GATE WALLAH

ESE-2024

MAIN EXAM DETAILED SOLUTION

CIVIL ENGINEERING

PAPER-II

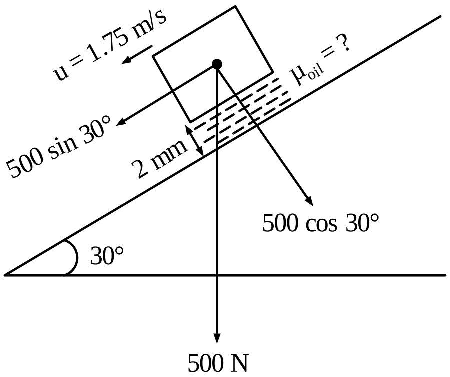
EXAM DATE - 23 JUNE 2024

2 : 30 PM TO 5 : 30 PM

SECTION-A

Q.1. (a) A rectangular plate of 0.50 m × 0.50 m dimensions and weighing 500 N slides down an inclined plane making 30º angle with the horizontal. The velocity of the plate is 1.75 m/s. If the 2 mm gap between the plate and the inclined surface is filled with lubricating oil, find the viscosity of oil and express it in units of poise as well as N-s/m^2. Assume the plate as frictionless.

Sol.



Given data:

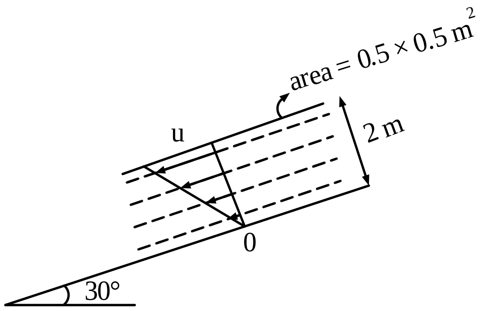
Weight of plate = 500 N
Angle of inclination from horizontal = 30°
Plate dimension = 0.5 × 0.5 m^2
Velocity of plate = 1.75 m/s
Gap between plate and surface = 2 mm
To calculate: μ = ?

From the FBD of given diagram:

$$\text{Shear force} = 500 \sin 30° = 500 \times \frac{1}{2} = 250\,\text{N}$$

$$\text{Shear stress }(\tau) = \frac{\text{Shear force}}{\text{Area of plate}}$$

$$\tau = \frac{250}{0.5 \times 0.5} = 1000\,\text{N/m}^2$$



From Newton's law of viscosity:

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

$$1000 = \mu\left(\frac{1.75-0}{2\times10^{-3}}\right) \Rightarrow \mu = 1.1428\ \text{N-s/m}^2$$

In C.G.S. unit:

1 Poise = 0.1 N-s/m^2
1.1428 × 10 poise
μ = 11.428 poise

Q.1. (b) The following is the set of observed data for successive 15 minutes period of 105 minutes storm in a catchment:

Duration (min)	15	30	45	60	75	90	105
Rainfall (cm/hr)	2.0	2.0	8.0	7.0	1.25	1.25	4.5

If the value of -index is 3.0 cm/hr, estimate the net runoff, the total rainfall and the value of W-index.

Sol. Total storm duration = 105 mins

t (mins)	0-15	15-30	30-45	45-60	60-75	75-90	90-105
t (hrs)	0-0.25	0.25-0.5	0.5-0.75	0.75-1	1-1.25	1.25-1.5	1.5-1.75
i (cm/hr)	$i_1 = 2.0$	$i_2 = 2.0$	$i_3 = 8.0$	$i_4 = 7.0$	$i_5 = 1.25$	$i_6 = 1.25$	$i_7 = 4.5$
P (cm)	$P_1 = 0.5$	$P_2 = 0.5$	$P_3 = 2$	$P_4 = 1.75$	$P_5 = 0.3125$	$P_6 = 0.3125$	$P_7 = 1.125$

Total rainfall P = 0.5 + 0.5 + 2 + 1.75 + 0.3125 + 0.3125 + 1.125

P = 6.5 cm

. or $\left\{P = 26 \times \frac{1}{4}\right\} = 6.5\text{cm}$

ϕ-index = 3.0 cm/hr

As i_1, i_2, i_5 & i_6 < ϕ-index, they don't produce runoff

t_e = 45 mins with respect to i_3, i_4 and i_7.

$P_e = P_3 + P_4 + P_7 = 2 + 1.75 + 1.125$

P_e = 4.875 cm

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

$$3 = \frac{4.875 - R}{\left(45/60\right)}$$

R = 2.625 cm

I.L-Initial losses all not given

For simple solution let us assume I.L = 0

Then W-index = ϕ-index = 3 cm/hr

Note: To compute w-index

1. Deduct I.L from hyetograph starting from first.
2. Using resulting hyetograph, follow the procedure as discussed for ϕ-index.

Q.1. (c) A hydraulic turbine has an output of 6600 kW when it works under a head of 25 m and runs at 100 r.p.m. What is the type of the turbine? What would be its speed and what power will it develop when working under a head of 16 m?

Sol. Given

Output power, P_1 = 6600 kW

Head, $H_1 = 25$ m
Speed, $N_1 = 100$ rpm
(i) Type of turbine = ?
(ii) If new working head, $H_2 = 16$ m
Then N_2 = ?
P_2 = ?
From the ration of specific speed of the turbine

$$N_s = \frac{N_1\sqrt{P_1}}{H_1^{5/4}}$$

Here,
N_s = Specific speed
P = Power is kW
H = Working head in metres

$$N_s = \frac{100\times\sqrt{6600}}{(25)^{5/4}} = 145.327$$

Impulse turbine (pelton): High head and low discharge.
Francis turbine: Medium head and medium discharge.
Kaplan and Propeler turbine: Low head and high discharge.

Turbine	Specific speed, N_s, (MKS)
1. Pelton wheel turbine (Single jet)	10-35
2. Pelton wheel turbine (multiple jet)	35 – 60
3. Francis turbine	60 – 300
4. Kaplan turbine	> 3000

∵ Comparing from the above table we can say that it is a Francis turbine
When working under a head of 16 m, from the performance characteristics of turbine we can find speed and power as under:

$$\boxed{\frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}} \Rightarrow \frac{100}{\sqrt{25}} = \frac{N_2}{\sqrt{16}} \Rightarrow \therefore N_2 = 80rpm$$

Similarly,

$$\boxed{\frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}}} \Rightarrow \frac{6600}{(25)^{3/2}} = \frac{P_2}{(16)^{3/2}} \Rightarrow P_2 = 3379.2kW$$

Q.1. (d) A large stream flowing through an industrialised area is the only source of raw water for the community water supply. The stream water is consistently turbid, has hardness in excess of 300 mg/L as $CaCO_3$ and has refractory organics that are known precursor of trihalomethanes. Draw a schematic diagram of a treatment plant that could render this water potable. Identify all the units. State their purpose, show points of chemical addition and identify all the chemicals.

Sol.

Intake
↓
Screening
↓
Coagulation and Flocculation
↓
Sedimentation
↓
Lime-Soda Softening
↓
Filtration
↓
Disinfection
↓
pH Adjustment
↓
Advanced Oxidation
↓
Fluoridation
↓
Storage of Potable Water
↓
Distribution

1. Intake

- Purpose: To draw water from the stream for treatment.
- Chemical Addition: None at this stage.

2. Screening

- Purpose: To remove large debris and suspended particles (pre-treatment).
- Chemical Addition: None.

3. Coagulation and Flocculation

- Purpose: To destabilize suspended particles and colloids, aiding their agglomeration.
- Chemicals Used:
    - Coagulant: Typically aluminum sulfate (alum) or ferric chloride.
    - Coagulant Aid: Polymers like polyaluminum chloride (PAC) or polyDADMAC.
    - Chemical Addition Points: In the rapid mix or flocculation basin.

4. Sedimentation

- Purpose: To allow floc particles to settle out from the water.
- Chemical Addition: None at this stage.

5. Lime-Soda Softening

- Purpose: To remove hardness (calcium and magnesium ions) from the water.
- Chemicals Used:
    - Quicklime (Calcium Oxide): for raising pH and precipitating calcium ions.
    - Soda Ash (Sodium Carbonate): for precipitating magnesium ions.
    - Chemical Addition Point: After sedimentation, typically in a separate softening basin.

6. Filtration

- Purpose: To remove remaining suspended particles and floc.
- Chemical Addition: None at this stage.

7. Disinfection

- Purpose: To kill or inactivate harmful microorganisms.
- Chemical Used: Chlorine gas or sodium hypochlorite.
- Chemical Addition Point: Before or after filtration, depending on the design.

8. pH Adjustment

- Purpose: To optimize the pH of the water for corrosion control and disinfection.
- Chemical Used: Sodium hydroxide (for raising pH) or carbon dioxide (for lowering pH).
- Chemical Addition Point: Before or after disinfection, to achieve the desired pH.

9. Advanced Oxidation (optional for organic removal)

- Purpose: To degrade refractory organics and reduce precursors of disinfection by-products (like trihalomethanes).
- Chemical Used: Hydrogen peroxide or ozone.
- Chemical Addition Point: Before disinfection, if implemented.

10. Fluoridation (if needed)

- Purpose: To adjust fluoride levels in the treated water to optimal levels for dental health.
- Chemical Used: Fluorosilicic acid or sodium fluoride.
- Chemical Addition Point: After disinfection.

11. Storage of Potable Water

- Purpose: To store treated water before distribution.
- Chemical Addition: None.

12. Distribution

- Purpose: To deliver potable water to consumers.

Chemicals Used in Treatment Process

- Coagulant: Aluminum sulfate (alum) or ferric chloride.
- Coagulant Aid: Polymeric coagulants like polyaluminum chloride (PAC) or polyDADMAC.
- Lime-Soda Softening: Quicklime (Calcium Oxide) and Soda Ash (Sodium Carbonate).
- Disinfectant: Chlorine gas or sodium hypochlorite.
- pH Adjustment: Sodium hydroxide or carbon dioxide.
- Advanced Oxidation (optional): Hydrogen peroxide or ozone.
- Fluoridation (if needed): Fluorosilicic acid or sodium fluoride.

Note :-

Lime-soda softening is a crucial step specifically designed to remove hardness (calcium and magnesium ions) from water. It works by precipitating these ions out of solution, which helps in reducing scaling issues in pipes and appliances, as well as improving the effectiveness of soaps and detergents. This step is typically placed after sedimentation but before filtration and disinfection in the treatment process.

In conclusion, the inclusion of lime-soda softening is essential for effectively addressing the hardness issue in the stream water, ensuring that the treated water meets potable water standards and is suitable for distribution to consumers.

Q.1. (e) For BOD analysis, 30 mL of treated wastewater sample with DO of zero was mixed with 270 mL of dilution water with DO of 10 mg/L. The 5th and 6th days being holidays, the lab was closed. The final DO was measured as 4 mg/L on the 7th day. It was also found that the incubator was set at 30 °C. Assuming the BOD reaction rate constant as 0.23 day^{-1} at 20 °C and the temperature coefficient as 1.047, determine the 5 day, 20 °C BOD of the sample.

