ESE-2020
(MAINS)

QUESTIONS WITH DETAILED SOLUTIONS

CIVIL ENGINEERING

PAPER-II

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CIVIL ENGINEERING

ESE_MAINS_2020_PAPER – II

Questions with Detailed Solutions

SUBJECT WISE WEIGHTAGE

S.No	NAME OF THE SUBJECT	Marks
01	Fluid Mechanics & Hydraulic Machines	67
02	Hydrology	38
03	Irrigation Engineering	29
04	Environmental Engineering	116
05	Geotechnical Engineering	99
06	Surveying	42
07	Transportation Engineering	89

01. (a)

(i) Find out the pH of a mixture formed by mixing the following two water solutions:

Solution A : Volume 450 mL , pH = 7.5

Solution B : Volume 550 mL, pH = 6.5 **(8)**

Sol: Solution A V_A : 450 ml $(pH)_A$: 7.5 $(H^+)_A$: $10^{-7.5}$ mol/lit

Solution B V_B : 550 ml $(pH)_B$: 6.5 $(H^+)_B$: $10^{-6.5}$ mol/lit

$$(H^+)_{mix} = \frac{V_A(H^+)_A + V_B(H^+)_B}{V_A + V_B}$$

$$= \frac{450\times10^{-7.5} + 550\times10^{-6.5}}{450+550} = 1.881\times10^{-7}\ \text{mol/lit}$$

$$(pH)_{mix} = \log_{10}\frac{1}{(H^+)_{mix}} = \log_{10}\frac{1}{(1.881\times10^{-7})} = 6.725$$

(ii) Compute the theoretical oxygen demand of 108.75 mg/*l* of glucose. **(4)**

Sol: Glucose : 108.75 mol/lit

Mol weight of glucose : 180

Mol weight of oxygen : 192

180 parts of glucose demand : 192 parts of oxygen

$\therefore$ 108.75 mg/l of glucose demand : $\frac{192}{180}\times108.75$ mg/lit of oxygen

$\therefore$ Theoretical oxygen demand of glucose = $\frac{192}{180}\times108.75 = 116$ mg/l

(b)

(i) A rectangular plate of 0.5 m × 0.5 m dimensions, weighing 500 N slides down an inclined plane making 30° angle with the horizontal at a velocity of 1.75 m/s. If the 2 mm gap between the plate and inclined surface is filled with a lubricating oil, find its viscosity in poise. **(6)**

Sol:

Given: Rectangular Plate

Cross section = 0.5 m × 0.5 m = 0.25 m²

W = 500 N

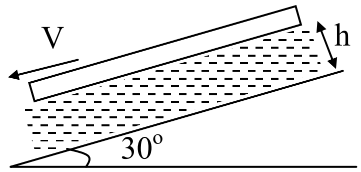
Incline Angle = 30°

Velocity 1.75 m/s

Lubrication clearance = 2 mm

$= 2 \times 10^{-3}$ m

To find: Viscosity in Poise

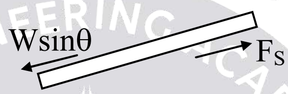


Assumption:

1. The velocity is constant, therefore equilibrium is applicable
2. Velocity profile is linear

Solution:

For Equation: $W \sin\theta = F_s$



$$\Rightarrow W \sin\theta = \tau . A_s$$

$$\Rightarrow W \sin\theta = \mu . \frac{du}{dy} . A_s$$

$$\Rightarrow W \sin\theta = \mu \frac{V-0}{h} . A_s$$

$$\mu = \frac{W.h.\sin\theta}{V.A_s}$$

$$= \frac{500 \times 2 \times 10^{-3} \times 0.5}{1.75 \times 0.25}$$

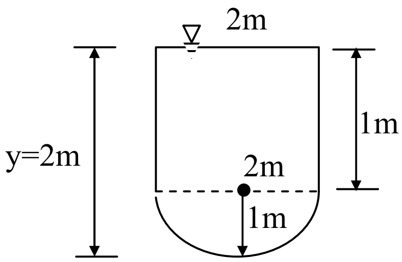
= 1.1428 Pa.s

= 11.428 Poise

The viscosity of the oil is 11.428 poise

(ii) A channel has two sides vertical and semi-circular bottom of 2 m diameter. Calculate the discharge of water through the channel, when depth of flow is 2 m. Take C = 70 and slope of bed as 1 in 1000. (6)

Sol:



Given

C = 70

$$S_0 = \frac{1}{1000}$$

y = 2m

$$A = 2\times1+\frac{\pi\times1^2}{2}$$

A = 3.57 m^2

P = 1 + π ×1+1 = 5.14 m

$$Q = C.A.\sqrt{R.So} \qquad R = \frac{A}{P} = \frac{3.57}{5.14} = 0.694$$

$$= 70\times3.57\times\sqrt{0.694\times\frac{1}{1000}}$$

Q = 6.585 m^3/s

Q = 6.59 m^3/s

(c) A rectangular sewer with width twice its depth is hydraulically equivalent to a circular sewer. Find the relation between the width of the rectangular sewer and the diameter of the circular sewer assuming that sewer is running completely full. (12)

Sol: For rectangular sewer

d = depth

B = width

For circular sewer

d = depth = diameter

R = d/4

$$B = 2d \Rightarrow d = \frac{B}{2} \qquad R = \frac{A}{P} = \frac{B\times d}{B+2d}$$

For hydraulically equivalent sections for full flow

$Q_{rect} = Q_{circ}$ [They are same grade, same material & carry same flow rate]

$$(B\times d)\times\frac{1}{n}\times(R)^{2/3}(S)^{1/2} = \frac{\pi}{4}d^2\times\frac{1}{n}\times(R)^{2/3}(S)^{1/2}$$

$$B\times\frac{B}{2}\times\left(\frac{B\times B/2}{B+2\times\frac{B}{2}}\right)^{2/3} = \frac{\pi}{4}d^2\times\left(\frac{d}{4}\right)^{2/3}$$

$$\frac{B^2}{2}\times\frac{B^2/2}{2B}=\frac{\pi}{4}d^2\times d$$

$$\frac{B^3}{8}=\frac{\pi}{4}d^3 \Rightarrow B=\frac{8\times\pi}{4}d=2\pi d$$

(d) After how many days will you supply water to soil (clay loam) in order to ensure efficient irrigation of the given crop, if: (12)

Field capacity of soil = 27%

Permanent wilting point = 14%

Density of soil = 1.5 g/cm^3

Effective depth of root zone = 75 cm

Daily consumptive use of water for the given crop = 11 mm

Sol: FC = 27%

PWP = 14%

Density = 1.5 gm/cc

d = 75 cm = 750 mm

C_u = 11 mm/day

To ensure efficient irrigation of the given crop,

d_w = Sd (FC – OMC)

= 0.6 Sd (FC – PWP)

$$= 0.6\,(1.5)\,(750)\left(\frac{27-14}{100}\right)$$

= 87.75 mm

Frequency of irrigation $= f = \frac{d_w}{C_u}$

$$f=\frac{87.75\,\text{mm}}{11\,\text{mm/day}}=7.977\,\text{days}\approx 8\text{ days}$$

Note: Efficient irrigation means external supply of water to the field, when the soil in the field is at its optimum moisture content

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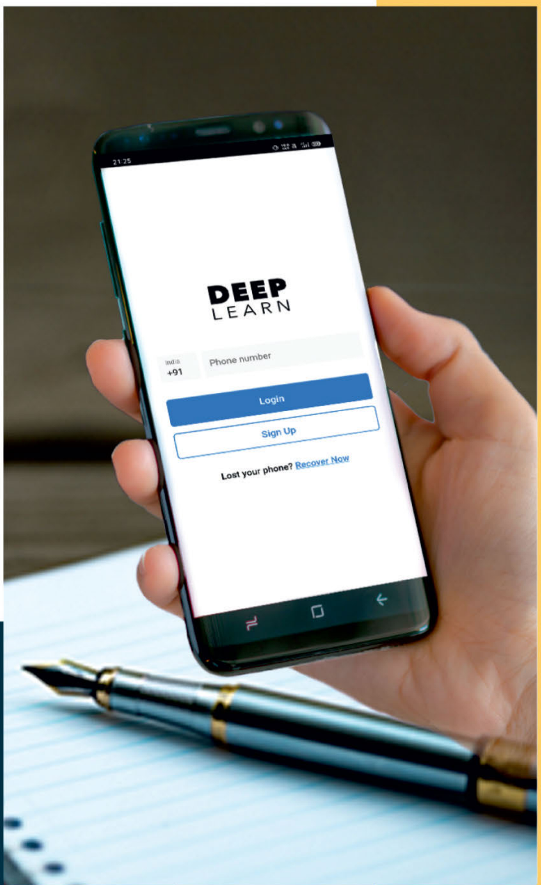

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(e)

(i) A town with a population of 3 lakh produces solid waste at a rate of 2.5 kg/capita/day. If the waste is compacted to a density of 1500 kg/m^3, how much volume of landfill site is needed in a year? Assuming that the ratio of solid waste to cover is 4 : 1, what volume of cover soil is needed in a year? What type of soil would you recommend as a cover? (4)

Sol: Population = 3 lakh

Rate of S.W. generation = 2.5 kg/capital/day

$[\rho_{com}]_{sw}$: 1500 kg/m^3

Volume of cover soil is needed / year = ?

Type of soil = ?

Total wt of s.w. generated/year = Rate of generation × Population × no. of days

$= 2.5 \times 3 \times 10^5 \times 365$ kg

Volume of compacted land fill required = Volume of compacted S.W. in fill

$$= \frac{\text{Total wt of SW generated}}{[\rho_{com}]_{sw}} = \frac{2.5\times 3\times 10^5 \times 365}{1500} = 182500 \text{ m}^3$$

$$\text{Volume of sewer soil required} = \frac{\text{Volume of land fill}}{4} = \frac{182500}{4} = 45625 \text{ m}^2$$

Loamy (or) silty soils that are free of large stones and excess gravel are the best cover for a land fill. Clayee soils may be sticky and difficult to spread, & sandy soils are subjected to wind erosion.

