



MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-2 : Section A : Highway Engineering + Surveying and Geology [All topics]

Section B : Geo-technical & Foundation Engg. - 1 + Env. Engg. - 1 [Part syllabus]

Name :

Roll No :

Test Centres	Student's Signature
Delhi <input checked="" type="checkbox"/> Bhopal <input type="checkbox"/> Jaipur <input type="checkbox"/> Pune <input type="checkbox"/> Hyderabad <input type="checkbox"/>	

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	48
Q.2	50
Q.3	—
Q.4	—
Section-B	
Q.5	52
Q.6	60
Q.7	43
Q.8	—
Total Marks Obtained	253

Signature of Evaluator

Cross Checked by

sb

Good Accuracy

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.

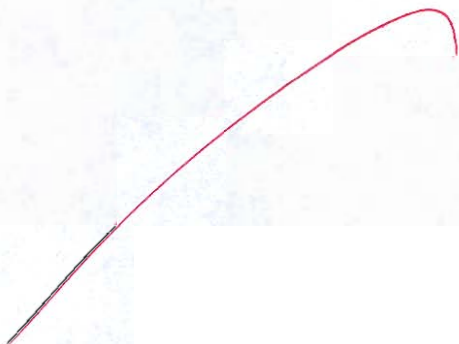
DO'S

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 : Highway Engineering + Surveying and Geology

- (a) (i) Write the short notes on
1. Prime coat vs tack coat
 2. Bitumen emulsion vs Cutback bitumen
- (ii) Discuss the requirements of highway drainage system.

[3 + 3 + 6 = 12 marks]



- (b) The following observations were made to determine the sensitivity of two bubble tubes. Determine which bubble tube is more sensitive. The distance of the staff from the instrument was 75 m and the length of one division of both the bubble tubes is 2 mm.

Bubble tube	Bubble reading		Staff reading (m)
	L.H.S.	R.H.S.	
A	14	6	1.718
	13	9	1.867
B	16	4	1.735
	15	7	1.888

[12 marks]

for Bubble A -

$$n_A = \frac{(14-6) + (13-9)}{2} = 6$$

$$\begin{aligned} \alpha_A &= \frac{S_A}{n_A D} \times 206265'' \\ &= \frac{(1.867 - 1.718)}{6 \times 75} \times 206265 \\ &= 68.296'' \end{aligned}$$

12

for Bubble B -

$$n_B = \frac{(16-4) + (15-7)}{2} = 10$$

$$\begin{aligned} \alpha_B &= \frac{S_B}{n_B D} \times 206265'' \\ &= \frac{(1.888 - 1.735)}{10 \times 75} \times 206265 \\ &= 42.078'' \end{aligned}$$

Since $\alpha_B < \alpha_A \rightarrow$ Bubble Tube B is more sensitive.

Q.1(c) Calculate the stresses at the interior, edge and corner regions of a cement concrete pavement using Westergaard's stress equations based on the given data.

Design wheel load = 4200 kg

E value of cement concrete = 2.8×10^5 kg/cm²

Thickness of pavement slab = 20 cm

Poisson's ratio of cement concrete = 0.15

Modulus of subgrade reaction = 10.0 kg/cm³

Radius of contact area = 14 cm

[12 marks]

Solⁿ

$$P = 4200 \text{ kg}$$

$$E = 2.8 \times 10^5 \text{ kg/cm}^2$$

$$h = 20 \text{ cm}$$

$$\mu = 0.15$$

$$K = 10 \text{ kg/cm}^3$$

$$a = 14 \text{ cm}$$

$$\text{Radius of Relative Stiffness } r = \left[\frac{(2.0 \times 10^5) (20)^3}{12 \times 10 (1 - 0.15^2)} \right]^{\frac{1}{4}}$$

$$= 66.10 \text{ cm}$$

Now

$$a = 14 \text{ cm} < 1.724 h$$

So

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

$$= \sqrt{1.6 (14)^2 + 20^2} - 0.675 \times 20$$

$$= 13.21 \text{ cm}$$

Also

AT Interior -

$$S_i = \frac{0.316 \times 4200}{(20)^2} \left[4 \log \frac{66.10}{13.21} + 1.069 \right]$$

$$= 12.03 \text{ Kg/cm}^2$$

AT Edge -

$$S_e = \frac{0.572 \times 4200}{(20)^2} \left[4 \log \frac{66.10}{13.21} + 0.359 \right]$$

$$= 18.96 \text{ Kg/cm}^2$$

AT Corner -

$$S_c = \frac{3 \times 4200}{(20)^2} \left[1 - \left(\frac{14 \sqrt{2}}{66.10} \right)^{0.6} \right]$$

$$= 16.22 \text{ Kg/cm}^2$$

- Q.1 (d) Using Webster's method, design a two-phase traffic signal with pedestrian crossing for a road intersection. The average normal traffic flow during the design hour on cross roads A and B is 460 PCU per hour and 240 PCU per hour respectively. The corresponding saturation flows on roads A and B are 1300 PCU per hour and 1000 PCU per hour respectively. Assume that the total red time required for pedestrian crossing is 12 seconds and an amber (clearance) time of 2 seconds is to be provided in each phase. Draw the signal phase diagram also.

[12 marks]

Solⁿ

$$\text{Total Red Time } R = 12 \text{ sec}$$

$$\text{Amber Time} = 2 \text{ sec per phase}$$

Now

$$\begin{aligned} \text{All Red Time } L &= 2 \times 2 + 12 \\ &= 16 \text{ sec} \end{aligned}$$

Now

$$y_1 = \frac{460}{1300} = 0.354$$

$$y_2 = \frac{240}{1000} = 0.24$$

Now

$$Y = y_1 + y_2 = 0.594$$

Cycle Time —

$$C_0 = \frac{1.5L + 5}{1 - Y}$$

$$C_0 = \frac{1.5(16) + 5}{1 - 0.594} = 71.43 \text{ sec}$$

$$\approx 73 \text{ sec}$$

Effective Green Time -

$$G_1 = \frac{y_1}{Y} (C_0 - L)$$

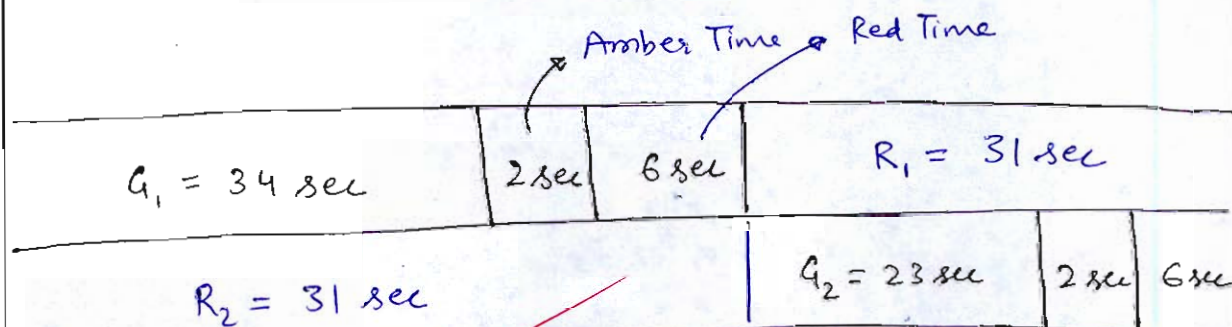
$$= \frac{0.354}{0.594} (73 - 16)$$

$$\approx 34 \text{ sec}$$

$$G_2 = \frac{0.24}{0.594} (73 - 16)$$

$$\approx 23 \text{ sec}$$

12



Two Phase System

Q.1(e)

A vertical photograph was taken from a height of 1200 m above the mean sea level with a camera of focal length 30 mm. It contains two points a and b corresponding to ground point A and B respectively. Calculate the horizontal length AB and the average scale along the line ab from the following data:

Photo point	Elevation above MSL	Photo co-ordinates	
		x(mm)	y(mm)
a	250	20.5	15.5
b	210	-15.5	-20.5

[12 marks]

Solⁿ

$$H = 1200 \text{ m}$$

$$f = 30 \text{ mm}$$

Now

$$h_{\text{avg}} = \frac{250 + 210}{2} = 230 \text{ m}$$

$$\text{Avg Scale } S = \frac{f}{H - h_{\text{avg}}}$$

$$S = \frac{30 \times 10^{-3}}{1200 - 230}$$

$$S = \frac{1}{32333.33}$$

$$S \approx \frac{1}{32334}$$

Now

$$S_a = \frac{30 \times 10^{-3}}{1200 - 250} = \frac{20.5 \times 10^{-3}}{X_A} = \frac{15.5 \times 10^{-3}}{Y_A}$$

$$X_A = \frac{20.5 \times 10^{-3}}{S} = 649.17 \text{ m}$$

$$X_B = \frac{-15.5 \times 10^{-3}}{S} = 490.83 \text{ m}$$

Now

$$S_B = \frac{30 \times 10^{-3}}{1200 - 210} = \frac{-15.5 \times 10^{-3}}{X_B} = \frac{-20.5 \times 10^{-3}}{Y_B}$$

$$X_B = -511.5 \text{ m}$$

$$Y_B = -676.5 \text{ m}$$

(12)

