# MADE EASY

## Civil Engineering

### Toppers Handwritten Notes

### DESIGN OF STEEL STRUCTURES

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# Design of Steel Structure

GATE :- 2M — 1Q = 2M → 4M
2Q - 1M = 2M

ESE: (Pre) :- 10 - 15Q (20-30M)

(Mains) :- 60M

BARC, ISRO, DRDO } 10% Q Steel

[S.K Duggal]

IS 800:2007 [L.S.M]
800:1984 (WSM)
Steel Table

Syllabus

2] Design Philosphy (ESE)
→ WSM
→ Plastic Method of design
→ Limit State method of Design

3] Connection Design

Simple Connection
- Rivets
- Bolts
- Welding (GATE/ESE)

(GATE) Eccentric
- Type I
- Type II

4] Member Design (ESE)

- Tension Member
- GATE Compression Member
- GATE Flexural Member
  - → Beam → Base Plate
  - → Builtup Beam → Splices
  - only ESE { → ~~Beam~~ Gantry Girder
  - → Plate Girder

6] Industrial Roof (ESE)

→ Roof truss

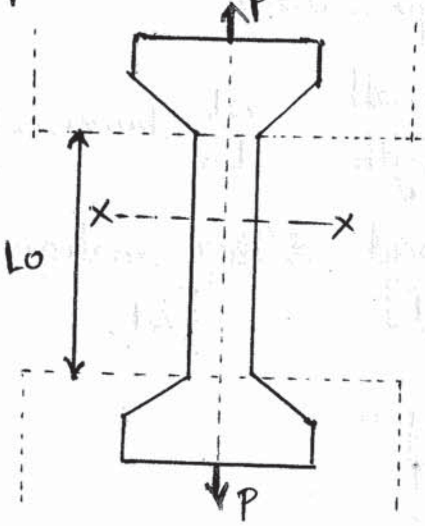
→ Purlin

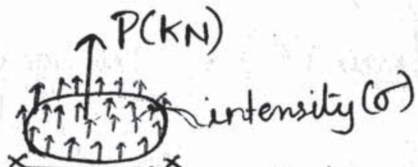
# Chapter 1: Plastic Analysis of Beams & Frame

## # Stress Strain Curve for Mild Steel

→ A tensile test is conducted on a Mild steel specimen (ie Coupon)

→ Specimen is tested in universal testing machine (U.T.M)



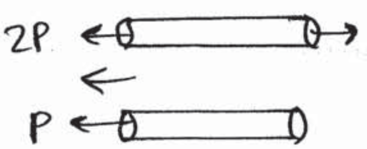

Circular Cross Section ($A_0$)

$A_0$ → Orignal Cross sectional area ($mm^2$)

P → Applied load (KN)

σ → Nominal Tensile stress

$\sigma = P/A_0$




$\Sigma F = 0$ {Rigid body Translation}

→ As material is assumed to be homogenous & Isotrophic, the ~~intensity~~ distribution of load on the cross section can be assumed to be equal

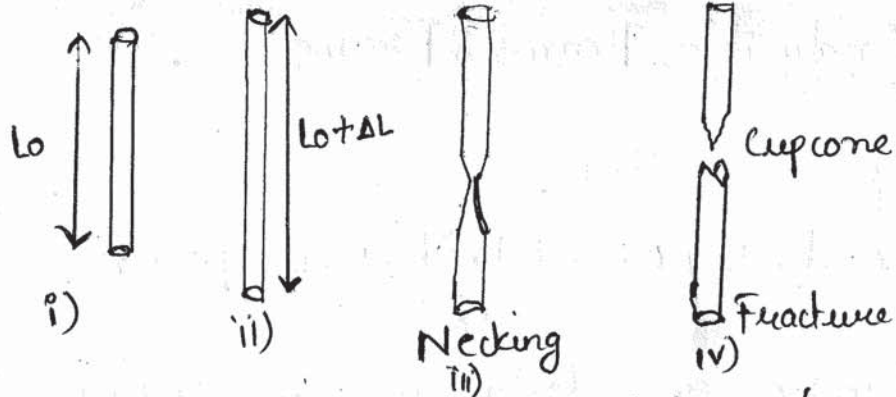
→ The intensity of load over cross-sectional is termed as stress

$$\left[\sigma = \frac{P}{A_0} \frac{(N)}{(mm^2)} \rightarrow \text{Unit } N/mm^2 \text{ or MPa}\right]$$

