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UPSC ESE 2020

Main Exam Detailed Solutions

Civil Engineering

PAPER-II

EXAM DATE : 18-10-2020 | 02:00 PM to 5:00 PM

MADE EASY has taken due care in making solutions. If you find any discrepency/ error/typo or want to contest the solution given by us, kindly send your suggested answer with detailed explanations at info@madeeasy.in

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Civil Engineering Paper Analysis
ESE 2020 Main Examination

ESE Mains Paper-II

Sl.	Subjects	Marks	Percentage Weightage
1.	Fluid Mechanics & Hydraulic Machines	79	16.46
2.	Engineering Hydrology	20	4.17
3.	Water Resource Engineering	17	3.54
4.	Environmental Engineering	124	25.83
5.	Soil Mechanics & Foundation Engg.	99	20.6
6.	Surveying and Geology	52	10.83
7.	Transportation Engineering	89	18.54
	Total	**480**	**100.00**

Scroll down for detailed solutions

SECTION 'A'

1. (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 Marks]

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

[4 Marks]

Solution:

(i) Solution A : Volume 450 mL; pH = 7.5

Solution B : Volume 550 mL; pH = 6.5

$$pH = -\log_{10}[H^+]$$

For solution A:

$$7.5 = -\log_{10}[H^+]$$

$$\Rightarrow \quad [H^+]_A = 10^{-7.5} \text{ M}$$

For solution B:

$$6.5 = -\log_{10}[H^+]$$

$$\Rightarrow \quad [H^+]_B = 10^{-6.5} \text{ M}$$

Now,

$$[H^+]_{mix} = \frac{V_A \cdot [H^+]_A + V_B \cdot [H^+]_B}{V_A + V_B}$$

$$= \frac{450 \times 10^{-7.5} + 550 \times 10^{-6.5}}{450 + 550} = 1.88 \times 10^{-7} \text{ M}$$

$$\therefore \quad (pH)_{mix} = -\log_{10}[H^+]_{mix}$$

$$= -\log_{10}(1.88 \times 10^{-7}) = 7 - \log_{10}(1.88) = 6.72$$

Hence, pH of the mixture, $(pH)_{mix} = 6.72$.

Note: '*M*' refers to moles/*l*

(ii) Given, concentration of glucose ($C_6H_{12}O_6$) = 108.75 mg/*l*

To find theoretical oxygen demand (Th.O.D.)

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

180 g   192 g

$\Rightarrow$ 1 part of glucose requires $\left(\frac{192}{180}\right)$ part of oxygen for oxidation to carbon di-oxide and water.

$\therefore$ 108.75 mg/*l* of glucose will require $\left(\frac{192}{180} \times 108.75\right)$ oxygen = 116 mg/*l*

$\therefore$ Theoretical oxygen demand (ThOD) = 116 mg/*l*

End of Solution

1. (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.

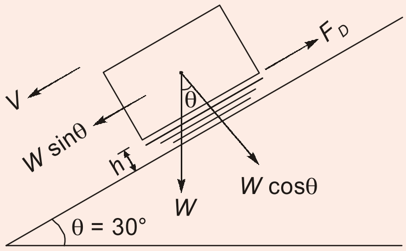
[6 Marks]

(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 How is 2 m. Take C = 70 and slope of bed as 1 in 1000.

[6 Marks]

Solution:

(i)



Force analysis in direction of motion

$$F_D = W \sin\theta$$

$$\tau A = 500 \sin 30° \quad \text{...(i)}$$

∵ Shear stress, $\tau = \mu \dfrac{du}{dy}$

{Since the gap is very-very small so velocity variation is considered as linear.}

$$\tau = \mu \frac{V-0}{h}$$

$$\tau = \mu \frac{V}{h}$$

By eq. (i)

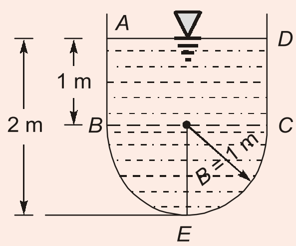
$$\mu \frac{V}{h} A = 500 \sin 30°$$

$$\mu \frac{(1.75)}{0.002} \times 0.5 \times 0.5 = 500 \sin 30°$$

$$\mu = 1.143 \text{ Ns/m}^2$$

$$\mu = 11.43 \text{ Poise}$$

(ii)



Given, Chezy's constant (C) = 70

Bed slope, $s = \frac{1}{1000}$

From figure,
Wetted Area, A = Area $ABCD$ + Area BEC

$$= (1\times 2) + \left(\frac{\pi\times 1^2}{2}\right) = 3.57 \text{ m}^2$$

Wetted perimeter, $P = AB + BEC + CD$

$$= 1 + (\pi \times 1) + 1 = 5.14 \text{ m}$$

∴ Hydraulic mean depth 'or' Hydraulic radius

$$(R) = \frac{A}{P} = \frac{3.57}{5.14} = 0.695 \text{ m}$$

∴ Discharge, $'Q' = AC\sqrt{R\cdot S}$ (from Chezy's equation

$$= 3.57\times 70\sqrt{0.695\times\frac{1}{1000}} = 6.58 \text{ m}^3/\text{s}$$

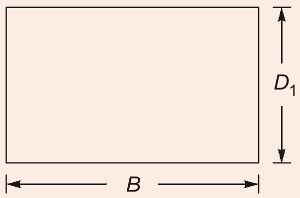
End of Solution

1. (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 Marks]

Solution:

Let B and D_1 represents the width and depth of the rectangular sewer, respectively.

∴ $B = 2D_1$



Now, when this rectangular sewer is running completely full.

The area of flow, $A = B\cdot D_1 = 2D_1\cdot D_1 = 2D_1^2$

The wetted perimeter, $P = 2(B + D_1)$

As it is mentioned in the question that the rectangular sewer is running completely full, thus wetted perimeter is

$$P = 2(2D_1 + D_1) = 6\cdot D_1$$

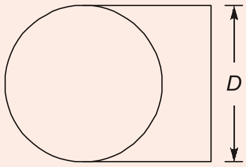
∴ Hydraulic radius, $R = \frac{A}{P} = \frac{2D_1^2}{6D_1} = \frac{D_1}{3}$

Discharge capacity of rectangular sewer while running full

$$Q = \frac{1}{N}\cdot AR^{2/3}\cdot S^{1/2}$$

$$= \frac{1}{N}\cdot\left(2D_1^2\right)\cdot\left(\frac{D_1}{3}\right)^{2/3}\cdot S^{1/2} \quad ...(1)$$

Now, let D be the diameter of circular sewer.



When this circular sewer is running completely full,

The area of flow, $$A = \frac{\pi}{4}D^2$$

The wetted perimeter, $$P = \pi D$$

∴ Hydraulic radius, $$R = \frac{A}{P} = \frac{\frac{\pi}{4}D^2}{\pi D} = \frac{D}{4}$$

Discharge capacity of rectangular sewer while running full

$$Q = \frac{1}{N}\cdot AR^{2/3}\cdot S^{1/2}$$

$$= \frac{1}{N}\cdot\left(\frac{\pi}{4}D^2\right)\cdot\left(\frac{D}{4}\right)^{2/3}\cdot S^{1/2} \quad \text{...(2)}$$

Two conduits or a system of conduits, may be said to be hydraulically equivalent when they will discharge at the same rate when both are on the same hydraulic gradient.

Note: Since sewers are designed to ensure flow when gravity, this implies, for the sewer, bed slope is same if they are hydraulically equivalent.

∴ From equation (1) and equation (2)

$$Q_1 = Q_2$$

$$\Rightarrow \quad \frac{1}{N}\cdot\left(2D_1^2\right)\cdot\left(\frac{D_1}{3}\right)^{2/3}\cdot S^{1/2} = \frac{1}{N}\cdot\left(\frac{\pi}{4}D^2\right)\cdot\left(\frac{D}{4}\right)^{2/3}\cdot S^{1/2}$$

$$\Rightarrow \quad \frac{2}{(3)^{2/3}}\cdot D_1^{8/3} = \frac{\pi}{(4)^{5/3}}\cdot D^{8/3}$$

$$\Rightarrow \quad D_1^{8/3} = \frac{\pi\cdot(3)^{2/3}}{2\cdot(4)^{5/3}}\cdot D^{8/3}$$

$$\Rightarrow \quad D_1 = \left(\frac{\pi\cdot(3)^{2/3}}{2\cdot(4)^{5/3}}\right)^{3/8}\cdot D$$

$$D_1 = 0.655\, D \quad \text{...(3)}$$

But, $$B = 2D_1$$

∴ $$D_1 = \frac{B}{2} \quad \text{...(4)}$$

$\therefore$ from equation (3) and equation (4)

$$\frac{B}{2} = 0.655D$$

$$\Rightarrow \quad B = 1.31D$$

This is the required relation between width of rectangular sewer (B) and diameter of circular sewer (D).

Sources: MADE EASY Conventional Practice Question (Pg.180-181) Q.37 (Similar Question) Click here for reference

End of Solution

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

[12 Marks]

Solution:

Given,

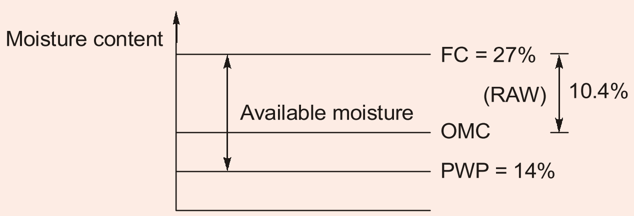
Field capacity, (FC) = 27%

Permanent witting point, (PWP) = 14%

Density of soil, (ρ_d) = 1.5 g/cm^3 (Assuming dry density)

Effective depth of root zone, (d) = 75 cm

Daily consumptive use of water for the given crop (C_u) = 11 mm/day



OMC = Optimum moisture content
RAW = Readily available water

The available moisture = FC – PWP = 27 – 14 = 13%

Let us assume that the readily available moisture 'or' the optimum soil moisture is 80% of available moisture.

i.e. Readily Available Moisture (RAW) = 0.80 × 13 = 10.4%

∴ Optimum moisture content (OMC) = 27 – 10.4 = 16.6%

It means that the moisture will be filled by irrigation between 16.6% and 27%.

Depth of water stored in root zone between these two limits:

$$d' = \frac{\rho_d}{\rho_w} \cdot [FC - OMC]$$

$$d' = \frac{1.5}{1} \times 0.75\ [0.27 - 0.166] = 0.177\ m$$

$$d' = 117\ mm$$

Now, frequency of irrigation

$$(FOI) = \frac{d'}{C_u} = \frac{117}{11} = 10.63\ days \simeq 10\ days$$

Hence, after 10 days, water should be applied to the given crop.

Sources: MADE EASY ESE Mains Test Series-2020

(Similar Question) (Test-15) Q.3(b)(ii) Click here for reference

End of Solution

1. (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 Marks]

(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 Marks]

Solution:

(i) Given, Population, (P) = 300000

Rate of productivity = 2.5 kg/capita/day

∴ Total solid waste produced = $2.5 \times 3 \times 10^5 = 7.5 \times 10^5$ kg/day

Density of waste = 1500 kg/m^3

$$\therefore \quad V_{\text{solid waste}} = \frac{7.5 \times 10^5}{1500} = 500\ m^3/day$$

Ratio of solid waste to cover = 4 : 1

$$\therefore \quad V_{\text{cover soil}} = \frac{V_{\text{solid waste}}}{4} = \frac{500}{4} = 125\ m^3/day$$

$\therefore$ Total volume of landfill site required (per day)

$$= V_{\text{solid waste}} + V_{\text{cover soil}} = 500 + 125 = 625 \text{ m}^3/\text{day}$$

Volume of landfill site required in a year = 625 × 365 = 228125 m^3

Volume of cover soil required in a year = 125 × 365 = 45625 m^3

For cover purposes, it is recommended by GOI manual on MSWM, 2016 to use clay after thorough compaction.

