MADE EASY

Leading Institute for ESE, GATE & PSUs

Detailed Solutions

ESE-2024 Mains Test Series

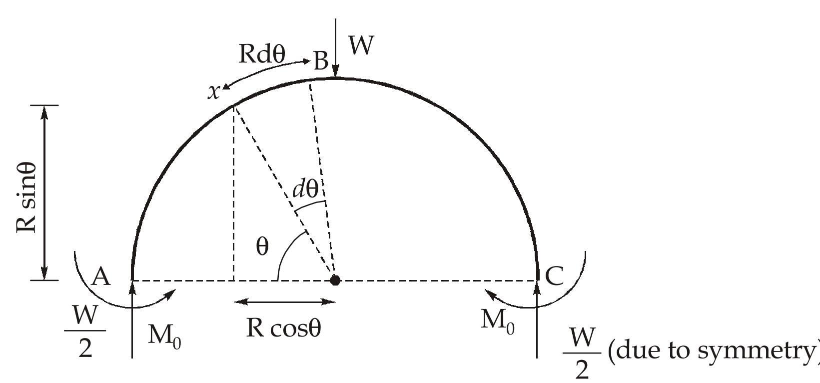
Civil Engineering Test No : 12

Detailed Explanation

Q.1 (a) Solution:

Consider the equilibrium of one half of the ring *ABC*

Considering an element of length $Rd\theta$ at an angle θ with the horizontal.



Let the reacting moments be M_0 at A and C.

Bending moment at the section x,

$$M = \frac{W}{2}(R - R\cos\theta) - M_o$$

Now, strain energy stored in the part ABC,

$$U = U_{AB} + U_{BC} = 2\,U_{AB} \qquad \text{(Due to symmetry)}$$

$$= 2\int_0^{\pi/2} \frac{M^2 ds}{2EI}$$

For strain energy to be minimum,

$$\frac{\delta U}{\delta M_0} = 0$$

$$\therefore \quad \frac{\delta U}{\delta M_0} = 2\int_0^{\pi/2} \frac{M\left(\frac{\delta M}{\delta M_0}\right)ds}{EI}$$

$$\Rightarrow \quad 0 = \frac{2}{EI}\int_0^{\pi/2}\left[\frac{W}{2}(R - R\cos\theta) - M_0\right](-1)Rd\theta$$

$$\Rightarrow \quad 0 = \frac{2R}{EI}\left[M_0\theta - \frac{W}{2}(R\theta - R\sin\theta)\right]_0^{\pi/2}$$

$$\Rightarrow \quad 0 = \frac{2R}{EI}\left[M_0\frac{\pi}{2} - \frac{W}{2}\left(\frac{R\pi}{2} - R\right)\right]$$

$$\Rightarrow \quad M_0 = \frac{WR}{2\pi}(\pi - 2)$$

BM at any section,

$$M = \frac{W}{2}(R - R\cos\theta) - \frac{WR}{2\pi}(\pi - 2)$$

At $\theta = 0$, $$M = \frac{-WR}{2\pi}(\pi - 2)$$

At $\theta = \frac{\pi}{2}$, $$M = \frac{+WR}{\pi}$$

Q.1 (b) Solution:

(i) Concreting in hot weather poses some special problems such as,

- Strength reduction
- Cracking of flat surfaces due to rapid drying.

Concrete that stiffens before consolidation is caused by too rapid setting of cement and too much absorption and evaporation of mixing water. This leads to difficulty in finishing flat surfaces. Therefore limitations are imposed on placing concrete during hot weather and on the maximum temperature of the concrete; quality and durability suffer when concrete is mixed, placed and cured at high temperature

(ii) Bogue's compounds of cement:

1. **Tricalcium Silicate (C_3S):** It is supposed to be the best cementing material and is about 25-50% of cement. It renders the clinker easier to grind. It increases the

resistance to freezing and thawing, hydrates rapidly generating high beat and develops an early hardness and strength. The hydrolysis of this compound is mainly responsible for 7 days strength and hardness. The heat of hydration is about 500 J/gram.

2. **Dicalcium Silicate (C_2S):** It is about 25-40% of cement. It hydrates and hardens slowly and takes long time to add the strength (after a year or more). It imparts resistance to chemical attack. Raising of C_2S content renders clinker harder to grind, reduces early strength, decreases resistance to freezing and thawing at early stages. The heat of hydration is about 260 J/g.

3. **Tricalcium Aluminate (C_3A):** It is a about 5-11% (normally about 10.5%) of cement. It rapidly reacts with water and is responsible for flash set of finely ground drinker. Tricalcium aluminate is responsible for the initial set, high heat of hydration and has greater tendency to volume changes causing cracking. The heat of hydration is about 865 J/gram.

4. **Tetracalcium AluminoFerrite (C_4AF)**: It is about 8-14% of cement. It is responsible for flash set but generates less heat. It has poorest cementing value. Raising the C_4AF content reduces the strength slightly. The heat of hydration is about 420 J/g.

(iii) Segregation: It usually implies separation of coarse aggregates from fine aggregates, paste from coarse aggregate or water from the mix and the ingredients of the fresh concrete no longer remain uniformly distributed. It can be reduced by increasing small size coarse aggregates, air entrainment, using dispersing agents and pozzolana.

The causes of segregation are dropping concrete from heights, badly designed mix, concrete carried over long distances-pumping, belt conveyor system, excessive vibration and during concrete finishing extra floating and tamping.

Bleeding: It is defined as the autogenous flow of mixing water within or emergence to the surface from freshly placed concrete. No matter how well concrete may have been completed, the force tends to pull the heavy solid particles downward, the lighter water being displaced outward. The upward migration of water is known as bleeding. It ceases either when the solid particles touch each other and cannot settle any more or when the concrete stiffens due to cement hydration and prevents further movement.

Mixes which bleed excessively are those which are harsh and not sufficiently cohesive.

Methods of checking bleeding: It can be checked by:

- Use of uniformly graded aggregates.
- Use of pozzolana-by breaking the continuous water channel.
- By using air entraining agents, finer cements, alkali cement and rich mix.

Q.1 (c) Solution:

For 4.6 grade bolts, f_{ub} = 400 MPa

Partial factor of safety, γ_{mo} = 1.10

γ_{mb} = 1.25

Since the column ends are machined, 50% of the loads are transferred directly and remaining 50% by the splice (fasteners).

$\therefore$ Direct load on the splice $= \frac{500}{2} \times 0.5$ ($\because$ Splicing is done for both ends)

$= 125$ kN

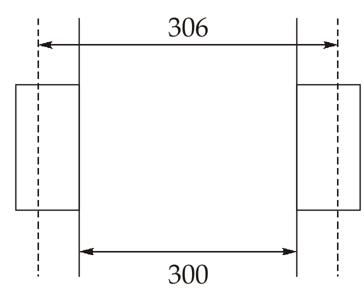
Let's assume the thickness of the splice as 6 mm, then

Load on the splice due to moment $= \frac{40 \times 10^3}{300 + 6}$

$= 130.72$ kN

lever arm = 300 + 6 = 306 mm

$\therefore$ total design force = 125 + 130.72 = 255.72 kN



Let's assume the width of the splice plate as 200 mm.

Thickness of the splice required $= \frac{255.72 \times 10^3}{250 \times 200}$

$= 5.1144$ mm

$\because$ $f_y = 250$ N/mm^2

Hence adopt the splice plate of size (150 × 6) mm.

Let's find out length of the plate. It depends on the number of bolts in vertical row.

Let's provide 20 mm diameter bolts of grade 4.6

Shear strength of the bolt $= 0.78 \times \pi \times \frac{20^2}{4} \times \frac{400}{\sqrt{3} \times 1.25} \times 10^{-3}$ kN

$= 45.3$ kN

Strength of bolt in bearing $= 2.5 \times 0.5 \times \frac{(20 \times 6)}{1.25} \times 410 \times 10^{-3}$ kN

$= 49.2$ kN (Assuming $k_b = 0.5$)

$\therefore$ Bolt value $= 45.3$ kN

$$\text{Number of bolts required} = \frac{255.72}{45.3} = 5.65 \simeq 6 \text{ bolts}$$

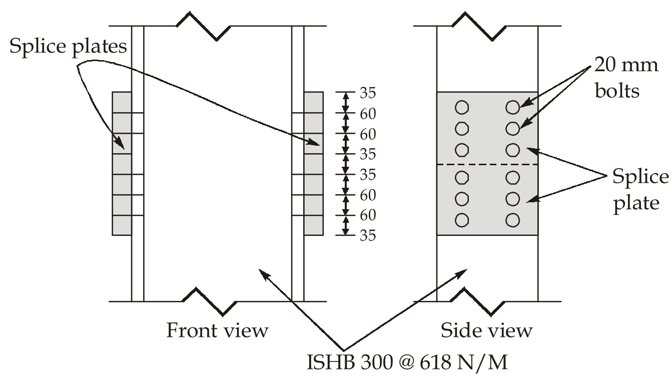
$$\text{Minimum pitch} = 2.5 \times \text{bolt dia} = 2.5 \times 20 = 50 \text{ mm}$$

$$\text{End distance} = 1.5 \times \text{bolt hole dia} = 1.5 \times 22 = 33 \text{ mm}$$

Let's provide bolts at a pitch of 60 mm and end distance of 35 mm.

$\therefore$ Minimum length of the plate = $4 \times 60 + 4 \times 35 = 380$ mm

Let's provide a splice plate of size 380 mm × 200 mm × 6 mm



Q.1 (d) Solution:

Distempers:

- The main object of applying distemper to the plastered surfaces is to create a smooth surface.
- They are cheaper than paints and varnishes and they present a neat appearance. They are available in variety of colors.
- The coatings of distemper are usually thick and they are more brittle than other types of water paints
- They are less durable than oil paints.
- They can be applied on brickwork, cement and lime plastered surface, etc.
- They exhibit poor workability.
- They prove to be unsatisfactory in damp locations such as kitchen, bathroom, etc.
- A distemper is composed of base, carrier, colouring pigments and size. For base, the whiting or chalk is used and for carrier water is used.

Enamels:

- This paint is available in different colours.
- It contains white lead or zinc white, oil, petroleum spirit and resinous matter.

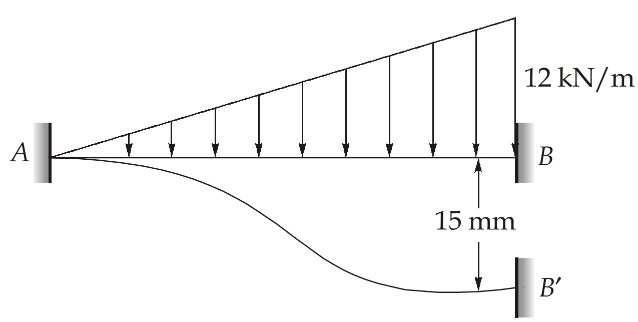
- It dries slowly and forms a hard and durable surface.
- The surface provided with this paint is not affected by acids, alkalies, fumes of gas, hot and cold water etc.
- It can be used for both internal and external walls.
- In order to improve the appearance, it is desirable to apply a coat of enamel paint.

Varnish:

- The terms varnish is used to indicate the solutions of resins or resinous substances prepared either in alcohol, oil or turpentine.
- It brightens the appearance of the grain in wood.
- It renders brilliancy to the painted surface.
- It protects the painted surface from atmospheric actions.
- It protects unpainted wooden surfaces of doors, windows, floors, etc., from the actions of atmospheric agencies.
- Resins like lac, amber, mastic etc., driers like litharge, white copper and lead acetate, and solvents like linseed oil, methylated spirits of wine, turpentine and wood naptha are ingredients of varnish.

Q.1 (e) Solution:

Fixed end moment due to loading and sinking,



At end A,

$$M_A = \frac{-wL^2}{30} - \frac{6EI\delta}{L^2} = \frac{-12\times6^2}{30} - \frac{6\times1.5\times10^{10}\times10^{-6}\times15\times10^{-3}}{6^2}$$

$$= -14.4 - 37.5 = -51.9 \text{ kN-m}$$

At end B,

$$M_B = \frac{wL^2}{20} - \frac{6EI\delta}{L^2} = \frac{12\times6^2}{20} - \frac{6\times1.5\times10^{10}\times10^{-6}\times15\times10^{-3}}{6^2}$$

$$= 21.6 - 37.5 \text{ kN-m}$$

$$= -15.9 \text{ kN-m}$$

Taking moments about B,

$$\sum M_B = 0$$

$$\Rightarrow \quad V_A \times 6 + M_A + M_B - \frac{12\times 6}{2} \times \frac{6}{3} = 0$$

$$\Rightarrow \quad V_A \times 6 - 51.9 - 15.9 - 72 = 0$$

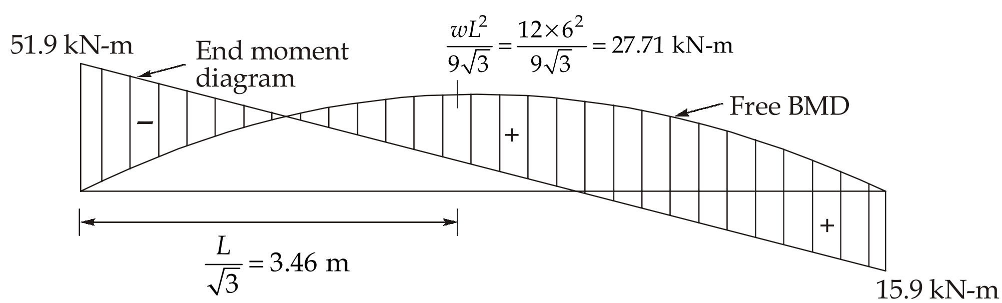
$$\Rightarrow \quad V_A = 23.3 \text{ kN}$$

$$\sum F_y = 0$$

$$\Rightarrow \quad V_A + V_B = \frac{1}{2}\times 6 \times 12 = 36 \text{ kN}$$

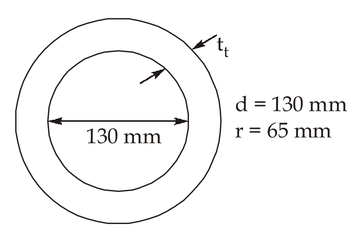
$$\Rightarrow \quad V_B = 12.7 \text{ kN}$$

Bending moment diagram is shown below.