→ The length over which Specimen is tested is called as gauge length & it is given by

$$* \quad \boxed{L_0 = 5.65\sqrt{A_0}}$$

→ Specimen is subjected to gradually increasing tensile loading

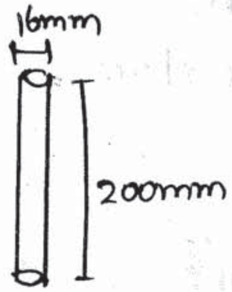



$\Delta L$ = Change in length (mm) / Extension / Deformation

→ <u>Normal tensile strain</u> ($\epsilon$) ⇒ $\frac{\text{Change in length}}{\text{Original length}} = \frac{\Delta L}{L_0}$ (Dimensionless)

→ Reading observed during testing → Load [P] & Deformation [ΔL]

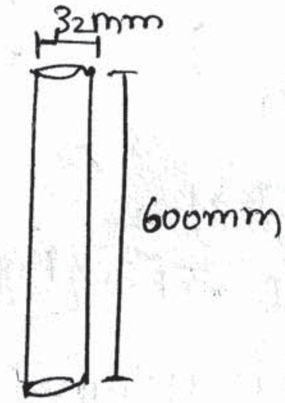
Always (Same) Stress Strain




$\Delta L = 10mm$
$P_U = 100kN$

$\sigma_U = \frac{P_U}{A_0} = \frac{100 \times 10^3}{\frac{\pi}{4} \times 16^2} = 497.36 \; N/m^2$

$\epsilon = \frac{\Delta L}{L} = \frac{10}{200} = 5 \times 10^{-2}$




$\sigma_U = \frac{P_U}{A_0} \therefore 497.36 = \frac{P_U}{\frac{\pi}{4} \times 32^2}$

