242/350

* Attempt of paper is good.
* Do stepwise calculation.

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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-8 : Full Syllabus Test (Paper-II)

Name : ....

Roll No :

Test Centres			Student's Signature
Delhi ☐	Bhopal ☐	Jaipur ☐	
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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

Signature of Evaluator ....

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IMPORTANT INSTRUCTIONS

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DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Do not write in this margin

Section - A

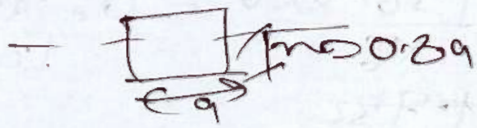
Q.1 (a) A plastic cube with side length 'a' and specific gravity 0.80 is floating in water.

(i) Determine whether the cube is in a stable equilibrium position

(ii) For the given cube identify the range of specific gravity values between 0 and 1 for which the cube remains stable while floating in water.

[12 marks]

Solution



$\Sigma F_y = 0$

$0.8\rho_w(a)^3 = \rho_w(a^2)h$

$h = 0.8a$

$BG = a/2 - 0.8a/2 = \frac{0.2a}{2} = 0.1a$

$I = \frac{a^4}{12}$

$\forall$ = volume of submerged water

$\Rightarrow a^2 \times (0.8a) = 0.8a^3$

$GM = \frac{I}{\forall} - BG$

$\Rightarrow \frac{a^4}{12 \times 0.8a^3} - 0.1a$

$= 4.166 \times 10^{-3} a$

as $GM > 0$

So it is in Stable Equilibrium

(ii) let specific gravity of cube = ρ_s

$\rho_s(\rho_w) \times a^3 = \rho_w a^3 h$

$h = \rho_s a$

$BG = \frac{a - \rho_s a}{2} = a\left[\frac{1-\rho_s}{2}\right]$

$GM = \frac{a^4}{12 \times \rho_s a^3} - a\left[\frac{1-\rho_s}{2}\right]$

$= \frac{a}{12\rho_s} - a\left[\frac{1-\rho_s}{2}\right]$

$GM > 0$ for stable eq.

$\frac{1}{12\rho_s} > \frac{1-\rho_s}{2}$

12

Do not write in this margin

$$\frac{1}{6\rho_s} \geq 1-\rho_s$$

$$6\rho_s - 6\rho_s^2 \leq 1$$

$$6\rho_s^2 - 6\rho_s + 1 \geq 0$$

$$\rho_s = \frac{6 \pm \sqrt{36-4\times 6}}{2\times 6} = \frac{6 \pm 3.46}{12}$$

~~ρs = 4.732~~

$\rho_s = 0.7886,\ 0.2116$

+   −   +
0.2116   0.7886

cube remain stable equillibrium in [0.7886, 1] range and [0, 0.2116] range

Q.1 (b) (i) The recorded rates of rainfall at successive 15 minutes interval of a 2.5 hr are 3.3, 3.0, 9.5, 6.0, 4.5, 8.0, 2.0, 5.5, 5.5 and 2.5 cm/hr. Taking the value of ϕ-index as 3.9 cm/hr determine the value of W-index.

(i) Discuss advantages and disadvantages of 'wet collectors'.

[12 marks]

Solution

Rainfall intensity = 3.3, 3, 9.5, 6, 4.5, 8, 2, 5.5, 5.5, 2.5 cm/hr.

$\phi = 3.9$ cm/hr

for $\phi > i$ No Runoff will be there

so Runoff $= \sum (P - \phi) t$

$$= [9.5+6+4.5+8+5.5+5.5] \times \frac{15}{60} - 3.9 \times \frac{15}{60} \times 6$$

Runoff = 3.9 cm

Now for W-index

$$W = \frac{P-R}{\sum t} = \frac{[3.3+3+9.5+6+4.5+8+2+5.5+5.5+2.5]\times 15/60 - 3.9}{10 \times 15/60}$$

12

Do not write in this margin

W index = 3.42 cu/hr | Ar

(ii) Solution

Advantages of wet collector:-

- wet collector can collect particular matter of very small size around (5 µm - 25 mm)
- Efficiency of wet collector is very high
- In this water spray is used to remove the particles with the help of centrifugal acceleration
- No Technical skill is required to operate the

Disadvantages of wet cyclonic collector

- As water is being used there is contamination of water this water have to be treated for purification it requires very advanced equipment
- Cost of wet cyclonic collector is high as compared to other equipment

Q.1 (c) An elbow type draft tube has a circular section of 1.8 m² at the top and a rectangular section of 13.5 m² at the exit section. The turbine is set at a height of 2 m above the tail race level. The velocity at the inlet of the draft tube is 12.5 m/s. Determine

(i) Negative pressure head at the inlet to the draft tube.

(ii) Power thrown away into the tail race and

(iii) Efficiency of the draft tube

Assume the frictional losses in the draft tube to be 10% of the inlet velocity head

[12 marks]

Solution:

$V_1 = 12.5 m/s$

$A_2 = 13.5 m^2$

Using Continuity equation

$A_1V_1 = A_2V_2$

$1.8 \times 12.5 = 13.5 \times V_2$

$\boxed{V_2 = 1.667 m/s}$

$h_L = 0.1 \times \frac{V_1^2}{2g}$

$\Rightarrow 0.1 \times \frac{(12.5)^2}{2 \times 9.81}$

Using Bernoulli's equation ① and ②

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

$$\frac{P_1}{\rho g} + \frac{(12.5)^2}{2 \times 9.81} + 2 = 0 + \frac{(1.667)^2}{2 \times 9.81} + 0 + \frac{0.1 \times (12.5)^2}{2 \times 9.81}$$

(i) $\boxed{P_1 = -83.543 kN/m^2}$ Ans

Power thrown away into tail race

$= \rho Q g h$

$= (1.8 \times 12.5) \times 9.81 \times \frac{(1.667)^2}{2 \times 9.81}$

(ii) $\boxed{P = 31.262 kWatt}$

(iii) Efficiency of draft tube

$$\eta = \frac{\frac{V_1^2}{2g} - \frac{V_2^2}{2g} - h_{Loss}}{\frac{V_1^2}{2g}}$$

$$= \frac{\frac{(12.5)^2}{2g} - \frac{(1.667)^2}{2g} - \frac{0.1 \times (12.5)^2}{2g}}{\frac{(12.5)^2}{2g}}$$

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$\eta = \frac{137.846}{156.25} \times 100$

(iii) $\eta = 88.22\%$ Ans

Q.1 (d) Calculate the required size of high-rate trickling filter based on the following given parameters:

Flow rate = 5 million liters per day

Recirculation ratio = 1.5

BOD of raw sewage = 260 mg/l

BOD removal in primary clarifier = 30%

Desired final effluent BOD = 45 mg/l

[12 marks]

Solution

High rate Trickling filter

$Q = 5MLD$

$R = 1.5$

BOD of inlet of Trickling filter $= 0.7 \times 260$
$= 182$ mg/L

BOD effluent $= 45$ mg/L

$\eta = \frac{182 - 45}{182} \times 100 = 75.274\%$

$$F = \frac{1+R}{(1+0.1R)^2}$$

$$= \frac{1+1.5}{(1+0.1\times1.5)^2} = 1.89$$

$$\eta = \frac{100}{1+0.0044\sqrt{\frac{W}{VF}}}$$

$W = Q S_0 = 5 \times 182 = 910$ kg/day

$$75.274 = \frac{100}{1+0.0044\sqrt{\frac{910}{V\times1.89}}}$$

$V = 0.0889$ hac-m

$V = 863.974\ m^3$

Assuming Height of Trickling filter
$H = 3m$

$\frac{\pi}{4} D^2 \times H = 863.974$

$D = 19.15m < 60$ ok

So provide $D = 20m$ and $H = 3m$
of Trickling filter
(High rate)

Q.1 (e) An activated sludge aeration tank of length 30 m, width 14 m and liquid depth 4.3 m has the following parameters:

Flow 0.0796 m^3/sec, soluble BOD_5 after primary settling 130 mg/l, mixed liquor suspended solids (MLSS) 2100 mg/l, mixed liquor volatile suspended solids (MLVSS) 1500 mg/l, 30 minute settled sludge volume 230 ml/l, and return sludge concentration 9100 mg/l. Determine the

1. aeration period
2. (F/M) ratio
3. sludge volume index (SVI) and
4. return sludge rate.

