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ESE-2021
(MAINS)

QUESTIONS WITH DETAILED SOLUTIONS

CIVIL ENGINEERING

PAPER-II

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CIVIL ENGINEERING

ESE _MAINS_2021_PAPER – II

Questions with Detailed Solutions

SUBJECT WISE WEIGHTAGE

S.No	NAME OF THE SUBJECT	Marks
01	Fluid Mechanics & Hydraulic Machines	106
02	Hydrology	30
03	Irrigation Engineering	10
04	Environmental Engineering	74
05	Geotechnical Engineering	104
06	Surveying	52
07	Transportation Engineering	104

SECTION A

01.

(a). If velocity components for two dimensional flow are given by

$u = \dfrac{x}{x^2+y^2}$ **and** $v = \dfrac{y}{x^2+y^2}$,

Determine the acceleration components in X and Y direction and rotation in Z direction at two points in the flow field (i) 2, 3 and (ii) 4, 5. Coordinates are in meters. (12 M)

Sol: Given, $u = \dfrac{x}{x^2+y^2}$; $v = \dfrac{y}{x^2+y^2}$

$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}$$

$$a_y = u\frac{\partial v}{\partial u} + v\frac{\partial v}{\partial y}$$

$$\frac{\partial u}{\partial x} = \frac{1}{x^2+y^2} + \frac{(x)(-1)(2x)}{(x^2+y^2)^2} = \frac{1}{x^2+y^2} - \frac{2x^2}{(x^2+y^2)^2}$$

$$\frac{\partial u}{\partial y} = \frac{(x)(-1)(2y)}{x^2+y^2} = \frac{-2xy}{(x^2+y^2)^2}$$

$$\frac{\partial v}{\partial x} = \frac{y(-1)(2x)}{(x^2+y^2)^2} = \frac{-2xy}{(x^2+y^2)^2}$$

$$\frac{\partial v}{\partial x} = \frac{1}{x^2+y^2} - \frac{y(-1)(2y)}{(x^2+y^2)^2} = \frac{1}{x^2+y^2} - \frac{2y^2}{(x^2+y^2)^2}$$

$$\therefore\ a_x = \left(\frac{x}{x^2+y^2}\right)\left(\frac{1}{x^2+y^2} - \frac{2x^2}{(x^2+y^2)^2}\right) + \left(\frac{y}{x^2+y^2}\right)\left(\frac{-2xy}{(x^2+y^2)^2}\right)$$

a_x (x =2, y =3) = –0.0178

a_x (x =y, y = 5) = – 0.00238

$$\text{Similarly } a_y = \left(\frac{x}{x^2+y^2}\right)\left(\frac{-2xy}{(x^2+y^2)^2}\right) + \left(\frac{y}{x^2+y^2}\right)\left(\frac{1}{x^2+y^2} - \frac{2y^2}{(x^2+y^2)^2}\right)$$

a_y (x =2, y = 3) = – 0.01175

a_y (x = 4, y = 5) = – 0.00297

Rotation $\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = \frac{1}{2}\left(\frac{-2xy}{(x^2+y^2)^2} - \left(\frac{-2xy}{(x^2+y^2)^2}\right)\right) = 0$

$\therefore$ Rotation is 0 for any coordinates as it is irrotational flow.

(b). What are the different forces acting in a moving fluid? Also discuss different similarity model laws used to study the dynamic similarity of a prototype. (12 M)

Sol: Types of Forces Present in a Moving Liquid are:-

i) Inertia Force,
ii) Viscous Force,
iii) Gravity Force,
iv) Surface Tension Force,
v) Pressure Force,
vi) Compressibility force, and
vii) Elastic Force etc.

Type of Forces Acting in the Moving Fluid

Inertial force : It is equal to product of the mass and acceleration of the moving fluid.

$$F_i = \rho A V^2$$

Viscous force: It is equal to the shear stress caused due to viscosity and surface area of the flow. It is present in the flow problems where viscosity is having an important role to play.

$$F_v = \tau A = \mu \frac{du}{dy} A = \mu \frac{U}{d} A$$

Gravity force : Product of mass and acceleration due to gravity.

$$F_g = \rho A L g$$

Pressure force: Product of pressure intensity and flow area.

$$F_p = pA$$

Surface tension force: Product of surface tension and the length of the surface of the flowing fluid.

$$F_s = \sigma d$$

Elastic force: Product of elastic stress and area of the flow.

$$F_e = \text{Elastic stress} \times \text{Area} = KA$$

Different Similarity Model Laws:

The laws on which models are designed for dynamic similarity are called as model laws or similarity law.

- Performance of the prototype can be predicted from tests made with model. With the help of similarity laws the results obtained from experiments done with air or water can be applied to a fluid.
- Three type of similarities must exist between the model and prototype.

1. Geometric Similarity:

The ratio of all corresponding linear dimension in the model and prototype are equal.

2. Kinematic Similarity:

It means the similarity of motion between model and prototype. Thus kinematic similarity is said to exist between the model and the prototype if the ratios of the velocity and acceleration at the corresponding points in the model and prototype are the same in magnitude; the directions also should be parallel.

3. Dynamic Similarity:

It means the similarity of forces between model and prototype. Thus dynamic similarity is said to exist between the model and the prototype if the ratios of the forces acting at the corresponding points in the model and prototype are the same in magnitude; the directions also should be parallel.

- For the dynamic similarity between the model and the prototype the ratio of the corresponding forces acting at the corresponding points in the model and prototype should be equal.

- It means for dynamic similarity between the model and prototype, the dimensionless numbers should be same for model and prototype.
- It is quite difficult to satisfy the condition that all the dimensionless numbers are the same for the model and prototype. Therefore model are designed on the basis of equating the dimensionless number which dominate the phenomenon.

Following are the dynamic similarity laws:
1. Reynolds model law
2. Froude model law
3. Euler model law
4. Weber model law
5. Mach model law

Reynolds model law: (Pipe flow, sub-marines, aeroplane etc)

$$[R_e]_m = [R_e]_p \Rightarrow \frac{V_m \rho_m d_m}{\mu_m} = \frac{V_p \rho_p d_p}{\mu_p}$$

Froude's model law: (Free-surface flow, jet from orifice or nozzle etc)

$$[F_r]_m = [F_r]_p \Rightarrow \frac{V_m}{\sqrt{g_m L_m}} = \frac{V_p}{\sqrt{P_p L_p}}$$

Euler's model law: (Pressure force is a dominant force)

$$[E_u]_m = [E_u]_p \Rightarrow \frac{V_m}{\sqrt{p_m / \rho_m}} = \frac{V_p}{\sqrt{p_p / \rho_p}}$$

Weber model law: (Surface tension is a dominant force)

$$[W_e]_m = [W_e]_p \Rightarrow \frac{V_m}{\sqrt{\sigma_m / \rho_m L_m}} = \frac{V_p}{\sqrt{\sigma_p / \rho_p L_p}}$$

Mach model law: (Velocity of flow is comparable to the velocity of sound; compressible flow)

$$[M]_m = [M]_p \Rightarrow \frac{V_m}{\sqrt{K_m / \rho_m}} = \frac{V_p}{\sqrt{K_p / \rho_p}}$$

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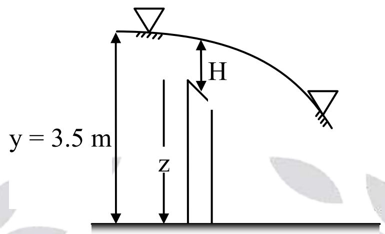
(c). A stream has a width of 25 m, depth of 2.5 m and mean velocity of 1.5 m/sec. Find the height of weir to be constructed on the stream floor to raise the water level by 1 m. Assume value of discharge coefficient as 0.95. (12 M)

Sol: Given : $C_D = 0.95$, V = 1.5 m/sec



width of stream

B = 25 m

depth of stream

y = 2.5 m

Area of flow, $A = 25 \times 2.5 = 62.5\ m^2$

Mean velocity of flow, $V = 1.5 m sec$

$Q = AV = 62.5 \times 1.5 = 93.75\ m^3/sec$

The weir to be constructed to raise the heater level of 1 m

$\therefore$ Depth of flow on the upstream of the weir

= 2.5 + 1 = 3.5 m

$\therefore\ A = By = 25 \times 3.5 = 87.5\ m^2$

$$\therefore \text{ Velocity of approach } (V_a) = \frac{Q}{25 \times 3.5}$$

$$= \frac{93.75}{87.5} = 1.071 m/sec$$

$$h_a = \frac{V_a^2}{2g} = \frac{(1.071)^2}{2\times 9.81} = 0.0584\,m$$

$$\text{Now, } Q = \frac{2}{3}c_d L\sqrt{2g}\left[(H+h_a)^{3/2} - h_a^{3/2}\right]$$

$$93.75 = \frac{2}{3}\times 0.95\times 25\times\sqrt{2\times 9.81}\left[(H+0.0584)^{3/2} - (0.0584)^{3/2}\right]$$

H = 1.1636 m

The height of weir above the bottom of the steam (z) = 3.5 – H

= 3.5 – 1.1636

= 2.3364 m

(d). Define 'noise' and explain as to why and how it should be regarded as an environmental pollutant. Also explain briefly the major factors and actions that may help in noise abatement in a modern society. (12 M)

Sol: **Noise:** Unwanted sound pollutant which produces undesirable psychological and physiological effects in an individual, by interfering with one's social activities like rest, work, recreation etc.

It is regarded as a "pollutant" due to following reasons: -

- Noise inducer annoyance
- Noise inducer disease
- Came sleep lesser
- Came communication interference
- Inducer hearing loss
- Affects wildlife

Factors that may help in Noise Abatement in Modern Society are:

- Forestation
- Use of noise absorbents

- Proper lubricating and better maintenance of machines
- Acoustic zoning
- Legislature Measures
- Control at receiver's end
- Suppression of sound (noise) at source

(e). A wastewater treatment plant discharges 1.0 m^3/sec of effluent having an ultimate BOD of 45.0 mg/L into a river flowing at 10.0 m^3/sec. Just upstream from the discharge point, the river water has an ultimate BOD of 4.0 mg/L. the deoxygenation constant (k_d) is 0.22/day. Answer the following:

(i). Assuming complete and instantaneous mixing, what would be the ultimate BOD of the mixture of waste and river just downstream from the outfall? (6 M)

Sol: Plant waste water

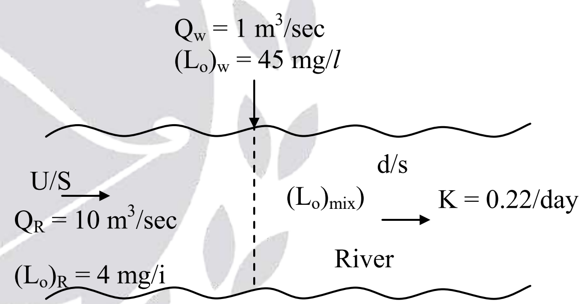
$Q_P = 1 m^3/s$

$(L_O)_P = 45$ mg/L

River

$Q_R = 10 m^3/s$

$(Lo)_R = 4$ mg/L



$$(L_0)_{mix} = \frac{Q_R (L_o)_R + Q_w (L_0)_w}{Q_R + Q_w} : \frac{10 \times 4 + 1 \times 45}{10+1} = 7.72 \,\text{mg}/1$$

(ii). Assuming a constant cross-sectional area for the river equal to 60 m^2, what ultimate BOD would you expect to find at a point 10.0 km downstream? (6 M)

Sol: As ultimate BOD does not depend on distance or c/s area it would be same, hence BOD at 10 km downstream also will be 7.72 mg/l

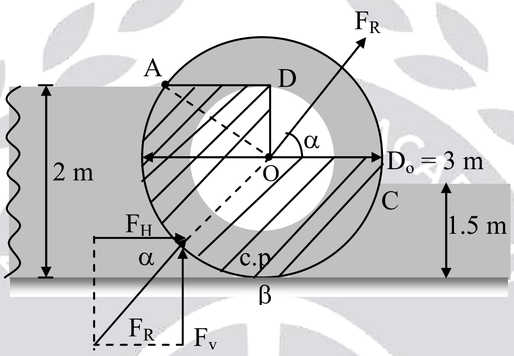
02.