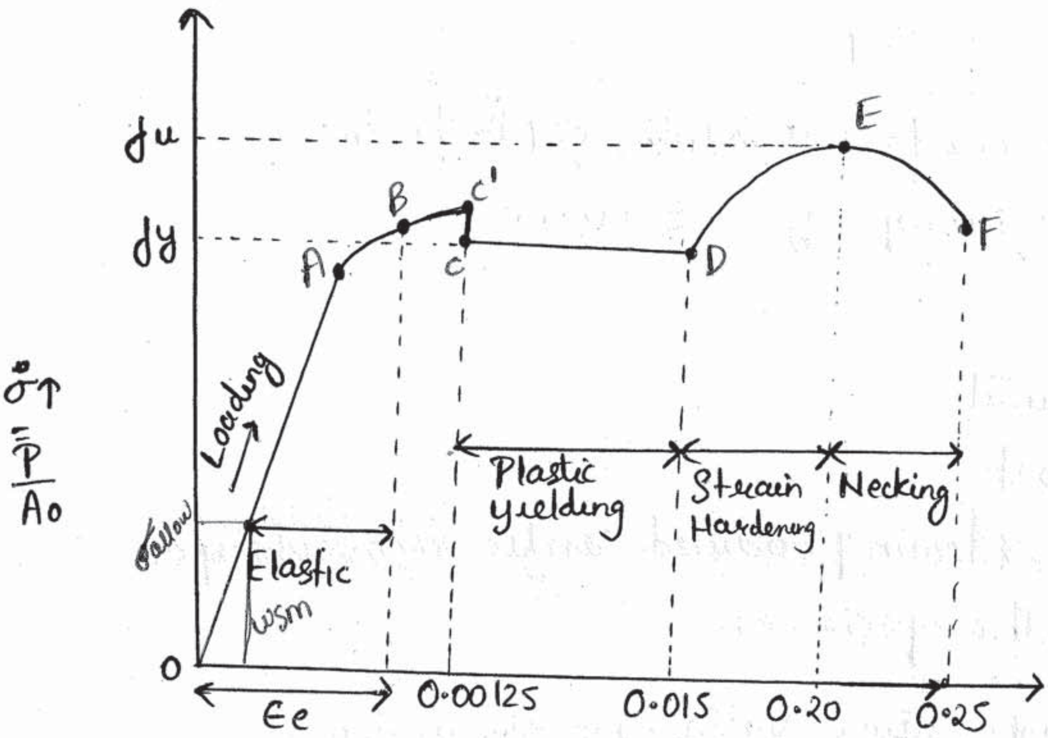
$P_U = \underline{400kN}$

$\epsilon = 5 \times 10^{-2} = \frac{\Delta L}{600}$

$\Delta L = 30mm$

→ P–Δ graph will be different for different size of specimen

→ Hence σ–ϵ curve is plotted for specimen {It will be same for a given material}




$$\frac{\Delta L}{L_o} = \epsilon \rightarrow$$

$f_y$ = yield strength (N/mm²)

$f_u$ = Ultimate tensile strength (N/mm²

| | (y) P | (x) ΔL |
|---|---|---|
| | 0 | 0 |
| i) | 10KN | 1mm |
| ii) | 20KN | 2mm |
| iii) | 30KN | 3mm |
| iv) | 38KN | 4mm |

$$\text{Slope} = \frac{dy}{dx} = \frac{y_2 - y_1}{x_2 - x_1}$$

$\frac{20-10}{2-1} = 10\,\text{KN/mm}$

$\frac{30-20}{3-2} = 10\,\text{KN/mm}$

$\frac{38-30}{4-3} = 8\,\text{KN/m}$

} ex. for graph

$$y = m \cdot x$$

$$\boxed{y \propto x}$$

⇒ <u>Imp Points</u> :-

1] Region OA
→ A is a proportional limit
→ Graph is linear (ie slope is constant)

→ $\sigma \propto \epsilon$ (Hook's law)

→ $\sigma = E \cdot \epsilon$ , $\frac{\sigma}{\epsilon} = E$

→ E = Elastic constant / Modulus of Elasticity

$E = \tan\theta$ → Slope of $\sigma$, $\epsilon$ Curve

2] Region AB

→ B → Elastic limit

→ Linearity is lost

→ upto point B, strain produced can be recovered upon unloading of the speciemen

→ Assume: Hook's law is Valid upto elastic limit

3] Region B - C' - C

→ C' = upper yield point {transient → short interval}

→ C = Lower yield point {Stable, designates yield strength of material}

→ It is a point below which material behaves elastically (or) Above which material behave plastically

4] C - D Region

→ Plastic yielding or yield Plateau

→ Material / specimen deforms to very large extent without resisting any stress

→ It is a limiting slope

→ Yielding Failure

5] Region D-E

→ Strain Hardening

→ Specimen re-crystallizes due to which it resist stresses along with its further extension

→ It occurs upto point E

→ E ⇒ Point of Ultimate strength

→ Till Date this part is not used in design

6] E-F Region

⇒ ~~Neglecting~~ ⇒

→ Necking : Reduction in cross sectional area

→ F ⇒ Breaking point / Fracture point

→ Fracture is also termed as Rupture

→ Shape : Cup & Cone failure

⇒ Mechanical property from σ & ε Curve

1) $f_y$ 3) E

2) $f_u$ 4) Ductility

⇒ Ductility :- Ability of material to undergo large deformation without breaking. It is measured in terms of % Elongation

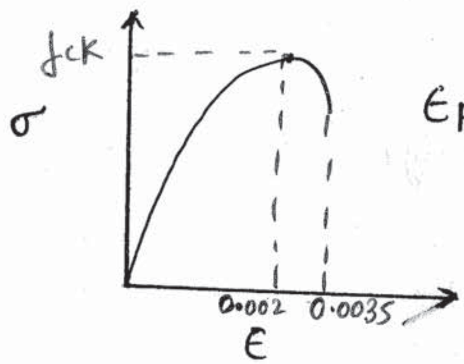
$$\% \text{ elongation} = \frac{\text{Final length} - \text{gauge length}}{\text{gauge length}} \times 100$$

| % Elongation | Material |
|---|---|
| > 15% | Ductile (Steel, Al) |
| 15 – 5% | Interm. Ductile (Mn) |
| < 5% | Brittle (concrete, cast iron) |