[12 marks]

Solution

l = 30m
B = 14m
H = 4.3m

$V = lBH$
$= 30 \times 14 \times 4.3$
$V = 1806 \, m^3$

$Q = 0.0796 \, m^3/s$

Aeration period $= \frac{V}{Q} = \frac{1806}{0.0796} \times \frac{1}{3600}$

$t = 6.302$ hr

$S_0 = 130$ mg/L $X_{MLVSS} = 1500$ mg/L
$X_{MLSS} = 2100$ mg/L

$F/M = \frac{QS_0}{VX} = \frac{0.0796 \times 130}{1806 \times 2100}$

$F/M = 0.2357 \, day^{-1}$, for MLSS

2

For MLVSS

$F/M = \frac{Q S_0}{V X}$

$= \frac{0.0796 \times 130}{1806 \times 1900}$ $X_u = 9100 mg/L$

$F/M = 0.33 day^{-1}$

Sludge volume Index $= \frac{106}{X_u} = \frac{106}{9100}$

$SVI = 109.89$ Ans

< 150 ml/gm

OK

$\frac{Q_R}{Q_0} = \frac{X}{X_u - X}$

$\frac{Q_R}{0.0796} = \frac{2100}{9100-2100}$

$Q_R = 0.02388 m^3/s$ Ans

Q.2 (a) **(i)** A large stream has a reoxygenation constant of 0.4 per day (base 10). At a velocity of 0.85 m/s and at the point at which an organic pollutant is discharged, it has a dissolved oxygen content of 10 mg/*l* (D_o = 0.8 mg/*l*). Below the outfall, the ultimate demand for oxygen is found to be 20 mg/*l* and the deoxygenation constant is 0.2 per day (base 10). What is the dissolved oxygen at 48.3 km downstream?

(ii) What is sewage sickness? Explain various methods used to prevent sewage sickness.

(iii) Explain the key factors affecting the natural self purification process in rivers.

[10 + 5 + 5 = 20 marks]

Q.2 (b) **(i)** A 300 mm diameter pipe carries water with a velocity of 24.4 m/s. The pressures at two points *A* and *B* were measured as 361 kN/m^2 and 288 kN/m^2 respectively. The elevations of points *A* and *B* were 30.5 m and 33.5 m respectively. Determine the loss of head between points *A* and *B*.

(ii) A 4 metre wide rectangular channel carries a discharge of 16 cumecs. Check whether a jump can occur at initial depth of 0.5 m or not. Calculate the sequent depth to this initial depth if however the jump forms. Also find the energy loss in this jump.

[10 + 10 = 20 marks]

Q.2 (c) **(i)** Demand of domestic water for a certain city is observed to follow the following pattern:

Time (hr)	0	2	4	6	8	10	12	14	16	18	20	22	24
Demand at the stated time (m^3/s)	0.00	0.10	0.15	0.20	0.50	0.60	0.40	0.30	0.15	0.20	0.25	0.10	0

Assuming uniform rise or fall in demand in the successive time interval, calculate the minimum required capacity of service reservoir, if treated water supply by pumping is constant throughout the day.

(ii) Explain self cleansing velocity and non-scouring velocity and their importance in the design of sewers.

[12 + 8 = 20 marks]

Q.3 (a) **(i)** Design an irrigation channel based on Kennedy's theory required to carry a discharge of 45 cumec. The value of Manning's roughness coefficient '*N*' is 0.0225 and critical velocity ratio 'm' is 1.05. The channel has a bed slope of 1 in 5000. Take the initial value of depth as 2.2 m.

(ii) A catchment experiences a 2 hour duration isolated storm and the peak of the flood hydrograph due to this storm was found to be 220 m^3/s. The total depth of rainfall was 47 mm. Estimate the peak of the 2 hour unit hydrograph of this catchment, assuming a constant base flow of 15 m^3/s and an average infiltration rate of 2.5 mm/hr. If the area of the catchment is 445 km^2, determine the base width of the 2 hour unit hydrograph assuming that the unit hydrograph is triangular in shape.

[10 + 10 = 20 marks]

Solution

Kennedy's Theory

$Q = 45\ m^3/s$ $S = \frac{1}{5000}$

$N = 0.0225$

$m = 1.05$

Assuming initial depth $y = 2.2$

critical velocity $V = 0.55\, m\, y^{0.64}$

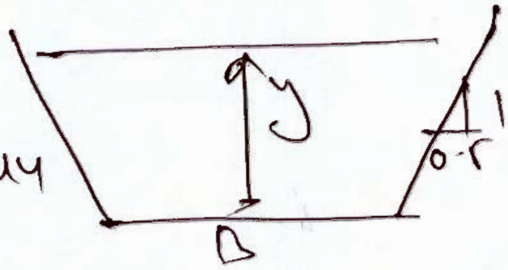
$V_c = 0.55 \times 1.05 \times (2.2)^{0.64}$

$V_c = 0.956\ m/s$.

$A = \frac{Q}{V} = \frac{45}{0.956} = 47.044$

$(B + my)y = A$

$(B + 0.5y)y = 47.044$



$\boxed{B = 20.283\ m}$

Now $P = B + 2y\sqrt{1+m^2}$

$P = 20.282 + 2 \times 2.2\sqrt{1 + 0.5^2}$

$P = 25.202\ m$

$R = A/P = \frac{47.044}{25.202} = 1.866$

$$C = \frac{\frac{1}{n} + 23 + \frac{0.00155}{S}}{1 + \left[23 + \frac{0.00155}{S}\right]\frac{n}{\sqrt{R}}}$$

$C = 49.913$

$V = C\sqrt{RS}$

$V = 49.913\sqrt{1.866 \times 1/5000}$

$V = 0.964\ m/s$

for $V = 0.964\ m/s$,

$A = Q/V = \frac{45}{0.956} = 46.663\ m$

$y = 2.22\ m$

$(B + 0.5y)y = 46.663$

$\boxed{B = 19.84\ m}$

$P = B + 2y\sqrt{1+n^2}$

$P = 24.804$

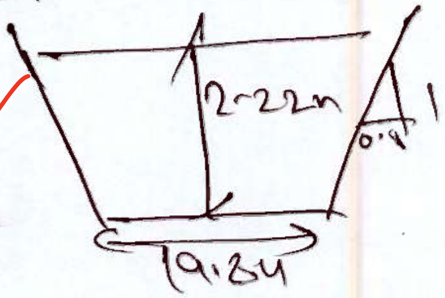
$R = A/P = 1.881$

$$C = \frac{1/n + 23 + \frac{0.00155}{S}}{1 + \left[23 + \frac{0.00155}{S}\right]\frac{n}{\sqrt{R}}}$$

