Excellent

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	57
Q.2	42
Q.3	—
Q.4	47
Section-B	
Q.5	28
Q.6	43
Q.7	—
Q.8	—
Total Marks Obtained	217

Signature of Evaluator KL ..... Cross Checked by .....

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.

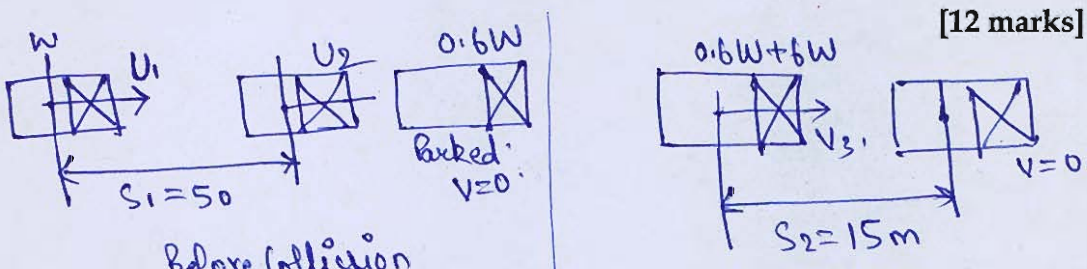
DO'S

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

(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]



After collision:

$V_3 = \sqrt{2gfS_2} = 13.288$ m/s (By Third Eqn of motion.)

Conserve momentum before & after collision

$m_1 U_2 = (m_1 + m_2) V_3$.

$U_2 = \dfrac{(1.6W) \times 13.288}{W} = 21.261$ m/s.

Before collision:

$\Rightarrow U_2^2 - U_1^2 = -2gfS_1$

$\Rightarrow U_1 = \sqrt{U_2^2 + 2gfS_1}$

$\Rightarrow \boxed{U_1 = 32.26 \text{ m/s}}$ Ans.

12

Assumptions:

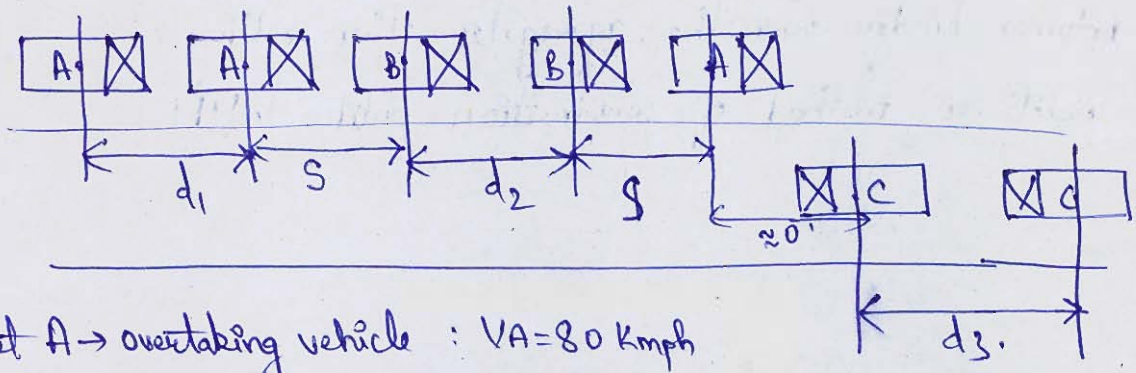
- Collision is perfectly elastic.
- No external force is there so momentum is conserved.
- After collision, velocity of separation is ~~zero~~.
- No energy loss in the collision.

(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]

(1)



Let A → overtaking vehicle : $V_A = 80$ Kmph
B → overtaken vehicle : $V_B = 50$ Kmph

$d_1 = 0.278 \times V_B \times t_R$ (as V_A will be V_B before overtaking)
$= 27.8$ m.

T = overtaking time $\Rightarrow \sqrt{\frac{2(S_1+S_2)}{a}} = \sqrt{\frac{4S}{a}} = 9.6$ sec.

$d_2 \Rightarrow 0.278 V_B T = 133.44$ m.

$d_3 \Rightarrow 0.278 V_C T$ (where $V_C = V_A$)
$\Rightarrow 213.504$.

OSD $\Rightarrow d_1 + d_2 + 2S + d_3$ (When Two-way Traffic road and single lane).

$\Rightarrow$ **406.744 m** Ans.

(11) WBM roads → Wet Bound Macadam.

- Premix method
- Larger aggregates used
- filler material like Plastic is used
- Aggregates placed first in layers and compacted.
- Bitumen binder over the aggregates then rolling.
- Traditional method of construction unlike WMM

3

(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]

Elevation Correction : 7% for 300m rise above MSL.

Corrected Length (L) $\Rightarrow 1900 + \frac{7}{100} \times \frac{600}{300} \times 1900$

$\Rightarrow 2166\ m$

Temp Correction : 1% for 1°C rise over ART.

ART (Airport Reference Temp) $\Rightarrow T_a + \frac{T_m - T_a}{3} \Rightarrow 16 + \frac{(21-16)}{3} = 17.67^\circ C$

Temp. at 600m $\Rightarrow 15^\circ C - 0.0065 \times 600$

$\Rightarrow 11.1^\circ C$

Rise $\Rightarrow 17.67 - 11.1$

$\Rightarrow 6.57^\circ C$

$L_2 \Rightarrow 2166 + \frac{1}{100} \times \frac{65.7^\circ C}{1^\circ C} \times 2166 \Rightarrow 2308.31 m.$

Check: $C_{elevation} + C_{Temp} < 35\%$

$$\frac{2308.31 - 1900}{1900} \times 100 = 21.5\%$$

OK.

Gradient Correction: @ 20% for 1° eff. grad.

$\Rightarrow 2308.31 + \frac{20}{100} \times \frac{0.6}{1} \times 2308.31$

$\Rightarrow$ **2585.31 m**

Ans.

12

(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]

Tractive effort/Hauling Capacity $\geq$ Total Resistance.

UWN W → Weight of Locomotive

N → No of Driving axles.

N = 4

W = 120t.

~~Say $\mu = 1/6$.~~

15 tonnes.

~~$\frac{1}{6} \times 120t \times 4$~~ $\Rightarrow (R)_{Rolling} + (R)_{Dependent\ on\ Speed} + (R)_{Atmospheric} + W\tan\theta$.

$R_{Rolling} = R_{wagons} + R_{Locomotive}$

$\Rightarrow 2.5\frac{Kg}{t} \times 20 \times 18t + 3.5\frac{Kg}{t} \times 120t$

$\Rightarrow 1.320t$.