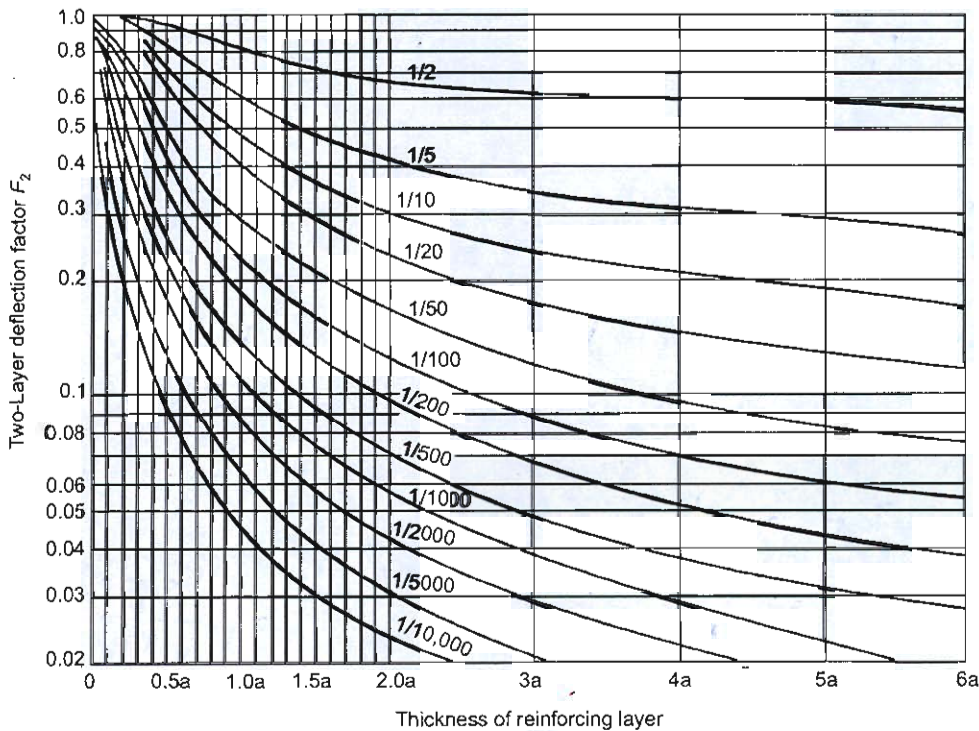
Now

$$\text{Horizontal distance } AB = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2}$$

$$D = 1646.15 \text{ m}$$



- 2(a) (i) Plate bearing test conducted with 30 cm diameter plate on a soil subgrade yielded a pressure of 1.25 kg/cm² at 5 mm deflection. The test carried out over 20 cm base course yielded a pressure of 5 kg/cm² at 5 mm deflection. Design the pavement section for wheel load of 4100 kg with a tyre pressure of 6 kg/cm² and allowable deflection of 5 mm. Use Burmister's method.



Relationship of F_2 and h in a two - layer system

- (ii) Differentiate between Rigid and Flexible Pavement.

[12 + 8 = 20 marks]

Solⁿ

Plate load Test on Soil subgrade —

$$\frac{E_s}{E_p} = 1 \quad \rightarrow \quad F_2 = 1$$

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

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

$$E_s = 94.25 \text{ kg/cm}^2$$

Plate load Test on Base Course —

$$h = 20 \text{ cm}$$

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

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

$$F_2 = 0.25$$

$$\frac{h}{a} = \frac{20}{15}$$

$$h = 1.33a$$

from Graph —

$$F_2 = 0.25 \quad \& \quad \frac{h}{a} = 1.33$$

$$\frac{E_s}{E_p} = \frac{1}{50}$$

$$\rightarrow E_p = 50 \times 44.25 = 2212.5 \text{ kg/cm}^2$$

Wheel load Test on Pavement —

$$\Delta = 1.5 \frac{pa}{E_p} F_2$$

$$0.5 = 1.5 \times \frac{6 \times 14.75}{(2212.5/50)} F_2$$

$$F_2 = 0.1666$$

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

$$= \sqrt{\frac{4100}{6 \pi}}$$

$$= 14.75 \text{ cm}$$

Corresponding to $f_2 = 0.166$ & $\frac{E_s}{E_p} = \frac{1}{50}$

$$\frac{h}{a} = 2.3$$

$$h = 2.3 \times 14.75$$

$$h = 33.925 \text{ cm}$$

17

i)

Flexible Pavement	Rigid Pavement
→ Load Transfer is through grain to grain Contact	→ Load Transfer through Slab Action
→ Rutting & Fatigue Failure is mainly Cause for failure	→ Structural Cracks & mud pumping is Cause for Failure
→ Suitable For Relatively Lighter loads	→ suitable for superior quality of roads & heavy loads
→ Construction cost is relatively less	→ Construction Cost is relatively more
→ Shorter life span (≈ 10-15 Years)	→ Longer life span ≈ (50 years)
→ Bituminous material is used	→ RCC materials are used

- 2.(b) (i) An expressway having four lanes with a divided carriageway passes through flat terrain. The horizontal curve provided on the expressway has a radius equal to the ruling minimum radius. If the design speed of the expressway is 110 km/h, determine the following elements of the curve:
- I. Ruling minimum radius
 - II. Super elevation
 - III. Extra widening
 - IV. Length of the transition curve
- (ii) List down the advantages and disadvantages of traffic signals.
- (iii) What are the necessary requirements for provision of intersection at grade?
[12 + 4 + 4 = 20 marks]

No. of lanes $n = 4$ on each side (divided carriageway)
 Flat Terrain $\rightarrow e_{max} = 0.07$
 design speed $V = 110$ kmph
 $f = 0.15$

Ruling minimum Radius -

$$RMR = \frac{V^2}{127(e_{max} + f)}$$

$$= \frac{(110)^2}{127(0.07 + 0.15)}$$

$$= 433.07 \text{ m}$$

$$\approx \underline{433 \text{ m}}$$

Superelevation -

$$\rightarrow e = \frac{V^2}{225R} = \frac{110^2}{225 \times 433} = 0.124 > e_{max}$$

→ Provide $e_{max} = 0.07$ & check f

$$f = \frac{110^2}{127 \times 433} - 0.07 = 0.15 \quad \text{OK}$$

Provide Superelevation $e = 0.07 = 7\%$

III Extra widening — let wheel base = 6.1 m

$$W_e = \frac{nd^2}{2R} + \frac{v}{9.5\sqrt{R}}$$

$$= \frac{8 \times (6.1)^2}{2 \times 433} + \frac{110}{9.5\sqrt{433}}$$

$$= 0.9 \text{ m}$$

(Providing 0.45 m extra widening on each side)

IV length of Transition Curve —

a) $L_t = \frac{0.0215 V^3}{CR}$

$$= \frac{0.0215 \times 110^3}{0.5 \times 433}$$

$$= 99.31 \text{ m}$$

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

$$= \frac{80}{75+110}$$

$$= 0.43 < 0.5$$

Adopt $C = 0.5$

19

b) Elevating road about Centre line —

$$L_t = \frac{1}{2} eN (w + w_e)$$

$$= \frac{1}{2} \times 0.07 \times 150 (8 \times 3.5 + 0.9)$$

$$= 151.73 \text{ m}$$

Flat Terrain
 $N = 150$

c) $L_t = 2.7 \frac{V^2}{R}$

$$= 2.7 \times \frac{110^2}{433}$$

$$= 75.45 \text{ m}$$

length of T.C. = $\max \left\{ \begin{array}{l} 99.31 \\ 151.73 \\ 75.45 \end{array} \right.$

$$= 151.73 \text{ m}$$

$$\approx \underline{152 \text{ m}}$$

-ii) Advantages of Traffic Signals -

- Chances of Accident reduces due to less weaving & merging traffic.
- Every lane gets equal opportunity to cross the intersection.

Disadvantages of Traffic Signal -

- Vehicles have to wait at intersection which leads to delay.
- Queue formation takes place which leads to Shockwave if not dissipated properly.
- maintenance and operating Cost may comes out to be huge and uneconomical for relatively less traffic.

