248/300

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ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

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

Name : .....

Roll No :

Test Centres	Student's Signature
Delhi ☐ Bhopal ☐ Jaipur ☐ 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	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

Signature of Evaluator ..... 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

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

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

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

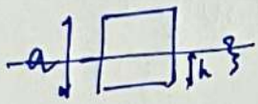
[12 marks]

Given: Side $= a$

$G_p = 0.8$

for stability, $GM = BM - BG$

$GM = \frac{I}{V} - BG$ (To be +ve)



Weight of cube = Buoyant force

$a^3 \times \gamma_p = a^2 \times h \times \gamma_w$

$a^3 \times 0.8 = a^2 \times h \times 1$

$h = 0.8a$ —(i) or $(h = G_p a)$

Now, $BM = \frac{a \times a^3}{12} \Big/ a^2 \times h$

$= \frac{a^4/12}{a^2 \times 0.8 \times a}$

$BG = \left[\frac{a}{2} - \frac{h}{2}\right] = \left[\frac{a}{2} - \frac{0.8a}{2}\right]$

$GM = \frac{a}{9.6} - \frac{a}{10}$

i) which is a +ve value, therefore in Equilibrium

ii) $GM = \frac{a^2}{12 \times G_p \times a} - \left[\frac{a}{2} - \frac{G_p a}{2}\right]$

$GM = \frac{a}{12G_p} - a\left(\frac{1-G_p}{2}\right)$

Now, $GM = 0$, for neutral

$0 = \frac{a}{12G_p} - a\left[\frac{1-G_p}{2}\right)$

(12)

$$0 = q\left[\frac{1}{12 G_p} - \left(\frac{1-G_p}{2}\right)\right]$$

$$\frac{1}{12 G_p} = \frac{1-G_p}{2}$$

$$G_p = 0.788$$

Range, $G_p = 0.788$ to

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

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

[12 marks]

(i)

$$W\text{-index} = \frac{\text{Total Rainfall} - \text{Total Runoff}}{\text{Total Time}}$$

$$\phi\text{-index} = \frac{\text{Effective Rainfall} - \text{Runoff}}{\text{Effective Time}}$$

$$3.9 = \frac{(9.5 + 6 + 4.5 + 5.5 + 5.5) \times 0.25 - R}{0.25 \times 6}$$

$$R = 3.9 \text{ cm}$$

$$W\text{-index} = \frac{47.3 \times 0.25 - 3.9}{2.5}$$

$$= 3.17 \text{ cm/hr}$$

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

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

(ii) Power thrown away into the tail race and

(iii) Efficiency of the draft tube

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

[12 marks]

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

Flow rate = 5 million liters per day

Recirculation ratio = 1.5

BOD of raw sewage = 260 mg/l

BOD removal in primary clarifier = 30%

Desired final effluent BOD = 45 mg/l

[12 marks]

Given: $Q = 5$ MLD

$R = 1.5$

$BOD = 260$ mg/L

$BOD_e = 45$ mg/L

BOD for TF $= 260 - 0.3 \times 260 = 182$ mg/L

Efficiency required $= 1 - \frac{45}{182} \times 100 =$ ~~[illegible]~~

$= 75.27\%$

$$OLR = \frac{182 \times 5\times10^6}{\times 10^6} = \frac{910 \text{ kg/d}}{} \quad \text{— i}$$

(10)

for $R = 1.5 \rightarrow f = \frac{1+1.5}{(1+(1-0.9)R)^2}$ (Assume $f = 0.95$)

$$f = 1.89$$

$$\eta = \frac{100}{1+0.44\sqrt{\frac{OLR}{f}}}$$

$$75.27 = \frac{100}{1+0.44\sqrt{\frac{OLR}{1.89}}}$$

$$OLR = 1.054 \text{ kg/d}$$

Putting in (i)

$$1.054 = \frac{910}{}$$

Volume, $= 863.54 \text{ m}^3$

Assume, $H = 2.5 \text{ m}$

$$\text{Area} = \frac{863.54}{2.5} = 345.4 \text{ m}^2$$

$$\frac{\pi}{4} D^2 = 345.4 \text{ m}^2$$

$D = 20.97 \text{ m}$

Say $21 \text{ m} < 60 \text{ m}$ OK

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

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

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

[12 marks]

Given

$L = 30m$
$b = 14m$
$D = 4.3m$

$Q = 0.0796 m^3/s$
$BOD_5 = 130 mg/L$
$MLSS = 2100 mg/L$
$MLVSS = 1500 mg/L$
$30 min.\ SV = 230 ml/L$

