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 ☑	Bhopal ☐	Jaipur ☐	
Pune ☐	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	35
Q.2	46
Q.3	—
Q.4	—
Section-B	
Q.5	50
Q.6	44 + 8
Q.7	56
Q.8	—
Total Marks Obtained	239

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

Good

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]

(a)

(i) Prime coat:

Prime coat is a layer which is sprayed over granular base course in order to fill the bitumen to the base course in order to fill/block voids and increase the life of pavement.

(ii) Tack Coat:

Tack coat is provided between two layers in order to provide the binding between both the layers. This is provided between the base course and surface course.

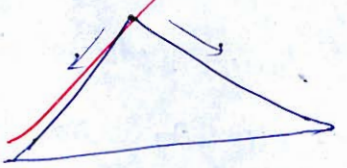
3

(ii) Bitumen emulsion

(ii) Drainage requirement of highway

→ For the drainage purpose on highway a combination of longitudinal slop and camber should be maintained to drain the water off.

(1) The camber is the elevation of centre line of road.



4

→ For Bituminous concrete : camber = 2.5%.

→ For cement concrete pavements = 2%.

and slope of shoulder should also be provided such that; camber of shoulder = (camber + 0.5%) which should not be less than 3%.

(2) Longitudinal slope is also provided in order to drain the water.

As per IRC 73:2023; longitudinal slops for

(1) Concrete drains = $\frac{1}{500}$

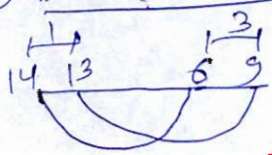
(2) Natural (soil) drain = $\frac{1}{200}$

(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]

① Bubble Tube A



sensitivity; $\left(\alpha = \left(\frac{S}{nD} \times 206265\right)''\right)$ · (2)

$n = \frac{1+3}{2} = 4$

for Tube A;

$S = 1.867 - 1.718$
$= 0.149$

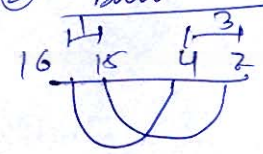
$D = 75\ m$

$\therefore \quad \alpha = \frac{0.149}{2 \times 75} \times 206265$

$\alpha_A = 204.8899''$

Do work on the Concept

② Bubble Tube B



$n = \frac{1+3}{2} = 2$

$\therefore \quad S = 1.888 - 1.735 = 0.153$

$\alpha_B = \frac{0.153}{2 \times 75} \times 206265$

$\alpha_B = 210.3903''$

$\therefore \quad \alpha_A < \alpha_B$ $\therefore$ A is more sensitive than B.

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/cm^2

Thickness of pavement slab = 20 cm

Poisson's ratio of cement concrete = 0.15

Modulus of subgrade reaction = 10.0 kg/cm^3

Radius of contact area = 14 cm

[12 marks]

Given

$P = 4200$ kg

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

$h = 20$ cm

$\mu = 0.15$

$K = 10$ kg/cm^2

$a = 14$ cm

(1) Radius of relative stiffness (ℓ)

$$\ell = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4}$$

$$\ell = \left[\frac{2.8\times10^5 \times (20)^3}{12\times10(1-0.15^2)}\right]^{1/4}$$

$$\ell = 66.1054 \text{ cm}$$

12

(2) Equivalent Radius of resisting section (b)

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

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

$$b = 13.213 \text{ cm}$$

$a = 14\text{cm} < 1.724h = 34.48$ OK

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

$$S_i = \frac{0.316\times4200}{20^2}\left[4\log_{10}\left(\frac{66.1054}{13.213}\right) + 1.069\right]$$

