

Free Mock Test



Test ID:- C25

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SOLUTIONS

CIVIL ENGINEERING : PAPER-1

Full Length Test -C25

Exam Date :- 15 March 2026

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2 Marks

Q.1

Sol. Difference between Normal Stress and Normal Strain

- **Normal Stress (σ):**

It is the **intensity of internal resisting force** set up per unit area, when the material is subjected to normal loading.

Unit: N/mm^2

- **Normal Strain (ϵ):**

It is the **ratio of change in dimension to the original dimension** produced by the action of normal stress.

$$\epsilon = \Delta L / L$$

It is a dimensionless quantity.

Q.2

Sol. It is the stress which is being transferred in soil mass by grain-to-grain contact which tends to force the particles to come into Closer State of Contact resulting in its decreased void ratio, increased degree of denseness & mobilization of shear strength.

Q.3

Sol. $m\ddot{u} + c\dot{u} + ku = 0$

where,

u - displacement

c - damping coeff.

k - stiffness

m - mass

Q.4

Sol. Characteristic strength is the strength below which not more than 5 percent of the test results are expected to fail.

Q.5

Sol. It is a secondary torsion. This type of torsion arises due to need of the member to undergo a certain angle of twist to maintain compatibility conditions.

Q.6

Sol. Main types of damping:

- (1) Structural damping
- (2) Viscous damping
- (3) Coulomb damping

We generally idealise damping in structure as viscous damping.

Q.7

Sol. Given that

Basic wind speed i.e. $V_b = 44 \text{ m/sec.}$

Risk factor i.e. $K_1 = 1$

Terrain factor i.e. $K_2 = 0.98$

Topographic factor i.e. $K_3 = 1.0$

Design wind speed i.e. $V_z = K_1 K_2 K_3 V_b$

$$= 1 \times 0.98 \times 1 \times 44 = 43.12 \text{ m/sec.}$$

Design wind pressure i.e. $p_z = 0.6 V_z^2$

$$p_z = 0.6 \times 43.12^2 = 1115.60 \text{ N/m}^2$$

Q.8

Sol. Torsion, Torsional Rigidity, and Polar Moment of Inertia

- **Torsion:**

The twisting of a shaft when subjected to a torque about its longitudinal axis.

- **Torsional Rigidity:**

The torque required to produce a unit angle of twist per unit length.

$$\text{Torsional Rigidity} = TL / \theta = GJ$$

- **Polar Moment of Inertia (J):**

The moment of inertia of the cross-sectional area about its polar axis.

$$\text{For solid circular shaft, } J = \frac{\pi d^4}{32}$$

Q.9

Sol. Relation between E, G and K

For an isotropic material:

$$E = 2G(1 + \mu)$$

$$E = 3K(1 - 2\mu)$$

Eliminating Poisson's ratio (μ):

$$E = 9KG / (3K + G)$$

Where,

E = Modulus of Elasticity

G = Modulus of Rigidity

K = Bulk Modulus

μ = Poisson's Ratio

Q.10

Sol. Kern of section is that area of cross-section through which if load is passing then complete section will have compressive stress i.e. there would not be tension anywhere. The shape of the kern depends on the shape of the cross-section of the column.

Q.11

Sol. (a) The flexibility matrix will always be a square matrix ($n \times n$) in which diagonal elements will be non negative and non-zero,
(b) Order of flexibility matrix will be equal to degree of static indeterminacy (i.e. no. of redundants).

Q.12

Sol. The Mohr-Williot diagram is used to determine the deflection of joints in a truss due to applied loads, temperature changes, or lack of fit.

It helps in finding both the magnitude and direction of joint displacements graphically.

Application:

- Used in truss analysis to find joint deflections and member elongations or contractions accurately.

Q.13

Sol. Liquefaction of sand is the phenomenon where saturated, loose sand temporarily loses its strength and stiffness from earthquake shaking or other rapid loading, behaving like a liquid. This occurs because the sudden shaking increases the water pressure within the soil's pore spaces, which reduces the contact forces between the sand grains and causes them to lose their solid structure.



Q.14

Sol. For a Plane Frame:

1. Static Indeterminacy (D_s):

$$D_s = 3m + r - 3j$$

where,

- m = number of members
- r = number of support reactions
- j = number of joints

2. Kinematic Indeterminacy (D_k):

$$D_k = 3j - r$$

Each joint in a plane frame has three degree of freedom (Two translation + one rotation)

Q.15

Sol. As we know,

$$\beta = \frac{w}{w_n}$$

where, w - excitation frequency

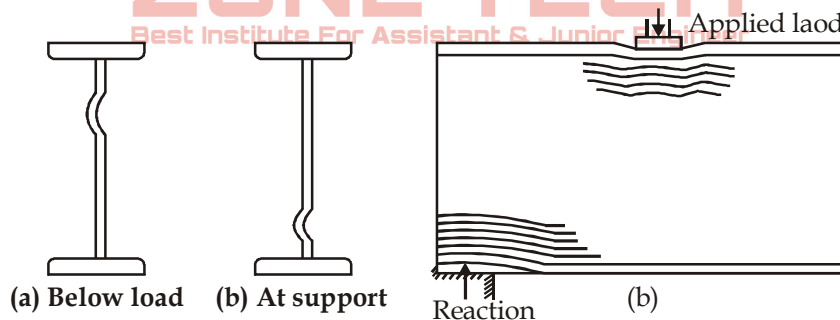
w_n - natural frequency

If

- (i) $\beta < 1$ - Undertuned system
- (ii) $\beta = 1$ - Tuned system
- (iii) $\beta > 1$ - Over Tuned system

Q.16

Sol. Web crippling is the localized failure of a beam web due to introduction of an excessive load over a small length of the beam. It occurs at point of application of concentrated load at point of support of a beam.



Q.17

Sol. Minimum eccentricity = Maximum of $\left[\frac{\text{Unsupported length}}{500} + \frac{\text{Lateral length}}{30} \right]$
20 mm

Q.18

Sol. It is stretched element in a concrete member to pre-stress to the concrete, in general, high tensile steel wires are used as tendos.

Q.19

Sol. Strength of a tension member is a function of its net area. Since bolt holes are made, the stress concentration occurs around the bolt holes.

An increase in ductility allows a better redistribution of stress concentration over the cross section. The stress is distributed more uniformly when the steel is in plastic state. This results in increased net section strength.

