MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-4

Section A : Transportation Engineering [All Topics]

Section B : Environmental Engineering [All Topics]

Name : .....

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
Pune ☐	Kolkata ☐	Hyderabad ☐	

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	54
Q.2	48
Q.3	
Q.4	50
Section-B	
Q.5	54
Q.6	47
Q.7	
Q.8	
Total Marks Obtained	253

Signature of Evaluator: Sheoyal

Cross Checked by: .....

Keep it up

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

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.

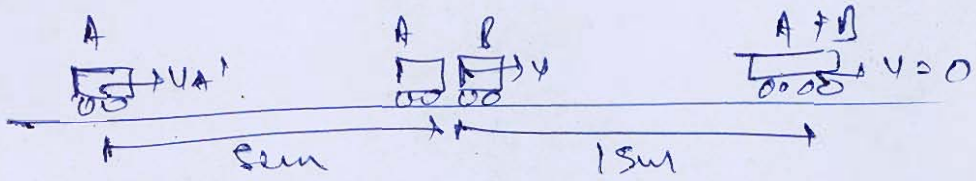
DO'S

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.

Section A : Transportation Engineering

Q.1 (a) A vehicle applies brakes and skids through a distance of 50 m before colliding with another parked vehicle. The weight of parked vehicle is 60% of the colliding vehicle. If distance travelled by both the vehicles after collision is 15 m before coming to rest, then determine the initial speed of the moving vehicle. [Take $f = 0.6$]
Also write the assumptions used.

[12 marks]



$m_B = 0.6 m_A$

After collision,

$\Delta KE = W\Delta$

$0 - \frac{1}{2}(m_A + m_B)v^2 = -f(m_A + m_B)g \times 15$

$v = \sqrt{2 \times 0.6 \times 9.81 \times 15}$

$v = 13.29$ m/s

At time of collision,

$m_A v_A = (m_A + m_B)v$

$m_A v_A = (m_A + 0.6 m_A) \times 13.29$

$v_A = 21.26$ m/s

Before collision,

$\Delta KE = W\Delta$

$-\frac{1}{2} m_A v_A' + \frac{1}{2} m_A v_A^2 = -f m_A g \times 50$

$-\frac{v_A'^2}{2} + \frac{21.26^2}{2} = -0.6 \times 9.81 \times 50$

$v_A' = 32.25$ m/s (initial velocity)

Assumption,

(1) coeff. of restitution is zero.

(2) No loss of energy while collision.

12

Q.1 (b) (i) On a two way traffic road, the speeds of overtaking and overtaken vehicles are 80 kmph and 50 kmph, respectively. If the acceleration of the overtaking vehicle is 2.5 kmph per second, calculate the safe overtaking sight distance (Assume: spacing between vehicles = 16 m; reaction time of driver = 2 seconds).

(ii) How WBM roads are constructed? What are the advantages and disadvantages of WBM roads?

[7 + 5 = 12 marks]

(i) $a = 2.5 \times \frac{5}{18} = 0.7$ m/s²

$S = 16$ m
$t_R = 2$ sec

$V_B = 50$ kmph
$V_C = 80$ kmph

$OSD = 0.278 V_B t_R + \left(2S + 0.278 V_B T\right) + 0.278 V_C T$

$T = \sqrt{\frac{4S}{a}} = \sqrt{\frac{4 \times 16}{0.7}} = 9.56$ sec

$OSD = 405.29$ m

(ii) Construction of water Bound macadam (WBM)

→ large size aggregates are used (40-90mm),

→ Aggregate, fillers, Bitumen are placed one over the other.

Advantages

→ Good Bond between layer

→ Better skid resistance developed

Disadvantages

→ Poor Drainage
→ Low strength
→ Slow process than WMM.

10

Q.1 (c) Determine the actual runway length after applying necessary corrections for elevation and temperature as per ICAO and gradient correction as per FAA specification for the data given below:

Basic runway length = 1900 metres

Elevation of airport site = 600 metes

Monthly mean of average daily temperature for the hottest month of the year = 16°C

Monthly mean of maximum daily temperature for the same month = 21°C

Effective gradient = 0.6%

[12 marks]

$L = 1900\ m$

$EL = 600\ m$

$T_a = 16^\circ C$

$T_M = 21^\circ C$

① Elevation correction

$\text{corr.} = \frac{7\%}{300} \times 600 = 14\%$

$\text{corr. length} = 1.14 \times 1900 = 2166\ m$

② Temp. correction

$SAT = 15 - 0.0065 \times 600 = 11.1^\circ C$

$ART = T_a + \frac{T_M - T_a}{3} = 17.67^\circ C$

% increase = 17.67 - 11.1

= 6.56 %

corr. length = 1.0656 × 2166

= 2308.09 m

(8) Gradient correction

20% ⟶ 1 %

0.6 × 20% ⟶ 0.6 %

12 %

12

corrected length = 1.12 × 2309.09

L' = 2586.18 m

check: temp & elevation corr.

$\frac{2308.09 - 1900}{1900} \times 100$

= 21.53 % < 35 %

Ok.

Q.1 (d) A train having 20 wagons weighing 18 tonnes each is to run at a speed of 50 kmph. The tractive effort of a 2-8-2 locomotive with 22.5 tonnes load on each driving axle is 15 tonnes. The weight of locomotive is 120 tonnes. Rolling resistances of wagons and locomotive are 2.5 kg/tonne and 3.5 kg/ tonne respectively. The resistance which depend upon the speed is computed as 2.65 tonnes. Find out the steepest gradient for these conditions.

[12 marks]

Total Rolling resistance = (2.5 × 20 × 18 + 3.5 × 90)

TRR = 1.215 t

Total weight of wagon = 20 × 18 = 360 t

Total weight of locomotive = (22.5 × 4) t = 90 t

Total weight, W = 450 t

10

Tractive effort = TRR + Resistance depend on speed + Resistance independent on speed + gradient resistance

Avoid Calculation Error

$$15 = 1.215 + 2.65 + 0.00006 \times 450 \times 50^2 + \frac{50}{N} \times 450$$

$N = 43.021$ 46.56.

Q.1 (e) (i) The specific gravities and weight proportions for aggregates and bitumen are as under for the preparation of Marshall moulds:

	Aggregate-1	Aggregate-2	Aggregate-3	Aggregate-4	Bitumen
Weights (gm)	800	1200	350	150	100
Specific Gravity	2.62	2.52	2.40	2.42	1.042

The volume and weight of one Marshall mould was found to be 475 cc and 1100 gm. Assuming absorption of bitumen in aggregate as zero, find.

1. percentage air voids.
2. percentage bitumen by volume.
3. percentage voids in mineral aggregates.

(ii) What is diamond crossing on a railway track? Give a sketch of such crossing for a B.G. track. Explain the salient features of different parts of the crossing.