(a). **A cylindrical gate of 3.0 m dia and having 4.0 m length is made of 60 mm thick steel sheet of 7.8 ton/m^3 density. The gate has water on both its sides.**

(i). **Water level is up to 2.0 m depth from bottom of gate on the left side and up to 1.5 m depth on the right side of the gate. Determine the magnitude, location and direction of the resultant hydrostatic force. Also determine whether the gate will float in this case or not.**

(10 M)

Sol:



$$F_H = F_{H,AB} - F_{H,\,BC}$$
$$= \{P_{C.G}\ A\}_{proj,\ AB} - \{P_{C.G}.\ A\}_{proj,\ BC}$$
$$= 9810 \times 1 \times (2 \times 4) - 9810 \times 0.75 \times (1.5 \times 4)$$
$$= 34.335 \text{ kN } (\rightarrow)$$

The vertical component is given by,

$F_V = \rho g\ V_{ODABC}$

i.e. $F_V = \rho g L\ [A_{OABC} + A_{ODA}]$ …………… (1)

Now, $\theta = \sin^{-1}\left(\dfrac{0.5}{1.5}\right) = 19.47^\circ$

$$\therefore\ A_{OABC} = \left(\frac{180 + 19.47}{360}\right) \times \pi \times 1.5^2$$
$$= 3.917 \text{ m}^2$$

and $\quad A_{ODA} = \dfrac{1}{2} \times AO \times OD = \dfrac{1}{2} \times R_O \cos\theta \times R_O \sin\theta$

$$= \frac{1}{2} \times \sin(19.47) \times \cos(19.47) \times 1.5^2$$

$$= 0.3535 \text{ m}^2$$

$\therefore$ $F_V = 9810 \times 4 \times (3.917 + 0.3535)$

$= 167.57$ kN (↑)

As pressure distribution is redial over the cylindrical surface, the resultant force must also be in the radial direction. Hence for the cylinder, the resultant force passes through centre of pressure as well as centre of the cylinder as shown in the figure. Hence, centre of pressure can be located by simply knowing angle of inclination of resultant force (α).

$$\therefore \quad \alpha = \tan^{-1}\left(\frac{F_V}{F_H}\right) = \tan^{-1}\left(\frac{167.57}{34.335}\right)$$

$= 78.42^o$

Let us calculate weight of the gate,

$w = \rho_s\, g\, V_s = \rho_s g \pi \left(R_0^2 - R_1^2\right) \times L$

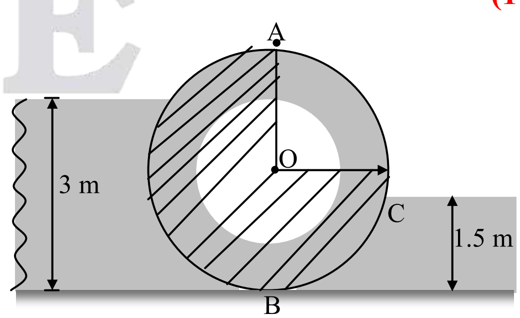
$= 7800 \times 9.81 \times \pi\, (1.5^2 - 1.44^2) \times 4$

$= 169.92$ kN

As $w > F_V$, the cylindrical gate will not float

(ii). If the water level rises up to 3.0 m on the left of the gate (up to the top of the gate), determine whether the gate will float or not. If yes, what should be the thickness of the gate sheet to prevent it from floating? (10 M)

Sol:



$F_V = \rho g\, V_{OABC}$

$= \rho g\, L\, (A_{OABC})$

$$= 9810 \times 4 \times \frac{3}{4} \times \pi \times 1.5^2 = 208.03 \text{ kN}$$

As $F_V > W$ the gate will float. In order to keep the gate in current position thickness of the gate must be increased.

In new equilibrium position,

$F_V = W$

$= \rho_s g L \times \pi\left(R_o^2 - R_i^2\right) \times L$

i.e. $208.03 \times 10^3 = 7800 \times 9.81 \times \pi \left(1.5^2 - R_i^2\right) \times 4$

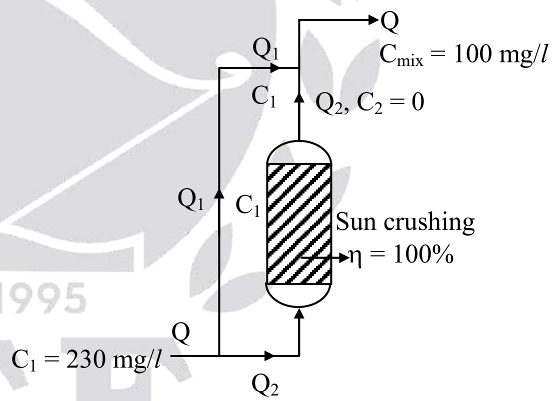
$\Rightarrow R_i = 1.426$ m

$\therefore$ $t = R_0 - R_i = 1.5 - 1.426 = 0.074$ m = 74 mm

$\therefore$ Thickness should be greater than 74 mm for preventing cylinder to float.

(b). A water softener has 0.05 m^3 of ion exchange resin with an ion exchange capacity of 40 kg/m^3. The water requirement of users is 1000 litres per day. If the water contains 230 mg/L of hardness as $CaCO_3$ and users want to soften it to 100 mg/L as $CaCO_3$, how much water should bypass the softener daily ? What is the time between regeneration cycle if it is assumed that the complete saturation of the resin occurs before regenerating? (20 M)

Sol: Q_1 = flow to be bypassed



$$C_{mix} = \frac{Q_1C_1 + Q_2C_2}{Q}$$

$$100 = \frac{Q_1 \times 230 + 0}{1000}$$

$$Q_1 = \frac{1000 \times 100}{230} = 434.78 \text{lit/day}$$

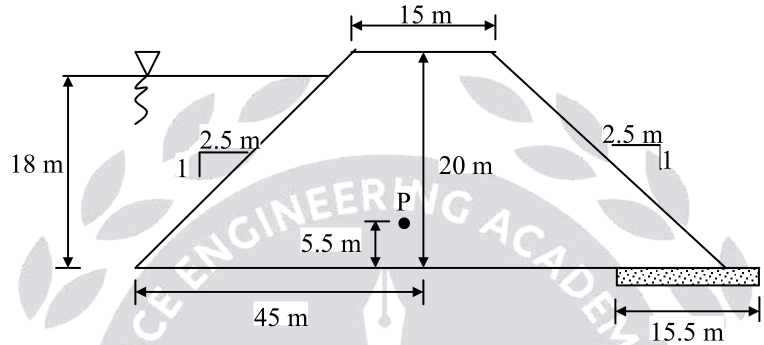
$Q_2 = (1000 - 434.78)$ lit/day

Time between regenerated cycles

$$= \frac{\text{Total Capacity of exchanger}}{\text{Total Hardness to be removed}}$$

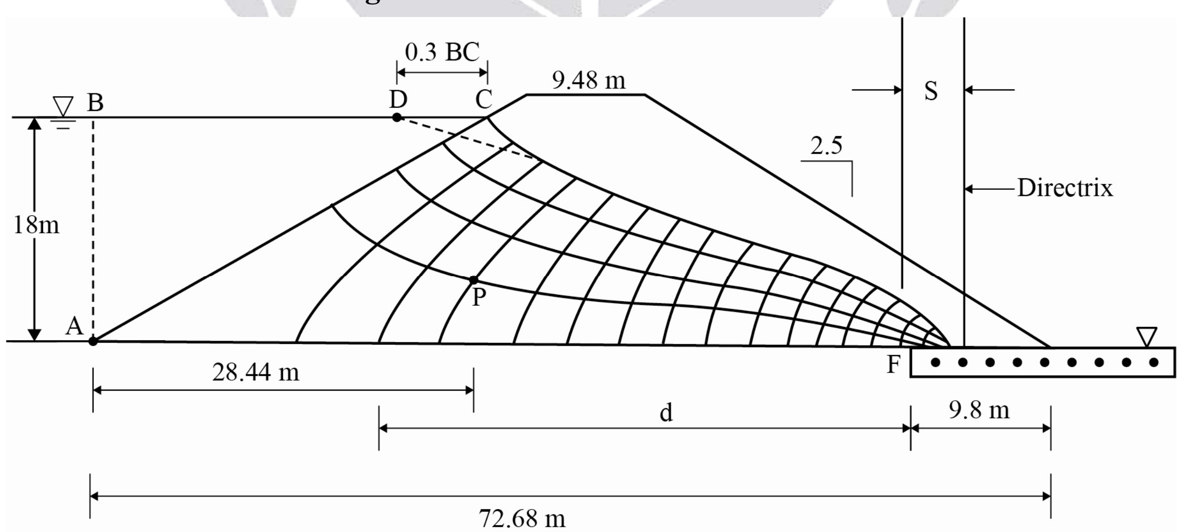
$$= \frac{40 \times 0.05}{(1000 - 434.78) \times \dfrac{1}{10^6} \times 230} = 15.38 \text{days}$$

(c). **A homogeneous anisotropic embankment dam section is shown in the figure, the coefficient of permeability in the x and z directions being 5×10^{-8} m/s and 2×10^{-8} m/s respectively. Construct the flow net and determine the quantity of seepage through the dam. What is the pore water pressure at point 'P'?** **(20 M)**



Sol: As there is anisotropic coefficients of permeability, the section is transformed by keeping the dimensions in the z-direction unchanged but reducing the dimensions in the x-direction by a factor,

Transformed flow net diagram:



$$\sqrt{\frac{k_z}{k_x}} = \sqrt{\frac{2\times10^{-8}}{5\times10^{-8}}} = 0.632$$

The transformed section is drawn as shown to a scale of 1 cm = 5 m

The phreatic line (parabola) is drawn units F as focus and p assign through D.