Q.2 (a) Solution:

(i)



For shop fillet weld,

$f_u = 410 \text{ N/mm}^2, f_y = 250 \text{ N/mm}^2$

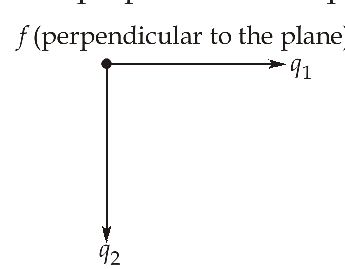
Torsional moment, $T = 0.4 \times 5 = 2$ kN-m

Bending moment, $M = 5 \times 1.2 = 6$ kN-m

Load in transverse direction, $P_u = 5$ kN

Assuming 't_t' as throat thickness of weld.

Now at the point of maximum stress there is a torsional shear stress in horizontal direction, direct shear stress in vertical direction and a bending stress perpendicular to plane of these stresses.



Let, q_1 = Torsional shear stress.

q_2 = direct shear stress

q_3 = Bending stress

$$q_1 = \frac{T}{J} \times r$$

where, polar moment of inertia, $J = 2\,\pi\, r\, t_t \times r^2 = 2\,\pi\, r^3\, t_t$

$$= 2 \times \pi \times 65^3 \times t_t$$

$\therefore$
$$q_1 = \frac{2\times10^6\times65}{2\pi\times65^3\times t_t} = \frac{75.34}{t_t}\text{N/mm}^2$$

$$\text{Direct shear stress, } q_2 = \frac{P_u}{A} = \frac{5\times1000}{2\times\pi\times65\times t_t} = \frac{12.24}{t_t}\text{N/mm}^2$$

$$\text{Resultant shear stress on the weld } q_r = \frac{1}{t_t}\sqrt{(75.34)^2+(12.24)^2} = \frac{76.33}{t_t}\text{N/mm}^2$$

$$\text{Bending stress, } q_3 = \frac{M}{I_{xx}} \times r$$

where
$$I_{xx} = \frac{J}{2} = \pi r^3 t$$

$\therefore$
$$f_3 = \frac{6\times10^6\times65}{\pi\times65^3\times t_t} = \frac{452.04}{t_t}\text{N/mm}^2$$

$\therefore$
$$\text{Resultant stress} = \sqrt{3q_r^2+f_3^2} = \frac{1}{t_t}\sqrt{3\times(76.33)^2+(452.04)^2}$$

$$= \frac{470.98}{t_t}\text{N/mm}^2$$

$$\text{Strength of the weld} = \frac{f_u}{\sqrt{3}\times\gamma_{mw}} = \frac{410}{\sqrt{3}\times1.25}\ \text{N/mm}^2$$

$\therefore$
$$\frac{470.98}{t_t} \le \frac{410}{\sqrt{3}\times1.25}$$

$\Rightarrow$
$$t_t \ge 2.487$$

$\therefore$
$$\text{Size of the weld} \ge \frac{2.487}{0.7} = 3.55\text{ mm}$$

We can select size of the weld as 4 mm. but minimum size of the weld for 12 mm gusset plate is 5 mm.

$\therefore$ Provide 5 mm weld size.

(ii)

Tension members are usually angle section, Tee-section or channel section and are connected to gusset plate by one leg only. The force transferred to the connected leg by the end connection which gets transferred as tensile stress over the entire cross section will not be uniform. Consequently, connected leg will have higher stress at failure than outstanding leg. Since stress in one part lags behind the other part of the section, it is referred to as shear lag. However at some distance away from the connection the stress becomes uniform throughout the section.

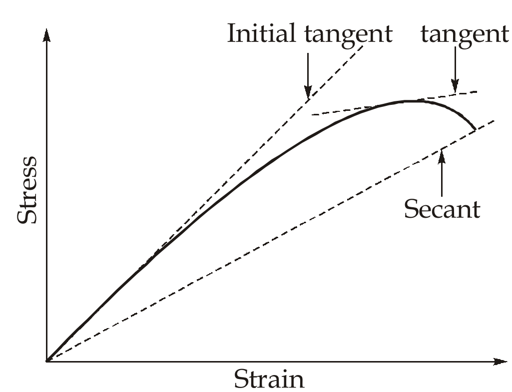
The shear lag reduces the effectiveness of the component of the section which is not connected to the guest plate. This results in decrease in the strength of tension member. Therefore area of steel in outstanding leg should be as small as possible. This consequently results in unequal angle section with long leg connected since this is more efficient.

Q.2 (b) Solution:

(i)

Different modulii of elasticity of plain concrete:

1. **Static modulus of elasticity**: The term Young's modulus of elasticity can strictly be applied only to the straight part of the stress-strain curve. In case of concrete, since no part of the graph is a straight line, the modulus of elasticity is found out with reference to the tangent drawn to the curve at origin. The modulus found from this tangent is called initial tangent modulus. This gives satisfactory results only at low stress value.



Tangent can also be drawn at any other point on the stress-strain curve. The modulus of elasticity calculated with reference to this tangent is then called tangent modulus. The tangent modulus also does not give a realistic value of modulus of elasticity for the stress level much above or much below the point at which the tangent is drawn.

A line can be drawn connecting a specified point on the stress-strain curve to the origin of the curve. If the modulus of elasticity is calculated with reference to the slope of this line, the modulus of elasticity is called as secant modulus.

If the modulus of elasticity found out with reference to the chord drawn between two specified points on the stress-strain curve then such value of the modulus of elasticity is known as chord modulus.

The static modulus of elasticity is used in design of structures. Secant modulus is the most commonly used modulus of elasticity. Since the value of secant modulus decreases with increase in stress, the stress at which the secant modulus has been found out should always be stated.

Dynamic modulus of elasticity: The modulus of elasticity can also be determined by subjecting the concrete member to longitudinal vibration at their natural frequency. This modulus of elasticity is known as dynamic modulus of elasticity. The value of dynamic modulus is somewhat higher than that of static or secant modulus. This is because dynamic modulus is unaffected by creep.

Factors affecting modulus of elasticity:

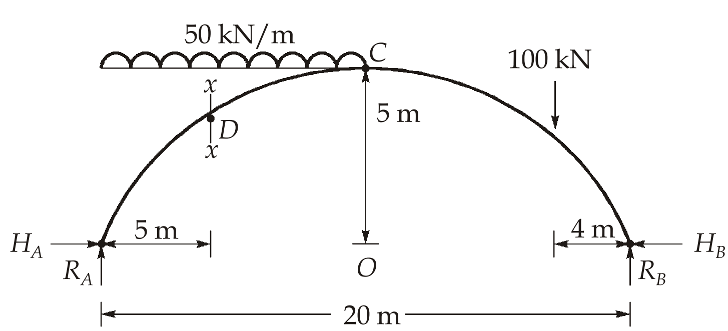
(i) The most important factor affecting the modulus of elasticity of concrete is the strength of concrete.

(ii) The modulus of elasticity also depends upon the state of wetness of concrete when other conditions being the same. Wet concrete will show higher modulus of elasticity than dry concrete.

(iii) The quality and quantity of aggregate will have a significant effect on the modulus of elasticity.

(iv) The age of concrete is also a factor which affect modulus of elasticity. Older the concrete, stronger it will be thereby giving high modulus of elasticity.

(ii)



Using equilibrium equations,

$$\sum F_x = 0$$

$\Rightarrow$ $H_A = H_B$

Also, $\sum F_y = 0$

$\Rightarrow$ $R_A + R_B = 50 \times 10 + 100 = 600$ kN

Also, $\sum M_A = 0$

$\Rightarrow$ $R_B \times 20 = 50 \times 10 \times 5 + 100 \times 16$

$\Rightarrow$ $R_B = 205$ kN,

$\therefore$ $R_A = 395$ kN

As C is hinged, $\sum M_C = 0$ [From right]

$\Rightarrow$ $R_B \times 10 = 100 \times 6 + H_B \times 5$

$\Rightarrow$ $H_B = 290$ kN

$\therefore$ $H_A = 290$ kN

Using equation of parabola,

$$y = \frac{4hx}{l^2}(l-x)$$

At $x = 5$ m,

$$y = \frac{4\times5\times5}{20^2}\times(20-5)$$

$$= 3.75 \text{ m}$$

At section D,

$$\tan\theta = \frac{dy}{dx} = \frac{4h}{l^2}(l-2x)$$

$$= \frac{4\times5}{20^2}\times(20-2(5))$$

$$= 0.5$$

$\therefore$ $\cos\theta = 0.894$ and $\sin\theta = 0.447$

At section D,

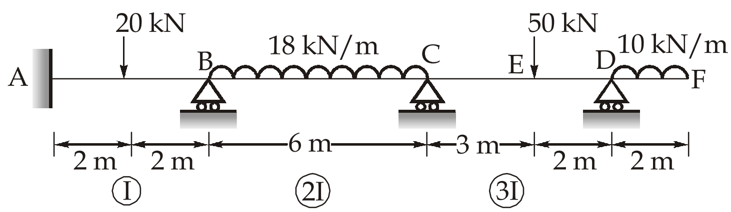
$$\text{Bending moment, } M = R_A \times 5 - H_A \times 3.75 - 50 \times 5 \times \frac{5}{2}$$

$$= 395 \times 5 - 290 \times 3.75 - 50 \times 5 \times \frac{5}{2}$$

$$= 262.5 \text{ kN-m}$$

$$\text{Radial shear at } D, SF = V_x \cos\theta - H\sin\theta$$
$$= (395 - 50 \times 5) \times 0.894 - 290 \times 0.447$$
$$= 0$$
$$\text{Normal thrust}, N = H\cos\theta + V_x \sin\theta$$
$$= 290 \times 0.894 + (395 - 50 \times 5) \times 0.447$$
$$= 324.075 \text{ kN}$$

Q.2 (c) Solution:



(i) Fixed end moments:

$$M_{FAB} = -\frac{WL}{8} = \frac{-20 \times 4}{8} = -10 \text{ kN-m}$$
$$M_{FBA} = \frac{WL}{8} = +10 \text{ kN-m}$$
$$M_{FBC} = -\frac{WL^2}{12} = \frac{-18 \times 6^2}{12} = -54 \text{ kN-m}$$
$$M_{FCB} = \frac{WL^2}{12} = 54 \text{ kN-m}$$
$$M_{FCD} = \frac{-Wab^2}{L^2} = \frac{-50 \times 3 \times 2^2}{5^2} = -24 \text{ kN-m}$$
$$M_{FDC} = \frac{Wba^2}{L^2} = \frac{50 \times 2 \times 3^2}{5^2} = 36 \text{ kN-m}$$
$$M_{DF} = -10 \times 2 \times \frac{2}{2} = -20 \text{ kN-m}$$

(ii) Slope deflection equations:

1. For member AB

$$M_{AB} = M_{FAB} + \frac{2EI}{L}(2\theta_A + \theta_B)$$
$$= -10 + \frac{2EI}{4}(\theta_B) \quad [\because \text{ End A is fixed}]$$

$$= -10 + \frac{EI\theta_B}{2}$$

$$M_{BA} = M_{FBA} + \frac{2EI}{L}(2\theta_B + \theta_A)$$

$$= 10 + \frac{2EI}{4}(2\theta_B) \qquad [\because \text{ End A is fixed}]$$

$$= 10 + EI\theta_B$$

2. For member BC

$$M_{BC} = M_{FBC} + \frac{2E(2I)}{L}(2\theta_B + \theta_C)$$

$$= -54 + \frac{4EI}{6}(2\theta_B + \theta_C)$$

$$= -54 + \frac{4EI\theta_B}{3} + \frac{2EI\theta_C}{3}$$

$$M_{CB} = M_{FCB} + \frac{2E(2I)}{L}(2\theta_C + \theta_B)$$

$$= 54 + \frac{4EI}{6}(2\theta_C + \theta_B)$$

$$= 54 + \frac{2}{3}EI\theta_B + \frac{4}{3}EI\theta_C$$

3. For member CD

$$M_{CD} = M_{FCD} + \frac{2E(3I)}{L}\times(2\theta_C + \theta_D)$$

$$= -24 + \frac{6EI}{5}(2\theta_C + \theta_D)$$

$$= -24 + \frac{12}{5}EI\theta_C + \frac{6EI\theta_D}{5}$$

$$M_{DC} = M_{FDC} + \frac{2E(3I)}{L}(2\theta_D + \theta_C)$$

$$= 36 + \frac{6EI\theta_C}{5} + \frac{12EI\theta_D}{5}$$

Joint Equilibrium conditions:

At joint B,

$$\Sigma M_B = 0$$

$$\Rightarrow \quad M_{BA} + M_{BC} = 0$$

$$\Rightarrow \quad 10 + EI\theta_B - 54 + \frac{4}{3}EI\theta_B + \frac{2}{3}EI\theta_C = 0$$

$$\Rightarrow \quad \frac{7EI\theta_B}{3}+\frac{2EI\theta_C}{3}-44 = 0 \quad \ldots(i)$$

At joint C, $\Sigma M_C = 0 \Rightarrow$

$$M_{CB} + M_{CD} = 0$$

$$\Rightarrow \quad 54+\frac{2}{3}EI\theta_B+\frac{4}{3}EI\theta_C-24+\frac{6EI\theta_D}{5}+\frac{12}{5}EI\theta_C = 0$$

$$\Rightarrow \quad \frac{2EI\theta_B}{3}+\frac{56EI\theta_C}{15}+\frac{6EI\theta_D}{5}+30 = 0 \quad \ldots(ii)$$

At joint D, $\Sigma M_d = 0 \Rightarrow M_{DC} + M_{DF} = 0$

$$\Rightarrow \quad 36+\frac{12EI\theta_D}{5}+\frac{6EI\theta_C}{5}-20 = 0$$

$$\Rightarrow \quad \frac{6EI\theta_C}{5}+\frac{12EI\theta_D}{5}+16 = 0 \quad \ldots(iii)$$

From above three equations,

$$EI\theta_B = 22.21$$
$$EI\theta_C = -11.75$$
$$EI\theta_D = -0.79$$

So,
$$M_{AB} = -10+\frac{22.21}{2} = 1.105 \text{ kN-m}$$

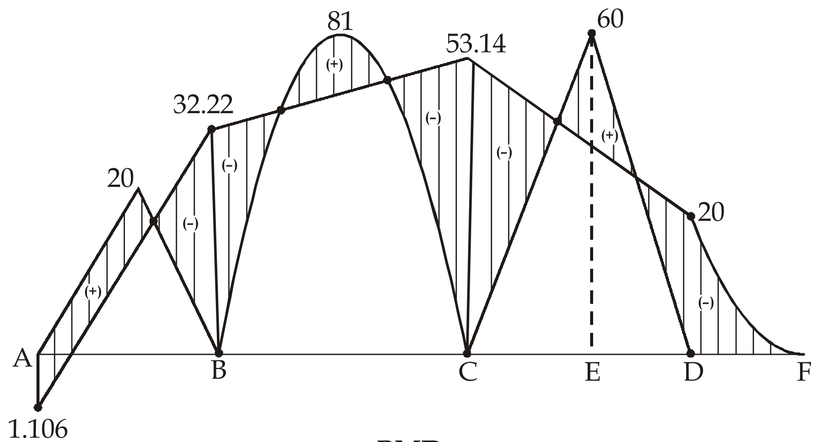
$$M_{BA} = 10+22.21 = 32.21 \text{ kN-m}$$

$$M_{BC} = -54+\frac{4}{3}\times 22.21+\frac{2}{3}(-11.75)$$
$$= -32.22 \text{ kN-m}$$

$$M_{CB} = 54-\frac{4}{3}\times 11.75+\frac{2}{3}\times 22.21$$
$$= 53.14 \text{ kN-m}$$

$$M_{CD} = -24+\frac{6}{5}\left(-2(11.747)-0.792\right)$$
$$= -53.15 \text{ kN-m}$$

$$M_{DC} = 36+\frac{6}{5}\left(-2(0.792)-11.747\right) = 20 \text{ kN-m}$$



BMD

Q.3 (a) Solution:

(i)

The various methods of artificial seasoning are as follows:

(a) Boiling
(b) Chemical seasoning
(c) Electrical seasoning
(d) Kiln seasoning
(e) Water seasoning.

(a) Boiling: In this method of artificial seasoning, the timber is immersed in water and water is then boiled. This is a very quick method. The timber is thus boiled with water for about three to four hours. It is then dried very slowly under a shed. The periods of seasoning and shrinkage are reduced by this method, but it affects the elasticity and strength of wood. In place of boiling water, the timber may be exposed to the action of hot steam. This method of seasoning proves to be costly.

(b) Chemical seasoning: This is also known as the salt seasoning. In this method, the timber is immersed in a solution of suitable salt. It is then taken out and seasoned in the ordinary way. The interior surface of timber dries in advance of exterior one and chances of formation of external cracks are reduced.

(c) Electrical seasoning: In this method, the use is made of high frequency alternating currents. The timber, when it is green, offers less resistance to the flow of electric current. The resistance increases as the wood dries internally which also results in the production of heat. This is the most rapid method of seasoning. But the initial and maintenance costs are so high that it becomes uneconomical to season timber on commercial basis by this method.

(d) Kiln seasoning: In this method, the drying of timber is carried out inside an airtight chamber or oven. The process of seasoning is as follows:

(i) The timber is arranged inside the chamber such that spaces are left for free circulation of air.

(ii) The air which is fully saturated with moisture and which is heated to a temperature of about 35°C to 38°C is then forced inside the chamber by suitable arrangement.

(iii) This forced air is allowed to circulate around the timber pieces. As air is fully saturated with moisture, the evaporation from the surfaces of timber pieces is prevented. The heat gradually reaches inside the timber pieces.

(iv) The relative humidity is now gradually reduced.

(v) The temperature is then raised and maintained till the desired degree of moisture content is attained.

Depending upon the mode of construction and operation, the kilns are of two types, namely, stationary kilns and progressive kilns.

A stationary kiln is also known as a compartment kiln and in this kiln, the process of seasoning is carried out in a single compartment only.

The drying operations are adjusted as drying proceeds. This kiln is adopted for seasoning timber which requires humidity and temperature. In a progressive kiln, the carriage with timber sections travels slowly from one end of kiln to the other and in doing so, it gets seasoned. The hot air is supplied from the discharging end so that the temperature is less at the charging end and it increases towards the discharging end. It is used for seasoning timber on a large scale. If not properly attended, the drying in this kiln may prove to be unsatisfactory. The kiln seasoning, though costly, gives well seasoned timber as it controls three important conditions, namely, circulating air, relative humidity and temperature.

(e) **Water seasoning:** In this method, the following procedure is adopted:

(i) The timber is cut into pieces of suitable sizes.

(ii) These pieces are immersed wholly in water, preferably in running water of a stream. The care should be taken to see that the timber is not partly immersed.

(iii) The thicker or larger end of timber is kept pointing on the upstream side.

(iv) The timber is taken out after a period of about 2 to 4 weeks. During this period, the sap contained in timber is washed away by water.

(v) The timber is then taken out of water and allowed to dry under a shed having free circulation of air. The water that has replaced sap from the timber dries out and the timber is seasoned.

The water seasoning is a quick method and it renders timber less liable to shrink or warp. It also removes organic materials contained in sap of timber. It however weakens the timber and makes it brittle.

(ii)

The glass may be given any of the following treatments:

(1) **Bending:** The glass may be bent into desired shape by placing it in ovens in which the temperature can be regulated. The glass in the form of rods, sheets or tubes is placed in such ovens and heated. It is then bent when it is suitably heated.

(2) **Cutting:** The glass is cut in required sizes with the help of diamond or rough glasses or small wheels of hardened steel.

(3) **Opaque making:** The glass can also be made opaque or impervious to light. It is done by grinding the glass surface with emery. It can also be achieved chemically by the application of hydrofluoric acid which causes itching of glass.

(4) **Silvering:** This process consists in applying a very thin coat of tin on the surface of glass. The silver is deposited on this layer of tin. A suitable paint is then applied to give protection against the atmospheric effects.

Q.3 (b) Solution:

(i)

Fibre glass reinforced plastic:

The fibre glass reinforced plastic or FRP is formed by using two materials in conjunction with each other to form a composite material of altogether different properties. It is also sometimes referred to as the Glass Fibre Reinforced Plastic or GRP.

The composite materials are also shortened as composites. They are formed by combining two or more different materials to make better use of their attributes and by minimizing their deficiencies.

The composites can be tailored as per the requirements by using tougher and light materials. Each material retains its physical or chemical properties separately and distinctly within the finished product. The composites can be natural or man-made. Wood is a natural composite of cellulose fibres in a matrix of lignin. Bricks made from straw and mud in ancient time was man-made composite. The composites are made from at least one of the main constituent materials viz. matrix and reinforcement. The matrix material surrounds and supports the reinforcement materials, while reinforcement imparts special mechanical and physical properties to enhance matrix properties. Plywood and concrete are commonly encountered composites. FRP, GRP, RCC, carbon-fibres reinforced plastic (CFRP), wire reinforced tiles, engineered wood like wood fibre board, pykrete (saw dust in ice matrix), etc., are the examples of composites.

In FRP or GRP, the glass fibres provide stiffness and strength while resin provides a matrix to transfer load to the fibres. The use of various additives lend special properties to the FRP. The combination of glass fibres, resins and additives to fabricate the FRP can be done in a number of ways.

Following are the five principal methods for manufacture of fibre glass reinforced plastic:

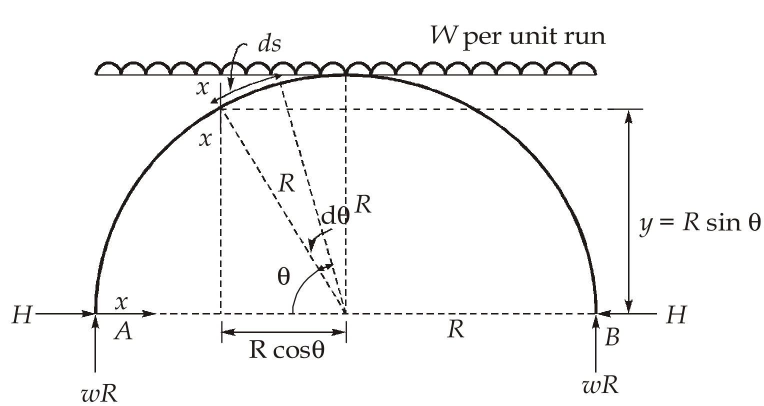
(i) Filament winding
(ii) Hand lay-up
(iii) Pultrusion
(iv) Resin transfer moulding
(v) Spray-up.

The FRP offers a combination of properties not easily found in the traditional materials. It has come as a boon especially for the building and construction industry.

The other industries which benefit the most from the continuous use of the FRP can be enumerated as follows:

(i) Chemical process industry;
(ii) Fertilizer industry;
(iii) Food processing industry;
(iv) Oil and gas producing industry;
(v) Paper industry;
(vi) Petrochemical industry;
(vii) Pharmaceutical industry;
(viii) Thermal power generation;
(ix) Water and wastewater treatment; etc.

(ii)



Because of symmetry, vertical reaction at A and B is wR.

Now, beam moment at section x-x,

$$M = wR(R - R\cos\theta) - w(R - R\cos\theta)\times\left(\frac{R - R\cos\theta}{2}\right)$$

$$= wR^2\left[1-\cos\theta-\frac{1}{2}-\frac{\cos^2\theta}{2}+\cos\theta\right]$$

$$= \frac{wR^2}{2}\sin^2\theta$$

$\therefore$ Horizontal thrust at support is,

$$H = \frac{\int Myds}{\int y^2 ds} = \frac{2\int_0^{\pi/2}\frac{wR^2}{2}\sin^2\theta.R\sin\theta.Rd\theta}{2\int_0^{\pi/2}R^2\sin^2\theta.Rd\theta}$$

$$= \frac{wR}{2}\frac{\int_0^{\pi/2}\sin^3\theta d\theta}{\int_0^{\pi/2}\sin^2\theta d\theta} = \frac{wR}{2}\times\frac{\frac{2}{3}}{\frac{1}{2}\times\frac{\pi}{2}} = \frac{4wR}{3\pi}$$

Q.3 (c) Solution:

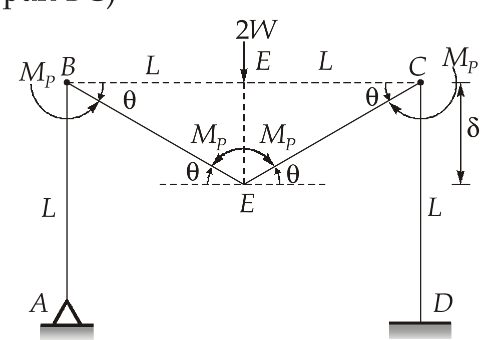
Total number of locations where plastic hinge formation can take place

= 4 (B, E, C, D)

Degree of static indeterminacy = 2

$\therefore$ Number of independent mechanisms = 4 – 2 = 2

(1) Beam mechanism (span BC)