Q.20

Sol. Long term static modulus of elasticity,

$$E_{\theta} = \frac{E_c}{1 + \theta} = \frac{5000\sqrt{f_{ck}}}{1 + \theta} = \frac{5000\sqrt{25}}{1 + 1.5} = 10,000$$

5 Marks

Q.21

Sol. Natural frequency of motor (w_n) = $\sqrt{\frac{k_{eq}}{m}}$

$$\Rightarrow w_n = 28.28 \text{ rad/s.}$$

$$\text{Angulas speed of motor (w)} = 1000 \text{ rev/min.}$$

$$\Rightarrow w = 104.72 \text{ rad/s.}$$

The magnitude of centrifugal

$$\text{force due to unbalance (P}_0\text{)} = m'ew^2$$

$$\Rightarrow P_0 = 263.16 \text{ N}$$

$$\text{Static deflection (}\mu_{st,0}\text{)} = \frac{P_0}{k} = \frac{263.16}{240 \times 10^3}$$

$$\Rightarrow \mu_{st,0} = 1.1 \times 10^{-3} \text{ m} = 1.1 \text{ mm}$$

$$\text{Now, the amplitude of vibration (}\mu_0\text{)} = \frac{P_0/k}{1 - \left(\frac{w_f}{w_n}\right)^2}$$

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$$\mu_0 = -0.864 \times 10^{-3} \text{ m}$$

Here negative sign means vibration is in opposite phase.

Q.22

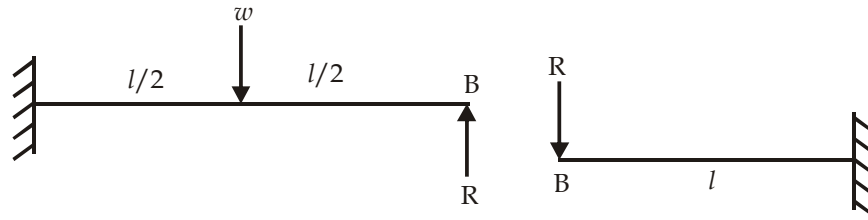
Sol.

Force Method		Displacement Method	
1	Also called Compatibility method or Method of consistent deformation or Flexibility method	1	Also called Stiffness method or Equilibrium method
2	Unknowns in this case are Forces (Reaction, BM, SF)	2	Unknowns in this case are Displacement (Δ)
3	Force-displacement equation are written and solution for unknown Forces is obtained from Compatibility equations.	3	Force-displacement equations are written and solution for unknown Displacement is obtained from Equilibrium equations.
4	Once unknown forces are known. The reactive forces like BM, SF etc. are found using equilibrium equation.	4	Once unknown displacements are known, internal forces are found using compatibility and load-displacement equation.
5	Force method of analysis of indeterminate structure is suitable when degree of static indeterminacy is less than degree of kinematic indeterminacy.	5	Displacement method is suitable when degree of kinematic indeterminacy is less than degree of static indeterminacy.



Q.23

Sol. Let the reaction at B be R. Hence FBD of the structural components are :



Total downward deflection of B for AB

$$\Delta_1 = \frac{w \left(\frac{l}{2} \right)^3}{3EI} + \frac{w \left(\frac{l}{2} \right)^2}{2EI} \times \frac{l}{2} - \frac{Rl^3}{3EI}$$

Total downward deflection of BC

$$\Delta_2 = \frac{Rl^3}{3EI}$$

Since,

$$\Delta_1 = \Delta_2$$

Hence,
$$\frac{wl^3}{EI} \left(\frac{1}{24} + \frac{1}{16} \right) = \frac{2Rl^3}{3EI}$$

$$\Rightarrow \frac{5wl^3}{48EI} = \frac{2Rl^3}{3EI}$$

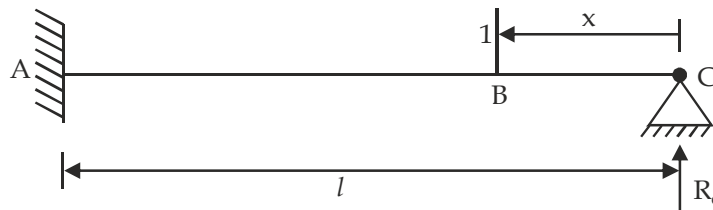
$$R = \frac{5wl^3}{48EI} \times \frac{3EI}{2l^3} = \frac{5w}{32}$$



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Q.24

Sol.



Using compatibility condition,

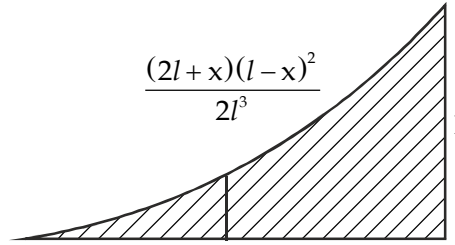
$$\frac{1 \times (l-x)^3}{3EI} + \frac{1 \times (l-x)^2}{2EI} \times x = \frac{R_c \times l^3}{3EI}$$

$$\Rightarrow (l-x)^2 \left\{ \frac{l}{3} - \frac{x}{3} + \frac{x}{2} \right\} = \frac{R_c \times l^3}{3}$$

$$\Rightarrow (l-x)^2 \times \frac{2l+x}{6} = \frac{R_c \times l^3}{3}$$

$$\Rightarrow R_c = \frac{(2l+x)(l-x)^2}{2l^3}$$

ILD for R_c



$$\begin{aligned} \text{Area under curve} &= \int_0^l \frac{(2l+x)(l-x)^2}{2l^3} dx \\ &= \frac{1}{2l^3} \int_0^l (x^3 - 3l^2x + 2l^3) dx \\ &= \frac{1}{2l^3} \left\{ \frac{l^4}{4} - 3l^2 \times \frac{l^2}{2} + 2l^4 \right\} = \frac{1}{2l^3} \times l^4 \left(\frac{1}{4} - \frac{3}{2} + 2 \right) \\ &= \frac{3l}{8} \end{aligned}$$

Q.25

Sol. From equation $\rho_{\min} = \frac{M_{\min}}{V_m} = \frac{410}{290} = 1.414 \text{ gm/ml}$

From equation $\rho_{\max} = \frac{M_{\max}}{V_m} = \frac{410}{215} = 1.907 \text{ gm/ml}$

From equation $D_r = \frac{\rho_{\max}}{\rho_d} \left(\frac{\rho_d - \rho_{\min}}{\rho_{\max} - \rho_{\min}} \right) \times 100$

or $= \frac{1.907}{1.816} \left(\frac{1.816 - 1.414}{1.907 - 1.414} \right) \times 100$

or $D_r = 85.63\%$

Q.26

Sol. Liquidity Index (I_L)