CD = 0.3 BC

Focal distance, $S = \sqrt{H^2+d^2} - d$

H = 18 m, d = 43 m

$\therefore\ S=\sqrt{18^2+43^2} - 43 = 3.62$ m

From the flow net drawn,

Number of flow channels, $N_f = 4$

Number of potential drops, $N_d = 16$

Equivalent coefficient of permeability, $k'=\sqrt{k_x.k_z}$

$k'=\sqrt{5\times10^{-8}\times2\times10^{-8}} = 3.16 \times 10^{-8}$ m/s

Quantity of see page, $q = k'H.\frac{N_f}{N_d}$

$$= 3.16 \times 10^{-8} \times 18 \times \frac{4}{16} = 14.22 \times 10^{-8}\ m^3/s/m$$

To find pore water pressure at point 'p'

Total head at p = $H - \frac{H}{N_d}.n$

$= 18 - \frac{18}{16} \times 3$

= 14.63 m

Elevation head at p = 5.5 m

$\therefore$ Pressure head = 14.63 – 5.5 = 9.13 m

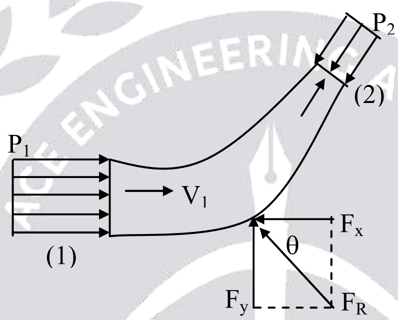
Pore water pressure = γ_w × pressure head

= 9.81 × 9.13 = 89.57 kN/m^2

03.

(a). Alignment of a water pipeline has been changed by 45° in horizontal plane using a reducing bend having 40 cm and 20 cm dia at the beginning and end of the bend respectively. A discharge of 400 lit/sec is flowing in the pipeline. The pressure in the pipeline at the starting end of the bend is 3000 bar. The frictional head loss due to the bend may be assumed as 5% of the kinetic energy at the exit of the bend. Determine the force exerted on the bend. Also determine the direction of resulting force. (20 M)

Sol: Assuming given pressure is gauge pressure. All calculations are done using gauge pressure.



$$V_1 = \frac{Q}{A_1} = \frac{0.4\times 4}{\pi\times 0.4^2}$$

$$= 3.183 \text{ m/s}$$

$$V_2 = \frac{Q}{A_2} = \frac{4\times 0.4}{\pi\times 0.2^2}$$

$$= 12.73 \text{ m/s}$$

By Bernoulli's equation,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_f$$

$$\therefore \quad P_2 = P_1 - \frac{\rho}{2}\left(V_2^2 - V_1^2\right) - \rho g\ h_f$$

$$= P_1 - \frac{\rho}{2}\left(V_2^2 - V_1^2\right) - \rho g \times 0.05 \times \frac{V_2^2}{2g}$$

$$= P_1 - \frac{\rho}{2}\left(1.05\ V_2^2 - V_1^2\right)$$

$$= 3000\times10^5 - \frac{10^3}{2}\times\left(1.05\times12.73^2 - 3.183^2\right)$$

$$= 2999.2 \text{ bar}$$

Applying momentum equation for the C.V

$$\vec{F} = \left(\dot{m}\ \vec{V}\right)_{out} - \left(\dot{m}\ \vec{V}\right)_{in}$$

$$x: P_1A_1 - P_2A_2\cos45^0 - F_x = \dot{m}\left[V_2\cos45^0\right] - \dot{m}\left[V_1\right]$$

$$F_x = P_1A_1 - P_2A_2\cos45 - \dot{m}\left(V_2\cos45^\circ - V_1\right)$$

$$= 3000\times10^5\times\frac{\pi}{4}\times0.4^2 - 2999.2\times10^5\times\frac{\pi}{4}0.2^2\times\cos45 - 400\times\left(12.75\cos45 - 3.183\right)$$

$$= 31034.24 \text{ kN}$$

Similarly

$$-P_2A_2\sin45 + F_y\dot{m}\left[V_2\sin45\right] - \dot{m}(0)$$

$$\therefore\ F_y = P_2\ A_2\sin45 + \rho Q + V_2\sin45$$

$$= 2999.2\times10^5\times\frac{\pi}{4}\times0.2^2\times\sin45^\circ + 10^3\times0.4\times12.73\times\sin45^\circ$$

$$F_y = 6666.15\ \text{kN}$$

$$F_R = \sqrt{{F_x}^2 + {F_y}^2}$$

$$= \sqrt{31034.24^2 + 6666.15^2}$$

$$= 31742.85 \text{ kN}$$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = 12.1^\circ$$

(b). Determine the size and depth of a high rate single stage trickling filter for treating the following domestic and industrial wastewater of a town of 50,000 populations. Also determine the efficiency of filter and BOD_5 of the effluent.

- **Domestic sewage @ 150 litres per capita per day having 225 mg/L of BOD_5, and**
- **Industrial wastewater @ 2,00,000 litres per day having 650 mg/L of BOD_5.**

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Assume the following data :

- **BOD_5 removal in primary clarifier = 35%**
- **Permissible organic loading of trickling filter = 900 g/day/m^3 (excluding recirculated sewage)**
- **Recirculation ratio = 1.0**
- **Permissible hydraulic loading = 20 m^3/day/m^2 (including recirculated sewage)**

(20 M)

Sol: High rate trickling filter

Population = 50000

Per capita flow = 150 lit/day/per capita

$Q_d = 50000 \times 150$ lit/day

$y_d = 225$ mg/l

$Q_i = 200000$ lit/day

$y_i = 650$ mg/l

$$y_{mix} = \frac{Q_d \times y_d + Q_i \times y_i}{Q_d + Q_i} = 236.04 \text{ mg/l}$$

$$Q_{mix} = Q_d + Q_i = (50000\times150+200000)\times\frac{1}{10^6} \text{ MLD} = 7.7 \text{ MLD}$$

BOD applied to TF $\quad y_1 = 236.04 - \frac{35}{100}\times 236.04$

$= 153.426$ mg/l

OLR = 900 gm/day/m^3 = 900×10^{-3} kg/day/m^3

$$OLR = \frac{Q \times y_1}{V}$$

$$\text{Volume of TF(V)} = \frac{Qy_1}{OLR} = \frac{77 \times 153.426}{900\times10^{-3}} = 1312.644 m^3$$

$$\text{Surface area TF (As)} = \frac{2Q_{mix}}{HLR} = \frac{2\times77\times10^6}{20} = 770 m^2$$

$$\frac{\pi}{4}d^2 = 770 \Rightarrow \text{dia of TF} = \sqrt{\frac{770\times4}{\pi}} = 31.32 m$$

Diameter of TF = 31.32 m

$$\text{Depth of TF} = \frac{V}{As} = \frac{1312.644}{770} = 1.705\,\text{m}$$

$$\eta_{TF} = \frac{100}{1 + 0.44\sqrt{\frac{Qy_1}{VF}}}$$

$$R = 1 \Rightarrow F = \frac{1+R}{(1+0.1R)^2} = 1.65$$

$$= \frac{100}{1 + 0.44\sqrt{\frac{7700 \times 10^3 \times 153.42 \times 10^{-6}}{1312.64 \times 1.65}}} = 75.47\%$$

$$\eta = \frac{y_1 - y_2}{y_1} \times 100 \Rightarrow 75.47 = \frac{153.426 - y_2}{153.426} \times 100$$

$y_2 = 37.63$ mg/l

$\therefore$ Effluent BOD is 37.63 mg/l

(c). Calculate the infiltration rate and cumulative infiltration after 1.50 hours of rainfall of 4.0 cm/hr intensity on a silt loam soil with an initial effective saturation of 25%. Value of saturated hydraulic conductivity is 0.65 cm/hr, effective porosity of silt loam soil is 0.486, and wetting front soil suction head is 16.70 cm. (20 M)

Sol: For silt loam soil

Wetting front soil suction head = 16.70 cm

Saturated hydraulic conductivity K = 0.65 cm/hr

Effective porosity of silt loam (n) = 0.486

(θ) Initial effective saturation = 25%

$\theta n = 25\% \times 0.486 = 0.1215$

$\Delta\theta = n - \theta n = 0.486 - 25\% \times 0.486$

$\Delta\theta = 0.3645$

$\psi\Delta\theta = 16.7 \times 0.3645 = 6.098$ cm

Cumulative infiltration after t = 1.5 hrs:

Kt = 0.65 cm/hr × 1.5 hr

Kt = 0.975 cm

From Green-Ampt Method Relation:

$$F(t) = Kt + \psi\Delta\theta \ell n\left(1 + \frac{F(t)}{\psi\Delta\theta}\right)$$

$$0.975 = F(t) - 6.087.\ell n\left(1 + \frac{F(t)}{6.087}\right)$$

After number of iteration (F) converges to (4.12 cm)

Infiltration rate after 1.5 hr from Green Ampt equation

$$f = K\left(\frac{\psi\Delta\theta}{F(t)} + 1\right)$$

$$f = 0.65 \times \left(\frac{6.087}{4.12} + 1\right)$$

f = 1.61 cm/hr

04.

(a). **An inward flow reaction turbine works under a head of 40.0 m and discharge of 12 cu.m/sec. the speed of the runner is 350 r.p.m. At the inlet tip of runner vane, the peripheral velocity of wheel is 25.20 m/s and the radial velocity of flow is 8.40 m/s. If the overall efficiency and hydraulic efficiency of the turbine are 80% and 90% respectively, *determine***

(i) power developed by the turbine in kW,

(ii) diameter and width of runner at inlet,

(iii) guide blade angle at inlet,

(iv) inlet angle at runner vane, and

(v) diameter of runner at outlet.

Assume flow is radial at outlet. Also assume no blade friction and radial velocities at inlet and outlet are equal

(20 M)

Sol:

Given data

$H = 40$ m

$Q = 12\ m^3/s$

$N = 350$ rpm

$u_1 = 25.2$ m/s

$V_{f_1} = 8.4$ m/s

$\eta_0 = 80\%$

$\eta_h = 90\%$

Find

(i) S.P = ?

(ii) $D_1, B_1 = ?$

(iii) $\alpha_1 = ?$

(iv) $\beta_1 = ?$

(v) $D_2 = ?$

$\text{S.P} = \eta_0\,\rho g Q H$

$= 0.8 \times 9810 \times 12 \times 40 = 3767$ kW

$$u_1 = \frac{\pi D_1 N}{60}$$

$$\therefore\ 25.2 = \frac{\pi \times D_1 \times 350}{60}$$

$\Rightarrow D_1 = 1.375$ m

Now, $Q = \pi D_1 B_1\ V_{f_1}$

$12 = \pi \times 1.375 \times B1 \times 8.4$

$\therefore\ B_1 = 0.331$ m

The hydraulic efficiency is given by,

$$\eta_h = \frac{V_{w_1} u_1}{gH}$$

$$0.3 = \frac{V_{w_1} \times 25.2}{9.81 \times 40}$$

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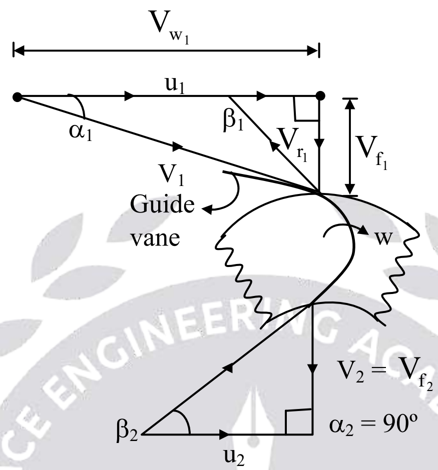
$\therefore\ v_{w_1} = 14.01$ m/s

As $u_1 > v_{w_1}$ runner type is fast runner. The velocity triangles for fast runner francis turbine are shown below.



