Q.1(a) Attempt any FIVE of the following. [10]

Q.1(a) Define moment of Inertia. State MI of triangular section about its base. [2]

Ans.: It is the second moment of area which is equal to product of area of the body and square of the distance of its centroid from that axis, is called as moment of Inertia.

OR

Moment of inertia of a body about an axis is defined as the sum of second moment of all elementary areas about that axis.

\[ \text{MI of triangular section about base } I_{\text{base}} = \frac{bh^2}{12} \]

Where, \( b = \) Base of triangle and \( h = \) Height of triangle

Q.1(b) If polar moment of inertia of circular section is 2000 mm\(^4\) then calculate diameter of the section. [2]

Ans.: Given: \( I_p = 2000 \text{mm}^2 \) for circular section

\[ I_p = I_{xx} + I_{yy} \]

\[ I_p = \frac{\pi D^4}{64} + \frac{\pi D^4}{64} \]

\[ 2000 = \frac{2\pi D^4}{64} \]

\[ D = 11.946 \text{mm} \]

Q.1(c) Define ductility and plasticity. [2]

Ans.: When a body is subjected to three mutually perpendicular like stresses of same intensity then the ratio of direct stress and the corresponding volumetric strain of the body is constant and is known as Bulk Modulus. It is denoted by \( K \).

SI unit: N/m\(^2\) or Pascal

\[ \text{Bulk Modulus, } K = \frac{\text{Direct stress}}{\text{Volumetric strain}} = \frac{\sigma}{e_v} \]
Q.1(d) For a certain material, the modulus of elasticity is 200 N/mm². If Poisson's ratio is 0.35, calculate Bulk modulus.

Ans.: Data: \( E = 200 \text{ N/mm}^2, \) Poisson's ratio = 0.35

\[
\begin{align*}
E &= 3K(1 - 2\mu) \\
200 &= 3K(1 - (2 \times 0.35)) \\
K &= 222.22 \text{ N/mm}^2
\end{align*}
\]

Q.1(e) Define effective length in column with its application.  
Ans.: Effective Length: The length of the column which bends or deflects as if it is hinged at its ends is called as effective length. It is denoted by \( L_e \).

Application: It is used in Rankine's and Euler's formula to determine buckling load on column.

Q.1(f) Give the expression for maximum bending stress with meaning of each term.

Ans.: Maximum bending stress \( \sigma_b \) = \( \frac{M}{I} \times \gamma \)

Where, \( M = \) Maximum bending moment (kN-m) or (N-mm)
\( I = \) Moment of Inertia (mm⁴)
\( \gamma = \) Distance of neutral axis from top or bottom (mm)

Q.1(g) Along with expression, define slenderness ratio.

Ans.: Slenderness Ratio: Slenderness ratio is defined as the ratio of effective length of column to its minimum radius of gyration.

\[
\text{Slenderness Ratio} (\lambda) = \frac{\text{Effective Length}}{\text{Least Radius of Gyration}} = \frac{L_e}{K_{\text{min}}}
\]

Q.2 Attempt any THREE of the following:

Q.2(a) Determine moment of Inertia about the centroidal axes X-X and Y-Y of an Unsymmetrical I section with following details.

Top flange - 100 mm \( \times \) 20 mm
Bottom flange - 160 mm \( \times \) 20 mm
Web - 80 mm \( \times \) 20 mm

Ans.: (i) Calculation of centroid:

As given section is unsymmetrical about y-y axis,

\[
\bar{X} = \frac{\text{Large flange width}}{2} = \frac{160}{2} = 80 \text{mm}
\]

\( A_1 = 160 \times 20 = 3200 \text{mm}^2 \),

\( A_2 = 80 \times 20 = 1600 \text{mm}^2 \),

\( A_3 = 100 \times 20 = 2000 \text{mm}^2 \)
\[ Y_1 = \frac{20}{2} = 10\text{mm}, \quad Y_2 = 20 + \frac{80}{2} = 60\text{mm}, \]
\[ Y_3 = 20 + 30 + \frac{20}{2} = 110\text{mm}, \]
\[ \bar{Y} = \frac{(3200\times10) + (1600\times60) + (2000\times110)}{6800} = 51.17\text{mm}, \]

