5ME4-04 : Design of Machine Elements-I.

Unit-5

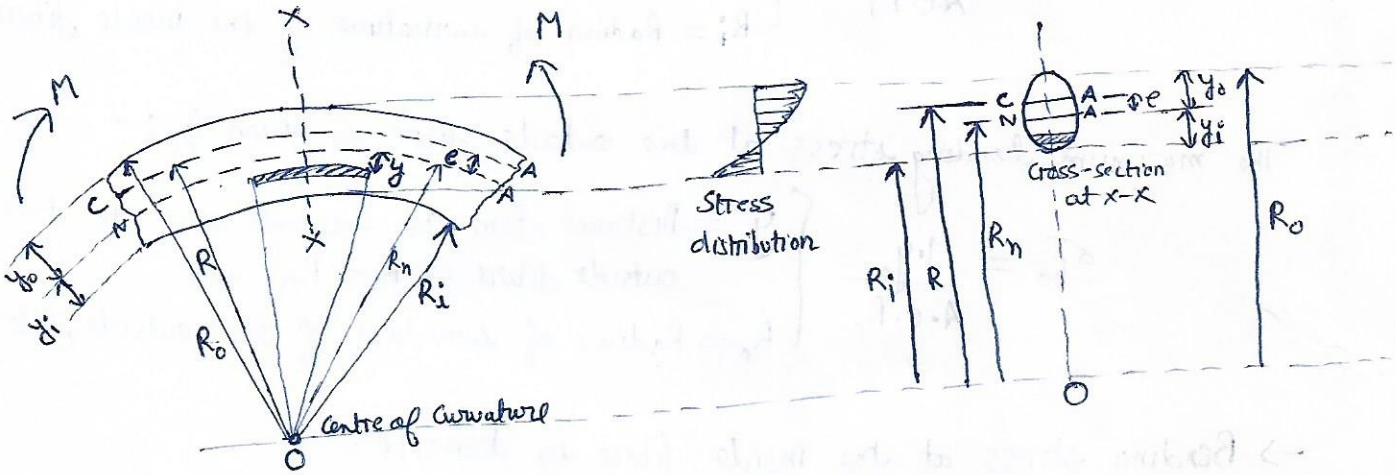
CO-4 : To Design threaded fasteners.

* Design of Threaded fastners: Bolt of uniform strength, Preloading of Bolt - Effect of Initial Tension and applied loads.
* Power screw like load screw, screw jack
* Design of member which are curved like crane hook, body of C-clamp, machine frame etc.

Unit - 5

Bending Stress in Curved Beams :- (Design Data book :- pg → 26.2 — 26.4)

→ For the straight beams, the neutral axis of the section coincides with its centroidal axis and the stress distribution in the beam is linear. But in case of curved beams, the neutral axis of the cross-section is shifted towards the centre of curvature of the beam causing a non-linear distribution of stress. The neutral axis of the curved beam lies between the centroidal axis and the centre of curvature and always occurs within the curved beams. The application of curved beam principle is used in crane hooks, chain links and frames of punches, presses, planers, etc.



→ The general expression for the bending stress (σ_b) in a curved beam at any fibre at a distance y from the neutral axis is given by :-

$$\sigma_b = \frac{M}{A \cdot e}\left(\frac{y}{R_n - y}\right)$$

M = Bending moment acting at the given section about the centroidal axis

A = Area of cross-section

e = Dist b/w neutral axis and centroidal axis

R = Radius of curvature of the centroidal axis

R_n = Radius of curvature of the neutral axis

y = Distance from the neutral axis to the fibre under consideration. It is positive for the distance towards the centre of curvature and negative for the distance away from the

Important points :-

① The bending stress in the curved beam is zero at a point on the neutral axis.

② If the section is symmetrical such as a circle, rectangle, I-beam with equal flanges, then the maximum bending stress will always occur at the inside fibre.

③ If the section is unsymmetrical, then the maximum bending stress may occur at either the inside fibre or the outside fibre.

The maximum bending stress at the inside fibre is given by :-

$$\sigma_{bi} = \frac{M y_i}{A.e.R_i}$$

{ y_i = Distance from the neutral axis to the inside fibre $= R_n - R_i$

R_i = Radius of curvature of the inside fibre }

The maximum bending stress at the outside fibre is given by :-

$$\sigma_{bo} = \frac{M.y_o}{A.e.R_o}$$

{ y_o = Distance from the neutral axis to the outside fibre $= R_o - R_n$, and

R_o = Radius of curvature of the outside fibre }

→ Bending stress at the inside fibre is tensile.

