Syllabus

1. Concept of Stress and Strain.
2. Constitutive Relationship.
3. Deformation due to tension, compression & temperature change
4. Beam statics: Reactions, Axial force, Shear force, bending moments. ~~dia~~
5. Axial force, shear force & bending moments diagram — using method of section and Summation approach.
6. Elastic Analysis of circular shaft, Solid non-circular and thin walled tubular members subjected to torsion
7. Flexural and Shear Stresses in Beams, Shear centre
8. Thin pressure vessels.

Lec-2 Mechanics of Solids

Sat
16.13.13

Purpose: To design the component. parts of structure in order to resist the actual / Probable forces.

Examples:

1) Wall thickness of pressure vessels. such as — Water tank, Gas sylinder.
2) Adequate floor size for intended use.
3) Size of machine shaft for torque.
4) Wing of an Aeroplane to with stand. Aerodynamic forces — in flight, Take off, Landing.
5) Deflection → must not exceed certain level.
6) Failure through Elastic Instability (Collapse through buckling due to slenderness under compressive load).

* We do not know the Actual load. So all calculation is done by probable load.
* National building code.

Scope: In Engineering practice all above will be satisfied with minimum expenditure of a given material. Besides, weight of the package may determine success of mission.

Gist: Mechanics of Solids involves Analytical Methods for determining 3 important condition —

1. Strength.
2. Stiffness.
3. Stability.

Important contributors:

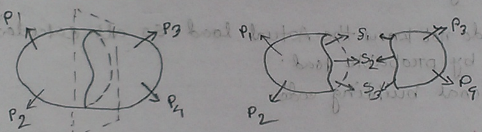
Indian → Galileo → Early 17^{th} century

Franch → Coloumb, Poisson, Navier, ST. Venant, Cauchy → 19^{th} century

English → R. Hooke, Thom. Young → Late 17^{th} century

German. → Otto Mohr → 19^{th} century.

Method of section:



Section of a body

Basic approach:

1. Isolate a member
   Draw free body diagram of a whole member.

2. Determine reaction using equations of statics or Boundary condition.
   For indetermine structures statics is supplemented with kinematic condition.

3. Pass a section perpendicular to the member axis at the location of interest.

axis → Locas of the CG of the cross section of is the axis. Axis is parallal to the direction of the length of the member.

Isolate any one part of the segment with all forces.

4. Determine these internal forces using equation; condition of the isolated segment.

* Beam length এর দিক থেকে ঠিক থাকলেও deflection বেশি হলে section বাড়াতে হবে।

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Lec-3

Beam Statictics

Sunday
17.11.13

Beam: In many structural and machine design, members must resist forces applied laterally or transversely to their axes. Such members are called Beams. The main member of supporting floors of buildings are beams.

N.B— Coloumn — Axial loaded member. Load transmits along the axis.

Moment = Force × Perpendicular direction.

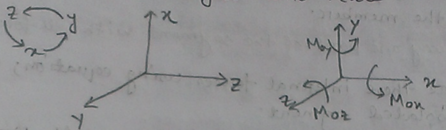
Mechanics → deals with forces

Solid " → deals with forces of solid materials.

Statictis :- 3 equations

$$\left.\begin{matrix} \Sigma F_x = 0 & \Sigma_x M = 0 \\ \Sigma F_y = 0 & \Sigma_y M = 0 \\ \Sigma F_z = 0 & \Sigma_z M = 0 \end{matrix}\right\}$$ Forces are equillibrium

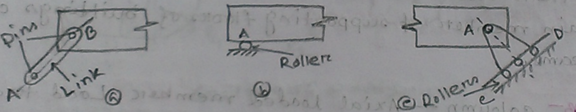
Statictis ~~ed~~ law for 3 dimensional body.
Moment along the z axis.
All most 2 dimension.
We always use right hand rule.



Diagrammatic Conventions for support:

Types of supports: Three types of supports are recognised for planar structures.

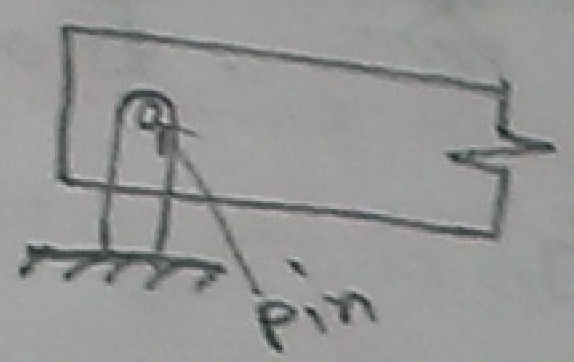
1. **Link support** – It is capable of resisting a force in only one specific line of action.



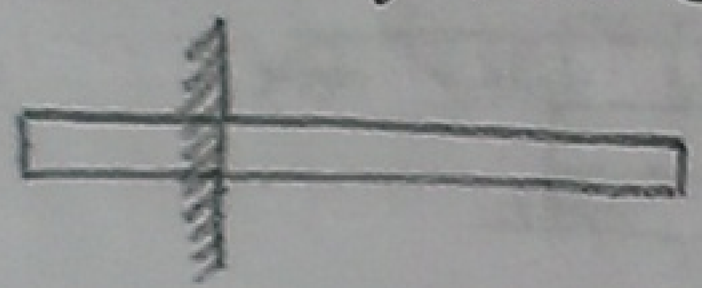
In Fig (a) can resist a force only in the direction of line AB. In the fig (b) can resist only a vertical force whereas the rollers in fig (c) can resist only a force that acts perpendicular to the plane CD.

A rollar support is capable of resisting a force in either direction along the line of action of the reaction.

2. **Pin support:** A pinned support is capable of resisting a force acting in any direction of the plane. Hence, in general the reaction ~~component~~ at such a support may have two components. One is horizontal and the other is vertical direction.

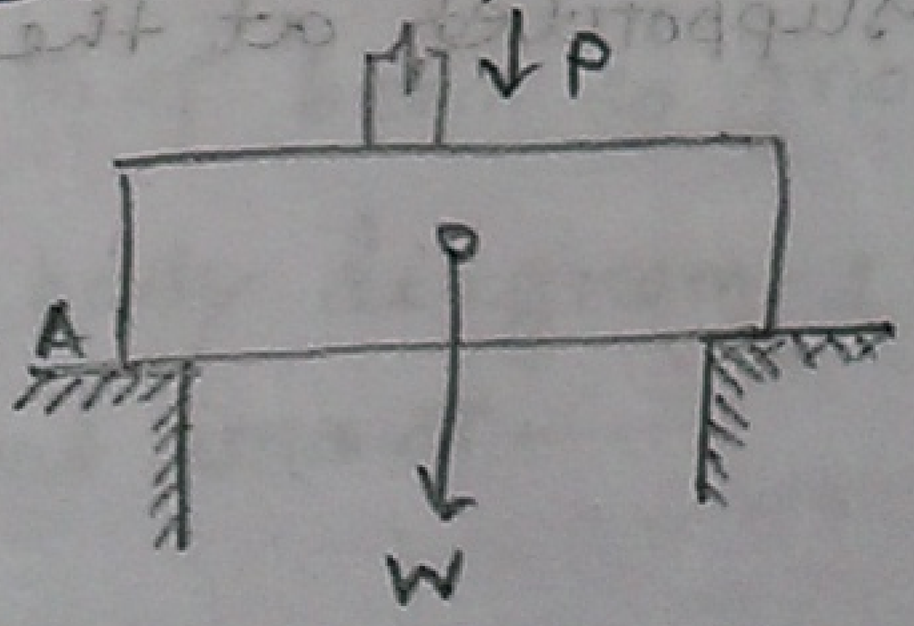


3. **Fixed support:** This type of support is able to resist a force in any direction and is also capable of resisting a moment or a couple. A system of three forces can exist at such a support, two component of force and moment.



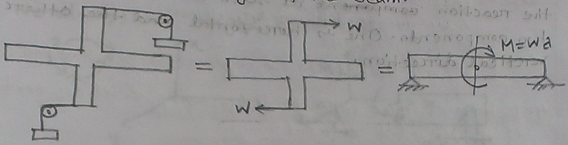
Diagrammatic convention for loading:

1. **Concentrated forces:** A force is applied to a beam through a post, a hanger, or a bolted detail. Such arrangements apply the force over a very limited portion of the beam and are idealized for the purposes of beam analysis as concentrated forces.



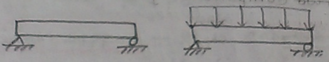
2. Uniformly distributed load:

The load is usually expressed as force per unit length of the beam.

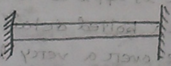


Classification of Beam:

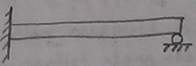
1. Simple supported beam: If the supports are at the ends and are either pin or rollers.



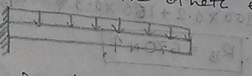
2. Fixed ended beam: The beams if the ends have fixed supports.



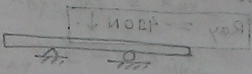
3. Restrained beam: The fixed at one end and ~~completely free at the~~ simply supported at the other.



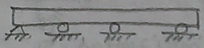
4. <u>Cantilever beam:</u> A beam fixed at one end and completely free at the other end.



5. <u>Overhanging beam:</u> If the beam projects beyond a support.



6. <u>Continuous beam:</u> If intermediate supports are provided for a physically continuous member acting as a beam.



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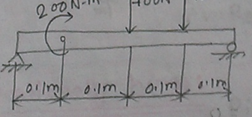
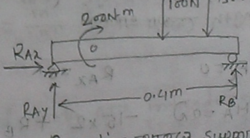
<u>Examples</u>

<u>Calculation of Beam Reactions</u>

1.





Depth of beam is ignored. free body diagram-এ কোন support থাকে না।

Reaction থাকলে support থাকবে না। Reaction passes through the centroid of the cross section.

$\Sigma F_x = 0$ $\boxed{R_{Ax} = 0.}$

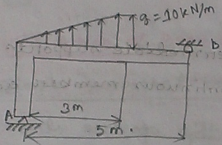
$\Sigma M_A = 0$ ↻ $200 + 100 \times 0.2 + 150 \times 0.3 - R_B \times 0.4 = 0$

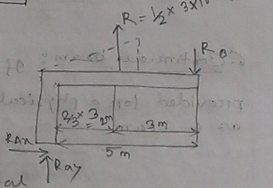
$\therefore \boxed{R_B = 670 N \uparrow}$

$\Sigma M_B = 0$ ↻ $200 - 100 \times 0.2 - 150 \times 0.1 + Ray \times 0.4 = 0$

$\Rightarrow \boxed{Ray = -410 N \downarrow .}$

2.





* All frame has a horizontal part and a verticle part.
* The intensity of force is varied.
* Centroid বের করতে হবে।
* যদি frame এর উপর কোন force দেওয়া থাকে তবে of course length দেওয়া থাকবে।

$\Sigma F_x = 0$ $R_{Ax} = 0.$

$\Sigma M_A = 0$ ↻ $-15 \times 2 + R_B \times 5 = 0$

$\Rightarrow R_B = 6 KN \downarrow$

$\Sigma M_B = 0$ ↻ $15 \times 3 + Ray \times 5 = 0$

$\Rightarrow Ray = -9 KN \downarrow .$

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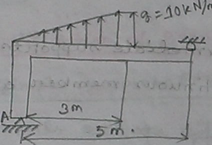

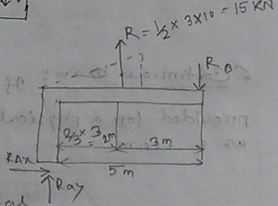

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$\Sigma F_x = 0$ $\boxed{R_{Ax} = 0.}$ 3.

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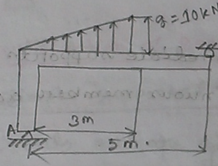

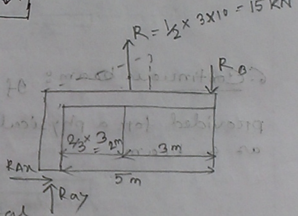

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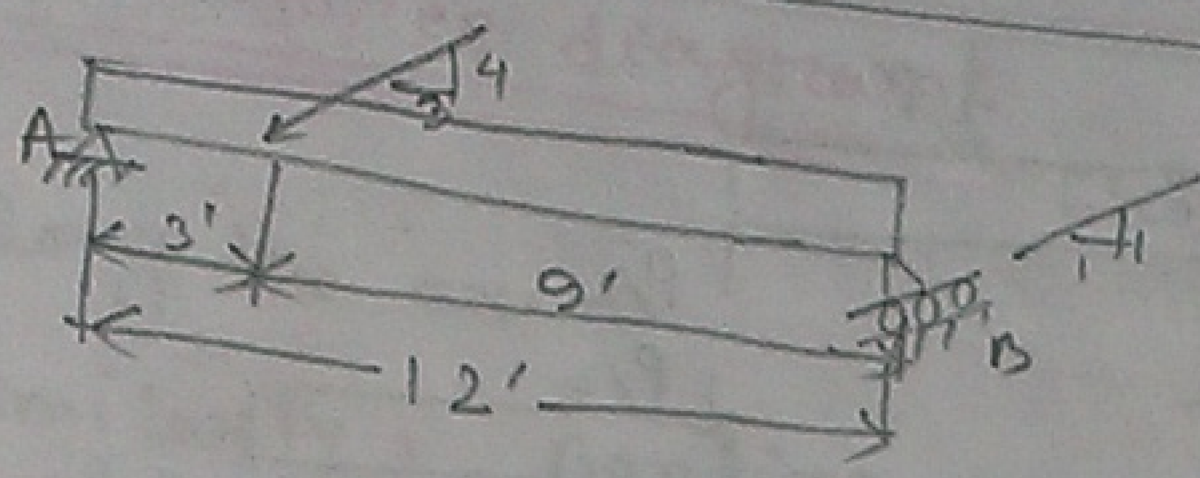
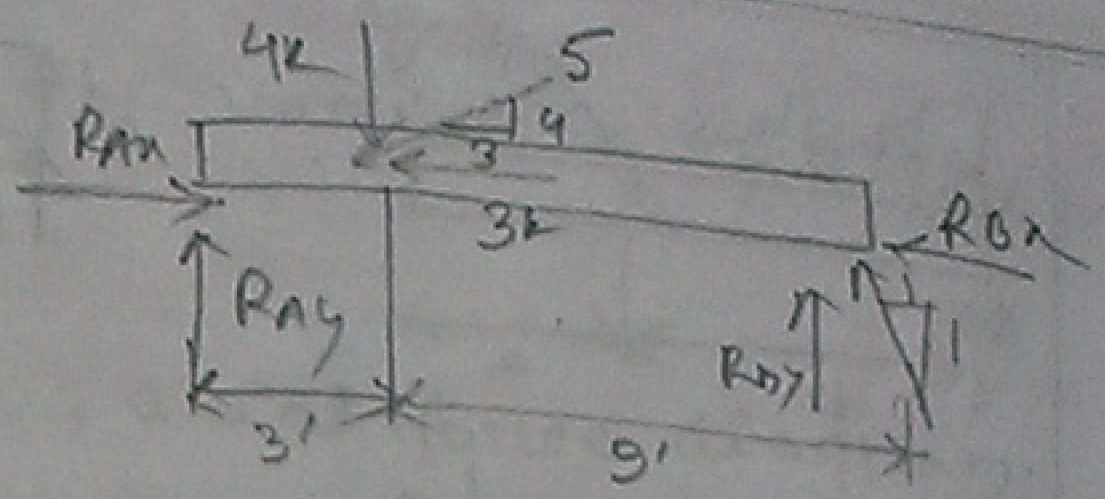




$\Sigma M_A = 0 \curvearrowright \quad 4 \times 3 - R_{By} \times 12 = 0$

$\therefore R_{By} = 1k \uparrow = R_{Bx}$

R.

$\Sigma M_B = 0 \curvearrowright \quad R_{Ay} \times 12 - 4 \times 9 = 0$

$\therefore R_{Ay} = 3k \uparrow$

$\Sigma F_x = 0 \rightarrow \quad R_{Ax} - 3 - 1 = 0$

$\therefore R_{Ax} = 4k$

$1^t = 10{,}000$ N
$= 10$ KN
$= 1000$ kg
$= 2240$ lbs

$1^t =$ যুক্তরাজ্য (2240 lbs)
যুক্তরাষ্ট্র
$= 2000$ lbs

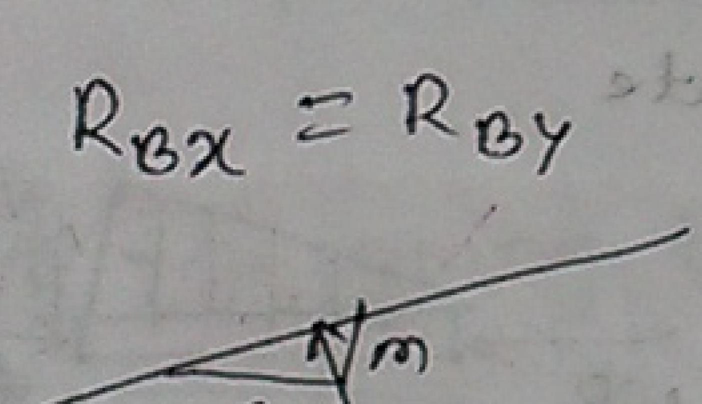
$1^t = 1$ Metric ton

$1^t = 9.81$ KN

$R_A = \sqrt{4^2 + 3^2} = 5k$

$R_B = \sqrt{1^2 + 1^2} = \sqrt{2}k$

$R_{Bx} = R_{By}$

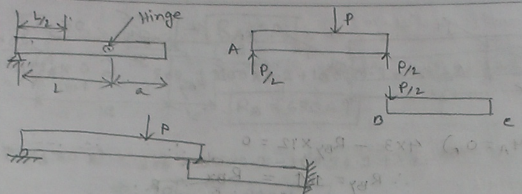


$\frac{R_{Bx}}{m} = \frac{R_{By}}{n}$

$\therefore R_{Bx} = \frac{m}{n} R_{By}$

Occasionally hinges: Pinned joints are introduced into Beam.

A hinge can transmit only horizontal and vertical forces no moment.



So these hinge points are locations for sub dividing structures into parts.

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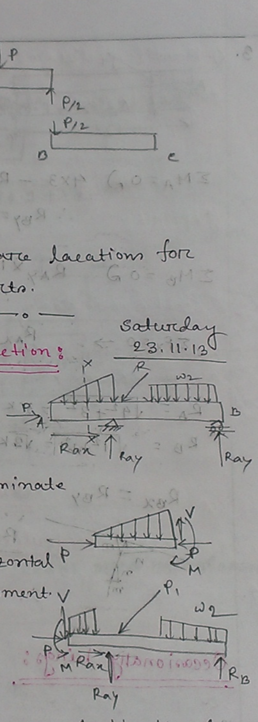
Saturday
23.11.13

Application of the method of section:

- A free body diagram.
- Compute reactions.
- Apply method of section
- Simple it statically Determinate structure.



At a section in general a horizontal force P vertical force V and moment M are necessary to maintain equillibrium —

P → axial force

V → shear force

M → Bending moment at the section

Application of method of section.

[x axis এর against-এ যে moment is called twisted moment]

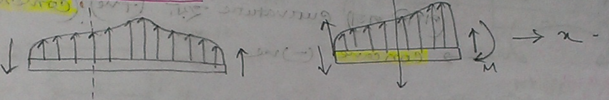
Shear force diagram:

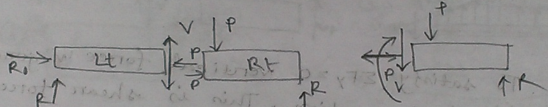
Show the variation of shear force along the axis.

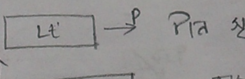
Similarly, Bending moment, axial force diagram.

Shear in Beams:

Resultant left end



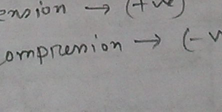




→ Rt face of left segment

Rt face force নিচের দিকে থাকলে (+ve)

Left → going to up (+ve)



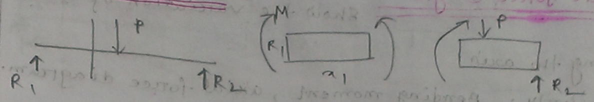
Pর সৃষ্টি করলে (+ve)

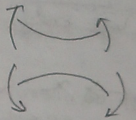
বাম দিকে হবে (+ve)

tension → (+ve)

compression → (-ve)

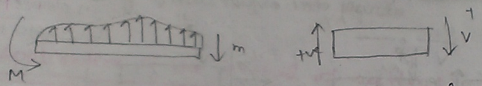
Bending moment :





→ (+ve) bending moment which tries to bend the beam in such a way that (হাসি দেয়া) curvature হয়। (+ve) (convex)

→ concave (−)ve



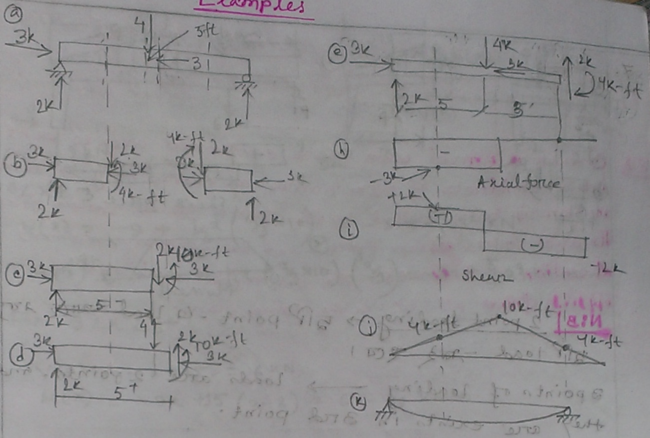
To satisfy $\Sigma F_y = 0$ vertical force 'V' generally must exist at a section. This is shear force.

Left side → segment GOING UP (+ve) shear.

An upward force on left face → (+ve)

* Calculation সহজ করার জন্য sign কখনো কখনো অন্য রকম হয়

Examples



Solve:

$0 < x < 5 \qquad V = +2k$

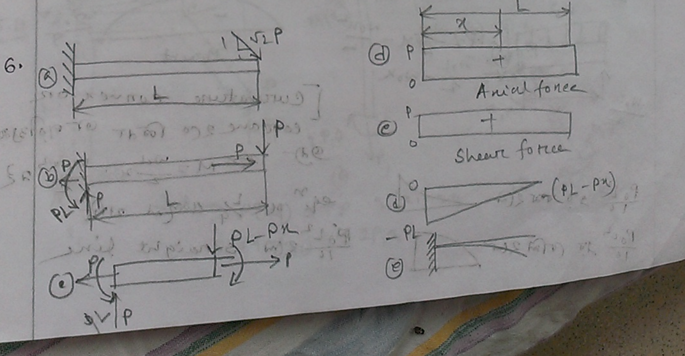
$5 < x < 10 \qquad V = -2k$

$0 \le x \le 5 \qquad M = 2x \text{ k-ft}$

$5 \le x \le 10 \qquad M = 2x - 4(x-5)$

$= 2x - 4x + 20 = (20 - 2x) \text{ k-ft}.$

6.



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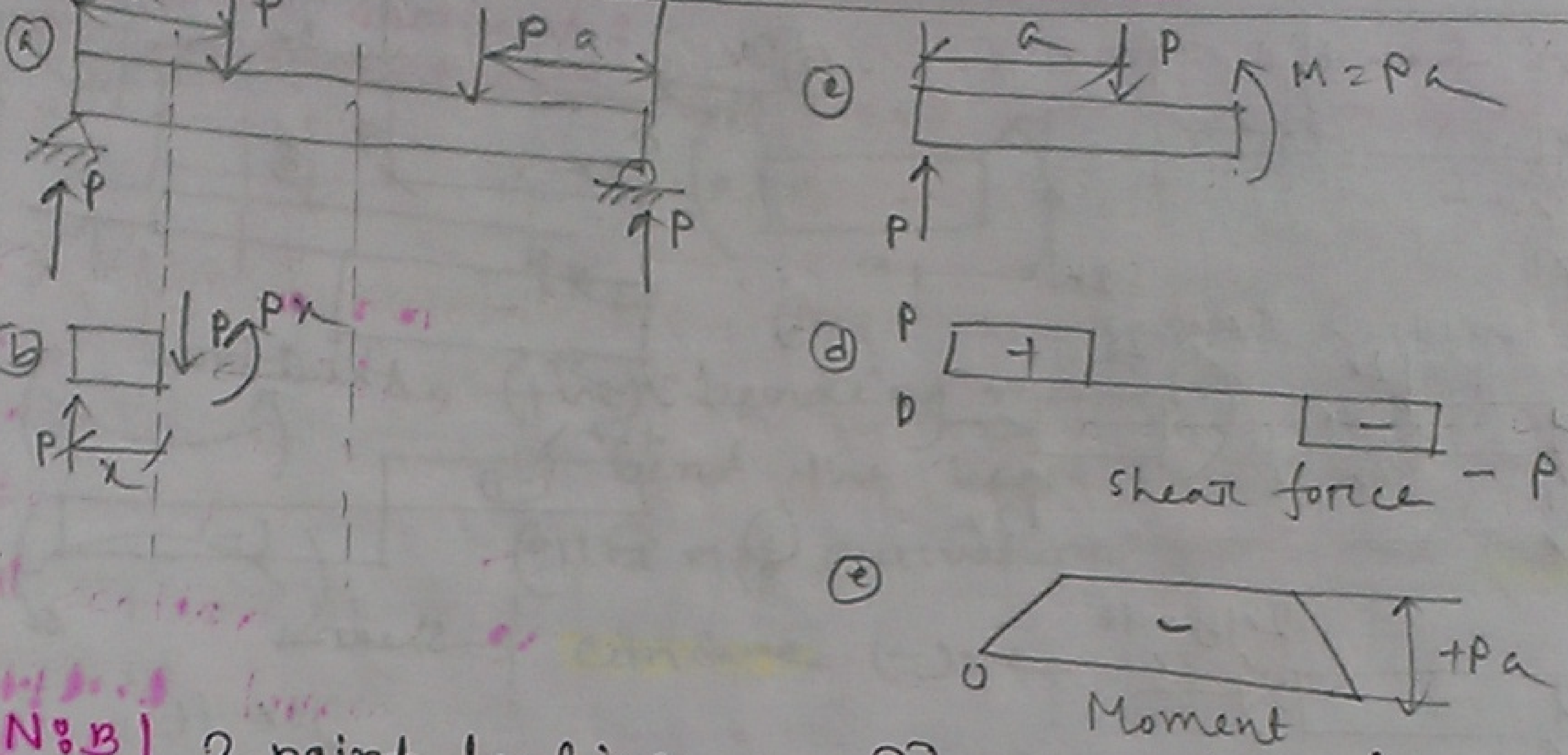
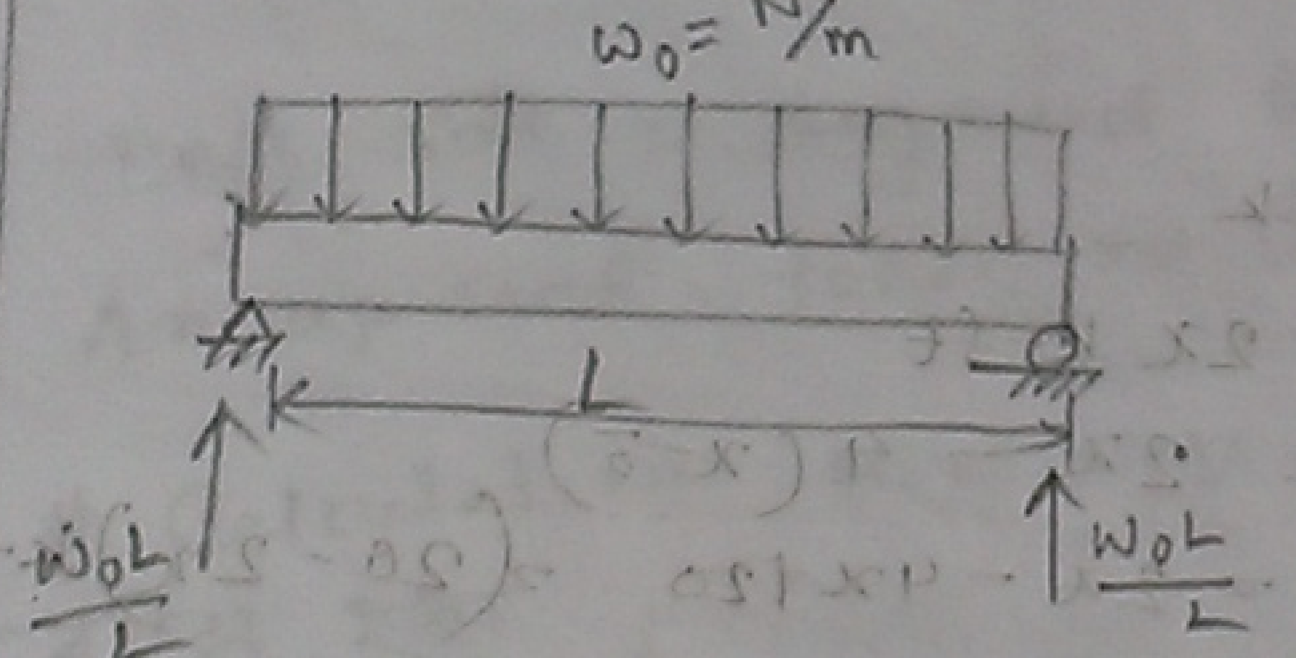
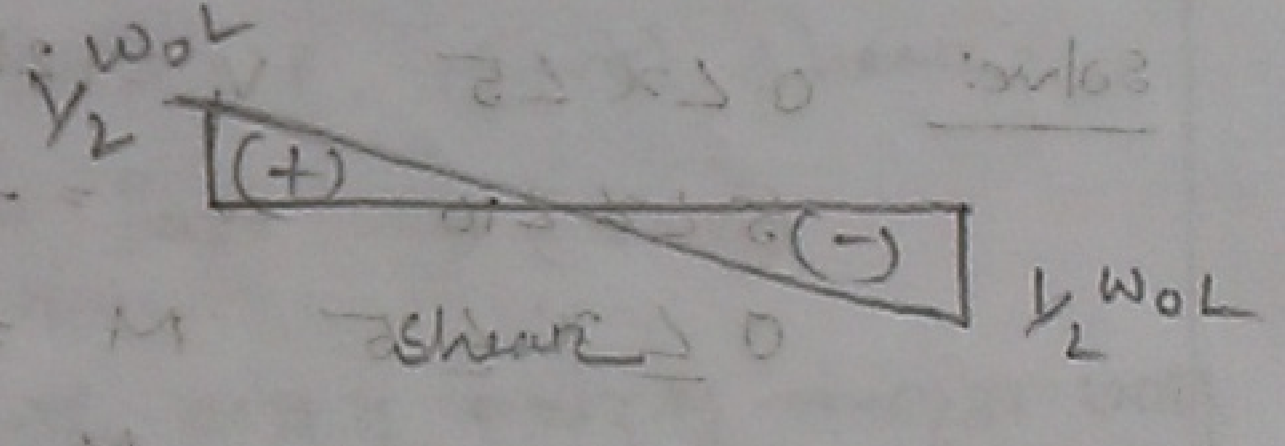


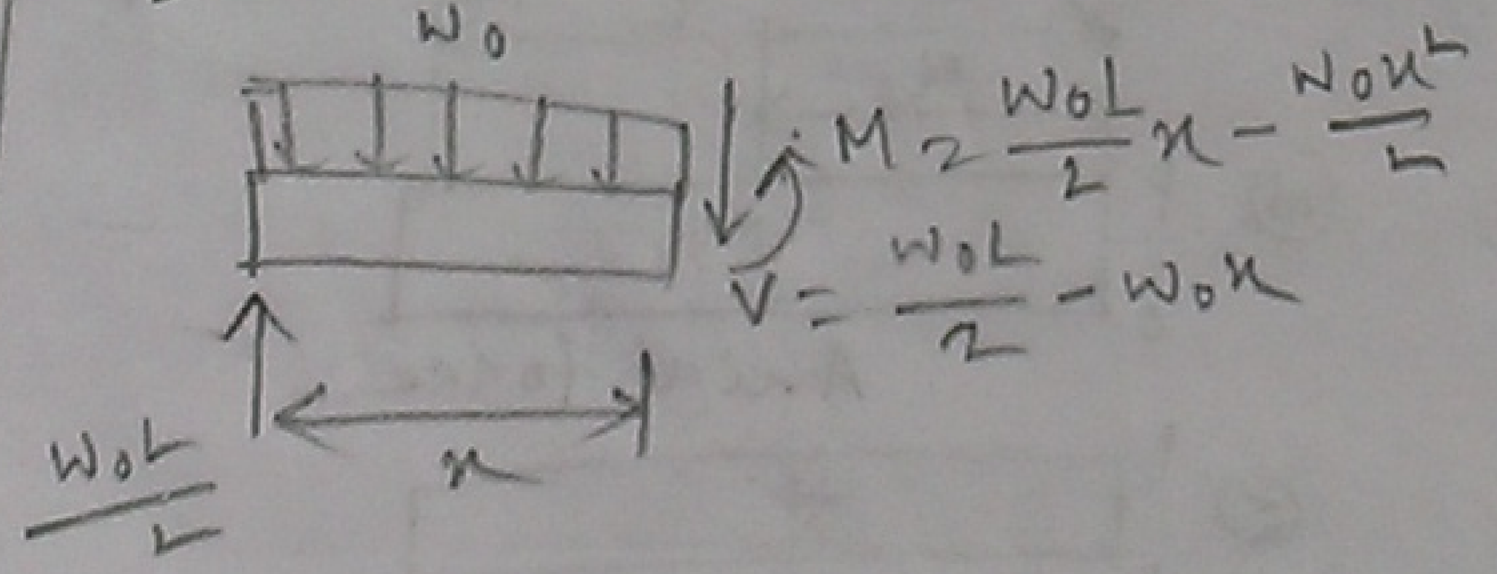
N.B | 2 point loading → দুটি point-এ load আছে এবং দুটি load একই হবে।

3 points of loading ⟶ loads are 2 points, and they are exists in 3rd point.

