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Detailed Solutions

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

Civil Engineering Test No : 4

Q.1 (a) Solution:

Average water supply = Population × daily per capita water supply

= 42000 × 135 = 5.67 MLD

$\therefore$ Dry weather flow = $\dfrac{0.75 \times 5.67 \times 10^6}{10^3 \times 24 \times 60 \times 60} = 0.0492 \text{ m}^3/\text{s}$

But design discharge, Q = 3 × Dry weather flow when running full = 3 × 0.0492 = 0.1476 m^3/s

If the diameter of the sewer is D, and hydraulic mean depth is R, then R = $\dfrac{D}{4}$ when sewer is running full.

As per Manning's equation, the velocity of flow is given by

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$\therefore \quad Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

$$\Rightarrow \quad 0.1476 = \frac{1}{0.012} \times \frac{\pi}{4} \times D^2 \times \left(\frac{D}{4}\right)^{2/3} \times \left(\frac{1}{625}\right)^{1/2}$$

$$\Rightarrow \quad 0.1476 = \frac{1}{0.012} \times \frac{\pi}{4} \times \left(\frac{1}{4}\right)^{2/3} \times \left(\frac{1}{625}\right)^{1/2} \times (D)^{8/3}$$

$$\Rightarrow \quad (D)^{8/3} = \frac{0.1476 \times 0.012 \times 4 \times \sqrt[3]{16} \times \sqrt{625}}{\pi}$$

$$\Rightarrow \quad (D)^{8/3} = 0.142$$

$$\Rightarrow \quad D = 0.481 \text{ m}$$

$$\therefore \quad \text{Velocity, } V = \frac{Q}{A} = \frac{0.1476}{\frac{\pi}{4} \times (0.481)^2} = 0.812 \text{ m/s}$$

Q.1 (b) Solution:

(i) Let c and f be effective shear strength parameters of the soil.

Assuming, $c = 0$ for CD triaxial test on saturated sand.

Given:

Deviator stress at failure, $\Delta\sigma_f = \sigma_{1_f} - \sigma_{3_f} = 220$ kPa

$$\Rightarrow \quad \sigma_{1_f} - \sigma_{3_f} = 220 \text{ kPa}$$

Confining cell pressure at failure, $\sigma_{3_f} = 100$ kPa

$$\therefore \quad \sigma_{1_f} = (220 + 100) = 320 \text{ kPa}$$

We know,

$$\sigma_{1_f} = \sigma_{3_f} \tan^2\left(45° + \frac{\phi}{2}\right) + 2c\tan\left(45° + \frac{\phi}{2}\right)$$

$$= \sigma_{3_f} \tan^2\left(45° + \frac{\phi}{2}\right)$$

Substituting above values, we get

$$\tan^2\left(45° + \frac{\phi}{2}\right) = \frac{\sigma_{1_f}}{\sigma_{3_f}} = \frac{320}{100} = 3.2$$

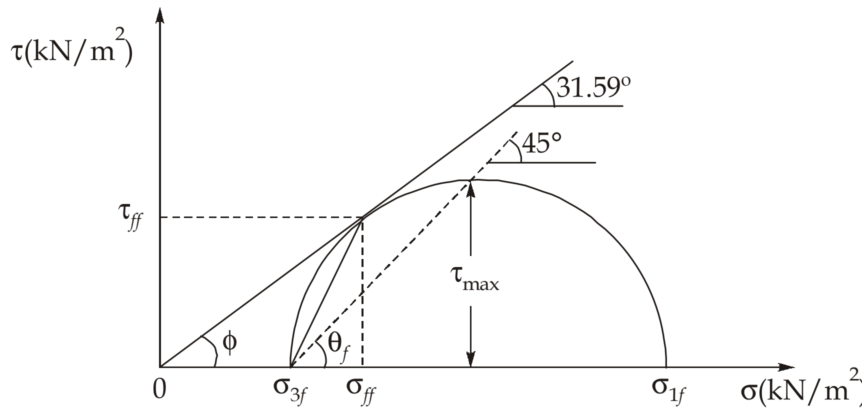
$$\Rightarrow \quad \tan\left(45° + \frac{\phi}{2}\right) = 1.78885$$

$$\Rightarrow \quad 45° + \frac{\phi}{2} = 60.794°$$

$$\Rightarrow \quad \phi = 31.59° = 31°35'24''$$

$\therefore$ The shear strength parameters (c, ϕ) are (0, 31.59°) respectively.

(ii) Mohr's circle at failure is drawn below.



$$\text{Angle of failure plane, } \theta_f = 45° + \frac{\phi}{2} = 45° + \frac{31.59°}{2}$$

$$\Rightarrow \qquad \theta_f = 60.795°$$

Using Mohr-Coulomb equation,

$$\text{Shear stress on failure plane, } \tau_{ff} = c + \sigma_{ff} \tan\phi$$

From above geometry,

$$\sigma_{ff} = \frac{\sigma_1 + \sigma_3}{2} + \frac{(\sigma_1 - \sigma_3)}{2}\cos 2\phi$$

$$= \left(\frac{320+100}{2}\right) + \left(\frac{320-100}{2}\right)\cos(2 \times 60.795°)$$

$$= 152.38 \text{ kPa}$$

$$\therefore \qquad \tau_{ff} = 0 + 152.38 \tan 31.59° = 93.71 \text{ kN/m}^2$$

(iii) Maximum shear stress occurs at $\theta_f = 45°$

$$\therefore \qquad \tau_{max} = \left(\frac{\sigma_{1f} - \sigma_{3f}}{2}\right) = \left(\frac{320-100}{2}\right) = 110 \text{ kN/m}^2$$

$$\therefore \qquad \tau_{ff} = 93.71 \text{ kN/m}^2$$

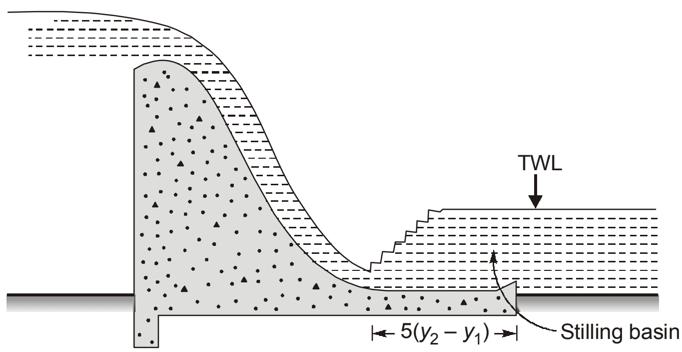
$$\text{and} \qquad \tau_{max} = 110 \text{ kN/m}^2$$

Q.1 (c) Solution:

In relation to the relative positions of tail water rating curve (TWC) and Jump height rating curve (JHC) **following types of energy dissipation devices** may be recommended:

(i) When TWC coinciding with JHC at all discharges

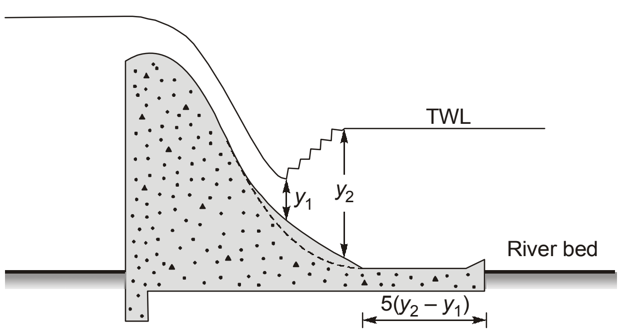
This is the most ideal condition for jump formation. The hydraulic jump will form at the top of the spillway at all discharges. In such a case a simple concrete apron of length 5 (y_2 – y_1) is generally sufficient to provide protection in the region of hydraulic jump.



