MADE EASY

India's Best Institute for IES, GATE & PSUs

Detailed Solutions

ESE-2019 Mains Test Series

Civil Engineering Test No : 12

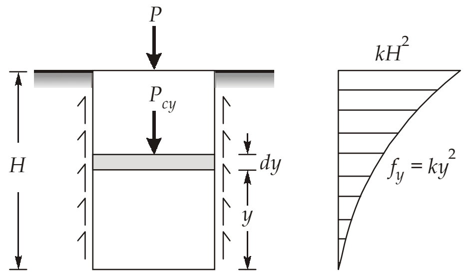
Section A

Q. 1 (a) Solution:

The characteristics of an efficient insulating material are:

- **Acoustical efficiency :** This is the most important consideration for selection of suitable sound-insulating material. The material should be able to reduce noise to the desired level.
- **Environmentally friendly :** Preferably, it should be a green material and water-based product.
- **Vermin and rot resistance :** The sound must be resistant to vermin, insects, termite and dry rot attack.
- **Incombustibility :** An insulating material should be fire resistant. Most of these materials are imparted fire retardant or incombustibility properties during the manufacturing process itself.
- **Resistance to moisture :** Under humid conditions, the sound insulating material should not absorb any moisture.
- **Weight :** The material should be light for ease in handling and fixing.
- **Maintenance :** The material should be easy to clean up (with soap and water), and must be suitable for application of paints etc.
- **Aesthetic appeal :** The material, in its finished form should have good light reflecting characteristics for pleasing appearance.

Q.1 (b) Solution:



The variation of frictional resistance (f) along the depth is shown in figure above.

$\therefore$ Total frictional resistance, $F = \int_0^H f_y dy = \int_0^H ky^2 dy = \frac{kH^3}{3}$

Thus, $F = P = \frac{kH^3}{3} \Rightarrow k = \frac{3P}{H^3}$

The compressive force on pile varies with depth. At any height y above the bottom of pile, the total compressive force will be equal to the frictional resistance (F_y) of the clay.

$\therefore$ Total compression, $P_{cy} = \int_0^y f_y dy = \int_0^y ky^2 dy = \frac{ky^3}{3}$

$\Rightarrow$ $P_{cy} = \frac{3P}{H^3} \cdot \frac{y^3}{3} = \frac{Py^3}{H^3}$

Now, shortening of small length dy of pile,

$$= \frac{P_{cy} dy}{AE}$$

$\therefore$ Total shortening $= \int_0^H \frac{P_{cy} dy}{AE}$

$$= \int_0^H \frac{Py^3}{H^3} \cdot \frac{dy}{AE} = \frac{PH}{4AE}$$

Q.1 (c) Solution:

Taking moments about point B,

$$R_A \times 24 + H \times 3 = 2000 \times 12 + 4000 \times 8 + 4000 \times 4$$

$\Rightarrow$ $R_A = 3000 - \frac{H}{8}$

Taking $M_C = 0$ from left,

$$H \times 9 - R_A \times 12 = 0$$

$$\Rightarrow \quad 9H - \left(3000 - \frac{H}{8}\right) \times 12 = 0$$

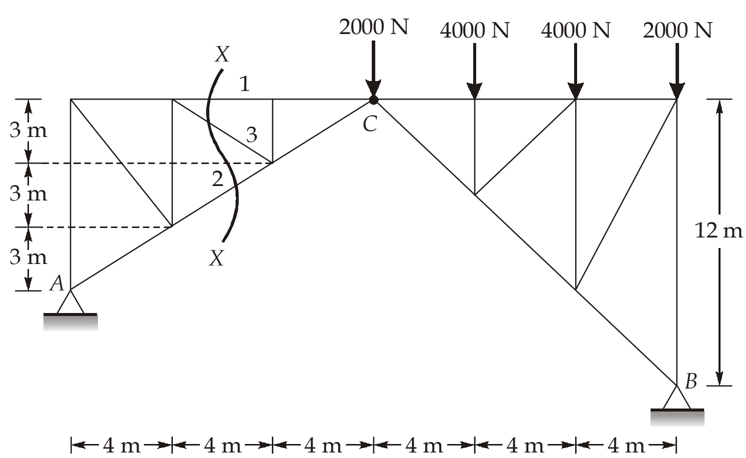
$$\Rightarrow \quad 9H + 1.5H = 36000$$

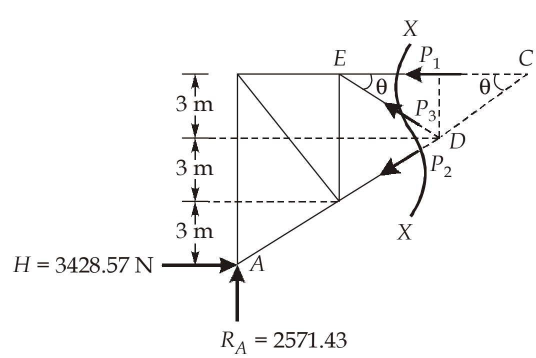
$$\Rightarrow \quad H = \frac{36000}{10.5} = 3428.57\text{N}$$

$$\therefore \quad R_A = 3000 - \frac{3428.57}{8} = 2571.43\text{N}$$

$$\therefore \quad R_B = 12000 - 2571.43 = 9428.57 \text{ N}$$

Take section *X-X*





To find P_1 , take moments about point D

$$P_1 \times 3 + H \times 6 - R_A \times 8 = 0$$

$$\Rightarrow \quad P_1 = \frac{8}{3} \times 2571.43 - 2 \times 3428.57$$

$$= 0$$

To find force P_2 take moments about E

$$H \times 9 - P_2 \times 8 \sin\theta - R_A \times 4 = 0$$

$$\Rightarrow \quad P_2 \times 8 \times \frac{3}{5} = 3428.57 \times 9 - 4 \times 2571.43$$

$$\Rightarrow \quad P_2 = 4285.7\text{N (C)}$$

To find force P_3 take moments about C

$$P_3 \times 8 \sin\theta + R_A \times 12 - H \times 9 = 0$$

$$\Rightarrow \quad P_3 \times 8 \times \frac{3}{5} = 9 \times 3428.57 - 12 \times 2571.53$$

$$\Rightarrow \quad P_3 = 30857.13 - 30857.13$$

$$\Rightarrow \quad P_3 = 0$$

Q.1 (d) Solution:

$$\text{Area of rod, } A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(15)^2 = 176.71 \text{ mm}^2$$

$$\text{Moment of inertia of rod, } I = \frac{\pi d^4}{64} = \frac{\pi \times 15^4}{64} = 2485.05 \text{ mm}^4$$

Since both ends are hinged

$$\therefore \quad L_{eff} = 2000 \text{ mm}$$

$$\text{Euler's buckling load, } P = \frac{\pi^2 EI}{L^2} = \frac{\pi^2 \times 2.1 \times 10^5 \times 2485.05}{(2000)^2} = 1287.6 \text{ N}$$

$$\text{Direct compressive stress, } p_c = \frac{P}{A} = \frac{1287.6}{176.71} = 7.29 \text{ N/mm}^2$$

Let the maximum bending stress corresponding to buckling condition be p_b

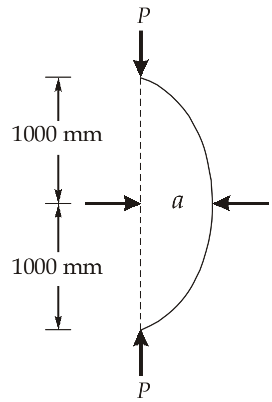
$$\therefore \quad p_b + p_c = \text{Yield stress } (f_y)$$

$$\Rightarrow \quad p_b = 250 - 7.29 = 242.71 \text{ N/mm}^2$$

Let M be the maximum bending moment which occurs at mid-height of column,

$$\because \quad \frac{M}{I} = \frac{p_b}{(d/2)}$$

$$\Rightarrow \quad M = \frac{242.71}{7.5} \times 2485.05 = 80419.53 \text{ Nmm}$$



Let the maximum deflection be a mm

$$\therefore \quad M = Pa$$

$$\Rightarrow \quad 80419.53 = 1287.6a$$

$$\Rightarrow \quad a = 62.46 \text{ mm}$$

Q.1 (e) Solution:

Important properties of concrete governing design of concrete mix:

(a) *Grade of Concrete :* The grade M20, M25 etc. connotes the characteristic strength, f_{ck} of 20 N/mm^2, 25 Nmm^2 respectively and the corresponding target mean strength is based on degree of control to be exercised at site.

(b) *Type of cement:* The grade of OPC such as 33, 43 or 53 grade or PPC to relevant specification affects the design mix.

(c) *Type and size of aggregate :* Natural sand, crushed stone, gravel etc. conforming to IS : 383-1970 quoting source of supply.

(d) *Nominal maximum size of aggregate:* 40, 20 mm, 10 mm as per **IS : 383-1970.**

(e) *Type of mixing and curing water :* This is required for durability consideration.

(f) *Maximum free water/cement ratio by weight :* Whether fresh potable water, seawater, ground water to be used.

(g) *Degree of workability :* This is dependent on placing and compaction condition.

(h) *Air content and type of admixture :* This is inclusive of entrained air.

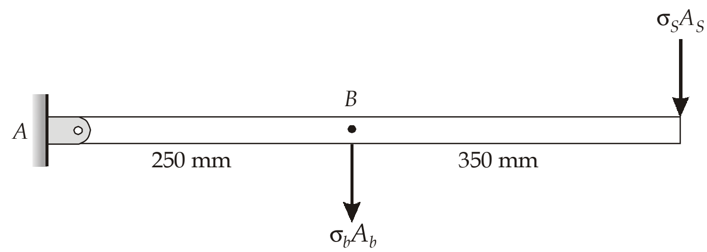
(i) *Maximum/minimum density of concrete :* These are considered in design of concrete mix.

(j) Maximum/minimum temperature of fresh concrete.