6

ii) Necessary Requirements for provision of intersection at grade -

- when there is heavy chances of accidents that rotary cant handle that situation.
- Vehicles from every dirⁿ are in proportion and is on relatively busy / important road.

- Q.2(c) A baseline was measured using a steel tape suspended in catenary under a pull of 155 N at a mean temperature of 15°C. The lengths of the individual tape segments and the corresponding differences in level between the ends of each segment are given below:

Bay/Span	Length (m)	Difference in level (m)
1	29.988	-0.346
2	29.895	+0.214
3	29.838	-0.309
4	29.910	-0.106

The tape was standardized on level ground under a pull of 95 N at a temperature of 18°C. Determine the correct length of the baseline.

The following additional data are provided:

Cross-sectional area of tape = 3.35 mm²

Mass of tape = 0.025 kg/m

Coefficient of linear expansion = 0.9×10^{-6} per °C

Young's modulus = 14.8×10^4 MN/m²

Mean height of the line above M.S.L. = 120 m

Radius of the Earth = 6370 km

[20 marks]

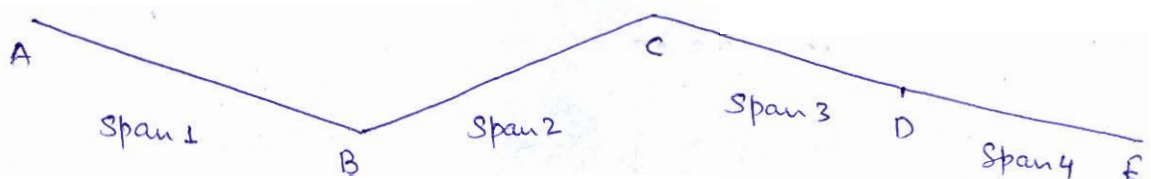
Solⁿ

$$P_m = 155 \text{ N}$$

$$T_m = 15^\circ \text{C}$$

$$P_0 = 95 \text{ N}$$

$$T_0 = 18^\circ \text{C}$$



For Span 1 -

Correction due to Temp -

$$C_1 = (15 - 18) \times 29.988 \times 0.9 \times 10^{-6} = -8.09 \times 10^{-5} \text{ m}$$

Correction due to Pull -

$$C_2 = \frac{(155 - 95) \times 29.988}{3.35 \times 14.8 \times 10^4} = 3.63 \times 10^{-3} \text{ m}$$

Correction due to Sag -

$$C_3 = \frac{w^2 l_0}{24 P_m^2} - \frac{w^2 l_0}{24 P_0^2}$$

$$C_3 = \frac{(0.025 \times 29.988 \times 9.01)^2 \times 29.988}{24 \times (95)^2} - \frac{(0.025 \times 9.01)^2 \times 29.988^3}{24 \times (155)^2}$$

$$= 4.67 \times 10^{-3}$$

Total correction $C = C_1 + C_2 + C_3$
 $= 8.219 \times 10^{-3} \text{ m}$

15

Similarly for span 2 -

$$\text{Total Correction} = (15-10) \times 29.895 \times 0.9 \times 10^{-6}$$

$$+ \frac{(155-95) \times 29.895}{3.35 \times 14.0 \times 10^4}$$

$$+ \frac{(0.025 \times 9.01)^2 \times 29.895^3}{24 \times 95^2} - \frac{(0.025 \times 5.01)^2 \times 29.895^3}{24 \times 155^2}$$

$$= 0.17 \times 10^{-3} \text{ m}$$

Span 3 -

Total Correction $C = 0.14 \times 10^{-3} \text{ m}$

Span 4

Total Correction $C = 0.10 \times 10^{-3} \text{ m}$

Corrected length -

Span 1 - $L_1 = 29.996 \text{ m}$

Span 2 - $L_2 = 29.903 \text{ m}$

Span 3 - $L_3 = 29.846 \text{ m}$

Span 4 - $L_4 = 29.910 \text{ m}$

$L_c = 119.663 \text{ m}$

After Applying MSL Correction -

$$C_{msl} = -\frac{l_0 h}{r}$$

$$= \frac{-119.663 \times 120}{6370 \times 10^3}$$

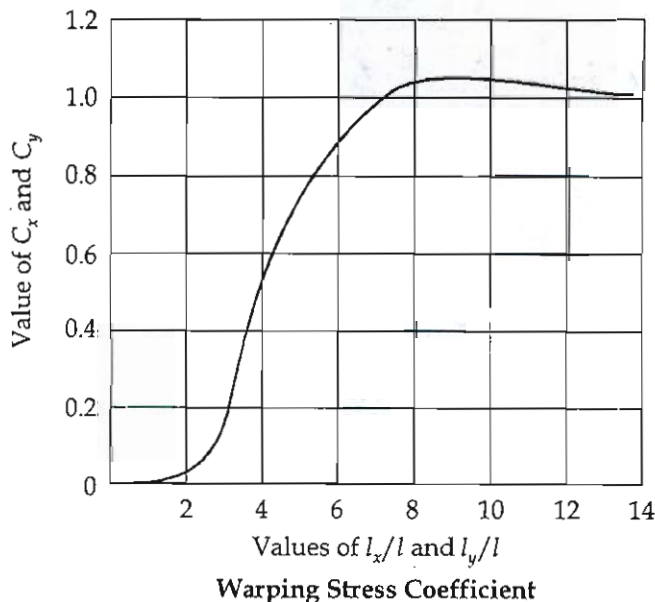
$$= -2.254 \times 10^{-3} \text{ m}$$

Final Corrected length = $119.663 - 2.254 \times 10^{-3}$

$$l_{\text{final}} = 119.661 \text{ m}$$

- Q.3 (a) (i) Determine the warping stresses at interior, edge and corner region in a 30 cm thick concrete pavement with transverse joints and longitudinal joints at 4.5 m and 3.6 m interval respectively. The modulus of subgrade reaction is 6 kg/cm^3 . Assume temperature differential for a day condition to be 12°C and radius of contact area is 15 cm. Additional data for cement concrete pavement is given below:

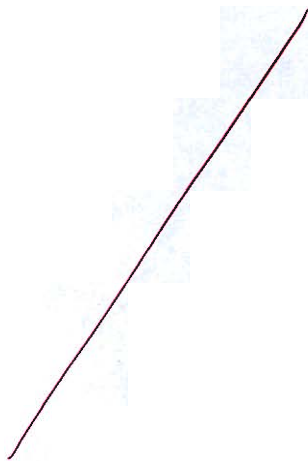
$$\alpha = 10 \times 10^{-6} \text{ per } ^\circ\text{C}, E = 3 \times 10^5 \text{ kg/cm}^2, \mu = 0.14,$$



(ii) The following staff readings were taken in succession with a level. The instrument was shifted after the fourth and the seventh reading. Enter the data in a page of a level book by rise and fall method. The first reading was taken on a Bench Mark of reduced level 68.235 m.

1.735, 1.625, 1.580, 1.250, 1.115, 2.010, 1.325, 1.055, 1.095, 0.955. Show also the arithmetical check.

[12 + 8 = 20 marks]



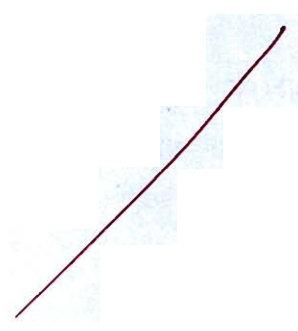




- 3(b) A two-lane, two-way highway is designed for design speed of 65 km/hr. A vertical curve is to be provided at intersection of downward gradient of 1 in 50 with another downward gradient of 1 in 20. Calculate the length of the vertical curve based on overtaking sight distance and stopping sight distance. The coefficient of longitudinal friction and the acceleration may be taken as 0.35 and 3.6 km/hr/sec respectively.


[20 marks]





- Q.3 (c) (i) Explain folds and faults and their importance in engineering works.
- (ii) Explain the concept of resolution in remote sensing. Describe the different types of resolution and discuss their importance in image interpretation.

[10 + 10 = 20 marks]







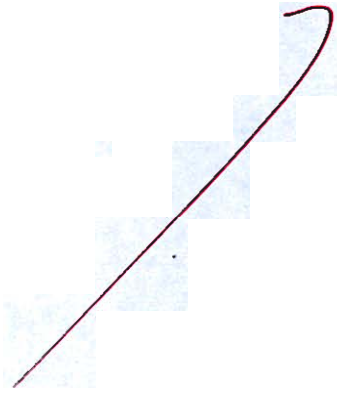
- 4 (a) (i) Adjust the angular error in the observations (if any) and calculate the bearings of the traverse lines in the following systems if whole circle bearing of the line AB is 30° :

Traverse station	Included angle
A	$120^\circ 35' 00''$
B	$89^\circ 23' 40''$
C	$131^\circ 01' 00''$
D	$128^\circ 02' 20''$
E	$94^\circ 54' 40''$
F	$155^\circ 59' 20''$

- (ii) Describe the raster and vector data models in GIS. Compare them with respect to data structure, advantages, and limitations.