8.

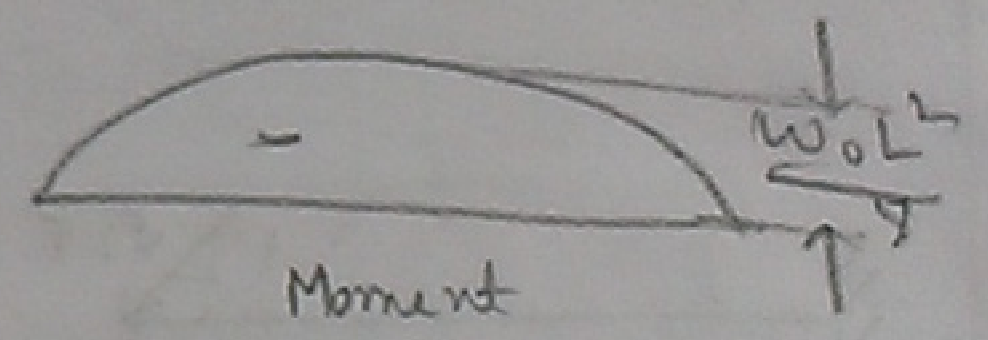




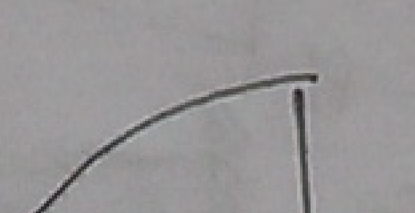


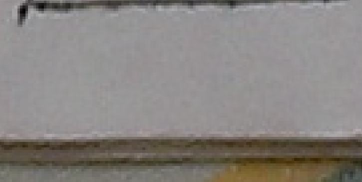
$M = \frac{w_0L}{2}x - \frac{w_0x^2}{2}$

$V = \frac{w_0L}{2} - w_0x$

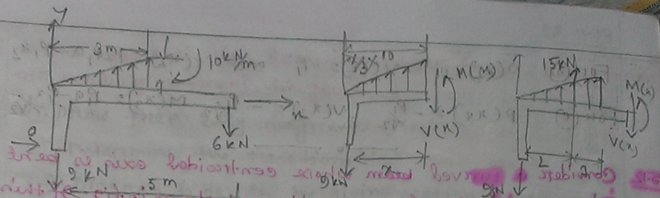


[Curvature convex or concave হবে কিনা তা নির্ণয়ের জন্য $M = \frac{w_0L}{2}x - \frac{w_0x^3}{2}$ হয় eqn $x = L/4$ বসালে যদি $\frac{P_0L^2}{16}$ হলে straight line

$\frac{P_0L^2}{16}$ এর কম হলে 

$\frac{P_0L^2}{16}$ এর বেশি হলে 

5-9



$0 < x < 3$

$$V(x) = -9 + \frac{1}{2}x\left(\frac{x}{3}\times 10\right) = -9 + \frac{5}{3}x^2 \text{ kN}$$

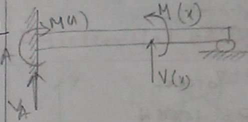
$$M(x) = -9x + \frac{1}{2}x\left(\frac{x}{3}\times 10\right)\left(\frac{x}{3}\right) = -9x + \frac{5}{9}x^3 \text{ kN-m.}$$

For $3 < x < 5$

$$V(x) = -9 + 15 = 6 \text{ kN}$$

$$M(x) = -9x + 15(x-2) = 6x - 30 \text{ kN-m.}$$

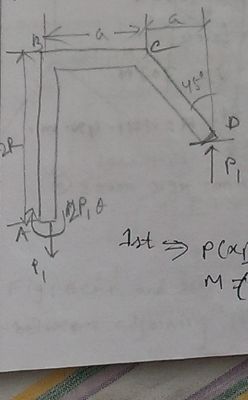
5-10

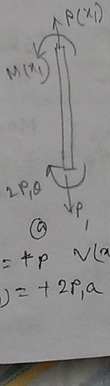


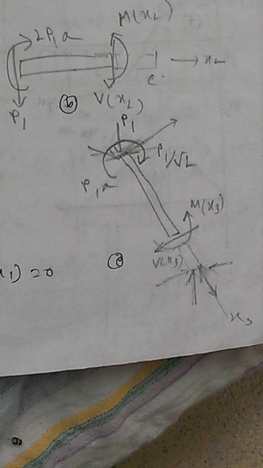
$$V = V_A - w_0 x$$

$$M = M_A + V_A x - \frac{w_0 x^2}{2}$$

5.11



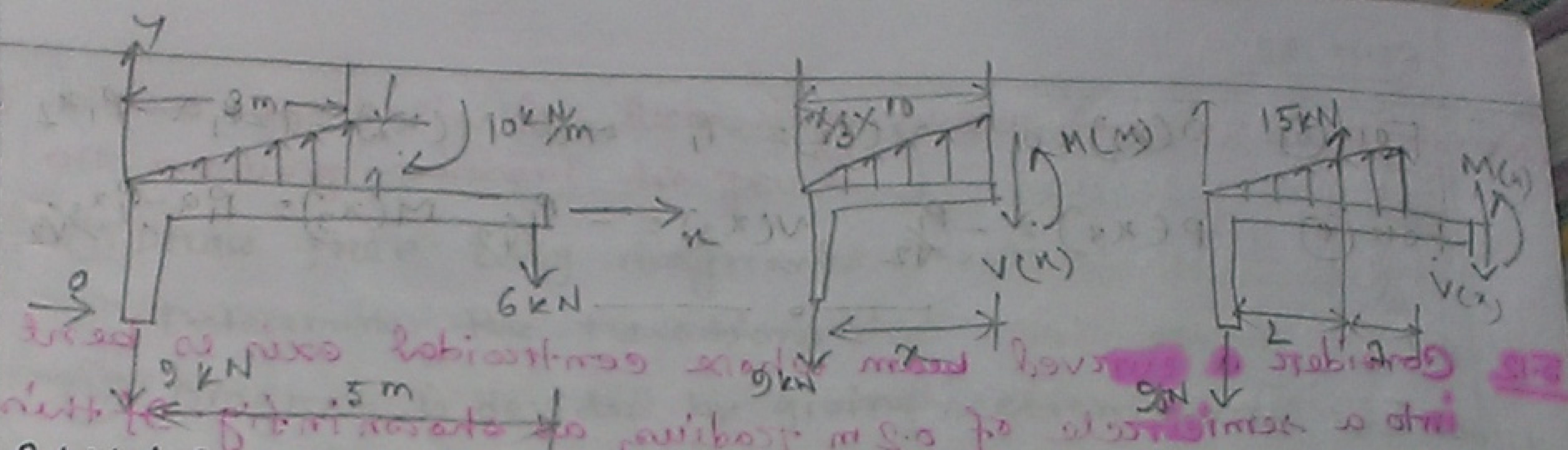




1st $\Rightarrow$ $P(x_1) = +P$ $\quad V(x_1) = 0$

$M(x_1) = +2P_1 a$

5-9



$0 < x < 3$

$V(x) = -9 + \frac{1}{2}x\left(\frac{x}{3}\times 10\right) = -9 + \frac{5}{3}x^2$ kN

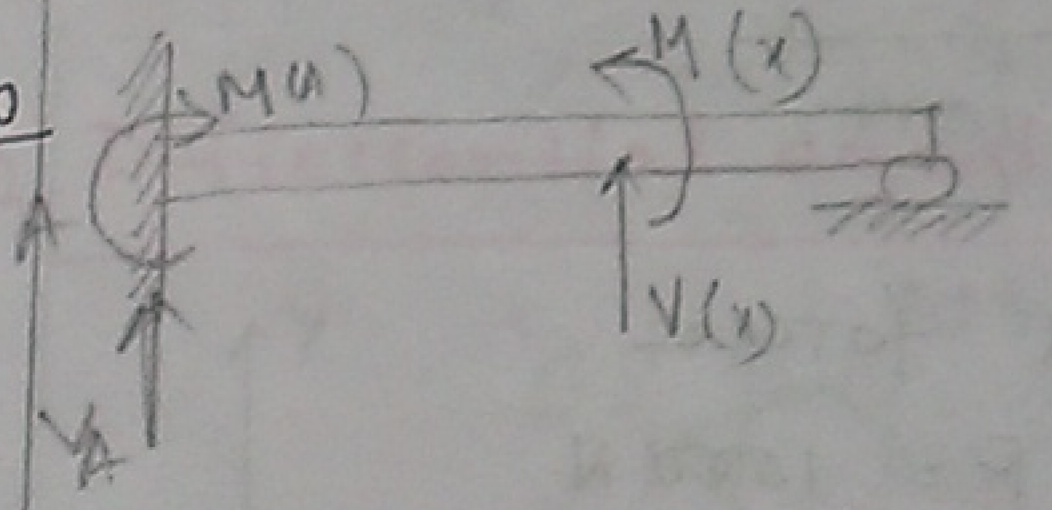
$M(x) = -9x + \frac{1}{2}x\left(\frac{x}{3}\times 10\right)\left(\frac{x}{3}\right) = -9x + \frac{5}{9}x^3$ kN-m.

For $3 < x < 5$

$V(x) = -9 + 15 = 6$ kN

$M(x) = -9x + 15(x-2) = 6x - 30$ kN-m.

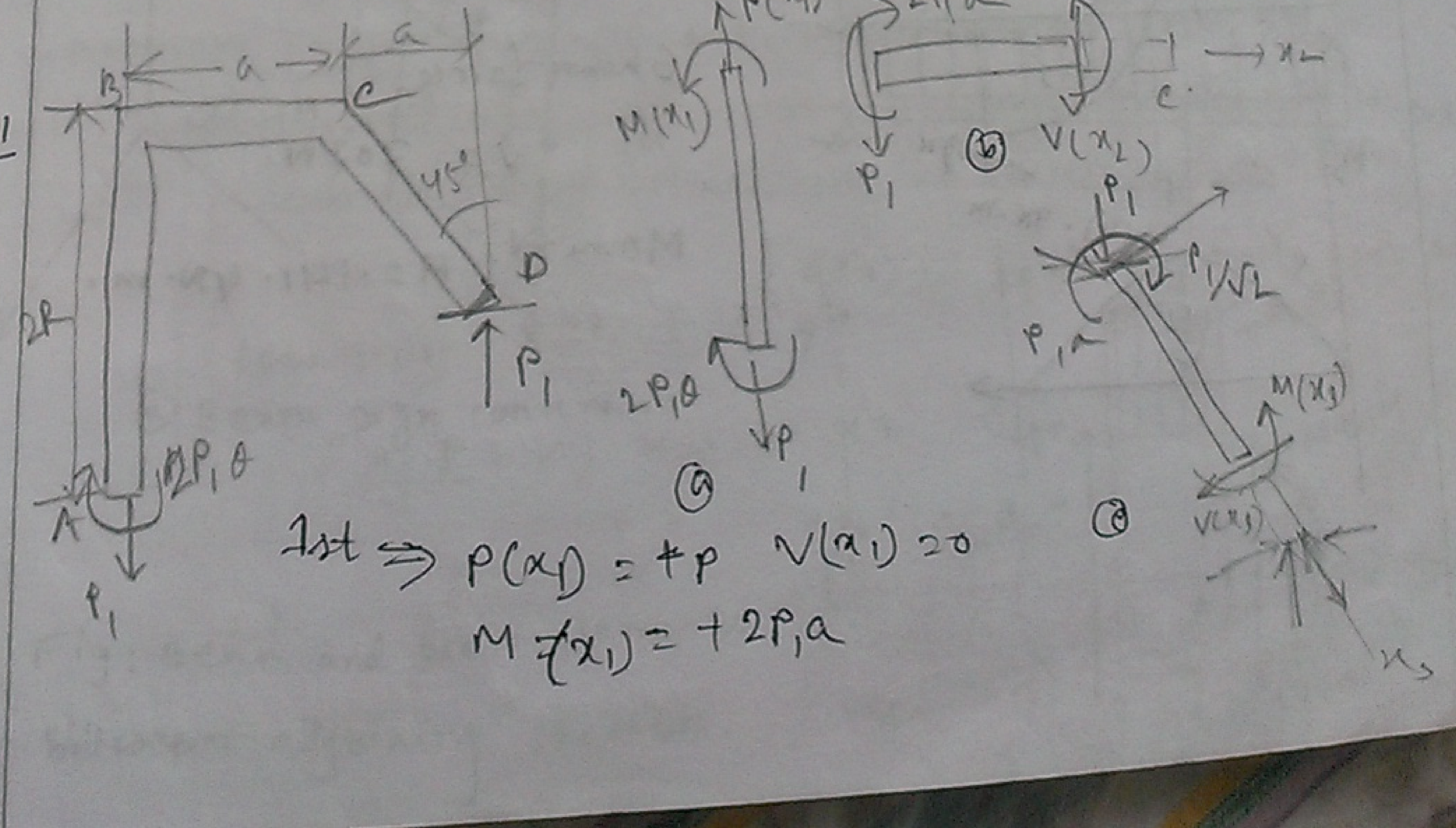
5-10



$V = V_A - w_0 x$

$M = M_A + V_A x - \frac{w_0 x^2}{2}$.

5.11



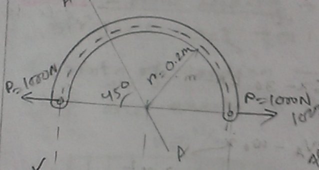
1st $\Rightarrow$ $P(x_1) = +P$ $\quad V(x_1) = 0$

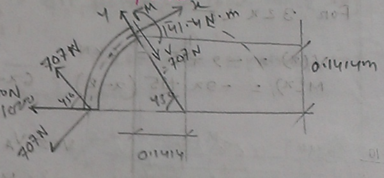
$M(x_1) = +2P_1 a$

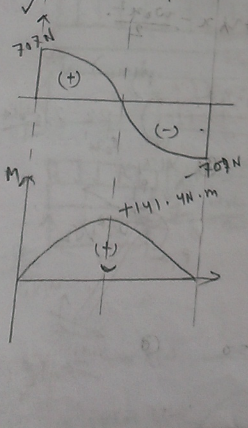
For (b) $P(x_2) = 0 \quad V(x_2) = -P_1$ and $M(x_2) = +2P_1 a - P_1 x_2$

For (c) $P(x_3) = -\frac{P_1}{\sqrt{2}}, V(x_3) = -\frac{P_1}{\sqrt{2}} \; M(x_3) = P_1 a - P_1 x_3/\sqrt{2}$

5.12 Consider a curved beam whose centroidal axis is bent into a semicircle of 0.2 m radius, as shown in fig. If this member is being pulled by the 1000-N forces shown, find the axial force, shear force and the bending moment at section A–A $\alpha = 45°$. The centroidal axis and the applied forces all lie in the same plane.







Axial force

$P = 1000$ N

Shear force,

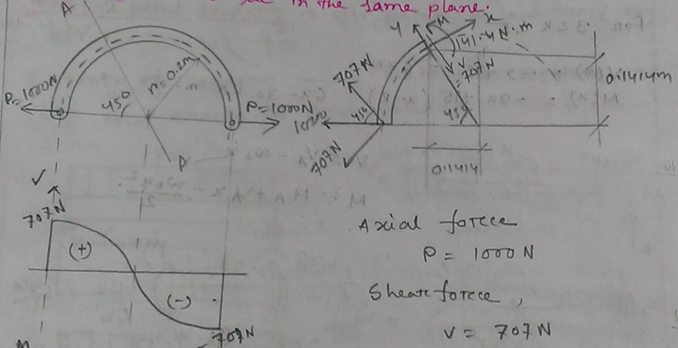
$V = 707$ N

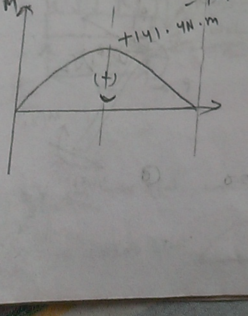
Moment, $M = 141.4$ N·m.

For (b) $P(x_2) = 0 \quad V(x_2) = -P_1$ and $M(x_2) = +2P_1 a - P_1 x_2$

For (c) $P(x_3) = -\frac{P_1}{\sqrt{2}}, V(x_3) = -\frac{P_1}{\sqrt{2}}$ $M(x_3) = P_1 a - P_1 \frac{x_3}{\sqrt{2}}$

5.12 Consider a curved beam whose centroidal axis is bent into a semicircle of 0.2 m radius, as shown in fig. If this member is being pulled by the 1000-N forces shown, find the axial force, shear force and the bending moment at section A-A $\alpha = 45°$. The centroidal axis and the applied forces all lie in the same plane.





Axial force

$P = 1000\ N$

Shear force,

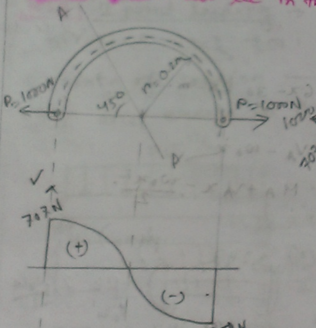
$V = 707\ N$

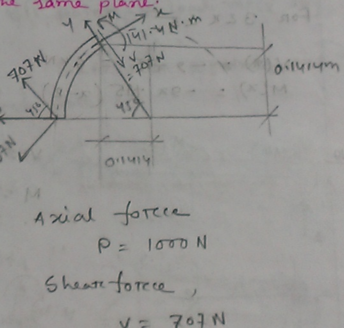
Moment, $M = 141.4\ N \cdot m$.

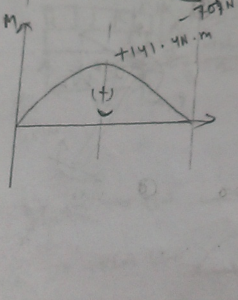
For (b) $P(x_2) = 0$ $V(x_2) = -P_1$ and $M(x_2) = +2P_1 a - P_1 x_2$

For (c) $P(x_3) = -\frac{P_1}{\sqrt{2}}$, $V(x_3) = -\frac{P_1}{\sqrt{2}}$ $M(x_3) = P_1 a - P_1 \cdot \frac{a}{\sqrt{2}}$

5.12 Consider a curved beam whose centroidal axis is bent into a semicircle of 0.2 m radius, as shown in fig. If this member is being pulled by the 1000-N forces shown, find the axial force, shear force and the bending moment at section A–A $\theta = 45°$. The centroidal axis and the applied forces all lie in the same plane.







Axial force

$P = 1000$ N

Shear force,

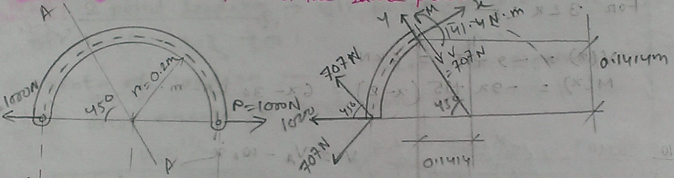
$V = 707$ N

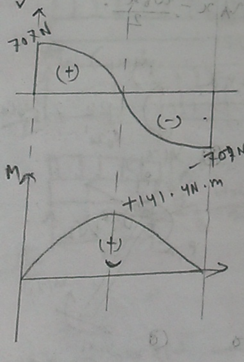
Moment, $M = 141.4$ N·m.

For (b) $P(x_2) = 0 \quad V(x_2) = -P_1$ and $M(x_2) = +2P_1 a - P_1 x_2$

For (c) $P(x_3) = -P_1/\sqrt{2}$, $V(x_3) = -P_1/\sqrt{2}$ $M(x_3) = P_1 a - P_1 x_3/\sqrt{2}$

Consider a curved beam whose centroidal axis is bent into a semicircle of 0.2 m radius, as shown in fig. If this member is being pulled by the 1000-N forces shown, find the axial force, shear force and the bending moment at section A-A $\alpha = 45°$. The centroidal axis and the applied forces all lie in the same plane.





Axial force

$P = 1000\ N$

Shear force,

$V = 707\ N$

Moment, $M = 141.4\ N\cdot m$.

25.11.13

[I] Basic approach for drawing shear force, axial force or bending moment diagram.

(i) Draw free body diagram.

(ii) Determine the reactions.

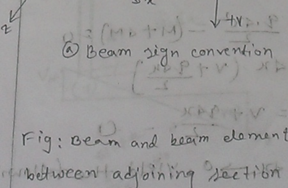
(iii) Diagram is devided by giving section mark and work is done by taking one of the section.

(iv) $\Sigma F_x = 0$, $\Sigma F_y = 0$ & $\Sigma M_z = 0$.

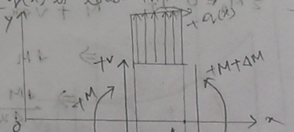
N.B In the case of Beam it has no relation with the Axial force and Bending moment but relation has for the other case.

Otherwise it has relation with the Shear force & Bending moment. ~~The re~~

[II] Differential equations of equillibrium for a Beam element:



(a) Beam sign convention



[q(x) is load intensity, not load]

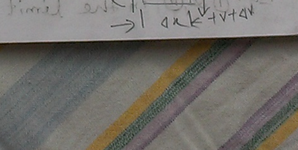


Fig: Beam and beam elements between adjoining section.

Consider a beam element Δx long, isolated by two adjoining sections taken perpendicular to its axis. In figure such an element is shown as a free-body diagram. All the forces shown acting on this element have positive sense. The positive sense of the distributed external force q is taken to coincide with the direction of positive y axis. As the shear force & the moment may each change from one section to the next note that on the right side of the element these quantities are, respectively designated $V+\Delta V$ and $M+\Delta M$.

From the condition for equillibrium of vertical forces, one obtains –

$$\Sigma F_y = 0 \rightarrow \quad V + q\Delta x - (V+\Delta V) = 0$$

$$\Rightarrow \Delta V = q\,\Delta x$$

$$\therefore \frac{\Delta V}{\Delta x} = q \quad ----(1)$$

For equillibrium, the summation of moments around A also must be zero. So, upon noting that from point A the arm of the distributed force is $\Delta x/2$.

$$\Sigma M_A = 0 \circlearrowleft + \quad M + V\Delta x + \frac{q.\Delta x^2}{2} - (M+\Delta M) = 0$$

$$\Rightarrow \Delta M = \Delta x\left(V + \frac{q\Delta x}{2}\right)$$

$$\Rightarrow \frac{\Delta M}{\Delta x} = V + \frac{q\Delta x}{2} \quad - (ii)$$

Eqn (i) & (ii) in the limit $\Delta x \rightarrow 0$, yield the following two basic differential equations —

$$\frac{dV}{dx} = q \quad \text{--- (iii)} \qquad \& \qquad \frac{dM}{dx} = V \quad \text{--- (iv)}$$

From (3) & (4)

$$\frac{d}{dx}\left(\frac{dM}{dx}\right) = q \Rightarrow \frac{d^2M}{dx^2} = q.$$

This differential equation can be used for determining reactions of statically determinate beams from the boundary conditions, whether these eqn (3&4) are very convenient for construction of shear & moment diagram.

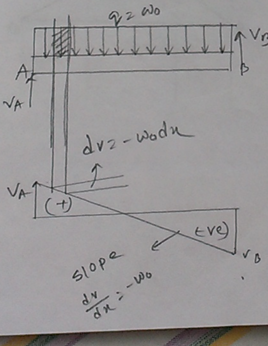
— o —

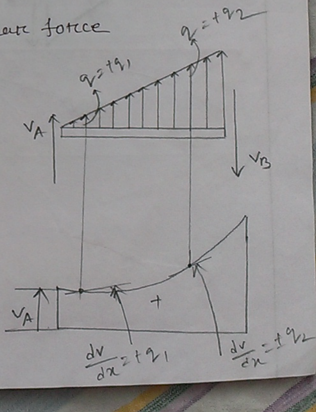
Shear diagrams by integration of the load:

From the equation 3 —

$$V = \int_0^x q\,dx + C_1$$

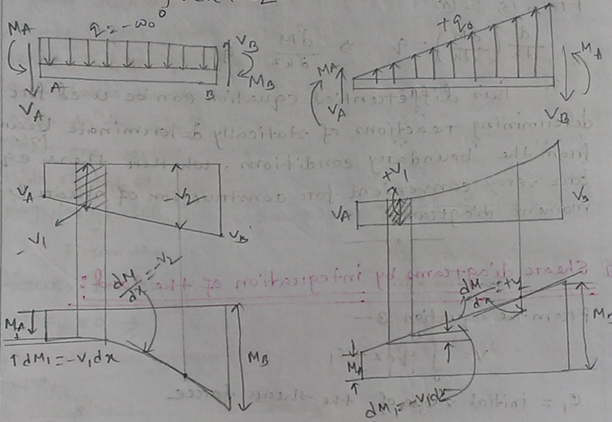
C_1 = initial value of the shear force





Moment diagrams by integration of the shear:

$$M = \int_0^x V\,dx + C_2 \quad \text{-------} \quad (1)$$



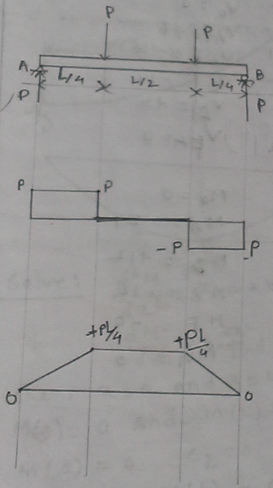
Shear Force and Bending moment

12.01.14

Example:

Formula: $V = \int p\,dx + c_1$ $\qquad \frac{dV}{dx} = p$

$M = \int V\,dx + c_2$ $\qquad \frac{dM}{dx} = V$



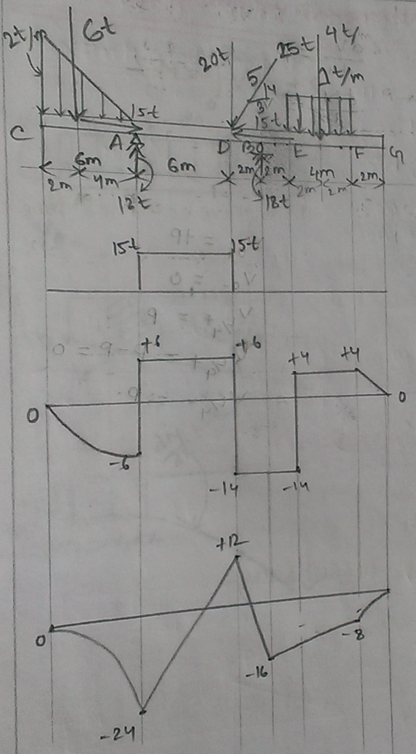
$V_{0+} = +P$

$V_{0-} = 0$

$V_{L/4^{*}} = P$

$V_{L/4^{+}} = P - P = 0$

$V_{L/4^{-}} = P.$



$R_{Ax} = 15t$

$M_A = 0$

$-24 + 120 - R_B \times 8 + 4 \times 12 = 0$

$R_B = 18t$

$V_0 = 0$

$V_{A+} = +6$

$V_{A-} = -6$

$V_D = -14$

$V_{E+} = +4$

$V_{F+} = 0$

$M_0 = 0$

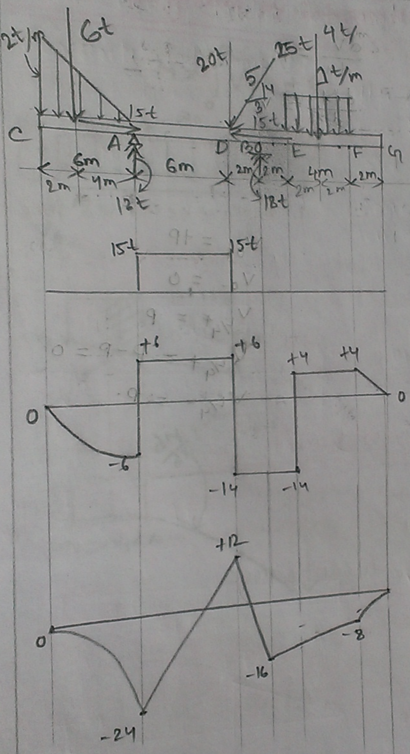
$M_A = -24$

$M_B = +12$

$M_B = -16$

$M_F = -8$

$M_G = 0$



$R_{Ax} = 15t$

$M_A = 0$ ↻+

$-24 + 120 - R_B \times 8 + 4 \times 12 = 0$

$R_B = 18t$

$V_0 = 0$

$V_{A+} = +6$

$V_{A-} = -6$

$V_D = -14$

$V_{E+} = +4$

$V_F = 0$

$M_0 = 0$

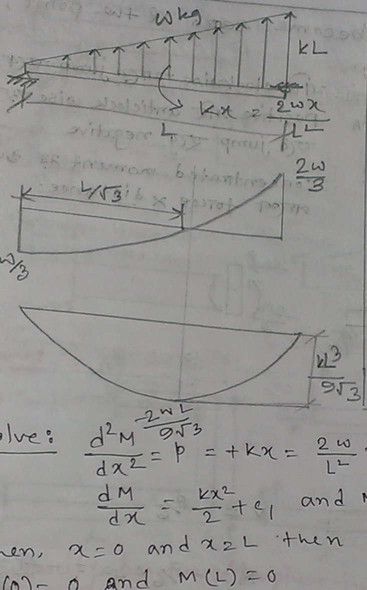
$M_A = -24$

$M_B = +12$

$M_B = -16$

$M_F = -8$

$M_G = 0$



$\frac{1}{2} \cdot kL \cdot L = w$

$\Rightarrow k = \frac{2w}{L^2}$

$\frac{dM}{dx} = v$, $\frac{dv}{dx} = p$

$\frac{d^2M}{dx^2} = p$ (load intensity)

$x=0$ থেকে $x=L$ পর্যন্ত continuous load আছে

* Math-এ unit change করা যাবে না, যে unit এ দেয়া আছে সেই unit রাখতে হবে।

Solve: $\frac{d^2M}{dx^2} = p = +kx = \frac{2w}{L^2}x$

$\frac{dM}{dx} = \frac{kx^2}{2} + c_1$ and $M = \frac{kx^3}{6} + c_1 x + c_2$

when, $x=0$ and $x=L$ then

$M(0) = 0$ and $M(L) = 0$

$M(0) = 0 \quad c_2 = 0$

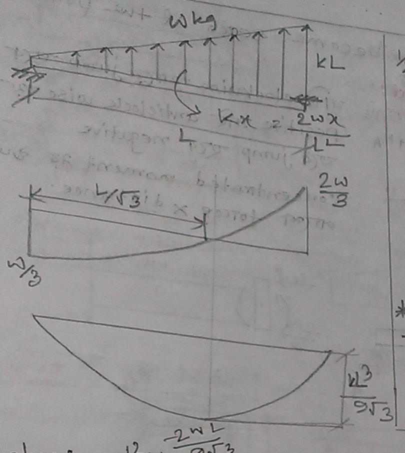
similiarly $M(L) = 0$

$\frac{kL^3}{6} + c_1 L = 0$

$\Rightarrow c_1 = -\frac{kL^2}{6} = -\frac{1}{3}w$

$V = \frac{dM}{dx} = \frac{kx^2}{2} - \frac{kL^2}{6} = \frac{wx^2}{L^2} - \frac{w}{3}$

$M = \frac{kx^3}{6} - \frac{kL^2 x}{6} = \frac{wx^3}{3L^2} - \frac{wx}{3}$



13.01.14

$\frac{1}{2} \cdot kL \cdot L = w$

$\Rightarrow k = \frac{2w}{L^2}$

$\frac{dM}{dx} = V \quad \frac{dV}{dx} = p$

$\frac{d^2M}{dx^2} = p$ (load intensity)

$x = 0$ থেকে $x = L$ পর্যন্ত continuous load আছে

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Solve: $\frac{d^2M}{dx^2} = p = +kx = \frac{2w}{L^2}x$

$\frac{dM}{dx} = \frac{kx^2}{2} + c_1$ and $M = \frac{kx^3}{6} + c_1 x + c_2$

when, $x = 0$ and $x = L$ then

$M(0) = 0$ and $M(L) = 0$

$M(0) = 0 \quad c_2 = 0$

similiarly $M(L) = 0$

$\frac{kL^3}{6} + c_1 L = 0$

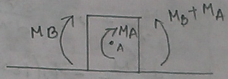
$\Rightarrow c_1 = -\frac{kL^2}{6} = -\frac{1}{3}w$

$V = \frac{dM}{dx} = \frac{kx^2}{2} - \frac{kL^2}{6} = \frac{wx^2}{L^2} - \frac{w}{3}$

$M = \frac{kx^3}{6} - \frac{kL^2 x}{6} = \frac{wx^3}{3L^2} - \frac{wx}{3}$

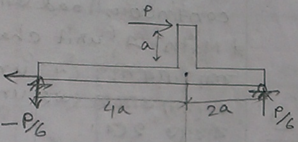
The shear force become zero at the point,

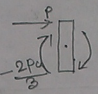
Concentrated moment:

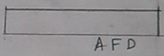


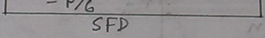
যদি clockwise থাকে jump হবে positive যদি anticlock wise হয় তবে jump হবে negative

Concentrated moment এর মান সমান force × distance.