Sol. V_s = 30 ml = Volume of treated waste water

V_D = Volume of Dilution water = 270 ml

$(D_O)_s$ = 0 mg/l, $(D_O)_D$ = 10 mg/L

$$D_{O\ initial} = D_{O\ mix} = \frac{V_S (D_O)_S + V_D (D_O)_D}{V_S + V_D}$$

$D_{O\ initial} = \dfrac{30\times(0)+270\times10}{300} = 9$ mg/l

$K_{30} = K_{20}\ (1.047)^{(30-20)}$

$\boxed{K_{30} = 0.364\ mg/L}$

$(D_O)_{final} = 4$ mg/L

$(BOD)_7^{30} = L_0\left(1-e^{-K_{30}\times7}\right)$

$\left(D_{O_{in}} - D_{O_f}\right)\times DF = L_0\left(1-e^{-K_{30}\times7}\right)$

$(9-4)\times\dfrac{300}{30} = L_0\left(1-e^{-0.364\times7}\right)$

$50 = L_0\left(1-e^{-0.364\times7}\right)$

$L_0 = \dfrac{50}{1-e^{-0.364\times7}}$

$\boxed{L_0 = 54.2439\ mg/L}$

$BOD_5^{20°C} = L_0\left(1-e^{-K_{20}\times5}\right)$

$= 54.2439\left(1-e^{-0.23\times5}\right)$

$\boxed{BOD_5^{20°C} = 37.068\ mg/L}$

Q.2. (a) Treated wastewater having a peak flow rate of 12000 m³/day, BOD5 of 30 mg/L, DO concentration of 1 mg/L and temperature of 27 °C is discharged in a stream. Before getting mixed with the wastewater, the stream has a minimum flow rate of 0.4 m^3/s, BOD_5 of 4 mg/L, DO concentration of 7 mg/L and temperature of 25°C. After instantaneous and complete mixing, the velocity of the mixed flow is 0.2 m/s. For the mixed flow, the BOD reaction rate constant is 0.2 day^{-1} and the reaeration constant is 0.4 day^{-1} at 20 °C. Estimate the initial oxygen deficit and DO after two days of flow. Take temperature coefficient for BOD reaction rate constant as 1.047 and for stream reaeration rate constant as 1.016. Take equilibrium concentration of DO for water after mixing as 8.3 mg/L.

Sol. Given data

$Q_w = 12000\ m^3/day = 0.1388\ m^3/sec$

$(Y_i)_w = 30$ mg/l

$(DO)_w = 1$ mg/L

$T_w = 27°$

$Q_R = 0.4\ m^3/s$

$(Y_i)_R = 4$ mg/L

$(DO)_R = 7$ mg/L

$T_R = 25°$ C

$V_{mixed\ flow} = 0.2$ m/s

$K_D = 0.2\ d^{-1}$

$K_R = 0.4\ d^{-1}$ at 20° C

Temperature Coefficient for Reoxygenation = 1.016,

Temperature Coefficient for deoxygenation = 1.047

$(DO)_{sat} = 8.3$ mg/L

$$T_{mix} = \frac{Q_R T_R + Q_w T_w}{Q_R + Q_W}$$

$$T_{mix} = \frac{0.4 \times 25 + 0.1388 \times 27}{0.4 + 0.1388}$$

$$\boxed{T_{mix} = 25.5152°C}$$

$$(DO)_{mix} = \frac{Q_R \times (DO)_R + Q_w (DO)_w}{Q_R + Q_w}$$

$$= \frac{0.4 \times 7 + 0.1388 \times 1}{0.4 + 0.1388}$$

$$\boxed{DO_{mix} = 5.4543 mg/L}$$

$$(BOD)_{mix} = \frac{Q_R \times (BOD)_R + Q_w (BOD)_w}{Q_R + Q_w}$$

$$(BOD)_{mix} = \frac{0.4 \times 4 + 0.1388 \times 30}{0.4 + 0.1388}$$

$$\boxed{(BOD)_{mix} = 10.697 mg/L}$$

D_o = Intial oxygen deficit

$D_o = (DO)_{sat} - (DO)_{mix}$

$D_o = 8.3 - 5.4543$

$$\boxed{D_o = 2.8457 mg/L}$$

For reoxygenation

$K_{25.5152} = K_{20}(1.016)^{25.5152-20}$

K_R at 25.5152°C = 0.4365 d^{-1}

For Deoxygenation

$K_{25.5152} = K_{20}(1.047)^{25.5152-20}$

$= 0.2\ (1.047)^{5.5152}$

K_D at 25.5152°C = 0.2576 d^{-1}

$(BOD)_{mix} = L_o\ (1 - e^{-K_D \times 5})$

$$L_o = \frac{10.697}{1 - e^{-0.2576 \times 5}}$$

$L_o = 14.7712$ mg/L

D_t = Oxygen deficit at any time

$$D_2 = \frac{K_D L_0}{K_R - K_D}\left(e^{-K_D t} - e^{-K_R t}\right) + D_0 e^{-K_R t}$$

$$D_2 = \frac{0.2576 \times 14.7712}{0.4365 - 0.2576}\left(e^{-0.2576 \times 2} - e^{-0.4365 \times 2}\right) + 2.8457 \times e^{-0.4365 \times 2}$$

$$\boxed{D_2 = 5.01\ mg/L}$$

As we know,

$(DO)_2 = (DO)_{sat} - D_2$

$(DO)_2 = 8.3 - 5.01$

$(DO)_2 = 3.29$ mg/L

Hence, Initial oxygen deficit = 2.8457 mg/L

Dissolved oxygen after 2 days of flow = 3.29 mg/L

Q.2. (b) **(i)** For a hydraulic jump in a rectangular channel, the velocity and depth after the jump are known to be 0.80 m/s and 1.75 m respectively. Calculate the depth before jump, the energy loss and the power dissipated per metre width.

(ii) What do you mean by diversion headworks? Distinguish clearly between a weir and a barrage.

Sol. **(i)** Given, Rectangular Channel

Velocity after jump, $v_2 = 0.80$ m/s

Depth after jump, $y_2 = 1.75$ m

Depth before jump, $y_1 = ?$

Energy loss, $E_L = ?$

Power dissipated for meter width = ?

Assuming Rectangular Channel to be horizontal and frictionless.

$$F_{r_2}^2 = \frac{v_2^2}{gL_c} \text{ or } F_{r_2}^2 = \frac{v_2^2}{gy_2}$$

Here, F_{r2} = Froude Number corresponding to depth y_2

L_c = Characteristic length = y (for rectangular channel)

$$\therefore F_{r_2}^2 = \frac{(0.80)^2}{9.81 \times 1.75} = 0.03727$$

From the relation of sequent depth:

$$\frac{y_1}{y_2} = \frac{1}{2}\left[-1+\sqrt{1+8F_{r_2}^2}\right]$$

or $$y_1 = \frac{1.75}{2}[-1+\sqrt{1+8(0.03727)}$$

$\therefore$ $y_1 = 0.1219$m (Depth before jump)

$$\text{Energy Loss, } E_L = \frac{(y_2 - y_1)^3}{4y_1 . y_2}$$

$$= \frac{(1.75 - 0.1219)^3}{4 \times 0.1219 \times 1.75} = 5.057 \text{ m}$$

Power dissipated per metre width, $P = r_w . q . E_L$

$q = v_2 . y_2$

$= 0.80 \times 1.75$

$= 1.4 \text{ m}^2/\text{s}$

$P = r_w \, q \, E_L$

$= 9.81 \times 1.4 \times 5.057$

$= 69.45$ W

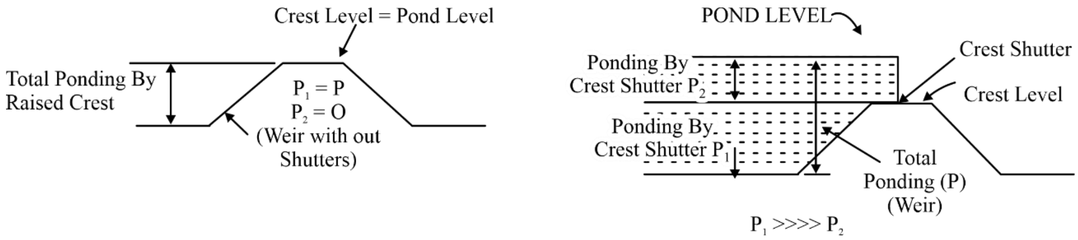
(ii) **Diversion Headworks**

A diversion headwork serves to raise the level of water in the river & divert the required quantity into the canal.

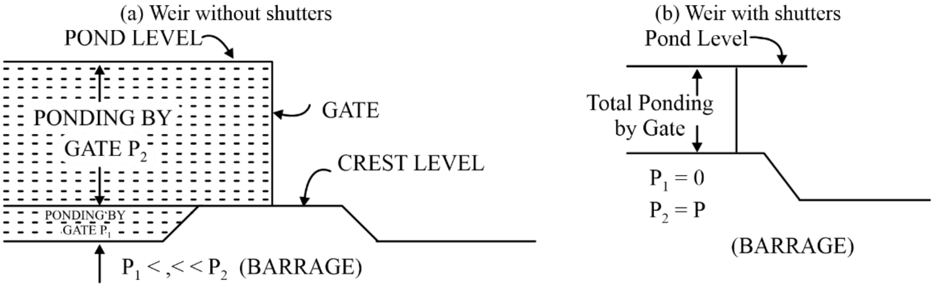
Weir vs Barrage

WEIR	BARRAGES
Low cost	High cost
Low control on flow	Relatively high control on flow and water levels by operation of gates

No provision for transport communication across the river	Usually, a road or a rail bridge can be conveniently and economically combined with a barrage wherever necessary
Chances of silting on the upstream is more	Silting may be controlled by judicial operation of gates
Excessive afflux in high floods	High floods can be passed with minimum afflux
Ponding is done against the raised crest or partly against crest and partly by shutters	Ponding is done by means of gates
Shutters are of smaller height, 2 m	Gates are of greater height



(a) Weir without shutters (b) Weir with shutters



(a) Barrage with a small raised crest (b) Barrage without any raised crest

Q.2. (c)

(i) A water treatment plant in a city of 100000 population supplies water at the rate of 150 lpcd. Two equal capacity circular settling tanks are to be provided to settle flocculent suspension through Type-II settling. Design the tanks. Take SOR as 20 $m^3/m^2.d$ and water depth of 3.5 m. Leave sludge zone of 0.5 m and keep inlet and outlet zones equal to the side water depth. Calculate the weir loading. Draw the sketch of the tank showing all the zones and dimensions.

(ii) In an ideal granular media filter, the entire depth of the filter media should contribute to the retention and removal of solids, ensuring longer filter runs, less head loss and greater filtration rates. Why will the single media filters fail to achieve this? How can the mixed media filter approach an ideal filter in performance?

