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ESE - 2018
MAINS EXAMINATION
Questions with Detailed Solutions

CIVIL ENGINEERING

PAPER - II

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CIVIL ENGINEERING

ESE _MAINS_2018_PAPER – 2

PAPER REVIEW

Most of the questions given in paper-II are relatively easy to answer. Good marks can be scored in this paper. As expected, Fluid Mechanics, Geotechnical Engineering & Environmental Engineering are given relatively good weightage compared to other subjects of paper-II.

SUBJECT-WISE MARKS

SUBJECT(S)	LEVEL	Marks
SECTION-A		
Fluid Mechanics	Moderate	76
Hydraulic Machines	Moderate	20
Environmental Engineering	Easy	84
Hydrology	Moderate	40
Irrigation	Moderate	20
SECTION-B	**LEVEL**	**Marks**
Geotechnical Engineering	Moderate	104
Surveying	Moderate	47
Highway Engineering	Moderate	39
Geology	Easy	5
Airport Engineering, Railway Engineering, Harbours, Docks & Tunnels	Easy	45

Getting about 225 marks is a great achievement in view of time constraints and QCAB.

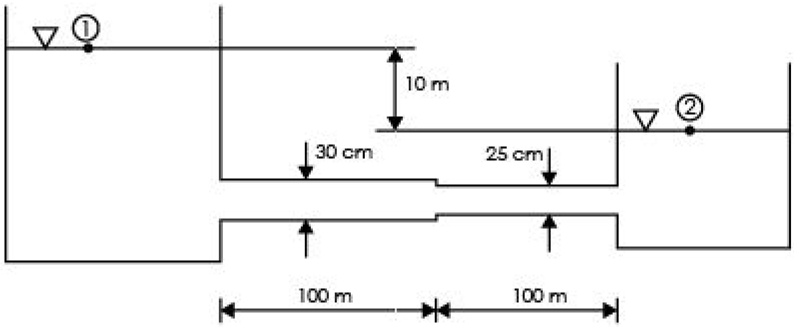
Subject Experts,

ACE Engineering Academy

01(a) There are two reservoirs, A and B, with the water surface elevation in A 10 m higher than that in B. These are connected through two pipes in series with pipe 1 starting from A and pipe 2 ending in B. Lengths of both the pipes are 100 m, diameter of pipe 1 is 30 cm and diameter of pipe 2 is 25 cm. At the junction of these pipes, water is being withdrawn at the rate of 0.02 m^3/s. Friction loss in the pipes is given by $h_f = f\dfrac{L}{D}\dfrac{v^2}{2g}$ and the Darcy friction, f, for both pipes is 0.02. Neglecting the head losses at the entrance and at the junction, estimate the total water withdrawal from reservoir A.

(12 M)

Sol:



f = 0.02

Apply Bernoulli's equation between (1) & (2)

$$\cancelto{0}{\frac{P_1}{\rho g}} + \cancelto{0}{\frac{V_1^2}{2g}} + z_1 = \cancelto{0}{\frac{P_2}{\rho g}} + \cancelto{0}{\frac{V_2^2}{2g}} + z_2 + h_f$$

$$\therefore z_1 - z_2 = h_f = h_{f1} + h_{f2}$$

$$10 = \frac{f_1L_1V_1^2}{2gD_1} + \frac{f_2L_2V_2^2}{2gD_2}$$

$$= \frac{f_1L_1Q^2}{2g\left(\frac{\pi}{4}\right)^2 D_1^5} + \frac{f_2L_2Q^2}{2g\left(\frac{\pi}{4}\right)^2 D_2^5}$$

$$\therefore 10 = \frac{0.02\times 100}{2\times 9.81\times\left(\frac{\pi}{4}\right)^2}\left[\frac{1}{0.3^5}+\frac{1}{0.25^5}\right].Q^2$$

$$Q = 0.205 \text{ m}^3/\text{s}$$

(b) A circular cylinder is placed in a uniform flow with its axis perpendicular to the flow direction. The drag force on the cylinder per unit length, F_D, depends on the flow velocity, V, fluid density, ρ, fluid viscosity, μ, and the cylinder diameter, D. Obtain the non-dimensional sets (Pi numbers) which could be used to analyse this problem.

(12 M)

Sol: $F_D = f(v, D, \rho, \mu)$

$n = 4 + 1 = 5$

$m = 3$

π terms $= n - m = 2$

Let D, V & ρ be the repeating variables

$\therefore \pi_1 = F_D D^{a_1} V^{b_1} \rho^{c_1}$

Equating dimensions on both sides

i.e., $[M^oL^oT^o] = [MLT^{-2}][L]^{a_1}[LT^{-1}]^{b_1}[ML^{-3}]^{c_1}$

$\therefore$ M : $0 = 1 + c_1$

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

T : $0 = -2 - b_1$

$\Rightarrow c_1 = -1,\ b_2 = -2,\ a_1 = -2$

$\therefore \pi_1 = F_D D^{-2} V^{-2} \rho^{-1}$

i.e. $\pi_1 = \dfrac{F_D}{\rho V^2 D^2}$

Similarly

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

Equating dimensions on both sides,

$[M^oL^oT^o] = [ML^{-1}T^{-1}][L]^{a_2}[LT^{-1}]^{b_2}[ML^{-3}]^{c_2}$

i.e. M : $0 = 1 + c_2$

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

T : $0 = -1 - b_2$

$\Rightarrow c_2 = -1,\ b_2 = -1,\ a_2 = -1$

$$\therefore \pi_2 = \mu D^{-1} V^{-1} \rho^{-1} = \frac{\mu}{\rho V D}$$

$\therefore\ \pi_1 = \phi_1\ (\pi_2)$

$$\frac{F_D}{\rho V^2 D^2} = \phi_1\left(\frac{\mu}{\rho V D}\right)$$

Any π term can be replaced by its reciprocal without loss in generality. The form of function will change from ϕ_1 to ϕ_2

$$\therefore\ \frac{F_D}{\rho V^2 D^2} = \phi\left(\frac{\rho V D}{\mu}\right) = \phi_2(R_e)$$

(c) Design a most economical trapezoidal canal section for carrying discharge of 45 cumecs and side slope of $1\frac{1}{2}$:1 at a velocity of 0.9 m/sec. Assume value of n = 0.022 (Manning's coefficient).

(12 M)

Sol:

Given:

Discharge, $Q = 45\ m^3/sec$

Side slope, $m = 1.5$

Velocity of flow, $V = 0.9$ m/sec

Manning's $n = 0.022$

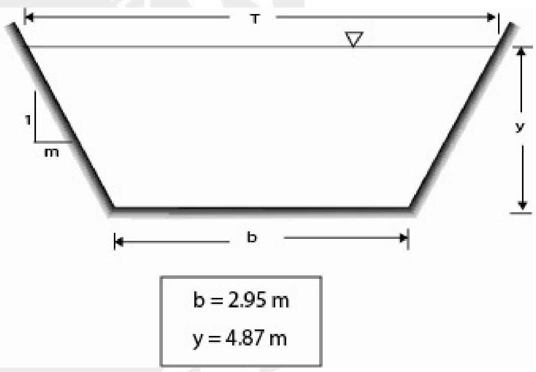
For economical trapezoidal channel, the condition is

Top width = 2×inclined side

$$b + 2my = 2y\sqrt{1+m^2}$$

$$b + 2(1.5)y = 2y\sqrt{1+(1.5)^2}$$

solving, $b = 0.605y$



According to continuity equation,

$Q = AV$

$\Rightarrow 45 = A \times 0.9$

Wetted area, $A = \frac{45}{0.9} = 50m^2$

$A = (b + my)\ y = 50$

$(0.605y+1.5y)y = 50$

$\Rightarrow y = 4.87$ m

$b = 0.605\times4.87 = 2.948 \approx 2.95m$

(d)(i) A water treatment plant is to treat water at the rate of 6000 m^3/day. If there are two rectangular sedimentation tanks (27 × 5 × 3.8 m) with total weir length of 50 m, determine (6 M)

(i) Detention time

(ii) Overflow rate

(iii) Weir loading

Sol: Q = 6000 m^3/day

L × B × H = 27 m × 5m × 38 m

Length of weir = 50 m

No.of tanks = 2

Flow rate in each tank

$$Q' = \frac{Q}{2} = \frac{6000}{2}$$

$$= 3000 \text{ m}^3/\text{day}$$

$$\text{(i) DT} = \frac{V}{Q^1} = \frac{27\times5\times3.8}{3000/24} = 4.10 \text{ hr}$$

$$\text{(ii) over flow rate } v_o = \frac{Q^1}{A} = \frac{3000}{27\times5} = 22.22 \text{ m}^3/\text{day/m}^2$$

$$\text{(iii) WLR} = \frac{Q^1}{\text{Length of weir}}$$

$$= \frac{6000}{50} = 120 \text{ m}^3/\text{day/m}$$

(ii) A treatment plant disposes 50 MLD of treated effluent into a river. The river flow rate is 20 m^3/s and its DO is 8 mg/L before the mixing point. If the BOD of the effluent is 50 mg/L, find the BOD and DO of the river water at the d/s of mixing point. Assume BOD of river water as 0 and DO in WW effluent as 0.

(6 M)

Sol: $Q_w = 50$ MLD

$$= \frac{50\times10^6}{10^3\times24\times60\times60}$$

$Q_w = 0.5787\ m^3/sec$

$y_w = 50\ mg/l$

$(DO)_w = 0$

$Q_R = 20\ m^3/sec$

$(DO)_R = 8\ mg/l$

$y_R = 0\ mg/l$

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

$$= \frac{20\times0 + 0.5787\times50}{20+0.5787}$$

$= 1.406\ mg/l$

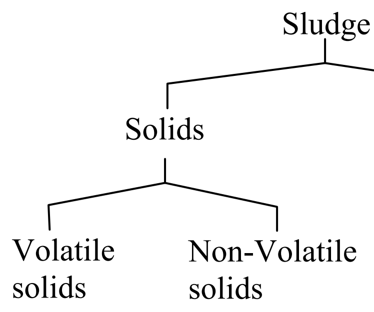
$$(DO)_{min} = \frac{Q_R (DO)_R + Q_w (DO)_w}{Q_R + Q_w}$$

$$= \frac{20\times8 + 0.5787\times0}{20+0.5787}$$

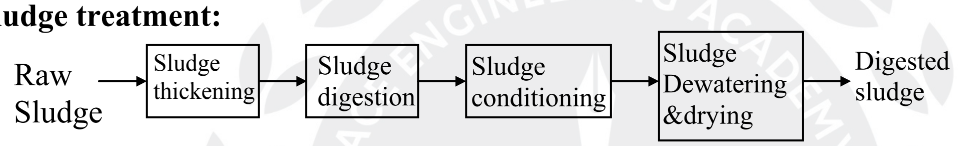
$= 7.775\ mg/l$

(e) What is sludge and how is it classified? With the help of flow chart, explain different processes/operations involved in sludge treatment and indicate the objectives of each process/operation. (12 M)

Sol: Sludge is a mixture of dry solids and water



Sludge treatment:



Sludge thickening → concentrate the sludge by reducing moisture content

Sludge digestion → Anaerobic decomposition of sludge

Sludge conditioning → Improving the drainability of sludge

Sludge dewatering and drying → To remove remaining moisture content

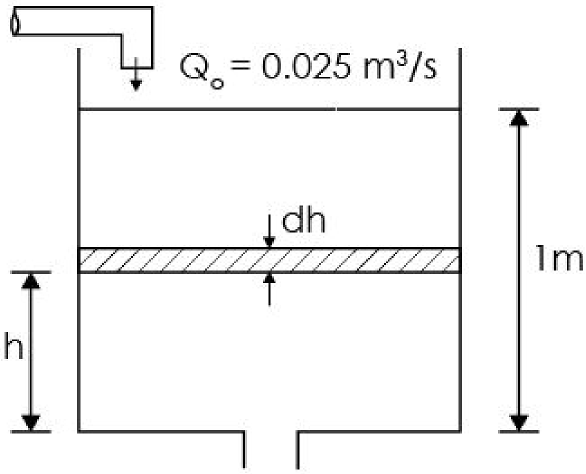
02(a) The circular base of a cylindrical tank is of 1m diameter and has an orifice of 10 cm diameter. The discharge coefficient, C_d, for the orifice is 0.6. Initially the tank is empty and then it is filled from the top using a pipe discharging 0.025 m^3/s. How long will it take to fill the tank up to a height of 1 m? What will be the maximum height to which the tank can be filled? (20 M)

Sol: The velocity through the orifice is given by Torricelli's law as $V = \sqrt{2gh}$

As velocity depends upon head available in tank outgoing discharge is time dependent hence integration is required.

$$\therefore\ dt = \frac{A\ dh}{Q_o - C_d a\sqrt{2gh}}\ ....(1)$$

Let $\sqrt{h} = x$, $\quad \therefore \frac{dh}{2\sqrt{h}} = dx$



i.e. $dh = 2\sqrt{h}dx = 2xdx$

at h = 0, x = 0 & at h = 1, x = 1

$$\therefore dt = \frac{A(2xdx)}{Q_o - C_d a\sqrt{2g}.x}$$

$$= \frac{nxdx}{m - x}$$

where $n = \frac{2A}{C_d a\sqrt{2g}}$, $m = \frac{Q_o}{C_d a\sqrt{2g}}$

$$\therefore dt = \frac{n(x - m + m)dx}{(m - x)}$$

$$= \frac{mndx}{m - x} + (-ndx)$$

$$\int_0^T dt = \int_0^1 \frac{mndx}{m - x} + \int_0^1 - ndx$$

$$T = mn\left[\frac{\ell n(m - x)}{-1}\right]_0^1 - n[x]_0^1$$

$$= -mn[\ell n(m - 1) - \ell n(m)] - n$$

$$= -mn\ \ell n\left(\frac{m - 1}{m}\right) - n$$

$$T = mn\ \ell n\left[\frac{m}{m - 1}\right] - n\ ....(2)$$

$$m = \frac{Q_o}{C_d a\sqrt{2g}} = \frac{0.025}{0.6 \times \frac{\pi}{4} \times 0.1^2 \times \sqrt{2 \times 9.81}} = 1.1977$$

$$n = \frac{2A}{C_d a\sqrt{2g}} = \frac{2\times\frac{\pi}{4}\times 1^2}{0.6\times\frac{\pi}{4}\times 0.1^2\times\sqrt{2\times 9.81}} = 75.25$$

$$\therefore T = 1.1977\times 75.25\,\ell n\left[\frac{1.1977}{0.1977}\right] - 75.25$$

$$= 87.1 \text{ sec}$$

Maximum height will be achieved

if $Q_{in} = Q_{out}$

$$Q_o = C_d a\sqrt{2gh_{max}}$$

$$0.025 = 0.6\times\frac{\pi}{4}\times 0.1^2\times\sqrt{2\times 9.81\times h_{max}}$$

$\therefore h_{max} = 1.434$ m

(b) Give the characteristics of different formations in which groundwater exists. A fully penetrating artesian well is discharging at a rate of 25 litres/sec. The storage coefficient and transmissivity of the aquifer are 4.5×10^{-4} and 0.15 m^2/min respectively. Find the drawdown at (20 M)

(i) A radius of 5 m distance after 2 hours pumping.

(ii) A radius of 150m distance after one day pumping.

Use the following approximation well function

$W(u) = -0.5772 - \mathit{ln}(u) - u$.

Sol: Artesian well

$Q = 25\ l/s = 2160\ m^3/day$

$S = 4.5\times 10^{-4}$

$T = 0.15\ m^2\ /min = 216\ m^2/day$

$W_u = -0.5772 - \mathit{ln}(u) - u$

$$u = \frac{s}{4T}.\frac{r^2}{t}$$

(i) At 5 m distance after 2 hours pumping

$$u = \frac{0.00045}{4\times 216}\times\frac{5^2}{(0.0833)} = 1.5625\times 10^{-4}$$

$W_u = -0.5772 - ln(u) - u = 8.1867$

$$S = \frac{Q}{4\pi T}\times W_u = \frac{2160}{4\times\pi\times 216}\times 8.1867$$

$S = 6.515$ m

(ii) At 150 m distance after 1day pumping

$$u = \frac{0.00045}{4\times 216}\times\frac{150^2}{1} = 0.01172$$

$W_u = -0.5772 - ln(u) - u = 3.858$

$$S = \frac{Q}{4\pi T}\times W_u = \frac{2160}{4\times\pi\times 216}\times 3.858$$

$S = 3.07$ m

(c) Present the permissible drinking water quality standards of the following parameters. Also, explain the effects of presence of these parameters in water bodies:

(20 M)

(i) Fluorides

(ii) Total Hardness

(iii) Iron

(iv) Nitrates

Sol:

(i)Fluorides :

- **Fluoride**< 1 ppm, cause formation of fever cavities in the teeth.
- Fluoride > 1.5 ppm causes Flourosis (mottling and discolouration of teeth) and deformation of bones.
- Permissible limit : between 1 ppm and 1.5 ppm.
- It is estimated by colorometry
- The process of raising the fluoride content of water is known as *fluoridation. Sodium fluoride*(NaF), is usually adopted for fluoridation of public water supplies.
- The process of reducing fluoride concentration in water is called Defluoridation. Nalgonda-Technique, Lime-soda process, activated carbon are used for deflourination purpose.

(ii)Total Hardness:

A characteristic which prevents formation of lather or foam with soap.

Types of Hardness:

1. Carbonate Hardness(**CH**)
2. Non Carbonate Hardness(**NCH**)

- Temporary or carbonate hardness: Caused by HCO_3 and CO_3 of Ca & Mg.
- Can be removed to some extent by simple boiling or removed fully by addition of lime.
- Permanent or non Carbonate hardness Caused by SO_4, Cl, NO_3 of Ca & Mg.

- Can be removed by water softening methods such as Lime soda process, Deminerlization process and Zeolite Process.

: For boiler feed waters < 75 ppm.

permissible drinking water quality standards For drinking purpose: between 75&115 ppm

If Hardness is < 75 ppm is called 'Soft'

If Hardness is > 200 ppm , is called 'Hard'

Measurement: Measured in terms of ppm or mg/lit of $CaCO_3$

Measured by EDTA test (Ethylene Diamine Tetracetic Acid test).

Effects of Hardness : Scaling of boilers, greater soap consumption, corrosion and incrustation of pipe lines, food becomes tasteless etc.

(iii) Iron:

Drinking water standard is < 0.3 mg/*l*

It is measured by colorometery

Iron in water cause reddish colour to water

iv) : Nitrates: indicates fully oxidized organic matter.

Permissible drinking water quality standards : < 45 ppm.

Total Kjeldahl Nitrogen (TKN)=Free ammonia + organic nitrogen

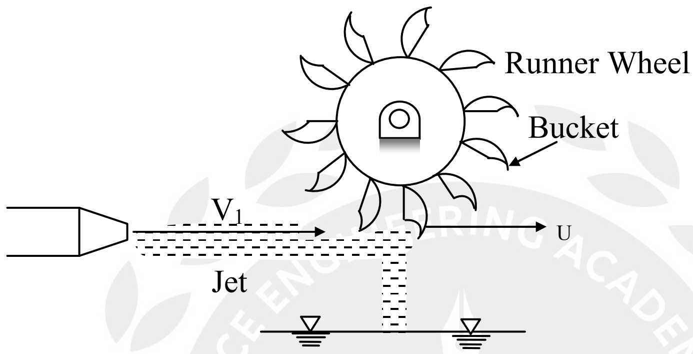
Excess causes the disease called "**Methemoglobenima**" (Blue baby disease)

03(a)

(i) A pelton wheel turbine bucket deflects the water jet by an angle θ. Show that if friction losses are ignored, the maximum power will be developed when the bucket speed is half of the jet speed. If friction on the bucket surface reduces the relative velocity of the jet by 10% at the exit, find the ratio of the bucket speed and jet speed for maximum power.

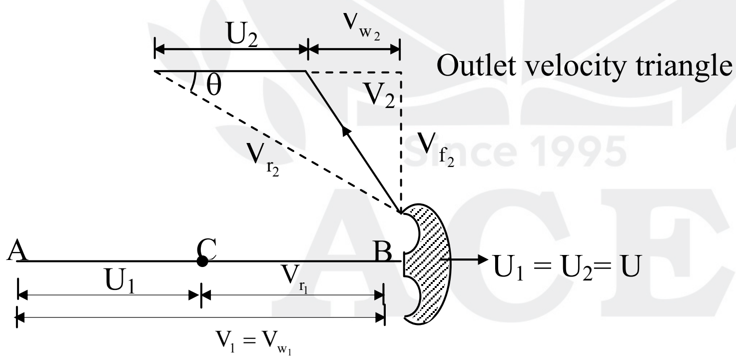
(14 M)

Sol: Consider a Pelton wheel and its velocity diagrams.



Let V_1 = Jet Velocity

θ = Back deflected angle at exit



Inlet velocity diagram (Straight line)

(I) **Friction losses are ignored** i.e $V_{r_2} = V_{r_1}$ (Relative velocities at inlet time exit are equal)

Power developed by the runner wheel (P)

$P = F_{Jet} \times U$

= Jet Force × Tangential velocity of runner wheel

$= \dot{m}(\Delta V)_{whirl} \times U$

$= \dot{m}\left(V_{w_1} + V_{w_2}\right)U$

$= \rho Q\left(V_1 + V_{w_2}\right)U$

From outlet velocity triangle

$\cos\theta = \dfrac{U + V_{w_2}}{V_{r_2} = V_{r_1}}$

$V_{w_2} = V_{r_1}\cos\theta - U$

$P = \rho.\ Q\ (V_1 + V_{r_1}\cos\theta - U)\ U$

Where $V_{r_1} = V_1 - U$ From inlet velocity diagram

$P = \rho.\ Q\ (V_1 + (V_1 - U)\cos\theta - U)\ U$

$P = \rho\ Q\ (V_1 - U)\ (1 + \cos\theta)\ U$

$P = \dot{m}\left(V_1 U - U^2\right)\left(1 + \cos\theta\right)$

In order to maximize power developed differentiate above power (P) expression with respect to U i.e $\dfrac{d(P)}{dU} = 0$

$\dfrac{d}{dU}\left(\dot{m}V_1 U - U^2\right)\left(1 + \cos\theta\right) = 0$

$\dot{m}(1 + \cos\theta)\dfrac{d}{dU}\left(V_1 - U^2\right) = 0$

$\dot{m}(1 + \cos\theta)(V_1 \times 1 - 2U) = 0$

If $\dot{m}(1 + \cos\theta) \neq 0$

$V_1 - 2U = 0$

$\therefore\ V_1 = 2U$

$\Rightarrow U = \dfrac{V_1}{2}$

Hence proved i.e for maximum power developed back tangential velocity is equal to half of the jet velocity at inlet of the buckets of runner wheel.