Q.2 (a) Solution:

Let stress in brass = σ_b (Tensile)

stress in steel = σ_s (Compressive)

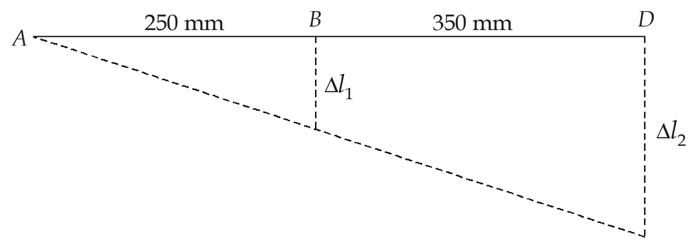


$$\Sigma M_A = 0$$

$$\sigma_b A_b \times 250 + \sigma_s A_s \times 600 = 0$$

$$\Rightarrow \quad \sigma_b = -1.2\,\sigma_s \quad \text{...(i)}$$

Now,



$$\frac{\Delta l_1}{250} = \frac{\Delta l_2}{600}$$

$$\Rightarrow \quad \Delta l_2 = 2.4\Delta l_1 \quad \text{...(ii)}$$

But
$$\Delta l_1 = 300 \times 20 \times 10^{-6} \times 25 - \frac{\sigma_b}{0.9 \times 10^5} \times 300$$

$$\Rightarrow \quad \Delta l_1 = 0.15 - 3.33 \times 10^{-3}\,\sigma_b \text{ (mm)} \quad \text{...(iii)}$$

$$\Rightarrow \quad \Delta l_2 = l_s \alpha_s \Delta T - \frac{\sigma_s}{E_s} l_s$$

$$\Rightarrow \quad \Delta l_2 = 250 \times 12 \times 10^{-6} \times 25 - \frac{\sigma_s}{2 \times 10^5} \times 250$$

$$\Rightarrow \quad \Delta l_2 = 0.075 - 1.25 \times 10^{-3}\,\sigma_s \text{ (mm)} \quad \text{...(iv)}$$

From (ii), (iii) and (iv)

$$0.075 - 1.25 \times 10^{-3}\,\sigma_s = 2.4\,(0.15 - 3.33 \times 10^{-3}\,\sigma_b)$$

$$\Rightarrow \quad 8\sigma_b - 1.25\sigma_s = 285 \quad \text{...(v)}$$

From (i) and (v)

$$\sigma_b = 31.52 \text{ N/mm}^2 \text{ (Tensile)}$$

$$\sigma_s = -26.27 \text{ N/mm}^2 \text{ (Compressive)}$$

Q.2 (b) Solution:

(i)

The following tests are usually conducted in laboratory to assess the quality of cement:

1. **Fineness test:** The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Fineness of cement can be tested in two ways viz. by sieving and by determination of specific surface using air permeability apparatus.
2. **Setting time test:** In actual construction dealing with cement paste, mortar or concrete, certain time is required for mixing, transporting, placing, compacting and finishing. During this time cement paste, mortar or concrete should be in plastic condition. This time is known as initial setting time. Once the concrete is placed in the final position, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. This time is known as final setting time. Setting time test is carried out with the help of Vicat apparatus.
3. **Compressive strength test:** The compressive strength of hardened cement is the most important of all the properties. Therefore, it is not surprising that the cement is always tested for its strength in laboratory before the cement is used in important works.
4. **Soundness test:** It is very important that the cement after setting shall not undergo any appreciable change of volume. The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance. Unsoundness in cement is due to excess of lime, excess of magnesia or excessive proportions of sulphates. Unsoundness due to lime can be tested using Le Chatelier apparatus. Unsoundness due to magnesia can be tested using Autoclave test. Unsoundness due to calcium sulphate can be tested using chemical analysis.
5. **Heat of hydration test:** The reaction of cement with water is exothermic. It is estimated that about 120 calories of heat is generated in the hydration of 1 gm of cement. The total quantum of heat produced in a conservative system such as the interior of a mass concrete dam, a temperature rise of about 50°C has been observed. This unduly high temperature developed at the interior of a concrete dam causes serious expansion of the body of dam and with the subsequent cooling considerable shrinkage takes place resulting in serious cracking of concrete. Heat of hydration test can be easily carried out over a few days by vacuum flask methods, or over a

longer period in an adiabatic calorimeter.

6. **Chemical composition test:** The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement, in addition to rate of cooling and fineness of grinding. Thus the chemical composition test is carried out in laboratory.

(ii) Structural grading: It is also sometimes known as stress grading. Structural grading however refers to the principle by which the material is graded on the basis of visible defects which have known effects on strength properties of the material. On the other hand, stress grading refers to the principle by which the material is graded by consideration of maximum principle stresses to which it can be subjected to. Structural grading is further divided as:

1. Grading based on known effects of defects and estimating accumulative value.
2. Machine grading

Commercial grading : It is also known as yard grading or utility grading and refers to the principle by which the material is graded by consideration of usefulness of the material and price factors.

Commercial grading is further subdivided in the following types:

S.No.	Basis	Prevalency
• Grade A	On dimensions and general appearance.	Kerala and Mysore
• Grade B	Best ultimate use of the material.	Andhra Pradesh & Tamil Nadu
• Grade C	Qualitative evaluation of defects and rough estimate	Madhya Pradesh

Q.2 (c) Solution:

(i)

PVC pipes are ideal for carrying potable water and also for sewerage. For potable was supplies, PVC are manufactured **IS 4985-1988.** The advantages offered by PVC pipes are : these are flexible in nature, easy to install, and cost-effective; have a good life expectancy of 50 years; sustain greater dynamic/point loads due to their ability to deflect; do not crack under deflection loads; no root instrusion; good abrasion resistance; and quick restoration/replacement in case of failure.

Advantages of using PVC pipes : The following are the additional advantages of commonly used PVC pipes over metal pipes.

- One of most important advantages of using PVC pipe in water supply systems is their resistance to corrosion by chlorides in water (brackish water). Whereas, CI pipes tend to corrode.

- They are unaffected by atmospheric pollution.
- PVC pipes are highly cost effective as compared to metal pipes.
- They are light in weight and hence easy to transport and handle.

(ii)

$$\because \quad GJ\frac{d\theta}{dx} = T_x$$

$$\therefore \quad GJ\frac{d^2\theta}{dx^2} = \frac{dT_x}{dx} = -t_x = -\frac{kx^2}{L^2} \quad \text{...(i)}$$

On integrating (*i*), $$GJ\frac{d\theta}{dx} = T_x = -\frac{kx^3}{3L^2} + C_1 \quad \text{...(ii)}$$

At $x = 0$, $T_A = T(0) = 0$ and hence $C_1 = 0$

At $x = L$, $T_B = T(L) = -\frac{kL}{3}$

Again integrating (ii) $$GJ\theta_x = -\frac{kx^4}{12L^2} + C_2$$

At $x = L$, $\theta_B = 0$ and hence $C_2 = \frac{kL^2}{12}$

$$\therefore \quad \theta_x = \frac{1}{GJ}\left(\frac{-kx^4}{12L^2} + \frac{kL^2}{12}\right) = \frac{k\left(L^4 - x^4\right)}{12L^2GJ}$$

At free end A, $x = 0$,

$$\therefore \quad \theta_A = \frac{kL^2}{12GJ}$$

Q.3 (a) Solution:

(i)

A pozzolana is a finely ground siliceous material which as such does not possess cementitious property in itself but reacts in the presence of water with calcium hydroxide at normal temperature to form compounds of low solubility having cementitious properties. The action is known as pozzolanic action.

The reaction can be shown as

$$\textbf{Pozzolana} + \mathbf{Ca(OH)_2} + \mathbf{H_2O} \rightarrow \textbf{C-S-H (gel)}$$

This reaction is called pozzolanic reaction. The characteristic feature of pozzolanic reaction is initially slow, with the result that heat of hydration and strength development will accordingly be slow. The reaction involves the consumption of $Ca(OH)_2$ and not production of $Ca(OH)_2$. It may be noted that on hydration of C_3S and C_2S present in cement, $Ca(OH)_2$ is formed as one of the products of hydration. This compound has no cementitious value and it is soluble in water and may be leached out by the percolating water. It is pointed out that $Ca(OH)_2$, otherwise, a water soluble material is converted into insoluble cementitious material by reaction of pozzolanic materials.

The reduction of $Ca(OH)_2$ also improves the durability of cement paste by making the paste dense and impervious. Pozzolanic materials can be natural or artificial. Clay and shales, opaline cherts, diatomaceous earth and volcanic tuffs are natural pozzolanic materials. Fly ash, blast furnace slag, silica fume, rice husk ash are artificial pozzolanic materials.

The pozzolanic action also reduce the expansion caused by the alkali-aggregate reaction in concrete. Excessive expansion causes pattern cracking of concrete. This expansion can usually be controlled by using of pozzolana ranging from 2 to 35% by mass of cement depending upon the type of aggregate and alkali content of cement.

(ii)

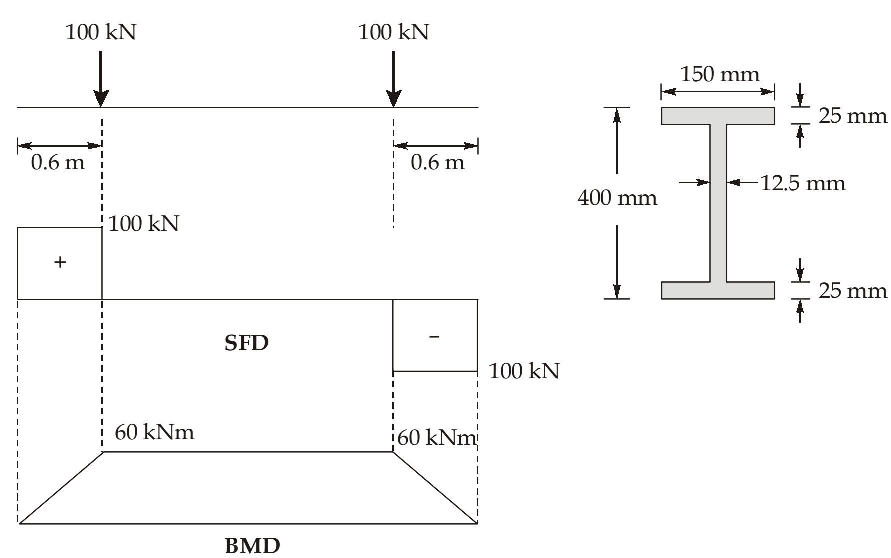
The various test which are performed on clay bricks are :

1. **Water absorption test:** The clay bricks are tested in accordance with the procedure laid down in **IS : 3495-1992**. The code recommends that this test should be performed in both cold water and boiling water. This is because water absorption in bricks occur in the pores and many times pores are completely sealed and hence inaccessible to water under ordinary conditions. As per the code the average water absorption of common building bricks should not be more than 20% by weight upto class 12.5 MPa and 15% by weight for higher classes.
2. **Crushing strength test:** Bricks often have to withstand great compressive stresses. The durability of the masonry depends upon the strength of the bricks. The crushing or compressive strength of a brick is found out by placing it in a compression testing machine. It is pressed till it breaks. As per **IS:1077-1992**, the minimum crushing strength of bricks is 3.5 MPa.
3. **Hardness test:** In this test a scratch is made on brick surface with the help of a finger nail. If no impression is left on the surface, the brick is treated to be sufficiently hard.
4. **Soundness test:** In this test the two bricks are taken and they are struck with each other. The bricks should not break and a clear ringing sound be produced. The bricks will fail soundness test if there is excess of lime present in it because excess

lime causes the brick to melt and disintegrate. As a result the shape of the bricks will be lost. However, a small quantity of lime not exceeding 5% is desirable in good bricks.