12

$(R)_{speed} = 0.00008wV^2$. $\Rightarrow 2.65t$ (Given).

W = Total weight $\Rightarrow 20 \times 18t + 120t$

$\Rightarrow 480t$.

$R_{Atm} \Rightarrow 0.0000006wV^2 = 0.72t$

$15 = 1.320 + 2.65 + 0.72 + 480\tan\theta$

$\tan\theta = \frac{10.31}{480} \Rightarrow \boxed{\frac{1}{46.56}}$ Ans.

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]

(i) $G_{im} \Rightarrow \frac{W_{Mould}}{V_{Mould}} = \frac{1100}{475.} = 2.316\ g/cc.$ ✓

$G_{it} = \frac{W_1+W_2+W_3+W_4+W_5}{\sum \frac{W_i}{G_i}} \Rightarrow \frac{2600\ gms}{1085.32\ ml.} = 2.3956.$ ✓

$V_v \Rightarrow$ Air voids $= \frac{G_{it}-G_{im}}{G_{it}} \times 100 = \boxed{3.323\%}$. 1 Ans.

V_b (% Volume) $\Rightarrow \frac{W_b/G_{ib}}{W_{Total}/G_{im}} \times 100\%$

$\Rightarrow \frac{100}{1.042} \times \frac{2.316}{2600} \times 100\%.$

$\Rightarrow \boxed{8.549\%}.$ 2 Ans ✓

7

VMA $\Rightarrow V_v + V_b.$

$\Rightarrow 3.323 + 8.549$

$\Rightarrow \boxed{11.872\%}$ 3 Ans ✓

(ii) • Diamond Grooving:

→ When two tracks crosses each other at an angle. that may be right or any without the provision to turn direction perpendicularly

→ If the provision to turn perpendicularly is there then it is called Slip system.

$\alpha \rightarrow$ crossing angle.

Length of longer diagonal (d_1)

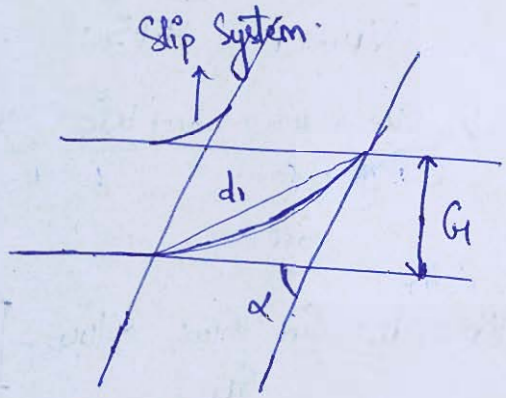
$\Rightarrow$ G closed.

Shorter diagonal $\Rightarrow$ G seat.

2- acute angle crossing

+

2- obtuse angle crossing.



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]

(1) e_{max} limited $\rightarrow$ 10%.

1 in N $\Rightarrow$ 1/60 (Rate of intro. of superelevation).

Design of Extra-widening: $We \Rightarrow \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$.

Assume $l = 6m$

$$We = \frac{2 \times 6^2}{2 \times 60} + \frac{40}{9.5\sqrt{60}} = 1.144\ m.$$

Total width of Pavement: $W + We \Rightarrow 7 + 1.144$

$\Rightarrow 8.144\ m.$

Design of 'e': $e = \frac{V_{design}^2}{225R} < e_{max}\ (0.10)$.

$\Rightarrow 0.1185 > 0.10$ 0.07

Limit 'e' to 0.10 & check 'f'

$f \Rightarrow \frac{V^2}{127R} - e_{max} < 0.15$

$\Rightarrow 0.11 < 0.15$ OK. e = 0.07

Length of Curve: By rate of rate of centrifugal acceleration.

$L_T = \frac{0.0215V^3}{CR}$ where $C = \frac{80}{75+V}$, $0.5 < C < 0.8$ m/s³

$L_T = \frac{0.0215 \times 40^3}{0.696 \times 60} = 32.95$ m. C = 0.696.

5

Criteria 2: By rate of intro. of SE.

Assume rotation about inner-edge.

$L_T = eN(w+we)$ where $N = 60$, $e = e_{max} = 0.10$

$\Rightarrow 48.864$ m

Criteria 3: Min^m Length: $L_T = \frac{V^2}{R}$ (For Hilly Terrain)

$= 26.67$ m

Steps correct but due to incorrect value of e answers are wrong.

Provide $(32.95, 48.87, 26.67)_{maxm} = 48.87$ m

For $\Delta = 60°$, Tangent Length $\Rightarrow (R+S)\tan\frac{\Delta}{2}$

$S = \frac{L_T^2}{24R} = 1.658$ m $\Rightarrow$ 35.6 m. Ans.

Length of Circular Curve $(L_c) \Rightarrow \frac{2\pi R}{360°} \times (\Delta - 2\phi)$

$\Rightarrow 16.42$ m

$\phi = \frac{L_T/2}{R} \Rightarrow 22.16°$.

Total Length of Curve $\Rightarrow L_c + L_T + L_T$ (on either side) $\Rightarrow$ 114.16 m

(11) Commonly adopted Transition curves are Clothoid Spiral, lemniscate, Parabola.

- The shape of curve to be provided depends on the requirement and the rate of change of elevation in such distance.
- ~~For steeper~~ For areas of higher elevation, the curvature to be provided for the smooth movement is of prime importance and concern as generally there is risk of overturning.
- The most generally shape which we provide is square Parabola bcz. the rate of change of sight distance is constant. ~~square parab~~
- In railways, cubic Parabola is preferred Transition curve as the centrifugal ratio varies since weight of Train is much higher

5

figure

- As far as ideal transition curve is concerned we can provide circular transition curve since the radius is ~~constant~~. Spiral is most ideal.
- Magnitude of outward force will remain same at every point in circular transition curve.
- The prime purpose of gradually providing super-elevation and extra-widening is tackled easily in such curve. So, we prefer such shape.

(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) Total loss Time $\Rightarrow 2n+R$

$n \rightarrow$ no of phases : $2\times2+12$

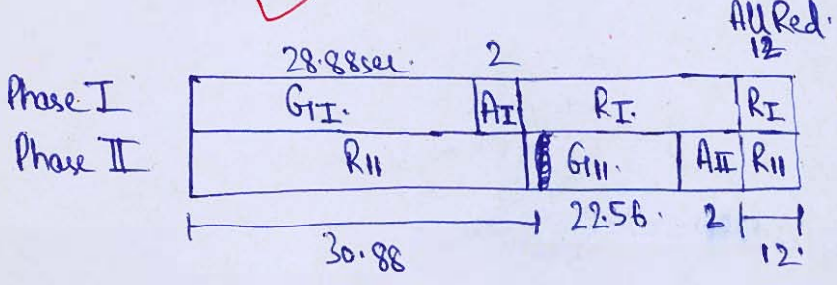
$\Rightarrow 16$ sec.