II. Friction losses consideration:

Friction on the bucket surface reduces the relative velocity of jet at exit $\left(V_{r_2}\right)$

Let k = Bucket friction coefficient

$$k = \frac{V_{r_2}}{V_{r_1}}$$

Given k = 0.9 (i.e 10% or relative velocity of jet at exit reduced)

From outlet velocity triangle

$$\text{Cos}\theta = \frac{U + V_{w_2}}{V_{r_2} = k.V_{r_1}}$$

$$\therefore\ V_{w_2} = kV_{r_1}\cos\theta - U$$

$$V_{w_2} = k\left(V_1 - U\right)\cos\theta - U$$

Power of runner wheel (with bucket friction) P = $\dot{m}\left(V_{w_1} + V_{w_2}\right)\times U$

$$P = \dot{m}\left(V_1 + k\left(V_1 - U\right)\cos\theta - U\right)\times U$$

$$P = \dot{m}\left(V_1 - U\right)\left(1 + k\cos\theta\right)\times U$$

Condition for maximum power developed $\frac{dP}{dU} = 0$

output power $P_o = \dot{m}V_1\left[1 - \frac{U}{V_1}\right](1 + k\cos\theta)U$

$$P_o = \dot{m}V_1U\left(1 + k\cos\theta\right)\left(1 - \frac{U}{V_1}\right)$$

With losses effect, Efficiency of turbine $\eta = \frac{P_o}{P_{water}} = \frac{P_o}{\frac{1}{2}\dot{m}V_1^2 = \rho gQH}$

$$\eta = \frac{\dot{m}V_1U(1 + k\cos\theta)\left(1 - \frac{U}{V_1}\right)}{\frac{1}{2}\dot{m}V_1^2}$$

$$\eta = 2\left(\frac{U}{V_1}\right)(1 + k\cos\theta)\left(1 - \frac{U}{V_1}\right)$$

Let $\phi = \frac{U}{V_1}$

$\eta = 2\ (1 + k\cos\theta)\ (\phi)\ (1 - \phi)$

$\eta = 2\ (1 + k\cos\theta)\ (\phi - \phi^2)$

For maximum $\frac{d(\eta)}{d\phi} = 0$

$\frac{d(\eta)}{d\phi} = 0 \Rightarrow \frac{d(\eta)}{d(U/V_1)} = 0$

$0 = 2\ (1 + k\cos\theta)\ (1 - 2\phi)$

If $2\ (1 + k\cos\theta) \neq 0$

$1 - 2\phi = 0$

$\therefore \phi = \frac{1}{2} = \frac{U}{V_1}$

Where $\phi = \frac{U}{V_1}$

$\frac{U}{V_1} = \frac{1}{2}$ (Condition for maximum power)

$$\eta_{max} = \frac{1 + k\cos\theta}{2} = \frac{1 + 0.9\cos\theta}{2}$$

$$\eta_{max} = 0.5 + 0.45\cos\theta$$

(ii) When does cavitation occur in a pump and what are its harmful effects? How is the available net positive suction head defined and used in the analysis of cavitation? (6 M)

Ans: Cavitation does occurs in a pump, when flow fluid pressure is below vapour pressure at the entry of impeller too high velocity flow.

Harmful Effects of Cavitation:

(i) Excessive vibration (leads to premature of seals, packing, bearing failure)

(ii) Erosion of metal surfaces due to cavities formation

(iii) Failure of pump housing and impeller blades

(iv) Vapour lock

(v) Pressure pulsations

(vi) Mechanical damages to parts

(vii) Reduction of efficiency & head developed by impeller

NPSH definition:

NPSH is a minimum amount of suction pressure head needed for a pump to operate without cavitating.

$$NPSH = H_{\underset{\text{Local}}{\text{Atm}}} - H_{\text{Suction pipe}} - H_{\text{Vapour}} - h_{\underset{\text{Losses}}{f}}$$

Where, H_{Atm} = Local atmospheric pressure head (m)

$H_{\text{suction pipe}}$ = Static lift on suction side

H_{vapour} = Vapour pressure head

h_f = Losses in the suction side head

NPSH use in analysis of cavitation:

NPSHA is dependent on the pump-setting and on -site conditions.

Always provide adequate margin (m) = NPSHA – NPSHR

Usually margin is 10% of NPSHA

Pump - Setting process:

If NPSHA > NPSHR the setting is OK

If NPSHA < NPSHR the setting is not OK and cavitation will be a problem arise

Hence NPSHA should always be greater than (NPSHR+ m)

(b) What are the basic assumptions of a unit hydrograph? Six hour unit hydrograph of a watershed having a drainage area equal to 393 km^2 is as follows:

Time (hours)	0	6	12	18	24	30	36	42	48
Unit hydrograph (cumec/cm)	0	1.8	30.9	85.6	41.8	14.6	5.5	1.8	0

For a storm over the watershed having excess rainfall of 5 cm for first six hours and 15 cm for second six hours, compute the stream flow hydrograph assuming constant base flow of 100 m^3/sec.

(20 M)

Sol: Basic Assumption of UH

- Linear response
- Time invariance

Time	6hr UH	1st DRH $R_1 = 5$ cm	Lag 6 hr 2nd DRH $R_2 = 15$ cm	Total DRH	BF	FH, m^3/s
0	0	0	-	0	100	100
6	1.8	9	0	9	100	109
12	30.9	154.5	27	181.5	100	281.5
18	85.6	428	463.5	891.5	100	991.5
24	41.8	209	1284	1493	100	1593
30	14.6	73	627	700	100	800
36	5.5	27.5	219	246.5	100	346.5
42	1.8	9.0	82.5	91.5	100	191.5
48	0	0	27	27	100	127
			0	0	100	100

(c) Explain the phenomena responsible for self purification in rivers. Discuss the factors influencing the self purification capacity.

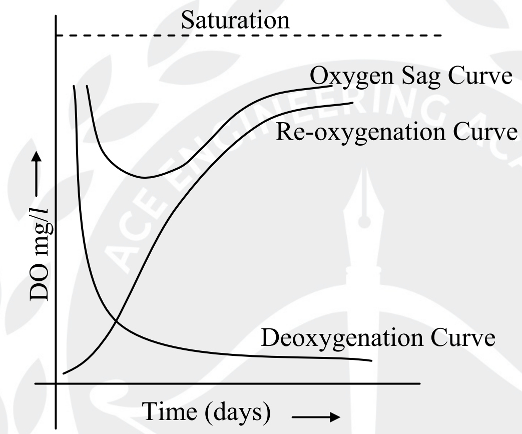
(20 M)

Sol: Self purifications of water bodies occur due to re-oxygenation of water bodies

Oxygen sag curve is the means of measuring self purification of water bodies.

It is a function of both De-oxygenation and Re-oxygenation.

The oxygen deficit of a Polluted River-stream (D) = saturation D.O. – Actual D.O



Re-oxygenation: oxygen is absorbed from the atmosphere to counteract the depletion of D.O. content.

The analysis of oxygen sag curve can be easily done by superimposing the rates of de-oxygenation and re-oxygenation as suggested by **Streeter – Phelps equation**

$$D_t = \frac{K_D L}{K_R - f}\left[10^{-K_D.t} - 10^{-K_R.t}\right] + \left[D_0 . 10^{-K_R.t}\right]$$

D_t = The D.O. deficit of the mixture in mg/l after 't' days

L = Ultimate first stage B.O.D. of mixture at the point of waste discharge in mg/l

D_O = Initial oxygen deficit of mixture in mg/l at the mixing point

D_C = Critical or maximum oxygen deficit

K_D =De-oxygenation Rate ;

$K_{R=}$ Re-oxygenation Rate

Self Purification constant, $f = K_R/K_D$

Where $t_c = \dfrac{1}{K_D(f-1)}\log\left[\left\{1-(f-1)\dfrac{D_o}{L}\right\}f\right]$

$$\left(\frac{L}{D_C.f}\right)^{f-1} = f\left[1-(f-1)\frac{D_o}{L}\right] \textbf{ (or) } t_c = \frac{1}{K_2-K_2}\ell n\left[\frac{K_2}{K_1}\left(1-D_o\frac{K_2-K_1}{K_1L_o}\right)\right]$$

Mechanisms of Self purification:

Physical forces are:

(i) Dilution and dispersion

(ii) Sedimentation

(iii)Sunlight

Chemical forces aided by biological forces

(iv) Oxidation.

(v) Reduction

(i) Dilution and Dispersion: Dilution causes mixing which reduces concentration.

Dispersion spread of pollutants cause reduction in concentration of pollutants.

When sewage of concentration C_s flows at a rate Q_s in to a river stream with concentration C_R flowing at a rate Q_R, the concentration C of the resulting mixture is given by

$$C = \frac{(C_SQ_S + C_RQ_R}{(Q_S+Q_R)}$$

The above equation is applicable to the concentrations of D.O., B.O.D. etc.

ii. **Sedimentation:** Settleable Solids will settle down into bed of the river.

iii. **Sun-light:** It causes disinfection of water. Algae plants by absorbing carbon dioxide and releasing oxygen by a process as Photo-synthesis.

iv. **Oxidation:**It is like aerobic decomposition process. Oxidation will continue till the organic matter has been completely oxidized. This is the most important action responsible for effecting self purification of rivers.

v. **Reduction:** Anaerobic bacteria at the bottom of river bed will help in splitting the complex organic constituents of sewage into liquids and gases, and thus paving the way for their ultimate stabilization by oxidation

Factors Influencing Self purification:

(i) Volume of water
(ii) Dissolved oxygen of water bodies
(iii) Temperature
(iv) Wind currents
(v) Turbulence
(vi) Rate of re-aeration etc,.

Zones of pollution in a River-Stream:

(i) Zone of degradation
(ii) Zone of active decomposition
(iii) Zone of recovery
(iv) Zone of cleaner water.

(i) Zone of degradation or zone of pollution: This zone is found for a certain length just below the point where sewage is discharged. Water becomes dark and turbid with formation of sludge deposits at the bottom. D.O. is reduced to about 40% of the saturation value.

(ii) Zone of active decomposition: This zone is marked by heavy pollution. D.O concentration falls down to zero, and anaerobic conditions may set in. Fish life will be absent

(iii) Zone of recovery: Stream tries to recover B.O.D falls down and D.O. content rises above 40% of the saturation value. The organic material will be mineralized to form nitrates, sulphates, phosphates, carbonates, etc

(iv) Zone of cleaner water: The river attains its original conditions with D.O. rising up to the saturation value. Fish (requires at least 4 mg/l of D.O) and usual aquatic life prevails.

04(a) **A hydraulic jump occurs in a horizontal rectangular channel, which is 1 m wide. The pre-jump depth is 5 cm and the post-jump depth is 20 cm. Assuming the channel to be frictionless, estimate the discharge of water. If the friction is not neglected, and the friction force is estimated to be 20 N over the jump-length, what will be the estimated discharge?**

(20 M)

Sol:

Given:

Rectangular Channel

Width, b = 1 m

Pre-jump depth, y_1 = 5 cm

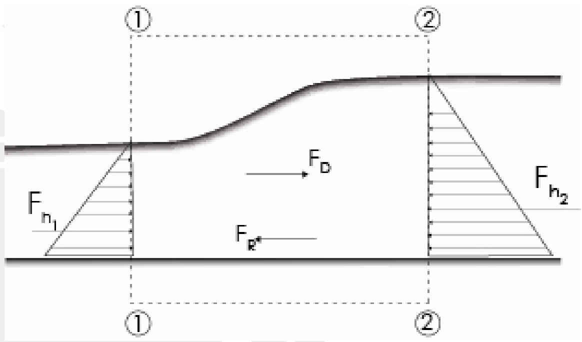
Post jump depth, y_2 = 20 cm

Horizontal bed

Calculation of

(i) Q without friction

(ii) 'Q' with friction of 20 N



Apply momentum equation in the control volume

$\sum F = \rho Q[V_2 - V_1]$

Assuming uniform flow at the entry and exit of control volume

$F_{h1} - F_{h2} + F_D - F_R = \rho Q[V_2 - V_1]$

$$= \rho Q\left(\frac{Q}{A_2} - \frac{Q}{A_1}\right)$$

$$= \rho Q^2\left(\frac{1}{A_2} - \frac{1}{A_1}\right) = \rho Q^2\left(\frac{1}{y_2} - \frac{1}{y_1}\right) \text{.....................} \quad \text{(i)} \qquad \because b = 1 \text{ m}$$

F_{h1} = Hydrostatic pressure at section 1

$$= \frac{\gamma y_1^2}{2} = 9810 \times \frac{0.05^2}{2} = 12.2625 \text{ N/m}$$

F_{h2} = Hydrostatic pressure at section 2

$$= \frac{\gamma y_2^2}{2} = 9810 \times \frac{0.20^2}{2} = 196.2 \text{ N/m}$$

$\because$ Channel is horizonal, $F_D = 0$

Right hand side of equation (i) = $1000\ Q^2 \left(\frac{1}{0.2} - \frac{1}{0.05}\right) = -15000\ Q^2$ N/m

Case 1: Neglecting friction (F_R) substituting the above values in equation (i)

$12.2625 - 196.2 = -15000\ Q^2$

Solving, $Q^2 = 0.0122$

$\boxed{Q = 0.110 \text{ m}^3\text{/sec}}$ .... Neglecting frictional loss

Short cut: For Hydraulic Jump in rectangular channel

$$\frac{2q^2}{g} = y_1 y_2 (y_1 + y_2)$$

$q = 0.110$ m^3/s

$b = 1$ m

$\therefore Q = q \times b = 0.110$ m^3/s

Note: If you adopt the above equation directly the paper evaluator may not give full marks because it is a conventional question, with this part carrying approximately 10 marks.