[7 + 5 = 12 marks]

$$G_t = \frac{w_1+w_2+w_3\ldots+w_5}{\frac{w_1}{G_1}+\frac{w_2}{G_2}+\frac{w_3}{G_3}\ldots+\frac{w_5}{G_5}}$$

$G_t = 2.395$

$G_M = \frac{1100}{475} = 2.315$

(1) $V_a = \left(\frac{G_t - G_M}{G_t}\right)\times 100 = 3.34\%$

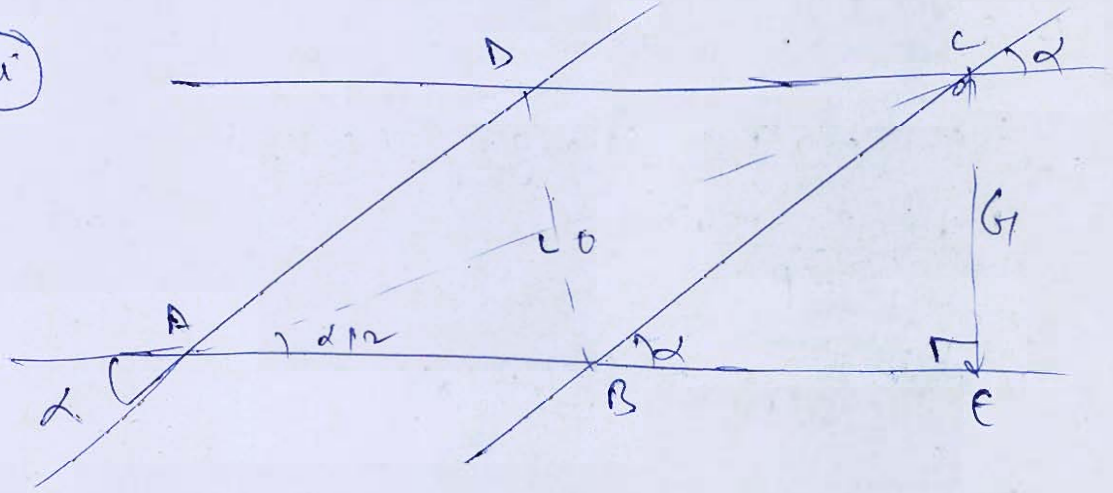
(2) $V_b = \frac{w_5}{G_5} \times \frac{G_M}{(w_1+w_2\ldots w_5)} \times 100$

$V_b = 8.544\%$

$V_{FB} = \frac{V_b}{V_b+V_a} = 71.9\%$

(3) $V_{MA} = (V_b+V_a) = 11.884\%$

(ii)



In ΔBEC, $BC = G \operatorname{cosec}\alpha$

$AB = BI = CD = DA = G \operatorname{cosec}\alpha$

In ΔAEC, $AE = G \operatorname{cosec}\alpha/2$

$AO = OC = \frac{G}{2} \operatorname{cosec}\alpha/2$

In ΔAOB, $OB = OD = \frac{G}{2} \sec\alpha/2$

7+3

Salient features

(1) it contains two Acute & two obtuse crossing Angles.

Q.2 (a) (i) A two lane pavement (7.0 m) on a National Highway in hilly terrain (snow bound) has a curve of radius 60 m. The design speed is 40 kmph. Determine the length of the transition curve. Determine the total length of the curve and tangent length if the deflection angle is 60°. Make suitable assumptions.

(ii) What are the types of transition curves commonly adopted in horizontal alignment? Which transition curve fulfils the requirements of ideal transition curve and why?

[12 + 8 = 20 marks]

(i) $n = 2$

$R = 60\,m$

$V = 40$ kmph

$\Delta = 60°$

(2) As per rate of change of Accl.

$L_{T_1} = \frac{0.0215\,V^3}{RC}$

$C = \frac{80}{75+V} = 0.7\ m/s^3$

$L_{T_1} = 32.76\,m$

(i) As per introduction of Super elevation

$L_{T_2} = N_c(W + W_e)$

$W = \frac{nl^2}{2R} + \frac{V}{9.5R}$ Assume; N = 60 (Hilly)
l = 6m

$W_e = 1.14$ m

$e = \frac{V^2}{225R} = 0.11f > 0.1$ $e_{max} = 10\%$ (Hilly).

Check f: $f = \left(\frac{V^2}{127R} - e_{max}\right)$

$f = 0.109 < 0.15$ (OK)

$e = 0.1$

$L_{T_2} = 60 \times 0.1 (7 + 1.14)$
$= 49.84$ m

(ii) As per IRC

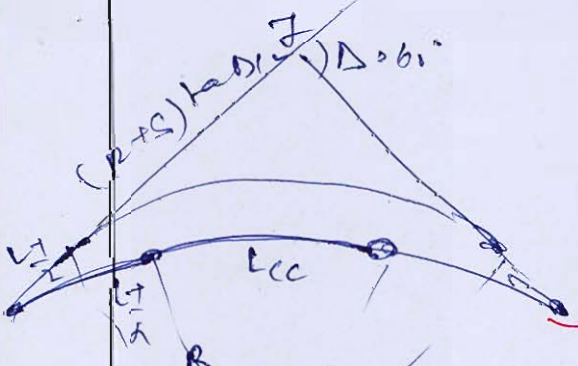
$L_{T_3} = \frac{V^3}{R} = 26.67$ m

$L_T = 49.84$ m (maximum value)

$\Delta = \frac{L_T}{2R} \times \frac{180}{\pi} = 23.32°$

$L_{CC} = \frac{2\pi R}{360}(\Delta - 2\theta)$

$L_{CC} = 14$ m

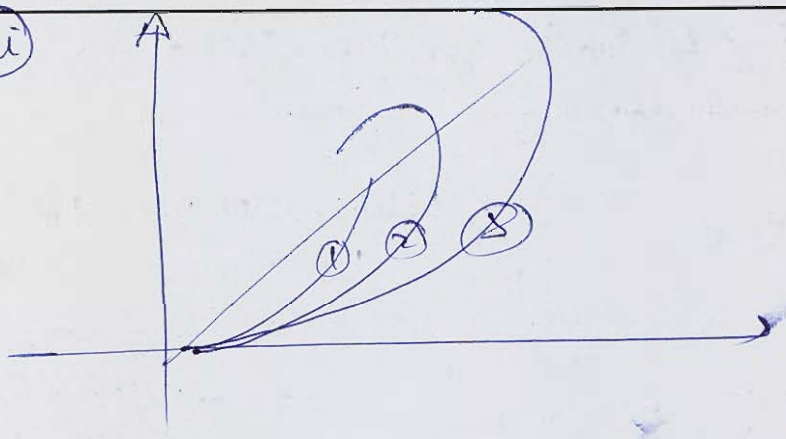


$\therefore \frac{L_T'}{24R} = 1.65$ m

length of tangent $= \frac{L_T}{2} + (R+S)\tan\Delta/2$

length of tangent = 60 m

(ii)



10+6

types of transitional curve :

1. Spiral.
2. Bernoulli lemniscate
3. cubical parabola

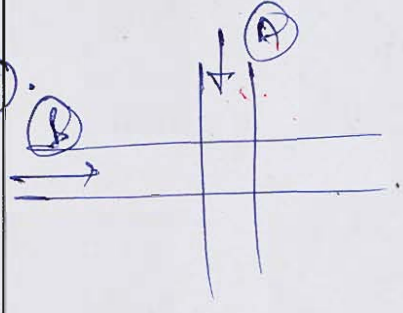
→ Spiral curve is provided for pavement design because in spiral curve, rate of change of centrifugal acceleration is constant.