(ii) Q = Measured quantity of sound intensity = 0.002 W

Q_0 = Reference standard quantity of sound intensity = 10^{-12} W/m^2

Assuming A unit area $\perp_r$ to the direction of wave motion.

$$\therefore \text{ Sound power level (in dB)} = 10 \cdot \log_{10} \cdot \left(\frac{Q}{Q_0}\right) = 10\log_{10}\left(\frac{2\times10^{-3}}{10^{-12}}\right) = 93 \text{ dB}$$

Now, at a distance of 10 m from the source,

Since, the sound radiates freely in all the directions,

$$I = \frac{P}{4\pi r^2} \text{ W/m}^2$$

where, r is the radius of imaginary sphere enclosing the sound source.

$$\therefore \qquad I_{10\text{ m}} = \frac{0.002W}{4\pi\times10^2 \text{ m}^2} = 1.5915\times10^{-6} \text{ W/m}^2$$

Sound intensity level,
$$L_I = 10\log_{10}\left(\frac{1.5915\times10^{-6}}{10^{-12}}\right) = 62.018 \text{ dB}$$

Sound pressure level is measured in rms (root mean square).

$$62.018 \text{ dB} = 20\log_{10}\left(\frac{p_{rms}}{p_{rms_0}}\right)$$

p_{rms_0} is reference standard rms pressure

$$p_{rms_0} = 20\,\mu\text{Pa}$$

$$\therefore \qquad 62.018 \text{ dB} = 20\log_{10}\left(\frac{p_{rms}}{20\mu Pa}\right)$$

$$\Rightarrow \qquad p_{rms} = 25230\,\mu\text{Pa}$$

Sources: MADE EASY ESE Mains Test Series-2020 (Test-1) Q.5

(Similar Question) **Click here for reference**

End of Solution

2. (a) (i) What is ϕ index? How is it estimated? What are the factors that affect ϕ index? [8 Marks]

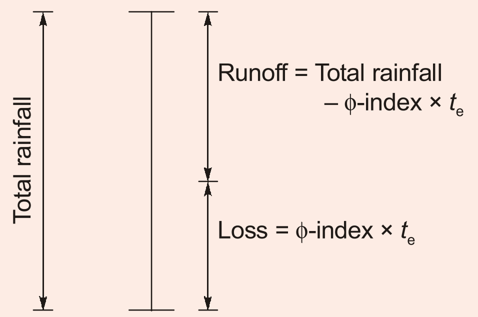
(ii) A storm with 10 cm precipitation produced a direct runoff of 5.8 cm. The time distribution of the storm is given below. Estimate the ϕ index of the storm.

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

[12 Marks]

Solution:

(i) **ϕ-index:** It is defined as the average rate of loss such that the volume of rainfall in excess of that rate will be equal to volume of direct runoff.



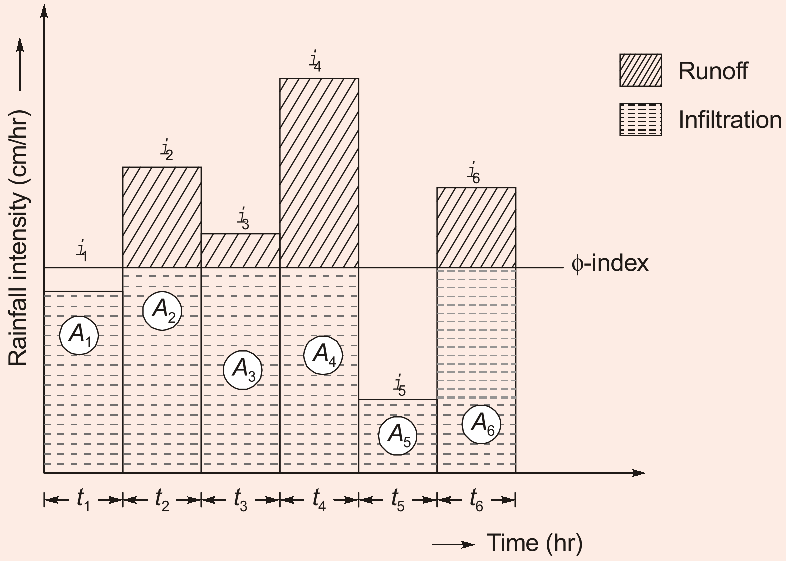
t_e = Time period of rainfall excess

OR

ϕ-index is defined as the ratio of total infiltration in which rainfall excess occur to the time period in which rainfall excess occur.

Procedure for calculation of φ-index:

Let us consider an example of a storm by means of hyetrograph as given below:



Mathematically,

$$\phi\text{-index} = \frac{\text{Total infiltration in which rainfall excess occur}}{\text{Time period in which rainfall excess occur}}$$

$$= \frac{(A_2 + A_3 + A_4 + A_6)}{(t_2 + t_3 + t_4 + t_6)} \text{ cm/hr}$$

Factors affecting φ-index:

(i) Vegetal coverage

(ii) Initial moisture conditions

(iii) Storm durations

(iv) Intensity of storm

(v Type of soil

To obtain the complete information on the interrelationship among above factors, a detailed study of catchment is necessary.

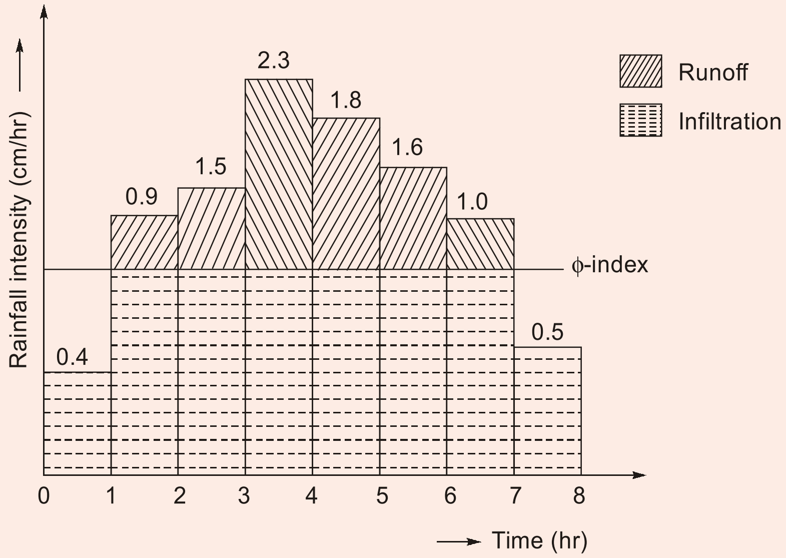
(ii) Total infiltration = Total rainfall – Runoff

$= 10 - 5.8$

$= 4.2$ cm

$$\therefore \quad \text{w-index} = \frac{\text{Total infiltration}}{\text{Total duration of storm}} = \frac{4.2}{8} = 0.525 \text{ cm/hr}$$

Hyetograph for the given storm is as shown below:



As $\qquad \phi\text{-index} > w\text{-index}$

Hence storm of intensities 0.4 cm/hr and 0.5 cm/hr will not produce rainfall excess or runoff.

Let us consider the are storms after then 0.4 cm/hr and 0.5 cm/hr will produce rainfall excess.

$$\therefore \qquad \phi\text{-index} = \frac{\text{Total infiltration in which rainfall excess occur}}{\text{Time period in which rainfall excess occur}}$$

$$= \frac{\text{Total infiltraion} - \text{Infiltration in which no rainfall excess occur}}{t_e}$$

$$= \frac{4.2\text{ cm} - (0.4 \times 1 + 0.5 \times 1)}{6}$$

$$= \frac{4.2 - 0.9}{6} = \frac{3.3}{6} = 0.55\text{ cm/hr}$$

Now, **check:**

Total runoff = Area of hatched portion

$$\Rightarrow \quad \text{Total runoff} = (0.9 - \phi\text{-index}) \times 1 + (1.5 - \phi\text{-index}) \times 1 + (2.3 - \phi\text{-index}) \times 1 + (1.8 - \phi\text{-index}) \times 1 + (1.6 - \phi\text{-index}) \times 1 + (1 - \phi\text{-index}) \times 1$$

$$= (0.9 - 0.55) \times 1 + (1.5 - 0.55) \times 1 + (2.3 - 0.55) \times 1 + (1.8 - 0.55) \times 1 + (1.6 - 0.55) \times 1 + (1.0 - 0.55) \times 1$$

$$= 5.8\text{ cm} = \text{given runoff}$$

Hence all right.

Our assumption is correct.

$$\therefore \qquad \phi\text{-index} = 0.55\text{ cm/hr}$$

Sources: MADE EASY Conventional Practice Qusetion (Pg.92) Q.26 Click here for reference

End of Solution

2. (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

(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 24 assume $C_D = \dfrac{24}{R}$.

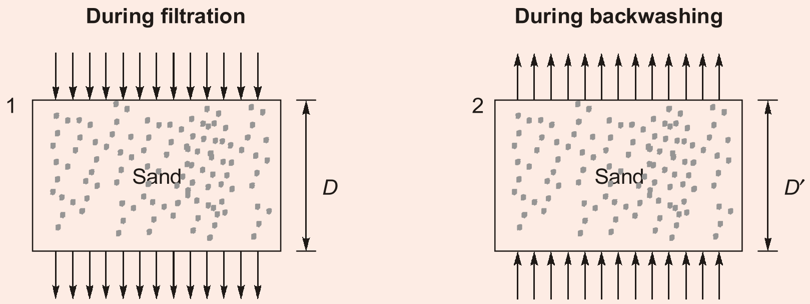
[10 Marks]

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

[10 Marks]

Solution:

(i)



D = Depth of sand bed = 0.75 m
n = Porosity of sand bed = 0.48

D' = Depth of expanded sand bed = 1.5 D = 1.5 × 0.75

n' = Porosity of expanded sand bed

Given,

$$\text{Particle size } (d) = 0.65 \text{ mm}$$

$$\text{Specific gravity } (G_s) = 2.66$$

To hydraulically expand the filter medium during backwashing loss of head through the medium is equal to buoyant weight of sand particles the analysis is done by assuming no impurity is present and the loss of head is due to sand particles only

i.e $$h_L = D \times (1-n) \times (G_s - 1) \quad \text{...(i)}$$

The buoyant weight during backwashing as well as filtration is constant hence, loss of head through the bed is constant.

$$h_{L1} = h_{L2}$$

$$D(1-n)(G_s - 1) = D'(1-n')(G_s - 1)$$

$$\Rightarrow \quad 0.75 \times (1 - 0.48) = 1.125\,(1 - n')$$

$$\Rightarrow \quad n' = 0.653$$

(a) Porosity in the expanded condition is a function of backwash velocity (V_b) and terminal settling velocity as :

$$n' = \left(\frac{V_b}{V_s}\right)^{0.22} \quad \text{...(ii)}$$

$$V_s = \sqrt{\frac{4}{3}\cdot\frac{gd(G_s-1)}{C_D}}$$

$$C_D = \frac{24}{\text{Re}} = \frac{24}{\left(\frac{V_s.d}{\nu}\right)}$$

$$V_s^2 = \frac{4}{3}\frac{gd(G_s-1)}{24}\cdot\frac{V_s.d}{\nu}$$

$$V_s = \frac{g}{18}(G_s-1)\frac{d^2}{\nu}$$

Given, kinematic viscosity (ν) = 1.3×10^{-2} cm^2/s

$$\therefore \quad V_s = \frac{9.81}{18}(2.66-1)\frac{(0.65\times10^{-3})^2}{1.3\times10^{-6}} = 0.294 \text{ m/s}$$

Now, from equation (i)

$$0.653 = \left(\frac{V_b}{0.294}\right)^{0.22}$$

$$\Rightarrow \quad V_b = (0.653)^{1/0.22}\times 0.294$$
$$= 0.0423 \text{ m/s} = 2.538 \text{ m/min}$$

Hence, Backwash rate = 2.538 m/min

(b) Head loss

$$h_L = D(1-n)(G_s-1)$$
$$= 0.75(1-0.48)(2.66-1)$$
$$= 0.647 \text{ m} \simeq 0.65 \text{ m}$$

(ii) Various factors affecting bactericidal efficiency of chlorine in water treatment process are as following:

1. If the turbidity in the water increases the bactericidal efficiency decreases.
2. Metallic compound such as (iron, manganese) use chlorine in oxidising themselves thereby reducing bactericidal efficiency.
3. Ammonia combines with chlorine to form chloramines which reduces efficiency of chlorine.