(ii) Considering frictional loss:

from the equation (i)

$$F_{h1} - F_{h2} + F_D - F_R = \rho Q^2 \left(\frac{1}{y_2} - \frac{1}{y_1}\right)$$

$12.2625 - 196.2 + 0 - 20 = -15000\ Q^2$

Solving, $Q^2 = 0.0136$

$\boxed{Q = 0.1166 \text{ m}^3\text{/sec}}$ .... Considering frictional loss

(b) Find the capacity of a reservoir for irrigating an area having G.C.A = 40,000 ha. The cropping pattern consists of mainly the following crops :

Crop	Period	Base period (days)	Outlet factor (ha/cumec)	Intensity of cropping (%)	Crop ratio
Sugarcane	Oct-Sept	360	800	60	4
Cotton	May-Nov	180	1200	60	3
Wheat	Dec-April	120	1800	70	2
Gram	Dec-April	120	2000	70	3

The area has 25% non-culturable area.

Assume

(i) Time factor = 7/10

(ii) Extra allowance for period of peak water use = 20%

(iii) Conveyance losses = 20%

(iv) Reservoir losses = 10%

Also calculate design discharge and capacity factor of the main canal. (20 M)

Sol:

Gross command area = 40,000 ha

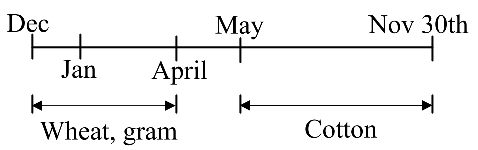
Non-culturable area = 25%

$$\text{CCA} = \frac{75}{100}(40{,}000) = 30{,}000\text{ ha}$$

Different crops are grown for different time durations.

To calculate reservoir capacity, we must get total volume of water required for all the crops throughout year.

$V = A\Delta$



Sugarcane Oct-Nov throughout year.

I. Dec-April: Sugarcane, wheat, gram

$$A_{sugarcane} = A_1 = 30{,}000 \times \frac{4}{12} \times \frac{60}{100}$$

$$= 6000 \text{ ha}$$

$$A_{cotton} = A_2 = 30{,}000 \times \frac{3}{12} \times \frac{60}{100}$$

$$= 4500 \text{ ha}$$

$$A_{wheat} = A_3 = 30{,}000 \times \frac{2}{12} \times \frac{70}{100}$$

$$= 3500 \text{ ha}$$

$$A_{gram} = A_4 = 30{,}000 \times \frac{3}{12} \times \frac{70}{100}$$

$$= 5250 \text{ ha}$$

$$V = V_{sc} + V_w + V_{gram}$$

$$= A_1\Delta_1 + A_3\Delta_3 + A_4\Delta_4$$

$$= 6000\left(8.64\frac{B_1}{D_1}\right) + 3500\left(8.64\frac{B_3}{D_3}\right) + 5250\left(8.64\frac{B_4}{D_4}\right)$$

$$= (2700 + 233.33 + 315)\ 8.64$$

$$= 28065.6 \text{ ha-m}$$

II for cotton:

$$4500 \times 8.64 \times \frac{B_2}{D_2} = 5832 \text{ ha-m}$$

Total Net volume = 28065.6 + 58.32

= 33897.6 ha-m

Peak allowance = 20%

Net volume = 28065.6 × 1.2 + 5832

= 33678.72 + 5832

= 39510 ha-m

Conveyance efficiency = 0.8

Reservoir efficiency = 0.9

Time factor influence = $\dfrac{10}{7}$

Total Gross volume

$$= \frac{39510}{0.8 \times 0.9} \times \frac{10}{7}$$

= 78392 ha-m

Reservoir capacity = 78392 ha-m

(b) Design discharge of the main canal:

$$Q = \frac{A}{D}$$

Dec-April:

$$Q = \frac{A_1}{D_1} + \frac{A_3}{D_3} + \frac{A_4}{D_4}$$

$$= \frac{6000}{800} + \frac{3500}{1800} + \frac{5250}{2000}$$

$$= 7.5 + 1.94 + 2.625$$

$$= 12.065 \text{ cumec}$$

May-Nov:

$$Q = \frac{A_1}{D_1} + \frac{A_2}{D_2}$$

$$= \frac{6000}{800} + \frac{4500}{1200}$$

$$= 7.5 + 3.75$$

$$= 11.25 \text{ cumec}$$

Greater value = 12 cumec

With peak factor, $Q_{\text{main canal}} = 12 \times 1.2 = 14.4$ cumec

$$\text{Capacity factor} = \frac{Q_{max}}{Q_{mean}} = \frac{12.065}{\frac{12.065 + 11.25}{2}} = \frac{12.065}{11.6575} = 1.035$$

(c)

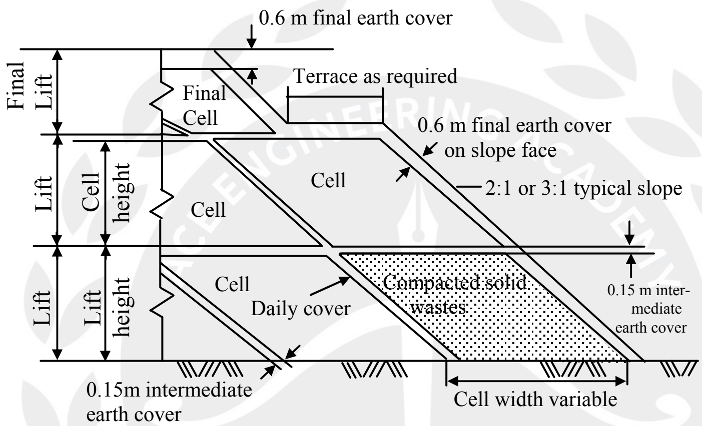
(i) Explain in detail how landfills are environmentally safe over open dumps. Explaining landfill operations, state the problems associated with landfills. (10 M)

Sol:

Disposal of MSW (Refuse) by Sanitary Land filling (Land fill operations) :

In this method, refuse is dumped and compacted in layers of about 0.5 m thickness, and after the days work,when the depth of filling becomes about 1.5m, it is covered by good earth of about 15 cm thickness. This cover of good earth is called the daily cover. Since the refuse is well compacted with bulldozers, trucks, rollers, etc

The filling of refuse is actually done in sanitary land filling by dividing the entire land – fill area into smaller portions, called cells. These cells are initially filled with daily compacted refuse of about 1.5m depth, in turn. After filling all the cells with first lift, the second lift is laid in about 1.5m height, and covered with good earth cover of about 0.15 depth, called the intermediate cover. After all the cells have been filled up with second lift, the third and more lifts can be piled up in about 1.5m depth each, all laid over by the intermediate earth covers, turn by turn. The process will continue till the top most lift is piled up, over which the final cover of good earth of about 0.6m depth shall be laid and well compacted, to prevent the rodents from burrowing into the surface. A cap system may also be installed over the top of the final cover.



Comparision with open dumps:

Land filling is the controlled and scientific method of biodegradable solid waste. Biodegradable solid waste decomposes aerobically and anaerobically and converts to humus. i.e. part of soil system. Open dumping of solid waste cause nuisance by decomposing and leads to pollution problems. In controlled land fill operations, no such pollution problems related to environment occurs.

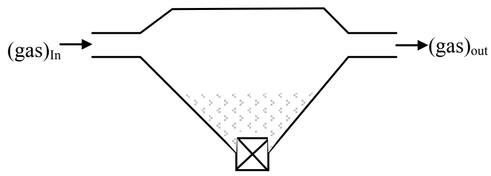
Problems of Land Filling

Land fills experience lechate problems during rainy season which can be addressed by placing geomembrane as a bottom side and top cover. Otherwise lechates contaminate precious ground water.

(ii) With the help of line sketches, explain the working principles of gravity settlers and electrostatic precipitators used for air pollution control. Also, list their applications and limitation (10 M)

Ans:

(ii) Air pollution control equipment:



Gravity settling chamber

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

$v_s \geq v_o$

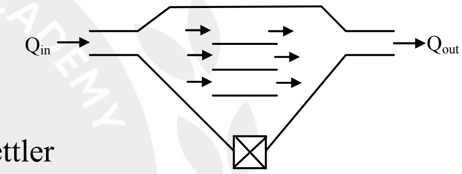
Area of gravity settler $= \dfrac{Q}{v_o}$

In gravity settling chambers, particles settle due to gravitation force when flow velocity is retarded as c/s area increases.

Diameter of particles removed (d_p) > 50 μm

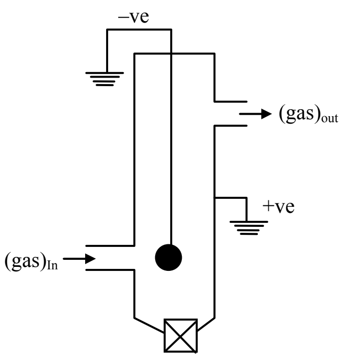
Particles removal efficiency (η) < 50 %

This can be increased by providing plates in the gravity settler

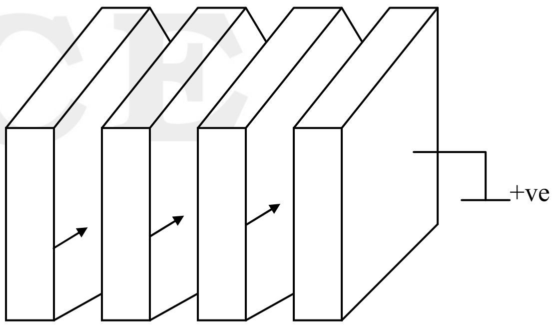


Electrostatic precipitators (ESP):

Very fine particles from gas stream are separated by electrostatic precipitators. In electrostatic precipitators particles are passed through high energy field known as carona and given negative charges to particles. Negatively charged particles drift towards positively charges plates (or) cylinder and separated from gas stream.



Cylindrical ESP



Parallel Plate ESP

Diameter of particles ESP removed $d_p < 1\mu m$

Efficiency of particles removed η = 95 to 99%

Paricle removed efficiency $\eta = (1 - e^{-wA/Q}) \times 100$

Where

w = drift velocity, A = area of plates, Q = gas flow rate

SECTION-B

05.

(a) A conventional consolidated drained (CD) triaxial test was conducted on saturated clean sand sample by using the following steps :

(1) Set cell pressure to 250 kPa and allow the sample to consolidate with its drainage valve open at 100 kPa back pressure.