(ii) The sound power from a voice shouting is 0.002 W. What is the Sound Power Level ? What are the Sound Intensity, Sound Intensity Level, the Sound Pressure and the Sound Pressure Level at a distance of 10 metres from the source? Assume that sound radiates from the source in all directions. (8)

Sol: P = 0.002 w = 0.002 × 10^{12} Pa = 2000 μ Pa

SPL $\quad L = 20\log_{10}\frac{P}{P_o} = 20\log_{10}\frac{2000}{20} = 40 \text{ dB}$

Sound 'P' $10\log_{10}\frac{I}{I_o}$

I_o : 1 × 10^{-12} w/m^2 $\quad$ I = Intensity of sound

$$40 = 10\log_{10}\frac{I}{1\times 10^{-12}} \Rightarrow I = 1\times 10^{-12}\times 10^4$$

Intensity I = 1 × 10^{-8} w/m^2

02. (a)

(i) What is ϕ index ? How is it estimated ? What are the factors that affect ϕ index? (8)

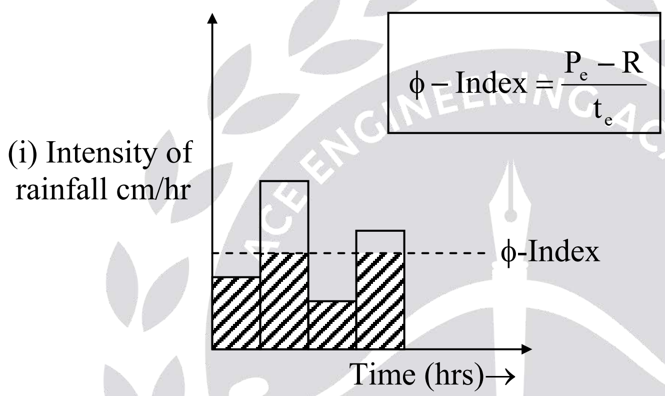
Sol:

For consistency in hydrological calculations, a constant value of infiltration rate for the entire storm duration is adopted. The average infiltration rate is called the infiltration index.

The two commonly used infiltration indices are

(1) ϕ-Index (2) w-index

1. **ϕ-Index:** This is defined as the rate of infiltration above which the rainfall volume equals runoff volume.



The method to determine the ϕ-Index would usually involve some trial. Since the infiltration capacity decreases with a prolonged storm, the use of an average loss rate in the form of ϕ-Index is best suited for design storms occurring on wet soils in which case the lose rate reaches a final constant rate prior to or early in the storm.

$$\phi - \text{Index} = \frac{P_e - R}{t_e}$$

P_e = Rainfall depth corresponding to time t_e

R = Runoff depth

t_e = Time of excess

Steps to be Followed:

1. Assume a trial value of t_e, [take P_e corresponding to t_e]
2. Compute ϕ-Index
3. Plot hytograph and check. If i > ϕ-Index, then assumed t_e is correct and obtained ϕ-Index is correct or continues trials.

Factors affecting ϕ-Index:

- Soil type
- Vegetation cover
- Initial moisture conditions

(ii) A storm with 10 cm precipitation produced a direct runoff of 5.8 cm. The time distribution of the storm is given below.

Estimate the ϕ index of the storm. **(12)**

Time from start (h)	Incremental rainfall in each hour (cm)
1	0.4
2	0.9
3	1.5
4	2.3
5	1.8
6	1.6
7	1.0
8	0.5

Sol:

P = 10 cm, R = 5.8 cm, ϕ-Index = ?

Time (hrs)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8
i, cm/hr	0.4	0.9	1.5	2.3	1.8	1.6	1.0	0.5
P, cm	0.4	0.9	1.5	2.3	1.8	1.6	1.0	0.5

Trial-1

Assume $t_e = 8$ hours

$P_e = 0.4 + 0.9 + 1.5 + 2.3 + 1.8 + 1.6 + 1.0 + 0.5 = 10$ cm

$$\phi_1\text{-Index} = \frac{P_e - R}{t_e} = \frac{10 - 5.8}{8} = 0.525 \text{ cm/hr}$$

Check: Compare i & ϕ_1-Index

$i_1 = 0.4$ cm/hr, $i_8 = 0.5$ cm/hr < ϕ_1-Index

Doesn't produce runoff

Trial-2

Assume t_e = 6 hours (Remove I & i_8)

$P_e = 10 - (0.4 + 0.5) = 9.1$ cm

$$\phi_2\text{-Index} = \frac{9.1 - 5.8}{6} = 0.55\,\text{cm/hr}$$

Check: Compare i & ϕ_2-Index

i_2, i_3, i_4, i_5, i_6 & $i_7 > \phi_2$-Index

ϕ-Index = 0.55 cm/hr

(b)

(i) A bed of uniform sand, having particle size 0.65 mm diameter and specific gravity 2.66, porosity 0.48 and depth 75 cm is to be washed hydraulically. Compute

(10)

(a) Backwash rate so that expansion will be 50 percent.

(b) Head loss at this rate.

Take kinematic viscosity of water as 1.3×10^{-2} cm²/sec and assume $C_D = \frac{24}{R}$.

Sol: $d = 0.65 \text{ mm} = 0.65 \times 10^{-3}$ m

$S = 2.66$ $n = 0.48$ $Z = 75 \text{ cm} = 0.75$ m

Rate of backwash (ROB) v_B = ? H_b = ?

% expansion = 50% i.e, $Z_C = Z + \frac{50}{100} Z = 1.5Z$

$$\frac{Z_e}{Z} = \frac{1-n}{1-n_e} \Rightarrow \frac{1.5Z}{Z} = \frac{1-0.48}{1-n_e} \Rightarrow n_e = 0.653$$

ROB $v_B = v_s[n_e]^{4.5}$

$$= \frac{g(s-1)d^2}{18\gamma} \times [n_e]^{4.5}$$

$$= \frac{9.81 \times [2.66-1](0.65 \times 10^{-3})}{18 \times 1.3 \times 10^{-2} \times \frac{1}{(100)^2}} \times [0.653]^{4.5}$$

= 0.0432 m/sec

$H_b = Z(1-n)(S-1) = 0.75\,(1-0.48)\,(2.66-1)$

= 0.6474 m

(ii) Briefly explain various factors affecting bactericidal efficiency of chlorine in water treatment process. (10)

Sol: Factor affecting bacterial efficiency of chlorine are

(i) chlorine dose

(ii) Contact time

(iii) Temperature

(iv) pH

(v) Number of organisms (or) density of organisms i.e., quality of water

(vi) Form of chlorine

(c)

(i) A flat plate of 2 m width and 4 m length is kept parallel to air flowing at 5 m/s velocity at 15° C. Determine the length of the plate over which boundary layer is laminar, shear at the location where boundary layer ceases to be laminar and total force on both sides on that portion of plate the boundary layer is laminar. (15)

Take $\rho = 1.208$ kg/m^3 and $\nu = 1.47 \times 10^{-5}$ m^2/s.

Sol: **Given:** A flat plate C/S = 4 m × 2 m

$U_\infty = 5\, m/s$

$\rho_{air} = 1.208\, kg/m^3$

$\nu = 1.47 \times 10^{-5}\, m^2/s$

To Find:

1. The length "x" uptill which laminar B.L exists

2. τ_o at x

3. F_D on both sides in laminar B.L.

Assumptions:

1. The plate is smooth, therefore critical $R_e = 5 \times 10^5$

2. Blasius velocity profile (exact velocity profile) exists.

Solution:

$$R_{ex} = \frac{U_\infty . x}{\nu}$$

$$\Rightarrow 5 \times 10^5 = \frac{5.x}{1.47 \times 10^{-5}}$$

$$x = 1.47 \text{ m} \qquad \text{———— (1)}$$

$\tau_o = C_f \frac{1}{2}\rho U_\infty^2$

$C_f = \frac{0.664}{\sqrt{R_{ex}}}$ for Blasius V.P.

$C_f = \frac{0.664}{\sqrt{5\times10^5}} = 9.39\times10^{-4}$

$\tau_o = 9.39\times10^{-4}\times\frac{1}{2}\times1.208\times5^2$

$\tau_o = 0.01418$ Pa (OR) 14.18 Milli Pa ——— (2)

$C_D = \frac{1.328}{\sqrt{R_{eL}}}$ for Blasius V.P

$= \frac{1.328}{\sqrt{5\times10^5}} = 1.878\times10^{-3}$

$F_D = 2C_D.(L\times B)\frac{1}{2}\rho U_\infty^2$

$= 2\times1.878\times10^{-3}\times4\,m\times2m\times\frac{1}{2}(1.208)\times5^2$

$F_D = 0.1667$ N (or) 166.7 milliN ——— (3)

(ii) What are the functions of a surge tank ? (5)

Sol: The functions of surge Tank:

- When the flow through penstock has to be reduced, the penstock can experience water hammer effect. Surge Tank helps in avoiding the bursting of penstock, as the fluid rises in surge tank, thus absorbing the rise in pressure.
- Surge Tanks also can behave as secondary reservoirs. If the flow in penstock has to be increased, the fluid flows from surge tank in order to create the required flow rate.