→ Hardness :- Resistance to Wear & Tear (ie Abrasion)

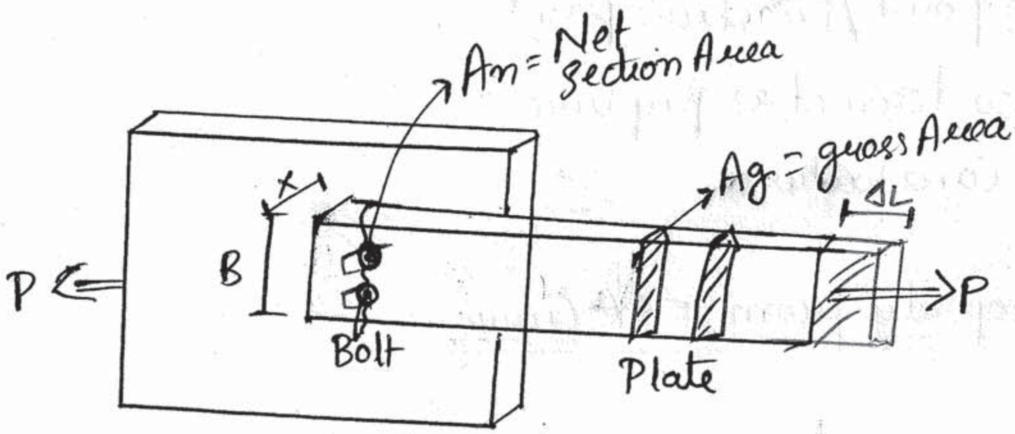
→ Toughness :- Resistance to impact loading

Concrete Compression test



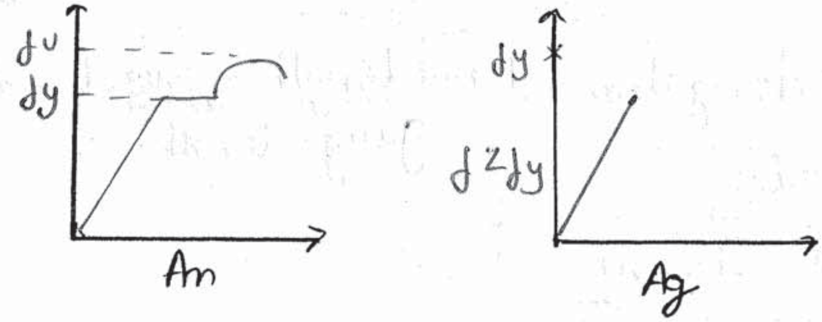

$\epsilon_F = 0.0035$ or $0.35\%$

⇒ Practical Case of Tension member




There are two type of limiting Stage

1) Gross Section yielding
2) Net - Section Rupture

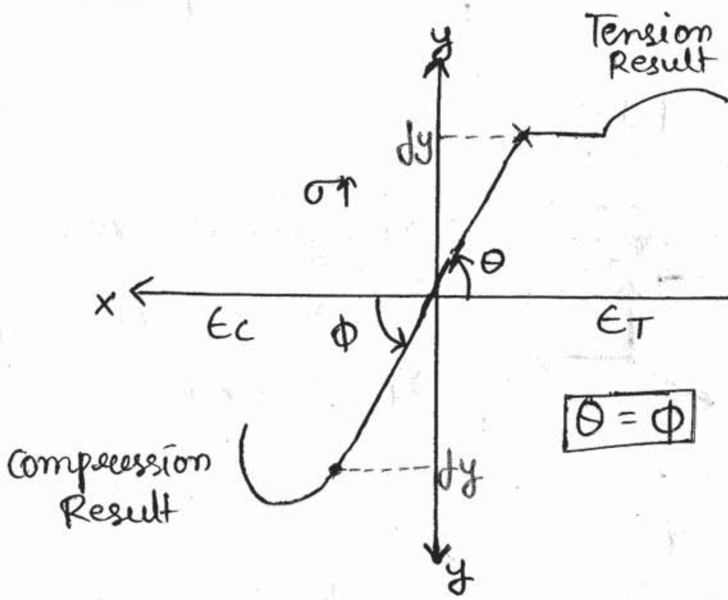



Note :