1. Aeration Period or $HRT = \frac{V}{Q} = \frac{30 \times 14 \times 4.3}{3600 \times 0.0796}$

$HRT = 6.3 hrs$

(12)

2. F/M ratio $= \frac{Q_o S_o}{VX} = \frac{0.0796 \times 130 \times 86400}{30 \times 14 \times 4.3 \times 1500}$

$F/M = 0.33\ d^{-1}$ 9

3. $SV = \frac{V_s}{X_s} = \frac{230}{2100 \times 10^{-3}} \Rightarrow$ **109.524 ml/g**

4. Q_L, $\frac{Q_L}{Q_0} = \frac{X}{X_u - X} = \frac{2100}{9100 - 2100}$

$Q_L = 0.02388 \, m^3/s$

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

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

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

[10 + 5 + 5 = 20 marks]

(i) Given $k_2 = 0.4/d$ $V = 0.85$ m/s

$DO_{sat} = 10$ mg/L

$D_0 = 0.8$ mg/L

$L_0 = BOD_4 = 20$ mg/L

$k_1 = 0.2/d$

To find DO @ 48.3 km

$t = \frac{\text{Distance}}{\text{velocity}} = \frac{48.3 \times 10^3}{0.85} \times \frac{1}{86400} = 0.6577$ days

08

DO Deficit at $t = 0.6577$ days

$$D_t = \frac{k_1 L_0}{k_2 - k_1}\left[10^{-k_1 t} - 10^{-k_2 t}\right] + \left[D_0 10^{-k_2 t}\right]$$

$$= \frac{0.2 \times 20}{0.4 - 0.2}\left[10^{-0.2 \times 0.6577} - 10^{-0.4 \times 0.6577}\right] + \left[0.8 \times 10^{-0.4 \times 0.6577}\right]$$

$D_t = 4.297$ mg/L

DO present at 48.3 km = $10 - 4.297$

DO = 5.703 mg/L

(ii) Sewage Sickness

Due to continuous application of sewage on the land, the pores of soil get clocked due to solids in sewage or soil becomes sodic due to leachate from sewage, thus looses its fertility. Called as Sewage Sickness.

Methods to prevent it :-

3

i) placing geomembrane sheets to prevent leachate into the soil.

ii) Avoiding long term disposal of sewage on same land.

iii)

(iii) Key factors includes :-

a) Sedimentation : Settling of excess solid matter at the bottom of river with time.

b) Oxygenation : Replenishing lost oxygen from atmosphere as per Henry's Law

c) Dilution : Dispersing of pollutant in the entire volume of river thus reducing its concentration.

3

(iv) Decomposition: Reducing concentration of organic matter in pollutant by decomposition by microorganisms.

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

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

[10 + 10 = 20 marks]

(i) Given: $D = 300\,m$, $V = 24.4\,m/s$, $p_A = 361\,kN/m^2$, $p_B = 288\,kN/m^2$, $Z_A = 30.5\,m$, $Z_B = 33.5\,m$

To find: h_L ?

Applying Energy Eqn between A & B

$$\frac{p_A}{\rho g} + \frac{V_A^2}{2g} + Z_A = \frac{p_B}{\rho g} + \frac{V_B^2}{2g} + Z_B + h_L \quad (\because V_A = V_B)$$

$$\frac{361 \times 10^3}{9810} + 30.5 = \frac{288 \times 10^3}{9810} + 33.5 + h_L$$

$$h_L = 4.44\,m$$

10

(ii) Given: $B = 4m$, $Q = 16 m^3/s$, $y_1 = 0.5m$

To find: y_2 =? E_l?

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

$$\frac{(16/4)^2}{9.81} = 0.5 \times y_2 \left(\frac{0.5 \times y_2}{2}\right)$$

$$y_2 = 2.316m$$

Check

$$y_2 = \frac{y_1}{2}\left(-1 \pm \sqrt{1 + 8Fr_1^2}\right)$$

$$2.316 = \frac{0.5}{2}\left(-1 \pm \sqrt{1 + 8(Fr_1)^2}\right)$$

$$Fr_1 = 3.61$$

Similarly, $Fr_2 = 0.36$

∴ flow is changing from supercritical to subcritical, this jump can occur

$$\Delta E = \frac{(y_2 - y_1)^3}{4 y_1 y_2} = \frac{(2.316 - 0.5)^3}{4 \times 2.316 \times 0.5}$$

$$\boxed{\Delta E = 1.293}$$

10

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

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

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

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

[12 + 8 = 20 marks]

(i) Time (hr)
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16

Given → Uniform rise
or fall in successive time
→ pumping throughout the
day.