4. pH of water also influences bactericidal efficiency. pH in the range of 5-7 is most effective. Beyond this range, bactericidal efficiency decreases.
5. The requirement of chlorine increases with decrease in temperature and increase in pH beyond 7.
6. More the time of contact of chlorine more will be the efficiency.

Sources: MADE EASY Theory Book (Pg. 186) Click here for reference

End of Solution

2. (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.
Take ρ = 1.208 kg/m^3 and ν = 1.47 × 10^{-5} m^2/s.

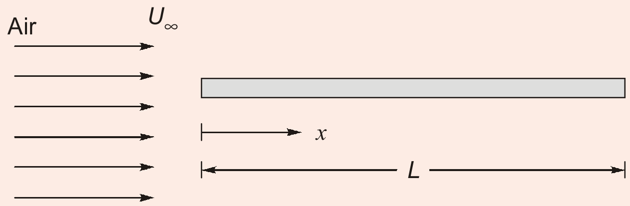
[15 Marks]

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

[5 Marks]

Solution:

(i)



Given:

Plate width, $B = 2$ m

Plate length, $L = 4$ m

$U_\infty = 5$ m/s

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

$\nu_{air} = 1.47 \times 10^{-5}$ m^2/s

Let, the length of plate over which boundary layer is laminar = x

So, $Re_x = 5 \times 10^5$

$$\frac{\rho U_\infty x}{\mu} = 5 \times 10^5$$

$$\frac{U_\infty x}{\nu} = 5 \times 10^5$$

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

$$x = 1.47 \text{ m}$$

Shear stress at the location where boundary layer cases to be laminar

$$\frac{\tau_{0,x}}{\frac{1}{2}\rho U_\infty^2} = C_{f,x} \qquad \left[\text{According to Blasius result } C_{f,x} = \frac{0.664}{\sqrt{\text{Re}_x}}\right]$$

$$\tau_{0,x} = C_{f,x} \times \frac{1}{2} \times \rho \times U_\infty^2$$

$$= \frac{0.664}{\sqrt{\text{Re}_x}} \times \frac{1}{2} \times \rho \times U_\infty^2$$

$$= \frac{0.664}{\sqrt{5\times 10^5}} \times \frac{1}{2} \times 1.208 \times 5^2$$

$$\tau_{0,x} = 1.418 \times 10^{-2}\ \text{N/m}^2$$

Drag force on that portion of plate where the boundary layer is laminar considering both the sides of plate.

$$= 2\times\left[\bar{C}_{f,x} \times \frac{1}{2} \times \rho \times A \times U_\infty^2\right]$$

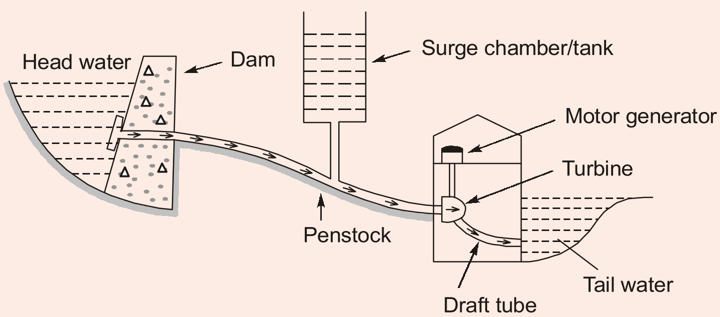
$$= 2\times\left[\frac{1.328}{\sqrt{\text{Re}_x}} \times \frac{1}{2} \times 1.208 \times (1.47\times 2) \times 5^2\right]$$

$$= 2\times\frac{1.328}{\sqrt{5\times 10^5}} \times \frac{1}{2} \times 1.208 \times 1.47 \times 2 \times 25$$

$$= 0.1668\ \text{N}$$

(ii) **Surge tank:** It is a device introduced within a hydropower water conveyance system having a rather long pressure conduit to absorb the excess pressure rise in case of a sudden value closure thus eliminating water hammer effect.

- It also acts as a small storage from which water may be supplied in case of a sudden valve opening of the turbine.
- It reduces the distance between turbine and free surface.



End of Solution

3. (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 Marks]

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

[10 Marks]

Solution:

(i) For a second

$$\text{Coal burnt} = 1 \text{ kg}$$

$$\text{Sulphur content in coal} = 3\% = \frac{3}{100} \text{ kg}$$

$$\text{Sulpher in ash} = \frac{5}{100} \times \left(\frac{3}{100}\right) = 0.0015 \text{ kg}$$

Amount of sulphur which reacted with O_2 to become SO_2

$$= 0.03 - 0.0015 = 0.0285 \text{ kg} = 285 \text{ g}$$

Chemical reaction $S + O_2 \longrightarrow SO_2$

Using mole concept

1 mole of sulphur produces 1 mole of SO_2

$$n_S = \frac{28.5}{32} = 0.89 \quad \left[\text{No. of moles} = \frac{\text{Weight (g)}}{\text{Molecular weight}}\right]$$

$$n_{SO_2} \text{ required} = 0.89$$

$$(\text{wt})_{SO_2} = 0.89 \times 64 = 57 \text{ g}$$

$$(\text{wt})_{SO_2} = 0.057 \text{ kg}$$

In one second 0.057 kg of SO_2 is emitted

In a year SO_2 emission = $0.057 \times 86400 \times 365 = 1797.552\ t$

(ii) **Functional elements of a solid waste management system**

The activities involved with the management of solid wastes from the point of generation to final disposal have been grouped into six functional elements.

1. Waste generation
2. On-site handling, storage and processing
3. Collection
4. Transfer and transport
5. Processing and recovery
6. Disposal

Table : Description of the functional elements of a solid waste management system	
Component	**Description**
Waste generation	Those activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal
On site handing. storage, and processing	Those activities associated with the handling, storage and processing of solid wastes at or near the point of generation.
Collection	Those activities associated with the gathering of solid wastes and the hauling of wastes after collection to the location where the collection vehicle is emptied
Transfer and transport	Those activities associated with (1) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and (2) the subsequent transport of the wastes, usually over long distance, to the disposal site.
Processing and recovery	Those techniques equipment and facilities used to improve the efficiency of the other functional elements and to recover usable materials, conversion products or energy from solid wastes
Disposal	Those activities associated with ultimate disposal of solid wastes, including those wastes collected and transported directly to a landfill site, semisolid wastes (sludge) from wastewater treatment plants, incinerator residue, compost or other substances from the various solid-waste processing plants that are of no further use.

Sources: MADE EASY Theory Book (Pg. 253-254) Click here for reference

End of Solution

3. (b) (i) What are the effects of water logging?

[5 Marks]

(ii) A centrifugal pump runs at 1000 rpm against a head of 16 m and carries 145 liters/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°, determine the manometric efficiency.

[15 Marks]

Solution:

(i) Effect of water logging are as follows:

- Normal cultivation operations, such as tiling, ploughing etc. cannot be easily carried out in wet soils. In extreme cases, the free water may rise above the ground level making agricultural operations impossible.
- Certain water loving plants like grasses, weeds etc. grow profusely and luxuriantly in waterlogged lands, thus affecting and interfering with the growth of the crop.
- Water logging also leads to a condition called salinity, which is caused when the capillary fringe of the elevated water table rises within the root zone of plants. Since the roots of the plants continuously draw water from this zone, there is steady upward movement of water which causes rise of salts, especially alkali salts, to come up to the ground surface. This situation is termed as salinity.

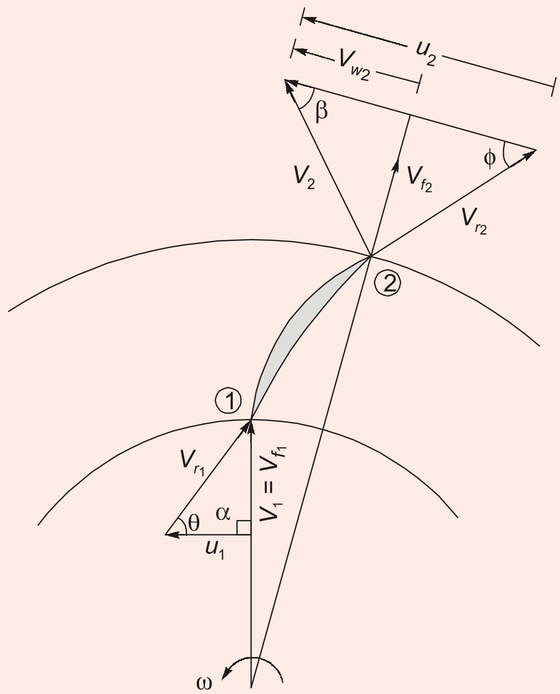
- A water logged soil warms up slowly and due to lower temperature, action of soil bacteria is sluggish and plant food available is less.
- When the water table is high, the drainage becomes impossible and the carbon dioxide liberated by the plant roots cannot be dissolved and taken away. Consequently fresh air containing oxygen is not drawn and activity of soil bacteria and plant growth suffers.
- In waterlogged soils, natural flora such as water hyacinth grows profusely. This reduces the crop yield.
- The climate of a waterlogged area becomes damp. Formation of stagnant pools may become breeding places for mosquitoes. The climate thus becomes extremely detrimental to the health of community.

(ii) Given

$N = 1000$ rpm, $H_{mano} = 16$ m, $Q = 145$ L/s, $D_2 = 300$ mm $= 0.3$ m

$B_2 = 60$ mm $= 0.06$ m, $\phi = 40°$

$$\eta_{mano} = ?$$



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

$$Q = \pi D_2 B_2 V_{f_2}$$

$$0.145 = \pi(0.3)(0.06)V_{f_2}$$

$$V_{f_2} = 2.564 \text{ m/s}$$

At outlet.

$$V_{w_2} = u_2 - V_{f_2} \cot\phi$$
$$= 15.71 - 2.564 \cot 40°$$
$$V_{w_2} = 12.654 \text{ m/s}$$

$$\eta_{mano} = \frac{H_{mano}}{\frac{V_{w_2} u_2}{g}} = \frac{16}{\frac{(12.654)(15.71)}{9.81}} = 0.7896$$

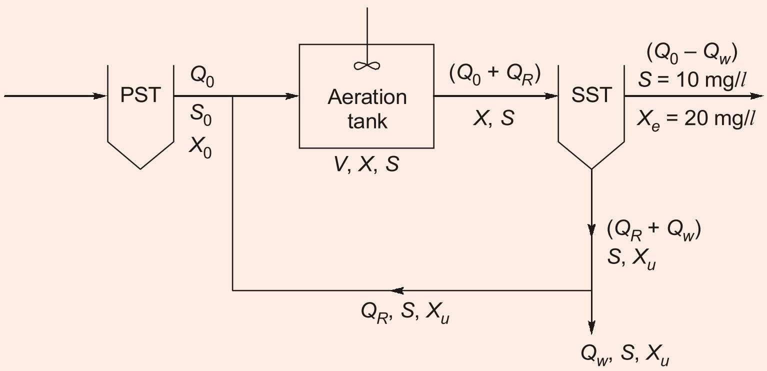
$$\eta_{mano}(\%) = 78.96$$

Sources: MADE EASY ESE Mains Test Series-2020 (Similar Question) (Mock Test-4) Q.3(a)(ii) **Click here for reference**

End of Solution

3. (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. BOD5 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 Marks]

Solution:



$$Q_0 = 0.15 \text{ m}^3\text{/s}$$
$$S_0 = 80 \text{ mg}/l$$
$$X = 2000 \text{ mg}/l$$

$$y = 0.5 \begin{Bmatrix} \text{fraction of food} \\ \text{mass converted to biomass} \end{Bmatrix}$$

For completely mix process,

Biomas in + Biomass growth = Biomass out

$$Q_0 \cdot X_0 + (k - k_d)\, X \cdot V = (Q_0 - Q_w)\, X_e + Q_w X_u \qquad ...(1)$$

Assuming influent and effluent biomass concentration are negligible compared to biomass at other points (i.e. X_0 and X_e) are negligible .