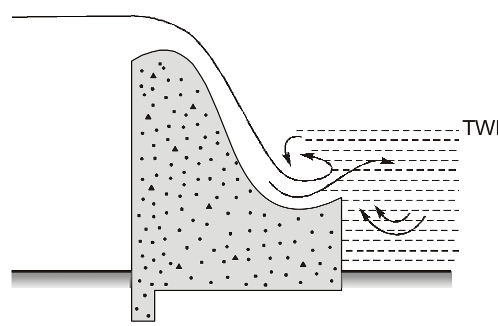
Simple horizontal apron

(ii) When TWC is lying above the JHC at all discharges

In this case, when y_2 is always below the tail water, the jump forming at toe will be drowned out by the tail water and little energy will be dissipated. This problem can be solved by providing a sloping apron above the river bed level or by providing a roller bucket type of energy dissipator.



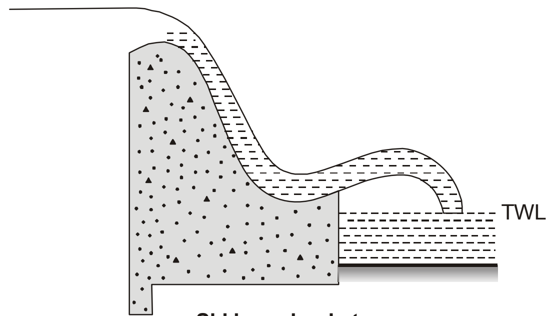
Sloping apron above the bed



Roller bucket

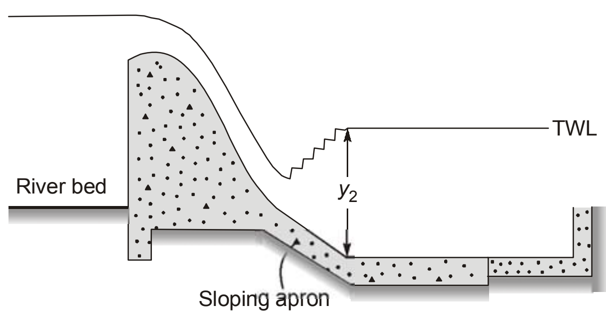
(iii) When TWC lies below the JHC at all discharges

If the tail water depth is very low, the water may shoot out of the above bucket and fall harmlessly into the river at some distance downstream of the bucket. This bucket is then known as Ski jump.



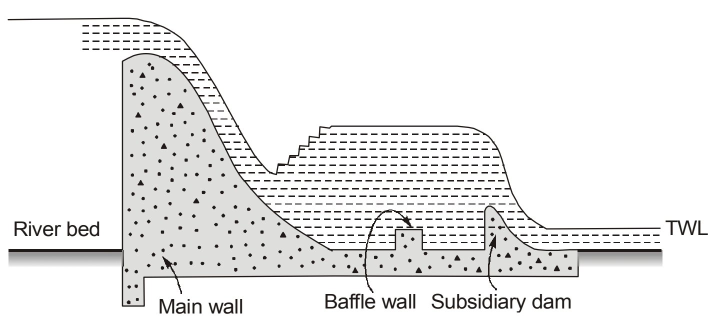
Ski jump bucket

The second solution to this problem can be the provision of providing a sloping apron but below the river bed. The required depth y_2 which is greater than TW depth can thus be made available by letting the jump form on this sloping apron as shown.



Sloping apron above the bed

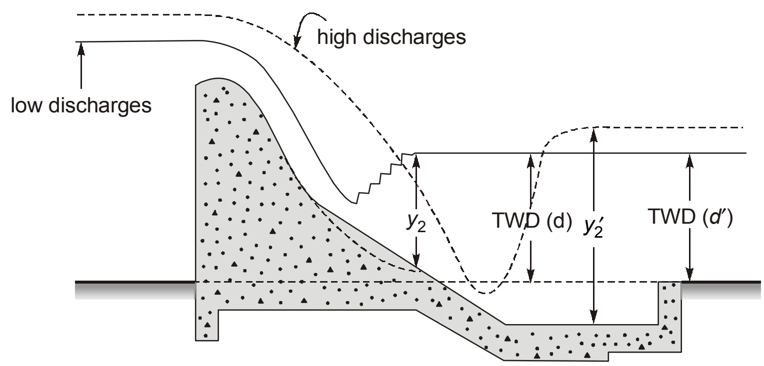
The third solution to this problem may be the construction of a subsidiary dam below the main dam, so as to increase the tail water depth and cause a jump to form at the toe of the main dam.



If the tail water deficiency is small, a baffle wall or a row of friction blocks may be provided so as to dissipate the residual energy.

(iv) When TWC lies above JHC at low discharges and lies below JHC at high discharges.

In this case at low discharges, the jump will be drowned and at high discharges tail water is insufficient. The solution to this problem lies in providing a sloping apron partly above and party below the river bed.



Sloping apron partly above and partly below the ground level

(v) When TWC lies below JNC at low discharges and lies above at high discharges. This case is just the reverse of above case and hence the same arrangement which is made above will serve the purpose. The only difference will be that at low discharges, the jump will form on the apron below the bed and at high discharges, the jump will form on the apron at a point above the bed.

Q.1 (d) Solution:

For comfort condition,
$$L = 2\sqrt{\frac{NV^3}{C}} = 2\times\sqrt{\frac{6}{100}\times\frac{0.0215\times 90^3}{0.5}} = 86.74\,\text{m} \quad \text{...(i)}$$

Head light sight distance, when $L > SSD$,

$$SSD = 0.278\,Vt + \frac{V^2}{254\,f} = 0.278\times 90\times 2 + \frac{90^2}{254\times 0.45} = 120.91\ \text{m}$$

Assuming, $L > SSD$

$$L = \frac{Ns^2}{1.5+0.035s} = \frac{0.06\times 120.91^2}{1.5+0.035\times 120.91}$$
$$= 153.03\text{ m} > \text{SSD} \quad \text{...(ii)}$$

Length of valley curve is maximum of above two conditions.

$\therefore$ $$L = 153.03\text{ m}$$

Q.2 (a) Solution:

$$X_A = x_a\cdot\frac{(H-h_a)}{f} = 68.27\times\left(\frac{3200-273}{210}\right) = 951.554\text{ m}$$

$$Y_A = y_a\cdot\frac{(H-h_a)}{f} = -32.37\times\frac{(3200-273)}{210} = -451.176\text{ m}$$

$$X_B = x_b\cdot\frac{(H-h_b)}{f} = -87.44\times\frac{(3200-328)}{210} = -1195.846\text{ m}$$

$$Y_B = y_b \cdot \frac{(H - h_b)}{f} = 26.81 \times \frac{(3200 - 328)}{210} = 366.659 \text{ m}$$

$$\Rightarrow \qquad L_{AB} = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2} = 2297.864 \text{ m}$$

Q.2 (b) Solution:

(i) Least Count: It is the smallest possible value of one division of any scale. For a vernier scale, least count is thus equal to the value of the smallest division on the main scale divided by the total number of divisions on the vernier.

If S is smallest division of main scale and n is smallest division of vernier scale

$$\text{Then, least count} = \frac{S}{n}$$

(ii) Closing error: In a complete circuit, the sum of north latitudes must be equal to that of south latitudes and the sum of eastings must be equal to that of westings, if linear as well as angular measurements of the traverse along with their computation are correct. If not, the distance between the starting station and the position obtained by calculation is known as closing error.

The closing error is generally expressed as a ratio of the closing error(e) and the perimeter of the traverse (P). In that form it is called relative closing error. Thus,

$$\text{Relative closing error} = \frac{\text{Error of closure}}{\text{Perimeter of traverse}} = \frac{e}{P}$$

It is conventional to express the relative closing error with the numerator as unity.