03. (a)

(i) In a factory, coal is burnt at a rate of 1 kg/second. Analysis of the coal reveals a sulphur content of 3 percent. The sulphur in the ash is 5 percent of the input sulphur. What is the annual rate of emission of sulphur dioxide ? (10)

Sol: Rate of coal burnt = 1 kg/second

% sulphur in coal = 3

% ash in sulphur = 5

% gaseous sulphur = 100 – 5 = 95

SO_2 emission / year = ?

$$\text{Sulphur gas emission/ year} = 1\times\frac{3}{100}\times\frac{95}{100}\times\frac{1}{1000}\times 1365\times 24\times 60\times 60 \quad t/\text{year}$$

= 898.776 t/year

1 part of sulphur = 2 parts of SO_2

$$\left[\begin{array}{ll} S+O_2 \rightarrow SO_2 & \text{mol wt of } S = 32 \\ & \text{mol wt of } SO_2 = 64 \end{array}\right]$$

$\therefore$ SO_2 gas emission rate = 2 × 898.776 t/year

= 1797.552 t/year

(ii) Describe various functional elements of a solid waste management system. (10)

Sol: Functional elements of solid waste management are

1. Generation
2. Collection
3. Transfer & transport
4. Processing & recovery
5. Disposal

(b)

(i) Water are the effects of water logging? (5)

Sol: Effects of Water logging:

- **Inhibiting activity of soil bacteria** due to lack of circulation of air in the soil
- **Decrease in available capillary water**
- **Fall in soil temperature**, as waterlogged soil warms up very slowly, as a result of action of soil bacteria is sluggish
- **Defective air circulation** because of high GWT, drainage becomes impossible, CO_2 liberated by the plant roots cannot be dissolved and taken away
- **Rise of Salt:** Accumulation of alkali salts in the surface soil by the upward flow of water.

Note: Alkaline deposit changes the pH value of soil

Soils with pH 7.0 to 8.5 normal yields

Soils with pH 8.0 to 9.0 decreased yield

Soils with pH > 11 infertile

- Delay in cultivation operations

- Growth of wild flora, leading to wastage of money and time
- Adverse effect on community health

(b)

(ii) A centrifugal pump runs at 1000 rpm against a head of 16 m and carries 145 litres/s of water discharge. The impeller diameter at the outlet is 300 mm and the width there is 60 mm. If the vane angle ϕ at the outlet is 40^o, determine the manometric efficiency. (15)

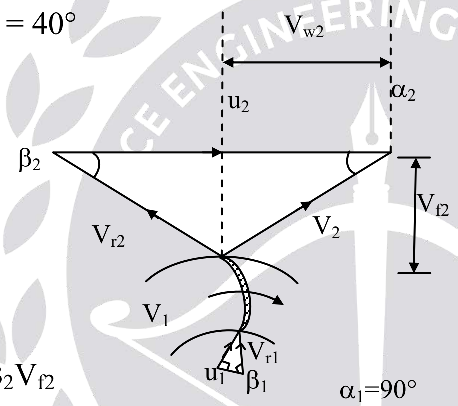
Sol:

Given data:

$N = 1000$ rpm, $H_m = 16$ m

$Q = 145$ lit/s, $D_2 = 300$ mm

$B_2 = 60$ mm, $\beta_2 = 40°$



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

i.e., $0.145 = \pi \times 0.3 \times 0.06 \times V_{f2}$

$\Rightarrow V_{f2} = 2.564$ m/s

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.3 \times 1000}{60} = 15.71 \text{ m/s}$$

From exit velocity triangle

$$\tan\beta_2 = \frac{V_{f2}}{u_2 - V_{w_2}}$$

$$\text{i.e., } \tan 30 = \frac{2.564}{15.71 - V_{\omega_2}}$$

$$\Rightarrow \quad V_{\omega_2} = 11.27 \text{ m/s}$$

The manometric efficiency is given by

$$\therefore \ \eta_{mano} = \frac{gH_m}{u_2 V_{\omega_2}} = \frac{9.81 \times 16}{15.71 \times 11.27} = 0.886$$

$$= 88.6\%$$

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(c) A municipality has directed to upgrade its primary wastewater treatment unit to a secondary unit that can meet an effluent standard of 20 mg/*l* BOD_5 and 20 mg/*l* total suspended solids. They have selected a completely mixed activated sludge system. BOD_5 of total suspended solids is 63% of TSS concentration. Estimate the required volume of aeration tank. The following data is available from existing primary plant:

Flow = 0.150 m^3/s, BOD_5 = 80 mg/*l*.

Assume the following values for half velocity constant = 95 mg/*l* of BOD_5 ; maximum growth rate constant = 2.5/day; Decay rate of micro-organism = 0.050/day; Yield coefficient = 0.50 mg VSS per mg BOD_5 removed ; MLVSS = 2000 mg/*l*. (20)

Sol.

S : y_e = 20 mg/l V = ?

S_o : y_i = 80 mg/l Q_o = 0.15 m^3/sec : 0.15×24×60×60 m^3/day

K_s : 95 mg/l K_o : 2.5 d^{-1} K_d : 0.05 d^{-1}

Y = 0.5 mg/mg of VSS X = 2000 mg/l

$$\frac{K_o S}{K_s + S} = \frac{Q_o Y}{VX}(S_0 - S)$$

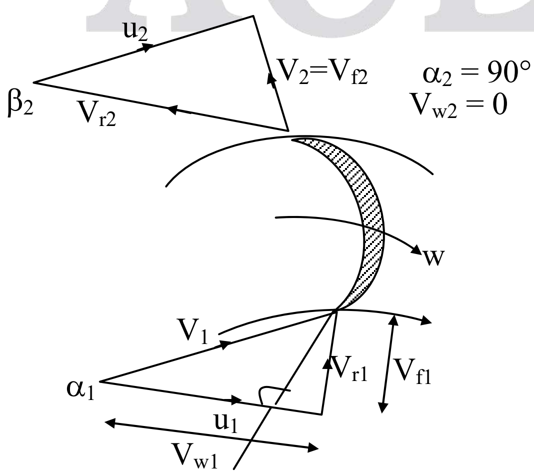
$$\frac{2.5\times 20}{95+20} = \frac{(0.15\times 24\times 60\times 60)\times 0.5}{V\times 2000}\times(80-20)$$

$$V = 447.12\ m^3$$

04.

(a) An outward flow turbine running at 200 rpm, works on a discharge of 5 m^3/s under a head of 40 m. Internal and external diameters of the wheel are 2 m and 2.5 m respectively while the width at the inlet and outlet is 200 mm. Assuming the discharge to be radial at the outlet, determine angles of the turbine at the inlet and outlet. Also draw the velocity triangles for outward flow turbine. (20)

Sol:



Given data:

N = 200 rpm

Q = 5 m^3/s

D_1 = 2m

H = 40 m

D_2 = 2.5 m

$B_2 = B_1$ = 200 mm

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

$$= \frac{\pi \times 2 \times 200}{60}$$

= 20.94 m/s

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 2.5 \times 200}{60} = 26.18\,m/s$$

$Q = \pi D_1 B_1 V_{f1}$

$5 = \pi \times 2 \times 0.2 \times V_{f1}$

$\Rightarrow V_{f1} = 3.98$ m/s

Similarly,

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

$5 = \pi \times 2.5 \times 0.2 \times V_{f2}$

$\Rightarrow V_{f2} = 3.183$ m/s

From exit velocity triangle

$$\tan \beta_2 = \frac{V_{f2}}{u_2} = \frac{3.183}{26.18}$$

$\Rightarrow \beta_2 = 6.93°$ $\rightarrow$ 9Ans)

Similarly, from inlet velocity triangle

$$\tan(180 - \beta_1) = \frac{V_{f1}}{V_{w_1} - u_1} \quad \rightarrow (1)$$

In inlet velocity triangle only two parameters (u_1 & V_{f1}), are known. At least three parameters are required to calculate any parameter related to inlet velocity triangle. As the data is insufficient we assume.

$$V_1 = \sqrt{2gH} \quad \rightarrow (2)$$

(**Note:** However, the above assumption is very crude because in reaction turbine available head is not completely converted in kinetic energy as some part of head is available in the form of pressure energy as well).

$\therefore V_1 = \sqrt{2\times 9.81\times 40} = 28.01\,\text{m/s}$

But $V_1^2 = V_{f1}^2 + V_{w_1}^2$

$\therefore\; V_{w1} = \sqrt{28.01^2 - 3.98^2} = 27.73\,\text{m/s}$

From equation (1)

$$\tan\;\beta_1 = \frac{V_{f1}}{V_{w1}-u_1} = \frac{3.58}{27.73-20.94}$$

$\Rightarrow\;\; \beta_1 = 30.4° \qquad \rightarrow \text{(Ans)}$

(b)

(i) Explain the factors that cause sludge bulking in activated sludge process for waste water treatment. (10)

Sol: Bulking Sludge Problems:

Bulking Sludge is a major problem that can cause serious operational issues to the management of wastewater treatment plant. Basically with this condition around, it will be very difficult in order to get a good separation of sludge and water and this will lead to carry over of solids to the discharge side and clog up the final polishing filter.

A bulking sludge is a condition defined by solids with poor settling characteristic (which are either slow or unable to settle at all and will just float on top) and this can be observed by the high SV test result. As a general guide, the SV test will indicate the volume of settled solids after 30 minutes time period. Another characteristic which we can use to refer to the bulking sludge problem is the poor compactibility of the sludge in which there are water or gas trapped in between the solid floc and thus leads to the sludge having a low density and it won't agglomerate well together in a compact matter. Both

sludge characteristics are the main reasons that will affect quality of wastewater discharge.

Growth of filamentous bacteria is the main cause that leads to poor settling characteristic of the waste sludge. Although presence of these microorganisms can help towards efficient removal and breakdown of organic matter, they have weak floc forming behavior and sludge mass containing these bacteria will be slow to settle. Although presence of large number of filamentous bacteria is generally blamed and identified as the main cause, there could be other microorganisms that could also lead to the same condition which are the growth of acid-favoring fungi which predominates due to the low nitrogen content of the feed water and acidic condition in the pond. There are no specific names towards naming of these microorganisms but they are all grouped under the slime producing genera.

