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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	51
Q.2	43
Q.3	—
Q.4	51
Section-B	
Q.5	41
Q.6	37.
Q.7	—
Q.8	—
Total Marks Obtained	223

Signature of Evaluator RL. 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]

1) (a) Given,

Distance travelled before collision, $s_1 = 50$ m.

Distance travelled after collision, $s_2 = 15$ m

$f = 0.6$

let mass of running vehicle, $m_A = m$

mass of parked vehicle, $m_B = 0.6m$

let speed of vehicle before collision $= u_1$

speed of ~~vehicle~~ after collision $= u_2$

speed of vehicle just before collision $= v_2$

speed of vehicle just after collision $= v_3$

$$v_3^2 = u_3^2 + 2as_2$$

$$= 0 + 2gfs_2$$

$$v_3 = \sqrt{2gfs_2} = \sqrt{2 \times 9.81 \times 0.6 \times 15}$$

$$\boxed{v_3 = 13.28 \text{ m/s}}$$

Applying momentum & conservation

$$m_A v_2 + m_B v_2 = (m_A + m_B) v_3$$

$$m \times v_2 + 0.6m \times 0 = (m + 0.6m) \times 13.28$$

$$v_2 = \frac{1.6m}{m} \times 13.28$$

$$\boxed{v_2 = 21.26 \text{ m/s}}$$

Again ~~kineti~~ change in kinetic energy = work done

$$v_1^2 = v_2^2 + 2as_1$$

$$v_1 = \sqrt{v_2^2 + 2gfs_1}$$

$$v_1 = \sqrt{21.26^2 + 2\times 9.81\times 0.6\times 50}$$

$$\boxed{v_1 = 32.25 \text{ m/s}}$$

Initial speed of moving vehicle, $v_1 = 32.25$ m/s

Assumptions

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① There is elastic collision between the vehicles

② Total change in kinetic energy equal to work done & loss of energy is neglected.

(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 (b)(i) Given,

Speed of overtaking vehicle, v_A & v_C = 80 kmph

Speed of overtaken vehicle, v_B = 50 kmph

acceleration, a = 2.5 kmph/sec

$a = 0.694$ m/sec^2

Reaction time, t_R = 2 seconds.

spacing between vehicle, s = 16m

Overtaking sight distance is given by

$OSD = d_1 + d_2 + d_3$

$d_1 = 0.278\, v_B \times t_R$

$d_1 = 0.278 \times 50 \times 2$

$\boxed{d_1 = 27.78 \text{ m}}$ ✓

$d_2 = b + 2s$

$= 0.278\, v_B \times T + 2s$

$T = \sqrt{\frac{4s}{a}} = \sqrt{\frac{4 \times 16}{0.694}} = 9.60$ sec

$d_2 = 0.278 \times 50 \times 9.60 + 2 \times 16$

$\boxed{d_2 = 165.44 \text{ m}}$ ✓

$d_3 = 0.278\, v_C \times T$

$= 0.278 \times 80 \times 9.60$

$\boxed{d_3 = 213.50 \text{ m}}$

Hence OSD = 27.78 + 165.44 + 213.50

OSD = 406.72 m ✓ (7)

Ans→1(b) (ii) Construction of WBM roads.

- Layer of aggregate are spread over the subgrade having size 45 mm–90 mm
- Then ~~spread~~ watering is done on the surface.
- Finally the surface is compacted by roller having capacity 8–10 tonne.

Advantage

- Good load dispersion.
- Good drainage.

(3)

Disadvantage

- Slow process.

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]

1 ⇒ 1 (c) Given, BRL, $L = 1900$ m

Elevation, $H = 600$ m

$T_a = 16\,^\circ C$

$T_m = 21\,^\circ C$

Effective gradient $= 0.6\%$

(i) Correction for Elevation

For 300 m elevation, BRL is increase by 7%.

$$q = 600 \times \frac{7}{100} \times \frac{1}{300} \times 1900$$

$$q = 266 \text{ m}$$

Runway length after elevation correction

$$L_1 = 1900 + 266$$

$$\boxed{L_1 = 2166 \text{ m}}$$

(ii) Correction for temperature

For 1°C increase in temperature, Runway length is increased by 1%.

$ART = Ta + \frac{Tm - Ta}{3} = 16 + \frac{21-16}{3} = 17.66°C$ ✓

Standard atmospheric temperature

$SAT = 15 - 0.0065 \times 600$

$= 11.1°C$ ✓

Change in Temp $= \Delta T = 17.66°C - 11.1°C$

$= 6.56°C$ ✓

So correction for temperature

$C_2 = 6.56 \times \frac{2166}{100} = 142.08\ m$

Runway length after temp. correction

$L_2 = 2166 + 142.08 = 2308.08\ m$

Check

Total % increase in length $= \frac{2308.08 - 1900}{1900} \times 100$

$= 21.47\% < 35\%$ OK ✓

(iii) Correction for Effective gradient

for 1% gradient runway length is increased by 20%

$C_3 = \frac{20}{100} \times 0.6 \times 2308.08 = 276.97\ m$

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Final Runway length $= 2308.08 + 276.97$

$\boxed{L_{final} = 2585.05\ m}$ ✓

(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]

(d) No. Given,

No. of wagon = 20

Weight of each wagon = 18 tonnes

Total weight of wagon = $20 \times 18 = 360$ tonnes

speed of train, $V = 50$ kmph

No. of Driving axle pair = $\frac{8}{2} = 4$

Weight of axle = ~~22.5 to 15 tonnes~~ 22.5 tonnes

Weight of locomotive = ~~22.5 tonnes~~ 120 tonnes

Tractive effort = 15 tonnes

Rolling resistance of wagon = 2.5 kg/tonne

Rolling resistance of locomotive = 3.5 kg/tonne

speed resistance = 2.65 tonnes.

Total Resistance by wagon & locomotive

$= 360 \times 2.5 + 120 \times 3.5$

$= 1320$ tonnes

Total weight of train = $360 + 120 = 480$ tonnes

Now,

Total resistance = Tractive effort.

$\Rightarrow$ Total resistance = speed resistance + Rolling resistance + Atmospheric resistance + wind resistance + Gradient Resistance

Wind Resistance ??

$= 2.65 + 1.32 + 0.00008 \times 480 \times 50 + 0.0000006 \times 480 \times 50^2 + \frac{W}{\eta}$

(Atmospheric resistance)

$= 6.61 + \frac{480}{n}$

Tractive effort = 15 tonnes

$\therefore \Rightarrow 6.61 + \frac{480}{n} = 15$

$\Rightarrow n = 57.21$

Steepest gradient is 1 in 57.21.

Refer solution

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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]

5) (e)

1.042	Bitumen	100
2.42	A-4	150
2.40	A-3	350
2.52	A-2	1200
2.62	A-1	800

Given,

Volume of mould = 475 cc

Weight of mould = 1100gm

$\gamma_b = 2.315 \text{ g/cc} = G_m$ ✓

(i) percentage air voids

$$\%V_v = \left(1 - \frac{G_m}{G_t}\right) \times 100$$

$$G_t = \frac{W_1 + W_2 + W_3 + W_4 + W_5}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_4}{G_4} + \frac{W_5}{G_5}}$$

$$G_t = \frac{800 + 1200 + 350 + 150 + 100}{\frac{800}{2.62} + \frac{1200}{2.52} + \frac{350}{2.40} + \frac{150}{2.42} + \frac{100}{1.042}}$$

$G_t = 2.395$ ✓

$$\%V_v = \left(1 - \frac{2.315}{2.395}\right) \times 100$$

$\%V_v = 3.36\%$ ✓

(ii) Percentage bitumen in volum

$$\%V_b = \left(\frac{W_b}{W_{total}}\right) \times \frac{G_m}{G_b} \times 100$$

$$= \left(\frac{100}{2600}\right) \times \frac{2.315 \times 100}{1.042}$$

$\%V_b = 8.90\%$ ✗

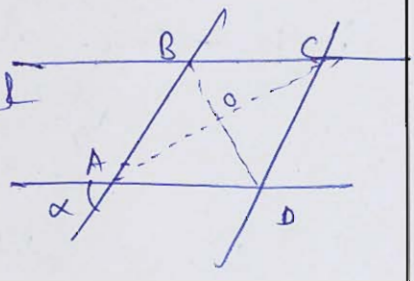
(iii) percentage voids in mineral aggregat

$$VMA = V_v + V_b$$
$$= 3.36\% + 8.90\%$$
$$\boxed{VMA = 12.26\%}$$

4

Ans⇒5> (e) (ii) Diamond crossing on a railway track.

* When two rail track crosses in such a way it forms the shape of diamond is called as dimond crossing.
* It has two acute angle crossing & two obtuse angle crossing.



$$\boxed{AC = G \operatorname{cosec} \frac{\alpha}{2}}$$

$$\boxed{BD = G \sec \frac{\alpha}{2}}$$

3

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]

Ans⇒2> (a) (i) Given, $W = 7m$ $R = 60\ m$ $V_{design} = 40$ kmph

Length of transition curve

a) $L_{T_1} = \frac{V^3}{CR}$ $C = \frac{80}{75+V}$

$$C = \frac{80}{75+40} = 0.695\ m/sec^3 \text{ ok.}$$

$$L_{T_1} = \frac{\left(\frac{5}{18} \times 40\right)^3}{0.695 \times 60} = 32.89\ m$$

(b) As per rate of introduction of superelevation

$$L_{T_2} = \frac{2N(W + We)}{}$$

Assuming rotation about inner edge.

$$e = \frac{V^2}{225R} = \frac{40^2}{225 \times 60} = 0.118 \approx 0.10.$$

0.07

$$L_{T_2} = 0.10 \times 60 (7 + 0) = 42 m$$

(c) As per IRC

$$L_{T_3} = \frac{V^2}{R} = \frac{40^2}{60} = 26.67.$$

So length of transition curve = max { 32.89, 42, 26.67

$$L_T = 42 m$$

X

5

Total length of curve

$$\frac{L.C}{2\pi R} = \frac{\Delta}{360^\circ}$$

$$L = \frac{60}{360} \times 2\pi \times 60$$

$$L_C = 62.83 m$$

X

Length of tangent

$$L_{Tan} = R \tan \frac{\Delta}{2}$$

$$= 60 \tan\left(\frac{60}{2}\right)$$

$$L_{Tan} = 34.64 m$$

X

Ans⇒ 2 (a) (ii) Different type of transition curve commonly adopted in horizontal alignment are

(i) Spiral transition curve

(ii) Bernoulli lemniscate curve

(iii) Parabolic curve.

★ Spiral transition curve is taken as ideal transition curve in horizontal alignment for highway.

★ This is because, ~~rate~~

(i) Length of transition curve is inversely proportional to curvature

$$L_T \propto \frac{1}{R}$$

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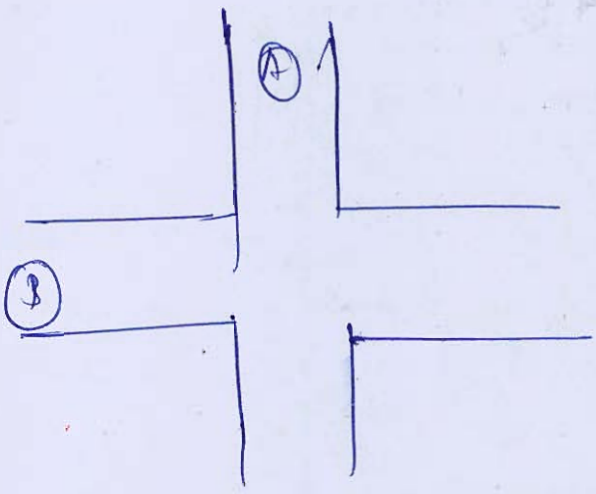
(ii) It offers smooth movement of vehicle without any sudden jerk.

(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]

(b)(i)



$N_A = 400$ PCU/hr $\quad N_B = 250$ PCU/hr

$S_A = 1250$ PCU/hr $\quad S_B = 1000$ PCU/hr

$R = 12$ sec $\quad n = 2$ (For two phase)

Start up lost time = 2 sec

Design as per webster Method

$$C = \frac{1.5L + 5}{1 - Y}$$

$$Y = Y_A + Y_B = \frac{400}{1250} + \frac{250}{1000} = 0.57$$

$$C = \frac{1.5[2 \times 2 + 12] + 5}{1 - 0.57}$$

$C = 67.44$ sec

Effective Green time

$$G_A = \frac{Y_0}{Y}[C_0 - L] = \frac{0.32}{0.57}[67.44 - 16)$$

$= 28.87$ sec ✓

$G_B = 22.56$ sec ✓

12

Road A	28.87	2	6	30.56	
Road B	36.87			22.56	2 6

✓

Ans ⇒ 2 (b) (ii)

(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.