Thus, $$\text{Relative closing error} = \frac{1}{P/e}$$

(iii) Arithmetic check: These are simple arithmetic calculations which are made to check the correctness of entries in height of instrument method or rise and fall method. The arithmetic calculations can be checked by using the following equation:

$$\Sigma\text{Back sight} - \Sigma\text{Fore sight} = \text{Last } RL - \text{first } RL = \Sigma\text{Rise} - \Sigma\text{fall}$$

Thus, if the calculations on left hand side as well as on right hand side are equal, then the calculations made in filling the entries are correct.

(iv) Local attraction: Local attraction is the attraction of magnetic needle to a local magnetic field other than earth's magnetic field. The local magnetic field is caused by iron fences, iron pipes, steel bars, vehicles, steel doors and windows, iron deposits, etc. Even small items made of iron or steel such as the wrist watch case, pen, belt buckle, tapping arrows and steel tapes cause local attraction. DC power lines also develop a local magnetic field. A freely suspended magnetic needle takes the direction of the earth's magnetic field only if these is no local attraction. The magnetic needle will deviate from the magnetic meridian under the local magnetic field (forces).

(v) **Whole to the part:** It is the first principle of surveying. The surveyor should first establish accurately large main framework consisting of widely spaced control points. Between the large main framework, subsidiary small frameworks can be established by relatively less accurate surveys. The errors in small framework are thus localised and are not magnified and the accumulation of errors is controlled. In the reverse process of working from the part to whole, the small frameworks will be expanded to the large framework and the errors will get magnified.

Q.2 (c) Solution:

Maximum permissible speed on main line,

$$V_{max} = 70 \text{ kmph}$$

By Martin's formula, allowable speed for main curve of 3°,

$$V_{max} = 4.35\sqrt{R-67}$$

$$= 4.35\sqrt{\frac{1720}{D^\circ}-67} = 4.35\sqrt{\frac{1720}{3}-67}$$

$$= 97.88 \text{ kmph} > 70 \text{ kmph}$$

Hence, safe.

Theoretical cant required for main line,

$$e_{th} = \frac{GV^2}{127R_{main}} = \frac{1.676\times(70)^2}{127\times\frac{1720}{3}} = 0.1128 \text{ m}$$

$$e_{th} = 11.28 \text{ cm} < 16.5 \text{ cm} \quad \text{(OK)}$$

Maximum cant deficiency for BG track = 7.6 cm

$\therefore$ Actual cant for main track $= 11.28 - 7.6$

$$e_{Act} = 3.68 \text{ cm}$$

Now for branch track

$$e_{Act} \text{ of branch track} = -e_{Act} \text{ of main track}$$

$\therefore$ e_{Act} of branch track $= -3.68$ cm

Theoretical super elevation for branch track

$$e_{th} = e_{Act} + \text{Cant deficiency}$$
$$= -3.68 + 7.6$$
$$= 3.92 \text{ cm}$$

Maximum permissible speed on branch line

$$e_{th} = \frac{GV_{max}^2}{127R}$$

$$\Rightarrow \quad \frac{3.92}{100} = \frac{1.676 \times (V_{max})^2}{127 \times \frac{1720}{7}}$$

$$\Rightarrow \quad V_{max} = 27.02 \text{ kmph}$$

According to Martin's formula, allowable speed on branch track,

$$V_{max} = 4.35\sqrt{R - 67}$$

$$= 4.35\sqrt{\frac{1720}{7} - 67} = 58.15 \text{ kmph} \qquad \text{OK}$$

So, the restricted maximum speed on branch track = 27.02 kmph, say 25 kmph.

Q.2 (d) Solution:

Reactions at support A and B are 1.75 and 2.75 kN respectively. A concentrated downward load of 1.5 kN is applicable at 1 m from support B.

There is no load between A & C and D & E.

As the shear force diagram is a 2° curve, therefore, loading should be 1° curve i.e. a uniformly varying load.

Let function of shear force between C and D, $f(x) = ax^2 + bx + c$ (2° curve)

where x = distance of point to the right of C

at C, shear force = 1.75 kN

$$\Rightarrow \quad f(0) = a(0)^2 + b(0) + c = 1.75$$

$$\Rightarrow \quad c = 1.5$$

at D, shear force = – 1.25 kN

$$\Rightarrow \quad f(3) = a(3)^2 + b(3) + 1.75 = -1.25$$

$$\Rightarrow \quad 3a + b + 1 = 0 \qquad \text{...(i)}$$

It is given that shear force is zero at a distance of 3.29 m from A, i.e., 2.29 m to the right of C.

$$\Rightarrow \quad f(2.29) = a(2.29)^2 + b(2.29) + 1.75 = 0$$

$$\Rightarrow \quad 2.29a + b + 0.764 = 0 \qquad \text{...(ii)}$$

By solving equation (i) and (ii)

we get, $a = -0.333,\ b = 0$

$\therefore$ Function of shear force $= -0.333x^2 + 1.75$

we know that, $\dfrac{dS_x}{dx} = -w_x$

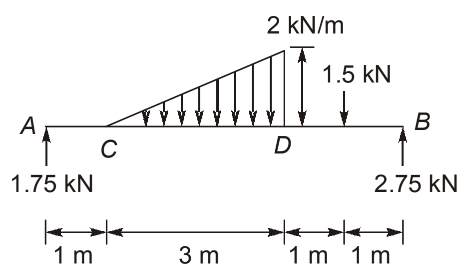
where w = loading rate

S_x = shear force at location x

$$\therefore \quad \frac{dS_x}{dx} = -0.667x = -w_x$$

$$\therefore \quad w_x = 0.667x$$

at $x = 3$, $w = 0.667 \times 3 = 2$ kN/m



Q.3 (a) Solution:

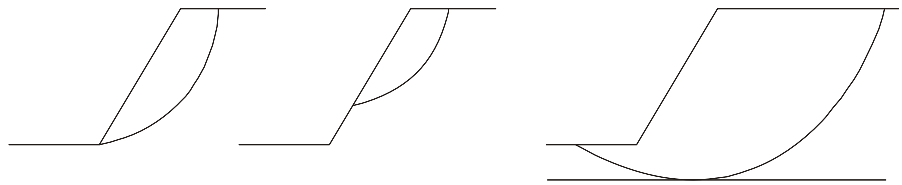
A slope may have any one of the following types of failures:

- **Rotational failure:** This type of failure occurs by rotation along a slip surface by downward and outward movement of the soil mass. Rotational slips are further divided into 3 types:

  (i. Toe failure, in which the failure occurs along the surface that passes through the toe of slope.

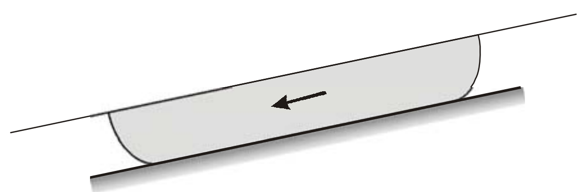
  (ii. Slope failure, in which the failure occurs along a surface that intersects the slope above the toe of slope.

  (iii. Base failure, in which the failure surface passes below the toe of slope.



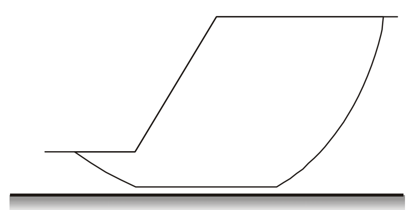
Toe failure Slope failure Base failure

- **Translational failure:** Translational failure occurs in an infinite slope along a long failure surface parallel to the slope. The shape of the failure surface is influenced by the presence of any hard stratum at a shallow depth below the slope surface. Translational failures may also occur along slopes of layered materials.