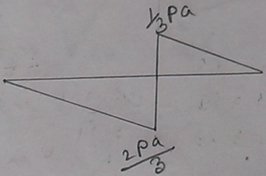




$V = -P/6$

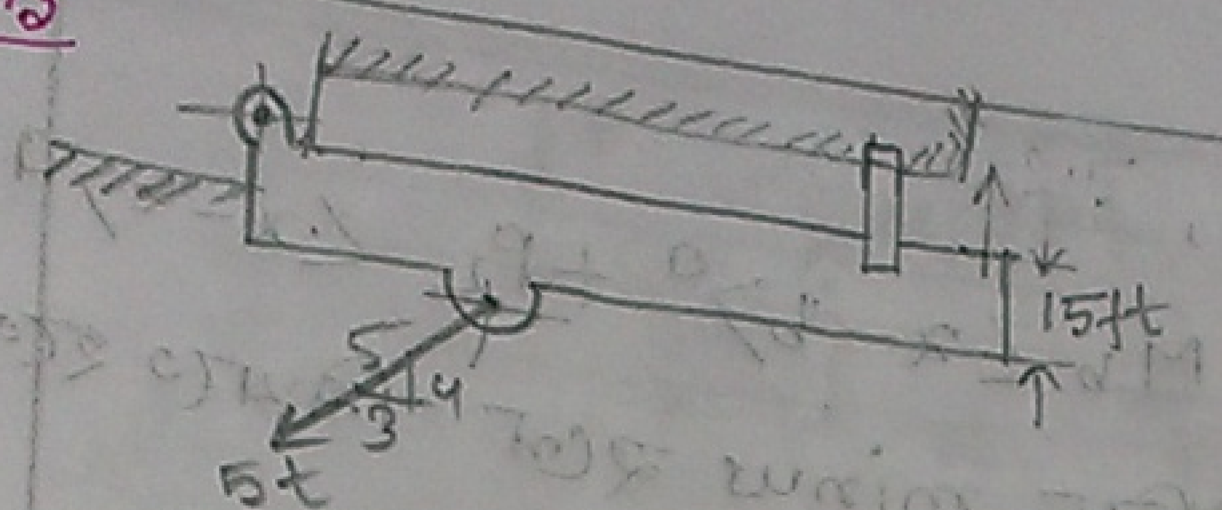
$M_{4a^-} = -P/6 \times 4a = -\frac{2Pa}{3}$

$M_{4a^+} = \frac{P}{6} \times 2a = \frac{Pa}{3}$

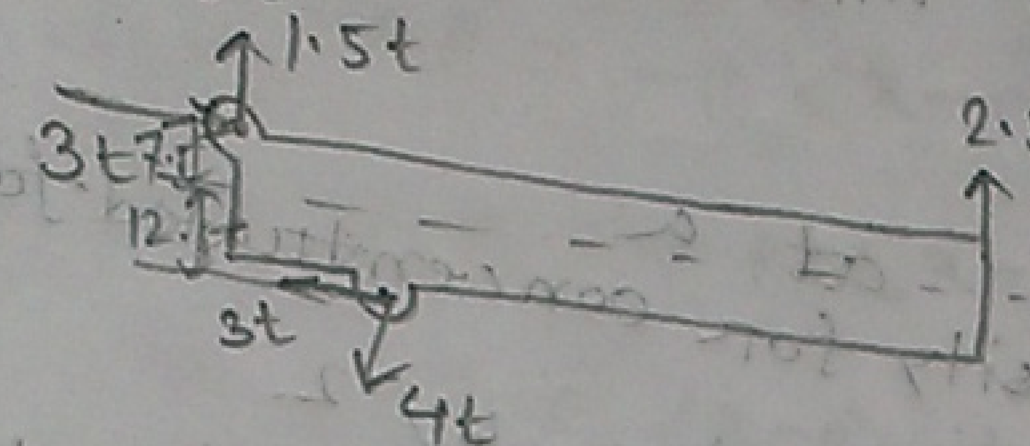


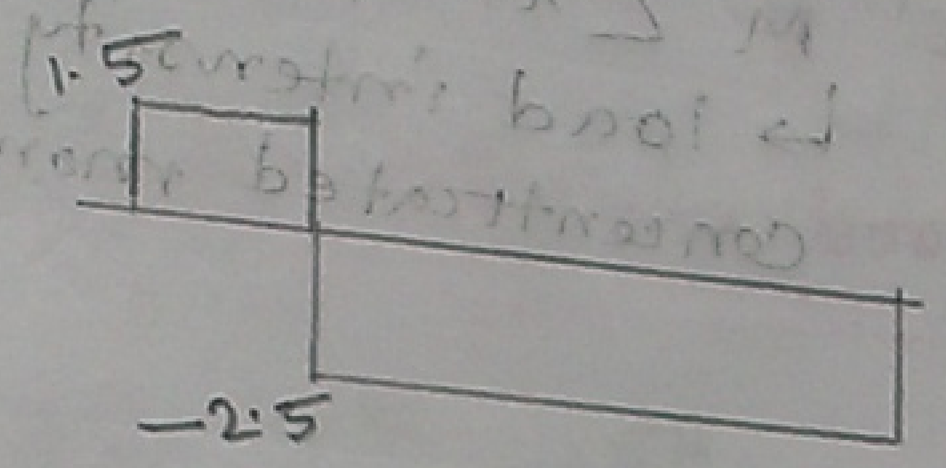
$M = \int V\,dx$ valid upto concentrated moment and beyond but not there.

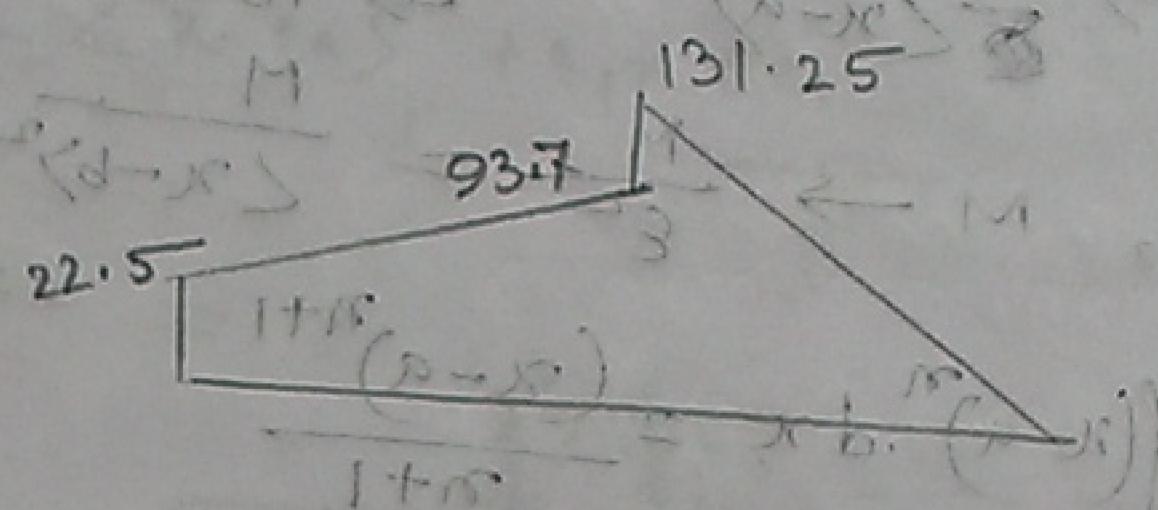
2.13



Shear force diagram এর ও -হিসাবে করা হয় normally

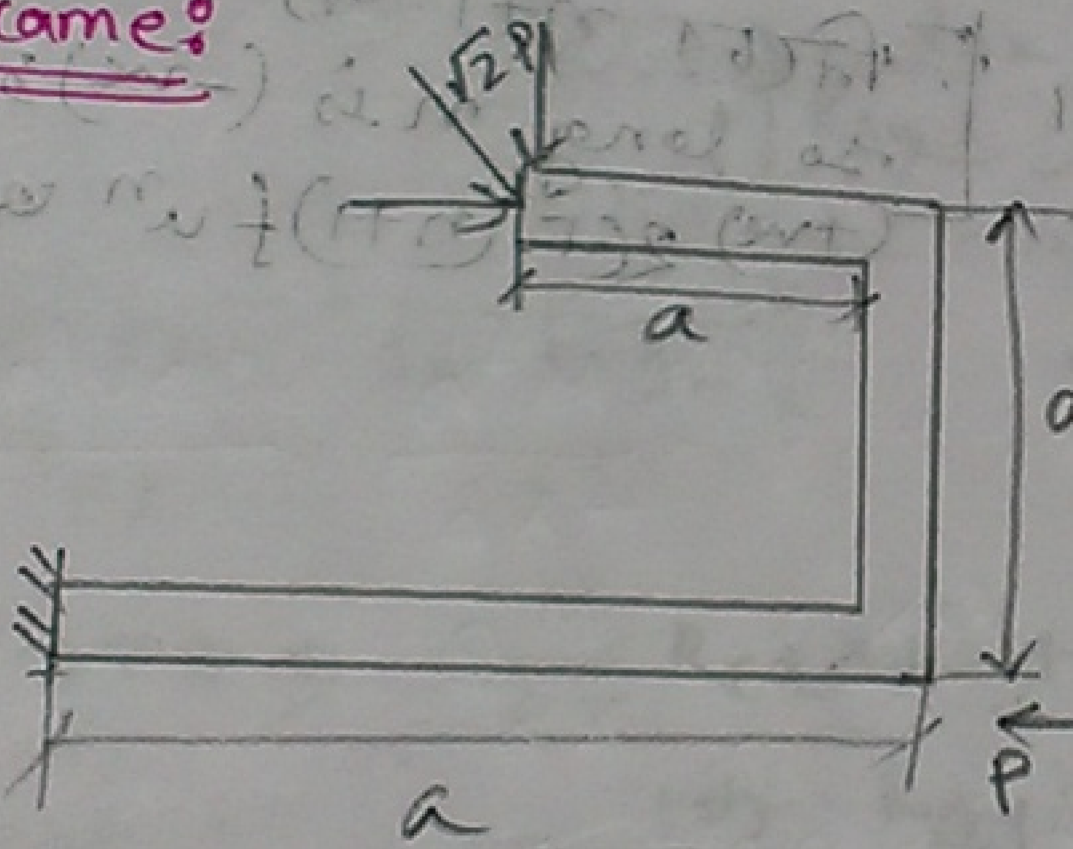


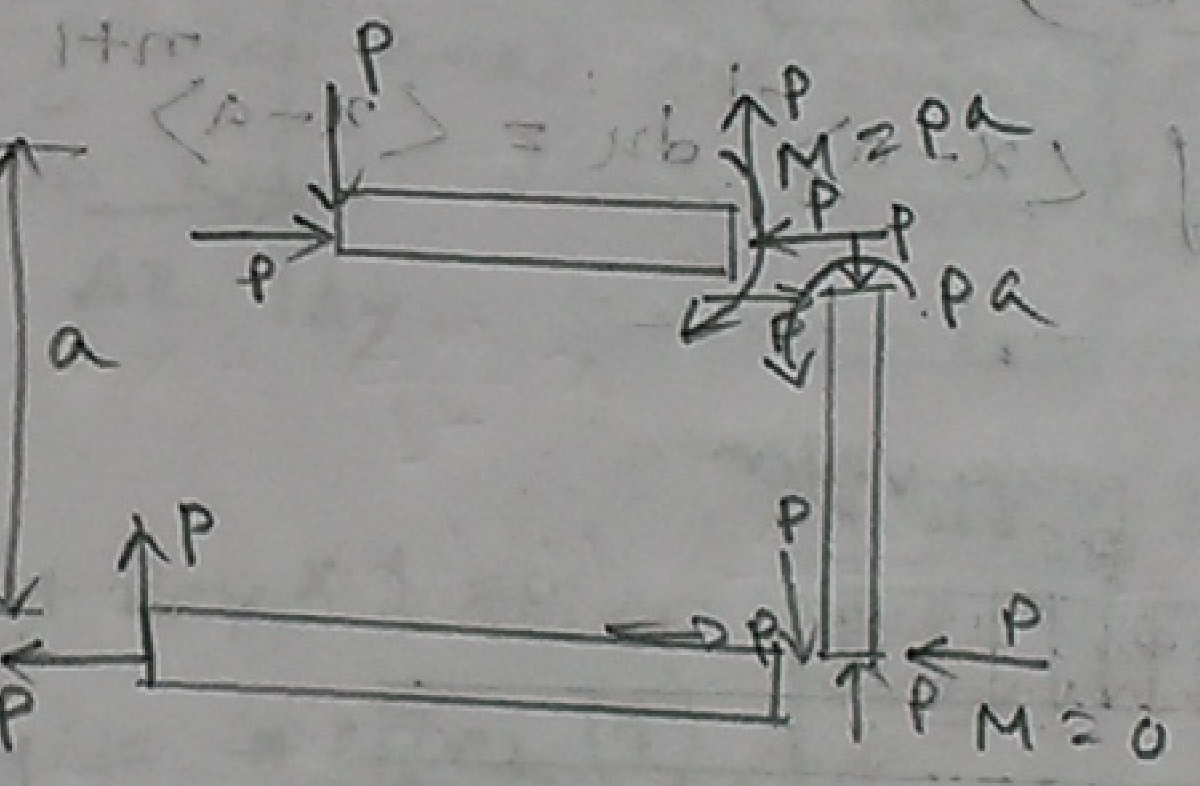




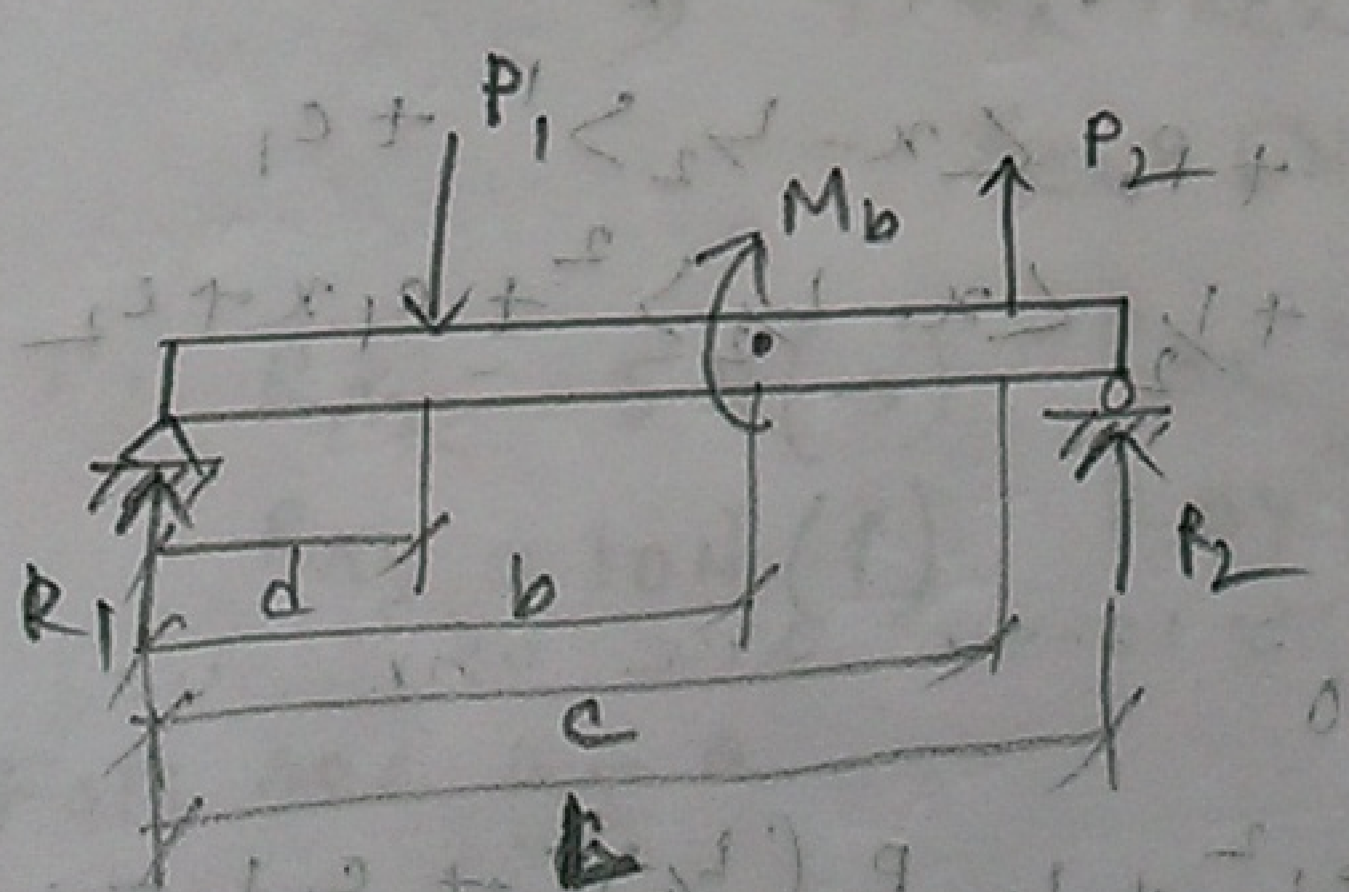
18.01.14

III Frame:





IV Singularity function / Impluse function:



$M = R_1 x \qquad 0 \le x \le d$

$M = R_1 x - P_1(x-d) \qquad d \le x < b$

$M = R_1 x - P_1(x-d) + M_b \qquad b < x \le c$

$M = R_1 x - P_1(x-d) + M_b + P_2(x-c) \qquad c \le x \le L$

By the rule of impluse function,

$M = R_1 \langle x-0\rangle^1 - P_1 \langle x-d\rangle^1 + M_b \langle x-b\rangle^0 + P_2 \langle x-c\rangle^{?}$

* Pointed braket এর ভিতরের জিনিস minus হলে লিখতে হবে zero '0'

$P \rightarrow \frac{P}{\langle x-a\rangle} \rightarrow P\langle x-a\rangle^{-1}$ at a

↳ load intensity for concentrated force

at b, $M \rightarrow \frac{M}{\varepsilon^2} = \frac{M}{\langle x-b\rangle^2} = M\langle x-b\rangle^{-2}$

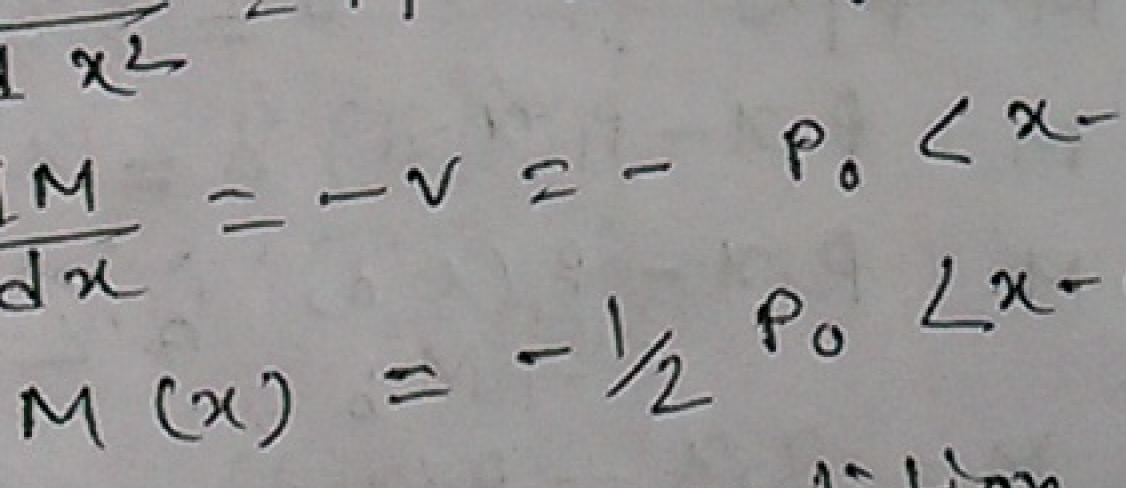
↳ load intensity for concentrated moment.

$$\int (x-a)^n\,dx = \frac{(x-a)^{n+1}}{n+1}$$

$$\int (x-a)^{-1}\,dx = \ln(x-a)$$

But $\int \langle x-a\rangle^{-1}\,dx = \langle x-a\rangle^{n+1}$ [∵ নিচের n+1 অক্রশাই হবে না so long n is (-ve); n is (+ve) হলে (n+1) fu^n আসবে]

Ex



$$\frac{d^2M}{dx^2} = +p = -P_0\langle x-0\rangle^0 + P_0\langle x-L/2\rangle^0$$

$$-P_0\langle x-0\rangle^1 + P_0\langle x-L/2\rangle^1 + c_1$$

$$\frac{dM}{dx} = -V = -P_0\langle x-0\rangle + \frac{1}{2}\langle x-L/2\rangle^2 + c_1x + c_2$$

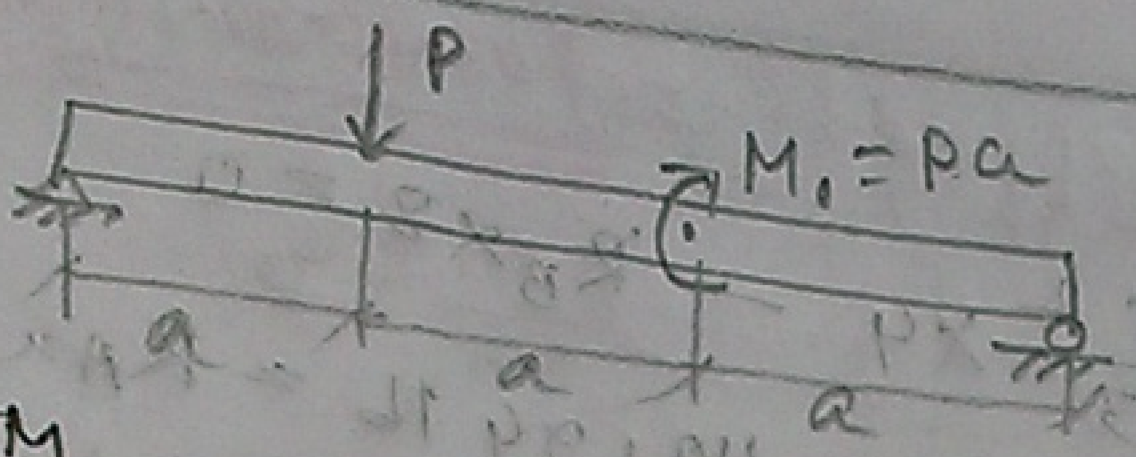
$$M(x) = -\frac{1}{2}P_0\langle x-0\rangle$$

By Boundary condition

(i) $M(0) = 0$, yeilds $c_2 = 0$

(ii) $M(L) = 0$, yields $-\frac{1}{2}P_0L^2 + \frac{1}{2}P_0\left(\frac{L}{2}\right)^2 + c_1L = 0$

$\Rightarrow c_1 = \frac{3}{8}P_0L$

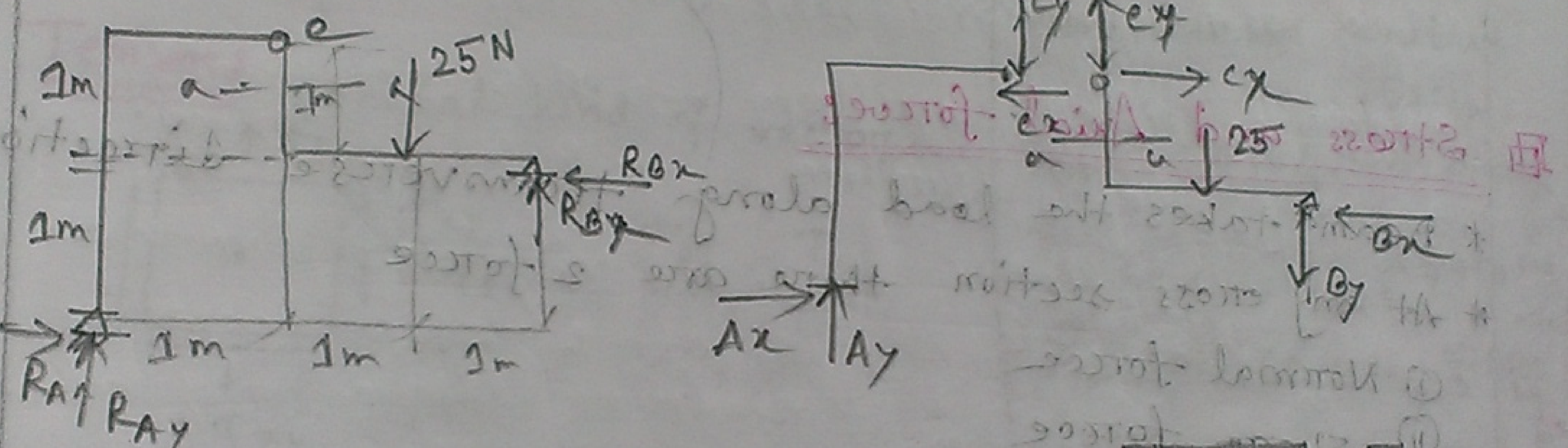


$$\frac{d^2M}{dx^2} = +P = -P\langle x-a\rangle^{-1} + Pa\langle x-2a\rangle^{-2}_{*}$$

$$\frac{dM}{dx} = -V = -P\langle x-a\rangle^{0} + Pa\langle x-2a\rangle^{-1}_{*} + c_1$$

$$M = -P\langle x-a\rangle^{1} + Pa\langle x-2a\rangle^{0} + c_1x + c_2$$

Exercises of Popov book:



$\Sigma M_A = 0 \Rightarrow \quad -R_{Cx}\times 2 + R_{Cy}\times 1 = 0$

$\Rightarrow R_{Ay} = 2R_{Cx}\ (\uparrow)$

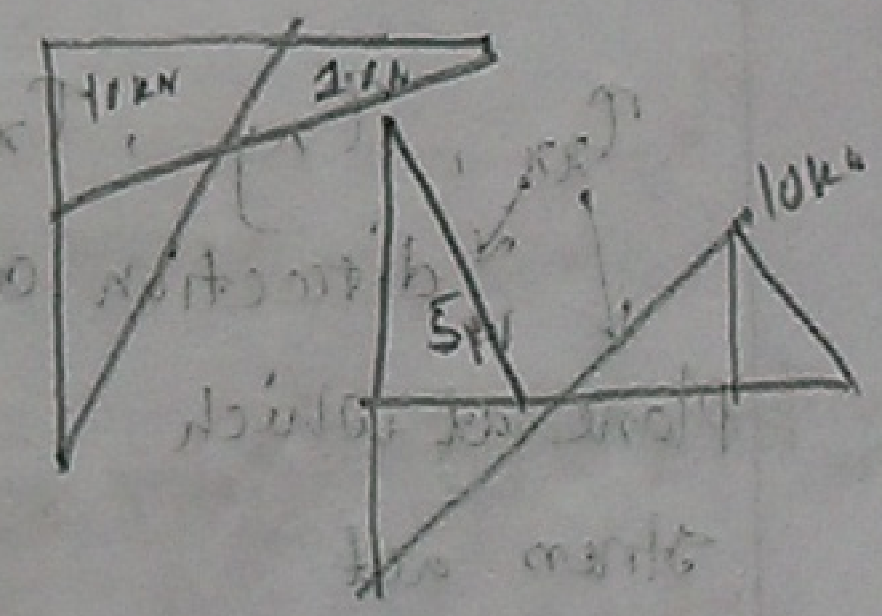
$\Sigma M_B = 0 \Rightarrow R_{Cy}\times 1 + R_{Cx}\times 1 - 25\times 1 = 0$

$\Rightarrow 4R_{Cx} + R_{Cx} = 25$

$R_{Cx} = 5N\ (\rightarrow)$

$\therefore R_{Ax} = 5N\ (\rightarrow) \qquad R_{Bx} = 5N\ (\leftarrow)$

$R_{Ay} = 10N\ (\uparrow) \qquad R_{By} = -10N\ (\uparrow)$

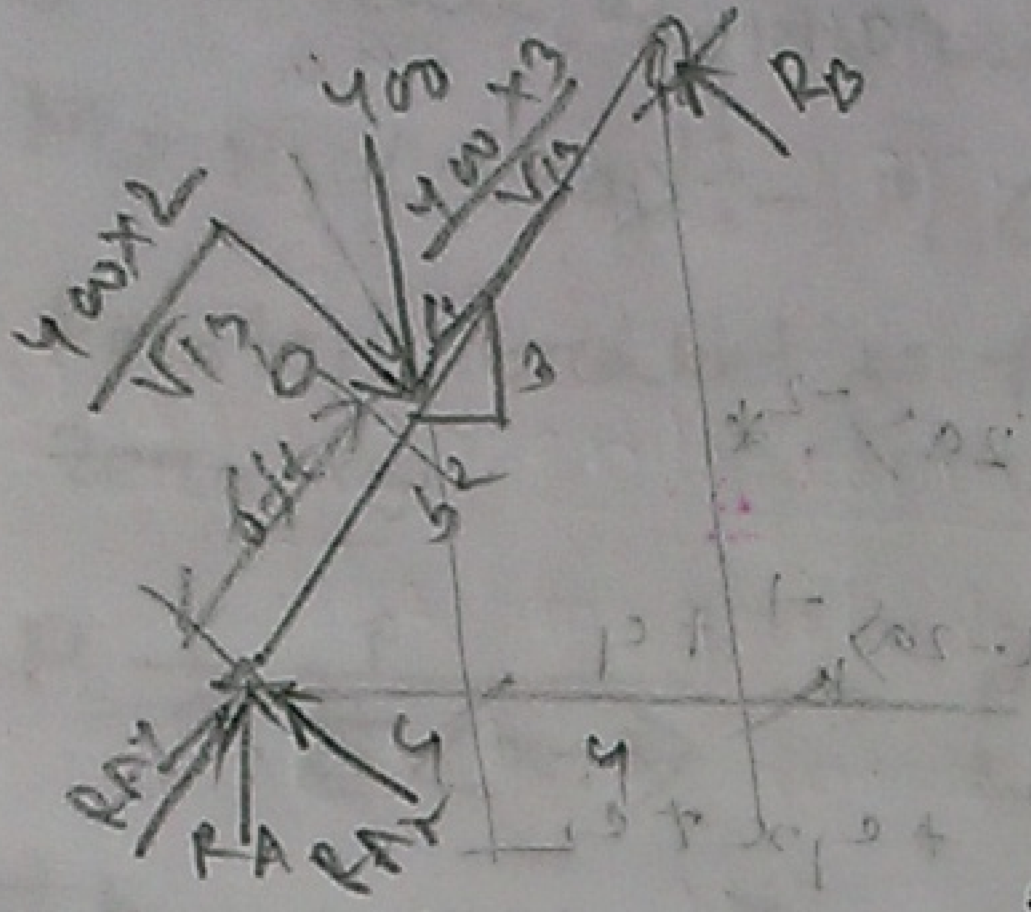


For sec a-a

$P = +10\,N$

$V = +5\,N$

$M = +2.5\ N.m$



$\Sigma M_A = 0$

$\Rightarrow \frac{400 \times 2}{\sqrt{13}} \times 4 - R_B \times 8 = 0$

$\Rightarrow R_B = 110.94$ lb $= R_{Ax}$

$R_{Ax} = 332.82$ lb

For sec b – b

$P = 332.82$ lb

$V = 110.94$ lb

$M = \cancel{332}\ 110.94 \text{ lb} \times 6 \text{ ft} = 665.64$ lb/ft

Stress and Axial force:

* Beam takes the load along transverse direction
* At any cross section there are 2 force
  (i) Normal force
  (ii) shear force
* Stress always relates to a point.