5. **Presence of soluble salts test:** The soluble salts, if present in bricks will cause efflorescence on the surface of bricks. For finding out the presence of soluble salts in a bricks it is immersed in water for 24 hours. It is then taken out and allowed to dry in shade. The absence of grey or white deposits on its surface indicates absence of soluble salts. The liability of efflorescence is reported as 'nil', 'slight', 'moderate', 'heavy' and 'serious' according to the limits specified by **IS 3495 : 1992.**
   - **(a) Nil :** When there is no perceptible deposit of efflorescence.
   - **(b) Slight :** When no more than 10% of the area of the brick is covered with a thin deposit of salts.
   - **(c) Moderate :** When deposition is more than 10% and covering upto 50% of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surface.
   - **(d) Heavy :** When there is a heavy deposit of salts covering 50% or more of the exposed area of the brick surface but unaccompanied by powdering or flaking of the surface.
   - **(e) Serious :** When there is a heavy deposit of salts accompanied by powdering and/or flaking of the exposed surfaces.

Q.3 (b) Solution:



$$\text{Moment of inertia, } I = \frac{150 \times 400^3}{12} - \frac{137.5 \times 350^3}{12} = 3.087 \times 10^8 \text{ mm}^4$$

$$\text{Maximum SF} = 100 \text{ kN}$$

$$\text{Maximum BM} = 0.6 \times 100 = 60 \text{ kNm}$$

The bending and shear stresses would be found at the junction of web and flange at web, because at this point we will get principal stresses.

At web-flange junction,

$$\text{Bending stress in web} = \frac{M}{I}y$$

$$\Rightarrow \quad \sigma_x = \frac{60 \times 10^6 \times 175}{3.087 \times 10^8} = 34.01 \text{ N/mm}^2$$

$$\text{Shearing force in web, } q = \frac{Sa\bar{y}}{Ib}$$

$$= \frac{100 \times 10^3 \times 150 \times 25 \times 187.5}{3.087 \times 10^8 \times 12.5} = 18.22 \text{ N/mm}^2$$

The principal stresses are given by

$$\sigma_{p1/p2} = \frac{\sigma_x}{2} \pm \sqrt{\frac{\sigma_x^2}{4} + q^2}$$

$$= \frac{34.01}{2} \pm \sqrt{\frac{(34.01)^2}{4} + 18.22^2}$$

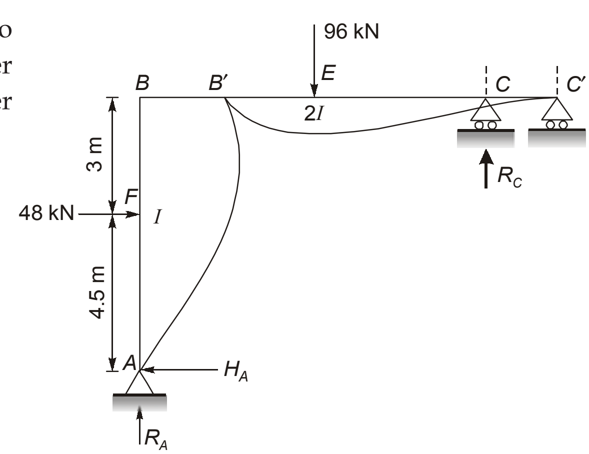
$$= 41.92 \text{ N/mm}^2, -7.92 \text{ N/mm}^2$$

$$\therefore \quad \sigma_{p1} = 41.92 \text{ N/mm}^2$$

$$\text{and} \quad \sigma_{p2} = -7.92 \text{ N/mm}^2$$

Q.3 (c) Solution:

Since support D is a roller support, there will be no horizontal reaction at D, hence no BM in the member CD. Thus the structure can be represented in another way



Equilibrium condition

$\Sigma F_x = 0;$ $\quad H_A = 48$ kN

$\Sigma M_C = 0$

$$R_A \times 6 + 48 \times 7.5 - 48 \times 3 - 96 \times 3 = 0$$

$$R_A = 12 \text{ kN}$$

$\Sigma F_y = 0$ $\quad R_C = 84$ kN

From modified diagram, support C has roller support it can not be deflected in vertical direction. So vertical deflection at $C = 0$

Since support A is hinged support, so deflection at A zero (0).

Thus we have to calculate slope at A and slope and horizontal deflection at C.

Using unit load method:

$$\Delta = \int \frac{Mmdx}{EI}, \theta = \int \frac{Mm'dx}{EI}$$

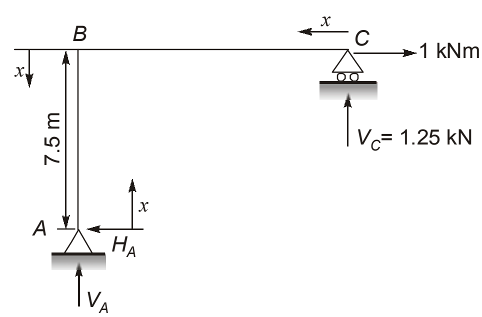
where, $M \to$ BM due to external loading

$m \to$ BM when external loads are removed and unit load is applied at that point where deflection is required.

$m' \to$ BM when external loads are removed and unit moment is applied at that point where slope is required.

Segment	Limit	M	m_C	$m_{\theta c}$	$m_{\theta A}$
CE (2I)	0-3	$84x$	$1.25x$	$\left(1-\frac{x}{6}\right)$	$\frac{x}{6}$
EB (2I)	3-6	$84x - 96(x-3)$ $=(-12x + 288)$	$1.25x$	$\left(1-\frac{x}{6}\right)$	$\frac{x}{6}$
BF (I)	0-3	$84 \times 6 - 96 \times 3 = 216$	$1.25 \times 6 - 1 \times x = 7.5 - x$	$1-\frac{1}{6}\times 6 = 0$	1
AF (I)	0-4.5	$48x$	x	0	1

$m_c \to$ BM due to horizontal unit load at C



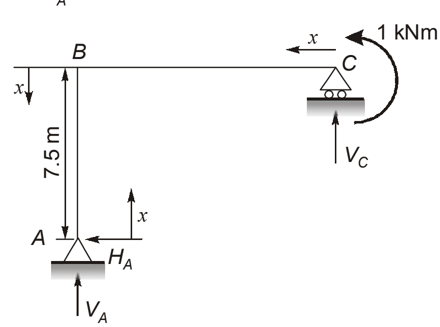
$\Sigma F_x = 0;$ $H_A = 1$ kN

$\Sigma M_A = 0;$ $V_C \times 6 = 1 \times 7.5$

$V_C = 1.25$ kN

$\Sigma F_y = 0;$ $V_A = -1.25$ kN

$m_{\theta_C} \to$ BM due to unit anticlockwise moment at C



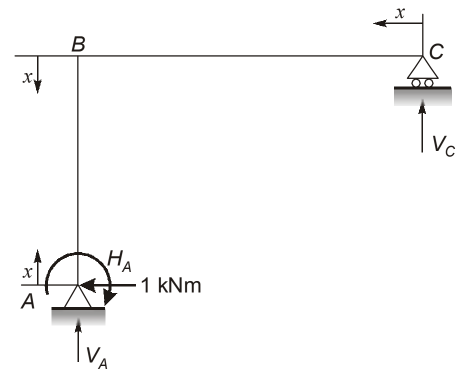
$\Sigma F_x = 0;$ $H_A = 0$

$\Sigma M_A = 0;$ $V_C \times 6 + 1 = 0$

$V_C = -\frac{1}{6}$KN

$\Sigma F_y = 0;$ $V_A = \frac{1}{6}$KN

$m_{\theta_A} \rightarrow$ BM due to unit clockwise moment at A



$\Sigma F_x = 0; \quad H_A = 0$

$\Sigma M_C = 0; \quad V_A \times 6 + 1 = 0$

$\Sigma f_y = 0; \quad V_A = -\frac{1}{6}\text{KN}$

$V_C = \frac{1}{6}\text{KN}$

$$\Delta_C = \int \frac{Mm_C dx}{EI} = \int_0^3 \frac{84x \times 1.25x dx}{2EI} + \int_3^6 \frac{(-12x + 288)1.25x dx}{2EI} + \int_0^3 \frac{216(7.5 - x)dx}{EI} + \int_0^{4.5} \frac{48x^2}{EI} dx$$

$$\Delta_C = \frac{472.5}{EI} + \frac{1957.5}{EI} + \frac{3888}{EI} + \frac{1458}{EI} = \frac{7776}{EI} (\rightarrow)$$

$$\theta_C = \int \frac{Mm_{\theta_C} dx}{EI} = \int_0^3 \frac{84x\left(1 - \frac{x}{6}\right)dx}{2EI} + \int_3^6 \frac{(-12x + 288)\left(1 - \frac{x}{6}\right)dx}{2EI} + 0 + 0$$

$$\theta_C = \frac{126}{EI} + \frac{90}{EI} = \frac{216}{EI} (\text{Anticlockwise})$$

$$\dot{\theta}_A = \int \frac{Mm_{\theta_A} dx}{EI} = \int_0^3 \frac{84x \times \frac{x}{6} dx}{2EI} + \int_3^6 \frac{(-12x + 288)\frac{x}{6} dx}{2EI} + \int_0^3 \frac{216 dx}{EI} + \int_0^{4.5} \frac{48x \times 1 dx}{EI}$$

$$\theta_A = \frac{63}{EI} + \frac{261}{EI} + \frac{648}{EI} + \frac{486}{EI}$$

$$\theta_A = \frac{1458}{EI} (\text{clockwise})$$

At A, $\quad \theta_A = \frac{1458}{EI} (\text{clockwise}), \Delta_A = 0$

At C, $\quad \theta_C = \frac{216}{EI} (\text{anticlockwise}), \Delta_{C_H} = \frac{7776}{EI} (\rightarrow)$

$\Delta_{C_V} = 0$

Q.4 (a) Solution:

Let V_E and H_E be the vertical and horizontal reactions respectively at E.