Translational Failure

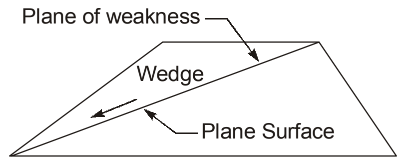
- **Compound failure:** A compound failure is a combination of the rotational slip and the translational slip. A compound failure surface is curved at the two ends and plane in the middle portion. A compound failure generally occurs when a hard stratum exists at considerable depth below the toe.



Compound Failure

- **Wedge failure:** A failure along an inclined plane is known as plane failure or wedge failure or block failure. It occurs when distinct blocks and wedges of the soil mass become separated.

  A plane failure is similar to translation failure is many respects. However, unlike translation failure which occurs in an infinite slope, a plane failure may occur even in a failure slope consisting of two different materials or in a homogeneous slope having cracks, fissures, joints or any other specific plane of weakness.



Wedge Failure

- **Miscellaneous failure:** In addition to the above four types of failures, some complex types of failures in the form of spreads and flows may also occur.

Q.3 (b) Solution:

$$\text{Self weight of beam} = 0.30 \times 0.60 \times 1 \times 25 = 4.5 \text{ kN/m}$$

$$\text{Super imposed load} = 30 \text{ kN/m}$$

$$\text{Total load} = 34.5 \text{ kN/m}$$

$$\text{Factored load, } w_u = 1.5 \times \text{Total load}$$

$$= 51.75 \text{ kN/m}$$

$$\text{Maximum shear force, } V_u = \frac{w_u l}{2} = \frac{51.75 \times 8}{2} = 207 \text{ kN}$$

$$\text{Nominal shear stress, } \tau_v = \frac{V_u}{B \cdot d} = \frac{207 \times 1000}{300 \times 560} = 1.23 \text{ N/mm}^2 < \tau_{c\max} \text{ (Hence OK)}$$

$$\text{From given table, for 0.6\% steel, } \tau_c = 0.48 + \frac{(0.56 - 0.48)}{(0.75 - 0.50)} \times (0.6 - 0.5)$$

$$= 0.512 \text{ N/mm}^2$$

$$\Rightarrow \qquad \tau_c < \tau_v < \tau_{c\max}$$

Thus shear reinforcement is required.

Design shear reinforcement for a shear force of

$$V_{us} = (\tau_v - \tau_c) Bd$$

$$= (1.23 - 0.512) \times 300 \times 560 = 120.624 \text{ kN}$$

Providing vertical 2 legged 8 mm ϕ bars,

$$A_{sv} = 2 \times \frac{\pi}{4} \times 8^2 = 100.53 \text{ mm}^2$$

$$\text{Spacing, } S_v = \frac{0.87 f_y A_{sv} \cdot d}{V_{us}}$$

$$= \frac{0.87 \times 415 \times 100.53 \times 560}{120.624 \times 1000} = 168.51 \text{ mm}$$

Provide 150 mm c/c spacing, check for minimum shear reinforcement,

$$\frac{A_{sv\,min}}{B \cdot S_v} = \frac{0.4}{0.87\,f_y}$$

$$\Rightarrow \quad A_{sv\,min} = \frac{0.4 \times 300 \times 150}{0.87 \times 415}$$

$$= 49.85\,\text{mm}^2 < A_{sv} \text{ provided } (= 100.53\,\text{mm}^2) \quad \text{(OK)}$$

Also provided spacing should be less than

Minimum of
- (i) 150 mm (as calculated above)
- (ii) 0.75d (for vertical stirrups) = 0.75 × 560 = 420 mm
- (iii) 300 mm

Thus, $S_v = 150$ mm c/c

Q.3 (c) Solution:

For the inverted differential U-tube manometer.

$$\Delta h = \text{difference in Piezometric heads}$$

$$= y\left(1 - \frac{S_m}{S_P}\right) = 30\left(1 - \frac{0.75}{1.0}\right)$$

$$= 7.5 \text{ cm} = 0.075 \text{ m}$$

The loss of head between inlet and throat,

$$H_{L_i} = \left[\frac{1}{C_d^2} - 1\right]\left[1 - \left(\frac{D_2}{D_1}\right)^4\right]\frac{V_2^2}{2g}$$

$$\Rightarrow \quad \frac{0.1 V_2^2}{2g} = \left[\frac{1}{C_d^2} - 1\right]\left[1 - \left(\frac{D_2}{D_1}\right)^4\right]\frac{V_2^2}{2g}$$

$$\Rightarrow \quad \left[\frac{1}{C_d^2} - 1\right] = 0.10667$$

$$\Rightarrow \quad C_d = 0.95$$

Also, $$H_{L_i} = \left(1 - C_d^2\right)\Delta h$$

$$\therefore \quad \frac{0.1 V_2^2}{2g} = \left(1 - (0.95)^2\right)(0.075)$$

$$= 7.313 \times 10^{-3}$$

$$\Rightarrow \qquad \frac{V^2}{2g} = 0.07313$$

$$\Rightarrow \qquad V_2 = 1.198 \text{ m/s}$$

$$\text{Discharge, } Q = A_2V_2$$

$$= \frac{\pi}{4} \times (0.1)^2 \times 1.198$$

$$= 9.41 \times 10^{-3} \text{ m}^3/\text{s}$$

$$= 9.41\ l/\text{s}$$

Q.3 (d) Solution:

Advantages of welded joints:

(i) As no holes are required for welding, the structural members are more effective in taking load.

(ii) The overall weight of structural steel required is reduced by the use of welded joints.

(iii) Welded joints are often economical as less labour and material are required for a joint.

(iv) The speed of fabrication is higher with the welding process.

(v) Any shape of joint can be made with ease.

(vi) Complete rigid joints can be provided with the welding process.

Disadvantages of welded joints:

(i) Skilled labour and electricity are required for welding.

(ii) Internal stresses and warping are produced due to uneven heating and cooling.

(iii) Welded joints are more brittle and therefore their fatigue strength is less than the members joined.

(iv) Defects like internal air pockets, slag inclusion and incomplete penetration are diffcult to detect.

Q.4 (a) Solution:

Given Data:

$$w_c : w_s : w_a = 1 : 2 : 3.6$$

Water-cement ratio = 0.5

Air content = 5%

Total volume of concrete = 0.25 m^3

Specific gravity of cement, G_c = 3.15

Specific gravity of sand, $G_s = 2.65$

Specific gravity of aggregate, $G_a = 2.7$

Let the weight of cement $= w_c$ kg

Let the weight of sand $= w_s$ kg

Let the weight of aggregate $= w_a$ kg

Now, net volume of concrete = Total volume of concrete – Volume of air in concrete

$$= 0.25 - \left(\frac{5}{100} \times 0.25\right) = 0.25 - 0.0125$$

$\therefore$ Net volume of concrete $= 0.2375 \text{ m}^3$

We have $\dfrac{w_c}{w_s} = \dfrac{1}{2}$ and $\dfrac{w_c}{w_a} = \dfrac{1}{3.6}$

