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Detailed Solutions

SSC-JE 2018 Mains Test Series (PAPER-II)

Civil Engineering Test No : 3

Q.1 (a) Solution:

Primary pollutants: Primary pollutants are chemicals or pollutants emitted directly from the source. Example: SO_2, nitrogen oxides (NO_x), carbon dioxide (CO_2), volatile organic compounds (VOCs) and other hazardous air pollutants (HAPs). Particulate matter emitted from combustion process such as automobile exhaust , industrial process or heating and cooking is also considered as primary pollutant.

Secondary pollutants : Pollutants that form from chemical or photochemical reactions in the atmosphere are called secondary pollutants. Secondary pollutants are produced most efficiently on bright, sunny days in the summer, when VOCs and NO_x react photochemically in a complex series of reactions in the presence of sunlight. Ozone is a important secondary pollutant because of its potential adverse effects on vegetation, human health and property damage. Other secondary pollutants are PAN, HNO_3, formaldehyde etc.

Q.1 (b) Solution:

Let V_0, e_0 be the specific volume and void ratio of the compacted soil in the dam and V_i, e_i be the specific volume and void ratio of the soil from the borrow pits where i = 1, 2, 3.

Now, $$\frac{V_i}{V_0} = \frac{1+e_i}{1+e_0}$$

and $$V_i = V_0\left(\frac{1+e_i}{1+0.8}\right) = \frac{1\times10^6}{1.8}(1+e_i)$$

Substituting the void ratio from the table into the last equation and multiplying by the swell factor, we obtain;

$$V_1 = 1555555 \times 1.10 = 1711111 \text{ m}^3$$
$$V_2 = 1055555 \times 1.20 = 1266666 \text{ m}^3$$
$$V_3 = 1388888 \times 1.1 = 1527777 \text{ m}^3$$

Now, the transportation costs are as follows:

$$V_1 = 1711111 \times 0.6 = \text{Rs. } 1026667$$
$$V_2 = 1266666 \times 1.0 = \text{Rs. } 1266666$$
$$V_3 = 1527777 \times 0.75 = \text{Rs. } 1145832$$

Borrow pit 1 is therefore the most economical.

Q.1 (c) Solution:

Causes of failure of weirs and preventive measures :

The combined effect of surface flow and subsurface flow may cause the failure of weir.

Failure due to subsurface flow:

- **By piping or undermining :** The water from the upstream side continuously percolates through the bottom of foundation and emerges at the downstream end of the weir or barrage floor. The force of percolating water removes the soil particles by scouring at the point of emergence. As the process of removal of soil particles goes on continuously, a depression is formed which extends backwards towards the upstream through the bottom of the foundation. A hollow pipe like formation thus develops under the foundation which may cause failure by subsiding. This phenomenon is known as piping or undermining.
- **By uplift pressure :** The percolating water exerts an upward pressure on the foundation of the weir or barrage. If this uplift is not counter balanced by the self weight of the structure, it may fail the structure by rupture.

Failure due to surface flow:

- **Hydraulic jump :** When the water flows with a very high velocity over the crest of the weir or over the gates of the barrage, then hydraulic jump develops. This hydraulic jump causes a suction pressure or negative pressure on the downstream which acts in the direction of uplift pressure. If thickness of the impervious floor is not sufficient, then the structure fails by rupture.
- **By scouring during floods :** During floods, the gates of the barrage are kept open and the water flows with high velocity. The water may also flow with very high velocity over the crest of the weir. Both the case can result in scouring effect on the downstream and on the upstream side of the structure. Due to

scouring effect on the downstream and on the upstream side of the structure, its stability gets endangered by shearing of foundation material.

Preventive measures :

- **Remedial measure for piping :**
- Decrease hydraulic gradient i.e. increase the path of percolation by providing sufficient length of impervious floor.
- Providing curtains or piles at both upstream and downstream.
- **Remedial measures for uplift:**
- Providing impervious floor of sufficient length of appropriate thickness.
- Providing pile at upstream to reduce uplift pressure downstream.
- **Remedial measures on the upstream and downstream of the weir :**
- Piles at greater depth than scour level.
- Launching aprons.

Q.1 (d) Solution:

Given,

2-lane flexible pavement having 7.0 m wide carriageway

Commercial traffic per day, P = 600 (As on 01.01.2012) (on last count)

Planning and construction period, x = 1 year

Rate of traffic growth = 10% per annum

Design life = 15 years, Vehicle damage factor = 2.0

We know,

As per revised IRC method, design traffic in million standard axles,

$$N = \frac{365 \times \left[(1+r)^n - 1\right]}{r} \times A \times D \times F$$

Where, A =Initial traffic after construction (in CVPD)

D = Lane distribution factor = 0.75 (For two lane-two way traffic direction)

Also, $A = P(1 + r)^x$ where P = 600 and x = No. of years between last count and the year of completion of construction.

$$\therefore \quad A = 600(1 + 0.1)^1 = 660 \text{ CVPD}$$

$$\therefore \quad N = \frac{365 \times 660 \times \left[(1+0.10)^{15} - 1\right]}{0.10} \times 2 \times 0.75 \times 10^{-6} \text{ msa}$$

$= 11.481$ msa

Hence, pavement is designed for 11.481 msa.

Now, the project is delayed by 4 years.

Hence, $x_{new} = 1 + 4 = 5$ years

$\therefore$ $A_{new} = P(1 + 0.1)^{x_{new}}$

$= 600 \times (1.1)^5 = 966.306$ CVPD

But since the pavement design remains the same, design traffic in msa will remain the same.

$$\therefore \quad N = 11.481 \times 10^6 = \frac{365\left[(1+r)^{n_{new}} - 1\right]}{r} \times A_{new} \times D \times F$$

where, n_{new} = New design life of the road.

$$\text{Hence,} \quad 11.481 \times 10^6 = \frac{365\left[1.1^{n_{new}} - 1\right] \times 966.306 \times 0.75 \times 2}{0.10}$$

$\Rightarrow$ $(1.1)^{n_{new}} - 1 = 2.170$

$\Rightarrow$ $(1.1)^{n_{new}} = 3.170$

Taking logarithm of both sides, we get

$n_{new} \log_{10}(1.1) = \log_{10}(3.170)$

$\therefore$ $n_{new} = 12.1 \simeq 12$ years

Hence, there are severe implications in the design life of the road project as new design life has reduced by 3 years.