Time (hr)	Cumulative demand (m^3/s)	CD (ML)	Cum supply (ML)	CD-CS
0-2	0.1	0.72	1.77	-7.05
2-4	0.25	1.8	3.54	-7.74
4-6	0.45	3.24	5.31	-2.07
6-8	0.95	6.84	7.08	-0.24
8-10	1.55	11.16	8.85	2.31
10-12	1.95	14.04	10.62	3.42
12-14	2.25	16.2	12.39	3.81
14-16	2.4	17.28	14.16	3.14
16-18	2.6	18.72	15.93	2.79
18-20	2.85	20.52	17.7	2.82
20-22	2.95	21.24	19.47	1.77
22-24	2.95	21.24	21.24	0

(12)

Supply rate = $\frac{\text{Cum demand}}{24/2} = \frac{21.24}{12} = 1.77$ (ML)

Capacity of Reservoir = Greatest cumulative difference

$= |-2.07| + |3.81|$

$= \boxed{5.88 \text{ ML}}$

(ii) Self Cleansing Velocity

It is the minimum velocity of sewage in the sewer with which settling of solid particles at the sewer's surface is resuspended from the flow.

Importance :- It will make sure no settling is happening inside sewage, thus not affecting the velocity in surface area & avoiding choking condition

(6)

* Non Scouring Velocity

It is maximum velocity of sewage flow inside the sewer which does not erode the surface of sewer by scouring action.

Importance :- It will make sure the material is intact & not reducing its life span by wear & tear.

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

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

[10 + 10 = 20 marks]

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

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

[10 + 10 = 20 marks]

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

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

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

$\eta_{PST} = 60\%$

Moisture content of raw sludge = 90%

Moisture content of digested sludge = 80%

Depth of tank = 6 m

[20 marks]

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

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

[10 + 10 = 20 marks]

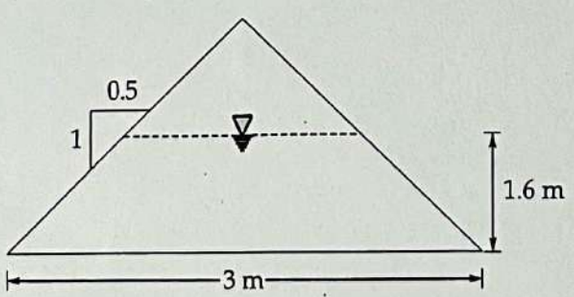
Q.4 (b) (i) A bag house filter is having 20 compartments, 360 bags per compartments and each bag of diameter 11 m and bag length 30 m with gas flow rate of 1200,000 m^3/min. Calculate the gross and net air to cloth ratios respectively. Assume that two compartments are out of service when calculating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

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

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

[10 + 10 = 20 marks]

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

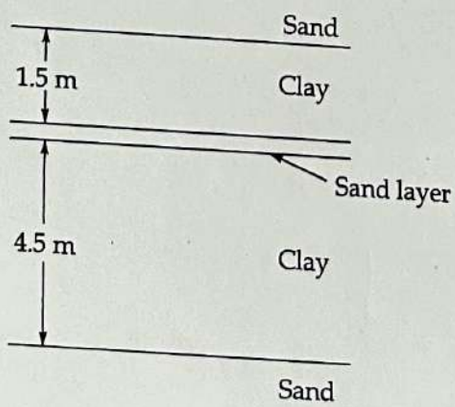


(ii) Consider a trapezoidal rigid boundary channel of 3 m base width with side slopes 1 H to 0.5 V, with depth of flow being 1.2 m, and n = 0.012, with adequate free board. Sketch the shear stress distribution on wetted perimeter. Explain points of zero and maximum, shear stresses on each of side slopes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

[5 + 15 = 20 marks]

Section - B

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



[12 marks]

Given $C_v = 4.92 \times 10^{-2}\ mm^2/sec$

To find Time for 50% Settlement

~~Ultimate Settlement~~

~~for Top Clay Layer,~~

$$T_{v_1} = \frac{\pi}{4} U_1^2 = \frac{C_v t}{d_1^2} \quad \text{— i}$$

$$T_{v_2} = \frac{\pi}{4} U_2^2 = \frac{C_v t}{d_2^2} \quad \text{— ii}$$

Dividing i & ii)

$$\frac{U_1^2}{U_2^2} = \frac{d_2^2}{d_1^2}$$

$$\frac{U_1}{U_2} = \frac{4.5/2}{1.5/2} = 3 \quad \text{— iii}$$

Also, $U_T = \frac{U_1 \times 1.5 + U_2 \times 4.5}{6}$

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

$3 = U_1 \times 1.5 + U_2 \times 4.5$

Putting $U_1 = 3U_2$ from eqn (iii)