From principle of virtual work done

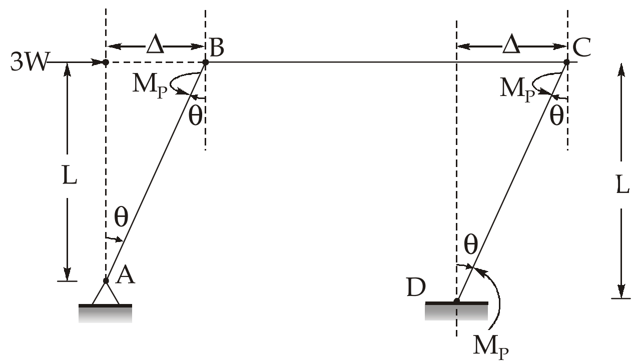
Internal work done = External work done

$\Rightarrow$ $$4M_p\theta = 2W\times\delta$$

$\Rightarrow$ $$4\times M_P\times\frac{\delta}{L} = 2W_u\times\delta \qquad [\because \theta=\frac{\delta}{L}]$$

$\Rightarrow$ $$W_u = \frac{2M_P}{L}$$

II. Sway mechanism

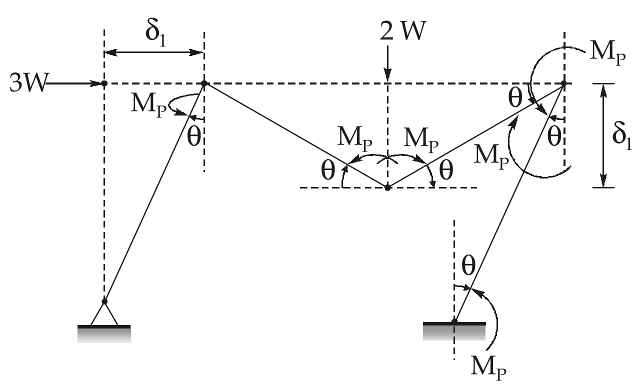


$$3\,W_u \times \Delta = 3M_p \times \theta$$

$$\Rightarrow \quad 3\,W_u \times \Delta = 3M_p \times \frac{\Delta}{L} \qquad \left[\because \theta = \frac{\Delta}{L}\right]$$

$$\Rightarrow \quad W_u = \frac{M_P}{L}$$

(iii) Combined mechanism



$$\Rightarrow \quad 5\,M_p\,\theta = 3W_u\,\delta_1 + 2\,W_u\delta_1$$

But, $$\theta = \frac{\delta_1}{L}$$

$$\therefore \quad 5M_P\frac{\delta_1}{L} = 5W_u \times \delta_1$$

$$\Rightarrow \quad W_u = \frac{M_P}{L}$$

So the collapse load is minimum of the following:

(1) Beam mechanism

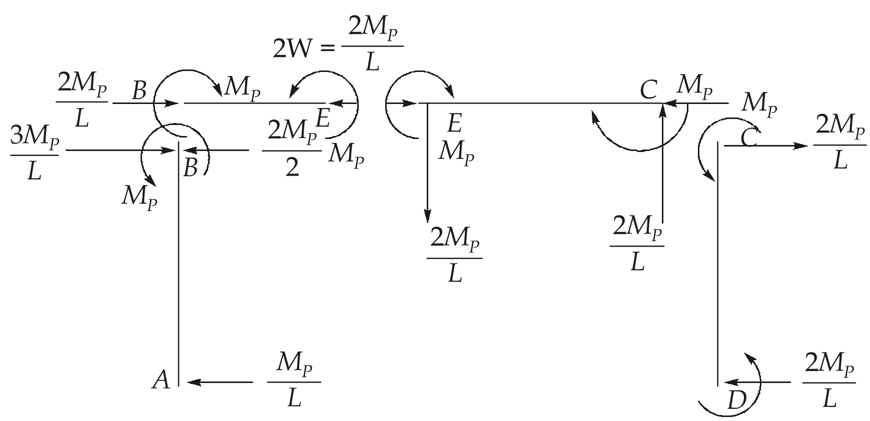
(2) Combined mechanism

(3) Sway mechanism

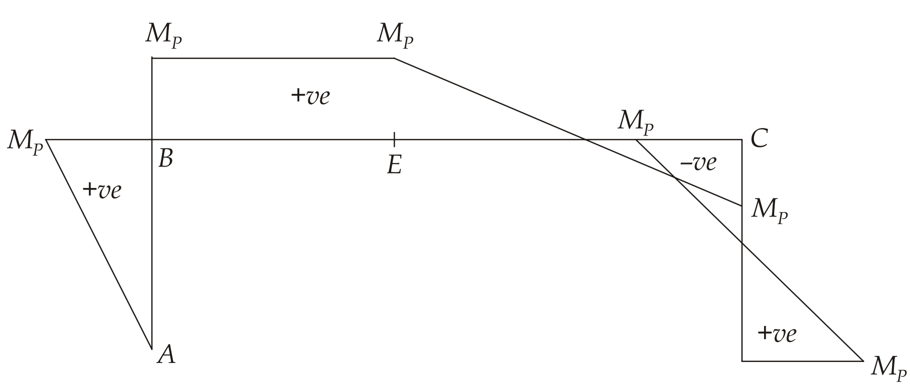
i.e. $$W = \frac{M_P}{L}$$

Since the value obtained from sway and combined mechanisms are equal, the actual collapse takes place under the action of both the mechanisms acting simultaneously. So hinges will be formed at B, C, D and E.

The free body diagram is as follows:

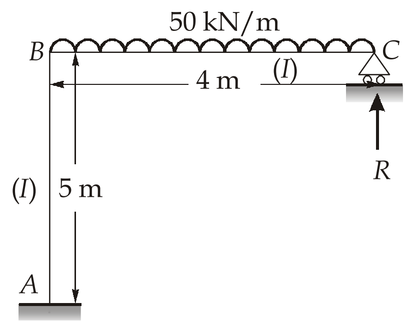


FBD



BMD

Q.4 (a) Solution:



Distribution factors:

Joint	Member	Relative Stiffness	Total relative stiffness	D.F
B	BA	$\frac{I}{5}$	$\frac{31I}{80}$	0.516
	BC	$\frac{3}{4}\left(\frac{I}{4}\right)$		0.484

Non sway Analysis:

Fixed end moments:

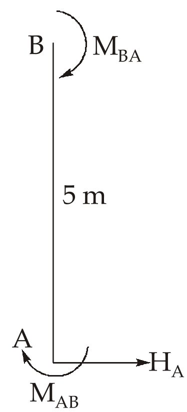
$$M_{FAB} = M_{FBA} = 0$$

$$M_{FBC} = -\frac{wL^2}{12} = \frac{-50\times 4^2}{12} = -66.67 \text{ kN-m}$$

$$M_{FCB} = \frac{wL^2}{12} = \frac{+50\times 4^2}{12} = 66.67 \text{ kN-m}$$

	A	B (0.516)	B (0.484)	C
FEM	0	0	–66.67	+66.67
End correction;			–33.33	–66.67
Corrected Moments;	0	0	–100	0
Balancing Moments;		51.6	48.4	
	25.8			
	25.8	51.6	–51.6	0

FBD of *AB*:



$$\sum M_B = 0$$

$$\Rightarrow \quad H_A = \frac{M_{AB}+M_{BA}}{5} = \frac{25.8+51.6}{5} = 15.48 \text{ kN}(\rightarrow)$$

$$\text{Now, sway force, } S = 15.48 \text{ kN } (\rightarrow)$$

Now we will analyze for sway force of 15.48 kN $(\rightarrow)$

Sway Analysis:

Let Δ be the transverse sway displacement due to sway force.

$$\therefore \quad M_{AB} = M_{BA} = \frac{-6EI\Delta}{L^2} = \frac{-6EI\Delta}{25}$$

Let $\quad M_{AB} = M_{BA} = -1$ kN/m

A	B		C
	0.516	0.484	
−1	−1	0	
	0.516	0.484	
0.258			
−0.742	−0.484	0.484	

From FBD of AB,

$$H'_A = \frac{-0.742-0.484}{5} = -0.2452 \text{ kN } = 0.2452 \text{ kN}(\leftarrow)$$

Let S' be the sway force for which the moments given above are tabulated.

Now, $S' + H'_A = 0$

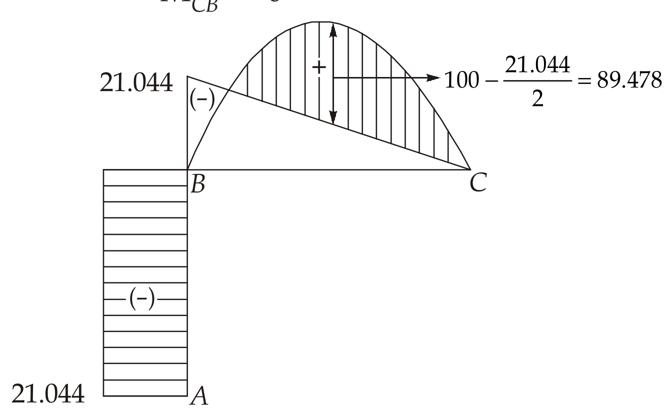
$\Rightarrow$ $S' = 0.2452$ kN ($\rightarrow$)

$\therefore$ For actual sway force i.e. 15.48 kN, sway moments are to be multiplied by

$$\frac{15.48}{0.2452} = 63.132$$

$\therefore$ Final moment = Non-sway moment + Sway moment

$$\therefore \quad M_{AB} = 25.8 - 0.742 \times 63.132$$
$$= -21.044 \text{ kN-m}$$
$$M_{BA} = 51.6 - 0.484 \times 63.132$$
$$= 21.044 \text{ kN-m}$$
$$M_{BC} = -51.6 - 0.484 \times 63.132$$
$$= -21.044 \text{ kN-m}$$
$$M_{CB} = 0$$



Bending moment diagram

Q.4 (b) Solution:

Each wheel load reaction = 30 kN

Impact factor = 1.25

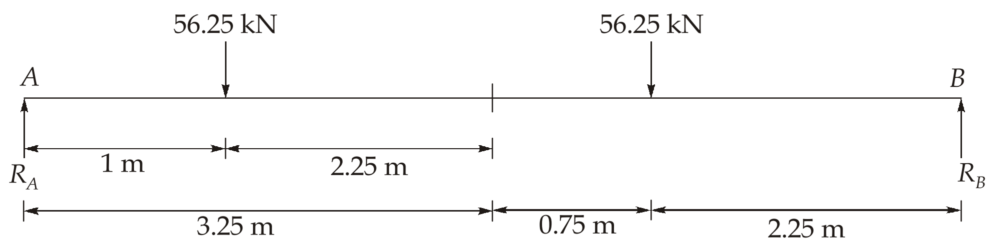
Partial factor of safety = 1.5

$\therefore$ Factored wheel load, $W = 1.25 \times 1.5 \times 30 = 56.25$ kN

Since the ends of the beam are restrained against rotation (torsion).

Effective length of the compression flange of the beam = Length of the beam = 6.5 m

To get maximum bending moment, one of the wheels and resultant should be placed at equal distance from the centre of the beam.



$$\sum M_A = 0$$

$\Rightarrow$ $$56.25 \times 1 + 56.25 \times 4 = R_B \times 6.5$$

$\Rightarrow$ $$R_B = 43.27 \text{ kN}$$

Maximum bending moment,

$$M = 43.27 \times 2.5 = 108.175 \text{ kN-m}$$

Factored moment carrying capacity of beam (M_u)

For $$\frac{kL}{r_{min}} = \frac{6500}{35.2} = 184.66$$

and $$\frac{h}{t_f} = \frac{500}{17.2} = 29.07$$

$\frac{kL}{r_{min}}$	$\frac{h}{t_t}$		
	25		30
180	127.1		112.2
184.66	122.6	**110.68**	107.96
190	117.5		103.1

From table, $$f_{cr,\,b} = 110.68 \text{ kN/mm}^2$$

Let's find out f_{bd} for $f_{cr,\,b} = 110.68$ N/mm^2

$$\frac{150-100}{106-77.3} = \frac{150-110.68}{106.8-f_{bd}}$$

$\Rightarrow$ $$f_{bd} = 84.23 \text{ N/mm}^2$$

$$M_u = \text{Factored moment carrying capacity}$$

$$= f_{bd} \times Z_p \text{ (for plastic section)}$$

$$= 84.23 \times \frac{2074.67 \times 10^3}{10^6} = 174.75 \text{ kN-m}$$

Since factored moment carrying capacity is more than maximum bending moment (108.175 kN-m)

Hence the beam is safe in bending.

Q.4 (c) Solution:

(i)

Provisions of IS 456: 2000 to ensure durability of reinforced concrete structures: CI 8.1 defines durable concrete as "the one that performs satisfactorily in the working environment during its anticipated exposure conditions during service."

Requirements for durability:

- **Shape and size of member (Cl. 8.2.1):** The shape or the design details of the exposed structures should be such as to promote good drainage of water and to avoid standing pools and rundown of water. Care must be taken to minimize any cracks that may collect or transmit water. Adequate curing is essential to make for early loss of water.
- **Exposure conditions (CI. 8.2.2):** The general environment to which concrete is exposed during its working life is classified into five levels as mild, moderate, severe, very severe and extreme.
  - (i) Where freezing and thawing actions under wet conditions exist, enhanced durability can be achieved by use of suitable air entraining admixtures. But since air entrainment reduces the strength of concrete and thus suitable adjustments must be made in the design mix. (Cl. 8.2.2.3)
  - (ii) Table 4 of IS 456: 2000 specifies requirements for the type of cement, maximum free water-cement ratio and minimum cement content for concrete exposed to sulphate environment.
- **Cover requirements (CI. 8.2.3)**: Table 16 of IS 456: 2000 specifies nominal cover to meet durability requirements as described below.