$\tau_{xx} = \lim_{\Delta A \to 0} \frac{\Delta P_x}{\Delta A}$; $\tau_{xy} = \lim_{\Delta A \to 0} \frac{\Delta P_y}{\Delta A}$; $\tau_{xz} = \lim_{\Delta A \to 0} \frac{\Delta P_z}{\Delta A}$

$\tau_{xx}, \tau_{xy}, \tau_{xy}$

direction at which stress act.

Plane at which stress act

* Any cross section total 9 loads are observed
  (i) Normal stress → 3
  (ii) Shear stress → 6

Stress tensor:

25.01.14

$\sigma = \frac{dP}{dA}$ Stress always relates to a point.

There are 9 types of stress at a point

$$\begin{matrix} \tau_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \tau_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \tau_{zz} \end{matrix} = \begin{matrix} \sigma_x & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z \end{matrix}$$

$\tau_{xx} = \sigma_x$, $\tau_{yy} = \sigma_y$, $\tau_{zz} = \sigma_z$

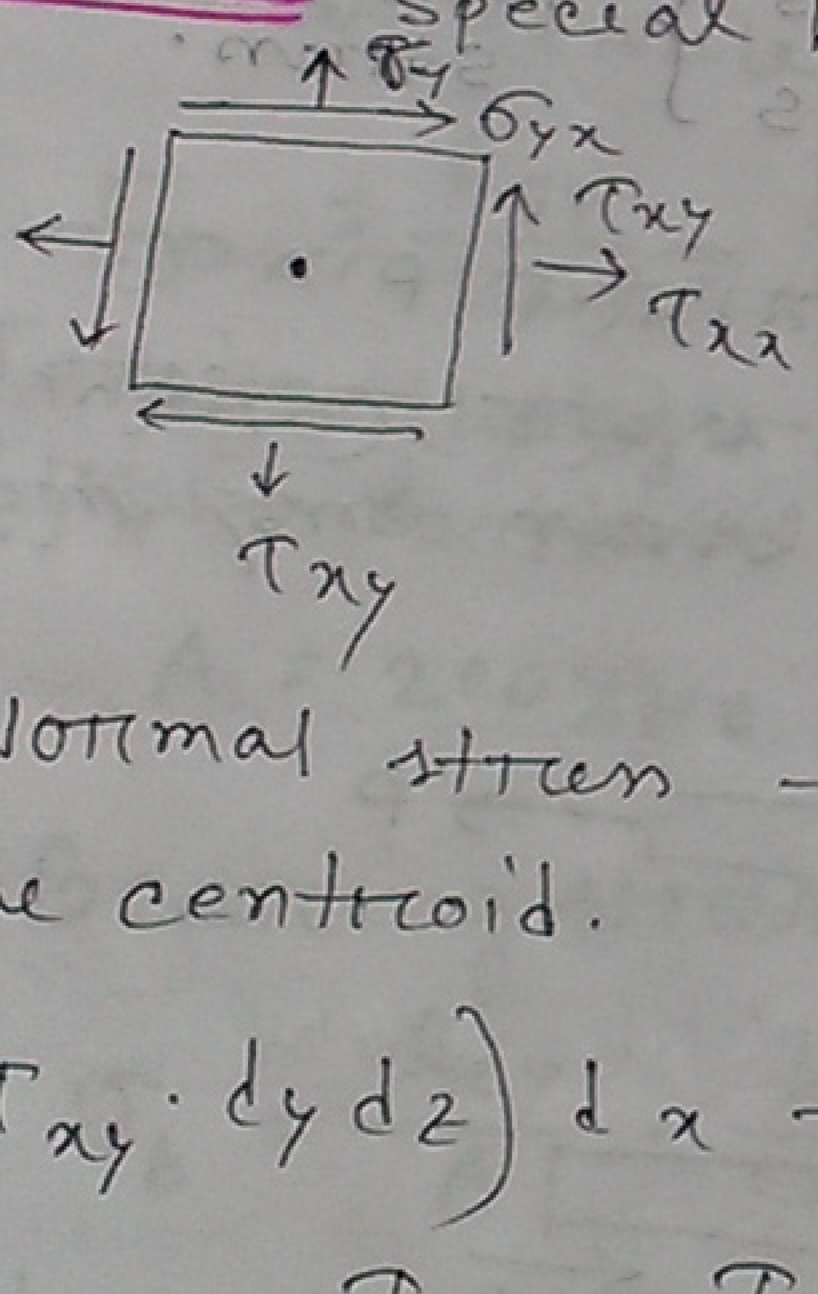
$\tau_{ij} \rightarrow$ stress at a point

$i = 1, 2, 3$

$j = 1, 2, 3$

σ_x, σ_y & σ_z = Normal stress.

Tensor: Special kind of vector.



$\tau_{xy} = \tau_{yx}$

Concrete এর unit wt. 25 kN/m²

$\gamma_{con} = 150\ lb/ft^3 \Rightarrow 2400\ kg/m^3$

$\gamma_{steel} = 490\ lb/ft^3 \Rightarrow 7850\ kg/m^3$

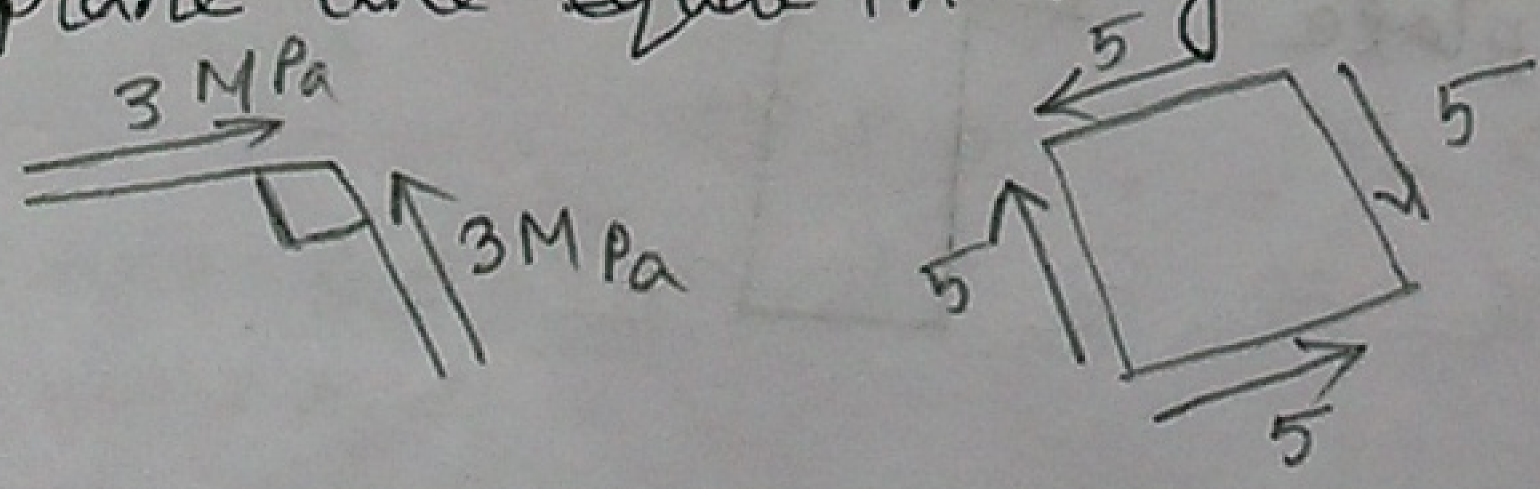
$\gamma_{water} = 62.4\ lb/ft^3 \Rightarrow 1000\ kg/m^3$

Normal stress → moment হবে না। They passing through the centroid.

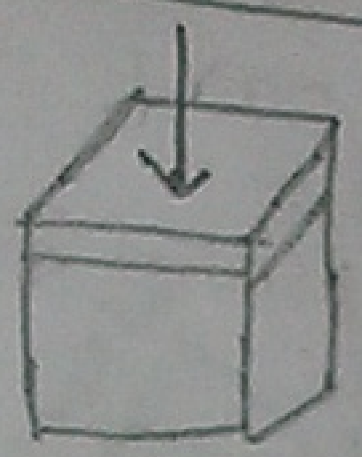
$$(\tau_{xy} \cdot dy\, dz)\, dx - (\tau_{yx} \cdot dx\, dz)\, dy = 0$$

$$\tau_{xy} = \tau_{yx}$$

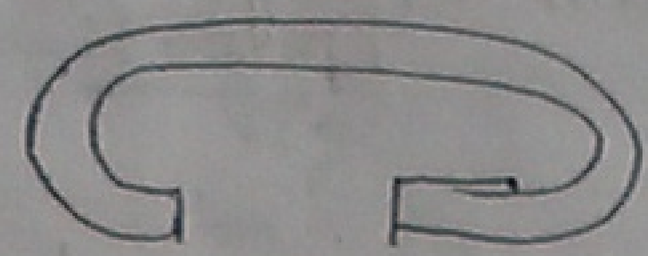
*** Complementory:** Shearing stress of two mutually perpendicular plane are equal in magnitude.



Axial load & Normal stress



যে point-এ force applied হয় তার কাছাকাছি প্রস্থচ্ছেদে P/A হবে না।



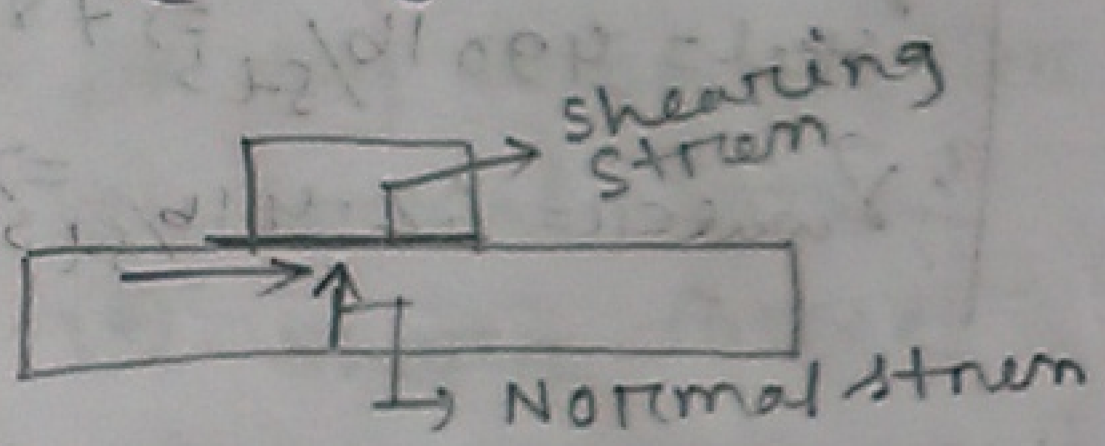
Stress concentration:

The magnitude of stress on the force applied ~~plane~~ point is more than P/A.

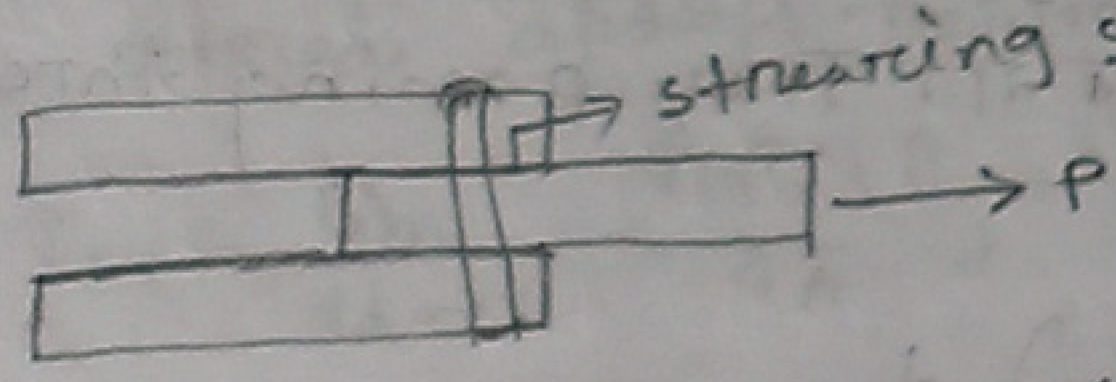
Bearing stress:

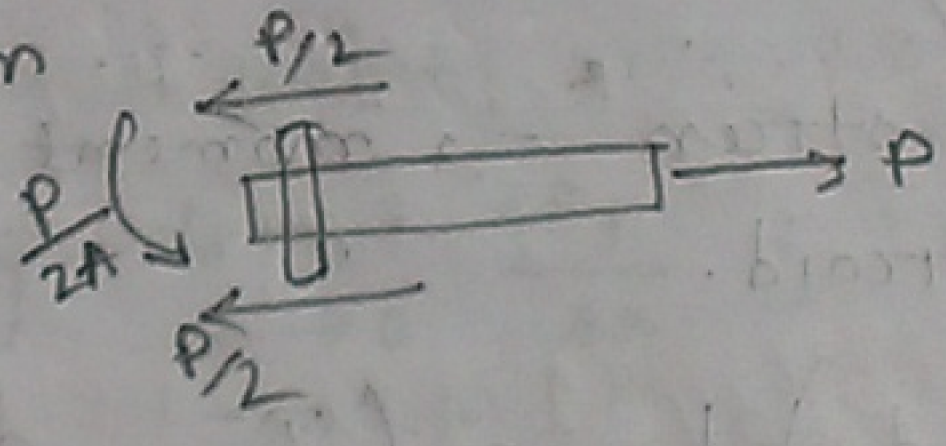
The stress of 2 dissimilar surface is called bearing stress. They are only normal stress.

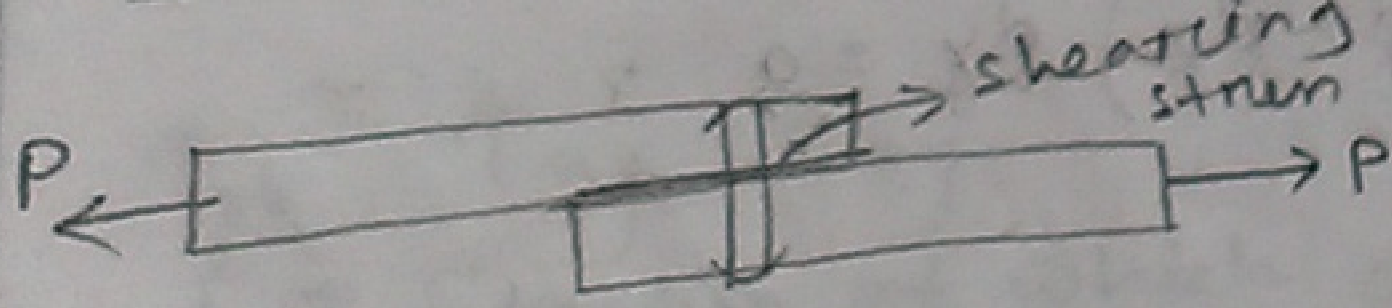
(column + footing) surface → B.S } Normal
(footing + soil) surface → B.S } Stress.

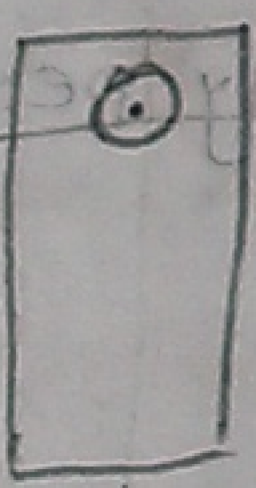


} board ছেঁদা দিলে pin যে point-এ ছিদ্রে সেখানে shearing stress কাজ করে।





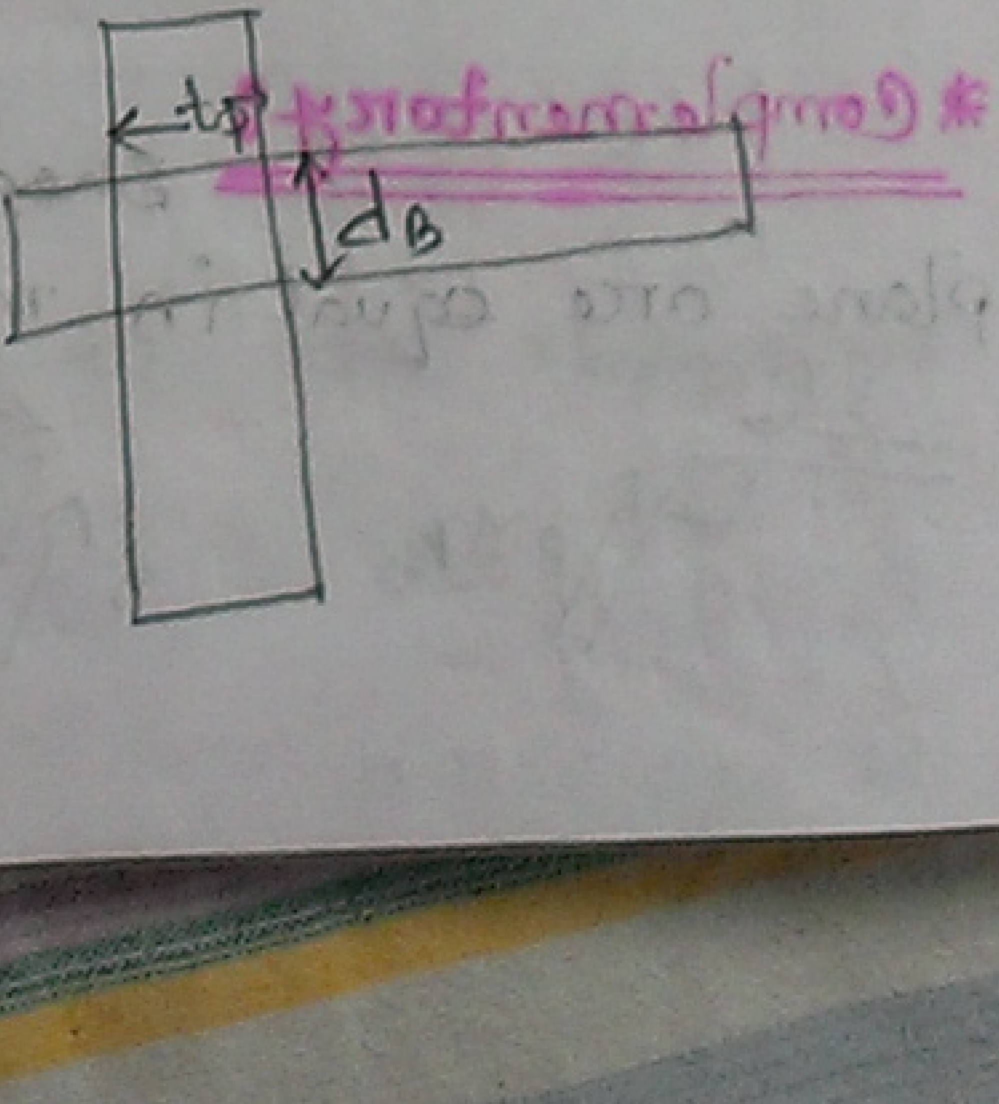




$A = d_B \cdot t_P$

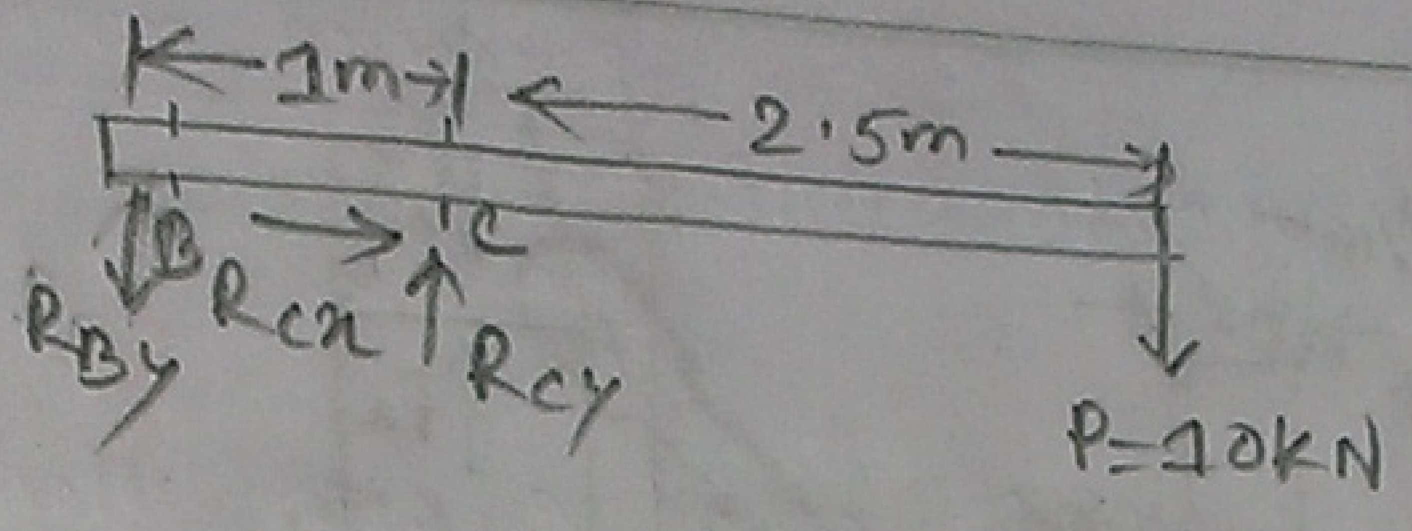
d_B ↓ diameter of the board

t_P thickness of plate



1.1

01.02.14



$\Sigma F_x = 0 \Rightarrow R_{cx} = 0.$

$\Sigma M_B = 0 \Rightarrow 10 \times 3.5 - R_{cy} \times 1 = 0$

$\therefore R_{cy} = 35 \text{ kN} \uparrow$

$\Sigma M_c = 0 \Rightarrow R_{By} \times 1 + 10 \times 2.5 = 0$

$\therefore R_{By} = -25 \text{ kN} \downarrow.$

Cross - Sectional area of BD

$A = \pi \times 10^2 = 314 \text{ mm}^2$

This is not the min area of bolt.

So, $A_{net} = \frac{\pi \times 16^2}{4} = 201 \text{ mm}^2$

Normal tensile stress of Bolt BD

$\sigma_{max} = \frac{R_{By}}{2A} = \frac{25 \times 10^3}{2 \times 201} = 62 \text{ MPa} = 62 \text{ N/mm}^2$

Tensile strength of Bolt BD, $\sigma = \frac{25 \times 10^3}{2 \times 314} = 39.8 \text{ MPa}$

Cross - sectional area of C

$A = 200 \times 200 = 4 \times 10^4 \text{ mm}^2$

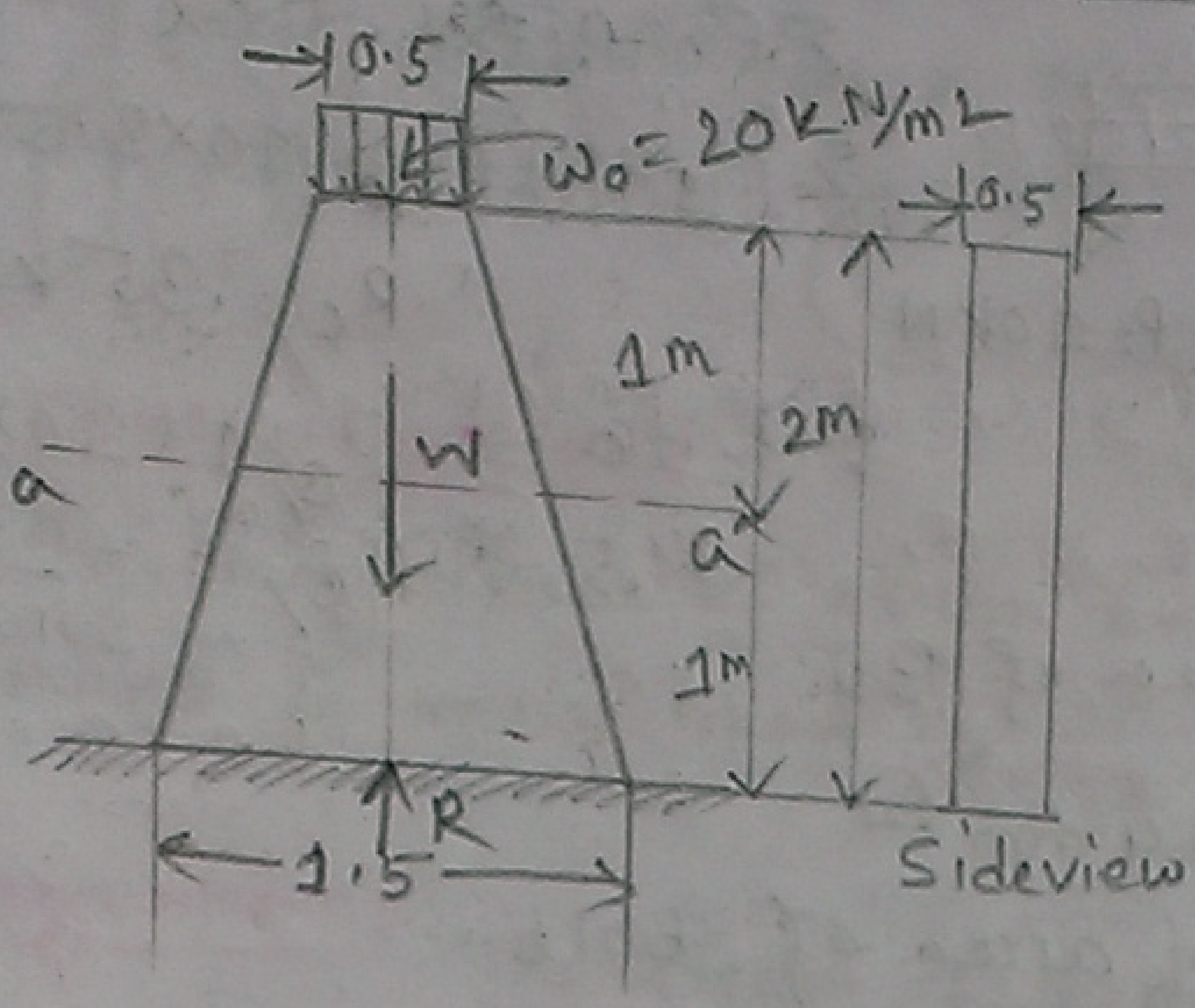
$\therefore$ Bearing stress of C.

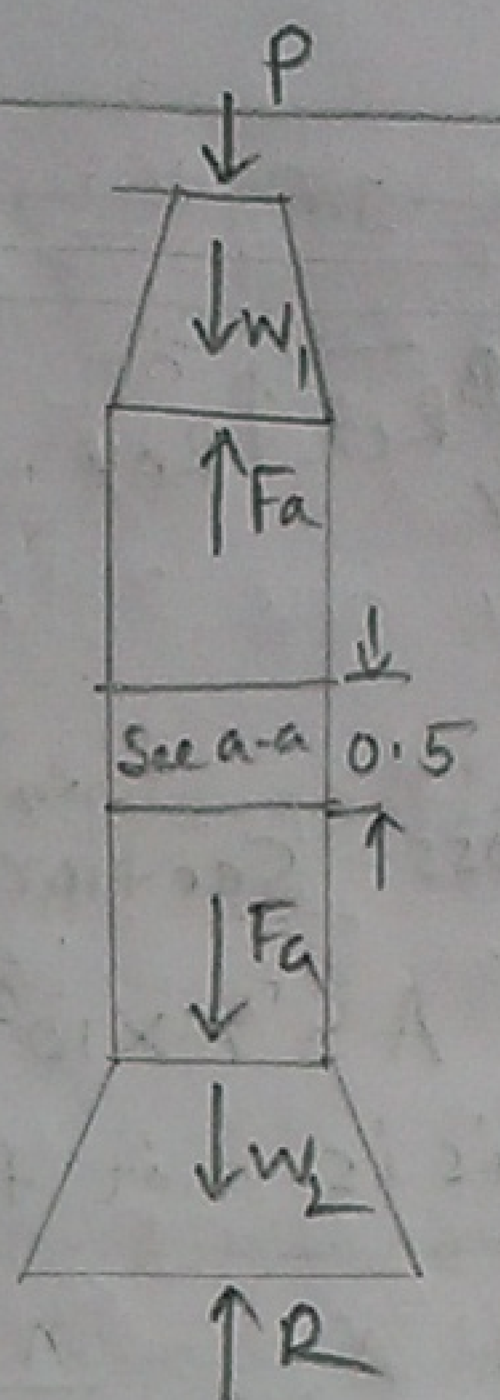
$\sigma_b = \frac{R_{cy}}{A} = \frac{35 \times 10^3}{4 \times 10^4} = 0.875 \text{ MPa} = 0.875 \text{ N/mm}^2$

This calculation can also be represented as

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & +39.8 & 0 \\ 0 & 0 & 0 \end{pmatrix} \text{MPa}$$

1.2





Weight of the whole pier:

$$W = \left[(0.5+1.5)/2\right] \times 0.5 \times 2 \times 25 = 25\ kN.$$

Total applied force,

$$P = 20 \times 0.5 \times \tfrac{1}{2} = 20\ kN.$$

Then, $\Sigma F_y = 0 \quad R - W - P = 0 \Rightarrow R = W + P = 25 + \cancel{20} = 30\ kN$

Using the upper part of sec a-a.

$$W_1 = (0.5 + 1) \times 0.5 \times 1 \times 25/2 = 9.4\ kN$$

The applied force $P = 5$.