(ii) **Calculation of** \( I_{xx} \):
\[ I_{xx} = I_{xx1} + I_{xx2} + I_{xx3} \]
\[ I_{xx} = \left( I_{g1} + A_1 h_1^2 \right) + \left( I_{g2} + A_2 h_2^2 \right) + \left( I_{g3} + A_3 h_3^2 \right) \]
\[ I_{xx} = \left( \frac{bd^3}{12} + A_1 h_1^2 \right) + \left( \frac{bd^3}{12} + A_2 h_2^2 \right) + \left( \frac{bd^3}{12} + A_3 h_3^2 \right) \]

Here, \( h_1 = \bar{Y} - Y_1 = 1.17 - 10 = 41.17\text{mm} \)
\( h_2 = Y_2 - \bar{Y} = 60 - 51.17 = 8.83\text{mm} \)
\( h_3 = Y_3 - \bar{Y} = 110 - 51.17 = 58.83\text{mm} \)

\[ I_{xx} = \left( \frac{160\times20^3}{12} + 3200\times41.17^2 \right) + \left( \frac{20\times80^3}{12} + 1600\times8.83^2 \right) \]
\[ + \left( \frac{100\times20^3}{12} + 2000\times58.83^2 \right) \]
\[ I_{xx} = 13.496 \times 10^6\text{mm}^4 \]

(iii) **Calculation of** \( I_{yy} \):
\[ I_{yy} = I_{yy1} + I_{yy2} + I_{yy3} \]
\[ I_{yy} = \left( I_{g1} + A_1 h_1^2 \right) + \left( I_{g2} + A_2 h_2^2 \right) + \left( I_{g3} + A_3 h_3^2 \right) \]
\[ I_{yy} = \left( \frac{db^3}{12} \right) + \left( \frac{db^3}{12} \right) + \left( \frac{db^3}{12} \right) \]
\[ I_{yy} = \left( \frac{20\times160^3}{12} \right) + \left( \frac{80\times20^3}{12} \right) + \left( \frac{20\times100^3}{12} \right) \]
\[ I_{yy} = 8.546 \times 10^6\text{mm}^4 \]
Q.2(b) For a circular lamina of diameter 100 mm, calculate the moment of inertia and radius of gyration about any tangent.

Ans.: Data: \( d = 100 \text{ mm} \)

(i) MI about tangent:
\[
I_{AB} = \frac{\pi}{64} d^4 + Ah^2
\]
\[
= \frac{\pi}{64} (100)^4 + \pi(50)^2 \times (50)^2
\]
\[
= 2453692.61 \text{ mm}^4
\]

(ii) Radius of gyration about tangent:
\[
K_{AB} = \sqrt{\frac{I_{AB}}{A}} = \sqrt{\frac{24543692.61}{7853.982}} = 3152 = 55.90
\]

Q.2(c) Find the least M.I. of a symmetrical I-section having following details: Flanges : 100 mm \( \times \) 20mm Overall depth : 280 mm Thickness of web : 10 mm

Ans.: \( I_{xx} \) and \( I_{yy} = ? \)

Above figure symmetrical @ XX and YY axis
So, M.I. of I-section @ XX-Axis
\[
M.I_{xx} = M.I_{ABCD} - M.I_{PQRS} - M.I_{LMNO} \quad \ldots (i)
\]
\[
M.I_{ABCD} = \frac{100 \times 280^3}{12} = 182.93 \times 10^6 \text{ mm}^4
\]
\[
M.I_{PQRS} = \frac{45 \times 240^3}{12} = 51.84 \times 10^6 \text{ mm}^4
\]
\[
M.I_{LMNO} = \frac{45 \times 240^3}{12} = 51.84 \times 10^6 \text{ mm}^4
\]
From (i)
\[
M.I_{xx} = 182.93 \times 10^6 - [2 \times 51.84 \times 16^6]
\]
\[
M.I_{xx} = 79.25 \times 10^6 \text{ mm}^4
\]
M.I. of I-section @ YY axis