Q.2 (b) (i) The average normal flow of traffic on cross roads *A* and *B* during design period are 400 and 250 PCU/hr. The saturation flow values on these roads are 1250 and 1000 PCU/hr. All red time required for pedestrian crossing is 12 sec. Design a two phase traffic signal by Webster's method. Take startup lost time before each green signal as 2 sec.

(ii) Explain with neat sketches the commonly adopted unchannelised and channelised intersections.

[12 + 8 = 20 marks]

(i)



road (A) $\equiv y_A = \frac{\text{normal flow}}{\text{saturation flow}} = \frac{400}{1250} = 0.32$

road (B) $\equiv y_B = \frac{250}{1000} = 0.25$

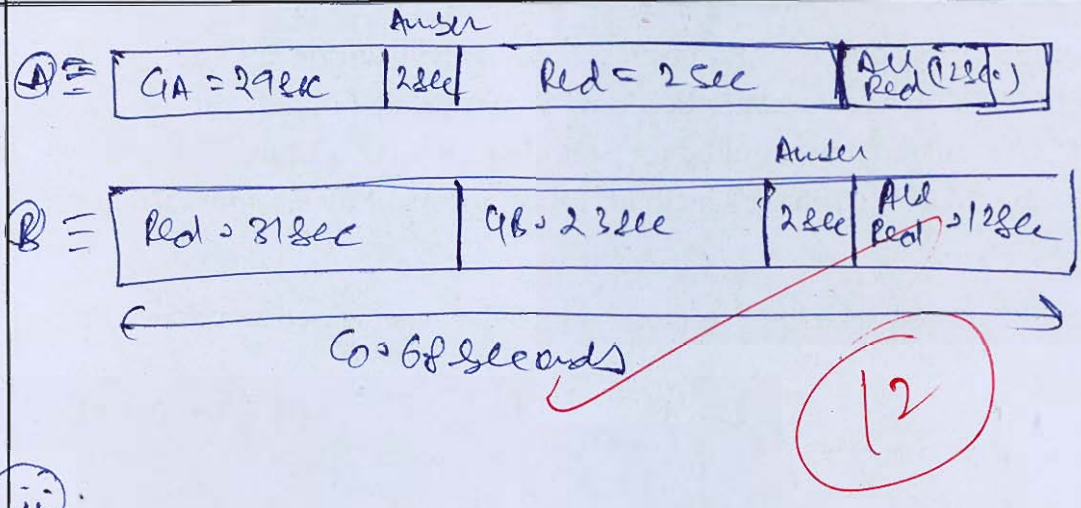
$L = (2n + R) = (2 \times 2 + 12) = 16$ sec

optimum cycle time, $C_0 = \frac{1.5L + 5}{1 - Y}$

$C_0 = \frac{1.5 \times 16 + 5}{1 - (0.32 + 0.25)} = 67.44 \simeq 68$ sec

$G_{1A} = \frac{y_A}{Y}(C_0 - L) = 29.19 \simeq 29$ sec

$G_{1B} = \frac{y_B}{Y}(C_0 - L) = 22.8 \simeq 23$ sec



12

(ii)

Q.2 (c) A road intersection has five legs designated as 1, 2, 3, 4 and 5. Leg 1 is in N-S direction and others are marked clockwise. The traffic volumes in terms of PCU (V_{ij}) per hour during peak period are given below.

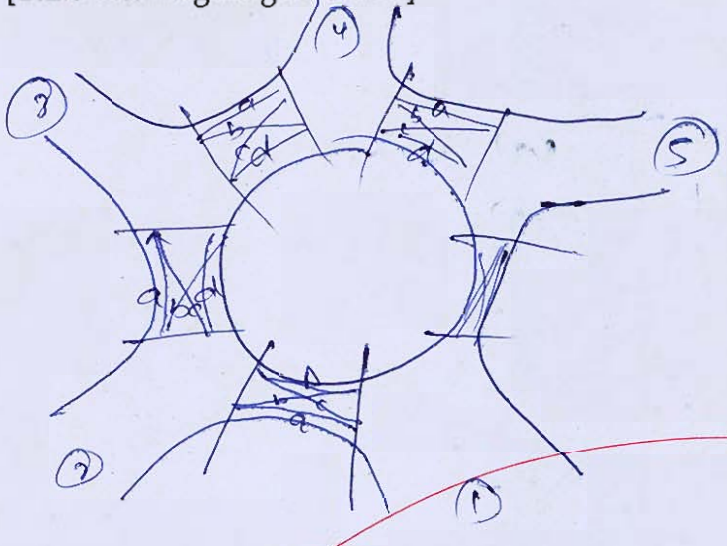
V_{12}	37	V_{31}	466	V_{41}	182	V_{51}	45
V_{13}	303	V_{32}	122	V_{42}	54	V_{52}	132
V_{14}	64	V_{34}	47	V_{43}	18	V_{53}	62
V_{15}	52	V_{35}	657	V_{45}	116	V_{54}	15

Find the weaving ratio between the legs 1 and 2. Also calculate the capacity of rotary, if both roads have carriage way width of 15 m and width of carriageway at entry and exit is 10 m.

[Take weaving length = 50 m]

[20 marks]

(c)



$a = V_{12} = 37$

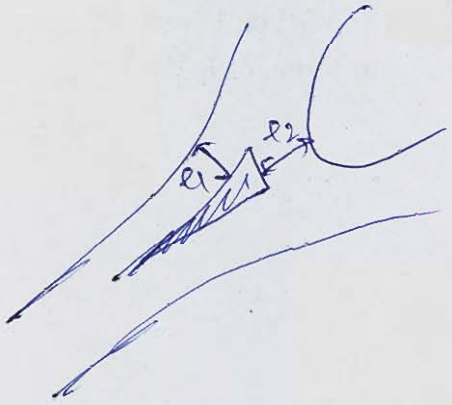
$c = V_{13} + V_{14} + V_{15} = 419$

$b = V_{52} + V_{42} + V_{32} = 304$

$d = V_{53} + V_{54} + V_{41} = 95$

$$p = \left(\frac{b+c}{a+b+c+d}\right) = 0.846$$

$$Q_p = \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{P_M}{3}\right)}{\left(1+\frac{w}{L}\right)}$$



$d_1 = d_2 = 10m$

$w = \left(\frac{d_1 + d_2}{2} + 3.5\right)$

$w = 13.5m$

$L = 50m$ (given)

$P_{1-2} = 0.946$ (2)

$P_{2-3} =$

$a = y_{23}$

$b = y_{24} + y_{25} + y_{21}$

$c = y_{13} + y_{51} + y_{41}$

$d = y_{14} + y_{15} + y_{54}$

not given (1)

$P_{3-4} =$

$a = y_{34}$

$b = y_{35} + y_{31} + y_{32}$

$c = y_{54} + y_{14} + y_{24}$

$d = y_{25} + y_{21} + y_{15}$

$P_{4-5} =$

$a = y_{45}$

$b = y_{41} + y_{42} + y_{43}$

$c = y_{15} + y_{25} + y_{35}$

$d = y_{31} + y_{34} + y_{32}$

P_{5-1}

$a = y_{51}$

$b = y_{52} + y_{53} + y_{54}$

$c = y_{21} + y_{31} + y_{41}$

$d = y_{42} + y_{32} + y_{41}$

$Q_p = \dfrac{2\pi \times 13.5 \times \left(1 + \frac{}{13.5}\right)\left(1 - \frac{0.246}{3}\right)}{1 + \frac{13.5}{57}}$

$Q_p = 3720.03$ PCU/Hr

20

do work on handwriting for better representation

Q.3 (a) (i) What are the various tests carried out on bitumen? Briefly mention the principle and uses of each test.