$\therefore$ Equation (1) becomes,

$$(k - k_d)\, X \cdot V = Q_w X_u$$

$$k - k_d = \frac{Q_w X_u}{VX}$$

$$k = \frac{Q_w X_u}{VX} + k_d$$

$$k = \frac{1}{\theta_c} + k_d \qquad \because \left\{ \text{Sludge age } (Q_c) = \frac{VX}{Q_w X_u} \right\}$$

$$k = \frac{k_0 S}{k_s + S} + \frac{1}{\theta_c} + k_d \text{ (Monod's equation)}$$

k_0 = Maximum growth rate constant = 2.5 d^{-1}

S = Concentration of limiting food (in mg/l)

= 20 – 0.63 × 20 = 7.4 mg/l

k_s = Half saturation constant = 95 mg/l

Now,
$$\frac{2.5 \times 7.4}{95 + 7.4} = \frac{1}{\theta_c} + 0.05$$

$$\frac{1}{\theta_c} = \frac{669}{5120}$$

$\Rightarrow$ θ_c = 7.65 days

Also,

$$VX = \frac{y \cdot Q_0 (S_0 - S) \cdot \theta_c}{1 + k_d \cdot \theta_c}$$

$$V \times 2000 = \frac{0.5 \times 0.15 \times 86400 \times (80 - 7.4) \times 7.65}{1 + (0.05 \times 7.65)}$$

$\Rightarrow$ V = 1301.6 m^3

$\therefore$ Volume of aeration tank = 1301.6 m^3

End of Solution

4. (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 Marks]

Solution:

Outward flow turbine

$$N = 200 \text{ rpm}$$
$$Q = 5 \text{ m}^3/\text{s}$$
$$H = 40 \text{ m}$$
$$D_1 = 2 \text{ m}$$
$$D_2 = 2.5 \text{ m}$$
$$B_1 = B_2 = 200 \text{ mm}$$
$$\beta = 90°, V_{w_2} = 0 \text{ (Discharge is radial at output)}$$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi(2)(200)}{60} = 20.94 \text{ m/s}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi(2.5)(200)}{60} = 26.18 \text{ m/s}$$

$$Q = \pi D_2 B_2 V_{f_2}$$

$$5 = \pi(2.5)(0.2)V_{f2}$$

$$V_{f_2} = 3.183 \text{ m/s}$$

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

$$5 = \pi(2)(0.2)V_{f\,1}$$

$$V_{f\,1} = 3.98 \text{ m/s}$$

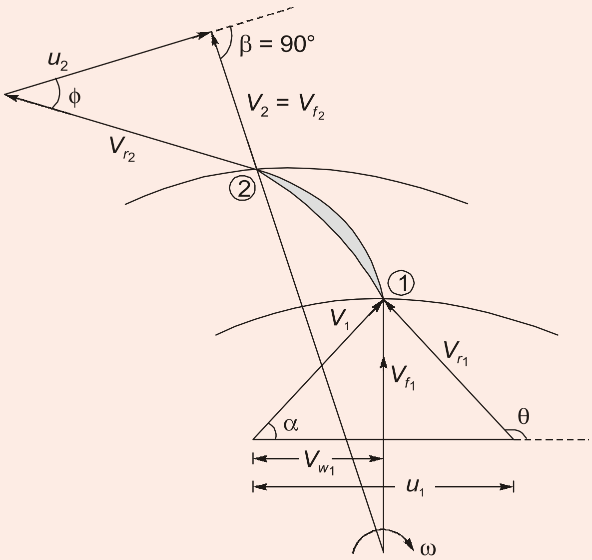
$$H = \frac{RP}{wg} + \frac{V_2^2}{2g} \qquad (V_2 = V_{f_2})$$

$$40 = \frac{V_{w_1}u_1}{g} + \frac{V_{f_2}^2}{2g}$$

$$40 = \frac{V_{w_1}(20.94)}{g} + \frac{(3.183)^2}{2g}$$

$$40 = \frac{V_{w_1}u_1}{g} + \frac{(3.183)^2}{2g}$$

$$V_{w_1} = 18.5 \text{ m/s}$$



At outlet

$$\tan\phi = \frac{V_{f_2}}{u_2} = \frac{3.183}{26.18}$$

$$\phi = 6.93°$$

At inlet

$$\tan(180° - \theta) = \frac{V_{f_1}}{u_1 - V_{w_1}} = \frac{3.98}{20.94 - 18.5}$$

$$\theta = 121.51°$$

Sources: MADE EASY Theory Book (Pg.474-475) Ex.17.5

(Similar Question) **Click here for reference**

End of Solution

4. (b) (i) Explain the factors that cause sludge bulking in activated sludge process for wastewater treatment.

[10 Marks]

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

[10 Marks]

Solution:

(i) **Sludge bulking:** A sludge that exhibits poor settling characteristics is called a bulking sludge. It may be due to either.

(a) The growth of filamentous micro-organisms which do not allow desirable compaction.

(b) Due to the production of non-filamentous highly hydrated biomass.

- There are many reasons for sludge bulking, the presence of toxic substances in influent, lowering of temperature, insufficient aeration and shock loading can also cause sludge bulking.
- Proper supply of air and proper design to maintain endogenous growth phase of metabolism will not produce bulking of sludge.
- The sludge bulking can be controlled by restoring proper air supply, eliminating shock loading to the aerator, or by increasing temperature of the wastewater or by small hypochlorite dosing to the return sludge line to avoid the growth of filamentous hygroscopic micro-organisms.

(ii) **Anaerobic digestion process and composting process used for solid waste treatment**

Anaerobic Digestion:

- It is common process for dealing with wastewater sludge containing primary sludge, because it contains large amounts of readily available organics that would induce a rapid growth of biomass if treated anaerobically.
- The anaerobic decomposition produces considerably less biomass than aerobic process.
- The principal function of anaerobic digestion, therefore is to convert as much of the sludge as possible to end products such as liquids and gases while producing little residual biomass as possible.
- In anaerobic process, the organisms are broadly classified as
  (a) acid formers
  (b) methane formers

Acid formers:

(i) They consist of facultative and anaerobic bacteria and include organisms that solubilize the organic solids through hydrolysis.

(ii) The soluble products are then fermented to acids and alcohols of low molecular weight.

Methane formers:

(i) They consist of strict anaerobic bacterias that convert the acids and alcohols, along with the hydrogen and carbon dioxide to methane.

(ii) Methane former act in the pH range of 6.5 - 7.5 and they are very delicate. A shock loading can be disastrous to such anaerobic bacteria.

(iii) Acid former respond quickly to food supply and hence acid increase quickly. The methane formers do not respond so quickly and hence pH may reduce.

(iv) As pH level falls down below "pH tolerance level" of the methane former, methane formation ceases and the pH may fall to even toxic level. To control this lime is added.

Advantage of Anaerobic Digestion:

1. Recovery the energy in form of Methane
2. Anaerobically digested sludge contains nutrients and organic matter that can improve the fertility of soil.
3. Pathogens in the sludge die off during relatively long detention period.

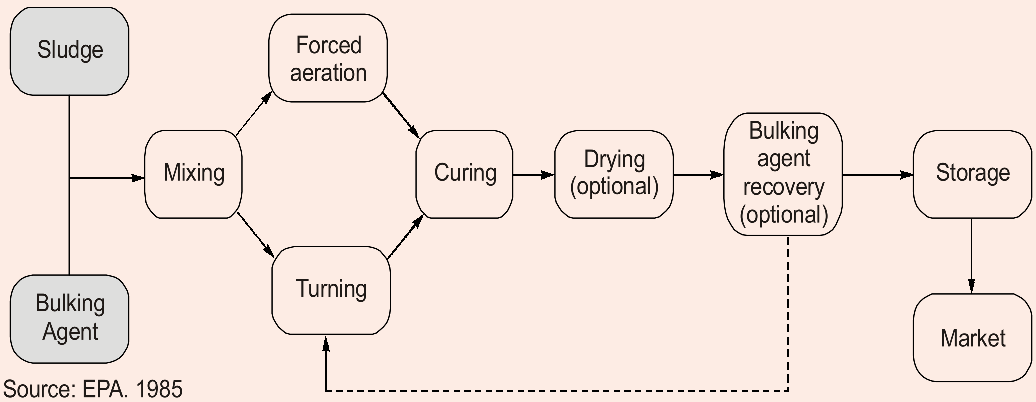
Disadvantage of Anaerobic Digestion:

1. Close process. Control is required to prevent upsets.
2. Supernatant liquid from an anaerobic disaster have high O_2 demand.

The digested sludge is dewatered, dried up and used as fertilizer; while the gases produced are also used for fuel or for driving gas engines.

Composting:

- Composting may be defined as a method of solid waste treatment in which the organic component of the solid waste stream is biologically decomposed under controlled aerobic conditions to a state in which it can be easily and safely handled, stored and applied to the land without adversely affecting the environment.
- Thus, composting is a controlled or engineered biological system.
- It is often a cost effective and environmentally alternative for the stabilisation and ultimate disposal of wastewater sludge.



Source: EPA. 1985

- The three major types of composting systems used are the aerated static pile, window and invessel system.
- Majority are aerated static pile followed by windows and by invessel.

Sources: MADE EASY Theory Book (Pg. 157 & 168) Click here for reference

End of Solution

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

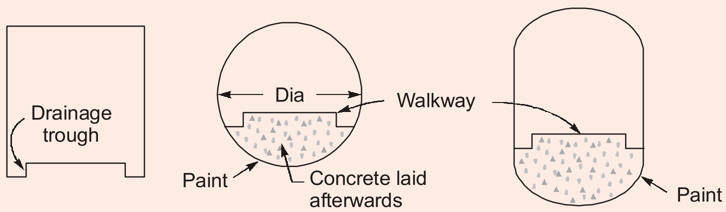
[12 Marks]

(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 Marks]

Solution:

(i) Galleries are the horizontal or sloping openings or passages left in the body of dam. They may run longitudinally (i.e. parallel to the dam axis) or transversely (i.e. normal to the dam axis) and are provided at various elevations. All the galleries are interconnected by steeply sloping passages or by vertical shafts fitted with stairs or mechanical lifts. The size of gallery will depend upon the size of the dam and the function of the gallery. Certain important shapes of the commonly used galleries are shown in figure below.



Rectangular gallary Circular gallery Oval shaped gallery

The provision of a gallery in a dam body, changes the normal pattern of stresses in the body of the dam. Stress concentration may occur at corners and hence in order to minimise this stress concentrations, the corner must be rounded smoothly. Tension and compression zones may be work out and proper reinforcement etc. are provided to counteract them.