\[ I_{yy} = I_{yy1} + I_{yy2} + I_{yy3} \]  \hspace{1cm} \text{(ii)}

\[ I_{yy1} = \frac{\partial b^3}{12} = \frac{20 \times 100^3}{12} = 1.67 \times 10^6 \text{mm}^4 \]

\[ I_{yy2} = \frac{\partial b^3}{12} = \frac{240 \times 10^3}{12} = 20 \times 10^3 \text{mm}^4 \]

\[ I_{yy3} = I_{yy1} = 1.67 \times 10^6 \text{ mm}^4 \]

From equation (ii)

\[ I_{yy} = 1.67 \times 10^6 + 20 \times 10^3 + 1.67 \times 10^6 = 3.36 \times 10^6 \text{ mm}^4 \]  \text{ least M.I.}

Q.2(d) Define 'radius of gyration' and state its application. Calculate radius of gyration for circular lamina of diameter 500 mm.

**Ans.:**

Data: \( d = 500 \text{ mm} \)  \hspace{1cm} Calculate: \( K \)

Radius of gyration (\( K \)): The radius of gyration of a given area about any axis is the distance from the given axis at which the area is assumed to be concentrated without changing the MI about the given axis.

\[ K = \sqrt{\frac{I}{A}} \]

where \( I = \text{Moment of Inertia (mm}^4\) \)

\( A = \text{Cross Sectional Area (mm}^2\) \)

\( K = \text{Radius of Gyration (mm)} \)

Application: It is used in Euler's formula to determine buckling load on long column.

\[ K = \sqrt{\frac{I}{A}} = \sqrt{\frac{\pi d^4/64}{\pi d^2/4}} = \sqrt{\frac{\pi 500^4/64}{\pi 500^2/4}} = \sqrt{\frac{3.068 \times 10^9}{196.35 \times 10^3}} = 125 \text{ mm} \]

Q.3 Attempt any THREE of the following:

Q.3(a) Sketch the standard stress-strain curve for mild steel and tor steel bar under axial tension and show important points on it.

**Ans.:** Stress-Strain Curve for Mild Steel
Q.3(b) A steel rod 15 m long is at a temperature of $15^\circ C$. Find the free [4] expansion of the length when the temperature is raised to $65^\circ C$. Find the temperature stresses when the expansion of the rod is fully prevented. Take, $\alpha = 12 \times 10^{-6}$ per $^\circ C$, $E = 2 \times 10^5$ N/mm$^2$.

Ans.: Data: $L = 15m$, $t_1 = 15^\circ C$, $t_2 = 65^\circ C$, $\alpha = 12 \times 10^{-6}$ /$^\circ C$, $E = 2 \times 10^5$ N/mm$^2$

Find: $\delta L_1 = ?$, $\sigma_t = ?$

$\delta L_1 = \alpha \times t \times L = 12 \times 10^{-6} \times 50 \times 15 \times 10^3 = 9$ mm

$\sigma_t = \alpha \times t \times E = 12 \times 10^{-6} \times (65 - 15) \times 2 \times 10^5 = 120$ N/mm$^2$

Q.3(c) A steel rod is subjected to an axial pull of 25 kN. Find minimum [4] diameter if the stress is not exceed 100 N/mm$^2$. The length of rod is 2000 mm and take $E = 2.1 \times 10^5$ N/mm$^2$.