$C = 49.413$

$V = C\sqrt{RS}$

$V = 0.969 \, m/s$



(ii) Solution

Flood Hydrograph Qmax = 220 m3/s

Base flow = 15 m3/s

Direct runoff Hydrograph peak = 220 − 15 = 205 m3/s

average infiltration rate = 2.5 mm/hr

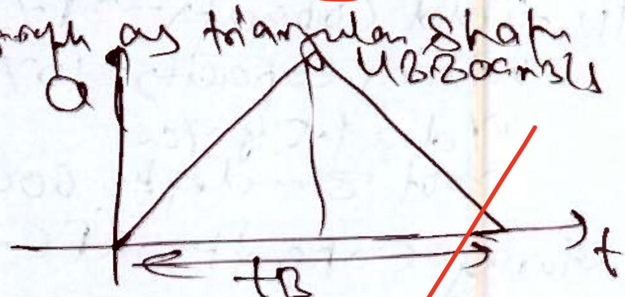
Total Rainfall = 47 mm

Effective rainfall = 47 − 2.5 × 2 = 42 mm

Peak of 2 hr unit Hydrograph = $\frac{205}{4.2}$ = 48.809 m3/s

Peak Q = 48.809 m3/s Ans

Assuming Hydrograph as triangular Shape



$\frac{1}{2} \times Q \times t_B = A \times 1\,cm$

$\frac{1}{2} \times 48.809 \times t \times 3600 = 445 \times 10^6 \times 10^{-2}$

$t = 50.65 \, hr$ Ans

Do not write in this margin

Q.3 (b) (i) Define creep in reference to railway track. What are possible causes and effects of creeps? Briefly describe various preventive and remedial measures.

(ii) A loam soil has a field capacity of 25% and wilting coefficient of 10%. The dry unit weight of soil is 1.5 gm/cc. If the root zone depth is 60 cm, determine the storage capacity of the soil. Irrigation water is applied when moisture content falls to 15%. If the water application efficiency is 75%, determine the water depth required to be applied in the field.

[10 + 10 = 20 marks]

Solution

(ii) field Capacity = 25%
wilting Capacity = 10%
$\gamma_d = 1.5$ gm/cc
root zone depth = 60 cm

Storage Capacity = $\frac{(FC - WC)\gamma_d \times d}{\gamma_w}$

$= \frac{(0.25 - 0.1) \times 1.5 \times 0.6}{1}$

$d = 0.135\,m$ Capacity of soil

Water applied when moisture Content falls to 15%.

depth required = $\frac{(Fc - 15\%) \times d \times \gamma d}{\gamma w}$

$= \frac{(0.25 - 0.15) \times 0.6 \times 1.5}{1}$

d = 0.09 m

Given water application efficiency = 0.75.

depth of water required = $\frac{0.09}{0.75}$ = 0.12 m

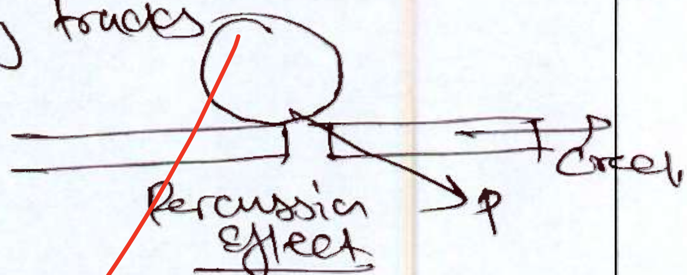
Depth = 0.12 m | Ans

(1) Solution

Creep is the Movement of railway track in direction or opposite of direction of rail wagon depending on the situation

Creep occurs due to

- Drag: as wagon moves forwards it applied some drag on railway track due to this movement of rail occurs.
- due to Percussion Effect:
  Due to this when there is rail joint and wagon applied force to that joint it will lead to movement of railway tracks.



- due to wave theory:
  as there is Movement of train there is formation of upward and downward formation of wave of track, when wheels strike these wave it will lead to creep.

Preventive and Remedial Measure:

- we can use Anti creeper for prevention of creep
- Creep occur More on upward and downward slope so prevent this slope we can reduce creep.
- we can place the track again back to its position by manually
- creep occure more on wear track so we can lay fresh track to avoid creep.

10

Q.3 (c) A sludge digestion tank is designed in waste water treatment plant for 15 MLD average flow of sewage carrying 215 mg/l concentration of organic suspended solids. It has been observed that out of all organic suspended solids, 600 kg of nonvolatile solids and 30% of volatile solids get digested. Calculate the diameter of sludge digestion tank required for carry out the digestion of sewage in 30 days. Assume

$G_{\text{Non-volatile solids}} = 2.45$

$G_{\text{Volatile solids}} = 1.03$

$\eta_{PST} = 60\%$

Moisture content of raw sludge = 90%

Moisture content of digested sludge = 80%

Depth of tank = 6 m

[20 marks]

Solution

$Q_{avg} = 15$ MLD

Sewage = 215 mg/L (suspended solid)

$\eta_{PST} = 60\%$

Removal of solids $= 15 \times 215 \times 0.6 = 1935$ kg/day.

Non volatile solids = 600 kg/day

Volatile solids (initially) $= 1935 - 600$
$= 1335$ kg/day

Firstly

Volume of raw sludge $= (V)_{VS} + (V)_{NVS} + (V)_{W}$

$$= \frac{1335}{1.03 \times 1000} + \frac{600}{2.45 \times 1000} + \frac{0.9 \times 1935}{1000}$$

$V_{Raw} = 3.282$ m3/day.

After digestion of volatile solids

Volatile solid remaining $= 0.7 \times 1335 = 934.5$ kg

Non volatile solid = 600 kg/day

Volume of digested sludge $= (V)_{VS} + (V)_{NS} + (V)_{W}$

$$= \frac{934.5}{1030} + \frac{600}{2450} + \frac{0.8 \times (934.5 + 600)}{1000}$$

$(V)_d = 2.379$ m3/day.

Volume of digestion $= [V_1 - \frac{2}{3}(V_1 - V_2)]\, t_d$

$t_d = 30$ days

$V = [3.282 - [3.282 - 2.379] \times \frac{2}{3}] \times 30$

$V = 80.415$ m3 Ans

Depth = 6 m

$\frac{\pi}{4} D^2 = 80.415$

$D = 4.13$ m Ans

Approach is ok

10

Cal: Mistake

Q.4 (a) (i) What is a high speed exit taxiway? Discuss the factors that affect the number and location of exit taxiways. Show typical exit taxiway configuration.

(ii) A centrifugal pump with 1.2 m diameter runs at 200 r.p.m. and pumps 1880 litres/s, the average lift being 6 m. The angle which the vanes make at exit with the tangent to the impeller is 26° and the radial velocity of flow is 2.5 m/s. Determine the manometric efficiency and the least speed to start pumping against a head of 6 m, the inner diameter of the impeller being 0.6 m.