[10 + 10 = 20 marks]







- 4 (b) (i) Discuss the role of joints in rock masses and explain the problems they create in civil engineering works.
- (ii) Spot Speed Studies were conducted at a certain stretch of a highway and the consolidated data collected are given below:

Speed Range (kmph)	No. of Vehicles observed
0 - 10	12
10 - 20	35
20 - 30	55
30 - 40	60
40 - 50	140
50 - 60	230
60 - 70	320
70 - 80	95
80 - 90	45
90 - 100	28

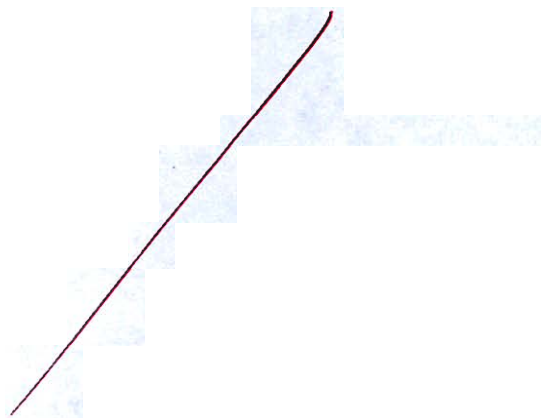
Determine:

- (i) The upper and lower values of speed limits for regulation of mixed traffic flow.
- (ii) The design speed for checking the geometric design elements of the highway.

[10 + 10 = 20 marks]





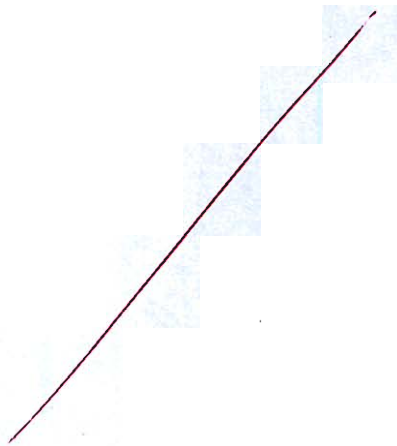


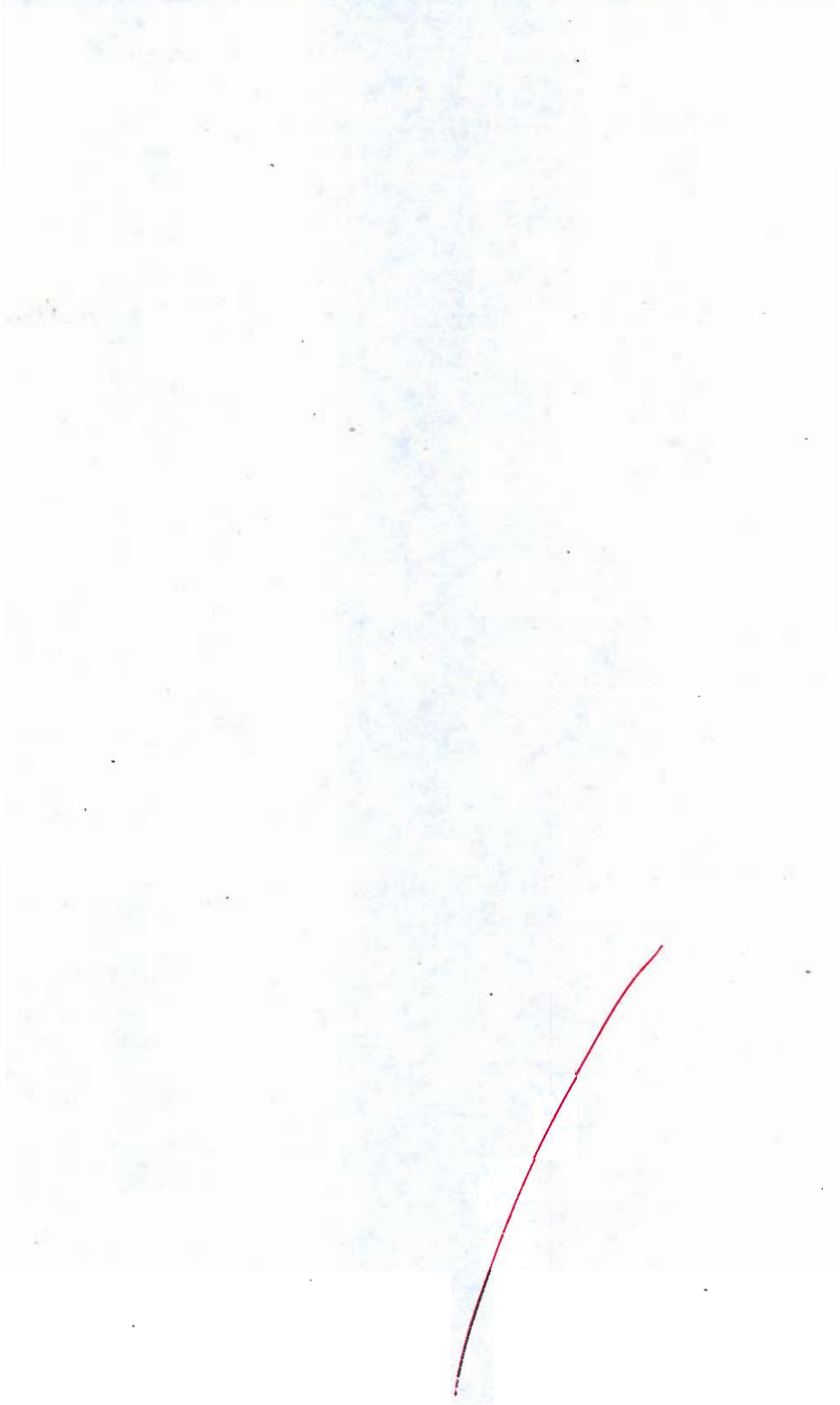
- Q.4(c) A tachometer fitted with an anallatic lens was set up at station *B* and the following observations were recorded. The value of the multiplying constant is 100.

Station	Station sighted	Bearing	Vertical angle	Staff readings (m)
<i>B</i>	<i>A</i>	$325^{\circ}30'$	$+3^{\circ}20'$	0.750, 1.000, 1.250
	<i>C</i>	$55^{\circ}30'$	$+2^{\circ}30'$	1.250, 2.000, 2.700

- (i) Find the horizontal distance between *A* and *C*.
(ii) Find the difference of level between *A* and *C*.

[20 marks]





Section B : Geo-tech & Found. Engg. - 1 + Environmental Engg. - 1

5(a) Describe the triaxial test? State the merits and demerits of Triaxial test?

[12 marks]

Triaxial Test —

It is a best & accurate method to determine Total stress and effective stress parameters of a soil mass (c, ϕ, c', ϕ')

Merits of Triaxial Test

- Proper drainage control
- Can be performed in both drained and Undrained Condⁿ.
- Pore water pressure can be measured accurately
- Failure plane is not predetermined which means failure takes place along which plane is weaker.

Demerits of Triaxial Test —

- Very Costly Apparatus Setup .

Types of Triaxial Test -

- (i) Unconsolidated Undrained Test (UU Test)
- (ii) Consolidated Undrained Test (CU Test)
- (iii) Consolidated drained Test (CD Test)



- 5(b) A 6 m thick clay layer ($e_0 = 1.05$, $C_c = 0.40$, $C_\alpha = 0.025$) is subjected to an increase in pressure of 75 kPa. The initial effective overburden pressure at the centre of the clay layer is 125 kPa. The clay is underlain by dense gravel and has a coefficient of consolidation $c_v = 3.5 \text{ m}^2/\text{year}$. Calculate the total settlement (in mm) after 20 years, assuming primary consolidation is complete at $U = 95\%$.

[12 marks]

$$\bar{\sigma}_0 = 125 \text{ kPa}$$

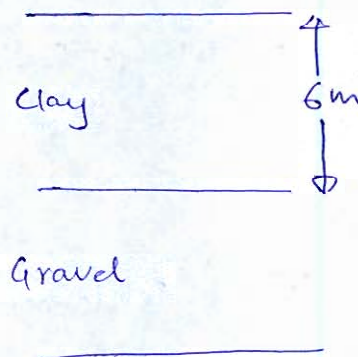
$$\Delta\bar{\sigma} = 75 \text{ kPa}$$

Total Settlement of Clay layer -

$$\Delta H = \frac{H_0 C_c}{1 + e_0} \log \left(\frac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0} \right)$$

$$\Delta H = \frac{6000 \times 0.4}{1 + 1.05} \log \left(\frac{125 + 75}{125} \right)$$

$$\Delta H = 230.97 \text{ mm}$$



After 20 Year -

$$T_v = C_v \frac{t}{d^2}$$

$$T_v = 3.5 \times \frac{20}{\left(\frac{6}{2}\right)^2}$$

$$T_v = 7.77 > T_{v_{95}}$$

($d = \frac{H}{2}$ → Two way drainage)

ie. Secondary Settlement will start.