But we also know that

Net volume of concrete = Volume of water + Volume of solids

$$\Rightarrow \quad 0.2375 = \frac{\text{Weight of water}}{\text{Density of water}} + \frac{\text{Weight of solids}}{\text{Density of solids}}$$

$$\Rightarrow \quad 0.2375 = \frac{0.5 \times w_c}{1000} + \left[\frac{w_c}{G_c \times 1000} + \frac{w_s}{G_s \times 1000} + \frac{w_a}{G_a \times 1000}\right]$$

$$\Rightarrow \quad 0.2375 \times 1000 = 0.5\, w_c + \left[\frac{w_c}{G_c} + \frac{2w_c}{G_s} + \frac{3.6\, w_c}{G_a}\right]$$

$$\Rightarrow \quad 237.5 = w_c\left[0.5 + \frac{1}{3.15} + \frac{2}{2.65} + \frac{3.6}{2.7}\right]$$

$$\Rightarrow \quad w_c = \frac{237.5}{2.9055}$$

$$\Rightarrow \quad w_c = 81.74 \text{ kg}$$

$$\therefore \quad w_s = 2 \times w_c = 2 \times 81.74 = 163.48 \text{ kg}$$

$$w_a = 3.6 \times w_c = 3.6 \times 81.74 = 294.26 \text{ kg}$$

Q.4 (b) Solution:

$$\eta_0 = \frac{P}{wQH}$$

$$\Rightarrow \quad 0.85 = \frac{330 \times 10^3}{9810 \times Q \times 68}$$

$$\therefore \quad Q = 0.582 \text{ m}^3/\text{s}$$

$$V_f = \psi\sqrt{2gH}$$

$$= 0.15 \times \sqrt{2 \times 9.81 \times 68} = 5.48 \text{ m/s}$$

Also, $Q = (k\,\pi\,n\,D^2)\,V_f$

$\Rightarrow$ $0.582 = 0.94 \times \pi \times 0.10 \times D^2 \times 5.48$

$\therefore$ $D = 0.60 \text{ m} = 600 \text{ mm}$

Since $n = \left(\dfrac{B}{D}\right) \Rightarrow B = (0.10 \times 600) = 60 \text{ mm}$

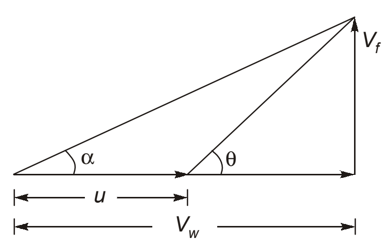
$$u = \frac{\pi DN}{60} = \frac{\pi \times 0.60 \times 750}{60} = 23.56 \text{ m/s}$$

$$\eta_h = \frac{V_w u}{gH}$$

$\Rightarrow$ $0.94 = \dfrac{V_w \times 23.56}{9.81 \times 68}$

$\Rightarrow$ $V_w = 26.62 \text{ m/s}$

From inlet velocity triangle, we have



$$\tan\alpha = \frac{V_f}{V_w} = \frac{5.48}{26.62} = 0.2059$$

$\therefore$ $\alpha = 11°38'$

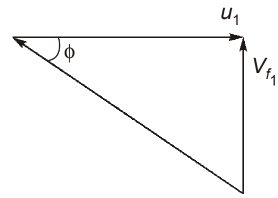
$$\tan\theta = \frac{V_f}{V_w - u} = \frac{5.48}{26.62 - 23.56} = 1.7908$$

$\therefore$ $\theta = 60°49'$

Now, $D_1 = \dfrac{D}{2} = 0.30 \text{ m} = 300 \text{ mm}$

$$\frac{u}{D} = \frac{u_1}{D_1} \Rightarrow u_1 = 11.78 \text{ m/s}$$

Since the flow is radial at exit and $V_f = V_{f1}$, from outlet velocity triangle.



$$\tan\phi = \frac{V_{f1}}{u_1} = \frac{5.48}{11.78} = 0.4652$$

$$\phi = 24°57'$$

Q.4 (c) Solution:

$\because$ One end of short span is continuous and other discontinuous.

Assuming discontinuous end to be simply supported.

$\therefore$ Limiting span to depth ratio $= \dfrac{26+20}{2} = 23$

$\therefore$ Depth of slab required, $D = \dfrac{4000}{23} = 173.9 \text{ mm} \simeq 175 \text{ mm (say)}$

Let effective cover = 25 mm

$\therefore$ Effective depth of slabs, $d_x = 175 - 25 = 150 \text{ mm}$

$$d_y = d_x - \text{Bar diameter}$$
$$= 150 - 10 = 140 \text{ mm}$$

$\therefore$ **Effective spans:**

$$l_x = 4 + 0.15 = 4.15 \text{ m}$$
$$l_y = 5 + 0.14 = 5.14 \text{ m}$$

$\therefore$ $$r = \frac{l_y}{l_x} = \frac{5.14}{4.15} = 1.24 < 2$$

$\therefore$ Two way slab.

Loads

Self weight of slab $= 0.175 \times 1 \times 1 \times 25 = 4.375 \text{ kN/m}^2$

Finishes $= 1 \text{ kN/m}^2$

Live load $= 8 \text{ kN/m}^2$

$\therefore$ Total load $= 13.375 \text{ kN/m}^2$

$\therefore$ Factored load, $w_u = 1.5 \times 13.375 = 20.0625 \text{ kN/m}^2 = 20.06 \text{ kN/m}^2$

Moments

Positive mid-span moment in short direction $\left(M_{ux}^{+}\right)$

$$= \alpha_x^{+} w_u l_x^2$$

$$= (0.047)\ 20.06\ (4.15)^2$$

$$= 16.24 \text{ kNm/m}$$

Positive mid-span moment in long direction $\left(M_{uy}^{+}\right)$

$$= \alpha_y^{+} w_u l_x^2$$

$$= 0.035\ (20.06)\ (4.15)^2$$

$$= 12.09 \text{ kNm/m}$$

Negative support moment in short direction $\left(M_{ux}^{-}\right)$

$$= \alpha_x^{-} w_u l_x^2$$

$$= 0.062\ (20.06)\ (4.15)^2$$

$$= 21.42 \text{ kNm/m}$$

Negative support moment in long direction $\left(M_{uy}^{-}\right)$

$$= \alpha_y^{-} w_u l_x^2$$

$$= 0.047\ (20.06)\ (4.15)^2$$

$$= 16.24 \text{ kNm/m}$$

Depth of slab required

Maximum moment, $M = 21.42$ kNm/m

For Fe415, $M_{u,\lim} = 0.138 f_{ck} b d^2$

$\therefore \quad M_{u,\lim} = M$

$\Rightarrow \quad 0.138 f_{ck}\, bd^2 = 21.42 \times 10^6$

$\Rightarrow \quad 0.138(20)(1000)d^2 = 21.42 \times 10^6$

$\Rightarrow \quad d = 88.1 \text{ mm} < 150 \text{ mm}$ (OK)

Reinforcement

$$M_{ux}^{+} = 16.24 \text{ kNm/m}$$

$$d_x = 150 \text{ mm}$$

$$\therefore \quad p_{tx,reqd.}^{+} = 0.21\% \quad \left[\text{From } \frac{p_t}{100} = \frac{A_{st}}{bd} = \frac{f_{ck}}{2f_y}\left(1-\sqrt{1-\frac{4.598M_u}{f_{ck}bd^2}}\right)\right]$$

$$\therefore \quad A_{stx,reqd.}^{+} = \frac{0.21}{100} \times 1000 \times 150 = 315 \text{ mm}^2/\text{m}$$

$$\therefore \quad \text{Spacing of } 10\phi \text{ bars} = \frac{1000 \times \frac{\pi}{4} \times 10^2}{315} = 249.3 \text{ mm c/c} \simeq 220 \text{ mm (say)}$$

∴ Provide 10ϕ bars @ 220 mm c/c in short direction at mid-span.

$$M_{uy}^{+} = 12.09 \text{ kNm/m}$$

$$d_y = 140 \text{ mm}$$

$$\therefore \quad p_{ty,reqd.}^{+} = 0.18\% \quad \left[\text{From } \frac{p_t}{100} = \frac{A_{st}}{bd} = \frac{f_{ck}}{2f_y}\left(1-\sqrt{1-\frac{4.598M_u}{f_{ck}bd^2}}\right)\right]$$

$$\therefore \quad A_{sty,reqd.}^{+} = \frac{0.18}{100} \times 1000 \times 140 = 252 \text{ mm}^2/\text{m}$$

$$\therefore \quad \text{Spacing of } 10\phi \text{ bars} = \frac{1000 \times \frac{\pi}{4} \times 10^2}{252} = 311.7 \text{ mm} > 300 \text{ mm}$$