→ For design of tension member connected with Rivet/Bolts there are two types of limit State

1) Gross Section yielding 2) Net section Rupture

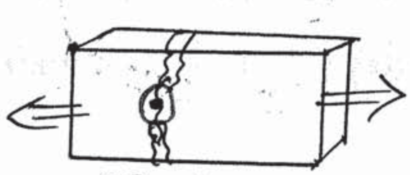
# Compressive σ - ε Curve for mild Steel



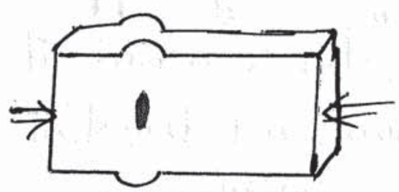

Compression test

→ Steel is equally strong in tension as well as in compression

→ Modulus of Elasticity in tension = Modulus of elasticity in compression



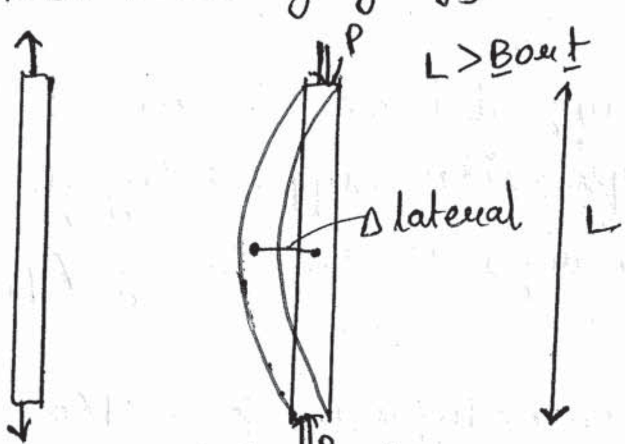
(Rupture)



(Yielding)

→ Type of limit stage for compression member

1) Gross section yielding ($f_y$)
2) Lateral buckling ($f < f_y$)

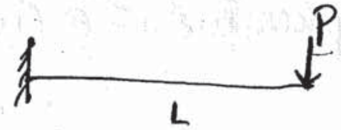


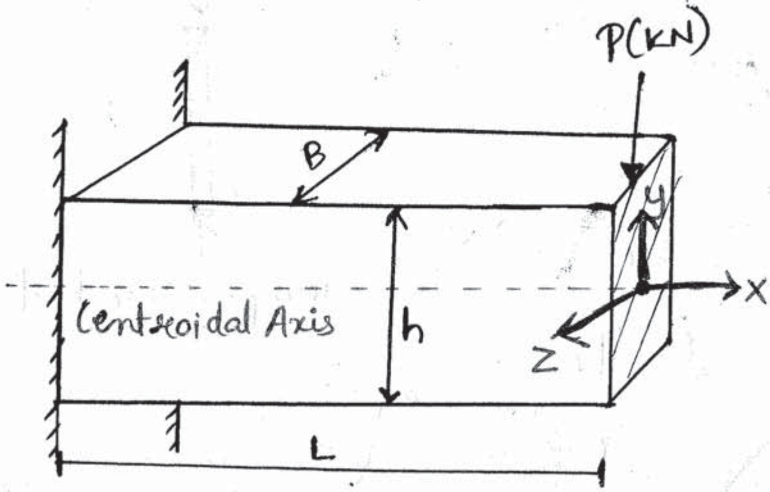

(Buckling)

Elastic buckling ($f < f_y$)

Inelastic buckling ($f > f_y$)