Time Taken to Complete Primary Settlement -

$$1.781 - 0.933 \log(100 - 95) = 3.5 \times \frac{t}{\left(\frac{6}{2}\right)^2}$$

$$t_{95} = 2.90 \text{ Year}$$

Void Ratio after primary settlement -

$$\frac{-\Delta e}{1+e_0} = \frac{\Delta H}{H_0}$$

$$\frac{e_0 - e_{100}}{1+e_0} = \frac{238.97}{6000}$$

$$e_{100} = 0.968$$

Now

Secondary settlement $\Delta H_s = \frac{6000 \times 0.025}{1+0.968} \log \frac{20}{2.90}$

$$= 63.92 \text{ m}$$

Total settlement $\Delta H_{\text{Total}} = 238.97 + 63.92$

$$= 302.89 \text{ mm}$$

Q.5(c) The BOD of a sewage incubated for 5 days at 20°C is 110 mg/l. Calculate the ultimate BOD and one day BOD at 37°C. Assume k_D at 20°C as 0.10 day⁻¹.

[12 marks]

Solⁿ

$$BOD_5 = BOD_u (1 - 10^{-k_D t})$$

$$110 = BOD_u (1 - 10^{-0.1 \times 5})$$

$$BOD_u = 160.87 \text{ mg/l}$$

Now

$$k_{D_{37^\circ\text{C}}} = k_{D_{20^\circ\text{C}}} (1.047)^{37-20}$$

$$= 0.1 (1.047)^{17}$$

$$= 0.218 \text{ day}^{-1}$$

Now

$$BOD_{1/37^\circ\text{C}} = 160.87 (1 - 10^{-0.218 \times 1})$$

$$BOD_{1/37^\circ\text{C}} = 63.49 \text{ mg/l}$$

5 (d) Design a septic tank for a colony for the following data:

Population of colony = 100

Sewage produced per capita per day = 120 litres

Dislodging period = 1 year

Length: Width = 4 : 1

Rate of deposited sludge = 30 litres/capita/year

Detention time = 24 hours

Depth of tank = 1.5 m

[12 marks]

Total Sewage produced per day —

$$V_1 = (100 \times 120 \times 10^{-3}) \times 1$$

$$= 12 \text{ m}^3$$

Total Volume of Sludge Zone Req. —

$$V_2 = (30 \times 10^{-3} \times 100) \times 1$$

$$= 3 \text{ m}^3$$

Total Volume of Septic Tank Req. $V = V_1 + V_2$

$$= 15 \text{ m}^3$$

$$\text{SA. of Septic Tank} = \frac{15}{1.5} = 10 \text{ m}^2$$

$$LB = 10$$

$$(4B)B = 10$$

$$B^2 = 2.5$$

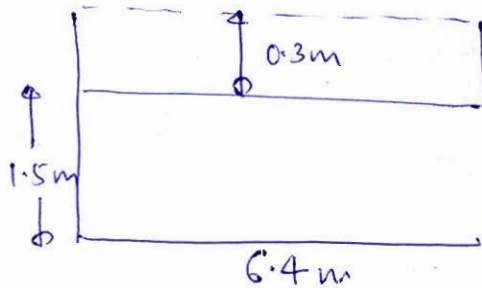
$$B = 1.58 \text{ m}$$

$$B \approx 1.6 \text{ m}$$

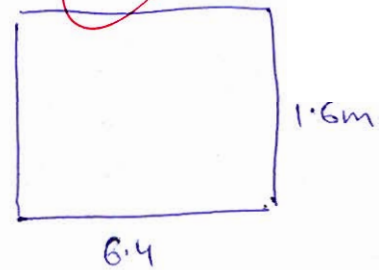
$$\begin{aligned} \text{length } L &= 4B \\ &= 6.4 \text{ m} \end{aligned}$$

$$\text{Height / Depth } H = 1.5 \text{ m}$$

Provide 0.3m freeboard.



Elevation

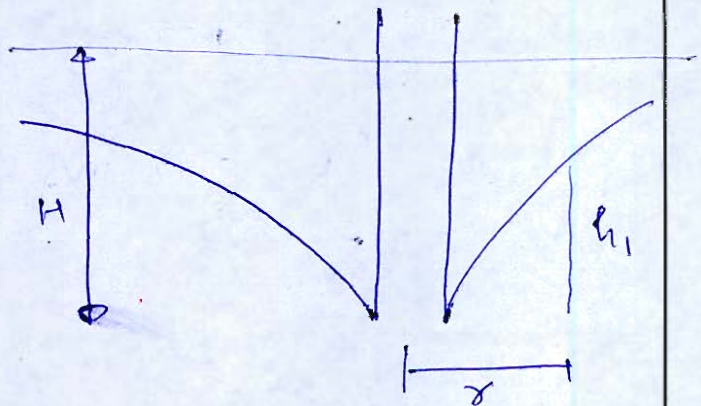


Plan

- Q.5 (e) Derive an expression for determination of permeability in a well Penetrated fully in a unconfined aquifer. For conducting permeability tests on a well which has an unconfined aquifer, two observation wells A and B are bored at distances 20 m and 35 m respectively from the centre of the well. When water is pumped at the rate of 7.5 litres per sec, it is observed that the elevations of the watertable above the impervious layer up to which the well is excavated are 12 m and 12.5 m respectively at A and B. Calculate the permeability of the aquifer.

[12 marks]

Consider a unconfined aquifer of thickness H . Consider drawdown curve as shown at distance r —



$$dq = +k \, idA$$

$$dq = +k \times \frac{dh}{dr} \times (2\pi r h)$$

$$\frac{dr}{r} = \frac{2\pi k}{Q} h \, dh$$

Integrating both sides

$$\int_{r_1}^{r_2} \frac{dr}{r} = \frac{2\pi k}{Q} \int_{H_1}^{H_2} h \, dh$$

$$\ln \frac{r_2}{r_1} = \frac{2\pi k}{Q} \left[\frac{H_2^2 - H_1^2}{2} \right]$$

$$Q = \frac{\pi k (H_2^2 - H_1^2)}{\ln \frac{r_2}{r_1}}$$

Now

$$r_1 = 20 \text{ m}$$

$$r_2 = 35 \text{ m}$$

$$Q = 7.5 \text{ l/s} = 7.5 \times 10^{-3} \text{ m}^3/\text{s}$$

$$H_1 = 12 \text{ m}$$

$$H_2 = 12.5 \text{ m}$$

Now

$$7.5 \times 10^{-3} = \frac{\pi k (12.5^2 - 12^2)}{\ln \left(\frac{35}{20} \right)}$$

$$K = 1.09 \times 10^{-4} \text{ m/s}$$

$$K = 9.42 \text{ m/d}$$

12

- Q.6 (a) (i) With necessary assumptions, derive the expression for permeability of soil for a falling head test.
- (ii) A falling head permeability test was performed on a 20 cm long cylindrical sample of silty clay. The diameter of the soil sample was 10.0 cm and the internal diameter of the standpipe was 1.0 cm. During the test, the water level in the standpipe was observed to fall from an initial height of 80 cm to 50 cm in 15 minutes.
- Determine:
- The coefficient of permeability (k) of the soil in m/day.
 - The height of the water level in the standpipe after an additional 25 minutes of testing.
 - The total time required for the water level to drop to 15 cm.