New design life of road = 12 years

Q.2 (a) Solution:

Except that one of the intermediate sights was taken with an inverted staff, the other sights were taken as usual and since we need only the RLs of the change points, the height of collimation system can be used.

BS (m)	IS (m)	FS (m)	Height of collimation (m)	RL (m)	Remarks
2.650			126.100	123.450	A (starting BM)
	3.740				
	–2.830			128.930	B (Inverted staff reading)
4.640		4.270	126.47	121.830	C (Change point)
	0.380				
1.640		0.960	127.15	125.510	D (Change point)
	2.840			124.31	
4.680		3.480	128.35	123.670	E (Change point)
		4.260		124.090	F (Bench mark)
ΣBS = 13.610		ΣFS = 12.970		Rise = 0.640	

Arithmetical checks

$$\Sigma BS - \Sigma FS = 13.610 - 12.970$$

$$= 0.640 = \text{Last RL} - \text{First RL} = 0.640 \qquad \text{(OK)}$$

Q.2 (b) Solution:

From the measured length of 810 m, the following results can be calculated

1. Correction for temperature:

$$c_t = L\alpha t = 810 \times 11.7 \times 10^{-6} (30 - 20) \text{ m}$$

$$= 0.094770 \text{ m (+ve)}$$

2. Correction for pull:

$$c_p = \frac{PL}{AE} = \frac{(120-75)\times 810}{4\times 2.1\times 10^5} = 0.043393 \text{ m (+ve)}$$

3. Correction for sag:

$$c_s = \frac{L}{24}\left(\frac{W}{P}\right)^2 = \frac{810}{24}\left(\frac{30\times 1000\times 4\times 7.8\times 10^{-5}}{120}\right)^2$$

$$= 0.205335 \text{ m (-ve)}$$

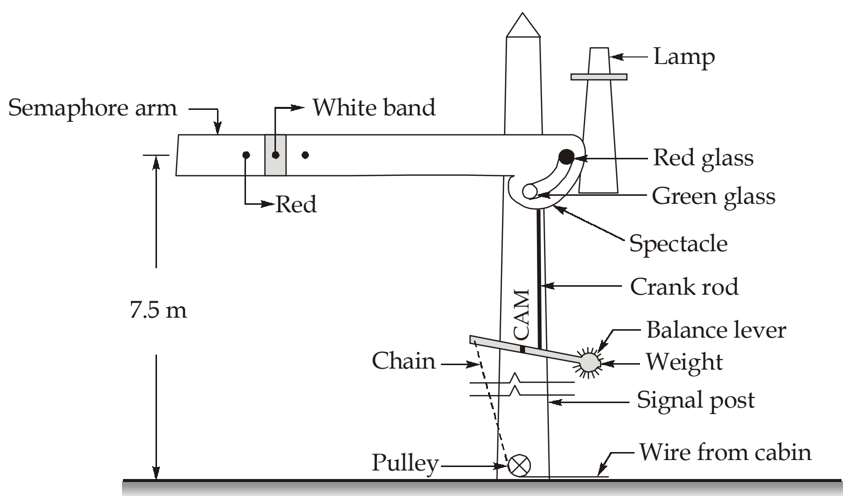
Hence, the corrected length of survey line is

(810 + 0.094770 + 0.043393 – 0.205335) m $\simeq$ 809.933 m.

Q.2 (c) Solution:

Objectives of signalling system:

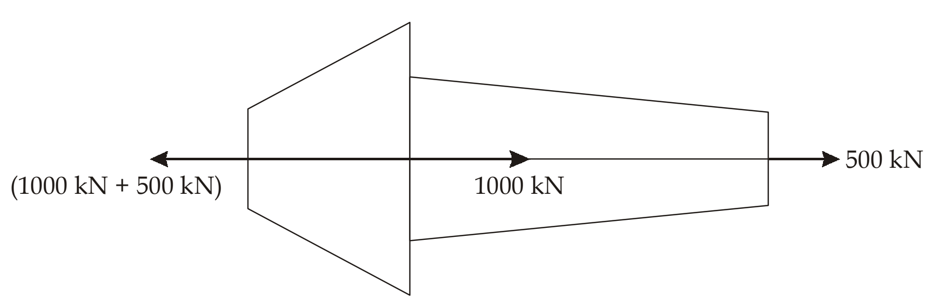
- To provide facilities for the efficient and safe movement of trains.
- To ensure safety between two or more trains which cross or approach each other's path.
- To provide facilities for maximum utility of the track.
- To provide facilities for safe and efficient shunting operations.
- To guide the trains movement during maintenance and repairs of the track.
- To safeguard the trains at converging junctions and to give directional indications at diverging junctions.



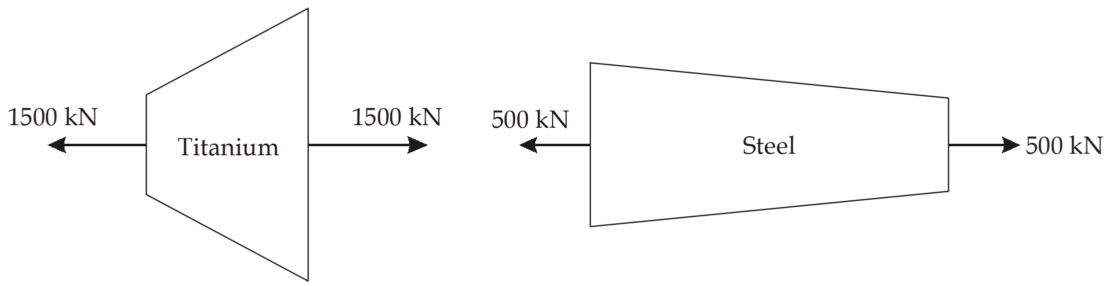
Semaphore signal

Q.2 (d) Solution:

The free body diagram of the system appears as shown below:



and free body diagram of each bar is shown below



We know, for a solid truncated conical bar of circular cross-section tapers uniformly from diameter d at its small end to D at large end, and length of L, the elongation due to an axial force P applied at each end is given by,

$$\Delta = \frac{4PL}{\pi DdE}$$

Now,

$$\Delta_{\text{titanium}} = \frac{4 \times 1500 \times 1000 \times 0.45}{\pi \times 0.10 \times 0.05 \times 110 \times 10^9} = 0.00156 \text{ m} = 1.56 \text{ mm}$$

$$\Delta_{\text{steel}} = \frac{4 \times 500 \times 1000 \times 0.90}{\pi \times 0.07 \times 0.05 \times 200 \times 10^9} = 0.00082 \text{ m} = 0.82 \text{ mm}$$

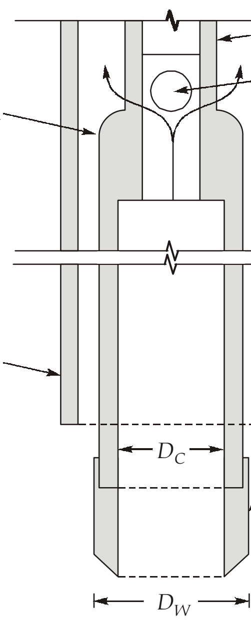
Using superposition,

$$\Delta_{\text{total}} = \Delta_{\text{steel}} + \Delta_{\text{titanium}} = 1.56 + 0.82$$
$$= 2.38 \text{ mm}$$

Q.3 (a) Solution:

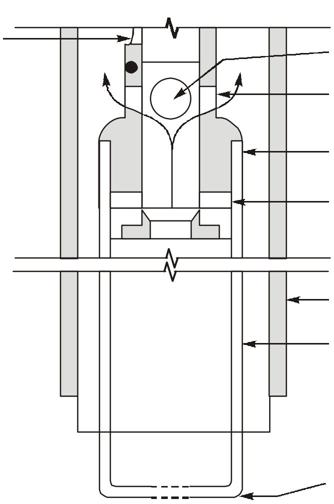
Types of samplers:

Open-Drive Sampler : It consists of a steel tube with a screw thread at each end. The lower end is generally fitted with a cutting shoe but sometimes with an extension piece. The upper end is fitted with a sampler head which incorporates a non-return valve.



The non-return valve allows air and water to escape while the sample enters the sampler and closes as the sampler is raised to the surface, thus retaining the sample within the tube. This is the simplest and most common type of sampler.

Thin-Walled Sampler : To obtain undisturbed samples in soft to firm clays and plastic silts, thin-walled samplers may be used **(IS:11594-1985)**. No separate cutting shoe is attached to the lower end, but the sampler's lower end is itself machined to serve as a cutting edge.



Good-quality undisturbed samples are possible if area ratio < 10% and the soil is not disturbed during the boring operation. This sampler can be used more conveniently in trial pits and shallow boreholes.

Split-Spoon Sampler : It consists of a longitudinally split tube or barrel fitted with a shoe and a sampler head with provision for air release **(IS:9640-1980)**. The splitting aspect of the sampler permits it to be opened for a sample examination and for onward transmission in sample containers to laboratories.

Samples obtained using this sampler are rated as representative. This sampler is suited for sands and is used only in the standard penetration test (SPT). Split-spoon samplers may be provided with a liner, which is a thin metal or plastic tube fitted within the split spoon, in which case it is called as composite sampler. The purpose of the liner is to protect the sampler during handling, shipping and storage.

Piston Sampler : For very soft alluvial silts and clays, piston samplers are quite useful. These consist of a thin-walled tube which includes a piston device that serves to push the thin-walled tube into the undisturbed soil from the bottom of the boring **(IS:10108-1982)**. The piston is locked in the lower position and the sampler is lowered to the bottom of the borehole. The piston is provided with a seal which prevents the entry of water and debris. When it is unlocked, the tube is driven down into the soil to the full length of travel of the piston. The whole assembly is withdrawn to the surface after locking the piston at the top of the tube. The sampler is separated from the sample head and the piston. It is then sealed at both ends.

Q.3 (b) Solution:

Anchorage length of bar at simply supported end of beam can be determined by,

Development length, $$L_d \leq \frac{1.30M_u}{V_u} + l_0$$

Anchorage length, $$l_0 \geq L_d - \frac{1.3M_u}{V_u}$$

where, $$L_d = \frac{0.87 \times f_y \times \phi}{4 \times \tau_{bd}} = \frac{0.87 \times 415 \times 20}{4 \times 1.92} = 940 \text{ mm}$$

$$M_u = f_s A_{st}(d - 0.416x_u)$$

where $$x_u = \frac{f_{st} A_{st}}{0.36 f_{ck} b}$$

$f_{st} = 0.87 f_y$, if the section is balanced/under-reinforced.

$< 0.87 f_y$, if the section is over-reinforced.

Assume $x_u \leq x_{u,lim}$ (balanced/under-reinforced section)

$\therefore$ $$x_u = \frac{0.87 f_s A_{st}}{0.36 f_{ck} b}$$

where $A_{st} = 3 \times 20\phi = 942\ \text{mm}^2$

$$\therefore \quad x_u = \frac{0.87 \times 415 \times 942}{0.36 \times 20 \times 300} = 157.458\ \text{mm}$$

and $x_{u,lim} = 0.48d = 0.48 \times 500 = 240$ mm

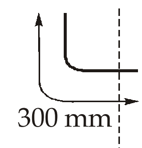
$\because$ $x_u < x_{u,lim}$, therefore section is under-reinforced and computed value of x_u is correct.

$$\therefore \quad M_u = 0.87 \times 415 \times 942\ (500 - 0.416 \times 157.458)\ \text{Nmm}$$

$$= 147.78\ \text{kNm}$$

Hence,
$$l_0 \geq 940 - \frac{1.3 \times 147.78 \times 10^6}{300 \times 10^3} \geq 299.62\ \text{mm}$$

$\therefore$ Therefore, anchorage length of 300 mm is provided.