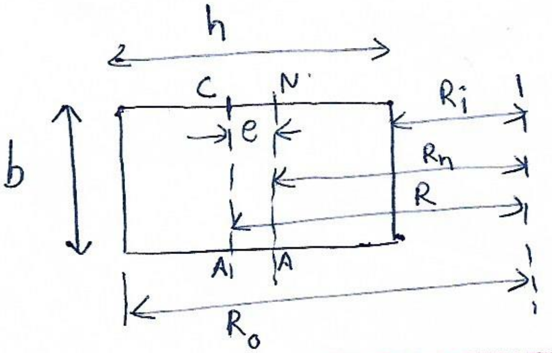
→ Bending stress at the outside fibre is compressive.

④ If the section has an axial load in addition to bending, then the axial or direct stress (σ_d) must be added algebrically to the bending stress, in order to obtain the resultant stress on the section.

i.e Resultant stress, $\boxed{\sigma = \sigma_d \pm \sigma_b}$

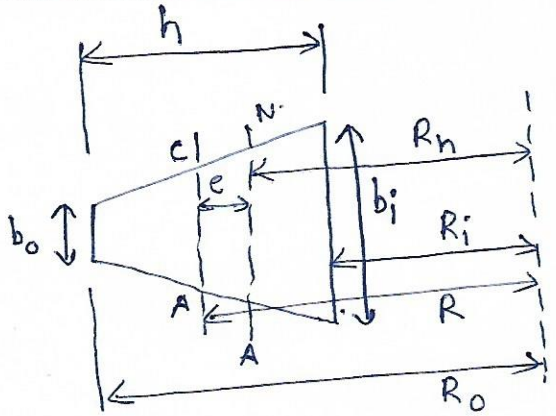
Values of R_n and R for various commonly used cross-section in curved beams :-

Section | **Values of R_n and R**



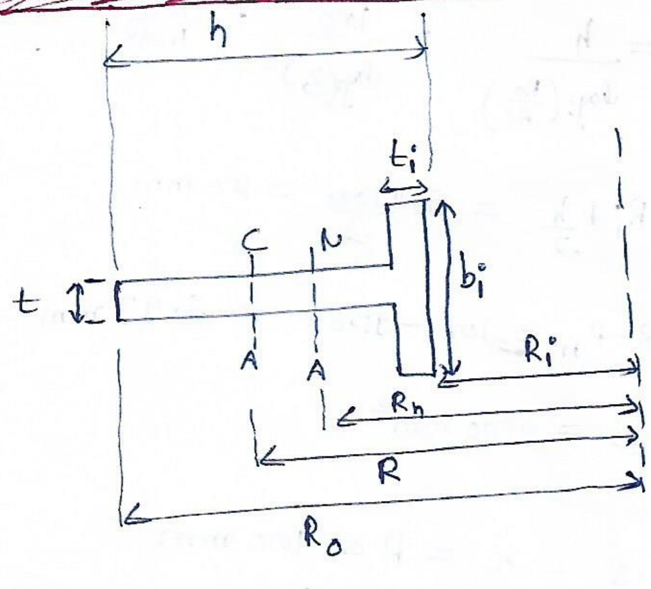
$$R_n = \frac{h}{\log_e\left(\frac{R_o}{R_i}\right)}$$

$$R = R_i + \frac{h}{2}$$



$$R_n = \frac{\left(\frac{b_i + b_o}{2}\right)h}{\left(\frac{b_i R_o - b_o R_i}{h}\right)\log_e\left(\frac{R_o}{R_i}\right) - (b_i - b_o)}$$

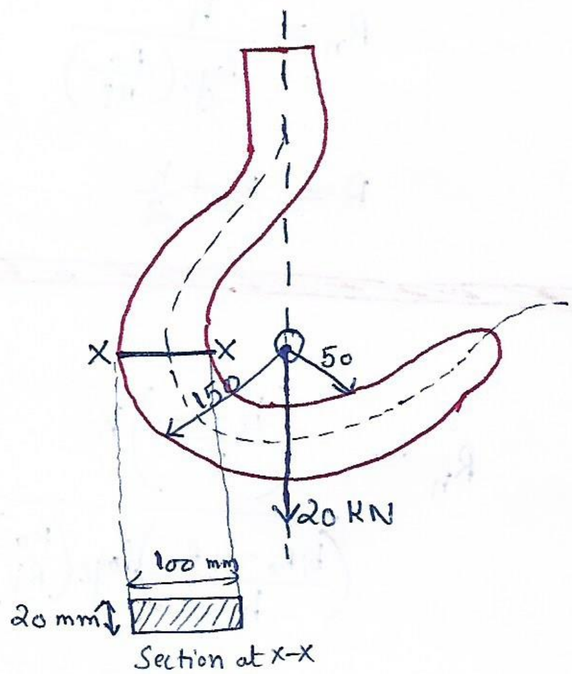
$$R = R_i + \frac{h(b_i + 2b_o)}{3(b_i + b_o)}$$