Provide = 10ϕ bars @ 280 mm c/c (< 300 mm) is long direction at mid-span.

$$M_{ux}^{-} = 21.42 \text{ kNm/m}$$

$$d_x = 150 \text{ mm}$$

$$\therefore \quad p_{tx,reqd.}^{-} = 0.28\% \quad \left[\text{From } \frac{p_t}{100} = \frac{A_{st}}{bd} = \frac{f_{ck}}{2f_y}\left(1-\sqrt{1-\frac{4.598M_u}{f_{ck}bd^2}}\right)\right]$$

$$\therefore \quad A_{st,reqd.}^{-} = \frac{0.28}{100} \times 1000 \times 150 = 420 \text{ mm}^2/\text{m}$$

$\therefore$ Spacing of 10ϕ bars $= \dfrac{1000 \times \frac{\pi}{4} \times 10^2}{420} = 187$ mm c/c $\simeq 180$ mm c/c (say)

$\therefore$ Provide 10ϕ bars 180 mm c/c in short direction at support.

$$M_{uy}^{-} = 16.24 \text{ kNm/m}$$

$$d_y = 140 \text{ mm}$$

$$\therefore \quad p_{ty,reqd.}^{-} = 0.24\% \qquad \left[\text{From } \frac{p_t}{100} = \frac{A_{st}}{bd} = \frac{f_{ck}}{2f_y}\left(1 - \sqrt{1 - \frac{4.598 M_u}{f_{ck} bd^2}}\right)\right]$$

$$\therefore \quad A_{sty,reqd.}^{-} = \frac{0.24}{100} \times 1000 \times 140 = 336 \text{ mm}^2/\text{m}$$

$\therefore$ Spacing of 10ϕ bars $= \dfrac{1000 \times \frac{\pi}{4} \times 10^2}{336} = 233.7$ mm c/c $\simeq$ 220 mm c/c (say)

$\therefore$ Provide 10ϕ bars @ 220 mm c/c in long direction at support.

Deflection check:

$$A_{stx,reqd}^{+} = 315 \text{ mm}^2/\text{m}$$

$$A_{stx,prov.}^{+} = \frac{1000 \times \frac{\pi}{4} \times 10^2}{220} = 357 \text{ mm}^2/\text{m}$$

$$\therefore \quad f_{st} = 0.58 f_y \cdot \frac{A_{stx,reqd}^{+}}{A_{stx,prov.}^{+}}$$

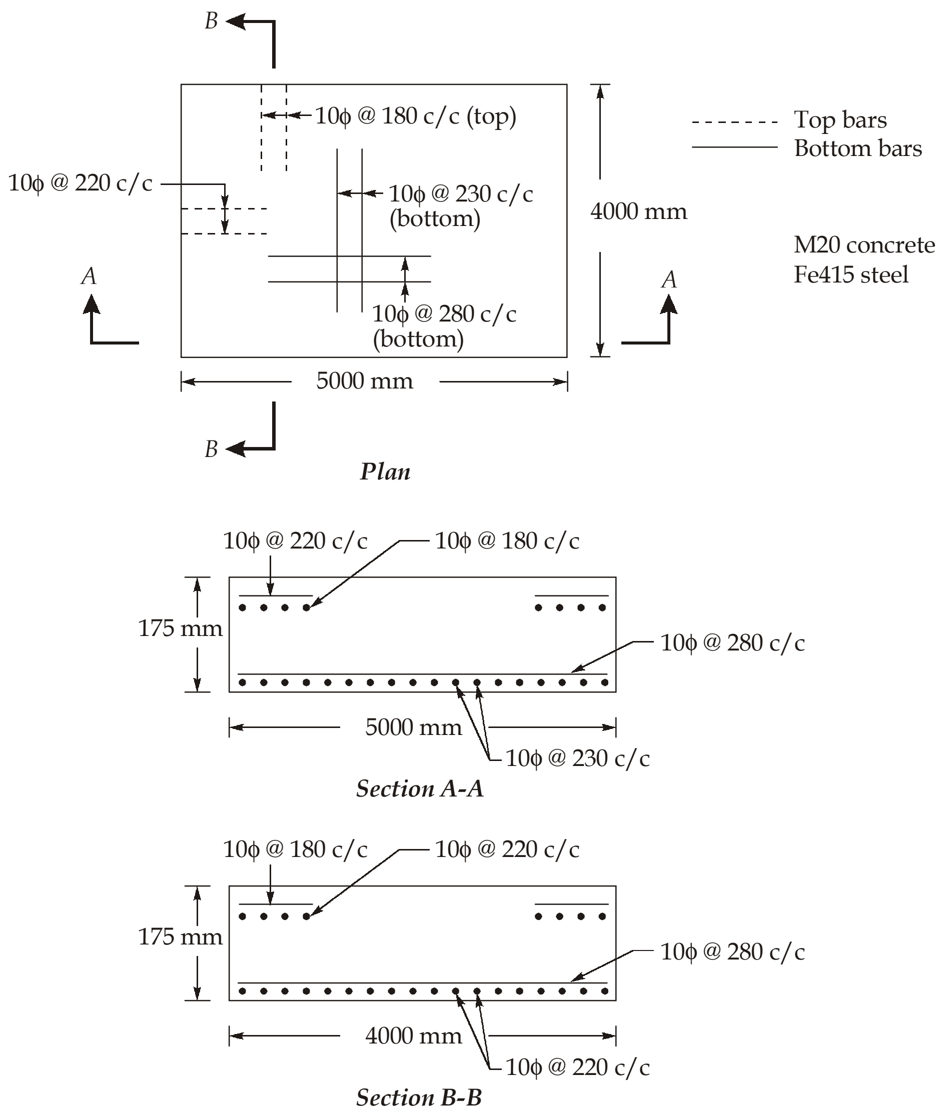
$$= 0.58(415)\frac{315}{357} = 212.38 \text{ N/mm}^2$$

$$\therefore \quad k_t = 1.6 \text{ (from figure 4 of IS 456:2000)}$$

$$\therefore \quad \left(\frac{l}{d}\right)_{\max} = \left(\frac{l}{d}\right)_{basic} \cdot k_t\, k_c \text{ where } k_c = 1 \qquad (\because p_c = 0)$$

$$= 23 \times 1.6 = 36.8$$

$$\left(\frac{l}{d}\right)_{prov} = \frac{4150}{150} = 27.7 < 36.8 \quad \text{(OK)}$$



Reinforcement details

Q.5 (a) Solution:

$$\text{For Fe410 steel, } f_u = 410 \text{ MPa}, f_y = 250 \text{ MPa}$$

$$\text{for 4.6 grade bolts, } f_{ub} = 400 \text{ MPa}, f_y = 0.6 \times 400 = 240 \text{ MPa}$$

$$A_{nb} = \text{stress area of bolts}$$

$$= 0.78 \times \frac{\pi}{4} \times d^2 = 0.78 \times \frac{\pi}{4} \times 20^2 = 245 \text{ mm}^2$$

$$d_0 = 20 + 2 = 22 \text{ mm}$$

$$\gamma_{mb} = \text{Partial factor of safety of bolt material} = 1.25$$

$\because$ Bolts are in single shear and strength of bolt in single shear,

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

Strength of bolt in bearing, $V_{pd} = 2.5 k_b d t \dfrac{f_u}{\gamma_{mb}}$ $\quad (f_u = \text{minimum of } f_u \text{ and } f_{ub})$

