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ESE – 2019 MAINS
OFFLINE TEST SERIES

CIVIL ENGINEERING

TEST – 14
SOLUTIONS

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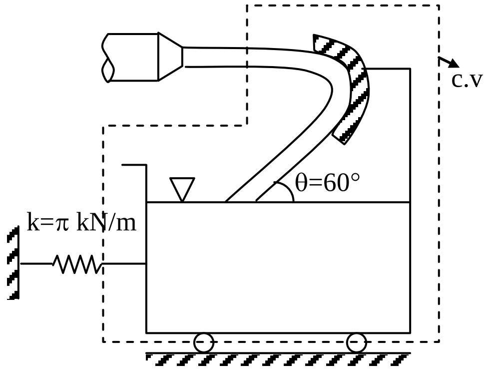
01(a).

Sol: Consider the control volume as shown in the diagram. The only external force acting on the control volume in horizontal direction is the spring force (F)



Applying linear momentum equation for the control volume we get,

$$\sum \vec{F} = (\dot{m}\vec{V})_{out} - (\dot{m}\vec{V})_{in} + \frac{\partial}{\partial t}(m\vec{V})_{c.v.} \text{ ------ (1)}$$

$$\vec{F} = -F \quad (\because \vec{F} \text{ acts in } -\text{ve 'x' direction })$$

$(\dot{m}\vec{V})_{out} = 0$ ($\because$ No mass is going out of C.V.)

$$(\dot{m}\vec{V})_{in} = (\rho a V)(V) = \rho a V^2$$

$\frac{\partial}{\partial t}(m\vec{V}) = 0$ ($\because \vec{V} = 0$, free surface velocity)

$\therefore$ equation (1) becomes

$$-F = 0 - \rho A V^2 + 0$$

$$\therefore F = \rho A V^2 = 1000 \times \frac{\pi}{4} \times 0.02^2 \times 10^2 = 10\pi N$$

$$\delta = \frac{F}{k} = \frac{10\pi}{1000\pi} = 0.01 \text{ m} = 1\text{cm}$$

Note: Even though mass is increasing inside the C.V. $\frac{\partial}{\partial t}(m\vec{V})$ is zero because velocity of that mass (which is equal to free surface velocity) is zero.

01(b).

Sol:

Possible sources				
Pollutant	**Natural**	**Anthropogenic**	**Effects on human**	**Environmentand property**
Sulphur dioxide (SO_2) A chemical compound produced by volcanoes and in various industrial processes and is also a precursor to particulates in the atmosphere.	• Volcanoes (67%)	• Combustion of fossil fuel (coal, heavy fuel oil) in thermal power plants, office factories. • Paper industry • Extravation and distribution of fossil fuels • Smelting of metals (sulfide ores to produce copper, lead and zinc) • Petroleum refining • Combustion process in diesel, petrol, natural gas driven vehicles.	• Respiratory illness • Visibility impairment • Aggravate existing heard and lung diseases	• Acid rain • Aesthetic damage
Oxides of nitrogen(NO_x) They are a generic term for a group of highly reactive gases that contain nitrogen and oxygen in varying amounts. NO_x are emitted as nitrogen oxide (NO) which is rapidly oxidized to more toxic nitrogen dioxide (NO_2). Nitrogen dioxide (NO_2) is a reddish- down toxic gas with a characteristic sharp, bitting odor and is a prominent air pollutant.	• Lightning • Forest fires • Bacterial activity of soil	• High temperature combustion (Internal combustion engines, fossil fuelfired power stations, industrial). • Burning of biomas and fossil fuels.	• Irritates the nose and throat • Increase susceptibility to resipratory infections	• Precursor of ozone formed in the troposphere • Form atmospheric fine particulate matter burden as a result of oxidation to form nitrate aersol.

Respirable suspended particulate matter (PM_{10}, size ≤ μm, coarse fraction PM_{10}– PM_{23}). Also called thoracic fraction. Particulate matter (PM) is a complex mixture of Suspended solid liquid particle in semi-equilibrium with surrounding gases. The major constituents of RSPM are organic and elements carbon, metal/elements like silicon, magnesium, iron, ions like sulphates, nitrates, ammonium etc. PM_{10} can settle in the bronchi and lungs and cause health problems.	• Coarse particles are produced by the mechanical break-up of larger solid particles. • Wind blown dust such as road dust, fly ash, soot, agricultural processes by the mechanical break-up of larger solid particles. • Wind blown dust such as road dust, fly ash, soot agricultural processes. • Physical process of crushing, grinding and abrasion of surfaces photochemically. • Produced particles, such as those foundin urban haze. • Pollen grains, mould spores, and plant and insect parts • Non-combustible materials released when burning fossil fuels.	• Road traffic emissions particularly from diesel vehicles • Industrial combustion plants some public power generation • Commercial and residential combustion particularly from diesel vehicles • Industrial combustion plants some public power generation • Commercial and residential combustion • Non-combustion processes (e.g. quarrying). • Agricultural activities	• Cardiopulmonary problems • Asthma, bronchitis, and pneumonia in elder people. • Asthma, bronchitis, and pneumonia in elder people.	• Visibility reduction

Particular matter 2.5 (PM $_{2.5}$ size ≤ 2.5 μm, fine fraction size up to 2.5 μm, respirable fraction). Airborne particles smaller than 2.5 μm called fine particles. Composed mainly of carbonaceous materials (organic and elementals), inorganic compounds (sulfate, nitrate, and ammonium), and trace metal compounds (iron, aluminium, nickel, copper, zinc, and lead). Pulse the greatest problems, $PM_{2.5}$ send to penetrate into the gas exchange regions of the lung, and very small particles (<100 nanometers) may pass through the lungs to affect other organs. The smallest particles, however, less than 100nm (nanoparticles) can get into the bloodstream and affect the cardiovasular system.	• Fie particles are largely formed from gasses. • Ultrafine particles are formed by nulceation, which is the initial state in which gas becomes a particle. These particles can grow up to a size of 1 μm either through condensation, when additional gas condensates (coagulation).	• Vehicular emission. • Industrial combustion plants for some public power generation • Commercial and residential combustion	• Oxidative stress • Respiratory symptoms such as irritation of the airways, coughing, or difficulty in breathing. • Decreased lung function • Aggravated ashthma • Chronic bronchitis • Irregular heartbeat, cardiopulmonary disorders • premature death in people with heat or lung disease	• Aesthetic damage • Visibility reduction

Ozone (O_3) A pale blue gas, soluble in water and non-polar solvents with specific sharp odor somewhat resembling chlorine bleach. Ozone is a secondary pollutant formed in the atmosphere by reaction between oxides of nitrogen and volatile organic compounds (VOCs) in the presence of sunlight. Peack O_3 levels occur typically during the warmer times of the year.	• Ozone is present in the stratosphere zone (between about 10 and 50 km above the troposphere) of the atmosphere as ozone layer. This ozone protects us from UV radiations.	• Tropospheric ozone (about 10 km above the earth surface) it harmful. It is formed by the reaction of sunlight with air, containing hydrocarbons and nitrogen oxides emitted by car engines, industrial perations, chemical solvents to form zone. • Electronic equipment such as photocopies.	**Tropospheric ozone:** • Lung function deficits • Respiratory illness • Premature death, asthma, bronchitis, heart attack, and other cardiopulmonary problems. • Ground-level ozone and pollution which interfaces with photosynthesis and stunts overall growth of some plant species.	• Ozone cracking in car tires, gaskets, O-rings is caused by attack of ozone on any polymer possessing olefinic or double bonds within its chain structure. • Ozone present in the upper troposphere acts as a greenhouse gas,absorbing some of the infrared energy emitted by the earth.
Lead A bright silvery soft, dense, ductile, highly malleable, bluish-white metal that has poor electrical conductivity and is highly resistant --------------.	• Food (lead is absorbed by plants).	• Waste incineration • Metal processing • Paint industry • Lead solder in food cans, breast milk, drinking water, cosmetics, ceramic pottery, burning of firewood or kerosence, indigenouos remedies, tobacco and tobacco products, contaminated drinking water, toys, industrial effluents, lead and batteries, ammunition, paints and varnishes, water pipes Automobile exhaust	• Lead is rapidly absorbed into the bloodstream and is believed to have adverse effects on the central nervous system, the cardiovascular system, kidneys, and the immune system. • Causes blood disorders like anemia, increase in blood pressure. • Potent neurotoxin that accumulates both in soft tissues and the bones. • Causes nephropathy, and colic-like abdominal paints. • Weakness in fingers, wrists, or ankles. • Miscarriage and reduction of fertility in males, delayed puberty in girls.	

Carbon monoxide (CO) Also called carbonous oxide, is a colorless, odorless and tastless gas which is slightly lighter than air. It is highly toxic to humans and animals in higher quantities. Mainly formed by incomplete combustion of carbon containing fuels.	• Produced during normal animal metabolism (by the action of hemeoxygenase 1 and 2 on the heme from hemoglobin breakdown and produces carboxyhemo-globin in normal persons) in low quantities and has some normal biological functions (signalling molecule). • Volcanic activity • Forest and bushfires	• Exhaust of internal combustion engines, especially of vehicleswith petrol engines. • Burning of carbon fules. • Organic combustion in waste incineration. • Power station processes • Iron smelting • Burning of crop residues	• This gas enters the blood stream through lungs and combines with hemoglobin forming carboxyhemoglobin. This condition is known as anoxemia, which inhibits blood's oxygen carrying capacity to organs and tissues. • Persons with heart disease are sensitive to CO poisoning and may experience chest pain if they breathe the gas while exercising. • Adverse effects on the fetus of a pregnant woman. • Infants, elederly persons, and individuals with respiratory diseases are also particularly sensitive. • Anti inflammatories, vasodialators and encouragers of neovascular growth.	

Ammonia (NH_3) A compound of nitrogen and hydrogen, a colourless gas with a characteristic pungent colour. Contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers, and either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals.	• Putrefaction of nitrogenous animals and vegetable matter. Ammonia and ammonium salts are also found in small quantities in rainwater, fertile soil and in seawater. • During volcanic erruption. • The kidneys secrete NH_3 to neutralize excess acid.	• Farms • Fertilizers industry • Industrial sites that store ammonia or use it as a refrigerant can release high levels if the chemicals leaks or is spilled	• Irritation to skin, eyes, throat, and lungs and cause coughing. • Burns. • Lung damage and death may occur after exposure to very high concentrations of ammonia.	• Odour.
Arsenic (AS) A solid layered, a ruffled analogue of graphic, metallic gray in color and is a semiconductor. It is a potent poison. (IARC) recognizes arsenic and group I carniogen.	• Volcanic ash weathering of the arsenic-containing mineral and ores as well as ground water. • Food, water, soil and air.	• Smelting of metals. • Combustion of fuels (especially of low grade brown coal). • Use of pesticides • Wood preservation, glass production, nonferrous metal alloys, electronic semi-conductor manufacturing. • Coke oven emissions associated with the smelter industry.	• Epigenetic changes • Multi-system organ failure • Arsenic poisoning	

Nickel (Ni) A silvery-white lustrous corrosion- resistant metal with a slight golden tinge.	• Urease (an enzyme which assists in the hydrolysis of urea) contains nickel.	• Combustion of fossil fuels. • Nickel plating. • Metallurgical processes.	• Nickel sulfide fume and dust is believed to be carcinogenic. • Allergy, dermatitis. Sensitivity to nickel may also be present in patient with pompholyx.	Explosive in air.
Carbon dioxide (CO_2)	• Respiration animals and plants	• Fossil fuels Burning for cooking, heating in power plant furnaces.	• Breathlessness, headache, chest congestion. • Indirect effect due to increase in temperature during green- house effect.	• Greenhouse effect and climate change.
Chlorofluorocarbons (CFCs)		• Air conditioners, refrigerators, • Foam insulations • Extinguishers • Solvent cleaners • Aerosol propellents • Supersonic aircraft	• Indirect effects through depletion of ozone in stratosphere which protects Human from Harmful UV radiation. Enhanced UV radiations cause skin cancer, cataracts etc.	• Depletion of stratospheric ozone.