Sol. **(i)** Given,

Population = 10^5

Per capital water demand = 150 lpcd

Q = Population * per capital water demand

$$Q = \frac{10^5 \times 150}{10^3} = 15 \times 10^3 m^3 / day$$

As given, two equal capacity circular settling tank are provided.

$$Q_{\text{each settling tank}} = \frac{15\times10^3}{2} = 7.5\times10^3\,\text{m}^3/\text{d}$$

Design of circular settling tank

S.O.R = 20 $m^3/m^2/d$

Water depth = 3.5 m

Sludge zone = 0.5 m

$$\text{Surface area required} = \frac{Q}{S.O.R}$$

$$= \frac{7.5\times10^3}{20} = 375m^2$$

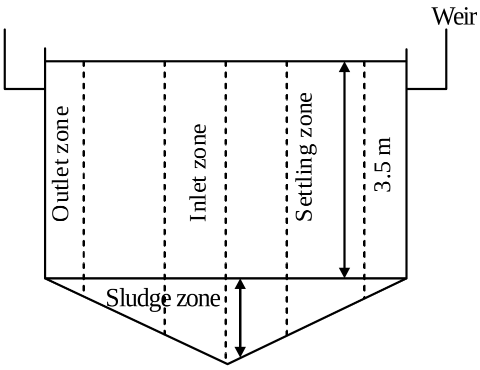
Then, $\frac{\pi}{4}(d)^2 = 375$

$\boxed{d = 21.85 \text{ meter}}$

$$\text{Weir loading rate (WLR)} = \frac{Q}{\text{length of weir}}$$

$$\text{WLR} = \frac{7.5\times10^3}{\pi\times21.85}$$

$\boxed{\text{WLR} = 109.259\ \text{m}^3/\text{d/m}}$



(ii) In an ideal granular media filter, the entire depth of the filter media indeed plays a crucial role in retaining and removing solids. However, single-media filters may fall short in achieving this due to limitations inherent to a single type of filter media. Let's explore this further:

1. **Single-Media Filters:**
   - Single-media filters, such as sand filters, use only one type of filter media (e.g., sand or anthracite coal).
   - These filters can effectively remove larger particles but struggle with finer particles due to limited particle size distribution within the media bed.
   - As water flows through the filter, the upper layers capture larger particles, while the lower layers remain underutilized.
   - Consequently, the entire depth of the filter media does not contribute equally to filtration, leading to suboptimal performance.
2. **Mixed-Media Filters (Multimedia Filters):**
   - Mixed-media filters combine multiple layers of different filter media to enhance filtration efficiency.

- By using a variety of media (e.g., sand, anthracite, and garnet), these filters address the limitations of single-media filters.

Here's how mixed-media filters approach the ideal filter performance:

- Particle Size Range: Each media layer has a specific particle size range. Coarser media at the top capture larger particles, while finer media at the bottom handle smaller particles.
- Progressive Filtration: Water flows through the layers sequentially, allowing each layer to ontribute to particle removal.
- Comprehensive Removal: Mixed-media filters can remove a wider range of particle sizes and types, resulting in better overall filtration.
- Longer Filter Runs: The combination of media extends filter life by distributing the load more evenly.
- Reduced Head Loss: With efficient particle capture, head loss accumulation is minimized.
- Improved Filtration Rate: Mixed-media filters achieve higher filtration rates while maintaining quality.

In summary, mixed-media filters optimize the entire depth of the media bed, approaching the ideal granular media filter performance by combining complementary properties of different media types.

Q.3. (a)

(i) Design a tube well for the following data:

Yield required 0.10 m^3/s

Radius of circle of influence = 200 m

Coefficient of permeability = 60 m/day

Drawdown 6 m

Thickness of confined aquifer = 30 m

(ii) Describe briefly the various methods adopted as anti-waterlogging measures.

Sol. **(i)** Data given

$Q = 0.10\ m^3/s$

$R = 200$ m

$K = 60$ m/day

$S_w = 6$ m

$B = 30$ m

Confined aquifer

To find: Diamter of tube well d_w = ?

$$Q = \frac{0.1}{\left(\frac{1}{24\times 60\times 60}\right)} = 8640 m^3/day$$

$$Q = \frac{2\pi T S_w}{\ln\left[\frac{R}{r_w}\right]}$$

$$8640 = \frac{2\times\pi\times 60\times 30\times 6}{\ln\left[\frac{200}{r_w}\right]}$$

$r_w = 0.08$ m

$d_w = 2\ r_w = 16$ cm

(ii) Water-logging Control

It is evident that water-logging can be controlled only if the quantity of water into the soil below is checked and reduced. To achieve this, the inflow of water into the underground reservoir should be reduced and the outflow from this reservoir should be increased, as to keep the highest position of water-table at least about 3m below the ground surface. The various measures adopted for controlling water- logging are enumerated below:

(1) Lining of Canals and Water Courses: Attempts should be made to reduce the seepage of water from the canals and water courses. This can be achieved by lining them. It is a very effective method to control water-logging.

(2) Reducing the Intensity of Irrigation: In areas where there is a possibility of water-logging, intensity of irrigation should be reduced. Only a small portion of irrigable land should receive canal water in one particular season. The remaining areas can receive water in the next season, by rotation.

(3) By Introducing Crop-rotation: Certain crops require more water and others require less water. If a field is always sown with a crop requiring more water, the chances of water-logging are more. In order to avoid this, a high water requiring crop should be followed by one requiring less water, and then by one requiring almost no water. Rice may be followed by wheat, and wheat may be followed by a dry crop such as cotton.

(4) By Optimum Use of Water: It is a known fact that only a certain fixed amount of irrigation water gives best productivity. Less than that and more than that, reduces the yield. But most of our cultivators are unaware of these tech- nicalities, and they feel that by using more water they can increase crop yield. Therefore, they try to use more and more water. This can be checked by educating the cultivators by proper propaganda. Moreover, the revenue should not be charged on the basis of irrigated area but should be charged on the basis of the quantity of water utilised. A strict watch should also be kept at the outlet, in order to stop undue tapping.

(5) By Providing Intercepting Drains: Intercepting drains along the canals should be constructed, wherever necessary. These drains can intercept and prevent the seeping canal water from reaching the area likely to be water-logged.

(6) By Provision of an Efficient Drainage System: An efficient drainage system should be provided in order to drain away the storm water and the excess irrigation water. A good drainage system consists of surface drains as well as sub-surface drains (described in details a little later).

(7) By Improving the Natural Drainage of the Area: To reduce the percola- tion, the water should not be allowed to stand for a longer period. Some relief in this direction can be obtained by removing the obstructions from the path of natural flow. This can be achieved by removing bushes, jungles, forests, etc. and improving the slopes of the natural drainage lines.

(8) By Adopting Consumptive Use of Surface and Subsurface Water: The introduction of lift irrigation to utilize ground water helps in lowering the water table in a canal irrigated area, where water-table tends to go up. Hence, the ground water should also be used in conjunction with canal water for irrigation, as the continuous use of ground water will not allow any appreciable rise in the level of water-table, due to continuous seepage of canal water.

This combined use of subsurface water (ground water) and the surface water (canal water) in a judicious manner, as to derive maximum benefits, called **conjunctive use**, should hence be adopted to control water-logging.

Q.3. (b)

(i) Design an irrigation channel in alluvial soil according to Lacey's silt theory for the following data:
Full supply discharge = 10 m^3/s
Lacey's silt factor = 0.9
Side slopes of channel = ½ (H): 1 (V)

(ii) What is the gravity dam? Enumerate the various forces acting on grvaity dm.

Sol. **(i)** Given Data:

$Q = 10\ m^3/s$

$f = 0.9$

Side slope 0.5 H : 1 V

To find : B, D & S

(a) $f = 1.76\sqrt{d} = 0.9$ (given)

(b) $$v = \left(\frac{Qf^2}{140}\right) = \left(\frac{10\times 0.9^2}{140}\right)^{1/6} = 0.622\ m/s$$

(c) $P = 4.75\sqrt{Q} = 15.02\ m$

(d) $$A = \frac{Q}{V} = \frac{10}{0.622} = 16.08\ m^2$$

(e) $A = (B + 0.5\ D)D$ $\qquad$ [$\because$ 0.5H : 1V] x = 0.5

$16.08 = (B + 0.5D)D\ldots(i)$ $\qquad$ $A = (B + xD)$

$D = B + 2D\ \sqrt{1+0.5^2}$ $\qquad$ $P = B + 2D\ \sqrt{1+x^2}$

$15.02 = B + 2D\ \sqrt{1+0.5^2}$

$15.02 = B + 2.236\ D$

$B = 15.02 - 2.236\ D$ $\qquad$ …(ii)

Substitute in equation (i)

$16.08 = (15.02 - 2.236\ D + 0.5\ D)D$

$16.08 = 15.02\ D - 1.736\ D^2$

$1.736\ D^2 - 15.020\ D + 16.08 = 0$

$$D = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{15.0 \pm \sqrt{(15.02)^2 - (4\times 1.736\times 16.08)}}{2\times 1.736}$$

$D = 7.4\ m \rightarrow B = 15.02 - (2.236 \times 7.4) = -1.526\ m$

$D = 1.25\ m \rightarrow B = 15.02 - (2.236 \times 1.25) = 12.225\ m$

$\therefore\ B = 12.225\ m$ $\qquad$ $D = 1.25\ m$

(f) $$R = \frac{A}{P} = \frac{16.08}{15.02} = 1.07$$

$$V = \sqrt{\frac{2}{5} fR}$$

$$0.622 = \sqrt{\frac{2}{5}\times 0.9\times R}$$

$R = 1.07$

(g) $$S = \frac{f^{5/3}}{3340\ Q^{1/6}} = \frac{0.9^{5/3}}{3340\times 10^{1/6}}$$

$$S = \frac{1}{5844} = \frac{1}{5844}$$

$$S = \frac{1}{5844} = \frac{1}{5850}$$

(ii) Gravity Dams:

(NOTE: Define Gravity dam, list the forces & only in short describe about forces acting on Gravity Dam)

1. Gravity Dam

A gravity dam is a concrete (or) masonry Dam which resist the forces excreted on it by its own weight.

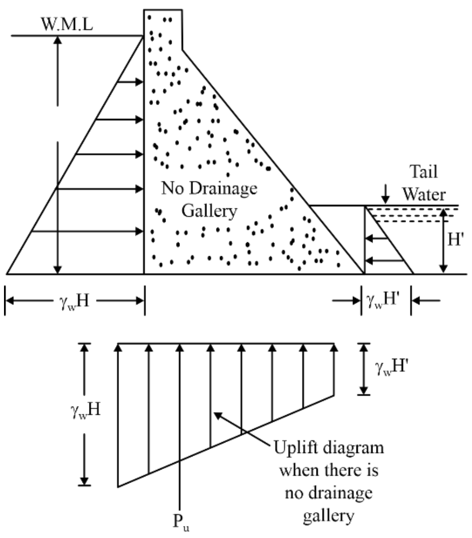
FORCES ON A GRAVITY DAM:

1. Weight of the dam
2. Water pressure
3. Uplift pressure
4. Earthquake Force
5. Silt Pressure
6. Wave Pressure
7. Ice pressure
8. Wind Pressure

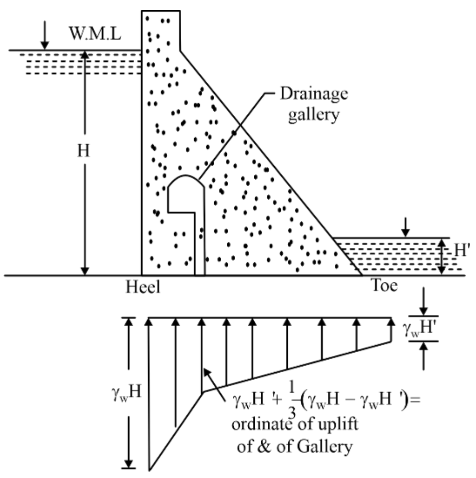
WEIGHT OF THE DAM:

- Weight of the Dam is main stabilizing force, acts along C.G. of the cross-section.
- Weight per unit length of the dam is given by the product of the area of cross section of the dam & the specific weight of the construction material.
- For preliminary designs, the specific weight of concrete can taken as 24 kN/m^3.

UPLIFT PRESSURE:



(a) Uplift Pressure (U) Diagram, when no drainage gallery is provided.