$Y = \frac{\text{Average Flow}}{\text{Saturation Flow}} \Rightarrow y_1 + y_2 \Rightarrow \frac{400}{1250} + \frac{250}{1000} = 0.57$

C_o (Cycle length) $\Rightarrow \frac{1.5L+5}{1-Y} = \frac{1.5\times16+5}{1-0.57} = 67.442$ sec.

$G_{1I} = \frac{y_I}{Y}(C_o - L) \Rightarrow \frac{0.32}{0.57}(67.442-16) = 28.88$ sec.

$G_{II} = 22.56$ sec.



12

(ii) Diamond Interchange : These are Unchannelised.
Trumpet Interchange which are
Half - Cloverleaf
Full - Cloverleaf

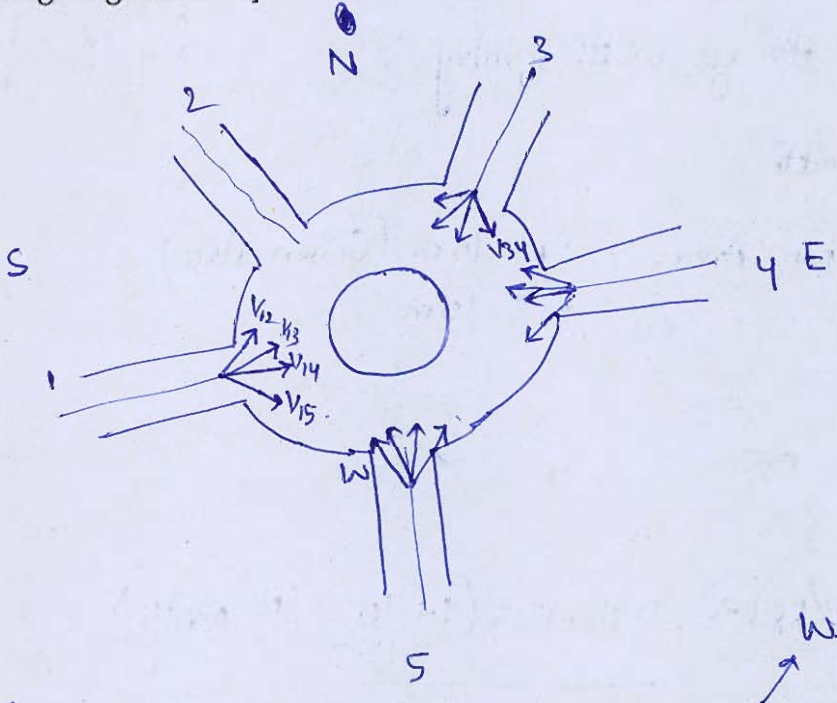
(c) A road intersection has five legs designated as 1, 2, 3, 4 and 5. Leg 1 is in N-S direction and others are marked clockwise. The traffic volumes in terms of PCU (V_{ij}) per hour during peak period are given below.

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]



Weaving Traffic

$$P_{1-2} \Rightarrow \frac{(\text{Traffic from 1 except (1-2)} + \text{Traffic to 2 except (1-2)})}{\text{Total Traffic}}$$

$$\Rightarrow \frac{V_{13}+V_{14}+V_{15}+V_{32}+V_{42}+V_{52}}{V_{12}+V_{13}+V_{14}+V_{15}+V_{32}+V_{42}+V_{43}+V_{52}+V_{53}+V_{54}}$$

$$\Rightarrow \frac{727}{859} = 0.846$$

Similarly finding all: $P_{34} = \underline{1624}$ can't find as Traffic from 2 not given

So, assume $p_{max} = P_{12} = 0.846$.

$$\text{Capacity} \Rightarrow \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{p_{max}}{3}\right)}{1+\frac{w}{L}}$$

Lanes	Rural (entry width)	Urban (entry width)
2	6.5	7
3	7	7.5
4	8	(10)
6	13	15

$w \Rightarrow$ weaving length $= \frac{e_1+e_2}{2} + 3.5$.

$e = \frac{e_1+e_2}{2}$ = Average width of entry

e_1 = entry width

Assume Urban Area $\rightarrow$ $e_1 = 10$ m (Given also)

$e_2 = 10$ m.

$e \Rightarrow 10$ m

$w = 10 + 3.5 = 13.5$ m

$L = 50$ m.

20

$$\text{Capacity (PCU/hr)} \Rightarrow \frac{280 \times 13.5\left(1+\frac{10}{13.5}\right)\left(1-\frac{0.846}{3}\right)}{1+13.5/50}$$

$\Rightarrow$ ~~3644.53~~ 3720.03 PCU/hr

$R_{entry} \Rightarrow \frac{V^2}{127f} \Rightarrow 15$ m $\left.\begin{matrix} V = 30 \text{ Kmph} \\ f = 0.47 \end{matrix}\right\}$ for urban

$R_{exit} = 1.5\, R_{entry} \Rightarrow 22.62$ m

$R_{C.I} = 1.33 \times R_{entry} \Rightarrow 20$ m.

(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]

(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]

(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) At interior :

$$S_f(\text{kg/cm}^2) \Rightarrow \frac{0.316P}{h^2}\left[4\log_{10}\left(\frac{\ell}{b}\right)+1.069\right]$$

$\ell \Rightarrow \left\{\frac{Eh^3}{12K(1-\nu^2)}\right\}^{1/4}$ → ~~radius~~ of relative stiffness.

$$\ell \Rightarrow \left[\frac{3.3\times10^5 \text{ kg/cm}^2 \times 18^3 \text{ cm}^3}{12\times 25 \frac{\text{kg}}{\text{cm}^3}\,(1-0.15^2)}\right]^{1/4} = 50.614 \text{ cm}$$

(a) $1.724h$.

$12\text{cm} \leq \Rightarrow 31.032\text{cm}$

$$S_f \Rightarrow \frac{0.316\times 4100}{18^2}\left[4\log_{10}\left(\frac{50.614}{11.396}\right)+1.069\right]$$

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

$\Rightarrow 11.396$ cm

$\Rightarrow \boxed{27.96 \text{ kg/cm}^2}$ Ans.