(ii) Explain with sketches the requirements of joints filler and sealer. Discuss the desirable properties and the various materials in use.

[10 + 10 = 20 marks]

Q.3 (b) (i) A driver travelling at the speed limit of 50 kmph was cited for crossing an intersection. He claimed that the duration of the amber display time was improper and consequently a dilemma zone existed at that location. Using the following data, determine whether the driver's claim was correct.

(i) Amber duration = 4.5 sec

(ii) Perception reaction time = 1.5 sec

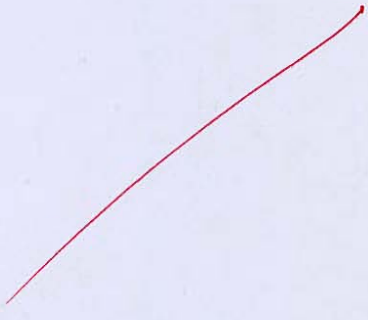
(iii) Comfortable deceleration = 3 m/sec^2

(iv) Car length = 4.6 m

(v) Intersection width = 15 m

(ii) Explain various type of walls used as protective work for hill roads.

[15 + 5 = 20 marks]



Q.3 (c) (i) If a cross-over occurs between two M.G. parallel tracks of same crossing number 1 in 12 with straight intermediate portion between the reverse curves and the distance between the centres of tracks is 3.5 m, then find the intermediate straight distance and over-all length of the cross-over.

(ii) An exit taxiway is to be designed for Boeing 707 with turn off speed of 65 km/hr. Calculate the turning radius of the exit taxiway using the following data:

Coefficient of lateral friction = 0.13

Wheel base = 18.0 m

Tread of main landing gear = 7.0 m

Width of taxiway = 22.5 m

[10 + 10 = 20 marks]

Q.4 (a) **(i)** Calculate the stresses at interior, edge and corner regions of a cement concrete pavement using Westergaard's stress equations using the following data:

Wheel load, $P = 4100$ kg

Modulus of elasticity of cement concrete, $E = 3.3 \times 10^5$ kg/cm^2

Pavement thickness, $h = 18$ cm

Poisson's ratio of concrete, $\mu = 0.15$

Modulus of subgrade reaction, $K = 25$ kg/cm^3

Radius of contact area, $a = 12$ cm

(ii) What are various type of failures in flexible pavements? Explain the causes of failures.

[12 + 8 = 20 marks]

(i) $l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4} = 50.61$ cm

load stress

$$S_i = \frac{0.316P}{h^2}\left[4\log\frac{l}{b} + 1.069\right]$$

$b = \sqrt{1.6a^2 + h^2} - 0.675h$

$b = 11.4$ cm

$a \le 1.724h$

$12 < 31.032$ cm

$S_i = 14.63$ kg/cm

$$S_e = \frac{0.572P}{h^2}\left[4\log\frac{L}{5} + 0.159\right]$$

$$S_e = 21.34 \text{ kg/cm}^2$$

$$S_c = \frac{3P}{h^2}\left[1 - \left(a\frac{\sqrt{2}}{L}\right)^{0.6}\right]$$

$$S_c = 18.26 \text{ kg/cm}^2$$

(ii) Types of failure

(i) Surface failure

(i) fatty surface - Due to excess Bitumen.

(ii) smooth surface - Due to use of low viscosity Bitumen

(iii) Hungry surface - Due to insufficient Bitumen

(iv) Stripping - Due to non uniform Application of Bitumen

(2) Crack:

(i) Hairline cracks - minute cracks

(ii) Alligator cracks - large spaced cracks.

(iii) Edge cracks - on to edge Area, due to ~~No~~ lateral support.

(3) Deformation

(i) corrugation - undulation in road.

(ii) Rutting - Due to excess wheel load.

(iii) Slippage - Due to uneven settlement

12+5

(4) Disintegration

(i) pot holes -

(ii) Stripping

(iii) Revelling.

Q.4 (b) (i) A branch curve of 7° diverges from main curve of 3° in an opposite direction in a layout of BG track. Calculate the superelevation and the speed on the branch track, if the maximum speed permitted on main line is 70 kmph.

(ii) A linear relationship exists between speed and density for a length of road section. Free mean speed was 80 km/hr and jam density was 70 veh/km. What is the maximum flow which could be expected on this section and at what speed and density it would occur? Sketch the fundamental diagram of road traffic and show the values obtained. What is the shape of this diagram?

[10 + 10 = 20 marks]

(i)