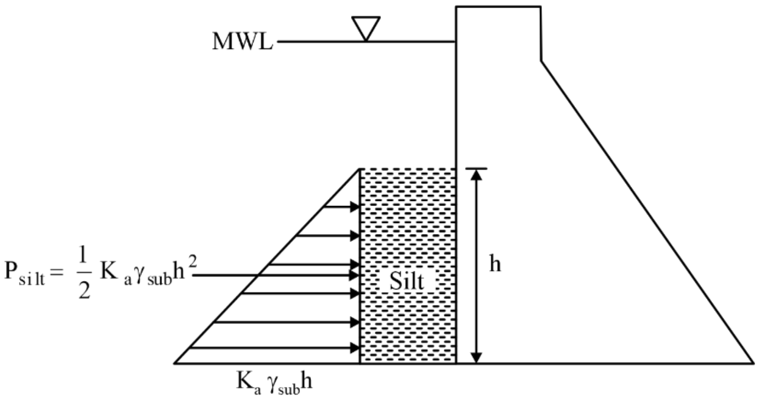


(b) Uplift Pressure (U) Diagram, when drainage gallery is provided.

- Uplift pressure is the force exerted by the water seeping through the pores, cracks & fissures of the foundation material.
- It acts vertically upwards.
- The percentage of area on which the uplift pressure acts is defined as the area factor.

- As per some earlier investigators recommended, for both concrete & rock, a value of area factor ranging from 1/3rd to 2/3rd of the area may be considered as effective area over which the uplift pressure acts.
- According to Terzaghi, Harza & Leliavasky for both concrete & Rock, area factor is nearly equal to unity.

SILT PRESSURE:



$$P_{silt} = \frac{1}{2} K_a \gamma_{sub} h^2$$

Where,

$$K_a = \frac{1-\sin\phi}{1+\sin\phi}$$, Coefficient of active earth pressure

ϕ = angle of internal friction of soil.

γ_{sub} = submerged unit weight of silt material.

h = height of silt deposited.

- For horizontal component silt & water is assumed to have a specific weight of $1360 kg/m^3$
- For vertical component silt & water is assumed to have a specific weight of $1925 kg/m^3$.

WAVE PRESSURE:

- Waves are generated on surface of reservoir by wind blowing over surface of reservoir which causes a pressure towards downstream side.
- Wave pressure depends on wave height. Wave height may be given as per (IS 6512-1972 Moliter's Formula)

Case-1 for F < 32km

$$h_w = 0.032\sqrt{VF} + 0.763 - 0.271(F)^{1/4}$$

Case-II for F > 32km

$$h_w = 0.032\sqrt{VF}$$

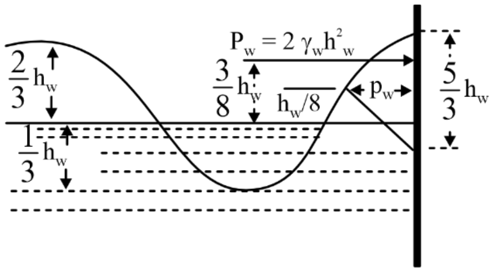
Where

h_w = height of wave (meters).

v = wind velocity (km/hr).

F = Fetch length of water (km).

WAVE PRESSURE:



Max Pressure Intensity

$$p_w = 2.4\gamma_w h_w \rightarrow @h_w/8$$

Total wave force

$$P_w = \frac{1}{2}(2.4\gamma_w h_w) \times \frac{5}{3}h_w$$

$$P_w = 2\gamma_w h_w^2 \rightarrow @3/8\ h_w$$

ICE PRESSURE & WIND PRESSURE:

Ice Pressure: In cold areas, Dam face has to resist an extra pressure due to expansion of ice. Generally, a value of 500 kN/m^2 (250 kN/m^2 — 1500 kN/m^2)is applied to the face of Dam over anticipated area of contact of ice with Dam face.

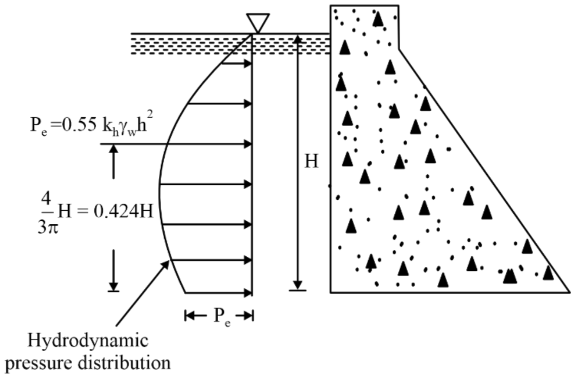
Wind Pressure: Wind pressure can be taken as 1 — 1.5 kN/m^2 over the exposed area to the wind.

EARTHQUAKE FORCE:

- For design purpose acceleration can be resolved into 2 components i.e., Horizontal acceleration (α_h) & vertical acceleration (α_v)
- Values of α_h & α_v are expressed in terms of % age of acceleration due to gravity.
- α = 0.1g -0.2g.
- On an average, a value of a equal to 0.1 to 0.15g is generally sufficient for high dams in seismic zones.
- Bhakra dam → 0.15g.
- Ramganga dam → 0.2g.
- Areas not subjected to extreme earthquakes, α_h = 0.1g & α_v = 0.05g.

1. A vertical acceleration may either act downward or upward.
2. When it is acting in the upward direction, then foundation of the dam will be lifted upward & becomes closer to the body of the dam, & thus the effective weight of the dam will increase & hence, the stress developed will increase.
3. When it is acting in the downward direction, the foundation shall try to move downward away from the body of the dam, thus reducing the effective weight, & the stability of the dam, & hence is the worst case for designs.

Hydrodynamic Force :



1. If is acting upstream, then an extra pressure force is exerted by water on the Dam which is called a "Hydrodynamic Force".
2. According to Von-Karman;
   $Pe = 0.555\ k_h\ \gamma_h\ H^2$

Q.3. (c)

(i) A settling column analysis is run to determine the settling characteristics of sludge from an activated sludge reactor with the following results:

Concentration of MLSS (mg/L):	1000	2000	3000	4000	5000	6000
Settling velocity (m/hr):	2.8	1.4	0.4	0.2	0.1	0.06

The flow to the secondary clarifier is 4200 m^3/day with MLSS concentration of 2000 mg/L. Determine the required diameter of the clarifier for a preselected solid flux rate of 2.5 kg/m^2.hr. check the area requirement for the clarification function also.

(ii) Why do the conventional channel type horizontal flow grit chambers require the velocity control devices? What are the common velocity control devices that are used? What advantages the aerated grit chamber has over the conventional grit chamber?

Sol. **(i)** Surface area based on overflow rate criteria $(SA)_1 = \dfrac{Q_0}{\text{Over flow rate}}$

$$= \frac{4200/24}{1.4} = 125 m^2$$

Note: Consider Over flow rate equal to settling velocity.

So, Overflow rate at MLSS = 2000 mg/l is equal to 1.4 m/hr

Surface area based on solid flux rate $= \dfrac{Q_0 x}{\text{Solid flux rate}}$

$$= \frac{(4.2)\times 2000}{2.5\times 24}$$

$(SA)_2 = 140\ m^2$

Surface area adopted should be maximum of the surface area from solid loading rate and overflow rate.

Hence, $(SA)_{Final} = 140\ m^2$

$\Rightarrow \frac{\pi}{4}(d)^2 = 140$

$\Rightarrow \boxed{d = 13.351 \text{meter}}$

(ii) Conventional channel-type horizontal flow grit chambers utilize velocity control devices to maintain a consistent upstream velocity of approximately 0.3 m/s during grit removal. These devices help optimize the removal process and prevent unnecessary wear and accumulation.

Common velocity control devices include Proportional weirs and rectangular control sections, such as Parshall flumes.

On the other hand, aerated grit chambers offer several advantages over conventional ones:

1. **Consistent Removal Efficiency:** Aerated grit chambers maintain reliable removal efficiency across a wide flow range.

2. **Organic Content Removal:** They can effectively remove a relatively low putrescible organic content by controlling aeration rates.

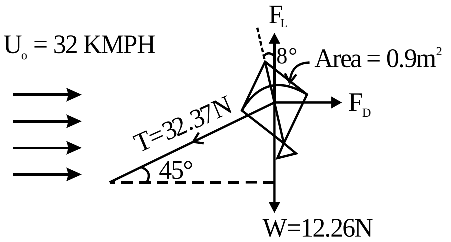
3. **Improved Downstream Performance:** Pre-aeration in aerated grit chambers can enhance downstream unit performance by reducing septic conditions in incoming wastewater.

Q.4. (a)

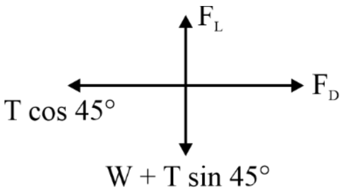
(i) A kite weighing 12.26 N has an effective area of 0.9 m^2. The tension in the kite string is 32.37 N when the string makes an angle of 45° with the horizontal. For a wind of 32 km/hr, what are the coefficients of lift and drag if the kite assumes an angle of 8º with the horizontal? Take specific weight of air as 11.801 N/m^3.

(ii) A 1.25 m diameter pipe has to be provided to convey oil of specific gravity 0.85 and kinematic viscosity of 2.75 centistokes at a velocity of 1.25 m/s. In order to model the flow, if a 120 mm diameter pipe is used to convey water of kinematic viscosity 1.0 centistokes, what should be the velocity and the discharge in the model?

Sol. **(i)**



(1) F.B.D. of Forces on kite



(2) $F_D = T \cos 45°$

$= 32.37 \times \frac{1}{\sqrt{2}} = 22.89$ N

$F_D = C_D \frac{\rho A V^2}{2}, V = \frac{32}{3.6} m/s = 8.89 \ m/s$

$$22.89 = \frac{C_D}{2} \times \left(\frac{11.801}{9.81}\right) \times 0.9 \times 8.89^2$$

$\boxed{C_D = 0.535}$ → Drag Coefficient

(3) $F_L = C_L \dfrac{\rho A V^2}{2}$

$$F_L = (W + T\sin 45°) = 12.26 + 32.37 \times \frac{1}{\sqrt{2}} = 35.15 \text{ N}$$

$$\text{Now, } 35.15 = \frac{C_L}{2}\left(\frac{11.801}{9.81}\right) \times 0.9 \times 8.89^2$$

$\boxed{C_L = 0.822}$ → Lift Coefficient

(ii) Given data: In prototype:

Diameter of pipe (D_p) = 1.25 m

ρ_{oil} = 0.85 × 1000 = 850 kg/m^3

Kinematic viscosity (ν_p) = 2.75 centistokes = 2.75 × 10^{-6} m^2/s

Velocity (V_p) = 1.25 m/s

In model:

Diameter of pipe (D_m) = 120 mm = 0.12 m

Kinematic viscosity (ν_m) = 1 centistoke = 10^{-6} m^2/s

To find: Velocity and discharge in model = ?

$$\text{Length scale ratio } (L_r) = \frac{D_m}{D_p} = \frac{0.12\text{m}}{1.25\text{m}} = \frac{1}{10.416}$$

$$\text{Discharge in prototype} = \frac{\pi}{4}(D_P)^2 \times (V_P)$$

$$Q_P = \frac{\pi}{4} \times (1.25)^2 \times (1.25)$$

$$Q_P = 1.533\text{m}^3/\text{s}$$

$$\nu_r = \frac{\nu_m}{\nu_p} = \frac{10^{-6}}{2.75 \times 10^{-6}}$$

$$\nu_r = \frac{1}{2.75}$$

Now:

From Reynold's model law:

$$(R_e)_m = (R_e)_p$$

$$\left(\frac{VD}{\nu}\right)_m = \left(\frac{VD}{\nu}\right)_p$$

$$V_m = \left(\frac{\nu_m}{\nu_P}\right) \times \left(\frac{D_p}{D_m}\right) \times V_P$$

$$V_m = \nu_r \times \frac{1}{L_r} \times V_p$$

$$V_m = \frac{1}{2.75} \times 10.416 \times 1.25$$

Velocity in model = V_m = 4.73 m/s

Now:

Discharge scale ratio:

$$Q_r = A_r . V_r$$

$$Q_r = L_r^2 \times \frac{\nu_r}{L_r}$$

$Q_r = L_r \times \nu_r$

$$\frac{Q_m}{Q_p} = \frac{1}{10.416} \times \frac{1}{2.75}$$

$$Q_m = \frac{1}{10.416 \times 2.75} \times 1.533$$

$Q_m = 5.35 \times 10^{-2}$ m^3/s

Q.4. (b) A city of 1 million population generates 0.45 kg per capita per day of MSW. Collection trucks of capacity 4.5 metric tonnes averaging two trips per day at 75% capacity operate all the days in a week to transfer the waste to centralised processing and landfill site. How many trucks per day will be required to transfer the waste? If about 45% waste is recycled, what is the mass of MSW entering the landfill? If the density of the waste is 280 kg/m^3, what is the volume of MSW? Determine the area required for the landfill with the projected life of 30 years, if the density of the compacted waste is 450 kg/m^3 and the maximum height of the landfill is limited to 15 m. Neglect the volume of cover.

Sol. Mass of MSW collected per day = 0.45×10^6 kg

Amount of MSW transported by a single truck per day = 4.5 × 1000 × 0.75 × 2

$$\text{Number of truck require per day } = \frac{0.45 \times 10^6}{6750} = 66.67 \approx 67 \text{track}$$

Considering 45% of waste is reduced

then,

Mass of MSW entering land fill per day = $(1 - 0.45) \times 0.45 \times 10^6$

= 247.5×10^3 kg/day

As given,

Density of waste = 280 kg/m^3

$$\text{Volume of uncompacted MSW } = \frac{247.5 \times 10^3}{280}$$

$V_{uncompacted} = 883.928$ m^3/day

Mass of waste collected in 30 year = $(0.45 \times 10^6 \times 30 \times 365)$kg

$$\text{Volume of compacted waste } = \frac{\text{Mass of MSW put into land fill}}{\text{Compacted waste density}}$$

$$= \frac{0.45 \times 10^6 \times 30 \times 365 \times (1 - 0.45)}{450} = 6022500 \text{m}^3$$

Neglect the volume of cover

$$\text{(SA) of landfill } = \frac{\text{Volume of compacted waste}}{\text{Height of landfill}}$$

$$\text{SA of landfill } = \frac{6022500}{15} = 401.5 \times 10^3 \text{m}^2$$

Q.4. (c)

(i) Explain the following characteristic terms for biological organisms based on their carbon and energy sources:

(I) Phototrophs (II) Chemotrophs
(III) Autotrophs (IV) Heterotrophs

Arrange the following organisms according to their trophic levels giving your reasoning:

(A) Chemoheterotrophs (B) Photoheterotrophs
(C) Photoautotrophs (D) Chemoautotrophs

(ii) The ambient air concentration of carbon monoxide was reported as 4 mg/m^3 at the temperature of 25 °C and pressure of 103.193 kPa. What will be the concentration in ppm at STP?

Sol. (i)

i. Phototrophs:
- Carbon Source: Phototrophs obtain their carbon from CO_2 (carbon dioxide).
- Energy Source: They derive their energy from sunlight (photons).
- Examples: Plants, algae, and some bacteria are examples of phototrophs. They use photosynthesis to convert light energy into chemical energy in the form of glucose.

ii. Chemotrophs:
- **Carbon Source:** Chemotrophs acquire their carbon from organic molecules (chemoorganotrophs) or CO_2 (chemolithotrophs).
- **Energy Source:** They obtain energy from the oxidation of chemical compounds.
- **Examples:** Chemotrophs include many bacteria and archaea. Chemoorganotrophs derive energy from breaking down organic molecules (e.g., sugars, fats), while chemolithotrophs oxidize inorganic substances (e.g., hydrogen gas, ammonia, sulfur).

iii. Autotrophs:
- **Carbon Source:** Autotrophs assimilate carbon directly from CO_2, thus they are self-sustaining in terms of carbon.
- **Energy Source:** They can be either phototrophs (using light energy) or chemotrophs (using chemical energy) as described above.
- **Examples:** Plants, algae, and some bacteria are autotrophs. They can manufacture their own organic molecules from simple inorganic compounds.

iv. Heterotrophs:
- **Carbon Source:** Heterotrophs obtain their carbon from organic molecules that are synthesized by other organisms.
- **Energy Source:** They acquire energy by breaking down organic molecules through processes like respiration or fermentation.
- **Examples:** Animals, fungi, and many bacteria are heterotrophs. They rely on consuming or absorbing preformed organic compounds to meet their carbon and energy needs.

These characteristics help categorize organisms based on how they obtain carbon (autotrophs vs. heterotrophs) and how they obtain energy (phototrophs vs. chemotrophs).

Organisms can be categorized into trophic levels based on their energy and carbon sources. Here's the arrangement of the given organisms:

i. Chemoautotrophs:

- Chemoautotrophs derive both their energy and carbon from inorganic substances through chemosynthesis. They are typically found in environments such as deep-sea hydrothermal vents or certain soil bacteria.
- **Examples:** Certain bacteria like Nitrosomonas, which oxidizes ammonia to nitrite.

ii. Photoautotrophs:

- Photoautotrophs use light as an energy source to synthesize organic compounds from $C0_2$. They are primary producers at the base of many food chains and are essential for supporting life through photosynthesis.
- **Examples:** Plants, algae, and some bacteria like cyanobacteria.

iii. Chemoheterotrophs:

- Chemoheterotrophs obtain both energy and carbon from organic compounds. They rely on consuming organic molecules produced by other organisms.
- **Examples:** Most animals, fungi, and many bacteria are chemoheterotrophs. They play roles as consumers and decomposers in ecosystems.

iv. Photoheterotrophs:

- Photoheterotrophs use light as an energy source but rely on organic compounds as their carbon source rather than fixing CO_2.
- **Examples:** Certain bacteria such as purple non-sulfur bacteria (e.g., Rhodospirillum), which can perform photosynthesis but also require organic carbon for growth.

Reasoning for the Arrangement:

- Chemoautotrophs are placed highest as they are primary producers that synthesize organic compounds from inorganic substances, often found in environments devoid of light.
- Photoautotrophs follow, utilizing light energy to produce organic compounds and forming the foundation of many ecosystems.
- Chemoheterotrophs come next, as consumers and decomposers that rely on consuming organic matter produced by autotrophs or other organisms.
- Photoheterotrophs are placed last, as they utilize light energy but still require organic compounds for their carbon needs, making them less common and specialized compared to the other groups.

This arrangement reflects their roles in energy and nutrient flow within ecosystems, with autotrophs supporting higher trophic levels through the production of organic matter, and heterotrophs consuming and recycling this organic matter.

(ii) As given:

1 m^3 of air contains 4 mg of CO

So, 10^6 m^3 of air will have 4000 gm of CO

At given Ambient condition

$P_{ambient} = 103.193$ Kpa $= 1.018435$ atm

$T_{ambient} = 298.15$ K

Using ideal gas equation

$PV = nRT$

$$V_{ambient} = \frac{nRT_{ambient}}{P_{ambient}}$$

$$V_{ambient} = \frac{\frac{4000}{28.01} \times 0.082 \times 298.15}{1.018435}$$

$$\boxed{V_{ambient} = 3.428\ m^3} \quad [\because\ 1000 \text{ litre} = 1\ m^3]$$

Now, again using Ideal gas equation to find V_{STP} for above condition. Considering value of R and n (no of mole) to be same.

$$\frac{P_{ambient} V_{ambient}}{T_{ambient}} = \frac{P_{STP} V_{STP}}{T_{STP}}$$

$$V_{STP} = \frac{P_{ambient} \times V_{ambient} \times T_{STP}}{P_{STP} \times T_{ambient}}$$

$$V_{STP} = \frac{103.193 \times 3.428 \times 273.15}{298.15 \times 101.325}$$

$$\boxed{V_{STP} = 3.198\ m^3}$$

Therefore, at STP $10^6\ m^3$ of air will have $3.198\ m^3$ of [CO]

Hence, at STP, concentration of carbon monoxide will be 3.198 ppm.

Q.5. (a) A field vane 25 er test was carried out on a deep-seated soft clay layer. The vane was 11.25 cm high and 7.5 cm across the blades. The equivalent torque recorded at the torque head at failure was 800 kg/cm. The vane was then rotated very rapidly in order to completely remould the soil. It was found that the remoulded soil can be sheared by applying a torque of 400 kg-cm. Compute the shear strength of the soil in the undisturbed and remoulded states and its sensitivity.

Sol. H = 11.25 cm

d = 7.5 cm

T_1 = 800 kg – cm

T_2 = 400 kg – cm (Remoulded soil)

Shear strength in undisturbed soil

$$= S_1 = \frac{T_1}{\pi d^2 \left(\frac{H}{2} + \frac{d}{6}\right)}$$

$$= \frac{800}{\pi (7.5)^2 \left[\frac{11.25}{2} + \frac{7.5}{6}\right]}$$

$= 0.658\ kg/cm^2$

Shear strength in remoulded soil

$$S_2 = \frac{T_2}{\pi d^2 \left(\frac{H}{2} + \frac{d}{6}\right)}$$

$$= \frac{400}{\pi (7.5)^2 \left[\frac{11.25}{2} + \frac{7.5}{6}\right]}$$

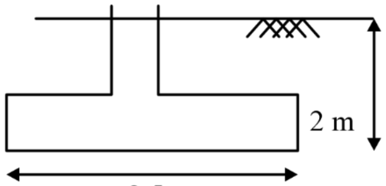
$= 0.329\ kg/cm^2$

$$\text{Senstivity} = \frac{\text{Shear strength in undistrubed}}{\text{Shear strength in remoulded}} = \frac{0.658}{0.329} = 2$$

Q.5. (b) A 2.5 m wide strip footing is founded at a depth of 2.0 m below the ground level in a homogeneous pure clay bed. The unit cohesion of clay is 35 kPa. Due to seasonal fluctuations of water table from peak summer (fully dry soil) to peak monsoon (fully saturated soil), compute the change in the net ultimate bearing capacity as per Terzaghi's theory.