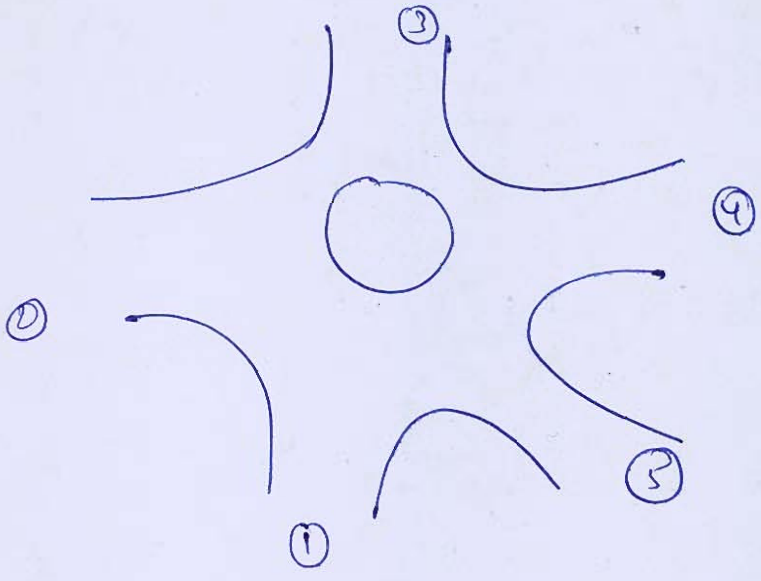
V_{12}	37	V_{31}	466	V_{41}	182	V_{51}	45
V_{13}	303	V_{32}	122	V_{42}	54	V_{52}	132
V_{14}	64	V_{34}	47	V_{43}	18	V_{53}	62
V_{15}	52	V_{35}	657	V_{45}	116	V_{54}	15

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]

⇒ 2) (c) Weaving ratio $= P_{1-2} = \dfrac{b+c}{a+b+c+d}$



$a = V_{12} = 37$

$b = V_{13} + V_{14} + V_{15} = 303 + 64 + 52 = 419$

$c = V_{32} + V_{42} + V_{52} = 122 + 54 + 132 = 308$

$d = V_{54} + V_{43} + V_{53} = 15 + 18 + 62 = 95$

$$P_{1-2} = \frac{419 + 308}{37 + 419 + 308 + 95}$$

$P_{1-2} = 0.846$

Capacity of Rotary is given by

$$Q_p = \frac{280\, w \left(1 + \frac{e}{w}\right)\left(1 - \frac{p}{3}\right)}{\left(1 + \frac{w}{l}\right)}$$

$w = \frac{e_1 + e_2}{2} + 3.5 = \frac{10 + 10}{2} + 3.5 = 13.5$ ✓

$e = \frac{10+10}{2} = 10$

$l = 50$ m.

$p_{3-4} = \frac{657 + 466 + 122 + 15 + 64 +}{47 + 657 + 466 + 122 +}$

$$Q_p = \frac{280 \times 13.5 \left(1 + \frac{10}{13.5}\right)\left(1 - \frac{0.846}{3}\right)}{\left(1 + \frac{13.5}{50}\right)}$$ ✓

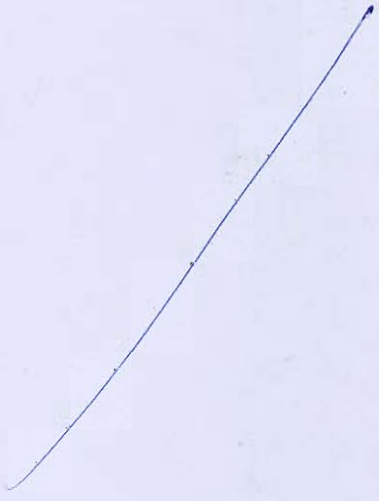
$Q_p = 3720.03$ veh/hr ✓ 20

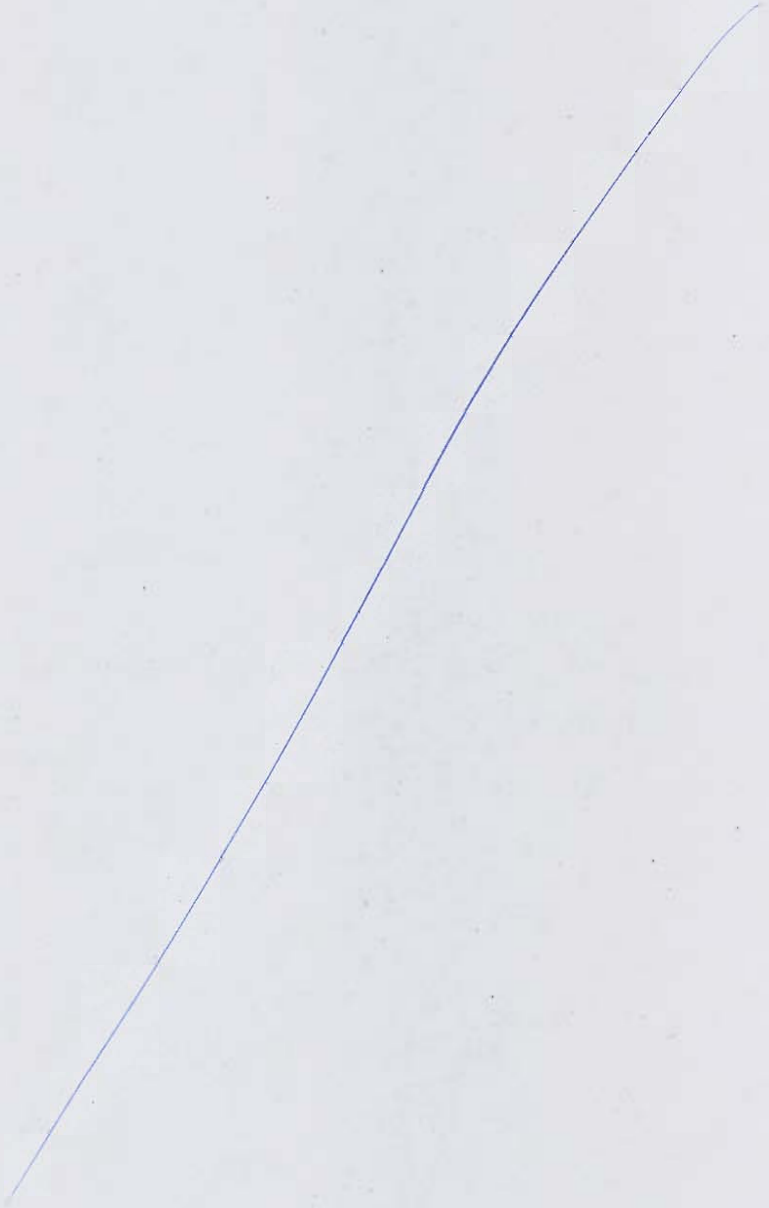
∴ capacity of rotary = 3720. veh./hr.

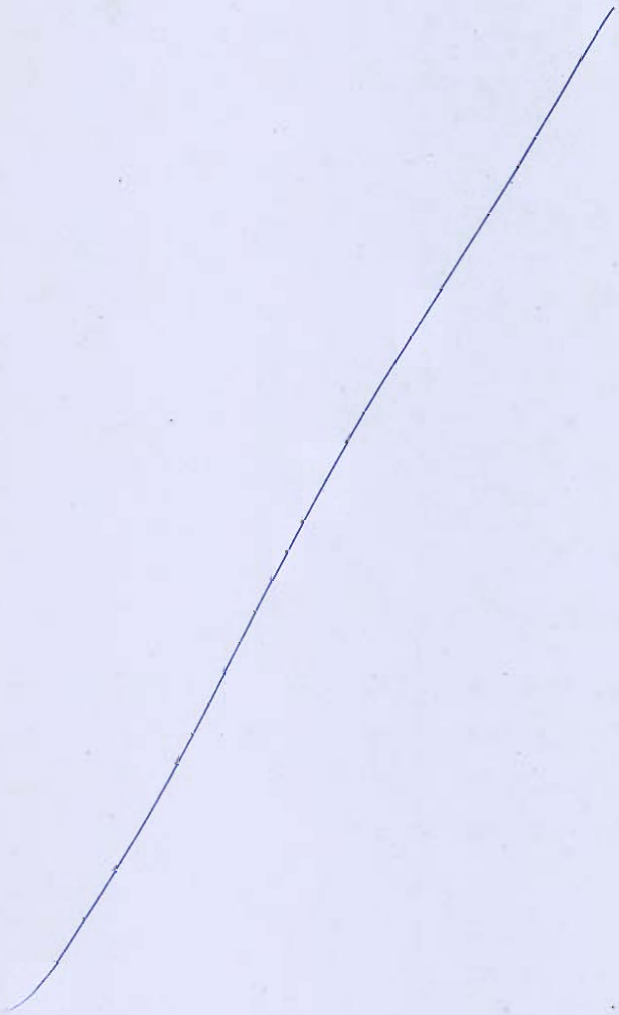
3 (a) (i) What are the various tests carried out on bitumen? Briefly mention the principle and uses of each test.

(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

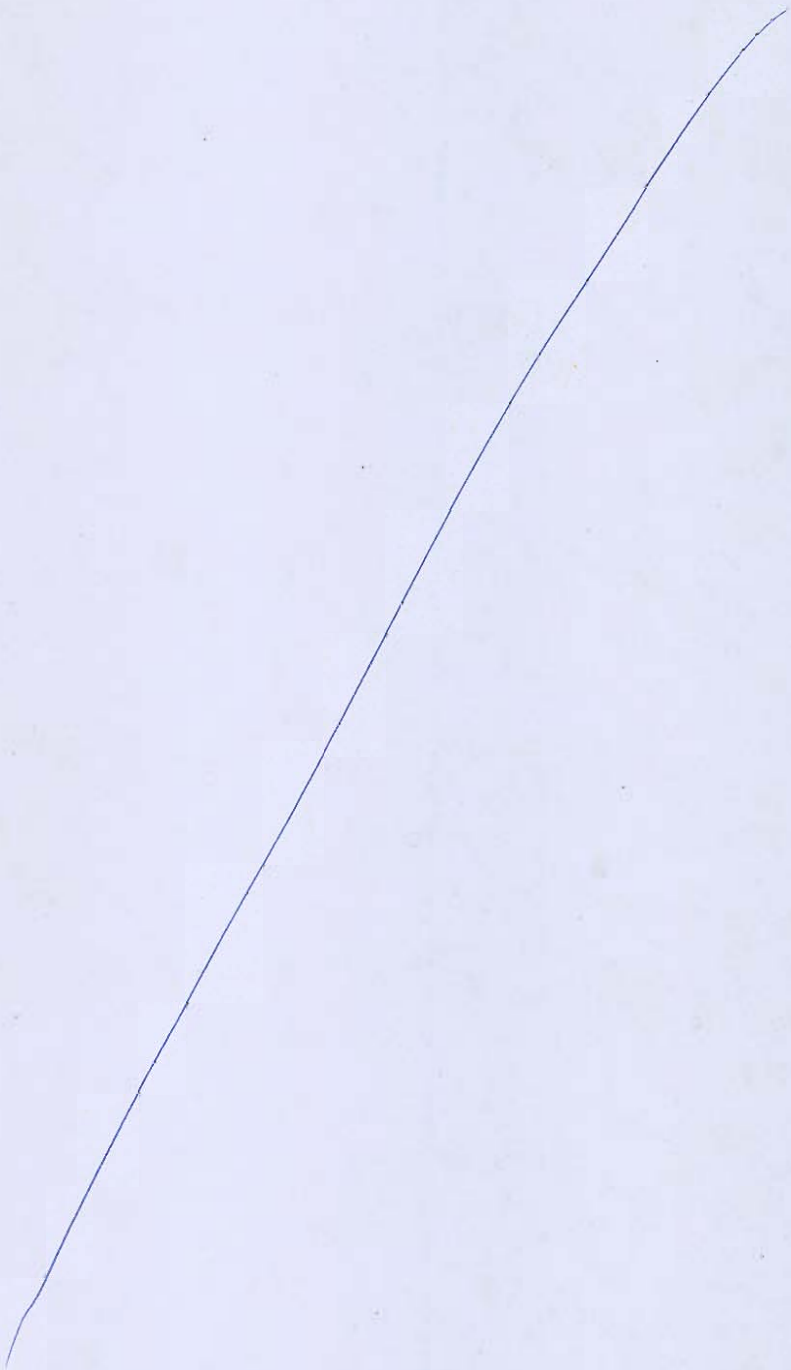
(iii) Comfortable deceleration = 3 m/sec^2