14.63 check calculations

$$S_f(\text{at edge}) = \frac{0.572P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right)+0.359\right]$$

$$= \boxed{29.142\ \text{Kg/cm}^2} \quad \times \quad 21.34$$

check calculation

8

$$S_f(\text{at corner}) \Rightarrow \frac{3P}{h^2}\left[1-\left(\frac{a\sqrt{2}}{e}\right)^{0.6}\right] = \boxed{18.256\ \text{Kg/cm}^2}$$

(11) Types of Failure in Flexible Pavement

① Cracks
- Reflection Cracking
- Edge Crack.
- Alligator cracks

② Disintegration
- Pot-holes.
- Ravelling.

③ Deformation
- Frayed Surface.
- Rutting.

④ Stripping.
Streaking
Fatty Surface.
Hungry Surface

6 8

Causes of Failure:
- Less Bitumen binder. for defects like Hungry surface.
- Improper grading of aggregates.
- Improper mix design.
- Less quality material used during construction.
- Due to impact loading repeatedly onto surface.
- Improper washing of aggregates leading to no bond.
- Weather cond's of the prevailing area.

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) $D_{BC} = 7°$ $\quad R_{BC} = \frac{1750}{D_{BC}^{\circ}} = 250\,m$

$D_{MC} = 3°$ $\quad R_{MC} = \frac{1750}{D_{MC}} = 583.33\,m.$

MC → Main Curve
BC → Branch Curve

$(e_{Th})_{M.C} \Rightarrow \frac{G\,V_{max\,MC}^2}{127\,R_{MC}} = \frac{1.676 \times 70^2}{127 \times 583.33} = 0.1157\,m.$ ✗

$(e_{Th})_{MC} = (e_{ac})_{MC} + CD.$

As $V_{max} < 100$ Kmph, Let $CD = 7.5\,cm$

$(e_{ac})_{MC} \Rightarrow 0.1157 - 0.075 \Rightarrow 0.0407\,m$

$\Rightarrow 4.07\,cm$ $< 16.5\,cm$ (on BG).

Steps are correct

Refer solution for exact formulas & value

OK.

5

$(e_{ac})_{BC} = -(e_{ac})_{MC} = \boxed{-0.0407}$ Ans

$(e_{Th})_{BC} = -0.0407 + 0.075 = \boxed{0.0343}$ Ans.

$\Rightarrow (e_{Th})_{BC} = \frac{G\,(V_{max\,BC})^2}{127 \times R_{BC}}$

$\Rightarrow (V_{max})_{BC} = \boxed{24.946\ \text{Kmph}}$ Ans.

(11) $V_f = 80$ Kmph

$K_j^\circ = 70$ veh/Km.

From Greenshield model: $V = V_f\left(1 - \frac{K}{K_j}\right)$

$\Rightarrow 80\left(1 - \frac{K}{70}\right)$

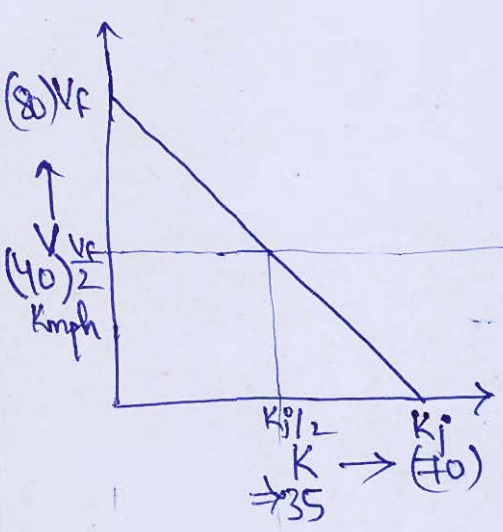
As $q = VK \Rightarrow 80\left(1 - \frac{K}{70}\right)K$.

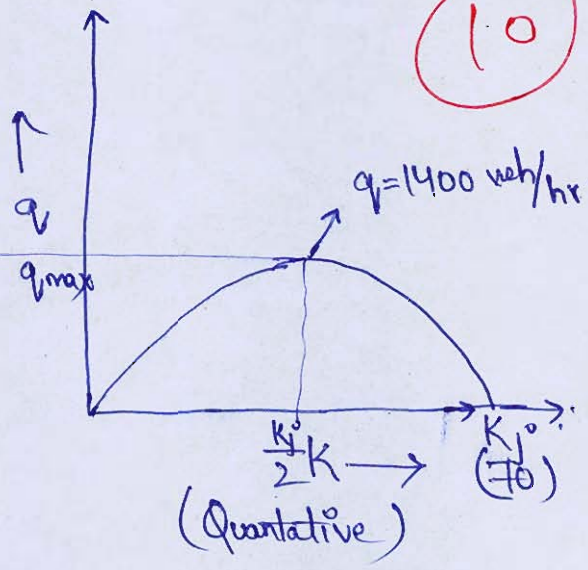
For q_{max}: $\frac{dq}{dK} = 0 : 80\left(1 - \frac{2K}{70}\right) = 0$

$K = \frac{70}{2} = \frac{K_j^\circ}{2} = \boxed{35 \text{ veh/Km.}}$

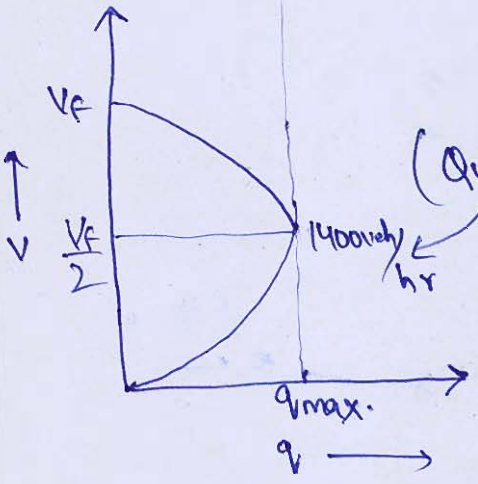
and $V = 80\left(1 - \frac{35}{70}\right) = \frac{V_f}{2} = \boxed{40 \text{ Kmph.}}$

10





(Quantative)