Ans.: Data: $P = 25$ kN, $\sigma = 110$ N/mm$^2$, $E = 2 \times 10^5$ N/mm$^2$

Find: $d_{\min}$

$\sigma = \frac{P}{A} = \frac{P}{(\pi d^2/4)}$

$d^2 = \frac{P}{(\pi \sigma/4)}$

$d = \sqrt{\frac{P}{(\pi \sigma/4)}} = \sqrt{\frac{25 \times 10^3}{(\pi \times 100/4)}} = 17.84$ mm

Q.3(d) State any four assumptions made in theory of pure bending. [4]

Ans.: Assumption in the theory of pure bending:

(i) The material of the beam is homogenous & isotrophic.

(ii) The beam material is stressed to obey Hooke’s law.

(iii) The transverse sections, which were plane before bending, remain plane after bending.
(iv) Each layer of beam is free to expand or contract independently.
(v) Value of E is the same in tension & compression.

Q.4 Attempt any THREE of the following: [12]

Q.4(a) A cube of 200 mm side is subjected to a compressive force of 3600 kN on all its faces. The change in the volume of cube is found to be 5000 mm³. Calculate the Bulk modulus. If μ = 0.28, find the Young's modulus.

Ans.:

\[
\sigma = \frac{P}{A} = \frac{300 \times 10^3}{200 \times 200} = 90 \text{ N/mm}^2
\]

\[
V = L^3 = (200)^3 = 8 \times 10^6 \text{ mm}^3
\]

\[
\frac{\delta V}{V} = \frac{\sigma x + \sigma y + \sigma z}{E} (1 - 2\mu)
\]

\[
E = \frac{3\sigma}{(1 - 2\mu)} = \frac{3 \times 90}{\left( \frac{5000}{8 \times 10^6} \right) (1 - 2 \times 0.28)} = 1.9 \times 10^5 \text{ N/mm}^2
\]

Q.4(b) For a given material, Young's modulus is 110 GN/m² and shear modulus is 42 GN/m². Find the Bulk modulus and lateral contraction of a round bar of 37.5 mm diameter and 2.4 m length when stretched by 2.5 mm. when subjected to an axial load.

Ans.:

Data: \( E = 110 \text{ GN/m}^2 = 110 \times 10^3 \text{ N/mm}^2, G = 42 \text{ GN/m}^2 = 42 \times 10^3 \text{ N/mm}^2 \)

\( d = 37.5 \text{ mm}, L = 2.4 \text{ m} = 2400 \text{ mm}, \delta L = 2.5 \text{ mm} \)

Find: \( K = ?, \delta d = ? \)

To calculate Possion's ratio (μ):

\[
E = 2G \left( 1 + \mu \right)
\]

\[
110 \times 10^3 = 2 \times 42 \times 10^3 \left( 1 + \mu \right)
\]

\[
\mu = 0.309
\]

To calculate Bulk Modulus (K):

\[
E = 23K \left( 1 - 2\mu \right)
\]

\[
110 \times 10^3 = 3K \left( 1 - 2 \times 0.309 \right)
\]

\[
K = 95.986 \times 10^3 \text{ N/mm}^2
\]

To calculate change in diameter (δd):

\[
\mu = \frac{\text{Lateral strain}}{\text{Linear strain}} = \frac{\varepsilon_L}{\varepsilon} = \frac{\delta d / d}{\delta L / L}
\]

\[
0.309 = \frac{\delta d / 37.5}{2.4 / 2400}
\]

\[
\delta d = 0.012 \text{ mm}
\]
Q. 4(c) Draw SFD and BMD of a beam as shown in figure. Also find the point of contra flexure.

Ans.: (i) To find reactions \( R_A \) and \( R_B \)
\[
R_A + R_B = 20 \times 10
\]
\[
R_A + R_B = 200
\]

\[
\sum M_A = 20 \times 10 \times \frac{10}{2} - R_B \times 8
\]
\[
\sum M_A = 1000 - 8R_B
8R_B = 1000
R_B = 125 \text{ kN}
\]
\[
\therefore R_A = 200 - R_B = 200 - 125 = 75 \text{ kN}
\]

(ii) Shear force calculation
\[
F_C = 0
\]
\[
F_{BR} = 20 \times 2 = 40 \text{ kN}
\]
\[
F_{BL} = 40 - 125 = -85 \text{ kN}
\]
\[
F_A = -85 + 20 \times 8 = -85 + 160 = 75 \text{ kN}
\]

