^3 - (250)(200)^3}{6 \times 300}$$

$$= 4.888 \times 10^6 \text{ mm}^3$$

$$e_x = \frac{z_y}{A} = \frac{6.697 \times 10^6}{70000}$$

$$= 95.24 \text{ mm}$$

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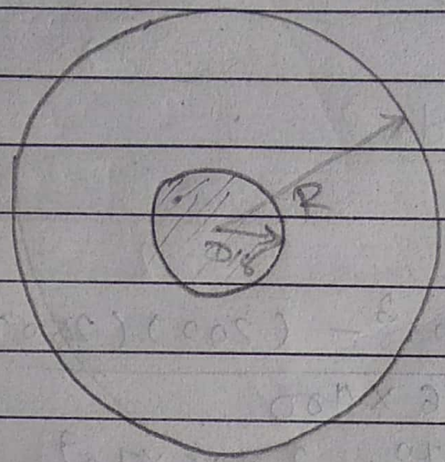
$$\rightarrow \quad e_y = \frac{Z_x}{A} = \frac{4.88 \times 10^6}{7000}$$

$$= 69.71 \text{ mm}$$

ex:-) (2)

uniform type of the stress

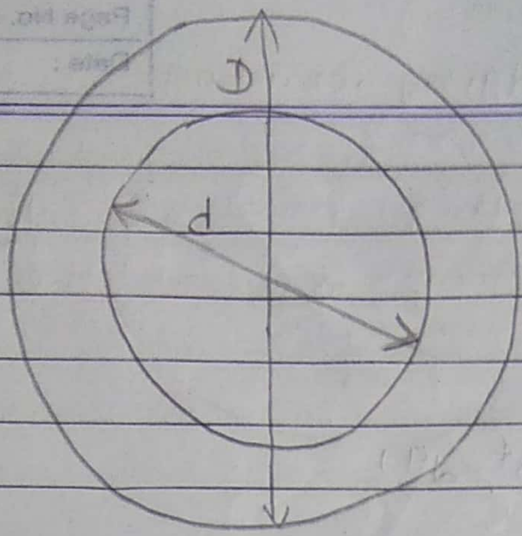


$$Z_x = \frac{I_{xx}}{y} = \frac{\frac{\pi}{64} D^4}{D/2} = \frac{\pi}{32} D^3$$

$A = \pi R^2$

$$e_y = \frac{Z_x}{A} = \frac{\pi/32 \, D^3}{\frac{\pi}{4} D^2} = \frac{D}{8}$$

exp 3



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

$$y = \frac{D}{2}$$

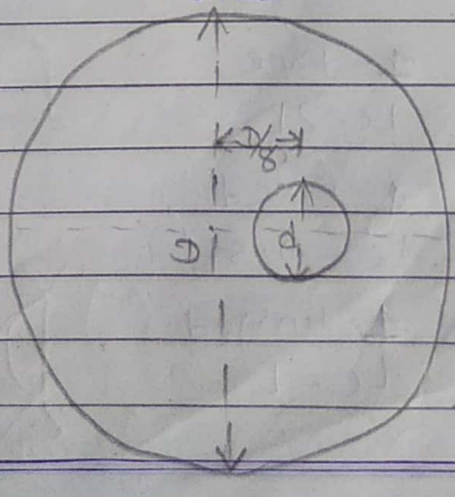
$$Z = \frac{\pi}{32} \frac{(D^4 - d^4)}{D} \qquad A = \frac{\pi}{4}(D^2 - d^2)$$

$$e = \frac{Z}{A} = \frac{1}{8D} \frac{(D^4 - d^4)}{(D^2 - d^2)}$$

$$= \frac{(D^2 - d^2)(D^2 + d^2)}{8D(D^2 - d^2)}$$

$$= \frac{D^2 + d^2}{8D}$$

exp 4
H.W.



D = 100
d = 25

Strut → To carry the compressive stress
Long column → Buckling
Short column → Buldging → crushing

Long column → Force is acting in core then compressive
→ Force is acting out of the core then Buckling.