$3 = 3U_2 \times 1.5 + U_2 \times 4.5$

$U_2 = 1/3$

$U_1 = 1$

Now, $\frac{\pi}{4} \times (1)^2 = \frac{C_v \times t}{\left(\frac{1.5}{2}\right)^2}$

$$\boxed{t = 103.93 \text{ days}}$$

12

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

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

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

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

[12 marks]

Given $B = 1\,m$, $D_f = 1.5\,m$, $c'_{cu} = 30\ kN/m^2$, $\phi'_{cu} = 25°$, $FOS = 3$, $\gamma = 18.3\ kN/m^3$

Mobilised shear parameters

$$c'_m = \frac{2}{3} \times 30 = 20\ kN/m^2$$

$$\tan\phi'_m = \frac{2}{3}\tan\phi = \frac{2}{3}\tan(25°)$$

$$\phi_m = 17.3°$$

For strip footing

$$q_u = cN_c + \gamma D_f N_q + 0.5 B \gamma N_\gamma$$

for $\phi'_m = 17.3°$, $N'_c = 13.91$, $N'_q = 5.17$, $N'_\gamma = 4.02$

(12)

$$q_u = 20 \times 13.91 + 18.3 \times 1.5 \times 5.17 + 0.5 \times 1 \times 18.3 \times 4.02$$

$$q_u = 456.8995\ kN/m^2$$

$$q_{net} = q_u - \gamma D_f$$

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

$$= \frac{456.8995 - 18.3 \times 1.5}{3} + 18.3 \times 1.5$$

$$= 170.6\ kN/m^2$$

$$Q_{safe} = 170.6 \times 1 \times 1$$

$Q_{safe} = 170.6\ kN$ per length of wall

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

Wheel load = 4000 kg

Radius of contact area = 16 cm

Traffic coefficient, $X = 1.6$

Rainfall coefficient $Y = 1.0$

Design deflection, $\Delta = 0.25$ cm

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

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

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

[12 marks]

$$T_{Base} = \sqrt{\left(\frac{3Pxy}{2\pi ES\Delta}\right)^2 - a^2} \times \left(\frac{Es}{Ep}\right)^{1/3}$$

$$= \sqrt{\left(\frac{3\times4000\times1.6\times1}{2\pi\times100\times0.25}\right)^2 - 16^2} \times \left(\frac{100}{400}\right)^{1/3}$$

$$= 76.34 \text{ cm}$$

Thickness of Base in terms of Bitumen

$$\frac{T_{Base}}{T_{Bit.}} = \left(\frac{E_{Bit.}}{E_{Base}}\right)^{1/3}$$

$$\frac{T_{Base}}{7.5} = \left(\frac{1000}{400}\right)^{1/3}$$

$$T_{Base} = 10.18 \text{ cm}$$

12

∴ Remove 10.18 cm to add 7.5 cm Bitumen

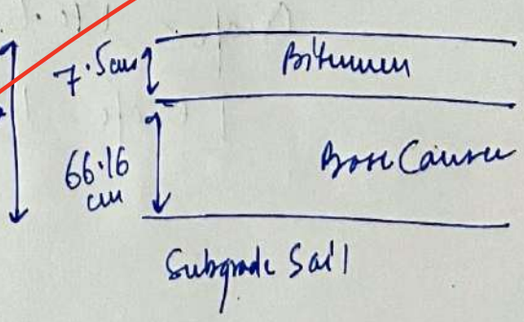
Design Thickness

$$T_B = 76.34 - 10.18 = \boxed{66.16 \text{ cm}}$$

$$T_{Bit.} = \boxed{7.5 \text{ cm}}$$

Total Thickness = 66.16 + 7.5

$$= \boxed{73.66 \text{ cm}}$$



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

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

[12 marks]