[10 + 10 = 20 marks]

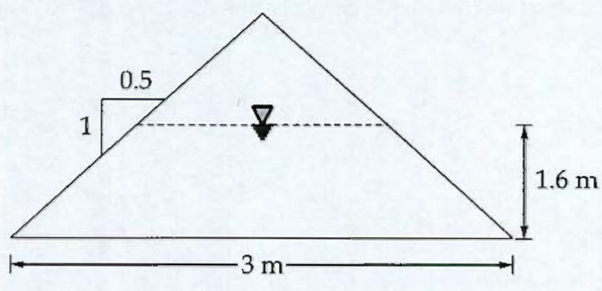
Q.4 (b) **(i)** A bag house filter is having 20 compartments, 360 bags per compartments and each bag of diameter 11 m and bag length 30 m with gas flow rate of 1200,000 m^3/min. Calculate the gross and net air to cloth ratios respectively. Assume that two compartments are out of service when calculating net air to cloth ratio.

(ii) 1. Write a short note on sludge density index.

2. An air conditioner generates a noise level of 75 dB for five minutes every hour. If the background noise level is 55 dB then compute the equivalent noise level.

[10 + 10 = 20 marks]

Q.4 (c) **(i)** Water is flowing at critical depth at a section in a triangular shaped channel, with side slope of 0.5 H: 1V as shown. If the critical depth is 1.6 m, estimate the discharge in the channel and the specific energy at this critical section.

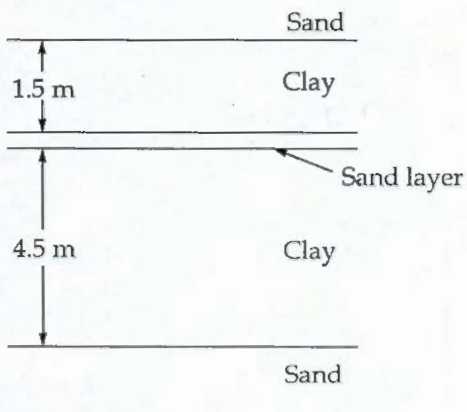


(ii) Consider a trapezoidal rigid boundary channel of 3 m base width with side slopes 1 H to 0.5 V, with depth of flow being 1.2 m, and $n = 0.012$, with adequate free board. Sketch the shear stress distribution on wetted perimeter. Explain points of zero and maximum, shear stresses on each of side slopes and on bed with reasons therefore.

[5 + 15 = 20 marks]

Section - B

Q.5 (a) A 6.0 m thick layer of clay is located between two layers of free-draining sand. Also, there is a thin drainage layer within the clay at a depth of 1.50 m from its top surface. The average value of C_V is found as 4.92×10^{-2} mm^2/sec. If a structure is constructed above the clay layer, how many days would be required for it to attain half its ultimate settlement? Assume that the expression $T_V = \frac{\pi}{4}U^2$ is applicable for the entire range of consolidation.



[12 marks]

Solution

$C_v = 4.92 \times 10^{-2}$ mm²/sec

$T_v = \frac{\pi}{4} U^2$

$U = \frac{S_t}{S_T} = 50\% = 0.5$ [for Half settlement]

$U_1 h_1 + U_2 h_2 = U H$

$U_1 \times 1.5 + U_2 \times 4.5 = 0.5 \times 6$

$\boxed{U_1 + 3U_2 = 2}$ — (1)

for layer (1)

$T_v = \frac{C_v t}{(H_d)^2}$

$\frac{\pi}{4}(U_1)^2 = \frac{4.92 \times 10^{-2} \times t}{(1500/2)^2}$

$U_1 = 3.3371\sqrt{t} \times 10^{-4}$

for layer (2)

$T_v = \frac{C_v t}{(H_d)^2}$

$\frac{\pi}{4} U_2^2 = \frac{4.92 \times 10^{-2} \times t}{(4500/2)^2}$

$U_2 = 1.1123 \times 10^{-4} \sqrt{t}$

from eq (1)

$[3.3371 \times 10^{-4} + 3 \times 1.1123 \times 10^{-4}]\sqrt{t} = 2$

$\boxed{t = 103.929 \text{ days}}$ Ans

Q.5 (b) A 1 meter wide wall footing is located at a depth of 1.5 m from the ground surface. The supporting soil is compressible and has shear strength parameters C'_{cu} = 30kN/m^2 and ϕ'_{cu} = 25°.

The total unit weight of the soil is γ = 18.3kN/m^3. The water table is at a great depth.

Compute the safe load that can be carried by the wall footing per metre length of the wall. Adopt factor of safety of 3.0.

ϕ'	N'_C	N'_q	N'_γ
15.4°	12.90	4.40	2.50
17.3°	13.91	5.17	4.02
20.5°	17.70	7.40	5.00
25.5°	25.10	12.70	9.70

[12 marks]

Solution

for $\phi_{cu} = 25°$

$$N_c' = 17.7 + \left[\frac{25.1 - 17.7}{25.5 - 20.5}\right] \times [25 - 20.5]$$

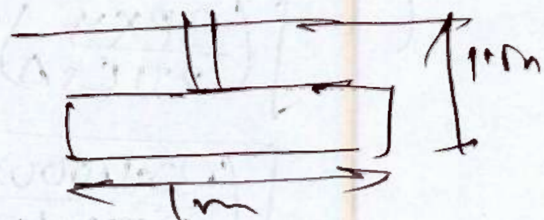
$$N_c' = 24.36$$

$$N_q' = 7.40 + \left[\frac{12.70 - 7.40}{25.5 - 20.5}\right] \times [25 - 20.5]$$

$$N_q' = 12.17$$

$$N_\gamma' = 5 + \left[\frac{9.7 - 5}{25.5 - 20.5}\right] \times [25 - 20.5]$$

$$N_\gamma' = 9.23$$



Strip footing

$C'_{cu} = 30\,kN/m^2$

$$q_u = CN_c' + qN_q' + 0.5B\gamma N_\gamma'$$

$$= 30 \times 24.36 + [18.3 \times 1.5] \times 12.17 + 0.5 \times 1 \times 18.3 \times [9.23]$$

$$q_u = 1149.321\,kN/m^2$$

$$q_{safe} = \frac{q_u - \gamma D_f}{FOS} + \gamma D_f$$

$$q_{safe} = \frac{1149.321 - 18.3 \times 1.5}{3} + 18.3 \times 1.5$$

$$q_{safe} = 401.407\,kN/m^2$$

for safe load P, $= q_{safe} \times (1 \times 1)$

$$P = 401.407\,kN$$ Ans

Q.5 (c) Design the pavement section by triaxial test method using the following data:

Wheel load = 4000 kg

Radius of contact area = 16 cm

Traffic coefficient, $X = 1.6$

Rainfall coefficient $Y = 1.0$

Design deflection, $\Delta = 0.25$ cm

E-value of subgrade soil, $E_s = 100 \text{ kg/cm}^2$

E-value of base course material, $E_b = 400 \text{ kg/cm}^2$

E-value of 7.5 cm thick bituminous concrete surface course = 1000 kg/cm^2.