For main track

$e_M = (e_d)_M + C_D$

$\frac{G V_M^2}{127 R} = (e_d)_M + C_D$

$\frac{1.75 \times 70^2}{127 \times 1750/3} = \frac{7.5}{100} + (e_d)_M$

$(e_d)_M = 4.07\,cm$

$(e_d)_R = -(e_d)_M = -4.07\,cm$

For Branch track

$(e_d)_R = (e_d)_B + C_D$

$\frac{G V_M^2}{127 R} = -\frac{4.07 + 7.5}{100}$

$V_M = 24.928$ kmph

(ii) $v_f = 80$ kmph

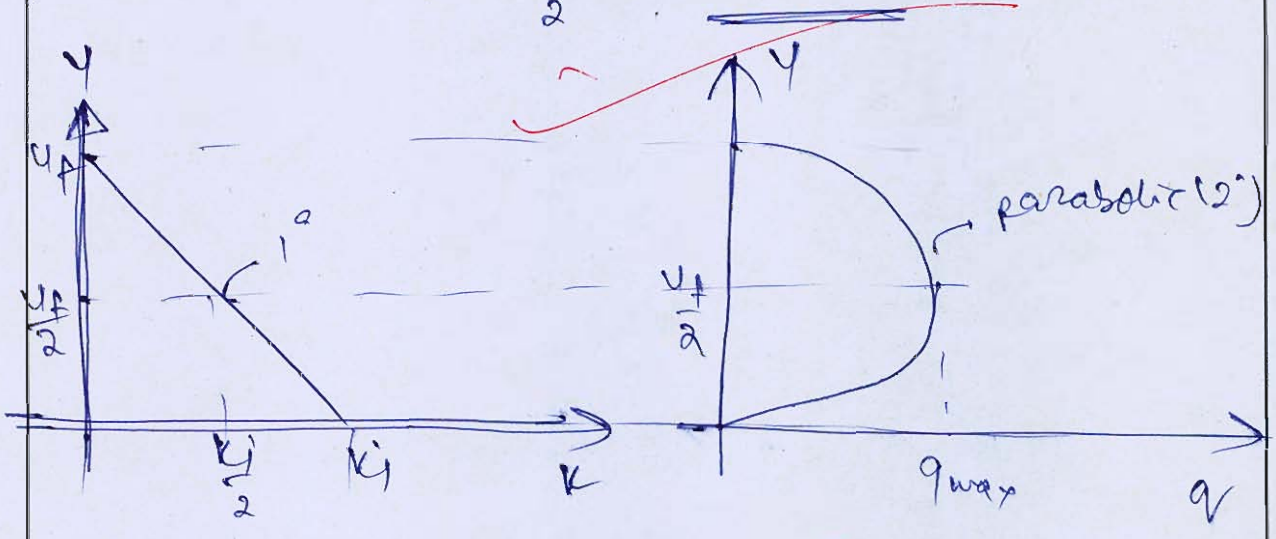
$k_j = 70$ v/km

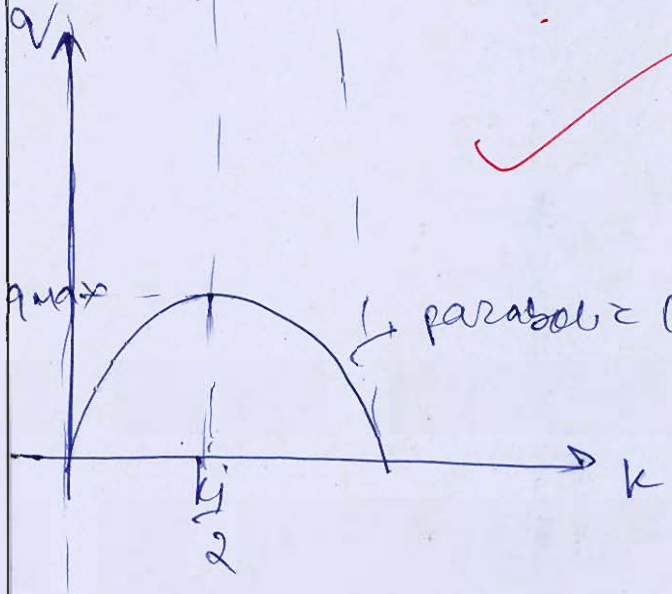
$q_{max} = \frac{1}{4} k_j v_f = \frac{1}{4} \times 70 \times 80 = 1400$ v/Hr.

q_{max} at $v = \frac{v_f}{2} = 40$ kmph

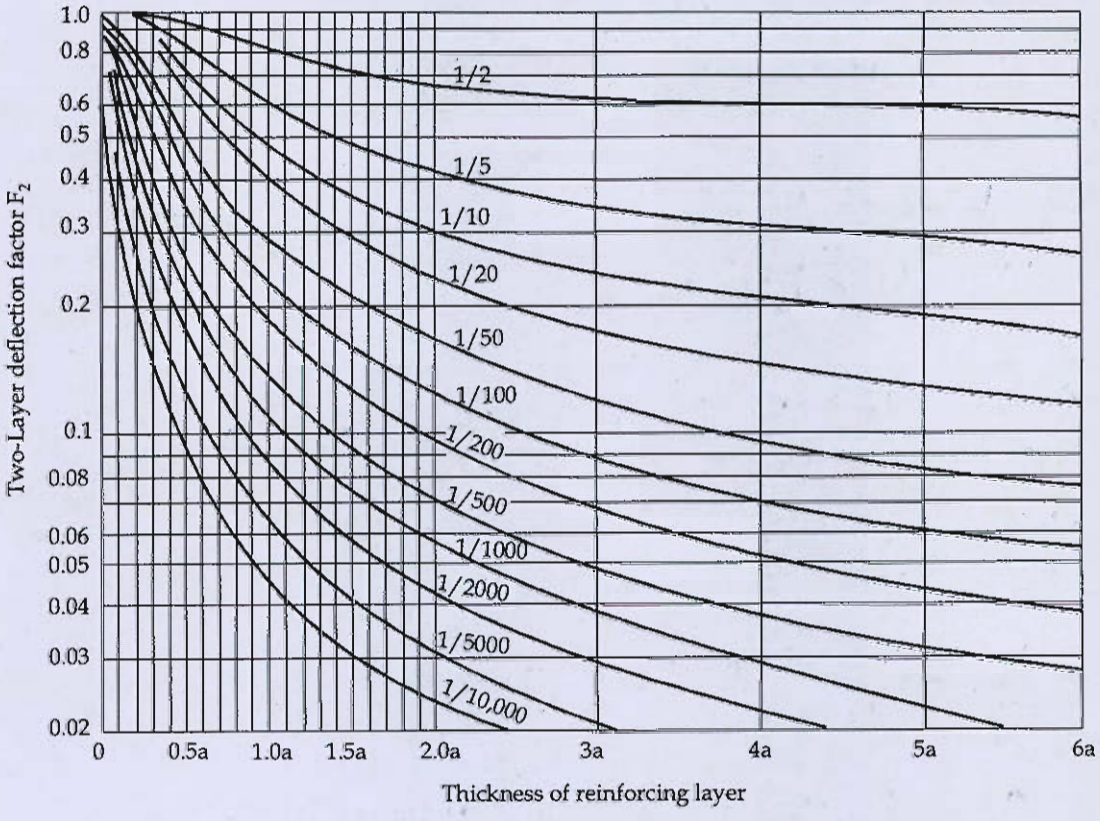
$k = \frac{k_j}{2} = 35$ v/km

3+10





Q.4 (c) (i) Plate bearing tests were conducted with 30 cm diameter plate on a soil subgrade and over 15 cm base course. The pressure recorded at 0.5 cm deflection are 1.25 kg/ cm^2 and 5.0 kg/cm^2, respectively on soil subgrade and 15 cm base course. The relationship of F_2 and h in a two-layer system (Burmister's method) is given in the diagram.



Design the pavement section for 4100 kg wheel load with tyre pressure of 5 kg/cm^2 for an allowable deflection of 0.5 cm using Burmister's approach.

(ii) Determine the spacing between contraction joints for 3.5 meter slab width having thickness of 20 cm and $f = 1.5$, for the following two cases:

1. For plain cement concrete, allowable $S_c = 0.8$ kg/cm^2, $S_s = 1200$ kg/cm^2
2. For reinforced cement concrete, 1.0 cm dia. bars at 0.30 m spacing. Assume unit weight of cement concrete as,

$$W = 2400 \text{ kg/m}^3$$

[12 + 8 = 20 marks]

(i) on subgrade $a = 15\,cm$

$$\Delta = 1.18 \frac{pa}{E_s} \times f_2$$

$$0.5 = 1.18 \times \frac{1.25 \times 15}{E_s}$$

$$E_s = 44.25\ kg/cm^2$$

on base course

$$\Delta = 1.18 \frac{pa}{E_s} f_2$$

$$0.5 = \frac{1.18 \times 5 \times 15}{44.25} f_2 \Rightarrow f_2 = 0.25$$

$$\left(\frac{h}{a}\right) = \frac{15}{15} = 1$$

$$\frac{E_1}{E_2} = \frac{1}{100} \text{ (for graph)}$$

$$E_2 = 100 \times 44.25 = 4425\ kg/cm^2$$

$P = 41100\ kg \quad p = 5\ kg/cm^2$

$$a = \sqrt{\frac{P}{\pi p}} = 16.16\ cm$$

$$\Delta = 1.5 \frac{pa}{E_s} f_2$$

$$0.5 = 1.5 \times \frac{5 \times 16.16}{44.25} f_2$$

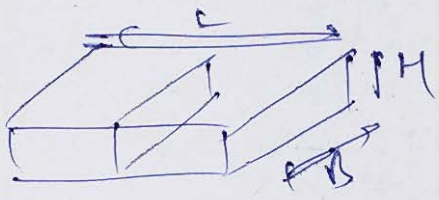
$$f_2 = 0.182$$

$$\frac{h}{a} = 1.6 \text{ (graph)} \qquad h = 1.6 \times 16.16$$

$$h = 25.856\ cm$$

provide, thickness = 26cm

(iii) (1).