We know, $\Sigma L = 0$ & $\Sigma D = 0$

$$\Sigma L = 217.5 \cos 120°15' + 300 \cos 62°30' + 375 \cos 322°24' + 280 \cos 335°18' + L_{EA} \cos\theta$$

$$0 = 580.697 + L_{EA}\cos\theta \quad \text{--- (i)}$$

$$\Sigma D = 217 \sin 120°15' + 300 \sin 62°30' + 375 \sin 322°24' + 280 \sin 337°18' + L_{EA} \sin\theta$$

$$0 = 107.75 + L_{EA}\sin\theta \quad \text{--- (ii)}$$

Now, dividing ii with i

$$\frac{L_{EA}\sin\theta}{L_{EA}\cos\theta} = \frac{+107.75}{-580.697}$$

$$\tan\theta = \frac{107.75}{580.697}$$

$$\boxed{\theta = 10.512°}$$

Squaring Eqn i & ii & adding them

$$(L_{EA}\sin\theta)^2 + (L_{EA}\cos\theta)^2 = (-107.75)^2 + (-580.697)^2$$

$$L_{EA}^2(\sin^2\theta + \cos^2\theta) = 107.75^2 + 580.697^2$$

$$\boxed{L_{EA} = 590.61 \text{ lbs}}$$

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

[12 marks]

Factors ~~depends~~

i) on Rail length
ii) on Gauge
iii) no. of joints
iv) Spacing in normal section & below joints

→ It is expressed as (n+x), where n represents the no. of sleeper equivalent to length of single rail & x represents the additional no. of sleepers provided below one rail length to cater for reduced spacing below joints.

10

Given $L = 640\,m$

$SD = n + 5$

$L_R = 12.8\,m$ (BG)

for 12.8m length, No. of sleeper $= 12.8 + 5$

$\therefore$ for 640m length, $N = \frac{640}{12.8} \times (12.8 + 5)$

$N = 890$ Sleepers

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

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

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

[20 marks]

(i) Given $V_{ruling} = 80$ km/hr

Assume $e = 7\%$

$f = 0.15$

$$R_{ruling} = \frac{V_{ruling}^2}{127(e_{max}+f)} = \frac{80^2}{127(0.07+0.15)}$$

$$R_{ruling} = 229.06 m$$

a) Super elevation

$$e_d = \frac{V^2}{225R} = \frac{80^2}{225 \times 229.06} = 0.124 > 0.07$$

provide, $e = 7\%$

Check for f.

$$0.07 + f = \frac{80^2}{127 \times 229.06} \Rightarrow f = 0.15$$ ok

b) Extra Widening

$$W_e = W_m + W_p = \frac{n l^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

$n = 2$ (given)

$l = 6$ m (assume)

20

$$We = \frac{2\times 6^2}{2\times 229.06} + \frac{80}{9.5\sqrt{229.06}}$$

$$\boxed{We = 0.713\ m}$$

C) Transition Curve

1) Change of centrifugal acceleration

$$L_T = \frac{0.0215\ V^3}{CR}$$

$$= \frac{0.0215\times 80^3}{0.516\times 229.06}$$

$$L_T = 93.134\ m$$

$$C = \frac{80}{75+V} = \frac{80}{75+80}$$

$$= 0.516\ m/s^3$$

2) Super Elevation

$$L_T = eN(W+We) \qquad (N = 150 \text{ for Rolling})$$

$$= 0.07\times 150\,(7+0.713) \qquad (W = 7m \text{ for 2 lane})$$

$$L_T = 80.98\ m$$

3) As per IRC

$$L_T = \frac{2.7V^2}{R} = \frac{2.7\times 80^2}{229.06} = 76.1\ m$$

L_T, max of 1, 2 & 3

$$\boxed{L_T = 93.134\ m}$$

(ii) Given for ISD

$l_c > ISD$

$$m = l - (l-d)\cos\frac{\alpha}{2}$$

$$\frac{\alpha}{2} = \frac{ISD}{2(l-d)} \times \frac{180}{\pi}$$

$$ISD = 2 \times SD = 2\left[0.278 \times 80 \times 2.5 + \frac{80^2}{254 \times 0.36}\right)$$

Assuming $t_r = 2.5$ second, $f = 0.36$

$$DSD = 251.18 m$$

$$d = \frac{7.713}{4} = 1.928 m$$

$$\frac{\alpha}{2} = \frac{251.18}{2(229.06 - 1.928)} \times \frac{180}{\pi} = 31.68°$$

$$m = 229.06 - (229.06 - 1.928) \times \cos(31.68)$$

$$m = 35.77 m$$

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

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

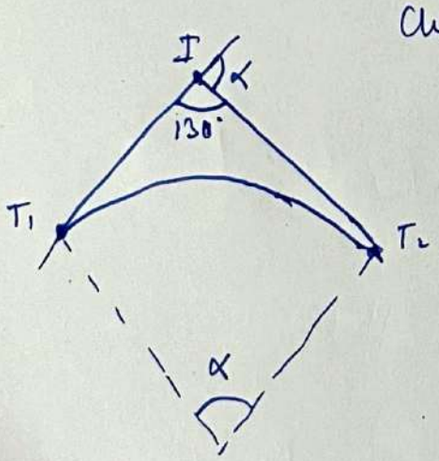
[12 + 8 = 20 marks]