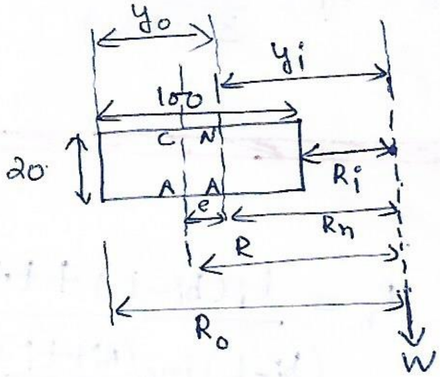
$$R_n = \frac{t_i(b_i - t) + t \cdot h}{(b_i - t)\log_e\left(\frac{R_i + t_i}{R_i}\right) + t \cdot \log_e\left(\frac{R_o}{R_i}\right)}$$

$$R = R_i + \frac{\frac{1}{2}h^2 t + \frac{1}{2}t_i^2(b_i - t)}{ht + t_i(b_i - t)}$$

Q1. The crane hook carries a load of 20 KN as shown in figure below. The section at X-X is rectangular whose horizontal side is 100 mm. Find the stresses in the inner and outer fibres at the given section.



Solution:-



$R_i = 50$ mm

$R_o = 150$ mm

$$R_n = \frac{h}{\log_e\left(\frac{R_o}{R_i}\right)} = \frac{100}{\log_e(3)} = \frac{100}{1.098} = 91.07 \text{ m}$$

$$R = R_i + \frac{h}{2} = 50 + \frac{100}{2} = 100 \text{ mm}$$

$$e = R - R_n = 100 - 91.07 = 8.93 \text{ mm}$$

Area of X/sc at X-X $= A = bh = 20 \times 100 = 2000 \text{ mm}^2$

distance b/w load and the centroidal axis $= x = R = 100$ mm

$\therefore$ Bending Moment about the centroidal axis $= M = Wx$
$= 2 \times 10^6$ N-mm

The Section at X-X is subjected to a direct tensile load of $W = 20 \times 10^3$ N and a bending moment of $M = 2 \times 10^6$ N-mm.

direct tensile Stress at Section X-X :-

$$\sigma_t = \frac{W}{A} = \frac{20 \times 10^3}{2000} = 10 \text{ N/mm}^2 = 10 \text{ MPa}$$

The distance from the neutral axis to the inside fibre $= y_i = R_n - R_i$

$= 91.07 - 50 = 41.07$ mm

distance from the neutral axis to outside fibre $= y_o = R_o - R_n$

$= 150 - 91.07 = 58.93$ mm

$$\therefore \sigma_{bi} = \frac{M \cdot y_i}{A \cdot e \cdot R_i} = \frac{2 \times 10^6 \times 41.07}{2000 \times 8.93 \times 50} = 92 \text{ N/mm}^2 = 92 \text{ MPa (tensile)}$$

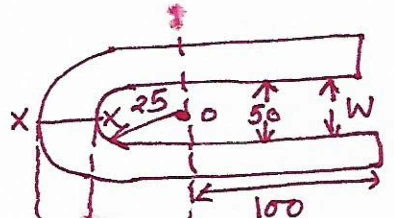
$$\sigma_{bo} = \frac{M \cdot y_o}{A \cdot e \cdot R_o} = \frac{2 \times 10^6 \times 58.93}{2000 \times 8.93 \times 150} = 44 \text{ N/mm}^2 = 44 \text{ MPa (Compressive)}$$

$\therefore$ Resultant stress at the inside fibre $= \sigma_t + \sigma_{bi} = 10 + 92 = 102$ MPa (tensile) Ans

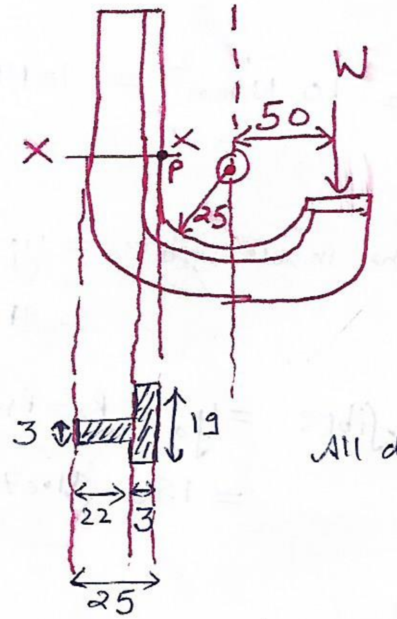
Resultant stress at the outside fibre $= \sigma_t - b_o = 10 - 44 = -34$ MPa

$= 34$ MPa (compressive) Ans

Q2. The frame of a punch press is shown in figure below. Find the stress at the inner and outer surface at section X-X of the frame if W = 5000 N.



Q3. A C-Clamp is subjected to a maximum load of W. If the maximum tensile stress in the clamp is limited to 140 MPa. Find the value of load W.



All dimensions are in mm.