Q.3 (c) Solution:

The velocity gradient = $\left(\frac{du}{dy}\right)$ can be found out by differentiating given relationship of velocity distribution. Shear stress can be found out by using shear stress and velocity gradient relationship.

Given
$$u = \frac{u_{\max}}{3}\left[\frac{2y}{h} - \frac{y^3}{h^3}\right]$$

$$\Rightarrow \quad \frac{du}{dy} = \frac{u_{\max}}{3}\left[\frac{2}{h} - \frac{3y^2}{h^3}\right]$$

(i) At solid surface, $y = 0$,

$$\left(\frac{du}{dy}\right)_{y=0} = \frac{u_{\max}}{3} \times \frac{2}{h}$$

$$\Rightarrow \quad \left(\frac{du}{dy}\right)_{y=0} = \frac{u_{\max}}{3} \times \frac{2}{0.01} = \frac{0.3}{3} \times \frac{2}{0.01} = 20\text{s}^{-1}$$

$$\tau_0 = \mu\left(\frac{du}{dy}\right)^{1.5} = 0.5 \times (20)^{1.5} = 44.72\ \text{N/m}^2$$

(ii) For Newtonian fluid,

$$\tau_0 = \mu\left(\frac{du}{dy}\right)$$

$$44.72 = \mu \times 20$$

$$\Rightarrow \quad \mu = \left(\frac{44.72}{20}\right) = 2.236 \text{ N s/ m}^2$$

Newtonian fluid of viscosity, 2.236 Ns/m^2 can induce same shear stress.

Q.3 (d) Solution:

The assumptions made while analyzing the reinforced concrete beam using Limit State Method as per **IS 456:2000 Code** are as follows:

1. Plane sections normal to the beam axis remain plane after bending, i.e., in an initially straight beam, strain varies linearly over the depth of the section. Thus, strain diagram is linear.
2. The maximum compressive strain in concrete at the outermost fiber (ε_{cu}) is taken as 0.0035, regardless of whether the beam is under-reinforced or over-reinforced, because collapse invariably occurs by the crushing of concrete.
3. IS 456: 2000 allows the use of any other possible shape of the stress-strain curve of concrete which results in substantial agreement with the results of the tests on reinforced concrete.
4. For design purposes, compressive strength of concrete may be assumed as **0.67** times the characteristic strength of concrete. The partial safety factor of γ_c = 1.5 shall be applied in addition to this.
5. The tensile strength of concrete is ignored i.e. not taken into account. **Cl. B-1.3(b) of IS 456: 2000** states that all tensile stresses are to be taken up by reinforcement and none by concrete, except as otherwise specifically permitted.
6. The stress in reinforcement is derived from representative stress-strain curve for the type of steel used.
7. For design purpose, the partial safety factor for steel is taken as γ_s = 1.15 i.e. design

   stress of steel $= \dfrac{f_y}{1.15} = 0.87 f_y$
8. The maximum strain (ε_{st}) in the tension reinforcement at the level of centroid of reinforcement steel at the ultimate limit state shall not be less than ε^*_{st} which is defined as:

$$\varepsilon^*_{st} = \frac{0.87\, f_y}{E_s} + 0.002$$

Q.4 (a) Solution:

Decay due to fungal and Bacterial attack :

Wood is essentially organic substance made up of skeleton of cellulose impregnated with lignin. Fungi are system of plant organisms which live in and attack timber causing rot and decay. Fungi reproduce through spores which send out mycelia which in turn destroy the wood tissues by secretions of solvents and enzymes. Basic requirements for the existence of fungi are moisture, suitable temperature and food supplies.

Control of fungal and bacterial attack :

- Dryness of timber and it should not be subjected to alternate wet and dry conditions.
- Felled trees should be air dried as early as possible and sawn timber should be kiln seasoned properly in accordance with good air-seasoning practice.
- Adequate ventilation around the timber to prevent fungal attack.

Damages due to insects :

Termites : White ants are most destructive agencies. They completely excavate the wood at the centre leaving the outer shell intact. They also attack furniture and wood work in houses and railway sleepers etc.

Beetles : These are small insects and they cause rapid decay of timber by converting them into fine powder. Usually, the outer shell of timber remains intact and hence the timber looks sound until the timber fails completely.

Carpenter ants : They are usually black in colour and vary in size within the same nest. They do not eat wood but merely tunnel it out for habitation. They normally attack slightly rolled or water softened wood.

Control of insects :

- Large scale fumigation is carried out using powerful hydrocyanic acid gas.
- The best alternative is very common turpentine mixed with a small quantity of orthodichlorobenzene. This vapour is very deadly to insects.

Damage due to rodents : They are more serious in food handling establishments.

Control of Rodents :

The guiding principle is to close all openings or passages and making doors and windows capable of closure in a tight manner by fixing metal sheets over the lower part of doors.

Q.4 (b) Solution:

(i)