01(c).

Sol: **a) Lapse Rate:** The rate of change of temperature of air with altitude is known as "Lapse rate" (Environmental Lapse Rate, ELR). In the lower atmosphere (known as troposphere) upto a distance of about 11 km above the earths surface, the temperature decreases linearly with increases in altitude. In the upper region of the atmosphere. which is know as stratosphere which extends from about 11 km to 32 km, constant temperature prevails.

b) Adiabatic Lapse Rate (ALR): The internal decrease of temperature with height which occurs in the rising parcel of air mass can be theoretically calculated by assuming the cooling process to be adiabatic (i.e. occurring without the addition or loss of heat). This rate of decrease of temp. with height is referred to as Adiabatic Lapse Rate (ALR).

c) Super – Adiabatic Lapse Rate (SALR): When the prevailing environmental Lapse Rate (ELR) is greater than the ALR, the ELR is known as Super – Adiabatic Lapse Rate.
In such a case, the rising parcel of air will always remain warmer and lighter than the surrounding environment and the parcel of air will continue to accelerate and go up. In such a case, the atmospheric condition is said to be 'unstable' and the dispersion of the pollutants will be rapid, effective and less intensity of air pollution.

d) Sub – Adiabatic Lapse Rate: When the prevailing environmental lapse rate (ELR) is less than the ALR, then the ELR is known as sub – adiabatic lapse rate. In such a case, the rising parcel of air will be cooling more quickly than its surroundings and hence it will not be able to rise up to greater altitudes. Such an atmospheric condition is said to be 'stable' which is however, not favorable for effective dispersion of the pollutants. . It results in more pollution.

e) Neutral atmosphere: When the prevailing ELR is equal to the ALR, the atmospheric condition is said to be neutral.

f) Negative Lapse Rate: When the temp of the ambient air increases with increase in altitude, then the lapse rate is termed as negative or inverted lapse rate. The condition under which negative lapse rate occurs is referred to as "inversion". During inversion the atmosphere is said to be stable. It results in more pollution

Significance:

Atmosphere is considered stable when ELR< ALR and unstable when ELR > ALR

In an unstable atmosphere there is more dispersion of pollutants and hence air pollution is reduced. Whereas in case of stable atmosphere dispersion of pollutants is not possible and pollutants keep on accumulating leading to air pollution.

01(d).

Sol: River training works are the various measures adopted on a river to direct and guide the river flow, to train and regulate the river bed or to increase the low water depth.

River training is necessary to

(i) Pass high flood discharge safely and quickly

(ii) Transport sediment load efficiency

(iii) Stabilise river course

(iv) Provide sufficient draft for navigation

(v) Direct flow through certain defined reach

Essential river training works are

(i) Guide bank system

(ii) Groynes or spurs

(iii) Levees or embankment

(iv) Bank protection and pitched banks

(v) Pitched islands

Guide bank system:

Guide banks are made for guiding the stream near a structure so as to confine if in a reasonable width of the river. The guide bank usually consists of a heaving built emabkment in the shape of ball mouth on both sides of constricted channel. A symmetrical layout of the guide bank in plan n very essential for the successful performance of the band. The two guide banks on both sides of stream can be made parallel, diverging or converging at upper end. If high and stable river bank on one side is available, only one guide bank embankment on other side is required.

Groynes or spurs:

Groynes are structures constructed transverse to the river flow and extend from the bank into river upto a limit.

The purposes of Groynes are:

(i) Contracts a river channel to improve its depth
(ii) Protects the river banks
(iii) Silts up the area in the vicinity by creating a slack flow
(iv) Trains the flow along a river course

Levees or Marginal bund:

Marginal bund or Levee is an earthen dike constructed roughly parallel tot he river rather than across the channel.

Effect of Levees on flood flows:

1. Increases the intensity of flood water travel downstream
2. Increases the water surface elevation of the river at flood
3. Increases maximum discharge at all points downstream
4. Increases the velocity and scouring action through levee section
5. Decreases the surface slope of the stream above the levee portion.
6. Increases the flood peak and decreases the valley storage.

Bank Protection:

In a broad sense bank protection includes any protection work that aims at maintaining the stability of land against the action of water

Pitched Islands:

This consists generally of a sand core pitched with boulders along its side and slopes and protected at the toe by a falling apron.

01(e).

Sol: When a discrete particle settles down in water, its downward settlement is opposed by the drag force offered by the water. The effective weight of the particle (actual weight – buoyancy) causes the particle to accelerate in the beginning till it attains a sufficient velocity (V_s) at which the drag force becomes equal to the effective weight of the particle. After attaining that velocity (V_s) the particle falls down with that constant velocity.

Now, we know that

Effective weight of the particle = Total weight – Buoyancy

$$= \frac{4}{3}\pi r^3 \times \gamma_s - \frac{4}{3}\pi \gamma^3 \times \gamma_w \text{ ....(i)}$$

Where is radius of particle, γ_s is unit weight of particle and γ_w is unit weight of water

Also, Drag Force $C_D \times A \times \rho_w \times \frac{V^2}{2}$ ....(ii)

Where, C_D is coefficient of drag, A is area of particle, ρ_w is density of water and V = Velocity of fall

Now, when V becomes equal to V_s, the drag force becomes equal to the effective weight of the particle

$$\therefore C_D A \rho_w \frac{V_S^2}{2} = \frac{4}{3}\pi r^3(\gamma_s - \gamma_w) \qquad [\because A = \pi r^2]$$

$$\Rightarrow C_D \pi r^2 . \rho_w \frac{V_s^2}{2} = \frac{4}{3}\pi r^3(\gamma_s - \gamma_w)$$

$$\Rightarrow V_s^2 = \frac{4}{3} \times \frac{2r(\gamma_s - \gamma_w)}{\rho_w . C_D}$$

$$\Rightarrow V_s^2 = \frac{4}{3} \times \frac{d(\gamma_s - \gamma_w)}{\rho_w . C_D} \qquad [\because f_s = \rho_s \times g \text{ and } \gamma_w = \rho_w \times g]$$

$$\Rightarrow V_s^2 = \frac{4}{3} \times \frac{d(\rho_s g - \rho_w g)}{\rho_w \times C_D} = \frac{4}{3} \times d \times \rho_w g\left(\frac{\rho_s}{\rho_w} - 1\right) \times \frac{1}{\rho_w . C_D}$$

$$\Rightarrow V_s^2 = \frac{4}{3} \times g \times d \times (S_s - 1) \times \frac{1}{C_D} \text{ ....(iii)}$$

Where d is the diameter of particle and S_s is the specific gravity of the particle

Now for laminar flow and for small particles coefficient of drag, $C_D = \frac{24}{Re}$; where Re is particle Reynolds number

$Re = \frac{V_s - d}{\nu}$, where ν is the kinematic viscosity

$$\therefore V_s^2 = \frac{4}{3}\times g\times d\times(S_s - 1)\times\frac{1}{\frac{24}{Re}}$$

$$\Rightarrow V_s^2 = \frac{4}{3}\times g\times d\times(S_s - 1)\times\frac{V_s\times d}{\nu\times 24}$$

$$\Rightarrow V_s = \frac{9}{18}(S_s - 1)\times\frac{d^2}{\nu}\ \ldots\ldots\ldots\ldots\ldots\ldots\text{(iv)}$$

Equation (iii) is the general equation for settling of a particle. Equation (iv) is valid for laminar flow and when particle diameter is less than 0.1 mm

02(a). (i)

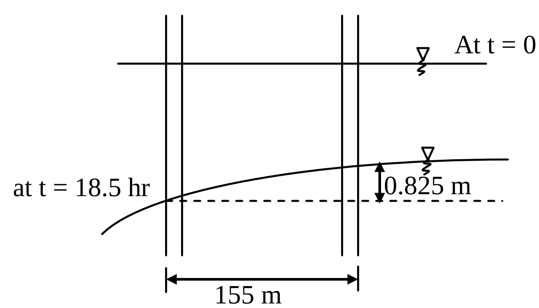
Sol: $n = 37.5\% = 0.375$

Porus velocity = $\frac{\ell}{t} = \frac{155}{18.5\times 3600} = 2.33\times 10^{-3}$ m/sec

$V_{superficial} = ki$

$V_{seepage} = \frac{V_{superficial}}{n} = \frac{ki}{n}$

$V_{seepage} = V_{tracer} = \frac{ki}{n}$



$i = \frac{0.825}{155} = 5.322\times 10^{-3}$

$$2.33\times 10^{-3} = \left(\frac{5.322\times 10^{-3}}{0.375}\right)\times k \Rightarrow \quad k = 0.164\text{ m/s}$$

Intrinsic permeability

$$K_s = \frac{K}{\left(\frac{\rho g}{\mu}\right)} = \frac{K\nu}{g} \Rightarrow K_s = \frac{0.164\times 10^{-6}}{9.81} = 1.675\times 10^{-8}\text{ m}^2$$

02(a). (ii)

Sol: Bio-Towers

- These are super high rate trickling filters in which plastic medium is used which provides more surface area for the growth of biomass layer resulting in increased efficiency.
- The porosity of this plastic medium is very high which ensures higher hydraulic loading rate. Leading to the increased sloughing in filter medium which results in higher rate of removal of organic matter.
- Odour problem, pending and fly nuisance is not observed in these types of filters.
- A well separated bio-towers result in the decomposition of organic matter upto the nitrate level.
- BOD of the effluent coming out of these filters can be computed using Eckenfedler's equation.

$$S_e = S_o\, e^{-kD/Q^n}$$

Where,

S_e - BOD of effluent in mg/L S_o - BOD of influent in mg/L D – depth of tank in m

K – Treatibility constan (min^{-1})

Q – hydraulic loading rate ($m^3/m^2/min$)

n = constant depending on type of medium (n = 0.5, for plastic medium)

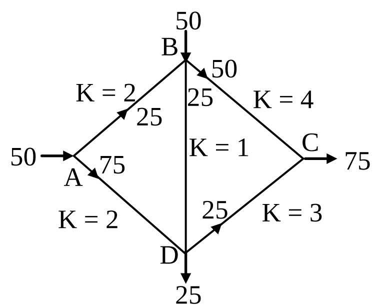
Rotating Biological contractors (Aerobic attached growth system)

- In this case rotating discs are used which are closely placed with each other as a medium for growth of biomass layer
- This biomass layer comes in contact with organic matter when disc is emerged in wastewater & utilises o_2 when exposed to atmosphere to oxidise organic matter resulting in formation of biomass which gets itself attached to rotating disc.
- Over a period of time thickness of biomass layer over the rotating disc increases and is sloughed off sheared off due to turbulence created by rotation of disc in wastewater and is finally taken to SST for its settlement.
- The depth of emersion of disc is kept to be 40% size of disc in wastewater.