→ $I_{xx} = \frac{\pi}{64}(D^4 - d^4)$ $D = 100$, $d = 25$

$Z = \frac{\pi}{8}\frac{(D^4 - d^4)}{D}$ $A = \frac{\pi}{4}(D^2 - d^2)$

$= \frac{\pi}{4}((100)^2 - (25)^2)$

$Z = 390.96 \times 10^3$ $= 7.35 \times 10^3$

$e = \frac{Z}{A} = \frac{390.96 \times 10^3}{7.35 \times 10^3}$

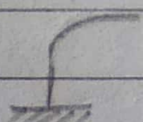
$= 53.19$

Euler's Theory

Buckling failure → P_{cr} → Crippling force

$= \frac{\pi^2 EI}{(Le)^2}$

(1) 1- Fixed 1- Free
$Le = 2L$



(2) 1 fixed 1- Fixed
$Le = 0.5L$

(3) 1 Hinged 1- Hinged
$Le = L$

$P_{cr} > P$ → Relation for short colums

$P_{cr} < P$ → Relation for long column

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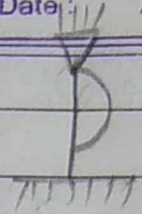
(4) 1 Hinged 1- Fixed

$L_e = 0.707L$



★ **Euler's Assumptions:**

→ Material follows hook's law
(Hook's law valid upto proposonal limit)

→ failure → Buckling

→ Material used to be uniform. Member

★ limitations:

Ex:- Mild steel as Material:

$F_y = 250\ MPa$ $\qquad I = Ad^2$

$F_p = 200\ MPa$ $\qquad I = Ak^2$

k = list radius of gyration

$$P_{cr} = \frac{\pi^2 E A k^2}{(L_e)^2}$$

$$\therefore \frac{P_{cr}}{A} = \frac{\pi^2 E k^2}{(L_e)^2}$$

$$\therefore \sigma = \frac{\pi^2 E k^2}{(L_e)^2}$$

$$\therefore \sigma_{cr} = \frac{\pi^2 E}{\left(\frac{L_e}{k}\right)^2}$$

$\left(\frac{L_e}{k}\right)$ → Slenderness ratio (λ)

$$\therefore \sigma_{cr} = \frac{\pi^2 E}{\lambda^2}$$

$\lambda = \frac{L_e}{k}$ — constant

$\lambda \propto L_e$

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$$(200) = \frac{\pi^2 \times (2\times 10^5)}{\lambda^2}$$

$$\therefore \lambda^2 = \frac{(3.141)^2 \times 2\times 10^5}{200}$$

$$\therefore \boxed{\lambda = 99.29}$$

$$\lambda > 99.3$$

ex.1 (1) A Mild Steel cube of 25 mm internal diameter and 32 mm External diameter has one end fixed and othered hinged. calculate the crippiing load assuming modulus of Elasticity $E = 2\times 10^5$ N/mm² take length of column = 3 m

→ $P_{cr} = \frac{\pi^2 E I}{(L_e)^2}$ e = effective

$L_e = 0.707 L$

$L = 3m$

$L = 3000$ mm

$L_e = 0.707 \times 3000$

$= 2121$ mm

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

$$= \frac{\pi}{64}\left((32)^4 - (25)^4\right)$$

$$= 32.28 \times 10^3 \text{ mm}^4$$

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$$P_{cr} = \frac{\pi^2 E I}{(L_e)^2}$$

$$= \frac{(3.14)^2 \times 2 \times 10^5 \times 32.28 \times 10^3}{(2121)^2}$$

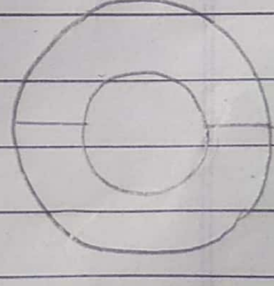
$$= 14.14 \times 10^3 \text{ N}$$

Ex: compare the crippling load of a solid circular section of 250 mm diameter with a hollow circular of same area and 40 mm thickness. the other conditions are same for the columns.

$$\frac{(P_{cr})_S}{(P_{cr})_H} = \frac{\frac{\pi}{64} D^4}{\frac{\pi}{64}(D^4 - d^4)} = 1.11 \times 10^8$$

$D - d = 80 \quad \rightarrow (i)$

area same: $\frac{\pi}{4} D^2 = \frac{\pi}{4}(D^2 - d^2)$



$\therefore D^2 = D^2 - d^2$

$\therefore D^2 = (D+d)(D-d)$

$\therefore \frac{D^2}{D-d} = D + d \quad \therefore D + d = 781.25$

$\therefore \frac{(250)^2}{80} = 250 + d$

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$D + d = 781.25$

$D - d = 80$

$2D = 861.25$

$\therefore D = 430.62 \text{ mm}$

$\therefore d = 350.62 \text{ mm}$

$$\frac{(P_{cr})_s}{(P_{cr})_H} = \frac{I_s}{I_H} = \frac{1.91 \times 10^8}{\frac{\pi}{64}\left((430.62)^4 - (350.62)^4\right)}$$

$(P_{cr})_s = 0.2019\ (P_{cr})_H$