Exposure condition	Minimum nominal cover (mm)
Mild	20
Moderate	30
Severe	45
Very severe	50
Extreme	75

- **Maximum cement content (Cl. 8.2.4.2)**: Cement content not including fly ash and ground granulated blast furnace slag in excess of 450 kg/m^3 must not be used.
- **Compaction, finishing and curing (Cl. 8.2.7)**: Adequate compaction without segregation must be ensured by providing suitable workability and by proper placing and compaction. Good finishing is essential for durable concrete.

- **Concrete in sea water (Cl. 8.2.8)**: Concrete in sea water or exposed directly along the sea coast shall be at least M20 grade for plain concrete and M30 grade for reinforced concrete. Use of slag or pozzolana is beneficial under such conditions.

(ii)

Five basic parts of paint are as follows:

1. **Base:** A base is a solid substance in a fine state of division and it forms the bulk of a paint. It determines the character of a paint and imparts durability to the surface which is painted. It reduce shrinkage crack formed on drying and it also forms an opaque layer to obscure the surface of material to be painted. e.g White lead, red lead, etc.
2. **Vehicle:** It is the liquid substance which holds the ingredients of a paint in liquid suspension. It is required mainly for two reasons:
   (i) to make it possible to spread the paint evenly and uniformly on the surface in form of a thin layer.
   (ii) to provide a binder for the ingredients of a point so that they may stick or adhere to the surface. e.g. Linseed oil, tung oil, etc.
3. **Drier:** It is the substance accelerate the process of drying. A drier absorbs oxygen from the air and transfers it to the linseed oil, which in turn, gets hardened. It may be in the form of soluble drier or paste drier.

   e.g. Litharge, red lead and sulphate of manganese.
4. **Colouring pigments:** When it is desired to have different colour than the base of a paint, a coloring pigment is to be added. The pigments are available in the form of fine powders in various colours and qualities.

Following are five types of the colouring pigments:

   (i) Natural earth colours such as ochres, umbers, etc.
   (ii) Calcined colours such as lamp black, Indian red, etc.
   (iii) Precipitates such as Prussian blue, chrome green, etc.
   (iv) Lakes prepared by discolouring barytes or china clay with help of suitable dyes.
   (v) Metal powders such as aluminium powder, bronze powder, etc.

5. **Solvents:** The function of a solvent is to make the paint thin so that it can be easily applied on the surface It also helps the paint in penetrating through the porous surfaces. The most commonly used solvent is the spirit of turpentine.

Q.5 (a) Solution:

Given data: Width of section, $B = 300$ mm

Depth of section, $D = 600$ mm

Effective depth of section, $d = 600 - 50 = 550$ mm

Area of steel provided, $A_{st} = 4\times\frac{\pi}{4}\times 16^2 = 804.25 \text{ mm}^2$

Modular ratio, $m = 19$

Permissible stress in bending compression, $\sigma_{cbc} = 5$ MPa

Permissible stress in steel, $\sigma_{st} = 230$ MPa

Critical depth of neutral axis is given by,

$$x_c = K_0.d$$

$$= \left(\frac{m.\sigma_{cbc}}{m\sigma_{cbc}+\sigma_{st}}\right).d$$

$$= \left(\frac{19\times 5}{19\times 5+230}\right)\times 550 = 160.77 \text{ mm}$$

Actual depth of neutral axis is given by,

$$\frac{B}{2}.x_a^2 + m.A_{st}.x_a - m.A_{st}.d = 0$$

$$\Rightarrow \frac{300}{2}.x_a^2 + 19\times 804.25\times x_a - 19\times 804.25\times 550 = 0$$

$$\Rightarrow 150x_a^2 + 15280.75x_a - 8404412.5 = 0$$

$$\therefore \quad x_a = 191.19 \text{ mm}$$

$\because$ $x_a > x_c$, therefore section is over reinforced

i.e. $C_a = \sigma_{cbc} = 5$ MPa

$t_a < \sigma_{st} = 230$ MPa

Now moment of resistance is given by,

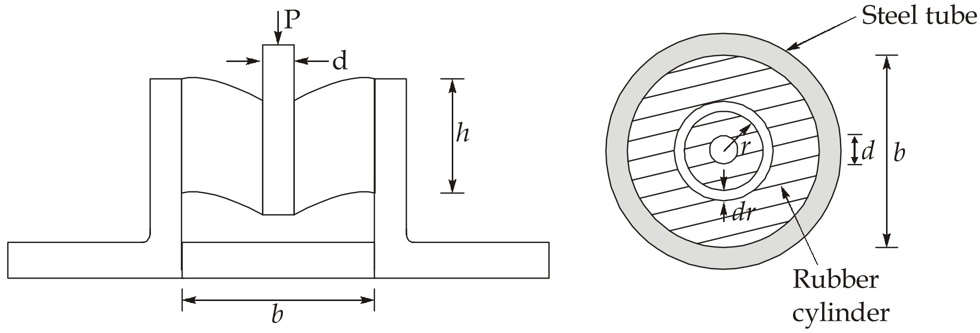
$$M_R = \frac{B}{2}.C_a.x_a\left(d-\frac{x_a}{3}\right)$$

$$= \frac{300}{2}\times 5\times 191.19\left(550-\frac{191.19}{3}\right)\times 10^{-6} \text{ kN-m}$$

$$= 69.727 \text{ kN-m}$$

Q.5 (b) Solution:

Let us consider an element at distance 'r' from centre of thickness 'dr' having vertical displacement '$d\delta$'.



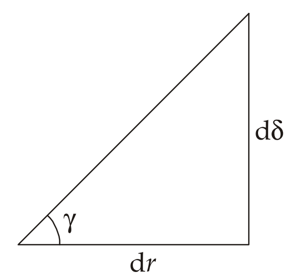
Shear stress at radial distance r,

$$\tau = \frac{P}{\text{Shear area}} = \frac{P}{2\pi rh}$$

$\therefore$ Shear strain at distance r,

$$\gamma = \frac{\tau}{G} = \frac{P}{2\pi rhG}$$

For an element



$$\gamma = \frac{d\delta}{dr}$$

$\Rightarrow$ $$d\delta = \gamma . dr$$

$$= \frac{Pdr}{2\pi rhG}$$

Now, displacement of bar, $\delta = \int d\delta = \frac{P}{2\pi hG}\int_{d/2}^{b/2}\frac{dr}{r} = \frac{P}{2\pi hG}[ln\, r]_{d/2}^{b/2}$

$\Rightarrow$ $$\boxed{\delta = \frac{P}{2\pi hG} ln \frac{b}{d}}$$

Q.5 (c) Solution:

- Before beginning the actual work of demolition, a careful and detailed study of the structure to be demolished should be made. While working out the plan of demolition, safety of the adjoining structures must be ensured.

Prior to demolition:

- Suitable bracing, shoring etc. should be provided to prevent accidental collapse of the building which has already been damaged by fire, flood or earthquake.
- All safety equipments including PPEs must be issued to the workers.
- Suitable safety precautions for the fire must be ensured.

During demolition:

- All materials of fragile nature like glass etc. must be removed first.
- All openings should be boarded up.
- Dust must be controlled by suitable means to prevent harm to workmen and environment.
- Adequate natural or artificial lighting and ventilation should be provided for the workmen.
- Easy exit must be provided to arrange for quick evacuation of the workmen during emergency.
- The demolition should always proceed systematically storey by storey in the descending order.

Q.5 (d) Solution:

For rod, $E_R = 3.1$ GPa, $d_0 = 30$ mm

For sleeve, $E_S = 2.4$ GPa, $d_0 = 45$ mm, $d_i = 30$ mm

(i) Since no slippage occurs, the deformations are equal in sleeve and rod in CD portion.

$$\delta_R = \delta_S$$

$$\Rightarrow \quad \frac{P_R L_{CD}}{A_R E_R} = \frac{P_S L_{CD}}{A_S E_S} \quad \dots(i)$$

where P_R and R_S are load resisted by rod and sleeve respectively in portion CD.

Also, $P_R + P_S = P \quad \dots(ii)$

$\Rightarrow \quad P_R + P_S = 20$

$$\therefore \quad \frac{P_R}{\frac{\pi}{4} \times 30^2 \times 3.1} = \frac{P_S}{\frac{\pi}{4} \times \left(45^2 - 30^2\right) \times 2.4}$$

$$\Rightarrow \quad P_R = \frac{31 P_S}{30}$$

$\therefore \quad P_S = 9.836$ kN, $P_R = 10.164$ kN

Now, $L_{AC} = L_{BD}$,

$$\therefore \quad \text{Total elongation} = \frac{2 \times P L_{AC}}{A_R E_R} + \frac{P_R L_{CD}}{A_R E_R}$$

$$= \frac{2 \times P L_{AC} + P_R L_{CD}}{A_R E_R} = \frac{2 \times 20 \times 0.1 + 10.164 \times 0.4}{\frac{\pi}{4} \times (0.03)^2 \times 3.1 \times 10^6}$$

$$= 3.68 \times 10^{-3} \text{ m} = 3.68 \text{ mm}$$

(ii) For extended sleeve case,

$$\text{Elongation} = \frac{P_R L}{A_R E_R} = \frac{P_S L}{A_S E_S} = \frac{10.164\times0.6}{\frac{\pi}{4}\times0.03^2\times3.1\times10^6}$$

$$= 2.78 \times 10^{-3} \text{ m} = 2.78 \text{ mm}$$

Q.5 (e) Solution:

- Observed horse power, H_0 = 75.5 HP
- Observed absolute temperature, T_0 = 273 + 35 = 308 K
- Observed pressure, P_0 = 740 mm of Hg
- Standard horse power = H_S
- Standard absolute temperature, T_S = 273 + 15.5° = 288.5 K
- Standard pressure, P_S = 760 mm of Hg.

Now using the formula,

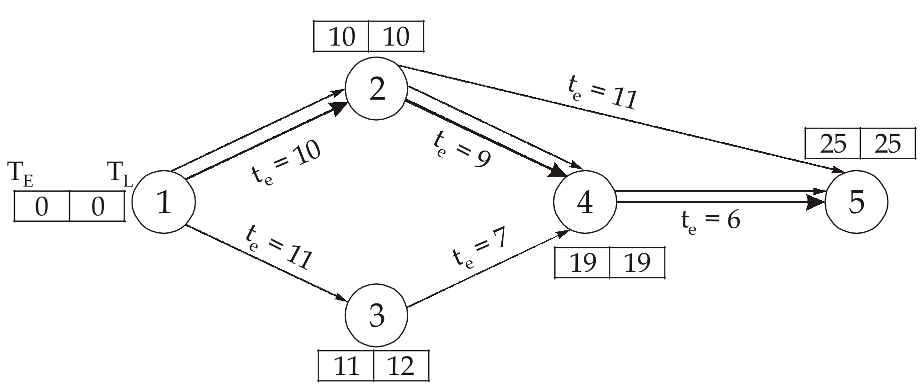
$$H_S = H_0 \frac{P_S}{P_0}\times\sqrt{\frac{T_0}{T_S}} = 75.5\times\frac{760}{740}\times\sqrt{\frac{308}{288.5}} = 80.12 \text{ HP}$$

(ii) Factors affecting selection of a tractor:

1. The size required as per magnitude of the job.
2. The type of footing over which it is to operate i.e. high tractive or low tractive efficiency.
3. The firmness of haul road.
4. The smoothness of haul road.
5. The slope of haul road.
6. The length of haul.
7. The type of work it is to do after this job is completed.

Q.6 (a) Solution:

(i)



Hence critical path is 1 – 2 – 4 – 5 and the project duration is 25 days.