- This system takes the advantage of both attached and the suspended growth system.
- It is highly effective method of treatment of organic matter which oxidises the biological solids upto nitrate level.

02(b).

Sol: First of all, the magnitudes as well as directions of well direction of the possible flows in each pipe are assumed keeping in consideration. The lane of continuity at each junction. The assumed flows are given as



Given that H_L KQ^n. Thus using Darcy-Weisbach formula for rough pipes and turbulent flow, we get

$H_L = KQ^2$

The various values of K for different pipes are given in the figure which can be used will analysing the two loops; i.e. loop ABDA and loop BCDB both these loops are analysed by Hardy-Cross method.

Pipe Assumed Flows K $H_L = KQ_a^2 \left|\frac{H_L}{Q_a}\right|$ corrected Q after First correction

Q_a $= Q_{a_1} = Q_a + \Delta_1$

For Loop ABDA:

AB	25	2	1250	22.5
BD	25	1	625	35.0
DA	–25	2	–1250	–27.5

$$\Sigma H_L = 625 \quad \Sigma\left|\frac{H_L}{Q_a}\right| = 125$$

For loop BCDB:

BC	50	4	10000	37.5
CD	–25	3	–1875	–37.5
DB	–14	1	–625	–35.0

$$\Sigma H_L = 7500 \quad \Sigma\left|\frac{H_L}{Q_a}\right| = 300$$

Note: We know that $\Delta = \dfrac{-\Sigma H_L}{n\Sigma\left|\dfrac{H_L}{Q_a}\right|}$

For common pipe BD, $\Delta_1 = \dfrac{-625}{2\times 125} = -2.5$

For common pipe DB, $\Delta'_1 = \dfrac{7500}{2\times 300} = -12.5$

But in the direction of BD, it becomes + 12.5

$\therefore$ Corrected flow in common pipe BD = $Q_a + \Delta_1 + \Delta'_1$ = 25 – 2.5 + 12.5 = 35

II Iteration:

Pipe	Q_{a1}	K	H_L	$\left\|\frac{H_L}{Q_{a_1}}\right\|$	Corrected flows
For Loop ABDA:					
AB	22.5	2	1012.5	45	19.8
BD	35	1	1225	35	32.6
DA	–27.5	2	–1512.5	55	–30.2

$$\Sigma H_L = 725 \quad \Sigma\left|\frac{H_L}{Q_{a_1}}\right| = 135$$

For loop BCDB:

BC	37.5	4	5625	150	37.5
CD	–37.5	3	–4218.75	112.5	–37.8
DB	–35.0	1	–1225	35	–32.6

$$\Sigma H_L = 181.25 \qquad \Sigma\left|\frac{H_L}{Q_{a_1}}\right| = 297.5$$

$$\Delta_2 = \frac{-\Sigma H_L}{n\Sigma\left|\frac{H_L}{Q_{a_1}}\right|} = \frac{-725}{2\times 135} = 2.7$$

$$\Delta'_2 = \frac{161.25}{2\times 297.5} = -0.3$$

For common pipe corrected flow $= Q_{a_1} + \Delta_2 + \Delta'_2 = 35 - 2.7 + 0.3 = 32.6$

III. Iteration:

Pipe	Q_{a2}	K	H_L	$\left\lvert\frac{H_L}{Q_{a_2}}\right\rvert$	Corrected flows
For Loop ABDA:					
AB	19.8	2	784.08	39.6	19.7
BD	32.6	1	1062.76	32.6	32.8
DA	–30.2	2	–1824.08	60.4	–30.3

$$\Sigma H_L = 22.76 \quad \Sigma\left|\frac{H_L}{Q_{a_2}}\right| = 132.6$$

For loop BCDB:

Pipe	Q_{a2}	K	H_L	$\left\lvert\frac{H_L}{Q_{a_2}}\right\rvert$	Corrected flows
BC	37.2	4	5535.36	148.8	36.9
CD	–37.8	3	–4286.52	113.4	–38.1
DB	–32.6	1	–1062.76	32.6	–32.8

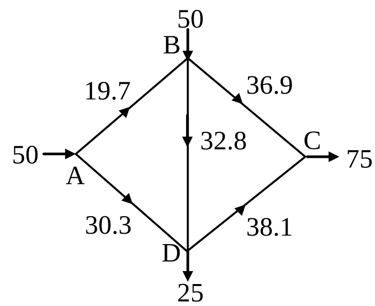
$$\Sigma H_L = 186.08 \qquad \Sigma\left|\frac{H_L}{Q_{a_2}}\right| = 0.1$$

$$\Delta_3 = \frac{-\Sigma H_L}{n\Sigma\left|\frac{H_L}{Q_{a_2}}\right|} = \frac{-22.76}{2\times 132.6} = 0.1$$

$$\Delta'_3 = \frac{186.08}{2 \times 294.8} = -0.3$$

For common pipe corrected flow $= Q_{a_2} + \Delta_3 + \Delta'_3$ = 32.6 – 0.1 + 0.3 = 32.8

Thus the final corrected flows after the third iteration can now be plotted on the network to check balancing of flow at each point, to verify the answer.



02(c).

Sol: Volume of sewage sample = 6 m*l*

Total volume after dilution = 300 m*l*

Dilution factor = $\frac{6}{300} = \frac{1}{50}$

5 day BOD at 20° C = $\frac{D.O_i - D.O_F}{\text{Dilution Factor}}$

$= \frac{9 - 1.82}{\frac{1}{50}}$

= 359 mg/*l*

Assume $BOD_5 = BOD_{ultimate}\left(1 - e^{-K_{20}\times 5}\right)$

$= BOD_u\,(1 - e^{-0.23\times 5})$

(i) $BOD_u = \frac{BOD_5}{0.6834} = \frac{359}{0.6834}$ = 525.31 mg/*l*

(ii) $K_T = K_{20}\,(1.047)^{T-20}$

$K_{20} = 0.23$

$K_{30} = 0.23\,(1.047)^{10} = 0.364$

8 day BOD at 30^{o}C

$= L_o (1 - e^{-Kt}) = 525.31 (1 - e^{-0.364\times8}) = 496.77$ mg/*l*

(iii) $K_{15} = K_{20} (1.047)^{T-20} = 0.23 (1.047)^{-5} \Rightarrow K_{15} = 0.183$

3 day BOD at 15^{o}C

$= L_o (1 - e^{-Kt}) = 525.31 (1 - e^{-0.183\times3}) = 221.75$ mg/*l*

(iv) Organic matter remaining after 3 day at 30^{o}C

$= L_o e^{-Kt} = 525.31 e^{-0.364\times3} = 176.26$ mg/*l*

03(a). (i)

Sol: T = 20^{o}C, P_s = 8.2 , k = 0.75

PET = ?

$T_f = 1.8\, t^oC + 32 = (1.8 \times 20) + 32 = 68$

$$E_T = \frac{2.54\times kP_H T}{100}$$

$$= \frac{2.54\times0.75\times8.2\times68}{100} = 10.62 \text{ cm/month}$$

E_T = 3.54 mm/day

03(a). (ii)

Sol: $\Delta s = (-)\,\frac{2560\times10^4}{14960\times10^4} = (-)\,0.1711$ m

$\Delta s = (-)\,17.11$ cm

Inflow = (+) $\frac{25.5\times3600\times24\times30}{14960\times10^4} = (+)44.182$ cm

Outflow = (–) $\frac{38.7\times3600\times24\times30}{14960\times10^4} = (-)\,67.05$ cm

P = (+) 8.8 cm

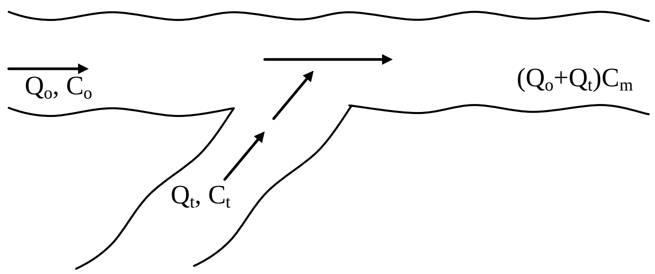
S.L = $(-)\frac{25\times10^4}{14960\times10^4} = (-)\,0.167$ cm

(+) 44.182 (+) 8.8 (–) 67.05 (–) 0.167 (–) E = (–) 17.11 cm

E = 2.877 cm/month

03(a). (iii)

Sol.



Let a stream has discharge, Q_o, with concentration of a selective tracer element in it as C_o. that tracer element (obviously non-toxic) is permitted to get mixed up at a known concentration of C_t with a rate of supply of Q_t. At a distance of 1 km d/s, the mixture concentration (i.e. after dilution) C_m is measured.

By principle of concentrations,

$$Q_o C_o + Q_t C_t = (Q_o + Q_t) C_m$$

$$Q_o C_o + Q_t C_t = C_m Q_o + C_m Q_t$$

$$Q_o (C_m - C_o) = Q_t (C_t - C_m)$$

$$Q_o = Q_t\left(\frac{C_t - C_m}{C_m - C_o}\right)$$

Gives rate of flow water in that stream.

Generally, $C_m >>>> C_o$

$$C_m - C_o \approx C_m$$

$$\Rightarrow Q_o = Q_t\left(\frac{C_t}{C_m} - 1\right)$$

Generally, by dilution C_m will get reduced by atleast $\frac{1}{5000}$ to $\frac{1}{10000}$

i.e., $\frac{C_t}{C_m} >>>>>>>>> 1 \Rightarrow Q_o = \frac{Q_t\, C_t}{C_m}$

Gives discharge of the stream

03(b).