# Bending and shear Stress

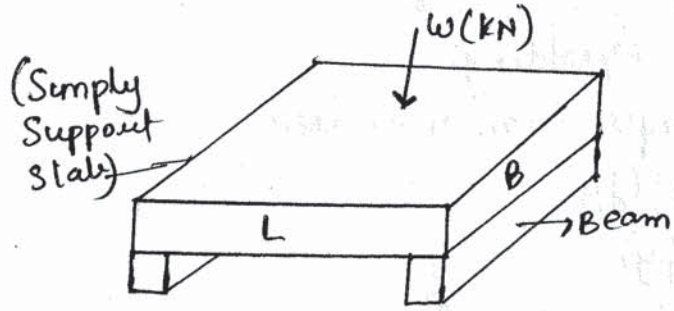



X → longitudinal Axis
y → Transverse Axis
Z → Lateral Axis

→ Flexural Member such as beam are subjected to transverse loading due to which internal Forces/Moment Produced are shear force & Bending moment

→ Load :- Beam generally support slab's or other beam over it, due to which it is subjected to loading in downward direction



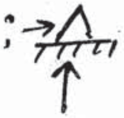

$$\frac{W(KN)}{B \times L(m^2)} = w$$

→ Reaction :- Beam are supported over Column or other Beam which provides support by generating Forces/Moment in opposite direction of Applied loading / Moment

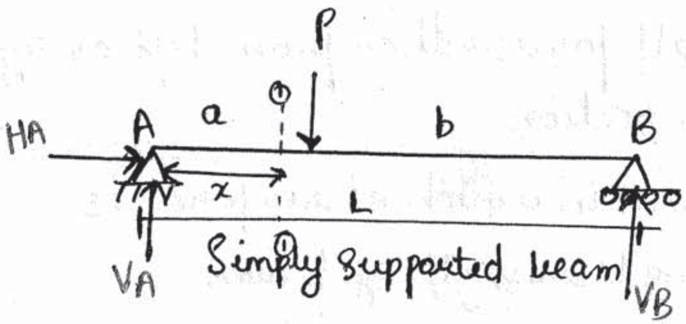
Note: Reactions are determine by using force Moment Equillibrium

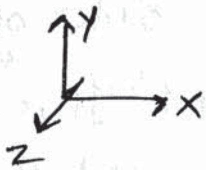
$$\{\Sigma F = 0 \;,\; \Sigma M = 0\}$$

→ Types of support :-

 Roller support ;  Hinge Support ;

 Fixed Support




$\Sigma F_x = 0 \longrightarrow HA = 0$

$\Sigma F_y = 0 \longrightarrow VA + VB = P$

$\Sigma M_B = 0$

Moment → Rotational effect of external Forces

$M = F \times \perp$lar distance upto point

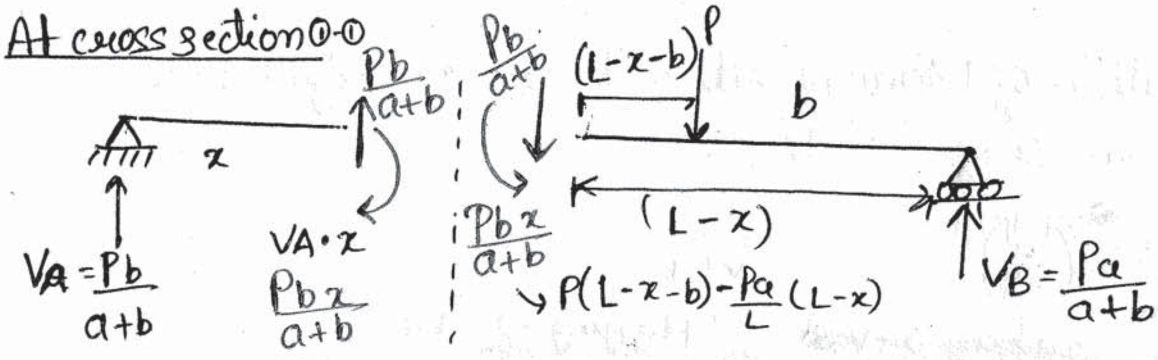
$+ VA \times L - P \times b = 0$

$$\boxed{VA = \frac{Pb}{L} = \frac{Pb}{a+b}}$$

Also, $VB =$ ~~P-PA~~ $P - VA = P - \frac{Pb}{a+b}$

$$\boxed{VB = \frac{Pa}{a+b}}$$

At cross section ①-①



→ At any cross section, let us take at a distance $x$ from support A $\{0 \leq x \leq a\}$

