BALASORE SCHOOL OF ENGGINEERING
STRENGTH OF MATERIAL
THEORY-01
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CHAPTER—1
SHORT QUESTION [2 MARKS]

1. Show the condition of Equilibrium (new chem.)

Soln. An object in equilibrium if the resultant force acting on the object is zero

i.e. $\Sigma v = 0$. $\Sigma H = 0$, $\Sigma M = 0$

2. What is free body diagram ? (2018 1a,2017)

Soln. After removing the support from the objects the diagrametic representation is known as free body diagram.

CHAPTER – 2 (S.Q.)

1. State the parallel axis theorem 2015(w) 2(a),2018 1(d)

Soln. It states, if the moment of inertia of a plane area about an axis through its centre of gravity is denoted by I_G, then moment of inertia of the area about any other axis AB, parallel to the first and at a distance h from the C.G. is given by

Where $IA_B = I_G + ab^2$

I_{AB} = M.I. of the area about an axis AB

I_G = M.I. of the area about its C.G.

a = Area of the seen

h = Distance between C.G. of the seen & axis AB

2. Define polar modulus 2017 (w) 1(g)

Soln. It is the ratio of polar moment of inertia of shaft section to maximum radious

$$\text{Polar modulus } Z_P = \frac{I_C}{R}$$

Where R – Radious of shaft section.

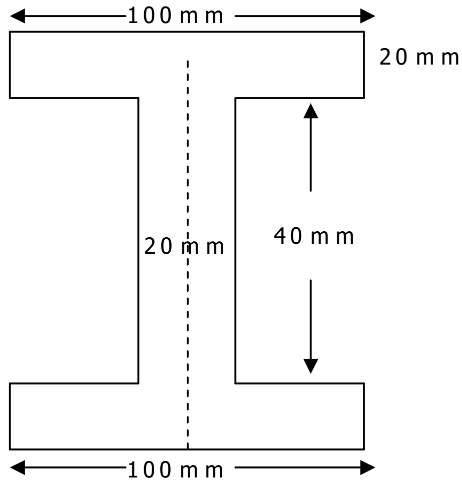
3. Define Malleability and fatigue of a material 2015(w) 7(a),2017 8(a)

Soln. Malleability : The property by which materials allow to be hammered into thin sheets, load applied in compressive stress.

Ex: Cu, Ag, Alluminium

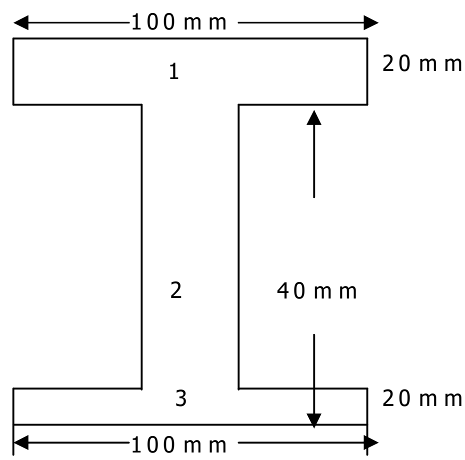
Fatigue : It is a progressive and localized structure damage that occurs when a material is subjected to cyclic loading

4) Find out the CG of the section given below 2014 (1.b)



Ans: As the seem is symmetrical about y – yaxis bisecting the web. It's centre of gravity will lie on this axis. Now split up the sew into the three rectangles.

Let bottom of the bottom flange be the axis of reference.



(i) Top flange

$a_1 = 100 \times 20 = 20{,}00\ mm^2$

$y_1 = \frac{20}{2} + 140 + 20 = 70\ mm$

(ii) Web

$a_2 = 40 \times 20 = 800\ mm^2$

$y_2 = \frac{40}{2} + 20 = 40\ mm$

(ii) Bottom flange

$a_3 = 100 \times 20 = 2000\ mm^2$

$y_3 = 20/2 = 10\ mm$

We know that distance between centre of gravity of the seen & bottom of the flange

$$y = \frac{a_1 y_1 + a_2 y_2 + a_3 y_3}{a_1 + a_2 + a_3}$$

$$= \frac{2000 \times 70 + 800 \times 40 + 2000 \times 10}{2000 + 800 + 2000}$$

$$= 40mm$$

CHAPTER: 2

LONG QUESTION[6 MARKS]

1. A 250 gm depth into 150 mm width rectangles beam is subjected to maximum bending of 750 KN Determine.

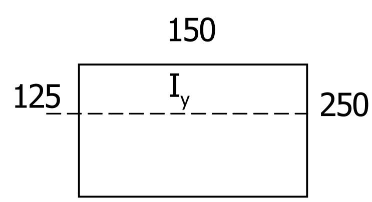
   (i) Maximum stress in the beam

   (ii) If the value of E for the beam material is 200 GN/m^2. Find out the radius of curvature of that portion of the beam, where the B.M. is maximum

   (iii) Longitudinal stress at a distance of 65 mm from the top surface of the beam.

Soln. Maximum B.M. = 750 Kn×m

$= 750 \times 10^6$ Nmm



we know that $\frac{6}{y} = \frac{M}{I}$

$$\Rightarrow 6\,\text{maximum} = \frac{m \times y}{I}$$

$$\text{Ixx.} \quad \frac{b \times d^3}{12} = \frac{150 \times (250)^3}{12} = 195312500\,\text{max}.$$

$$6\,\text{max.} = 480\,N/mm^2$$

(ii) we know that

$$\frac{M}{I} = \frac{6}{y} = \frac{E}{R} \Rightarrow \frac{E}{R} = \frac{6}{y}$$

$$\Rightarrow \; R = \frac{Ey}{6} = 52.08\text{mm}$$

(iii) $y = 125 - 65 = 60\text{mm}$

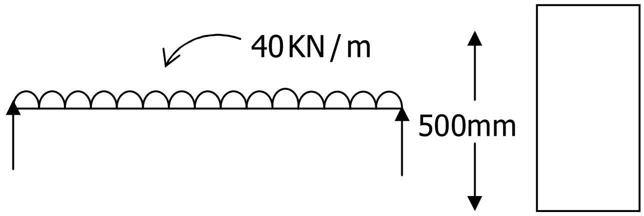
$$6 = \frac{m \times y}{I} = \frac{750 \times 10^6 \times 60}{195312500} = 230.4\,N/mm^2$$

CHAPTER 2

LONG QUESTIONS [8 MARKS

1. A beam is simply supported and carries a uniformly distributed load of 40 KN/m run over the whole span. The section of the beam is rectangle having depth as 500 mm. If the maximum stress in the material of the beam is 120 N/mm^2 & moment of inertia of the section is 7×10^8 mm^4, find the span of the beam . 2018 (w) (2)

Soln.



Given data

Depth, d= 500 mm

Maximum stress 6_{max} = 120 N/mm^2

$I = 7 \times 10^8$ mm^4

L = ?

$W = 40 \times 10^3$ N/m

Maximum bending moment

$$M = \frac{wl^2}{8}$$

$$= \frac{40 \times 10^3 \times l^2}{8}$$

$$\Rightarrow M = 5000\,l^2 Nm = 5000 \times 10^3 l^2\ Nmm$$

Using bending equation

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\Rightarrow \frac{M}{I} = \frac{\sigma}{d/2} (\therefore y = \frac{d}{2})$$

$$\Rightarrow \frac{5000 \times 10^3 L^2}{7 \times 10^8} = \frac{120}{\frac{500}{2}}$$

$$\Rightarrow l^2 = \frac{120 \times 2 \times 7 \times 10^8}{500 \times 5000 \times 10^3}$$

$$\Rightarrow l = \sqrt{\frac{120 \times 2 \times 7 \times 10^8}{500 \times 5000 \times 10^3}}$$

$$= 8.2\,m \qquad \text{(Ans)}$$

2. A water main at 1000 mm internal dia & 10 mm thick is running full. If the bending stress is not to exceed 60 N/mm^2, find out the greatest span in which the pipe may be preely supported steel & water weigh 76.8 KN/m^3 & 10 NM/m^3

2011 (N) (4)

Soln. Consider 1 meter run of main area of pipe section.

$$Ap = \frac{\pi}{4}\left(D^2 - d^2\right)$$

D = 1000 + 2 × 10 + 1020mm = 10.2 m

d = 1000 mm = 1m

Ap = $\pi/4(1.02^2 - 1^2) = 0.03\ m^2$

Area of water (A_w) = $\pi/4\ (1)^2 = 0.78\ m^2$

Wt. of pipe for one meter run

= $0.03 \times 1 \times 76.8 \times 10^3 = 2304$ N

Wt. of water for 1m run

= $0.78 \times 1 \times 10 \times 10^3 = 7800$ N

$\therefore$Total load on pipe for 1m run.

= 2304 + 7800 = 10104 N/m

Let the maximum span = 1m

$\therefore$ maximum B.M.

$$M = \frac{wl^2}{8}$$

$$= \frac{10104 \times l^2}{8} Nm$$

$$= 1263\, l^2 Nm = 1263 \times 10^3 l^2 Nm$$

$$M.I.I = \frac{\pi}{64}\left(1.02^4 - l^4\right)$$

$$= 4.04N0 / mm^4$$

$$we\,have\,\frac{M}{I} = \frac{6}{y}$$

$$\Rightarrow \frac{1263 \times 10^3 l^2}{4.04 \times 10^9} = \frac{60}{D/2}$$

$$\Rightarrow \frac{1263 \times 10^3 l^2}{4.04 \times 10^9} = \frac{60}{510}$$

$$\Rightarrow l = \sqrt{\frac{60 \times 4.04 \times 10^9}{510 \times 1263 \times 10^3 = 19.4m}} \quad \text{(Ans)}$$

CHAPTER-2
LONG QUESTION 5 MARKS

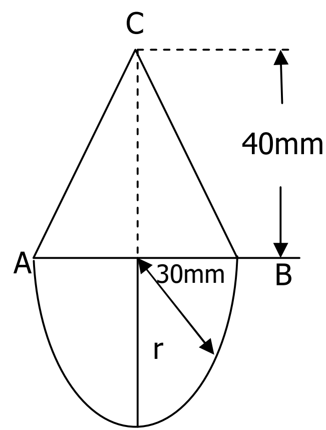
1. A body consists of a right circular solid cone of the 40,,, radius 30 mm placed on a solid hemisphere of radius 30 mm of the same material. Find the position of CG of the body 2015 1(b)

Ans: As the body is symmetrical about y-axis, therefore its C.G. will tie on this axis

(i) Hemisphere

$$V_1 = \frac{2\pi}{3} \times \pi^3 = \frac{2\pi}{3}(30)^3\ mm^3$$

$$y_1 = r - \frac{3\pi}{8} = \frac{5\pi}{8} = \frac{5 \times 30}{8} = 18.75\,mm$$



(ii) Right circular cone

$$V_2 = \frac{\pi}{3} \times r^2 \times h = \frac{\pi}{3}(30)^2 \times 40\,mm^3$$

$$= 12,000\,\pi\,mm^3$$

$$y_2 = 30 + \frac{40}{4} = 40\,mm$$

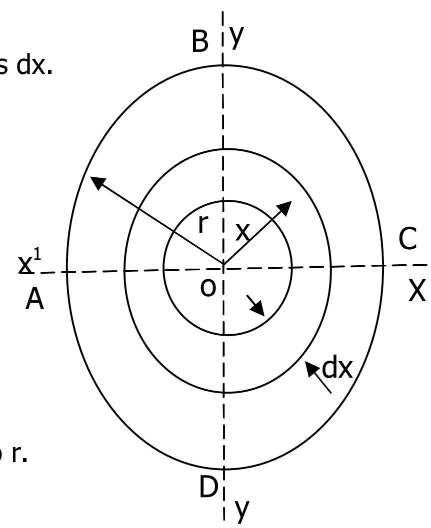
we know that distance between C.G. of the body and bottom of hemisphere D

$$y = \frac{v_1 y_1 + v_2 y_2}{v_1 + v_2} = (18,000\pi \times 18.75) + \frac{(12,000\pi \times 40)\,mm}{18000\pi + 12000\pi}$$

$$= 27.3\,mm$$

2. Derive the M.I. of a circular section 2015 (w) 2(b)

Soln. Consider a circle ABCD of radius ® with centre O & $x\text{-}x^1$ & $y\text{-}y^1$ be two axes of reference through O as shown in fig.



Now consider on elementary ring of radius x & thickness dx.