$\therefore \Sigma F_y = 0 \Rightarrow F_a = W_1 + P = 5 + 9.4 = 14.4\ kN$

$\therefore$ The normal stress,

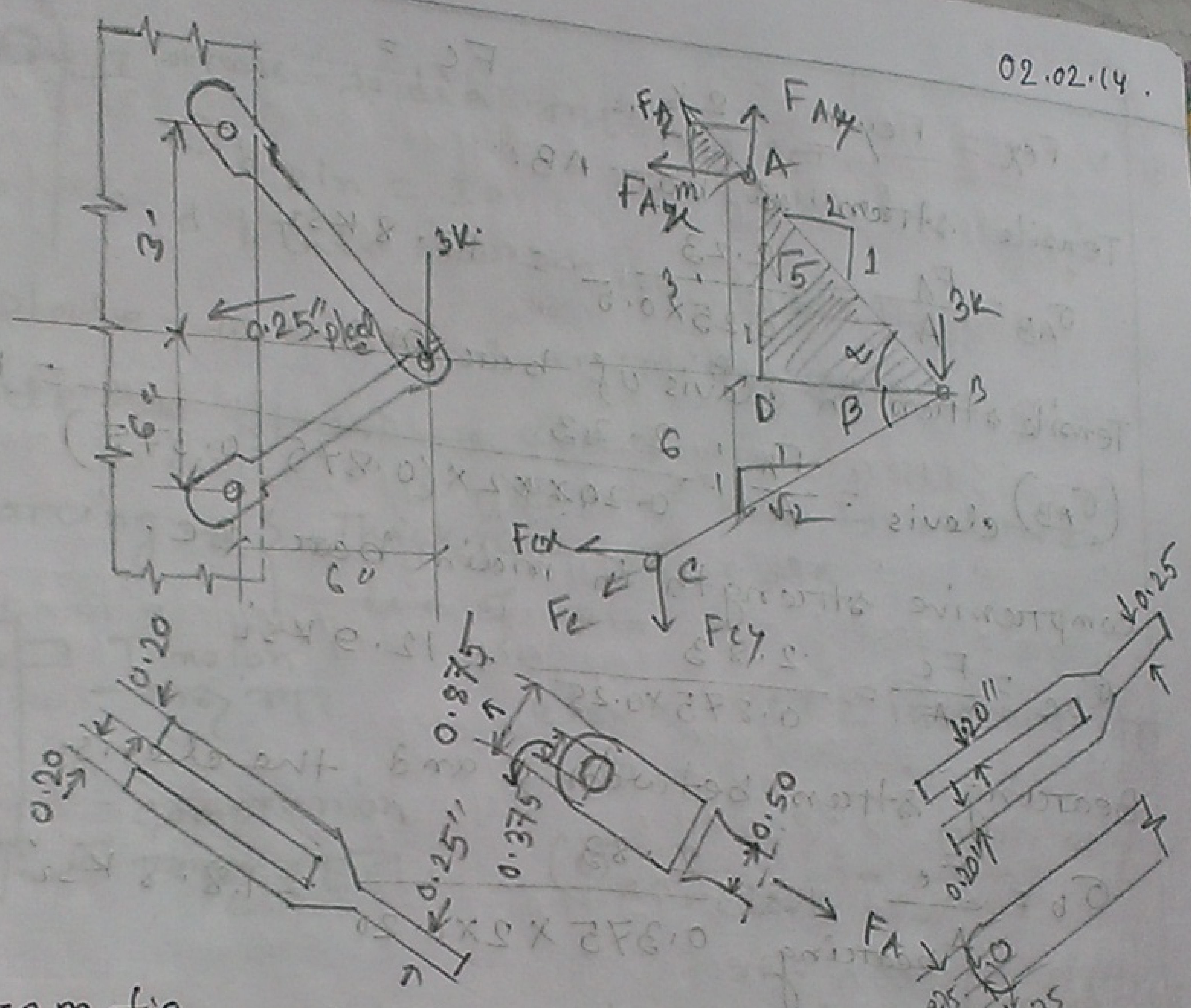
$$\sigma_a = \frac{F_a}{A} = \frac{14.4}{0.5 \times 1} = 28.8\ kN/m^2$$

similiarly the lower part of the sec.

$$W_2 = (1 + 1.5) \times 0.5 \times 1 \times 25/2 = 15.6\ kN.$$

$\Sigma F_y = 0 \Rightarrow R = F_a + W_2 \Rightarrow F_a = R - W_2 = 30 - 15.6\ k$
$= 14.4\ kN.$

02.02.14.



From fig: ΔAKM & ΔADM are similiar

$\therefore \dfrac{F_A}{F_{Ax}} = \dfrac{AB}{DB} \Rightarrow F_A = \dfrac{AB}{DB} \times F_{Ax}$

& $\dfrac{F_{Ay}}{F_{Ax}} = \dfrac{AB}{DB} \Rightarrow F_{Ay} = \dfrac{AD}{BD} F_{Ax} = F_{Ax}$

So for the member AB & BC:

$F_A = \sqrt{5}/2 \; F_{Ax}$ & $F_{Ay} = F_{Ax}/2$.

$\Sigma M_C = 0 \Rightarrow 3 \times 6 - F_{Ax} \times 9 = 0 \Rightarrow F_{Ax} = +2k$

$\Sigma M_A = 0 \Rightarrow 3 \times 6 + F_{Cx} \times 9 = 0 \Rightarrow F_{Cx} = -2k.$

$\therefore F_{Ay} = +1\,K.$

$F_A = \sqrt{5} = +2.23k.$

$\therefore F_{cx} = F_{cy} = -2k, \quad F_C =$

Tensile stress at bar AB.

$$\sigma_{AB} = \frac{F_A}{A} = \frac{2.23}{0.25 \times 0.5} = 17.8 \text{ ksi}$$

Tensile stress in clevis of bar AB.

$$(\sigma_{AB})_{clevis} = \frac{F_A}{A} = \frac{2.23}{0.20 \times 2 \times (0.875 - 0.375)} = 11.2 \text{ ksi}$$

Compressive strength in main bar BC.

$$\sigma_{BC} = \frac{F_C}{A} = \frac{2.83}{0.875 \times 0.25} = 12.9 \text{ ksi}$$

Bearing stress between C and the clevis.

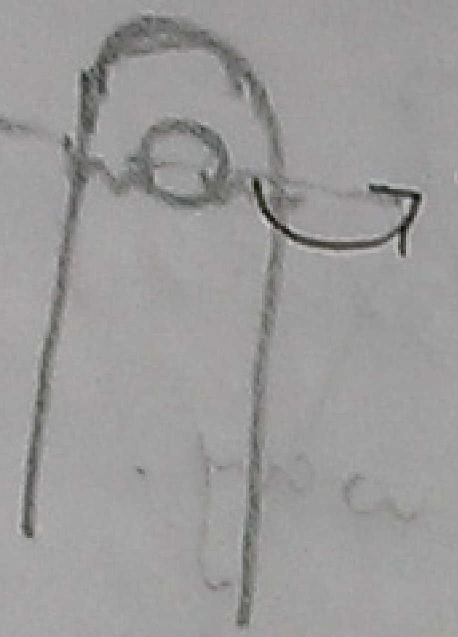
$$\sigma_b = \frac{F_C}{A_{bearing}} = \frac{2.83}{0.375 \times 2 \times 0.20} = 18.8 \text{ ksi}$$

Bearing between the main plate

$$\sigma_b = \frac{F_C}{A} = \frac{2.83}{0.375 \times 0.25} = 30.2 \text{ ksi}$$

Double shear in pin C.

$$\tau = \frac{F_C}{A} = \frac{2.83}{2\pi \left(0.375/2\right)^2} = 12.9 \text{ ksi}$$



→ stress-এর dia বাদ দিতে হবে।

$d_{pin} = 20$

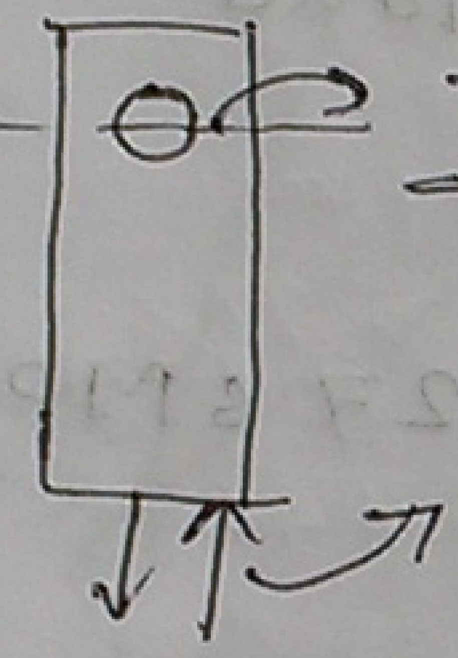
$d_{plate} = 22 \cdot mm$

plate-এর dia 2-3 mm বড় করা হয়।

Plate-এর stress → dia of pin

dia of hole → 2-3mm বড়

bearing → { Thickness of plate
dia of pin.



→ Tension কাজ করে

→ compression কাজ করে না।

clevis হলে 2 দিয়ে ভাগ দিতে হবে।

$$(\sigma_{AB})_{clevis} = \frac{F_A}{A_{net}}$$

Universal testing machine → material-এর properties.

03.02.14.

Working stress:

Repeated loading → fatigue test.
↳ material do not behave in same way.

Stress reverse হলে।

SN → Stress- number → infinity time stress দেওয়ার পর tolerance ability.

Factor of safety → $\frac{\text{ultimate load}}{\text{working load / design load}}$

f.s = 1 → margin of safety.

Mild stress → 2800 kg/cm², 40 ksi i.e 276 MPa

Yield stress is the greatest.

High carbon steel.

40 grade → 60 এর বেশি.

90,000 এর উপরে হবে ultimate stress.

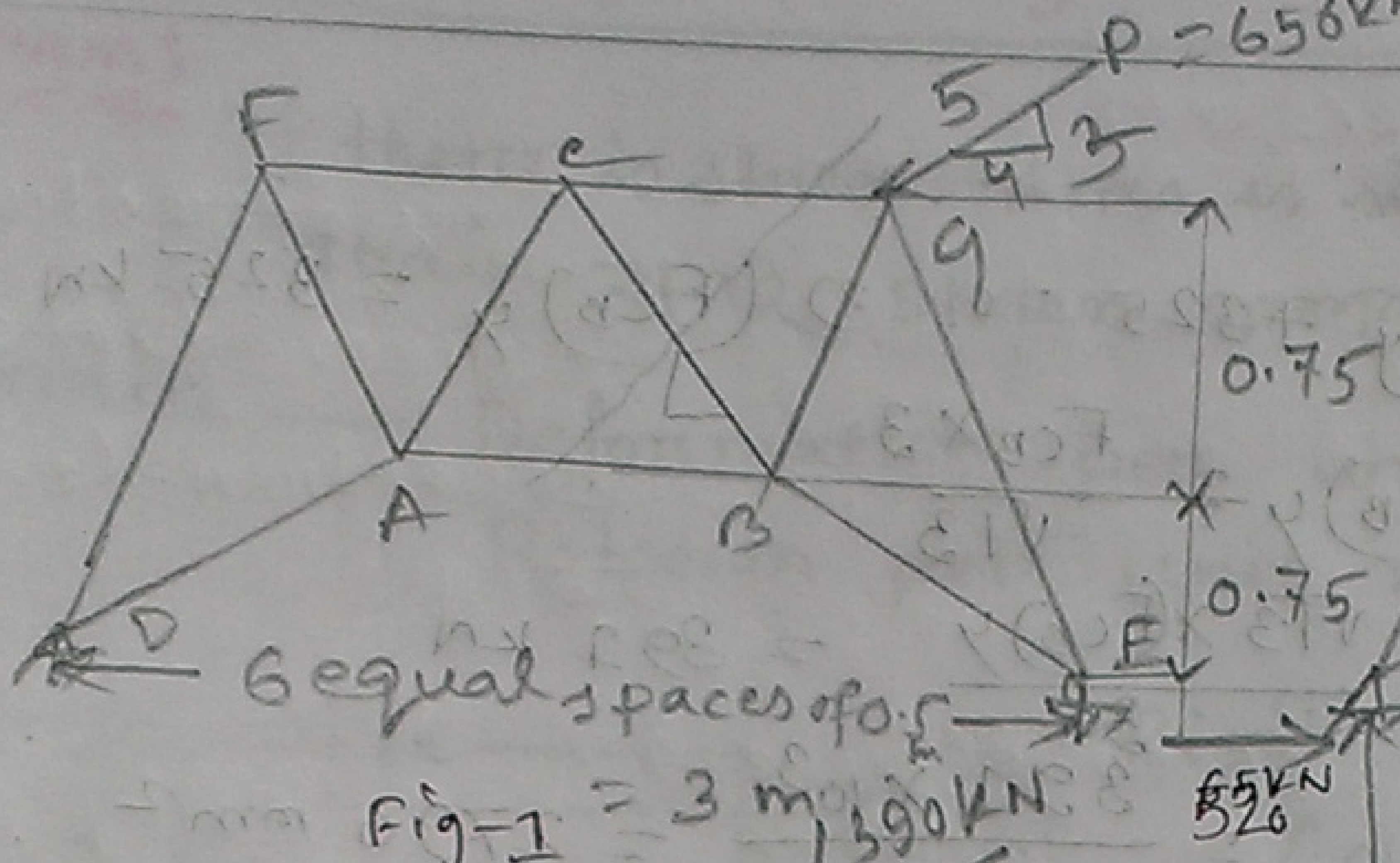
Design of axiality loaded members & pins:

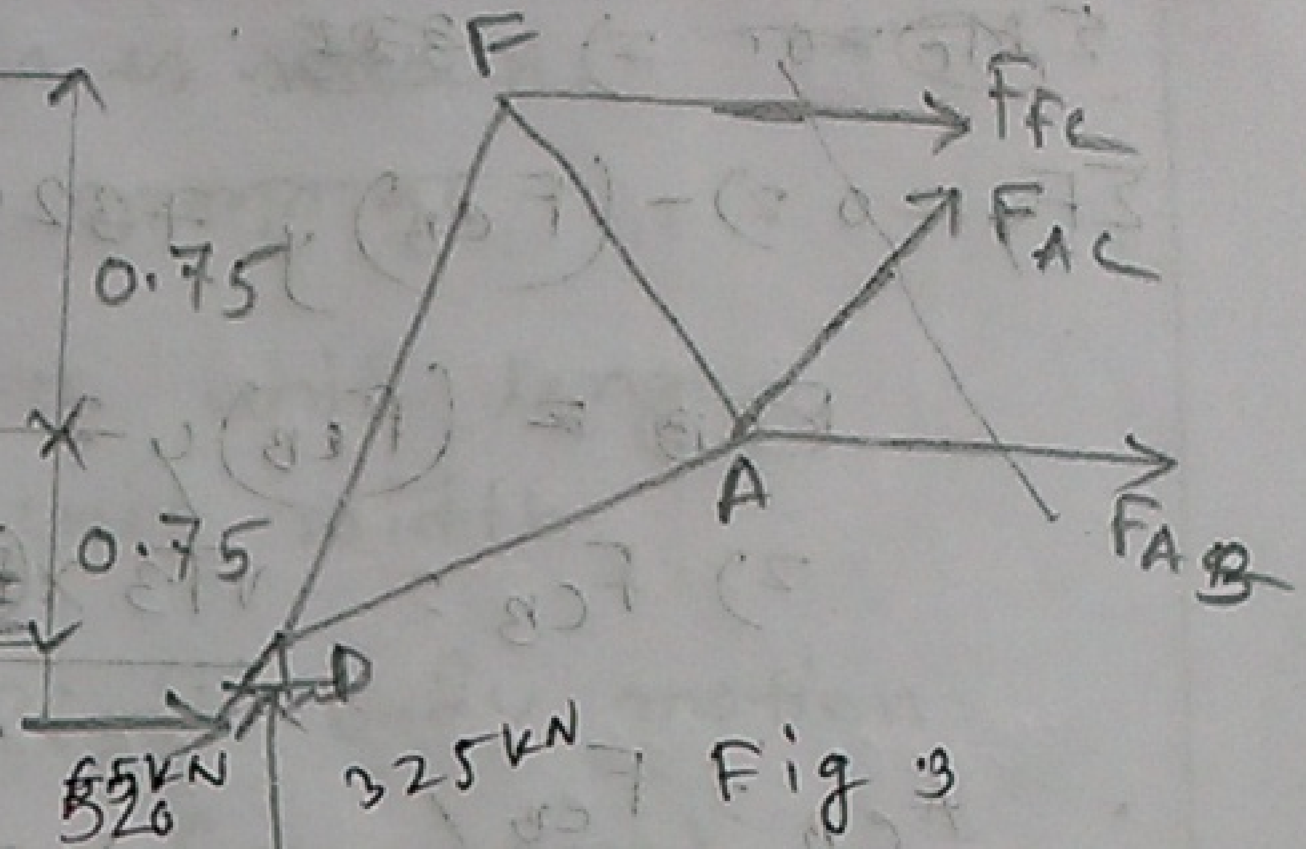
$$F_{os} = \frac{U}{A} \Rightarrow A = \frac{U}{F_{os}}$$

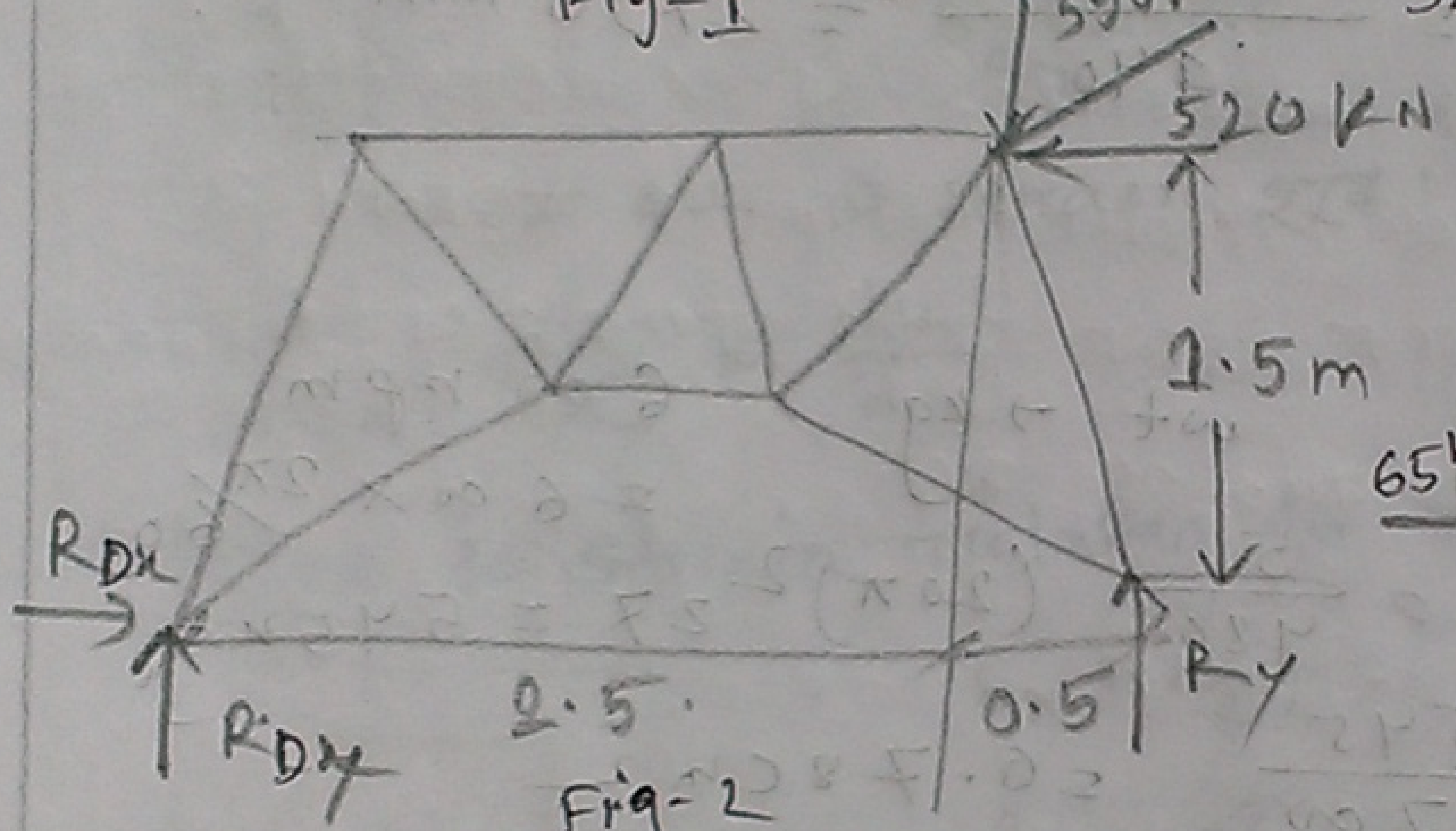
$$F = \sigma A \Rightarrow A = \frac{F}{\sigma_{allow}}$$

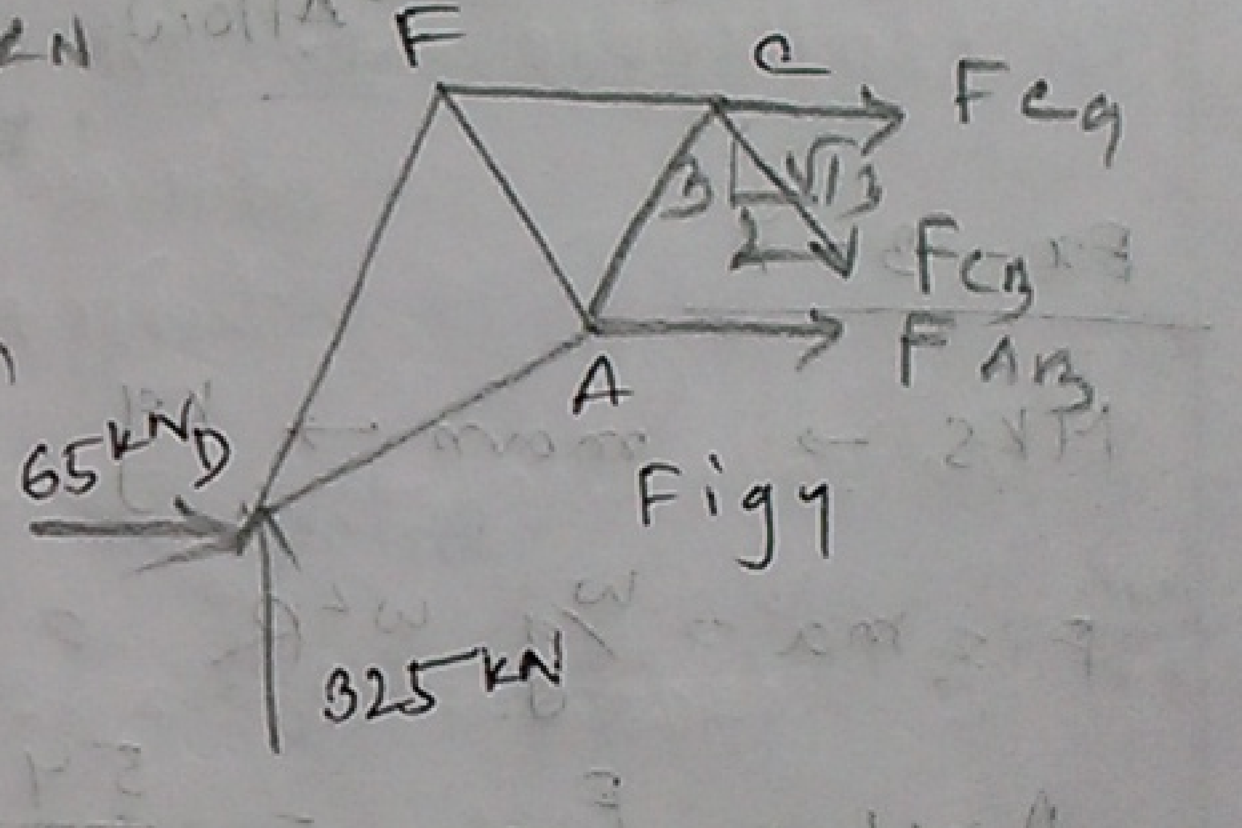
$0.33\ cm^2 \Rightarrow 0.11 \times 0.3 \Rightarrow 0.7 \times 0.5 = 0.35$

1.5









For the whole dia —

$\Sigma F_x = 0 \Rightarrow R_{Dx} = 520$ KN

$\Sigma M_D = 0 \Rightarrow -R_{Ey} \times 3 + 390 \times 2.5 - 520 \times 1.5 = 0$

$\Rightarrow R_{Ey} = 65$ KN

$\Sigma M_E = 0 \Rightarrow R_{Dy} \times 3 - 390 \times 0.5 - 520 \times 1.5 = 0$

$\therefore R_{Dy} = 325$ KN.

From fig-3.

$\Sigma M_A = 0 \Rightarrow 325 \times 0.5 - 65 \times 0.75 + F_{FC} \times 0.75 = 0$

$\therefore F_{FC} = +86.7$ KN

$$A_{FC} = \frac{F_{FC}}{\sigma_{Allow}} = \frac{86.7 \times 10^3}{140} = 620 \text{ mm}^2$$

Fig-4

$\Sigma \cancel{M_O = 0} \Rightarrow \cancel{325}$.

$\Sigma F_y = 0 \Rightarrow -(F_{CB})_y + 325 = 0 \Rightarrow (F_{CB})_y = 325$ kN

$\cancel{F_{CB}} = (F_{CB})_y = \frac{F_{CB} \times 3}{\sqrt{13}}$

$\Rightarrow F_{CB} = \frac{\sqrt{13} \times (F_{CB})_y}{3} = 391$ kN

$\therefore A_{CB} = F_{CB}/\sigma_{Allow} = \frac{391 \times 10^3}{140} = 2790\ mm^2$.

Ex - 3 - 7

MKS → mass → kg wt → kg 600 rpm

$= 600 \times 2\pi/60$

$F = ma = w/g\ \omega^2 R = \frac{5}{980} (20\pi)^2 27 = 545$ kg

$A_{net} = \frac{F}{\sigma_{allow}} = \frac{545}{700} = 0.78\ cm^2$

$F_1 = \int_0^R (m_1 dr)\ \omega^2 r = m_1 \omega^2 \frac{R^2}{2}$ $m_1 = \frac{\sigma}{g} A$

dia ber ~~ঞ্জ~~ হল $d = 1$ cm → dia of rod.

additional pull → rod এর self weight এর

জন্য $P_1 = \int_0^R (m_1 dr)\ \omega^2 r$

$\checkmark$ = (unit wt) × Area

= t wet of unit weight.

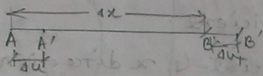
বইয়ের- Chap-3 (Part B) -Pg(143-151)

Strain:

08.02.14

If there is stress, there is strain.
Strain হলেই stress থাকবে না।

Strain $\longrightarrow$ Deformation per unit length
Rotation per unit width.

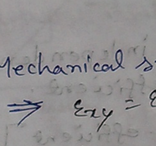


Rigid body motion
(Δu same)

$\Delta u \neq \Delta u_1 \Rightarrow$ strain হবে।

$$\lim_{\Delta x \to \infty} \frac{\Delta u}{\Delta x} = \frac{du}{dx}$$

* Stress & strain relates to a point.



$$\varepsilon_x = \frac{\delta u}{\delta x}, \quad \varepsilon_y = \frac{\delta v}{\delta y}, \quad \varepsilon_z = \frac{\delta w}{\delta z}$$

$$\left.\begin{aligned} \gamma_{xy} &= \gamma_{yx} = \frac{\delta v}{\delta x} + \frac{\delta u}{\delta y} \\ \gamma_{xz} &= \gamma_{zx} = \frac{\delta w}{\delta x} + \frac{\delta u}{\delta z} \\ \gamma_{yz} &= \gamma_{zy} = \frac{\delta w}{\delta y} + \frac{\delta v}{\delta z} \end{aligned}\right\} \text{Total angular strain.}$$

* Mechanical strain

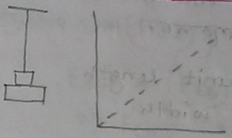
$$\Rightarrow \varepsilon_{xy} = \varepsilon_{yx} = \frac{\gamma_{xy}}{2}$$

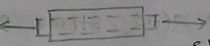
$$\varepsilon_{yz} = \varepsilon_{zy} = \frac{\gamma_{yz}}{2}$$

$$\cancel{\varepsilon_{xz}} = \cancel{\varepsilon_{zx}} = \frac{\cancel{\gamma_{xz}}}{2}$$

$$\varepsilon_{zx} = \varepsilon_{xz} = \frac{\gamma_{zx}}{2}$$

Generalized Hooks law:





x direction এ stress দিলে y ও z direction এ stress হবে।

There are 36 co-efficient.

(i) Isotropic → যে material এ x direction এ stress, y direction এ যেমন হয় উল্টো দিলে একই রকম হবে। (Identical)

(ii) Anisotropic → এ রকম হবে না।
↓
is responsible to a strain

(i) Homogeneous → চোখে যদি সমান দেখা যায়

(ii) Heterogeneous → stress-strain এর কোনো relation নাই.

$$\{\varepsilon\}_{ij} = [A_{ij}]\{\tau_{ij}\} \rightarrow 36 \text{ independent co-efficient.}$$

$$\hat{\varepsilon}_{ij} = A_{ij} \cdot \hat{\tau}_{ij}$$

→ 3 co-efficient] for isotropic material.

τ-এর 1st 3 0 হয়ে যায়।

last 3 → 0 হয়ে যায়।

$$\varepsilon_{xx} = \frac{\tau_{xx}}{E}$$

$$\varepsilon_{yy} = -\nu\frac{\sigma_x}{E}$$; ν is poison ratio

$$A_{11} = \frac{1}{E} \quad A_{12} = -\frac{\nu}{E}, \quad A_{13} = \frac{1}{E}$$

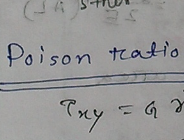
$$
\begin{Bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{zz} \\ \varepsilon_{xy} \\ \varepsilon_{yz} \\ \varepsilon_{zx} \end{Bmatrix}
=
\begin{bmatrix}
\frac{1}{E} & -\frac{\nu}{E} & -\frac{\nu}{E} & 0 & 0 & 0 \\
-\frac{\nu}{E} & \frac{1}{E} & -\frac{\nu}{E} & 0 & 0 & 0 \\
-\frac{\nu}{E} & -\frac{\nu}{E} & \frac{1}{E} & 0 & 0 & 0 \\
0 & 0 & 0 & \frac{1}{2G} & 0 & 0 \\
0 & 0 & 0 & 0 & \frac{1}{2G} & 0 \\
0 & 0 & 0 & 0 & 0 & \frac{1}{2G}
\end{bmatrix}
\begin{Bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \tau_{xy} \\ \tau_{yz} \\ \tau_{zx} \end{Bmatrix}
$$

$$\{\varepsilon\} = [A]\{\sigma\}$$

$$\{\sigma\} = [A^{-1}]\{\varepsilon\} \quad ; [A^{-1}] \Rightarrow \text{constitutive matrix}$$

* Strain - এ C.M দিয়ে stress calculate করতে হবে।

Determine ⟶ constitutive matrix for normal stress



⟶ linear এবং এর slope

$E = \frac{\sigma}{\varepsilon}$ $\quad \varepsilon = 1$ হলে $E = \sigma$

Poison ratio: $\nu = \frac{|\varepsilon_x|}{\varepsilon_x}$ → lateral direction

$\tau_{xy} = G\gamma_{xy}$; $G = \frac{E}{2(1+\nu)}$ [memorize]

E & ν test দিয়ে G বের করা যায়।

2" থেকে বেশি না নিলে diameter কতটুকু বোঝা যাবে না।

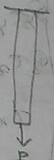
ε_1 = transverse direction ?? $G = \frac{75}{2.67} \times 10^4 = 28 \times 10^4$ kg/cm^2

chp-2-pg(91-94)

Energy:

09.02.14

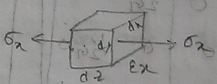
Capacity to do work.