Sol:

River	**Waste water**
$Q_R = 0.5\ m^3/s$	$Q_w = 0.1\ m^3/s$
$(DO)_R = 8\ mg/l$	$y_w = 40\ mg/l$

$(DO)_{sat} = 9.2\ mg / l$

$V = 0.2\ m/s$

$k_1 = 0.2\ d^{-1},\ k_2 = 0.4\ d^{-1}$

$$y_{mix} = \frac{Q_R y_R + Q_w y_w}{Q_R + Q_w}$$

$$= \frac{0.5\times 0 + 0.1\times 40}{0.5 + 0.1} = 6.6\ mg/l$$

$$y_{mix} = L_o\,[1 - e^{-k_1\times t}]$$

$$6.6 = L_o[1 - e^{-0.2\times 5}]$$

$L_o = 10.536\ mg/l$

$$(DO)_{min} = \frac{Q_R DO_R + Q_w DO_w}{Q_R + Q_w}$$

$$= \frac{0.5\times 8 + 0.1\times 0}{0.5 + 0.1} = 6.66\ mg/l$$

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

$= 9.2 - 6.66$

$= 2.54\ mg/l$

$$t = \frac{25\times 10^3}{0.2}\times\frac{1}{24\times 60\times 60}$$

$= 1.446$ days

$$D_t = \frac{k_1 L_o}{k_2 - k_1}\left[e^{-k_1 t} - e^{-k_2 t}\right] + D_o e^{-k_2 t}$$

$$D_{1.446} = \frac{0.2\times 10.536}{0.2}\left[0.7488 - 0.56079\right] + 2.54\times 0.56079$$

$= 3.4052\ mg/l$

$(DO)_{25\ km} = (DO)_{sat} - D_{1.446}$

$= 9.2 - 3.405$

$= 5.794$ mg/*l*

$$t_c = \frac{1}{k_2 - k_1}\ln\left[\frac{k_2}{k_1}\left(1 - \frac{D_o(k_2 - k_1)}{k_1 L_o}\right)\right]$$

$$= \frac{1}{0.4 - 0.2}\ln\left[\frac{0.4}{0.2}\left(1 - \frac{2.54(0.4 - 0.2)}{0.2\times 10.536}\right)\right]$$

$$= \frac{1}{0.2}\ln\left[2\left(1 - \frac{2.54\times 0.2}{0.2\times 10.536}\right)\right]$$

$= 2.086$ days

$\therefore$ Critical oxygen deficit, $D_c = \frac{k_1}{k_2} L_o e^{-k_1(t_c)}$

$$\Rightarrow D_c = \frac{0.2}{0.4}\times 10.5\times e^{-0.2\times 2.086}$$

$= 3.471$ mg/*l*

03(c).

Sol: Given

$L = 3$ m

$W = 1.8$ m

$\rho = 900$ kg/m^3

$u_\infty = 1.5$ m/s

$\upsilon_{oil} = 1.2 \times 10^{-4}$ m^2/s

$$(\text{Re})_{L/2} = \frac{u_\infty (L/2)}{\upsilon} = \frac{1.5\times 1.5}{1.2\times 10^{-4}}$$

$(\text{Re})_{L/2} = 1.875 \times 10^4$

$$(\text{Re})_L = \frac{u_\infty L}{\upsilon} = \frac{1.5\times 3}{1.2\times 10^{-4}}$$

$(\text{Re})_L = 3.75 \times 10^4$

Laminar boundary layer

$$\delta_{L/2} = \frac{KL/2}{\sqrt{\text{Re}_{L/2}}} = \frac{5\times1.5}{\sqrt{1.875\times10^4}}$$

$\Rightarrow \delta_{L/2} = 0.05477$ m

= 54.77 mm ----------(1)

$$\delta_L = \frac{KL}{\sqrt{\text{Re}_L}} = \frac{5\times3}{\sqrt{3.75\times10^4}}$$

$\Rightarrow \delta_L = 0.077459$ m

$\delta_L = 77.46$ mm ----------(2)

$$(G)_{L/2} = \frac{0.664}{\sqrt{(\text{Re})_{L/2}}} = 0.00485$$

$$(G)_L = \frac{0.664}{\sqrt{(\text{Re})_L}} = 0.00342$$

$$(\tau_o)_{L/2} = (G_{L/2})\times\frac{1}{2}\rho u_\infty^2$$

$$= 0.00485\times\frac{1}{2}\times900\times1.5^2$$

$(\tau_o)_{L/2} = 4.91\ Pa$ ------- (3)

$$(\tau_o)_L = (G_L)\times\frac{1}{2}\rho u_\infty^2$$

$$= 0.00342\times\frac{1}{2}\times900\times1.5^2$$

$(\tau_o)_L = 3.4722\ Pa$ ------- (4)

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

$$= \frac{1.328}{\sqrt{\text{Re}_L}}\times3\times1.8\times\frac{1}{2}\times900\times1.5^2$$

= 37.4948 N /side

∴ Towing is done

∴ Boundary layer formation takes place on both the sides.

∴ $F_D = 74.99$ N

Power = $F_D \times u_\infty$

= 112.48 watts --------- (5)

At center

δ = 54.77 mm

τ_o = 4.91 Pa

At trailing edge

δ = 77.46 mm

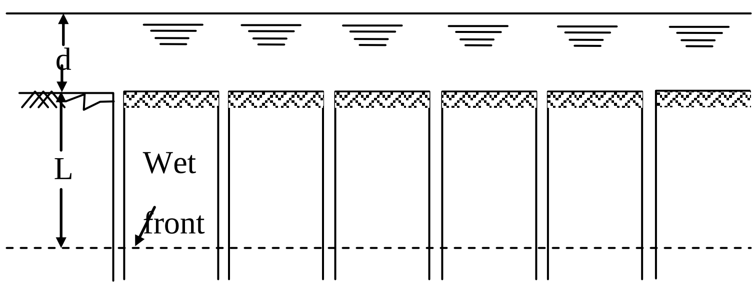
τ_o = 3.47 Pa

Power = 112.48 watts

04(a).

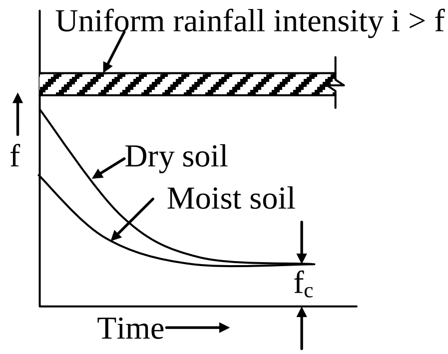
Sol: Factors affecting infiltration capacity:

Depth f Surface Detention and Thickness of Saturated layer. Infiltration takes place due to combined influences of gravity and capillary forces. The infiltration of water through a soil surface may be visualized as a flow through a large n umber of tiny pipes as shown in fig.



Infiltration process

the infiltration continues the wet front will be traveling downwards. At any instant of time the resistance to flow is proportional to the thickness of the saturated layer up to wet front L, while the driving head is proportional to (L+d), d being the depth of detention. At the beginning of the process when L is either less than d or of comparable magnitude with d, the resistance to flow is rather less and hence water enters rapidly. This is one of the reasons why f is large at the beginning of the process.



Variation of infiltration capacity with time

Soil Moisture: If a soil is completely dry at the beginning of rain there is a strong capillary attraction for moisture in the subsurface layers that acts in the same direction as gravity and gives high initial value of infiltration. As water percolates down, the surfaces layers become semi-saturated and the capillary forces diminish and hence f also reduces.

Compaction: The clay surfaced soils are compacted even by the impact of rain drops which reduce. This effect is negligible on sandy soils. Compaction not only reduces the porosity but also the pore sizes. When the compaction is artificial due to man-made effects the initial infiltration capacity is very low and it is further reduced during the storm. Overgrazed pastures, playgrounds, and areas subjected to heavy vehicular traffic will have less infiltration capacities.

Surface cover conditions: The nature of surface cover has also an important influence on the infiltration. The presence of a dense cover of vegetation on the surface increases f. The vegetative cover retards the movement of overland flow and causes high depths of detention. It reduces the effect of rain drop compaction.
Surfaces covered with snow, and paved urban areas will obviously have very low or zero infiltration capacity.

Temperature : The effect of temperature on infiltration is explained through viscosity. The flow through soil pores is by and large laminar for which the resistances is directly proportional to viscosity. At high temperatures since viscosity of water is low, high infiltration capacities are expected. In winter months when low temperatures prevail, the infiltration capacity is also low. This is one of the factors responsible for seasonal variations in f.

Others: The other factors which may marginally affect the infiltration capacity include the entrapped air in the pores, the quality of water, freezing, etc. The presence of entrapped air increases the resistance to flow and therefore reduces infiltration. The quality of water, particularly its turbidity in terms of clay an colloids it contains, and the salts it contains such as fertilizer residues from alkaline soils or other sources, may have diminishing influence on infiltration capacity.

Annual and seasonal changes in infiltration capacity:

The infiltration capacity at a given location changes both seasonally and annually. Many factors influencing infiltration which are discussed earlier are not constant throughout the year. The seasonal variation in them, in turn, produces the seasonal variation in f. For example, soil moisture, temperature, soil cover produce high variability in f. Usually f will have higher values in summer because of low soil moisture and high temperatures.

The annual changes in f are mainly because of changes in land use pattern. Except for major changes in land use the variation occurs very slowly and it may not be noticeable. However, when an entire catchment or a large portion of it is subjected to sudden deforestation or intense agriculture the variation is very marked.

1. Infiltration depth in 1st 30 mins

$$F = \int_0^{0.5}\left(5+15e^{-2t}\right)dt = 5t - \frac{15e^{-2t}}{2}\Bigg]_0^{0.5} = \left[5t - 7.5e^{-2t}\right]_0^{0.5}$$

$$= 2.5 - 2.76 - 0 + 7.5 = 7.241 \text{ mm}$$

2. Infiltration depth in 2nd 30 mins

$$F = \int_{0.5}^{1.0}\left(5+15e^{-2t}\right)dt = 5t - 7.5e^{-2t}\Big]_{0.5}^{1.0} = 5 - 1.015 = 2.5 + 2.76$$

$$= 4.245 \text{ mm}$$

04(b).