Therefore area of the ring da = $2\pi x.dx$

M.I. of ring, about x – y axis or y-y axis

= Area × (Distance)^2

= 2π x dx × x^2

= 2π x^3 dx

Now M.I. of the whole section, about the central axis can be found out by integrating the above equation for the whole radius of the circle i.e. from O to r.

$$Izz = \int_0^r 2\pi x^3.dx = 2\pi \int_0^r x^3.dx$$

$$Izz = 2\pi\left[\frac{x^4}{4}\right]_0^r = \frac{\pi}{2} \times r^4 = \frac{\pi}{32}(d)^4 \left(\therefore \pi = d/2\right)$$

we know from the theorem of ⊥ r axis that

$$Ixx + Iyy = Izz$$

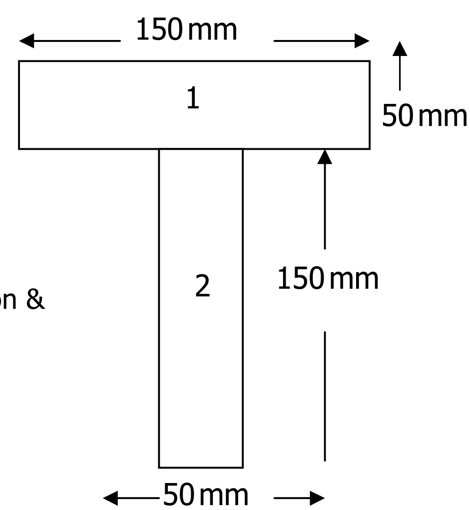
$$\Rightarrow Ixx = Iyy = \frac{Izz}{2} = \frac{1}{2} \times \frac{\pi}{32} \times (d)^4$$

$$= \frac{\pi}{64} \times d^4$$

CHAPTER-2
LONG QUESTION 7 MARKS

1. Find the moment of inertia of a T section with flange as 150 mm × 50 mm & web as 150 mm about x-x & y-y axis through the C.G. of the section (2015(w) 1(c),2018 2(d)

Ans. Rectangle (1) = 150 × 50 = 7500 mm^2



$$y_1 = 150 + \frac{50}{2} = 175mm$$

Rectangle (2) a_2 = 150 × 50 – 7500 mm^2

$$y_2 = 150 + \frac{50}{2} = 75mm$$

We know that distance between C.G. of the section & bottom of the web

$$y = \frac{a_1y_1 + a_2y_2}{a_1 + a_2} = \frac{(7500 \times 175) + (7500 \times 75)}{7500 + 7500}$$

M.I. about x-x axis = 125 mm

We also know that M.I. of rectangle (1) about an axis through its C.G. & parallel to x-x axis

$$IG_1 = \frac{150 \times (50)^3}{12} = 1.5625 \times 10^6 mm^3$$

& distance between C.G. of rectangle (1) & x – x axis

$$h_1 = 175 - 125 = 50mm$$

$$IG_1 = a_1h_1^2 = (1.5625 \times 10^6) + [7500 \times (50)]^{27}$$

$$= 20.3128 \times 10^6 mm^4$$

$$IG_2 = \frac{50(150)^3}{12} = 14.0625 \times 10^6 mm^4$$

Distance between C.G. of rectangle (2) & x-x axis

H_2 = 125 – 75 = 50 mm

M.I. of rectangle $IG_2 + a_2h_2^2 = (14.0625 \times 10^6) + [7500 \times (50)^2]$

About x-x axis = 32.8125×10^6 mm^4

Now M.I. of the whole section about x-x axis

Ixx = $(20.3125 \times 10^6) + (32.8125 \times 10^6)$

$= 53.125 \times 10^6 \text{ mm}^4$

M.I. about y-y axis

We know that M.I. of rectangle (1) about y-y axis

$$= \frac{50(150)^3}{12} = 14.0625 \times 10^6 \text{mm}^4$$

& M.I. of rectangle (2) about y – y axis

$$= \frac{50(50)^3}{12} = 1.5625 \times 10^6 \text{mm}^4$$

Now M.I. of the whole section about y-y axis

Iyy = $14.0625 \times 10^6) + (1.5625 \times 10^6)$

$= 15.625 \times 10^6 \text{ mm}^4$.

CHAPTER – 3

SHORT QUESTION

1. What is creep. 2015 (w) 4(a)

Ans. When loaded for long periods of time some material develop additional strain & are said to creep.

Chapter: 02

1. Define antisymmetrical & asymmetrical shape of an object 2015 1(a)

Ans: Antisymmetrical: It is a structural system can be effectives exploited for the purpose of analyzing structural systems.

Assymmetrical : It means the opposite, the two sides are different in some way.

CHAPTER -3

1. Hooke's law 2014 1(a)

Ans: It states when a material is loaded, within its elastic limit, the stress is proportional to the strain mathematically

$$\frac{\text{stress}}{\text{strain}} = E = \text{constant}$$

2. Define stress & strain 2014 2(a)

Ans: Stress : stress may be defined as the force per unit area is known as stress.

σ = P/A

P = load or force acting on the body

A = c/s area of the body

Strain :

Strain may be defined as the deformation per unit length i.e. strain.

$$\frac{\Delta \ell}{\ell}$$

E =

$\Delta\ell$ = change in length

ℓ= original length

Q.i) What is isotropic material ? 2013 1(f)

Ans: The material having same property in all direction is known as isotropic material

ii) What is proof stress 2013

Ans: It is also a common term, used for the maximum strain energy, which can be stored in a body (This happens when the body is stressed up to the elastic limit). The corresponding stress is known as proof stress.

iii) What is Ductile matetial & example 2013 (1)

Ans: The material which doesn't undergo undergradable deformation but fails how much is known as ductile bamboo.

CHAPTER – 3

SHORT QUESTION [2 MARKS]

1. Define ductility. 2014(w) 6(a), (2013 (w) 1 (c)

Ans: In material science ductility can be defined as the ability of a solid material to deform under tensile load. This is often characterized by the ability of material to be stretched in to a wire

2. What is Malleability ? 2014 6 (a)

Ans: The property by which material allow to be hammered in to thin sheets, load applied in compressive stress.

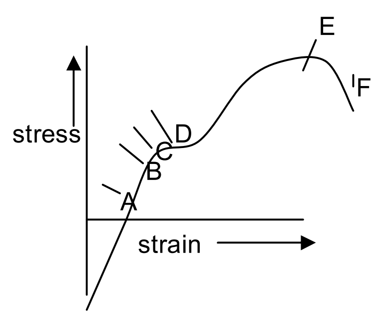
Ex- Cu, Ag , Aluminium

3. What is the factor of safety ? 2013 (w) 1 (b),2017 3(a)

Ans: It is the ratio of ultimate or yield strength in a component to be actual working stress.

→ It has no unit

4. What is ultimate stress ? 2015(w)(1-b)



Ans: A → proportional limit

B → Elastic limit

C → yield stress point

D → Beginning of strain hardening

E → Ultimate stress point

F → Breaking stress point

Ultimate stress → It is the maximum stress that a material can with stand while being stretched on pulled before failing or breaking point

4. Write the relation between three elastic constants 2013(w) 1(j)

$$E = \frac{9kc}{3k + c}$$

Soln.

Where E = young's modulus/ modulus of elasticity

K = Bulk modulus

C = modulus of rigidity

5. Define Bulk modulus. 5(a) 2012 (w)

Soln. It is defined as the ratio of normal shear stress (linear stress) to the volumetric strains it is denoted k.

$$K = \sigma_n/ev$$

6. Define poisson's ratoo 2.(a) 2017 (w),2018 1(c)

Soln. It is defined as the ratio of lateral strain to the linear strain, is known as poisons ratio

$$\frac{\text{lateral strain}}{\text{linear strain}} = \text{a constant}$$

It is denoted by 1/m. It has no unit

7. Define compressive stress 2007 (w) 1(a)

Soln. Compressive force per unit area is known as compressive stress

$\sigma_C = P/A$

Unit is N/mm^2

8. What is a brittle material ? 2007 (w) 1(b)

Soln. The material which does not goes any deformation is known as brittle material

Ex. Class

9. Define torsional rigidity. 2014(w) 1(i)

Soln. It is the towque required to produced a twist of 1 radian per unit length of the shaft.

$$\frac{T}{I_P} = \frac{c\theta}{l}$$

$$CI_P = \frac{Tl}{\theta}$$

Where I = least M.I.

E = Young's modulus of column materials

L= length of column

10. Define modulus of elasticity. 2013 (w) 4(a)

Soln. It is the ratio between tensile stress & tensile strain or compressive stress & compressive strain.

It is denoted by E. It is the same as Young's modulus

$$E = \frac{\sigma}{e}\left(\frac{\sigma t}{et} \text{ or } \frac{\sigma c}{ec}\right)$$

11. What is isotropic material. 2013 (w) 1(f)

Soln. The material which has some properties along all the direction of the material is known as isotropic material.

Ex. All Engg. Material

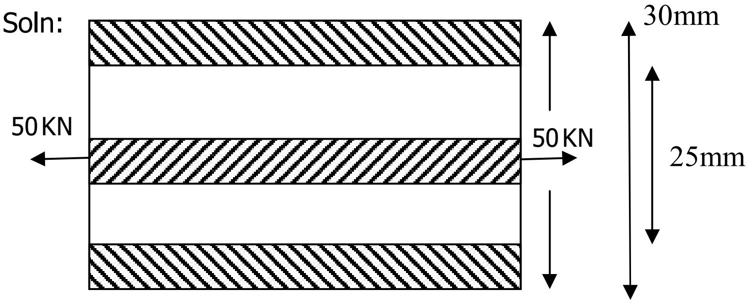
CHAPTER – 3 [6 MARKS]

1. A mile stress rod of 20 mm dia & 300 mm long is enclosed centrally inside a hollow copper to be of external dia 30 mm & internal dia. 25 mm. the ends of the rod & tube are braced together & the composite bar is subjected to an axial pull of 50 KN. Find out the stress developed in the rod & the tube 2013 (w) (6)

E_s= 200 GN/m^2

E_C= 100 GN/m^2

Soln:



D_s = 20 mm

Area of steel rod

$A_S = \pi/4\ (20)^2\ 314.16\ mm^2$

Area of copper tube.

$A_C = \pi/4\ (30^2 — 25^2) = 216\ mm^2$

$E_S = 200\ GN/m^2 = 2010 \times 10^3\ N/mm^2$

$E_C = 100\ GN/m^2 = 100 \times 10^3\ N/mm^2$

$P = 50\ KN = 50 \times 10^3\ N$

Let σ_S & σ_C be the stress developed in steel & copper respectively

$$\frac{\sigma_s}{E_s} = \frac{\sigma_C}{E_C}$$

$$\sigma_S = \frac{E_s}{E_c}\sigma_c = \frac{200 \times 10^3}{100 \times 10^3} \times \sigma_c = 2\sigma_c$$

Total load = load in steel + load in copper

$50 \times 10^3 = \sigma_S A_S + \sigma_C A_C$

$\Rightarrow 50 \times 10^3 = 2\sigma_C \times 314.16 + \sigma_c \times 216$

$$\Rightarrow \sigma_c = \frac{50 \times 10^3}{2 \times 314.16 + 216} = 59.11\,N/mm^2$$

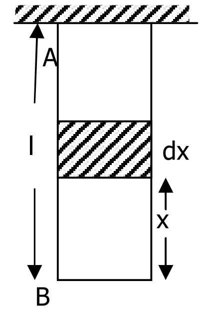
$$\sigma_c = 2\sigma_c 2 \times 59.22$$

$$= 118.44\,N/mm^2$$

2. Derive the expression of deformation of a body due to its self weight 2015(w) 2

Soln. Consider a bar, AB having freely under its own weight

Let l = length of the bar



A = C/s area of bar

E = Young's modulus for the bar material

W = Specific out of the bar material

Now consider a small section dx of the bar at a distance x from B

Wt. of the bar for a length of x

P = Wax

$\therefore$ Elongation of the small section of the bar, due to wt of the bar for a small section of length x

$$= \frac{Pl}{AE} = \frac{(WA)dx}{AE} = \frac{wx.dx}{E}$$

Total elongattion of the bar

$$\Delta l = \int_0^l \frac{wx.dx}{E}$$

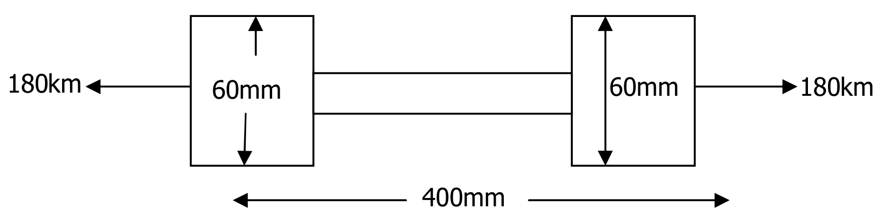
$$= \frac{w}{E}\int_0^l x.dx$$

$$= \frac{w}{E}\left[\frac{x}{2}\right]$$

$$\therefore \Delta l = \frac{wl^2}{2E} = \frac{Wl}{2AE} \qquad (\because w.wAL)$$

$$\rightarrow \Delta l = \frac{Wl}{2AE}$$

3. A bar shown in fig. is subjected to a tensile load of 180 KN. If the stress on the middle portion is limited to 160 N/mm^2, determine the diameter of the middle portion & also find the length of the middle portion of the total elongation of the bar is to be 0.25 mm ?2018 3©