- Liquidity index is defined as the ratio of the 'difference between natural water content (w)' of soil and the plastic limit (w_p)' to the plasticity index i.e.,

$$I_L = \frac{w - w_p}{I_p} = \frac{w - w_p}{w_L - w_p}$$

- This index indicates as to in what part of its plastic range, a given soil mass lies.
- The soil is softer in consistency if its natural moisture content is closer to liquid limit i.e., when $I_L = 1$

- Similarly, the soil is stiff if $I_L = 0$

Activity Number (A_c)

- Activity number is the ratio of the plasticity index (I_p) to clay fraction (i.e., percentage by mass of particles finer than 2 microns)

Thus, $A_c = \frac{I_p}{\% \text{ of clay size particles (i.e. } < 2\mu) \text{ in soil}}$

- It signifies the swelling characteristics of clays. Higher activity number implies higher swelling.
- The soil containing the clay mineral montmorillonite have very high activity (>4). The soil containing the mineral Kaolinite are least active ($A < 1$), whereas the soils containing the mineral illite are moderately active ($A = 1$ to 2)
- Depending upon activity, the soils are classified into three types:

S.No.	Activity	Soil type
1.	$A < 0.75$	Inactive
2.	$A = 0.75$ to 1.25	Normal
3.	$A > 1.25$	Active

Q.27

Sol. **Given :** Diameter of the shaft (D) = 100 mm ; Power transmitted (P) = 120 kW and speed of the shaft (N) = 150 r.p.m.

Let T = Torque transmitted by the shaft, and

τ = Intensity of shear stress in the shaft.

We know that power transmitted by the shaft (P).

$$120 = \frac{2\pi NT}{60} = \frac{2\pi \times 150 \times T}{60} = 15.7 T$$

$$\therefore T = \frac{120}{15.7} = 7.64 \text{ kN-m} = 7.64 \times 10^6 \text{ N-mm}$$

We also know that torque transmitted by the shaft (T).

$$7.64 \times 10^6 = \frac{\pi}{16} \times \tau \times D^3 = \frac{\pi}{16} \times \tau \times (100)^3 = 0.196 \times 10^6 \tau$$

$$\tau = \frac{7.64}{0.196} = 39 \text{ N/mm}^2 = 39 \text{ MPa}$$

Q.28

Sol. **Given :** Span = l ; Load at the free end = W ; Prop reaction (P) = $\frac{W}{2}$ and constant of proportionality of

sinking to the load = k .

From the given data, we find that sinking of the prop.

$$\delta = \frac{k.W}{2}$$

We know that the downward deflection of the cantilever due to load W at its free end (neglecting prop reaction),

$$y_1 = \frac{Wl^3}{3EI} \quad \dots(i)$$

and upward deflection of the cantilever due to prop reaction (neglecting load),

$$y_2 = \frac{Pl^3}{3EI} = \frac{\frac{W}{2} \times l^3}{3EI} = \frac{Wl^3}{6EI} \quad \dots(ii)$$

$\therefore$ Sinking of the prop,

$$\delta = y_1 - y_2$$

$$\therefore \frac{k.W}{2} = \frac{Wl^3}{3EI} - \frac{Wl^3}{6EI} = \frac{Wl^3}{6EI}$$

$$k = \frac{l^3}{3EI}$$

Q.29

Sol. Acceptance Criteria for Concrete- Now it depends on quantity of concrete so, basic requirement for concrete acceptance are as:

1. For all concrete: M15 grade and above

The average strength of four (4) non overlapping consecutive test result shall be not less than For M15 or higher:

$$f_{\text{average}} \leq (f_{ck} + 0.825\sigma) \text{ N/mm}^2$$

(Rounded off to 0.5 N/mm²)

or

$$(f_{ck} + 3) \text{ N/mm}^2$$

(whichever is more)

2. Individual test results of any sample

$$ITR \geq (f_{ck} + 3) \text{ N/mm}^2$$

3. The test result of the sample shall be average of the strength of three specimen and the individual variation shall be not more than $\pm 15\%$ of average strength. If more the test result of the sample are invalid.

Q.30

Sol. Given :

Width of beam, $B = 250 \text{ mm}$

Effective depth, $d = 500 \text{ mm}$

Design shear strength, $\tau_c = 0.3 \text{ N/mm}^2$

Now, $V_e = \tau_c B d$

$$= 0.3 \times 250 \times \frac{500}{1000} = 37.50 \text{ kN}$$

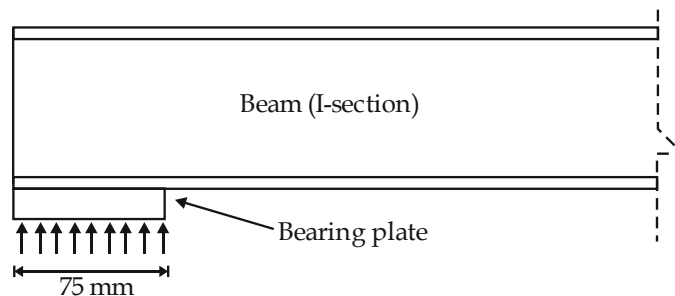
& $V_e = V_u + \frac{1.6 T_u}{B}$

$$37.5 = 0 + \frac{1.6 T_u}{0.25}$$

$\therefore T_u = 5.86 \text{ kN-m}$

Q.31

Sol.