(iii) B.M. calculation
\[
M_C = 0 \text{ kN.m}
\]
\[
M_B = -(20 \times 2) \times \frac{2}{2}
\]
\[
= -20 \times 2 \times 1
\]
\[
= -40 \text{ kN.m}
\]
\[
M_A = 0 \text{ kN.m}
\]

(iv) To locate the position of point of contrashear
\[
\frac{85}{8-x} = \frac{75}{x}
\]
\[
85x = 75(8-x)
85x = 600 - 75x
\]
\[
\therefore 160x = 600
\]
\[
x = 3.75 \text{ m from left}
\]
\[
M_{XX} = M_{PCS} = 75 \times x - 20 \times x \times \frac{x}{2}
\]
\[
M_{XX} = 75 \times 3.75 - 20 \times 3.75 \times \frac{3.75}{2}
\]
\[ M_{XX} = 281.25 - 140.625 \]
\[ M_{XX} = 140.625 \text{ kN.m (sagging)} \]

To locate the point of contraflexure \( (P_{CF}) \)

\[ M_{x_1} = 75 x_1 - 20 x_1 \times \frac{x_1}{2} \]
\[ 0 = 75 x_1 - 10 x_1^2 \]
\[ 0 = x_1 (75 - 10 x_1) \]
\[ \therefore 75 = 10 x_1 = 0 \]
\[ 75 = 10 x_1 \]
\[ x_1 = 7.5 \text{ m from } A \]

Point of contraflexure \( (P_{CF}) = 7.5 \text{ cm from 'A'} \)

Q. 4(d) State the flexural formula, giving meaning of the symbols used in it. [4]
Ans.: Flexural formula
\[
\frac{M}{I} = \frac{\sigma}{\frac{E}{y}} = \frac{E}{R}
\]
Where
\( m = \text{max bending moment which is equal to moment of resistance of beam.} \)
\( I = \text{M.I. of beam section about the neutral axis since neutral axis always lies at the centroid of the section.} \)
\( I = I_{NA} = I_{XX} \)
\( \sigma = \text{Bonding stress in a layer at a distance } y \text{ from N.A.} \)
\( y = \text{distance of the layer from the N.A. of the beam material.} \)
\( R = \text{Radius of curvature of the bentup beam.} \)

Q. 5 Attempt any TWO of the following : [12]

Q. 5(a) Draw shear force and bending moment diagrams for the cantilever [6] beam loaded as shown in figure. Indicate all important values.

Ans.: I) Reaction Calculation:
\[ \sum F_y = 0 \]
\[ R_A = 3 + (1 \times 3.5) + 2 = 8.5 \text{kN} \]

III) BM Calculation:
\( BM \text{ at } E = 0 \text{kN.m (Eis Free end)} \)
\[ E = 0 \text{kN.m} \]
\[ C = -2 \times 1 = -2 \text{kN.m} \]
\[ B = -2 \times 3.5 - (1 \times 2.5) \times 1.25 = -10.125 \text{kN.m} \]
\[ A = -2 \times 4.5 - (1 \times 3.5) \times 1.75 - 3 \times 1 = -18.125 \text{kN.m} \]

II) SF Calculation:
\( \text{SF at } A = +8.5 \text{kN} \)
\[ B_L = +8.5 - 1 \times 1 = +7.5 \text{kN} \]
\[ B_R = +7.5 - 3 = +4.5 \text{kN} \]
\[ C = 4.5 - 1 \times 2.5 = 2.0 \text{kN} \]
\[ D_L = +2.0 \text{kN} \]
\[ D_R = +2 - 2 = 0 \text{kN} \]
\[ E = 0 \text{kN} \] (\( \square \text{ ok} \))
Q. 5(b) Draw shear force and bending moment for simply supported beam as shown in Figure.