(ii) Differentiate and compare anaerobic digestion process and composting process used for solid waste treatment. (10)

Sol:

ANAEROBIC DIGESTION	COMPOSTING
1.The Process of Anaerobic – Without Oxygen Biological decomposition occurs in a enclosed structure and naturally - occuring microorganisms breakdown organic materials	1. The Process of Composting is Aerobic – With Oxygen Biological decomposition occurs in a controlled. Open air setting where microorganisms breakdown organic material
2. The Emissions of Low Methane is collected and used to create energy	2. The Emissions of High Commercial scale compost can release significant amounts of methane into the atmosphere
3. The Soil Benefits of Digested Waste is Nutrient Dense No Chemicals are released into the soil	3. The Soil Benefits of Composted Waste is Healthy Regenerates poor soil and produces healthy microorganisms
4. The Energy Produced of Large Amounts Processed waste creates biogas which can be used to power homes, cars, and more	4. The Energy Produced is None
5. The Environmental Impact of Immense Keeps waste our of landfills, produces clean energy and prevents erosion and pollution	5. The Environmental Impact is High Keeps waste out of landfills and can prevent erosion and pollution
6. The Processing Time is 20 – 30 Days	6. The Processing Time is 12 Weeks

(c)

(i) What do you understand by galleries and shafts and why are they provided in gravity dams? (12)

Sol: Galleries and Shafts in Gravity Dams:

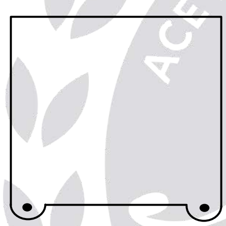
A gallery is a formal opening left in a gravity dam. This may run in transverse or longitudinal direction and may run horizontally or on a slope. The shape and size varies from dam to dam and is generally governed by the functions it has to perform.

Purposes of galleries:

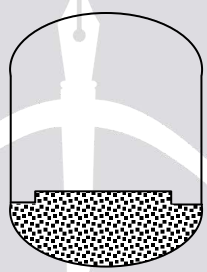
- To provide drainage of the dam section i.e., constant seepage water is drained off through galleries
- To provide facilities for drilling and grouting operations for foundations
- To provide space for header and return pipes for post cooling of concrete and grouting the longitudinal joints after the completion of dam
- To provide access to observe and measure the behaviour of structure, examining development of cracks etc.
- To provide an access of mechanical contrivances needed for the operation of outlet gates.

Shafts:

- Vertical opening in the dam are called shafts
- Shafts are provided to connect galleries at various levels.
- Plumber shaft is provided to measure the deflections of dam by suspending a plumbob in t.



Rectangular DG



Oval Shaped DG

(ii) During a recuperation test, the water in an open well was depressed by 2.5 m by pumping and it recuperated 1.8 m in 80 minutes. Find yield from a well of 4 m diameter under a depression head of 3 m. (8)

Sol:

$h_1 = 2.5$ m

Recuperated head = 1.8 m

$h_2 = 2.5 - 1.8 = 0.7$ m

$T_r = 80$ mins

$D = 4$ m $H = 3$m$Q_y = ?$

$$k_s = \frac{1}{T_r}\ell n\left[\frac{h_1}{h_2}\right]$$

$$k_s = \frac{1}{80}\ell n\left[\frac{2.5}{0.7}\right]$$

$k_s = 0.015912$ min

$Q_y = k_s\, A\, H$

$$Q_y = 0.015912 \times \left(\frac{\pi \times 4^2}{4}\right) \times 3$$

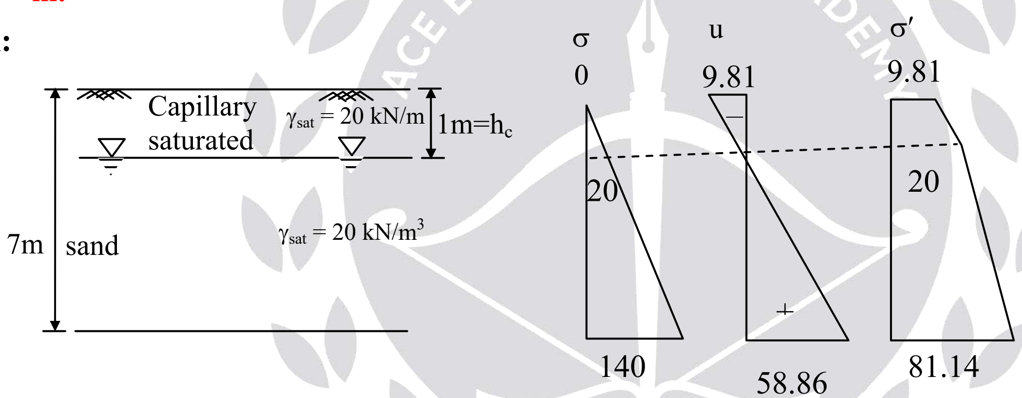
$Q_y = 0.6\ m^3$/mins

$Q_y = 10$ lit/sec

05.

(a) The soil profile in a particular site consists of 7 m thick sandy layer overlain by a layer of clay. The water table is at 1 m below the ground surface. Above the water table, the sand is saturated with capillary moisture. The dry unit weight of sand is 17 kN/m³ and its saturated unit weight is 20 kN/m³. Plot the total stress, neutral stress and effective stress with depth up to a depth of 7 m. (12)

Sol:



At G.L:-

$\sigma = 0$

$u = -\gamma_w h_c = -9.81 \times 1 = -9.81\ kN/m^2$

$\therefore \sigma' = \sigma - u = 0 - (-9.81) = 9.81\ kN/m^2$

At W.T :

$z = 1$ m

$\sigma = \gamma_{sat} \times 1 = 20 \times 1 = 20$ kPa,

$u = 0$

$\sigma' = 20 - 0 = 20$ kPa

At z = 7m:

$\sigma = \gamma_{sat} \times (1+6) = 20 \times 7 = 140\ kN/m^2$

$u = \gamma_w \cdot h_p = 9.81 \times 6 = 58.86$ kPa

$\sigma' = 140 - 58.86 = 81.14$ kPa

(b) What is meant by N value ? Why should we apply corrections for the N value obtained from the field? Briefly explain the corrections (12)

Sol:

N value is the number of blows required to penetrate the last 30 cm of sampler while collecting the sample. In standard penetration test, it is represented as standard penetration number.

Standard penetration number is corrected for over burden correction and dilatancy correction.

Overburden correction:

In granular soils, over burden pressure affects penetration resistance.

- If two soils having same relative density but different confining pressure, the one with high confining pressure gives higher penetration number.
- 'N' value is underestimated at shallow depths and overestimated at deeper depths. for uniformity, over burden pressures are corrected to standard effective over burden pressure.

According to Gibbs and Holtz: $N' = N_R \times \frac{350}{\sigma_o' + 70} \left(\sigma_o^1 \le 280\,kPa\right)$

According to Peck, Hansen and Thornburn: $N' = 0.77 \times N_R . \log\left(\frac{19.05}{\sigma_o'}\right)$

N' : Corrected N – value

N_R : ObservedN – value

Dilatancy correction:

Silty fine sands and fine sands below water table develop pore water pressure, inturn increase the resistance of soil and hence penetration number.

Terzaghi and peck recommend

$$N'' = 15 + \frac{1}{2}(N' - 15) \Rightarrow \text{if } N' > 15$$

$N'' = N'$ (if $N' < 15$)

Dilatancy correction should apply after over burden correction only.

N'' : corrected N-value after dilatancy correction

N': corrected N-value after overburden correction

(c) Define optimum signal cycle time. Design two phase traffic signal with pedestrian crossing by Webster's method for an average normal flow of traffic on cross roads A and B during design hour as 480 PCU and 250 PCU per hour, the saturation flows on roads A and B are given as 1200 PCU and 1000 PCU per hour respectively. All red time required for pedestrian crossing is 12 seconds and amber times of 2 seconds for clearance in each phase is to be provided. (12)

Sol: Optimum Signal Time:

It is the length of cycle of a signal corresponding to minimum total delay to all the vehicle at the approach roads of intersection

Given:

Saturation flow on road A = S_a = 1200 PCU/hr

Saturation flow on road B = S_b = 1000 PCU/hr

Normal flow on road A = q_a = 480 PCU/hr

Normal flow on road B = q_b = 250 PCU/hr

All red time T = 12 sec

Amber time = 2 sec

No. of phases n = 2

For road A, $y_A = \frac{q_a}{s_a} = \frac{480}{1200} = 0.4$

For road B, $y_B = \frac{q_b}{s_b} = \frac{250}{1000} = 0.25$

$y = y_a + y_b = 0.4 + 0.25 = 0.65$

Lost time per cycle 'L' = 2n + R

= 2(2) + 12

= 16 sec

Cycle length = $\frac{1.5L + 5}{1 - y}$

$= \frac{1.5(16) + 5}{1 - 0.65} = 82.85 \text{ sec}$

say 83 sec

Green time for road A = $G_a = \frac{y_a}{y}(C_o - L)$

$= \frac{0.4}{0.65}(83 - 16)$

= 41.23 sec

Say 41.5 sec

Green time for road B = $G_B = \frac{y_B}{y}(C_o - L)$

$$= \frac{0.25}{0.65}(83-16)$$

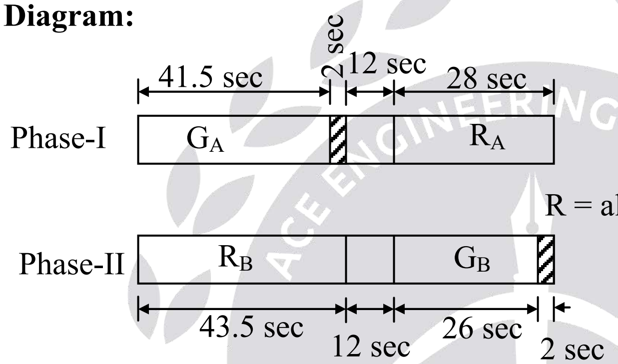
$$= 25.77 \text{ sec}$$

Say 26 sec

For Amber time of 2 sec each for clearance

total cycle time = 41.5 + 26 + 12 + 2 + 2 = 83.5 sec

Phase Diagram:



(d) Calculate lead and radius of a turnout on a Broad Gauge railway track with the following data:

Heel divergence = 130 mm

Straight length between theoretical nose of crossing and tangent point of crossing = 1.3 m

Angle of crossing = 4°45'49"

Angle of switch = 1°08'00"

Broad Gauge width = 1.676 m

Show the values on a neat sketch of turnout. (12)

Sol: Given:

Angle of crossing 'α' = 4°45'49"

Angle of switch 'β' = 1°08'00"

Heed divergence 'd' = 0.13 m

Straight length between theoretical nose of crossing a tangent point of crossing 'x' = 1.3 m

Width of BG track 'G' = 1.676 m

$$\text{Lead} = x\cos\alpha + (G - d - x\sin\alpha)\cot\left(\frac{\alpha+\beta}{2}\right)$$

$$= (1.3\cos 4^\circ 45'49'') + (1.676 - 0.13 - 1.3\sin 4^\circ 45'49'')\cot\left(\frac{4^\circ 45'49'' + 1^\circ 08'}{2}\right)$$

$$= 29.207 \text{ m}$$

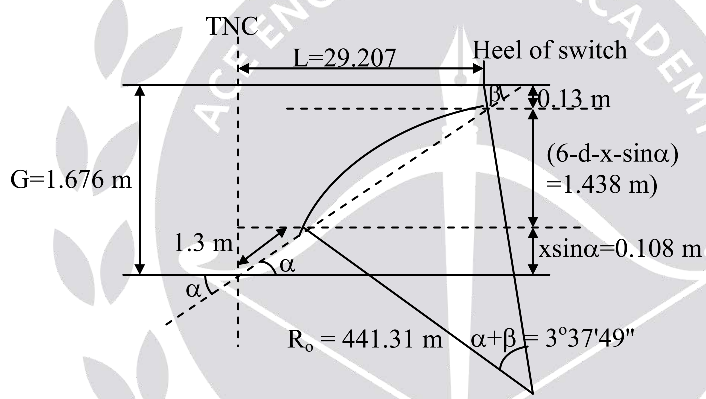
Radius of outer curve, $R_o = \dfrac{G - d - x\sin\alpha}{\cos\beta - \cos\alpha}$

$$= \frac{1.676 - 0.13 - 1.3\sin(4^\circ 45'49'')}{\cos 1^\circ 08'00'' - \cos 4^\circ 45'49''}$$

$$= 441.31 \text{ m}$$

Radius of centre line of turnout = $R_o - \dfrac{G}{2}$

$$= 441.31 - \frac{1.676}{2} = 440.47 \text{ m}$$



(e) In a running fly level from a benchmark of RL 187.215, the following reading were obtained.

BS	1.115	2.135	1.880	2.725
FS	0.805	3.930	0.880	-

From the last position of the instrument, five pegs at 20 m intervals are to be set out on a uniformly falling gradient of 1 in 40. The first peg is to have an RL of 185.670. Work out the staff readings required for setting the tops of the pegs on the given gradient. (12)

Sol:

BS	1.115 m	2.135 m	1.880 m	2.725 m
FS	0.805 m	3.930 m	0.880 m	-

-5 pegs @ 20 m interval

- falling gradient of 1/40
- RL peg_1 =185.670 (Given)

–RL $peg_2 = 185.670 - \left(20\times\frac{1}{40}\right) = 185.170\,m$

–RL $peg_3 = 185.670 - \left(40\times\frac{1}{40}\right) = 184.670\,m$

–RL $peg_4 = 185.670 - \left(60\times\frac{1}{40}\right) = 184.170\,m$

–RL $peg_5 = 185.670 - \left(80\times\frac{1}{40}\right) = 183.670\,m$

	BS	IS	FS	HI	RL	Remark
1	1.115			188.330	187.215	Bench mark
2	2.135		0.865	189.600	187.465	
3	1.880		3.930	187.550	185.670	
4	2.745		0.880	189.415	186.67	
5		3.745			185.670	Peg_1
6		4.245			185.170	Peg_2
7		4.745			184.670	Peg_3
8		5.245			184.170	Peg_4
9			5.745		183.670	Peg_5

$HI_1 = RL_{BM} + BS_1$
$= 187.215 + 1.115$
$= 188.330$ m

$HI_2 = RL_2 + BS_2$
$= 187.465 + 2.135$
$= 189.6$ m

$RL_2 = HI_1 - FS_2$
$= 188.330 - 0.805$
$= 187.465$ m

$RL_3 = HI_2 - FS_3$
$= 185.670$ m

$HI_4 - IS_5 = 185.670$ (RL of peg 1)

$\Rightarrow 189.415 - IS_5 = 185.670$

$IS_5 = 3.745$ m

$HI_4 - IS_6 =$ RL peg 2

$\Rightarrow 189.415 - IS_6 = 185.170$

$IS_6 = 4.245$ m

Check:

$$\Sigma Bs - \Sigma Fs = L.R_L - F.R_L$$

$$(7.875) - (11.42) = 183.670 - 187.215$$

$$-3.545 \text{ m} = -3.545 \text{ m}$$

06.

(a) Consolidated undrained type triaxial test were carried out to failure on two identical specimens of silty clay with pore water pressure measurements, as given below:

S.No	Confining pressure (kPa)	Deviator stress (kPa)	Pore pressure (kPa)
1	100	150	40
2	200	220	70

Determine the shear strength parameters, if

(i) construction is done at a faster rate,

(ii) construction is done slowly. **(20)**

Sol:

Consolidated Undrained test: CU test

	σ_c	σ_d	u
1	100	150	40
2	200	220	75

(i) If construction is done at faster rate:

no time for dissipation of pore water

$\therefore$ total stress analysis:

$\sigma_3 = \sigma_c$

$\sigma_1 = \sigma_c + \sigma_d$

	σ_3	σ_1
1	100	250
2	200	420

From plastic equilibrium condition.

$\therefore \sigma_1 = \sigma_3 \tan^2\alpha_f + 2c\tan\alpha_f$

$250 = 100 \tan^2\alpha_f + 2C_u\tan\alpha_f \quad \rightarrow (1)$

$420 = 200 \tan^2\alpha_f + 2C_u\tan\alpha_f \quad \rightarrow (2)$

$(2) - (1) \Rightarrow 170 = 100 \tan^2\alpha_f$

$\therefore \tan\alpha_f = 1.304$

$\alpha_f = 52.51°$

$$45 + \frac{\phi_u}{2} = 52.51°$$

$\phi_u = 15.026°$

From equation (1)

$250 = 100 \times 1.304^2 + 2\times C_u \times 1.304$

$C_u = 30.66$ kPa

(ii) **If construction is done at slower rate**:

allows time for pore water to dissipate results in development of effective stresses

$\therefore \sigma_3' = \sigma_3 - u$

$\sigma_1' = \sigma_1 - u$

	σ_3'	σ_1'
1	60	210
2	125	345

$\sigma_1' = \sigma_3^1 \tan^2\alpha_f + 2C'\tan\alpha_f$

$210 = 60\tan^2\alpha_f + 2C' + \tan\alpha_f \rightarrow (1)$

$345 = 125\tan^2\alpha_f + 2C'\tan\alpha_f \rightarrow (2)$

$(2) - (1) \Rightarrow 135 = 65 \tan^2\alpha_f$

$\tan\alpha_f = 1.44$

$$45 + \frac{\phi'}{2} = 55.24°$$

$\phi' = 20.487°$

$= 20.49°$

From equation(1) : -

$210 = 60\times 1.44^2 + 2C' \times 1.44$

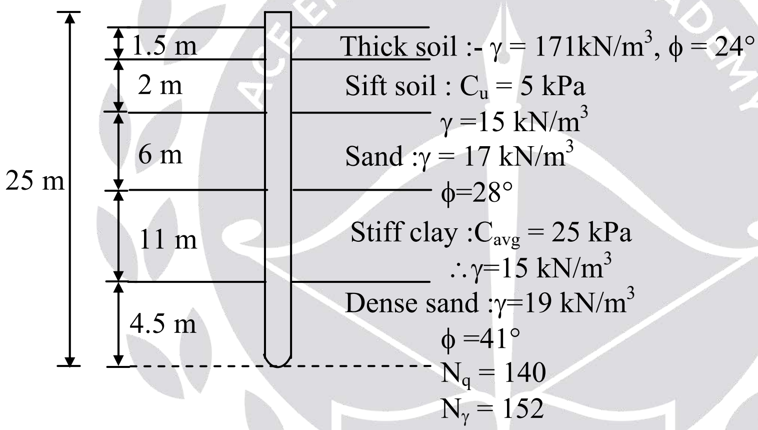
$C' = 29.72$ kPa

(b) The soil profile in a particular site consists of a 1.5 m thick filled up soil (N = 3, γ = 15 kN/m^3). This is followed by 6 m thick sandy layer (av. N value = 8 and γ = 17 kN/m^3), which is followed by 11 m thick stiff clay layer (av. Cohesion = 25 kN/m^2, γ = 15 kN/m^3). This is followed by dense sand upto 30 m (av. N value = 50, γ = 19 kN/m^3). The water table is at 1.5 m below GL. Calculate the safe load that a 25 m long 600 mm dia bored cast in situ pile can carry. (20)

Take for N = 3, $\phi = 24^o$, N = 8, $\phi = 28^o$

for N = 50, $\phi = 41^o$, N_q = 140 and N_γ = 152.