Flange width (beam) = 20 mm

Web width (beam) = 8mm

$F_y = 250 \text{ MPa}$

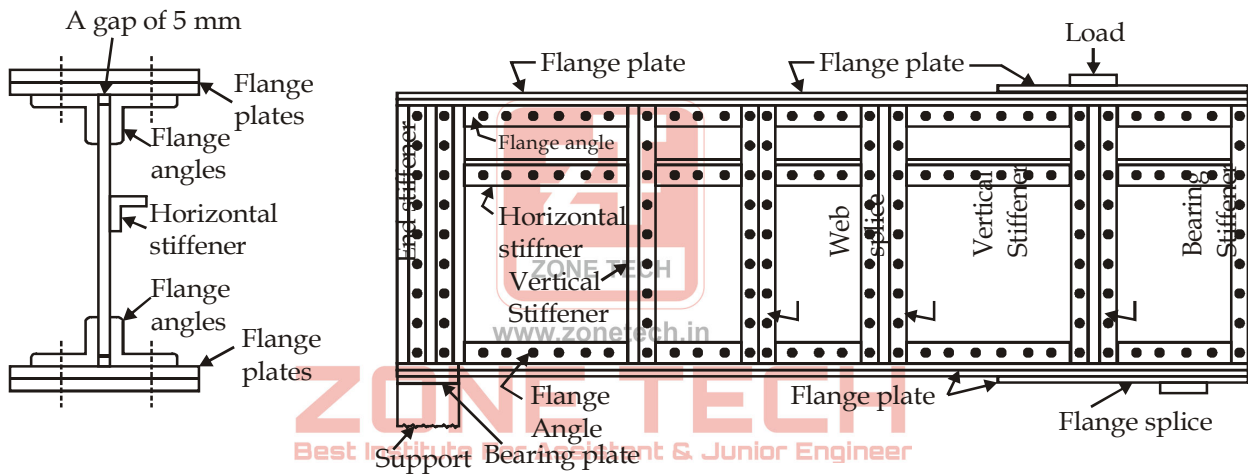
$\gamma_{mo} = 1.10$

Root radius of I-section = 10mm

$$\begin{aligned} \text{Web bearing strength} &= \left[b + 2.5(t_f + R) \right] t_w \frac{f_y}{\gamma_{mo}} \\ &= \left[75 + 2.5(20 + 10) \right] \times 8 \times \frac{250}{1.1} = 272.72 \text{ kN} \\ &= \boxed{272.73 \text{ kN}} \end{aligned}$$

Q.32

Sol.



20 Marks

Q.33

Sol.

$$(i) \quad \frac{\text{Effective length}}{\text{Least lateral dimension}} = \frac{3600}{460} = 7.83 < 12$$

Hence, the column will be designed as short column.

$$(ii) \text{ Adopting } e_{min} = 20 \text{ mm}$$

But e_{min} shall not exceed 0.05 B and 0.05 D

$$\therefore 20 \leq 0.05 \times 460 \quad \text{and} \quad 20 \leq 0.05 \times 600$$

$$20 \leq 23 \quad \text{and} \quad 20 \leq 30 \quad \text{Hence OK}$$

Hence, the equation $P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$ can be used

(iii) Service load = 2500 kN

Factored load,

$$f_{ck} = 20 \text{ N/mm}^2,$$

$$P_u = 1.5 \times 2500 = 3750 \text{ kN}$$

$$A_c = A - A_{sc}$$

where

$$A = 460 \times 600 = 276000 \text{ mm}^2$$

$$f_y = 415 \text{ N/mm}^2$$

$\therefore$

$$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$$

$\Rightarrow$

$$3750 \times 10^3 = 0.4 \times 20 \times (276000 - A_{sc}) + 0.67 \times 415 \times A_{sc}$$

$\Rightarrow$

$$A_{sc} = \frac{3750 \times 10^3 - 2208000}{270.05}$$

$\Rightarrow$

$$A_{sc} = 5710 \text{ mm}^2$$

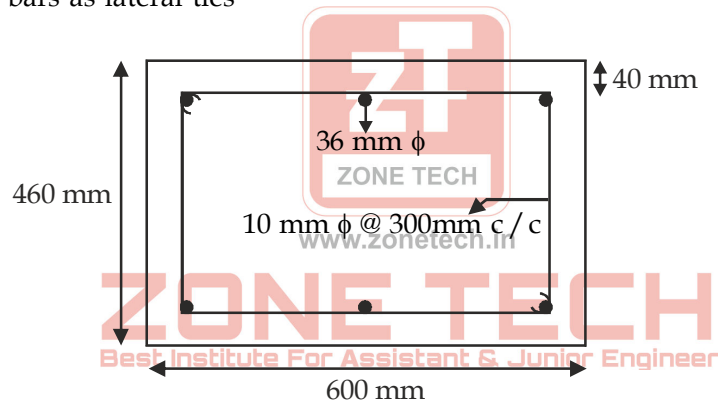
Adopting 36 mm bars, we get number of bars $= \frac{5710}{\frac{\pi}{4} \times (36)^2} = 5.61 \approx 6 \text{ bars}$

(iv) Diameter of lateral ties

(a) $\frac{1}{4} \times 36 = 9 \text{ mm}$

(b) 6 mm

$\therefore$ Provide 10 mm bars as lateral ties



(v) Spacing of lateral ties

(a) Least lateral dimension = B = 460 mm

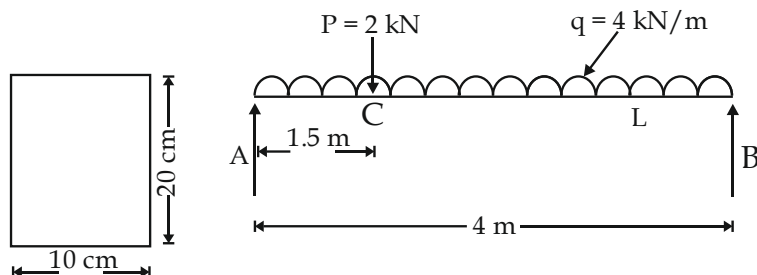
(b) $16\phi - 16 \times 36 = 576 \text{ mm}$

(c) 300 mm

Lesser of the above three will be provided as the spacing. Hence 10 mm ϕ bars will be provided at 300 mm c/c

Q.34

Sol.



Now

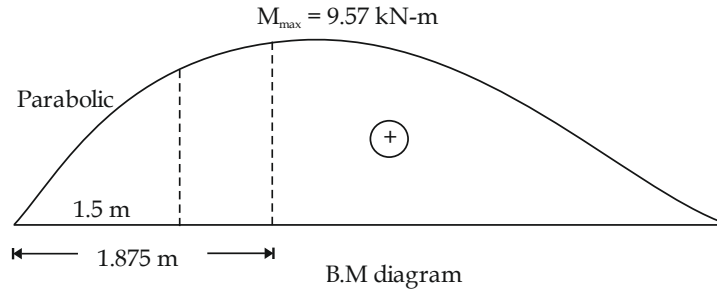
$$R_A + R_B + 4 \times 4 = 18 \text{ kN}$$