(2) Shear the sample without any change in the drainage condition.

The sample failed when the deviator stress reached 300 kPa. Use analytical solution to determine:

(i) The slope of failure envelope in degrees. Assume c′ to be zero.

(ii) Slope of the failure plane in degrees.

(iii) Shear stress and normal stress on the failure plane (in kPa).

(iv) The maximum shear stress at failure (in kPa).

(12 M)

Sol: **Given data:**

$\sigma_3 = 250$ kPa

$u = 100$ kPa

$\sigma_d = 300$ kPa

$C' = 0$

$$\sigma_3' = \sigma_3 - u = 250 - 100 = 150\,\text{kPa}$$

$$\sigma_1' = \sigma_1 - u = (250+300) - 100 = 450\text{ kPa}$$

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

$$450 = 150\tan^2\left[45 + \frac{\phi'}{2}\right] + 0$$

$$\sqrt{3} = \tan\left[45 + \frac{\phi'}{2}\right]$$

$$\therefore \phi' = 30°$$

(i) The slope of failure envelope, $\phi' = 30°$

(ii) The slope of failure plane with respect to horizontal, α_f

$$\alpha_f = 45 + \frac{\phi'}{2} = 45 + \frac{30°}{2} = 60°$$

(iii) On the failure plane:

Normal stress, $\sigma' = \frac{\sigma_1' + \sigma_3'}{2} + \frac{\sigma_1' - \sigma_3'}{2}\cos 2\alpha_f$

$$= \frac{450+150}{2} + \frac{450-150}{2}\cos 2\times 60$$

$$= 225 \text{ kPa}$$

Shear stress, $\tau_f = \frac{\sigma_1' - \sigma_3'}{2}\sin 2\alpha_f$

$$= \frac{450-150}{2}\sin 2\times 60 = 129.90 \text{ kPa}$$

(iv) Maximum shear stress, $\tau_{max} = \frac{\sigma_1' - \sigma_3'}{2}$

$$= \frac{450-150}{2} = 150 \text{ kPa}$$

(b) Determine the ultimate load capacity of a 600 mm diameter and 12.5 m long concrete pile driven through a uniform clay layer. The pile is made to rest on top of dense silica sand layer. The water table is at the surface. What will happen to the above ultimate load capacity if the water table level is lowered by 5 m without any change in the soil property?

The properties of the two soil layers are :

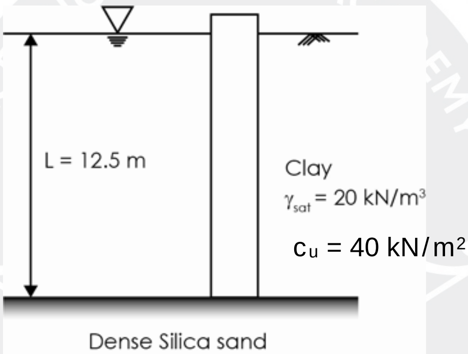
Clay : Undrained shear strength = 40 kN/m^2,

Unit weight = 20 kN/m^3, Adhesion factor = 0.8, N_c = 0.9.

Dense silica sand : ϕ' = 36^o, Unit weight = 18 kN/m^3. Use N_q = 88. Assume that the unit weight of water is 10 kN/m^3.

(12 M)

Sol:



As the critical depth (D_c) is not given, it is assumed that the effective vertical stress varies linearly.

Case (i)

When water table is at Ground level

$$\text{At bottom of pile, } \sigma'_v = \gamma'.L$$

$$= (\gamma_{sat} - \gamma_w)L$$

$$= (20–10)\ 12.5 = 125 \text{ kPa}$$

Ultimate load capacity, Q_u

$$Q_u = A_P.\sigma_v^{'}N_q + A_s.\alpha.C$$

$$= \frac{\pi}{4}D^2.\sigma_v^{'}.N_q + \pi D.L.\alpha.C$$

$$= \frac{\pi}{4}0.6^2 \times 125 \times 88 + \pi \times 0.6 \times 12.5 \times 0.8 \times 40$$

$$= 3110.177 + 753.98$$

$$= 3864.16 \text{ kN}$$

Case (ii)

When water is lowered by 5 m

Effective vertical stress at pile tip level, $\sigma_v^{'}$

$$\sigma_v^{'} = 5\gamma_{sat} + (12.5 - 5)\gamma'$$

$$= 5\times20 + (12.5–5)\ (20–10) = 175 \text{ kPa}$$

$$Q_u = \frac{\pi}{4}D^2\sigma_v^{'}.N_q + \pi DL.\alpha.C$$

$$= \frac{\pi}{4}0.6^2 \times 175 \times 88 + \pi \times 0.6 \times 12.5 \times 0.8 \times 40$$

$$= 4354.25 + 753.98$$

$$= 5108.23 \text{ kN}$$

Therefore, if the water level is lowered by 5 m, the ultimate load capacity of pile increases by 1244 kN.

While the skin friction due to the clay remains same, the end bearing resistance is increased due to increase of effective stress.

(c) Briefly describe planning surveys for highways. How are these used and interpreted?

(12 M)

Ans:

Planning surveys: The field surveys which are required for collecting the factual data for highway planning i.e. assessment of road length area, preparation of master plan etc.

Planning survey involves the following studies:

a) **Economic studies:** Details related to the economics of highway development are collected like

- Population distribution and forecast
- Agricultural , industrial groups and their future trends
- Existing facilities like education, recreation etc
- Percapita income

b) **Financial studies:** Financial aspects are studied like

- Source of income, estimated revenue from taxation
- Resources at toll taxes, vehicle registration etc
- Living standards
- Future financial aspects

c) **Traffic studies:** Surveys related to the present traffic criterias and future growth is studied like

- Traffic volume
- Traffic flow
- Transportation facilities
- Origin and destination studies
- Accident analysis
- Type of passengers and their choice

d) **Engineering studies:** The following details are collected

- Soil survey
- Topography studies
- Road life studies

- Drainage, construction and maintenance studies
- Future developments
- Existing roads and their location

  From the details collected above, plans are prepared showing existing road network, topography, population distribution, drainage structure, O-D surveys etc.

Interpretation:

Data plotted in the planning survey in the form of plans is interpreted and used for the following purposes.

- To arrive at the road network from the various alternatives
- For phase wise development of construction project and fixing the priority basis. Like the areas having more economic activities are given priority.
- Assess the actual road used by traffic flow patterns and study the congestion details.
- Requirements of new structures based on the existing performance of pavements, drainage structures etc.
- For assessing future developments in traffic growth.

(d) Explain single layer system in brief. Determine the total thickness of flexible pavement over subgrade having elastic modulus of 180 kg/cm^2.

Assume the following data :

Design wheel load = 5100 kg

Tyre pressure = 7 kg/cm^2

Permissible deflection = 0.25 cm **(12 M)**

Sol: Subgrades which are directly subjected to traffic may be considered as single layer system. Single layer systems are very uncommon. When there is a very thin layer of pavement placed over subgrade and if the strength of the subgrade contribution or rather the thin pavement is ignored , then both the layers together can be approximated to be single layer and can be analyzed as a single layer. Also, the multilayer system can be converted into an equivalent single layer system for easy analysis.

Boussinesq analysis is used for single layer system assuming it to be homogenous, isotropic and elastic. The expression for vertical stress due to a point load 'P' at any depth 'z' and radial distance 'r' as

$$\sigma_z = k\frac{P}{z^2}$$

$$k = \frac{3}{2\pi}\frac{1}{\left[1+(r/z)^2\right]^{5/2}}$$

Boussinesq solution of a single layer system subjected to a concentrated load can be expanded to a uniformly distributed circular load by integrating the point load on the entire area. Later several researchers, have used this for plotting charts and tables for finding the thickness of pavement.

One such method is triaxial method which is used for finding the thickness of the pavement assuming pavement as single elastic homogenous layer.

$$\Delta = \frac{3pa^2}{2E\left(a^2+z^2\right)^{1/2}}$$

$$p = \frac{P}{\pi a^2}\text{ ; a = radius of contact area}$$

$$\Rightarrow \Delta = \frac{3P}{2\pi E\left(a^2+z^2\right)^{1/2}}$$

$$\Rightarrow (a^2+z^2) = \left(\frac{3P}{2\pi E\Delta}\right)^2$$

$$\Rightarrow z = \sqrt{\left(\frac{3P}{2\pi E\Delta}\right)^2 - a^2}$$

Assuming pavement as incompressible and 'z' is thickness of pavement

$$T = \sqrt{\left(\frac{3P}{2\pi ED}\right)^2 - a^2}$$

P = Wheel load

Δ = Permissible deflection

E_s = Modulus of elasticity of subgrade

a = Radius of contact area

Given:

P = 5100 kg

E_s = 180 kg/cm^2

Δ = 0.25 cm

$$p = \frac{P}{\pi a^2}$$

$$\Rightarrow a = \sqrt{\frac{P}{\pi p}}$$

$$= \sqrt{\frac{5100}{\pi \times 7}}$$

$$= 15.23 \text{ cm}$$

$$\therefore\ T = \sqrt{\left(\frac{3\times 5100}{2\times\pi\times 180\times 0.25}\right)^2 - 15.23^2}$$

$= 51.92$ cm

$\therefore$ Thickness of flexible pavement = 51.92 cm

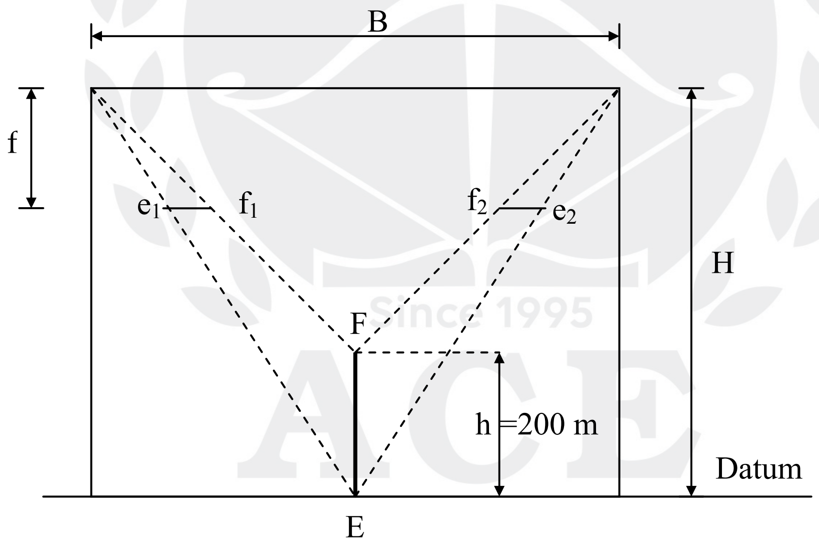
(e)

(i) A pair of overlap aerial photographs was taken with a camera from an altitude of 3000 m above datum. The focal length of camera was 120 mm and the mean distance between two principal points, both of which lie on the datum, was 71.20 mm. In the common overlap area, a tall chimney 200 m high with its base in the datum surface was observed. Find out the difference of parallax for the top and bottom of the chimney.

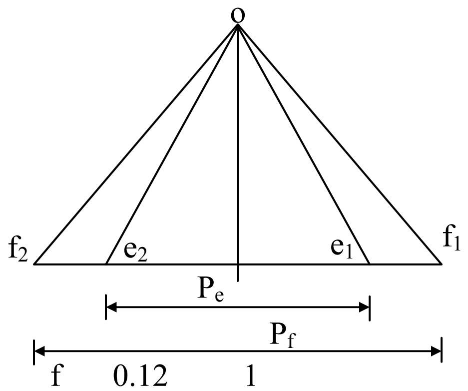
(6 M)

Sol: Given data: H = 3000 m; f = 120 mm; h = 200 m (Base & Datum coincides)

Mean distance between two principal points b = 71.20 mm



Combining both photographs taken on the top and bottom of chimney F & E respectively.