[10 + 4 + 3 + 3 = 20 marks]

Solⁿ
(i) Assumption while deriving Expression for Permeability of soil for falling head test -

- Flow Assumed to laminar
- Darcy law to be valid
- Viscous forces are negligible which can retard the flow
- one dimensional flow .
- Velocity through medium is directly proportional to hydraulic gradient which in actual it may not be the case

$$v \propto i$$

\Rightarrow

$$v = ki$$

Let Area of soil sample = A

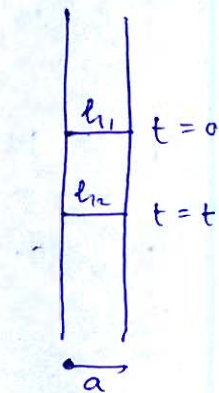
Area of stand pipe = a

length of sample = L

Permeability of soil = k

let at time $t = 0 \Rightarrow$ height of water column in stand pipe = h_1

at time $t = t \Rightarrow$ height = h_2



Acc to Darcy law -

$$Q = k i A$$

$$-a \frac{dh}{dt} = k \frac{h}{L} A$$

$$-\frac{dh}{h} = \frac{kA}{aL} dt$$

Integrating both sides

$$-\int_{h_1}^{h_2} \frac{dh}{h} = \frac{kA}{aL} \int_0^t dt$$

$$\ln \frac{h_1}{h_2} = \frac{kA}{aL} t$$

$$k = \frac{aL}{At} \ln \frac{h_1}{h_2}$$

ii) $L = 20 \text{ cm}$

$D = 10 \text{ cm}$

$d = 1 \text{ cm}$

$h_1 = 80 \text{ cm}$

$h_2 = 50 \text{ cm}$

$t = 15 \text{ min}$

a)

$$K = \frac{\frac{\pi}{4} (1)^2 \times 0.2}{\frac{\pi}{4} (10)^2 \times [15 \times 60]} \ln \left(\frac{80}{50} \right)$$

$$K = 1.04 \times 10^{-6} \text{ m/s}$$

$$K = 0.09 \text{ m/d}$$

b)

$$\text{at } t = 15 + 25 = 40 \text{ min}$$

Now

$$1.04 \times 10^{-6} = \frac{\frac{\pi}{4} (1)^2 \times 0.2}{\frac{\pi}{4} (10)^2 \times [40 \times 60]} \ln \frac{80}{h_2}$$

$$h_2 = 22.97 \text{ m}$$

90

c)

$$1.04 \times 10^{-6} = \frac{\frac{\pi}{4} (1)^2 \times 0.2}{\frac{\pi}{4} (10)^2 \times t} \ln \frac{80}{15}$$

$$t = 3219.18 \text{ sec}$$

$$t = 53.65 \text{ min}$$

- (b) (i) A core sample of undisturbed clay was retrieved from a construction site to assess its consolidation characteristics. To preserve its natural state, the sample was immediately coated with a layer of paraffin wax. In the laboratory, the total mass of the wax-coated specimen was recorded as 725.60 grams, while the mass of the soil specimen alone prior to coating was measured at 715.20 grams. The entire coated assembly was then carefully immersed in a tank, where it was found to displace 395 ml of water. A representative portion of the clay was used to determine the moisture content, which was found to be 21.5%. Given that the specific gravity of the soil solids is 2.72 and the specific gravity of the paraffin wax is 0.9, calculate the bulk density, the dry density, the void ratio, and the degree of saturation of the clay sample.
- (ii) Determine the effective height of a stack using the following data:
- Physical height of stack = 150 m with 1.2 m inside diameter
 - Wind velocity = 3.0 m/s
 - Ambient air temperature = 25°C
 - Barometric pressure = 950 millibars
 - Stack gas velocity = 14 m/s
 - Stack gas temperature = 180°C

[10 + 10 = 20 marks]

Solⁿ
(i)

$$M_{\text{soil}} + M_{\text{pw}} = 725.6 \text{ g}$$

$$M_{\text{soil}} = 715.2 \text{ g}$$

∴

$$V_{\text{soil}} + V_{\text{pw}} = 395 \text{ ml}$$

$$\omega = 21.5\%$$

$$G = 2.72$$

$$G_{\text{pw}} = 0.9$$

Now

$$715.2 + M_{\text{pw}} = 725.6$$

$$M_{\text{pw}} = 10.4 \text{ g}$$

∴

$$V_{\text{pw}} = \frac{10.4}{0.9} = 11.56 \text{ cc}$$

Now

$$V_{\text{soil}} = 395 - 11.56 \\ = 383.44 \text{ cc}$$

(a) Bulk density $\rho_b = \frac{M_{\text{soil}}}{V_{\text{soil}}} = \frac{715.2}{383.44} = 1.865 \text{ g/cc}$

(b) dry density $\rho_d = \frac{\rho_b}{1 + \omega} = \frac{1.865}{1 + 0.215} = 1.535 \text{ g/cc}$

(c) $\rho_d = \frac{G \rho_w}{1 + e}$

$$1.535 = \frac{2.72 \times 1}{1 + e}$$

$$e = 0.772$$

Degree of saturation —

$$S = \frac{wG}{e}$$

$$S = \frac{0.215 \times 2.72}{0.772}$$

$$S = 0.7575$$

$$S = 75.75\%$$

$$H = 150 \text{ m}$$

$$D = 1.2 \text{ m}$$

$$u = 3 \text{ m/s}$$

$$T_a = 25^\circ \text{C} = 298.15 \text{ K}$$

$$T_s = 180^\circ \text{C} = 453.15 \text{ K}$$

$$p = 950 \text{ millibar}$$

$$V_s = 14 \text{ m/s}$$

$$\left. \begin{array}{l} T_s = 180^\circ \text{C} \\ T_a = 25^\circ \text{C} \end{array} \right\} T_s - T_a = 155 \text{ K}$$

20

Acc to Holland's Eqⁿ —

$$\Delta h = \frac{V_s D}{u} \left[1.5 + 2.68 \times 10^{-3} p D \left(\frac{T_s - T_a}{T_s} \right) \right]$$

$$= \frac{14 \times 1.2}{3} \left[1.5 + 2.68 \times 10^{-3} \times 950 \times 1.2 \times \frac{155}{453.15} \right]$$

$$= 14.25 \text{ m}$$

Now

$$\text{Effective Stack Height } H_{eff} = H + \Delta h$$

$$= 150 + 14.25$$

$$= 164.25 \text{ m}$$

- Q.6 (c) (i) A dairy plant processes 1,15,000 kg of milk per day and produces an average of 250 m^3 of wastewater with a BOD of 1200 mg/l . Determine the following:
1. The rate of wastewater flow per 1000 kg of milk received at dairy plant
 2. BOD per 1000 kg of milk received.
 3. BOD equivalent and hydraulic equivalent of population. Assume 85 g of BOD per person per day and waste water at 350 lts per person per day.
- (ii) The per capita water demand of a city is 140 lpcd . Estimate the total daily demand of water for this city in the year 2050, given the population of past six decades of this city is as below:

Year	1970	1980	1990	2000	2010	2020
Population (in lacs)	10	15	21	28	34	37

Use incremental method of population forecasting.

[12 + 8 = 20 marks]

Solⁿ

(i) Rate of waste water flow per 115000 kg of milk -

(ii)

$$Q_w = 250 \text{ m}^3/\text{d}$$

Rate of waste water flow per 1000 kg of milk -

$$Q_w = \frac{250}{115000} \times 1000$$

$$= 2.17 \text{ m}^3/\text{d}$$

BOD of milk per 115000 kg of milk —

$$\text{BOD} = \left(1200 \frac{\text{mg}}{\text{l}} \times 250 \times 10^3 \text{ l} \right) / \text{day}$$

$$= 300 \text{ kg/d}$$

BOD of milk per 1000 kg of milk —

$$\text{BOD} = \frac{300}{115000} \times 1000$$

$$= 2.61 \text{ kg/d}$$

$$\text{BOD equivalent} = \frac{300 \times 10^3}{85} = 3529.41$$

$$\approx 3530$$

$$\text{Hydraulic Equivalent of population} = \frac{250}{0.35}$$

$$= 714.28$$

$$\approx 715$$

Incremental Increase method —

Year	Population (Lakh)	Increase in Population	Incremental Increase
1970	10	5	1
1980	15	6	1
1990	21	7	-1
2000	28	6	-3
2010	34	3	
2020	37		
		27	-2

$$\begin{aligned} \text{avg Increase in population } \bar{x} &= \frac{27}{5} \\ &= 5.4 \end{aligned}$$

$$\begin{aligned} \text{avg incremental Increase in population } \bar{y} &= \frac{-2}{4} \\ &= -0.5 \end{aligned}$$

Now

Population in 2050 —

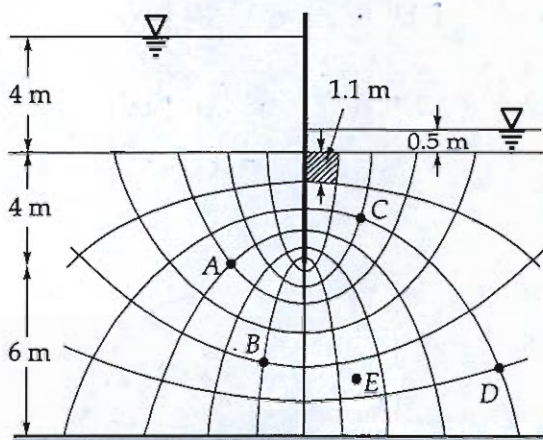
$$\begin{aligned} P_{2050} &= P_{2020} + n\bar{x} + \frac{n(n+1)}{2} \bar{y} \\ &= 37 + 3 \times 5.4 + \frac{3(3+1)}{2} (-0.5) \\ &= 50.2 \text{ lakh} \end{aligned}$$

$$\text{Total Daily demand of water} = (50.2 \times 10^5) \times 140 \text{ l/d}$$

$$Q_{\text{avg}} = 702.8 \times 10^6 \text{ l/d}$$

$$Q_{\text{avg}} = 702.8 \text{ MLD}$$

- (a) (i) With reference to Figure, determine the following:
- (a) The pressure heads at the points A and total head at E.
 - (b) The exit gradient.
 - (c) Factor of safety against piping.
 - (d) Quantity of Seepage beneath the per m length of sheet pile.
- Given, $G = 2.65$, $e = 0.90$, $k = 0.002$ cm/sec.