Let V_A and H_A be vertical and horizontal reactions respectively at A.

Taking moments about E,

$$H_A \times 2 = \frac{4 \times 3^2}{2} + 2 \times 3$$

$$\Rightarrow \quad H_A = 12 \text{ kN } (\rightarrow)$$

$$\therefore \quad H_E = 12 \text{ kN } (\leftarrow)$$

Let tension in ED be T

$$\therefore \quad T\cos\theta = H_E$$

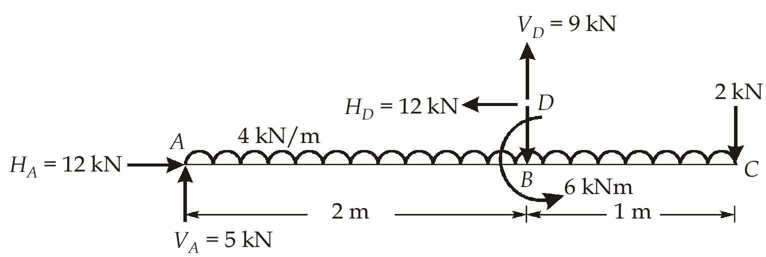
$$T\sin\theta = V_E$$

$$\tan\theta = \frac{2-0.5}{2} = \frac{1.5}{2} = \frac{V_E}{H_E}$$

$$\Rightarrow \quad V_E = \frac{1.5}{2} \times 12 = 9 \text{ kN}$$

$$V_A = (4 \times 3 + 2) - T\sin\theta$$

$$= 14 - V_E = 14 - 9 = 5 \text{ kN}$$



Now, the beam ABC is subjected to the following forces :

(i) External loading on beam

(ii) $V_A = 5$ kN, $H_A = 12$ kN

(iii) Vertical component of tension T at D, $V_D = 9$ kN

(iv) Horizontal component of tension T at D, $H_D = 12$ kN

(v) Anticlockwise moment due to H_D at B,

$$= 12 \times 0.5 = 6 \text{ kNm}$$

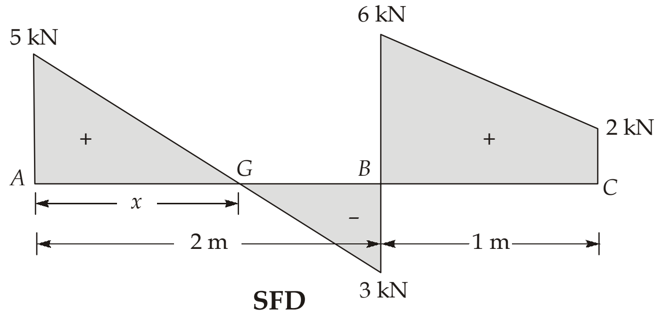
S.F. calculation

$$SF_A = +5 \text{ kN}$$

$$SF_B = 5 - 4 \times 2 = -3 \text{ kN} \quad \text{(Just left of } B\text{)}$$

$$= -3 + 9 = 6 \text{ kN} \quad \text{(Just right of } B\text{)}$$

$$SF_C = 2 \text{ kN}$$



SFD

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

$$\Rightarrow \quad x = 1.25 \text{ m}$$

BM Calculation

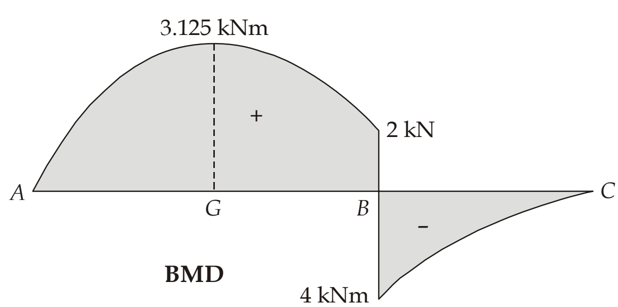
$$(BM)_A = 0$$

$$(BM)_G = 5 \times 1.25 - \frac{4 \times 1.25^2}{2} = 3.125 \text{ kNm}$$

$$(BM)_B = 5 \times 2 - \frac{4 \times 2^2}{2} = 2 \text{ kNm} \qquad \text{(Just left of } B\text{)}$$

$$(BM)_B = 2 - 6 = -4 \text{ kNm} \qquad \text{(Just right of } B\text{)}$$

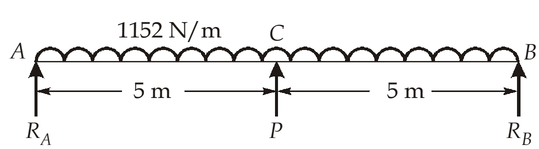
$$(BM)_C = 0$$



BMD

Q.4 (b) Solution:

(i)



If all three reactions (R_A, P, R_B) are equal then,

$$R_A = R_B = P = \frac{1152 \times 10}{3} = 3840 \text{ N}$$

Let δ = Amount by which the prop should yield, if all the reactions are to be equal

Let, y_1 = Downward deflection due to UDL

$$\therefore \qquad y_1 = \frac{5}{384}\frac{wL^4}{EI}$$

$$= \frac{5 \times 1152 \times (10 \times 10^3)^4}{384 \times 2 \times 10^5 \times 10^8 \times 10^3} = 7.5 \text{ mm}$$

Now upward deflection due to prop reaction at the point of prop is given by,

$$y_2 = \frac{PL^3}{48EI} = \frac{3840 \times (10 \times 10^3)^3}{48 \times 2 \times 10^5 \times 10^8} = 4 \text{ mm}$$

As, $\qquad y_1 = y_2 + \delta$

$\Rightarrow \qquad \delta = y_1 - y_2$

$$= 7.5 - 4 = 3.5 \text{ mm}$$

(ii)

Maximum bending moment due to UDL,

$$M = \frac{wL^2}{8} \qquad \text{...(i)}$$

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

$$\Rightarrow \qquad M = \sigma \times \frac{I}{y} = 8 \times \frac{I}{d/2} = \frac{16I}{d} \qquad \text{...(ii)}$$

From equations (i) and (ii), we get

$$\frac{wL^2}{8} = \frac{16I}{d}$$

$$\Rightarrow \qquad w = \frac{128I}{dL^2} \qquad \text{...(iii)}$$

The deflection at mid-span is given by,

$$\delta = \frac{5}{384}\frac{wL^4}{EI}$$

$$\Rightarrow \qquad 10 = \frac{5}{384} \times \frac{128I}{dL^2} \times \frac{L^4}{EI}$$

$$\Rightarrow \qquad 10 = \frac{5}{384} \times \frac{128L^2}{d \times E}$$

$$\Rightarrow \quad d = \frac{5 \times 128 \times L^2}{384 \times 10 \times E}$$

$$\Rightarrow \quad d = \frac{5 \times 128 \times \left(5 \times 10^3\right)^2}{384 \times 10 \times 1.2 \times 10^4} = 347.2 \text{ mm}$$

$$\Rightarrow \quad d = 34.72 \text{ cm}$$

Q.4 (c) Solution:

Seasoning of Timber: It is a process by which the moisture content of timber is reduced to a suitable level depending upon the use. Seasoned timber is definitely superior to unseasoned timber. While seasoning does not make timber safe from all destructive agencies, this is a prime process before timber can be put to use. By nature timber is hygroscopic and takes in moisture from air depending upon many factors. Timber should be seasoned as early as possible after felling because felled timber is nothing but dead vegetation that will rot and decay due to many environmental agencies.

The reasons or objectives for which seasoning is done are:

(i) To reduce the tendency to split, warp and shrink.

(ii) To make it immune from attack by insects.

(iii) To increase the strength, durability, workability and resilience.

(iv) To make the timber receptive to finish like preservative, paints and varnish.

(v) To reduce the weight and minimise cost of transportation.

(vi) To make the timber burn readily, if used as a fuel.

Seasoning methods can be basically classified into two groups namely, natural seasoning and artificial seasoning:

Natural Seasoning: In this method, the seasoning of timber is carried out by natural air and hence it is also sometimes referred to as air seasoning. The timber has to be stacked properly depending upon the species of timber and the environmental conditions. The timber log is cut and sawn into suitable section of planks or scantlings. Then they are stacked either horizontally or vertically. The stack is to be protected from fast blowing wind, rain and extreme heat of sun. Hence the stack should preferably be covered by a roof material. The advantage of natural seasoning is that it does not require skilled supervision. This method of seasoning timber is cheap and simple. The disadvantage of natural seasoning is that, as the process depends on the natural air, it some times become difficult to control it as well as the drying of different surface may not be even and uniform.

Artificial Seasoning: It is a quicker method of seasoning timber to the desired moisture content under controlled conditions. The drying conditions required for different species of timber are different and artificial seasoning makes it possible to provide conditions cited to each species. The advantages of artificial seasoning are speed, adaptability and precision.

The various methods of artificial seasoning are boiling, chemical seasoning, electrical seasoning and water seasoning which are as follows:

(i) 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.

(ii) Chemical Seasoning : This is also known as 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.

(iii) 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.