Sol:



Given:

Pile is bored cast insitu

d = 600 mm = 0.6 m

L = 25 m

Ultimate point bearing resistance, $Q_b = A_b.\ f_b$

f_b = ultimate bearing capacity at pile base

$f_b = \sigma_v^{'}.Nq$ [In deep foundations, generally $0.5\gamma BN_\gamma$ term is neglected]

$\sigma_v^{'}$ = vertical effective stress at pile tip or base

$$\sigma_v^{'} = \gamma_{thick}\times 1.5 + \gamma^1_{soft\,clay}\times 2 + \gamma^{'}_{sand}\times 6 + \gamma^{'}_{stiff\,clay}\times 11 + \gamma^{'}_{dense\,sand}\times 4.5$$

Assume γ_w = 9.81 kN/m^3

$$\sigma_v^1 = 1.5\times 17 + 2\times(15-9.81) + 6\times(17-9.81) + 11\times(15-9.81) + 4.5\times(19-9.81)$$

$$\sigma_v^{'} = 177.47\,\text{kN/m}^2$$

$f_b = 177.47 \times 140 = 24,845$ kPa

However, maximum value of f_b in normal silica sand is limited to 11,000 kN/m^2 (As per Tomlinson)

$\therefore f_b = 11,000$ kPa

Generally, $(f_b)_{\text{bored pile}}$ is $\frac{1}{2}$ to $\frac{1}{3}$ of f_b of driven pile

Assume $(f_b)_{\text{bored pile}} = \frac{1}{2} \times (f_b)_{\text{driven}}$

$$= \frac{1}{2} \times 11,000 = 5500 \text{ kPa}$$

$$\therefore Q_b = f_b A_b = 5500 \times \frac{\pi}{4} \times 0.6^2 = 1555.08 \text{ kN}$$

- As top 1.5 m thick filled soil is loose sand (N = 3, Q = 24°) and 2m soft clay. These soils settles more than surroundingPiles and induce a downward drag results inNegative skin friction, Q_n.

$$Q_n = (Q_n)_{\text{thick soil}} + (Q_n)_{\text{soft clay}}$$

For thick soil (1.5 m): (Loose sand)

$Q_{n1} = f_{n1}.A_s$

$Q_{n1} = K.\ \sigma'_a.\tan\delta.A_5$

Where,K = 1–sinϕ , "K" varies from 0.3 to 0.75 with a median value of 0.5 for bored piles in sand.

Given, ϕ = 24°, but should reduce by 3° due to being bored pile, to account the loosening of sand due to drilling of hole.

$\therefore$ K = 1–sin21° = 0.642

δ = angle of friction between pile and soil for negative skin friction computations, generally, $\delta = \frac{1}{2}\phi \text{ to } \frac{2}{3}\phi$

So, assume $\delta = \frac{2}{3}\phi$

$$\delta = \frac{2}{3} \times 24° = 16°$$

$\therefore \sigma'_a$ = average effective vertical stress

$$\sigma^1_a = \frac{0 + 17 \times 1.5}{2} = 12.75 \text{ kN/m}^2$$

$\therefore Q_{n1} = 0.642 \times 12.75 \times \tan16° \times \pi \times 0.6 \times 1.5 = 6.635$ kN

Soft clay: (2m)

$Q_{n2} = \alpha.C'.\pi DL$

IS: 2911 part I (1979) recommends, for bored piles

$\alpha = 0.7 \Rightarrow$ soft clays

$\alpha = 0.4 \Rightarrow$ stiff clays

$Q_{n2} = 0.7 \times 5\times \pi \times 0.6\times 2= 13.195$ kN

Ultimate skin frictional resistance, Q_s in sand layer (6m) :

$Q_{s_1} = A_s.f_s$

As N = 8, $\phi = 28°$; sand is considered as loose sand

ϕ should reduce by 3°

$K = 1–\sin25° = 0.58$

$f_s = K.\ \sigma_a'.\ \tan\delta.\ A_s$

$\delta = \phi$ for bored piles excavated in dry soil

$\delta<\phi$ for bored piles if bentonite slurry is used during boring

Therefore, Assume $\delta = \frac{3}{4}\phi$

$$\delta = \frac{3}{4}\times 28° = 21°$$

$$\text{As } \frac{L}{d} = \frac{6}{0.6} = 10 < (15-20)$$

No arching, effect:

σ_v^1 varies linearly with depth

σ_v^1 at top of sand layer $\Rightarrow (\sigma_v^1)_{top\ layer} = 1.5\gamma + 2\gamma'$

$= 1.5 \times 17 + 2\times (15–9.81)$

$= 35.88$ kPa

$\therefore (\sigma_v^1)_{bottom\ layer} = (1.5\gamma + 2\gamma_{clay}') + 6\gamma_{sand}'$

$= 35.88 + 6\times (17 –9.81)$

$= 79.02$ kPa

$$f_s = 0.58\times\left[\frac{35.88+79.02}{2}\right]\times \tan 21°\times 6$$

$f_s = 12.79$ kPa < 100 kN/m^2

Maximum value of f_s is limited to 100 kPa in normal silica sand

$\therefore Q_{s_1} = 12.79 \times \pi \times 0.6 \times 6 = 144.65$ kN

Ultimate skin frictional resistance in stiff clay (11 m):

$Q_{s2} = \alpha C \,.\, A_s$

$= 0.4 \times 25 \times \pi \times 0.6 \times 11 = 207.34$ kN

Ultimate skin frictional resistance in dense sand (4.5 m):

$\phi = 41°$

$\delta = 0.75 \times 41 = 30.75°$

$Q_{s3} = K.\sigma'_a . \tan\delta A_s$

$K = 1 - \sin 38° = 0.384$

$\frac{L}{d} = \frac{4.5}{0.6} = 7.5 < 15$

No arching effect:

$(\sigma'_v)_{20.5\,m} = 1.5\gamma + 2\gamma'_{soft\ clay} + 6\gamma'_{sand} + 11 \times \gamma'_{stiff\ clay}$

$= 1.5 \times 17 + 2 \times (15-9.81) + 6 \times (17-9.81) + 11 \times (15-9.81)$

$= 79.02 + 11 \times (15-9.81)$

$= 136.11$ kPa

At 25 m depth: $(\sigma'_v)_{25m} = 136.11 + \gamma'_{densesand} \times 4.5$

$= 136.11 + 4.5 \times (19-9.81) = 177.46$ kN/m^3

$f_s = K\sigma'_a \tan\delta$

$= 0.384\left[\frac{136.11 + 17.7.46}{2}\right] \times \tan 30.75°$

$f_s = 35.82$ kPa <100 kPa (Hence ok)

$Q_{s3} = 35.82 \times \pi \times 0.6 \times 4.5 = 303.84$ kN

Total ultimate load carrying capacity of pile

$Q_u = Q_b + Q_{s1} + Q_{s2} + Q_{s3} - (Q_{n1} + Q_{n2})$

$= 1555.08 + 144.65 + 207.34 + 303.84 - (6.635 + 13.195)$

$\therefore\ Q_u = 2191.08$ kN

Assume safety factor, F.O.S = 2.5

$$\therefore Q_{safe} = \frac{2191.08}{2.5} = 876.43\,kN$$

(c) Mention standard conditions assumed for basic runway length. Design the runway length for a proposed airport site at an altitude of 420 m above mean sea level. Use the following data:
Basic runway lengths for take-off and landing are 2000 m and 2400 m respectively.
Airport reference temperature is 23^o C.
Effective gradient along the proposed runway is 0.4%. (20)

Sol:

The assumed conditions of runway length for standard environment which decides the basic runway length are as follows

- No wind is blowing on the runway
- The aircraft is loaded to its full loading capacity
- The airport is situated at means ea level (MSL)
- There is no wind blowing on the way to the destination
- The runway is levelled in the longitudinal direction or in other words, it has zero effective gradients
- The same standard temperature is maintained along the runway
- The standard temperature if 15^{o}C exists at the airport (at MSL)

Given:

Basic length of runway for takeoff = L_1 = 2000 m

Basic length of runway for landing = L_2 = 2400 m

Elevation of airport = H = 420 m above MSL

Airport reference temperature = T = 23^{o}C

Effective gradient = 0.4%

(a) Correction runway takeoff length

Step I: Correction for elevation

As per ICAO, basic runway length is to be increased at the rate of 7% per 300 m elevation above MSL

$\therefore$ Correction $= \frac{7}{100} \times \frac{H}{300} \times$ Basic length

$= \frac{7}{100} \times \frac{420}{300} \times 2000$

$= 196$ m

Corrected length, L = 2000 + 196 = 2196 m

Step II: Correction for Temperature:

As per ICAO, runway length corrected to elevation is increased at rate of 1% per 1^{oC} rise in temperature

Standard temperature = 15 – 0.065 H

$T_s = 15 - 0.0065 \times 420 = 12.27^o$

Rise in temperature $= T_R - T_s = 23 - 12.27 = 10.73^o$

Correction $= \frac{10.73}{100} \times 2196 = 235.63$ m

Corrected length = 2196 + 235.6 = 2431.63 m

Check:

As per ICAO, total correction for elevation and temperature shall not exceed 35% of basic runway length

Total correction = 196 + 235.63 = 431.63 m

% correction $= \frac{431.63}{2000} \times 100 = 21.58\% < 35\%$

Heck OK

Step III: Correction for Gradient:

As per ICAO, runway length corrected to elevation and temperature shall further be increased at rate of 20% for every 1% of effective gradient

Correction for gradient $= \frac{20}{100} \times 0.4 \times 2431.63 = 194.53$ m

Corrected length = 2431.63 + 194.53 = 2626.16 m

Final runway length = 2626.16 m

(b) Correction for runway lading length

Step I: Correction for Elevation:

$$\text{Correction} = \frac{7}{100} \times \frac{420}{300} \times 2400$$

$$= 235.2 \text{ m}$$

Corrected length = 2400 + 235.2 = 2635.2 m

For runway landing length, correction for temperature and gradient is not required

Maximum of runway take-off length and runway landing length shall be considered

$\therefore$ Length of runway = 2635.2 m

07. (a)

(i). What is the basis for classifying foundations into shallow and deep ? Briefly explain the situations in which different types of shallow foundations are adopted. (8)

Sol: Foundations may be grouped as shallow (or) deep foundation depending on depth of installation of foundation

	Shallow foundation		Deep Foundation
1	If the depth of foundation 'D_f' less than width of footing $D_f \le B$	1	$D_f \ge B$
2	If load coming from structure is small Ex. Residential Buildings	2	If load coming from structure is more Ex: Super structures, sky scrappers
3	If the soil below footing is Dense (or) Stiff to medium dense	3	If the soil below footing is very loose (or) weak.