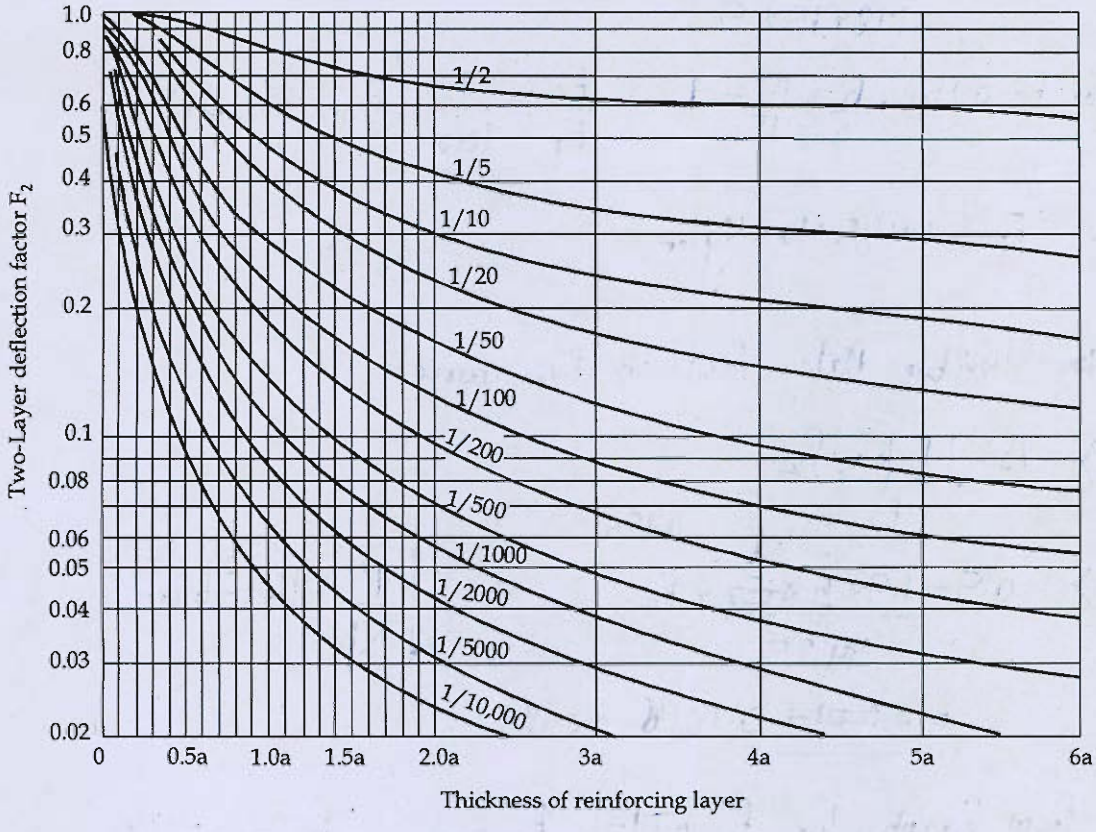
(Qualitative)

$q_{max} \Rightarrow \frac{V_f}{2} \times \frac{K_j^\circ}{2} = \frac{1}{4} V_f K_j^\circ$

$\Rightarrow 1400$ veh/hr.

Shape of V-K diagram → linear.
q-K ~~diagram~~ diagram → Parabolic
V-q " → Parabolic.

(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]

Sol?: Plate Load Test on Sub-grade.

$\Rightarrow \Delta = \frac{1.18\, p a f_2}{E_s}$ $\quad f_2 = 1$.

$a = 15$ cm.

$\Rightarrow E_s = \frac{\text{~~56.25~~ kg/cm}^2}{44.25}$. $\quad p = 1.25$ kg/cm^2

$\Delta = 0.5$ cm.

Plate load Test on Base course of $h = 15cm$.

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

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

For $f_2 = 0.25$, $\frac{h}{a} = \frac{15}{15} = 1$, $\frac{E_s}{E_p} = \frac{1}{100}$ (From Graph) ✓

$$E_p \Rightarrow 44.25 \times 10^2 \ Kg/cm^2$$

Now, Flexible Plate test on Base course:

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

12

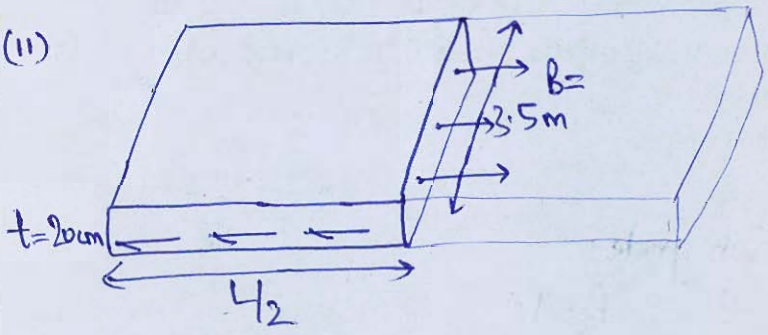
$$\Rightarrow 0.5 = \frac{1.5 \times 5 \times 16.156}{44.25} \times f_2. \qquad a = \sqrt{\frac{P}{\Pi p}} = 16.156 \ cm$$

$f_2 = 0.1826 \approx 0.183$. ✓

From Graph, for $f_2 = 0.183$, $\frac{E_s}{E_p} = \frac{1}{100}$, $\frac{h}{a} = 1.5$ (From Graph)

$$\boxed{h \Rightarrow 24.234 \ cm} \quad \text{Ans.}$$ ✓

(11)



$$S_f \times B \times t \Rightarrow f(\gamma \times \frac{L}{2} \times B \times t).$$

Stress developed in Concrete = Frictional Resistance.

$$L = \frac{2S_f}{\gamma_f} = \frac{2 \times 0.8\ Kg/cm^2}{1.5 \times 2400\ Kg/m^3} = \boxed{4.44\ m.}$$ Ans.

$< 4.5m$ in PCC

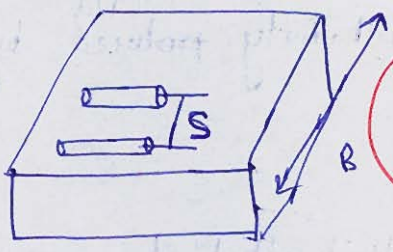
OK.

2. $A_{st} = \left(\frac{L}{2} \times B \times t\right)\gamma_f$ — (1)

$A_{st} = n \times \frac{\pi}{4} \times 1\ cm^2$

$n \Rightarrow \frac{B}{S} + 1.$

$n \Rightarrow \frac{3.5}{0.3} + 1 = 12.67$ Say 13.