Consider a rectangular channel section carrying a discharge q per unit width,

$\left(\text{i.e. } q = \frac{Q}{B}\right)$

$$\therefore \quad E = y + \frac{V^2}{2g} = y + \frac{q^2}{2gy^2}$$

$$\Rightarrow \quad q^2 = (E - y)2gy^2 = 2g(Ey^2 - y^3) \qquad \text{...(i)}$$

Keeping E = constant, for maximum discharge condition, $\frac{dq}{dy} = 0.$

Differentiating equation (i), w.r.t y, we get

$$2q\frac{dq}{dy} = 2g(2Ey - 3y^2) = 0$$

$$\Rightarrow \quad 2Ey - 3y^2 = 0$$

$$\Rightarrow \quad y = y_c = \frac{2}{3}E \qquad \text{Hence proved}$$

Since $E = y_c + \frac{V_c^2}{2g}$, where critical velocity = V_c

$$\Rightarrow \quad V_c = \sqrt{2g(E - y_c)} = \sqrt{2g\left(\frac{3}{2}y_c - y_c\right)} = \sqrt{gy_c}$$

$$\therefore \quad F = \frac{V_c}{\sqrt{gy_c}} = 1$$

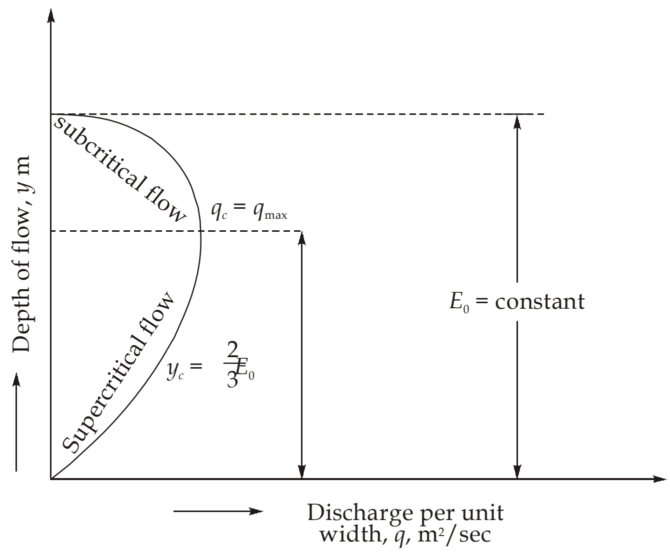
Thus, critical flow condition occurs when for a given specific energy discharge is maximum.

(ii)

$$\therefore \quad q_{\max} = V_c y_c = y_c\sqrt{gy_c} = \sqrt{gy_c^3} \qquad \left(\because y_c = \frac{2}{3}E_c\right)$$

$$= \sqrt{\frac{8}{27}gE^3}$$

(iii)



Variation of discharge of a rectangular channel for a given specific energy.

Q.4 (c) Solution:

- **Short column/slender column:**

Given; $l_x = l_y = 3000$ mm, $D_y = 450$ mm and $D_x = 600$ mm

Slenderness ratio, $$\begin{cases} \dfrac{l_{ex}}{D_x} = \dfrac{k_x l_x}{D_x} = k_x \times \dfrac{3000}{600} = 5k_x \\ \dfrac{l_{ey}}{D_y} = \dfrac{k_y l_y}{D_y} = k_y \times \dfrac{3000}{450} = 6.67k_y \end{cases}$$

As the column is braced against side sway in both directions, effective length ratios k_x and k_y are both less than unity and hence slenderness ratios are both less than 12.

Hence, the column may be designed as short column.

- **Minimum eccentricities:**

$$e_{x,\min} = \frac{l}{500} + \frac{D_x}{30} = \frac{3000}{500} + \frac{600}{30} = 26.0 \text{ mm } (> 20.0 \text{ mm})$$

$$e_{y,\min} = \frac{l}{500} + \frac{D_y}{30} = \frac{3000}{500} + \frac{450}{30} = 21.0 \text{ mm } (> 20.0 \text{ mm})$$

As $0.05D_x = 0.05 \times 600 = 30.0 \text{ mm} > e_{x,\min} = 26.0$ mm

and $0.05D_y = 0.05 \times 450 = 22.5 \text{ mm} > e_{y,\min} = 21.0$ mm

The IS:456 formula for axially loaded column can be used.

- **Factored load**

P_u = Service load × Partial load factor = 2000 × 1.5 = 3000 kN

- **Design of longitudinal reinforcement**

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

$$\Rightarrow \quad 3000 \times 10^3 = 0.4 \times 20 \times (450 \times 600) + (0.67 \times 415 - 0.4 \times 20) A_{sc}$$

$$= 2160 \times 10^3 + 270.05\, A_{sc}$$

$$\Rightarrow \quad A_{sc} = \frac{(3000 - 2160) \times 10^3}{270.05} \simeq 3111 \text{ mm}^2$$

In view of column dimensions (450 mm, 600 mm), it is necessary to place intermediate bars in addition to the four corner bars.

Provide 4-25ϕ bars at corners : $4 \times \frac{\pi}{4} \times 25^2 = 1964 \text{ mm}^2$

and 4-20ϕ at additional : $4 \times \frac{\pi}{4} \times 20^2 = 1256 \text{ mm}^2$

$$\therefore \quad A_{st} = 1964 + 1256 = 3220 \text{ mm}^2 > 3111 \text{ mm}^2$$

Percent reinforcement provided,

$$P = \frac{100 \times 3220}{(450 \times 600)}$$

$$= 1.193 > 0.8\% \text{ (minimum reinforcement) OK}$$

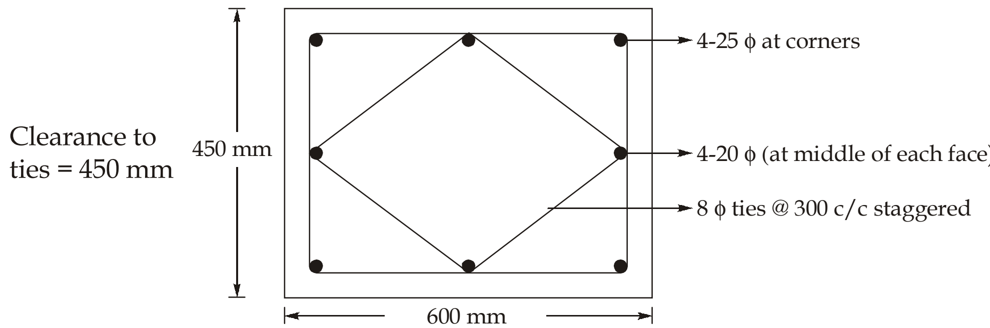
$$< 6\% \text{ (maximum reinforcement)}$$