Soln. Stress of middle portion σ = 160 N/mm^2.00 kN

Area required for middle portion

$$A = \frac{load}{stress} = \frac{180 \times 10^3}{160} = 1125mm^2$$

Let 'd' be the dia of middle portion

$$\Rightarrow \frac{\pi}{4} \times d^2 = 1125$$

$$\Rightarrow d = 37.85mm$$

Let the length of middle portion be x mm, stress in the end

$$\text{portion}(\sigma) = \frac{180 \times 10^3}{\left(\frac{\pi}{4} \times 60^2\right)}$$

$$= 63.66\,N/mm^2$$

The elongation produced in the bar is 0 mm

CHAPTER – 3 [5 MARKS]

1. A bronze specimen has modulus of rigidity 0.98×10^3 N/mm^2 & modulus of elasticity 1.392×10^3 N/mm^2. Determine the poison's ratio of the material 2014 4(c)

Ans: Given data

Modulus of rigidity c = 0'598 $\times$ 10^3 N/mm^2

Modulus of elasticity E = 1.392 $\times$ 10^3 N/mm^2

μ or L/m = poison's ratio of the material

We know that modulus of rigidity (c)

$$c = \frac{mE}{2(m+1)}$$

$$\Rightarrow 0.598 \times 10^3 = \frac{m \times 1.392 \times 10^3}{2(m+1)}$$

$$\Rightarrow 1.196 \times 10^3 m + 1.196 \times 10^3 = 1.392 \times 10^3 m$$

$$\Rightarrow 1.196 \times 10^3 = 0.196 \times 10^3 m$$

$$\Rightarrow m = \frac{1.196 \times 10^3}{0.196 \times 10^3}$$

$$= 6.1 = 6$$

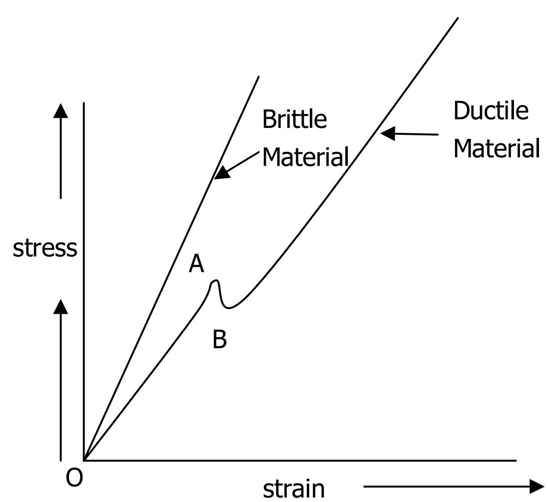
$$\Rightarrow \frac{1}{m} = \frac{1}{6}$$

2. Define stress strain relationship for ductile material 2014 2(b),2018 2(e),2017 2(b)

Ans: Consider a ductile material specimen of uniform section, subjected to a gradually increasing push

If we plot the stress along the corresponding strains along the horizontal axis & draw a curve passing through the vicinity of all such points

$\rightarrow$ 0 to A is a straight line, which represents that the stress is proportional to strain

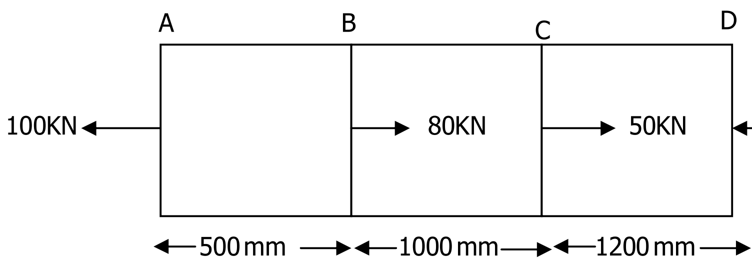


$\rightarrow$ up to elastic limit , all the metals have approximates the same modulus of elasticity in compression

→ If the specimen is stressed beyond the elastic limit, the strain increases more quickly than the stress.

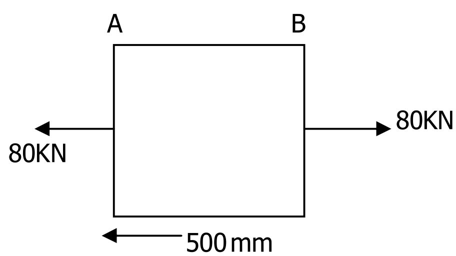
CHAPTER : 3
[LONG QUESTION 5 MARKS]

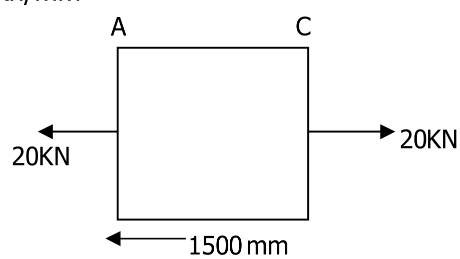
1. A brass bar having C/S area of 500 mm^2 is subjected to axial forces as shown in fig. Find the total elongation of the bar. Take E = 80 GPa. 2015(w) 3(b),2018 2(c)

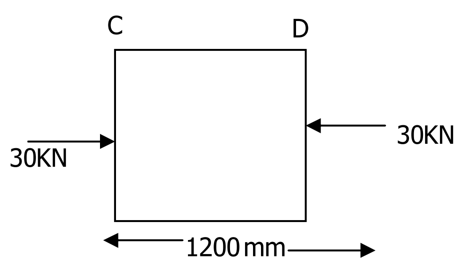


Ans: Given C/s area (A) = 500 mm^2

Modulus of elasticity (E) = 80 C/a = 80 kn/mm^2







We know that elongation of the bar

$$\delta l = \frac{1}{AE}\left(p_1 l_1 + p_2 l_2 + p_3 l_3\right)$$

$$= \frac{1}{500 \times 80}\left[(80 \times 500) + (20 + 1500) - (30 \times 1200)\right] mm$$

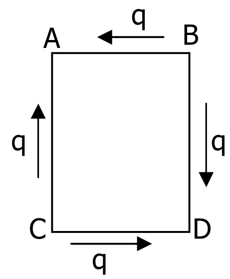
$$= 0.85 mm$$

5. Derive the relationship between the elastic constant.2017 3©

Ans: Consider a square block ABCD off side 'a' and thickness unity.

Let the block be subjected to shear stresses of intensity q.

Due to there stresses the block will be subjected to a deformation such that the diagonal AC is elongated and the diagonal BD is shortened.

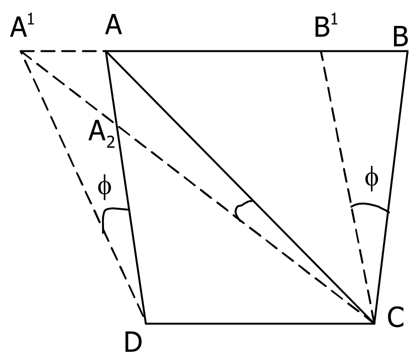


Strain in the length of diagonal AC

$$=\frac{q}{E}+\frac{q}{mE}-\frac{q}{E}\left(1+\frac{1}{m}\right)..................(1)$$

Let the block ABCD deform to the position A,B,C,D through the angle Q.

Increase in length of the diagonal AC = A_1C – AC



1st AA_1 be perpendicular to A_1C since single ACA_2 is very small, AC = A_3C

Increase in length of the diagonal AC

$=CA_1 - CA_2 = A_1A_2$

$AA_1 \cos (AA_1 A_2)$

But the angle AA_1A_2 is nearly equal to BAC = 45^o

Increase in length of diagonal AC

$AA_1 \text{ Cos } 45^o = \frac{AA_1}{\sqrt{2}}$

$$\text{But shear strain} = \theta = \frac{AA_1}{AD} = \frac{AA_1}{a}$$

$$AA_1 = \theta a$$

$$\text{Increase in length of diagonal } AC = \frac{a\theta}{\sqrt{2}}$$

$$\text{But } AC = a\sqrt{2}$$

$$\text{Strain in } AC = \frac{\text{increase in length}}{\text{original length}}$$

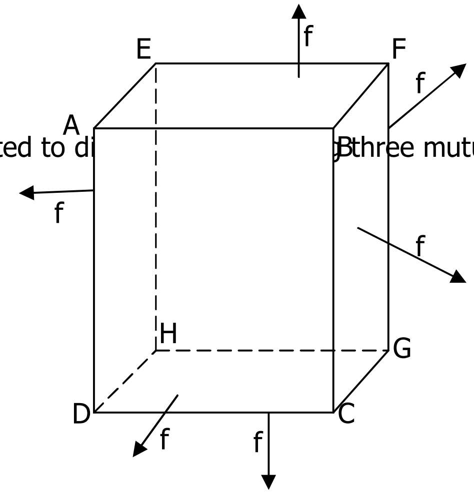
$$= \frac{a\theta\sqrt{2}}{a\sqrt{2}} = \frac{\theta}{2} \text{ ....(2)}$$

From (1) and (2) we have

$$\frac{\theta}{2} = \frac{q}{E}\left(1 + \frac{1}{m}\right)$$

$$E = 2C\left(1 + \frac{1}{m}\right) \text{ ....(3)}$$

Let us consider a cube ABCDEFGH subjected to di ... three mutualluy perpendicular directions.



$$\text{Strain in } AB = \frac{f}{E} - \frac{f}{mE} - \frac{f}{mE}$$

$$= \frac{f}{E}\left(1 - \frac{2}{m}\right)$$

Original volume of the cube

$$v = a^3$$

$$\Rightarrow \delta v = 3a^2\delta a$$

$$\text{Volumetric strain } e_v = \frac{\delta v}{V} = \frac{3a^2\delta a}{a^3} = 3\frac{\delta a}{a}$$

$$e_v = 3 \times \text{strain in } AB = 3\frac{f}{3}\left(1 - \frac{2}{m}\right) \text{ ....(5)}$$

$$\text{Bulk modulus } k = \frac{f}{e_v} = \frac{f}{3\frac{f}{3}\left(1 - \frac{2}{3}\right)}$$

$$\therefore E = BK\left(1 - \frac{2}{3}\right)$$

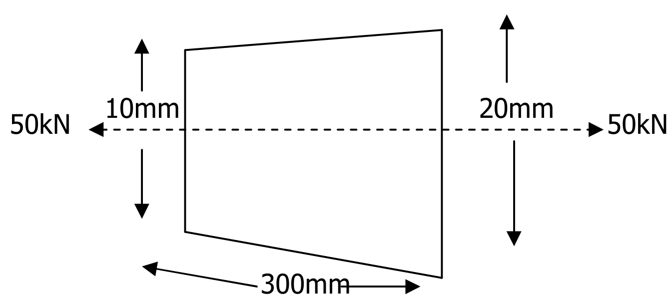
$$\text{from equation (3) } 1 + \frac{1}{m} = \frac{E}{2C}$$

$$\text{and equation (4), } 1 - \frac{2}{m} = \frac{E}{3K}$$

Cancale $\frac{1}{m}$, in abive two equations,

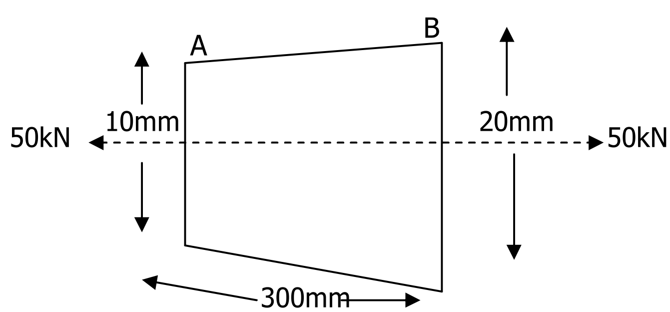
$$\text{we have } 3 = \frac{E}{C} + \frac{E}{3K}$$

6.