Sol:

The resisting force, F = f(L, V, μ, ρ, K)

n = 5 + 1 = 6

no. of fundamental dimensions/ repeating variables

m = 3 (Say L, V, ρ are repeating variables)

π terms = n – m = 6 – 3 = 3

Dimensions

$F = MLT^{-2}$

$L = L$

$V = LT^{-1}$

$\mu = ML^{-1}T^{-1}$

$\rho = ML^{-3}$

$K = ML^{-1}T^{-2}$

$$\pi_1 = L^{a_1}V^{b_1}\rho^{c_1}.F$$

$$\pi_2 = L^{a_2}V^{b_2}\rho^{c_2}.\mu$$

$$\pi_3 = L^{a_3}V^{b_3}\rho^{c_3}.K$$

π_1 term:

$$\pi_1 = L^{a_1}V^{b_1}\rho^{c_1}.F$$

$$M^\circ L^\circ T^\circ = L^{a_1}\left(LT^{-1}\right)^{b_1}(ML^{-3})^{c_1}.MLT^{-2}$$

$$M^\circ L^\circ T^\circ = M^{c_1+1}L^{a_1+b_1-3c_1+1}T^{-b_1-2}$$

∴ $c_1 + 1 = 0 \Rightarrow c_1 = -1$

$-b_1 - 2 = 0 \Rightarrow b_1 = -2$

$a_1 + b_1 - 3c_1 + 1 = 0$

$a_1 - 2 + 3 + 1 = 0$

$a_1 = -2$

substituting values of a, b, c in π

$\pi_1 = L^{-2}.V^{-2}.\rho^{-1}.F$

$$\boxed{\pi_1 = \frac{F}{\rho V^2 L^2}}$$

π_2 Term:

$$\pi_2 = L^{a_2}.V^{b_2}\rho^{c_2}.\mu$$

$$M^\circ L^\circ T^\circ = L^{a_2}\left(LT^{-1}\right)^{b_2}\left(ML^{-3}\right)^{c_2}.ML^{-1}T^{-1}$$

$$M^\circ L^\circ T^\circ = M^{c_2+1}L^{a_2+b_2-3c_2-1}T^{-b_2-1}$$

$c_2 + 1 = 0$

$-b_2 - 1 = 0$

$b_2 = -1$

$a_2 + b_2 - 3c_2 - 1 = 0$

$a_2 - 1 + 3 - 1 = 0$

$a_2 = -1$

By substituting $\pi_2 = L^{-1}V^{-1}\rho^{-1}\mu$

$$\pi_2 = \frac{\mu}{\rho VL} \text{ or } \boxed{\pi_2 = \frac{\rho VL}{\mu} = Re}$$

π_3 term:

$$\pi_3 = L^{a_3}V^{a_b}\rho^{c_3}.k$$

$$M^\circ L^\circ T^\circ = L^{a_3}\left(LT^{-1}\right)^{b_3}\left(ML^{-3}\right)^{c_3}.ML^{-1}T^{-2}$$

$$M^\circ L^\circ T^\circ = M^{c_3+1}L^{a_3+b_3-3c_3-1}T^{-b_3-2}$$

$c_3 + 1 = 0$

$c_3 = -1$

$-b_3 - 2 = 0$

$b_3 = -2$

$a_3 + b_3 - 3c_3 - 1 = 0$

$a_3 - 2 + 3 - 1 = 0$

$a_3 = 0$

by substituting $\pi_3 = L^\circ V^{-2}\rho^{-}1.K$

$$\boxed{\pi_3 = \frac{K}{\rho V^2}}$$

Functional relationship is

$$f_1\left(\frac{F}{\rho V^2 L^2}, Re, \frac{K}{\rho V^2}\right) = 0$$

$$\pi_1 = \phi(\pi_2, \pi_3)$$

$$\frac{F}{\rho V^2 L} = \phi\left(Re, \frac{K}{\rho V^2}\right)$$

04(c) (i).

Sol: σ for water = 0.073 N/m,

Clean glass plate, $\theta = 0$

$\gamma = 9.81 \text{ kN/m}^3$

$$\text{So, } h = \frac{2 \times 0.073}{1.2 \times 10^{-3} \times 9.81 \times 10^3}$$

$= 1.24 \times 10^{-2}$ m

= 1.24 cm = 12.4 mm

04(c). (ii)

Sol: Given:

$H_G = 245$ m; $h_f = 12$ m;

$N_s = 0.138$; $N = 39.27$ rad/s

No.of jets per wheel = 2;

$C_V = 0.97$;

$(\eta_{overall})_{max} = 81.5\%$

$\beta = 180° - 165° = 15°$ and k = 0.85;

Net head, H = 245 – 12 = 233 m

The dimensionless specific speed, N_s is given by

(i) $$N_S = \frac{N\sqrt{P/\rho}}{(gH)^{5/4}}$$

where P is power produced per wheel per jet.

$$0.138 = \frac{39.27\sqrt{P}}{\sqrt{10^3}(9.81 \times 233)^{5/4}}$$

$$\sqrt{P} = \frac{0.138\sqrt{10^3} \times (9.81 \times 233)^{5/4}}{39.27}$$

= 1,756.3 W

P = 3.0846 MW ⇒ Power per wheel per jet

$$\text{No.of wheels} = \frac{30\,\text{MW}}{2 \times 3.084\,\text{MW}} = 4.865$$

= 5 Wheels.

(ii) $\eta_O = \frac{P_{Total}}{\rho g Q_{Total.} H}$

$$Q_{Total} = \frac{P_{Total}}{\eta_o \times \rho g H} = \frac{30 \times 10^6}{0.815 \times 10^3 \times 9.81 \times 233}$$

= 16.104 m^3/s

Discharge per wheel per jet

$$= \frac{16.104}{5 \times 2} = 1.6104\,\text{m}^3/\text{s}$$

$$= C_V\sqrt{2gH} \times \frac{\pi}{4} d_j^2$$

$$d_j^2 = \frac{1.6014 \times 4}{\pi \times C_v \sqrt{2gH}} = \frac{1.6104 \times 4}{\pi \times 0.97 \times \sqrt{2 \times 9.81 \times 235}}$$

= 0.0313

⇒ d_j = 0.1768 or 17.68 cm

Jet velocity, $V_1 = C_V\sqrt{2gH}$

$$= 0.97\sqrt{2 \times 9.81 \times 233}$$

= 65.58 m/s

For maximum efficiency, for Pelton wheel,

$$\frac{u}{V_1} = \frac{1}{2}$$

So, $u = \frac{65.58}{2}$ = 32.79 m/s = π DN where N is in rps or, $D = \frac{32.79}{\pi \times 6.25}$

$D = 1.67$ m

(iii) Runner power = $[(V_1 - u)(1 + k\cos\beta)u]\rho Q$

$$\eta_h = \frac{[(V_1 - u)(1 + k\cos\beta)u]\rho Q}{\rho g Q H}$$

$$= \frac{(65.58 - 32.79)(1 + 0.85\cos 15^\circ) \times 32.79}{9.81 \times 233}$$

= 0.8566

= 85.66 %

05(a).

Sol: **Permanent way for straight BG track on embankment:** The combination of rails, sleepers, ballast and sub grade is called the railway track or permanent way. Sometimes temporary tracks are also laid for conveyance of earth and materials during construction works. The name permanent way is given to distinguish the final layout of track from these temporary tracks.

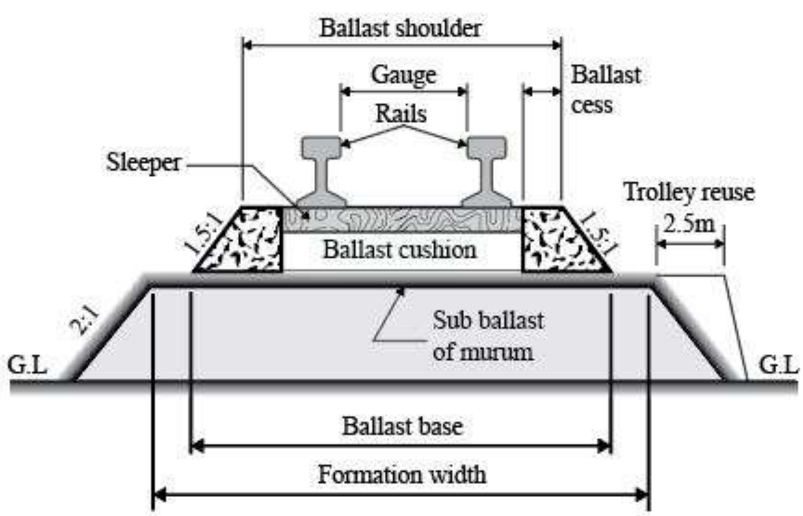


Fig: Typical c/s of a permanent way on embankment

Breathing length of LWR :A long welded rail is the rail whose central part does not undergo any longitudinal movement with temperature variation the minimum length of rail to function as LWR depends on range of temperature, c/s area of rail, resistance offered by sleeper ballast etc.

A long welded rail continuous to expand at its ends for a particular length till adequate resistance forces equals to thermal force. There is no movement of rail beyond this point. This portion of rail, which undergoes movement due to temperature variation and absence of resisting force is called breathing length.

(ii) Let 'L' be length of rail

Strain prevented = αt

$= 12 \times 10^{-6} \times 40$

$\varepsilon = 4.8 \times 10^{-4}$

Stress developed = εE

$= 4.8 \times 10^{-4} \times 2 \times 10^{6} = 960$ kg/cm^2

Force developed = 960 × 66.15 = 63504 kg

Resisting force = 350 kg/sleeper/rail

$\therefore$ no. of sleepers required $= \frac{63504}{350} = 181.44 \approx 182$

Sleeper spacing = 50 cm

$\therefore$ minimum length of LWR = (182 – 1) × 0.5 = 90.5 m

05(b).

Sol:

Effective length at 4 m depth

L' = L + z = 3 m + 4 m

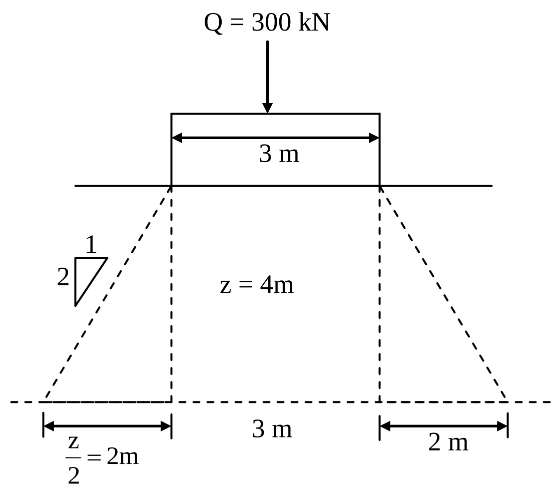
= 7 m

Effective width = B' = B + z = 2 + 4 m = 6 m

Increase in vertical stress $= \frac{Q}{B'L'}$

$= \frac{300}{7 \times 6} \text{kN/m}^2$

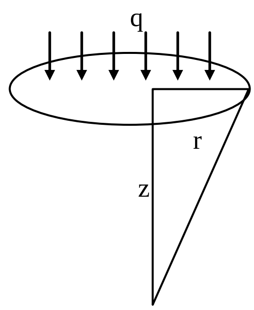
= 7.143 kN/m^2



(b) For a circular loaded area

σ_z (vertical stress) below centre of footing for q kN/m^2 load intensity

$$\sigma_z = q\left[1-\left(\frac{1}{1+\left(\frac{r}{z}\right)^2}\right)^{3/2}\right]$$



$$\Rightarrow \sigma_z = \left(\frac{Q}{\pi r^2}\right)\left[1-\left(\frac{1}{1+\left(\frac{r}{z}\right)^2}\right)^{3/2}\right]$$

$$\Rightarrow \left[1-\frac{\pi r^2\sigma_z}{Q}\right] = \left[\frac{1}{1+\left(\frac{r}{z}\right)^2}\right]^{3/2}$$

Substituting Q = 300 kN, σ_z = 7.143 kN/m^2, z = 4 m and applying trail and error method, we get r = 1.80 m

$\Rightarrow$ Diameter = 2r = 3.6 m

05(c).

Sol: The readings are setout in the table below. Inverted staff readings are taken as negative.