6

From (1)

$$1200\frac{Kg}{cm^2} \times 13 \times \frac{\pi}{4} \times 1\ cm^2 = \frac{L(m)}{2} \times 3.5m \times 0.2m \times 1.5 \times 2400\frac{Kg}{m^3}$$

$\boxed{L = 9.724\ m}$ Ans. ✗

Refer solution.

$< 14m$ (in Reinforced)

OK

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]

Sol: $Q = 40\,MLD$, dose = 18 mg/l.

Alkalinity needed by Alum $\Rightarrow \frac{0.45}{0.234} \times 18$ mg/l as $CaCO_3$.

$\Rightarrow 8.1$ mg/l.

Added alkalinity req^n: $\Rightarrow (8.1 - 5)$ mg/l.

$\Rightarrow 3.1$ mg/l.

Quantity of filter alum (Kg/d) $\Rightarrow 18\frac{mg}{l} \times 40\,MLD$

$\Rightarrow$ **720 Kg/d**

Quick lime Required $\Rightarrow \frac{(3.1 \times 40)\,Kg/d}{\text{Eq wt of } CaCO_3} \times \text{Eq wt of } CaO.$

$\Rightarrow \frac{3.1 \times 40}{50} \times 28.$

$\Rightarrow 69.44$ Kg/d (100% pure)

85% CaO required $\Rightarrow \frac{69.44}{0.85}$

$\Rightarrow$ **81.694 Kg/d**

12

Per Year : Alum : $720 \text{ kg/d} \times 365 \text{ d} \Rightarrow \boxed{262.8 \text{ t}}$ Ans.

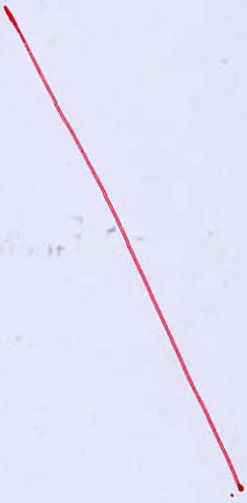
CaO : $81.694 \times 365 \Rightarrow \boxed{29.818 \text{ t}}$ Ans.

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]

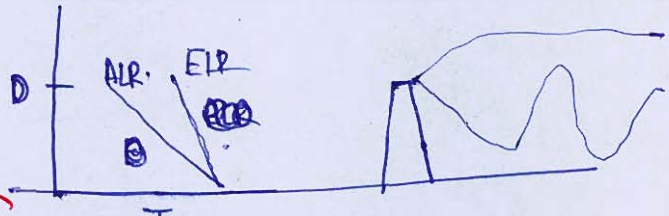
Trickling Filter	ASP
• Filter rotates by itself & discharge remain at rest.	• No need of sedimentation as occurs within.
•	



5 (c) Discuss about different types of plume behavior.

[12 marks]

Coning Plume: ELR < ALR.



Lofting Plume: ELR > ALR. Inversion.

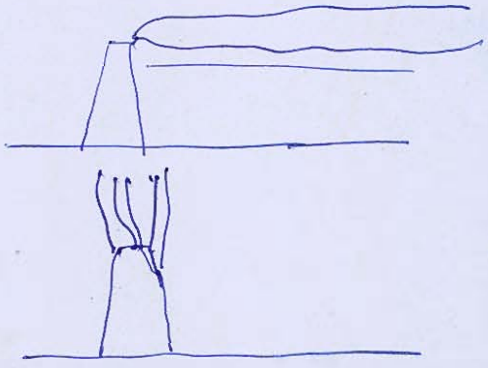
Neutral Plume: Vertical Spread of Pollutant

Fumigating Plume: Super-adiabatic over inversion. X

Trapping Plume: ELR between inversion.

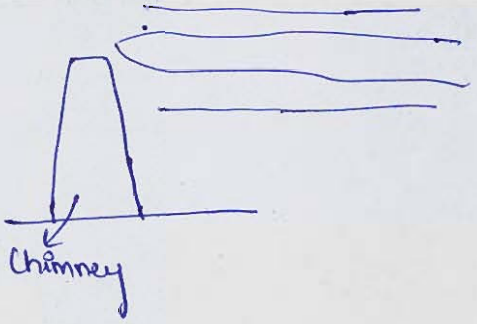
Fanning Plume: Horizontal Spread

3

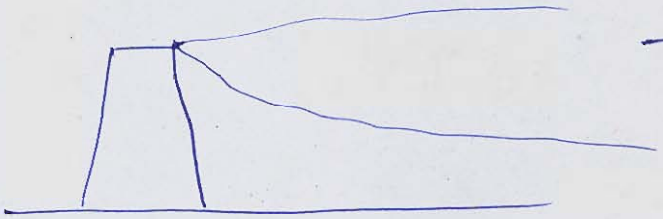


→ Fumigating (Best) X

→ Neutral:



→ Trapping Plume.



→ Fanning Plume.

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]

(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) $BOD_5(30^\circ C) = 150$ mg/l ——— (1)

$K_{20} = 0.23\ d^{-1}$

$BOD_8(15) = ?$

$K_{30} = K_{20} \times (\theta)^{T-20}$ $\quad \theta = 1.047$ when $T > 20^\circ C$.

$K_{30} = 0.23 \times 1.047^{10}$

$= 0.364\ d^{-1}$.

From (1): $BOD_5(30^\circ C) = BOD_u\left(1 - e^{-K_{30} \times 5}\right)$

$BOD_u \Rightarrow \dfrac{150}{1 - e^{-0.364 \times 5}} \Rightarrow 179$ mg/l ✓

$K_{15} = K_{20} \times (1.056)^{15-20}$ $\quad$ When $T < 20^\circ C$

$K_{15} = 0.175\ d^{-1}$. $\quad \theta = 1.056$.

$BOD_8(15^\circ C) = BOD_u\left(1 - e^{-K_{15} \times 8}\right)$

$\Rightarrow$ **134.86 mg/l** ✓ Ans.

8

(ii) Initial pH = 10, pOH = 4 & $[OH^-] = 10^{-4}$ moles/l.

$[OH^-]$ alkalinity as $CaCO_3 \Rightarrow \dfrac{[10^{-4}] \times 10^3 \times 17 \times 50}{17}$

$\Rightarrow$ 5 mg/l.

30 ml of 0.02N H_2SO_4 to pH=4.5.

means 1 mg/ml of sample neutralizes 1 mg of alk. as $CaCO_3$.

Total alkalinity $\Rightarrow \frac{30\text{ mg}}{0.2\ell} \Rightarrow 150$ mg/ℓ.