- **Lateral ties**

Tie diameter, ϕ_t >

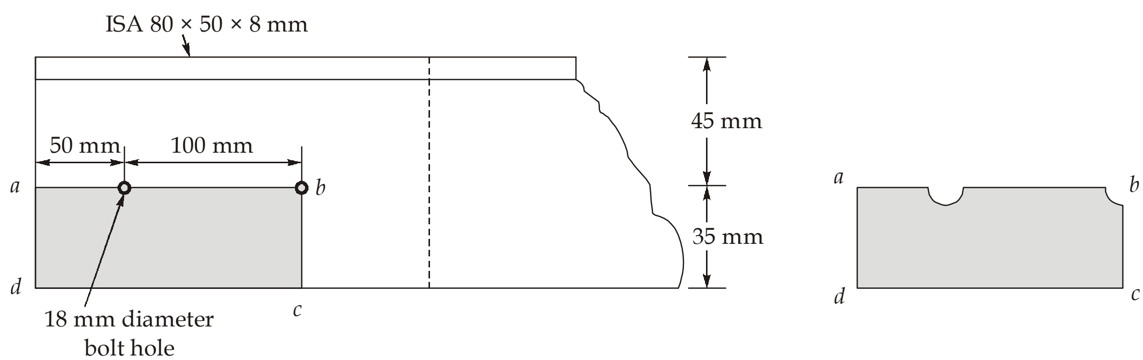
$$\begin{cases} \dfrac{\phi_{main,long}}{4} = \dfrac{25}{4} = 6.25 \text{ mm} \\ 6 \text{ mm} \end{cases} \quad \therefore \text{ Provide 8 mm diameter ties}$$

$$\text{Tie spacing, } S_t < \begin{cases} 450 \text{ mm} \\ 16 \times 20 = 320 \text{ mm} \\ 300 \text{ mm} \end{cases} \quad \therefore \text{ Provide ties spacing} = 300 \text{ mm}$$



The detailing of reinforcement is shown above.

Q.5 (a) Solution:



For Fe410 grade steel : f_u = 410 MPa, f_y = 250 MPa

Partial safety factors for materials : γ_{m0} = 1.10; γ_{m1} = 1.25

The shaded area will shear out

$$A_{vg} = (100 + 50) \times 8 = 1200 \text{ mm}^2$$

$$A_{vn} = \left(100 + 50 - \left(2 - \frac{1}{2}\right) \times 18\right) \times 8 = 984 \text{ mm}^2$$

$$A_{tg} = 35 \times 8 = 280 \text{ mm}^2$$

$$A_{tn} = \left(35 - \frac{1}{2} \times 18\right) \times 8 = 208 \text{ mm}^2$$

The block shear strength will be minimum of T_{db1} and T_{db2} as calculated below:

$$T_{db1} = \frac{A_{vg} f_y}{\sqrt{3}\gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$$

$$= \left[\frac{1200 \times 250}{\sqrt{3} \times 1.1} + \frac{0.9 \times 208 \times 410}{1.25}\right] \times 10^{-3}$$

$$= 218.86 \text{ kN}$$

$$T_{db2} = \frac{0.9A_{vn}f_u}{\sqrt{3}\gamma_{m1}} + \frac{A_{tg}f_y}{\gamma_{m0}}$$

$$= \left(\frac{0.9 \times 984 \times 410}{\sqrt{3} \times 1.25} + \frac{280 \times 250}{1.1}\right) \times 10^{-3}$$

$$= 231.34 \text{ kN}$$

Hence, the block shear strength of the tension member is 218.86 kN

Note: In the shaded area, *abcd* there are two bolts holes. In calculating the net area along surface *ab*. There will be $1\frac{1}{2}$ bolt holes and that along *bc* only $\frac{1}{2}$ bolt hole.

Q.5 (b) Solution:

(a) **Size of aggregate :** For big aggregate size, the total surface area to be wetted is less, also less paste is required for lubricating the surface to reduce internal friction. For a given water content big size aggregates give higher workability.

(b) **Cement content :** Cement content influences the workability to a large extent. The higher the cement content, less leaner will be the concrete.

(c) **Water cement ratio :** The fluidity of concrete increases with water cement ratio. At site, normal practice is to increase the water cement ratio to make the concrete workable which lowers its strength.

(d) **Entrained air :** Air entrained concrete is more workable. It is so because air forms bubbles on which the aggregates slide past each other increasing the workability. Another factor is that air entraining agents are surface active and they reduce the internal friction between the aggregates.

Q.5 (c) Solution:

The load of 8 kN will give rise to a clockwise couple of 8 × 0.5 = 4 kNm at *C*.

The point *C* will be displaced by an amount δ.

Slope deflection equation

There are two unknown θ_C and δ. We shall measure θ_C to be positive as δ for CA is assumed positive and that for CB, is assumed negative.

$$M_{AC} = \frac{2EI}{3}\left(\theta_C - \frac{3\delta}{3}\right) \quad \text{...(i)}$$

$$M_{CA} = \frac{2EI}{3}\left(2\theta_C - \frac{3\delta}{3}\right) \quad \text{...(ii)}$$

$$M_{CB} = \frac{2EI}{2}\left(2\theta_C + \frac{3\delta}{2}\right) \quad ...(iii)$$

$$M_{BC} = \frac{2EI}{2}\left(\theta_C + \frac{3\delta}{2}\right) \quad ...(iv)$$

Equilibrium equation

As there are two unknowns, two equations will be required for finding out the values of unknowns. One equation will be provided by the fact that the clockwise couple at *C*, causes clockwise moments in *CA* and *CB*.

$$\therefore \quad M_{CA} + M_{CB} = 4$$

$$\Rightarrow \quad \frac{2EI}{3}\left(2\theta_C - \frac{3\delta}{3}\right) + \frac{2EI}{2}\left(2\theta_C + \frac{3\delta}{2}\right) = 4$$

$$\Rightarrow \quad \frac{4}{3}EI\theta_C - \frac{2EI\delta}{3} + 2EI\theta_C + \frac{3}{2}EI\delta = 4$$

$$\Rightarrow \quad 20EI\theta_C + 5EI\delta = 24$$

$$\Rightarrow \quad 20\theta_C + 5\delta = \frac{24}{EI} \quad ...(v)$$

Shear equation

The couple acting at *C* also gives rise to horizontal reaction at *A* and *B*, the two being equal in magnitude but opposite in direction.