Taking moments about A

$$R_B \times 4 = (2 \times 1.5) + 16 \times 2$$

$$R_B = 8.75 \text{ kN}$$

$$R_A = 18 - 8.75 = 9.25 \text{ kN}$$



$$\text{Bending moment in AC} = (R_A \cdot x) - \frac{qx^2}{2}$$

$$\text{Bending moment at C} = (9.25 \times 1.5) - \left(\frac{4 \times 1.5^2}{2} \right) = 13.875 - 4.5 = 9.375 \text{ kN-m}$$

$$\text{Bending moment in portion CB, } M = (R_A \cdot x) - \frac{qx^2}{2} - 2(x - 1.5)$$

$$\text{For maximum BM } \frac{dM}{dx} = 0$$

$\Rightarrow$

$$R_A - qx - 2 = 0$$

$$x = \frac{9.25 - 2}{4} = 1.8125$$

$$\text{BM at this point} = 9.57 \text{ kN-m}$$

$$\text{Now equation of bending, } \frac{M}{I} = \frac{\sigma}{y}$$

$$\sigma = \frac{M}{I} \times y = \frac{9.57 \times 10^3}{\frac{bd^3}{12}} \times \frac{d}{2} = \frac{6 \times 9.57 \times 10^3}{bd^2}$$

$$= \frac{6 \times 9.57 \times 10^3}{10 \times 20^2 \times 10^{-6}} = 14.35 \text{ MPa}$$

$$\text{Maximum tensile and compressive stress} = \pm 14.35 \text{ MN/m}^2 = \pm 14.35 \text{ MPa}$$

Q.35

Sol.

$$e_0 = 1.90 \text{ at } 160 \text{ kN/m}^2 \text{ stress}$$

Δe change in void ratio, when stress increased from 160 kN/m^2 to 200 kN/m^2 .

$$C_c = \frac{-\Delta e}{\log \frac{\sigma_2}{\sigma_1}} = 0.27 = \frac{-\Delta e}{\log_{10} \frac{200}{160}}$$

$$\Delta e = -0.0261$$

∴ -ve sign show void ratio decreased with increased pressure.

$$(II) \quad \Delta H = \frac{C_c H_0}{1 + e_0} \log_{10} \left[\frac{\bar{\sigma}_1 + \Delta \sigma}{\bar{\sigma}_1} \right] = \frac{0.27 \times 7}{1 + 1.90} \log_{10} \frac{200}{160}$$

$$= 0.651 \times \log_{10} \frac{200}{160}$$

$$= 0.0630 \text{ m or } 63.088 \text{ mm}$$

$$(III) \quad T_v = 0.2 \text{ for } 50\% \text{ consolidation}$$

$$T_v = C_v \cdot t / d^2 \quad \dots(1)$$

$d \rightarrow$ length of drainage path

$$d = H_0 = 7 \text{ m (for single drainage)}$$

$$\therefore k = C_v \cdot m_v \cdot \gamma_w \quad \& \quad m_v = \frac{a_v}{1 + e_0} = \frac{\Delta e}{\Delta \sigma (1 + e_0)} = \frac{0.0261}{(200 - 160) \times (1 + 1.90)}$$

$$= \frac{0.0261}{40(2.90)} = 2.25 \times 10^{-4} \text{ m}^2 / \text{kN}$$

$$\text{now } \rightarrow k = c_v \cdot m_v \gamma_w$$

$$4.5 \times 10^{-6} = c_v \times (2.25 \times 10^{-4}) \times 9.81$$

$$C_v = \frac{4.5 \times 10^{-6}}{(2.25 \times 10^{-4}) \times 9.81}$$

$$c_v = 2.038 \times 10^{-3} \text{ m}^2 / \text{sec.}$$

now $\rightarrow$ substituting value of c_v and $T_v \rightarrow$ in eq. (1)

$$0.2 = \frac{2.038 \times 10^{-3} \times t}{7^2} = 4808.63 \text{ sec. } t = 1.33 \text{ hr.}$$

(IV) Let u be the degree of consolidation that will take place in 1 hour, since 50% consolidation completed in 1.33 hr, so degree of consolidation occurred in one hour must be less than 50%

$$T_v = \frac{2.038 \times 10^{-3} \times 1 \times 60 \times 60}{7^2} = 0.149$$

also, $T_v = \frac{\pi}{4} u^2 \quad [u \leq 60\%]$

$$\therefore 0.149 = \frac{\pi}{4} u^2 \quad u = \sqrt{\frac{0.149 \times 4}{\pi}}$$

$$u = \sqrt{0.189} = 0.434 \approx 43.4\%$$

Let Δh be the amount of settlement after the end of one hour.

$$u = \frac{\Delta h}{\Delta H} \quad \Delta H \rightarrow \text{ultimate settlement of soil stratum} = 75 \text{ cm}$$

$$0.434 = \frac{\Delta h}{75}$$

$$\Delta h = 0.434 \times 75 = 32.55 \text{ cm}$$



Q.36

Sol. Given data :

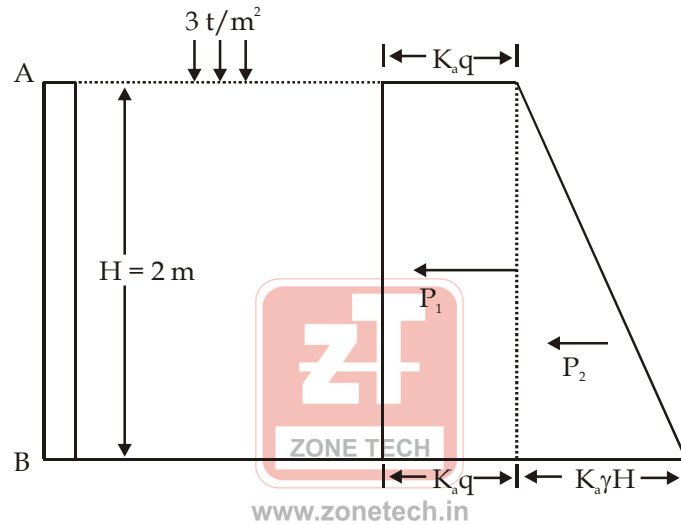
Height of retaining wall, $H = 2\text{ m}$

Density of backfill, $\gamma = 1.8 \text{ t/m}^3$

Shearing resistance, $\phi = 30^\circ$; $c = 0$

Uniformly distributed Surcharge load, $q = 3 \text{ t/m}^2$

$$\therefore \text{Active earth pressure coefficient, } K_a = \frac{1 - \sin \phi}{1 + \sin \phi} = \frac{1 - \sin 30^\circ}{1 + \sin 30^\circ} = \frac{0.5}{1.5} = \frac{1}{3}$$



At point A, $\sigma_z = 3 \text{ t/m}^2$

$$\therefore P_a = k_a \times \sigma_z = \frac{1}{3} \times 3 = 1 \text{ t/m}^2$$

At Point B $\sigma_z = 3 + 2 \times 1.8 = 6.6 \text{ t/m}^2$

$$\therefore p_a = k_a \times \sigma_z = \frac{1}{3} \times 6.6 = 2.2 \text{ t/m}^2$$

(i)

Active thrusts,

$$P_1 = K_a q \times H = \frac{1}{3} \times 3 \times 2 = 2 \text{ t/m at } (1)\text{m from base}$$

$$P_2 = \frac{1}{2} \times K_a \gamma H \times H = \frac{1}{2} \times \frac{1}{3} \times 1.8 \times 2^2$$