$[OH^-]+[CO_3^{-2}]+[HCO_3^-] = 150$ mg/ℓ as $CaCO_3$

Ans.

4

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]

Sol: Total supply of water ⇒ 4MLD.

Let Backwash (BW) water ⇒ 5% of filtered water done for 30min.

Q_{Design} (without BW) ⇒ $(4\times10^6\times1.8)$ L/d

Designed for 4×10^6.

Q_{Design} with B.W ⇒ $\frac{4\times10^6\times1.8}{0.95} \Rightarrow 7.58$ MLD.

Let Rate of Filtration (ROF) be 3000 ℓ/hr/m².

Effi ROF ⇒ $\frac{3000\times23.5}{24}$ ℓ/hr/m²

Area Req^n: ⇒ $\frac{Q_{Design\ with\ BW}}{Effi.\ ROF} \Rightarrow \frac{7.58\times10^6/24\ \ell/hr}{2937.5\ \ell/hr/m^2}$

⇒ 107.52 m²

No of units $\Rightarrow 1.22\sqrt{Q_{MLD}} \Rightarrow 4$:

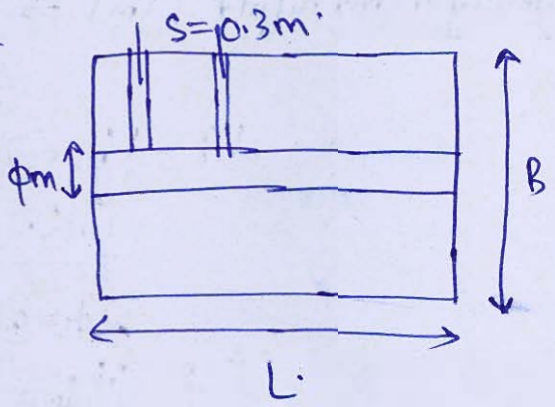
(Area) each $\Rightarrow \frac{107.52}{4} \Rightarrow 26.88\ m^2$

$\frac{L}{B} = 2$ (Say) so $B = 3.66\ m$ Say $3.7\ m$

$L = 7.33\ m$ Say $7.5\ m$.

Area of perforations $(A_p) = 0.3\%$ of BL

$\Rightarrow 0.08325\ m^2$



$(A)_{Laterals} = 2A_p = 0.1665\ m^2$

$(A)_{Manifold} = 2A_L = 0.333\ m^2$

$\phi_m \Rightarrow 0.651\ m$.

(L).

Length of lateral $\Rightarrow \frac{B - \phi_m}{2} \Rightarrow 1.5245\ m$.

Steps are correct

The filter is designed for actual discharge

Let $\phi \Rightarrow 12mm$ for each perforation:

Total Perforations $\Rightarrow \frac{0.08325}{\frac{\pi}{4} \times 0.012^2} = 736$.

Let Spacing bet. laterals $\Rightarrow 0.3m(s)$

Total Laterals $\Rightarrow \left(\frac{L}{S} + 1\right) \times 2 \Rightarrow 52$.

10

~~Area of~~ perforations per lateral $\Rightarrow \frac{736}{52} = 14.15$ Say 16.

dia. of lateral $(\phi_L) \Rightarrow \sqrt{\frac{4}{\pi} \times \frac{0.1665}{52}}$

$\Rightarrow 0.064m$.

Check: $\frac{L}{\phi_L} < 60$: $\frac{1.5245}{0.064} \Rightarrow 23.82 < 60$

OK.

Let wash water discharge = 45 cm/min.

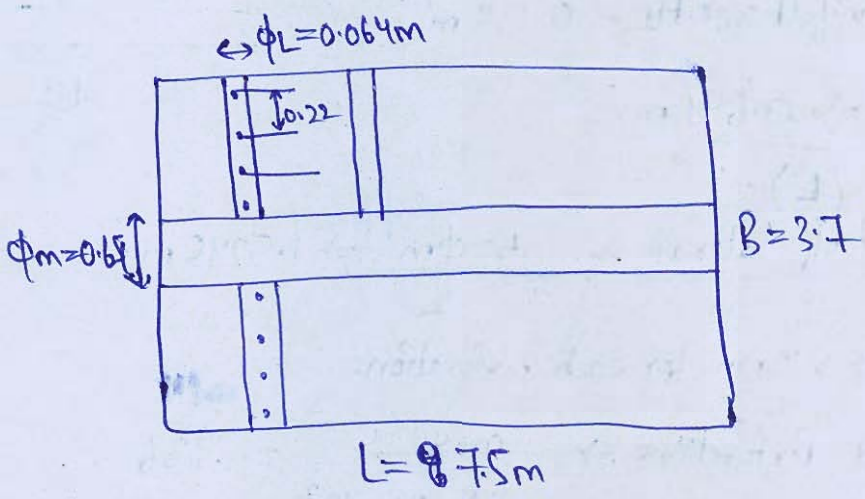
Discharge in $m^3/s = \frac{0.45}{60} \times 7.5 \times 3.7$

$\Rightarrow 0.208\ m^3/s$

Velocity in manifold $(V_m) \Rightarrow \frac{0.208}{0.333} \Rightarrow 0.625\ m/s.$

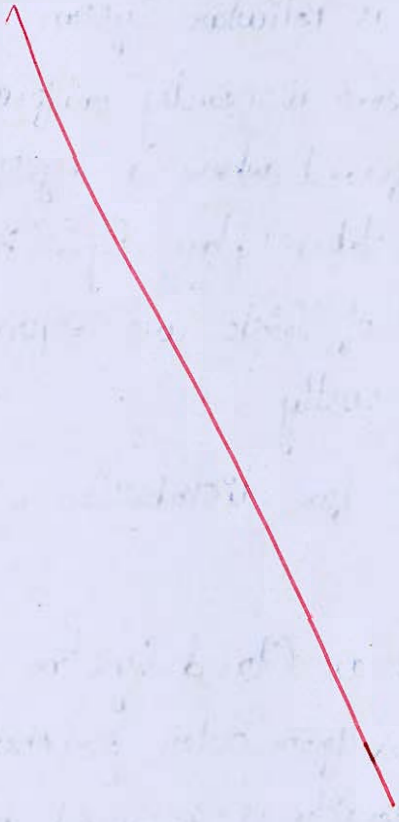
$1.8 < V_m < 2.4\ m/s$

OK.