Ans.:

I) Reaction Calculation:
\[ \sum M_A = 0 \]
\[ R_B \times 5.5 = (2 \times 2) \times 1 + 1.5 \times 2 + 30 \]
\[ R_B = 6.72 \text{kN} \]
\[ \sum F_y = 0 \]
\[ R_A + R_B = (2 \times 2) + 1.5 \]
\[ R_A = -1.22 \text{kN} \]

II) SF Calculation:
\[ \text{SF at A} = -1.22 \text{kN} \]
\[ C_L = -1.22 - (2 \times 2) = -5.22 \text{kN} \]
\[ C_R = -5.22 - 1.5 = -6.72 \text{kN} \]
\[ B_L = -6.72 \text{kN} \]
\[ B = -6.72 + 6.72 = 0 \text{kN} \]
\[ (: \text{ok}) \]

III) BM Calculation:
\[ \text{BM at A and B} = 0 \ (: \text{Supports A and B are simple}) \]
\[ C = -1.22 \times 2 - (2 \times 2) \times 1 = -6.44 \text{kN-m} \]
\[ D_L = 6.72 \times 2.5 - 30 = -13.2 \text{kN-m} \]
\[ D_R = 6.72 \times 2.5 = +16.8 \text{kN-m} \]
Q.5(c) A metal rod 20 mm diameter and 2 m long when subjected to tensile [6] force of 60 kN shows an elongation of 2 mm and reduction in diameter 0.006 mm. Calculate the modulus of elasticity and modulus of rigidity.

Ans.: 

\[ E = \frac{PL}{A\delta L} = \frac{60 \times 10^3 \times 2 \times 10^5}{\pi \times 20^2 \times 2} = 1.91 \times 10^5 \text{ N/mm}^2 \]

\[ \mu = \frac{\text{Lateral Strain}}{\text{Linear Strain}} = \frac{\delta d}{d} (\frac{0.006}{20}) = \frac{0.006}{2000} = 0.3 \]

\[ E = 2G(1 + \mu) \]
\[ = 2G(1 + 0.3) \]
\[ = 1.91 \times 10^5 = 2G(1 + 0.3) \]
\[ G = \frac{1.91 \times 10^5}{2 \times 1.3} = 7.345 \times 10^4 \text{ N/mm}^2 \]

Q.6 Attempt any TWO of the following: [12]

Q.6(a) (i) A simply supported beam of span `L' carries central point load [6] 'W'. Draw SED and BMD

(ii) Define shear force and bending moment. Write unit of each. Also state relation between them.

Ans.: (i) Step 1: Calculation of Reaction,

As, the load is at centre so,

Support reaction are equal'

\[ R_A = R_B = \frac{W}{2} \]

Step 2: Share force calculation

(a) S.F. at any section between A and C is,

\[ F_x = + R_A = \frac{W}{2} \]

(b) S.F. at any section between B and C is,

\[ F_x = - R_B = - \frac{W}{2} \]

Step 3: Bending Moment Calculation

Beam is simply supported at the end A and B,

\[ M_A = M_B = 0 \]

\[ M_{max} = MC = + \frac{W}{2} \times \frac{L}{2} \]

\[ M_C = \frac{WL}{4} \]
(ii) **Shear force**: Shear force at any cross section of the beam is the algebraic sum of vertical forces on the beam acting on right side or left side of the section is called as shear force.

**OR**

A shear force is the resultant vertical force acting on the either side of a section of a beam.

Unit :- kN or N

**Bending Moment**: Bending moment at any section at any cross section is the algebraic sum of the moment of all forces acting on the right or left side of section is called as bending moment.

Unit: kN-m or N-m

Relation between shear force and bending movement

\[ \frac{dM}{dx} = F \]

The rate of change of bending moment at any section is equal to the shear force at that section.

**Q.6(b)** A simply supported beam of span 6 m carries two point loads 18 kN [6] with 2 m spacing and symmetrical to span. Design square beam for bending if maximum bending stresses in beam is 10 N/mm².