(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]



(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:

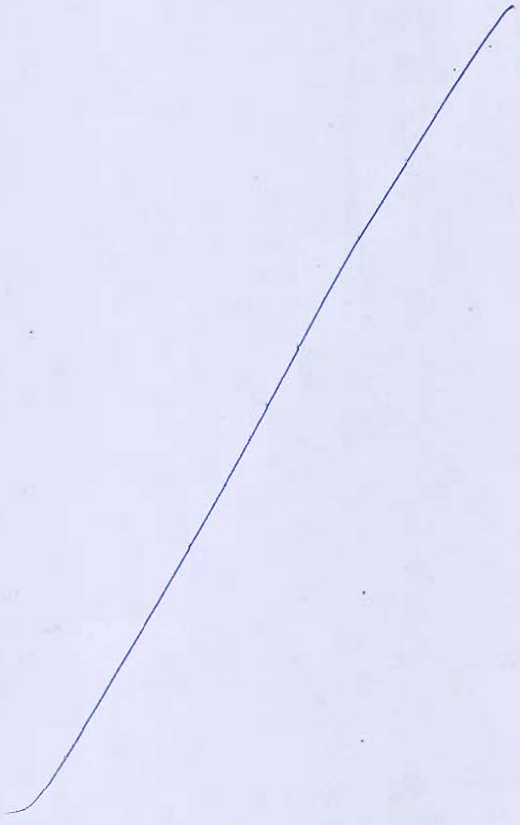
Coefficient of lateral friction = 0.13

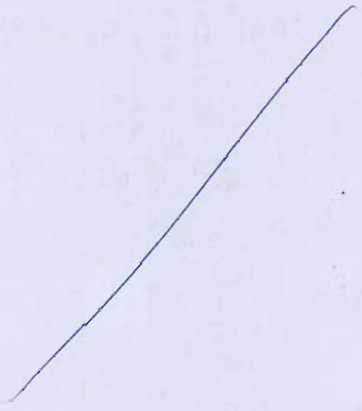
Wheel base = 18.0 m

Tread of main landing gear = 7.0 m

Width of taxiway = 22.5 m

[10 + 10 = 20 marks]





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]

y⇒4) (a) (i) Given,

$P = 4100$ kg $\quad E = 3.3 \times 10^5$ kg/cm^2 $\quad h = 18$ cm

$\mu = 0.15$ $\quad K = 25$ kg/cm^3 $\quad a = 12$

$$l = \left[\frac{E h^3}{12 K (1-\mu^2)}\right]^{1/4} = \left[\frac{3.3\times10^5 \times 18^3}{12 \times 25 \times (1-0.15^2)}\right]^{1/4}$$

$l = 50.61$ cm ✓

b = Radius of resisting section

$= \sqrt{1.6a^2 + h^2} - 0.675\,h$ if $a < 1.724h$

$a > 1.724h$.

$= a$

$a = 12$ cm $\quad 1.724h = 31.032$ cm

$$b = \sqrt{1.6 \times 12^2 + 18^2} - 0.675 \times 18$$

$b = 11.39$ cm ✓

Stresses

a) At Interior

$$S_i = \frac{0.316P}{h^2}\left[4\log_{10}\left(\frac{l}{b}\right) + 1.069\right]$$

$$= \frac{0.316 \times 4100}{18^2}\left[4\log_{10}\left(\frac{50.61}{11.39}\right) + 1.069\right]$$

$$= 14.63 \text{ kg/cm}^2$$

b) At Edges

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

$$= \frac{0.572 \times 4100}{18^2}\left[4\log_{10}\left(\frac{50.61}{11.39}\right) + 0.359\right]$$

$$= 21.35 \text{ kg/cm}^2$$

c) At corner

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

$$= \frac{3 \times 4100}{18^2}\left[1 - \left(\frac{12 \times \sqrt{2}}{50.61}\right)^{0.6}\right]$$

$$= 18.25 \text{ kg/cm}^2$$

12

Any=4 X (a) (ii) Different types of failure of flexible pavement is mainly categorised into 4 category -

(a) Surface Defects (b) Cracks
(c) Disintegration (d) Deformation.

* Surface Defects

i) Fatty surface - Heavy lines of bitumen.
Cause - Due to excess bitumen binder.

ii) Smooth surface - Too slippery surface
cause - polishing of aggregate.

(iii) Streaking - Heavy lines of bitumen.
Cause - Due to excess bitumen, careless operation & low maintenance.

(iv) Hungry surface - separation of aggregate
Cause - Due to insufficient bitumen binder.

★ Cracks

(i) Hair cracks - cracks on the surface of pavement
Cause - Improper compaction.

(ii) Aligator - Fine interconnected crack.
Cause - Improper compaction & less bitumen.

(iii) Longitudinal crack - separation along the road.
Cause - Heavy channelize traffic.

(iv) Edge crack - Edge can separated
Cause - Due to weak subgrade.

(v) Reflection cracks - Flexible pavement over concrete.

(vi) Shrinkage cracks - Due to shrinkage cracks appear.

★ Disintegration

(i) Slippage - Due to wet surface.

(ii) Ravelling - undulation across the surface.

(iii) corrugation - Due to weak subgrade & improper compaction.

(iv) stripping - Due to wet condition aggregates comes out

(v) Settlement - Due to ingress of water

(vi) Shallow Depression - localized settlement

★ Deformation

(i) Shoving

(ii) Ravelling - undulation & progressive deformation

(iii) Pot Holes - Bowl shaped to due to localized bulging

(iv) Edge Breaks - Edge break due to weak subgrade

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]

Ans ⇒ (b) (i)

~~$D_B = 7°$~~ B

$D_B = 7°$ $\quad D_M = 3°$

We know,

$$(e_{th})_M = (e_{act})_M + C_D$$

$C_D = 75$ mm for speed $\leq$ 100 kmph

$$(e_{th})_M = \frac{1750\, V_{max}^2}{127\, R} = \frac{1750 \times 70^2}{127 \times \frac{1750}{3}}$$

5

$$(e_{th})_m = 115.74 \text{ mm}$$

$$115.74 = (e_{act})_m + 75$$

$$(e_{act})_M = 40.74 \text{ mm}$$ ✗

Steps are correct But Refer solution for correct formulas & calculation

$$\therefore (e_{act})_B = -40.74 \text{ mm}$$

$$(e_{th})_B = (e_{act})_B + C_D$$

$$= -40.74 + 75$$

$$= 34.25 \text{ mm}$$ ✗

$$\Rightarrow \frac{1750 \times V_{max}^2}{127 \times \frac{1750}{7}} = 34.25$$

$$\boxed{V_{max} = 24.93 \text{ kmph}}$$

max^m speed permitted on branch track = 24.93 kmph

⇒ (b)(ii) Given, $v_f = 80$ km/hr

$k_j = 70$ veh/km

we know.

$$q = kv$$

$$q = v_f\left[k - \frac{k^2}{k_j}\right]$$

For max^m flow $\frac{dq}{dk} = 0$

which yield $v = \frac{v_f}{2}$ $k = \frac{k_j}{2}$ ✓

$$q_{max} = \frac{v_f}{2} \times \frac{k_j}{2} = \frac{80 \times 70}{4}$$

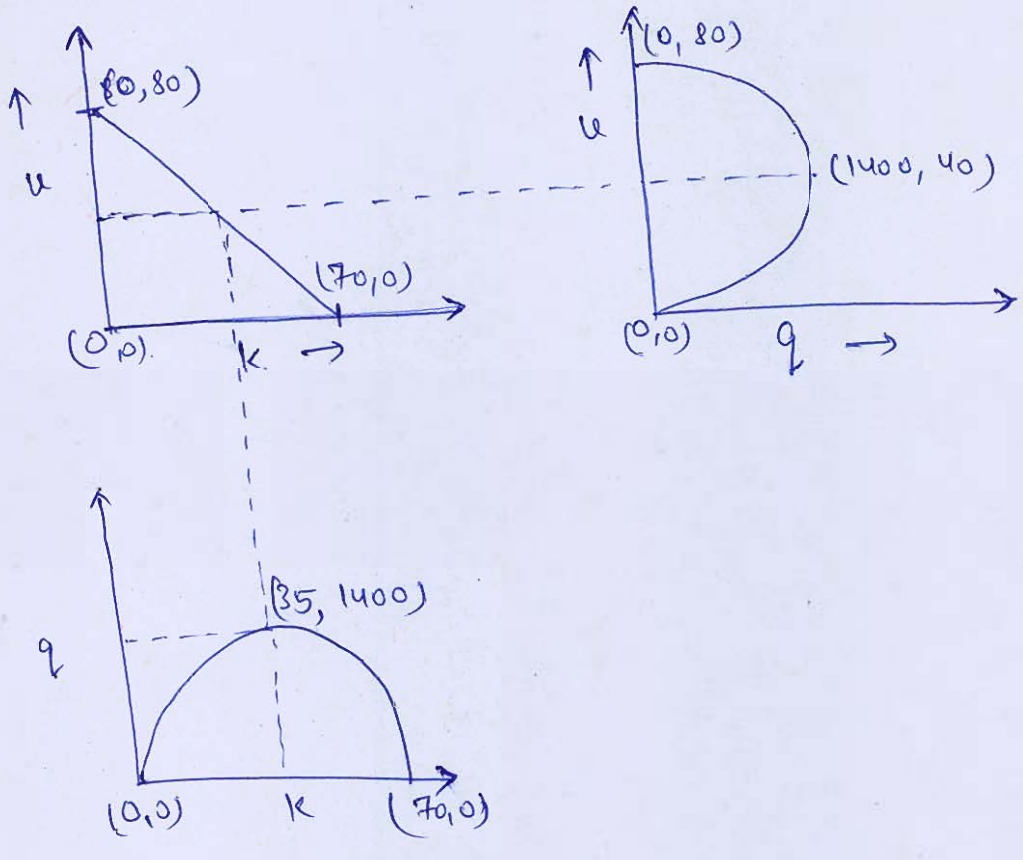
$$\boxed{q_{max} = 1400 \text{ veh/hr}}$$ ✓

10

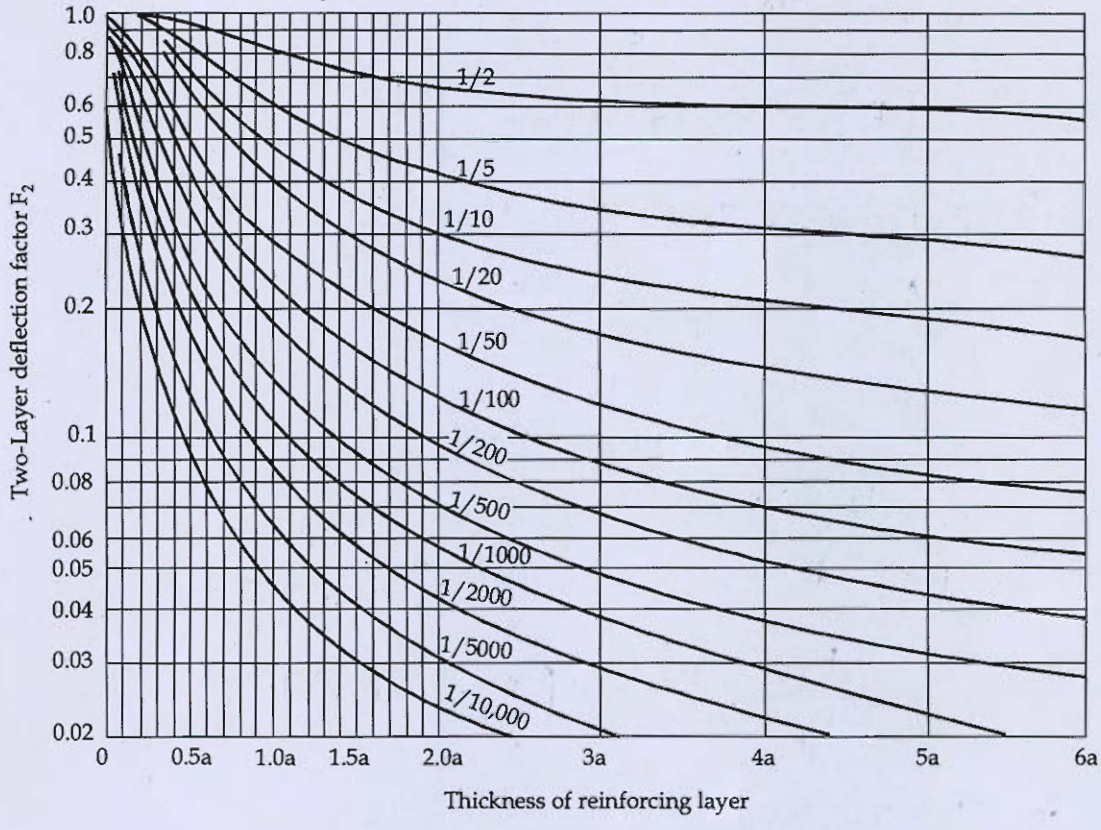
This will occur at $v = \frac{v_f}{2} = 40$ kmph