$W = F \cdot s$

Strain energy $\longrightarrow$ Strain for load

Unit point - 4 load $\longrightarrow$ force



Deformation, $\varepsilon_x dx$

$\varepsilon_x = \frac{du}{dx}$

σ_x = final end product

$\therefore du = \varepsilon_x dx$

$$F = d_y d_z \int \tfrac{1}{2} (\sigma_x \cdot d_y d_z)\, \varepsilon_x dx$$

$$U = \int \tfrac{1}{2} \sigma_x \varepsilon_x dv = \tfrac{1}{2} \sigma_x \varepsilon_x (dx\, dy\, dz)$$

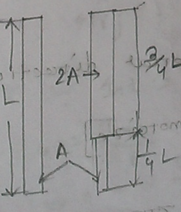
$$= \tfrac{1}{2} \sigma_x \varepsilon_x dv$$

$\therefore \varepsilon_x = \frac{\sigma_x}{E}$; $dv = \tfrac{1}{2} \times$ stress $\times$ strain $\times$ volume

$$= \int \frac{\sigma_x^2}{2E} dv \quad \text{(stress এর form)}$$

$$U_0 = \frac{dU}{dV} = \tfrac{1}{2} \sigma_x \varepsilon_x = \frac{\sigma_x^2}{2E} \quad \text{(strain energy density)}$$

Ex



$$U_1 = \int_V \frac{\sigma_x^2}{2E} dv = \frac{\sigma_1^2}{2E} \int_V dv = \frac{\sigma_1^2}{2E} (AL)$$

A = cross sectional area

L = Length.

$$U_2 = \int_v \frac{\sigma^2}{2E}\,dv = \frac{\sigma_2^2}{2E}\int_{\text{lower part}} dv + \frac{(\sigma_2/2)^2}{2E}\int_{\text{upper part}} dv$$

$$= \frac{\sigma_2^2}{2E}\left(\frac{AL}{4}\right) + \frac{(\sigma_2/2)^2}{2E}\left(2A\cdot\frac{3L}{4}\right) = \frac{\sigma_2^2 AL}{8E} + \frac{3\sigma_2^2 AL}{16E}$$

$$= \frac{2\sigma_2^2 AL + 3\sigma_2^2 AL}{16E} = \frac{5\sigma_2^2 AL}{16E} = \frac{\sigma_2^2}{2E}\left(\frac{5}{8}AL\right)$$

If $U_1 = U_2$

$$\frac{\sigma_1^2}{2E}(AL) = \frac{\sigma_2^2}{2E}\left(\frac{5}{8}AL\right) \quad \therefore \sigma_2 = 1.265\,\sigma_1$$

Hence for the same energy load, the stress in the reinforced bar is 26.5% higher than in the plain bar.

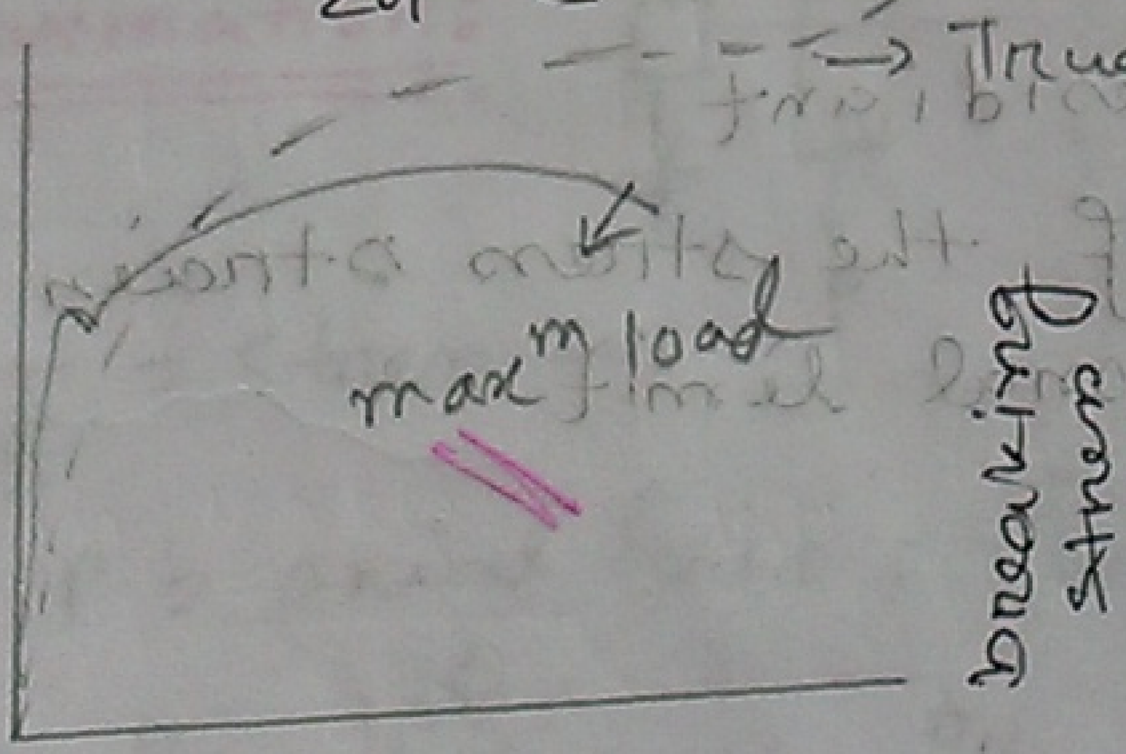
$$U_{shear} = \int_v \frac{1}{2}\tau_{xy}\gamma_{xy}\,dv = \int_v \frac{1}{2}\frac{\tau_y^2}{G}\,dv$$

$$U = \int_v \frac{1}{2}\sigma_x\varepsilon_x + \frac{1}{2}\sigma_y\varepsilon_y + \frac{1}{2}\sigma_z\varepsilon_z + \frac{1}{2}\tau_{xy}\gamma_{xy} + \frac{1}{2}\ldots$$

$$\varepsilon_x = \frac{\sigma_x}{E} - \frac{\nu}{E}\sigma_y - \frac{\nu}{E}\sigma_z$$

$$U = \frac{1}{2E}(\sigma_x^2 + \sigma_y^2 + \sigma_z^2) - \frac{\nu}{E}(\sigma_x\sigma_y + \sigma_x\sigma_z + \sigma_x\sigma_y)$$

chp-2 pg-62-75) $+ \frac{1}{2G}(\tau_{xx}^2 + \tau_{yy}^2 + \tau_{zz}^2)$



Flow of the material at constant stress → yield.

Creep: strain at constant load ধীরে ধীরে (বছরের পর বছর)

convention stress-strain

শুরু হলে deformation

থেকে " 20 গুণ

Breaking stress: যখন ভেঙে যাবে → will be highest.

Yield stress
Ultimate stress.
ছেঁড়ে যাওয়ার সময় একদিকে cup আর দিকে cone.
so this is called cup & cone structure.
ductile
Brittle → absence of ductility
concrete → Brittle.
যে পরিমান stress দেওয়ার কথা তার থেকে কম দেওয়া হয় যাতে concrete crash করার সময় warning দেয়।
Propotional limit : যেখানে proportionality শেষ হয়ে যায়

(i) Yield stress (ii) propotional limit (iii) Elastic limit
↓
use করা হয়.
↓
stress constant
elongation বাড়ছে

determine করা difficult
* ৩ টাই same.

↓
proportional limit এর কাছে।

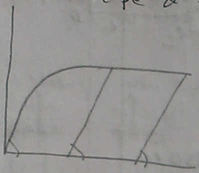
$\frac{1}{2}\sigma_p \varepsilon_p$ → strain energy which can be modulus of elastic resiliant
→ is the area of the stress strain diagram up to propotional limit.

Ch-2(93,95)

Yield point → elastic limit 10.02.14

non-linear elastic material

initial slope & final slope is same



cold working

Strain Hardening

1 in deformation more load

(i) Stronger

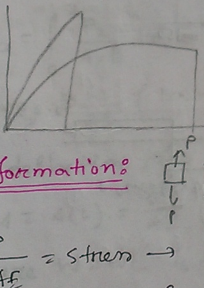
(ii) Tougher → fall করার আগে প্রচুর deformation.

↓

above more energy

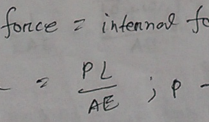
A > B

modulus of elasticity > M·E → strength বেশি



weak but tough

[4] Deformation:



$du = \varepsilon_x dx$ ⟶ strain energy

$u = \int_0^L \varepsilon_x dx$

$= \frac{\sigma_x}{E} = \frac{P}{AE} dx$

$= \int_0^L \frac{P}{AE} \cdot dx$

$\frac{P}{AE}$ = stress →

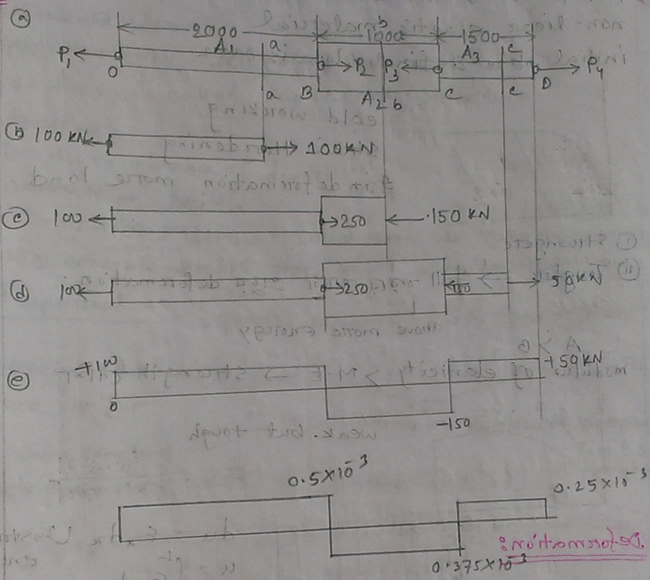
P = Axial force = internal force

$= \frac{P}{AE} \int_0^L dx = \frac{PL}{AE}$; P → axial force

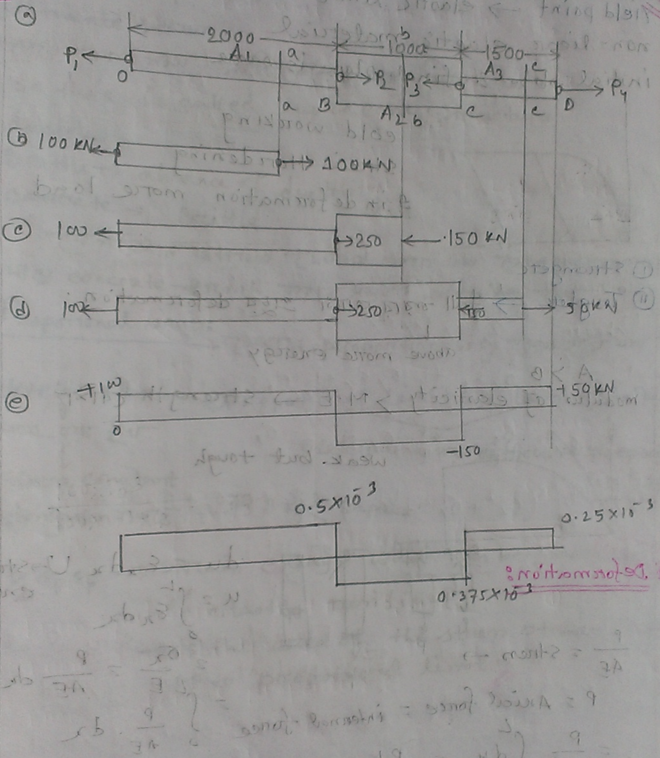
↓

internal force

Mech-chp-2-pg 76



Mech-chp-2-Pg 76

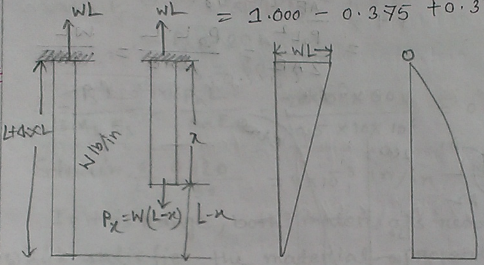


$$\Delta = \sum_i \frac{P_i L_i}{A_i E_i} = \frac{P_{OB} L_{OB}}{A_{OB} E} + \frac{P_{BC} L_{BC}}{A_{BC} E} + \frac{P_{CD} L_{CD}}{A_{CD} E}$$ Ex

$$= \frac{100\times10^3 \times 2000}{1000\times200\times10^3} - \frac{150\times10^3\times1000}{2000\times200\times10^3} + \frac{50\times10^3\times1500}{1000\times200\times10^3}$$

$$= 1.000 - 0.375 + 0.375 = 1.000\,\text{mm}$$

Ex



Ex

$$\Delta_x = \int_0^x \frac{P_x}{A_x E}\,dx = \int \frac{1}{AE}\, w(L-x)\,dx$$

$$= \frac{w}{AE}\left(Lx - \frac{x^2}{2}\right)$$

The deflection of B is,

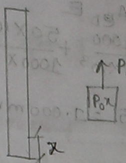
$$\Delta = \Delta(L) = \frac{w}{AE}\left(L^2 - \frac{L^2}{2}\right) = \frac{wL^2}{2AE} = \frac{WL}{2AE}$$

where $W = wL$ is the total weight of the bar.

$$\Delta = \frac{PL}{AE} + \frac{WL}{2AE} = \frac{\left[P + W/2\right] L}{AE}$$

Ex

Per unit length weight $= P_0$

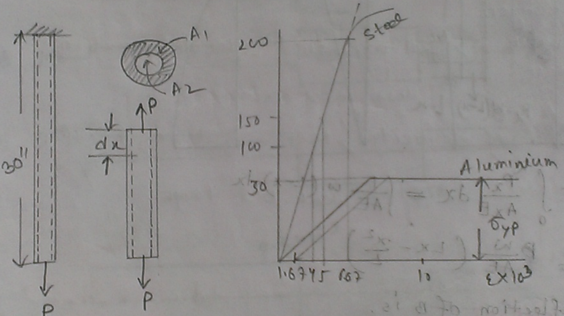


$$u = \int_0^L \frac{P_0 x}{AE} \cdot dx = \frac{P_0}{AE} \int_0^L x\, dx$$

$$= \frac{P_0}{AE} \left[\frac{x^2}{2} \right]_0^L$$

$$= \frac{P_0 L^2}{2AE} = \frac{P_0 L \cdot L}{2AE} = \frac{WL}{2AE}$$

Ex



From equilibrium: $P_a + P_s = P_1$ or P_2 — ①

From compatibility: $\Delta_a = \Delta_s$ or $\varepsilon_a = \varepsilon_s$

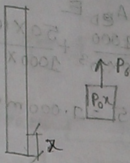
From material properties:

$$\varepsilon_a = \sigma_a / E_a \quad \text{and} \quad \varepsilon_s = \sigma_s / E_s$$

$$\sigma_a = \frac{P_a}{A_a}, \quad \sigma_s = \frac{P_s}{A_s}$$

$E_s = 30 \times 10^6$ psi and $E_a = 10 \times 10^6$ psi

Ex



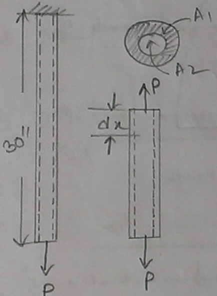
Per unit length weight $= P_0$

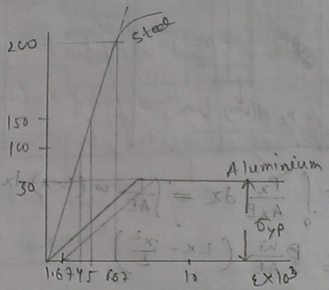
$$u = \int_0^L \frac{P_0 x}{AE} \cdot dx = \frac{P_0}{AE}\int_0^L x\, dx$$

$$= \frac{P_0}{AE}\left[\frac{x^2}{2}\right]_0^L$$

$$= \frac{P_0 L^2}{2AE} = \frac{P_0 L \cdot L}{2AE} = \frac{WL}{2AE}$$

Ex





From equilibrium: $P_a + P_s = P_1$ or P_2 — ①

From compatibility: $\Delta_a = \Delta_s$ or $\varepsilon_a = \varepsilon_s$

From material properties:

$$\varepsilon_a = \sigma_a / E_a \quad \text{and} \quad \varepsilon_s = \sigma_s / E_s$$

$$\sigma_a = \frac{P_a}{A_a}, \quad \sigma_s = \frac{P_s}{A_s}$$

$E_s = 30 \times 10^6$ psi and $E_a = 10 \times 10^6$ psi

B. $\varepsilon_a = \varepsilon_s = \frac{\sigma_a}{E_a} = \frac{\sigma_s}{E_s} = \frac{P_a}{A_a E_a} = \frac{P_s}{A_s E_s}$

$P_s = \left(\frac{A_s E_s}{A_a E_a}\right) P_a = 3 P_a$

From eq^n (1) $\Rightarrow$ $P_a + 3P_a = P_1 = 80K$

$\therefore P_a = 20K$

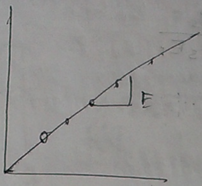
$P_s = 60K$

$\Delta = \frac{P_s L}{A_s E_s} = \frac{P_a L}{A_a E_a} = \frac{20 \times 10^3 \times 30}{0.5 \times 10 \times 10^6} = 0.120 \text{ in}$

Strain, $\frac{\Delta}{L} = \frac{0.120}{30} = 4 \times 10^{-3}$ in/in

In this range, both materials respond elastically, which satisfies the material - property assumption made at the begining of this solution. In fact

08.02.24



1st pt থেকে ছেড়ে দিতে হবে,
E বের করার জন্য

$14.5 \rightarrow \dfrac{1450}{\frac{\pi}{4}\times(5.6)^2} \rightarrow$ stress

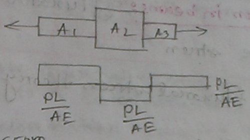
corr. strain → 0.000782 cm per cm

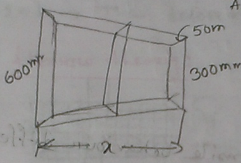
$$\frac{588}{0.000782} = 75\times10^4 \text{ kg/cm}^2$$

$$\eta = 28\times10^4 \text{ kg/cm}^2$$

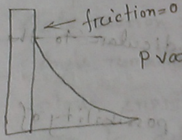
22.02.14

$$u = \int \frac{P_x}{A_x E}\,dx$$

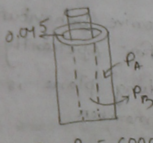




P & E constant
A variable হলে integration করে বের করতে হবে।



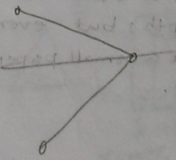
P variable



$\Delta = \frac{PL}{AE} > 0.0015$

$P_A + P_B = 6000$

$\Delta_B = \Delta_A + 0.0015$

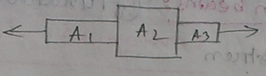


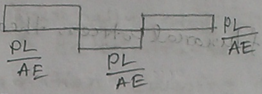
$$\Delta_{AB} = \frac{P_{AB} L_{AB}}{A_{AB} L_{AB}}$$

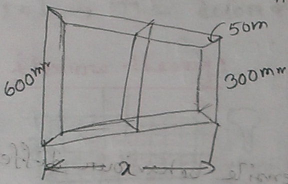
$$\Delta_{BC} = \frac{P_{BC} L_{BC}}{A_{BC} L_{BC}}$$

22.02.14

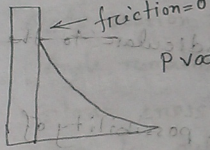
$$u = \int \frac{P_x}{A_x E} dx$$



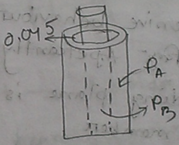




P & E constant
A variable হবে integration করে
বের করতে হবে



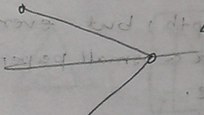
P variable



$$\Delta = \frac{PL}{AE} > 0.0015$$

$$P_A + P_B = 6000$$

$$\Delta_B = \Delta_A + 0.0015$$



$$\Delta_{AB} = \frac{P_{AB} L_{AB}}{A_{AB} L_{AB}}$$

$$\Delta_{BC} = \frac{P_{BC} L_{BC}}{A_{BC} L_{BC}}$$

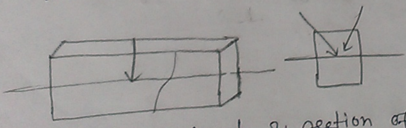
Bending stress in beams: (fluxaral stress)

$\frac{P}{A}$ average stress

Navier → fluxaral stress theory
↓
Navier hypothesis.

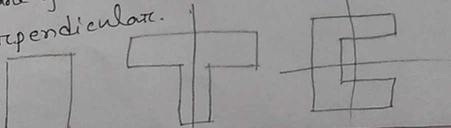
Limitation:

(i) Static analysis
(ii) member must be stable
 * Compressive behaviour, tensile behaviour different
 কিছু কিছু Apercantly stable
(iii) The loading plane is perpendicular to the axis of the member
(iv) An ~~an~~ example consider the possibility of using a sheet of paper on edge as a beam. such a beam is as a substantial depth, but even if it is used to carry a force over a small paper it will buck~~ed~~ sidewide and collaspe.



twisting moment

& section of member must be plane of the load perpendicular.



(iv) Symetric either major or minor axis.

Basic kinematic Asumption:

1st – reduce the internally statically indeterminate problem to a determinante

2nd → The deformation causing strain to relate

flexure theory:

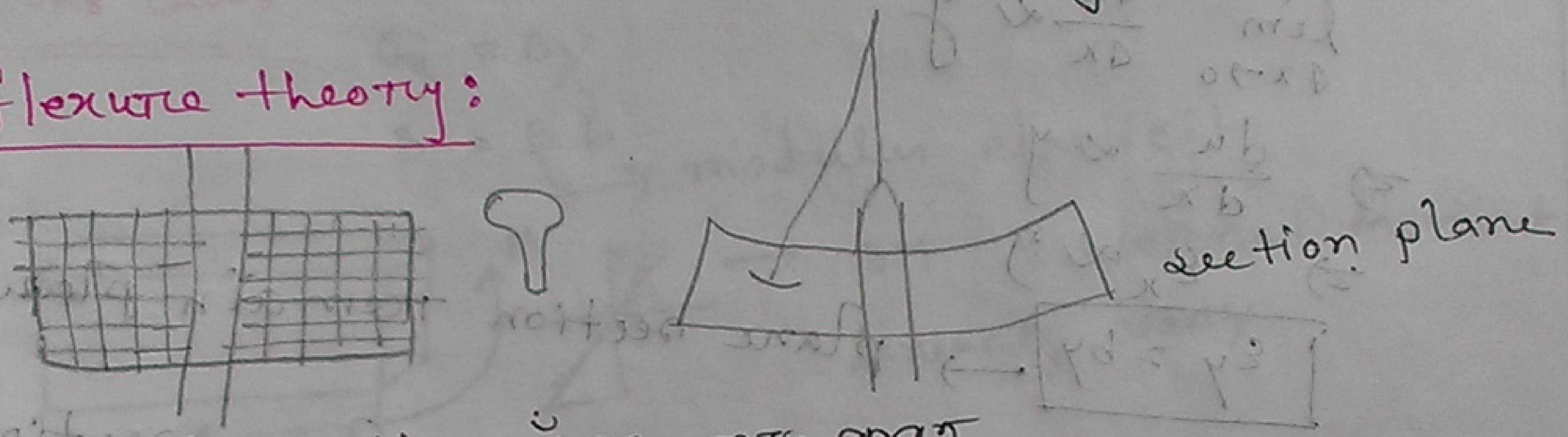
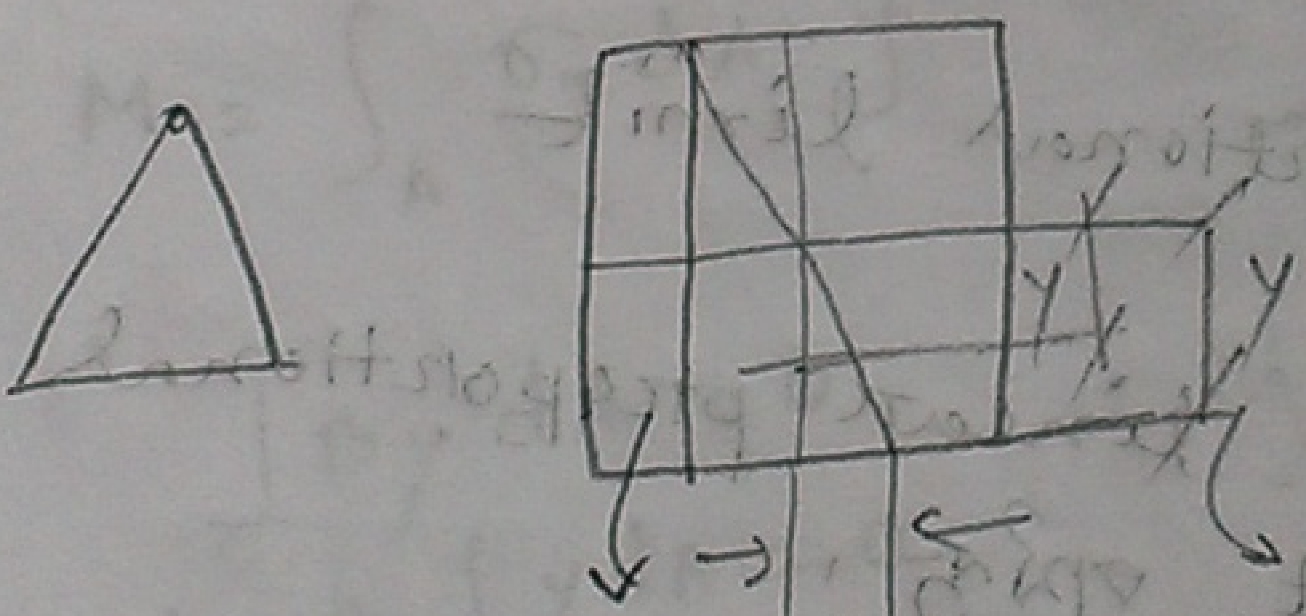


plate section বাঁকা হয়ে যায়

Angle remains constant → Navier hypothese

plane cross section beam remain plane after the beam is subjected to bending.

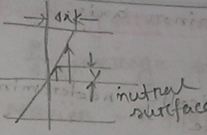


Nutral surface → বাঁকা surface

nutral surface & cross sectional plane.

intersection is line

This line is called → nutral axis



$\Delta u \propto y$

deformation ∝ the distance from the nutral surface

$$\lim_{\Delta x \to 0} \frac{\Delta u}{\Delta x} \propto y$$

$$\Rightarrow \frac{du}{dx} \propto y$$

$$\Rightarrow \varepsilon_x \propto y$$

$\boxed{\varepsilon_y = by}$ → plane section remain plane

linearly vary হবে → otherwise plane section থাকবে না।

Navier's hypothesis is true after breaking

$\boxed{\sigma_x = E\varepsilon_x}$ → hooks law

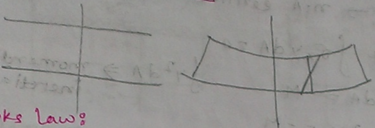
True up to proportional limit

$\boxed{\sigma_x = By}$ Stress linear proportional limit পর্যন্ত।

—o—

Navier's Hypothei's:

23.02.14



$u = c \cdot y$

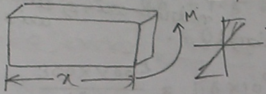
$\boxed{\varepsilon_x = by}$

mathmatical

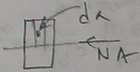
Hooks law:

$\sigma_x = By$

$B = E \cdot b$ → modulus elasticity



→ BM Internal moment linearly vary



Force $= \sigma_x \, da$

$dM = \sigma_x \, da \cdot y$

Net Horizontal force $= 0$

$M = \int_A \sigma_x \, dA \cdot y$

$dF = \sigma_x \, dA$

$\Sigma F_x = 0 \qquad \int \sigma_x \, dA = 0$

$\int By \, dA = 0$

$\Rightarrow B \int y \, dA = 0$

$\therefore B \cdot \bar{y} \cdot A = 0$

$\int y \, dA \Rightarrow$ moment of area

$\int y \, dA = \oint A\bar{y}$ = centroidal distance from reference line.

B is not equal to 0.

$\boxed{\bar{y} = 0}$ → That means nutral Axi's passing through the centroid.

For inelastic beam → n.A centroid দিয়ে যাবে না।

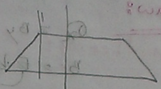
$\sum M = 0 \Rightarrow M + \int \sigma_x y \, dA = 0$

$\int B y^2 dA = -M$ $\qquad \int y^2 dA \Rightarrow$ moment of inertia

$\Rightarrow B \int y^2 dA = -M$

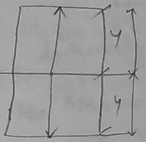
$B \cdot I = -M$

$B = -\frac{M}{I}$



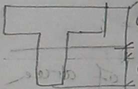
$\boxed{\sigma = By = -\frac{My}{I}}$ → elastic fluxaral formula.

nutral axis ⇒ centroidal axis



$\sigma_{max} = \frac{Mc}{I}$; $c_t = c_t$ or c_B

For rectangle section, $c_t = c_b$



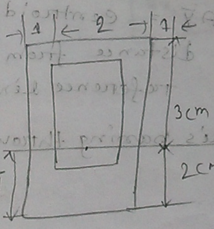
$c_b > c_t$

y (+) হলে M (+), max^m compression

Top fibre — y(+)

Bottom " — y(-) → max^m tension

(এখানে দুইটাই উল্লেখ করতে হবে।)



$$\bar{y} = \frac{\sum A_i y_i}{\sum A} = \frac{20 \times 3 - 6 \times 3.5}{10} = 2.83\text{cm}$$

$$\therefore I = \frac{bh^3}{12} - \frac{b_1 h_1^3}{12} = \cancel{2.83\text{ cm}}$$

$$= \left[\frac{4 \times 6^3}{12} + 24(0.17)^2\right] - \left(\frac{2 \times 3^3}{12} - 6 \cdot 6^2\right)$$

$$= 65.5 \text{ cm}^3$$

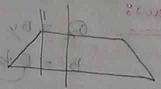
For inelastic beam → n.A centroid দিয়ে যাবে না।

$\Sigma M = 0 \Rightarrow M + \int \sigma_x y \, dA = 0$

$\int B y^2 dA = -M$ $\qquad$ $\int y^2 dA \Rightarrow$ moment of inertia

$\Rightarrow B \int y^2 dA = -M$

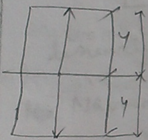
$B \cdot I = -M$



$\boxed{\sigma = By = -\frac{My}{I}}$ $\qquad B = -\frac{M}{I}$

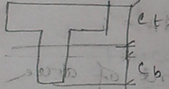
→ elastic fluxaral formula.

nutral axis ⇒ centroidal axis



$\sigma_{max} = \frac{Mc}{I}$; $c_t = c_t$ or c_B

For rectangle section, $c_t = c_b$



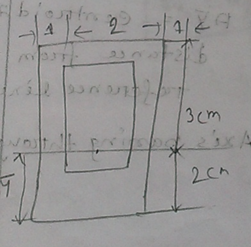
$c_b > c_t$

$y(+)$ হলে $M(+)$, max^m compression

Top fibre — $y(+)$

Bottom " — $y(-)$ → max^m tension

(এখানে দুইটাই উল্লেখ করতে হবে।



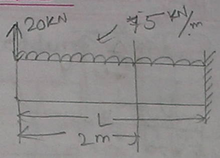
$\bar{y} = \frac{\Sigma A_i y_i}{\Sigma A} = \frac{20 \times 3 - 6 \times 3.5}{10} = 2.83$cm

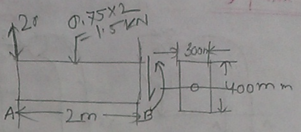
$\therefore I = \frac{bh^3}{12} - \frac{b_1 h_1^3}{12} = ~~2.83 cm~~$

$= \left[\frac{4 \times 6^3}{12} + 24(0.17)^2\right] - \left(\frac{2 \times 3^3}{12} - 6 \cdot u^2\right)$

$= 65.5 \text{ cm}^3$

Example:





$$\Sigma M_A = 0 \Rightarrow 20 \times 2 - 1.5 \times 1 - M = 0$$

$$\therefore M = 38.5 \text{ kN}\cdot\text{m}$$

$$\Sigma F_y = 0 \Rightarrow 20 - 1.5 - B = 0$$

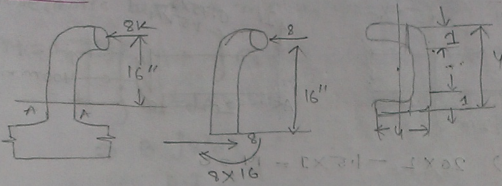
$$\therefore B = 18.5 \text{ kN}.$$

$$I = \frac{300 \times 400^3}{12\cancel{00}} = 1.6 \times 10^9 \text{ mm}^4$$

$$\sigma_{max} = \frac{M \cdot c}{I} = \frac{38.5 \times 10^6 \times 200 \text{ mm}}{1.6 \times 10^9 \text{ mm}^4} = \pm 4.81 \text{ MPa}$$

24.02.2014

Example:



$$\bar{y} = \frac{4\times1\times0.5 + 2\times3\times1\times2.5}{4\times1 + 2\times3\times1} = 1.7$$

$$I = \frac{4\times1^3}{12} + \left[4\times1\times(1.7-0.5)^2\right] + \frac{2\times1\times3^3}{12} + \left[2\times1\times3(2.5-1.7)^2\right]$$

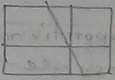
$$= 14.43\ in^4$$

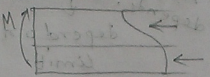
$$\sigma_{max} = \frac{Mc}{I} = \frac{8\times16\times2.3}{14.43} = 20.4\ ksi \quad \text{(compression)}$$

$$\sigma_{max} = \frac{Mc}{I} = \frac{8\times16\times1.7}{14.43} = 15.1\ ksi \quad \text{(tension)}.$$

Inelastic bending of beams:

Procedure same, 2 eqn





Stress diagram.