[12 marks]

Solution

For single layer of pavement

$$t = \sqrt{\left(\frac{3PXY}{2\pi E_s \Delta}\right)^2 - (a)^2}$$

$$= \sqrt{\left(\frac{3 \times 4000 \times 1.6 \times 1}{2\pi \times 100 \times 0.25}\right)^2 - (16)^2}$$

$t = 121.179$ cm

thickness of pavement of single layer = 121.179 cm

Now 7.5 cm of bituminous layer of E = 1000 kg/cm and Base course of Eb = 400 kg/cm is provided

$$\text{thickness of Base Course} = t \times \left[\frac{E_s}{E_b}\right]^{1/3}$$

$$= 121.179 \times \left[\frac{100}{400}\right]^{1/3}$$

$t_{bas} = 76.33$ cm

Now bituminous layer of 7.5 cm is equivalent to

$$\frac{t_{Bas}}{t_{Bit}} = \left(\frac{E_{bit}}{E_{ba}}\right)^{1/3}$$

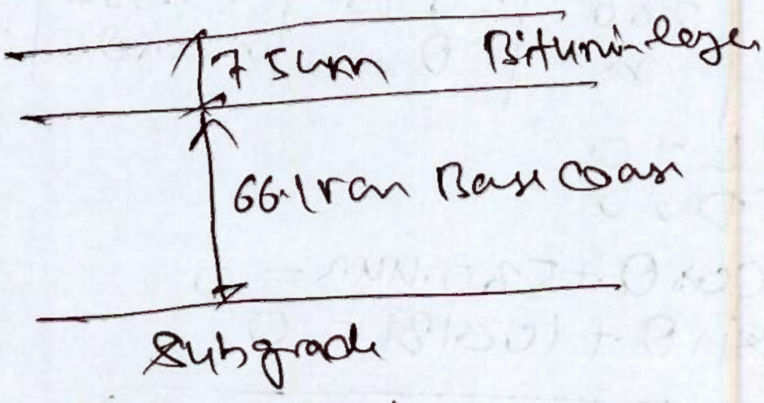
$$\frac{t_{Bas}}{7.5} = \left[\frac{1000}{400}\right]^{1/3}$$

$t_{Bas} = 10.17$ cm

12

So thickness of Base Coarse = 76.33 − 10.179

$t_{Base} = 66.15$ cm
$t_{Bit} = 7.5$ cm



Pavement Surface

Q.5 (d) The lengths and bearings were recorded for running a closed traverse *ABCDE*. The length and bearing of EA has been omitted. Find the length and bearing of line *EA*.

Line	Length (m)	Bearing
AB	217.50	120°15′
BC	300.00	62°30′
CD	375.00	322°24′
DE	280.00	335°18′
EA	?	?

[12 marks]

Do not write in this margin

Solution

Line	length	Bearing	lattitude	Departure
AB	217.5	120° 15'	-109.5708	187.884
BC	300	62° 30'	138.5245	266.103
CD	375	322° 24'	297.1086	-228.804
DE	280	335° 18'	254.382	-117.002
EA	x	θ	$x\cos\theta$	$x\sin\theta$

(6)

$\Sigma L = 0$

$\Sigma D = 0$

$x\cos\theta + 580.443 = 0$

$x\sin\theta + 108.181 = 0$

$x = \sqrt{(580.443)^2 + (108.181)^2}$

$x = 590.438\text{m}$

$\theta = 349.442°$

length of line = 590.438 m
Bearing = 349.442°

Q.5 (e) Discuss the factors on which sleeper density depends. How is the sleeper density expressed? Find out number of sleepers required for the construction of a BG railway track 640 m long. Assume sleeper density as (n + 5). Length of a rail for BG = 12.8 m.

[12 marks]

Solution

length of track = 640m

length of BG = 12.8m

No of rails required = $\frac{640}{12.2} = 50$

for 1 rail No of sleepers required = n+5

= 13+5 = 18

So total No of sleepers required

= 18×50 = 900

Total sleepers = 900

factors on which sleeper density depends

- it depends on the strength of permanent way.
- it depends on strength of sleeper as concrete sleeper has high strength as compared to wooden sleeper.

2

- It depends on the length of rails b/w the track
- It is also depends on the guage length of track
  for eg BG = n+5 = (13+5)

it is Expressed as No of sleepers required per rail length.
Nomally for ~~Berger~~ Border guage it is n+5
where n = length of Border guage in integer
so No of sleeper required per rail = n+5
= 13+5 = (18)
for Border guage

Q.6 (a) A State Highway passing through a rolling terrain has a horizontal curve of radius equal to the ruling minimum radius.

(i) Design all the geometric features of this curve, assuming suitable data.

(ii) Specify the minimum set-back distance from the centre line of the two lane highway on the inner side of the curve up to which the buildings etc. obstructing vision should not be constructed so that intermediate sight distance is available throughout the circular curve. Assume the length of circular curve greater than the sight distance. Highway may be assumed be of two lanes. (V_{Ruling} = 80 km/hr)

[20 marks]

Q.6 (b) **(i)** Two straights *PQ* and *QR* intersect at a chainage of 3150 m. The angle of intersection is 130°. It is required to set out a 4° simple circular curve to connect the straights. The chain used for setting out the curve is of 30 m length. Calculate all the necessary data required for setting out the curve using the method of offsets.

(ii) What is techeometer? What are methods of tacheometry?

[12 + 8 = 20 marks]

Q.6 (c) **(i)** Three point loads of 64 t, 16 t and 20 t, 2 m apart in a straight line act at the surface of soil mass. Calculate the resultant stress produced at a depth of 1.5 m below 64 t load. The Boussinesq's influence factor, I_B for depth $z = 1.5$ m are given below with respect to distance to depth (r/z) ratio.

r/z	0	0.67	0.75	1.333	1.50	2.00	2.67	3.00
I_B	0.4775	0.1910	0.1565	0.0374	0.025	0.0085	0.0025	0.0015

(ii) An anchored sheet pile supports a sandy back fill of a height 3 m having angle of shearing resistance of 30° and unit weight of 19 kN/m^3. The soil below dredge line is clay with a unit weight of 19 kN/m^3, cohesion 20 kN/m^2 and zero angle of internal resistance. The anchor rods are placed 1 m apart and 1 m below the level surface of the backfill. Assuming free earth support, calculate the force in anchor and the depth of sheet pile. Use Rankine's theory for earth pressure.

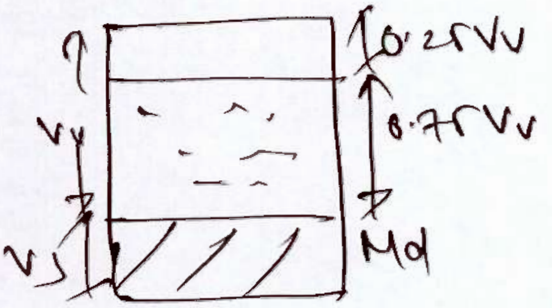
[12 + 8 = 20 marks]

Q.7 (a) **(i)** A soil mass is contaminated with gasoline. 75% of the void space of the soil is filled with gasoline and water. The volume of gasoline is 25% of the volume of water. The unit weight of soil solids is 26 kN/m^3 and water content of the soil is 25%. The specific gravity of gasoline is 0.9. Find the void ratio, porosity, total density and dry density of the soil. Take γ_w = 9.81 kN/m^3.

(ii) Briefly explain the use of plasticity chart in classifying fine grained soils.