& $k = \frac{k_j}{2} = 35$ veh/km ✓

Diagram of Road Traffic



(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]

(c) (i) Test-1) $d = 30$ cm $h = 15$ cm $\Delta = 0.5$ cm

$p_1 = 1.25$ kg/cm^2 $p_2 = 5$ kg/cm^2

Test-2)

$P = 4100$ kg $p_3 = 5$ kg/cm^2 $\Delta = 0.5$ cm

① Plate load Test (To find E_s)

$$\Delta = \frac{1.18\ pa}{E_s} \times F_2$$

$F_2 = 1$ (for test on soil subgrade)

$$0.5 = \frac{1.18 \times 1.25 \times 15}{E_s} \times 1$$

$$\boxed{E_s = 44.25\ kg/cm^2}$$ ✓

② Plate load Test (On base course)

$$\Delta = \frac{1.18\ pa}{E_s} \times F_2$$

$$0.5 = \frac{1.18 \times 5 \times 15}{44.25} \times F_2$$

$$F_2 = 0.25$$

for $F_2 = 0.25$ ✓ & $\frac{h}{a} = \frac{15}{15} = 1$

$$\frac{E_s}{E_p} = \frac{1}{100}$$

$$\boxed{E_p = 4425\ kg/cm^2}$$ ✓

③ Wheel load test

$$\Delta = \frac{1.5\ pa \times F_2}{E_s}$$

$$0.5 = \frac{1.5 \times 5 \times a}{44.25} \times F_2$$

12

$$p = \frac{P}{\pi a^2} \Rightarrow a = \sqrt{\frac{4100}{5 \times \pi}} = 16.16\ cm$$

$$F_2 = \frac{0.5 \times 44.25}{1.5 \times 5 \times 16.16} = 0.1825$$ ✓

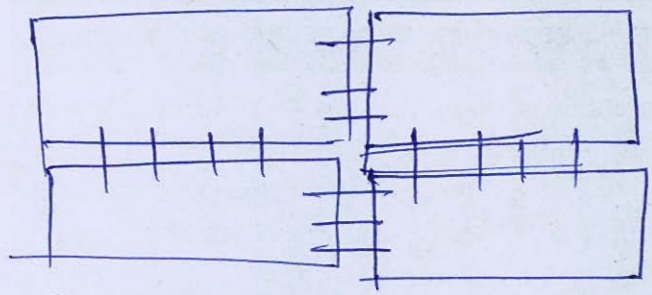
& $\frac{E_s'}{E_p} = \frac{1}{100}$. $\frac{h}{a} = 1.4$ (from graph)

$$h = 1.4 \times 16.16$$ ✓

$$\boxed{h = 22.624\ cm}$$ ✓

Thickness of pavement is 22.624 cms

=>4> (c) (ii)



Spacing for contraction joints

$B = 3.5\,m \qquad h = 20\,cm \qquad f = 1.5$

1> $S_c = 0.8\ kg/cm^2 \qquad S_s = 1200\ kg/cm^2$

Total friction force = Resistance by concrete

$$r \times f\left[\frac{L}{2} \times B \times h\right] = S_c \times B \times h.$$

$$= 2400\ \frac{kg}{m^3} \times 1.5\left[\frac{L}{2}\right] = 0.2 \times 10^4$$

$$L = 4.44\ m < 4.5\ m \quad ok$$

5

spacing = 4.44 m.

2> $r \times f\left[\frac{L}{2} \times B \times h\right] = T_{st} A_{st}$

$\Rightarrow 1.5 \times 2400 \times \left[\frac{L}{2} \times 3.5 \times 0.2\right] = 1200 \times \frac{\pi}{4} \times 1\,cm^2$

$\Rightarrow L = 0.748\ m$ X.

X

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]

Any=>5> (a) Given,

$Q = 40$ MLD

Qty of Alum = 18 mg/l

Alkalinity = 5 mg/L as $CaCO_3$ in raw water.

1 gm of Alum require $\frac{0.45}{}$ g. of Alkalinity as $CaCO_3$.

∴ 18 mg/L of Alum will require,

$= 18 \times \frac{0.45}{} = 8.1$ mg/l alkalinity.

Additional alkalinity require. $= 8.1 - 5$

$= 3.1$ mg/L

Now, Quantity of filter alum

$$= 18 \frac{mg}{l} \times 40 \times 10^6 \frac{l}{d} \times \frac{10^{-6} kg}{1 mg}$$

$$\text{Alum} = 720 \frac{kg}{day}$$

$$\text{Alum} = 262.8 \frac{tonn}{year}$$

12

Qty of Quick lime require

$$= \frac{28}{50} \times \frac{3.1 \text{ mg/L}}{0.85 \times 10^6} \times 40 \times 10^6 \times \frac{365}{1000} \times \frac{kg}{ton} \times \frac{ton}{year}$$

$$\text{Quick lime} = 29.81 \frac{tonne}{year}$$

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]

y⇒5) (b) Trickling filter - It is aerobic attached growth system in which decomposition ~~take~~ ~~place~~ of organic matter take place aerobically.

Advantages

- Arrangement is simple
- No costly setup setup required
- BOD removal efficiency is high.

4

Disadvantages

- Problems like ponding, fly nuisance, odour nuisance can occur.
- Too high organic loading will cause choking.

- Too ~~low~~ ~~org~~ high discharge will result in under decomposition of organic matter.
- No provision of Recirculation

2. Activated Sludge process

Advantages

- High BOD removal efficiency.
- Activated sludge can be recirculated to increase rate of decomposition.
- Completely mixed process, Extended aeration, can be adopted to get less nuisance effluent.

3

Disadvantages

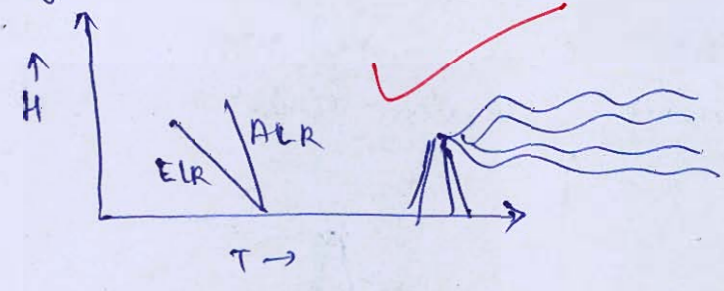
- Blanket Rising problem can occur.
- Aerated process can be costly.
-

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

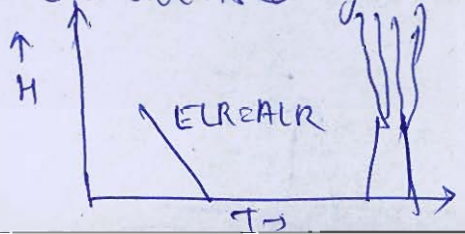
[12 marks]

⇒5> (c) Plume- The path followed by the effluent gases from the stack is known as plume. Different types of plume behaviours are :-

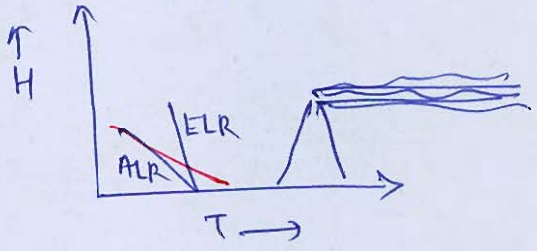
(i) Looping - This is observed ~~whe~~ in unstable atmosphere where ELR is greater than ALR. This is characterised by rapid downward mixing & wavy character.



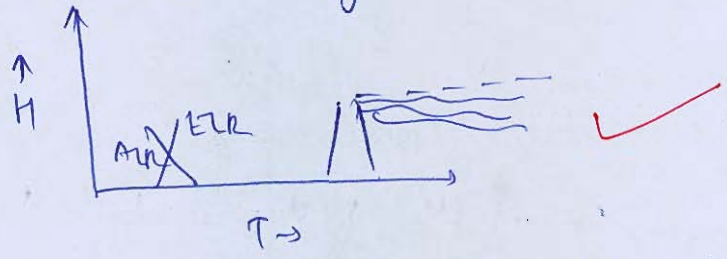
(ii) Neutral- This is observed in neutral atmosphere where ELR is equal to ALR. This type of plume is characterised by vertical rising of plum



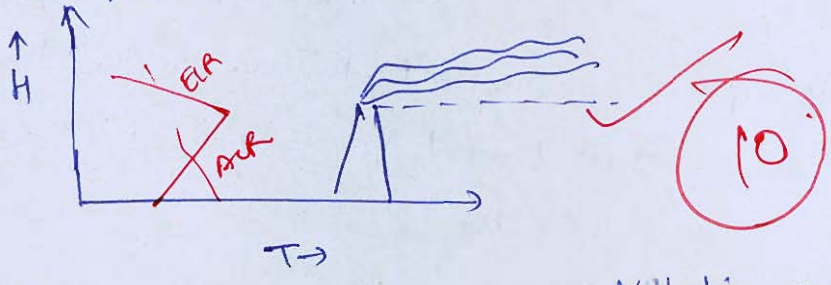
(iii) Coning - This is observed ~~when~~ in sub-adiabatic atmosphere when ELR is ~~rate~~ less than ALR. + can be observed when wind velocity is generally > 32 km ph.



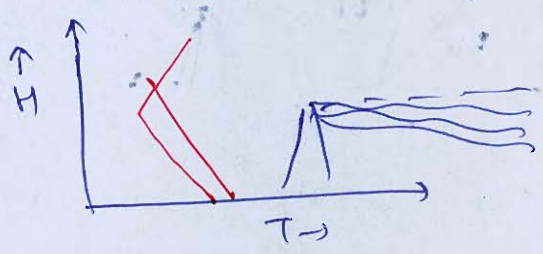
(iv) Fanning - This is characterize by inversion condition. This can be observed during winter mornings.



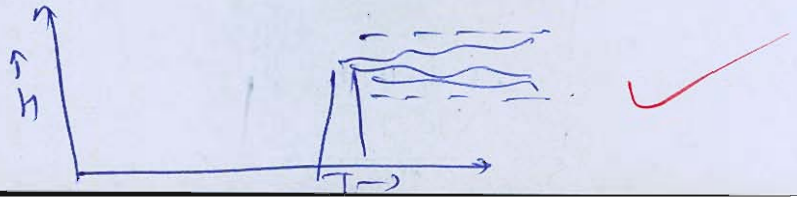
(v) Lofting - This is observed when superadiabatic condition occur over inversion condition.
This is best plume behavior



(vi) Fumigating - Occur when superadiabetic condition occur under inversion condition. Worst plume behaviour



(vii) Trapping - occur when super adiabatic condition occur between inversion condition

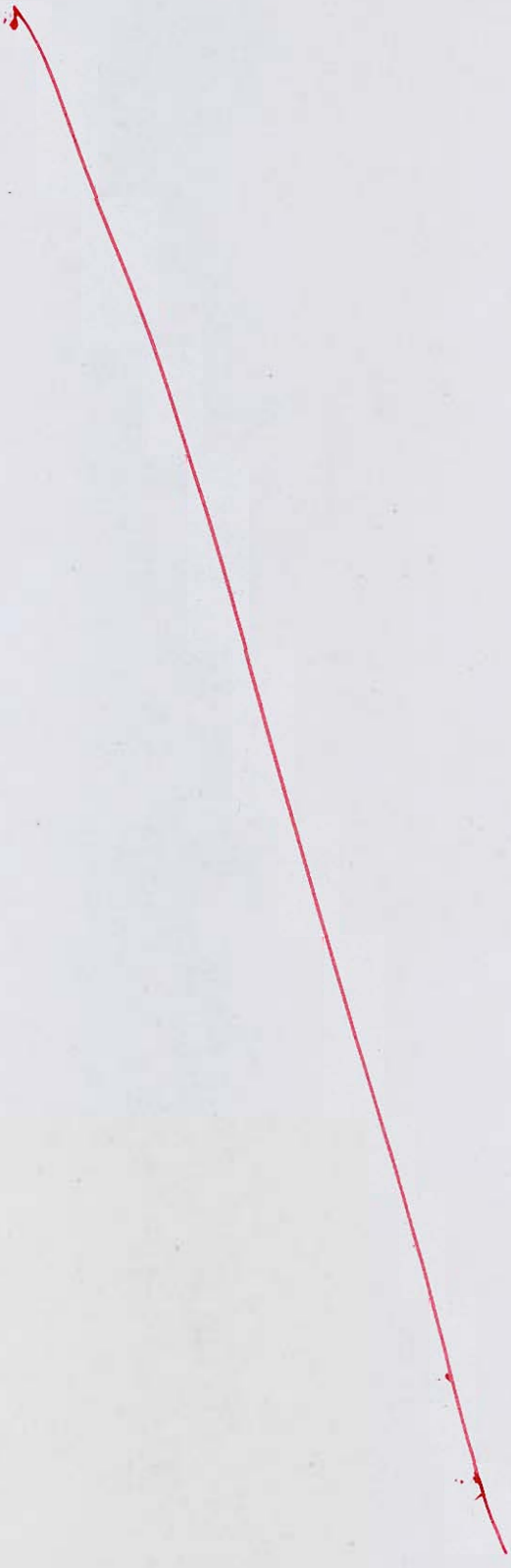


5 (d) Estimate the theoretical volume of methane gas that would be expected from the anaerobic digestion of a tonne of a waste having the composition $C_{50}H_{100}O_{40}N$, if 15% of the waste would be used for the synthesis of the cell tissue.