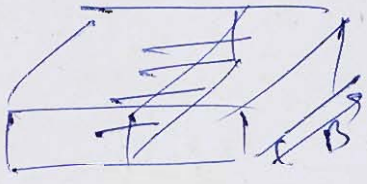
(resistance provided by concrete) = (friction developed in half block)

$S_c \times BH = f\gamma BHL/2$

$0.8 = 1.5 \times 2400 \times \frac{L}{2}$

$L = 4.44\ m$ < 4.5 m (OK).

(2).



12fB

$S_t A_t = f\gamma BH\frac{L}{2}$

$12000 \times \frac{B}{8} \times \frac{\pi}{4}\phi^2 = f\gamma BH\frac{L}{2}$

$12000 \times \left(\frac{3.5}{.3}\right) \times \frac{\pi}{4} \times 1^2 = 1.5 \times 2400 \times 3.5 \times 1.2 \times \frac{L}{2}$

$L = 8.726\ m$

Section B : Environmental Engineering

Q.5 (a) A coagulation-sedimentation plant clarifies 40 million litre of water every day. The quantity of filter alum required at the plant is 18 mg/*l*. If the raw water is having an alkalinity equivalent to 5 mg/*l* of $CaCO_3$, determine the quantity of filter alum and quick lime (containing 85% of CaO) required per year by the plant.

(Al = 27, S = 32, O = 16, H = 1, Ca = 40, C = 12)

[12 marks]

40 × 10⁶ l/d. Alum = 18 mg/l

Alk = 5 mg/l as $CaCO_3$.

Alum required = $\frac{18 \times 40 \times 10^6}{10^6}$ kg/d

= 720 kg/d

= 262800 kg/yr

12

1 gm Alum requires 0.45 gm of Alk as $CaCO_3$

Alk required = $(0.45 \times 18 - 5) \times \frac{40 \times 10^6}{10^6}$

= 124 kg/d as $CaCO_3$

= $\frac{124}{50} \times \frac{28}{0.85}$ kg/d as CaO

= 81.694 kg/d

= 29818.35 kg/yr

Q.5 (b) Write advantages and disadvantages of the following methods of treatment of sewage:

1. Trickling filter
2. Activated sludge process.

[6 + 6 = 12 marks]

① Trickling filter is a Attached growth type of Biological unit for waste treated..

Advantages

① Requires less floor area
② Operational cost is less, compared to Activated Sludge Process.

Disadvantages

① fly nuisance, odour nuisance & ponding is common observed in CRTF.

(2). Discharge Handling capacity is less.

(3) Less efficient in term of BOD removal than ASP.

(2) Activated sludge process is a suspended growth type Biological unit for waste removal.

Advantages

(1) Return Activated sludge is highly efficient in decomposing waste.

(2). BOD removal obtained is High

(3). Discharge Handling capacity is High.

DisAdvantages

(1) operational cost is High

(2). Floor area requirement is High.

4+4

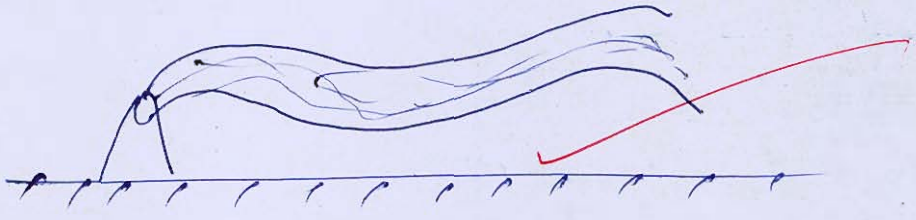
Q.5 (c) Discuss about different types of plume behavior. **[12 marks]**

(1) Looping plume

→ Happen when ELR > ALR

→ Unstable / Super Adiabtz condition

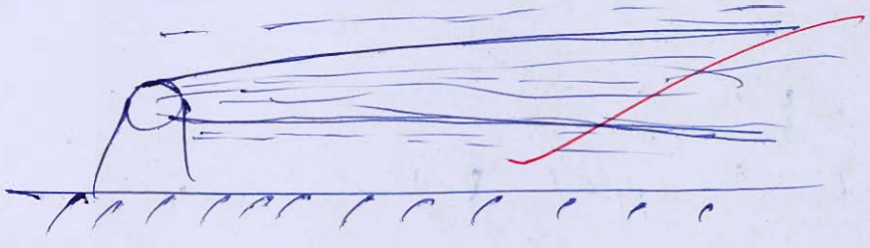
→ Rapid plume dispersion



(2) Coning plume

→ Happen when ELR < ALR

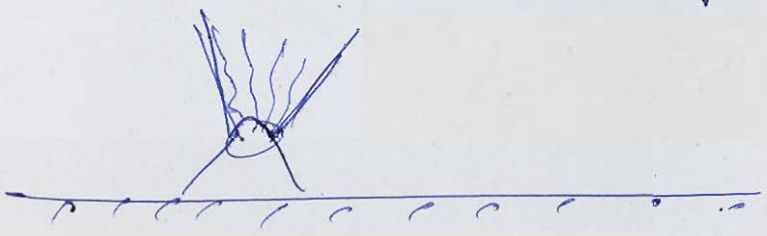
→ Stable / Sub Adiabtz condition



(2) Neutral plume

→ ELR = ALR

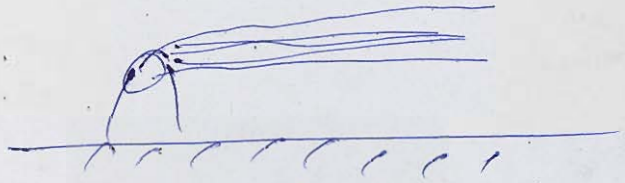
→ Neutral Nature of plume



(4) Fanning plume

→ Happen in complete inversion case.

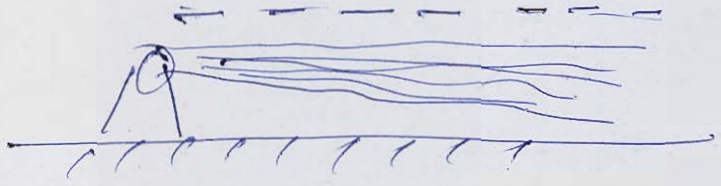
16



(5) Fumigating plume

→ ELR > ALR followed By inversion

→ worst type of plume.