From figure,

$$\tan\alpha_1 = \frac{v_{f_1}}{v_{\omega 1}}$$

$$\therefore\ \alpha_1 = \tan^{-1}\left(\frac{8.4}{14.01}\right) = 30.9°$$

Similarly, from figure,

‘

$$\tan\beta_1 = \frac{V_{f1}}{u_1 - V_{\omega 1}}$$

$$\therefore\ \beta_1 = \tan^{-1}\left(\frac{8.4}{25.2 - 14.01}\right) = 36.9°$$

$Q = A_{f2}\, V_{f2}$

$$= \pi D_2 B_2 V_{f2}$$

$$D_2 = \frac{Q}{\pi B_2 V_{f2}}$$

$$= \frac{12}{\pi \times B_2 \times 8.4}$$

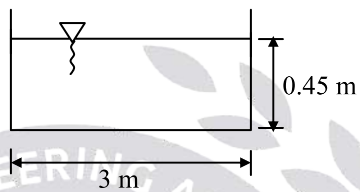
As B_2 is not given D_2 cannot be calculated

(b).

(i). The depth of flow of water at a certain section of a rectangular channel 3 m wide is 0.45 m. The discharge through the channel is 3.1 m^3/s. Determine whether a hydraulic jump will occur, and if so, determine its height and loss of energy per kg of water. (10 M)

Sol: **Given:** $Q = 3.1\ m^3/s$

C/S



Fraud No $F_r = \frac{v}{\sqrt{gD}}$

$$v = \frac{Q}{A} = \frac{3.1}{3 \times 0.45} = 2.296\ m/s$$

$$D = \frac{A}{T} = \frac{B \times y}{B} = y = 0.45\ m$$

$$\therefore F_r = \frac{2.296}{\sqrt{9.81 \times 0.45}} = 1.092 > 1$$

As F_r is greater than 1, the given flow is super critical.

As we know that hydraulic jump is always occurs when flow changes from supercritical to sub critical.

Hence, hydraulic jump will occur

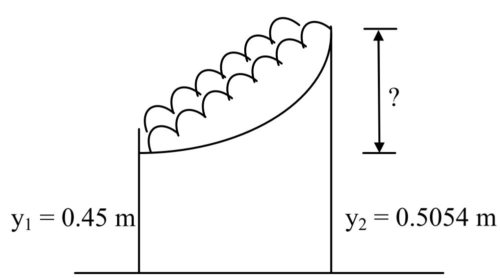
To find the conjugate depths to corresponding ($y_1 = 0.45$ nm) depth

$$y_2 = \frac{y_1}{2}\left[-1 + \sqrt{1 + 8F_{r1}^2}\right]$$

$$y_2 = \frac{0.45}{2}\left[-1 + \sqrt{1 + 8 \times 1.092^2}\right]$$

$y_2 = 0.5054$ m

Hydraulic jump:



Height of HJ = $y_2 - y_1 = 0.5054 - 0.45$

$= 0.0554$ m $= 55.4$ mm

Energy loss in 'm'

$$\Delta E = \frac{(y_2 - y_1)^3}{4y_1y_2} = \frac{(0.5054 - 0.45)^3}{4 \times 0.45 \times 0.5054} = 1.869 \times 10^{-4}\ m$$

Energy loss per unit weight = 1.869×10^{-4} m

Energy loss per unit mass of water (kg) = $1.869 \times 10^{-4} \times g$

$= 1.869 \times 10^{-4} \times 9.81$

$$\Delta E = 1.8334 \times 10^{-3} \frac{J}{kg}$$

(ii). The inflow hydrograph to a river reach is given in the table below. Determine the outflow hydrograph from this reach if coefficient K = 2.4 h, X = 0.15. Initial outflow in the reach is 85 m^3/s. Routing time step Δt = 1 h. (10 M)

S.No.	Routing Period (hr)	Inflow (m^3/s)
1	1	93
2	2	137
3	3	208
4	4	320
5	5	442
6	6	546
7	7	630
8	8	678
9	9	691
10	10	675
11	11	634
12	12	571
13	13	477
14	14	390
15	15	329
16	16	247
17	17	184
18	18	134
19	19	108
20	20	90

Sol: K = 2.4 hr, X = 0.15, Q =85 m^3/sec, Δt = 1 hr

$$C_0 = \frac{-Kx + 0.5\Delta t}{k - kx + 0.5\Delta t} = \frac{-2.4 \times 0.15 + 0.5 \times 1}{2.4 - 2.4 \times 0.15 + 0.5 \times 1} = 0.055$$

$$C_1 = \frac{kx + 0.5\Delta t}{k - kx + 0.5\Delta t} = 0.338$$

$C_2 = 1 - C_0 - C_1 = 1 - 0.055 - 0.338 = 0.607$

$Q_n = C_o I_n + C_1 I_{n-1} + C_2 Q_{n-1}$

$Q_2 = C_o I_2 + C_1 I_1 + C_2 Q_1$

$= 0.055 \times 137 + 0.338 \times 93 + 0.607 \times 85 = 90.564$ m^3/sec

Similarly other outflow discharges will be calculated

Time	**U/S F HG I m^3/sec**	**U/S FHG (out flow hydrograph) Q m^3/sec**
1	93	85
2	137	90.564
3	208	112.718
4	320	156.324
5	442	227.358
6	546	317.432
7	630	411.879
8	678	500.24
9	691	536.265
10	675	596.196
11	634	624.91
12	571	625.018
13	477	598.618
14	390	543.671
15	329	479.923
16	247	416.1
17	184	346.179
18	134	279.692
19	108	221.005
20	90	175.604

(c).

(i). **A city has its catchments area of 7500 hectares. If the population density of the city is 200 persons per hectare and the water is supplied at the rate of 175 litres per capita per day, what would be the design flow for a combined sewer? take intensity of rainfall equal to 30 mm/hour, average runoff coefficient equal to 0.50 and only 75% of water supplied contributes to the sewage. Also, peak discharge factor should be taken as 3. 0. (10 M)**

Sol: A = 7500 ha

Population density = 200/hectare

Population = 7500 × 200 = 150000

Per capita water supply = 175 lpcd

Sewage factor = 0.75

Peak discharge factor = 3

Q_{sewage} = population × per capita water supply × Sewage factor × Peak discharge factor

$$= \frac{150000 \times 175 \times 0.75 \times 3}{10^3 \times 24 \times 60 \times 60} = 6.835 \text{ m}^3/\text{sec}$$

$$Q_{rainfall} = CIA = \frac{0.5 \times 30 \times 10^{-3} \times 7500 \times 10^4}{3600} = 312.5 \text{ m}^3/\text{sec}$$

$Q_{design} = Q_{sewage} + Q_{rainfall} = 6.835 + 312.5 = 319.335 \text{ m}^3/\text{sec}$

Design flow for combined sewer = 319.34 m^3/sec

(ii). **What do you understand by aerobic digestion? What are its advantages and disadvantages? (10 M)**

Sol: Decomposing the sludge by employing aerobic bacteria by supplying oxygen externally employing surface aerator is known as aerobic digestion.

Advantages:

(i) Digestion occur very fast.

(ii) The process usually run at ambient temperature.

(ii) Process is less complex.

Disadvantages:

(i) Huge biomass is produced.

(ii) Operation cost is high due to external supply of O_2.

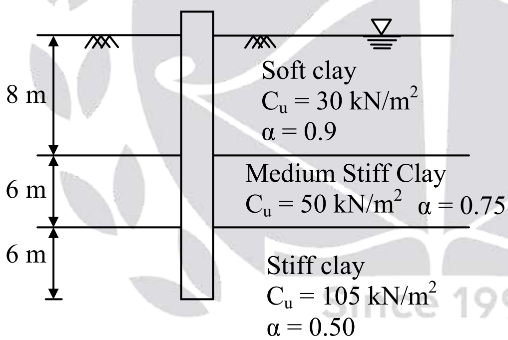
(iii) Energy yield is less.

SECTION B

05.

(a). A concrete pile 450 mm in diameter and 20 m long is driven through a system of layered cohesive soil. The top layer is 8 m thick and comprises of soft clay with cohesion of 30 kN/m^2 and adhesion factor of 0.90. The middle layer which is medium stiff clay has a thickness of 6 m and undrained cohesion of 50 kN/m^2 with adhesion factor of 0.75. The bottom-most layer which is stiff strata extends to a great depth with undrained cohesion of 105 kN/m^2 and adhesion of 0.50. Compute the ultimate and allowable capacity of pile if the factor of safety assumed is 3.0. The water table is observed to be at ground level. (12 M)

Sol:



It is assumed that there will not be any negative skin friction on the pile.

Considering pile tip resistance and skin friction, the ultimate load capacity of pile,

$Q_u = A_b\, C_u\, N_C + \sum(A_s.\ \alpha.\ C_u)$

$$Q_u = \frac{\pi}{4}D^2.C_u.N_C + \Sigma(\pi D.L.\alpha.C_u)$$

N_c is assumed to be 9 for clays

$$\therefore Q_u = \frac{\pi}{4}\times 0.45^2\times 105\times 9 + \pi\times 0.45\times 8\times 0.9\times 30 + \pi\times 0.45\times 6\times 0.75\times 50 + \pi\times 0.45\times 6\times 0.5\times 105$$

$= 150.30 + 305.36 + 318.09 + 445.32 = 1219.07$ kN

Safe capacity of pile, $Q_s = \frac{Q_u}{F}$

$$= \frac{1219.07}{3} = 406.36 \text{ kN}$$

(b). With a neat labelled sketch of stress conditions and failure envelope in a triaxial compression test, derive the relations between major and minor principal stress in terms of cohesion and angle of internal friction. (12 M)

$$\sigma_1 = \sigma_3 N_\phi + 2c\sqrt{N_\phi}$$

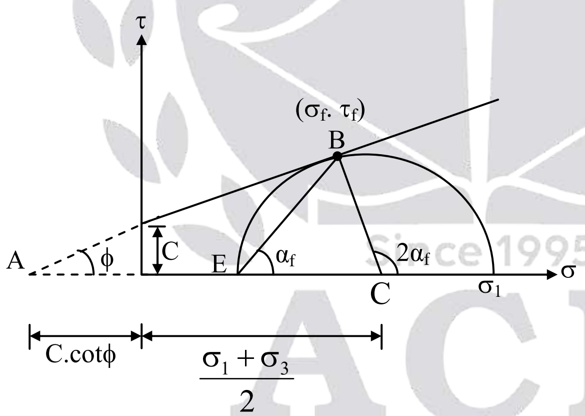
σ_1 : Major principal stress

σ_3 : Minor principal stress

c : Cohesion

ϕ : Angle of internal friction

Sol: The triaxial compression test stress condition and the failure envelope is shown below



The stress on failure plane at failure is indicated by the point B on the Mohr circle.