- Standard deviation of the project σ is given by,

$$\sigma = \sqrt{(\sigma_{1-2})^2 + (\sigma_{2-4})^2 + (\sigma_{4-5})^2}$$
$$= \sqrt{(2)^2 + (3)^2 + (2)^2}$$
$$= 4.123$$

Now,
$$Z = \frac{T_S - T_E}{\sigma} = \frac{32-25}{4.123}$$
$$= 1.69779$$
$$\simeq 1.7$$

Hence, probability, P corresponding to $Z = 1.7$ is obtained from table by interpolation.

$$\frac{2-1.5}{97.92-93.92} = \frac{1.7-1.5}{P-93.92}$$

$$\Rightarrow \quad P = 95.52\%$$

(ii)

To find torsional stiffness of solid shaft,

$$\text{Angular deformation, } \phi = \sum \frac{T_i L_i}{G_i I_{P_i}} = \frac{T(1.5)}{G\left(\frac{\pi}{32}\right)(0.08)^4} + \frac{T(1)}{G\left(\frac{\pi}{32}\right)(0.04)^4}$$
$$= \frac{32T}{\pi G} \times 427246.09$$

$$\therefore \quad \text{Torsional stiffness, } K_T = \frac{T}{\phi} = \frac{\pi G}{32} \times 2.341 \times 10^{-6} \quad \text{...(i)}$$

For hollow shaft,

$$D_o = d, D_i = d - 2t = d - \frac{2d}{10} = 0.8\,d \quad [\because t = 0.1\,d]$$

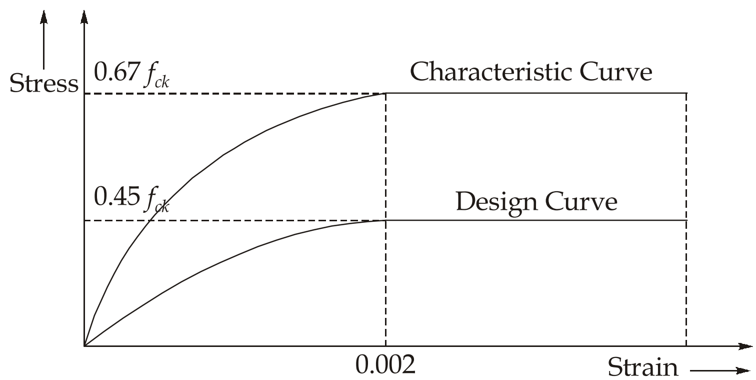
$$\text{Torsional stiffness, } K_T = \frac{GI_P}{L} = \frac{G \times \frac{\pi}{32} \times \left(d^4 - (0.8d)^4\right)}{2.5}$$
$$= \frac{\pi G}{32} \times 0.23616\,d^4 \quad \text{...(ii)}$$

Now, equating torsional stiffnesses,

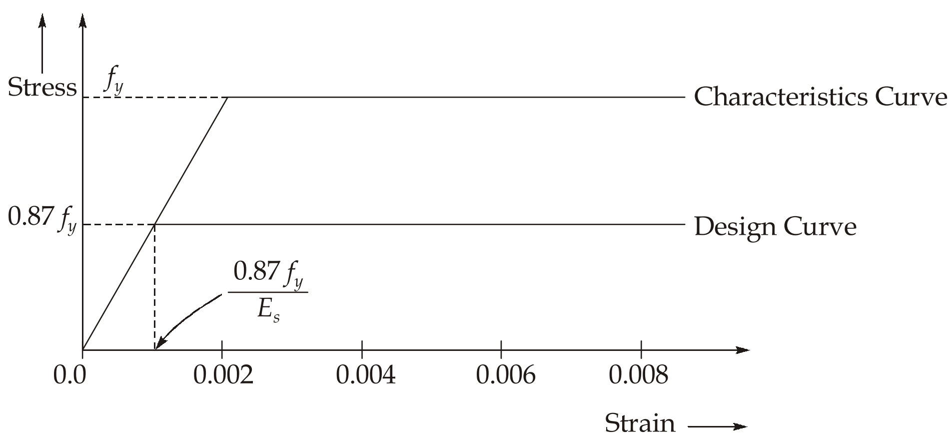
$$0.23616\,d^4 = 2.341 \times 10^{-6}$$
$$\Rightarrow \quad d = 0.0561 \text{ m}$$
$$= 56.1 \text{ mm}$$

Q.6 (b) Solution:

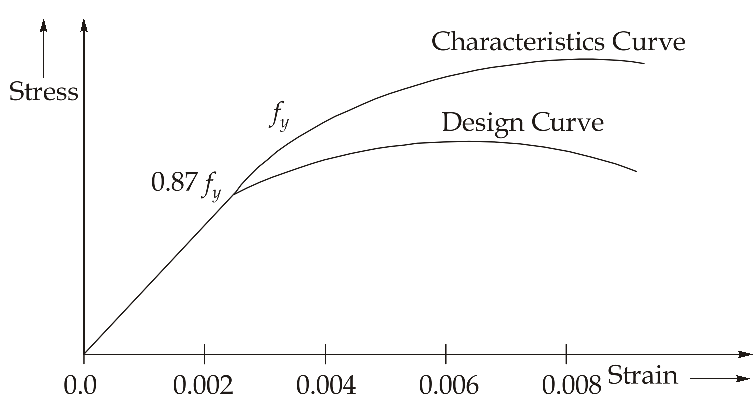
(i) Characteristic stress-strain curve for concrete:



Characteristic stress-strain curve for mild steel:



Characteristic stress-strain curve for HYSD steel:



(ii) Width of section, B = 250 mm

Effective depth, d = 500 mm

Effective cover, d_c = 50 mm

Bending moment, $BM = 200$ kN-m

Stress in compression reinforcement, $f_{sc} = 420$ MPa

Factored moment, $M_U = 1.5 \times 200 = 300$ kN-m

Limiting moment of resistance, $M_{u,\,\text{lim}}$ is given by

$$M_{u,\,\text{lim}} = R_0.f_{ck}.Bd^2 = 0.133 \times 25 \times 250 \times 500^2 \times 10^{-6} \text{ kN-m}$$
$$= 207.81 \text{ kN-m}$$

Now, $M_u > M_{u,\,\text{lim}}$

$\therefore$ The section has to be a doubly reinforced section.

Limiting depth of neutral axis, $x_{u\text{lim}} = K_0.d = 0.46 \times (500) = 230$ mm.

$$M_{u,\,\text{lim}} = 0.87\, f_y\, A_{\text{st, lim}}\, (d - 0.42.\, x_{u\text{lim}})$$

$$\Rightarrow \quad 207.81 \times 10^6 = 0.87 \times 500 \times A_{\text{st, lim}}\, (500 - 0.42 \times 230)$$

$$\Rightarrow \quad A_{st,\,\text{lim}} = 1184.24 \text{ mm}^2$$

$$(M_u - M_{u,\,\text{lim}}) = 0.87\, f_y.A_{st\,2}\, (d - d_c)$$

$$\Rightarrow \quad (300 - 207.81) \times 10^6 = 0.87 \times 500\, A_{st\,2}\, (500 - 50)$$

$$\Rightarrow \quad A_{st2} = 471 \text{ mm}^2$$

$\therefore$ Total tensile steel, $A_{st} = A_{st,\,\text{lim}} + A_{st,2}$

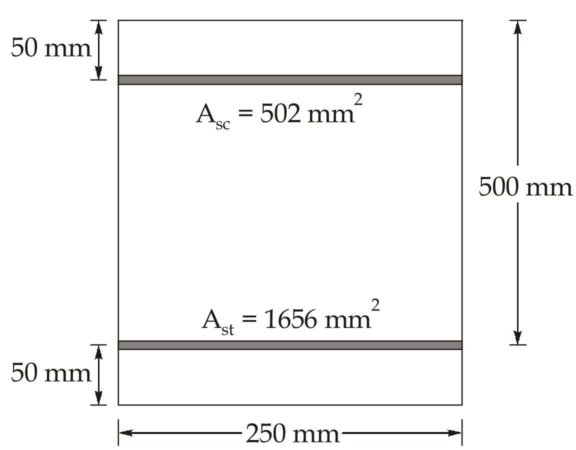
$$= 1184.24 + 471$$
$$= 1655.24 \text{ mm}^2 \simeq 1656 \text{ mm}^2 \text{ (say)}$$

Now area of steel on compression side is given by,

$$(M_u - M_{u,\,\text{lim}}) = (f_{sc} - 0.45\, f_{ck})\, A_{sc}(d - d_c)$$

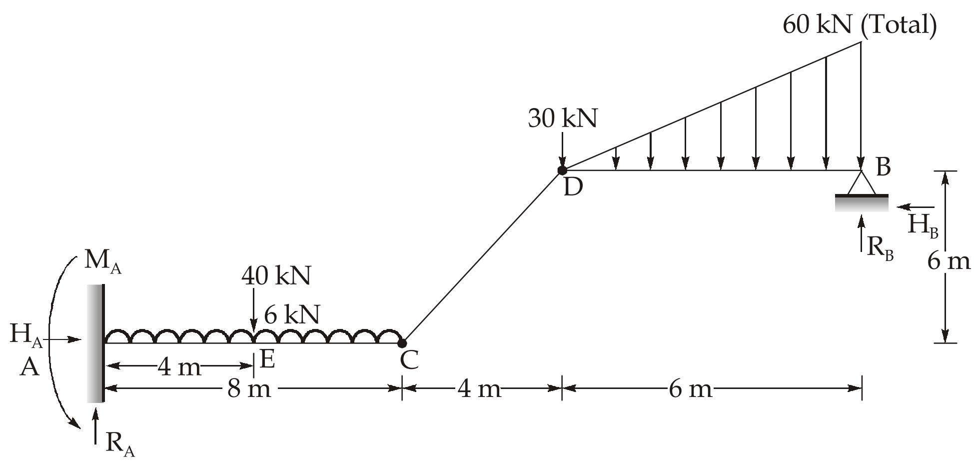
$$\Rightarrow \quad (300 - 207.81) \times 10^6 = (420 - 0.45 \times 25)\, A_{sc}(500 - 50)$$

$$\Rightarrow \quad A_{sc} = 501.20 \text{ mm}^2 \simeq 502 \text{ mm}^2 \text{ (say)}$$



Q.6 (c) Solution:

From equilibrium considerations,



$$\sum F_x = 0$$

$$\Rightarrow \quad H_A - H_B = 0$$

$$\Rightarrow \quad H_A = H_B \quad \text{...(i)}$$

Also, $\sum F_y = 0$

$$\Rightarrow \quad R_A + R_B = 40 + 6(8) + 30 + 60$$

$$= 178 \text{ kN} \quad \text{...(ii)}$$

At hinge C, taking moments about C from right

$$M_C \text{ (from right)} = 0$$

$$\Rightarrow \quad R_B(10) + H_B(6) = 30\,(4) + 60\left(4 + \frac{2}{3} \times 6\right)$$

$$10\,R_B + 6\,H_B = 600 \text{ kN} \quad \text{...(iii)}$$

At hinge D, taking moments about D from right,

$$M_D = 0 \qquad \text{(from right)}$$

$$\Rightarrow \quad 60 \times \left(\frac{2}{3} \times 6\right) = R_B \times 6$$

$$\Rightarrow \quad R_B = 40 \text{ kN} \quad \text{...(iv)}$$

At hinge C, taking moments about C from left,

$$M_C \text{ (from left)} = 0$$

$$\Rightarrow \quad 40 \times 4 + 6 \times 8 \times \frac{8}{2} + M_A = R_A \times 8$$

$\Rightarrow$ $8R_A - M_A = 352$ kN-m ...(v)

Reactions $R_A = 138$ kN

$R_B = 40$ kN

$M_A = 752$ kN-m

$H_A = 33.33$ kN

$H_B = 33.33$ kN

For SFD

Consider top face as reference face,

For portion AE

$S_x(x \text{ from A}) = R_A - 6x$

$= 138 - 6x$ $(0 \leq x < 4)$

For portion EC, $S_x = 138 - 6x - 40$ $(4 \leq x < 8)$

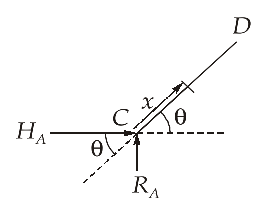
$= 98 - 6x$

At $x = 0$, $S_A = 138$ kN

At $x = 4$ m, S_E^- (Just left of E) $= 138 - 6 \times 4 = 114$ kN

S_E^+ (Just right of E) $= 98 - 6 \times 4 = 74$ kN

At $x = 8$ m, $S_C = 98 - 6 \times 8 = 50$ kN



Portion CD, $\tan\theta = \dfrac{6}{4} = 1.5$

$\therefore$ $\sin\theta = 0.832$

$\cos\theta = 0.554$

$S_x(x \text{ from C}) = -H_A\sin\theta + R_A\cos\theta = -(6 \times 8 + 40)\cos\theta$

$= -33.33 \times 0.832 + 138 \times 0.554 - 88 \times 0.554$

$\simeq 0$

Axial force in member CD,

$F = H_A\cos\theta + R_A\sin\theta - (6 \times 8 + 40)\sin\theta$

$= 33.33 \times 0.554 + 138 \times 0.832 - 88 \times 0.832$

$= 60.065$ kN (compression)

Portion DB,

Let the load intensity at B in porion DB is 'w'.

Now, $\dfrac{1}{2} \times w \times 6 = 60$

$$\Rightarrow \qquad w = 20 \text{ kN/m}$$

$$S_x(x \text{ from D}) = R_A - 40 - 6 \times 8 - 30 - \frac{1}{2}\times\left(\frac{20}{6}\times x\right)\times x \qquad [0 \le x < 6 \text{ m}]$$

$$= 20 - \frac{5x^2}{3}$$

At $x = 0$, $S_D^+ = 20$ kN

At $x = 6$, $S_B = -40$ kN

For zero shear force in DB,

$$20 - \frac{5x^2}{3} = 0$$

$$\Rightarrow \qquad x = 3.464 \text{ m}$$

For BMD,

Consider outer (top) face as reference,

Portion AC,

$$M_x(x \text{ from } A) = R_A x - M_A - \frac{wx^2}{2} \qquad (0 \le x \le 4)$$

$$= 138x - 752 - \frac{6x^2}{2}$$

$$= 138x - \frac{6x^2}{2} - 752$$

For $(4 \le x \le 8)$,

$$M_x = R_A x - M_A - \frac{wx^2}{2} - 40(x-4) \qquad [4 \le x < 8 \text{ m}]$$

$$= 138x - 752 - 3x^2 - 40x + 160$$

$$= 98x - 592 - 3x^2$$

At $x = 0$, $M_A = -752$ kN-m

$x = 4$ m, $M_E = -248$ kN-m

$x = 8$ m, $M_C = 0$ kN-m

Portion CD, $M_{CD} = 0$

CD will only carry axial force.