$\Sigma F_x = 0 \Rightarrow \int_x \sigma_x \, dA = 0$

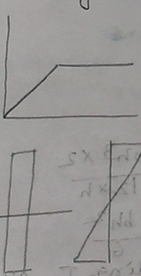
$\Sigma M_x = 0 \Rightarrow \int_A \sigma_x y \, dA = M$

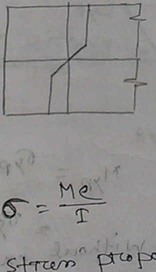
Nutral axis centroid দিয়ে যাবে না।

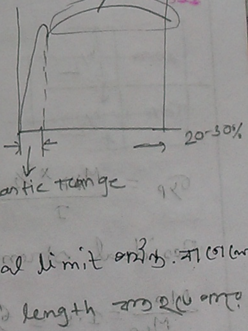
Total compression $\neq$ total tension

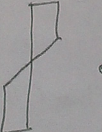
ব্যবহার করার ২৫ নেই.

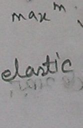
Bending moment → Normal stress.











$\sigma = \frac{Mc}{I}$

* Stress proportional limit পর্যন্ত না গেলে

max^m value σ_y

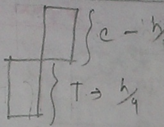
min^m length কত হলে আর?

don't know

elastic curve

$$M_{uH} = C \times \frac{h}{2} = \boxed{\sigma_{yp} \times \frac{bh^2}{4}}$$

ultimate moment, plastic moment,



sec. এর
উপর depends.

depend on proportional limit. cross sec-এ C & T এর value equal.

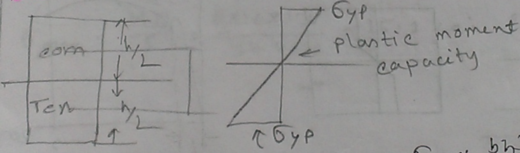
$$C = T = \left(\underbrace{\sigma_y}_{\text{stress}} \, \underbrace{b \frac{h}{2}}_{\text{area}}\right) = \text{max}^m \text{ force generated (fail)}$$

Total force

m_p = plastic moment.

Elastic moment capacity:

Q. What is the elastic moment capacity of a rectangular sec.



$$\sigma_{yp} = \frac{M_{yp} \times h/2}{I} \qquad M_{yp} = \sigma_{yp} \times \frac{bh^3 \times 2}{12 \times h} = \sigma_{yp} \times \frac{bh^2}{6}$$

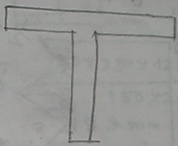
Residual stress → without exceeding Top fiber & bottom fibre.

$$\frac{M_p}{M_{yp}} = 1.5 = \frac{6}{4}$$

Elastic limit থেকে 50% বাড়লে ভেঙে যায়।

* Shape factor of a rectangular beam is $\boxed{1.5}$

What is the shape factor of T beam?

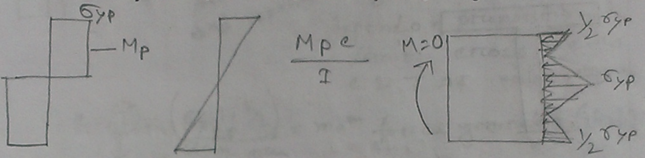


01.03.2013

load নাই moment = 0

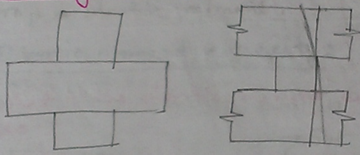
* Moment 0 হয়ে গেলেও internal stress থেকে যাবে,

* আবার সময় 100% hooks law follow করে।



$\frac{M_p c}{I}$

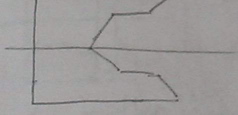
Bending stress of composite beam:



Strain linear হবে-

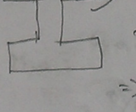
Timber এর ε_E অনেক কম.

steel এ বেশি



Stress diagram.

কাঠকে steel

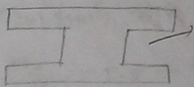


depth কমানো হল।

$n = \frac{E_s}{E_w} = \frac{E_1}{E_2}$ ratio

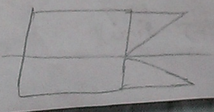
$\Rightarrow n_1 = \frac{E_2}{E_1}$

steel কে কাঠ:



depth কমানো হল

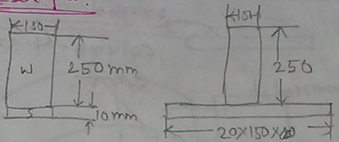
wight কমানোর জন্য না।



Modular ratio

= ratio of ε_E of two materials.

Example:



$$n = \frac{E_s}{E_w} = \frac{200}{10} = 20.$$

$$\bar{y} = \frac{150\times250\times125 + (20\times150\times10\times255)}{150\times250 + 20\times150\times10}$$

$= 183\ mm$

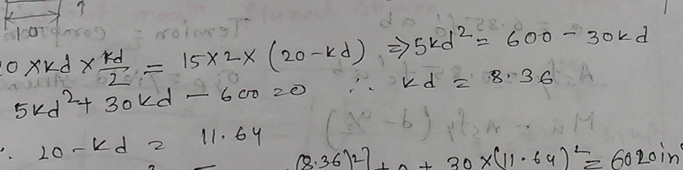
$$I = \frac{150\times250^3}{12} + \left[150\times250\times(183-125)^2\right] + \frac{20\times150\times10^3}{12} + \left[20\times150\times10\times(255-183)^2\right]$$

$= 4\cancel{7}8\times10^6\ mm^4$

$$(\sigma_w)_{max} = \frac{Mc}{I} = \frac{30\times10^6\times183}{478\times10^6} = 11.5\ Mpa$$

$$(\sigma_s)_{max} = n\sigma_w = \cancel{20\times183} = \frac{20\times30\times10^6\times77}{486\times10^6} = 96.7\ Mpa.$$

Example:



$$10\times kd\times\frac{kd}{2} = 15\times2\times(20-kd) \Rightarrow 5kd^2 = 600-30kd$$

$\Rightarrow 5kd^2 + 30kd - 600 = 0 \quad \therefore kd = 8.36$

$\therefore 20 - kd = 11.64$

$$I = \frac{10\times8.36^3}{12} + \left[10\times8.36\times\left(\frac{8.36}{2}\right)^2\right] + 0 + 30\times(11.64)^2 = 6020\ in^4$$

$$(\sigma_c)_{max} = \frac{50,000\times12\times8.36}{6020} = 833\ psi$$

$$\sigma_s = 15\times\frac{50,000\times12\times11.64}{6020} = 17400\ psi$$

$\overline{10} = 20.$

2

$$(\sigma_w)_{max} = \frac{Mc}{I}$$

$$= \frac{30 \times 10^6 \times 183}{478 \times 10^6}$$

$$= 11.5 \text{ Mpa}$$

$(55-183)^2$

$$(\sigma_s)_{max} = n\sigma_w$$

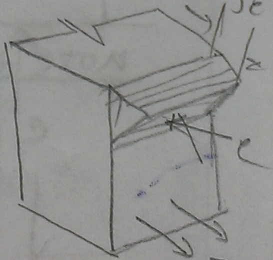
$$= \cancel{20 \times 1185}$$

$$= \frac{20 \times 30 \times 10^6 \times 77}{486 \times 10^6}$$

$$= 96.7 \text{ Mpa.}$$

$\leftarrow 10 \rightarrow$

d



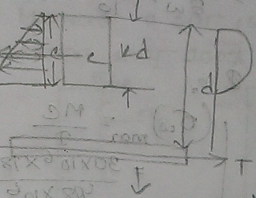
15×2

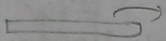
$\Rightarrow 5kd^2 = 600 - 30kd$

$kd = 8.36$

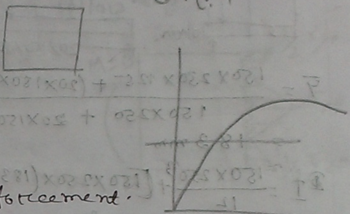
02.03.2019

Example:





column-এ tension হবে।



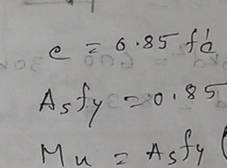
Modular ratio

* jd ⇒ depth of reinforcement.

Ultimate moment capacity:

Linear → depth of n.A = kd

Non Linear → " " " = c



$a = k_1 c$

original c depth-এ ratio fraction হবে।

$c = 0.85 f_c' ab$

Tension = compression

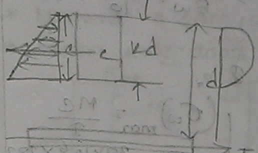
$A_s f_y = 0.85 f_c' ab$

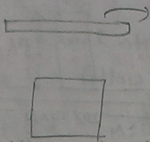
σ_{yp} = Yield stress.

$M_u = A_s f_y (d - a/2)$

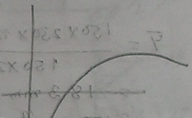
02.03.2019

Example:





column-এ torsion থাকে।



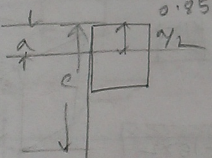
Modular ratio

* jd ⇒ depth of reinforcement.

Ultimate moment capacity:

linear → depth of n.A = kd

Non linear → " " " = c



$a = k_1 c$

original c depth-এ 1ter fraction থাকে।

$C = 0.85 f'_c ab$

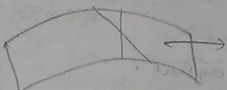
Tension = compression

$A_s f_y = 0.85 f_c' ab$

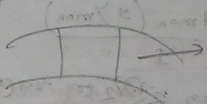
σ_{yp} = yield strain.

$M_u = A_s f_y (d - a/2)$

Curved bars:



deformation linearly vary করে।



original depth is not equal strain doesn't proportional.

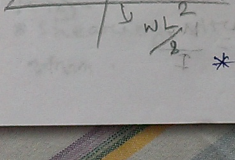
Straight beam — deformation linear stress-strain linear.

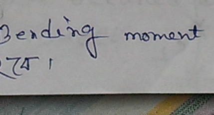
Curved beam: deformation linear stress strain non linear.

$$\boxed{\text{proved} \quad \sigma = \frac{My}{Ae(R-y)}} \rightarrow \text{প্রমাণ করতে হবে।}$$

* এদের Math আসবে দেখতে হবে।

Find out max^m flexural stress.





$$\sigma = \frac{My}{I}$$

$$I = \frac{bh^3}{12} - \frac{b_1 h_1^3}{12}$$

* Bending moment diagram আঁকতে হবে।

$$\frac{wL^2}{8} = \frac{10 \times 20^2}{8} = 25\ kNm$$

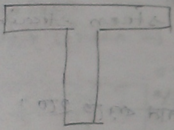
$$\sigma = \frac{M_{max}\, y_{max}}{I}$$

* I sec → y_{max} 2 side → equal.

± sign দিতে হবে। $\sigma = \frac{M_{max}(\pm y_{max})}{I}$

* Tensile & compressive stress দুইটিই বের করতে হবে।

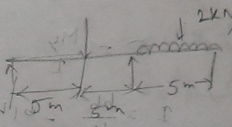
± = (−) top
(+) bottom.

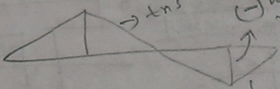


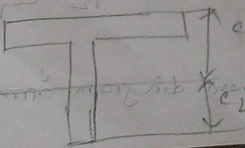
Nutral axis unsymmetric হলে tension or compression indicate করে দিতে হবে।

$$\sigma_{com} = \frac{Mc_1}{y} \quad \& \quad \sigma_{ten} = \frac{Mc_2}{I}$$

Example-2







$$\sigma = \frac{My}{I}$$

$$\frac{wL^2}{8} = \frac{10 \times 20^2}{8} = 25\ \text{kNm}$$

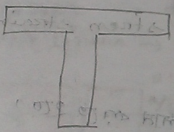
$$\sigma = \frac{M_{max}\, y_{max}}{I}$$

* I sec-এ y_{max} 2 side-এ equal.

± sign দিতে হবে। $\sigma = \frac{M_{max}(\pm y_{max})}{I}$

* Tensile & compressive stress দুইটি বের করতে হবে।

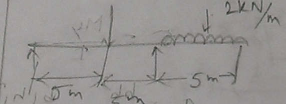
$\pm$ = (−) top
(+) bottom

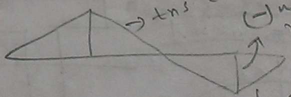


Nutral axis unsymmetric হলে tension or compression indicate করে দিতে হবে।

$\sigma_{com} = \frac{Mc_1}{y}$ & $\sigma_{ten} = \frac{Mc_2}{I}$

Example-2

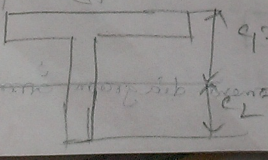




→ tns তাকি

(−)ve moment

↳ compression তাকি



$$\sigma = \frac{My}{I}$$

distance গুলো multiple হতে হবে।

30×210
25×390

4 stress বের করতে হবে।

σ_{top}, σ_{bottom} at + 30 kN/m

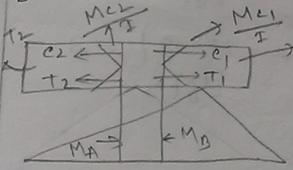
σ_{top}, σ_{bottom} at −25 kN.

Chapter-7

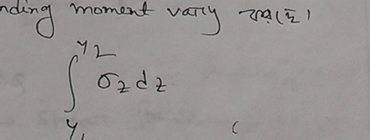
Shearing stress: (flexural shear)

all shear flexural এর সাথে associated হয়

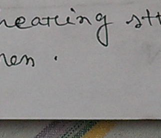
Direct shear stress.



$C_1 = T_1$ $\frac{dM}{dx} = V$



Bending moment vary করছে।

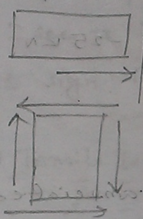


$$\int_{y_1}^{y_2} \sigma_z \, dz$$

* Shearing stress is occurred due to fluxural stress.

$F_A \neq F_B \rightarrow$ But can be calculated by integration

$c_1 - c_2 = 20 \Rightarrow$ difference of flexural stress.



Shearing stress does not exist along horizontal.

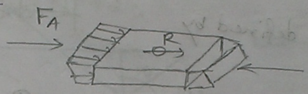
$$\tau_{xy} = \tau_{yx}$$

Example - 8.6

Consider a rectangular beam of two materials bonded together as shown in fig 8.14 (a). The upper 150

Shear flow:

8.03.14



$$\sigma = -\frac{My}{I}$$

$$I_A = \int_{Afghj} \sigma_L \, dA = -\int_{Afghj} \frac{M_A \cdot y}{I} \, dA$$

$$F_B = \int_{Afghj} \sigma_R \, dA = -\int_{Afghj} \frac{M_B \, y}{I} \, dA$$

$$= -\frac{M_B}{I} Q$$

$\int y \, dA = Q$ → Moment of area

$$F_B - F_A = df = -\frac{(M_B - M_A)}{I} \cdot Q$$

$$= -\frac{dM}{dx} Q$$

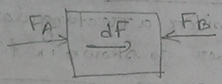
→ Shear force

Shear flow: resembles flow of water

$$q = \frac{VQ}{I}$$

$$\tau_{yx} = \frac{q}{t} = \frac{VQ}{It}$$

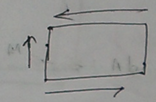
x এর দিকে



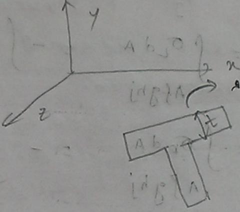
horizontal plane

$\longleftarrow dx \longrightarrow$

A plane is defined by normal

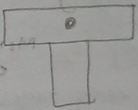


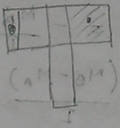
প্রত্যেক ক্ষেত্রে $\tau_{xy} = \tau_{yx}$

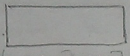


পার্শ্বতলের

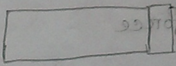
Example:

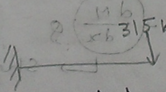






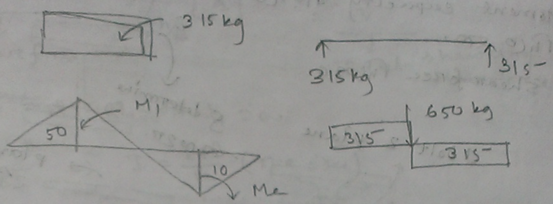
সাধারণ আকার
আকার beam.





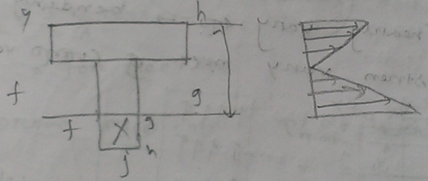
cantilever beam shear force শূন্য থাকলে ক্ষেত্রে সবই constant.

Two cases possible:



beam এর loading diagram → popov থেকে

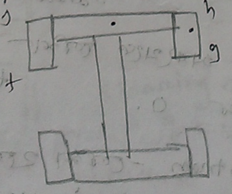
$F_A - F_B$ ৪ সমান হলে কাটা নিতে হবেনা



Nutral axis এর যেকোন এক side এ নিতে হবে।

unit → careful $q \rightarrow kg/cm^2$

$\boxed{4.13}$



From symmetry

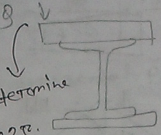
leg screw spacing
আগে shear force diagram

q কমে গেলে spacing বাড়বে

09.03.2014

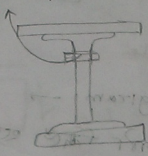
Moment capacity বাড়ানোর জন্যে নিচে plate জুড়ে দিতে হবে,

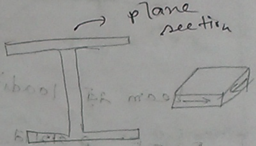
Shear force নিচ্ছে।



Q determine করছে।

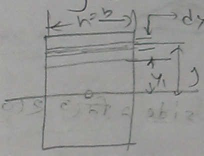
1 bolt 2 plane

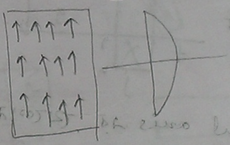




Example: linearly vary করে → bending stress.

Shearing stress vary করে Q কেমন vary করে।





$$\tau_{xy} = \tau_{yx} = \frac{VQ}{It}\int_{area} y\,dA = \frac{V}{Ib}\int$$

$y_1 = 0$ হলে সর্বোচ্চ বেশি

$y_1 = h/2$ হলে 0.

top fiber or bottom fiber → shearing stress 0.

Shearing stress বেশি হবে neutral axis.

" eqⁿ is the eqⁿ of parabola

ভাবলে stress এর dia হবে parabolic shape

$$\int_A \tau_{xy}\, dA = \frac{V}{2I}\int_{-h/2}^{h/2} \left[\frac{h}{2}\right]^2 = V$$

↓ shear force

↓ Total shearing ~~stress~~ force

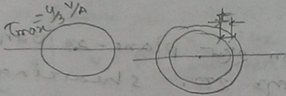
τ_{xy} max হবে যখন $y_1 = 0$.

$\frac{Vh^2}{8I} \Rightarrow I = \frac{bh^3}{12}$ (rec. sec)

$\tau_{max} = \frac{3V}{2A}$ | $1.5\, V/A$, Average shearing stress হবে বেশি

Assignment:

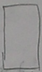
$\tau_{max} = \frac{4}{3} V/A$



$\tau_{max} = 2\frac{V}{A}$

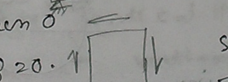
$\tau_{max} = \frac{3}{2} V/A$

= for rec. sec

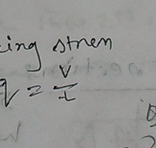


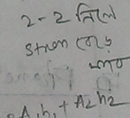
* prove করতে হবে $\tau_{max} = \frac{4}{3} V/A$ and, $\tau_{max} = \frac{2V}{A}$

Example:

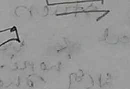


1.25cm

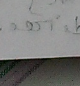




$\tau = \frac{VQ}{It}$, $Q \to 0$



top fb-র stress 0 হবে কারণ $Q = 0$.



Shearing stress -র $q = \frac{V}{I}$

$\tau_{max} \Rightarrow$ N.A তে

$Q = A_1 h_1$

2-2 নিচের stress বের করতে

$Q = A_1 h_1 + A_2 h_2$

2 টা Area

$$\underbrace{\int_A \tau_{xy}\, dA}_{\text{Shear force}} = \frac{V}{2I}\int_{-h/2}^{h/2}\left[\frac{h}{2}\right]^2 = \underbrace{V.}_{\text{Total shearing force}}$$

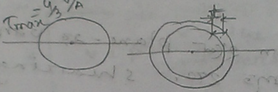
~~stress~~

τ_{xy} max হবে যখন $y_1 = 0$.

$\frac{Vh^2}{8I} \Rightarrow I = \frac{bh^3}{12}$ (rec. sec)

$\tau_{max} = \frac{3V}{2A}$ | $1.5\frac{V}{A}$, Average shearing stress এর দেড়া

Assignment:



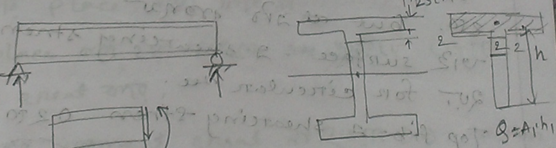
$\tau_{max} = \frac{4}{3}V/A$ $\qquad \tau_{max} = 2\frac{V}{A}$

$\tau_{max} = \frac{3}{2}\frac{V}{A}$

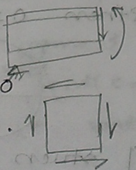
for rec. sec 

* prove করে হবে $\tau_{max} = \frac{4}{3}\frac{V}{A}$ and, $\tau_{max} = \frac{2V}{A}$

Example:



$\tau = \frac{VQ}{It} \rightarrow 0$



$Q = A_1 h_1$

2-2 নিলে stress বের করতে

top fib-এ stress 0 হবে কারণ $Q = 0$.

Shearing stress -এ $q = \frac{V}{I}$

$Q = A_1h_1 + A_2h_2$

দুটো Area

$\tau_{max} \Rightarrow$ N.A -তে

$$\underbrace{\int_A \tau_{xy}\, dA}_{\text{Shear force}} = \frac{V}{2I}\int_{-h/2}^{h/2}\left[\frac{h}{2}\right]^2 = \underbrace{V.}_{\text{Total shearing force}}$$

Total shearing ~~stress~~ force

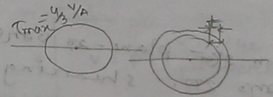
τ_{xy} max হবে যখন $y_1 = 0$.

$\frac{Vh^2}{8I} \Rightarrow I = \frac{bh^3}{12}$ (rec. sec)

$\tau_{max} = \frac{3V}{2A}$ | $1.5\ V/A$, Average shearing stress থেকে বেশি

Assignment:

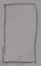
$\tau_{max} = 4/3\ V/A$



$\tau_{max} = 2\frac{V}{A}$

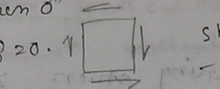
$\tau_{max} = \frac{3}{2} V/A$

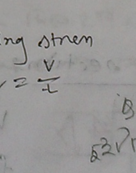
for rec. sec

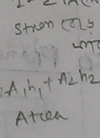


* prove করতে হবে $\tau_{max} = 4/3\ V/A$ and, $\tau_{max} = \frac{2V}{A}$

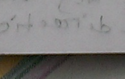
Example:







$\tau = \frac{VQ}{It}$, $Q \to 0$



$Q = A_1 h_1$

top fib-এ stress 0 হবে কারণ $Q = 0$.

2-2 নিলে stress বের হবে

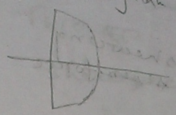
Shearing stress -এ $q = \frac{V}{I}$

$\tau_{max} \Rightarrow$ N.A. এ

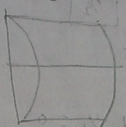
$Q = A_1h_1 + A_2h_2$

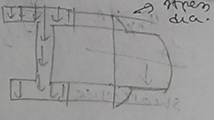
দুটো Area

q diagram

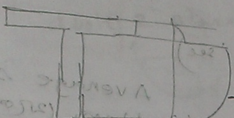


τ diagram





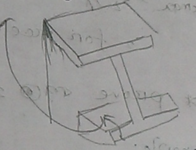
Shearing stress downward



→ shearing stress diagram

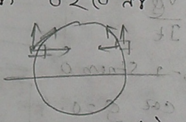
Limitations:

(i) Plane section হলে plane-এর উপরে shearing stress থাকতে হবে। shearing stress alone থাকতে পারে না।

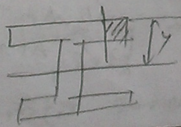


(ii) spherical হলে opposite surface line-এ থাকতে হবে, but এটা হয় না কারণ তাই surface-এ shearing stress inclined হবে। for circular sec.

Top fib-এ shearing stress 0 হবে না।

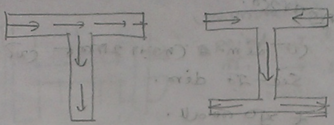


Plane section:



Shearing stress 2 direction horizontal & vertical.

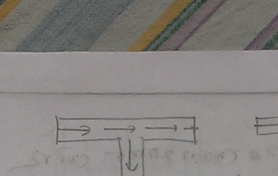
flange-এ হয় hori. shearing stress opposite direction.



Q = Shear flow → per unit section এর মধ্যে shearing stress প্রবাহিত flow-এর মত মনে হয় তাই Q কে shearing flow বলা হয়।

Vertical load দিলে
~~vertical~~, horizontal load তৈরি হয়ে থাকে।

channel section হলে,



V is the summation of all vertical load.
V ও P balance করছে.
Σ horizon force = 0

* horizontal force equal but moment create করছে তাহলে vertical force-কে section-এর কোথায় place করা হবে তা।

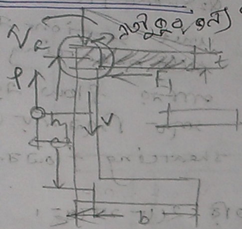
যদি place করা হয় তাহলে sec ঘুরিয়ে ফেলবে torsion create করবে.

* twisting moment create না হওয়ার জন্য section এর কোথায় vertical force দিতে হবে, সেই pt কে ~~vertical~~ shear center বলা হয়।

* tortion এর ~~co~~ কারণে

Shear centre:

এখানে ঘুরবে।



যে dim- দেওয়া থাকবে সেটা হবে see- এর dim.

t খুব small.

$$q = \frac{VQ}{I} = \frac{V(b \times t)\,h/2}{I}$$

$$= \frac{Vbth}{2I}$$

$$\tau = \frac{Vbh}{2I}$$ [τ হলে t দিয়ে ভাগ দিতে হবে]

$$F_1 = \frac{1}{2} q_a \cdot b = \frac{Vb^2th}{4I}$$

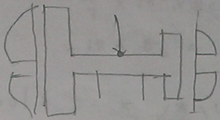
$$F_1 = \frac{1}{2} \times \tau_a \cdot (b \times t)$$ → shearing stress হয় যেখানে।

$$\text{Moment} = F_1 \times h = \frac{Vb^2th^2}{4I}$$

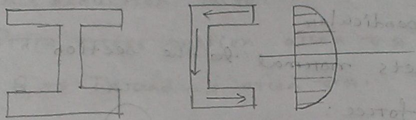
$$P \cdot e = F_1 h$$

$$e = \frac{F_1 \cdot h}{P} \quad P = V.$$

10.03.2014



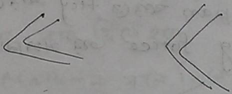
Unsymmetric beam হলে কোন point-এ load দিলে তা ঘুরবে না → Shear centre.



$V_2 - h = P.e$

$I = I_1 + I_2$

$\boxed{\frac{h I_2}{I}}$



$$e = \frac{h I_2}{I}$$

$$f = \frac{h I_1}{I} \qquad E.n_3$$

Parting section → canal section.

15.09.14

Thin pressure vessel:

দেওয়ালে tension

Riveted and Welded joints:

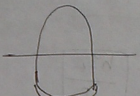
Pressure-এর সাথে tension-এর relation

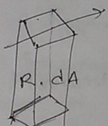
pressure perpendicular

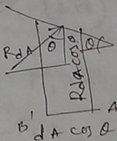
* Pressure acts normal to the section

* rupturing force:

যে force pass করছে try করছে bursting force এর সমান।







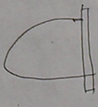
Force × projected area

Bursting force = R (pin) × Area enclosed of the Rupturing plane

Rupturing force = Area of the skin × stress.

Example: 1

bursting area = πr^2



circle এর উপর বাইরের force কাজ করে।

$\frac{\pi}{4} \times 20^2 \times 80$

→ যে bolt এর stress = σ

$F = \sigma \times A$

$BF = \frac{\pi}{4} \times 20^2 \times 80$

$= 18\lambda \; \sigma_b \cdot A = \pi/4 \times 20^2 \cdot 80$

$bolt = \frac{\pi}{4} \times \left(\frac{3}{4}\right)^2 \times R$

R = Reduction factor

* থাকলে cross section area কম

$R \rightarrow$ Thread-এ area কম।

Thread জন্য 20% / 25% use করতে হবে

* Thread এর জন্য বাদ দিতে হবে।

তা অবশ্যই Math-এ বলে দিতে হবে।

area বাড়তে → percentage বাদ যাবে কম।

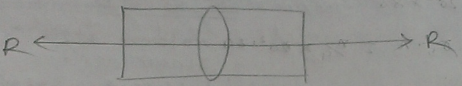
* $18000 + 6400 = $ Tension

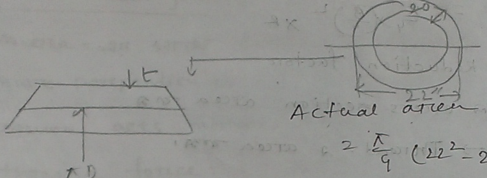
↑ আগে দেওয়া থাকবে pre tension [গ্যাস leak যাতে না হলে]

* Pre compressed না করলে gas বের হয়ে যাবে।

$\sigma = \frac{F}{A} = \frac{252000}{18} \times 0.3^2 = 4600$ psi

Normally stress আরো কম হবে কারণে force





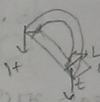
Actual area

$= \frac{\pi}{4}(22^2 - 20^2)$

$\approx \pi D' t$

$S = \frac{F}{A} = \frac{100\pi \times 80}{21\pi \times 1}$

Transverse direction -এ burst করে -



pressure intensity × area

= Rupturing force.