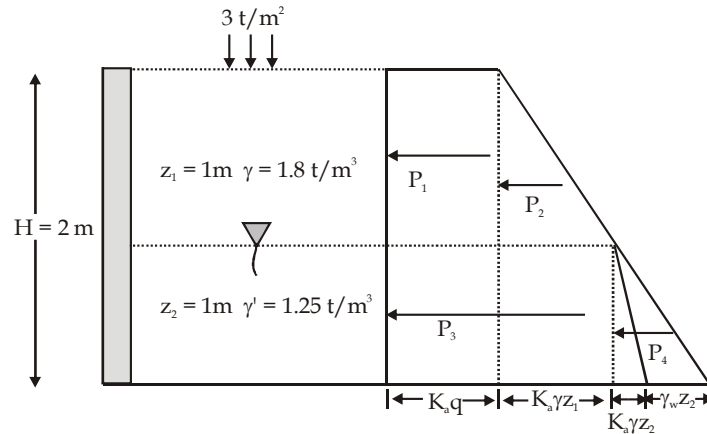
$$= 1.2 \text{ t/m at } \left(\frac{2}{3}\right)\text{m from base}$$

$\therefore$ Location of resultant thrust from base

$$= \frac{2 \times \frac{2}{3} + 1.2 \times \frac{2}{3}}{2 + 1.2} = 0.875 \text{ m}$$

Total active earth pressure per unit length of wall $= 2 + 1.2 = 3.2 \text{ t/m}$

(ii)



Active pressure,

$$P_1 = K_a q z_1 = \frac{1}{3} \times 3 \times 1 = 1 \text{ t/m at } \left(1 + \frac{1}{2}\right) \text{ m from base}$$

$$P_2 = \frac{1}{2} K_a \gamma z_1^2 = \frac{1}{2} \times \frac{1}{3} \times 1.8 \times 1^2 = 0.3 \text{ t/m at } \left(1 + \frac{1}{3}\right) \text{ m from base}$$

$$P_3 = (K_a q + K_a \gamma z_1) z_2 = \left(\frac{1}{3} \times 3 + \frac{1}{3} \times 1.8 \times 1\right) \times 1 = 1.6 \text{ t/m at } \left(\frac{1}{2}\right) \text{ m from base}$$

$$P_4 = \frac{1}{2} K_a \gamma' z_2^2 + \frac{1}{2} \times \gamma_w z_2^2 = \frac{1}{2} \times \frac{1}{3} \times 1.25 \times 1^2 + \frac{1}{2} \times 1 \times 1^2 = 0.71 \text{ t/m at } \left(\frac{1}{3}\right) \text{ m from base}$$

Total active earth pressure per unit length

$$= P_1 + P_2 + P_3 + P_4 = 1 + 0.3 + 1.6 + 0.71 = 3.61 \text{ t/m}$$

Location of resultant thrust from base

$$= \frac{(1 \times 1.5) + \left(0.3 \times \frac{4}{3}\right) + (1.6 \times 0.5) + \left(0.71 \times \frac{1}{3}\right)}{3.61} = 0.813 \text{ m}$$

Change in total active thrust due to rise in water table = 3.61 - 3.2 = 0.41 t/m

Q.37

Sol. For Fe 410 grade of steel: $f_u = 410 \text{ MPa}$

For bolts of grade 4.6: $f_{ub} = 400 \text{ MPa}$

Partial safety factor for the material of bolt: $\gamma_{mb} = 1.25$

A_{nb} = stress area of 20 mm diameter bolt = 245 mm²

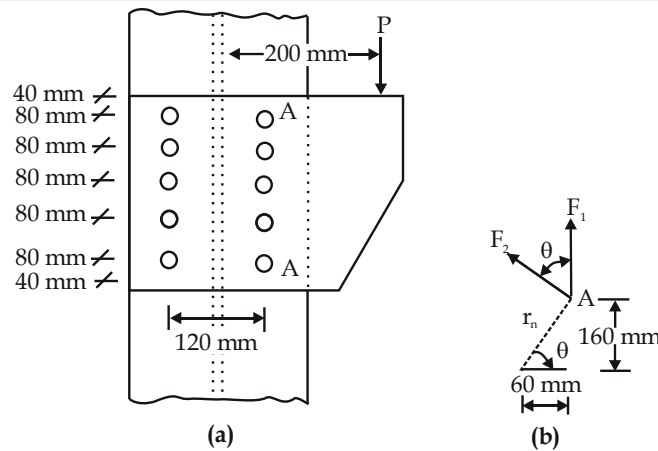


Fig.

Given: diameter of bolt, $d = 20$ mm; pitch, $p = 80$ mm; edge distance, $e = 40$ mm For $d = 20$ mm, do
 $= 20 + 2 = 22$ mm

Strength of the bolt in single shear,

$$V_{dsb} = A_{nb} \frac{f_{ub}}{\sqrt{3} \gamma_{mb}} = 245 \times \frac{400}{\sqrt{3} \times 1.25} \times 10^{-3} = 45.26 \text{ kN}$$

Strength of the bolt in bearing,

$$V_{dqb} = 2.5 k_b d t \frac{f_u}{\gamma_{mb}}$$

For 20 mm diameter bolt the diameter of bolt hole, $d_0 = 22$ mm

$$k_b \text{ is least of } \frac{e}{3d_0} = \frac{40}{3 \times 22} = 0.606; \frac{P}{3d_0} = \frac{80}{3 \times 22} - 0.25 = 0.96, \\ \frac{f_{ub}}{f_u} = \frac{400}{410} = 0.975; \text{ and } 1.0.$$

Hence,

$$k_b = 0.606$$

$$V_{dqb} = 2.5 \times 0.606 \times 20 \times 9.1 \times \frac{410}{1.25} \times 10^{-3} = 90.44 \text{ kN}$$

Hence, strength of the bolt, $V_{dsb} = 45.26$ kN.

Let, P_1 be the factored load,

$$\text{Service load, } P = \frac{P_1}{\text{load factor}} = \frac{P_1}{1.50}$$

The bolt which is stressed maximum is A.