Scale of photograph = $S_d = \frac{f}{H} = \frac{0.12}{3000} = \frac{1}{25000}$

Actual base length $= B = \frac{bH}{f}$

$$= \frac{71.20 \times 3000}{120} = 1780 \text{ m}$$

Parallax is given by $(P_f - P_e)$

Parallax at the bottom = $P_e = \frac{1780 \times 120}{3000} = 71.2\text{mm}$

Parallax at the top = $P_f = \frac{1780 \times 120}{3000 - 200} = 76.29 \text{ mm}$

$\therefore$ Difference in parallax = 76.29 – 71.2 = 5.09 mm

(ii) Explain briefly about the spatial and spectral resolution in Remote Sensing.

(6 M)

Sol: The following are the parameters of a sensor:

1. Spectral Resolution:

Spectral resolution of a remote sensing instrument (sensor) is determined by the band- widths of the electromagnetic radiation of the channels used. High spectral resolution, thus, is achieved by narrow bandwidths width, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad bandwidth.

2. Radiometric Resolution:

It refers to the smallest change in intensity level that can be detected by the sensing system. The intrinsic radiometric solution of a sensing system depends on the signal to noise ratio of the detector. In a digital image, the radiometric resolution is limited by the number of discrete quantization levels used to digitize the continuous intensity value.

3. Spatial resolution

It refers to the size of the smallest object that can be resolved on the ground. In a digital image, the resolution is limited by the pixel size, i.e., the smallest resolvable object cannot be smaller than the pixel size. The intrinsic resolution of an imaging system is determined primarily by the instantaneous field of view (IFOV) of the sensor, which is a measure of the ground area viewed by a single detector element in a given instant in time. However this intrinsic resolution can often be degraded by other factors which introduce blurring of the image, such as improper focusing, atmospheric scattering and target motion. The pixel size is determined by the sampling distance. A "High Resolution" image refers to one with a small resolution size. Fine details can be seen in a high resolution image. On the other hand, a "Low Resolution" image is on with a large resolution size, i.e., only coarse features can be observed in the image.

06.

(a) An 8 m thick saturated clay layer lies above a permeable dense sand layer. The clay settles by 40 mm in 2 years when subjected to a widespread load of 50 kN/m^2 at its surface.

(i) What will be the ultimate settlement of the clay?

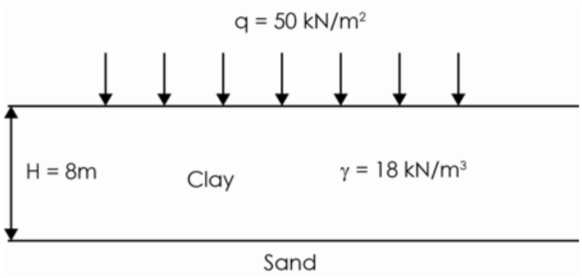
(ii) Calculate the compression index, C_c of the clay.

Assume that the water table is below the dense sand layer and will not influence the settlement. Properties of clay : Average bulk unit weight, γ_{bulk} = 18 kN/m^3, Coefficient of consolidation, C_v = 1 m^2/yr and Specific gravity, G_s = 2.65. Unit weight of water is equal to 9.81 kN/m^3.

(20 M)

Sol:

H = 8 m



Settlement, S = 40 mm

Time, t = 2 years

Drainage path, $d = \frac{H}{2} = 4\,\text{m}$ (double drained)

$$C_v = 1\ \text{m}^2/\text{year}$$

$$T_V = \frac{C_v . t}{d^2}$$

$$= \frac{1\times 2}{4^2} = 0.125$$

$$T_V = \frac{\pi}{4}\left[\frac{U}{100}\right]^2$$

$$0.125 = \frac{\pi}{4}\left[\frac{U}{100}\right]^2$$

$$U = 39.90\ \%$$

$$U = \frac{S}{S_f}$$

$\therefore$ Ultimate settlement $S_f = \frac{S}{U}$

$$= \frac{40}{0.399} = 100.25\ \text{mm}$$

To find compression index, C_c

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

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

$$18 = 9.81\left[\frac{2.65+e}{1+e}\right]$$

$$1.835 = \frac{2.65+e}{1+e}$$

$$1.835 + 1.835\,e = 2.65 + e$$

$$0.835e = 0.815$$

$$e = 0.976$$

At centre of clay layer, $\sigma_o' = \gamma \times 4 = 18\times4 = 72$ kPa

Increase in stress due to external load, $\Delta\sigma' = q = 50$ kPa

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

$$\frac{100.25}{1000} = 8\frac{C_c}{1+0.976}\log_{10}\left[\frac{72+50}{72}\right]$$

$\therefore\ C_c = 0.108$

(b)

(i) List four major uses of geotextiles. What is the difference between permittivity and transmissivity?

(6 M)

Ans: Geotextiles: They are textile type material consist of synthetic fibers. They are not biodegradable. The synthetic fibers are made into flexible fabrics by weaving machinery

- These are porous and allow flow of liquids through them.
- These are most used geosynthetics.
- Available in woven and non woven manner. Also available in knitted manner (limited extent).
- Made of polymers like polypropylene, polyster, high density polyethylene.

Functions: They can be used for separation, filtration, reinforcement, Drainage.

Permittivity: The change in thickness under normal stress also changes the cross-plane hydraulic conductivity of a geotextile. Thus, the cross-plane capability is generally expressed in terms of a quantity called "Permittivity", P;

$$P = \frac{k_n}{t}$$

Where,

P = permittivity

k_n= hydraulic conductivity for cross-plane flow (perpendicular to the plane of geotextile)

t = thickness of the geotextile

Transmissivity: To perform the function of drainage satisfactorily, geotextiles must possess excellent in-plane permeability. The in-plane drainage capability can thus be expressed in terms of a quantity called "Transmissivity", T;

$$T = k_p t$$

Where,

T = transmissivity

k_p = hydraulic conductivity for in-plane flow (Parallel to the plane of geotextile)

The units of k_n and k_p are cm/sec or m/sec; however, the unit of permittivity P is sec^{-1} or min^{-1}. In a similar manner, the unit of transmissivity T is m^3/sec. m

(ii) Indian Standard (IS) Light Compaction test is usually conducted in 3 layers in a 1000 cc mould. How many blows per layer would be necessary if the above test is conducted in a 2250 cc mould? (4 M)

Sol:

(ii) Number of blows per layer in a 1000 cc mould = 25 numbers

Number of blows per layer if 2250 cc mould is used

$$= \frac{25}{1000} \times 2250 = 56.25$$

Say 56 blows per layer

(iii) In a falling head permeability test on a 120 mm high and 100 mm diameter cylindrical sample, the water level in the standpipe dropped from a height of 750 mm to 250 mm in one hour. Determine the coefficient of permeability. Take the internal diameter of the standpipe equal to 6 mm.

(10 M)

Sol:

(iii) In a falling head permeability test, the coefficient of permeability, k is determined as follows

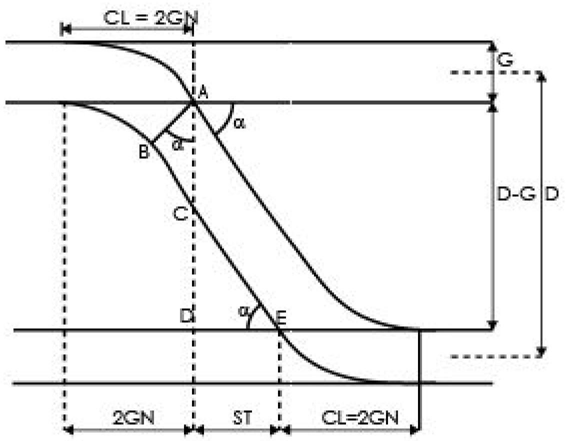
$$k = \frac{a.L}{A.t}\log_e \frac{h_1}{h_2}$$

$$= \frac{\frac{\pi}{4}(6)^2 \times 120}{\frac{\pi}{4}\times(100)^2 \times 1}\log_e\left[\frac{750}{250}\right] \qquad = 0.475 \text{ mm/hr}$$

(c) Draw a typical diagram showing all important features of a crossover with intermediate portion straight and crossing angles equal for two parallel railway tracks. Find intermediate straight distance and overall length of crossover for Broad Gauge tracks of same crossing number 1 in 12. The distance between centres of tracks is 5 m.

(20 M)

Sol: Crossover: It is a combination of two turnouts with central portion of track (being straight or curved) to divert the train from one track to another track.



(Crossover with straight intermediate portion between two parallel tracks and same crossing angle)

ST : Intermediate straight length

G : Gauge distance

D : c/c distance between tracks

N : Crossing number; α = Crossing angle; $\tan\alpha = \dfrac{1}{N}$

CL : Curve lead = 2 GN

Straight track (ST) :

In Δ^{le} CDE, DE = CD cot α = ST

In Δ^{le} ABC AB = G;

$$AC = AB \sec\alpha$$
$$= G\sec\alpha$$
$$\tan\alpha = \frac{1}{N}$$
$$\Rightarrow \sec\alpha = \frac{\sqrt{1+N^2}}{N}$$
$$\therefore AC = \frac{G\sqrt{1+N^2}}{N}$$

$$CD = D - G - AC = D - G - \frac{G\sqrt{1+N^2}}{N}$$

ST = DE = CD cotα

$$= \left(D - G - \frac{G\sqrt{1+N^2}}{N}\right)N$$
$$= (D-G)N - G\sqrt{1+N^2}$$

Overall length = 2GN + 2GN + ST

$$= 4GN + (D-G)N - G\sqrt{1+N^2}$$

Given:

Crossing number is 1 in 12

$\Rightarrow N = 12$

c/c distance between track 'D' = 5 m

Broad gauge track $\therefore$ G = 1.676 m

Intermediate straight distance $= (D - G)\,N - G\sqrt{1+N^2}$

$$= (5 - 1.676)12 - 1.676\sqrt{1+12^2}$$

$$= 39.888 - 20.181$$

$$= 19.707 \text{ m}$$

Total crossover length = 4GN + ST

$$= (4\times 1.676 \times 12) + 19.707 = 100.155 \text{ m}$$

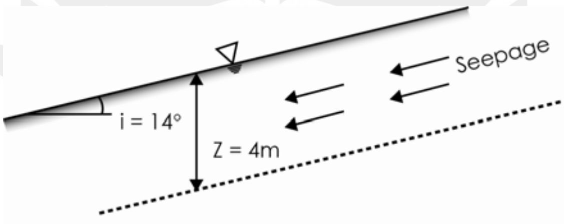
07. (a)

(i) A long natural slope in overconsolidated fissured clay of saturated unit weight 22 kN/m^3, is inclined at 14 degrees to the horizontal. The water table is at the surface and seepage is approximately parallel to the slope. A slip surface has developed on a plane parallel to the surface at a depth of 4 m. Determine the factor of safety along the slip plane using the residual strength parameter, ϕ'_r = 20 degrees.

(10 M)

Sol:

(i)



$\gamma_{sat} = 22$ kN/m^3

Assume $\gamma_w = 9.81$ kN/m^3

Factor of safety $F = \dfrac{\gamma'}{\gamma_{sat}}\dfrac{\tan\phi}{\tan i}$ (cohesion is considered to be negligible)

$$= \left[\frac{22 - 9.81}{22}\right]\frac{\tan 20°}{\tan 14°} = 0.809$$

(ii) A plate load test was conducted using a square plate of 30 cm side, at 2 m depth on loose sand. The plate settled by 8 mm at load intensity of 12 t/m^2. Determine the settlement of 2 m × 2 m square footing if it has to carry the same load intensity at 2 m depth at this site. Ignore the effect of embedment.