Sol. B = 2.5 m

C = 35 kPa



Net ultimate bearing capacity in peak summer

$q_{nu} = CN_C + q(Nq-1) + (0.5)\, B \times \gamma\, N_\gamma$

For pure clay

$N_C = 5.7$

$N_q = 1$

$N_\gamma = 0$

$= 35 \times 7.3 + 0 + 0$

$= 199.5$ kPa

Net ultimate bearing capacity in monsoon

$q_{nu} = CN_C + q(Nq - 1) + 0.5\, B\gamma N_\gamma$

For clay

$N_C = 5.7$

$N_q = 1$

$N_\gamma = 0$

$q_{nu} = 35 \times 5 = 7 = 199.5$ kPa

The change in net ultimate bearing capacity = 0

Q.5. (c) Design the thickness of a flexible pavement for the design life of 15 years having two-lane single carriageway 7-0 m wide and present traffic of 800 commercial vehicles per day (CVPD). Out of total 800 CVPD, 300 have vehicle damage factor (VDF) of 2.5 and 500 have VDF of 3.0. The planning and construction period is 2 years and annual vehicle growth rate is 7.5%. Design the flexible pavement from the data given below if the effective CBR of the subgrade is 9%. Assume any missing data suitably:

Design traffic	Wearing course (mm)	Binder cousre (mm)	Base (mm)	Sub-base (mm)
5 msa	25 SDBC	50 DBM	250	150
10 msa	40 BC	50 DBM	250	200
20 msa	40 BC	80 DBM	250	200
30 msa	40 BC	95 DBM	250	200

Sol. Design life = n = 15 years

For 300 cvpd, Vehicle damage factor = 2.5

$P_1 = 300, F_1 = 2.5$

For 500 cvpd, Vehicle damage factor = 3

$P_2 = 500, F_2 = 3$

Two lane single carriageway

Lane distribution factor = D = 0.5

Annual rate of growth r = 7.5%

Construction period = x = 2 years

Initial traffic $A_1 = P_1 (1 + r)^x = 300 (1.075)^2 = 346.6875$

$A_2 = P_2 (1 + r)^x = 500 (1.075)^2 = 577.8125$

Design traffic

$$N_{des} = 365\left[\frac{(1+r)^n - 1}{r}\right]D(A_1F_1 + A_2F_2)$$

$$N_{des} = 365\left(\frac{(1.075)^{15} - 1}{0.075}\right)\times\frac{0.5}{10^6}(346.6875\times 2.5 + 57.8125\times 3)$$

$$= \frac{365\times 26.1184\times 0.5\times 2600.15625}{10^6}$$

= 12.4 msa

From the data given

Wearing course = 40 BC (mm)

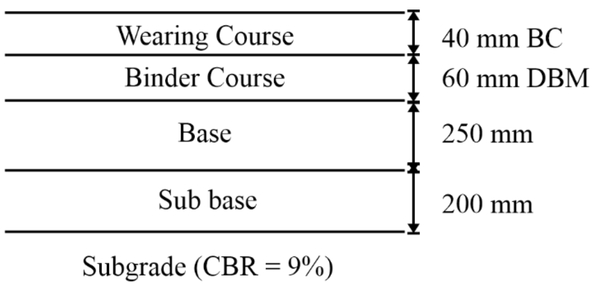
Base = 250 mm

Sub-base = 200 mm

Binder course thickness (DBM)

$$= 50 + \frac{(80-50)}{(20-10)}(12.4-10)$$

= 57.2 mm ≈ 60 mm



Q.5. (d) Calculate the speed restriction for a 2° curve on a broad-gauge section with maximum permissible speed of 100 km/hr. Due to space restrictions, the length of the transition curve is limited to 50 m and superelevation provided is 60 mm.

Sol. Degree of curve = 2°

Radius of curve = $\frac{1750}{2} = 875$

For maximum permissible speed of 100 km/hr and Broad gauge.

Cant deficiency = 75 mm = C_d

Cant provided = 60 mm = C_a
(Actual cant)
Allowable speed [as per Indian Railway Board]

$$V_m = 0.27\sqrt{R(C_d + C_a)}$$

$$= 0.27\sqrt{875(75+60)} = 92.79\,\text{kmph}$$

Alternatively
Cant (theoretical) – Cant provided = Cant deficiency

$$\Rightarrow \frac{GV_m^2}{127R} - 60 = 75$$

$$\Rightarrow \frac{1750 \times V_m^2}{127 \times 875} = 135$$

= V_m = 92.6 kmph.
Desirable length of transition curve
= 0.008 × C_d × V_m
= 0.008 × 75 × 92.6
= 55.56 m
Since Length of transition curve = 50 m (provided)
Speed is reduced.
50 = 0.008 × 75 × V_m
⇒ V_m = 83.3 kmph.

Q.5. (e) The following staff readings were taken with a level:
1.255, 1.950, 2.450, 3.100, 3.900, 1.215, 1.795, 2.800, 3.500, 0.560, 1.210, 1.900, 2.955
The level was shifted after the 5th and 9th reading, and the 7th reading was taken to a benchmark of RL 120.00 m. Arrange the date in tabular form and find the reduced level of all the points by rise and all method. Also apply the usual checks for calculations.

Sol.

Stn	B.S	I.S	F.S	Rise	Fall	R.L	Remarks
A	1.255	-	-	-	-	123.225	1st Point
B	-	1.950	-	-	0.695	122.530	
C	-	2.450	-	-	0.500	122.030	
D	-	3.100	-	-	0.650	121.380	
E	1.215	-	3.900	-	0.800	120.580	CP
F	-	1.795	-	-	0.580	120.000	RL
G	-	2.800	-	-	1.005	118.995	
H	0.560	-	3.500	-	0.700	118.295	CP
I	-	1.210	-	-	0.65	117.645	
J	-	1.900	-	-	0.69	116.955	
K	-	-	2.955	-	1.06	115.900	Last Point
sum	3.030	-	10.355	-	7.325	-	-

Arithmetic check
ΣB.S – ΣF.S = ΣRise – ΣFall = R.L of Last point – R.L of 1st point
3.030 – 10.355 = 0 – 7.325 = 115.900 – 123.225

$-7.325 = -7.325 = -7.325$
Check is O.K

Q.6. (a)

(i) Two straights AB and BC are to be connected by a 2° simple circular curve. Two points P and Q are selected on AB and BC respectively and the following observations are done in the field:

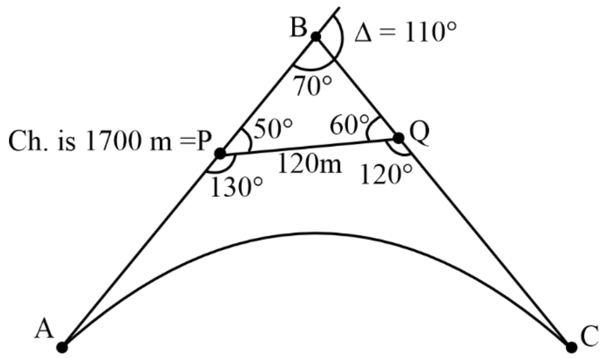
$\angle APQ = 130°$ Length PQ = 120 m

$\angle CPQ = 120°$ Chainage of point P = 1700 m

Calculate the chainages of intersection and all other important points in the curve. Assume the standard chord length of 20 m.

(ii) Explain the various sources of errors and their corrections in positioning with Global Positioning System (GPS).

Ans. **(i)**



In Δ PBQ,

$$\frac{PQ}{\sin 70°} = \frac{PB}{\sin 60°}$$

$$PB = \frac{120}{\sin 70°} \times \sin 60° = 110.593\text{m}$$

ch. of B = ch. of P + PB = 1700 + 110.593 m

ch. of B = 1810.593 m

∵ Chord length = 20 m & it is a 2° curve

∴ Degree of curve $(D) = \frac{1146}{R}$

$$R = \frac{1146}{2} = 573\text{m}$$

∴ Tangent length, $T = R \tan \Delta/2 = 573 \tan \frac{110°}{2}$

T = 818.329 m

∴ Length of curve, $l = \frac{\pi R \Delta}{180} = \frac{\pi \times 573 \times 110}{180}$

$l = 1100.081$ m

∴ ch. of A = ch. of B – T = 1810.593 – 818.329
= 992.264 m

∴ Ch. of C = Ch . of A + l = 992.264 + 1100.081
= 2092.345 m

(ii) Positioning with the Global Positioning System (GPS) can be affected by several sources of errors, each with its own methods of correction. Here are the main sources of errors and their respective corrections:

1. Satellite Clock Errors

Description: Inaccuracies in the satellite's onboard clock can lead to timing errors, affecting the calculation of distance from the satellite to the receiver.

Corrections :

- Satellite Clock Corrections : GPS satellites periodically transmit clock correction data to receivers, which account for the clock drift.
- Control Segment Updates : The GPS control segment continuously monitors satellite clocks and updates their statuses and corrections to the satellites.

2. Ephemeris Errors

Description : Errors in the satellite's reported position can lead to inaccuracies in positioning.

Corrections :

- Broadcast Ephemeris Data : The control segment updates and transmits ephemeris data regularly to improve satellite position accuracy.
- Precise Ephemeris Data : For higher precision, users can access precise ephemeris data, often used in post-processing for survey-grade applications.

3. Ionospheric Delays

Description : The ionosphere, a layer of the Earth's atmosphere, can cause delays in the GPS signal as it passes through, especially during periods of high solar activity.

Corrections :

- Ionospheric Models : GPS receivers use models to estimate and correct for ionospheric delays based on broadcast data.
- Dual-Frequency Receivers : Receivers that use two different frequencies (L1 and L2) can directly measure and correct for ionospheric delays by comparing the two signals.

4. Tropospheric Delays

Description : The troposphere, the lower part of the Earth's atmosphere, can cause signal delays due to weather conditions such as temperature, pressure, and humidity.

Corrections :

- Tropospheric Models : GPS receivers apply models to estimate and correct for these delays based on local meteorological data.
- Differential GPS (DGPS) : Ground-based reference stations provide real-time corrections for tropospheric delays.

5. Multi-path Effects

Description : Reflections of GPS signals off surfaces such as buildings, water, or terrain can cause the receiver to receive multiple signals, leading to positioning errors.

Corrections :

- Antenna Design : High-quality GPS antennas are designed to minimize multipath effects.
- Signal Processing Algorithms : Advanced algorithms in the receiver can help distinguish between direct and reflected signals.
- Site Selection : Choosing locations with minimal reflective surfaces for GPS equipment installation can reduce multi-path errors.

6. Receiver Noise

Description : Internal noise within the GPS receiver can introduce errors in signal processing.

Corrections :

- High-Quality Receivers : Using receivers with better components and noise filtering can reduce the impact of receiver noise.

Averaging Techniques : Averaging multiple position fixes over time can mitigate random noise effects.

7. Selective Availability (SA)

Description : Previously, the intentional degradation of GPS signals by the U.S. Department of Defence to limit the accuracy for civilian users.

Corrections :

- Discontinued : Selective Availability was turned off in May 2000, significantly improving civilian GPS accuracy.

8. Geometric Dilution of Precision (GDOP)

Description : The relative position of GPS satellites can affect the accuracy of position calculations. Poor satellite geometry (high GDOP) can lead to larger errors.

Corrections :

- Satellite Selection : Modern receivers can select the best combination of satellites to minimize GDOP.
- Planning Tools : Users can use planning tools to determine optimal times for GPS data collection when satellite geometry is favorable.

9. Human Errors

Description : Errors due to incorrect settings, poor maintenance, or improper use of GPS equipment.

Corrections :

- Training and Best Practices : Proper training for users and adherence to best practices can minimize human errors.
- Regular Calibration and Maintenance : Ensuring that GPS equipment is regularly calibrated and maintained.

10. Differential GPS (DGPS) and Real-Time Kinematic (RTK)

Description : Techniques to enhance GPS accuracy by using additional reference stations.