Function of a gallery:

1. To provide drainage of the dam section.
2. To provide space for equipment required for drilling holes and grouting the hole to form a grout curtain in the foundation.
3. To provide space for header and return pipes for post cooling of concrete.
4. A gallery provide an access to the interior of the dam for inspection and maintenance.
5. A gallery also provides space for installing various instruments in the dam to study its structural behaviour.
6. A gallery can provide space for the mechanical and electrical equipment required for the operation of gates for spillways and outlets.

Shaft in gravity dam: A shaft is a vertical opening provided in a dam. Shafts are required for locating headers of the post cooling system and for locating measuring devices.

- Shafts are also required for the movement of elevators and the hoisting equipment. Sometimes, shafts are constructed inclined to connect two galleries or the same gallery at two different elevations.

- A plumb line shaft is constructed at the maximum section of the dam to make observations of the deflection of the dam under loads.
- A stilling well shaft is a special shaft used to record fluctuations of the water level in the reservoir. The shaft is connected to the reservoir at a point below the minimum reservoir level.

(ii) **Recuperation test:**

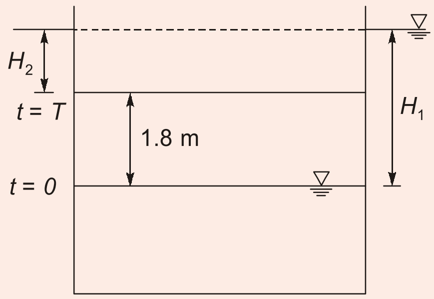
Yield from a well is given by

$$Q = k_s A h$$

Given: $A = \frac{\pi}{4} \times 4^2$, $H = 3$ m

k_s = Sp. capacity per unit well area

$$k_s = \frac{1}{T} \ln \frac{H_1}{H_2}$$



T = Recuperation time = 80 min

H_1 = Drawdown at (t = 0) = 2.5 m

H_2 = Drawdown at (t = T) = 2.5 – 1.8 = 0.7 m

$$k_s = \frac{1}{\frac{80}{60}} \ln\left(\frac{2.5}{0.7}\right) = 0.954 \text{ hr}^{-1}$$

$$Q = k_s A h = 0.954 \times \frac{\pi}{4} \times 4^2 \times 3 = 35.97 \text{ m}^3/\text{hr}$$

Therefore yield from the well is 35.97 m^3/hr

Sources: MADE EASY Conventional Practice Question (Book)(Pg.162-163) Q.17) (Similar Question) Click here for reference

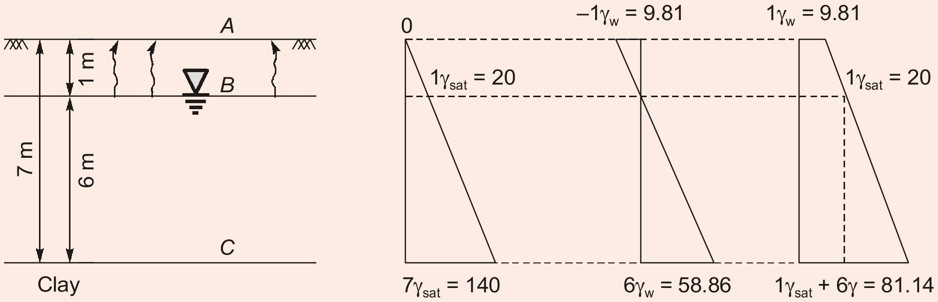
End of Solution

SECTION 'B'

5\. (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/m^3 and its saturated unit weight is 20 kN/m^3. Plot the total stress, neutral stress and effective stress with depth up to a depth of 7 m.

[12 Marks]

Solution:



At point A	At point B	At point C
$\sigma = 0$	$\sigma = 1\gamma_{sat} = 20$ kN/m^2	$\sigma = (1+6)\gamma_{sat} = 140$ kN/m^2
$u = -1\gamma_w = 9.81$ kN/m^2	$u = 0$	$u = 6\,\gamma_w = 58.86$ kN/m^2
$\bar{\sigma} = \sigma - u = 9.81$ kN/m^2	$\bar{\sigma} = \sigma - u = 20$ kN/m^2	$\bar{\sigma} = \sigma - u = 81.14$ kN/m^2

Sources: MADE EASY Class Notes (Ch-3) case-4, soil mass with Capillary Fringes

MADE EASY ESE Workbook, Similar Question (Ch.3 Q.36) Click here for reference

End of Solution

5\. (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 Marks]

Solution:

N-Value : In standard penetration test, the number of blows required for 300 mm of penetration beyond a seating drive of 150 mm is the SPT N-value.

The following corrections are required for N-values obtained :

(i) Overburden Pressure Correction : In granular soils, the overburden pressure affects the penetration resistance. If the two soils having same relative density but different confining pressures are tested, the one with a higher confining pressure gives a higher penetration number. As the confining pressure in cohesionless soils increases with the depth, the penetration number for soils at shallow depths is underestimated and that at greater depth is over-estimated. For uniformity, the N-values obtained from field tests under different effective overburden pressure are corrected to a standard effective overburden pressure.

$$N_0 = \text{Observed value of S.P.T.}$$

$$N_1 = N_0 \times \left(\frac{350}{\bar{\sigma}_o + 70}\right)$$

where, $\bar{\sigma}_o$ = Effective stress at test level (kN/m^2)

N_1 = Corrected N-value after overburden correction.

Overburden correction will not be applied if $\bar{\sigma}_o$ > 280 kN/m^2

(ii) **Dilatancy Correction:**

- It is applied to the already corrected N-values for overburden pressure. Dilatancy correction is required only if (N_1 > 15) in saturated fine sand silt. (i.e., when water table is above test level).
- N_1 > 15, basically represents the dense sand which will have the tendency to dilate under rapid loading (undrained condition) and negative pore water pressure will develop. Hence, observed N-value will be more because shear resistance will increase.

$$N_2 = 15 + \frac{1}{2}(N_1 - 15)$$

N_2 = Corrected N-value after dilatancy correction.

Sources: MADE EASY Class Notes (Ch-11) Click here for reference

End of Solution

5. (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 Marks]

Solution:

Optimum Signal Cycle Time: It is the time just enough to pass all the arrived traffic in same cycle at the intersection. There is a minimum cycle time of 25 sec fixed from safety considerations while a maximum cycle time of 120 sec is generally considered desirable.

Given data:

Normal flow	Saturation flow
q_A = 480 PCU/hr	S_A = 1200 PCU/hr
q_B = 250 PCU/hr	S_B = 1000 PCU/hr

All red time, R = 12 sec, n = 2, A = 2 sec

Total lost time = $(2n + R) = 2 \times 2 + 12 = 16$ sec

Sum of critial flow ratio

$$Y = y_A + y_B$$

$$y_A = \frac{q_A}{S_A} = \frac{480}{1200} = 0.4$$

$$y_B = \frac{q_B}{S_B} = \frac{250}{1000} = 0.25$$

$$Y = (0.4 + 0.25) = 0.65$$

Optimum cycle time

$$C_0 = \frac{1.5L + 5}{1 - Y} = \frac{1.5 \times 16 + 5}{1 - 0.65} = 82.857 \text{ sec}$$

Green time,

$$G_A = \frac{y_a}{Y}(C_0 - L) = \frac{0.4}{0.65} \times (82.857 - 16) = 41.14 \text{ sec}$$

$$G_B = \frac{y_b}{Y}(C_0 - L) = \frac{0.25}{0.65} \times (82.857 + 10) = 25.71 \text{ sec}$$

Now providing amber time of 2 sec and 12 sec of all red time.

Total cycle time = (41.14 + 25.71 + 12 + 2 + 2)

= 82.85 sec

Sources: MADE EASY Conventional Practice Question Pg. 345, Q.2

Click here for reference

End of Solution

5. (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 Marks]

Solution:

Given for a BG track,

Heel divergence, d = 130 mm

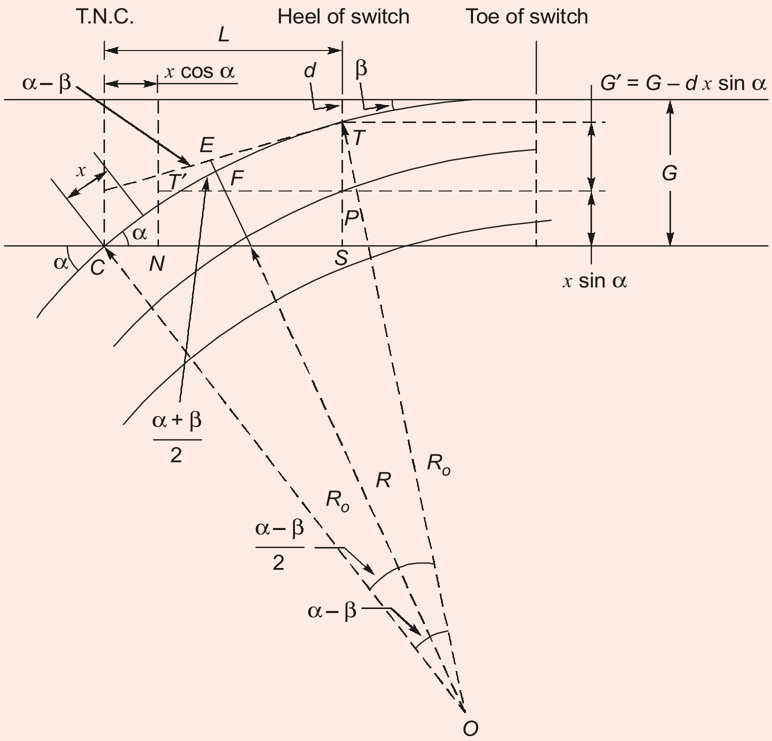
Straight length between theoretical nose of crossing and tangent point of crossing

x = 1.3 m

Angle of crossing, $\alpha = 4° 45' 49''$

Angle of switch, $\beta = 1° 8' 00''$

Gauge distance, G = 1.676 m



(i) Radius, R

$$R_o = \frac{G - d - x\sin\alpha}{\cos\beta - \cos\alpha}$$

$$= \frac{1.676 - 0.13 - 1.3 \times \sin(4°45'49'')}{\cos(1°08'00'') - \cos(4°45'49'')} = 441.31 \text{ m}$$

∴ Central radius

$$R = R_o - \frac{G}{2} = 441.31 - \frac{1.676}{2} = 440.472 \text{ m}$$

(ii) Crossing Lead (L) :

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

$$= 1.3\cos(4°45'49'') + (1.676 - 0.13 - 1.3\sin(4°45'49'')$$

$$\times \cot\left(\frac{4°45'49'' + 1°08'00''}{2}\right)$$

$$= 1.2955 + 1.438 \times 19.415 = 29.214 \text{ m}$$

End of Solution

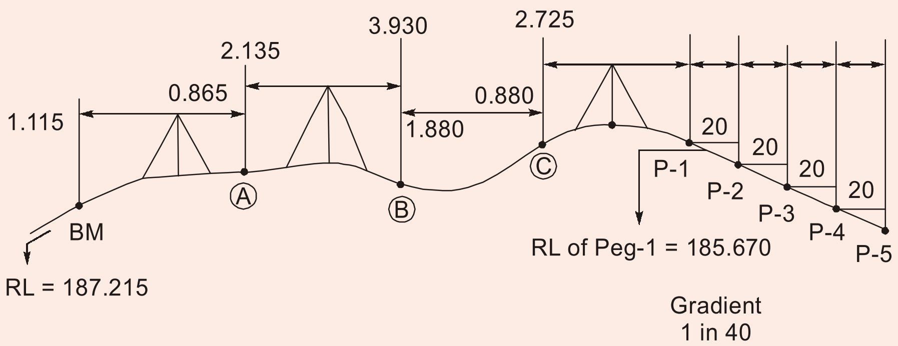
5. (e) In a running fly level from a benchmark of RL 187.215, the following readings were obtained.