The failure plane is indicated by the line BE

The failure plane makes an angle α_f with the major principal plane

From the triangle ABC, $\sin\phi = \frac{BC}{AC}$

$$\sin\phi = \frac{\sigma_1 - \sigma_3}{C.\cot\phi + \frac{\sigma_1 + \sigma_3}{2}}$$

$\sigma_1 - \sigma_3 = 2\ C\cos\phi + (\sigma_1 + \sigma_3)\sin\phi$

$\sigma_1 - \sigma_1\sin\phi = \sigma_3\sin\phi + \sigma_3 + 2\ C\cos\phi$

$\sigma_1(1 - \sin\phi) = \sigma_3(1 + \sin\phi) + 2\ C\cos\phi$

$$\sigma_1 = \sigma_3\frac{(1+\sin\phi)}{(1-\sin\phi)} + 2C\frac{\cos\phi}{(1-\sin\phi)}$$

$$\sigma_1 = \sigma_3\frac{1+\sin\phi}{1-\sin\phi} + 2C\sqrt{\frac{1+\sin\phi}{1-\sin\phi}}$$

It is also expressed in the form of

$$\sigma_1 = \sigma_3\tan^2\left(45 + \frac{\phi}{2}\right) + 2C\tan\left(45 + \frac{\phi}{2}\right)$$

Or $\sigma_1 = \sigma_3 N_\phi + 2C\sqrt{N_\phi}$

Where $N_\phi = \tan^2\left(45 + \frac{\phi}{2}\right) = \frac{1+\sin\phi}{1-\sin\phi}$

(c). Write a note on ten requirements of track drainage system for a typical B.G. railway line. (12 M)

Sol: Requirements of a Good Track Drainage System

A good drainage system should satisfy the following requirements.

1) **Surface water should not percolate to track** One of the basic requirements of good track drainage system is that surface water from rains and adjacent areas should not percolate and seep into the formation of the track.
2) **Effective side drains** The size of the side drains should be adequate with a proper slope, so that they effectively carry all the surface water away.
3) **Longitudinal drains to saucer-shaped** The longitudinal drains provided between two tracks should preferably have a saucer-shaped cross section so that they can collect water from both sides.

4) **Provision for clearing and inspection** The drains provided for drainage should be such that they can be inspected and cleared periodically.

5) **Drain top to be below cess level** Normally, the drain top should not be above the cess level for the effective drainage of the ballast bed.

6) **No erosion of banks** The flow of water along the slope and across the track should not cause erosion of the banks or the slopes of the banks.

7) **Formation to be of good soil** Ideally, the formation and sub-grade should be made of a pervious, coarse-textured soil. Such soils are more permeable, retain less capillary water, and respond more favourably to a surface drainage system.

8) **Proper sub-surface drainage** Arrangements should be made for a good sub-surface drainage system to drain off the water being retained is the track. This is more relevant in the case of defective formations.

9) **Proper outfall** Longitudinal drains should be designed so as to provide a proper outfall, from where the water can eventually drain off.

10) **Special arrangements for waterlogged areas and other difficult situations** A good track drainage system should have special arrangements for the drainage of waterlogged areas and for all other related perennial problems

(d). Clearly state the nine goals and objectives of National Transport Plan of India. (12 M)

Sol: Nine goals and objectives of National Transport plan

The following are the Nine goals in Indian National Transport plan

(i) Improvement in transport network

(ii) Increase in productivity and economic efficiency in the field of transport

(iii) Improvement in quality of transport

(iv) Better frequency of services

(v) control of environment pollution

(vi) control of noise nuisance and limiting degradation of the landscape

(vii) Better use of fuel in a economic manner

(viii) Reduction in accidents and increase in safety

(ix) Improvement in customer services.

(e). A star of declination 42°30′30″ S is to be observed at lower and upper transit at a place of latitude 75°30′30″ S. Draw a neat labelled figure depicting declination, latitude in upper transit, altitude in lower transit and find the approximate apparent altitude at which the star should be sought. (12 M)

Sol: $\theta = 75^\circ 30' 30''$

$\delta = 42^\circ 30' 30''$

$90 - \theta = 90^\circ - 75^\circ\ 30'\ 30'' = 14^\circ 29' 30''$

$\Rightarrow \delta > 90 - \theta$

Declination of star is greater then co-latitude of observer's position.

$\therefore$ The star is circumpolar i.e., always above celestial horizon.

Also, $\theta > S$ upper transit will be towards North of Zenith (Z)

Zenith distance @ upper transit (T_1)

$ZD = \theta - \delta$

$ZD = 75^\circ 30' 30'' - 42^\circ 30' 30''$

$ZD = 33^\circ$

$\Rightarrow 90 - \alpha = 33^\circ$

$\Rightarrow \alpha = 90^\circ - 33^\circ$

$= 57^\circ$ (@T_1)

Zenith distance @ upper transit (T_1)

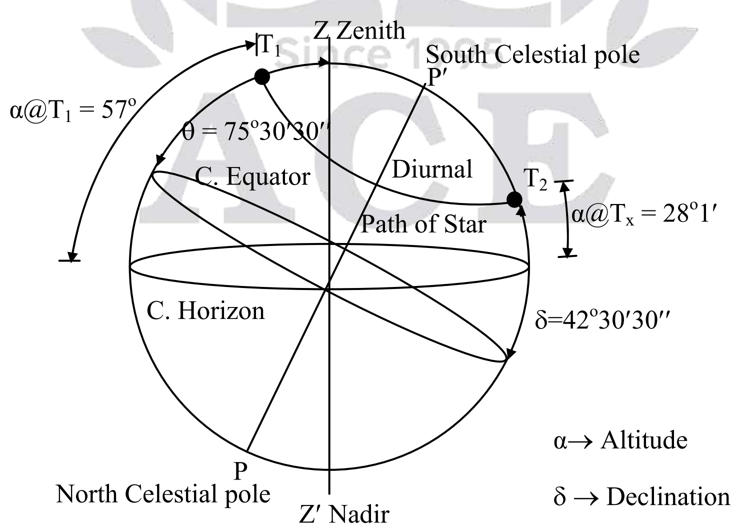
$ZD = 180^\circ - (\theta + \delta)$

$= 180^\circ - (75^\circ 30' 30'' + 42^\circ 30' 30'')$

$= 61^\circ.59'\ 0''$

$90 - \alpha = 61^\circ.591$

$\alpha = 28^\circ\ 1'$ (@ T_2)



α → Altitude

δ → Declination

θ → Latitude

Correction for altitude

1) At upper transit ($\alpha = 57^{o}$)

The altitude needed to be connected for

a) Refraction

b) Parallex

a) Refraction

Correction for refraction is always negative

$C_{ref} = -57'' \cot \alpha$

$= -57'' \cot 57^{o} = -37.02''$

b) Parallex

It is always positive

$C_p = +8.8'' \cos \alpha$

$= +8.8'' \cos 57^{o} = +4.79''$

Correction Attitude

$\alpha_c = \alpha + C_{ref} + C_p$

$= 57° -37.02'' + 4.79''$

$= 56^{o}\ 59'\ 27.77''$

2) At lower transit

$\alpha = 28^{o}\ 1'$

a) Correction for refraction

$C_{ref} = -57'' \cot \alpha$

$= -57'' \cot 28^{o}\ 1'$

$= 0^{o}1'\ 47.13''$

b) Correction for parallex

$C_p = +8.8'' \cos \alpha$

$= +8.8'' \cos 28^{o}\ 1'$

$= +7.77''$

Correction for altitude $= 28^{o}1' - c_{ref} + c_p$

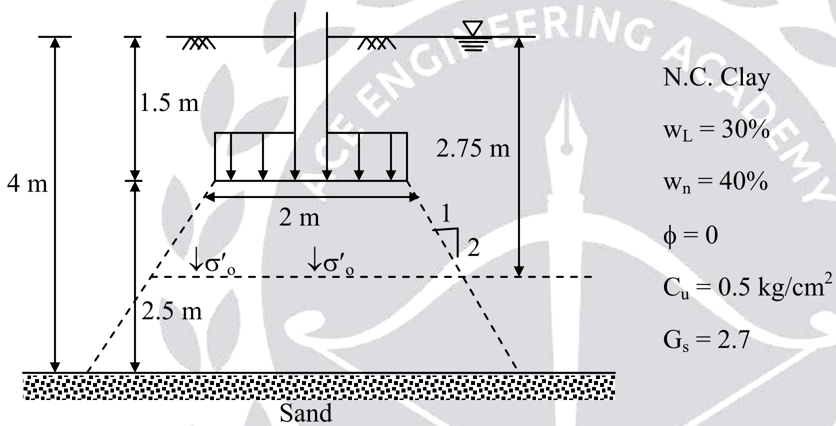
$= 28^{o}1' - 1.47.13'' + 7.7''$

$= 27^{o}59'20''$

06.

(a). **A square footing 2 m wide is resting on soft saturated clay. The depth of foundation is 1.5 m from existing ground level. The thickness of clay layer is 4.0 m and is underlain by a firm sand stratum. The properties of clay are as under : Liquid limit 30%, natural moisture content. 40%, specific gravity 2.7, angle of internal friction zero and undrained cohesion 0.5 kg/cm^2. The clay stratum is normally consolidated. Determine the net safe bearing capacity using the Vesic equation. Compute the settlement that would result if the load intensity were allowed to act on the footing. Natural water table is at ground level. Assume load spread 2 : 1. (20 M)**

Sol:



$C_u = 0.5$ kg/cm^2 = 0.5×10^4 kg/m^2 = 5000 kg/m^2

Bearing capacity as per Vesic's equation is

$q_u = CN_c.\ S_c.\ d_c\ i_c + q\ N_q\ .\ S_q\ .\ d_q\ .\ i_q + 0.5\ \gamma\ B.\ N_\gamma.\ S_\gamma.i_\gamma$

for $\phi = 0$, $N_c = 5.14$, $N_q = 1$, $N_\gamma = 0$

$\therefore$ For $\phi = 0$, net ultimate bearing capacity, $q_{nu} = CN_c\ .\ S_c\ ,d_c\ .\ i_c$

Shape factor, $S_c = 1 + \dfrac{N_q}{N_C}$ for square shape

$$= 1 + \frac{1}{5.14} = 1.195 \text{ say } 1.20$$

Depth factor, $d_c = 1 + 0.4\dfrac{D_f}{B}$ for $\dfrac{D_f}{B} \le 1$

$$= 1 + 0.4 \times \frac{1.5}{2} = 1.3$$

Inclination factor, $i_c = 1$ for vertical load

$\therefore\ q_{nu} = 5000 \times 5.14 \times 1.20 \times 1.3 \times 1 = 40092\ kg/m^2$

Assuming a factor of.safety of 3

$$q_{ns} = \frac{40092}{3} = 13{,}364\ kg/m^2$$

To find settlement (S_f) due to consolidation

For N.C clay

$$S_f = H.\frac{C_c}{1+e_o}\log_{10}\left[\frac{\sigma_0' + \Delta\sigma}{\sigma_0'}\right]$$

H = 2.5 m

$C_c = 0.009\ (w_L - 10)$

$= 0.009\ (30 - 10) = 0.18$

$e_o = w_n.\ G_s$ for fully saturated soil

$= 0.4 \times 2.7 = 1.08$

$$\gamma_{sat} = \gamma_w\left[\frac{G_s + e}{1+e}\right] \text{ for saturated soil}$$