Corrections :

- DGPS : Uses ground-based reference stations to broadcast correction signals to nearby GPS receivers, significantly improving accuracy.
- RTK : Provides real-time corrections based on phase measurements of the carrier signal, achieving centimeter-level accuracy for applications like surveying and precision agriculture.

By understanding and applying these corrections, users can greatly enhance the accuracy and reliability of GPS positioning.

Q.6. (b)

(i) A greenfield airport is proposed at an elevation of 250 m above mean sea level (m.s.l.). The monthly average of the maximum daily temperature at the proposed site is 45 °C during the hottest month of the year. During the same month, the average daily temperature is 35 °C. The maximum difference in elevation is 6.0 m along the proposed runway of basic length 2000 m. Calculate the actual length of runway to be provided.

(ii) What are the various considerations in the selection of the site for a harbour?

Sol. (i) Basic runway length = 2000 m

Elevation = 250 m

Elevation correction % $= \left(\frac{7}{300} \times 250\right) = 5.83\%$

[7% increase for 300 m rise in elevation]

Airport reference temperature = $T_a = 35 + \frac{45-35}{3} = 38.33°C$

45°C = Average maximum daily temperature

35°C = Average daily temperature

Standard temperature = $T_s = (15 - 0.0065 \times 250)°C = 13.375°C$

[decrease of 6.5°C per km]

Rise of temperature = $T_a - T_s = 24.96°C$

Temperature correction = 24.96%

Combined elevation and temperature correction

$$= \frac{(1.2496 \times 1.0583) - 1}{1} \times 100 = 32.25\%$$

32.25% < 35% O.K.

Gradient correction $= \frac{\text{Maximum elevation difference}}{L} \times 100$

$$= \frac{6}{2000} \times 100 = 0.3\%$$

Gradient correction = 0.3 × 20 = 6%

[20% increase per 1% gradient]

Actual corrected length of runway

= 2000 (1.2496 × 1.0583 × 1.06)

= 2803.7 m ≈ 2804 m

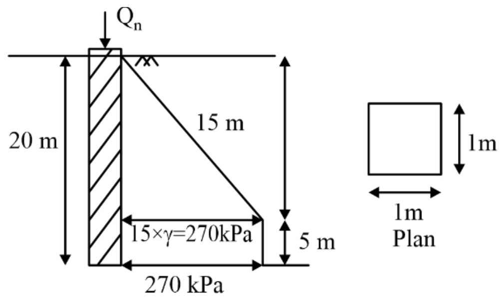
(ii) SITE SELECTION:

Following factors play a great role in the choice of site of a harbour.

1. Availability of cheap land & construction material.
2. Natural protection from waves & winds
3. Transport & communication facilities
4. Industrial development of the locality
5. Sea bed, sub soil & foundation conditions
6. Avaibility of electrical energy
7. Defence & strategic aspects
8. Trafic potentiality of harbour

Q.6. (c) A concrete driven pile of 20 m length and 1 m × 1 m in cross-section is fully embedded in sand having unit weight, γ = 18 kN/m^3 and ϕ' = 30°. Estimate the ultimate load Q_u which the pile can take and mention the contributions from point load (tip load Q_p using Meyerhof's method) and frictional resistance Q_s. Consider N_q = 55 (for ϕ' = 30°), δ' = 0.8ϕ', K = 1.8 (1–sin ϕ), L_{cr} = 15D.

Sol.



$\gamma = 18\ kNm^3$, $\phi' = 30°$

$N_q = 55$, $S = 0.8\ \phi' = 24°$, $K = 1.8(1 - \sin\phi') = 0.9$

$L_{cr} = 15\ D = 15 \times 1 = 15$

$Q_u = Q_P + Q_S$

$Q_P = \bar{\sigma} N_q A_b$

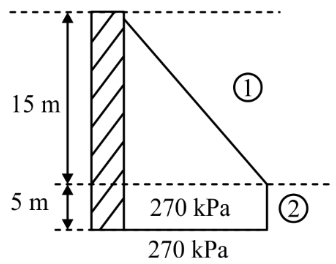
$\bar{\sigma} \rightarrow$ Effective stress at the tip of pile

$\bar{\sigma} = 270$ kPa, $A_b = 1 \times 1 = 1\ m^2$

$Q_P = 270 \times 55 \times 1 = 14850$ kN

$Q_s = f_s \times A_s$

$f_s = K\bar{\sigma}_{avg} \tan\delta$



$Q_s = f_{s1} A_{s1} + f_{s2} A_{s2}$

$$Q_s = 0.9 \tan 24° \times \frac{270}{2} \times 4 \times 15 + 0.9 \tan 24° \times 270 \times 4 \times 5$$

$= 5709.53$ kN

$Q_u = Q_p + Q_s = 20259.53$ kN

Q.7. (a) An infinite soil slope is having a slope angle as 25°. The soil properties are c' = 26 kN/m^2, 20°, e = 0.71 and G = 2-65. Given $Y_\omega = 10$ kN/m^3. Find out the critical height of the slope considering stability number which represents cohesion and $F_\phi = 1.0$, for cases (i) soil slope is dry and (ii) soil slope is submerged.

Sol. Slope angle (i) = 25°

$C' = 26\ kN/m^2$. $\phi' = 20°$, $e = 0.71$, $G = 2.65$, $F_\phi = 1$

$\gamma_w = 10\ kN/m^2$, $\tan\phi_m = \dfrac{\tan\phi}{F\phi} \Rightarrow \phi_m = \phi$

(i) Soil slope is dry

$S_n = \cos^2 i\ (\tan i - \tan\phi_m)$

$= \cos^2 25\ (\tan 25 - \tan 20°)$

$= 0.084$

$$S_n = \frac{C}{\gamma_d H_c}$$

$$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65 \times 10}{1+0.71} = 15.497\ kN/m^3$$

$$H_C = \frac{C}{S_n \gamma_d}$$

$$= \frac{26}{0.084 \times 15.497}$$

$[H_C = 19.97 \text{ m}]$

(ii) Soil slope is submerged

(Here, C & ϕ will remain same)

$S_n = 0.084$, and $\gamma = \gamma'$

$$H_C = \frac{C}{\gamma' S_n}$$

$$\gamma' = \frac{(G-1)}{1+e}\gamma_w$$

$$= \left(\frac{2.65-1}{1+0.71}\right) \times 10$$

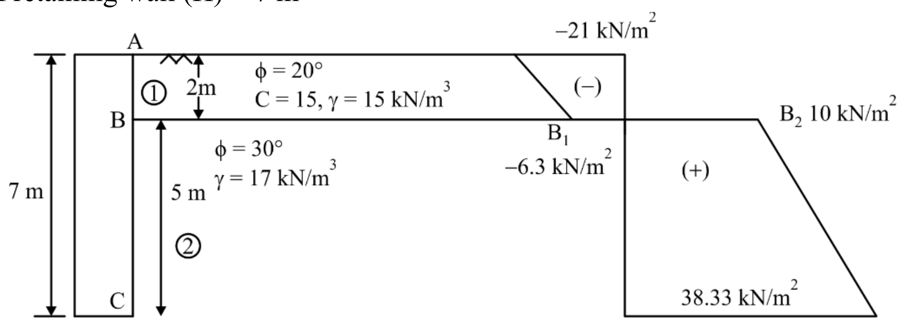
$\gamma' = 9.65 \text{ kN/m}^3$

$$H_C = \frac{26}{9.65 \times 0.084 \times 1}$$

$H_C = 32.07 \text{ m}$

Q.7. (b) A smooth rigid vertical retaining wall of height 7.0 m supports two layers of horizontal backfill. Top layer 1 is of 2.0 m depth having $\phi = 20°$, $c = 15 \text{ kN/m}^2$ and $\gamma = 15 \text{ kN/m}^3$. Bottom layer 2 is pure sand with $\phi = 30°$ and $\gamma = 17 \text{ kN/m}^3$. Mention the practical depth of tensile crack. Also draw active earth pressure diagram and compute the total active thrust on the wall. Assume that the entire soil layers are dry.

Sol. Ht. of retaining wall (H) = 7 m



$$(Ka)_1 = \frac{1-\sin 20°}{1+\sin 20°} = 0.49$$

$$(Ka)_2 = \frac{1-\sin 20°}{1+\sin 20°} = \frac{1}{3}$$

1) Depth of tensile crack

$$H_C = \frac{2C}{\gamma\sqrt{Ka_1}}$$

$$= \frac{2 \times 15}{15\sqrt{0.49}} = 2.857\text{m}$$

$H_C > 2$ m, depth of tensile crack = 2 m

2) P_a At A: $-2C\sqrt{Ka_1} = -2 \times 15 \times \sqrt{0.49} = -21 \text{ kN/m}^2$

P_a At B_1: $Ka_1(\gamma H)_1 - 2C\sqrt{Ka_1} = -6.3$ kN/m^2

P_a At B_2: $Ka_2(\gamma H)_1 = \frac{1}{3} \times 15 \times 2 = 10\text{kN/m}^2$

P_a At C: $Ka_2(\gamma H)_1 + (Ka_2) \cdot (\gamma H)_2$

$= \frac{1}{3} \times 17 \times 5 + 10$

= 28.33 + 10 = 38.33 kN/m^2.

Assuming tension crack has developed, earth pressure thrust = Area (PQRS)

$= \frac{1}{2}(10 + 38.33) \times 5 = 120.825$ kN/m

Earth pressure thrust = 120.825 kN/m

Q.7. (c)

(i) What is meant by wear of rails? How is it measured? Explain the methods adopted to reduce wear of rails.

(ii) What is 'mucking' in the construction of tunnels? Explain the various techniques for haulage of muck from the tunnel.

Sol. **(i)** "Wear of rail" refers to the gradual loss of material from the railhead due to the frictional forces generated by train wheels passing over it. This wear occurs primarily at the contact points between the wheel and the rail, and it can lead to various operational and safety issues if not managed properly.

Measurement of Rail Wear

Rail wear is typically measured in terms of the loss of material from the railhead, often expressed in millimeters or inches. The following methods are commonly used to measure rail wear:

1. **Gauge Face Wear:** This refers to the wear on the gauge face of the rail (the part of the rail in contact with the wheel flange). It is measured using wear calipers or ultrasonic measurement devices that can accurately gauge the depth of the wear.
2. **Top of Rail Wear:** This measures the wear on the top surface of the railhead, which comes into direct contact with the wheel tread. Specialized tools or gauges are used to measure the depth of the wear on the railhead.
3. **Profile Measurement:** This involves measuring the overall shape and dimensions of the rail profile, which can indirectly indicate wear patterns and loss of material from the railhead.

Methods to Reduce Wear of Rail

Reducing rail wear is crucial to maintaining safe and efficient railway operations. Several methods are adopted to minimize wear:

1. **Use of Harder Rail Materials:** Rail materials with higher hardness and wear resistance, such as high carbon or alloy steels, can reduce wear rates.
2. **Regular Rail Grinding:** Rail grinding involves using specialized grinding machines to remove surface defects and irregularities from the railhead. This process not only improves ride quality but also reduces wear by restoring the optimal shape of the rail profile.
3. **Controlled Lubrication:** Lubricants applied to the gauge face or top of the rail can reduce friction between the wheel and rail, thereby lowering wear rates. However, the

application must be carefully controlled to prevent adverse effects on traction and braking.