BS	1.115	2.135	1.880	2.725
FS	0.865	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 Marks]

Solution:



Gradient:

1 in 40

⇒ 1 m fall in 40 m distance

Hence for every 20 m distance fall = 0.5 m

$$\text{RL of Peg-1} = 185.670 \text{ m}$$
$$\text{RL of Peg-2} = 185.67 - 0.5 = 185.017 \text{ m}$$
$$\text{RL of Peg-3} = 185.17 - 0.5 = 184.67 \text{ m}$$
$$\text{RL of Peg-4} = 184.67 - 0.5 = 184.17 \text{ m}$$
$$\text{RL of Peg-5} = 184.17 - 0.5 = 183.67 \text{ m}$$

Level Book:

Station	BS	IS	FS	HI	RL	Remarks
BM	1.115			188.33	187.215	BM
A	2.135		0.865	189.60	187.465	CP
B	1.880		3.930	187.55	185.67	CP
C	2.725		0.880	189.395	186.67	CP
P-1		3.725			185.670	
P-2		4.225			185.170	
P-3		4.725			184.670	
P-4		5.226			184.170	
P-5			5.725		183.670	

Check:

$$\Sigma BS - \Sigma FS = (7.855 - 11.4) = -3.545$$

$$\text{Last RL} - \text{First RL} = (183.67 - 187.215) = -3.545 \qquad \text{(OK)}$$

Sources: MADE EASY ESE Conventional Practice Question, Pg. 304, Q.16

Click here for reference

End of Solution

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

Sl. No.	Confining pressure (kPa)	Deviator stress (kPa)	Pore pressure (kPa)
1	100	150	40
2	200	220	75

Determine the shear strength parameters, if

(i) Construction is done at a faster rate,

(ii) Construction is done slowly.

[20 Marks]

Solution:

(i) Construction is done at a faster rate i.e., soil will be in undrained condition hence total stress should be used.

(ii) Construction is done slowly i.e., soil will be in drained condition hence effective stress should be used.

SNo.	$\sigma_3 (i)$	$\sigma_d (ii)$	$u (iii)$	$\sigma_1 = \sigma_3 + \sigma_d$ $(iv) = (i + ii)$	$\bar{\sigma}_1 = \sigma_1 - u$ $= (iv) - (iii)$	$\bar{\sigma}_3 = \sigma_3 - u$ $= (i) - (iii)$
1	100	150	40	250	210	60
2	200	220	75	420	345	125

(i) Undrained/total shear parameters (construction is done at a faster rate)

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

$$250 = 100\tan^2\left(45 + \frac{\phi}{2}\right) + 2C\tan\left(45 + \frac{\phi}{2}\right) \quad \text{...(i)}$$

$$420 = 200\tan^2\left(45 + \frac{\phi}{2}\right) + 2C\tan\left(45 + \frac{\phi}{2}\right) \quad \text{...(ii)}$$

$$170 = 100\tan^2\left(45 + \frac{\phi}{2}\right)$$

$$\phi = 15.026°$$

From eq. (i)

$$C = 30.68 \text{ kN/m}^2$$

(ii) Drained/effective shear parameters (construction is done slowly)

$$\bar{\sigma}_1 = \bar{\sigma}_3 \times \tan^2\left(45+\frac{\phi}{2}\right) + 2C'\tan\left(45+\frac{\phi'}{2}\right)$$

$$210 = 60\tan^2\left(45+\frac{\phi'}{2}\right) + 2C'\tan\left(45+\frac{\phi'}{2}\right) \quad \text{...(iii)}$$

$$345 = 125\tan^2\left(45+\frac{\phi'}{2}\right) + 2C'\tan\left(45+\frac{\phi'}{2}\right) \quad \text{...(iv)}$$

$$135 = 65\tan^2\left(45+\frac{\phi'}{2}\right)$$

$\therefore$ $\phi' = 20.487°$

From eq. (iii)

$$C' = 29.63 \text{ kN/m}^2$$

Sources: MADE EASY ESE Workbook (similar question) (Ch-8, Q.43) **Click here for reference**

End of Solution

6. (b) The soil profile in a particular site consists of a 1.5 m thick filled up soil (N = 3, γ = 17 kN/m^3) followed by 2 m thick very soft clay layer (N = 0, C_u = 5 kN/m^2, 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.
Take for N = 3, ϕ = 24°; N = 8, ϕ = 28°
for N = 50, ϕ = 41°, N_q = 140 and N_γ = 152.

[20 Marks]

Solution:

For 1.5 m filled up soil : Filled-up soil is not compacted, hence assuming negative skin friction in soil.

$$Q_{nf} \text{ using static method} = \frac{1}{2}K\gamma L\tan\delta\cdot A_s = K\bar{\sigma}_V\tan\delta\cdot A_s$$

Note : Pile is bored pile $K = K_o = 1 - \sin\phi = 0.593 = 0.6$

As per IS 2911, take $\delta = \phi$

$$Q_{nf1} = 0.6\left[\frac{0+17\times1.5}{2}\right]\tan24(\pi\times0.6\times1.5)$$

$$= 9.63 \text{ kPa}$$

For 2 m very soft clay : Clay is very soft and $N = 0$. Hence assuming negative friction in soft clay.

$$Q_{nf2} = \alpha \bar{C}(\pi d L)$$
$$= 0.7(5) \times \pi \times 0.6 \times 2 = 13.19 \text{ kPa}$$

Note : For very soft clay assume $\alpha = 0.7$.

For 6 m sandy layer :

$$Q_{sf} \text{ using static method} = K(\bar{\sigma}_V)_{avg} \tan\delta \cdot A_s$$

Note : Assume $K = K_o = 1 - \sin\phi = 0.53$ for bored pile.

As per IS-2911, $\delta = \phi = 28°$

$$(\bar{\sigma}_V)_{avg} = \left[\frac{(1.5\times17+2\times5.19)+(1.5\times17+2\times5.18+6\times7.19)}{2}\right]$$
$$= 57.45 \text{ kPa}$$
$$Q_{sf3} = 0.53 \times 57.45 \tan 28(\pi \times 0.6 \times 6) = 183.101 \text{ kPa}$$

For 11 m stiff clay :

$$Q_{sf4} = \alpha \bar{C}(\pi d L)$$

Note : Assuming $\alpha = 0.4$ for stiff clay.

$$Q_{sf4} = 0.4 \times 25(\pi \times 0.6 \times 11) = 207.34 \text{ kPa}$$

For 4.5 m thick dense sand :

$$Q_{eb} = (\bar{\sigma}_V)_{base} \cdot N_q \cdot A_b + \left\{\frac{1}{2}B\gamma N_\gamma\right\} A_b$$
$$(\bar{\sigma}_V)_{base} = 1.5 \times 17 + 2 \times (5.19) + 6 \times 7.19 + 11 \times 5.19 + 4.5 \times 9.19$$
$$= 177.465 \text{ kPa}$$
$$Q_{eb} = 177.465\times140\left\{\frac{\pi}{4}(0.6)^2\right\}+\frac{1}{2}\times0.6\times19\times152\times\frac{\pi}{4}(0.6)^2$$
$$= 7024.786 + 244.96 = 7269.754 \text{ kN}$$

Note : For bored pile end bearing can be assumed as $\frac{1}{2}$ to $\frac{2}{3}$ of driven pile.

$$Q_{eb} = \frac{1}{2}(7269.754) = 3634.87 \text{ kN}$$
$$Q_{sf5} = K(\bar{\sigma}_V)\tan\delta A_s = 0.344(\bar{\sigma}_V)_{avg}\tan\phi(\pi\times0.6\times4.5)$$
$$(\bar{\sigma}_V)_{avg} = \left(\frac{136.11+177.465}{2}\right) = 156.7875 \text{ kPa}$$
$$Q_{sf5} = 0.344 \times 156.787 \tan(41)(\pi \times 0.6 \times 4.5) = 397.69 \text{ kPa}$$

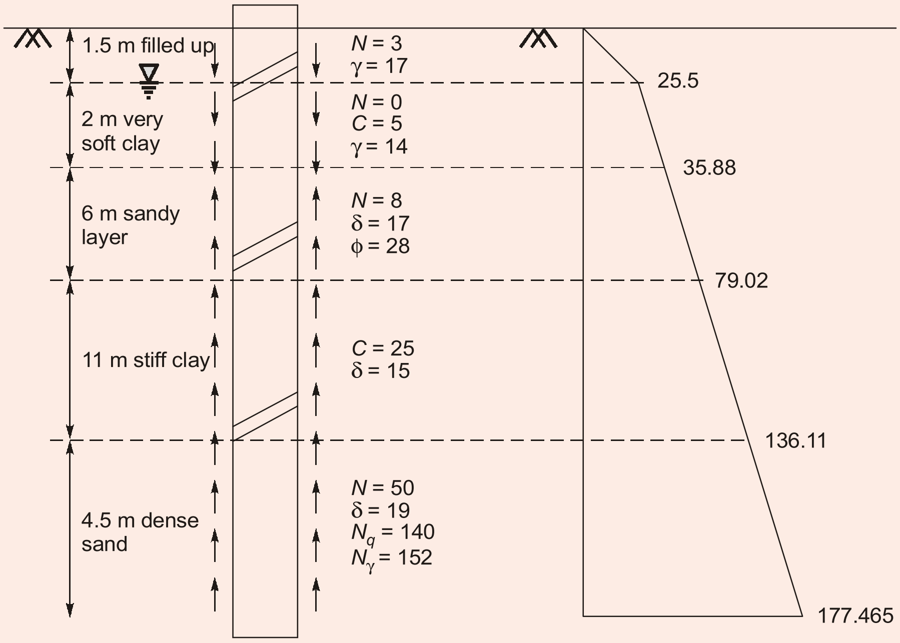
Using Static Method :

$$Q_{up} = Q_{eb} + (-Q_{nf})_1 + (-Q_{nf})_2 + Q_{sf3} + Q_{sf4} + Q_{sf5}$$

$$= 3634.87 - 9.63 - 13.19 + 183.101 + 207.34 + 397.69$$
$$= 4400.188 \text{ kN}$$

Safe Load Carrying Capacity : (Assuming F.O.S. = 2.5)

$$Q_{safe} = \frac{Q_{up}}{F} = \frac{4400.188}{2.5} = 1760.07 \text{ kN}$$



Note:

Consistency	N value	Bored piles	Driven cast in situ piles
Soft to very soft	<4	0.7	1.0
Medium	4-8	0.5	0.7
Stiff	8-15	0.4	0.4
Stiff to hard	>15	0.3	0.3

Values of α

Sources: MADE EASY Conventional Practice Question, Pg. 289 Q.63

Click here for reference

End of Solution

6. (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°C.
Effective gradient along the proposed runway is 0.4%.

[20 Marks]

Solution:

Standard conditions assumed for basic runway length are :

(a) Airport altitude is at sea level.

(b) Temperature at airport is standard 15°C.

(c) Runway is levelled in the longitudinal direction.

(d) Aircraft is loaded through its full loading capacity.

(e) Speed of wind should be zero on runway.