**Ans.:**

**Data:** L=6m, W₁=18kN, W₂=18kN, σₐ₇= 10N/mm², b = d

**Find:** b, d

RA=RB=18kN (Due to symmetry)

\[ M_{\text{max}} = M_{C} = M_{D} = 18 \times 2 = 36 \text{ kN}-\text{m} = 36 \times 10^{6} \text{ N-mm} \]

\[ I = \frac{b^4}{12} = \frac{b^4}{12} \]

\[ Y = \frac{d^3}{2} = \frac{d^3}{2} \]

\[ \frac{M}{I} = \frac{\sigma}{Y} \]

\[ 10 = \frac{36 \times 10^{6}}{b^3} \times \frac{b}{2} \]

\[ 10 = \frac{36 \times 10^{6}}{b^3} \times \frac{12}{b} \]

\[ b^3 = \frac{(36 \times 10^{6})}{10} \times 6 \]

\[ b^3 = 216 \times 10^{5} \]

\[ b = 278.495 \text{ mm} \]

\[ d = 278.495 \text{ mm} \]
Q.6(c) A simply supported beam carries a udl of intensity 2.5 kN/m over entire span of 5m. The cross section of beam is a T-section having the dimensions given below:

- Flange: 125 mm × 25 mm
- Web: 175 mm × 25 mm, overall depth = 200 mm.

Calculate the maximum shear stress for the section of the beam. Construct shear distribution diagram.

Ans.:

Data: L = 5m, W = 2.5kN/m,

Flange: 125mm x 25mm, Web: 175mm x 25mm, overall depth=200mm.

\[ S = \frac{wL}{2} = \frac{2.5 \times 5}{2} = 6.25 \text{kN-m} = 6.25 \times 10^6 \text{N-mm} \]

\[ \bar{Y} = \frac{a_1y_1 + a_2y_2}{a_1 + a_2} \]

\[ \bar{Y} = \frac{(125 \times 25) \times 12.5 + (25 \times 175)(25 + \frac{175}{2})}{(125 \times 25) + (25 \times 175)} \]

\[ \bar{Y} = \frac{(3125 \times 12.5) + (4375 \times 112.5)}{7500} \]

\[ \bar{Y} = 70.83 \text{mm from top} \]

\[ I_{st} = (I_{fl} + I_{wb}) \]

\[ I_{st} = \left( I_0 + ah^2 \right)_\text{fl} + \left( I_0 + ah^2 \right)_\text{wb} \]

\[ I_{st} = \left( \frac{bd^3}{12} + ah^2 \right)_\text{fl} + \left( \frac{bd^3}{12} + ah^2 \right)_\text{wb} \]

\[ I_{st} = \left( \frac{125 \times 25^3}{12} + (125 \times 25)(70.83 - \frac{25}{2}) \right) + \left( \frac{25 \times 175^3}{12} + (25 \times 175)(25 + \frac{175}{2} - 70.83)^2 \right) \]

\[ I_{st} = (10795225.73) + (18762066.02) \]

\[ I_{st} = 29857291.75 \text{mm}^4 \]

\[ AY = (125 \times 25)(70.83 - 12.5) + [25 \times (70.83 - 25)] \times \left( \frac{70.83 - 25}{2} \right) \]

\[ AY = (3125 \times 58.33) + (1145.75 \times 22.915) \]

\[ AY = 208536.1 \text{mm}^3 \]

\[ q = \frac{SAY}{bl} \]

\[ q_1 = \frac{6.25 \times 10^6 \times 3125 \times 58.33}{125 \times 29557291.75} = 308.352 \text{N/mm}^2 \]

\[ q_2 = \frac{6.25 \times 10^6 \times 3125 \times 58.33}{25 \times 29557291.75} = 1541.762 \text{N/mm}^2 \]

\[ q_{(\text{max})} = \frac{6.25 \times 10^6 \times 208536.11}{25 \times 29557291.75} = 1763.83 \text{N/mm}^2 \]