Use density of methane as 0.7167 kg/m^3

[12 marks]

25 (d)



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]

5) (e) (i) Given

$BOD_5 = 150$ mg/l @ 30°C

$k = 0.23$ day^{-1} @ 20°C

$BOD_8 = ?$ @ 15°C

$$k_{T°C} = k_{20°C}\,(1.047)^{T-20}$$

$$k_{30°C} = 0.23 \times (1.047)^{30-20} = 0.364 \text{ day}^{-1}$$ ✓

$$k_{15°} = 0.23 \times (1.058)^{15-20} = 0.175 \text{ day}^{-1}$$ ✓

$$BOD_5 = BOD_u\,(1 - e^{-k \times t})$$

$$150 = BOD_u\,(1 - e^{-0.364 \times 5})$$

8

$$\boxed{BOD_u = 179 \text{ mg/L}}$$ ✓

$$BOD_8 = BOD_u\,(1 - e^{-kt})$$

$$= 179\,(1 - e^{-0.175 \times 8})$$

$$\boxed{BOD_8 = 134.86 \text{ mg/L}}$$ ✓

(ii) pH = 10 POH = 4

$$\text{Total alkalinity} = \frac{\text{Volume of sample required to pH 4.5} \times 1000}{\text{Initial volume of the sample}}$$

$$= \frac{30}{200} \times 1000$$ ✓

$$= 150 \text{ mg/L}$$

4

Therefore total alkalinity = 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]**

Ans ⇒ 6> (a) Design for Rapid sand filter

Given, $Q = 4$ MLD

let 5% of filtered water use for backwashing for 30 minutes.

$Q = 4 + 0.05 \times 4 = 4.2$ MLD $\quad \frac{4}{0.95}$

~~Maximum Discharge~~

Design flow $= \frac{1.8 \times 4.2 \times 10^3 \text{ m}^3}{23.5 \times 60 \times 60 \text{ sec}}$

$= 0.0893 \text{ m}^3/\text{sec}$

Let ROF of $= 4000 \text{ l/hr/m}^2$

Area of ~~each~~ filter $= \frac{0.0893 \text{ m}^3/\text{sec}}{4000 \text{ l/hr/m}^2}$

$= 80.42 \text{ m}^2$

No. of filter bed $= 1.22\sqrt{q}$

where q is design flow in MLD

$N = 2.5 \simeq 3$

provide 3 filter bed

Area of each bed $= \frac{80.42}{3} = 26.80\ m^2$

let $\frac{L}{B} = 1.3$

Area $= 26.80$

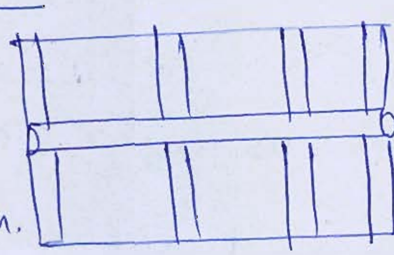
$\Rightarrow L \times B = 26.80$

$B = 4.54\ m \qquad L = 5.90\ m$

provide $\boxed{B = 4.6 m}$ $\boxed{L = 6\ m}$

So provide. 3 filter each of 6×4.6 dimension.

Design of under drainage system



Area of perforation $= 0.2\%$ Area of bed

$= 0.0552\ m^2$

Area of lateral $= 2\times$ Area of perforation.

$= 0.1104\ m^2$

Area of manifold $= 2\times$ Area of lateral

$= 0.2208\ m^2$

let D be diameter of manifold.

$\frac{\pi}{4} D^2 = 0.2208$

$D = 0.53 m$

$\boxed{\text{Dia of manifold} = 53\ cm}$

Length of lateral $= \frac{4.6 - 0.53}{2} = 2.035\ m$

let spacing of lateral $=$ 20 cm

No. of latral $= 2 \times \frac{600}{20} = 60$ lateral

8

steps be correct ut due to incorrect calculation

4Q the answers are wrong.

Let diameter of perforation be 12 mm

No of peration $\times \frac{\pi}{4} \times (0.012)^2 = 0.0552$

No. of perforation = 488.07

let No. of perforation $\simeq$ 540

No. of perforation in each lateral = $\frac{540}{60}$

$= 9$

Area of 1 lateration = $\frac{0.1104}{60} - 9 \times \frac{\pi}{4} \times (0.012)^2$

$= 0.000822 \text{ m}^2$

let d be dia of latral.

$\frac{\pi}{4} d^2 = 0.000822$

$d = 3.23$ cm

provide 3.5 cm dia of lateral.

So provide 53 cm dia manifold with 3.5 cm ~~to~~ dia of lateral & 12mm diameter of perforation with 9 perforation in each lateral.

.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]

⇒6> (b) (i) Characteristics of Good Distribution system

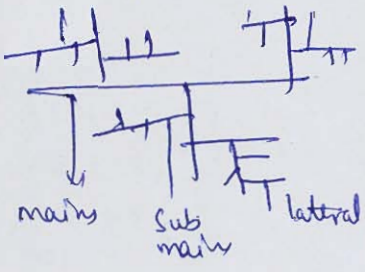
- It should required lesser length of pipe & lesser no. of valves.
- It should be planned in proper way.
- Good distribution system should have continuous supply even in the case of breakdown.
- Good distribution system should be designed in such a way, that multiple path should be there to distribute water.
- It should have uniform distribution of pressure.

- It should not have dead end.
- It should supply water in shortest possible time.

Advantages of following systems

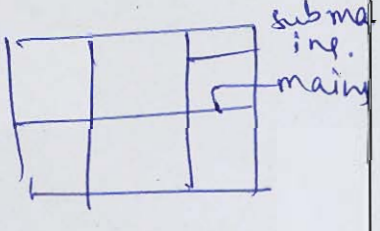
1) Dead End System

- For older cities set which has setup without proper planning.
- Lesser length of pipe required.
- Lesser length of valves requires.



2) Grid End system

- Dead Ends are eliminated.
- uniform supply of water.
- uniform pressure of water
- supply doesnot stop even during breakdown.
- multiple path of supply.



12

3) ~~Rig~~ Ring System

- less no. of valves are required
- Easy to lay the pipes.
- uniform pressure of water.
- multiple supply path for water
- water reach to user in shortest possible time.
- suitable for planned city.

or (b) (ii) factors affecting selection of a particular pump

- The speed of motor pump in RPM.
- Height to which water is to be raised.
- type of pump selection also depend on height from which water is extracted.
- power consumption of pump.
- Efficiency of the pump.
- Rated power and capacity of pump.
- Working hour of the pump.

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]

Ans ⇒ 6> (c) (i) Given,

$Q = 10,000\ m^3/day$ $\quad BOD_i = 150\ mg/l = S_o$

$BOD_e = 5\ mg/l = S$ $\quad Y = 0.5\ kg/kg$

$K_d = 0.05\ d^{-1}$ $\quad MLSS = 3000\ mg/l$

$X_u = 10\,000\ mg/l$ $\quad \theta_c = 10\ days$

(I) Volume of Reactor

$$VX = \frac{Q_o Y (S_o - S) \theta_c}{1 + K_d \theta_c}$$

$$\Rightarrow V \times 3000 = \frac{10000 \times 0.5 (150 - 5) \times 10}{1 + 0.05 \times 10}$$

$$\Rightarrow \boxed{V = 1611.11\ m^3}$$

5

Vol^m of aeration tank = 1611.11 m3

(II) the mass & volume of solids wasted each day

(III) Recirculation Ratio

$$R = \frac{Q_R}{Q_0}$$

$$\Rightarrow \quad Q_0 S_0 = (Q_0 - Q_w) X_e + Q_w \times X_u$$

$$\Rightarrow \quad R = \frac{Q_R}{Q_0} = \frac{X}{X_u - X_0} = \frac{3000}{10000 - 3000}$$

$$\boxed{R = 0.4285}$$

ns ⇒ 8) (c)(ii) Total effective height of stack is given by

$$H = h + \Delta h$$

where h = physical stack = 203 m

Δh = plume height.

$$\Delta h = \frac{V_s D}{u}\left[1.50 + 2.68 \times 10^{-3} p D \left(\frac{T_s - T_a}{T_s}\right)\right]$$

8

$V_s = 9.14$ m/s $D = 1.07$ m

$u = 3.58$ m/s $T_s = 149 + 273 = 422$

$T_a = 13 + 273 = 286$ $p = 1000$ mbar

$$\Delta h = \frac{9.14 \times 1.07}{3.58}\left[1.5 + 2.68 \times 10^{-3} \times 1000 \times 1.07 \times \left(\frac{422 - 286}{422}\right)\right]$$