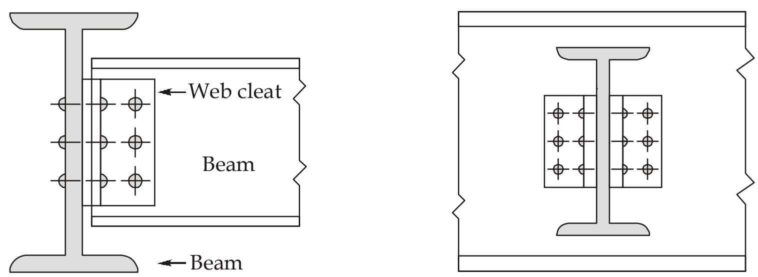
(iv) Kiln Seasoning: In this method, the drying of timber is carried out inside an airtight chamber or oven. Depending upon the mode of construction and operation, the kilns are of two types namely stationary kilns and progressive kilns. Stationary kiln is adopted for seasoning timber which requires a close control of humidity and temperature. It gives better results. Progressive kiln 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.

(v) Water seasoning: The water seasoning is a quick method and it renders timber which is less liable to shrink or warp. It also removes organic materials contained in sap of timber. It however weakens the timber and make it brittle.

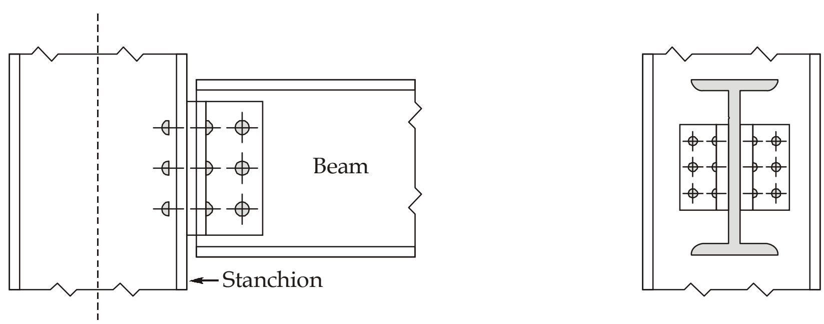
Section B

Q.5 (a) Solution:

(i) Framed connection : When end shear to be transferred is less, it is possible to connect the beam to main beam or to the column using cleat angles as shown in figure below.

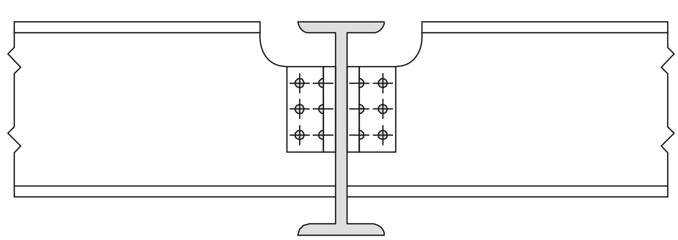


(a) Beam connected to beam



(b) Beam connected to stanchion/column

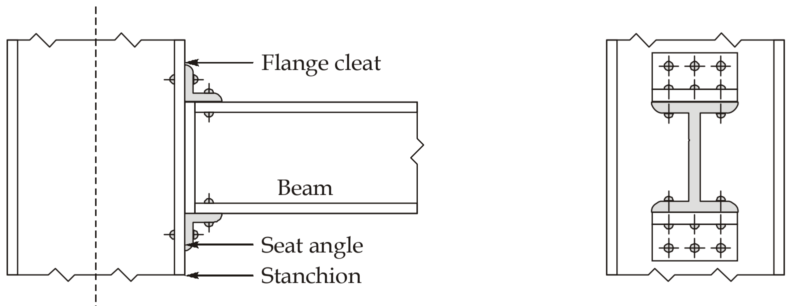
If the flanges of beam to be connected are at the same level, then the flanges of connecting beam are cut as shown in figure below.



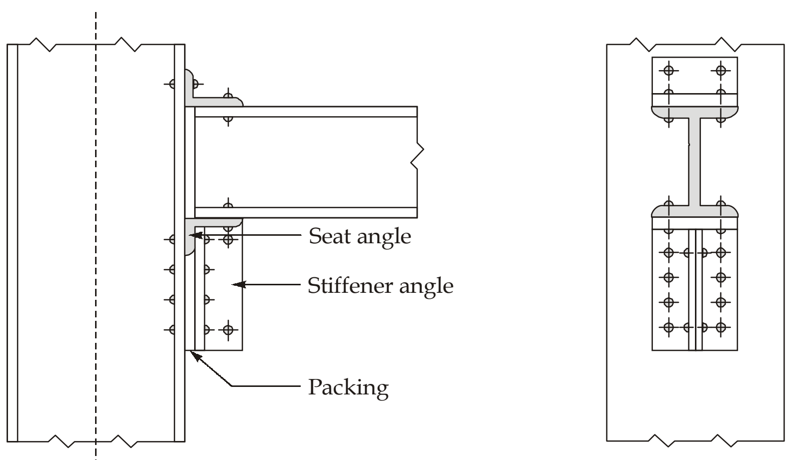
Framed connection if flanges are at the same level

This will not pose any structural problem, since at the ends of simply supported beams, moment is zero and shear strength depends mainly on the strength of web.

(ii) Unstiffened seated connection : When shear force is large then the depth of cleat angle required for framed connection may be more than that can be provided in the available space. In such cases, seat angles are connected to the column over which beam rests. At top, cleat angles are provided to prevent the lateral displacement of the beam after positioning it over seat angle. Figure below shows a typical unstiffened seated connection.



(iii) Stiffened seated connection : If shear force to be transferred in the beam is still large, the seat angle may fail. To strengthen it, a stiffener angle may be provided as shown in figure below. Such a connection known as stiffened seated connection.



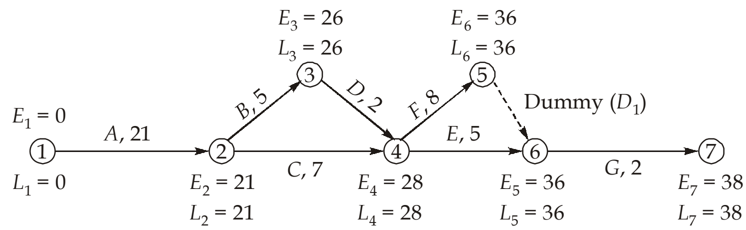
Q.5 (b) Solution:

(i)

Both PERT and CPM are tools of network analysis however the basic differences between them are as follows :

	PERT	CPM
1.	It is project evolution and review technique.	It is critical path method.
2.	It is event oriented.	It is activity oriented.
3.	It is based on probabilistic approach.	It is based on deterministic approach.
4.	Here three time estimates are made for an activity.	Here single time estimate is made for the complete activity.
5.	It is used where time required to complete various activities is not certain.	It is used for repetitive work where one has prior experience of handling similar project.
6.	It is used mainly for research and development projects.	It is used mainly for construction projects.

(ii) Network diagram will be:



Possible paths	Time (in weeks)
①—②—③—④—⑤—⑦	35
①—②—③—④—⑤—⑥—⑦	38
①—②—④—⑤—⑦	35
①—②—④—⑤—⑥—⑦	38

Thus critical paths are:

Either ①—②—③—④—⑤—⑥—⑦

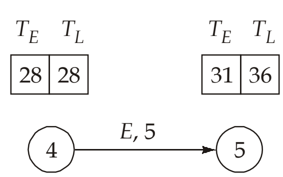
$[A \rightarrow B \rightarrow D \rightarrow F \rightarrow D_1 \rightarrow G]$

or ①—②—④—⑤—⑥—⑦

$[A \rightarrow C \rightarrow F \rightarrow D_1 \rightarrow G]$

Project completion time = 38 weeks

For activity *E*,



$$\text{EST} = T_E^i = 28 \text{ days}$$

$$\text{EFT} = T_E^i + t_{ij}$$

$$= 28 + 5 = 33 \text{ days}$$

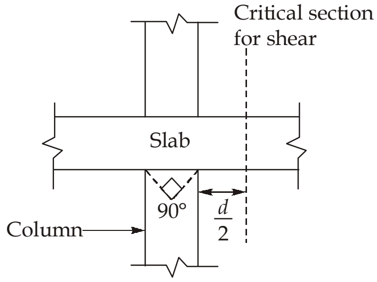
$$\text{LFT} = T_L^j = 36 \text{ days}$$

$$\text{LST} = T_L^j - t_{ij} = 36 - 5 = 31 \text{ days}$$

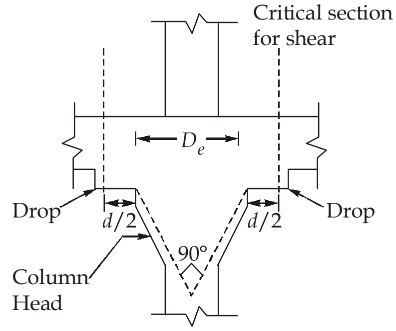
Q.5 (c) Solution:

Beams of large depth reduce the clear ceiling height available. Hence, flat slab is a RCC slab built monolithically with the supporting columns and reinforced in two or more directions. Beams are not provided in flat slabs to support it. The load carried by the slab is directly transmitted to the column. It provides greater clear ceiling heights.

Generally, in flat slabs, the columns are provided with enlarged heads called column heads or capitals. To support heavy loads, the thickness of slab over the columns is increased. This thickened portion of the slab is known as drop panel. lightly loaded flat slabs, column heads are omitted. Such a flat slab of constant thickness supported on columns is called flat plate.



(a) Slab without drop and column without column head



(b) Slab with drop and column with column head

Advantages of flat slab

(1) Floor systems require lesser depth and hence reduction in storey height.

(2) There is reduction of dead load and foundation loads because weight of structure is reduced due to reduction in floor height.

(3) Improved fire resistance and better illumination in flat slab construction.

(4) Easier to provide acoustical treatment to the underside of the slab.

(5) Flat slabs can better withstand point loads.

(6) Flat slab construction reduces the construction time as it eliminates the use of formwork for beams.