Backsight	Intersight	Foresight	Ht of collimation	R.L.	Distance	Remark
0.765			42.584	41.819	0	A
	1.064			41.520	20	
	[0.616]			43.200	40	
	1.835			40.749	60	
2.356		1.524	43.416	41.060	80	
	1.378			42.038	100	
	[2.063]			45.479	120	
	0.677			42.739	140	
		2.027		41.389	160	B
Σ 3.121	Σ 2.275	Σ 3.551				

Check: Σ B.S - Σ F.S = 3.121 – 3.551

= – 0.430

Last R.L – 1st R.L = 41.389 – 41.819

= – 0.430

Gradient from A to B = $\frac{0.430}{160} = 1 \text{ in } 372.09$

05(d).

Sol: From unconfined compressive strength , $q_u = 100$ kN/m^2

$$q_u = 2C_u \tan\alpha_f = 100 \text{ kN/m}^2$$

From triaxial test:

$\sigma_3 = \sigma_c = 50$ kN/m^2

$\sigma_d = 200$ kN/m^2

$\sigma_1 = \sigma_c + \sigma_d = 250$ kN/m^2

$\sigma_1 = \sigma_3 \tan^2 \alpha_f + 2C_u \tan \alpha_f$

$250 = 50 \tan^2 \alpha_f + 100$

$\tan^2\alpha_f = 3$

$\alpha_f = 60^o$

$45 + \frac{\phi}{2} = 60^o$

$\Rightarrow \phi_u = 30^o$

$\sigma_{5m} = 5\gamma = 5 \times 18 = 90$ kN/m^2

$q_u = 2C_u \tan \alpha_f = 100$

$\Rightarrow 2 \times C_u \times \sqrt{3} = 100$

$\Rightarrow C_u = 28.86$ kPa

$S = C_u + \sigma \tan\phi_u$

$S = 28.86 + 90 \times \tan 30^o$

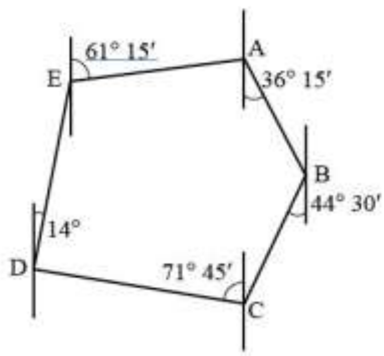
$S = 80.83$ kN/m^2

05(e).

Sol: A rough sketch of the traverse is shown in Fig. below. It is observed that the bearings of AB and BA are numerically equal and the quadrants are reversed, which are correct. Stations A and B are thus not affected by local attraction.

Taking the bearing of BA to be correct, the bearing of BC is also correct. The bearing of CB should be 44^0 30'. The local attraction at station C = 1^0 30', the needle having rotated clockwise. This correction is applied to the bearing of CD. Therefore,

Bearing of CD = 71^0 45' - 1^0 30' = 70^0 15'



The bearing of DC should be equal to S70^0 15'E. Local attraction at D = 00^0 45', the needle having rotated counter clockwise. Therefore

Bearing of DE = 14^0 00' + 00^0 45' = 14^0 45'

Bearing of ED = S14^0 45'W

The error at E due to local attraction = 00^0 15', the needle having rotated counterclockwise. Therefore,

Bearing of EA = 61^0 15' - 00^0 15' = 61^0 00'

This is correct as station A is not affected by local attraction. The corrected bearings can be listed as in table below

Table Corrected bearings

Line	Fore bearing	Back bearing
AB	S36^0 15'E	N36^0 15'W
BC	S44^0 15'W	N44^0 30'E
CD	S70^0 15'W	S70^0 15'E
DA	N14^0 45'E	S14^0 45'W
EA	N61^0 00'E	S61^0 00'W

06(a).

Sol: At 2.5 mm penetration:

Standard load = 1370 kg;

Standard pressure = 70 kg/cm

At 5.0 mm penetration

Standard load = 2055 kg

Standard pressure = 105 kg/cm

CBR value @ 2.5 mm penetration

$$= \frac{3.06}{70} \times 100 = 4.37\%$$

A 5.0 mm penetration $= \frac{4.08}{105} \times 100 = 3.88\%$

$\therefore$ CBR value used for the pavement design is maximum of above= 4.37%

(i) Thickness of pavement above soil subgrade

$$= \sqrt{\frac{1.75P}{CBR(\%)} - \frac{p}{P\pi}}$$

P = 4085 kg; b = 7 kg/cm^2

$$= \sqrt{\frac{1.75 \times 4085}{4.37} - \frac{4085}{7 \times \pi}}$$

= 38.08 cm $\simeq$ 38.1 cm

(ii) Thickness of the pavement above compacted soil with CBR = 6%

$$= \sqrt{\frac{1.75P}{CBR\ \%} - \frac{p}{P\pi}}$$

$$= \sqrt{\frac{1.75 \times 4085}{6} - \frac{4085}{7\pi}}$$

= 31.7 cm

$\therefore$ Thickness of compacted soil = 38.1 – 31.7 = 6.4 cm

(iii) Thickness of pavement above poorly graded gravel with CBR of 15%

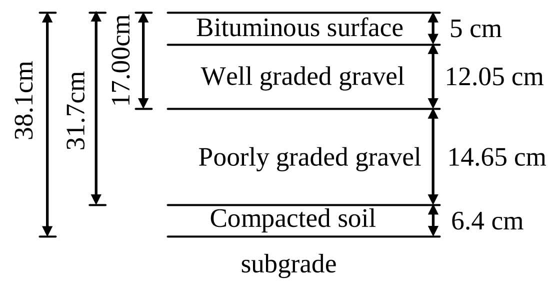
$$= \sqrt{\frac{1.75 \times 4085}{15} - \frac{4085}{7\pi}}$$

= 17.05 cm

∴ Thickness of poorly graded gravel = 31.7 – 17.05 = 14.65 cm

(iv) Thickness of well graded gravel

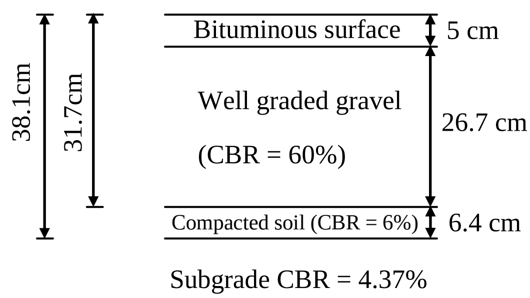
= 17.05 – 5 = 12.05 cm



II. If poorly graded gravel is not used in the design, then:

Thickness of well graded gravel

= 31.7 – 5 = 26.7 cm



Limitations of CBR:

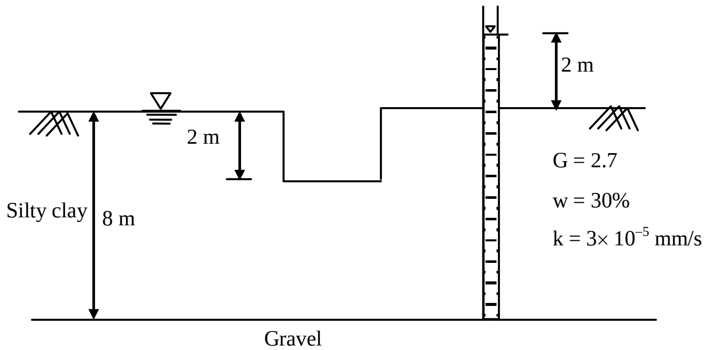
From the above two cases it can be concluded that despite using different materials (higher quality)the thickness of pavement remains same = 38.1 cm. ie. Thickness of above compacted soil is 31.7 cm even after replacing well graded gravel with poorly graded gravel.

Hence, the quality of materials does not affect thickness of pavement in CBR method which is a major draw back.

Also, from the above two design, first proposal is more economical as thickness of well graded gravel is partially replaced by inferior quality material at lower layer.

06(b)

Sol:



(a) $S\,e = w\,G$

$e = 0.3 \times 2.7 = 0.81$

$k = 3 \times 10^{-5} \times 10^{-3} = 3 \times 10^{-8}$ m/s

Critical hydraulic gradient

$$i = \frac{G-1}{1+e} = \frac{2.7-1}{1+0.81} = 0.94$$

$$Q = k\frac{h}{z}.A = \left(3\times10^{-8}\right)\times\frac{2}{8}\times1$$

$= 0.75 \times 10^{-8}$ m^3/s/m^2 = 0.237 m^3/year/m^2

(b) Factor of Safety:

(i) At the end of excavation:

$$FOS = \frac{\text{Downward force on the gravel layer}}{\text{Upward force on the Gravel layer due to artesian pressure}}$$

$$= \frac{\gamma_{sat}(8-2)}{\gamma_w \times 10}$$

$$\gamma_{sat} = \frac{\gamma_w(G+e)}{1+e} = \frac{9.81(2.7+0.81)}{1+0.81}$$

$\gamma_{sat} = 19.02$ kN/m^3

$$FOS = \frac{19.02\times6}{9.81\times10} = 1.16$$

(ii) After Construction:

$$FOS = \frac{(19.02\times6)+100}{9.81\times10} = 2.18$$

06(c).

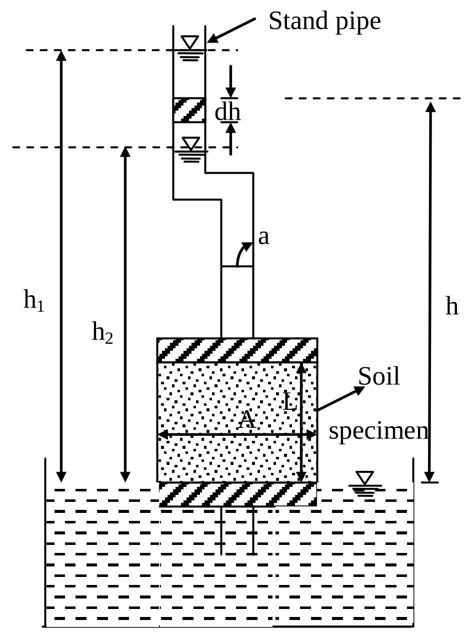
Sol:

(i) In variable or falling head test, water level in stand pipe falls from h_1 to h_2 in 't' time

Let at any intermediate time, level be 'h' and it falls by 'dh' in time 'dt'

Discharge, q = KiA (Darcy law)

$$= K\frac{h}{L}A$$



Volume of water collected in 'dt'

q. dt = a(–dh)

$$K\frac{h}{L}Adt = a(-dh)$$

$$\Rightarrow K = \frac{\frac{aL}{A}\int_{h_2}^{h_1}\frac{dh}{h}}{\int_{t_1}^{t_2}dt}$$

$$K = \frac{aL}{At}\ell n\frac{h_1}{h_2}$$

a = cross sectional area of stand pipe

A = cross sectional area of soil sample

L = Length of soil sample

(ii) Volume of sample = Area × Length

$$= 100 \times 15 = 1500 \text{ cm}^3$$

Dry unit weight or density = $\gamma_d = \frac{\text{Mass}}{\text{Volume}} = \frac{1.95}{1500}\times 1000$ g/cc = 1.3 g/cc

$$\gamma_d = \frac{G\gamma_w}{1+e}$$

$$\Rightarrow e = \frac{2.65}{1.3} - 1 = 1.038$$

at e = 1.038

$$K_1 = \frac{aL}{At}\ell n\left(\frac{h_1}{h_2}\right) = \frac{1\times 15}{100\times 8}\ell n\left(\frac{120}{40}\right)$$

= 0.0206 cm/min

$\Rightarrow K_1 = 3.43 \times 10^{-4}$ cm/s

We know that $K \propto \dfrac{e^3}{1+e}$

$$\frac{K_2}{K_1} = \left(\frac{e_2}{e_1}\right)^3 \left(\frac{1+e_1}{1+e_2}\right)$$

At void ratio (e_2) = 0.7, let $K = K_2$

$$\Rightarrow K_2 = 3.43 \times 10^{-4} \times \left(\frac{0.7}{1.038}\right)^3 \times \frac{(1+1.038)}{(1+0.7)}$$

$= 1.577 \times 10^{-4}$ cm/s

07(a).