[15 + 5 = 20 marks]

Solution



$V_g = 0.25 V_w$

$V_g + V_w = 0.75 V_v$

$(0.25+1) V_w = 0.75 V_v$

$V_w = 0.6 V_v$

$V_g = 0.15 V_v$

$G = 26$ kN/m^3

$w = 25\%$

$G_g = 0.9$

$\frac{W_w}{W_s} = 0.25$

$W_w = 0.25 W_s$

~~$S = \frac{V_w}{V_v} = \frac{0.6 V_v}{V_v} = 0.6$~~

~~$n = \frac{V_v}{V_T}$~~

~~$e = \frac{V_v}{V_s} = \frac{V_v}{}$~~

$V_w = 0.6 V_v$

$W_w = 0.6 V_v \gamma_w$

$W_s = \frac{W_w}{0.25}$

$W_s = 2.4 V_v \gamma_w$

$V_s = \frac{2.4 V_v \gamma_w}{G}$

$e = \frac{V_v}{V_s} = \frac{V_v \times G}{2.4 V_v \gamma_w}$

$e = \frac{G}{2.4 \times \gamma_w}$

$e = \frac{26}{2.4 \times 9.81} = 1.10$ Ans

$n = \frac{e}{1+e} = \frac{1.1}{2.1} = 0.523$ Ans

(5)

$$\gamma_T = \frac{W_w + W_s + W_g}{V_g + V_s + V_w + V_g}$$

$$\gamma_T = \frac{0.6 V_v \gamma_w + \frac{2.4 V_v \gamma_w}{} + 0.15 V_v \times 0.9 \gamma_w}{V_v + \frac{2.4 V_v \gamma_w}{G}}$$

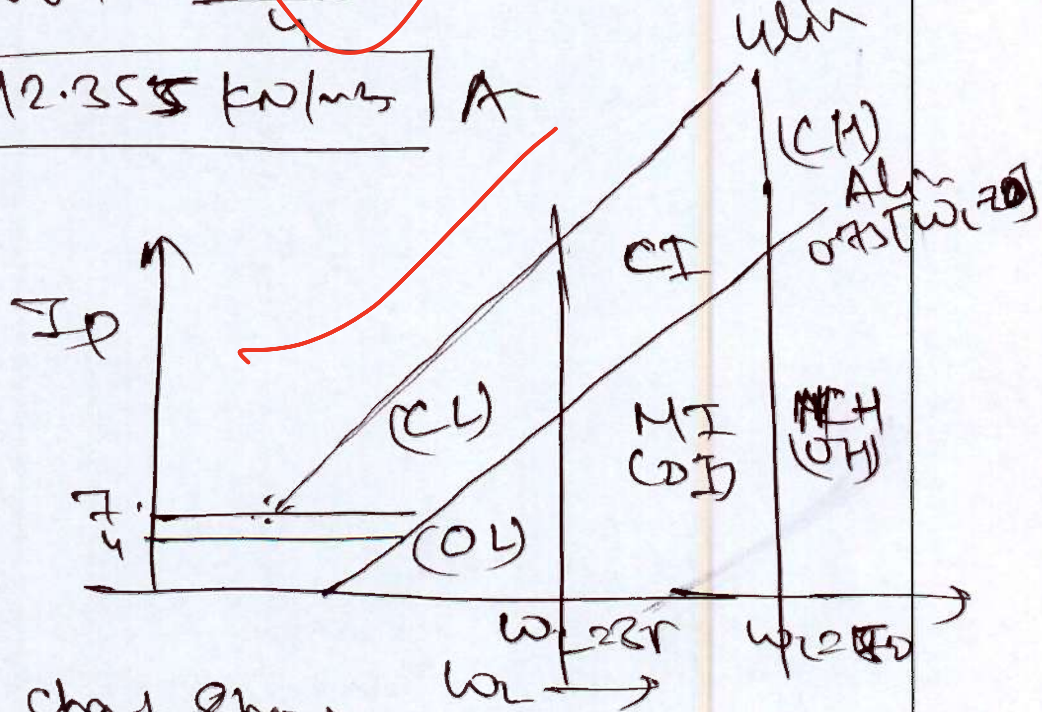
$$\boxed{\gamma_T = 16.139\ kN/m^3}\ \text{Ans}$$

$$\gamma_{dry} = \frac{W_s}{V_T}$$

$$= \frac{2.4 V_v \gamma_w}{V_v + \frac{2.4 V_v \gamma_w}{G}}$$

$$\boxed{\gamma_{dry} = 12.355\ kN/m^3}\ \text{A}$$

Solution (ii)



- Plasticity chart shows which type of soil is present based on
- Plasticity index (I_p) and liquid limit
- with use of A line we can determine if it is clay or organic (silt)

2

Q.7 (b) **(i)** A one lane urban road with one way traffic has maximum capacity of 2000 vehicles/hour. The average length occupied by each vehicle is 3.5 m. The traffic volume is 1200 vehicles per hour. Determine the traffic density. Assume linear relationship between flow speed and traffic density.

(ii) Explain the significance of stopping sight distance (SSD). Derive the expression used to calculate SSD on a one way single carriageway level road. Calculate the head light sight distance and intermediate sight distance for a highway having design speed of 80 kmph for the following data:

- Coefficient of friction, $f = 0.36$
- Reaction time, $t = 2.5$ seconds

[10 + 10 = 20 marks]

Solution

(i) Maximum Capacity = 2000 veh/hr

$$\frac{V_f K_j}{4} = 2000$$

length of vehicle = 3.5 m

~~S = 0.2 VR + 3.5~~

traffic volume = 1200 veh/hr

~~$q = \frac{VR \times 1000}{(0.2 VR + 3.5)} = 1200$~~

S = 3.5

~~VR = 5.526 km/ph~~

$$K_j = \frac{1000}{3.5} = 285.714 \text{ veh/km}$$

$$V_f = \frac{2000 \times 4}{285.714} = 28 \text{ km/hr}$$

$$V = V_f \left[1 - \frac{K}{K_j}\right]$$

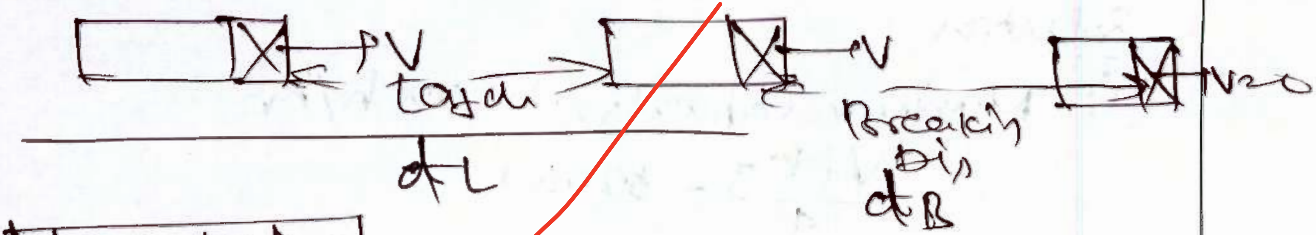
$$1200 = 28\left[1 - \frac{K}{285.714}\right] \times K$$

$\boxed{K = 233.207 \text{ veh/km}}$ Traffic den

(ii) Significance of SSD:-

It is the distance required to stop the vehicle when there is any warning or any issue in the traffic

- It consist of braking distance and Lag distance
- Braking distance is the distance required to stop the vehicle from the time of applying the brake
- Lag distance is the distance travelled by the vehicle in thought process according to PIEV Theory



$d_L = V \times t_r$

t_r = Reaction time Normally taken 2.5 sec

for Braking distance
Friction applied by road = μg

$V^2 - u^2 = 2gS$

$V^2 = 2\mu g\, d$

$$d_B = \frac{V^2}{2\mu g}$$

Total SSD = $d_L + d_B$

$$SSD = V \times t_r + \frac{V^2}{2\mu g}$$ Hence proved

Now vehicle speed V = 80 kmph
$f = 0.36$; $t = 2.5$ sec

$SSD = 80 \times 0.278 \times 2.5 + \frac{(80)^2}{2 \times 0.36 \times 9.81}$

SSD = 125.59 m

Head light sight distance = SSD = 125.59 m
Intermediate sight distance = 2 SSD = 251.18 m

Ans

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Q.7 (c) (i) The monthly mean temperature of the atmosphere, at a particular site, where an airport has to be developed, are given below. Determine the airport reference temperature. If the length of runway under standard condition is 1 km, then determine the actual runway length. The runway is assumed to be level at mean sea level.