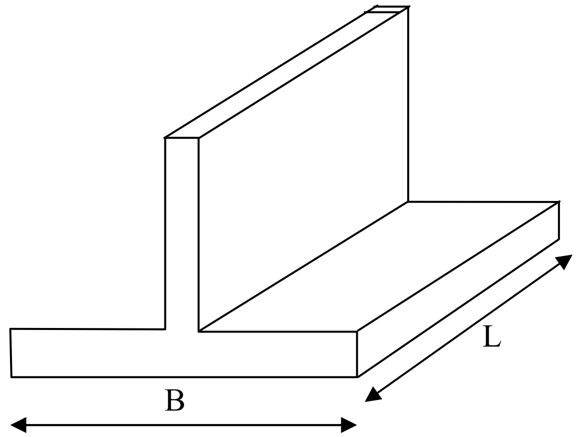
Types of Shallow foundations:

01. Strip footing:

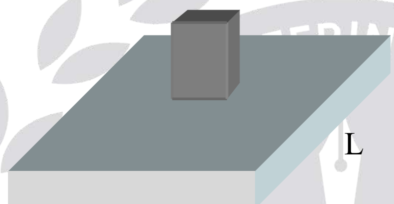
Provided for load bearing wall

It is also provided for closely spaced row of columns where spread footing may overlap.

$\therefore L >> B$

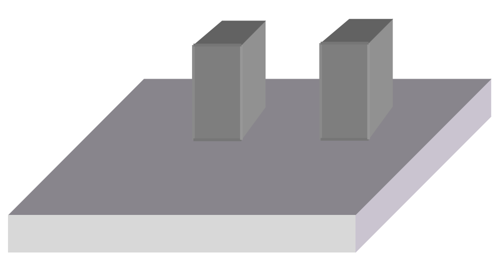


02. Spread (or) Isolated footing: to support individual columns



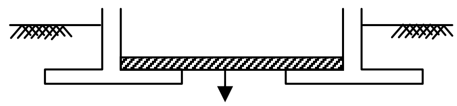
03. Raft / mat foundation: It is large slab supporting number of columns and walls under entire structure
It is useful in reducing differential settlement

04. Combined Footing: It supports two columns when they are so close to each other so that their individual footing may overlap.
It is also provided when the property line so close to column
It may be rectangular (or) trapezoidal in plan



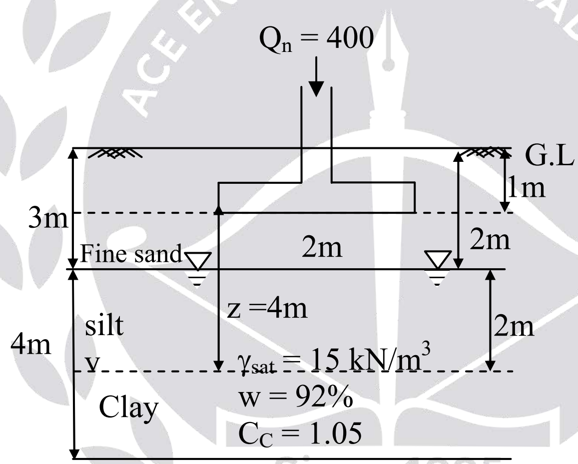
05. Strap (or) cantilever footing: It consists of two isolated footing connected with strap (or) lever such that they behave as one unit.

A strap footing is more economical than combined footing when allowable soil pressure is high.



(ii) A square footing (2 m × 2m) founded at a depth 1 m below GL has to support a column load of 400 kN. The soil profile consists of fine sand (γ = 17 kN/m^3) up to a depth of 3 m, followed by a 4 m thick layer of silty clay (γ = 15 kN/m^3, NMC = 92%, C_c = 1.05). This is followed by dense sandy layer up to 12 m. The WT is at 2 m below the GL. Compute the possible consolidation settlement and state whether it is within permissible limits. (12)

Sol:



For fine sand:

Assume $\gamma = \gamma_{sat}$ = 17 kN/m^3

$$\therefore \text{SF} = \frac{C_e}{1+e_o} \times H \times \log_{10}\left(\frac{\sigma_o^1 + \Delta\sigma'}{\sigma_o^1}\right)$$

C_C = 1.05

$e_o.S_r = w.G$

Assume G = 2.7

e_o = 0.92 × 2.7 = 2.484

H = 4 m

∴ At centre of clay layer

$$\sigma_o^1 = \gamma_{sand} \times 2 + \gamma'_{sand} \times 1 + \gamma'_{clay} \times 2$$

$\sigma_o^1 = 17\times2+(17-9.81)\times1+(15-981)\times2$

$\sigma_o^1 = 51.57$ kPa

$\Delta\sigma' = \frac{Q_n}{(B+z)^2} = \frac{400}{(2+4)^2} = 11.11\text{kPa}$

$s_f = \frac{1.05}{1+2.484}\times4\times\log_{10}\left(\frac{51.57+11.11}{51.57}\right) = 0.102\text{m} = 102.15$ mm

$\therefore S_f = 102.15$ mm

For Isolated footing in sands, maximum settlement is 50 mm and in clays, it is 75 mm. As obtained ultimate settlement is beyond those values, settlement obtained is not within limits.

(b) Determine the correct magnetic bearings of the lines of closed traverse having the following bearings as observed: (20)

Line	AB	BC	CD	DE	EA
FB	81°5′	100°20′	171°35′	210°50′	300°50′
BB	260°20′	282°35′	351°45′	30°05′	121°10′

Sol:

Line	FB	BB
AB	81°5′	260°20′
BC	100°20′	282°35′
CD	171°35′	351°45′
DE	210°50′	30°5′
EA	300°50′	121°10′

Included angle:

$\angle A = FB_{AB} - FB_{AE}$

$= FB_{AB} - BB_{EA}$

$= 81°5' - 121°10' \; (+360°)$

$= 319°\,55'$

$\angle B = FB_{BC} - BB_{AB}$

$= 100°20' - 260°20' \; (+360°)$

$= 200°$

$\angle C = FB_{CB} - BB_{BC}$

$= 249^{o}$

$\angle D = 219^{o}5'$

$\angle E = 270^{o}45'$

$\angle A + \angle B + \ldots\ldots + \angle E = 1258^{o}45'$

$(2n+4)\, 90^{o}$

$\Rightarrow (2 \times 5 + 4) 90^{o} = 1260^{o}$

$\therefore$ Total Error = $1258^{o}45' - 1260^{o} = -1^{o}15'$

Correction = $+\,1^{o}15'$

Correction per angle = $\dfrac{+1^{o}15'}{5} = 15'$

$\therefore$ Corrected angles

$\angle A = 320^{o}10'$,

$\angle B = 200^{o}15'$,

$\angle C = 249^{o}15'$,

$\angle D = 219^{o}20'$,

$\angle E = 271^{o}$

No line is free from local attraction

Line	| FB – BB|	Difference from 180°
AB	$179^{o}15'$	$45'$
BC	$182^{o}15'$	$2^{o}15'$
CD	$180^{o}10'$	$10'$ → Least difference
DE	$180^{o}45'$	$45'$
EA	$179^{o}40'$	$20'$

Adjusted FB and BB of line CD

$FB_{CD} = 171^{o}35' + \dfrac{10'}{2} = 171^{o}40'$

$BB_{CD} = 351^{o}45' - \dfrac{10'}{2} = 351^{o}40'$

Now,

Corrected $\angle C = FB_{CD} - BB_{BC}$

$249^{o}15' = 171^{o}40' - BB_{BC}$

$BB_{BC} = -77^o35'(+360^o)$

$= 282^o25'$

$FB_{BC} = 102^o25'$

Corrected $\angle B = FB_{BC} - BB_{AB}$

$200^o15' = 102^o25' - BB_{AB}$

$BB_{AB} = 262^o10'$

$FB_{AB} = 82^o10'$

Corrected $\angle A = FB_{AE} - BB_{EA}$

$320^o10' = 82^o10' - BB_{EA}$

$BB_{EA} = 122^o$

$\Rightarrow FB_{EA} = 302^o$

Corrected $\angle E = FB_{EA} - BB_{DE}$

$271^o = 302^o - BB_{DE}$

$BB_{DE} = 31^o$

$FB_{DE} = 211^o$

$\angle D = FB_{DE} - BB_{CD}$

$219^o20' = 211^o - BB_{CD}$

$BB_{CD} = 351^o40'$

$\therefore$ Checked

Corrected Bearings:

Line	FB	BB
AB	$82^o10'$	$262^o10'$
BC	$102^o25'$	$282^o25'$
CD	$171^o40'$	$351^o40'$
DE	211^o	31^o
EA	302^o	122^o

(c) Describe tunnel lining and various materials used for it (10)

Sol: Tunnel lining:

Tunnel lining is the finishing touch given to the cross section of tunnel and it acts as a ground support system to the periphery of a tunnel or shaft excavation. Tunnels may be completely lined, partially lined, or even unlined. If the tunnel is passing through hard stratum, it may be left unlined. Lining may be of two types:

Temporary lining: It is provided for supporting the roof and the walls of tunnel during construction.