Sol: **Sleeper density:** The number of sleepers per rail length is called sleeper density.

The spacing of sleepers is generally indicated by a formula (n+x) where n is the length of the rail in meter and x is a number 4, 5, 6 or 7 depending upon importance.

The sleeper density varies according to the following factors.

1. Speed and axle load
2. Type of rail section
3. Type of sleepers
4. Type and depth of ballast
5. Bearing area of sleeper on ballast
6. Nature of formation

Given: BG railway curved track

$e = 12.5$ cm

$V_{max} = 95$ kmph

$D^o = 4^o$

As per Indian Railway, The length of transition curve is maximum of following three conditions

(1) Based on arbitrary gradient 1 in 720

$L = 7.20e$

$L = 7.20 \times 12.5 \Rightarrow L = 90$ m

(2) Based on rate of change of cant deficiency

$L = 0.073\ DV_{max}$

D = cant deficiency in cm

D = 7.5 cm [Assumed for BG track]

$L = 0.073 \times 7.5 \times 95$

L = 52 m

(3) Based on rate of change of super elevation

$L = 0.073eV_{max}$

$L = 0.073 \times 12.5 \times 95$

L = 86.68 m

Take maximum of three

L = 90 m

To calculate offsets at every 15 m interval

$$R = \frac{1720}{D^o}$$

Where, D^o = Degree of curve

$D^o = 4^o$

$$R = \frac{1720}{4} = 430\ m$$

Cubic parabola equation for transition curve

$$y = \frac{x^3}{6RL}$$

Taking offsets at 15m interval

$$y_{15} = \frac{15^3}{6 \times 430 \times 90} = 0.0145\ m$$

$$y_{30} = \frac{30^3}{6 \times 430 \times 90} = 0.116\ m$$

$$y_{45} = \frac{45^3}{6 \times 430 \times 90} = 0.392\ m$$

$$y_{60} = \frac{60^3}{6 \times 430 \times 90} = 0.93\ m$$

$$y_{75} = \frac{75^3}{6\times 430\times 90} = 1.817 \text{ m}$$

$$y_{90} = \frac{90^3}{6\times 430\times 90} = 3.14 \text{ m}$$

Shift of the circular curve

$$S = \frac{L^2}{24R}$$

$$S = \frac{90^2}{24\times 430}$$

S = 0.785 m

07(b). (i)

Sol: Volume of soil, V = 800 m^3

Void ratio, e = 0.8

Total volume of solids, $V_s = \left(\frac{V}{1+e}\right)$

$$= \frac{800}{1.8} = 444.44 \text{ m}^3$$

Weight of solids, $W_s = V_s \times \gamma_s$

= 444.44 × 2.7 × 9.81 = 11772 kN

Initial water content, $w_1 = \frac{Se}{G_s} = \frac{0.6\times 0.8}{2.7} = 0.178$

Initial weight of water, $W_{w1} = w_1 W_s$ = 0.178 × 11772 = 2095.42 kN

We can add more water till soil gets fully saturated i.e. S = 1 so that total volume will not change.

At S = 1 ,Final water content, $w_2 = \frac{eS}{G_s} = \frac{0.8\times 1}{2.7} = 0.2963$

Final weight of water, $W_{w2} = w_2 W_s$ = 0.2963 × 11772 = 3488 kN

Amount of water added = $W_{w1} - W_{w2}$

$$= 3488 - 2095.42 \simeq 1392.6 \text{ kN}$$

$$= \frac{1392.6}{9.81} \text{kg} = 142 \text{ kg}$$

Bulk unit weight, $\gamma_t = \frac{W}{V} = \frac{W_s + W_{w2}}{V}$

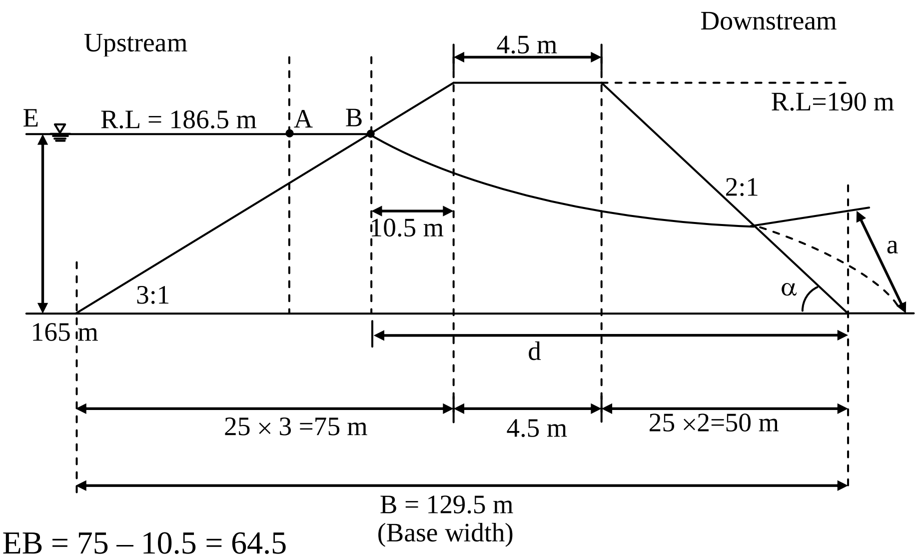
$$= \frac{11772 + 3488}{800} = 19.075 \text{ kN/m}^3$$

or $\gamma_t = \left(\frac{G_s + e}{1 + e}\right)\gamma_w = \left(\frac{2.68 + 0.8}{1.8}\right) 9.81$

$$= 19 \text{ kN/m}^3$$

07(b). (ii)

Sol:



EB = 75 – 10.5 = 64.5

AB = 0.3 EB

= 19.35 m

d = 10.5 + 4.5 + 50 = 65 m

H = 186.5 – 165 = 21.5 m

$$\tan\alpha = \frac{1}{2}$$

$\alpha = 26.54^o < 30^o$

$$a = \frac{d}{\cos\alpha} - \sqrt{\frac{d^2}{\cos^2\alpha} - \frac{H^2}{\sin^2\alpha}}$$ [no drainage filter provided]

$$a = \frac{65}{\cos 26.54^o} - \sqrt{\frac{65^2}{\cos^2 26.54} - \frac{21.5^2}{\sin^2 26.54}}$$

$$= 72.66 - \sqrt{5279 - 2315} = 18.22 \text{ m}$$

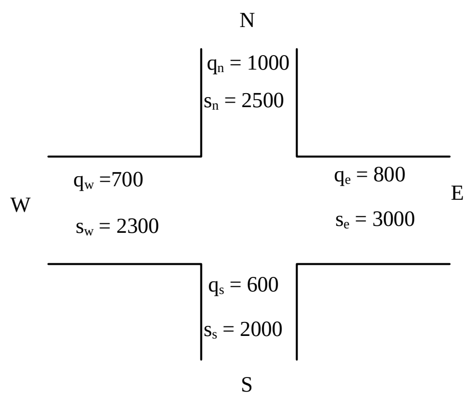
Discharge q = K.S = K (a sin α tan α)

$$= (4.8 \times 10^{-4} \times 10^{-2})\ 18.22 \sin 26.54 \times \tan 26.54$$

$$= 1.952 \times 10^{-5}\ m^3/s/m \text{ length of dam}$$

07(c). (i)

Sol:



North: $y_n = \frac{q_n}{s_n} = \frac{1000}{2500} = 0.4$

South: $y_s = \frac{q_s}{s_s} = \frac{600}{2000} = 0.3$

∴ Maximum value of 'y' for North-South = 0.4

East: $y_e = \frac{800}{3000} = 0.267$

West: $y_w = \frac{700}{2300} = 0.304$

∴ Maximum value for east – west = 0.304

$y = y_1 + y_2$

$= 0.4 + 0.304 = 0.704$

Lost time = 2n + R

L = 2(2) + 10

= 14 sec

∴ Optimum cycle time $= \frac{1.5L + 5}{1 - y}$

$$C_o = \frac{(1.5 \times 14) + 5}{1 - 0.704}$$

$$= 87.83 \text{ sec} \simeq 88 \text{ sec}$$

∴ Effective green time per cycle = $C_o - L$

$G_{eff} = 88 - 14 = 74$ sec

Effective green time in N-S direction $= \dfrac{y_1}{y} \times G_{eff}$

$$= \frac{0.4}{0.704} \times 74 = 42.04 \text{ sec} \simeq 42 \text{ sec}$$

Effective green time in E-W direction $= \dfrac{y_2}{y} \times G_{eff}$

$$= \frac{0.304}{0.704} \times 7.4 = 31.95 \simeq 32 \text{ sec}$$

All red time for pedestrian crossing = 10 sec

Providing 2 sec, amber time for clearance in each face, total cycle time

= 42 + 32 + 10 + 2(2) = 88 sec

07(c). (ii)

Sol: Basic runway length = 2500 m

(i) Correction for elevation:

As per ICAO; correction for elevation is 7% increase for every 300 m rise in elevation above mean sea level.

∴ Correction $= \dfrac{7}{100} \times \dfrac{400}{300} \times 2500 = 233.33\,\text{m}$

∴ Corrected length = 2500 + 233.33 = 2733.33 m

(ii) Correction for temperature:

As per ICAO, basic runway length corrected for elevation should be increased @ 1% for every 1°C in airport reference temperature.

Standard atmospheric temperature at given elevation

= 15 – 0.0065 × 400 = 12.4°C

Rise in temperature = 30 – 12.4 = 17.6°C

∴ Correction for temperature = $2733.33 \times \dfrac{1}{100} \times 17.6$

= 481.07 m

∴ Corrected length = 2733.33 + 481.07 = 3214.39 m ≃ 3214.4 m

(iii) Correction for gradient:

Effective gradient = $\dfrac{\text{Max.differance in elevation between highest and lowest point}}{\text{runway length}}$

$$= \frac{402.5 - 398.2}{2500} \times 100$$

= 0.172%

Correction for gradient = 20% for every 1% rise in effective gradient

$$= \frac{20}{100} \times 3214.4 \times 0.172$$

= 110.57 m

∴ Corrected length = 3214.4 + 110.57

= 3324.9 ≃ 3325 m

08(a). (i)

Sol: **(a) Observations on bright portion:**

$\theta = 60^0$, D = 8500 m, r = 0.5 m

$$\beta = 206265 \frac{r \cos^2 \theta/2}{D}$$

$$= 206265 \frac{0.5 \times \cos^2(60/2)}{8500}$$

β = 9.1 second

(b) Observations on the bright side:

$$\beta = 206265 \frac{r \cos \theta/2}{D}$$

$$= 206265 \times 0.5 \frac{\cos(60/2)}{8500}$$

β = 10.51 seconds

08(a). (ii)

Sol: **Tunnelling in rock:**

Tunnelling in rock comes into picture when tunnelling is done in hilly area.