$$\Delta h = 6.57 \text{ m}$$

Therefore total eff height of stack

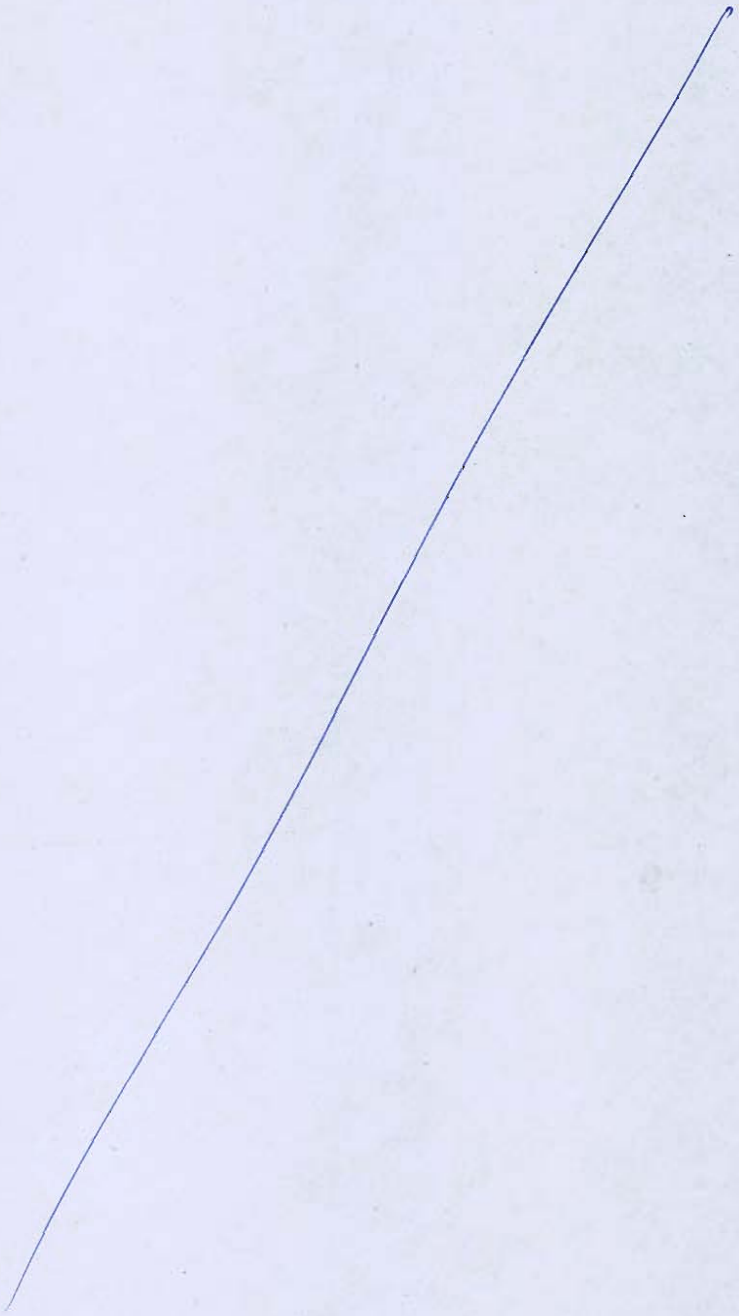
$H = 203 + 6.57$

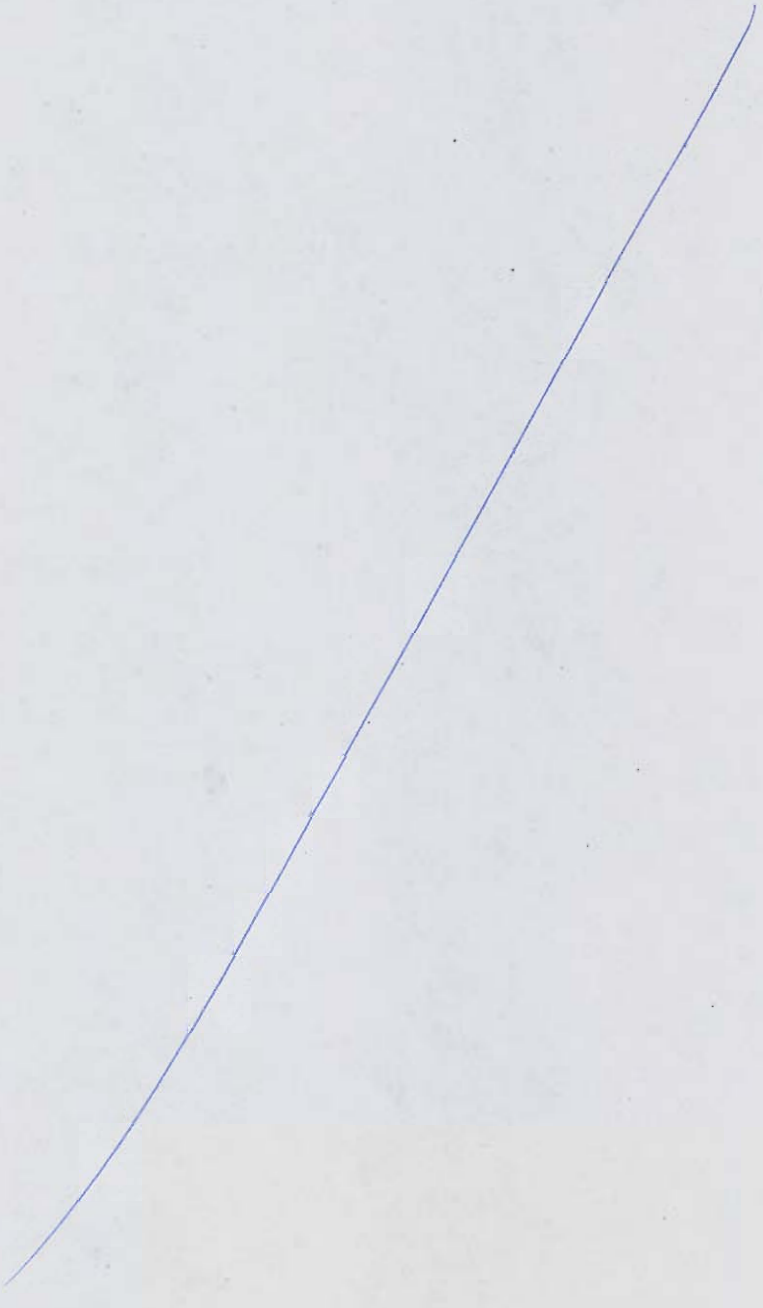
$H = 209.57\ m$

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

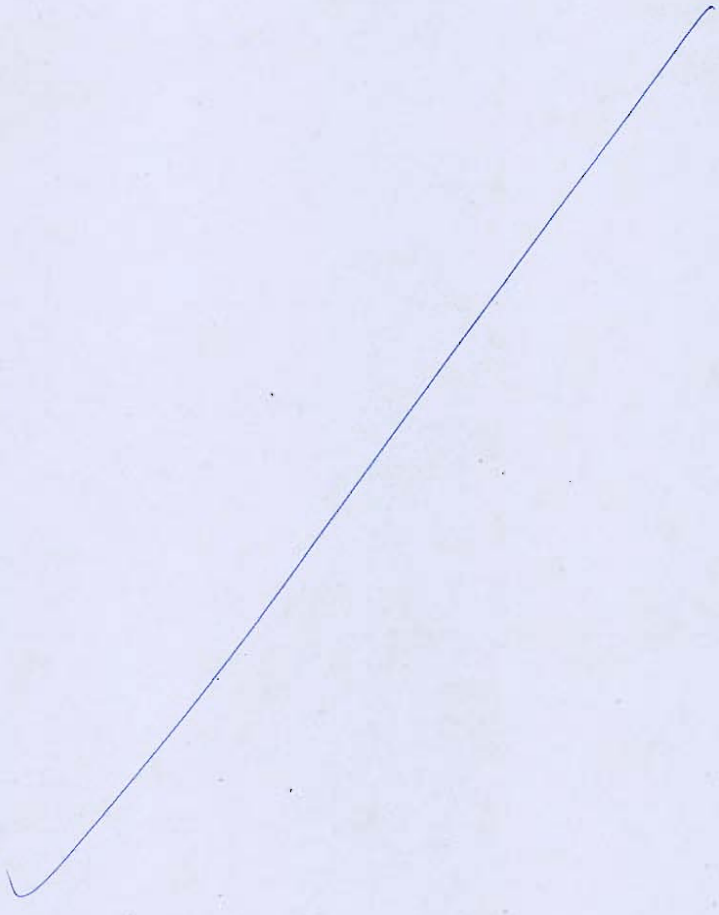
NO_x = 8 t/yr

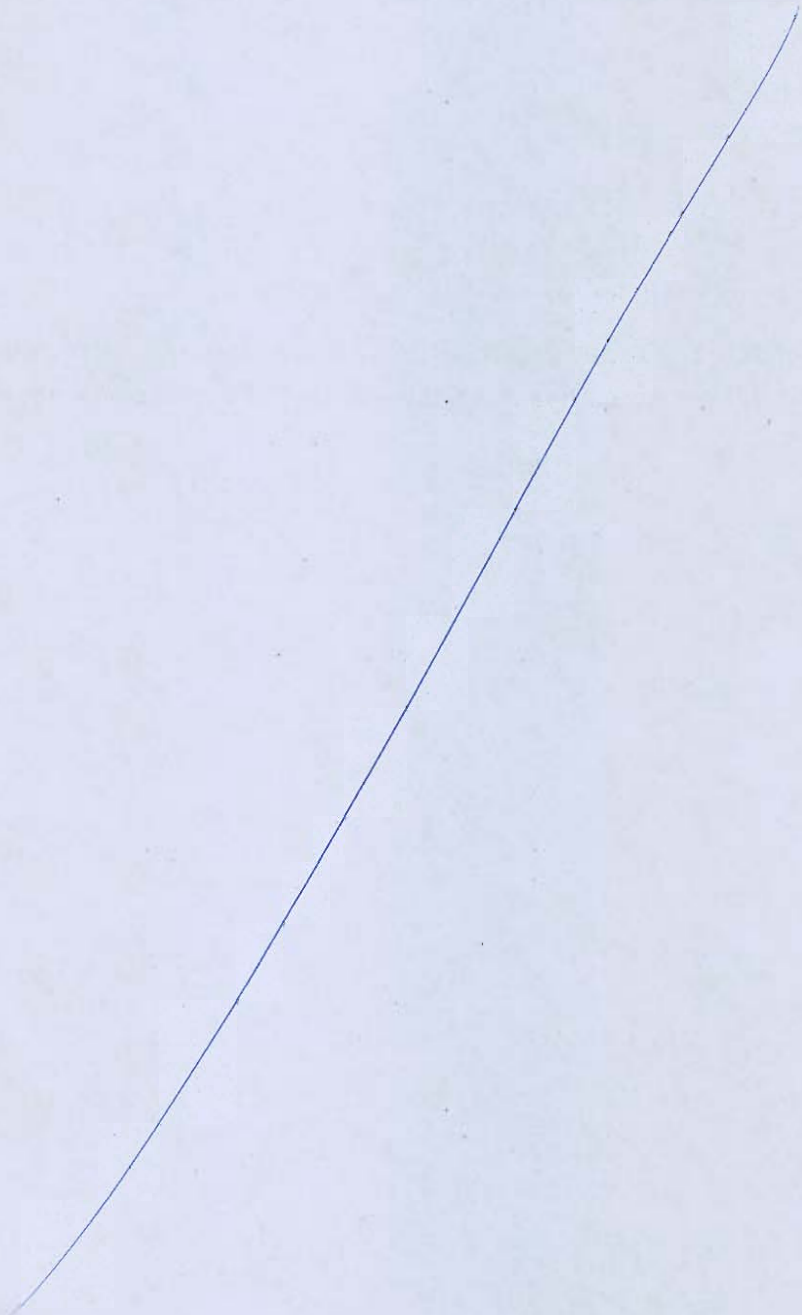
HC = 0.4 t/yr

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]