Permanent lining: It is provided in soft soil which is always liable to disintegrate.

The ideal lining should be easy to maintain, economical, durable, simple to construct and stable.

The advantages of providing a tunnel with permanent lining are:

1. It gives correct shape and cross section to the tunnel.
2. It withstands soil pressure when driven in soft soils.
3. It reduces losses in friction and erosive action, and ensures stream line motion, when the tunnel has to carry water by providing a smooth passage at good velocity, free from turbulence.
4. It forms a good protective covering to certain types of rocks prone to air slaking.
5. It keeps prevents water percolation into the tunnel.
6. It supports large slabs of rock which might have become loosened during blasting.
7. It strengthens the sides and roofs to withstand pressure and prevent the tunnel from collapsing

Materials used for tunnel lining:

(a) **Concrete:** It is used because of its superiority in structural strength, ease of placement, durability, and lower maintenance cost. Concrete can be cast insitu or prefabricated.

(b) **Flake concrete:** This is generally used to limit the usage of cement quantity and by using good quality stones . Flaked concrete is used in side wall lining for good rocks.

(c) **Shotcrete:** Shotcrete is formed by condensing dry mix of concrete, quick-setting agent and water with a high-speed concrete jetting machine on a clean rock surface.It has high compactness and can quickly close the cracks of the surrounding rock

(d) **Brick masonry:** This is generally used in underground sewers, as bricks are more acid resisting and suitable to carry sewage.

(e) **Steel and cast iron :** Perforated segments of steel and cast iron are used. The segments are jointed by bolting and joints are sealed.

(f) Timber

(d) Classify wet docks and write advantages and disadvantages of each of them. (10)

Sol: **Wet docks:** These are the docks which are used for berthing of vessels, to facilitate loading and unloading of passengers and cargo.

Classification of wet docks:

(a) Wet docks in tidal basins:

- These are provided in low tide areas.
- In ports on the open sea coats protected by an outlying break water, basins are provided within its shelter.
- In these basins, pier walls are projected at right angles to the shore along side which the vessels can lie and discharge their cargoes.
- The disadvantages is that the fluctuations in water level will cause rubbing of sides of ships against the berths. Also it cannot be used for high range tides.

(b) Wet docks in enclosed or impounded basins:

- These are used when tidal ranges are very marked and large.
- Docks are formed by enclosures and are shut off by entrances using locks in order to maintain fairly uniform level of water.
- It prevents the rubbing of sides of ships against the berths due to fluctuations in water level.

The disadvantages is that use of lock and gate arrangement is costly and ship will take time to enter and exit the dock.

08. (a)

(i) Comment on the statement "The net bearing capacity of a shallow foundation in clayey soil is unaffected by the position of water table, whereas in sandy soil, it is very much affected.

(5)

Sol:

For strip footing

Clays: $q_{nu} = CN_c$

Sands: $q_{nu} = CN_c + \gamma\alpha N_q{-}1) + 0.5\gamma BN_r$

Net ultimate bearing capacity in clay soil is independent on position of water table, so rise (or) fall of water table doesn't affect 'q_{nu}' in clayey soils but in sandy soils, if water table rises to G.L., q_{nu} reduces by almost 50%.

(ii) With respect to a compaction curve, explain how one can plot the zero air voids line, 90% saturation line and 10% air voids line. (10)

Sol: $\gamma_d = \dfrac{(1-n_a)G\gamma_w}{1+wG}$ (or) $\gamma_d = \dfrac{G\gamma_w}{1+\dfrac{wG}{S}}$

For Zero air void line:

$n_a = 0$

$a_c = 0$

$S_r = 100\%$

$$\gamma_{d_1} = \frac{G\gamma_w}{1+wG}$$

For 90% Saturation line:

$S_r = 90\%$

$a_c = 10\%$

$n_a < 10\%$

$$\gamma_{d_2} = \frac{G\gamma_w}{1+\dfrac{wG}{0.9}} = \frac{0.9G\gamma_w}{0.9+wG}$$

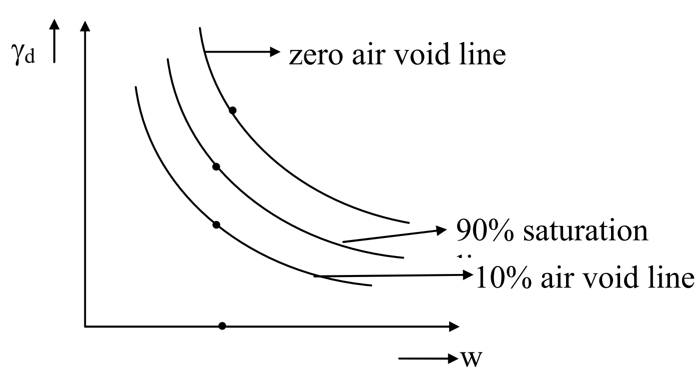
For 10% air void line:

$n_a = 10\%$

$$\gamma_{d_3} = \frac{(1-0.1)\times G\gamma_w}{1+wG}$$

$$\gamma_{d_3} = \frac{0.9G\gamma_w}{1+wG}$$

For all lines, γ_d varies inversely with water content



(b) Discuss the geological characteristics necessary for the design and construction of reservoirs.

(10)

Sol: Geological investigations of the dam and reservoir site are dams for the following purposes:

(i) Suitability of foundation for the dam

(ii) Water tightness of the reservoir basin

(iii) Location of the quarry sites for the construction materials

Geological characteristics necessary:

- The surrounding hills which constitute the rim of the reservoir should be water tight, so that there is no leakage of water through any part of the rim.
- Bed rock near the surface, if the rocks are massive intact it provides excellent supporting foundation material.
- Discontinuous, weathered rocks and fragile rocks should be removed or treated properly before laying foundation material.
- Granite, gneiss, quartzite provides best foundation
- Fine grained seelimentary rocks have higher shear strength than course grained rocks
- The river valley near the site should be narrow.
- The site should be such that as far as possible minimum level and property is submerged in the reservoir.
- As far as possible a deep reservoir must be formed so that the land costs per unit of capacity are low, evaporation is less.
- The ultimate bearing power of the supporting soil should be calculated so that to design the foundation can should be taken that the unit load at the base of a footing should not be larger than the safe having power of the supporting soil.
- Ground water table should be low.
- Highly jointed rocks should be investigated for joint intensity and spacing which will help in assessing the grouting.
- Valley sections in competent, hard resistant rocks like Granite, Quartzite, Gnesis provide excellent sites.

(c) Discuss how the sensors are classified in Remote Sensing and briefly explain their salient features. (10)

Sol: Sensors for remote sensing:

- Sensors may be classified as active or passive, imaging or non-imaging, commercial or military.
- An active sensor provides its own source of energy, directing it at the object in order to measure the returned energy
- A passive sensor records the energy that naturally radiates or reflects from an object.
- Photography with flash is active and without flash is passive remote sensing
- The main advantage of passive sensor is that they are simple, both electrically and mechanically and they do not have high power requirement.
- Their disadvantages are that, particularly in wave bands where natural emittance or reflectance levels are low high detector sensitiveness and wide radiation collection apertures are necessary to obtain a reasonable signal level
- Another dis-advantage of passive systems is dependency on good weather conditions.
- Non imaging sensors, in particular, are designed to give quantitative measures of the integrated intensity of electro-magnetic radiation from all objects within their field of view as functions of time and wave length.
- The imaging sensors, on the other hand, are designed to provide a visual image of their field of view either directly or indirectly through the stored information.
- Thus imaging sensors stress upon spatial resolution while non-imaging sensors stress upon time and wavelength resolution.
- Classification of sensors as commercial (or) military is based on their application or purpose.

(d) Design the length of transition curve to be provided on a horizontal curve of radius 484 m on a National Highway with double lane passing through heavy rainfall area. Following design data is given: (25)

Ruling design speed = 80 kmph

Type of terrain = Rolling terrain

Rate of introduction of superelevation = 1 in 150

Wheel base of design vehicle = 6 m

Sol: Given:

Radius of curve 'R' = 484 m

Ruling design speed = V = 80 kmph

Rate of introduction of super elevation 1 in 150 i.e., N = 150

Length of wheel base, L = 6 m

Length of transition curve is based on

(a) Rate of change of centrifugal acceleration

$$L_s = \frac{v^3}{CR}$$

v is speed in m/sec = 80 × 0.278 = 22.24 m/sec

C = Rate of change of centrifugal acceleration

$$= \frac{80}{75 + V}$$

$$= \frac{80}{75 + 80} = 0.516$$

0.5 < C < 0.8 Hence OK

R = 484 m

$$L_s = \frac{(22.24)^3}{0.516 \times 484}$$

= 44.04 m ……………(1)

(b) Rate of introduction of super elevation

Assuming pavement is rotated about inner edge

$L_s = e\,N\,(W + W_e)$

e = super elevation

For mixed traffic, $e = \frac{V^2}{225\,R}$

$$= \frac{80^2}{225 \times 484} = 0.0587$$

= 5.87 % < 7 % Hence OK

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

$$\Rightarrow 0.0587 + f = \frac{80^2}{127 \times 484}$$

$\Rightarrow$ f = 0.045 < 0.15 Hence OK

e = 5.87%

W = 7 m for two lane road

$$W_e = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

$$= \frac{2 \times 6^2}{2 \times 484} + \frac{80}{9.5\sqrt{484}}$$

$$= 0.457 \text{ m}$$

$\therefore$ L_s = 0.0587 × 150 (7 + 0.457)

= 65.66 m ……………….(2)

(c) As per IRC

$$L_s = \frac{2.7V^2}{R}$$

$$= 2.7 \times \frac{80^2}{484}$$

= 35.7 m ………….(3)

Length of transition curve is maximum of above three = 65.66 m say 66 m

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