Now, horizontal reaction at $A = \dfrac{M_{AC} + M_{CA}}{3}$ and horizontal reaction at $B = \dfrac{M_{CB} + M_{BC}}{2}$.

As the two are equal so, $\dfrac{M_{AC} + M_{CA}}{3} = \dfrac{M_{CB} + M_{BC}}{2}$

$$\Rightarrow \quad \frac{\frac{2EI}{3}(\theta_C - \delta) + \frac{2EI}{3}(2\theta_C - \delta)}{3} = \frac{\frac{2EI}{2}\left(2\theta_C + \frac{3}{2}\delta\right) + \frac{2EI}{2}\left(\theta_C + \frac{3}{2}\delta\right)}{2}$$

$$\Rightarrow \quad \frac{4}{3}EI\theta_C - \frac{4}{3}EI\delta + \frac{8}{3}EI\theta_C - \frac{4}{3}EI\delta = 6EI\theta_C + \frac{9}{2}EI\delta + 3EI\theta_C + \frac{9}{2}EI\delta$$

$$\Rightarrow \quad 30\,EI\theta_C = -70\,EI\delta$$

$$\Rightarrow \quad \theta_C = -\frac{7}{3}\delta$$

Substituting θ_c in equation (v), we get

$$-\frac{140}{3}\delta + 5\delta = \frac{24}{EI}$$

$$\Rightarrow \qquad \frac{-125\delta}{3} = \frac{24}{EI}$$

$$\Rightarrow \qquad \delta = \frac{-0.576}{EI} \qquad \text{...(i)}$$

$$\therefore \qquad \theta_C = -\frac{7}{3}\delta = -\frac{7}{3}\times\frac{0.576}{EI} = \frac{1.344}{EI}$$

Final moments

The values of moments may now be found out by substituting the values of θ_C and δ in equations (i) to (iv).

Thus,

$$M_{AC} = \frac{2EI}{3}\left(\frac{1.344}{EI}+\frac{0.576}{EI}\right) = 1.28 \text{ kNm}$$

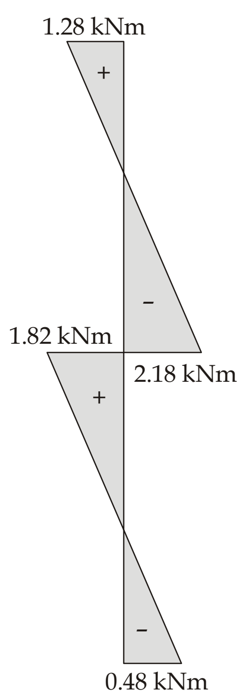
$$M_{CA} = \frac{2EI}{3}\left(\frac{2\times 1.344}{EI}+\frac{0.576}{EI}\right) = 2.18 \text{ kNm}$$

$$M_{CB} = \frac{2EI}{2}\left(\frac{2\times 1.344}{EI}-\frac{3\times 0.576}{2EI}\right) = 1.82 \text{ kNm}$$

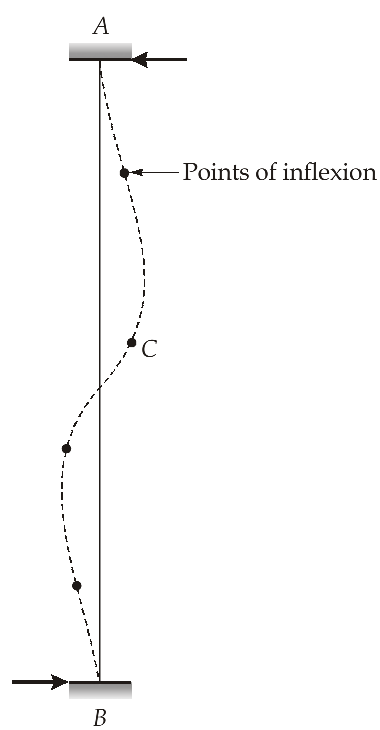
and

$$M_{BC} = \frac{2EI}{2}\left(\frac{1.344}{EI}-\frac{3}{2}\times\frac{0.576}{EI}\right) = 0.48 \text{ kNm}$$

The BM diagram and deflected shape has been shown below.



BMD



Deflected shape

Q.5 (d) Solution:

Given data : Consumptive use = 2.8 mm/day; Root zone depth, d = 80 mm; Irrigation efficiency = 65%

It is given that readily available moisture is 80% of root zone depth.

∴ Available soil moisture depth = 0.80 × 80 = 64 mm

We know,

$$\text{Frequency of irrigation} = \frac{\text{Depth of available soil moisture}}{\text{Moisture consumed per day i.e. consumptive use}}$$

$$= \frac{64}{2.8} = 22.85 \text{ days say } 22 \text{ days}$$

Hence, water should be applied to the field after 22 days time period.

$$\text{Depth of field irrigation requirement} = \frac{\text{Net irrigation requirement}}{\text{Irrigation efficiency}}$$

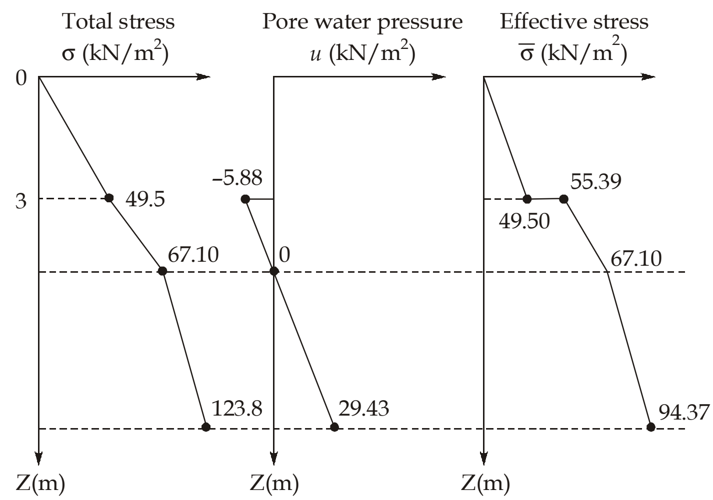
$$= \frac{64}{0.65} = 98.46 \text{ mm}$$