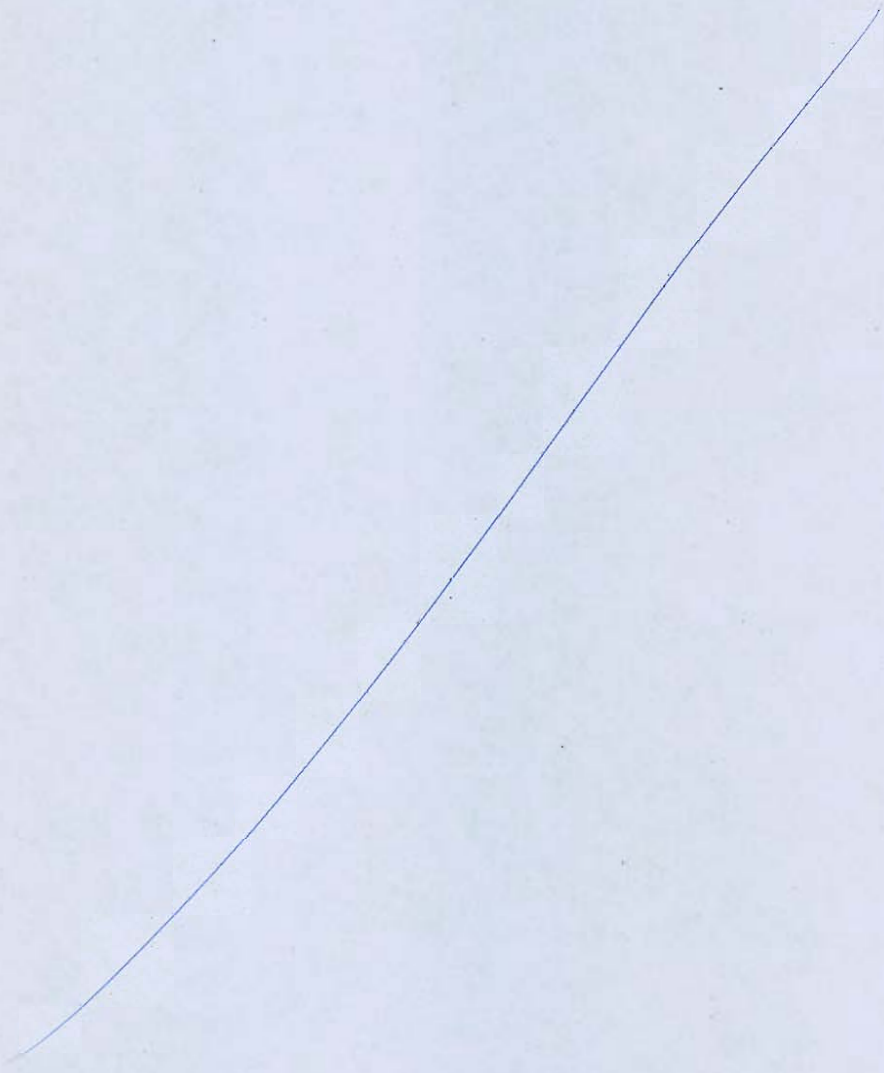


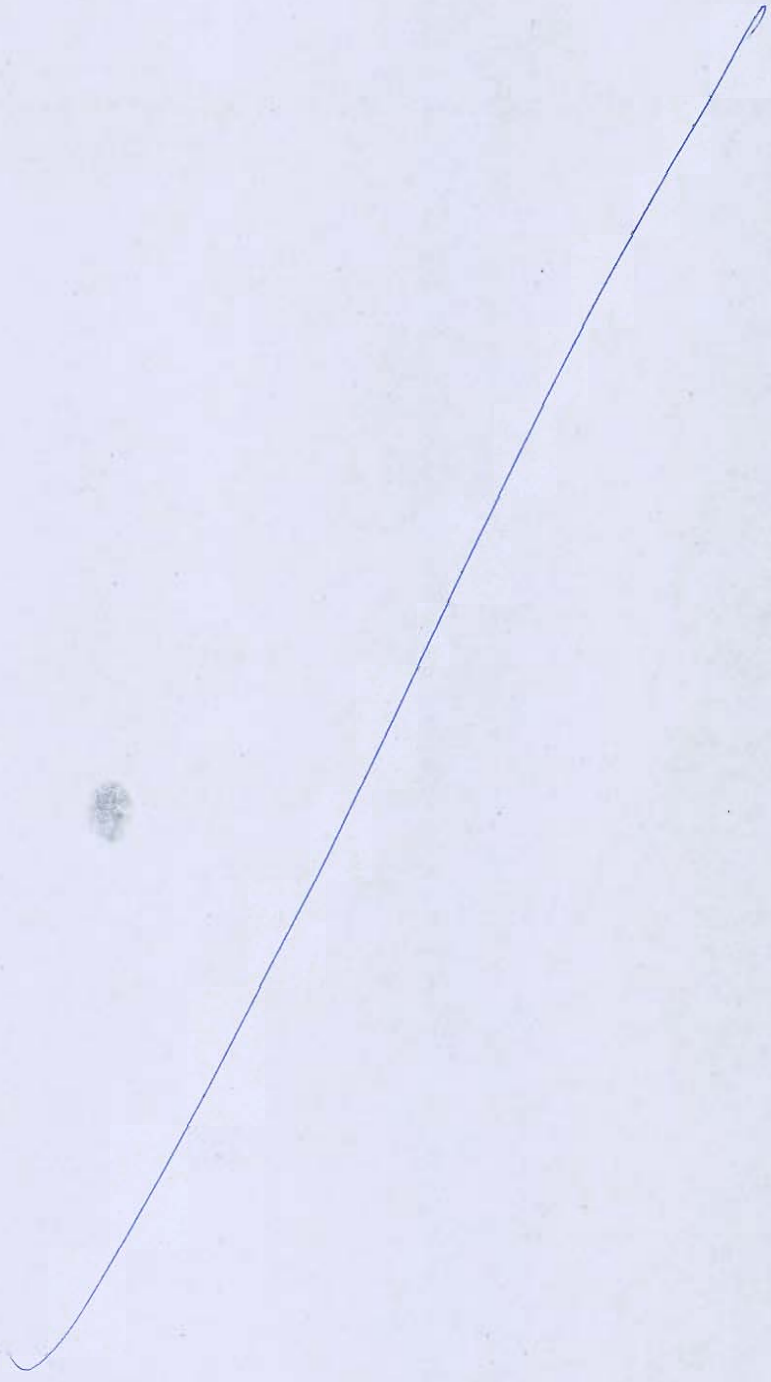


7 (c) (i) A main combined sewer was designed to serve an area of 60 sq. km with an average population of 185 persons/ha. The average rate of sewage flow is 350 litres/capita/day. The maximum flow is 50% in excess of the average, together with the rainfall equivalent of 12mm in 24 hours, all of which 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]



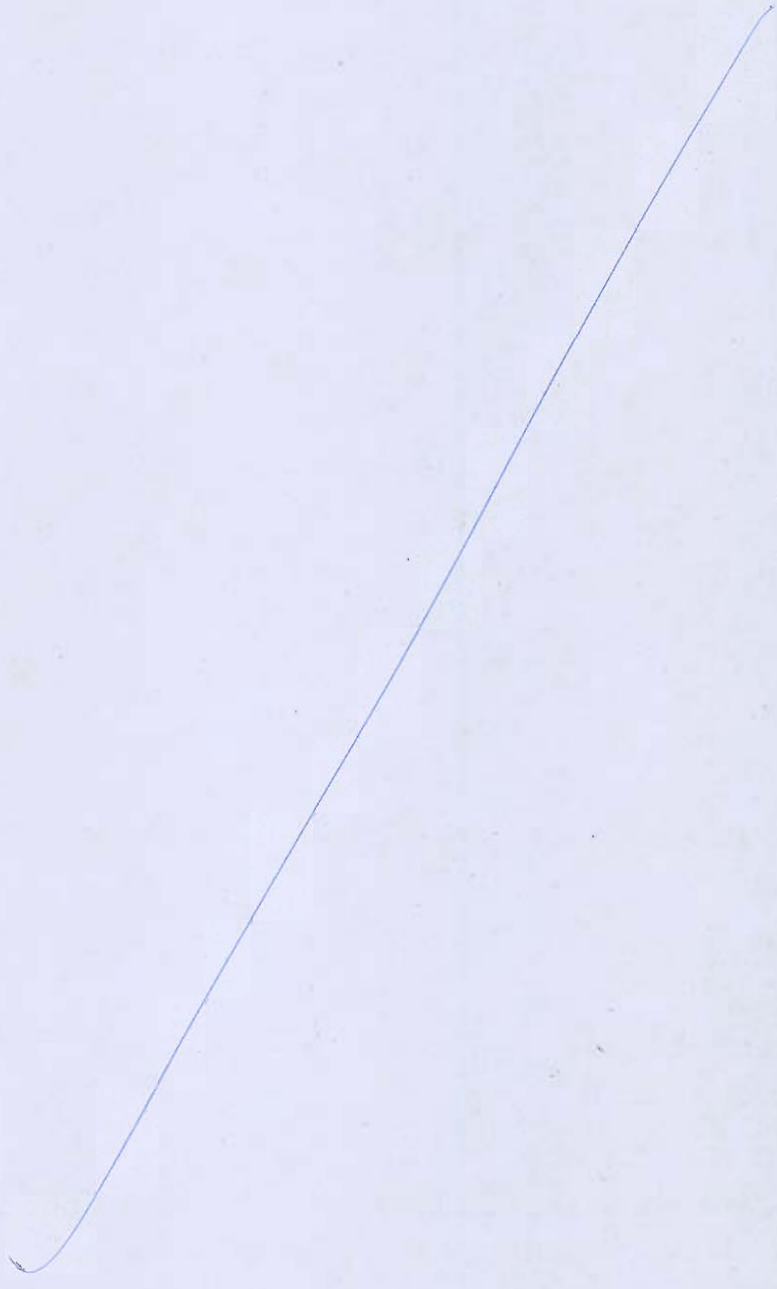


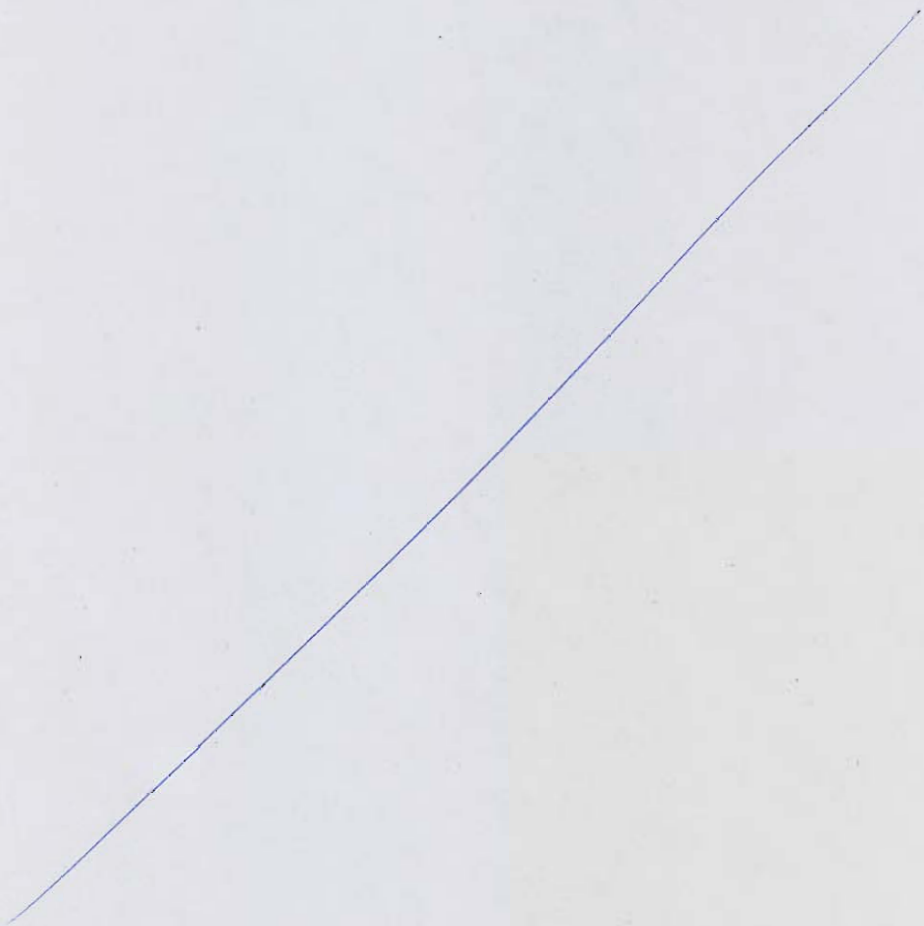
Q.8 (a) (i) Write in brief about the following sewer appurtenances :

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.

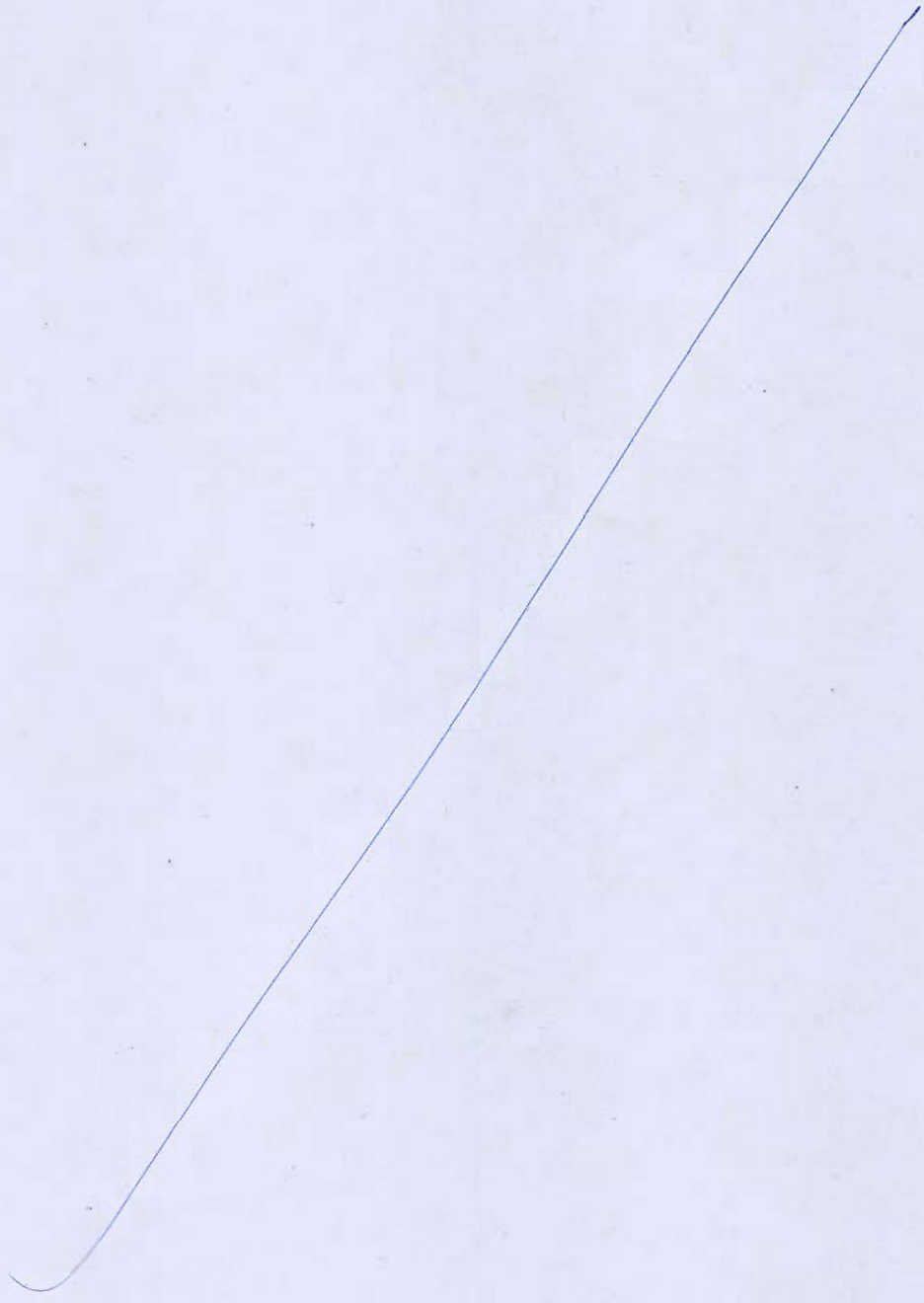
Year	Population
1940	80,000
1950	1,20,000
1960	1,68,000
1970	2,28,580