[3 + 2 + 2 + 3 = 10 marks]

- (ii) A 5 m thick clay layer in the field is underlain by an impermeable rock stratum and overlain by coarse sand. A 25 mm thick undisturbed sample of the same clay was tested in the laboratory with drainage at both top and bottom. The sample reached 60% consolidation in 12 minutes. Determine the time required for the field layer to reach 85% consolidation.

[10 marks]

Solⁿ

(i)

Consider Datum at Tail race level -
at Entry Point -

$$\text{Total Head } TH = 4 - 0.5 = 3.5 \text{ m}$$

$$\text{Datum Head } DH = -0.5 - 4 = -4.5 \text{ m}$$

$$\begin{aligned} \text{Pressure Head } PH &= TH - DH \\ &= 7.5 \text{ m} \end{aligned}$$

at E -

Total

Solⁿ

(i)

Consider Datum at Tail Race level -
at Entry Point -

$$\text{Pressure head } PH = 4 \text{ m}$$

$$\text{Datum head } DH = -0.5 \text{ m}$$

$$\begin{aligned} \text{Total Head } TH &= PH + DH \\ &= 3.5 \text{ m} \end{aligned}$$

at Exit point -

$$\text{Pressure head } PH = 0$$

$$DH = 0$$

$$\begin{aligned} TH &= PH + DH \\ &= 0 \text{ m} \end{aligned}$$

Net head under which flow takes place

$$h = 3.5 - 0 = 3.5 \text{ m}$$

$$\text{Total Flow Lines } N_f = 7$$

$$\text{Total Equipotential drop } N_e = 12$$

$$\begin{aligned} \text{Total head at A} &= 3.5 - \frac{3}{12} \times 3.5 \\ &= 2.625 \text{ m} \end{aligned}$$

$$DH = -4.5 \text{ m}$$

Now

$$\begin{aligned} PH &= TH - DH \\ &= 7.125 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{Total head at E} &= 3.5 - \frac{2.5}{12} \times 3.5 \\ &= 1.3125 \text{ m} \end{aligned}$$

~~DER~~

$$i_{\text{exit}} = \frac{h}{N_d l} = \frac{3.5}{(2 \times 1.1)} = 0.265$$

FOS piping - ?

$$i_{\text{cr}} = \frac{G-1}{1+e} = \frac{2.65-1}{1+0.9} = 0.868$$

$$FOS = \frac{i_{\text{cr}}}{i_{\text{exit}}} = \frac{0.868}{0.265} = 3.28$$

$$q = k h \frac{N_f}{N_d}$$

$$= 0.002 \times 10^{-2} \times 3.5 \times \frac{7}{12}$$

$$= 4.00 \times 10^{-5} \text{ m}^3/\text{s}/\text{m}$$

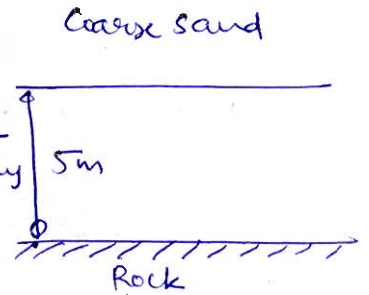
(ii)

one way drainage

$$d = H = 5 \text{ m}$$

For 25 mm sample at two way drainage -

$$T_{w_{60}} = 1.781 - 0.933 \log(100 - 60) \\ = 0.283$$



∴

$$0.283 = C_v \times \frac{12}{\left(\frac{25}{2}\right)^2}$$

$$C_v = 3.685 \text{ mm}^2/\text{min}$$

In field -

$$T_{w_{85}} = 1.781 - 0.933 \log(100 - 85) \\ = 0.6837$$

20

Now

$$0.6837 = 3.685 \times \frac{t}{(5000)^2}$$

$$t = 4638445.42 \text{ min}$$

$$t = 0.825 \text{ Year}$$

(b) (i) Explain the concept of break point chlorination in water treatment with a neat diagram.

(ii) The chemical analysis of a water sample gives the following ionic concentrations:

$$\text{Calcium (Ca}^{2+}\text{)} = 60 \text{ mg/L}$$

$$\text{Magnesium (Mg}^{2+}\text{)} = 24 \text{ mg/L}$$

$$\text{Bicarbonate (HCO}_3^{-}\text{)} = 183 \text{ mg/L}$$

$$\text{Carbonate (CO}_3^{2-}\text{)} = 30 \text{ mg/L}$$

$$\text{Chloride (Cl}^{-}\text{)} = 71 \text{ mg/L}$$

$$\text{Sulphate (SO}_4^{2-}\text{)} = 48 \text{ mg/L}$$

Assume that hydroxide alkalinity is absent.

(i) Calculate the total alkalinity of the water sample in mg/L as CaCO_3 .

(ii) Determine the total hardness in mg/L as CaCO_3 .

(iii) Compute the carbonate hardness and non-carbonate hardness of the water sample in mg/L as CaCO_3 .

[8 + 12 = 20 marks]

Conc of Ions as mg/L of CaCO_3 —

$$\text{Ca}^{++} = \frac{60}{20} \times 50 = 150 \text{ mg/L as CaCO}_3$$

$$\text{Mg}^{++} = \frac{24}{12} \times 50 = 100 \text{ mg/L as CaCO}_3$$

$$\text{HCO}_3^{-} = \frac{183}{61} \times 50 = 150 \text{ mg/L as CaCO}_3$$

$$\text{CO}_3^{--} = \frac{30}{30} \times 50 = 50 \text{ mg/L as CaCO}_3$$

$$\text{Cl}^{-} = \frac{71}{35.5} \times 50 = 100 \text{ mg/L as CaCO}_3$$

$$\text{SO}_4^{--} = \frac{48}{48} \times 50 = 50 \text{ mg/L as CO}_3$$

For Electrical Neutrality —



$$3 + 2 + \text{H}^{+} = 3 + 1 + 2 + 1$$

$$\boxed{\text{H}^{+} = 2 \text{ meq/L}}$$

$$\begin{aligned} H^+ &= 2 \times 50 \\ &= 100 \text{ mg/L as CaCO}_3 \end{aligned}$$

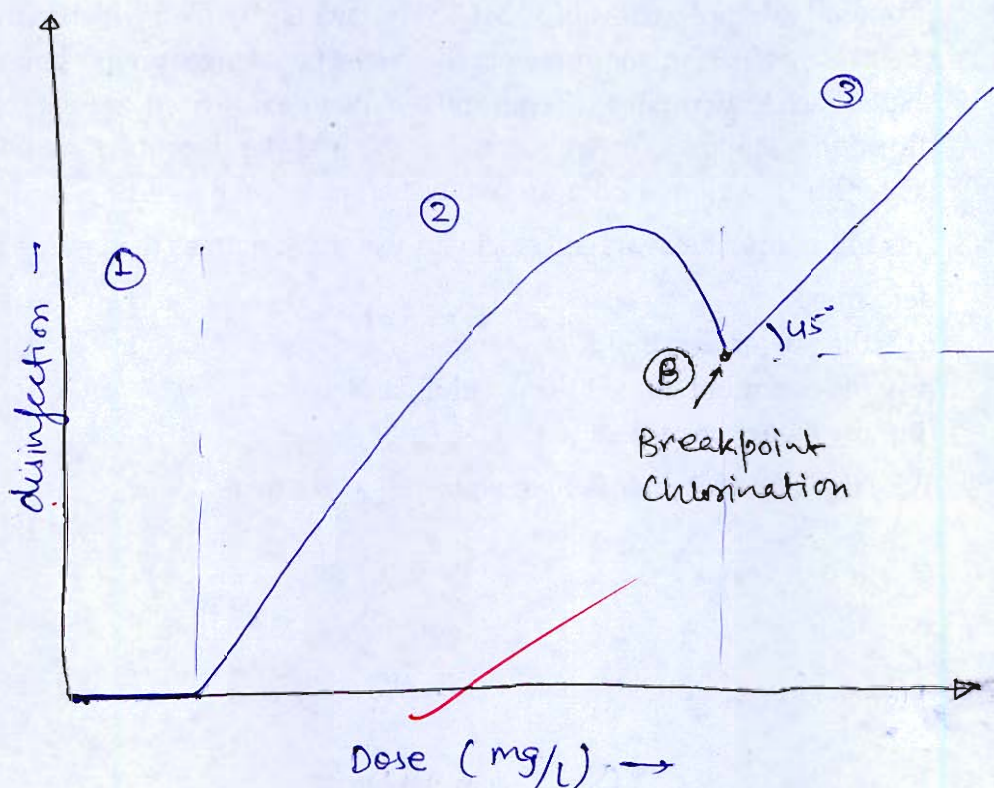
$$\begin{aligned} \text{(i) Total Alkalinity} &= \text{CO}_3^{--} + \text{HCO}_3^- + \text{OH}^- - \text{H}^+ \\ &= 50 + 150 + 0 - 100 \\ &= 100 \text{ mg/L as CaCO}_3 \end{aligned}$$