Q.5 (d) Solution:

For pure torsion case, equal amount of tension reinforcement will be provided on both side of neutral axis.

$$M_{ue_1} = M_u + \frac{T_u}{1.7}\left[1 + \frac{D}{B}\right]$$

$$= 0 + \frac{T_u}{1.7}\left[1 + \frac{600}{300}\right] = 1.765T_u$$

Now,

$$C = T$$

$$\Rightarrow \quad 0.36 f_{ck}\, x_u B = 0.87 f_y A_{st}$$

$$\Rightarrow \quad 0.36 \times 25 \times x_u \times 300 = 0.87 \times 415 \times \frac{\pi}{4} \times 20^2 \times 2$$

$$\Rightarrow \quad x_u = 84.02 \text{ mm}$$

For Fe415, $x_{u,\lim} = 0.48d = 0.48 \times (600 - 40) = 268.8 \text{ mm} > x_u$

So, section is under-reinforced

$$\therefore \quad M_{ue_1} = \text{MOR} = 0.87 \times f_y A_{st} [d - 0.42\, x_u]$$

$$1.765 T_u = 0.87 \times 415 \times \frac{\pi}{4} \times 20^2 \times 2[560 - 0.42 \times 84.02]$$

$$\Rightarrow \quad T_u = 67.044 \times 10^6 \text{ Nmm}$$

$$= 67.44 \text{ kNm}$$

Q.5 (e) Solution:

Prestressing force = 300 kN

Area of steel wires $= 60 \times \frac{\pi}{4} \times 2^2 = 188.5 \text{ mm}^2$

Average initial stress in concrete (f_c) $= \frac{300 \times 10^3}{250 \times 250} = 4.8 \text{ N/mm}^2$

Modular ratio (m) $= \frac{E_S}{E_C} = \frac{210}{32} = 6.5625$

Initial stress in steel wires (f_s) $= \frac{300 \times 10^3}{188.5} = 1591.5$ MPa

Loss of stress due to :

1. Elastic deformation of concrete $= mf_c = 6.5625 \times 4.8 = 31.5 \text{ N/mm}^2$
2. Creep of concrete $= \theta f_c E_c = (30 \times 10^{-6}) \times 4.8 \times 210 \times 10^3 = 30.24 \text{ N/mm}^2$
3. Shrinkage of concrete $= 200 \times 10^{-6} \times 210 \times 10^3 = 42 \text{ N/mm}^2$
4. Relaxation of steel stress $= \frac{5}{100} \times 1591.5 = 79.6 \text{ N/mm}^2$

So, total loss of stress $= 31.5 + 30.24 + 42 + 79.6$

$= 183.34 \text{ N/mm}^2$

$\therefore$ Effective prestress $= 1591.5 - 183.34 = 1408.16 \text{ N/mm}^2$

$\therefore$ Final stress in concrete $= \dfrac{1408.16 \times 188.5}{250 \times 250} = 4.25 \text{ N/mm}^2$

$\therefore$ % loss of stress in steel $= \dfrac{183.34}{1591.5} \times 100 = 11.52\%$

Q.6 (a) Solution:

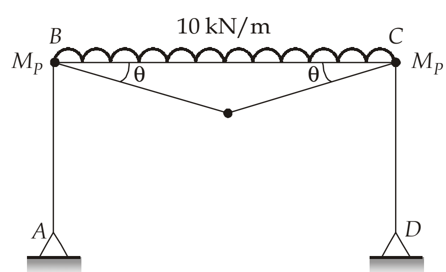
Possible location of plastic hinges (N) = 3

Static indeterminacy (D_S) = 2 + 2 – 3 = 1

$\therefore$ Number of hinges required for collapse (N) = D_S + 1 = 1 + 1 = 2

So number of independent mechanisms = $N - D_S$ = 3 – 1 = 2

(i) Beam mechanism



$$M_p\theta + M_p(\theta + \theta) + M_p\theta = \frac{1}{2} \times 4\theta \times 8 \times 10$$

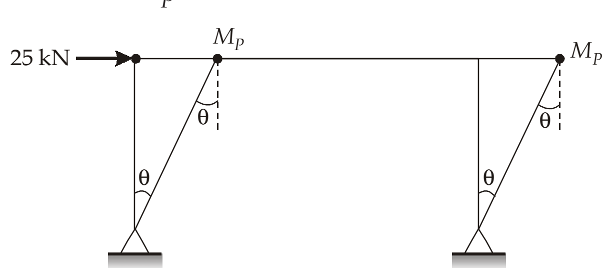
$\Rightarrow$ $4M_p\theta = 160\theta$

$\Rightarrow$ $M_p = 40$ kNm

(ii) Panel (or sway) mechanism

$M_p\theta + M_p\theta = 25 \times 4\theta$

$\Rightarrow$ $M_p = 50$ kNm



(iii) Combined mechanism

$$x\theta = (8 - x)\theta_1$$

$$\Rightarrow \qquad \theta_1 = \frac{x\theta}{(8-x)}$$

$$M_P(\theta + \theta_1) + M_P(\theta + \theta_1) = 25 \times 4\theta + \frac{1}{2} \times x\theta \times 8 \times 10$$

$$\Rightarrow \qquad 2M_P\left[\frac{8\theta - x\theta + x\theta}{8-x}\right] = 100\theta + 40\,x\theta$$

$$\Rightarrow \qquad M_P\left[\frac{16\theta}{8-x}\right] = 100\theta + 40\,x\theta \qquad \left(\because \theta_1 = \frac{x\theta}{8-x}\right)$$

$$\Rightarrow \qquad M_P = \frac{4\theta[25+10x]\times[8-x]}{16\theta}$$

For M_P to be minimum, $\dfrac{dM_P}{dx} = 0$

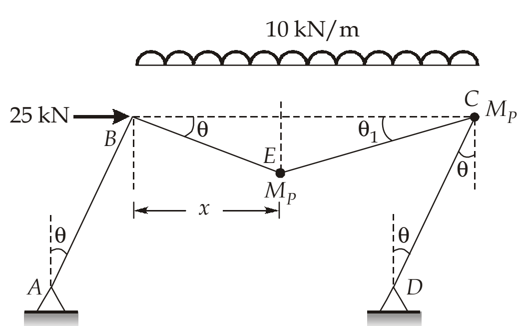
$$\Rightarrow \qquad x = 2.75 \text{ m}$$

So, $$M_P = \frac{[25+10\times 2.75][8-2.75]}{4}$$

$$= 68.91 \text{ kNm}$$

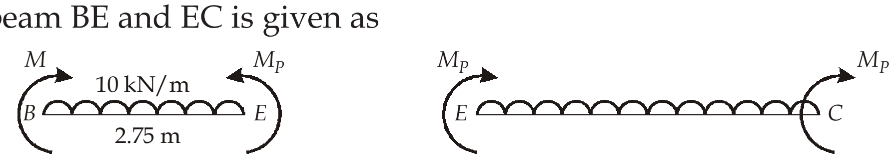
So the required plastic moment capacity will be maximum of [40 kNm, 50 kNm, 68.91 kNm]

$$= 68.91 \text{ kNm}$$



Now for collapse BMD

FBD of beam BE and EC is given as

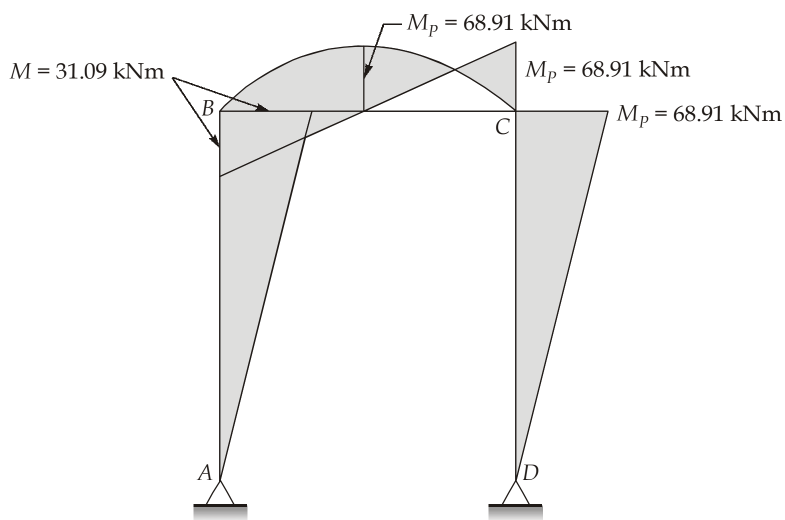


Now for BE portion to maintain equilibrium,

$$M_P - M - 10 \times 2.75 \times \frac{2.75}{2} = 0$$

$$M = 68.91 - 37.8125 \simeq 31.09 \text{ kNm}$$

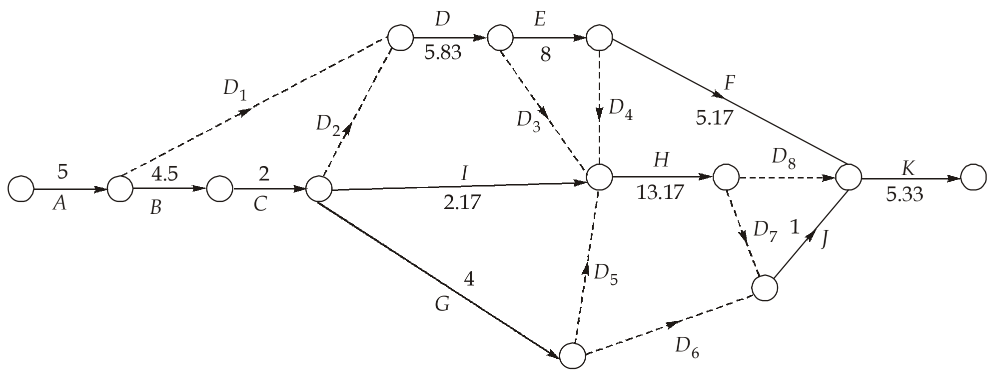
Collapse BMD



Q.6 (b) Solution:

Activity Name	$\left(t_e = \frac{t_0 + t_p + 4t_m}{6}\right)$ (in days)	$\sigma^2 = \left(\frac{t_p - t_0}{6}\right)^2$
A	5	0.11
B	4.5	0.694
C	2	0.11
D	5.83	0.694
E	8	0.11
F	5.17	0.25
G	4	0.11
H	13.17	0.25
I	2.17	0.25
J	1	0
K	5.33	1

Network diagram



Possible Paths

1. $A \rightarrow B \rightarrow C \rightarrow D_2 \rightarrow D \rightarrow E \rightarrow F \rightarrow K$ (35.83 days)