Find the elongation of the Lapering between 1f $E_S = 2 \times 10^5$ N/mm^2 2014 5(b)

Ans:



Given data, $l_1 = 300\,mm$

$d_1 = 10\,mm$

$d_2 = 20\,mm$

$p_2 = 50\,KN = 50 \times 10^3 N$

$E = 2 \times 10^5 N/mm^2$

Elongation of the lapering bar AB

$$\Rightarrow \quad \Delta lAB = \frac{4P_{AB}L_{AE}}{\pi E d_1 d_2}$$

$$\Rightarrow \quad \frac{4 \times 50 \times 10^3 \times 300}{\pi \times 2 \times 10^5 \times 10 \times 20}$$

$$= \quad \frac{15}{\pi \times 10} = 0.477$$

 0.5 mm

Total extension of the rod

Extension of end portion & extension of middle portion

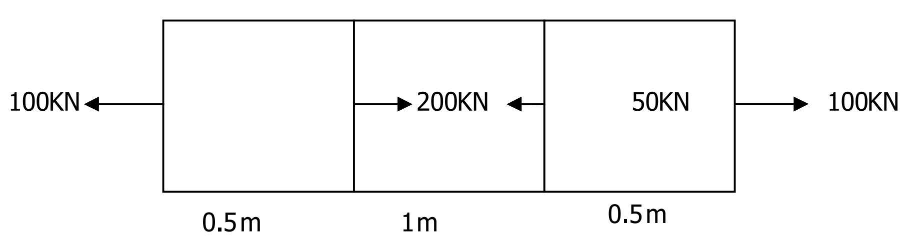
$\Rightarrow$ 0.25= σ/E $\times$ (400-x) + σ/E – x

$\Rightarrow$ x = 254.68 mm. (Ans)

CHAPTER 3

LONG QUESTIONS [6 MARKS]

1. A slender bar of 100 mm^2 C/S is subjected to loading as shown in the fig., if the modulus of elasticity is 200×10^9 pascal, then what is the elongation produced in the bar ? 2013 (w) 2(b)



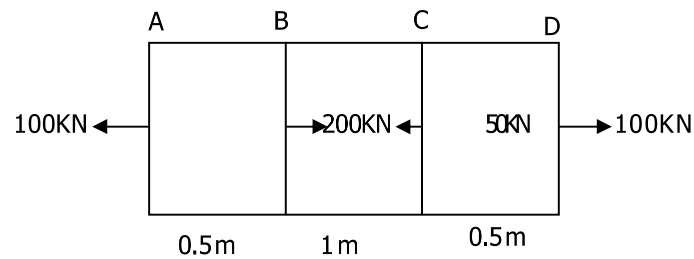
Soln. Given data

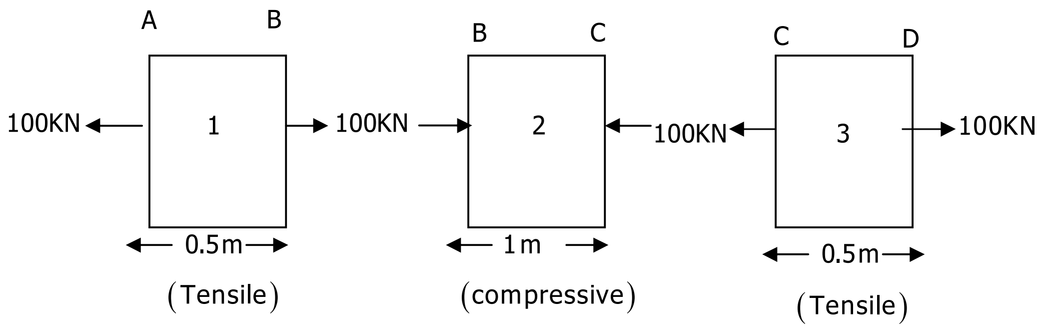
$A = 100\ mm^2$

$\in = 200 \times 10^9$ pascal

$\Delta l = ?$

$E = 200 \times 10^9\ N/mm^2$





$$\therefore \Delta l = \frac{p_1 l_1}{A_1 E_1} - \frac{p_2 l_2}{A_2 E_2} + \frac{p_3 l_3}{A_3 E_3} (\because A = const., E = const.)$$

$$\frac{I}{AE}(p_1 l_1 - p_2 l_2 + p_3 l_3)$$

$$= \frac{1}{100 \times 200 \times 10^9}\left(100 \times 10^3 \times 0.5 \times 10^3 - 100 \times 10^3 \times 1 \times 10^3 + 100 \times 10^3 \times 0.5 \times 10^3\right)$$

0 mm

The elongation produced in the bar is 0 mm.

CHAPTER -3 [7 MARKS]

1. A rod dia. 40 mm & length 6 m has an allowable tensile stress of 120 N/mm^2. If the young's modulus of the rod material is $2.1 \times 10^5\ N/mm^2$. Determine the 2017

(i) Maximum tensile load, that can be loaded apply to the load

(ii) Strain energy stored on the road

Given Data :

d = 40 mm

$l = 6\ m = 6 \times 10^3$ mm

tensile stress, 6 = 120 N/mm^2

$E = 2.1 \times 10^5\ N/mm^2$

Maximum tensile load in the rod

$\sigma = P/A$

$\Rightarrow P = \sigma \times A = 120 \times \pi/4 \times (40)^2 = 150.796 \times 10^3$ N

$\therefore$ Strain energy stored in the rod

$$U = \frac{\sigma^2}{2E} \times V$$

$$\text{Vol. of the rod}, V = l \times A$$

$$= 6 \times 10^3 \times \frac{\pi}{4} \times (40)^2$$

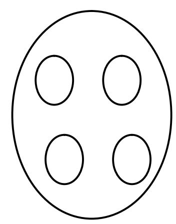
$$= 7.53 \times 10^6 \, mm^3$$

$$U = \frac{\sigma^2}{2E} \times V = \frac{(120)^2}{2 \times 2.1 \times 10^5} \times 7.53 \times 10^6 = 258.171 \, KN \times mm$$

2. A reinforced concrete column of circular section havind dia 500 mm has 4 steel rods of 20 mm dia . It carries a load of 850 KN. Find out the stresses in steel & concrete. Assume modular ratio of steel & concrete as 18.2015

Soln. Dia of the section , D = 500 mm

Total area of section $A = \frac{\pi}{4} . D^2$



$$= \frac{\pi}{4} . (500)^2$$

$$= 196349.54 \, mm^2$$

Area of the steel, $A_s = \frac{\pi}{4} \times (20)^2 \times 4$

$$= 1256.64 \, mm^2$$

Area of concrete, $A_c = A - A_s = 195092.9 \, mm^2$

Let σ_s/σ_c be the stresses in steel & concrete respectively.

Strain in concrete = strain in steel

$$\frac{\sigma_s}{E_s} = \frac{\sigma_c}{E_c}$$

$$\therefore \sigma_s = \frac{E_s}{E_c} \times \sigma_c \left(\frac{E_s}{E_c} = 18 \right)$$

Total load = load on steel + load on concrete

$\Rightarrow 850 \times 10^3 = \sigma_s A_s + \sigma_c A_c$

$\Rightarrow 850 \times 10^3 = 18 \times \sigma_c \times 1256.64 + \sigma_c \times 19509$

$\Rightarrow \sigma_c = 3.9 \, N/mm^2$

$\sigma_s = 18 \, \sigma_c$

$= 18 \times 3.90 = 70.2 \, N/mm^2$

2. A steel rod 30 mt. long is at a temp of 25°C. find the temp. stress produced when

(i) the expansion of the rod is prevented

(ii) rod is permitted to expand by 5 mm

Ans: Length of steel rod (l) = 30 mt.

Temp (t) = 25°C

Assume $E = 2 \times 10^5 \, N/mm^2$, $\alpha = 12 \times 10^{-6}$

(i) The expansion of the rod is prevented the stress in the rod

$\sigma = \alpha 7l$

$=12 \times 10^{-6} \times 25 \times (2 \times 10^5)$

$= 60\ N/mm^2$

(ii) Rod is permitted to expand by 5 mm

The stress in the rod

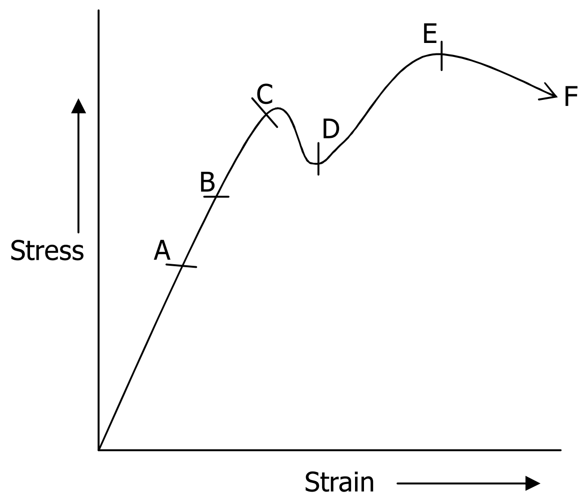
$$\sigma = \left(\alpha t - \frac{\Delta l}{l}\right)E$$

$$= \left[12 \times 10^{-6} \times 25 - \frac{5}{30 \times 10^3}\right] \times 2 \times 10^5$$

$$= 26.66\,N/mm^2$$

4. Draw the stress strain diagram for mild steel specimen showing the salient points.2018 2(e)

Soln.



When the mild steel bar of uniform c/s is subjected to a tensile test.

→ In case of mild steel in the initial stages strain is proportional to stress till the limite proportionality. A is reached. In this range material obeys Hooke's law

→ 'B' the material behaves in an elastic manner. Beyond this limit the rate of increase in strain will be more till the point C is reached.

→ Where the material undergoes additional strain without increase in stress & undergoes plastic deformation. This is known as yield point & the stress is known as yield stress.

→ Therefore there are two yield points, the upper C & D.

→ After yielding any further increase in stress will cause considerable increase in strain & curve rise till point E is reached, which is known as ultimate stress.

→ At this stress the bar will develop a neck & the stress will decrease & the bar will break at point 'F'.

CHAPTER – 4
SHORT QUESTION [2 MARKS]

1. Define point of contra flexture. 2013(w) 1c,2017 5(a)

Ans: the point at which the bending moment touches the zero line & changes the sign, i.e. known as point of contra flexure.

2. Define shear force. 2013 (w) 2014 3(a),2018 1(i)

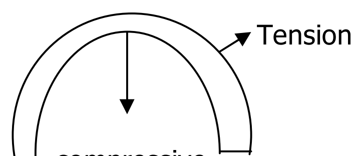
Ans: Shear force at any seen of a beam, If the algebraic sum of the vertical forces either left or right of the section.

3. Define Bending moment 2013 (w) 2014 3(a),2018 1(i)

Ans: B.M. at any section of a beam, if the algebraic sum of moments of vertical forces either left or right of a section.

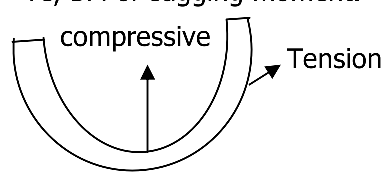
4. What is hugging moment . 2015(w)

Ans: If the bending moments bends the beam in a such way compression is in bottom & tension at top, that this type of bending moment is '—ve' BM or hugging moment

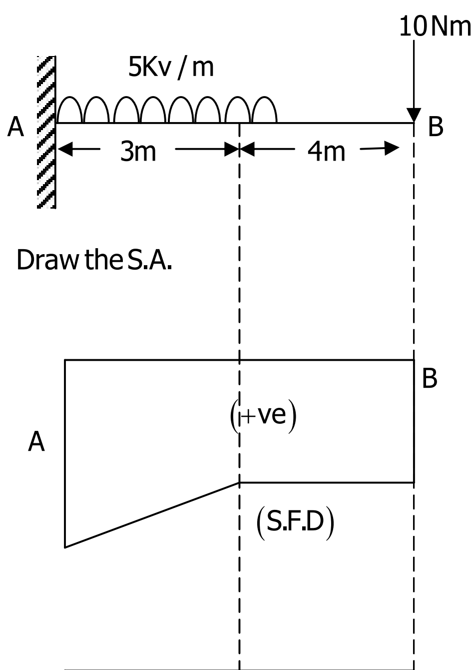


5. Define sagging moment. 2013 (w)

Ans: If the bending moments bends the beam in a such way that compression is in a top & tension is in bottom, that this type of B.M. is +ve, BM or sagging moment.



CHAPTER – 4 5 MARKS 2018 2(a),2017 5(c)



S.F. calculation

S.F. at B = 10 NM

S.F. at R.H.S. of C = 10 NM

S.F. at C = 10 NM

S.F. at R.H.S. of A = 10 + 5 × 3 =25 NM

S.F. at A = 25 NM

B.M. Calculation

B.M. at B = 0

B.M. at c = 10 × 4 = 40 NM

B.M. at A = 10 × 7 — 5 × 3 × 3/2

$$= 70 - \frac{45}{2} = \frac{95}{2} = 47.5NM$$

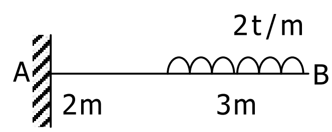
1.

CHAPTER – 4

[6 MARKS]

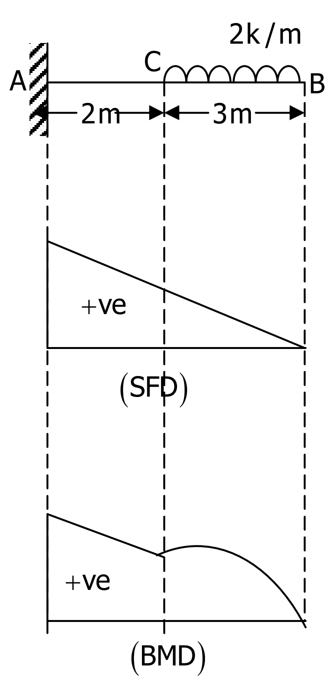
1. Draw the S.F. & B.M. dig. For the beam is shown below 2013 (w) 2(a)

Soln. S.F. calculation



S.F. at B = 0

S.F. at R.H.S. of C = 2 × 3 = 6 t.