Portion DB,

$$M_x\,(x \text{ from D}) = -30x - \frac{1}{2}\times\left(\frac{20}{6}\times x\right)\times x\times\frac{x}{3} = 20x - \frac{5x^3}{9}$$

At $x = 0,\quad M_D = 0$

$x = 6\text{ m},\quad M_B = 0$

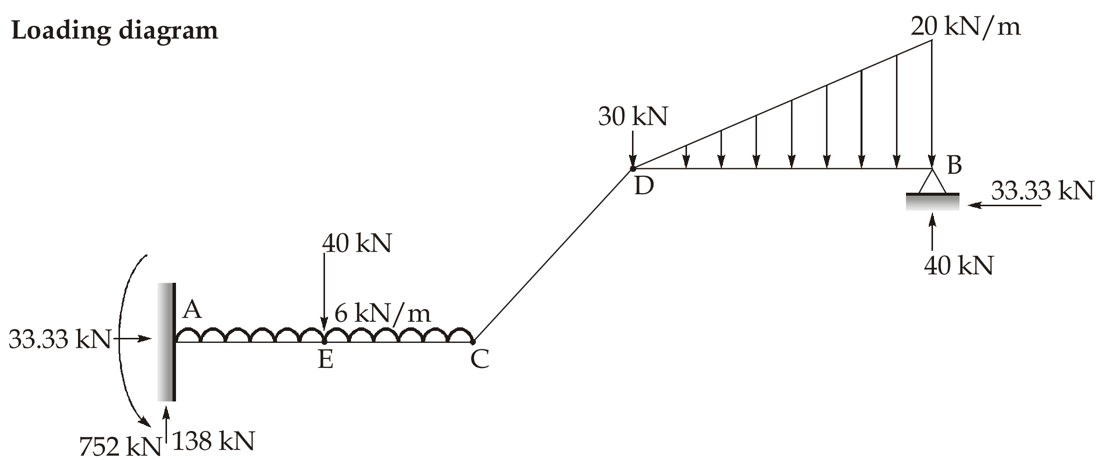
For maximum value of moment,

$$\frac{dM_x}{d_x} = 20 - \frac{15x^2}{9} = 0$$

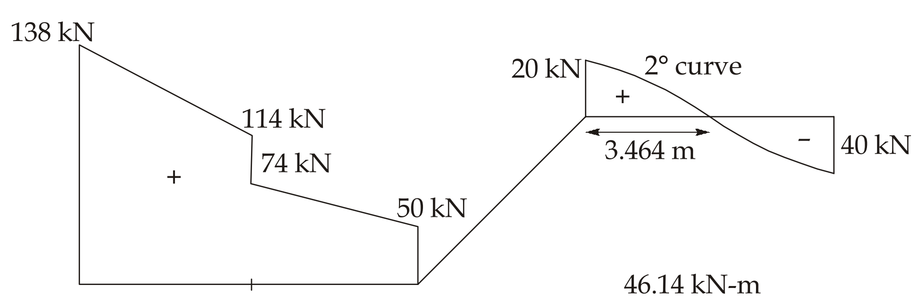
$$x = 0, 3.464\text{ m}$$

$$\therefore \quad M_x = 20(3.464) - \frac{5(3.464)^3}{9} = 46.19\text{ kN-m}$$

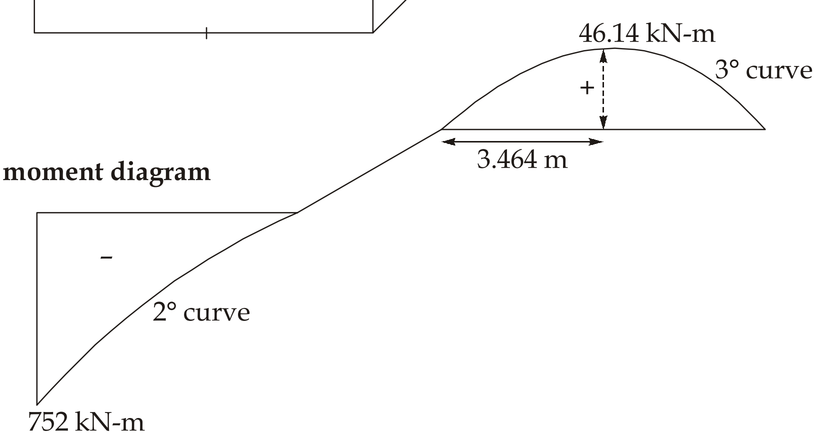
Loading diagram



Shear force diagram

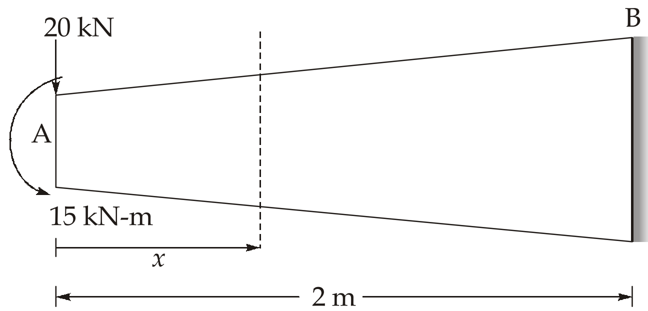


Bending moment diagram



Q.7 (a) Solution:

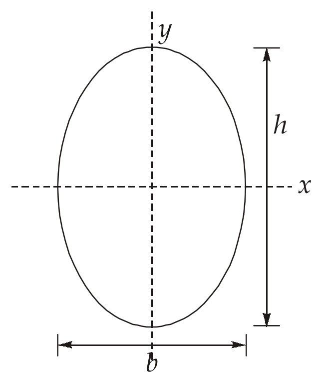
(i)



Bending moment at x from A,

$$M_x = -(15 + 20x) \text{ kNm}$$

For an elliptical cross-section,



$$I_x = \frac{\pi b h^3}{64}, \qquad I_y = \frac{\pi h b^3}{64}$$

Dimension at x from A,

$$b_x = 0.06 + \frac{0.08 - 0.06}{2} \times x = 0.06 + 0.01\,x$$

Similarly, $$h_x = 0.09 + \frac{0.12 - 0.09}{2} x = 0.09 + 0.015x$$

Section modulus, $$Z = \frac{I}{y_{max}} = \frac{\pi b_x h_x^3}{64 \times \frac{h_x}{2}} = \frac{\pi b_x h_x^2}{32}$$

∴ Maximum bending stress at x from A,

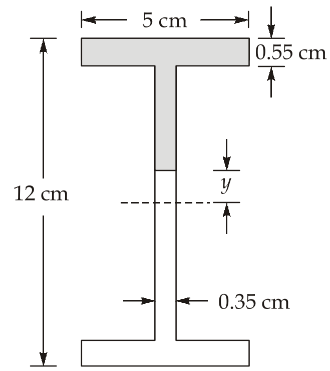
$$\sigma_x = \frac{M_x}{Z} = \frac{15 + 20x}{\frac{\pi b_x h_x^2}{32}} = \frac{32}{\pi}\left(\frac{15 + 20x}{b_x h_x^2}\right)$$

$$= \frac{32}{\pi}\left(\frac{15+20x}{(0.06+0.01x)\times(0.09+0.015x)^2}\right)$$

At $x = 0$, $\sigma_A = 314380.134 \text{ kN/m}^2 = 314.38 \text{ N/mm}^2$

At $x = 2$ m, $\sigma_B = 486.307 \text{ N/mm}^2$

(ii)



$$A\bar{y} = \left[\frac{(5\times0.55)5.725+(5.45-y)0.35[(5.45+y)]}{2}\right]$$

$$= \frac{15.75 + (5.45^2 - y^2)0.35}{2} = 20.95 - 0.175y^2 \text{ cm}^3$$

$$\tau = F.\frac{A\bar{y}}{bI} = \frac{10000(20.95-0.175y^2)}{0.35\times220}$$

At the neutral axis,

$$\tau = \frac{10000\times20.95}{0.35\times220\times100} = 27.2 \text{ N/mm}^2$$

At the top of the web,

$$\tau = \frac{100\times15.75}{0.35\times220} \quad (y = 5.45 \text{ cm}) = 20.1 \text{ N/mm}^2$$

Q.7 (b) Solution:

(i)

We know,

Cycle time = Loading time + Swing loading + Dumping time + Swing empty time

$= (9 + 4 + 4 + 4) = 21$ sec

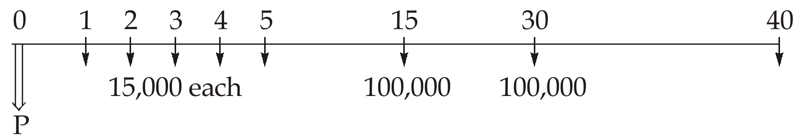
$$\therefore \quad \text{Production} = \frac{\text{3600 sec/hr} \times \text{Heaped bucket capacity} \times \text{Bucket fill factor} \times \text{Height swing factor}}{\text{Cycle time}} \times \left\{\frac{\text{Efficiency factor}}{1 + \text{\% swell}}\right\}$$

Substituting the values, we get

$$\text{Production rate} = \frac{3600 \times 81 \times 1 \times 0.73}{21} \times \left(\frac{30}{60}\right) \times \frac{1}{(1+0.6)}$$

$$= 3168 \text{ cubic feet/hour} = 89.70 \text{ m}^3\text{/hour}$$

(ii)



Let A be the equivalent uniform annual cost over the entire 40 years period.

P = Present worth of various maintenance cost.

$$\Rightarrow \quad P = 15000\left[\frac{P}{A}, 10\%, 5\right] + 100000\left[\frac{P}{F}, 10\% 15\right] + 100000\left[\frac{P}{F}, 10\%, 30\right]$$

$$\Rightarrow \quad = 15000\left[\frac{\left(1+\frac{10}{100}\right)^5 - 1}{\left(\frac{10}{100}\right).\left(1+\frac{10}{100}\right)^5}\right] + 100000\left[\frac{1}{\left(1+\frac{10}{100}\right)^{15}}\right] + 100000\left[\frac{1}{\left(1+\frac{10}{100}\right)^{30}}\right]$$

$$\Rightarrow \quad P = 56861.80 + 23939.20 + 5730.86$$

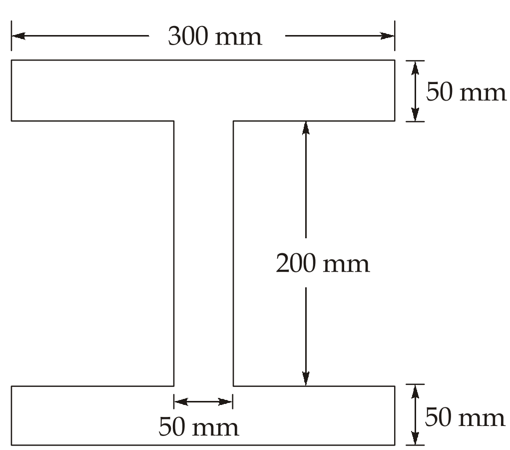
$$\Rightarrow \quad P = \text{Rs. } 86531.86 \qquad \simeq \text{Rs. } 86532 \text{ (say)}$$

Now,

$$A = 86532\left[\frac{A}{P}, 10\%, 40\right]$$

$$= 86532\left[\frac{\left(\frac{10}{100}\right)\left(1+\frac{10}{100}\right)^{40}}{\left[\left(1+\frac{10}{100}\right)^{40} - 1\right]}\right] = \text{Rs. } 8848.71$$

Q.7 (c) Solution:



Area of the beam section, is given by,

$$A = 300 \times 50 \times 2 + 200 \times 50$$

$$= 40,000 \text{ mm}^2$$

Moment of inertia is given by,

$$I = \frac{300 \times 300^3}{12} - \frac{250 \times 200^3}{12}$$

$$= 5.083 \times 10^8 \text{ mm}^4$$

Section modulus, Z is given by,

$$Z = \frac{I}{y_{\max}} = \frac{5.083 \times 10^8}{150} = 3.39 \times 10^6 \text{ mm}^3$$

$$\text{Dead load of the beam, } w_d = \frac{40,000}{10^6} \times 25 = 1 \text{ kN/m}$$