(6) Looping plume

→ inversion followed By ELR > ALR

(7) Trapped plume

→ ELR > ALR trapped Between inversion

Q.5 (d) Estimate the theoretical volume of methane gas that would be expected from the anaerobic digestion of a tonne of a waste having the composition $C_{50}H_{100}O_{40}N$, if 15% of the waste would be used for the synthesis of the cell tissue.

Use density of methane as 0.7167 kg/m^3

[12 marks]

Hydrolysis

$C_{50}H_{100}O_{40}N + (A)\,H_2O \longrightarrow (C)\,CH_4 + (D)\,CO_2 + NH_3$

$A + 2B = 4C + 3$

$97 = 4C - 2B$ ... (1)

$40 + B = 2D$ ... (2)

$50 = C + D$ ... (3)

$B = 5.75$

$C = 27.125$

$D = 22.875$

1 tonne = 1000 kg

cell synth = 0.15 t

cell left = 0.85 t

= 850 kg.

$\Rightarrow$ 1354 $\longleftrightarrow$ 27.125×16

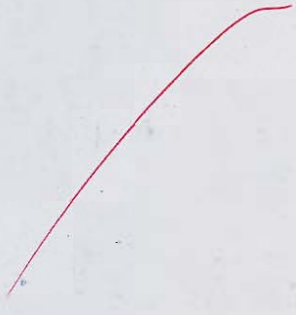
$= 434$

$850\ kg \longrightarrow \frac{434}{1354} \times 850$

$CH_4 = 272.45\ kg$ (12)

volume of $CH_4 = \frac{272.45}{0.7167}$

volume = 380.1478 m^3



Q.5 (e) (i) The BOD_5 of a wastewater is determined to be 150 mg/l at 30°C. The k value is known to be 0.23 per day at 20°C. What would the BOD_8 be if the test were run at 15°C?

(ii) A 200 ml sample of water has initial pH of 10. Thirty milliliters of 0.02 N H_2SO_4 is required to titrate the sample to pH 4.5. What is the total alkalinity of the water in mg/l as $CaCO_3$?

[8 + 4 = 12 marks]

(i) $BOD_5 = 150 mg/l \ (30^\circ C)$

$k_{30^\circ C} = 0.23 (1.047)^{30-20}$

$= 0.364 \ d^{-1}$

$L_0 = \frac{BOD_5}{1 - e^{-k t_5}} = 179 \ mg/L$

$k_{15^\circ} = 0.23 (1.056)^{15-20}$

$= 0.175 \ d^{-1}$

$BOD_8 = L_0 (1 - e^{-k' t_8})$

$BOD_8 = 134.86 \ mg/L$

12

(ii) 1 mg of 0.02N H_2SO_4 reacts with 1 mg of Alk as $CaCO_3$

30 ml of 0.02 N H_2SO_4 → 30 mg of Alk as $CaCO_3$

→ Alk in water $= \frac{30 \ mg}{.2 \ l}$

Alk. in water = 150 mg/L as $CaCO_3$

Q.6 (a) Design a rapid sand filter unit for 4 million liters per day of supply, with all of its principal components. Assume any other data suitably.

[20 marks]

(1) $Q_D = 4 \times 10^6$ lld

Assume, $f_r = 4000$ l/m²Hr

, 30 min Backwashing time

, 2% of filter water for Backwash

$Q_{Peak\ (after\ backwashing)\ Demand} = \frac{4 \times 1.8 \times 10^6}{0.9 f}$

$Q_f = 7.35 \times 10^6$ lld

$f_r = \frac{Q_f}{S A_{req}}$

$S A_{req} = \frac{7.35 \times 10^6\ l}{\frac{23.5\ Hr}{4000\ \frac{l}{m^2 Hr}}} = 1836.73\ m^2$

$n = 1.22\sqrt{\frac{Q}{n_d}} = 3.3 \simeq 4$

SA each filter $= \frac{1836.73}{4} = 459 \simeq 460\ m^2$

Let $\frac{L}{B} = 1.5$

$B \simeq 17.5m$

$L \simeq 26.25m$

provide, 4 filters of $L \times B = (17.5 \times 26.25)m$ and 1 filter as standby.

② Design of lateral & manifold

Let, area of perforation = 2%

$= \frac{2}{100} \times 17.5 \times 2.5$

$= 0.09187\ m^2$

area of lateral = 4 × (Area of perforation)

$= 3.675\ m^2$

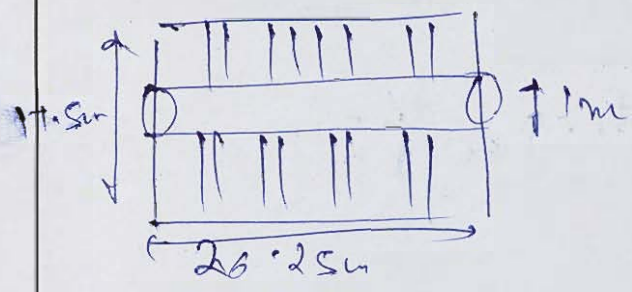
area of manifold = 2 × (area of lateral)

$\frac{\pi}{4} D^2 = 0.735\ m^2$

$D = 0.96\ m$

$D \simeq 1m$

Provide, Diameter of manifold = 1m



Assume spacing of lateral = .3m

length of lateral = $\frac{17.5-1}{2}$ = 8.25m

no. of lateral = $\frac{26.25}{.3} \times 2$ = 175

Assume dia. of perforation = 6mm

area of perforation = $\frac{\pi}{4}(0.006)^2 = 2.85\times10^{-5}$ m²

no. of perforation = $\frac{0.091875}{2.85\times10^{-5}}$ = 3250

no. of perf. on one lateral = $\frac{3250}{175} \simeq 19$

area of perf on one lateral = $19 \times 2.85\times10^{-5}$

= 5.37×10^{-4} m²

area of lateral = $4 \times 5.37\times10^{-4}$

$\frac{\pi}{4}d^2 = 2.14\times10^{-3}$ m²

$d = 5.23$ cm.

$d \simeq 6$ cm

provide, lateral dia = 6cm

Assume $v = 0.9$ m/min :

$$Q = \frac{0.9}{60} \times 17.5 \times 26.25 = 6.9 \text{ m}^3/\text{s}$$

velocity through manifold $= \dfrac{6.9}{\frac{\pi}{4} \times 1^2} = 8.77 \text{ m/s}$

velocity through lateral $= \dfrac{6.9}{175 \times \frac{\pi}{4} \times 0.06^2}$ (15)

$= 13.9 \text{ m/s}$

Q.6 (b) (i) What are the characteristics of a good distribution system? What are the advantages of the following distribution systems :

1. Dead End system 2. Grid Iron system 3. Ring system.

(ii) What are the factors affecting the selection of a particular type of pump?

[15 + 5 = 20 marks]

(i). characteristics of Good Distribution system:

(1). Uniform pressure distribution in length of pipe.

(2) No dead ends.

(3) Passage of water from more than one channel.

(4). Design life should be appropriate.

(5). Should be capable of running at peak requirements

(1) Dead end system

Advantages (1). Easy Design
(2). cheaper than other system
(3). Length of pipe required is least.
(4) Suitable for cities that are developed in Haphazard manner

(2) Grid Iron system

Advantages (1) uniform pressure Distribution in entire system of pipe Network
(2). water can pass through more than one channel;
(3) No Dead ends.