(10 M)

Sol:

B_P = 30 cm = 0.3 m; S_p = 8 mm

B_F = 2 m

Let the settlement of footing be S_F

In sands, $\frac{S_F}{S_P} = \left(\frac{B_F(B_P+0.3)}{B_P(B_F+0.3)}\right)^2$

$$\frac{S_F}{8} = \left[\frac{2(0.3+0.3)}{0.3(2+0.3)}\right]^2$$

$\therefore$ S_F = 24.2 mm

(b) What are the elements that are considered in the geometric design of a taxiway? Explain them in brief. Design the turning radius of a taxiway for a class B airport handing supersonic aircrafts with a wheel base of 30 m and a tread of main landing gear as 7.2 m. The aircraft design speed to negotiate the curve is given as 60 kmph and coefficient of friction as 0.13.

(20 M)

Sol:

A taxiway is a path for aircraft at an airport connecting runway with aprons, hangars and terminals.

Taxiway should be arranged such that

- Landing aircrafts should not interfere with take off aircrafts.
- Landing aircrafts should leave the runway as early as possible.
- Distance must be minimum between end of take off and terminal building.

Geometric elements of taxiway:

a) **Length:** Should be as minimum as possible

b) **Longitudinal gradient:** Levelled taxiways are preferable. Steep gradients consume more fuel. As per ICAO, it is 3% for A and B type airports and 1.5 % for C and D type airports.

c) **Rate of change of longitudinal gradient:** Change of grade should be smooth without causing any jerk. Vertical curves can be provided for smoothing. As per ICAO, the maximum change in the pavement longitudinal gradient is fixed as 4% for A and B category of airports and 3.33% for the C, D and E category of airports.

d) **Width of the taxiway:** The width of the taxiway is lesser than the width of the runway. Generally, the width of the taxiway varies between 22.5 metres and 7.5 metres. As per ICAO, if the airport code is A then the taxiway width is 7.5 metres, if it is B then it is 10.5 metres, if it is C then it is 15 metres.

e) **Sight distance:** As the speed of the aircraft on taxiway is lower than the speed on the runway, a smaller value of sight distance is sufficient on the taxiway. ICAO has certain recommendations based on the distance that should be visible from a particular height.

f) **Transverse gradient:** It is provided to drain water and make the taxiway dry to avoid slipping. ICAO recommends the maximum pavement transverse gradient of 2% for A and B category of airports, whereas in the case of C, D and E category of airports it is 1.5%.

g) **Width of the safety area:** pavement thickness should be thick enough to support the airport petrol vehicles, etc., Surface should be treated with bitumen and it should not disintegrate due to the hot blast of jet aircrafts and the surface should be smooth and impervious. ICAO has certain recommendations for shoulders, edge safety margins etc.

h) **Turning radius:** It provides the transformation from high speed to low speed. Hence a circular curve is provided which the aircraft should traverse.

Radius of circular curve = $\frac{V^2}{125f}$

V is speed in kmph

f = coefficient of friction

Horonjeff's equation:

$$R = \frac{0.388W^2}{\left(\frac{T}{2} - S\right)}$$

W = Wheel base of aircraft in 'm'

T = Width of taxiway pavement in 'm'

S = Distance between point midway of the main gear and the edge of taxiway pavement in 'm'

$$= 6 + \frac{W}{2}$$

Given:

Speed (V)= 60 kmph

Coefficient of friction (f) = 0.13

Wheel base (W) = 30 m

Tread of main landing gear = 7.2 m

Type 'B' airport

$\therefore$ Width of taxiway pavement = 10.5 m

(a) Turning radius = $\frac{V^2}{125f}$

$$= \frac{60^2}{125 \times 0.13} = 221.538\text{m}$$

(b) Horonjeff's equation:

$$S = 6 + \frac{W}{2} = 6 + \frac{7.2}{2} = 9.6\,\text{m}$$

$$R = \frac{0.388 \times 30^2}{\left(\frac{10.5}{2} - 9.6\right)}$$

R = –80.275

-ve value, radius can not be negative

So, Assuming width of taxiway pavement = 22.5 m

$$R = \frac{0.388 \times 30^2}{\frac{22.5}{2} - 9.6}$$

$= 211.63$ m

(c) Minimum radius for Supersonic Aircrafts = 180 m

Maximum of above values = 221.538 m

$\therefore$ Provide taxiway tuning radius of 221.538 m

(c)

(i) **The following consecutive readings were taken with auto level and a staff of length 4 m along the centre line of under constructed road having continuously sloping ground at a constant interval of 20 metres :**

3.105, 2.120, 1.115, 0.410, 3.655, 2.310, 1.275, 0.310, 3.310, 2.310, 1.200, 0.430

The reduced level of last station was 200.200 m. Rule out the page of level book and enter the readings.

Calculate the reduced level of the points by rise and fall method. Also, find the gradient of the line joining the first and last points.

(15 M)

Sol:

(i). Rise and Fall Method

Stn	B.S	I.S	F.S	Rise	Fall	R.L	Remarks
1	3.105					191.280	
2		2.120		0.985		192.265	
3		1.115		1.005		193.270	
4	3.655		0.410	0.705		193.975	
5		2.310		1.345		195.32	
6		1.275		1.035		196.355	
7	3.310		0.310	0.965		197.32	
8		2.310		1.000		198.32	
9		1.200		1.110		199.43	
10			0.430	0.77		200.200	

Check : $\Sigma BS - \Sigma FS = \Sigma Rise - \Sigma Fall = LRL - FRL$

$10.07 - 1.15 = 8.92 - 0 = 200.200 - 191.280$

$= 8.92 = 8.92$ m

$$\text{Gradient} = \frac{8.92}{180} = \frac{1}{20.18} \text{ (Rising)}$$


OUR GATE - 2018 TOP RANKERS
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and many more...
EC TOP 10 9 TOP 100 74
EE TOP 10 7 TOP 100 69
CE TOP 10 7 TOP 100 42
ME TOP 10 4 TOP 100 54
CSIT TOP 10 6 TOP 100 31
IN TOP 10 11 TOP 100 78
PI TOP 10 5 TOP 100 50

(ii) Explain various geological considerations for selection of tunnel sites.

(5 M)

Ans: Geological considerations are very important in laying a tunnel as it affects the total cost as well as the performance of the tunnel. The following are geological considerations for tunnelling .

a) Lithology of the rocks i.e Type of rocks, its strength, density and cohesion , mineral composition and texture of rocks, dipping angle , strike ,etc. It is one of the important factor in deciding the type of tunnelling to be carried out.

b) Presence and orientation of joints, shear zones, fault and fault zones will control the overall rock mass characteristics. Strong mass of rock is preferable as it is relatively free from joints or other structural features like shear zones or faults or rather fractures, i.e it is relatively free from bedding or lamination.

c) Self-supporting nature of tunnels is preferred bur it should not cause failure of rock.

d) Suitable for blasting or boring

e) Stress concentration should be minimum to avoid the failure of rock.

f) Flow pattern of surface and ground water. Groundwater level should be as low as possible as it affects the strength of the soil mass.

08.

(a) A 6 m deep excavation in sand is supported by a smooth vertical wall. The backfill is horizontal and supports a surcharge of 10 kN/m^2 on its surface.

(i) Determine the active thrust on the wall if the water table is far below the bottom of the excavation.

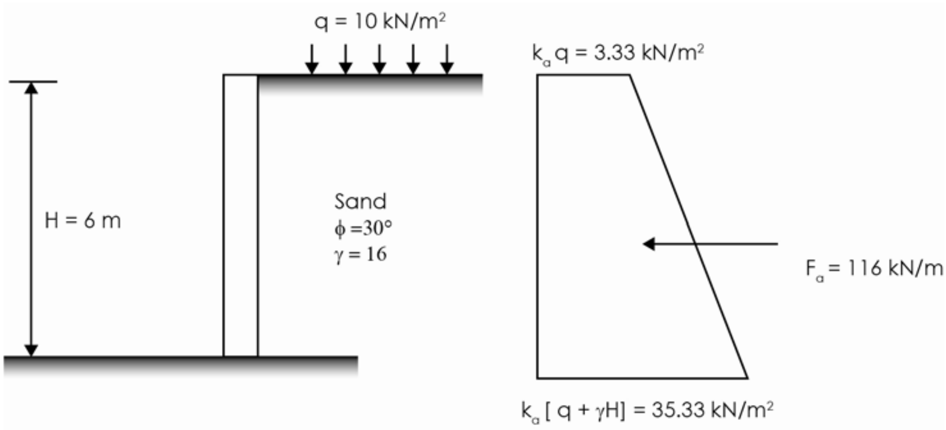
(ii) What should be the embedment depth if the wall in the above case is cantilever sheet pile wall?

Properties of the sand are : $c' = 0$, $\phi' = 30$ degrees and $\gamma_{bulk} = 16$ kN/m^3.

(20 M)

Sol:

(i)



$\phi = 30°$

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1}{3}$$

At top, $p_a = k_a.\ q = \frac{1}{3} \times 10 = 3.33$ kN/m^2

At base $p_a = k_a\ [q+\gamma\ H]$

$$= \frac{1}{3}[10 + 16 \times 6] = 35.33 \text{ kPa}$$

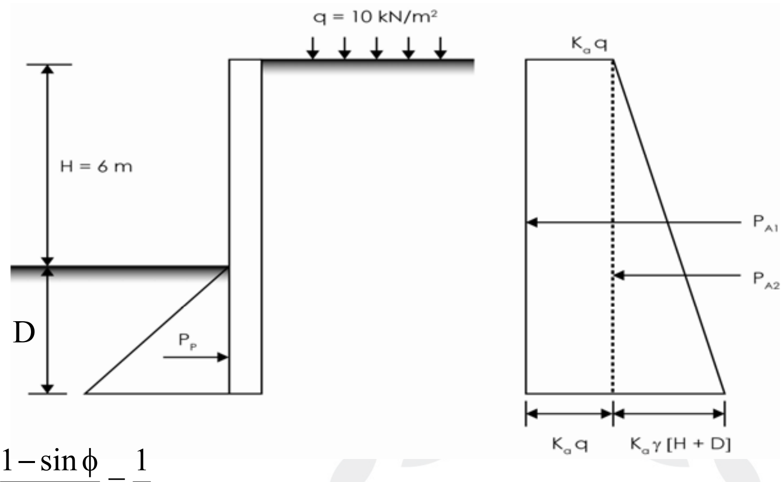
Active thrust, F_a = area of pressure diagram

$$= \left[\frac{3.33 + 35.33}{2}\right] \times 6$$

= 116 kN/m

(ii)

Sol:



$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \frac{1}{3}$$

$$K_p = \frac{1+\sin\phi}{1-\sin\phi} = 3$$

Approximate analysis is used to determine depth of embedment of sheet pile wall. In the approximate analysis, the active earth pressure on the back of the wall and the passive earth pressure infront of the wall are assumed to extend upto base of the wall as shown in figure.

Taking moments of all forces about bottom of sheet pile wall.

$$P_P \times \frac{D}{3} = P_{A_1} \times \left(\frac{H+D}{2}\right) + P_{A_2} \times \left[\frac{H+D}{3}\right]$$

$$k_p.\frac{\gamma D^2}{2}\frac{D}{3} = K_a.q(H+D)\left(\frac{H+D}{2}\right) + K_a\frac{\gamma(H+D)^2}{2}\left(\frac{H+D}{3}\right)$$

$$3\times 16\frac{D^3}{6} = \frac{1}{3}\times 10\frac{(6+D)(6+D)}{2} + \frac{1}{3}\times\frac{16(6+D)^3}{6}$$

$$48D^3 = 10(6+D)^2 + \frac{16}{3}(6+D)^3$$

$$4.8D^3 = (6+D)^2 + \frac{16}{30}(6+D)^3$$

Solving by trial & error

D	LHS	RHS
4m	307.2	633.3
5m	600	830.4
6m	1036.8	1065
6.1	1089	1091
6.2	1144	1117

From the above, the minimum embedment depth required is 6.1 m.