$H \quad BF = 2H = \sigma_h \cdot Lt$ [both sides]

$\Rightarrow 80 \times 20 \times 2 = 2\sigma_h \cdot L \cdot T$

$\Rightarrow \sigma_h = 800$ psi } transverse e বেশি- more than 2 times

$\sigma_1 = 381$ psi

বেলুনে gas ভরা হলে বেশি stress develop করে transverse direction.

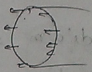
O_2 cylinder → Thin

CNG তে আরো cylinder লাগবে।

General formula for cylinderical section:

Rupturing plane in longitudinal direction

$BF = R \cdot \frac{\pi D^2}{4}$



$RF = \pi (D+t) \cdot L \cdot \sigma_l$

└→ inside dia

$= \frac{\pi R D^2}{4}$

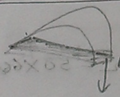
$\therefore \sigma_l = \frac{RD^2}{4(D+t) \cdot t}$ → longitudinal direction

$D >> t$.

$\therefore \sigma_l = \frac{RD}{4t} = \frac{80 \times 20}{4 \times 1} = 400$ psi

approximate.

Rupturing plane in transverse



$BF = RDL$

$RF = 2lt = 2\sigma_h L \cdot t$

$\Rightarrow 2\sigma_h Lt = RDL$

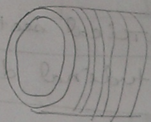
$\therefore \sigma_h = \frac{RD}{2t}$.

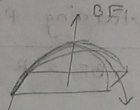
Example

Bursting force = Resisting force

16.03.2014

4-4





$H = \frac{A_s \cdot \sigma_h}{\text{area} \quad \text{stress}}$

Inside diam = 66 in

Hoops dia = 1 in

Pressure of water 50 psi

bursting force transverse direction.

$BF = R.D.L = 50 \times 66 \times 6 = $ lb.

$R.F = 2H = 2 \times \sigma_h \times A_h =$

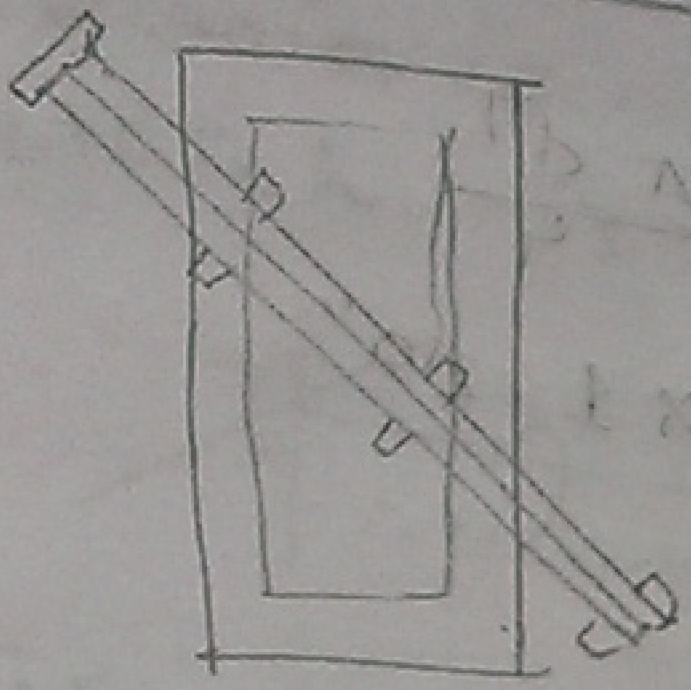
No thread, $= 0.785\ in^2$ [1 in of 5/4]

Threan $= 0.602\ in^2$

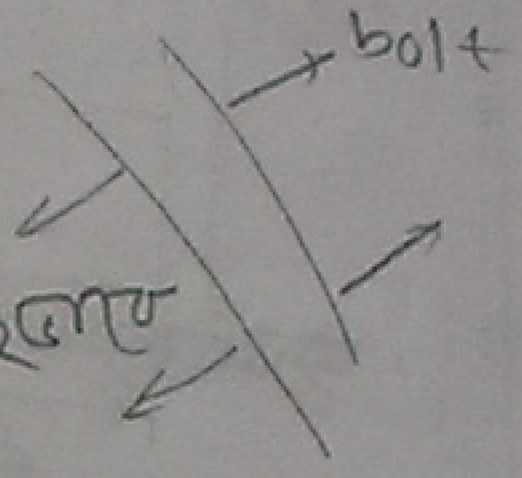
$\therefore$ considering thread $= 2 . \sigma_h \times A_h$

$= 2 \times \sigma_h \times 0.602 = 50 \times 66 \times 6$

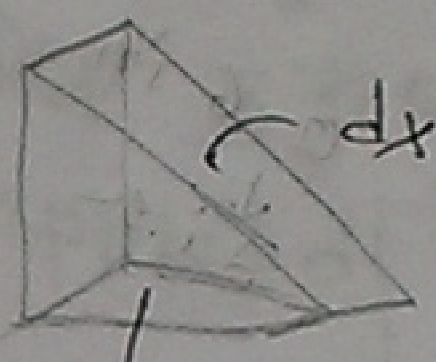
$\therefore \sigma_h = 16445$ psi



interior dimension
Area বললে = 20 square-in.
20 in = 20 × 20
Normally ENG → 300 + psi



* Area = 40 square in
Bursting force



$$BF = \underset{\text{pressure}}{210} \times (20 \times 20) \cos 45°$$

$$RF = A_b \cdot \sigma_b \times 10$$

$$A_b = (1.5)^2 \times 0.707 = 1.76$$

$$= 10 \times 1.76 \times \sigma_b$$

$$\therefore 10 \times 1.76 \times \sigma_b = \frac{210 \times 400 / 0.707}{10 \times 1.76}$$

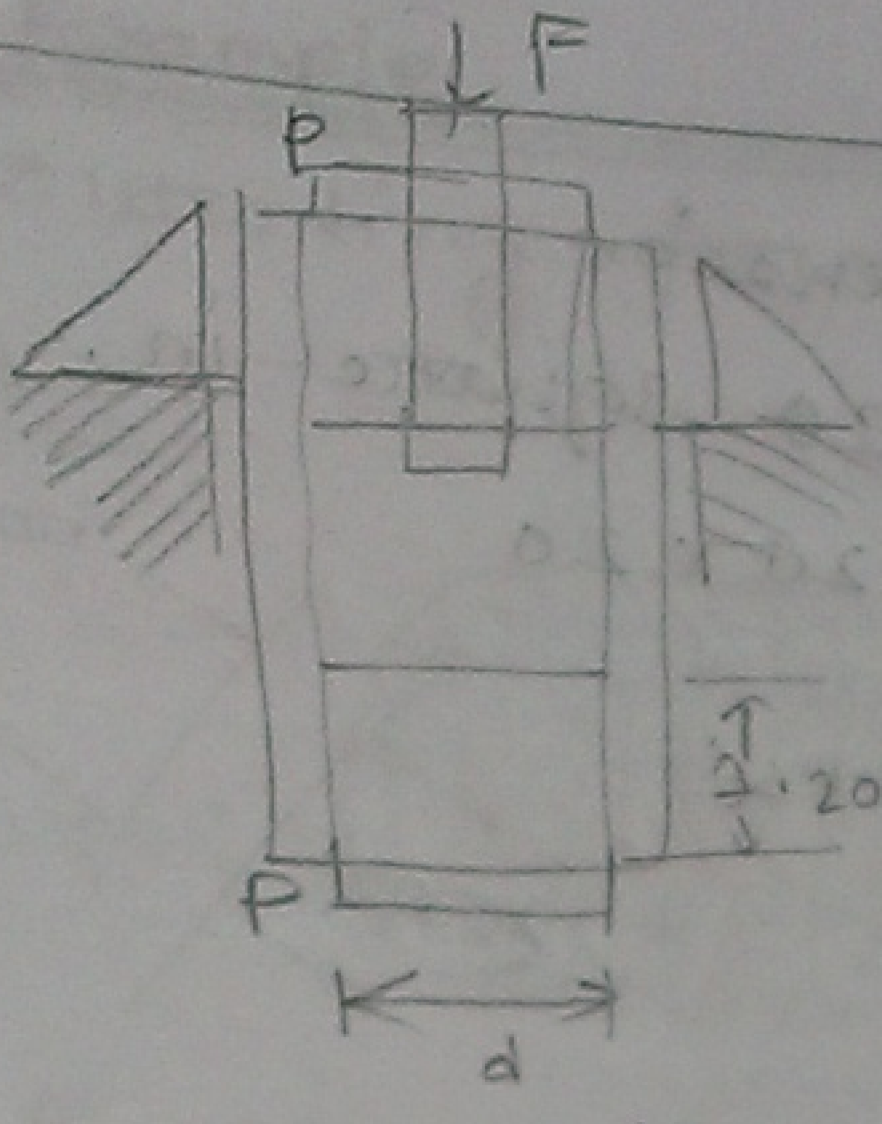
$$\therefore \sigma_b = 60\cancel{6}64 \text{ psi}$$

$$\text{factor of safety} = \frac{65000}{6064} = 11$$

For pressure container
f.F = 8, 10, 12

factor of safety অনেক বেশি-ই লাগে
bolt verticle দিলে rupture হয়।
bolt inclind → rupture.

4.7



Perimeter $= \frac{2\pi d^4}{4}$

Area $= \frac{\pi d^4}{4} \times 1.20"$

$R = \pi d t \cdot \tau$

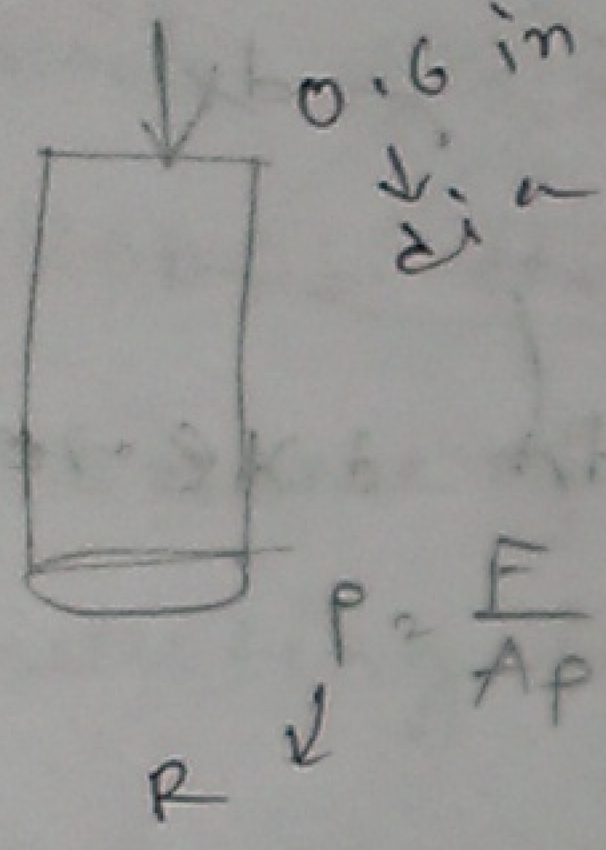
$F = R \times \frac{\pi D^2}{4}$

Pe shearing stress 1500psi

Find out R.

i) allowable plunger angle

F = pressure x area



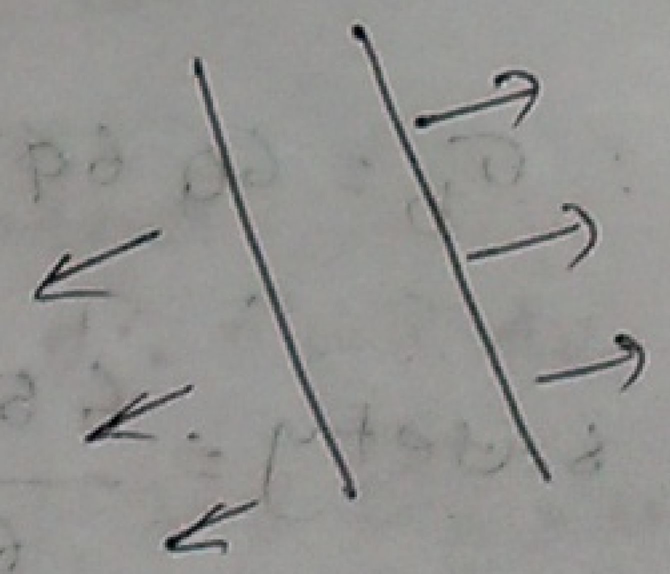
Andro bytle

Bolt

shearing stress হবে না। bolt vertically লাগাবে

shearing stress.

Rupture force



Brazing - welding

দুই প্রকারের brazing

inside dia 2"

0.6"

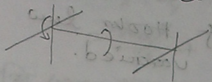
brazing এর কাজে তে

লাগে আছে।

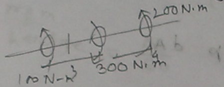
Torsion

22.03.2014

Torsoin is one kind of moment which is act on the axis.

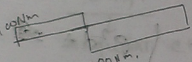


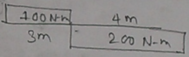
Torson এর জন্য twisting diagram আঁকতে হবে।

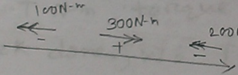


Machine ফিরে ঘুরানো - applied torque

1 motor - 3 machine - torson ভাগ হয়ে আছে।



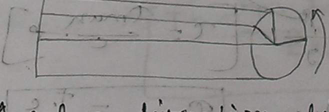




screw positive x axis এর দিকে গেলে (+) ve.

Basic assumption:

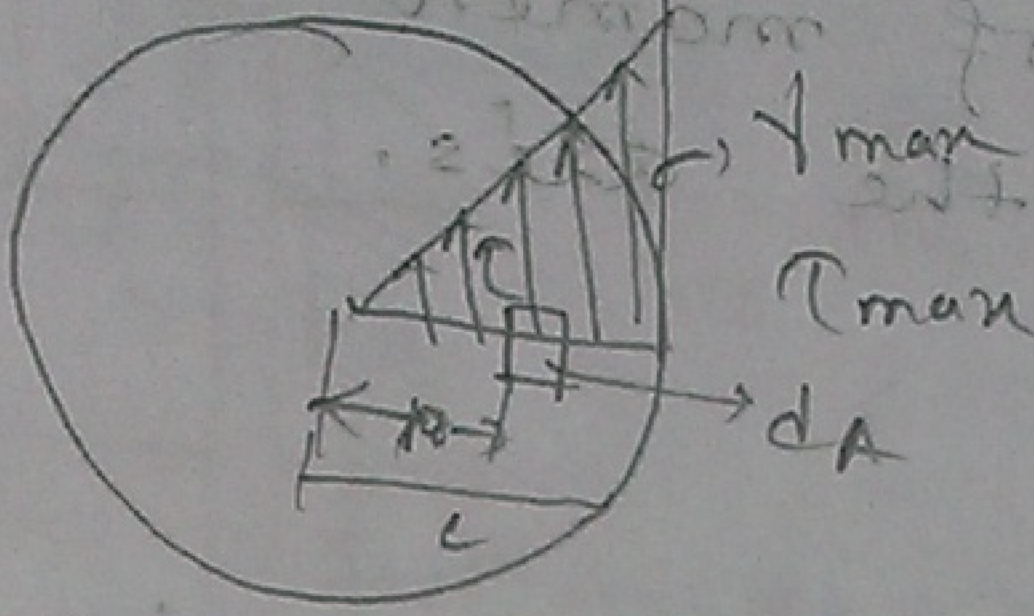
Physical movement outside-এ বেশি হবে।



Angular deflection linearly vary করবে।

Radial distance

plane sections remain plane.



$\tau_{max} = \tau_{max}$

if Hooke law varried.

Shearing stress $\tau \cdot dA \cdot \rho$

$$T = \int_A \tau\, dA \cdot \rho \; dA$$

$$\frac{\tau_{max}}{c} \cdot \rho \quad \Rightarrow T = \int_A \frac{\tau_{max}}{c} \cdot \rho \cdot \rho \, dA$$

$$= \frac{\tau_{max}}{c} \int \rho^2 dA$$

$\int \rho^2 dA = J$ polar

$$\therefore T = \frac{\tau_{max}}{c} J$$

$$\Rightarrow \tau_{max} = \frac{T \cdot c}{J}$$

ρ = radial distance

$$\tau = \frac{T \cdot \rho}{J} \qquad \left[\tau = \frac{\tau_{max}}{c} \cdot \rho\right]$$

max^m shearing stress, $\boxed{\tau_{max} = \frac{T \cdot c}{J}}$

$$\sigma_{max} = \frac{Mc}{I}$$

$$* \; \frac{\pi d^4}{32}$$

Polar moment of Inertia, $I_p = \frac{\pi d^4}{64}$

$J = I_p = I_x + I_y$

$= \frac{\pi d^4}{32} + \frac{\pi d^4}{32} = \pi$

বেশি স্পীড → torque কম

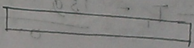
কম ন → বেশি

N – rpm

f – hertz $= \frac{N}{60}$

1 ঘুরে → 2π

f ঘুরে → $\underbrace{2\pi f}_{\text{Angular change}}$



যদি T Nm torque use করা হয়

Work done, $W = F \cdot S$

$= T \cdot 2\pi f = P$ (power) (Hp) (KW)

$Hp \times 746 = T \cdot 2\pi f$ N.m

$\Rightarrow \boxed{T = \frac{Hp \times 746}{2\pi f}}$

$= \frac{119\ Hp}{f}$

In KW $\Rightarrow T = \frac{159\ KW}{f}$

In FPS

$T = \frac{63000\ Hp}{N}$ in-lb $1\ Hp = 550$ ft-lb.

6-5

Select solid shaft. $P = 150$ kW

$\tau_{max} = 70$ MPa

$f_1 = 0.3$ Hz

$f_2 = 300$ Hz

Solve:

$$T_1 = \frac{159 \times 150}{0.3}\ N\text{-}m = 79,500\ N\text{-}m$$

$$T_2 = \frac{159 \times 150}{300}\ N\text{-}m = 79.5\ N\text{-}m.$$

$$\tau = \frac{Tc}{J} \Rightarrow \frac{T}{\tau} = \frac{J}{c} = \frac{\pi d^4}{32 \cdot d/2} = \frac{\pi d^3}{16}$$

$$\frac{\pi d^3}{16} = \frac{T}{\tau}$$

$$d^3 = \frac{16T}{\pi \tau}$$

$$d = \sqrt[3]{\frac{16T}{\pi \tau}}$$

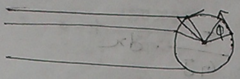
T এর value বসালে d_1 ও d_2 পাব

$d_1 = 180$ mm

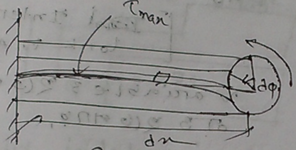
$d_2 = 18$ mm

যদি বেশি ওজন পুরাতন শক্তির shaft লাগে

23.03.2014



Perpendicular plane → shearing stress সমান
parallal to grain + to grain থেকে কম shearing stress দেখা



τ_{max} surface-এর উপর
centre-এ $\gamma_{max} = 0$.

$AA' = \gamma_{max} \cdot dx$

$AA' = c\, d\phi$ [centre থেকে মাপলে]

$c \cdot d\phi = \gamma_{max}\, dx$

$\frac{d\phi}{dx} = \frac{\gamma_{max}}{c}$ —— (1)

$\tau_{max} = G\gamma_{max}$

$\Rightarrow \gamma_{max} = \frac{\tau_{max}}{G}$

$\tau_{max} = \frac{T.c}{J}$, $\frac{1}{G}$

(1) $\Rightarrow \frac{d\phi}{dx} = \frac{\tau_{max}}{Gc}$

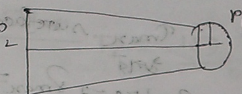
$= \frac{T \cdot c}{J \cdot G} \cdot \frac{1}{c} = \frac{T}{GJ}$

$$\int d\phi = \int \frac{T}{G.J} \cdot dx$$

$$\phi_{AB} = \int_A^B d\phi = \int \frac{T}{GJ} \cdot dx$$

$$= \frac{T}{GJ} \int dx$$

$$= \frac{Tx}{GJ}$$ [when T, G, J are constant]

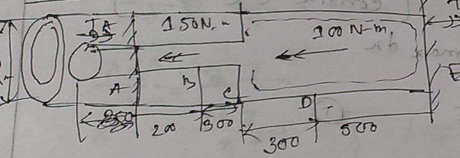


[Internal tork is A → B

variable ও হতে পারে

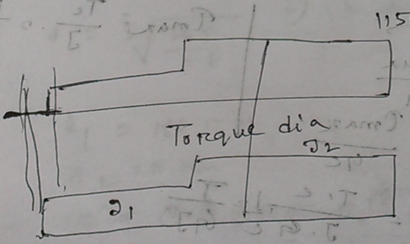
না ও হতে পারে,

Examples:



$$J_1 = \frac{\pi \cdot 25^4}{32}$$

$$J_2 = \frac{\pi (50^4 - 25^4)}{32}$$



$$\phi_{AE} = \phi_{AB} + \phi_{BC} + \phi_{CD} + \phi_{DE}$$

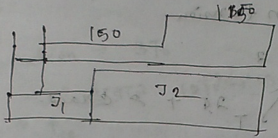
$$= 0 + \frac{150 \times 200}{G J_1} + \frac{150 \times 1000 \times 300}{G . J_2} + \frac{1150 \times 500}{G . J}$$

$$\phi = \frac{TL}{GJ}$$

$G = 80\,GMP$

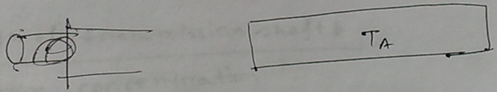
$= 80{,}000\ N/mm^2$

$$= 23.3 \times 10^{-3}\ rad$$



Statically indeterminante:

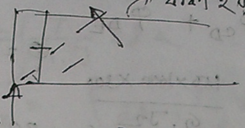
$$T_A + T_B = 150 + 1000$$



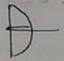
$$\phi'_{AB} = T_A \text{ (V)}$$

Bear & Johnstone

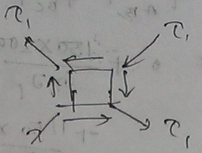
Warpage



এখানে হবে crack



$\frac{VQ}{It}$



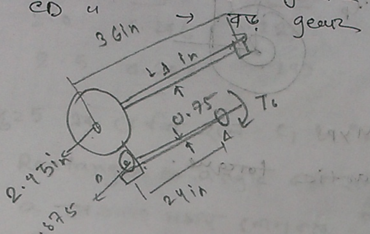
fail করে shear force -এর কারণে

concrete - weak in tension

corner - এ beam - এ

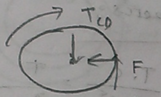
crack করে T হবে + ve crack.

Ex-1 AB shaft → ছোট gear
CD " → বড় gear



↳ Rotation → $3T_0$

45 -1° ঘুরলে ছোট → ৩ গুন বেশি কোণে ঘুরবে

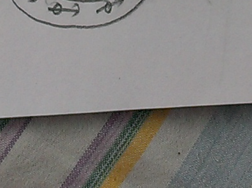


8000 psi হলে 561 lb দিলেই হবে

Design of transmission shaft:

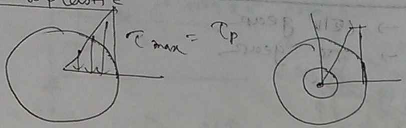
* Stress concentration

cross section area ~~adversely~~ change হলে
Stress বহুগুনে বেড়ে যাবে।



$N \cdot (F \cdot r) = T$

Elastoplastic



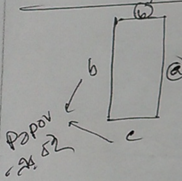
$M_p = 1.5\ M_{yp}$

$T_p = \frac{4}{3} T_y$ = plastic torque.

Residual stress:

Net moment 0 থাকবে;

* Torsion of Noncircular Members:



$$\tau = \frac{Tc}{J} = \frac{T.c}{\frac{\pi c^4}{2}} = \frac{T}{\frac{\pi}{2}.c^3} = \frac{T}{k.c^3}$$

$$\tau_{max} = \frac{T}{c_1 ab^2}$$

popov $\rightarrow \tau = \frac{T}{\alpha_1 bc^2}$ [square এর (2a) dimension]

$$\phi = \frac{TL}{c_2 ab^3 G}$$

popov $\rightarrow \phi = \frac{TL}{\beta\ bc^3 G}$

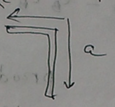
* small ~~influ~~ size → more influenced

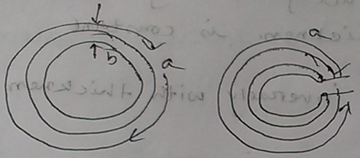
a/b	c_1	c_2
2.0	0.246	.229
2.5	0.258	.249.

$a/b = 5$. এর বেশি হলে c_1 & $c_2 = 0.333$

Rectangle কে angle করা হলেও capacity same

a কে ওয়াস সমান যোগ করে নিতে হবে।





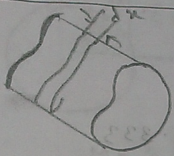
* compare the stiffinen of circular cube. with

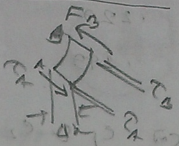
stiffnen $\Rightarrow k$. $\rightarrow$ unit length deformation এর জন্য যে force লাগে

Torque required to deform 1°.

$\phi = \frac{TL}{JG} \Rightarrow \frac{T}{\phi} = \frac{JG}{L}$

Thin walled Hollow shafts:



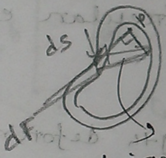


$$\tau_A t_A = \tau_B t_B = \tau t = q = \text{shear flow}$$

↓

product of shearing stress & thickness is constant

Shear stress varies inversely with thickness.



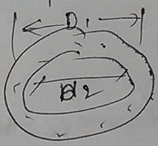
$\tau \cdot \cancel{ds} \cdot dF = q$ = shear flow

$\tau \cdot ds = q$

triangle-এর area

$= \frac{1}{2} \times ds \times p.$

$T = 2qA$ → মধ্যের area.

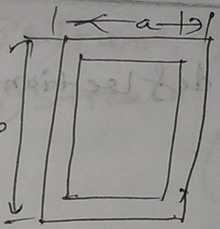


$$\pi\left[\frac{D_1^2 - D_2^2}{4}\right]$$

$$\tau = \frac{T}{2tA}$$

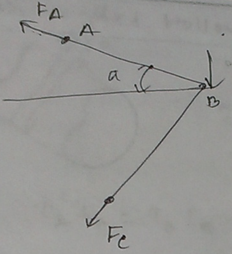
Angle

$$\phi = \frac{TL}{4A^2G} \cdot \oint \frac{ds}{t}$$

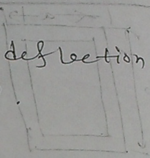


area $\Rightarrow ab$

Last class



B pt - এ deflection কত হবে?

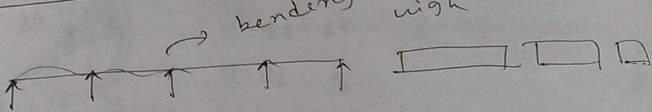


Thermal deflection

$\Delta = \alpha \cdot \Delta T \cdot L$

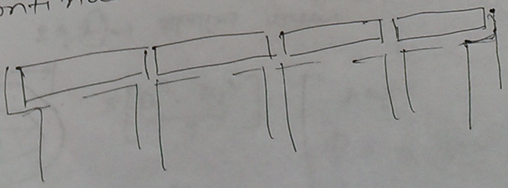
$\varepsilon = \alpha \cdot \Delta T$. * Strain এর জন্য length লাগবে না।

continuous beam



alluvial land →

continuous bridge করা হয় না।



(i) Stress, P/A

(ii) Strain $\varepsilon = \sigma/E$ $\quad \varepsilon_x = \frac{\sigma_x}{E} - \frac{\nu}{E}\sigma_y - \frac{\nu}{E}\sigma_z$

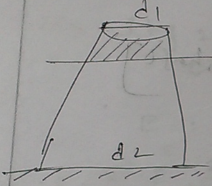
(Hooks Law)

$\downarrow$

σ_x, σ_y নাই.

$U = \int \cancel{\frac{\sigma_x}{AE}} \frac{P_{(x)}}{A\,E}\,dx = \int \frac{\sigma}{E}\,dx$ [if P & A is constant

$= \frac{PL}{AE}$; spacial case.



নিচে গেলে ওজন বাড়বে.

P variable, A variable,

E constant.

* Axial strain energy, $U = \int \frac{1}{2}\sigma_x \varepsilon_x\,dv$

$\frac{1}{2}$ = average $= \int \frac{\sigma_x^2}{2E}\,dv$.

* Temperature stain.

$\varepsilon = \alpha\,\Delta T$

deformation, $\Delta = \alpha\,\Delta T.L$

(iii) AF, BM & SF (cross sectional perpendicular

BM ⇒ Loading diagram.

$$\frac{dv}{dx} = M. \quad \frac{d\varphi}{dx} = V.$$

loading dia

(iv) Flextural stren, $\sigma = \frac{My}{I}$

(v) shearing $= \tau = \frac{VQ}{I}$

$$v = \frac{VQ}{I}$$

(vi) Torsoin $T \to \tau = \frac{Tc}{J}$ [circular shaft]

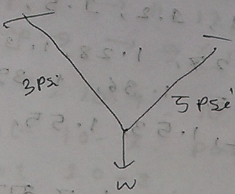
For rectangular.

$$\varphi = \frac{TL}{GJ}$$

$$\tau = \frac{T}{\alpha bc^2} = \frac{T}{\beta bc^3}$$

$$q = \frac{T}{2A}$$

$$\tau = \frac{q}{t} = \frac{T}{2At}$$



$\delta_{AB} = \dfrac{P_{AB} L_{AB}}{A E}$

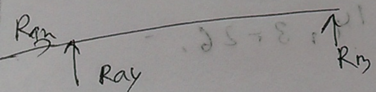
σ_{AB}.

Modulus of Elasticity of steel
— বা (নরম) থাকলে 200 GPa
29×10^{6} psi

$1\,kg = 9.81\,N$
$\simeq 10\,N$.

$E = 200$ GPA
$= \dfrac{200{,}000 \times 100}{10}\,N/mm^2$
$= 2 \times 10^{6}\,kg/cm^2$

Aluminium, $E_{al} = 70$ GPA
$E_{br} : 84$ GPA



Sttress – ~~[illegible]~~ Example – 1.1, 1.2, 1.5,
1.9, 1.10, 1.12, 1.21, 1.27, 1.28, 1.30, 1.32,
1.33, 1.34, 1.34, 1.35, 1.36, 1.39, 1.44,
1.47, 1.50, 1.51, 1.52, 1.53, 1.55, 1.57,
1.58,

1.55 ⇒ ACE two force member না
1-52 ⇒ DEF force ~~[illegible]~~ member না.

* 1.3.

page – 31.

Ex:– 1-5, 1.6.

P, –53,

Ex – 3.1, 3.2, 3.4, 3.3, 3.5, 3.7, 3.8

Art – 3.3 & 3.5 page – 104; fig 3.9.

Art – 5.6. Art –5.9.

page – 70 Ex – 2.1,

Art – 2.8 → fig 2.18 + fig 2-20.

Prob – 3.12, 3.13, 3.14, 3.26.

Ex 4.8.

Ex – 7.5, 7.6, 7.7, 7.8, 7.9, 7.11, 7.19
7.13, 7.15, 7.16, 7.17, 7.60, 7.6,

Ex – 8.4, 8.5, 8.12, 8.13, 8.11,

chap-8 ⟶ 11, 12, 13, 14, 15. ~~17~~, 18, 20, 21, 25, 26.

chap-9 ⟶ 9 (11, 12, 15)

10.2, 10.4 - 10.2, 10.2, 10.5,

Ant 10-7. page-~~93~~ 439.

Ant 10-8.

Ex-10.7,

ch-10 - 2, 3, 4, 6, 8, 9, 10, 13, 15, 18, 20, 21,
22, 23, 28, 29, 40, 41, 42.

Ex-6.1. 6.2, 6.4, 6.5, 6.6, 6.7, 6.9,
6.12,

Ant-6.3, 6.6, 6.14, 6.16,

4.5 Prob.

fig 4.9.