B.M. due to dead load of the beam,

$$M_d = \frac{w_d . L^2}{8} = \frac{1 \times 8^2}{8} = 8 \text{ kNm}$$

Stress in wires at transfer, $\sigma = 0.85 \times 1200$

$$= 1020 \text{ N/mm}^2$$

Area of 50 wires of 3.0 mm diameter,

$$A_{st} = \frac{50 \times \pi \times 3^2}{4} = 353.43 \text{ mm}^2$$

Just after transfer

Compressive stress in concrete due to prestressing force

$$= \frac{\sigma A_{st}}{A} = \frac{1020 \times 353.43}{40000}$$

$$= 9.01 \text{ N/mm}^2$$

Extreme stress due to dead load of beam

$$= \pm \frac{M_d}{Z} = \pm \frac{8 \times 10^6}{3.39 \times 10^6}$$

$$= \pm 2.36 \text{ N/mm}^2$$

Hence, just after transfer

Stress at top = 9.01 + 2.36 = 11.37 MPa

Stress at bottom = 9.01 – 2.36 = 6.65 MPa

(ii) B.M. due to additional superimposed load,

$$M' = \frac{3\times 8^2}{8} = 24 \text{ kNm}$$

B.M. due to moving point load = 6.0 kN-m

Total B.M., M = 8 + 24 + 6 = 38 kN-m

Stress in the wires = 0.75 × 1200 = 900 N/mm^2

Compressive stress in concrete due to prestressing force

$$= \frac{900\times 353.43}{40000} = 7.95 \text{ N/mm}^2$$

Extreme stress due to bending moment

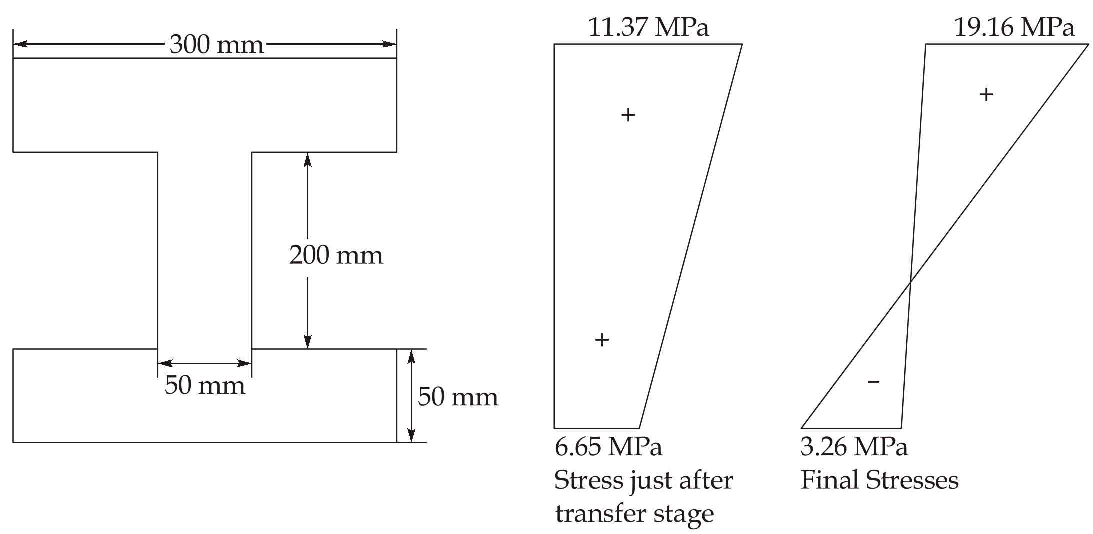
$$= \pm\frac{M}{Z} = \frac{38\times 10^6}{3.39\times 10^6} \text{ N/mm}^2$$

$$= 11.21 \text{ N/mm}^2$$

Final stresses

Stres

tom =7.95 – 11.21 = –3.26 MPa



Q.8 (a) Solution:

Design B.M., M_μ = 1.5 × 150 = 225 kN-m

Design S.F., V_μ = 1.5 × 220 = 330 kN-m

Effective depth, d = 2 × width

⇒ d = 2B

Given: Nominal cover = 30 mm

Also, for Fe415, $M_{u\,lim} = 0.138.f_{ck}.B.d^2$

$\therefore$ $$0.138 \cdot f_{ck} \cdot B.d^2 = 225 \times 10^6$$

$\Rightarrow$ $$0.138 \times 25 \times B.(2B)^2 = 225 \times 10^6$$

$\Rightarrow$ $$B = 253.57 \text{ mm}$$

$\therefore$ $$B = 255 \text{ mm (say)}$$

So, $$d = 2B = 510 \text{ mm}$$

Now, Overall depth, $$D = d + cc + \frac{\phi_m}{2} + \phi_s$$

$\Rightarrow$ $$D = 510 + 30 + \frac{20}{2} + 8 = 558 \text{ mm} \simeq 560 \text{ mm (say)}$$

Reinforcement at support

$$M_{u\,lim} = 0.138.f_{ck}.Bd^2 = 0.138 \times 25 \times 255 \times (510)^2 \times 10^{-6} \text{ kN-m}$$

$$= 228.82 \text{ kN-m} > M_u \text{ (225 kN-m)}$$

Hence beam will be under reinforced.

$\therefore$ $$A_{st\ support} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck}.Bd^2}}\right] B.d$$

$$= \frac{0.5 \times 25}{415}\left[\sqrt{1 - \frac{4.6 \times 225 \times 10^6}{25 \times 255 \times (510)^2}}\right] 255 \times 510$$

$$= 1515.83 \text{ mm}^2$$

Using 20 mm bars, number of bars $= \dfrac{1515.83}{\frac{\pi}{4} \times 20^2} = 4.83 \simeq 5$

Hence provide 5 nos. of bars of 20 mm diameter at support.

Reinforcement at mid span:

$$M_u = 1.5 \times 100 = 150 \text{ kN-m}$$

$$A_{st} \text{ mid span} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck}.Bd^2}}\right] B.d = \frac{0.5 \times 25}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 150 \times 10^6}{25 \times 255 (510)^2}}\right] \times 255 \times 510$$

$$= 924 \text{ mm}^2$$

No. of 25 mm dia bars required $= \dfrac{924}{\frac{\pi}{4} \times 20^2} = 2.94 \simeq 3$

Hence provide 3 nos. of bars of 20 mm diameter at mid span.

Design of shear reinforcement

$$\text{Design SF, } V_u = 330 \text{ kN}$$

$$\text{Nominal shear stress, } \tau_v = \frac{V_u}{B.d} = \frac{330\times10^3}{255\times510} = 2.54 \text{ N/mm}^2 < \tau_{c\,max}$$

$$= 0.625\sqrt{f_{ck}} = 0.625\sqrt{252} \ (3.1 \text{ N/mm}^2)$$

Design shear force to be resisted by shear stirrups,

$$V_{us} = V_u - \tau_c.Bd$$
$$= (330 \times 10^3 - 0.6 \times 255 \times 510)\text{N}$$
$$= 251.97 \text{ kN}$$

Now using 2-legged 8 mm stirrups, spacing, S_v is given by,

$$V_{us} = \frac{0.87 f_y.A_{sv}.d}{S_v}$$

$$\Rightarrow \quad S_v = \frac{0.87 f_y.A_{sv}.d}{V_{us}} = \frac{0.87\times415\times2\times\frac{\pi}{4}\times8^2\times510}{251.97\times10^3}$$
$$= 73.47 \text{ mm c/c}$$

Hence provide 2-legged 8 mm ϕ stirrups @ 70 mm c/c spacing

Check :

$$\text{Maximum spacing, } (S_v)_{max} = \text{Min}\begin{cases}0.75\text{ d}\\300\text{ mm}\end{cases} = \text{Min}\begin{cases}0.75\times510\\300\text{ mm}\end{cases}$$

$$\therefore \quad (S_v)_{max} = 300 \text{ mm}$$

$$\therefore \quad (S_v) < (S_v)_{max}$$

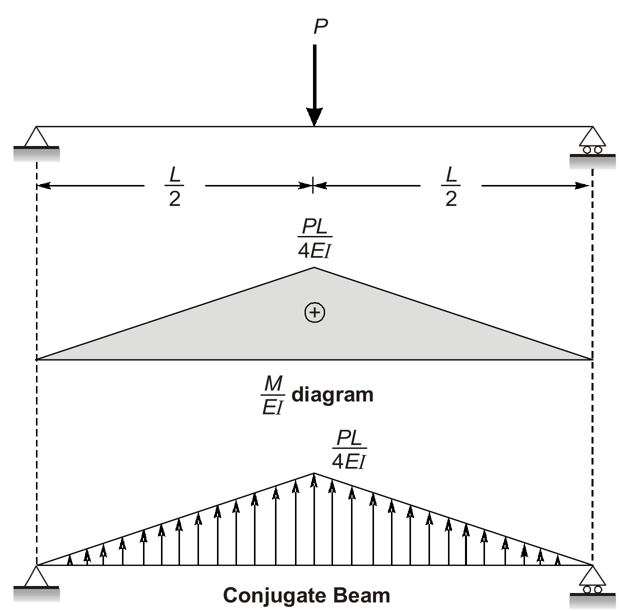
Q.8 (b) Solution:

(i) **Conjugate beam** is an imaginary beam for which loading diagram is M/EI diagram for a given real beam.

If real beam is determinate and stable then corresponding conjugate beam is also determinate and stable.

If real beam is indeterminate then conjugate beam will be unstable. Conjugate beam method is based on two theorems as below:

Theorem-1: The slope at any section in real beam is equal to the shear force at that section in conjugate beam.



It means shear force diagram of conjugate beam will represent slope curve for real beam.

Theorem-2: The deflection at any section in given real beam is equal to bending moment (BM) at that section in conjugate beam. It means BMD of conjugate beam will represent deflection curve of real beam.

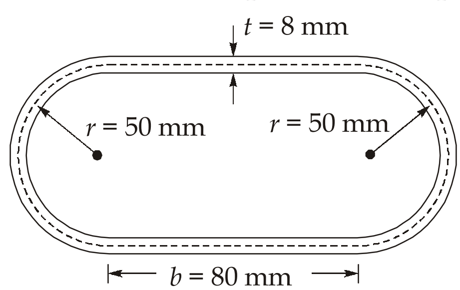
Sign Convention

End conditions in conjugate beam: The end conditions of conjugate beam will be such that slope and deflection in real beam will be shown by shear force and bending moment in conjugate beam respectively.

Algorithm for conjugate beam analysis:

1. Find support reactions for real beam.
2. Draw BMD for real beam.
3. Draw corresponding M/EI diagram.
4. The M/EI diagram of given beam becomes loading diagram for conjugate beam.
5. If M/EI diagram is positive (sagging BM), then loading will be taken upward and vice-versa.
6. The end conditions of conjugate beam will be according to the slope and deflection in real beam corresponds to shear force and BM in conjugate beam respectively.
7. If the shear force at a section in conjugate beam is positive then slope at that section in real beam will also be positive and vice-versa.
8. If the BM at a section in conjugate beam is positive (sagging) then deflection at that section in real beam will also be positive i.e. upward.

(ii)



$$\text{Mean area, } A_m = \pi r^2 + b \times 2r = \pi(50)^2 + 2(80 \times 50)$$
$$= 15853.98 \text{ mm}^2$$
$$\text{Mean length, } L_m = 2b + 2\pi r = 2(80) + 2\pi(50)$$
$$= 474.16 \text{ mm}$$

∴ Shear stress, $\tau = \frac{T}{2tA_m} = \frac{8\times10^6}{2\times8\times15853.98} = 31.54\ \text{N/mm}^2$

Angle of twist, $\phi = \frac{TL}{4A_m^2G}\left(\frac{L_m}{t}\right) = \frac{8\times10^6\times1400}{4\times15853.98^2\times80\times10^3}\times\left(\frac{474.16}{8}\right)$

$= 8.25\times10^{-3}\ \text{rad} = 0.473°$

Q.8 (c) Solution:

(i) Effective length of column, l_{eff} is given by -

$$l_{eff} = 0.65\,L_0 = 0.65\,(3.5) = 2.275\ \text{m}$$

Now, $\frac{l_{eff}}{b} = \frac{2.275}{0.5} = 4.55 < 12$

i.e. short column.

Minimum eccentricity, e_{min} is given by

$$e_{min} = \max^m\left\{\frac{l_0}{500}+\frac{b}{30} = \frac{3.5\times1000}{500}+\frac{500}{30} = 23.67\ \text{mm}\right.$$

$$e_{min} < 0.05\,(b)$$

⇒ $e_{min} < 0.05\times500$

⇒ $e_{min}\,(= 23.67\ \text{mm}) < 25\ \text{mm}$ (OK)

∴ Column can be designed as axially loaded column.

Now ultimate load, P_u is given by -

$$P_u = 0.4f_{ck}.A_g + (0.67\,f_y - 0.4\,f_{ck})A_{sc}$$

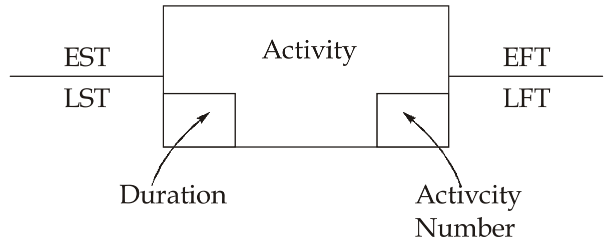
$$= 0.4\times20\times500\times500 + (0.67\times415 - 0.4\times20)\times8\times\frac{\pi}{4}\times20^2$$

$$= 2678709.677\ \text{N} = 2678.709\ \text{kN}$$

(ii)

In AON system sometimes called precedence diagram also, the nodes represent the activities and the arrow represents activities interdependence or precedence relationship.

Nodes are usually represented by squares or rectangles but circles and other conventional geometrical shapes may also be used. One of the most common types of node representation is shown in figure.



Advantages of AON system over AOA system :

1. AON system of the network completely eliminates the use of dummy activities.
2. This system can show activity which should be allowed to overlap each other or must be separated by a time delay.
3. This system is self sufficient as it contains all activity times (EST, LST, EFT, LFT) on the diagram itself. This facilitates efficient scheduling and control.
4. Pre-operations and post-operations of the activity under consideration are distinctly visible.
5. It is more advantageous in projects involving highly repetitive nature of series of operations.

■■■■