Total number of bolts in the joint, $n = 10$

$$\text{This direct force, } F_1 = \frac{P_1}{n} = \frac{P_1}{10}$$

$$\text{The force in the bolt due to torque, } F_2 = \frac{P e_0 r_n}{\sum r^2}$$

$$r_n = \sqrt{(80 + 80)^2 + \left(\frac{120}{2}\right)^2} = 170.88 \text{ mm}$$

$$\sum r^2 = 4 \times [(160^2 + 60^2) + (80^2 + 60^2)] + 2 \times 60^2 = 164,000 \text{ mm}^2$$

$$F_2 = \frac{P_1 \times 200 \times 170.88}{164,000} = 0.20839 P_1$$

$$\cos \theta = \frac{60}{\sqrt{60^2 + 160^2}} = 0.3511$$

The resultant force on the bolt should be less than or equal to the strength of bolt.

$$45.26 \leq \sqrt{\left(\frac{P_1}{10}\right)^2 + (0.20839 P_1)^2} + 2 \times \frac{P_1}{10} \times 0.20839 P_1 \times 0.3511$$

$$\Rightarrow P_1 = 173.49 \text{ kN}$$

The service load, $P = \frac{P_1}{\text{load factor}} = \frac{173.49}{1.5} = 115.65 \text{ kN}.$

Q.38

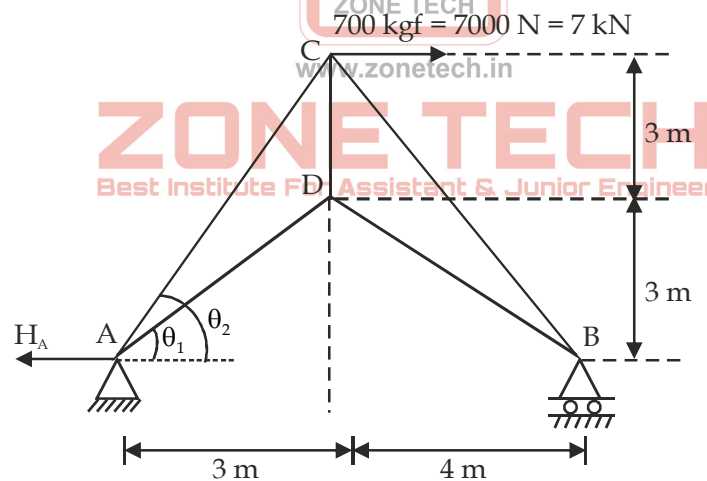
Sol. Degree of static indeterminacy,

$$D_s = m + r - 2j$$

Hence, $m = 5, r = 3, j = 4$

$$\therefore D_s = 5 + 3 - 8 = 0$$

Hence the given truss is statically determinate and unsymmetrical.



Reactions :

$$\sum F_y = 0 \Rightarrow R_A + R_B = 0$$

$$\Rightarrow [R_A = -R_B]$$

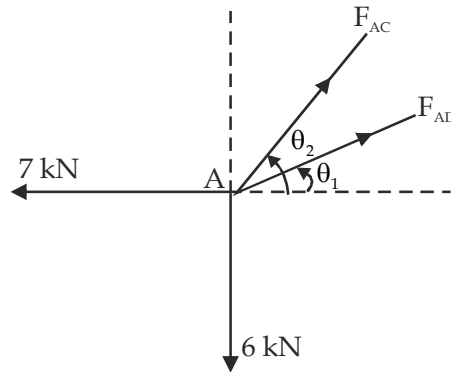
$$\sum M_A = 0 \Rightarrow R_B \times 7 - 7 \times 6 = 0$$

$$\Rightarrow R_B = 6 \text{ kN} (\uparrow)$$

$$\therefore R_A = -6 \text{ kN} \Rightarrow R_A = 6 \text{ kN} (\downarrow)$$

$$\sum F_x = 0 \Rightarrow H_A = 7 \text{ kN} (\leftarrow)$$

Joint A:



$$\tan \theta_1 = \frac{3}{3}$$

$$\tan \theta_2 = 2$$

 $\Rightarrow$

$$\sin \theta_1 = \frac{1}{\sqrt{2}}$$

$$\cos \theta_1 = \frac{1}{\sqrt{2}}$$


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$$\sin \theta_2 = \frac{2}{\sqrt{5}}$$

$$\cos \theta_2 = \frac{1}{\sqrt{5}}$$

$$\Sigma F_x = 0$$

$$F_{AD} \cos \theta_1 + F_{AC} \cos \theta_2 = 7$$

$$F_{AD} \times \frac{1}{\sqrt{2}} + F_{AC} \times \frac{1}{\sqrt{5}} = 7$$

$$F_{AD} \times \frac{1}{\sqrt{2}} + F_{AC} \times \frac{1}{\sqrt{5}} = 7$$

$$\Rightarrow \frac{F_{AD}}{\sqrt{2}} + \frac{F_{AC}}{\sqrt{5}} = 7$$

$$\Sigma F_y = 0$$

$$F_{AD} \sin \theta_1 + F_{AC} \sin \theta_2 - 6 = 0$$

$$\Rightarrow \frac{F_{AD}}{\sqrt{2}} + \frac{2F_{AC}}{\sqrt{5}} = 6$$

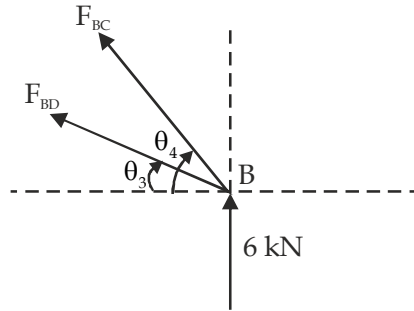
..(i)

By solving these two equations, we get,

$$F_{AD} = 11.314 \text{ kN (tensile)}$$

$$F_{AC} = -2.236 \text{ kN (compressive)}$$

Joint B:



$$\tan \theta_3 = \frac{3}{4}$$

$$\tan \theta_4 = \frac{6}{4} = \frac{3}{2}$$

$\Rightarrow$

$$\sin \theta_3 = \frac{3}{5}$$

$$\cos \theta_3 = \frac{4}{5}$$

$$\sin \theta_4 = \frac{3}{\sqrt{13}}$$

$$\cos \theta_4 = \frac{2}{\sqrt{13}}$$



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$$\Sigma F_x = 0$$

$$\Rightarrow F_{BC} \cos \theta_4 + F_{BD} \cos \theta_3 = 0$$

$$\Rightarrow \frac{2F_{BC}}{\sqrt{13}} + \frac{4F_{BD}}{5} = 0$$

$$\Sigma F_y = 0$$

$$\Rightarrow F_{BC} \sin \theta_4 + F_{BD} \sin \theta_3 + 6 = 0$$

$$\Rightarrow \frac{3F_{BC}}{\sqrt{13}} + \frac{3F_{BD}}{5} = -6$$

By solving these two equations we get,

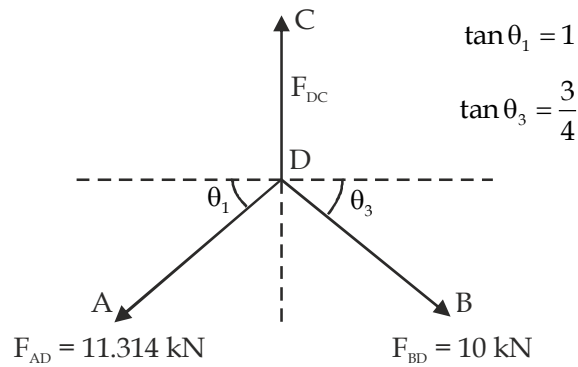
$$F_{BC} = -14.42 \text{ kN (compressive)}$$

$$F_{BD} = 10 \text{ kN (tensile)}$$

Joint D:

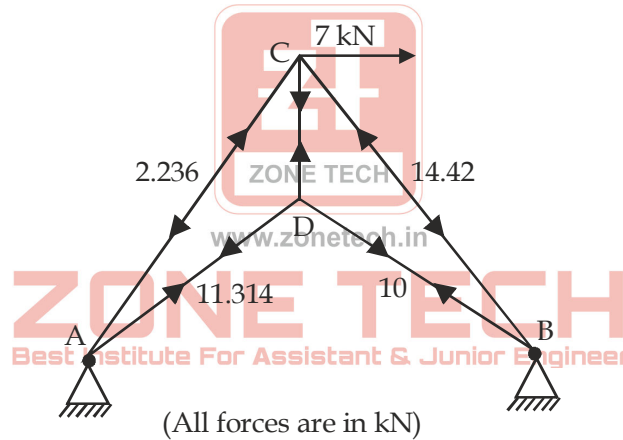
$$\Sigma F_y = 0$$

$$\Rightarrow F_{AD} \sin \theta_1 + F_{BD} \sin \theta_3 = F_{DC}$$



$$\Rightarrow 11.314 \times \frac{1}{\sqrt{2}} + 10 \times \frac{3}{5} = F_{DC}$$

$$\Rightarrow F_{DC} = 14 \text{ (tensile)}$$



Q.39

Sol. Case-I

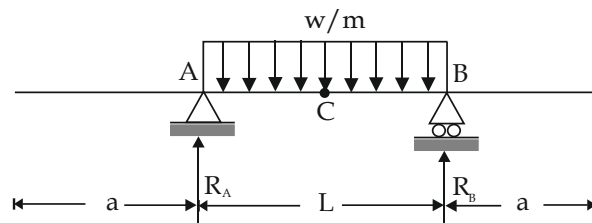
When uniformly distributed load w /unit length covering the length L between the supports. Let R_A and R_B be the reaction forces

$$R_A + R_B = wL$$

and

$$R_B \cdot L = \frac{wL^2}{2}$$

$$R_B = \frac{wL}{2} \text{ and } R_A = \frac{wL}{2}$$



and

$$M_x = R_A(x-a) - \frac{w(x-a)^2}{2}$$

$$= \frac{wL}{2}(x-a) - w \frac{(x-a)^2}{2} = \frac{w}{2}(x-a)(L-x+a)$$

$$M_x = \frac{w}{2}(x-a)(L+a-x)$$

$$M_c = \frac{w}{2} \left(a + \frac{L}{2} - a \right) \left(L + a - a - \frac{L}{2} \right) = \frac{w}{2} \left(\frac{L}{2} \times \frac{L}{2} \right) = \frac{wL^2}{8}$$

and

$$M_A = 0, M_B = 0$$

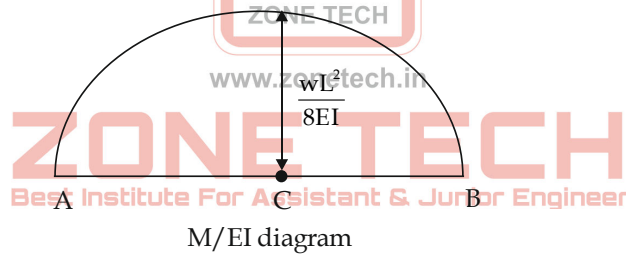
Therefore the curve of area moment diagram between A and B is parabolic in nature.

Using area moment diagram between C and B

$$y_B - y_C = \frac{-1}{EI} \left[\frac{2}{3} \times \left(\frac{wL^2}{8} \right) \times \left(\frac{L}{2} \right) \times \frac{5L}{16} \right]$$

$$0 - y_C = \frac{-5wL^4}{384EI}$$

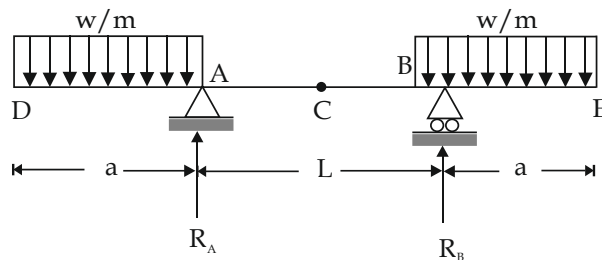
$$y_C = \frac{5wL^4}{384EI} \text{ (downwards)}$$



Case-II

When load is covering only two overhanging lengths

$$R_A = R_B = Wa$$



Between section D to A and B to E

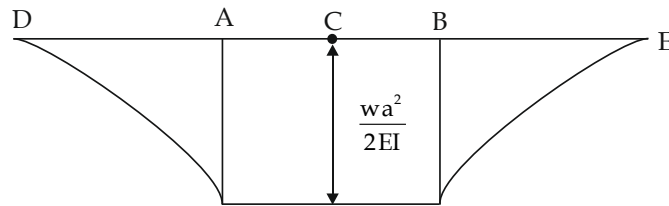
$$M_x = -\frac{wx^2}{2}$$

and between section A and B

$$M_x + wa \left(x - \frac{a}{2} \right) - wa(x-a) = 0$$

$$M_x + wax - \frac{wa^2}{2} - wax + wa^2 = 0$$

$$M_x = -\frac{wa^2}{2}$$



M/EI diagram

Using area moment diagram,

$$y_B - y_C = -\frac{1}{EI} \left[\frac{-wa^2}{2} \times \frac{L}{2} \times \frac{L}{4} \right]$$

$$0 - y_C = \frac{wa^2 L^2}{16EI}$$

$$y_C = \frac{-wa^2 L^2}{16EI} \text{ (upward direction)}$$

[∴ we have considered downward as positive.]

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