Given :

Altitude above MSL = 420 m

Airport reference temp. = 23°C

Effective gradient = 0.4%

Take off operation :

Basic runway length = 2000 m

Correction for elevation is 7% per 300 rise over MSL

$$\text{Correction for elevation} = \frac{7}{100} \times \frac{420}{300} \times 2000 = 196 \text{ m}$$

Corrected length after elevation correction

$$= 2000 + 196 = 2196 \text{ m}$$

Correction for temperature is 1% per 1°C rise over standard temperature.

$$\text{Standard temperature at airport} = 15°\text{ C} - 0.0065 \times 420 = 12.27°\text{C}$$

$$\Delta T = 23 - 12.27 = 10.73°\text{C}$$

$$\text{Correction for temperature} = 2196 \times \frac{1}{100} \times \frac{10.73}{1} = 235.63 \text{ m}$$

Corrected length after temperature correction

$$= 2196 + 235.63 = 2431.63 \text{ m}$$

$$\text{Total correction percentage} = \frac{196 + 235.63}{2100} \times 100$$

$$= 20.55\% < 35\% \text{ (OK)}$$

Correction for effective gradient

$$= 2431.63 \times \frac{20}{100} \times \frac{0.4}{1} = 194.53 \text{ m}$$

Corrected length after applying all corrections

$$= 2431.63 + 194.53 = 2626.16 \text{ m}$$

Landing operation :

Only elevation correction is required.

$$\text{Correction for elevation} = 2400 \times \frac{7}{100} \times \frac{420}{300} = 235.2 \text{ m}$$

Corrected length after elevation = 2635.2 m

Therefore, runway length = max{2626.16, 2635.2} = 2635.2 m

Sources: MADE EASY Class Notes Click here for reference

End of Solution

7. (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 Marks]

(ii) A square footing (2 m × 2 m) 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 Marks]

Solution:

(i) **According to Terzaghi :**

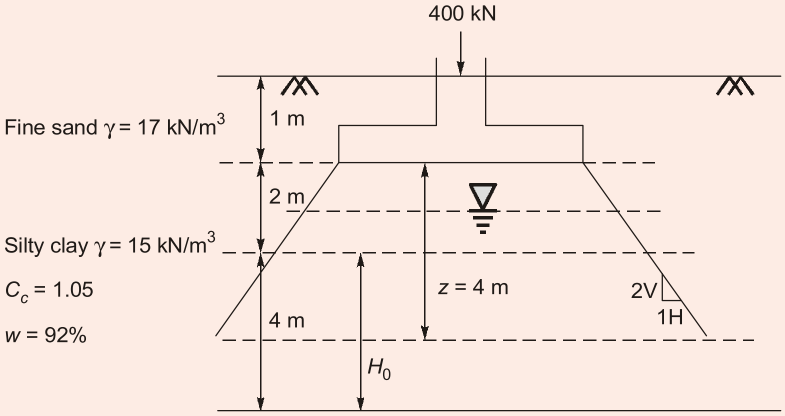
- Foundation can be classified as shallow foundation when the depth of footing is less than or equal to width of footing, i.e., $\frac{D_f}{B} \leq 1$.
- In shallow foundation, only base resistance is considered and in deep foundation, skin resistance as well as base resistance is considered.

According to Skempton :

- Foundation is shallow if depth of footing is less than 2.5 times the base of the footing.

S.No.	Type of Soil and Loading Condition	Suitable Foundation
1.	Structural load is less and soil is medium to dense	Shallow foundation
2.	Structural load is heavy and soil is medium to loose.	Either raft or deep footing
3.	Footing area is 40% or more than plinth area.	Either raft or combined footing
4.	For individual houses and light building 2 to 4 storey.	Strip or isolated.

(ii)



$$e_o = \frac{WG}{S} = 2.484$$

Note : Because G and void ratio of silty clay is not given hence assuming $G = 2.7$.

Note : Assuming γ and γ_{sat} same for fine sand because saturated unit weight of fine sand is not given.

Step 1 : H_o (Thickness of compressible layer) = 4 m

Step 2 : $\bar{\sigma}_o$ at c/c of compressible layer.

$$\bar{\sigma}_o = \sigma - u = (3\gamma + 2\gamma_{sat}) - 3\gamma_w$$

$$= 3 \times 17 + 2 \times 15 - 3 \times 9.81 = 51.57 \text{ kN/m}^2$$

Step 3 : Assuming load distribution as 2 V : 1 H

$$\Delta\bar{\sigma} = \frac{Q}{(B+2nz)^2} = \frac{400 \text{ kN}}{\left(2+2\times\frac{1}{2}\times4\right)} = 11.111 \text{ kN/m}^2$$

Step 4 :

$$\Delta H = \frac{H_o C_c}{1+e_o}\log\left(\frac{\bar{\sigma}_o + \Delta\bar{\sigma}}{\bar{\sigma}_o}\right)$$

$$= \frac{4\times1.05}{1+2.484}\log\left(\frac{51.57+11.111}{51.57}\right)$$

$$\Delta H = 0.102 \text{ m} = 102 \text{ mm}$$

Note : Settlement 102 mm is out of permissible limit hence there is risk of settlement failure.

Permissible limit as per IS Code :

A. For isolated footing on clay = 75 mm

B. For isolated footing on sand = 50 mm

C. For raft foundation on clay = 100 mm

D. For raft foundation on sand = 75 mm

Sources: (i) MADE EASY Class Notes Type of Foundation (Ch-11)

(ii) MADE EASY Workbook (similar question) (Ch-7, Q.53) Click here for reference

End of Solution

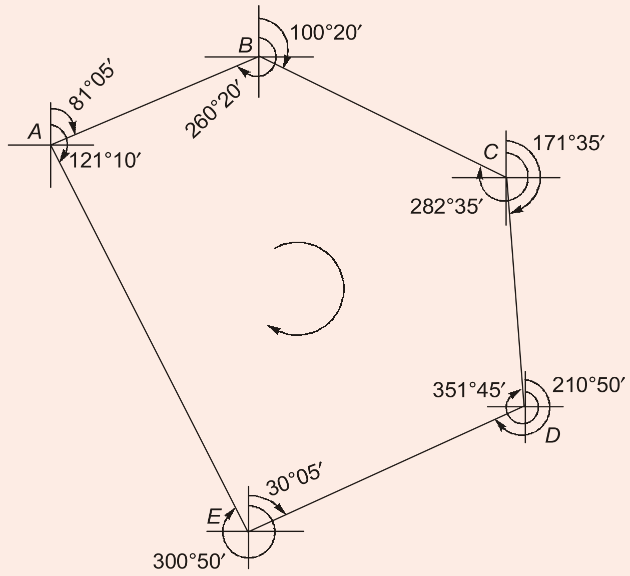
7. (b) Determine the correct magnetic bearings of the lines of closed traverse having the following bearings as observed:

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

[20 Marks]

Solution:

No any line creating difference of 180°.



Calculation of internal angle

:

$$\angle A = 121°\,10' - 81°\,05' = 40°\,5'$$
$$\angle B = 260°\,20' - 100°\,20' = 160°$$
$$\angle C = 282°35' - 171°35' = 111°$$
$$\angle D = 351°\,45' - 210°\,50' = 140°\,55'$$
$$\angle E = 360° - (300°\,50' - 30°\,05') = 89°\,15'$$

Designated sum of interior angle

$$= (2n - 4) \times 90$$
$$= (2 \times 5 - 4) \times 90$$
$$= 540$$

Total error in internal angle $= 541°\,15' - 540° = +1°15'$

Total correction $= -1°\,15'$

Correction per angle $= \frac{1}{2}(1°15') = -15'$

	Correction	Corrected angle
40°5′	–15′	39°50′
160°	–15′	159°45′
111°	–15′	110°45′
140°55′	–15′	140°40′
89°15′	–15′	89°
Total 541°15′	–1°15′	540°

Correction for reference:

Line with minimum deviation will have minimum error of local attraction

Line	$\Delta = \lvert FB - BB \rvert$	Deviation $\lvert 180 - \Delta \rvert$
AB	179°15′	45′
BC	182°15′	2′15′
CD	180°10′	10′
DE	180°45′	45′
EA	179°40′	20′

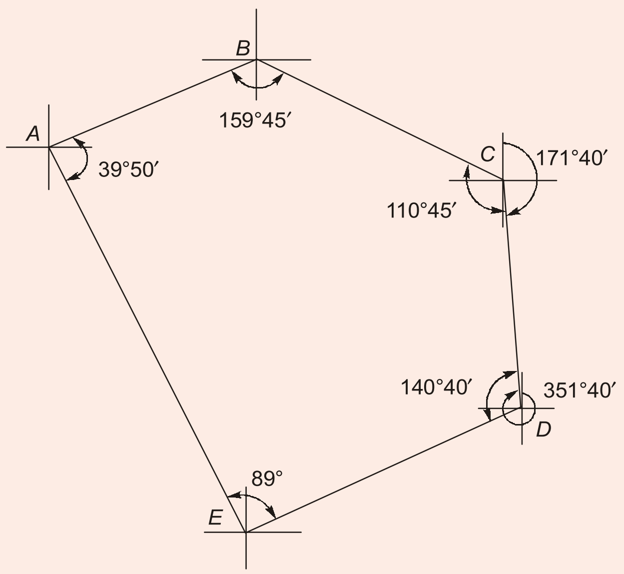
CD is the line of minimum deviation.

Hence bearings of line *CD* will be corrected.

$$\text{FB of line } CD = 171°30' + \frac{10'}{2} = 171°40'$$

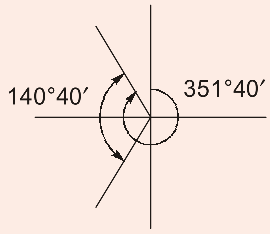
$$\text{BB of line } CD = 351'45' - \frac{10'}{2} = 351°40'$$

Now corrected beam:

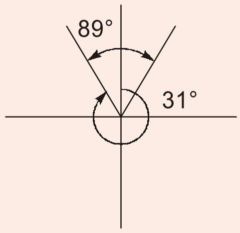


Calculation for corrected value

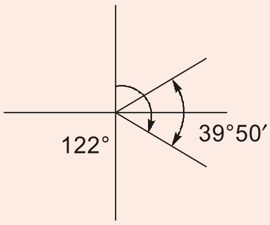
$$D\begin{bmatrix} BB \text{ of } CD = 351°40' \\ FB \text{ of } DE = 351°40° - 140°40' = 211° \end{bmatrix}$$



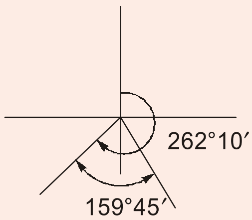
$$E\begin{bmatrix} BB \text{ of } DE = 211° - 180° = 31° \\ FB \text{ of } EA = 360° - (89° - 31°) = 302° \end{bmatrix}$$



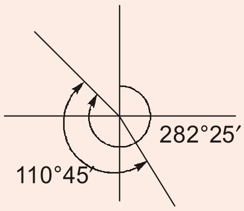
$$A\begin{bmatrix} BB \text{ of } EA = 302° - 180° = 122° \\ FB \text{ of } AB = 122° - 39°50' = 82°10' \end{bmatrix}$$



$$B\begin{bmatrix} BB \text{ of } AB = 180° + 82°10' = 262°10' \\ FB \text{ of } BC = 262°10' - 159°45' = 102°25' \end{bmatrix}$$



$$C\begin{bmatrix} BB \text{ of } BC = 102°25' + 180° = 282°25' \\ FB \text{ of } CD = 282°25' - 110°45' = 171°40' \end{bmatrix}$$



Sources: MADE EASY Conventional Practice Question, Pg. 64 Q.25

Click here for reference

End of Solution

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

[10 Marks]

Solution:

The objects of providing a tunnel with permanent lining are manifold.

1. It gives correct 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 the inside of the tunnel free from water percolation.
6. It supports large slabs of rock which might have become loosened during blasting.

Materials for Lining :

Masonry : Brick masonry was the standard material for tunnel lining, but is now rapidly going out of use, except in the case of underground sewers, as bricks are more acid resisting and suitable to carry sewage. A great disadvantage in using brick lining is the difficulty in back packing the space between the tunnel roof and the extrodas of the arch which at best has to be handpacked and is imperfect. At a later stage this may cause uneven pressures on the arch lining. The packing material employed is usually spalls, sand and brick bats, well rammed. On account of so many indeterminate factors in design, a very heavy section may be necessary the construction of which becomes cumbersome and costly.