Month	Temperature (°C)	
	Mean value of average daily temp. (T_a)	Mean value of maximum daily temp. (T_m)
January	3	5
February	15	17
March	20	23
April	25	32
May	35	47
June	40	50
July	32	37
August	30	35
September	27	31
October	22	28
November	12	18
December	6	9

(ii) If a crossover occurs between two B.G. parallel tracks of the same crossing number 1 in 8.5, with reverse curves of equal radii of 450 m and the distance between the tracks is 4.5 m, find out the overall length of the crossing and the intermediate curved length of cross-over.

[12 + 8 = 20 marks]

Solution (on June)

i) we have to design the Runway for
Max mean value of average daily temp = 40°C

Max Mean value of Maxi daily Temperature = 50°C
[For safety we have taken Maximum]

Now Airport referance Temperature
= 40 + 1/3 [50 − 40]
ART = 43.33°C

as Temprature at Mean sea level = 15°C

12

Difference of Temp = ART − SRT
= 43.33 − 15
= 28.33 °C

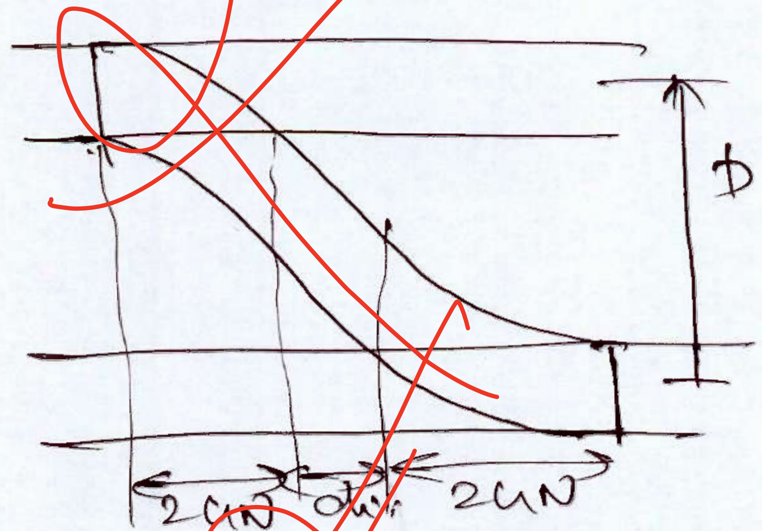
As Runway as Mean sea level
Elevation correction = 0
Temperature correction = 1% of difference
$l\left[1 + \frac{1}{100} \times 28.33\right]$

length = $1000\left[1 + \frac{28.33}{100}\right] = 1283.33$ m

Check $\frac{1283.33 - 1000}{1000} = 28.33\% < 35\%$
OK

| So length of Runway = 1283.33 |

(ii) Solution
N = 8.5
D = 4.5 m
Radius = 450 m
G = 1.676 m



overall length = $4GN + (D - G)N - G\sqrt{1 + N^2}$
$= 4 \times 1.676 \times 8.5 + (4.5 - 1.676) \times 8.5 - 1.676\sqrt{1 + 8.5^2}$

| length = 66.64 m |

overall length of Crossover 66.64m Ans

For intermediate curve length
= Total length − 4LN
= 66.64 − 4×1.670×8.5

Intermediate length = 9.659m, Ans

Q.8 (a) A 12 m long 300 mm diameter concrete pile is driven in uniform deposit of dense sand ($\phi' = 40°$). The water table is very much down and is not likely to rise in future. The average dry unit weight of sand is 18 kN/m^3. Using $N_q = 137$, calculate the safe load capacity of the pile with a factor of safety of 2.5. Assume the critical length of pile as 15 times the diameter and K for dense sand as 2.0.

[20 marks]

Solution

Dense Sand

critical length = 15d

= 15 × 0.3 = 4.5 m

$\gamma_d = 18 \, kN/m^3$

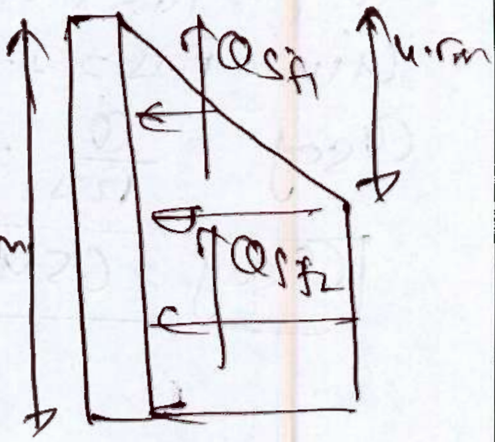
$N_q = 137$

FOS = 2.5

K = 2

Diameter = 0.3 m

length = 12 m



take

$\delta = \frac{3}{4}\phi$

= 30°

$Q = Q_{eb} + Q_{sf}$

$Q_{eq} = q N_q (A_b)$

$= 4.5 \times 18 \times 137 (A_b)$

$= \underline{11097} (A_b)$

$> 11000 \, kN/m^2$

So take $Q_{eb} = 11000 \times (\pi/4) \times (0.3)^2$

$Q_{eb} = 777.544 \, kN$

for skin friction

$Q_{sf} = Q_{sf_1} + Q_{sf_2}$

$Q_{sf_1} = K \bar{\sigma}_{avg} \tan\delta \times (\pi D L_1)$

$= 2 \times \left[\frac{0 + 4.5 \times 18}{2}\right] \tan 30 \times \pi \times 0.3 \times 4.5$

$= 198.338 \, kN$

$Q_{sf_2} = K \bar{\sigma}_{avg} \tan\delta \, (\pi D L_2)$

$= 2 [4.5 \times 18] \times \tan 30 \times \pi \times 0.3 \times (12 - 4.5)$

$Q_{sf_2} = 661.129 \, kN$

$Q_T = Q_{eb} + Q_{sf_1} + Q_{f_2}$

$Q = 777.544 + 198.338 + 661.1291$

$Q_T = 1637.011$ kN

Given FOS = 2.5

$Q_{safe} = \frac{Q}{FOS} = \frac{1637.011}{2.5}$

$Q_{safe} = 654.804$ kN / Ans

Q.8 (b) To determine the elevation of station *P* in a tacheometric survey, the following observations were made with the staff held vertical. The instrument was fitted with an anallactic lens and its multiplying and additive constants were 100 and zero respectively.