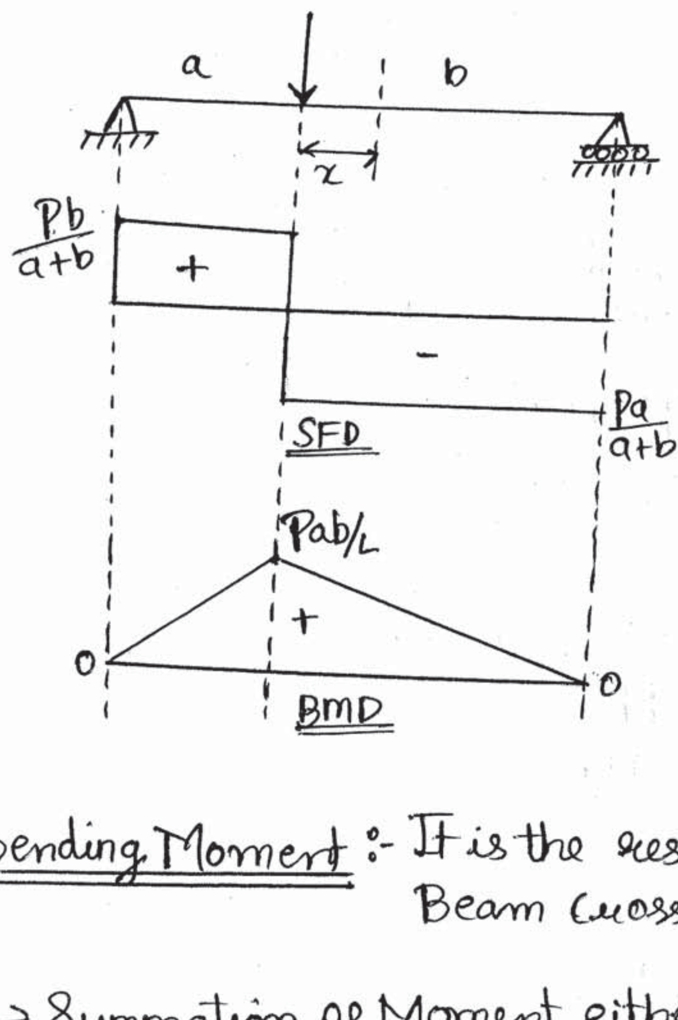
→ Resultant force in transverse direction $= \frac{Pb}{a+b}$

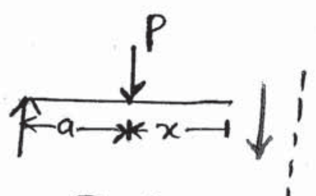
→ This is called as transverse shear force

Note:

<u>Shear force</u> :- Summation of all forces either from left or right sides of cross section

<u>Shear force dia</u> :- It is a diagram in which shear force is plotted along the length of beam



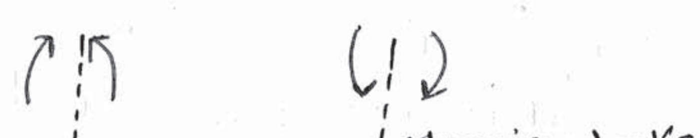




$P - V_A = V_B = \frac{Pa}{a+b}$

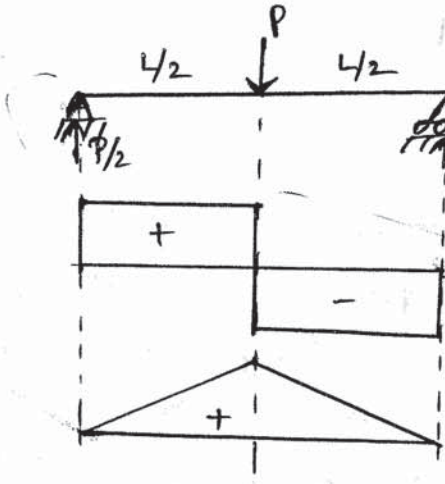
$[0 \leq x \leq b]$

<u>Bending Moment</u> :- It is the resultant Moment inside the Beam cross-section