Stone Masonry : It has more or less the same disadvantages as brick lining and in addition is very heavy necessitating very strong centres. But is still used for lining the sides.

Cement concrete has become the standard material for tunnel lining in both rock and soft soils. Its main advantage lies in its plasticity which allows it to be well packed between the form and the soil. The waterproof qualities of cement concrete, makes for a first class watertight lining. It could be used to form an unbroken ring right round, forming a shell. If unusual soil pressures have to be reckoned with, the thickness could be controlled and reinforced, suitably.

Timber : It is one of the oldest lining materials though of late, it is slowly yielding place to concrete. It is used both as a temporary support during construction and as a permanent support later.

Modern practice is to use either timber for semi-permanent lining and cement concrete as a standard practice. An attempt will be made to describe these two types of linings in detail. Masonry linings more or less follow the same modus operandi as concrete, like erection of centering, construction of the arch, easing of centres etc., except that the material is different.

End of Solution

7. (d) Classify wet docks and write advantages and disadvantages of each of them. [10 Marks]

Solution:

Classification of Wet Docks :

1. **Wet docks in tidal basin :** These are docks located on the open sea coast protected by an outlying breakwater.

   Advantages :
   - Vessel can come in and berth or leave any time.
   - Costly arrangement like lock gates for entrance closing are not required.

   Disadvantages :
   - If tidal range is more, then operations of loading and unloading are seriously effected.
   - The fluctuating water levels causes rubbing of sides of ships against the berths.

2. **Enclosed Wet Dock :**
   - In enclosed wet dock, water level remains constant by lock gates so that cargo handling and commercial activities are easy to perform.
   - Major disadvantages include that it is costly and because of lock gates ships will take more time for entry and exit.

   Advantages :
   - These helps in effective handling of cargo.
   - These prevent the rubbing of the ship sides.
   - These are effective when there is increase in draft of the vessel, or where considerable silting takes place.

Sources: MADE EASY Theory Book Click here for reference

End of Solution

8. (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 Marks]

(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 Marks]

Solution:

(i) As per Terzaghi's for strip footing :

Net ultimate bearing capacity (q_{nu}) :

$$q_{nu} = CN_C + \gamma_t D_f (N_q - 1) + 0.5B\gamma_t N_\gamma \quad ...(1)$$

Case 1 : In clayey soil,

$$N_C = 5.7m,\ N_q = 1,\ N_\gamma = 0$$

$$\therefore \quad q_{nu} = CN_C$$

From above, it is clear that net ultimate bearing capacity of a clayey soil is unaffected by the position of water table.

Case 2 : In sandy soil,

$$q_{nu} = \gamma_t . D_f(N_q - 1) + 0.5B\gamma_t N_\gamma$$

If water table rises from great depth,

$$q_{nu} = \gamma_{sub} . D_f(N_q - 1) + 0.5B.\gamma_{sub}.N_\gamma$$

As $$\gamma_{sub} \simeq \frac{\gamma_t}{2}$$

Hence, the bearing capacity will almost reduced to half, i.e., in sandy soil, position of water table much affected the net ultimate bearing capacity of soil.

(ii) **Zero Air Void Line :** A line which shows the water content dry density relation for the compacted soil containing a constant percentage air voids is known as an air-voids line,

$$\rho_d = \frac{(1-n_a)\cdot G_s \cdot \rho_w}{1+w.G_s}$$

n_a = Percent air voids

w = Water content

ρ_d = Dry density corresponding to w

G_s = Specific gravity

The theoretical maximum compaction for any given water content corresponds to zero air voids condition ($n_a = 0$). The line showing the dry density as a function of water content for soil containing no air voids is called the zero air void line or the 100% saturation line.

$$(\rho_d)_{theo,\ max} = \frac{G_s \cdot \rho_w}{1+w.G_s} \quad ...(i)$$

Alternatively, a line showing the relation between water content and dry density for a constant degree of saturation S is

$$\rho_d = \frac{G_s \cdot \rho_w}{1+\left(\frac{w.G_s}{S}\right)}$$

For 90% saturation

$$\rho_d = \frac{G_s \cdot \rho_w}{1+\left(\frac{w.G_s}{0.9}\right)} \quad ...(a)$$

Instead of drawing lines corresponding to different degrees of saturation, it is sometimes more convenient to draw lines corresponding to different percentage air voids (n_a)

$$\rho_d = \frac{(1-n_a)\cdot G_s \cdot \rho_w}{1+w.G_s}$$

For theoretical maximum density

$$n_a = 0$$

$$(\rho_d)_{\text{theo, max}} = \frac{G_s \cdot \rho_w}{1+w.G_s}$$

Thus, the zero air-void line and 100% saturation line are identical.

The line for other percentage of air voids such as 10%.

$$\rho_d = \frac{0.90(G_s\rho_w)}{1+wG_s} \quad \text{...(b)}$$

Thus, from equation (a) and (b), it may be noted that 10% air void line and 90% saturation lines are not identical.

Sources: MADE EASY Class Notes (Terzaghi Theory, Note No. 2 & Note No. 4) (Ch-11)

Click here for reference

End of Solution

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

[10 Marks]

Solution:

Reservoirs may broadly be defined as artificially created water storage basins with storage capacity that may range from a few thousand cubic meters to thousands of million cubic meters. Depending on the purpose of storage, reservoirs are classified into three main categories :

(i) Storage and conservation reservoirs, where river water is stored by creating barriers or dams in its path and is then released from gated or ungated outlets. These feed the canal systems for irrigation and power generation.

(ii) Flood control reservoirs which have as their main function accommodating large volumes of surplus water during peak flow times of a river. The surplus water is released after the flood abates. Such reservoirs are provided with large sluice ways to discharge the inflow received by the reservoir during a flood up to a volume which could be safely accommodated in the channel downstream. Excess or surplus inflow is retained back till a desirable time.

(iii) Distribution reservoirs are actually small storage reservoirs which hold water supplies in a water-supply system for short spells of time. Water is constantly pumped into these reservoirs, from where it is distributed for drinking and other purposes in a regulated manner.

Since reservoirs are essentially water storage basins, the area should possess such geological characteristics that favour holding of water in the basin so created. Such characters are : topographic suitability, ground water conditions, permeability and structural stability.

(a) Topographically, the area should be a broad natural valley preferably ending in a narrow gorge where a barrier could be placed. The valley could be a U-shaped glacial valley, or V-shaped river valley or a broad synclinal valley. Flatlands and plains cannot make convenient places for reservoirs. In alluvial plains, the reservoir area has to be an extensive low-lying stretch bordered by high-lands on flanks.

(b) Groundwater conditions in the proposed reservoir area must be thoroughly established for an approximately accurate evaluation of storage capacity of the reservoir. Any one of the three in view of such a close relationship between water table and storage capacity of the proposed reservoir, it is absolutely essential that water table position all along the reservoir areas, especially along the lanks, must be thoroughly established. This may necessitate drilling test holes upto required depths and numbering many hundreds or even thousands.

(c) Permeability is a critical property in reservoir area studies, especially in those areas where groundwater table is below the minimum water level of the reservoir. As mentioned earlier, permeability may be of primary nature, due to inherent porous texture of the rocks, or. of secondary character, where it is caused due to structural deformations of the rocks subsequent to their formation. Primary permeability may be extensive and all prevailing along the rock body whereas secondary permeability is often localized and amenable to treatment. In critical area where water loss from the proposed reservoir could be expected due to seepage and under hydraulic head difference, permeability-values, whether primary or secondary. Must be thoroughly established. This may also require drilling of test-wells at numerous places. Such studies then can be analysed to calculate possible loss due to expected seepage and suggest methods of treatment of rocks in critical zones to minimize the expected loss.

(d) Structural constitution of the area of the reservoir is important to identify those zones along the flanks which are liable to failure by sliding, creep or subsidence.

(e) Trend and rate of weathering in catchment area is of considerable importance in determining the age of the reservoir. If the catchment happens to be made up predominantly of weathered, barren slopes which are broken, falling, shattered and jointed profusely, the run off and slope wash would contribute heavy load of sediments to the reservoir after every rain. This would obviously decrease the effective storage capacity of the reservoir on the one hand and its total life on the other hand. However, stable rock slopes covered with thick forests and vegetation would make ideal catchment areas for reservoirs.

Sources: MADE EASY Class Notes (Compaction) (Ch-5)

End of Solution

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

[10 Marks]

Solution:

The instrument that measures the properties of electromagnetic radiations leaving a surface/ medium due to scattering or emission, is called a remote sensor.

Remote sensors are of two types :

1. Passive sensors
2. Active sensors

1. **Passive Sensors :** The remote sensors, which sense natural radiations either emitted or reflected from the earth, are called passive sensors.
2. **Active Sensors :** The remote sensors which produce their own electromagnetic radiation of specific wavelength or a band of wavelength, as a part of the sensor system, are called, active remote sensors.

As the technology involved in developing sensors throughout the electromagnetic spectrum, is not the same, the remote sensors, are also classified as under :

(i) The remote sensors which operate in the optical infrared region.

(ii) The remote sensors which operate in the optical microwave region.

Both the optical infrared and microwave sensors may be either imaging or non-imaging sensors. The imaging remote sensors give a two-dimensional spatial distribution of the emitted or reflected intensity of radiation (such as a photographic camera). The non-imaging sensors measure the intensity of radiation, within the field of view. Vertical temperature profiling radiometer (VTPR) is a type of non-imaging sensor.

Sensor on Board Satellite Scanning the Ground surface : Sensors mounted on aircraft or satellite platforms measure the amounts of energy reflected from or emitted by earth's surface. The sensor measures the ground surface along the one dimensional profile on the ground below the platform on either side of the ground track of the platform. The sensor scans the ground below the satellite platform. Movement of the platform in forward direction, enables the sensor to build an image of the earth's surface.

The satellite sensor scans the ground surface along line. Each scan line of a remotely sensed image is a digital or numerical record of radiance measurements made at regular intervals along the line. Consecutive scan lines form an image. Depending upon the direction of principal axis of the sensor, the sensors are called Nadir looking or side looking sensor.

A Nadir looking sensor images the ground area on either side of the satellite platform. Whereas a side-looking sensor images the earth's surface lying on one side of the satellite track.

End of Solution

8. (d) Design the length of transition curve to be provide 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:

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

[25 Marks]

Solution:

Given :

$R = 484$ m

$V = 80$ kmph (Rolling terrain)

$N = 150$

$l = 6$ m

Case (i) : Based on rate of change of centrifugal acceleration

$$C = \frac{80}{75+V} = \frac{80}{75+80} = 0.516 \text{ m/s}^3$$

$$L_T = \frac{V^3}{CR} = \frac{\left(\frac{5}{18}\times 80\right)^3}{0.516\times 484} = 43.94 \text{ m}$$

Case (ii) : As per rate of introduction of superelevation.

Design of superelevation

$$e = \frac{V^2}{225R} = \frac{80^2}{225\times 484} = 0.0587 < 0.07 \qquad \text{(Safe)}$$

$$e = 5.87\%$$

Assume rotation about centreline

(For radius $R > 300$ m extra widening is not required for 2 lane road)

$$L_T = \frac{1}{2}eN(W+W_e)$$

$$= \frac{1}{2}\times 0.0587\times 150\times 7 = 30.81 \text{ m}$$

Case (iii) : Minimum length

$$L_T = 2.7\frac{V^2}{R} = 2.7\times\frac{80^2}{484} = 35.70 \text{ m}$$

$$L_T = \max\begin{cases}43.94\\30.81\\35.70\end{cases} = 43.94 \text{ m}$$

Sources: MADE EASY ESE Workbook (Pg.11, Q. T.2) Click here for reference

End of Solution

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