(i) Given ⇒ ∠Intersection = 130°

Chainage of I = 3150 m

Curve Degree = 4°

Chain Length = 30 m



$\alpha = 180 - 130 = 50°$

$R = \frac{30}{2\sin(\frac{4}{2})} = \frac{30}{2\times \sin(\frac{4}{2})}$

$R = 429.84$

10

Curve setting (Perpendicular Offset)

$$Ox = R - \sqrt{R^2 - x^2}$$

Tangent length, $IT_1 = R \tan\frac{\Delta}{2}$

$IT_1 = 429.8 \times \tan\frac{50}{2}$

$= 200.42\text{m}$

Curve length, $L_c = \frac{2 \times \alpha \times \pi}{180}$

$= \frac{429.8 \times 50 \times \pi}{180}$

$= 375.07\text{m}$

Chainage at T_1 = 3150 − IT_1 = 3150 − 200.42

= 2949.58

Chord lengths, C_1 = 2970 − 2949.58

= 20.42 m

C_n = 375.07 − 20.42 − 330

= 24.65 m

No. of chords = $\frac{375.07 - 20.42 - 24.65}{30} + 2$

= 13

Offset lengths

$O_1 = R - \sqrt{R^2 - C_1^2} = 429.8 - \sqrt{429.8^2 - 20.42^2}$

O_1 = 0.485 m @ 2970 m chainage

Similarly $O_2 = 429.8 - \sqrt{429.8^2 - 30^2}$ ($\because C_2$ to C_{12} = 30 m)

O_2 = 1.0483 m @ 3000 m

O_3

$O_2 = 429.8 - \sqrt{429.8^2 - (20.42 + 30)^2} = 2.967\text{m}$

Similarly

O_3 = 7.59 m
O_4 = 14.426 m
O_5 = 23.585 m
O_6 = 35.28 m
O_7 = 49.59 m
O_8 = 66.98 m
O_9 = 87.88 m
O_{10} = 112.96 m
O_{11} = 143.34 m
O_{12} = 180.935 m
O_{13} = 219.92 m

Cal mistake

(ii) Tachometer

It is the modified version of theodolite in which a stadia diaphragm is attached with 3 cross hairs (horizontal) for simultaneous angular & distance measurement on the objective lens of theodolite.

Methods of Tachometry

① Staff & Stadia method

In this 3 staff readings are taken with help of 3 cross hairs on the stadia diaphragm & stadia interval is calculated, with the help of which distance is calculated

a) Staff held Vertical

$D = l \cos\theta$

$V = l \sin\theta$

$l = K s \cos\theta + C$

b) Staff held perpendicular

$D = L\cos\theta + s_2 \sin\theta$

$V = L\sin\theta$

$L = Ks + C$

(2)

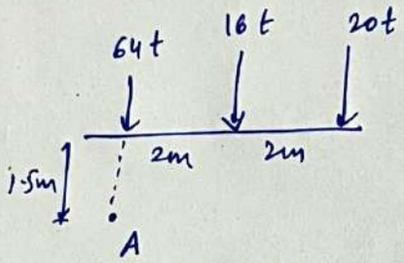
(i) Three point loads of 64 t, 16 t and 20 t, 2 m apart in a straight line act at the surface of soil mass. Calculate the resultant stress produced at a depth of 1.5 m below 64 t load. The Boussinesq's influence factor, I_B for depth $z = 1.5$ m are given below with respect to distance to depth (r/z)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

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

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

[12 + 8 = 20 marks]

(i) Given



Influence factor Calculation (from Table)

a) for 64t load

$\frac{r}{z} = 0 \rightarrow I_{B_1} = 0.4775$

b) for 16t Load

$\frac{r}{z} = \frac{2}{1.5} = 1.333 \rightarrow I_{B_2} = 0.037$

c) for 20t load

$\frac{r}{z} = \frac{4}{1.5} = 2.667 \rightarrow I_{B_3} = 0.0025$

Resultant Stress

$\nabla R = I_{B_1} \frac{Q_1}{z_1^2} + I_{B_2} \frac{Q_2}{z_2^2} + I_{B_3} \frac{Q_3}{z_3^2}$