→ Summation of Moment either to left or right side of Beam cross-section

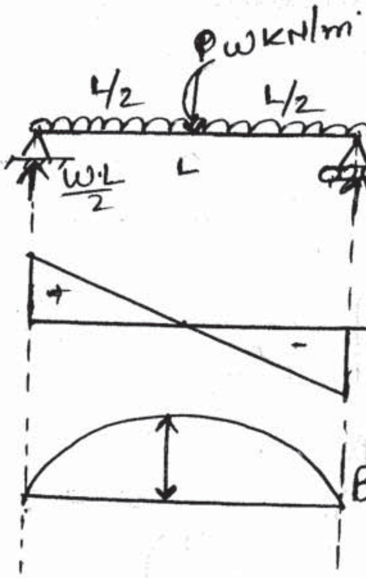


## ⇒ Standard Result



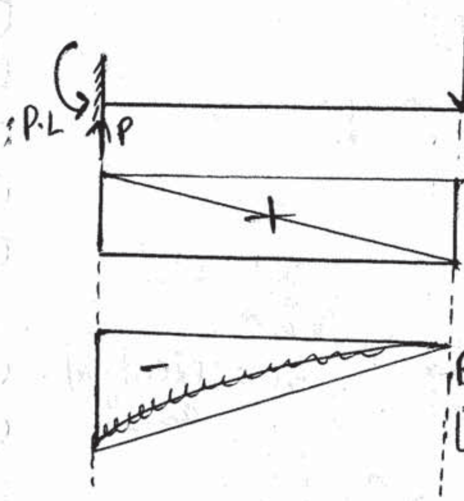

$V_{max} = P/2$ (support)

$BM_{max} = \frac{PL}{4}$ (Below point load)



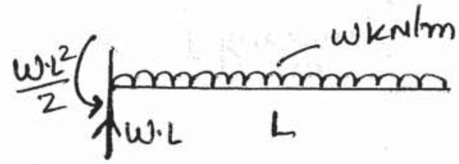

$\frac{wL}{2} = V_{max}$ (support)

$BM_{max} = \frac{wL^2}{8}$ (Below UDL)



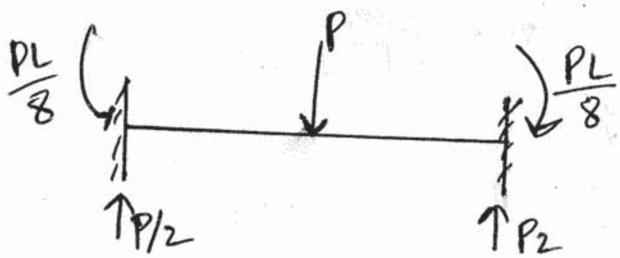

$V_{max} = P$ [at support]

$BM_{max} = P \cdot L$ [At Support]



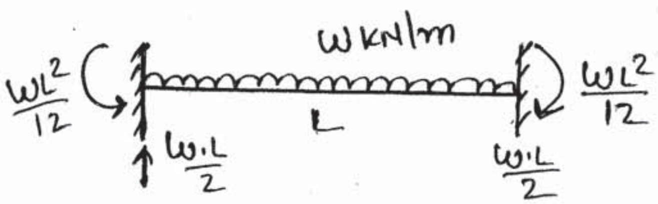

$V_{max} = w \cdot L$ [At support]

$B.M_{max} = \frac{w \cdot L^2}{2}$ [At support]




$V_{max} = \frac{P}{2}$

$B.M_{max} = \frac{PL}{8}$




$V_{max} = \frac{w \cdot L}{2}$ (At support)

$B.M_{max} = \frac{w \cdot L^2}{12}$ (At support)