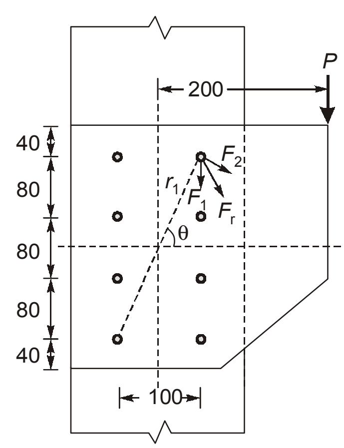
Taking, $k_b = 0.606$ (given)

$$V_{pd} = 2.5 \times 0.606 \times 20 \times 9.1 \times \frac{400}{1.25} \times 10^{-3}$$

$$= 88.23\text{ kN}$$

So, Bolt value $=$ minimum of V_{sb} and $V_{pb} = 45.26$ kN

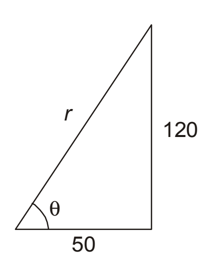
Critical bolt is top-right bolt,



(All dimensions are in mm)

Direct force in bolt, $F_1 = \dfrac{P'}{n} = \dfrac{P'}{8}$

Force in bolt due to torque, $F_2 = \dfrac{P'er}{\Sigma r^2}$



$$r = \sqrt{50^2 + 120^2} = 130\,\text{mm}$$

$$\Sigma r^2 = 4 \times [(50^2 + 40^2)] + [(50^2 + 120^2)]$$
$$= 84000 \text{ mm}^2$$

$$\cos\theta = \frac{50}{130} = 0.3846$$

$$\Rightarrow \quad F_2 = \frac{P' \times 200 \times 130}{84000} = \frac{P'}{3.23}$$

$$\text{Resultant force on bolt, } F_R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

$$= P'\sqrt{\frac{1}{8^2} + \frac{1}{3.23^2} + 2 \times \frac{1}{8} \times \frac{1}{3.23} \times 0.3846}$$

$$= 0.376\,P'$$

$$\text{Resultant force} \le \text{Bolt value}$$

$$0.376\,P' = 45.26 \text{ kN}$$

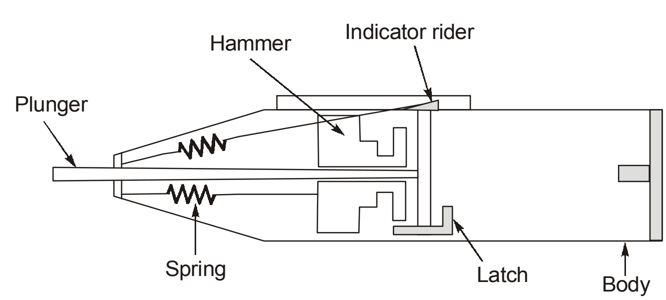
$$\text{Factored Load, } P' = 120.37 \text{ kN}$$

$$\text{Service load, } P = \frac{P'}{1.5} = \frac{120.37}{1.5} = 80.25\,\text{kN} \simeq 80\,\text{kN}$$

Q.5 (b) Solution:

Rebound hammer test is one of the commonly adopted equipments for measuring the surface hardness.

This method was developed by a Swiss Engineer, Ernst Schmidt as a practical rebound test. The Schmidt test hammer weight less than 2 kg and has an impact energy of 2.2 N-m. The spring controlled hammer mass slides on a plunger within a tubular casing.



The plunger retracts against a spring when pressed against the concrete surface and this spring is automatically released when fully tensioned causing the hammer mass to impact against the concrete through the plunger. When the spring controlled mass rebounds, it takes with it a rider which slides along a graduated scale and is visible through a small window in the side of the casing. The rider can be held in position on the scale by depressing the locking button. The equipment can be operated horizontally or vertically. The plunger is pressed strongly and steadily against the concrete surface to be tested at right angles, until the spring loaded mass is triggered from its locked position. The measurement taken is an arbitrary quantity referred to as rebound number. A calibration curve relating the compressive strength of the concrete with the rebound number is plotted. The test is suitable for concrete having strength in the range of 20-60 MPa. The concrete surface must be smooth, clean and dry. Loose material should be ground off. This test gives a measure of relative hardness of the test zone. It provides useful information about a surface layer of concrete upto 30 mm deep.

Q.5 (c) Solution:

(i) Fixed end moments:

Clamp all joints

$$\overline{M}_{AB} = \frac{-2\times 4^2}{12} = -2.67 \text{ kNm}$$

$$\overline{M}_{BA} = +2.67 \text{ kNm}$$

$$\overline{M}_{BC} = -2 \times 2 = -4 \text{ kNm}$$

$$\overline{M}_{BD} = \frac{-4\times 4}{8} = -2 \text{ kNm}$$

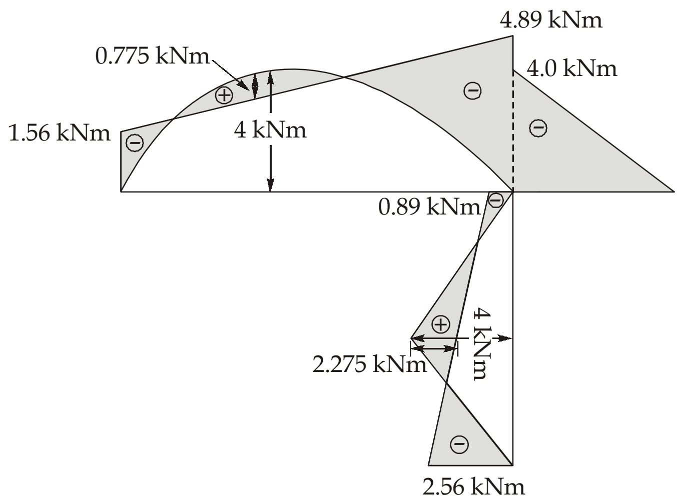
$$\overline{M}_{DB} = +2 \text{ kNm}$$

(ii) Distribution factors

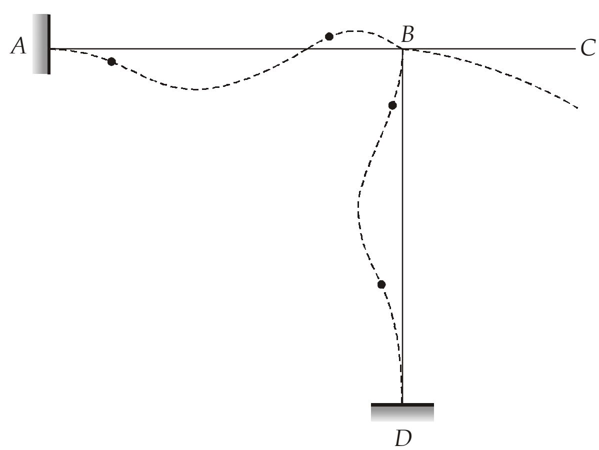
Joints	Member	Relative stiffness	Sum	DF
B	BA	$2I/4$	$3I/4$	2/3
	BC	0		0
	BD	$I/4$		1/3

(iii) Moment distribution

Joint	A	B			D
Member	AB	BA	BC	BD	DB
Distribution factor		2/3	0	1/3	
FEM	–2.67	+2.67	–4.0	–2.0	+2.0
Balance		+2.22	0	+1.11	–
Carry over balance	+1.11	–	–	–	+0.56
Final moments	–1.56	+4.89	–4.0	–0.89	+2.56



Bending moment diagram



Deflected Shape of Frame

Q.5 (d) Solution:

Given Data: Field capacity, F = 25%; Wilting coefficient, ϕ = 10%

Dry unit weight of soil, ρ_s = 1.5 gm/cc; Root zone depth, d = 60 cm

Moisture storage capacity of the soil in the root zone depth, d is given by

$$= \frac{\gamma_s}{\gamma_w} \times d\,[F - \phi] = \frac{\rho_s}{\rho_w} \times d\,[F - \phi] = \frac{1.5}{1} \times 60 \times \left[\frac{25}{100} - \frac{10}{100}\right] = 13.5 \text{ cm}$$

Now, when the moisture content falls to 15%, the deficiency of water depth created will be given by

$$= \frac{\rho_s}{\rho_w} \times d \times [F - \text{fall in moisture content}] = \frac{1.5}{1} \times 60 \times \left[\frac{25}{100} - \frac{15}{100}\right] = 9 \text{ cm}$$

Hence, 9 cm depth of water is the net irrigation requirement.