Q.6 (a) Solution:

The following table can be prepared:

Distance below the ground (m)	Depth below ground surface (m)	Total stress (σ) (kN/m^2)	Pore water pressure, u	Effective stress, $\bar{\sigma} = (\sigma - u)$ kN/m^2
0			0	0
3	Immediately above the capillary zone	3 × 16.5 = 49.50	0	49.50
	Just inside the capillary zone	3 × 16.5 = 49.50	$-S\gamma_w \times 1 = -0.6 \times 9.81 = -5.886$	55.38 ; 55.39
4		3 × 16.5 + 1 × 17.6 = 67.1	0	67.10
7		3 × 16.5 + 1 × 17.6 + 3 × 18.9 = 123.80	$3\gamma_w = 3 \times 9.81 = 29.43$	94.370

The plot of s, u and $\bar{\sigma}$ are as follows



Q.6 (b) Solution:

(i) Terzaghi's method,

For $\phi = 0°$, $N_c = 5.70$, $N_q = 1.0$ and $N_\gamma = 0$

$$q_u = C_u N_c\left(1+\frac{0.3B}{L}\right)+qN_q+0.5B\gamma N_\gamma\left(1-\frac{0.2B}{L}\right)$$

$$= 45.24\times 5.7\left(1+0.3\times\frac{3}{6}\right)+\gamma_{sub}D_f\times 1$$

$$= 45.24 \times 5.7 \times 1.15 + (18 - 9.81) \times 2 = 312.93 \text{ kN/m}^2$$

or, $$q_{nu} = q_u - \gamma' D_f = 312.93 - (18 - 9.81) \times 2 = 296.55 \text{ kN/m}^2$$

or, $$q_{na} = \frac{q_{nu}}{F_s} = \frac{296.55}{3} = 98.85 \text{ kN/m}^2$$

(ii) Skempton's method,

We know,

$$q_u = C_u N_{cr} + qN_q$$

For $\phi = 0$, $$N_{cr} = 5\left(1+0.2\frac{D_f}{B}\right)\left(1+\frac{0.2B}{L}\right)$$

$$= 5\left(1+0.2\frac{2}{3}\right)\left(1+\frac{0.2\times 3}{6}\right) = 6.23$$

$\Rightarrow$ $$q_u = 45.24 \times 6.23 + (18 \times 2) = 317.84 \text{ kN/m}^2$$

$$q_{nu} = 317.84 - 18 \times 2 = 281.84 \text{ kN/m}^2$$

$$q_{na} = \frac{q_{nu}}{F_s} = \frac{281.84}{3} = 94 \text{ kN/m}^3$$

Q.6 (c) Solution:

(i) Rapid Hardening Cement : Rapid hardening cement has high C_3S content and is normally obtained from OPC clinker by finer grinding (450 m^2/kg). The basis of application of rapid hardening cement (RHC) is hardening properties and heat emission rather than setting rate. This permits addition of little more gypsum during manufacture to control the rate of setting. RHC attains same strength in one day when requirement for workability is more. The cost of rapid hardening cement is about 10% more than the ordinary cement. Concrete made with RHC can be safely exposed to front since it matures more quickly.

Properties :

Initial setting time	30 minutes (minimum)
Final setting time	10 hours (maximum)
Compressive strength	
1 day	16.0 N/mm^2
3 days	27.5 N/mm^2

Uses : It is suitable for repair of roads and bridges where load is required to be applied in a short period of time.

(ii) Quick Setting Portland Cement : The quantity of gypsum is reduced and small percentage of aluminium sulphate is added. It is grounded much finer than OPC.

Properties :

Initial setting time = 5 minutes

Final setting time = 30 minutes

Uses : It is used when concrete is to be laid under water or in running water.

Q.6 (d) Solution:

Corrosion in Pipes (Metals): When water flows through a metal pipe (such as a cast iron or a steel pipe), it attacks and disintegrates the surface of the pipe. The material of the pipe thus gets dissolved and rusted, thereby reducing the life and carrying capacity of the pipe. This phenomenon which leads to the disintegrating of the pipe is known as corrosion. The corrosion of pipes reduces their life and carrying capacities, and may also impart colour and odour to the flowing water. There are various factor responsible for corrosion:

- Oxygen content of the water
- pH valve
- Temperature and Soil bacteria
- Moisture content

- Composition of pipe material

In general, the corrosion of metal pipes may occur if iron enter solutions as positive ions (i.e Fe^{++} ions) and combines with the negative ions of water (i.e. OH^- ions), thus forming ferrous hydroxide [Fe $(OH)_2$]

$$Fe^{++} + 2\,OH^- \rightarrow Fe\,(OH)_2$$

When water is alkaline and free from carbon dioxide

$$2Fe(OH)_2 + \frac{1}{2}O_2 + H_2O \rightarrow 2Fe\,(OH)_3$$ (Ferric hydroxide sticks to anode i.e. pipe surface)

When water is acidic and contains free CO_2

$$Fe(OH)_2 + 2CO_2 \rightarrow Fe\,(HCO_3)_2$$ Ferrous bicarbonate

$$2Fe(HCO_3)_2 + O_2 + H_2 \rightarrow 2Fe\,(OH)_3 + 4\,CO_2\uparrow$$ (Ferrous hydroxide sticks to anode)

This ferric hydroxide [$Fe(OH)_3$] is in the form of insoluble red precipitate and gets deposited on the pipe surface. This leads to the formation of tubercules of ferriec hydroxide on the inside surface of the pipe, this process is known as "tuberculation". Tuberculation leads to increase in pipe roughness and hence reduce the carrying capacity.

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