BF at C = 2 × 3 = 6t

SF at RHS of A = 6t

SF at A = 6t

BM Calculation

B.M. at B = 0

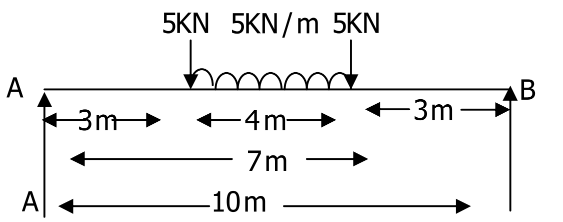
B.M. at C = 2 × 3 × 3/2 = 9 tm

B.M. at A = 2 × 3 ×(3/2 + 2) =21 tm

CHAPTER – 4

LONG QUESTIONS [8 MARKS]

1. A beam of length 10 m is simply supported & carries point loads of 5 KN each on a distance of 3 M & 7 M from the left support & also v.d.l of 5 KN/M between the point loads. Draw S.F.D. & BMD for the beam.2017 3(b)

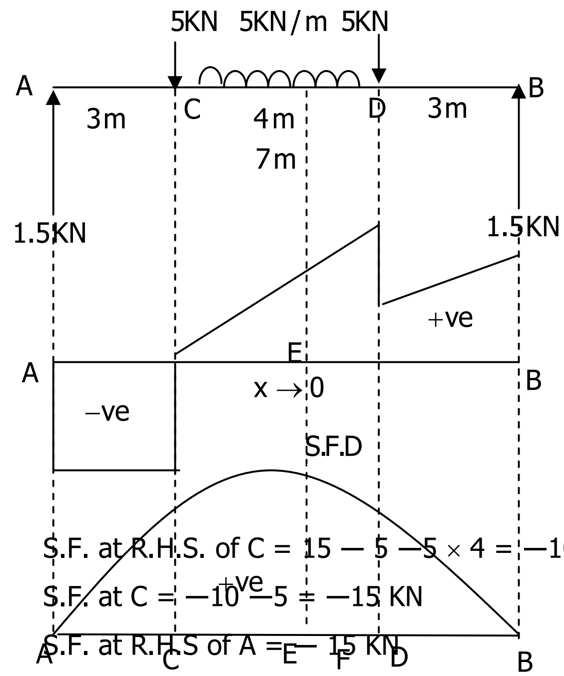


Reaction calculation

Taking moment of A

$R_0 \times 10 - 5 \times 7 - 5 \times 3$

$-5x\ 4 \times (4/2 + 3) = 0$



$\Rightarrow R_b \times 10 - 35 - 15 - 35 \times 6.5 = 0$

$\Rightarrow R_b = 15$ KN

$R_a + R_b = 5 + 5 + 5 \times 4 = 30$

$R_a = 15$ KN

S.F. calculation

S.F at B = 15 KN

S.F. at R.H.S of D = 5 KN

S.F. at D = 15 — 5 = 10 KN

S.F. at R.H.S. of C = 15 — 5 — 5 × 4 = —10 KN

S.F. at C = —10 —5 = —15 KN

S.F. at R.H.S of A = — 15 KN

S.F. at A = —15 + 15 = 0

Δ ceo $\simeq$ Dep

$$\frac{ce}{oe} = \frac{De}{Dp}$$

$$\frac{4-x}{10} = \frac{x}{10} \Rightarrow 10x = 40 - 10x$$

$$x = 2 \sim$$

B.M. calculation

B.M. at B = 0

B.M. at D = 15 × 3 = 45 KNM

B.M. at e = 15 × 2 – 5 × 2

—5 × 2 ×(2/2) = 55 KNM

B.M. at c = 15 × 7 — 5 × 4 —5 × 4 × 4/2

105 — 20 — 40 = 45 KNM

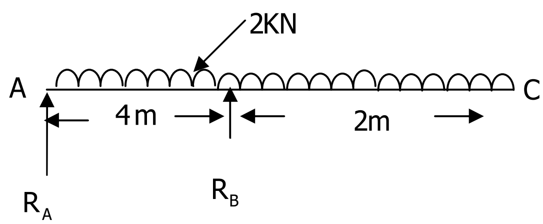
B.M. at A = 125 × 10 — 5 × 7 — 5 × 3 — 5 × 4 × (4/2 + 3)

= 150 — 35 —15 — 100 = 0.

02. Calculate and draw the S.F. & B.M. diagram for the overhanging beam carrying udl of 2 KN/m over the entire length ABC(6 m). BC; the right head side overhanging portion is of 2m long, ABS.S portion is 4m long. Also locate the point of controflexue

2016 (w) (4)

Ans.



Given

L = 6 m

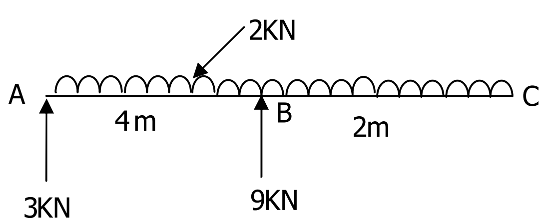
W= 2 KN/m

Reaction calculation

Taking moment at 'A'

$R_b \times 4 - 2 \times 6 \times 6/2 = 0$

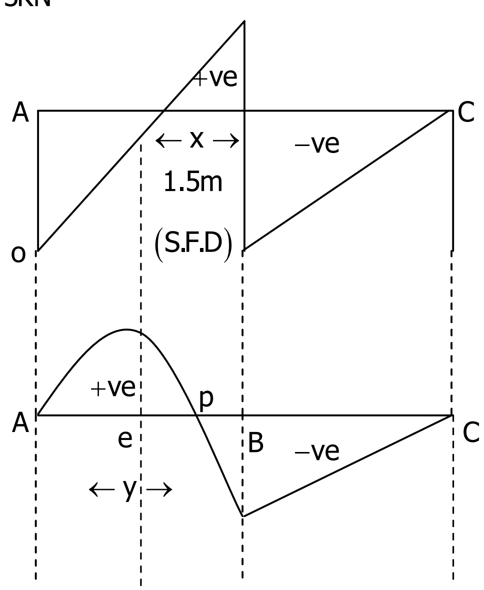
R_b = 9 KN.



$R_a + R_b - 2 \times 6 = 0$

$\Rightarrow R_a + R_b = 12$

$\Rightarrow R_a = 3$ KN



S.F. Calculation

S.F. at C = 0

S.F. at R.H.S. of B = 2 × 2 = 4 KN

S.F. at B = —2 × 2 + 9 = 5 KN

S.F. at R.H.S of A = —2 × 6 + 9 = 3 KN
at A = 0

$\Delta AeO \simeq BeP$

$$\text{B.M. at A} = 9\times 4 - 2\times 6\times \frac{6}{2} = 0$$

Point of centra flexure

we know that B.M. at 'P'

B.M. at e =

$$-2\times 3.5\times \frac{3.5}{2} + 9\times 1.5 = 1.25\,\text{KNm}$$

$$M_p = 3\times y - 2\times y\times \frac{y}{2} = 0$$

$$\Rightarrow y = 3m$$

$$\frac{Ae}{AOc} = \frac{Be}{Bp}$$

$$\frac{4-x}{3} = \frac{x}{5} \Rightarrow 3x = 20 - 5x$$

$$8x = 20$$

$$x = 1.5m$$

B.M. calculation

B.M. at C = 0

$$\text{B.M. at B} = -2\times 1.5\times \frac{1.5}{2} = -2.25\,\text{KNm}$$

B.M at e=-2×3.5.3.5/2+9 ×1.5=1.25KNM

B.M at A= -9×4-2×6×6/2=0

Point of contraflexure

We know that B.M at p

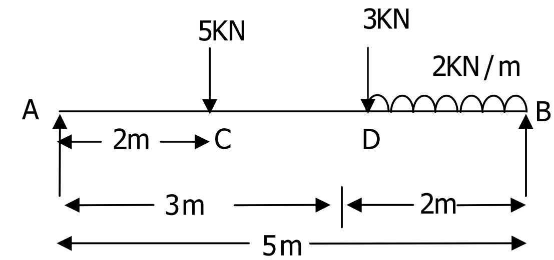
M_p=3×y-2×y×y/2=0

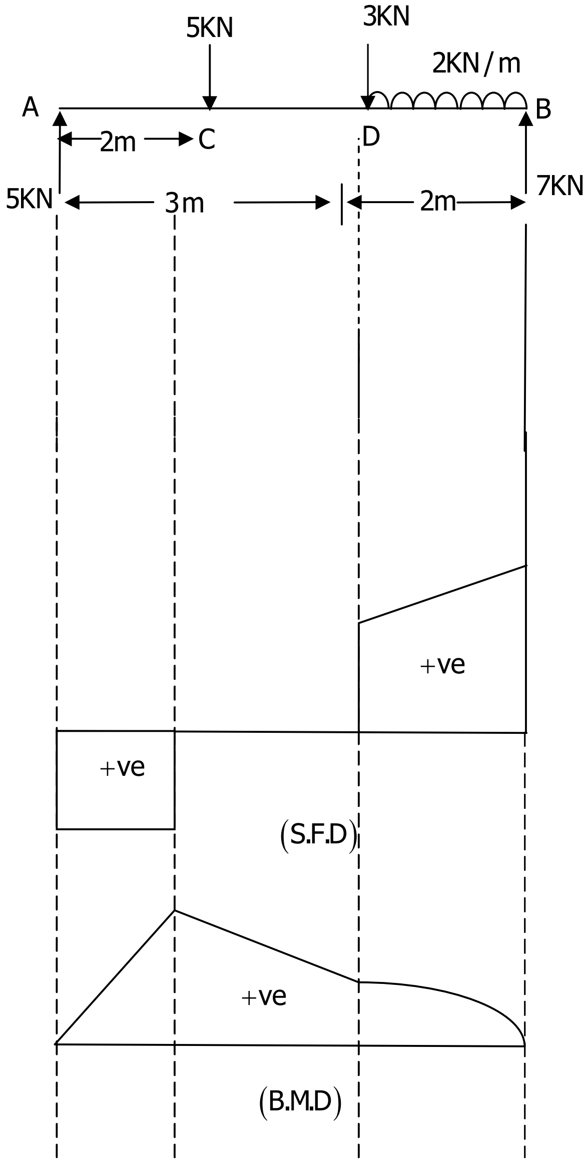
Y=3m

CHAPTER- 4

1. A beam of length 5 m is Δ/s at the ends, carries a udl of 2 KN/m throughout the length & two concentrated loads of 5 KN & 3 KN at a distance of 2 m & 3 m from the left end. Calculate S.F & B.M.D., 2014 2(c)

Ans:





Reaction calculation

Taking moment at 'A'

$\sum Ma = 0$

$$R_b \times 5 - 3\times 3 - 5\times 2 - 2\times 2\left(\frac{2}{2}+3\right) = 0$$

$$R_b = \frac{35}{5} = 7KN$$

$R_a + R_b - 5 - 3 - 2\times 2 = 0$

$R_a + R_b = 12$

$R_a = 5KN$

S.F. calculation

S.F. at $B = 7KN$

S.F. at R.H.S. of $D = 7 - 2\times 2 = 3KN$

S.F. at $D = 3 - 3 = 0$

S.F. at R.H.S of $C = 0$

at $C = 0 - 5 = -5KN$

S.F. at $A = -5 + 5 = 0$

B.M. calculation

B.M. at $B = 0$

$$\text{B.M. at } D = 7\times 2 - 2\times 2\times\left(\frac{2}{2}\right)$$

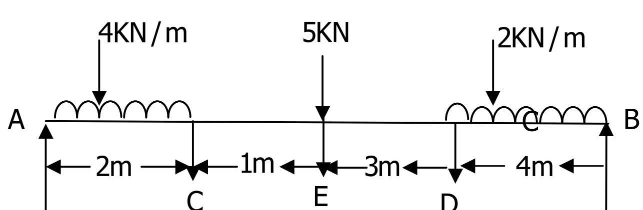
$= 14 - 4 = 10KNm$

$$\text{B.M. at } C = 7\times 5 - 2\times 2\times\left(\frac{2}{2}+3\right) - 3\times 3 - 5\times 2$$

$= 35 - 16 - 9 - 10 = 0$

CHAPTER-4 [7 MARKS]

1. A s/s beam AB, 10 m long is loaded as shown in fig. Construct the S.F. & B.M.D. for the beam & find the position & valve of maximum B.M. 2015(w)3(c)



$\text{Re action Calculation}$

$\text{Taking Moment at 'A'} \sum Ma = 0$

$R_b \times 10 - 2 \times 4\left(\frac{4}{2} + 6\right) - 5 \times 3 - 4 \times 2 \times \frac{2}{2} = 0$

$\Rightarrow R_b = 8.7KN$

$R_a = \text{Total force} - R_b$

$R_a + R_b - 2 \times 4 - 5 - 4 \times 2 = 0$

$\Rightarrow R_a + R_b = 21KN$

$R_a = 21 - 8.7 = 12.3KN$

S.F. calculation

S.F. at B = 8.7 KN

S.F. at R.H.S.ofD= 8.7 – 2 × 4 =.7KN

S.F. at D = .7 Kn

S.F. at R.H.S. pf E= .7 KN

At E = .7 – 5 = -4/3 KN

S.F. at R.H.S. of C = -4.3 KN

At C = - 4.3 KN

S.F. at R.H.S. of

A = -4.3 – 4 × 2, -12.3 KN

S.F. of A = -12.3 + 12.3 = 0

B. M. Calculation

B.M. of B = 0

B.M. of D=8.7 ×4.2×4×(4/2)