Instrument station	H.I. (m)	Staff Station	Vertical Angle	Staff Readings (m)
O	1.45	B.M	– 6°00′	1.335, 1.895, 2.460
O	1.45	C.P	+ 8°30′	0.780, 1.265, 1.745
P	1.45	C.P	– 6°30′	1.155, 1615, 2.075

The R.L. of the B.M is 250 m. Calculate the R.L. of station *P*.

[20 marks]

Solution

Staff held verticle

Analytic lens $K = 100$

$C = 0$

For instrument station O and BM

$L_{O/BM} = K S \cos^2\theta$

$= 100 \times [2.460 - 1.335] \cos^2(6°)$

$L_{O/BM} = 111.27 m$

2

$(RL)_O = (RL)_{BM} + [K S \cos\theta \sin\theta + 1.895] - HI$

$(RL)_O = 250 + [100 \times (2.460 - 1.335) \cos 6 \sin 6]$
$+ 1.895 - 1.45$

$(RL)_O = 262.14 m$

For instrument station at O and CP

$L_{O/CP} = K S \cos^2\theta$

$= 100 \times [1.745 - 0.780] \cos^2 8'30'$

$L_{O/CP} = 94.391 m$

$(RL)_{CP} = (RL)_O + HI + K S \cos\theta \sin\theta - 1.265$

$= 262.14 + 1.45 + 100[1.745 - 0.780] \cos\theta \sin\theta$
$- 1.265$

$(RL)_{CP} = 276.4319 m$

Now for instrument at P and CP

$L_{P/CP} = KS\cos^2\theta$

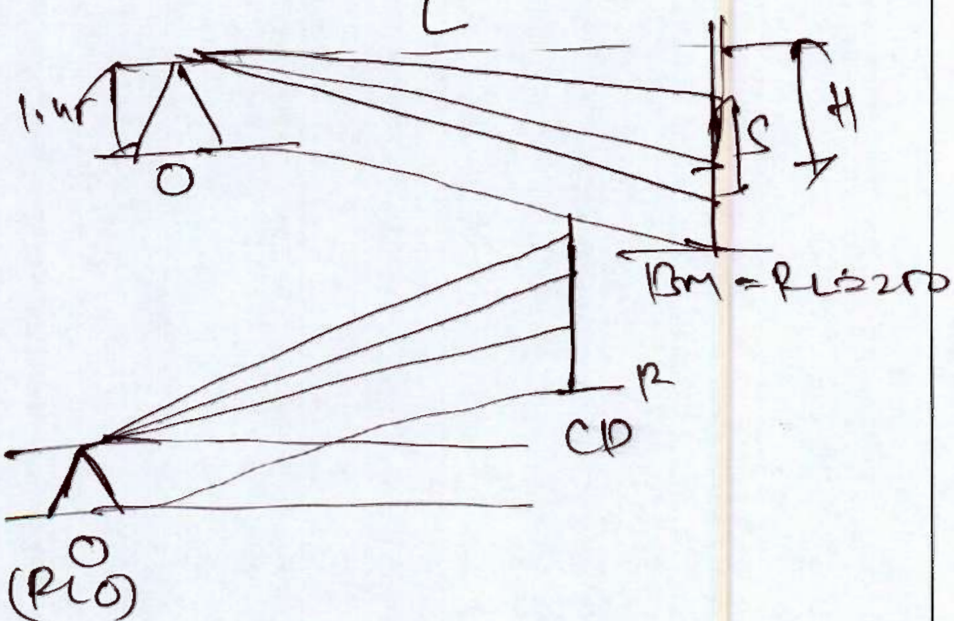
$= 100[2.075 - 1.155]\cos^2(6°30')$

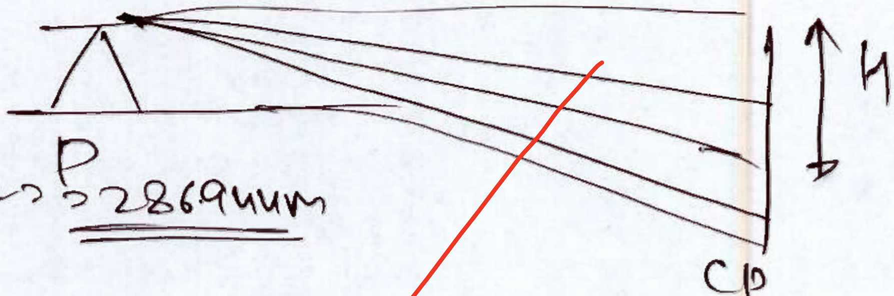
$L_{P/CP} = 90.821\,m$

$(RL)_P = (RL)_{CP} + 1.615 + KS\cos\theta\sin\theta - 1.45$

$= 276.4319 + 1.615 + 100[2.075 - 1.155]\cos\theta\sin\theta - 1.45$

$(RL)_P = 286.944\,m$ Ans





$RL_P = 286.944\,m$

Q.8 (c) **(i)** State the various types of bituminous dense surfacing. Write the construction steps and quality control tests for dense bituminous concrete surface course

(ii) A four-lane single carriageway road is subjected to the following traffic:

	Bus	**Truck**
No. of vehicles/day	500	2000
Rate of growth (%)	2%	10%
Gross wheel load (Tonnes)	16	20
Wheel configuration (Front/Rear)	Single Axle/Dual Axle	Single Axle/Tandem Axle

Calculate the design traffic for pavement design considering planning and construction period as 1.5 years and design life as 20 years. Assume necessary data suitably.

[8 + 12 = 20 marks]

Solution

(C)(i) Various types of bituminous dense Surfacing.

(1) Surface dressing :- In this first of all Bituminous layer is laid then after aggregate are rolled over the bituminous layer to get Compacted by roller Compacted roller.

- Rolling is done for Compaction (do Expulsion of air) and so that Bituminous layer is occupied by the aggregate for better bonding

2) Penetration Macadam :- In this opposite of Surface dressing is done in this aggregate are laid to the Base Coarse then Bituminous layer is laid so that Bitumin Can penetrate to the bottom of aggregate.

- In this way the aggregate are interlocked by the bitumin to provide better road.

5) Pre Mix :- In this aggregate and bituminous are gelleted in the mixer so that all the aggregate have layer of bitumin for grain to grain Contact (for load transfer)

- after which this Mix is laid over the Base Coarse and Compacted to get good surface Bituminous Pavement.

5

Solution (ii)

For Bus After Construction traffic

$P = 500 \times (1+i)^{1.n}$

$P_B = 500(1.02)^{1.n}$

$P_B = 515.074$

for Truck

$P_T = 2000(1+0.1)^{1.5}$

$P_T = 2307.379$

$N = 365A\frac{((1+r)^n - 1)}{r} \times LDF \times VDF \times LF$

Assuming load factor = 1.5

Lateral Distribution factor for four lane single carriageway = 0.5

$N = 365 \times 2307.379 \frac{[(1+0.1)^{20} - 1]}{0.1} \times 0.5 \times 1.5 (VDF)_T$

$+ 365 \times 515.074 \times \frac{[(1+0.02)^{20} - 1]}{0.02} \times 0.5 \times 1.5 \times (VDF)_{Bus}$

4

for Vehicle Damage Factor

for Bus

Gross wheel load = 16 Tonnes

Single Axle / Dual Axle load =

Incomplete soln

■■■■

Space for Rough Work

Space for Rough Work

Space for Rough Work