(3). Ring System

Advantages (1). water is supplied in 'outside-in' manner.
(2). pressure distribution uniform.
(3) No Dead ends.

(ii) factors affecting selection of A pumps:

1). viscosity of liquid to be pumped

2). Height upto ~~which~~ liquid is to be pumped

3). Discharge of liquid required.

12

Q.6 (c) (i) An activated sludge system is to be used for secondary treatment of 10,000 m^3/d of municipal waste water. After primary clarification, the BOD is 150 mg/l and it is desired to have not more than 5 mg/l of soluble BOD in the effluent. A completely mixed reactor is to be used and pilot-plant analysis has established the following kinetic values : Y = 0.5 kg/kg, K_d = 0.05 d^{-1}. Assuming MLSS concentration of 3000 mg/l and an underflow concentration of 10000 mg/l from the secondary clearifier, determine (I) the volume of the reactor (II) the mass and volume of solids that will be wasted each day (III) the recirculation ratio; Take θ_C = 10 days.

(ii) Determine the effective height of stack with the following data:

- Physical stack is 203m tall with 1.07m inside diameter.
- Wind velocity is 3.56 m/s
- Air temperature is 13°C
- Barometric pressure is 1000 millibars.
- Stack gas velocity is 9.14 m/s
- Stack gas temperature is 149°C

[12 + 8 = 20 marks]

(ii). $H = 203m$

$$\Delta H = \frac{V_s D}{u}\left[1.5 + 3.6e\times10^{-2}\,PD\left(\frac{T_s - T_a}{T_s}\right)\right]$$

$V_s = 9.14\ m/s$
$D = 1.07m$
$u = 2.56\ m/s$
$P = 1000\ mbar$
$T_s = 149 + 273.15 = 422.15\ ^\circ C$
$T_a = 13 + 273.15 = 286.15\ ^\circ C$

$\Delta H = 6.66m$

Effet Height $= (H + \Delta H)$

$H' = 209.66m$

20

(2). $Q = 10000\ m^3/d$
$S = 150\ mg/L$
$S_0 = 5\ mg/L$
$Y = 0.5$
$k_d = 0.05\ d^{-1}$
$X = 3000\ mg/L$
$X_0 = 10000\ mg/L$
$\theta_c = 10\ days$

(1) $$VX = \frac{Q\theta_c Y(S - S_0)}{1 + k_d\theta_c}$$

$V = 1611.11\ m^3$

(2). $Q_0 = \frac{4X}{Q_0 Y_0 + (Q_0 - Q_w) S_e} = 0$ (assume)

$Q_w Y_0 = \frac{611.11 \times 3000}{10} \times \frac{\pi}{4} \times \frac{4}{100} \times \frac{1}{100}$ kg

$Q_w Y_0 = 483.33$ kg/d ← mass wasted

$Q_w = \frac{483.33}{1000 \times 15\%}$ l/d

$Q_0 = 4833.33$ l/d ← volume wasted

(3) $\frac{Q_x}{Q_0} = \frac{X}{X_0 - X} = 0.428$

Q.7 (a) (i) Discuss the need of environmental impact assessment and also discuss the environment impact of mining and its contribution in air pollution.

(ii) The sewage is flowing at 4.5 million litres per day from a primary clarifier to a standard rate trickling filter. The 5 day BOD of the influent is 160 mg/l. The value of the adopted organic loading is to be 160 gm/m^3/day, and surface loading 2000 l/m^2/day. Determine the (I) volume of filter (II) depth and (III) efficiency of the filter unit.

[8 + 12 = 20 marks]

Q.7 (b) **(i)** What are 'primary air pollutants'? Discuss about the following air pollutants in detail:
(I) Carbon monoxide (II) Suspended particulate matter

(ii) An industry utilises 0.3 ML of oil fuel per month. It has also been estimated that for every 1 ML of fuel oil burnt in the factory per year, the quantities of various pollutants emitted are as below:

Particulate matter = 2.9 t/yr.

SO_2 = 60 t/yr

NO_x = 8 t/yr

HC = 0.4 t/yr

CO = 0.5 t/yr

Calculate the height of the chimney required to be provided for safe dispersion of the pollutants. Assume 300 working days in a year with 24 hr/day of working.

[12 + 8 = 20 marks]

Q.7 (c) (i) A main combined sewer was designed to serve an area of 60 sq. km with an average population of 185 persons/ha. The average rate of sewage flow is 350 litres/capita/day. The maximum flow is 50% in excess of the average, together with the rainfall equivalent of 12mm in 24 hours, all of which are run off. What should be the capacity of sewer in cubic meter per second?

(ii) Find the minimum velocity and gradient required to transport coarse sand through a sewer of 40 cm diameter with sand particles of 1mm diameter and specific gravity 2.65. Assume k for sand = 0.04. The Manning's roughness coefficient (n) for the sewage material may be assumed as 0.012.

[10 + 10 = 20 marks]

Q.8 (a) (i) Write in brief about the following sewer appurtenances :

1. Manholes
2. Catch Basins
3. Inverted siphons

(ii) Discuss about the characteristics of nitrogen content in municipal and industrial water.

[12 + 8 = 20 marks]

Q.8 (b) (i) Given the following data, calculate the population at the end of next three decades by decreasing rate method.

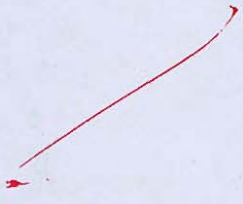
Year	Population
1940	80,000
1950	1,20,000
1960	1,68,000
1970	2,28,580

(ii) Two primary setting basins are 26 m in diameters with a 2.1 m side water depth. Single effluent weirs are located on the peripheries of the tank.

For a water flow of 26,000 m^3/d, calculate;

1. Surface area and volume
2. Overflow rate (in $m^3/m^2/d$)
3. Detention time (in hours)
4. Weir loading rate (in $m^3/m/d$)

[10 + 10 = 20 marks]



Q.8 (c) A municipal waste-water treatment plant discharges secondary effluent to a surface stream. The worst conditions are known to occur in the summer months when stream flow is low and water temperature is high. Under these conditions, measurements are made in the laboratory and in the field to determine the characteristics of waste water and the stream flows.

The wastewater is found to have maximum flow rate of 15,000 m^3/day, a BOD_5 of 40 mg/l, a dissolved oxygen concentration of 2 mg/l and a temperature of 25°C. The stream (upstream from the point of wastewater discharge) is found to have a minimum flow rate of 0.5 m^3/sec, a BOD_5 of 3 mg/l, a dissolved oxygen concentration of 8 mg/l and a temperature of 22°C. Complete mixing of wastewater and stream is almost instantaneous and the velocity of the mixture is 0.2 m/s. From the flow regime, the reaeration constant is estimated to be 0.4 day^{-1} for 20°C condition and deoxygenation constant is 0.23 day^{-1}(base e). Find dissolved oxygen concentration at point 20, 75 and 100 km from the point of discharge and the point of least DO. Assume the mix has saturation DO concentration of 8.7 mg/l.

[20 marks]

Space for Rough Work

Space for Rough Work

Space for Rough Work