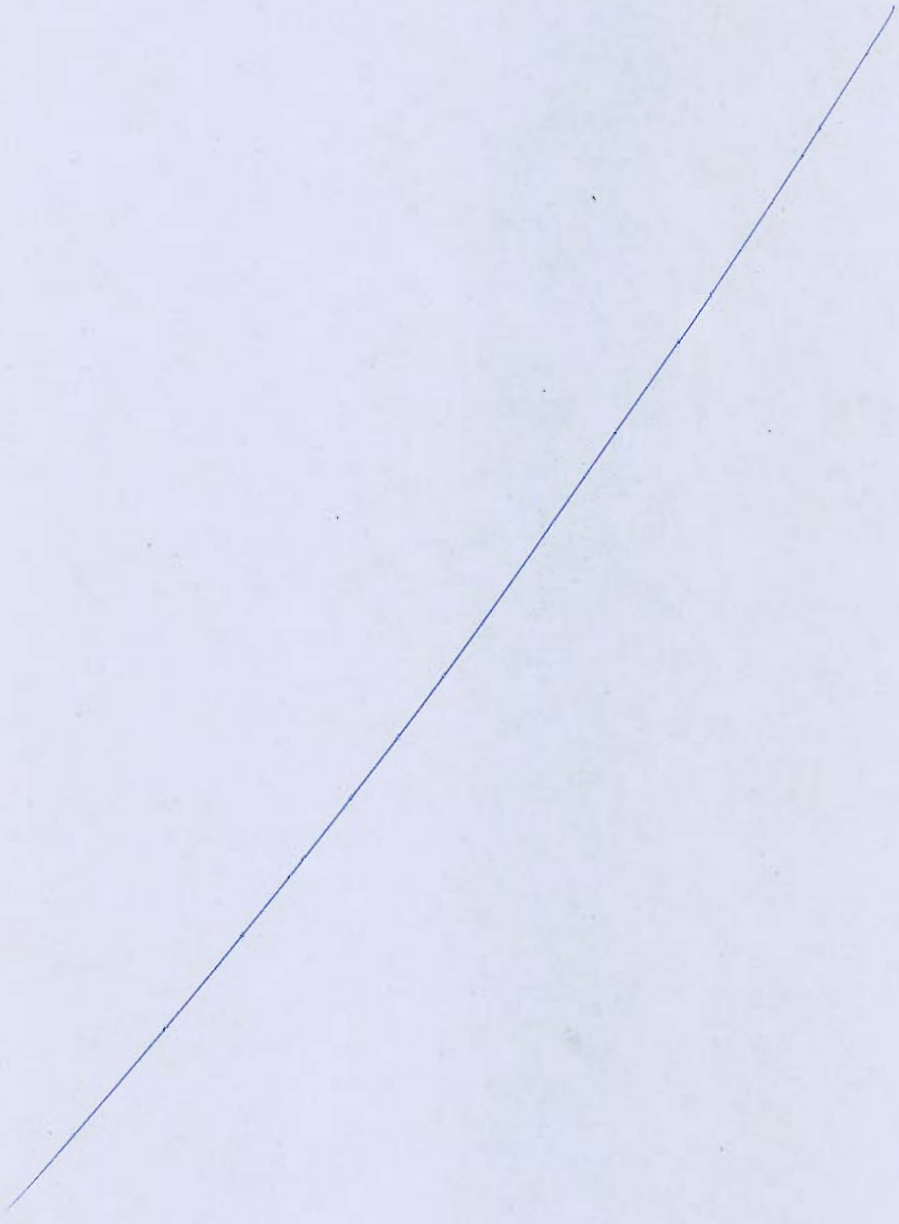
(ii) Two primary setting basins are 26 m in diameters with a 2.1 m side water depth. Single effluent weirs are located on the peripheries of the tank.

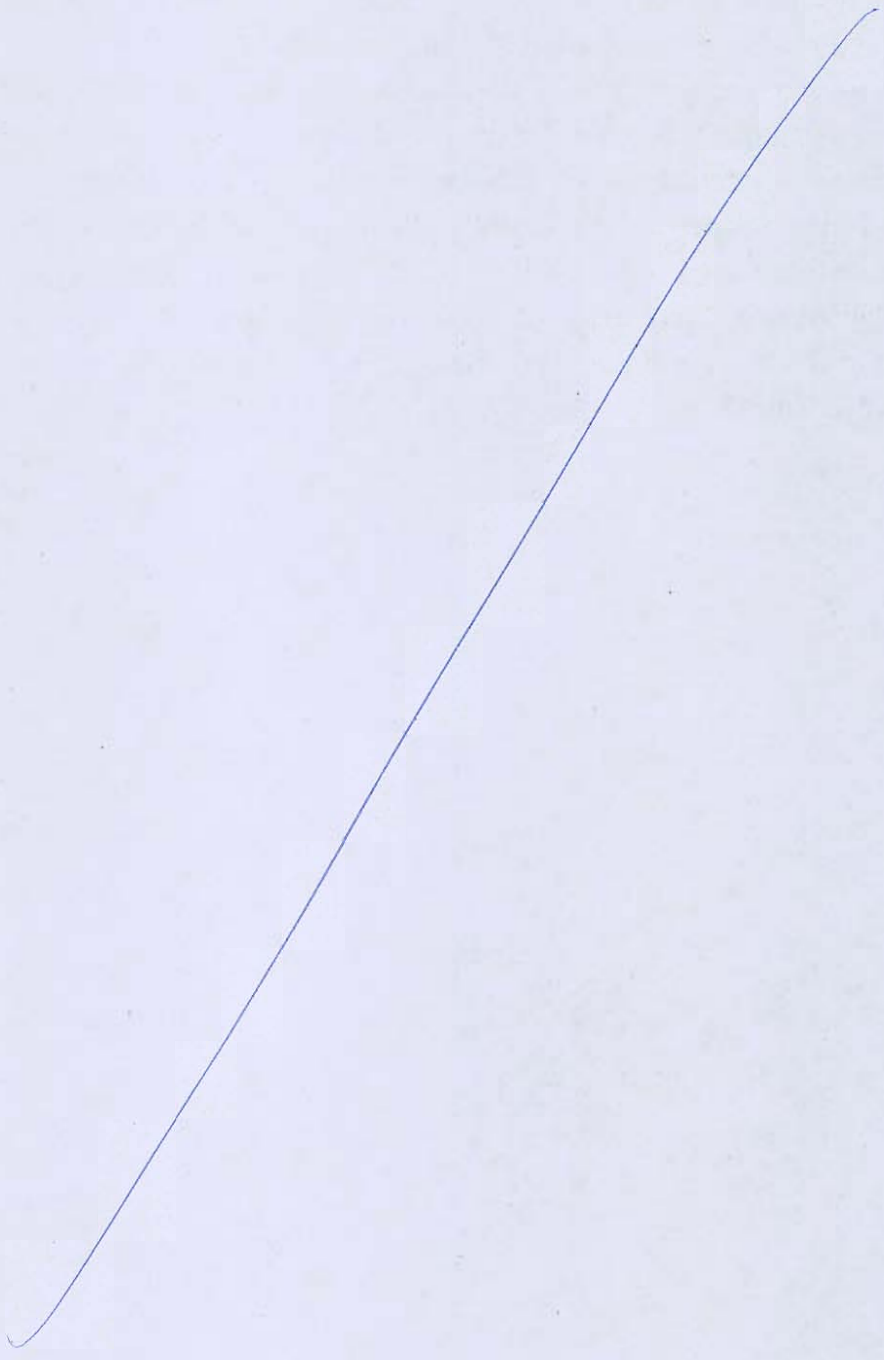
For a water flow of 26,000 m^3/d, calculate;

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]



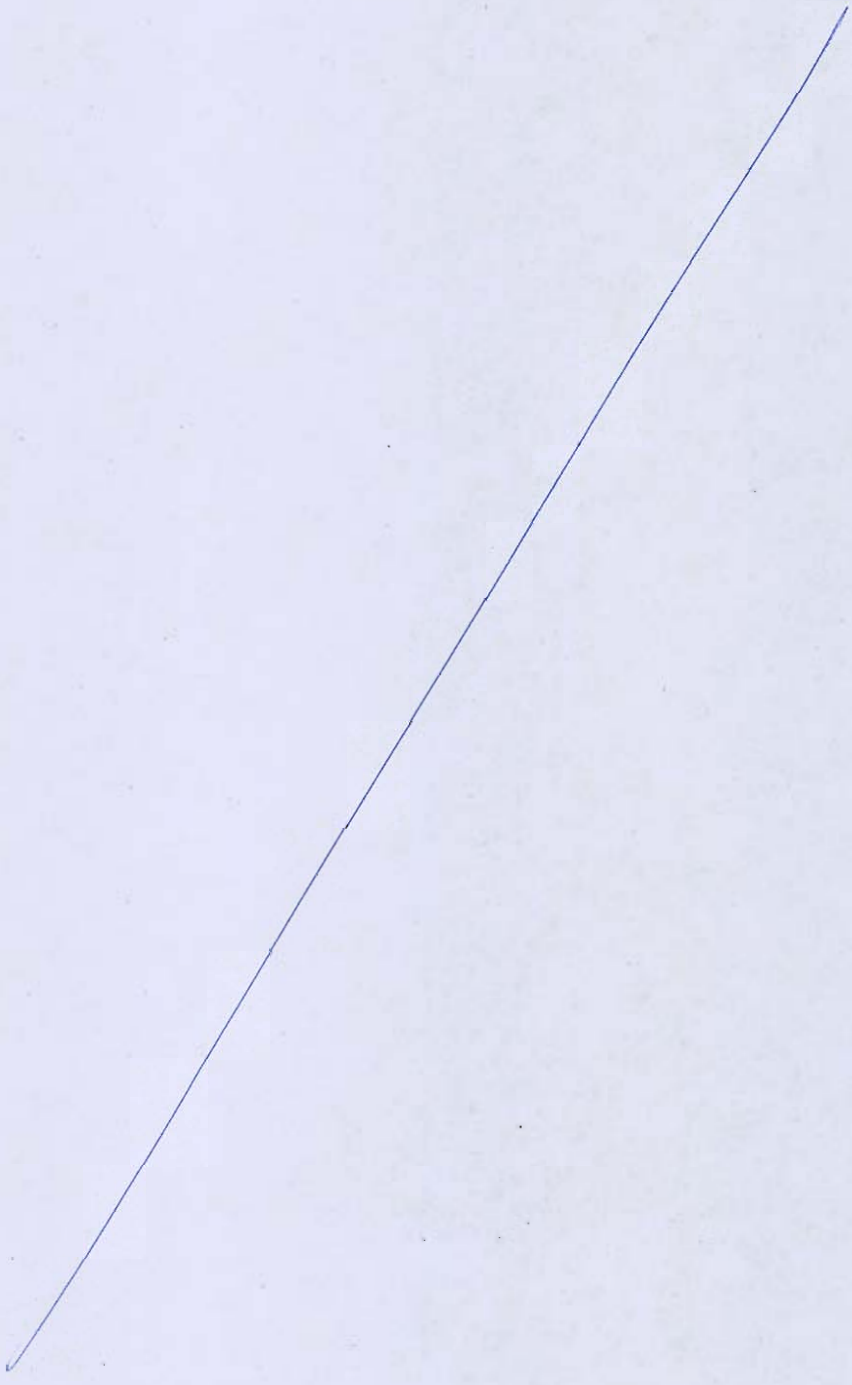




Q.8 (c) A municipal waste-water treatment plant discharges secondary effluent to a surface stream. The worst conditions are known to occur in the summer months when stream flow is low and water temperature is high. Under these conditions, measurements are made in the laboratory and in the field to determine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



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Space for Rough Work

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