=18.8 KNm

B.M. at E=8.7×7-2×4(4/2+3)

=20.9 KNm

B.M. at C=8.7×8—2×4(4/2+4)—5×1

=16.6 KNm

B.M. of A = 8.7 ×10—2×4×(4/2+6)

—5×3—4×2×2/2=0

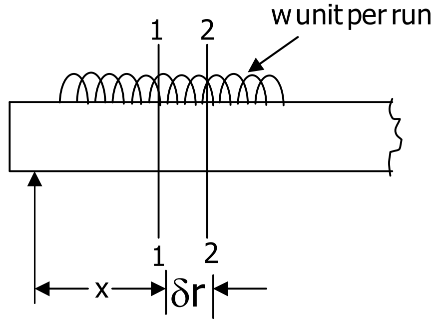
2. Derive the relationship between the rate of loading S.F. and B.M. at a section of beam. 2013 Q 2(c)

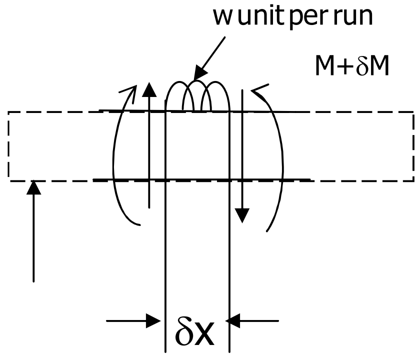
Ans: Figure shows a beam subjected to an external loading. Consider the equilibrium of the portion of the beam between sections 1-1 and 2-2, dx apart at a distance × from the left support.

Let the shear force at the sections 1-1 and 2-2 be S and S + δS respectively.

Let the bending moments at the sections 1-1 and 2-2 be M and M + δM respectively.

The forces and moments keeping the portion of the beam between the sections 1-1 and 2-2 in equilibrium consist of the following.





i) Upward force S at section 1-1

ii) Download force s & δs at section 2-2

iii) Download load wδx

iv) Moments M & (M + δM)

Resolving forces vertically δ + δs + wδx = s

8s + wδx = 0

Taking moments M + δM = M + s

δM = s. sx

$$\therefore \frac{\delta M}{\delta x} = S$$

i.e. the role of change of B.M. equal to the S.F.
similarly from equation (1)
δs = wδx=0

$$\therefore \quad \frac{\delta s}{\delta x} = 0$$

i.e. the rate of change of S.F. equals the rate of loading.

CHAPTER – 5
SHORT QUESTIONS [2 MARKS]

1.i) Write the equation flexural rigidity of a beam. 2015 (w) 5(a),2018 1(k)

Ans. The equation of flexural rigidity of a beam is $\frac{i}{\phi}$ cor Norg

Where i = shear stress

ϕ = shear strain

C = constant Nw as modulus of rigidity.

ii). What is a short column & long column 2013 1(b)

Ans. All short columns failed by crushing load but long columns failed due to criping load. The value of bussing load is lower long column & relatively high for short column.

2. Which of the following shafts of the same cross-sectional area resists more torque ? Hollow shaft or solid shaft 2009(w) 1(g)

Soln. The torque of a solid shaft

$$T = \frac{\pi}{16} \times \iota \times D^3 Nmm$$

The torque of a hollow shaft

$$T = \frac{\pi}{16} \times \iota \times \left(\frac{D^4 - d^4}{D} \right) Nmm$$

3. Define moment of resistance 2007(w) 1(f)

Soln. If a beam subjected an one side of the neutral axis there are compressive stress & on the other there are tensile stresses. These stresses from a couple, where moment must be equal to the external moment. The moment of this couple, which resists the external bending moment, is k/w as moment of resistance.

4. What is meant by principal plane ? 2015(w)

Soln. At any point in a strained materials, there are three planes, mutually $\perp$r to each other, which carry direct stress only & no shear stress. These planes are known as principal plane.

5. What is the tangential stress on a plane, inclined at an angle θ with the principal plane 2017(w) 1(h)

Soln. Tangential stress,

$$\delta_1 = \frac{\delta_1 - \delta_2}{2} \sin 2\theta$$

$\therefore$ where δ_1 & δ_2 are principal stresses

6. Define principal & principal stress 2015 (w),2018 1(h)

Soln. At any point in a strained material, these are three planes , mutually $\perp$r to each other, which carry direct stresses only & no shear stress. These planes are known as principal plane. The stresses on these planes known as principal stress.

7. Define parallel axis theorem with equation stating each them 2015(w),2018 1(d)

Soln. The M.I. of lamina about any axis in the plane of the lamina equals the sum of MI about parallel centrodial axis in the plane of the lamina & product of the area of the lamina & square of distance between the two axes

$I_{AB} = I_{GC} + Ah^2$

$\therefore$ I_{GG} = MI about centrodial fibs.

h = distance between the two axes

8. Define neutral axis & surface 2013(w) 1(c)

Soln. It is an imaginary pline, which divides the c/s of a beam into the tension & compression zone on the opposite sides of the plane

9. Define angle of obliquity. 2017(w) 1(b)

Soln. The angle that the line of action of resultant stress makes the normal to the plane is called the obliquity

Obliquity, $\theta = \tan^{-1} (\delta t/\delta n)$

δt= tangential stress

δn = norms stress

CHAPTER – 5

1. A cast iron hollow column of external dia 10 cm & internal dia 8 cm & length 2.2 ml using Rankine's formula, determine the cripping load when both ends are fixed. Take F_e = 6000 kg/cm^2 & Rankine's constant 1/1600. 2014 6(c)

Soln. Given data extra D_1 = 10 cm

Internal dia , d_1 = 8 cm

Length , l = 2.2 m = 220 cm

P_e = 6000 kg/cm^2

Rankine's constant a = 1/1600

Rankine's cripping load

We know that area of the column section

$$A = \frac{\pi}{4}\left(D_1^2 - d_1^2\right)$$

$$= \frac{\pi}{4}\times\left(10^2 - 8^2\right) = 28.27\,mm^2$$

$$\&\ \text{least radius or gyration is} = \sqrt{\frac{I}{A}}$$

$$\text{Maximum of the column sec tion } I = \frac{\pi}{64}\left(D^4 - d^4\right) = \frac{\pi}{64}\left(10^4 - 8^4\right) = 289.8L$$

Since the column is both ends are fixed therefore effective length of the colukn.

$$l_e = \frac{l}{2} = \frac{220}{2} = 110cm$$

CHAPTER – 5

LONG QUESTIONS [5 MARKS]

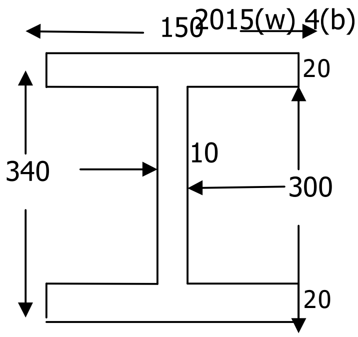
1. An I sections with rectangular ends, has the following dimensions

   Flanyes = 150 mm × 20 mm

   Web = 300 mm× 10 mm

   Find the maximum shearing stress developed in the beam for a s.f. of 100 KN.

2015(w) 4(b)



Ans: Given flange width (B) = 150 mm

Flange thickness = 20 mm

Depth of web (d) = 300 mm

Width of web = 10 mm

Overall depth of the section (D) = 340 mm

Shearing force (F) = 100 KN = 100×10^5 N

We know that moment of inertia (M.I.) of the I section about its centre of gravity and parallel to x-x axis

$$I_{XX} = \frac{150 \times (340)^3}{12} - \frac{140 \times (300)^3}{12} mm^4$$

$$= 176.3 \times 10^6 \, mm^4$$

& maximum shearing stress.

$$\tau max = \frac{F}{Ib}\left[\frac{B}{8}\left(D^2 - d^2\right) + \frac{bd^2}{8}\right]$$

$$= \frac{100 \times 10^3}{176.3 \times 10^6 \times 10}\left[\frac{150}{8}\left[(340) - (300)^2\right] + \frac{10 \times (300)^2}{8} N/mm^2\right]$$

$$= 33.6 \, N/mm^2$$

2. Write down the assumptions in the theory of simple bending 2015(w)5(b),2018 2(f)

Ans: a) The material of the beam is perfectly homogeneous and isotropic

b) the beam material is stressed within its elastic limit and thus obeys hookes law

c) The traverse sections which were plane before bending, remains plane after bending also

d) the value of E is the same in tension and compression

e) The beam is in equilibrium i.e. there is no resultant pull or posh in the beam section.

3. A solid circular shaft of 100 mm dia is transmitting 120 kw at 140 rpm. Find the intensity of shear stress in the shaft. 2015(w) 7(b),2017 4(c)

Soln. ⊥ Given D = 100 mm, p = 120 KW & N = 150 rpm

Se know that power transmitted by the shaft (p)

$$120 = \frac{2\pi NT}{60}$$

$$T = 7.64 \times 10^6 Nmm$$

we also know that torque transmittted by the shaft.(T)

$$7.64 \times 10^6 = \frac{\pi}{16} \times \iota \times D^3$$

$$\iota = \frac{7.64}{0.196} = 39 N/mm^2 = 39 Mpa$$

CHAPTER-5

1. A circular beam 150 mm diameter is subjected in a shear force of 7 kN. Calculate the value of maximum shear stress and sketch variation of shear stress along the depth of the beam. 2015(w) 7(b),2017

Ans: Diameter of the beam D = 150 mm = 0.15

Area of the cross-section $A = \frac{\pi}{4} D^2$

$$= \frac{\pi}{4}(0.15)^2 = 0.0176 m^2$$

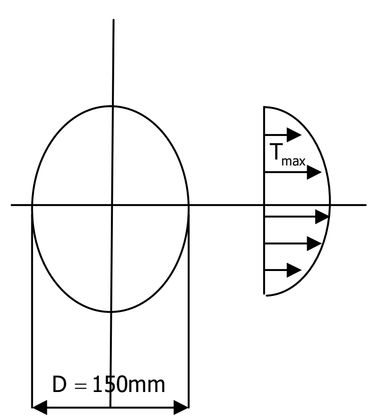
shear force, S = 7kN

Maximum shear stress

$$\iota_{max} = \frac{S}{A} = \frac{7}{0.0176} = 396 kN/m^2$$

$$\text{Using the relation, } \iota_{max} = \frac{4}{3}\iota_{max} = \frac{4}{3} \times 396$$

$$= 528 kN/m^2$$

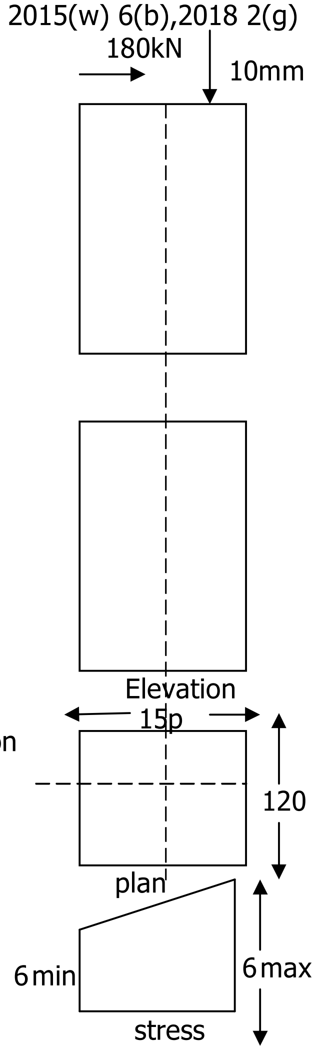


(i) Beam cross-section (ii) Shear stress distribution

CHAPTER – 5

[5 MARKS]

3.(b) A rectangular strut is 150 mm & 120 mm thicks it carries a load of 180 kN at an eccentricity of 10 mm in a plane bisecting the thickness. Find the maximum and minimum intensities of stress in the section 2015(w) 6(b),2018 2(g)