Take $\gamma_w = 1000\ kg/m^3$

$$\gamma_{sat} = 1000\left[\frac{2.7 + 1.08}{1 + 1.08}\right] = 1817.3\ kg/m^3$$

$\gamma' = \gamma_{sat} - \gamma_w = 817.3\ kg/m^3$

$\sigma'_o = \gamma'.y = 817.3 \times [1.5 + 1.25] = 2247.58\ kg/m^2$

$\Delta\sigma$ at centre of clay = $\dfrac{Q}{(B+z)^2}$ for 2V to 1H load dispersion

$$= \frac{Q \times q_{ns}}{(B+z)^2} \qquad z = \frac{H}{2} = \frac{2.5}{2} = 1.25\ \text{m}$$

$$= \frac{2^2 \times 13364}{(2+1.25)^2} = 5061\ kg/m^2$$

$$S_f = H.\frac{C_c}{1+e_o}.\log_{10}\left[\frac{\sigma_o^{'}+\Delta\sigma}{\sigma_o^{'}}\right]$$

$$= 2.5\times\frac{0.18}{1+1.08}\log_{10}\left[\frac{2247.58+5061}{2247.58}\right] = 0.1107 \text{ m}$$

$$S_f = 110.7 \text{ mm}$$

(b). List the five traffic surveys and elaborate all of them. (20 M)

Sol: List of Five traffic surveys

The following are five traffic surveys

1. Home Interview survey:

- The most reliable survey for the collection of origin-destination data
- The survey is essentially intended to yield data on the travel pattern
- The information collected includes number of trips, their origin and destination purpose of trip and travel mode.
- This is a costly method

2. Road side interview survey:

- This can be done by directly surveying from drivers of vehicles at a selected places
- The analysis consists of tallying the numbers of vehicles at the entry and exit points
- This method of survey is cumbersome

3. Parking surveys:

- Parking data is collected on the existing on street and off street parking facilities
- Data on parking place availability, parking charges, congestion of traffic due to parked vehicles is studied

4. Transportation facilities survey:

The following data related to traffic facilities are collected

- Traffic volume at peak and off-peak time

- Studies on traffic time by different modes
- Public transport facilities
- Accident data
- Petrol pumps, truck lay byes

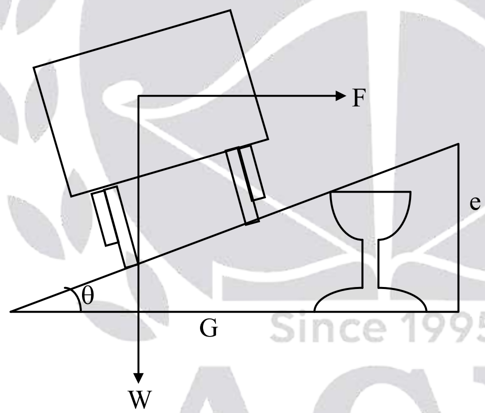
5. Public transport surveys

- This survey is to determine percentage usage of different traffic modes
- Different traffic modes are city buses, metro rail, mono rail, Auto rickshaws etc.

(c).

(i). With a neat labelled sketch, derive the relation between super elevation (e), for a broad gauge railway with a speed 'V' (km/h) and radius of curvature (R). (10 M)

Sol:



Let us consider a train travel on curve of Radius (R)

On Broad Gauge track (B.G)

θ = angle that inclined $\left(\tan\theta = \dfrac{\text{super elevation}}{\text{gauge}}\right)$ Plane makes with

$$\tan\theta = \frac{e}{G} \text{ ---- (1)}$$

$$\tan\theta = \frac{\text{centrifugal force(F)}}{\text{weight(W)}} = \frac{F}{W} \text{ ------ (2)}$$

Solve equations (1) and (2)

$$\frac{e}{G} = \frac{F}{W} \qquad e = G.\frac{F}{W} = F.\frac{G}{W}$$

$$F = \frac{mv^2}{R} = \frac{w}{g}\frac{v^2}{R}$$

$$e = \frac{wv^2}{gR} \times \frac{G}{w}$$

$$e = \frac{Gv^2}{gR}$$

G = gauss length (m), Where e = super elevation in (m), v = speed of train (m/s)

g = acceleration due to gravity (m/s^2) , R = Radius of curve

$$e = \frac{GV^2}{9.81} \times \frac{1}{(3.6)^2} \times \frac{1}{R}$$

$$e = \frac{GV^2}{127R} \qquad V = 4 \text{ mph}$$

For G.G. track G = 1.676

$$e = \frac{1.676V^2}{127R}$$

(ii). If the wheel base of a vehicle moving on B.G. track is 6 m, the diameter of wheel is 1.50 m and the depth of flanges below the top of rail is 3.20 cm, determine the extra width required to be provided on gauge, if the radius of the curve is 150 m. (10 M)

Sol: Wheel base of a vehicle = 6 m

Wheel Dia = 1.5 m

Depth of flange below top of Rail = 3.20 cm

Radius of curve = 150 m

Track type = Broad guage

Extra width of curve $= \dfrac{13(B+L)^2}{R}$

B = 6 m

L = 0.02 $(h^2+Dh)^{1/2}$ (where h and D in (cm) and L is in (m))

Online Test Series

GATE – 2022 Online Test Series	ESE – 2022 Prelims Online Test Series	GATE + ESE – 2022 Online Test Series Combination Pack
No. of Tests : 65 + Free 52 Practice Tests of GATE - 2021 Online Test Series Total Tests : 117	No. of Tests : 44 + Free 30 Practice Tests of ESE - 2021 Online Test Series Total Tests : 74	All tests will be available till GATE - 2022 & ESE -2022 (Prelims) examinations respectively.

TEST SERIES HIGHLIGHTS

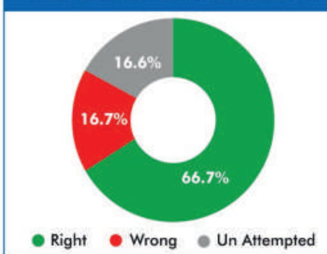
Detailed Solutions are Available | Video Solutions are Available for Difficult Questions.
All India rank will be given for each test | Comparison with all India toppers of ACE student

TEST WISE STATISTICS:

TIME

Test Duration : 3 Hours
Your Time : 2Hrs 45Min 23Sec

ANSWERS EVALUTION



RESULTS

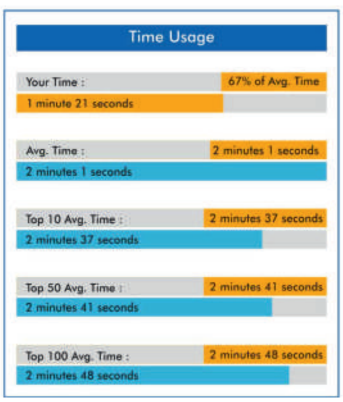
OBTAINED MARKS

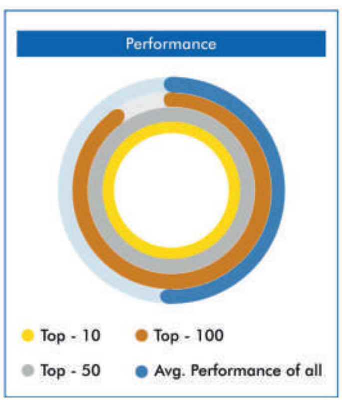
76 / 100

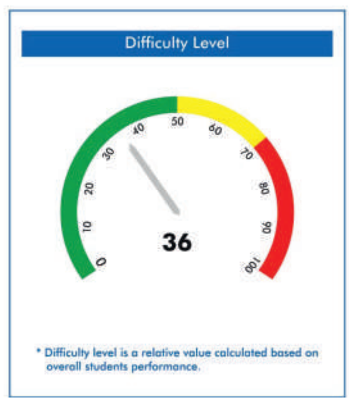
AIR 380

* Total Attempted Students (till now) : 11250

QUESTION WISE STATISTICS:







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$L = 0.02\ (3.2^2+150\times3.2)^{1/2}$

$L = 0.443.\ m$

Extra width on curve(w) $= \dfrac{13(6+0.443)^2}{150} = 3.598\,\text{cm}$

w = 36 mm

07.

(a). Soft saturated clay has a thickness of 6 m. After one year, when the clay consolidated by 50%, the observed settlement was to the tune of 10 cm. For an identical clay and loading condition, what will be the magnitude of settlement at the end of one year and five years if the thickness of the clay layer was 25 m? (20 M)

Sol: For clay layer of 6 m thickness:

$U_1 = 50\%$ $S_1 = 10$ cm, time, $t_1 = 1$ year

$$U_1 = \frac{S_1}{S_{f_1}}$$

$$\therefore \text{ Final settlement, } S_{f_1} = \frac{S_1}{U_1} = \frac{10}{0.5} = 20 \text{ cm}$$

$$T_{v_1} = \frac{\pi}{4}\left(\frac{U_1}{100}\right)^2 = \frac{\pi}{4}\left[\frac{50}{100}\right]^2 = 0.196$$

For Clay layer of 25 m thickness:

For identical clay and loading conditions, the final settlement (S_f) is proportional to thickness of clay

$\therefore S_f \propto H$

$$\frac{S_{f_2}}{S_{f_1}} = \frac{H_2}{H_1}$$

$$\frac{S_{f_2}}{20} = \frac{25}{6}$$

$$S_{f_2} = 83.33\,\text{cm}$$

$\therefore$ Final settlement of clay layer, 25 m thick is 83.33 cm

To find settlement, S_2 after 1 year for clay of 25 m

$$T_v = \frac{C_v.t}{H^2}$$

For identical clays (C_v will be same) and times

$$T_v \propto \frac{1}{H^2}$$

$$\frac{T_{v_2}}{T_{v_1}} = \left(\frac{H_1}{H_2}\right)^2$$

$$\frac{T_{v_2}}{0.196} = \left(\frac{6}{25}\right)^2$$

$\therefore$ Time factor, $T_{v_2} = 0.0113$

$$T_{v_2} = \frac{\pi}{4}\left(\frac{U_2}{100}\right)^2$$

$$0.0113 = \frac{\pi}{4}\left(\frac{U_2}{100}\right)^2$$

$\therefore$ Degree of consolidation, $U_2 = 12\%$

Let settlement be S_2

$$U_2 = \frac{S_2}{S_{f_2}}$$

$$0.12 = \frac{S_2}{83.33}$$

Settlement $\therefore$ $S_2 = 10$ cm

To find settlement of Clay layer of 25 m, after 5 years:

$$T_v \propto \frac{t}{H^2}$$

$$\frac{T_{v_2}}{T_{v_1}} = \frac{t_2}{t_1}.\left(\frac{H_1}{H_2}\right)^2$$

$$\frac{T_{v_2}}{0.196} = \frac{5}{1}.\left(\frac{6}{25}\right)^2$$

$$T_{v_2} = 0.0564$$

$$T_{v_2} = \frac{\pi}{4}\left(\frac{U_2}{100}\right)^2$$

$$0.0564 = \frac{\pi}{4}\left[\frac{U_2}{100}\right]^2$$

$U_2 = 26.81\%$

Settlement after 5 years, $S_2 = U_2 \times S_{f_2}$

$= 0.2681 \times 83.33 = 22.34$ cm

(b).