2. $A \rightarrow B \rightarrow C \rightarrow D_2 \rightarrow D \rightarrow E \rightarrow D_4 \rightarrow H \rightarrow D_7 \rightarrow J \rightarrow K$ (44.83 days)

3. $A \rightarrow B \rightarrow C \rightarrow G \rightarrow H \rightarrow J \rightarrow K$ (35 days)

4. $A \rightarrow B \rightarrow C \rightarrow I \rightarrow H \rightarrow D_7 \rightarrow J \rightarrow K$ (33.17 days)

Critical path $\rightarrow$ ($A \rightarrow B \rightarrow C \rightarrow D_2 \rightarrow D \rightarrow E \rightarrow D_4 \rightarrow H \rightarrow D_7 \rightarrow J \rightarrow K$) ($T_E$ = 44.83 days)

$$\sigma_{cp}^2 = 0.11 + 0.694 + 0.11 + 0.694 + 0.11 + 0 + 0.25 + 0 + 1$$

$$= 2.968$$

$$\therefore \quad \sigma_{cp} = 1.722$$

$$\therefore \quad Z = \frac{T - T_\varepsilon}{\sigma_{cp}}$$

$$\therefore \quad Z_{45} = \frac{45 - 44.83}{1.723} = 0.0987 \simeq 0.1$$

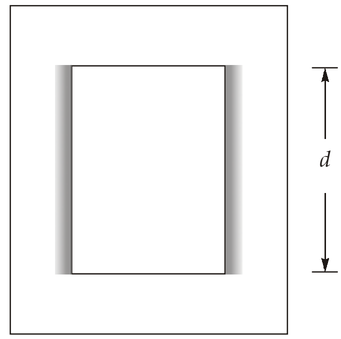
Probability of completion of project in 45 days = 0.0398 + 0.5 = 0.5398 i.e. 53.98%.

$$Z_{50} = \frac{50 - 44.83}{1.723} = 3$$

Probability of completion in 50 days = 0.4987 + 0.5 = 0.9987 i.e. 99.87%

Q.6 (c) Solution:

(i)



Let thickness of weld throat $= t$ mm

Direct shear stress in weld, $P_s = \dfrac{W}{2\times t\times d} = \dfrac{150\times10^3}{2\times250\times t} = \dfrac{300}{t}$ MPa

Horizontal shear stress due to bending at extreme fibre,

$$P_b = \frac{We}{\left(\frac{td^2}{6}\right)\times 2} = \frac{150\times10^3\times150}{2t\times\frac{250^2}{6}} = \frac{1080}{t}$$

Now as per LSM,

Equivalent stress in fillet weld $= \sqrt{P_b^2+3P_s^2}$

So, $\sqrt{P_b^2+3P_s^2} \le \dfrac{f_u}{\sqrt{3}\times1.25}$

$$\Rightarrow \sqrt{\left(\frac{1080}{t}\right)^2+3\times\left(\frac{300}{t}\right)^2} \le \frac{410}{\sqrt{3}\times1.25}$$

$$\Rightarrow \frac{1198.499}{t} \le \frac{410}{\sqrt{3}\times1.25}$$

$$\Rightarrow t \ge 6.33 \text{ mm}$$

So size of weld $= \dfrac{t}{0.7} = 9.041$ mm

So provide weld of size 10 mm.

(ii)

Merits of welded joints:

- As no holes are required for welding, the structural members are more effective in taking up the load.

- The overall weight of structural steel required is reduced by the use of welded joints.
- Welded joints are often economical as less labour and material are required for a joint.
- The speed of fabrication is higher with the welding process.
- Any shape of joint can be made with ease.
- Complete rigid joints can provided with the welding process.

Demerits of welded joints:

- Skilled labour and electricity are required for welding.
- Internal stresses and warping are produced due to uneven heating and cooling.
- Welded joints are more brittle and therefore their fatigue strength is less than the members joined.
- Defects like internal air pockets, slag inclusion and incomplete penetration are difficult to detect.

Q.7 (a) Solution:

Reduced plastic moment of flange plate

$$M_{fr} = 0.25 b_f t_f^2 f_{yf}\left[1-\left\{\frac{N_f}{\left(b_f t_f f_{yf}/\gamma_{m0}\right)}\right\}^2\right]$$

$$= 0.25\times 650\times 25^2\times 250\left[1-\left\{\frac{\left(\frac{4500\times 10^6}{1525}\right)}{650\times 25\times\frac{250}{1.1}}\right\}^2\right]$$

$$= 0.25\times 650\times 25^2\times 250\,[1-0.638]$$

$$= 9.191\times 10^6 \text{ Nmm}$$

Inclination of tension field, $\phi = \tan^{-1}[d/c] = \tan^{-1}\left[\frac{1500}{1500}\right] = 45°$

Anchorage length of the tension field in compression and tension flange

$$S = \frac{2}{\sin\phi}\left[\frac{M_{fr}}{f_{yw} t_w}\right]^{0.3} \le c$$

$$= \frac{2}{\sin 45°}\left[\frac{9.18\times10^6}{250\times15}\right]^{0.5} \le c$$

$\Rightarrow$ $140 \text{ mm} < 1500 \text{ mm}$

Width of tension field, $w_{tf} = d\cos\phi + [c - s_c - s_t]\sin\phi$

$$= 1500\cos 45° + [1500 - 2\times140]\sin 45°$$

$$= 1923.33 \text{ mm}$$

Yield strength of tension field,

$$f_v = \left[f_{yw}^2 - 3\tau_b^2 + \phi^2\right]^{0.5} - \psi$$

$$\psi = 1.5\,\tau_b \sin 2\phi = 1.5 \times 130 \sin 90° = 195 \text{ N/mm}^2$$

$$f_v = \left[250^2 - 3\times130^2 + 195^2\right]^{0.5} - 195 = 28.21 \text{ N/mm}^2$$

So, shear resistance

$$V_{tf} = \left[A_v\tau_b + 0.9 w_{tf} t_w f_v \sin\phi\right]$$

$$= [1500\times15\times130 + 0.9\times1923.33\times15\times28.21\sin 45°]$$

$$= 3443.02 \text{ kN}$$

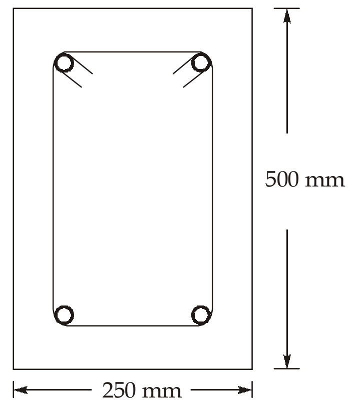
Check for V_P

$$V_P = \frac{1500\times15\times250}{\sqrt{3}} = 3247.59 \text{ kN} < V_{tf}$$

So the shear capacity will be 3247.59 kN.

[20 marks]

Q.7 (b) Solution:



$$\text{Effective depth, } d = 500 - 50 = 450 \text{ mm}$$

To calculate depth of neutral axis, we use,

$$C = T$$

$$\Rightarrow \quad 0.36 f_{ck} x_u B + (f_{sc} - 0.45 f_{ck}) A_{sc} = 0.87 f_y A_{st} \qquad \text{...(i)}$$

$$A_{sc} = A_{st} = 2 \times \frac{\pi}{4} \times 20^2 = 628.32 \text{ mm}^2$$

To get the value of f_{sc} iterations are required.

I^st trial

Let $x_u = 100$ mm

So, strain at the level of compression steel,

$$\in_1 = 0.0035\left(\frac{x_u - d'}{x_u}\right) = 0.0035\left[\frac{100-50}{100}\right] = 0.00175$$

So, stress corresponding to $\in_1$ strain

$$= 306.7 + \left(\frac{324.8 - 306.7}{0.00192 - 0.00163}\right) \times (0.00175 - 0.00163)$$

$$= 314.2 \text{ N/mm}^2$$

So, from equation (i),

$$0.36 \times 20 \times x_u \times 250 + (314.2 - 0.45 \times 20)\, 628.32 = 0.87 \times 415 \times 628.32$$

$x_u = 19.28$ mm So assumption is wrong

II^nd trial

Let $x_u = 67.5$ mm

Let strain at the level of compression steel = $\in_2$

$$\therefore \quad \in_2 = \frac{0.0035[67.5-50]}{67.5} = 0.00091$$

Since strain is very less so assuming linear variation.

$$\text{So stress in compression steel} = \frac{0.00091}{0.00144} \times 288.7 = 181.9 \text{ N/mm}^2$$

So again calculate x_u

$0.36 \times 20 \times x_u \times 250 + (181.9 - 0.45 \times 20)\ 628.32 = 0.87 \times 415 \times 628.32$

$$x_u = 65.67 \simeq 67.5 \text{ mm} \qquad \text{So OK}$$

Now,

$$MOR = 0.36 \times f_{ck} x_u B[d - 0.42 x_u] + (f_{sc} - 0.45 f_{ck})(d - d_c) A_{sc}$$

$$= 0.36 \times 20 \times 67.5 \times 250[450 - 0.42 \times 67.5] + (181.9 - 0.45 \times 20) \times 628.32 \times [450 - 50]$$

$$MOR = 94.67 \text{ kNm}$$

Q.7 (c) Solution:

(i)

Total quantity of earthwork to be handled = 20000000 m^3

Total number of working hours allowed = 1000 × 2 × 8 = 16000 hours

Hence progress of excavator required per hour

$$= \frac{20000000}{16000} = 1250 \text{ m}^3/\text{hr}$$

Given actual period of operation in one hour = 50 min.