Soln. Width (b) = 150 mm

Thickness (d) = 120 mm

Load (p) = 180 kN = 180×10^3 N

& eccentricity (e) = 10 mm

Maximum intensity of stress in the section

We know that area of the strut

A = b × d = 150 × 120 = 1800mm^2

Maximum intensity of stress in the section

$$6_{max} = \frac{P}{A}\left(1+\frac{6e}{b}\right)$$

$$= \frac{1800\times10^3}{18,000}\left(1+\frac{6\times10}{150}\right)\text{N/mm}^2$$

$$= 14\,\text{MPa}$$

Minimum intensity of stress in the section

We also know that minimum intensity of stress in the section

$$6_{min} = \frac{P}{A}\left(1-\frac{6e}{b}\right)$$

$$= \frac{1800\times10^3}{18,000}\left(1-\frac{6\times10}{150}\right)\text{N/mm}^2$$

$$= 6\,\text{MPa}$$

CHAPTER 5

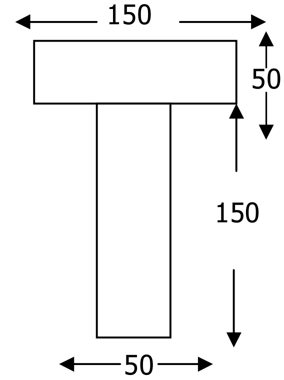
[7 MARKS]

1. Two wooden planks 150 mm × 50 mm each are connected to form a T-section of a beam if a moment of 8.4 kNm to applied around the horizontal neutral axis, ind. Cis tension below the neutral only, find the Bending stress at both the extreme fibres of the cross-section 2015(w) 5(c)

Soln. Given size of wooden planes = 150mm × 50 mm

Moment M = 8.4 Kn-m = 8.4 × 10^6 N.mm

We know that distance between the C.G. of the section & its bottom face.



$$y = \frac{(150 \times 50)175 + (150 \times 50)75}{(150 \times 50) + (150 \times 50)}$$

$$= \frac{1875000}{15000} = 125\text{mm}$$

Distance between the C.G. of the section & the upper extreme fibre y = 125 mm

Distance between the C.G. of the seen & lower extreme fibres y_c = 75 mm

We also know that M.I. of the T-section about an axis

Passes through its C.G. and parallel to the bottom face.

$$I = \left[\frac{150 \times (50)^3}{12} + (150 \times 50)(175 - 125)^2\right] + \left[\frac{50 \times (150)^3}{12} + (150 \times 50)(125 - 75)^2\right] \text{mm}^4$$

$$= 53.125 \times 10^6 \text{mm}^4$$

$\therefore$ Bending stress in the upper extreme fibre

$$6_I = \frac{M}{I} \times y_t = \frac{8.4 \times 10^6}{53.125 \times 10^6} \times 125\text{N/mm}^2$$

$$\Rightarrow 19.75\text{N/mm}^2 = 19.76\text{MPa}$$

Bending stress in the lower extreme fibre

$$6 = \frac{M}{I} \times y_c = \frac{8.4 \times 10^6}{53.125 \times 10^6} \times 75\text{N/mm}^2$$

$$= 11.86\text{N/mm}^2 = 11.86\text{Mpa (tension)}$$

2. Derive the general equation for the shear stress of a rectangular section and show that the maximum shear stress is 1.5 times the average shear stress. Also draw the shear stress diagram of the section 2013. 2(d),20178(b)

Ans: Rectangular section Fig. shows a rectangular section of width b and depth d. Let the section be subjected to shear force S.

Consider a level EF at a distance y from the neutral axis.

The intensity of shear stress at the level is given by $q = \frac{Say}{Ib}$

Where ay is the moment of the area above EF shown shaded about the neutral axis.

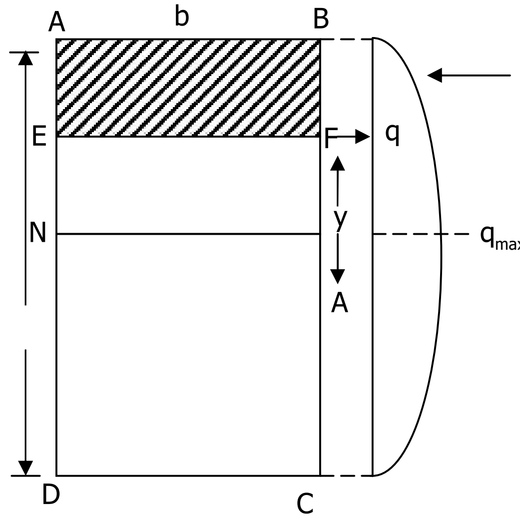
$$\therefore ay = b\left(\frac{d}{2} - y\right)\frac{1}{2}\left(\frac{d}{2} + y\right) = \frac{b}{2}\left(\frac{d^2}{4} - y^2\right)$$

$$\therefore q = \frac{S}{Ib}.\frac{b}{2}\left(\frac{d^2}{4} - y^2\right)$$

$$\text{But } I = \frac{bd^2}{12}$$

$$\therefore q = \frac{12}{bd^2}.\frac{S}{b}.\frac{b}{2}\left(\frac{d^2}{4} - y^2\right)$$

$$q = \frac{6S}{bd^2}\left(\frac{d^2}{4} - y^2\right)$$



$$\text{At the top edge i.e. at } y = \frac{d}{2}, q = 0$$

$$\text{At the neutral axis, i.e, at } y = 0$$

$$q = \frac{6S}{bd^2}.\frac{d^2}{4} = \frac{3}{2}.\frac{S}{bd}$$

Average shear stress

$$q_{avg} = \frac{S}{bd}$$

$$q_{max} = \frac{3}{2}q_{avg}$$

CHAPTER – 5

LONG QUESTIONS 7 MARKS

1. Derive the simple bending stress equation. 2015 4(c),2017 7©

$$\text{i.e.} \frac{M}{I} = \frac{E}{R} = \frac{\sigma_b}{y}$$

Ans: Now consider a small layer PQ of the beam section at a distance y from the neutral axis.

σa= Area of the large PQ

Intensity of stress in the larger PQ

σ= y $\times$ E/R

$\therefore$ Total stress in the larger PQ

$$y \times \frac{E}{R} \times \delta a$$

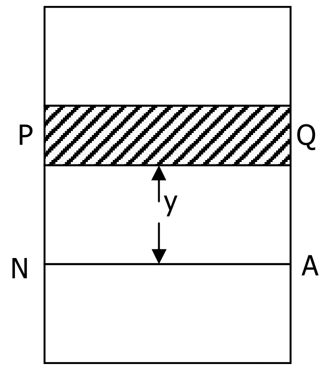
Moment of this total stress about the neutral and

$$y \times \frac{E}{R} \times \delta a \times y = \frac{E}{R} y^2.\delta a............(1)$$

The algebraic sum of all such moments about the neutral axis must be equal to M

$$\therefore \delta \frac{E}{R} y^2.\delta a = \frac{E}{R} \delta y^2.\delta a$$

The expression $\delta y^2 \cdot \delta a$ represents the moment of inertia of the area of the whole section about the neutral axis.



$$M = \frac{E}{R} \times I$$

$$\frac{M}{I} = \frac{E}{R}$$

we have already section

$$\frac{\sigma}{y} = \frac{E}{R}$$

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

2. Derive the equation Torsional equation 2015 7(c),2017 4(b)

i.e.; $\frac{\iota}{R} = \frac{T}{J} = \frac{C\theta}{l}$

soln. we know that

$$\frac{Z}{R} = \frac{C\theta}{l} \text{.....................(i)}$$

$$T = \frac{\pi}{16} \times Z \times D^3 \text{................(ii)}$$

$$\iota = \frac{16T}{\pi D^3}$$

Substituting the value of ι in equation $\frac{16T}{\pi D^3 \times R} = \frac{C.\theta}{l}$

$$\Rightarrow \frac{T}{\frac{\pi}{16} \times D^3 \times R} = \frac{C.\theta}{l}$$

$$\Rightarrow \frac{T}{\frac{\pi}{32} \times D^4} = \frac{C.\theta}{l}$$

$$\frac{T}{J} = \frac{C.\theta}{l} \text{.......................(iii)}$$

$$J = \frac{\pi}{32} \times D^4$$

$\therefore$ it is known as polar moment of inertia

The above equation (iii) may also be written as

$$\frac{Z}{R} = \frac{T}{J} = \frac{C\theta}{l}$$

3. A cast iron water main 12 m long of 500 mm inside diameter and 25 mm wall thickness runs full of water and is supported at its ends. Calculate the maximum stress in the metal it density of cast iron is 7200 kg/m^3 and that of water is 1000 kg/m^3. 2014 7(c)

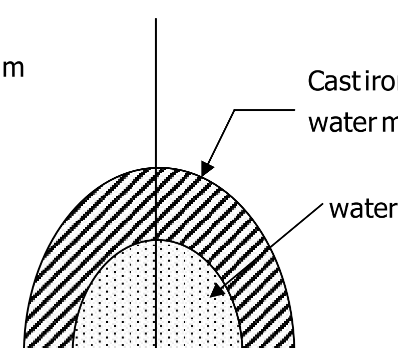
Ans: Inside diameter of C.I. water main, d = 500 mm = 0.5 m

Wall thickness, t = 25 mm = 0.025m

$\therefore$ Outside diameter of water main,

D = d + 2t = 500 + (2 $\times$ 25) = 550 mm = 0.55 m

Cross sectional area of main



$= \pi/4\ (0.55^2 - 0.5^2) = 0.04123 m^2$

Weight of watermain per metre length

$= 0.04123 \times 1 \times 7200 \times 9.81 = 2912.16$ N

Weight of water in one metre long main

$= \pi/4 \times (0.5)^2 \times 1 \times 1000 \times 9.81$

$= 1926.19$ N

Total wt. of pipe when full water

2912.16 + 1926.19 = 4838.35 N

$$S.M. = \frac{wl^2}{8} = \frac{4838.35 \times 12^2}{8}$$

$$= 87090.3 Nm$$

$$M.S.I = \frac{\pi}{64}\left[(0.55)^4 - (0.5)^4\right]$$

$$= 1.42384 \times 10^{-3} m^4$$

$$y = \frac{D}{2} = \frac{0.55}{2} = 0.275m$$

Using the relation

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\sigma = \frac{M \times 4}{I} = 16.82 MN/m^2$$

4. A masonary dam 4.5 m high, 1m wide at the top and 3.5 m wide at the base retains water to the full height. The water face of the dam is vertical. Determine the extreme pressure intensity at the base, water and masonary weights 9810 N/m^3 and 22500 N/m^3 respectively. Find also the extreme pressure intensity at the base when the dam is empty.

Ans: Total pressure of water per metre length of the dam

$$P = \frac{wh^2}{2} = \frac{9.81(4.5)^2}{2} = 99.32 N/m$$

$$= 99.32 kN$$

wt. of concrete per meter length

$$w = \rho\left(\frac{a+b}{2}\right) \times H = 22.5 \times \left(\frac{1+3.5}{2}\right) \times 4.5 = 227.8 kN$$

Let us find out the position of the C.G. of the dam section.

Taking moment about A

$$\left(4.5 \times 1 + \frac{4.5 \times 2.5}{2}\right) \times AJ = \left(4.5 \times 1 \times \frac{1}{2}\right) + \left[\frac{4 \times 2.5}{2}\left(1 + \frac{2.5}{3}\right)\right]$$

$$\Rightarrow 10.125\, AJ = 2.25 + 6.83 = 9.08$$

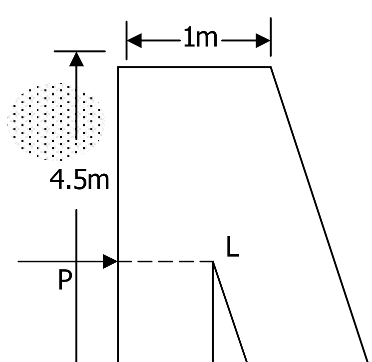
$$AJ = \frac{9.08}{10.1215} = 0.89m$$

$$x = \frac{p}{w} \times \frac{h}{3} = \frac{99.32}{227.8} \times \frac{4.5}{3} = 0.65m$$

Horiozontal distance AK,

$$d = AJ + x = 0.89 + 0.65 = 1.54m$$

$$\&\ eccentricity,\ e = d - \frac{b}{2} = 1.54 - \frac{3.5}{2} = 0.20m$$



CHAPTER -6

[7 MARKS]

1. Given Tensile along x-x axis, (σ_x) = 150 MPa, y-y axis σ_y = 50 MPa, Tensile stress (θ) = 60$^{o.}$

Normal stress on the inclined plane

$$\sigma_n = \frac{\sigma_n + \sigma_y}{2} - \frac{\sigma_n - \sigma_y}{2}\cos 2\theta$$

$$= \frac{150+50}{2} - \frac{150-50}{2}\cos(2\times 60^o)\text{MPa}$$

$$= 100 - 50\cos 120^o = 75\text{MPa}$$

Shear stress on the inclined plane

$$\iota = \frac{\sigma_x + \sigma_y}{2}\sin 2\theta$$

$$= \frac{150-50}{2}\sin(2\times 60^o) = 43.30 \text{ MPa}$$

Resultant stress on the inclined plane

$$\sigma_R = \sqrt{\sigma_n^2 + \iota^2}$$

$$= \sqrt{75^2 + 43^2} = 86.45\text{MPa}$$

Magnitude of the maximum shear stress in the component

$$\iota_{max} = \pm\frac{\sigma_x - \sigma_y}{2} = \pm\frac{150-50}{2} = \pm 50\text{MPa}$$

CHAPTER – 5

LONG QUESTIONS [6 MARKS]