Methods of tunneling in rock

1. Drift method
2. Heading and bench method
3. Full face method

Drift method: It consists in driving small sized heading, centrally at top or bottom of the face, which is later enlarged by widening and benching. The top drift method is popular and the main operations involved are as follows.

a. Boring or blasting a top centre heading of drift, end to end.
b. Widening and enlarging
c. Benching in stages

Disadvantages:

- The enlargement work cannot be started until the centre hold is constructed for the full length, and that as the enlarging and benching work commences, mucking tracks have to be shifted frequently from bench to bench.
- This method is extremely costly and is generally recommended for ground conditions which are difficult to solve.

Advantages:

- Elaborate supporting platforms are not necessary for drilling operations and during heading work, mucking work goes on undisturbed.
- The main feature of this method is that a small preliminary section for the full length has been accurately driven, which will considerably economize the excavation work.
- This method also provides good ventilation to the workers.

Heading and bench method:

This method involves the driving of the top portion in advance of the bottom portion. If the rock is hard and self supporting, the top heading advances ahead by ne round over the bottom, so that heading and benching follow each other. But in case the rock is badly broken, the top heading will need support, and the bench will afford the platform for this. In such cases, the heading is excavated and supported to the full length or part length of the tunnel before benching is started. It may be noted that the heading is always ahead of the benching.

Full face method:

This method is conveniently adopted for tunnels of small cross sections through stable and self supporting rocks. The full face is opened out once for all the driven. As the full section has to be tackled, extra units of tunneling equipment will become necessary. This method has become popular because of *Tunnel Boring Machines* (TBM).

Advantages:

- The amount of equipment required is minimum and it leads to simplicity in operation.
- It minimizes the total magnitude of ground disturbance and settlement.
- The work is easily and speedily completed.
- It provides a definite advantage in sensitive ground conditions where multiple phase excavation could generate unacceptable ground pressure and settlement effects
- The mucking trucks could be laid once for all on the tunnel floor and progressively extended
- This method is suitable for face diameters less than 6m and face areas less than $19m^2$.

MSL - Mean Sea Level : The average height of the sea measured over 18.61 years.

Mean Tide Level (M.T.L.) is the average value of all the heights of high and low waters over a period. It must not be confused with *Mean Sea Level* (M.S.L.), which is the average level taken up by the sea. The two values will only agree if the tidal curve is perfectly symmetrical. Mean Tide Level is obtained in the field more easily than Mean Sea Level, and from fewer observations. For this reason, it is sometimes used in calculations instead of M.S.L. Either term is replaced at times by the expression Mean Level (M.L.)

When tides are mainly semi – diurnal in character the values of Mean Higher High Water (M.H.H.W) and Mean Lower Low Water (M.L.L.W). are often referred to instead of M.H.W.S and M.L.W.S. Mean Higher High Water(M.H.H.W) is the mean of higher of the two daily high waters experienced over a period. Mean Lower Low Water (M.L.L.W). is the mean of the lower of the two daily low waters experienced over a period of time.

Lowest Astronomical Tide (L.A.T.) is the lowest tidal level which can occur under average meteorological conditions and under any combination of astronomical conditions.

Highest Astronomical Tide (H.A.T.) is the highest tidal level under average meteorological conditions and under any combination of astronomical conditions.

8(b). (i)

Sol: $C_v = \frac{K}{\gamma_w m_v} = \frac{5\times10^{-8}}{9.81\times10^{-6}\times125\times10^{-2}}$

$= 4.077 \times 10^{-3}$ cm^2/sec

$T_{20} = \frac{\pi}{4}\left(\frac{U}{100}\right)^2 = \frac{\pi}{4}\times0.2^2 = 0.0314$

$T_{80} = 1.781 - 0.933 \log_{10}(100 - U)$

$= 1.781 - 0.933 \log_{10}(100 - 80)$

$= 0.567$

d = H = 3m (single drainage)

= 300 cm

t_{20} = (time for 20% consolidation)

$= \frac{d^2T_{20}}{C_v} = \frac{(300)^2\times0.0314}{4.077\times10^{-3}\times60\times60}$ hrs

= 192.54 hrs

t_{80} = (time for 80% consolidation)

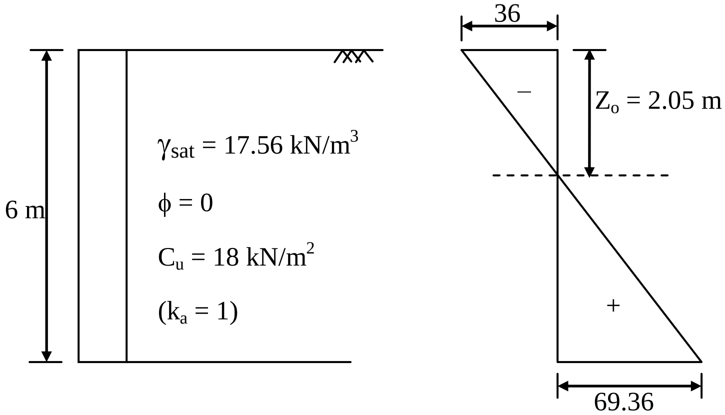
$= \frac{d^2T_{80}}{C_v} = \frac{(300)^2\times0.567}{4.077\times10^{-3}\times60\times60}$ hrs

= 3476.82 hrs

Reading in stopwatch = 3476.82 – 192.54 = 3284.28 hrs

8(b). (ii)

Sol:



At depth z = 0

Active pressure, $p_a = -2C\sqrt{k_a} = -36$ kN/m²

At z = 6 m

$p_a = k_a\gamma H - 2C\sqrt{k_a} = (17.56 \times 6) - (2 \times 18) = 69.36$ kN/m²

(a) Depth of Tensile crack $(Z_o) = \dfrac{2C}{\gamma\sqrt{k_a}} = \dfrac{2\times18}{17.56} = 2.05$ m

(b) Active Force before tensile crack

$$P_a = \frac{1}{2}k_a\gamma H^2 - 2CH\sqrt{k_a}$$

$$= \frac{1}{2}\times17.56\times6^2 - 2\times18\times6 = 100 \text{ kN/m}$$

(c) Total active Force after occurrence of tensile crack

$$P_a = \frac{1}{2}\left(k_a\gamma H - 2C\sqrt{k_a}\right)\left(H - Z_o\right)$$

$$= \frac{1}{2}\left(17.56\times6 - 2\times18\right)\left(6 - 2.05\right) = 137 \text{ kN/m}$$

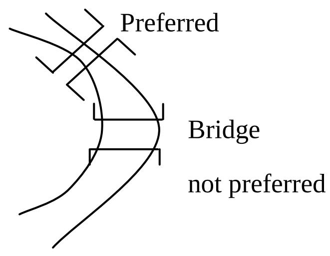
08(c).

Sol: Factors controlling highway Alignment on hilly areas:

General considerations

(1) Obligatory Points: There are control points through which alignment has to pass and not to pass.

- The road bridge across a river can be located only at a place where the river has a straight and permanent path, away from bends, where good foundation start is available.
- Alignment should pass along a hill side pass (if possible) so that a tunnel or heavy cutting is avoided.



(2) Traffic: Origin and destination studies are conducted not preferred and "desire lines" are drawn.

(3) Geometric design: Gradient, Radius, Sight distance etc.,

(4) Economy: Balance in cutting and filling.

(5) Other considerations: Drainage, hydrology, political and topography.

Special considerations:

(6) Stability: While aligning hill roads, special care should be taken to align the road along the side of the hill which is stable. A common problem in hill roads is that of land slides. The cutting an d filling of earth to construct roads on hill-side causes steepening of existing slopes and affect its stability.

(7) Drainage: Numerous hill-side drains should be provided for adequate drainage facility across the road. But the cross drainage structure being costly, attempts should be made to align the road in such a way where the number of cross drainage structures are minimum.

(8) Geometric standards of hill roads: Different sets of geometric standards are followed in hill roads with reference to gradient, curves and speed and they consequently influence the sight distance, radius of curve and other related features. The route should enable the ruling gradient to be attained in most of the length, minimising steep gradients, hair pin bands and needles rise and fall.

(9) Resisting length: The resisting length of a road may be calculated from the total work to be done to move the loads along the route taking the horizontal length, the actual difference in levels between the two station and the sum of ineffective rise and fall in excess of floating gradient. In brief, the resisting length of the alignment should kept as low as possible. Thus the ineffective rise and executive fall should be kept minimum.

Transition curve is to connect a straight road with circular curve.

The objectives of providing transition curve :

(i) To introduce gradually the centrifugal force between the Tangent point and beginning of circular curve, avoiding sudden jerk on the vehicle.

(ii) To enable the driver turn the steering gradually for comfort and security.

(iii) It introduces super elevation and extra widening on curves, gradually

(iv) To improve aesthetic appearance of road.

Problem: (a) Length of transition curve as per allowable rate of centrifugal acceleration 'C'

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

0.5 < C < 0.8 Hence Ok

$$L_s = \frac{V^3}{CR} \quad \text{since v in m/sec}$$

$$= \frac{(0.278\times 80)^3}{0.516\times 250} = 85.27\,\text{m} \qquad \text{------- (1)}$$

(b) Length of transition curve by allowable rate of introduction of superelevation 'E'

$$\text{Superelevation } e = \frac{V^2}{225R} = \frac{80^2}{225\times 250} = 0.1137$$

$e > 0.07 \quad \therefore$ limit $e = e_{max} = 0.07$

for safety against transverse skidding

$$f = \frac{V^2}{127R} - e = \frac{80^2}{127 \times 250} - 0.07$$

$$= 0.13 < 0.15$$

Since $f < 0.15$, $e = 0.07$ is safe for design speed = 80 kmph

Width of pavement = 7.8 m

Length of transition curve for the pavement rotated about inner edge

$L_s = eN (W + We)$

$= 0.07 \times 150 \times 7.8$

$= 81.9$ m -------- (2)

(c) Length of transition curve as per IRC

$$= \frac{2.7V^2}{R} = \frac{2.7 \times 80^2}{250} = 69.12\,\text{m} \text{ ------- (3)}$$

From (1), (2), (3)

Length of transition curve is maximum value

$= 85.27$ m $\simeq 85.5$ m

$$\text{Shift } S = \frac{L_s^2}{24R} = \frac{85.5^2}{24 \times 250} = 1.218\,\text{m}$$