$\therefore$ Production per hour of one 2.5 cum power shovel = $\frac{50}{60} \times 300 \text{ m}^3 = 250 \text{ m}^3$

Hence number of such shovels required = $\frac{1250}{250} = 5$

(ii)

Heaped capacity of one rear dump truck = 11.5 m^3 (loose volume) (Given)

$\therefore$ Effective capacity of one truck = 11.5 × 0.75 = 8.625 m^3 (b.m.)

$$\text{Loading time of one unit} = \frac{60 \times 8.625}{248} = 2 \text{ min}$$

$$\text{Hauling time} = \frac{5 \times 60}{20} = 15 \text{ min}$$

$$\text{Returning time} = \frac{5 \times 60}{30} = 10 \text{ min}$$

Given dumping, turning and stopping time = 3 min

$\therefore$ Cycle time = 2 + 15 + 10 + 3 = 30 min

$\therefore$ Actual number of trips per hour = $\frac{50}{30}$ (given actual period per hour = 50 mts)

Progress of one unit of truck per hour = $\frac{50}{30} \times 8.625 = 14.375 \text{ m}^3$

$\therefore$ No. of hauling units required = $\frac{1250}{14.375} = 86.957 \simeq 87$

Q.8 (a) Solution:

Percentage of steel, p = 1%

$$\therefore \quad \frac{p}{f_{ck}} = \frac{1}{20} = 0.05$$

$$\frac{P_u}{f_{ck}BD} = \frac{1200 \times 10^3}{20 \times 400 \times 400} = 0.375$$

From the interaction curve corresponding to $\frac{p}{f_{ck}} = 0.05$ and $\frac{P_u}{f_{ck}BD} = 0.375$ value of

$$\frac{M_u}{f_{ck}BD^2} = 0.08$$

$$\therefore \quad M_{ux_1} = 0.08 \times f_{ck} BD^2$$
$$= 0.08 \times 20 \times 400 \times 400^2 \text{ Nmm}$$
$$= 102.4 \text{ kNm}$$

Since $B = D$ $\quad \therefore M_{ux1} = M_{uy1} = 102.4$ kNm

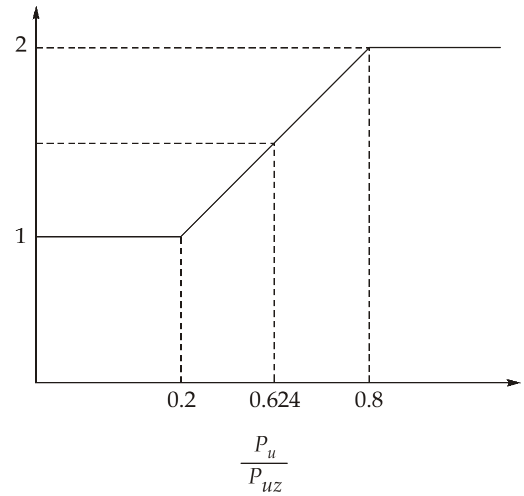
Now, $\quad P_{uz} = 0.45 f_{ck} A_c + 0.75 f_y A_{sc}$

$$A_{sc} = 1\% \text{ of } (400 \times 400) \text{ mm}^2$$
$$= 1600 \text{ mm}^2$$

$$\therefore \quad A_c = 400^2 - 1600 = 158400 \text{ mm}^2$$

So, $\quad P_{uz} = 0.45 \times 20 \times 158400 + 0.75 \times 415 \times 1600\text{N} = 1923.6$ kN

$\therefore \quad \frac{P_u}{P_{uz}} = \frac{1200}{1923.6} = 0.624$ which lies between 0.2 and 0.8



$$\alpha_n = 1+\left(\frac{2-1}{0.8-0.2}\right)\times(0.624-0.2) = 1.71$$

So, check according to interaction curve as,

$$\left[\frac{M_{ux}}{M_{ux_1}}\right]^{\alpha_n} + \left[\frac{M_{uy}}{M_{uy_1}}\right]^{\alpha_n} < 1$$

$$\left[\frac{85}{102.4}\right]^{1.71} + \left[\frac{45}{102.4}\right]^{1.71} < 1$$

$$\Rightarrow \quad 0.972 < 1$$

So the percentage of steel provided is satisfactory.

So, $A_{sc} = 1600 \text{ mm}^2$

Q.8 (b) Solution:

(i)

Scraper

- Scraper is a machine which can scrap the ground and load it simultaneously, transport it over the required distance, dump at the desired place and then spread the dumped material over the required area in required level and return to the pit for the next cycle.
- So, the scraper is self-sufficient and self operating construction equipment designed to dig, load, dump and spread.
- But it is not suited for (i) hard rock (ii) certain sands which will not pile up into a scraper and (iii) wet or muddy material which make discharging of a scraper difficult.

Basic Parts of a Scraper

A scraper as shown in figure consists of the following basic parts:

1. **Bowl:** It is a pan to hold scraped material and is capable of tilting down for digging or ejecting. The size of the bowl describes the size of scraper.
2. **Cutting Edge :** The bowl has a cutting edge attached at the bottom to make shallow cut.
3. **Apron :** This is a wall in front of the bowl which opens and closes to regulate the flow of earth.
4. **Tail gate or Ejector :** It is the rear of the pan which is capable of forward and backward movement inside the bowl.

   All these parts are controlled by the hydraulic system.

Types of Scrapers

Depending on the type of the tractor used, scrapers are classified as

(a) **Crawler tractor scraper** : It is used for short and difficult haul.

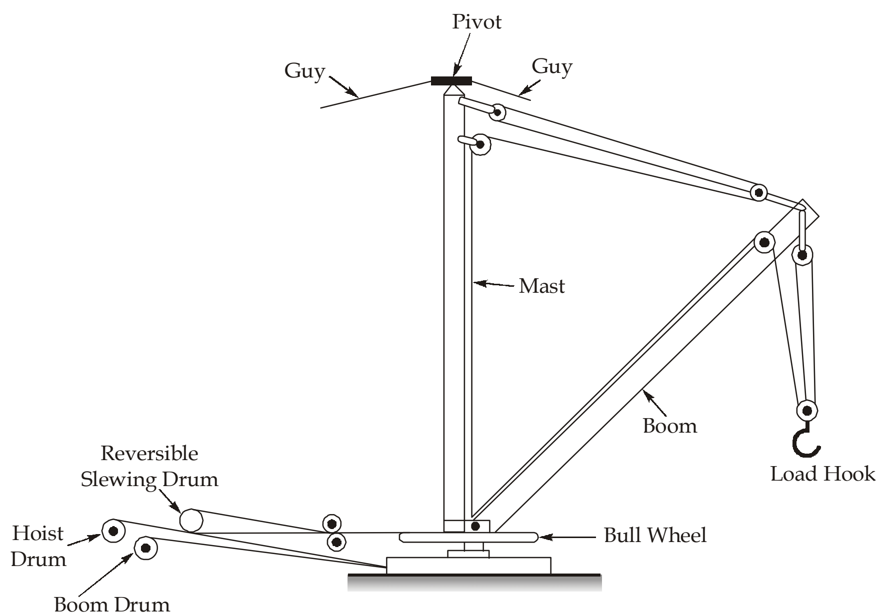
(b) **Wheel tractor scraper** : It is used for long and easy haul.

(c) **Motor scraper** : It has its own engine and motoring arrangement.

(ii)

Derrick cranes are also known as stationary cranes. Derrick cranes consist of a mast, a boom and a bull wheel on which the boom rotates about a vertical axis and guys or supporting members. These cranes are either electrically operated, diesel operated or diesel-electrically operated. A typical arrangement of a derrick crane is shown in figure:

The power driven cranes are mainly of two types i.e. (a) Guy derrick (b) stiff-leg derrick. The guy-derrick has a small mast supported by a number of guys and a boom pivoted at the lower end of the mast. The boom can revolve through 360°. This crane is used for heavy loads upto 200 tonnes. When the loads become less than 50 tonnes, guy ropes are replaced by trussed structure which becomes stiff-leg derrick. It consists of a mast, which can rotate and a boom. A stiff leg derrick is used for loads from 7 to 50 tonnes.



Q.8 (c) Solution:

$$\text{Total factored load} = 1.5 \times 40 = 60 \text{ kN}$$

$$\text{Maximum bending moment} = \frac{WL}{8} = \frac{60 \times 4}{8} = 30 \text{ kNm}$$

$$\text{Maximum shear force} = \frac{W}{2} = \frac{60}{2} = 30 \text{ kN}$$

Plastic section modulus required,

$$Z_{P,\text{required}} = \frac{M \times \gamma_{m0}}{f_y} = \frac{30 \times 10^6 \times 1.1}{250} = 132 \times 10^3 \text{mm}^3$$

Use ISMB 175 @ 191 N/m

$$Z_p = 166.1 \times 10^3 \text{ mm}^3 > 132 \times 10^3 \text{ mm}^3 \qquad \text{(OK)}$$

Section classification

$$\frac{b}{t_f} = \frac{b_f/2}{t_f} = \frac{90/2}{8.6} = 5.23 < 9.4 \in$$

where

$$\in = \sqrt{\frac{250}{f_y}} = \sqrt{\frac{250}{250}} = 1$$

$$\frac{d}{t_w} = \frac{h - 2(t_f + R_1)}{t_w} = \frac{175 - 2(8.6 + 10)}{5.5} = 25.05 < 84 \in$$

So section is plastic.

Check for shear capacity:

Design shear strength of section,

$$V_d = \frac{f_y}{\sqrt{3} \times 1.1} \times h \times t_w = \frac{250}{\sqrt{3} \times 1.1} \times 175 \times 5.5 \times 10^{-3}$$

$$= 126.29 \text{ kN} > 30 \text{ kN (safe)}$$

$$0.6V_d = 0.6 \times 126.29 = 75.77 \text{ kN} > 30 \text{ kN}$$

Hence low shear case.

Check for web buckling

$$\frac{d}{t_w} = \frac{175 - 2(8.6 + 10)}{5.5} = 25.05 < 67\epsilon \qquad \text{(safe)}$$

Check for design bending strength

∴ Section is plastic and thus $\beta_b = 1$

$$M_d = \frac{\beta_b f_y Z_p}{\gamma_{m0}} = \frac{1 \times 166.1 \times 10^3 \times 250}{1.1 \times 10^6} \text{ kNm}$$

$$= 37.75 \text{ kNm} > 30 \text{ kNm} \qquad \text{(Safe)}$$

Check for deflection

$$\delta = \frac{5wL^4}{384EI} = \frac{5 \times 40 \times 10^3 \times (4000)^3}{384 \times 2 \times 10^5 \times 1272 \times 10^4} = 13.1 \text{ mm}$$

$$\delta_{max} = \frac{L}{300} = \frac{4000}{300} = 13.33 \text{ mm} > 13.1 \text{ mm} \qquad \text{(Safe)}$$

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