1. A beam++ of rectangular c/s is 200 mm wide & 350 mm deep. If the section is subjected to a maximum shear force 30 kN, Find the maximum shear stress & sketch the shear stress distribution along the depth of the beam. 2012(w) 4(b)

Soln. Given, base width (b) 200 mm= 0.2 m

Height (h) = 350 mm = 0.35 m

S.F. (F) = 30 kN = 30 $\times$ 10^3 N

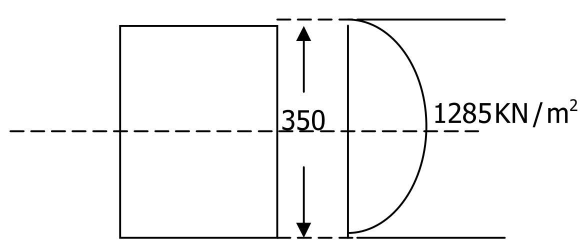
The area of beam section

A = bh/2 = 0.035 m^2

Average shear stress across the section

ι_{av} = F/A = 30/0.035 = 867 KN/m^2

$\therefore$ maximum shear stress,



ι_{max} = 1.5 × ι_{av} = 1285 KN/m^2

2. Find out the horse power, a solid circular shaft of 50 mm dia, can transmit of 120 rpm. The maximum shear stress in the shaft isn't to exceed 625 kg/m^2.2017

Soln. D = 50 mm = 5 cm

N = 120 rpm

σ_s = 625 Kg/cm^2

$$\text{Torque, } T = \frac{\pi}{16}\sigma_s D^3$$

$$= \frac{\pi}{16} \times 625 \times (5)^3 = 15340\,\text{kgm}$$

$$= 153.4\,\text{kgm}$$

$$\text{Power transmit}, P = \frac{2\pi NT}{60}$$

$$= \frac{2\pi \times 120 \times 153.4}{60}$$

$$= 1927.7\,\text{n.p.}$$

3. A hollow shaft to transmit 300 kw at 90 rpm, of the shear stress is not to exceed 60 MN/m^2 & internal dia is 0.60 of external dia . find the external & internal dia assuming maximum torque is 1.4 times the mean. 2018(w) (3)

Soln. Given power (p) = 300 Mn

N = 90 rpm

ι_{max} = 60 MN/m^2

D = 0.60

We know the transmitted by the shaft

$$T = \frac{\pi}{16} \times \iota \times \left[\frac{D^4 - d^4}{D}\right]$$

$$= \frac{\pi}{16} \times 60 \times \left[\frac{D^4 - (0.6D)^4}{D}\right] \text{Nmm}$$

$$= 10.3 \times 10^{-6} D^3 / \text{KNm}$$

$$\text{Power transmitted} P = \frac{2\pi NT}{60}$$

$$= 300 = \frac{2 \times \pi \times 90\left(10.3 \times 10^{-6} D^3\right)}{60}$$

$$D = 3.09 \times 10^6 \text{mm}^3$$

4. A solid circular shaft transmit 100 kw power at 250 rpm. Calculate the shaft dia, if the tensil in the shaft is not to exceed 10 in 2 mL length of shaft & shear stress is limited to 60 N/mm^2. Take C = 1 $\times$ 10^5 N/mm^2 2015 7(c)old

Soln. $P = 100\,Kw = 100 \times 10^3\,w$

$N = 250\,rpm$

$l = 2m = 2000\,mm$

$\iota = 60\,N/mm^2$

$P = \frac{2\pi NT}{60}, \quad 100 \times 10^3 = \frac{2\pi \times 250 \times T}{60}$

$T = 3819.71\,NM \times 10^3$

Shear stress consider

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

$\Rightarrow d = 69\,mm$

Twist consideration

$$\frac{T}{DP} = \frac{C\theta}{l}$$

$$\Rightarrow \frac{T}{\frac{\pi}{32} d^4} = \frac{C\theta}{l}$$

$$\Rightarrow d^4 = \frac{32 \times T \times l}{\pi c \theta}$$

$$d = \sqrt{\frac{32 \times 3819.71 \times 10^3 \times 2000}{\pi \times 1 \times 10^5 \times \frac{\pi}{180}}}$$

$$= 81.7\,mm$$

5. State the four modes of failure of a masonry dam with explanation 2013(w)2(g)

Soln. Four modes of failure of a masonry dams deverlop tension in the masonry at the base of the dam.

$\rightarrow$ overturning of dam

$\rightarrow$ sliding of dam

$\rightarrow$ crushing of masonry of the base of dam

$\rightarrow$ For stability of dam these should be avoided

$\rightarrow$ Coordination to avoid tension

$$\sigma_b \le \sigma_0$$

$$\frac{6w.e}{b^2} \le \frac{w}{b}$$

$$e \le \frac{b}{\sigma}$$

The eccentricity of resultant can be equal to b/6 on either side of base section.

Coordination to prevent overturning

Overturning moment must be equal to resting moment.

i.e. $p \times h/3 = w \times 5n$

$JK = p/w \times h/3$

Balancing moment = $w \times JB$

Coordination to prevent sliding σ_{max} is more than the water press P.

Coordination to prevent crushing of masonry the maximum stress σ_{max} permissible stress in the masonry.

CHAPTER 6

(SHORT QUESTION) [2 MARKS]

1. What is meant by principal plane 2018(w)

Soln. At any point in a strained material, there are three planes, mutually $\perp$r to each other, which carry direct stress only & no shear stress. These planes are known as principal plane.

2. What is the tangential stress on a plane inclined at an angle θ with the principal plane

2017(w) 1(h)

Soln. Tangential stress

$$\sigma_1 = \frac{\sigma_1 - \sigma_2}{2}\sin 2a$$

Where σ_1 & σ_2 are principal stresses.

3. Define principal plane & principal stress 2015(w)

Soln. At any point in a strained material, there are three planes, mutually $\perp$r to each other, which carry direct stresses only & no shear stress. These planes are known as principal plane. The stresses on these planes known as principal stress.

4. What is Mohr's circle & What is it's use 2015(w) 6(a)

Soln. Using the mohr's circle find the principal stress and orientation of their planes of action & the maximum shear stresses and orientation of their planes of action.

The solution of Biaxial stress problems by graphical method by drawing a circle with appropriate radius is known as Mohr's circle

CHAPTER 6

[6 MARKS]

1. If the stresses on two $\perp$r planes through a point are 60 N/mm^2 shear, find the stress components & resultant stress on a plane at 60^o to the tensile stress. 2013(w)2(f)

Soln. Given that

σ_1 = 60 N/mm^2 (tensile)

σ_2 = -40 N/mm^2 (compressive)

θ = 90° – 60° = 30°

ι = 30 N/mm^2

Normal stress on the plane

$$\sigma_1 = \frac{\sigma_1 + \sigma_2}{2} + \frac{\sigma_1 - \sigma_2}{2}\cos 2\theta + \iota \sin\theta$$

$$= \frac{60-40}{2} + \frac{60+40}{2}\cos 60^\circ + 30\sin 60^\circ$$

$$= 60.98\,N/mm^2\,(Tensile)$$

Tangential stress on the plane

$$\sigma_1 = \frac{\sigma_1 - \sigma_2}{2}\sin 2\theta - \iota\cos\theta$$

$$= \frac{60+40}{2}\sin 60^\circ - 30\sin 60^\circ = 28.30\,N/mm^2$$

$$\therefore \text{Resultant stress}\ \sigma_n = \sqrt{\sigma n^2 + \sigma r^2}$$

$$= 67.23\,N/mm^2$$

$$\text{Obliquity}, \phi = \tan^{-1}\left(\frac{\sigma_f}{\sigma_n}\right) = 24.89^\circ$$

2. Derive the expression for eccentricity in case of eccentric leading in rectangular column section. Find out the area of the core or kornel of the section. 2010(w)2(c)

Soln. Limit of eccentricity for a rectangular s/c consider a rectangle section of width (b) & thickness (d)

We know that the modulus

Z =$\sigma d^2/\sigma$

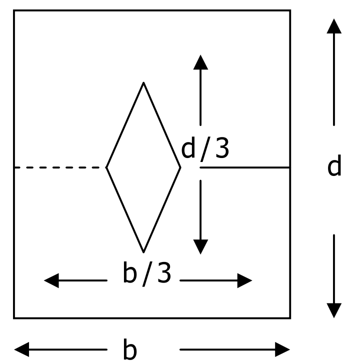
Area of the section A = bd

For no. tension condention

$$e \le \frac{Z}{A}$$

$$\le \frac{bd^2/\sigma}{bd}$$

$$\le \frac{b}{\sigma}d$$

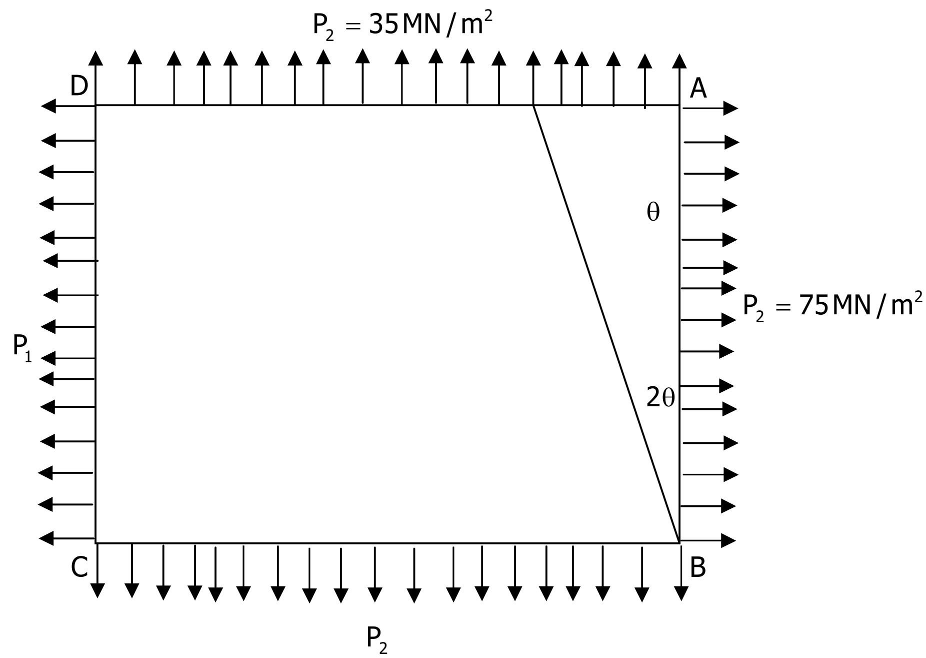


It means that the load can be eccentric on either of the geomnetrical axis by an amount equal to d/σ. Thus if the line of action of the load is within the middle third as shown by the doted area.

CHAPTER- 6
[LONG QUESTION 8 MARKS]

1. The principal stresses at a point across two ⊥r planes are 75 MN/m^2 & 35 MN/m^2 (tensile). Find the normal, tangential stresses & the resultant stress & its obliquity on a plane at 2i with major principal plane . 2009(w) (6) 2013 (5)

Soln.



$$p_n = \frac{P_1 + P_2}{2} + \frac{P_1 - P_2}{2}\cos 2\theta$$

$$= \frac{75+35}{2} - \frac{75-35}{2}\cos 2\theta = 70.32 N/m^2 (tensile)$$

$$P_f = \frac{P_1 - P_2}{2}\sin 2\theta = \frac{75-35}{2}\sin 40^\circ$$

$$= 12.85 MN/m^2$$

$$\text{Resultant stress} = \sqrt{Pn^2 + P_f^2}$$

$$= \sqrt{(70.32)^2 + (12.85)^2}$$

$$= 71.48 MN/m^2$$

$$\text{Obliquity} = \phi = \tan^{-1}\frac{P_f}{P_n} = \tan^{-1}\frac{12.85}{70.32} = 10^\circ 21'$$

$$\phi = 10^\circ 21'$$

2. At a certain point on a strained material the intensities of normal stresses planes at ι angles to each other are 23 N/mm^2 & 12 N/mm^2 tensile. They are accompanied by shear stresses 10 N/mm^2. Find the principal planes & principal stresses. Find also the maximum shear stresses.2018 (5)

Soln. Given $\sigma_x = 23 N/mm^2$

$\sigma_y = 12 N/mm^2, \iota_{xy} = 10 N/mm^2$

Maximum principal stress (σ_{max})

$$= \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \iota_{xy}}$$

$$= 28.19 MPa$$

Minimum principal stress

$$\sigma_{min} = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \iota_{xy}^2}$$

$$= 6.09 MPa$$

$$\tan 2\theta = \frac{2\iota_{xy}}{\sigma_x - \sigma_y} = 1.81$$

$$2\theta = 61.07$$

$$\theta = 30.53 = 30^\circ 3l'$$

Maximum shearing stress

$$\iota_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \iota_{xy}^2}$$

$$\sqrt{\left(\frac{23 - 12}{2}\right)^2 + 10^2} = 11.41 MPa$$