(i). How do the methods of tunnel construction in hard rock differ from the methods of tunnel construction in soft ground? State the various operations involved in hard rock tunnelling and soft ground tunnelling. (10 M)

Sol:

(i) Tunneling in hard rock has to be carried out at considerable depth from the natural ground surface.

(ii) Compared to soft soil tunneling the operation of hard rock tunneling is very costly.

(iii) Tunneling is rock does not require much of the support by timbering and other types of support.

(iv) Heavy machinery like TBM is required for this tunneling.

(v) Over cutting of section should be avoided.

The various operations involved in hard rock tunneling:

- Locating centre line on the ground.
- Construction of shaft.
- Transferring centre line to the inside of tunnel.
- Setting up and drilling hole for blasting.

- Loading holes and carrying out blasting.
- Providing ventilation.
- Loading and hauling muck.
- Pumping of ground water.
- Electric supports.
- Placing reinforcement steel.
- Placing concrete lining.

The various operations involved in soft ground tunneling:

- Sunking of shaft.
- Bent is placed from the sheeting.
- Driving of holes.
- Timber laid at the end of all spiles.
- Face sheeting broken out and ground is allowed to run.
- Put temporary supports at end called horse head.

(ii). List the typical features of a harbour. Elaborate any three at length. **(10 M)**

Sol: Typical features of harbours

Break water

Pier

Berths

Turning basin

Roadsted

Dock yard

Dolphins

Fenders

Jetties

1. **Piers:** The structures built perpendicular to shore of a sea. Piers are constructed at an area when the sea is not deep. Piers are constructed with piles (or) columns

2. Dolphins:

- A closely spaced cluster of piles is called dolphins
- The piles are pulled together and tied by cables
- Dolphins are used for trying up ships
- These are designed to resist impact

3. Jetties:

- These are structures in the form of piled projections and they are built out from the shore to deep water.
- In sea Jetties are provided at places where harbour entrance is affected by littoral drift
- Types single curved jetties
- Converging jetties
- Diverging jetties

(c). Write a detailed note on ideal and real remote-sensing system by highlighting their six components as well as their six shortcomings. (20 M)

Sol:

- Basic components of an ideal remote sensing system
  i) A uniform energy source: Provides constant, high level of output over all wavelengths
  ii) A non-interfering atmosphere: Does not modify the energy transmitted through it
  iii) A series of unique energy/matter interactions at the Earth's surface. Generates reflected / emitted signals that are
- Selective with respect to wavelength and
- Unique to each objector or earth surface feature type
  iv) A super sensor: Simple, accurate, economical and highly sensitive to all wavelengths Yields data on the absolute brightness (or radiance) from a sense as a function of wavelengths
  v) A real-time data handling system. Generates radiance-wavelength response and processes into an interpretable format in real time.

vi) Multiple data users: Posses knowledge in remote sensing techniques and in their respective disciplines. Use the collected information in their respective disciplines.

A Real Remote Sensing System Shortcomings

- Ideal system: Constant, high level of output over all wavelengths

Real system:

- Usually non-uniform over various wavelengths
- Energy output vary with time and space
- Affects the passive remote sensing systems
- The spectral distribution of reflected sunlight varies both temporally and spatially
- Earth surface features also emit energy in varying degrees of efficiency
- A real remote sensing system needs calibration for source characteristics

Real system

- Atmosphere modifies the spectral distribution and strength of the energy transmitted through it
- The effect of atmospheric interaction varies with the wavelength associated, sensor used the sensing application
- Calibration is required to eliminate or compensate these atmospheric effects

The Energy / Matter Interactions at the Earth's Surface

- Ideal system. A series of unique energy/matter interactions.

Real System

Spectral signatures may be similar for different material, making the differentiation difficult

Lack of complete understanding of the energy/matter interactions for surface features

The Sensor

Ideal system. A super sensor

Real system

- Fixed limits of spectral sensitivity i.e., they are not sensitive to all wavelengths.
- Limited spatial resolution (efficiency in recording spatial details)
- Sensor selection requires a trade-off between spatial resolution and spectral sensitivity.
- for example, photographic systems have very good spatial resolution, but poor spectral sensitivity. Non-photographic systems have poor spatial resolution.

The data handling system

- Ideal system: A real-time data handling system
- Real system:
- Real time data handling almost impossible human intervention is necessary for processing sensor data.

The multiple data users

- Idea system: Users having knowledge in their domain and in remote sensing techniques

Real system:

Success of a remote sensing mission lies on the user who transforms the data into information

User should have

- Thorough understanding of the problem
- Wide knowledge in the data generation
- Knowledge in data interpretation
- Knowledge to make best use of the data

Some of the drawbacks of remote sensing are

- The interpretation of imagery requires a certain skill level
- Needs cross verification with ground (field) survey data
- Data from multiple sources may create confusion
- Objects can be misclassified or confused
- Distortions may occur in an image due to relative motion of sensor and source

08.

(a). **Two sets of tacheometric readings were taken from an instrument station A (R. L. = 100.50m) to a staff station B as given below :**

Instrument	P	Q
Multiplying	95	90
Additive constant	0.25	0.35
Height of instrument	1.35 m	1.40 m
Staff held	Vertical	Normal

Instrument	Instrument station	Staff station	Vertical angle	Stadia readings (m)		
P	A	B	8°12′	0.905	1.305	1.555
Q	A	B	8°12′	?	?	?

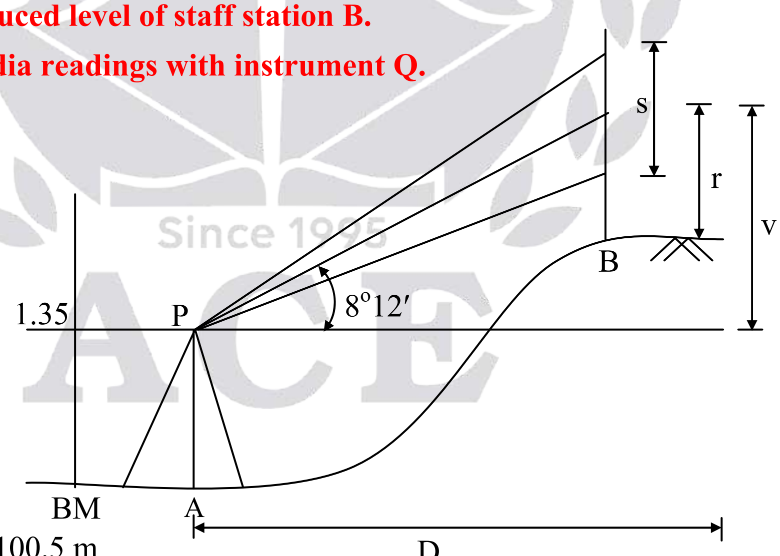
Determine :

(i) **The distance between instrument station and staff station.**

(ii) **The reduced level of staff station B.**

(iii) **The stadia readings with instrument Q.** **(20 M)**

Sol: Instrument P



K = 95

C = 0.25m

h_1 = 1.35cm

Staff vertical

$\theta = 8^\circ 12'$

S = 1.555 – 0.905

= 0.650m

r = 1.305m → central hair reading

G = 1.35m

i) Dist formula for inclined LOS, with staff held vertical,

$D = KS\cos\theta + C\cos\theta$

$= 95 \text{ x } 0.65 \times \cos^2 8^o\ 12' + 0.25 \cos 8^o\ 12' = 60.741$ m

ii) RL of B

$$V = \frac{KS}{2}\sin 2\theta + c\sin\theta$$

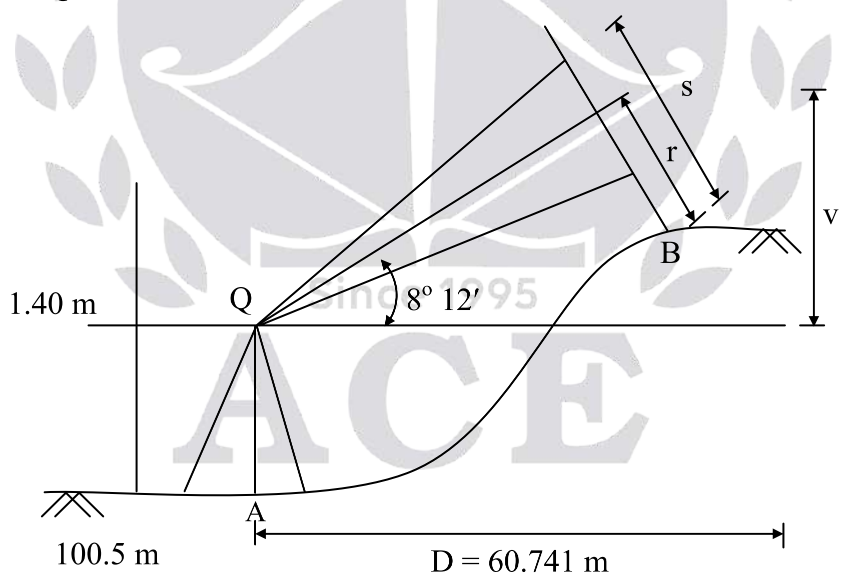
$$= \frac{95 \times 0.65}{2}\sin\left(2 \times 8^o\ 12'\right) + \left(0.258in8^o 12'\right)$$

$= 8.753$m

$RL_B = RL_{BM} + h + v - r$

$= 100.50 + 1.35 + 8.753 - 1.305 = 109.298$m

Instrument at Q:



Inst. Q.

K = 90

C = 0.35m

h = 1.40m

Staff normal

$\theta = 8^o\ 12'$

D = 60.741m

r $\rightarrow$ central hair reading

$D = (KS + C)\cos\theta + r\sin\theta$

$60.741 = (90\ S + 0.35)\cos 8^o\ 12' + r\sin 8^o\ 12'$

$89.08\ S + 0.143\ r = 60.395$…………..(i)

$RL_B = RL_{BM} + h + v - r\cos\theta$

$V = (KS + C)\sin\theta$

$= (90\ S + 0.35)\sin 8^o\ 12'$

$\Rightarrow 109.298 = 100.5 + 1.40 + (90\ S + 0.35)\sin 8^o 12' - r\cos 8^o\ 12'$

$12.84\ S - 0.99\ r = 7.348$……….(ii)

Solving (i) & (ii)

S = 0.676 m

r = 1.343m

Let staff reading be S_1, S_2 & S_3 & the top, central of bottom hairs

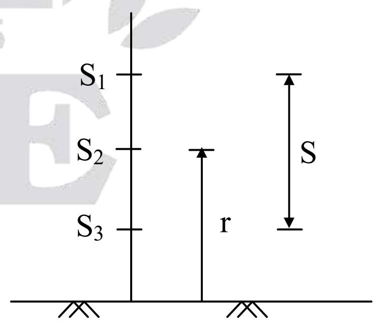
$\Rightarrow S_2 = r = 1.343$ m

$S_1 - S_3 = S$

$S_3 = r - S/2 = 1.343 - \frac{0.676}{2} = 1.005\text{m}$

$S_1 = r + \frac{S}{2} = 1.343 + \frac{0.676}{2} = 1.681\text{m}$

$\therefore$ Staff readings are 1.681 m, 1.343 m , 1.005 m



(b).