2 perforation on each location; Spacing $\Rightarrow \frac{15.45}{67} \Rightarrow 0.22m.$

Total '16' perforations



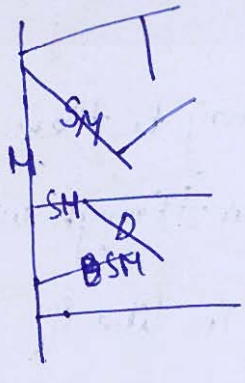
(b) (i) What are the characteristics of a good distribution system? What are the advantages of the following distribution systems :

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]

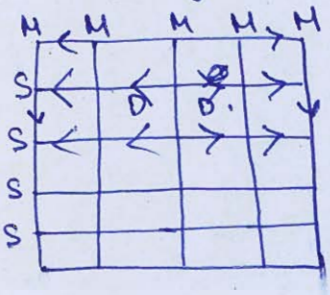
(i) Dead End System : Free end System.



- Only a fixed path of fixed.
- Pressure reaching to everyone may not be same.
- Several dead ends.
- Preferred when there is lack of space and random development taken Place.

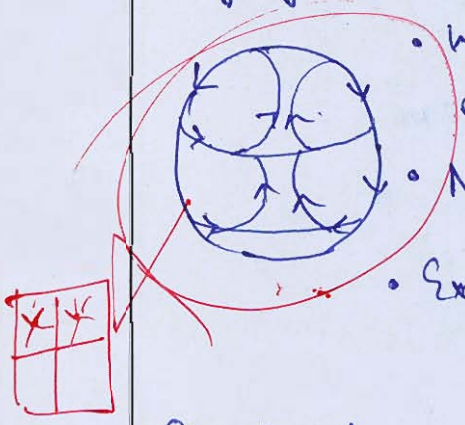
M → Mains
SM → Sub-Mains
D → Distributory.

Grid Iron System: • known as Reticular System.



- Pressure is nearly uniform.
- Preferred where a systemic development has taken place. Eg → Chandigarh.
- Lot of Joints are required so may be costly.
- Multiple path of water for distribution so dead ends are gone.

Ring System: Also known as Closed System.



- Water comes from outer-periphery and nearly equal intensity is received by all.
- No dead ends so no stagnation of water.
- Example: Mostly in South-Indian states like A.P, Telangana.

12

Characteristics:

- It should have multiple path to reach to consumer.
- Pressure should be same
- Less requirement of Joints as leakage may be there.
- No dead ends so less chances of infection through water.
- Based on the type of city, we are living in like if construction in haphazard manner then go for Dead end System.

(11) Factors affecting selection of a pump:

• Purpose of work and requirement like for more discharge Centrifugal is preferred & for more head: Reciprocating.

(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

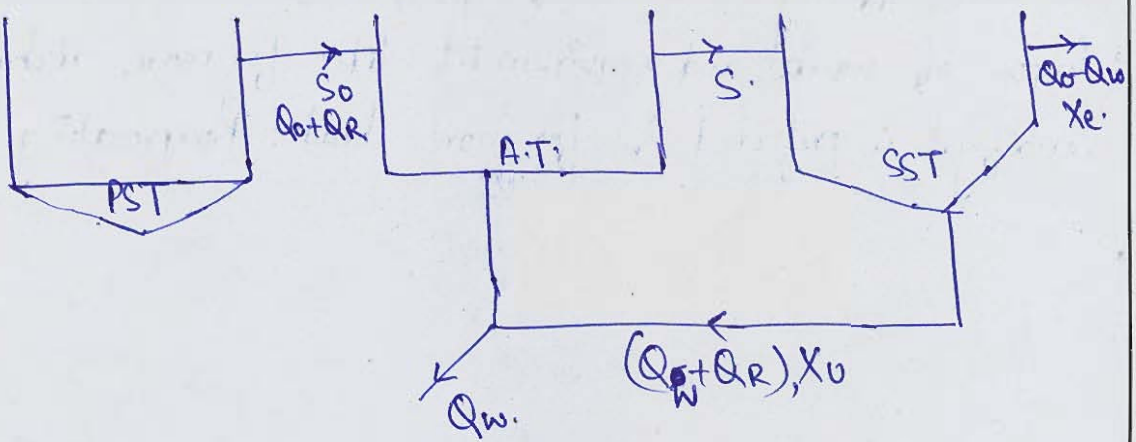
[12 + 8 = 20 marks]

(1) $Q_0 = 10000\ m^3/d$

$S_0 = 150\ mg/\ell$, $S = 5\ mg/\ell$. $\theta_c = 10\ d$

$X = 3000\ mg/\ell$

$X_U = 10000\ mg/\ell$.



(I)

Volume: $\dfrac{Q_0(S_0 - S)\theta_c Y}{(1 + k_0\theta_c)X} \Rightarrow \dfrac{10000\ m^3/d \times (150-5)\ mg/\ell \times 10\ d \times 0.5}{(1 + 0.05 \times 10) \times 3000\ mg/\ell}$

$\Rightarrow \boxed{1611.11\ m^3}$ Ans

(II) $\theta_c \Rightarrow \dfrac{VX}{Q_w X_U + (Q_0 - Q_w) X_e}$ $\quad X_e \approx 0$.

$Q_w X_U$: Mass of solids wasted $\Rightarrow \dfrac{1611.11\ m^3 \times 3000\ mg/\ell}{10\ d}$

$\Rightarrow \boxed{483.33\ Kg/d}$

Volume wasted $\Rightarrow \dfrac{483.33\ Kg/d}{10000\ mg/\ell} \Rightarrow \boxed{48.333\ m^3/d}$ Ans.

12

III $R = \frac{X}{X_v - X}$ neglecting X_e and

$\Rightarrow \frac{3000}{10000-3000} = \boxed{0.4286}$ Ans.

(II) $\Delta h = \frac{V_s d}{V_w}\left[1.5 + 2.68 \times 10^{-3} \times \frac{p \times \Delta T \times d}{T_s}\right]$.

$d \Rightarrow 1.07m$ $\quad p(\text{in mbar}) = 1000$.

$V_s = 9.14\ m/s$ $\quad \Delta T \Rightarrow (149-13) = 136K$.

$V_w = 3.56\ m/s$ $\quad T_s = 149^\circ C = 422K$.

$\Delta h \Rightarrow \frac{9.14 \times 1.07}{3.56}\left[1.5 + \frac{2.68 \times 10^{-3} \times 10^3 \times 136 \times 1.07}{422}\right]$

$\Rightarrow 6.66m$.

8

Eff. Height $\Rightarrow H + \Delta h$

$\Rightarrow \boxed{209.66\ m}$ Ans.

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]

(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]

(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

4,00,000