(b)

(i) Design the length of a valley curve which is formed by a descending grade of 1 in 30 meeting an ascending grade 1 in 40 for a design speed of 100 kmph. Assume : Driver's reaction time = 2.5 sec, Coefficient of friction = 0.35 and Allowable Rate of Change of Centrifugal Acceleration = 0.6 m/sec^3.

(15 M)

Given: Descending gradient = 1 in 30

Ascending gradient = 1 in 40

Design speed = 100 kmph

= 27.78 m/sec

(1) Length of valley curve based on comfort criteria:

$$L = 2\sqrt{\frac{Nv^3}{C}}$$

$$N = \text{Deviation angle} = \frac{-1}{30} - \left(\frac{1}{40}\right)$$

$$= \frac{-7}{120}$$

$\therefore$ C = rate of change of centrifugal acceleration = 0.6 m/sec^3

$$\therefore L = 2\sqrt{\frac{\frac{7}{120}\times 27.78^3}{0.6}}$$

$= 91.308$ m

(2) Based on head light sight distance criteria :

Assuming L > SSD;

$$L = \frac{NS^2}{2h_1 + 2S\tan\alpha}$$

h_1 = height of head light = 0.75 m

α = beam angle = 1^o

$$L = \frac{NS^2}{(1.5 + 0.035S)}$$

S = SSD = lag distance + braking distance

$$= vt + \frac{v^2}{2gf}$$

$$= (27.78\times 2.5) + \frac{(27.78)^2}{2\times 9.81\times 0.35}$$

$= 181.83$ m

$$\therefore L = \frac{\frac{7}{120}\times 181.83^2}{(1.5 + 0.035\times 181.83)}$$

$= 245.24$ m $>$ SSD

$\therefore$ Assumption is correct

From the above two criteria, length of valley curve = maximum value = 245.24 m

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CENTER	COURSE	BATCH TYPE	DATE
HYDERABAD - DSNR	GATE + PSUs - 2019	Regular Batch	8th, 22nd July 2018
HYDERABAD - Kukatpally	GATE + PSUs - 2019	Regular Batch	2nd July 2018
HYDERABAD - Abids	GATE + PSUs - 2020	Morning Batch	15th July 2018
HYDERABAD - DSNR	GATE + PSUs - 2020	Morning Batch	22nd July 2018
HYDERABAD - Kukatpally	GATE + PSUs - 2020	Morning Batch	22nd July 2018
HYDERABAD - DSNR	GATE + PSUs - 2020	Evening Batch	22nd July 2018
HYDERABAD - Kukatpally	GATE + PSUs - 2020	Evening Batch	22nd July 2018
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HYDERABAD - DSNR	ESE + GATE + PSUs - 2020	Morning Batch	22nd July 2018
HYDERABAD - Kukatpally	ESE + GATE + PSUs - 2020	Morning Batch	22nd July 2018
HYDERABAD - DSNR	ESE + GATE + PSUs - 2020	Evening Batch	22nd July 2018
HYDERABAD - Kukatpally	ESE + GATE + PSUs - 2020	Evening Batch	22nd July 2018
HYDERABAD - Abids	ESE - 2019 (PRELIMS) - G.S	Regular Batch	09th July 2018
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CHENNAI	GATE + PSUs - 2019	Regular Batch	07th July 2018
CHENNAI	GATE + PSUs - 2020	Weekend Batch	07th July 2018
BANGALURU	GATE + PSUs - 2019	Weekend Batch	07th July 2018
BANGALURU	GATE + PSUs - 2020	Weekend Batch	07th July 2018
PATNA	GATE + PSUs - 2020	Weekend Batch	14th July 2018
VISAKHAPATNAM	GATE + PSUs - 2019	Regular Batch	17th July 2018
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(ii) State the functions of docks. Compare floating dock and dry dock.

(5 M)

Sol: Docks are enclosed areas for berthing ships, to keep them afloat at a uniform level, to facilitate loading and unloading cargo.

Functions of docks:

- To maintain uniform level of water for handling cargo
- Passenger exchange
- Loading , unloading , building and repair of ships.

The following are the differences between floating dock and dry dock

Floating Dock	Dry dock
It is a floating vessel which can lift a ship out of water and retain it above water by means of its own buoyancy	It is a long, excavated chamber, having side walls, a semicircular end wall and a floor.
It is a generally a steel structure	The dock is constructed of concrete or masonry
Time required for construction is less	Time required for construction is more.
It can be transferred from point to point	This is a fixed structure
It has no elaborate entrance or gate arrangements	The open end of the chamber is provided with a gate and acts as the entrance to the dock.

(c)

(i) Two straights AB and BC falling to the right at gradients 12% and 6% respectively, are to be connected by a vertical parabolic curve of length 240 m. Chainage and reduced level of point B are 3000 m and 60.00 m respectively. Calculate the chainage and reduced level of the first three and last three points of the curve by tangent correction method. Take peg interval as 20 m. **(15 M)**

(i) As $g_1 > g_2$ it is a sag curve

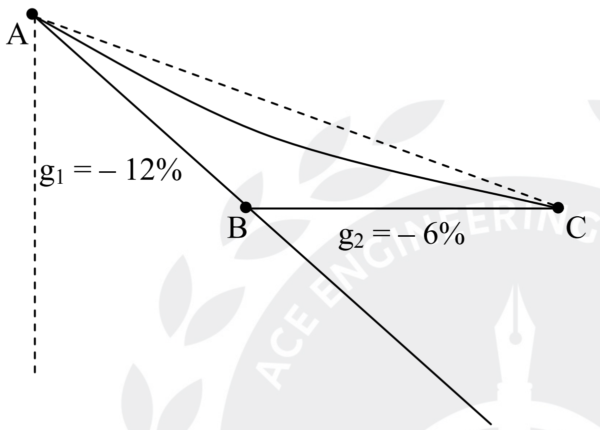
length of curve = L = 240 m ; Peg interval = 20 m

Total number of equal chords = $\frac{240}{20}$ = 12

Number of chords on one side of Apex = 6

Chainage of B = 3000 m

RL of B = 60 m



(i) Calculation of chainages:

Chainage of point A = 3000 – 6 × 20 = 2880 m

Chainage of point B = 3000 + 6 × 20 = 3120 m

(ii) Calculations of elevations of A & C points:

Change of elevation of first tangent per chord length of 20 m

$$e_1 = \frac{g_1}{100} \times 20 = \frac{-12}{100} \times 20 = -2.4\,\text{m}$$

Chainage of elevation of second tangent per chord length of 20 m

$$e_2 = \frac{g_2}{100} \times 20 = \frac{-6}{100} \times 20 = -1.2\text{m}$$

Elevation at the beginning of curve (A) = 60 – ne_1

= 60 – 6 × (– 2.4) = 74.4 m

Elevation at the end of curve (C) = 60 + ne_2

$= 60 + 6\,(-1.2) = 52.8$ m

Tangent correction with respect to the first tangent is given by

$h = kN^2$

$$K = \frac{e_1 - e_2}{4n} = \frac{(-2.4)-(-1.2)}{4\times 6} = -0.05\text{m}$$

$\therefore\ h = -0.05\ N^2$

Since sign convention of 'K' is negative, 'h' will be additive to tangent elevation to get elevations on the curve.

(iii) Calculation of tangent elevations:

Tangent elevation = Elevation of the beginning of the curve + e_1

Elevation of the 1st point on tangent = 74.4 – 2.4 = 72 m

Elevation of the 2nd point as tangent = $74.4 + 2e_1 = 74.4 - 2\,(2.4)$

$= 69.6$ m

Elevation on the 3rd point on tangent

$= 74.4 + 3e_1 = 74.4 - 3\,(2.4) = 67.2$ m

Similarly the elevation of 10th point on tangent = $74.4 + 10e_1 = 74.4 - 10\,(2.4)$

$= 50.4$ m

Elevation of 11th point on tangent

$= 74.4 + 11e_1 = 74.4 + 11(-2.4)$

$= 48$ m

Elevation of 12th point on tangent

$= 74.4 + 12e_1 = 74.4 + 12(-2.4)$

$= 45.6$ m

(iv) Calculation of Tangent correction:

$h = kN^2$

$h_1 = 0.05 \times 1^2 = 0.05$ m ($\because N = 1$)

$h_2 = 0.05 \times 2^2 = 0.2$ m ($\because N = 2$)

$h_3 = 0.05 \times 3^2 = 0.45$ m ($\because N = 3$)

Similarly

$h_{10} = 0.05 \times 10^2 = 5$ m

$h_{11} = 0.05 \times 11^2 = 6.05$ m

$h_{12} = 0.05 \times 12^2 = 7.2$ m

(v) Calculation of elevation of points on the curve:

Elevation of point '1' on the curve = 72 + 0.05 = 72.05 m

Elevation of point '2' on the curve = 69.6 + 0.2 = 69.8 m

Elevation of point '3' on the curve = 67.2 + 0.45 = 67.65 m

Similarly

Elevation of point '10' on the curve = 50.4 + 5 = 55.4 m

Elevation of point '11' on the curve = 48 + 6.05 = 54.05 m

Elevation of point '12' on the curve = 45.6 + 7.2 = 52.8 m (check verified)

(vi) Tabulated values:

Station	Chainage (m)	Tangent Elevation (m)	Tangent correction (m)	Curve Elevation (m)	Remarks
A	2880	74.4	0	74.4	Beginning of curve
1	2900	72.0	0.05	72.05	
2	2920	69.6	0.2	69.8	
3	2940	67.2	0.45	67.65	
10	3080	50.4	5	55.4	
11	3100	48	6.05	54.05	
C	3120	45.6	7.2	52.80	End of curve

(ii) Discuss the various methods of relative positioning in GPS. (5 M)

Sol:

1. Standard positioning Service (SPS)

The standard positioning and timing service which is available to all GPS users on a continuous, worldwide basis with no direct charge. SPS is provided on GPS L1 frequency which a coarse acquisition code and a navigation data message.

SPS Predictable Accuracy:

- 100 meter horizontal accuracy
- 156 meter vertical accuracy
- 340 nanoseconds time accuracy

These GPS accuracy figures are from the 1999 Federal Radio navigation Plan. The figure are 95% accuracies, and express the value of two standard deviations of radial error from the actual antenna position to an ensemble of position estimates made under specified satellite elevation angle (five degrees) and PDOP (less than six) conditions. For horizontal accuracy figures 95% is the equivalent of 2 drms (two-distance root-mean-squared), or twice the radial error standard deviation. For vertical and time errors 95% is the value of two-sandard deviation of vertical error or time error. Receiver manufacturers may use other accuracy measures. Root-mean-square (RMS) error is the value of one standard deviation (68%) of the error in one, two or three dimensions. Circular Error Probable (CEP) is the value of the radius of a circle, centered at the actual position that contains 50% of the position estimates. Spherical Error Probable (SEP) is the spherical equivalent of CEP, that is the radius of a sphere, centered at the actual position, that contain 50% of the three dimension position estimates. As opposed to 2 drms, drms, or RMS figures, CEP and SEP are not affected by large blunder errors making them an overly optimistic accuracy measure.

2. Precise Positioning Service (PPS):

The precise positioning service (PPS) is a highly accurate military positioning, velocity and timing service which will be available on continuous worldwide basis to the authorized user with cryptographic equipments and keys and specially receivers. Government agencies and selected civil users specially approved by the government can use the PPS.

PPS Predicable Accuracy

- 22 meter Horizontal accuracy
- 27.7 meter vertical accuracy
- 200 nanosecond time accuracy