(i). **The mass specific gravity of a fully saturated specimen of clay having a water content of 29% is 2.00. On oven drying, the mass specific gravity drops to 1.60. Calculate the specific gravity of clay assuming the void ratio to remain unchanged.** **(10 M)**

Sol: Given s = 100%, w = 29%, $Gm = \frac{\gamma_{sat}}{\gamma_w} = 2$

On during, $G_m = \frac{\gamma_d}{\gamma_w} = 1.60$ e = remain unchanged

For saturated clay

$$e.s = w.\,G_s \Rightarrow e.1 = 0.29 \times G_s$$

$$\frac{\gamma_{sat}}{\gamma_w} = \frac{G_s + e}{1+e}$$

$$2 = \frac{G_s + 0.29G_s}{1+0.29G_s}$$

$\therefore$ S_p gravity of clay, $G_s = 2.817$

(ii). **A footing 2 m × 2 m in plan, transmits a pressure of 100 kN/m^2 on a cohesive soil layer having E = 6 × 10^4 kN/m^2 and μ = 0.50. Determine the immediate settlement of the footing at the centre, assuming it to be (I) a flexible footing, and (II) a rigid footing.** **(10 M)**

Shape	I_f Flexible Foundation			I_f Rigid Foundation
	Centre	Corner	Average	
Circular	1.00	0.64	0.85	0.86
Square	1.12	0.56	0.95	0.82
Rectangular				
L/B = 1.5	1.36	0.68	1.20	1.06
L/B = 2	1.52	0.76	1.30	1.20
L/B = 5	2.10	1.05	1.83	1.70
L/B = 10	2.52	1.26	2.25	2.10
L/B = 100	3.38	1.69	2.96	3.40

Sol:

Given

Footing size = 2 × 2 m

Pressure, q = 100 kN/m^2

$E_s = 6 \times 10^4$ kN/m^2

$\mu = 0.50$

To find immediate settlement (S_i) at centre:

(a) Flexible footing

$$S_i = \frac{q}{E_s}.B.\left(1-\mu^2\right).I_f$$

Influence factor, $I_f = 1.12$

$$S_i = \frac{100}{6\times10^4}\times\left(1-0.5^2\right) \times 1.12 = 0.0028 \text{ m}$$

$$= 2.8 \text{ mm}$$

(b) Rigid Footing

$I_f = 0.82$

$$S_i = \frac{q}{E_s}.B\left(1-\mu^2\right).I_f$$

$$= \frac{100}{6\times10^4}\times2\left(1-0.5^2\right) \times 0.82 = 0.00205 \text{ m}$$

$$= 2.05 \text{ mm}$$

(c). Design a summit curve for a National Highway for a stopping sight distance of 200 m at the junction of a rising gradient of 1 in 60 and a falling gradient of 1 in 30. Set out the curve with a chord 25 m long. Determine the R.L. of the point immediately below the intersection point of the grade line and also the R.L. of the highest point on the curve. Assume sight distance is less than the length of vertical curve, R.L. at the start of the curve as 10.0, h_1 and b_2 as per current Indian practice IRC 66-1976. (20 M)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GATE - 2021 TOP RANKERS
AIR 1ST IN PRATIK PRAKASH SHINDE
AIR 1ST EE AAKASH DHILL
AIR 1ST ME SUYASH SHARMA
AIR 1ST PI GANESH ADIGAUR
AIR 1ST XE VARUN KAUSHIK
AIR 2nd ME JAY CHAVDA
AIR 2nd PI GOWTHAM GUDIMELLA
AIR 2nd EC M POOJASREE
AIR 2nd ES ANUSH VERMA
AIR 3rd ME MUNISH KUMAR
AIR 3rd ME NUKULA VISWA TEJA
AIR 3rd PI REHAN ANWAR DESAI
AIR 3rd EC MANOJ KUMAR
AIR 3rd CE SHASHIKANT KUMAR
AIR 3rd EE JAYMAL KHUNTI
AIR 4th PI ROHIT SONI
AIR 4th EC P AKHIL
AIR 4th IN DIVAKAR CH.
AIR 4th IN SAURABH JAISWAL
AIR 4th XE JATIN BHANDARI
AIR 4th ES HEMANTH TIWARI
AIR 5th ME ABHISHEKA
AIR 5th EC VAISHNAV KV
AIR 5th CE PRASHANT DWIVEDI
AIR 5th CS PANKAJ LAHKAR
AIR 5th CS S BHATTACHARJEE
AIR 5th PI SUBHANSHU TIWARI
AIR 6th ME ABHISHEK MEWAR
AIR 6th PI AKASH JAISWAL
AIR 6th EC PARAG SAROHA
AIR 6th IN HARSHIT GUPTA
AIR 6th IN RAJU SHARMA
AIR 6th CE TANMAY MAHAJAN
AIR 6th XE MANISH YADAV
AIR 7th ME VATSAL PANCHAL
AIR 7th PI SACHIN DUBOLIYA
AIR 7th PI ATULYA JYOTHI
AIR 8th ME RAJAT GUPTA
AIR 8th ME ROHIT S PATIL
AIR 8th EC ANKUR LAL MEENA
AIR 8th IN KUNAL SAURAV
AIR 8th CE PRANSHU JANGID
AIR 8th CE RAHUL PATI
AIR 8th EE UJJWAL KUMAR
AIR 8th EE HEMANT JINDAL
AIR 9th EC ABHISHEK SINGH
AIR 9th EC ALEESHA ROSE
AIR 9th EC SAI VAMSI DOSAPATI
AIR 9th IN RAMESH KUMAR
AIR 9th CS NIRANJAN NITIN DHOOT
AIR 9th XE RACHIT KUMAR
AIR 10th ME DEEPESH AGARWAL
AIR 10th PI VYOM SHARMA
AIR 10th IN PRAGYA KAUSHIK
AIR 10th CE GOVIND PRASAD B
AIR 10th XE D KUMAR PATIL
AIR 10th XE R SHIVAJI NALE
and many more...
Total 57 Ranks in Top 10
ME : 10
PI : 09
CE : 08
EE : 4
EC : 09
CS : 03
IN : 08
XE : 06

Sol: **Given:**

R.L. at start of the curve = + 10.00

Stopping sight distance (S) = 200 m

Rising gradient (η_1) = $\dfrac{1}{60}$

Falling gradient (η_2) = 1/30 $\left(\because -\dfrac{1}{30}\right)$

Given length of curve (L_s) > S

Length of summit curve for L_s > S

$$N = \eta_1 - (-\eta_2) = \eta_1 + \eta_2 = \frac{1}{60} + \frac{1}{30} = \frac{1}{20}$$

$$L_S = \frac{NS^2}{2(\sqrt{H_1} + \sqrt{H_2})^2}$$

For S.S.D (H_1 = 1.2 m, H_2= 0.15 m)

$$\Rightarrow L_S = \frac{NS^2}{4.4}$$

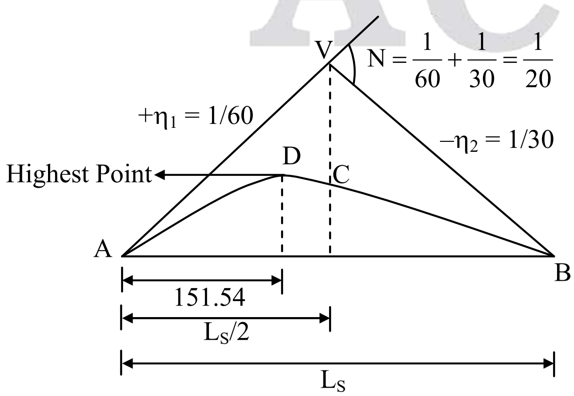
$$= \frac{\frac{1}{20} \times (200)^2}{4.4}$$

= 454.54 m

To find:

(i) R.L of point immediately below intersection point

(ii) R.L of highest point on the curve



(i) R.L. of point immediate below intersection point

$$(R.L)_C = (R.L)_A + \left[\frac{-N}{2L_S} \times x^2 + \eta_1(x)\right] \qquad \left\{x = \frac{L_S}{x}\right\}$$

$$= 10.00 + \left[\frac{\frac{-1}{20}}{2 \times L_S} \times \left(\frac{L_S}{2}\right)^2 + \frac{1}{60} \times \frac{L_S}{2}\right]$$

$$= 10.00 + \left[\frac{-\frac{1}{20} \times 454.54}{8} + \frac{1}{60} \times \frac{454.54}{2}\right] = 10.00 + 0.95$$

$(R.L)_C = 10.95$ m

(ii) R.L. at highest point D

Position of summit $x = \frac{\eta_1}{N} \times L_S$

$$= \frac{\frac{1}{60}}{\frac{1}{20}} \times 454.54$$

$x = 151.51$ m

$$(R.L)_D = (R.L)_A + \left[\frac{-N}{2L_S} \times x_D^2 + \eta_1 x_D\right]$$

$$= 10.00 + \left[\frac{-\frac{1}{20}}{2 \times 454.54} \times (151.51)^2 + \frac{1}{60} \times (151.51)\right]$$

$= 10.00 + 1.26$

$= 11.26$ m


Hearty Congratulations to our
ESE - 2020 TOP RANKERS
AIR 1 CHARUDATTA S ME
AIR 1 SHASHANK GAUR EE
AIR 1 PRAKASH JHA E&T
AIR 1 GAURAV KUMAR CE
AIR 2 K S SHARADRAO ME
AIR 2 ABHISHEK SINGH EE
AIR 2 PARTH BATRA E&T
AIR 2 PRASHANT SINGH CE
AIR 3 SURAJ KUMAR S ME
AIR 3 VIKASH SHANKAR EE
AIR 3 RAHUL NAREDI E&T
AIR 3 KULDEEP JANGRA CE
AIR 4 SHUBHAM B ME
AIR 4 ANUPAM S EE
AIR 4 SHUBHAM E&T
AIR 4 ANISH BAGGA CE
AIR 5 KAMLESH PARWAR ME
AIR 5 MANOJ KUMAR E&T
AIR 5 PAVITRA GOYAL CE
AIR 6 MD ZUHAIB ME
AIR 6 VISHWA SIMHAA EE
AIR 6 SAURAV KUMAR S E&T
AIR 7 PRATEEK S ME
AIR 7 DINESH KUMAR S EE
AIR 7 RAGHAV PURWAR E&T
AIR 8 V SAIKRISHNA REDDY ME
AIR 8 GAGAN GHUNAWAT EE
AIR 8 RAM KRISHNA E&T
AIR 9 GANESH KUMAR A ME
AIR 9 AKSHAY KUMAR T EE
AIR 9 CHHAVI JAIN E&T
AIR 9 ARPIT JAIN CE
AIR 10 HEMABH TRIVEDI ME
AIR 10 RAJAT DIXIT EE
AIR 10 L KUMARI JAISWAL E&T
AIR 10 AMIT SHARMA CE
and many more...
TOTAL 36 RANKS IN TOP 10
ME 10
EE 09
E&T 10
CE 07