$\therefore$ **Water application frequency** = $\dfrac{\text{Net irrigation requirement}}{\text{Water depth required in the field}}$

$$\Rightarrow \quad \frac{75}{100} = \frac{9}{\text{Water depth required in the field}}$$

$\Rightarrow$ Water depth required in the field = $\dfrac{9 \times 100}{75}$ = 12 cm

Q.6 (a) Solution:

Let H_a = thickness of sample A

H_b = thickness of sample B

m_{va} = coefficient of volume compressibility of sample A

m_{vb} = coefficient of volume compressibility of sample B

c_{va} = coefficient of consolidation for sample A

c_{vb} = coefficient of consolidated for sample B

Δp_a = increment of load for sample A

Δp_b = increment of load for sample B

k_a = coefficient of permeability for sample A

and k_b = coefficient of permeability of sample B.

We have the following relationship.

$$m_{va} = \frac{\Delta e_a}{1+e_a}\frac{1}{\Delta p_a}, \; m_{vb} = \frac{\Delta e_b}{1+e_b}\frac{1}{\Delta p_b}$$

where e_a is the initial void ratio of sample A and Δe_a is the change in void ratio. Similarly e_b and Δe_b apply to sample B.

$$\therefore \quad \frac{m_{va}}{m_{vb}} = \frac{\Delta p_b}{\Delta p_a}\frac{\Delta e_a}{\Delta e_b}\left(\frac{1+e_b}{1+e_a}\right), \text{ and } T_a = \frac{c_{va}t_a}{H_a^2}, \; T_b = \frac{c_{vb}t_b}{H_b^2}$$

where T_a, t_a, T_b and t_b correspond to samples A and B respectively.

Thus,
$$\frac{c_{va}}{c_{vb}} = \frac{T_a}{T_b}\frac{H_a^2}{H_b^2}\frac{t_b}{t_a}; \quad k_a = c_{va}m_{va}\gamma_w, \; k_b = c_{vb}m_{vb}\gamma_w$$

$$\therefore \quad \frac{k_a}{k_b} = \frac{c_{va}}{c_{vb}}\frac{m_{va}}{m_{vb}}$$

Given e_a = 0.572, and e_b = 0.61

Δe_a = 5.72 – 0.505 = 0.067

Δe_b = 0.610 – 0.557 = 0.053

$$\Delta p_a = \Delta p_b = 180 - 122 = 58 \text{ kN/m}^2, H_a = 1.5H_b$$

But $$t_b = 3t_a$$

We have, $$\frac{m_{va}}{m_{vb}} = \frac{0.067}{0.053} \times \frac{1+0.61}{1+0.572} = 1.29$$

$$\frac{c_{va}}{c_{vb}} = 1.5^2 \times 3 = 6.75$$

$\therefore$ $$\frac{k_a}{k_b} = 6.75 \times 1.29 = 8.7$$

Therefore, the required ratio is 8.7 : 1

Q.6 (b) Solution:

(i) We know, $$G = \frac{W_S}{W_S - (W_3 - W_4)}$$

Here, in this case; $W_S = 1.04$ N; $W_3 = 5.38$ N and $W_4 = 4.756$ N

$\therefore$ $$G = \frac{1.04}{1.04 - (5.38 - 4.756)} = 2.50$$

(ii) If some air is entrapped while the weight, W_3 is taken, the observed value of W_3 will be lower than if water occupied the air space. Since W_3 occurs with negative sign in the denominator, the computed value of G would be lower than the correct value. Since, the air entrapped is given as 3 ml, this space if occupied by water, would have enhanced the weight W_3 by 0.03 N.

$\therefore$ $$\text{Correct value of } G = \frac{1.04}{1.04 - (5.41 - 4.756)} = \frac{1.040}{0.386} = 2.694$$

$$\text{Percentage error} = \left(\frac{2.694 - 2.50}{2.694}\right) \times 100 = 7.2\%$$

Q.6 (c) Solution:

Sol.

The following are the constituent parts of paint:

(i) Base: It is very finely grounded metallic oxide and acts as the body of paint.
Because of film of base, the paint becomes hard and resistive to weathering action.
The most commonly used bases in paints are:
White lead, lead sulphate, zinc oxide and titanium oxide.

(ii) Vehicle: It is used in paints to help it to spread the base over the surface. It acts as a binder between base and pigment and causes it to adhere to the surface to be painted. Vehicle is mixed with the bases to form a paste.

The most commonly used vehicles are:

- Raw linseed oil
- Refined linseed oil
- Pale boiled linseed oil

(iii) Colouring pigment: It is added to the paints to obtain desired final colour of the paint different from that of the base.

(iv) Thinner: It is used in paints to reduce its consistency. It enables the paint to be spread over the surface to be painted with the brush and to penetrate into the surface. Most commonly used thinner is turpentine oil which dries up rapidly and helps to dry the paint soon.

(v) Drier: It is used in paints to accelerate the action of drying. Paints need to be dried soon to avoid the risk to catch dust and dirt. Most commonly used drier is litharge.

(vi) Adulterants: These are used to reduce the cost of paints and also to reduce the weight and to increase its durability. Barium sulphate is widely used as an adulterant because of its cheapness and its property of not reacting with paint.

Q.6 (d) Solution:

Assessing the nature and extent of degradation of environment due to human interference is called Environmental Impact Assessment.

Engineering projects involving development of thermal power, mining operations and even river valley projects have been found to be causing certain adverse and negative impacts on our surrounding environment, which has forced us to make it compulsory to evaluate these adverse impacts in details, well before the project is cleared for execution. With this point in view, all project clearance cells do evaluate and examine the detailed environmental assessment report, which is prepared and submitted along with Detailed Project Report (DPR) of every such project. Submission of such EIAs have been made compulsory by the GOI for all projects, which are likely to cause harm to our surrounding environment.

All such impact assessments should thoroughly examine and discuss the various possible environmental damages, whether pertaining to water pollution, air pollution, ground pollution, noise pollution, or any other kind of environmental pollution and their suggested remedial measures to prevent or to mitigate such hazardous environmental effects.

Methodology adopted for EIA: Environmental Impact Assessment essentially involves the following three steps:

(i) Impact identification: It may be carried out with the help of checklists, matrices or networks. Checklist merely present a list of environmental parameters to be investigated for possible impacts. Matrices are two dimensional checklists in which cause-effect relationships are established by listing possible project activities along one axis and potentially impacted environmental characteristics of conditions along the other. Network illustrates cause condition effect linkages as also temporal dimensions and therefore provide the most comprehensive methodology for impact identification.

(ii) **Prediction of environmental impacts:** It requires the greatest degree of scientific application. This step involves projecting the baseline environmental setting into future, with and without the project, and then performing the necessary calculations for predicting real impacts of the proposed development.

(iii) **Evaluation of impacts:** It calls for conversion of the predicted values for various environmental parameters to a comparable set of units using some system of normalisation. Ideally, the environmental impacts should be expressed in monetary units for easy and objective comparison with other costs and benefits of the project. The major problem arises when while assigning monetary values to intangible parameters. Methods involving numerical rating and ranking or weighting and scaling of environmental impacts are therefore commonly used.

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