4. **Wheel Maintenance:** Ensuring that train wheels are properly maintained and regularly profiled helps minimize wear on the rail by reducing the occurrence of irregularities and surface damage on the wheel treads.
5. **Optimized Operational Practices:** Smooth acceleration and braking, as well as reducing wheel slip, can help minimize wear by reducing the forces exerted on the railhead during train operation.
6. **Monitoring and Maintenance:** Regular inspection and monitoring of rail conditions allow for early detection of wear and proactive maintenance interventions, such as grinding or replacement of worn sections.

By implementing these methods, railway operators can effectively manage and reduce rail wear, thereby enhancing safety, prolonging rail life, and improving overall operational efficiency.

(ii) In tunnel construction, "mucking" refers to the process of removing excavated material or debris (often referred to as "muck") from the tunnel face or excavation area to the surface for disposal or further processing. The efficient removal of muck is crucial to maintaining progress in tunneling operations.

Here are some common techniques used for the haulage of muck from tunnels:

1. **Manual Wheelbarrows:**
   In smaller tunnels or where space is limited, manual wheelbarrows are used to transport muck manually from the excavation face to a designated collection point within the tunnel or to a waiting vehicle outside.
2. **Locomotive and Mine Cars (Muck Cars):**
   This method involves using locomotives or battery-powered locomotives to haul muck cars on rails laid along the tunnel floor. The muck cars are filled at the face and then transported to the tunnel entrance or a designated dumping area.
3. **Conveyor Belts:**
   Conveyor belts can be used to transport muck horizontally or vertically within the tunnel. They are particularly useful in tunnels with a consistent grade and where the distance between the face and the exit is not too great. Conveyor belts can be fixed or mobile and are efficient for continuous removal of muck.
4. **Dump Trucks and Haulage Vehicles:**
   Dump trucks or other types of haulage vehicles are used when the tunnel dimensions allow for vehicular access. These trucks typically operate between the tunnel entrance and the excavation face, loading muck directly from the face into the truck bed for transportation to disposal sites.
5. **Slurry Transport:**
   In soft ground or when dealing with highly fragmented material, slurry transport systems may be employed. This method involves mixing excavated material with water to form a slurry, which is then pumped to the surface through pipelines for separation and disposal.
6. **Mucking Machines (Load-Haul-Dump Machines - LHDs):**
   LHD machines are purpose-built for underground mining and tunneling operations. These machines can scoop up muck directly from the face and transport it to waiting haulage vehicles or conveyors for removal from the tunnel. LHDs are versatile and can operate efficiently in various tunnel conditions.
7. **Pneumatic Systems:**

Pneumatic systems use compressed air to transport muck through pipelines or tubes to the surface. This method is suitable for transporting muck over longer distances or where access for conventional haulage vehicles is limited.

The choice of muck removal technique depends on several factors including the tunnel size, geology. distance to the surface, and available infrastructure. Often, a combination of these techniques may be used sequentially or concurrently to optimize muck removal efficiency and minimize downtime during tunneling operations.

Q.8. (a) Estimate the traffic density and theoretical capacity of six-lane expressage length of red of 80 km/hr. The average reaction time is 0.75 s and the average vehicle is 5 m.

Sol. Speed of vehicles = $v = \frac{5}{18} \times 80 = 22.22\,\text{m/s}$ (stream speed)

Average length of vehicle = L = 5 m

Traffic density (k) = $\frac{1000}{5}$ veh/km/Lane.

S = Spacing between vehicles (centre to centre)

= vt + L = (22.22 × 0.75 + 5)

$= \frac{65}{3}\,\text{m}$

$k = \frac{1000 \times 3}{65} = 46.154\,\text{veh/km/Lane}$

For six-lane expressway

k = 46.154 × 6 = 276.95 veh/km.

Theoretical Capacity

= q = KV = 276.92 × 80

$= 22153.85 \frac{\text{veh}}{\text{hr}}$

Q.8. (b) List all the major methods of ground modifications (ground improvement) in (i) cohesive soil and (ii) cohesionless soil.

Sol. **Types of Ground Improvement Techniques**

Various techniques for ground improvement are classified based on the types of soil they address.

For Cohesive Soils

For cohesive soils, several methods are employed:

a. Pre-compression

Ground Improvement Techniques

Pre-compression, also referred to as preloading or surcharging, is a ground improvement technique tailored for clay and silt soils. In this approach, the designated construction area is temporarily covered with a surcharge before actual construction begins.

b. Sand drains

Ground Improvement Techniques

This ground improvement technique is employed to improve the characteristics of soils with cohesion, such as clay and silt.

Sand drains involve the construction of sand columns at specified depths, tailored to the requirements of the structure.

c. **Wick drains**

Wick drains serve as a cost-effective alternative to sand drains, which can be prohibitively expensive. This ground improvement technique, relatively recent in development by geotechnical engineers, involves the use of prefabricated vertical drains.

d. **Stone columns**

Ground Improvement Techniques

Stone columns serve as an effective ground improvement method for treating soft clays. The construction of stone columns involves creating holes in the ground to the desired depth and subsequently filling these holes with gravel or small stones.

For Cohesionless Soils

For cohesionless soils, the following methods are commonly employed:

a. **Vibrofloatation**

Ground Improvement Techniques

Vibroflot is a cylindrical tube-shaped apparatus equipped with a vibrator and jets positioned at both the top and bottom ends of the tube. Primarily utilized for compacting loose soils and mitigating the risk of differential settlement, this method involves sinking the vibroflot into the ground with the aid of a water jet or air until it reaches the weaker soil layer.

b. **Terra probe**

Similar to vibroflotation, this approach is a form of vibro-compaction specifically designed for cohesionless soils. The terra probe, featuring an open-ended pipe with a diameter of 75cm, incorporates a vibratory pile at its base.

c. **Compaction piles**

Compaction piles offer an effective solution for treating cohesionless soils. The construction of a compaction pile involves driving a close-ended, hollow pipe into areas of the ground exhibiting weaker soil properties.

Q.8. **(c)** A building is proposed to be constructed on a thick silty clay deposit. The maximum vertical load on a constructed 5000 kN. Using Boussinesq's stress distribution, calculate the minimum depth of soil exploration required for the foundation design. Note that per De Beer's recommendation, the vertical additional stress should be less than equal to 10% of the effective vertical stress. Take unit weight, γ, of soil as 18 kN/m^3 and γ_ω = 10 kN/m^3.

Sol. Assuming the soil to be fully submerged

Let depth of exploration be Z

$= \gamma' = \gamma_{sat} - \gamma_w, = 18 - 10 = 8 \text{ kN/m}^3$

Q = 5000 kN, r = 0

= Vertical effective stress at depth z = $\gamma' z$

= (8z)

According to De-Beer recommendation

$\sigma_z \le 10\%$ of 8z

$$= \frac{3}{2\pi} \times \frac{Q}{z^2}\left(\frac{1}{1+\left(\frac{r}{z}\right)^2}\right)^{3/2} \le \frac{10}{100} \times 8z$$

$$= \frac{3}{2\pi} \times \frac{5000}{z^2} \le \frac{10}{100} \times 8z$$

$= 14.39 \le z$

$z_{min} = 14.39$ m

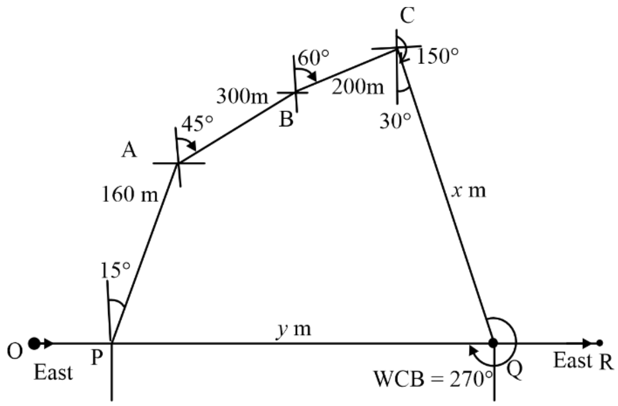
Q.8. **(d)** (i) A survey line OPQR running in the east direction has a lake between points P and Q, P and Q are intervisible but it is not possible to measure its length in the field. A traverse PABCQ was run around the lake and the following measurements were done in the field:

Line	Length (m)	Bearing
PA	160	N 15° E
AB	300	N 45° E
BC	200	N 60° E
CQ	–	S 30° E

Calculate the lengths of the lines CQ and QP.

(ii) Enlist the various geological challenges need to be considered for construction of tunnels in the Himalayan region.

Sol. **(i)**



It is a closed traverse

$L_{PA} + L_{AB} + L_{BC} + L_{CQ} + L_{QP} = 0$

$160 \cos 15° + 300 \cos 45° + 200 \cos 60° + x \cos 150° + y \cos 270° = 0$

$x = 538.876$ m [$\because \cos 270° = 0$]

$D_{PA} + D_{AB} + D_{BC} + D_{CQ} + D_{QP} = 0$

$160 \sin 15° + 300 \sin 45° + 200 \sin 60° + 538.876 \sin 150° + y \sin 270° = 0$

$y = 696.186$ m

$\therefore$ Length of CQ = 538.876 m

Length of QP = 696.186 m

(ii) Constructing tunnels in the Himalayan region presents several geological challenges due to its complex and dynamic geological setting. Here are some of the key challenges:

1. **Seismic Activity:** The Himalayan region is seismically active, prone to earthquakes of varying magnitudes. Engineers must design tunnels to withstand seismic forces and ensure the safety of the structure and users during earthquakes.
2. **Rock Mass Quality:** The quality and stability of the rock mass through which the tunnel passes vary widely. Engineers need to assess rock strength, jointing, fracturing, and weathering to determine support requirements and tunneling methods.
3. **Geological Structures:** The presence of faults, folds, and shear zones in the Himalayas complicates tunnel construction. These structures can influence tunnel alignment, stability, and groundwater flow, requiring careful geological mapping and design adjustments.

4. **High Overburden:** Tunnels in the Himalayas often have significant overburden due to the steep topography. High overburden can lead to increased stress on the tunnel walls and require robust support systems to prevent collapses.
5. **Geohazards:** Landslides, rockfalls, and debris flows are common in the Himalayan region, posing risks to tunnel infrastructure and operations. Engineers must implement mitigation measures such as slope stabilization, drainage systems, and protective structures.
6. **Glacial and Periglacial Conditions:** In higher elevations, tunnels may encounter glacial and periglacial conditions, including freezing and thawing cycles, which can affect rock stability and groundwater conditions. Specialized construction techniques and materials may be required.
7. **High Water Inflow:** Himalayan tunnels may encounter significant groundwater inflows due to fractured rock and proximity to glaciers or snowmelt zones. Effective drainage systems and waterproofing measures are crucial to maintain tunnel safety and functionality.
8. **Environmental Impact:** Construction in environmentally sensitive areas of the Himalayas requires careful planning to minimize disruption to ecosystems, water bodies, and local communities. Mitigation measures for noise, dust, and waste management are essential.
9. **Remote Location and Access:** The remote and mountainous terrain of the Himalayas presents logistical challenges for transporting equipment, materials, and workforce to construction sites. Construction schedules may be affected by seasonal variations in weather and accessibility.

Addressing these geological challenges requires a thorough understanding of local geology, advanced engineering techniques, and adherence to stringent safety and environmental standards. Successful tunnel projects in the Himalayas typically involve interdisciplinary collaboration among geologists, engineers, and environmental specialists to ensure sustainable and resilient infrastructure development.

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THANK YOU!