12

$$\sigma_R = 0.4775 \times \frac{64}{1.5^2} + 0.0037 \times \frac{16}{1.5^2}$$

$$+ 0.0025 \times \frac{20}{1.5^2}$$

$$\boxed{\sigma_R = 13.867\ t/m^2}$$

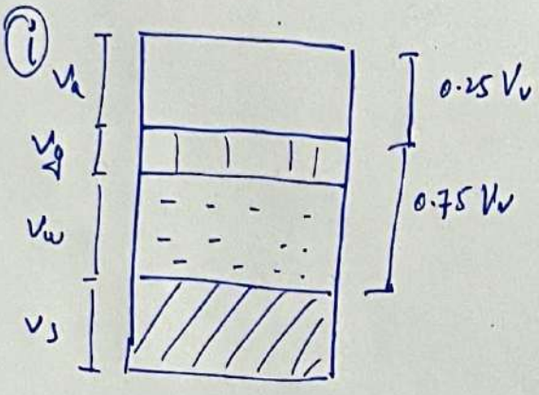
(ii)

Q.7 (a) (i) A soil mass is contaminated with gasoline. 75% of the void space of the soil is filled with gasoline and water. The volume of gasoline is 25% of the volume of water. The unit weight of soil solids is 26 kN/m³ and water content of the soil is 25%. The specific gravity of gasoline is 0.9. Find the void ratio, porosity, total density and dry density of the soil. Take $\gamma_w = 9.81$ kN/m³.

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

[15 + 5 = 20 marks]

(i)



Given

$V_g + V_w = 0.75\,V_v$ —(i)

$V_g = 0.25\,V_w$ —(ii)

$G_g = 0.9$

$w = 25\%$

$\gamma_s = 26\,kN/m^3$

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

Now, from equation (i) & (ii)

$0.25\,V_w + V_w = 0.75\,V_v$

$V_w = \frac{0.75}{1.25} V_v = \frac{3}{5} V_v$ —(iii)

15

Now, $w = \frac{W_w}{W_s} = \frac{V_w \times \gamma_w}{V_s \times \gamma_s} = \frac{(\frac{3}{5} V_v) \cdot \gamma_w}{V_s \cdot \gamma_s}$ (from iii)

Putting given values

$0.25 = \frac{(\frac{3}{5}) \cdot V_v \times 9.81}{V_s \times 26}$

$\frac{V_v}{V_s} = 1.1043$

$\therefore \boxed{e = 1.1043}$ $\left(\because e = \frac{V_v}{V_s}\right)$

Also, $\eta = \frac{e}{1+e} = \frac{1.1043}{1+1.1043} = \boxed{0.5248}$

Total density, $\gamma_b = \frac{(G+Se)\gamma_w}{1+e} = \frac{(2.65+0.6\times1.1043)9.81}{1+1.1043}$

$G = \frac{\gamma_s}{\gamma_w} = \frac{26}{9.81} = 2.65$ $\quad \boxed{\gamma_b = 15.44\ kN/m^3}$

Also, $Se = wG$

$S = \frac{wG}{e} = \frac{0.25\times2.65}{1.1043} = 0.6$

Dry. Density, $\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.65\times9.81}{1+1.1043} = \boxed{12.354\ kN/m^3}$

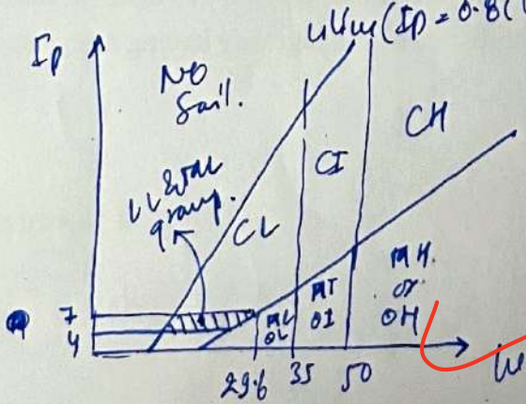
(2)

(ii) Plasticity Chart

→ plasticity chart is used to classify fine grained soil

→ It contains various zones divided on the basis of percentage finer, liquid limit on X axis & Plasticity index of soil. on Y axis.

→ Zones are as per diagram given below.