$$\begin{aligned} \text{(ii) Total Hardness} &= \text{Ca}^{++} + \text{Mg}^{++} \quad (3) \\ &= 150 + 100 \\ &= 250 \text{ mg/L as CaCO}_3 \end{aligned}$$

$$\begin{aligned} \text{(iii) Carbonate hardness CH} &= \min \left[\begin{array}{c} \text{TH} \\ \text{TA} \end{array} \right] \\ &= \min \left[\begin{array}{c} 100 \\ 250 \end{array} \right] \\ &= 100 \text{ mg/L as CaCO}_3 \end{aligned}$$

$$\begin{aligned} \text{Non Carbonate hardness NCH} &= \text{TH} - \text{CH} \\ &= 250 - 100 \\ &= 150 \text{ mg/L as CaCO}_3 \end{aligned}$$

Breakpoint chlorination -



Part 1 - Reduction of metals

Part 2 - Pathogen destroys

Ⓑ — Break point Chlorination (BPC) ⑤
 — (That means disinfection completes & any further dose results in free residual after BPC)

Part 3 - Any dose after Break point chlorination results in free residual.

$$\text{Dose} = \text{Demand} + \text{Free Residual}$$

- Q.7 (c) (i) Explain the mechanism of Coagulation in reference to water treatment.
- (ii) A mechanically mixed flocculation tank having dimensions $32 \text{ m} \times 10 \text{ m} \times 4.8 \text{ m}$ is proposed to handle a flow of 80 MLD. The tank is provided with rectangular paddles of size $10 \text{ m} \times 0.35 \text{ m}$, mounted parallel to the tank length on five horizontal rotating shafts. Each shaft rotates at 3 rpm and two paddles are fixed on each shaft in opposite directions. The paddles are located at the mid-depth of the tank with the paddle center line positioned 2.0 m from the shaft axis. Take $C_d = 1.8$

Assuming that the average velocity of water is 0.6 times the paddle tip velocity, determine:

- (i) the power required for mixing,
 (ii) the detention time of flocculation, and
 (iii) the velocity gradient (G).

Take the kinematic viscosity of water $1.0 \times 10^{-6} \text{ m}^2/\text{s}$.

[8 + 12 = 20 marks]

Soln.

(ii)

$$\text{Flocculation Tank} = 32 \times 10 \times 4.8 \text{ m}^3$$

$$Q = 80 \text{ MLD}$$

$$\begin{aligned} \text{Area of Paddles } A_p &= 10 \times 0.35 \times 5 \times 2 \\ &= 35 \text{ m}^2 \end{aligned}$$

$$\text{distance } r = 2 \text{ m}$$

$$C_d = 1.8$$

Now

$$V_p = V - V_w$$

$$= V - 0.6V$$

$$= 0.4V$$

$$= 0.4 \times 80$$

$$= 0.4 \times \frac{2\pi N}{60}$$

$$= \frac{\pi}{75} \text{ N/s}$$

Power Req -

$$P = F v$$

$$P = C_D \frac{1}{2} \rho A_P V^2 \cdot V$$

$$P = \frac{C_D}{2} \rho A_P V^3$$

$$P = \frac{C_D}{2} \rho A_P \left(\frac{\pi}{35} N r \right)^3$$

$$P = \frac{1.0}{2} \times 1000 A_P \left(\frac{\pi}{35} \right)^3 \times N^3 r^3$$

$$P = 0.066 A_P N^3 r^3$$

$$P = 0.066 \times 35 \times (3)^3 \times (2)^3$$

$$P = 498.96 \text{ W}$$

$$D_t = \frac{V}{Q} = \frac{32 \times 10 \times 4.8}{80 \times 10^6 \times 10^{-3}} \text{ day}$$

$$= 0.4608 \text{ hour}$$

$$= 27.648 \text{ min}$$

12

$$Q = \sqrt{\frac{P}{\mu v}}$$

$$\frac{\mu}{P} = r$$

$$Q = \sqrt{\frac{498.96}{(10^{-6} \times 10^3) (32 \times 10 \times 4.8)}}$$

$$Q = 18.03 \text{ sec}^{-1}$$

(i) Coagulation -

- It is a process of mixing raw water with coagulating agent in order to enhance the ability to set impurities in sedimentation tank.
- Coagulation is followed by flocculation which increases the efficiency of coagulation.
- Both these processes are now carried out in Clariflocculator.

Mechanism of Coagulation -

13

- (a) Ionic layer absorption
- (b) Interparticle bridging
- (c) Charge neutralisation
- (d) Sweep Coagulation.

- (a) (i) What is the earth pressure at rest? Derive the relationship.
- (ii) A 6 m high rigid retaining wall has to retain a backfill of dry, cohesionless soil having the following properties:
- $$\phi = 30^\circ, e = 0.72, G = 2.67, \mu = 0.35.$$
- (a) Plot the distribution of lateral earth pressure on the wall at rest.
- (b) Determine the magnitude and point of application of the resultant thrust.
- (c) Compute the percent change in the lateral thrust if the water table rises from a great depth to the top of the backfill.

[8 + 12 = 20 marks]

- Q.8 (b) (i) A square pile group of 16 piles penetrates through a filled-up compressible soil of 3 m depth the pile diameter is 250 mm and pile spacing is 0.75 m the unit cohesion of the material is 18 kN/m^2 . Sketch plan and elevation view of the pile group and compute the negative skin friction on the group.
(Take unit weight of soil is 15 kN/m^3 and adhesion factor as 0.4, use uniform cohesion)
- (ii) Design a raw water pumping station to draw water from a perennial river for a town with the following data:
Population to be served = 6.0 lakh
Average daily water demand = 160 lpcd
Peak summer demand = 180% of average demand
Pumping hours per day = 12 hours
Normal water level in river = RL 205.00 m
Lowest water level in summer = RL 201.50 m
Water is to be pumped to a treatment plant inlet at RL 220.00 m
Rising main diameter = 1.0 m
Head loss due to friction in rising main during peak summer = 2.8 m
Overall efficiency of pump and motor = 70%
- Determine:**
- Discharge capacity of the pump required during peak summer (m^3/s)
 - Horsepower (HP) of the pump required

[10 + 10 = 20 marks]



- Q.8 (c) (i) What is the zeolite process of removing hardness. Discuss the advantage and disadvantage of it.
- (ii) A water supply system is provided with an ion-exchange softener containing 0.06 m^3 of resin having an ion-exchange capacity of 45 kg/m^3 expressed as CaCO_3 . The daily water requirement of consumers is 900 litres per day. Chemical analysis of the raw water indicates that it contains 80 mg/L of calcium (Ca^{2+}) and 36 mg/L of magnesium (Mg^{2+}). The consumers require softened water having hardness not exceeding 100 mg/L as CaCO_3 . Assuming that the ion-exchange resin works with 100% efficiency and that complete saturation of the resin occurs before regeneration, determine
- (i) the quantity of water to be bypassed daily and
- (ii) the time interval between two successive regenerations interval of the resin.

[8 + 12 = 20 marks]

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

$$Q = \frac{\pi K (h_2^2 - h_1^2)}{\ln\left(\frac{R_2}{R_1}\right)}$$

$$Q = k \frac{dh}{dr} \quad (2\pi r dh)$$

$$Q = k \frac{dh}{dr} \quad 2\pi r h$$

$$\frac{dr}{r} = \frac{2\pi k \int h dh}{Q} \quad h^2$$