C = Clay
M = Silt
O = organic
H = highly Compressible
I = Intermediate "
L = Low "

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

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

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

[10 + 10 = 20 marks]

(i) Given $q_{max} = 2000$ vehicles/hour

Lane = 3.5 m

$q = 1200$ veh/hour

$$k_j = \frac{1000}{3.5} = 285.71 \text{ veh/km}$$

Also for linear Relationship.

$$q = V_{sf}\left(k - \frac{k^2}{k_j}\right) \quad \text{--(i)}$$

$$q_{max} = \frac{V_{sf} \cdot k_j}{4}$$

$$2000 = \frac{V_{sf} \times 285.71}{4}$$

$$V_{sf} = 28 \text{ km/hr}$$

putting values in Equ. (i)

$$1200 = 28\left[k - \frac{k^2}{285.71}\right]$$

$k = 52.5$ veh/km

(ii) Stopping Sight Distance

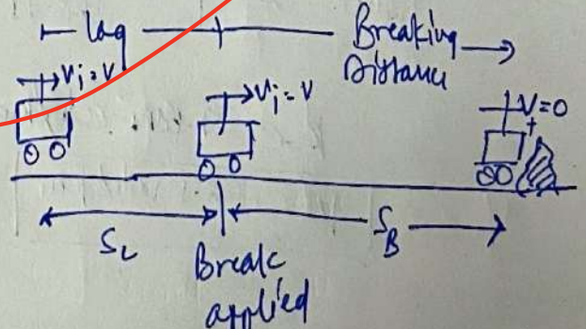
→ It is the minimum sight distance which a driver required to stop just before colliding with a object or vehicle in front of it on a road.

→ It includes perception, intellection, emotion & volition time in the form of lag & breaking distance in calculation

→ It is used to design road stretches, curves & other geometrical features to ensure minimum sight distance available to avoid collision.

Derivation (for One way single carriageway level road)

$SSD = S_L + S_B$



$S_L = v_1 \times$ Lag time

$S_L = v_1 \times t_r$

for S_B

$\Delta KE = WD$

$\frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = f(N) \cdot S_B$

$\because v_f = 0, \quad v_i = v$

$-\frac{1}{2} m v^2 = -f m \cdot g \cdot S_B$ (-ve, as retardation)

$$S_B = \frac{V^2}{2gf}$$

$$SSD = V \cdot t_r + \frac{V^2}{2gf}$$

where, V in m/s
t_r in sec

Head light sight Distance

Given $V = 80$ kmph
$f = 0.36$
$t_r = 2.5$ secs

$$HSD = 0.278\, V \cdot t_r + \frac{V^2}{254 f}$$

$$= 0.278 \times 80 \times 2.5 + \frac{80^2}{254 \times 0.36}$$

$$HSD = 125.6 \text{ m}$$

Intermediate Sight Distance

$$ISD = 2 \times SSD = 2 \times HSD \quad (\because SSD = HSD)$$

$$= 2 \times 125.6$$

$$ISD = 251.2 \text{ m}$$

(10)

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

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

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

[12 + 8 = 20 marks]

(i) Given: Basic RL = 1 km = 1000 m

Runway at mean sea level, $\therefore H = 0$

$SAT = 15 - 0.0065(H)$

$SAT = 15^\circ$ ($\because H = 0$)

For maximum runway length, ART should be maximum for safe design.

12

Calculation of ART for different month is shown in table

Month	T_a	T_m	$ART = T_a + \frac{(T_m - T_a)}{3}$
Jan	3	5	3.67
feb	15	17	15.67
Mar	20	23	21
Apr	25	32	27.33
May	35	47	39
June	40	50	43.33
July	32	37	33.67
Aug	30	35	31.67
Sept	27	31	28.33
Oct	22	28	24
Nov.	12	18	14
Dec.	6	9	7

$ART_{max} = 43.33$

$\Delta T = ART - SAT = 43.33 - 15$

$\Delta T = 28.33^\circ$

Temperature correction is 1% increase in BRL for 1° rise

∴ for 28.33° ΔT, Correction is 28.33%

Actual RL = 1000×1.2833

= **1283.3m**

(ii) Given ~~Ab = ...~~ N is 8.5 in)
R = 450 m D = 4.5 m

Crossing Length = $\sqrt{4R^2 - (4R^2 + D^2 - 4RD)}$

$= \sqrt{4 \times 450^2 - (4 \times 450^2 + 4.5^2 - 4 \times 450 - 4.5)}$

$l = 89.89 \text{ m}$

4

Elaborate it more

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

[20 marks]

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

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

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

[20 marks]

Do not write in this margin

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

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

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

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

[8 + 12 = 20 marks]

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