Stress Interior $S_i = 12.87 \text{ kg/cm}^2$ Ans 8

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

$$S_e = 18.9545 \text{ kg/cm}^2$$

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

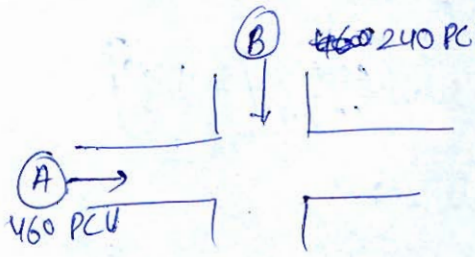
$$= \frac{3\times4200}{20^2}\left[1 - \left(\frac{14\sqrt{2}}{66.1054}\right)^{0.6}\right]$$

$$S_c = 16.2189 \text{ kg/cm}^2$$

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]

Ans



(1) $y_B = \frac{240}{1000} = 0.24$

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

$Y = 0.24 + 0.354$

$Y = 0.594$

Cond

(2) $L = 2n + R$

$= 2(2) + 12$

$L = 16$ sec (2 phase)

all red time = 12 sec

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

$C_0 = \frac{1.5(16) + 5}{1 - 0.594} = 71.428$ sec

and $G_A = \frac{y_A}{Y}(C_o - L)$

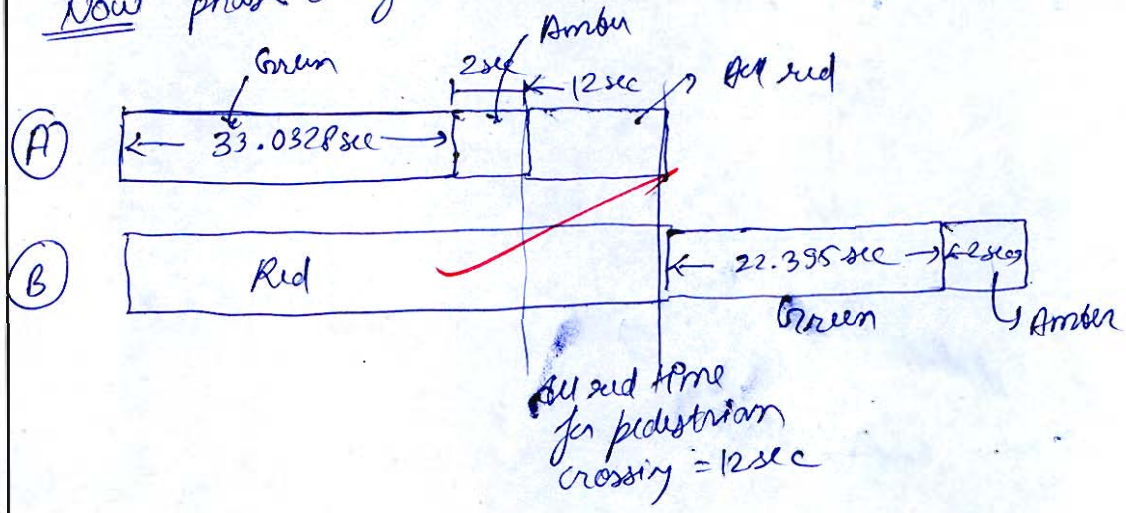
$= \frac{0.354}{0.594}(71.428 - 16)$

$G_A = 33.0328$ sec

similarly $G_B = 22.395$ sec

12

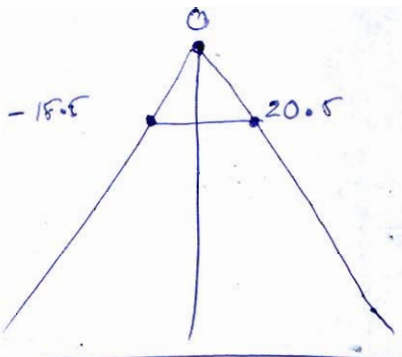
Now phase diagram



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]



$$\frac{x_a}{x} = \frac{y_a}{y} = \frac{f}{H-h_{avg}}$$

a) $\frac{20}{x} = \frac{15.5}{y} = \frac{30}{1200-250}$

$X_1 = 633.33\ m$

$Y_1 = 490.833 m$

b) $\frac{-15.5}{x} = \frac{-20.5}{y} = \frac{30}{1200-210}$

$X_2 = -511.5\ m$

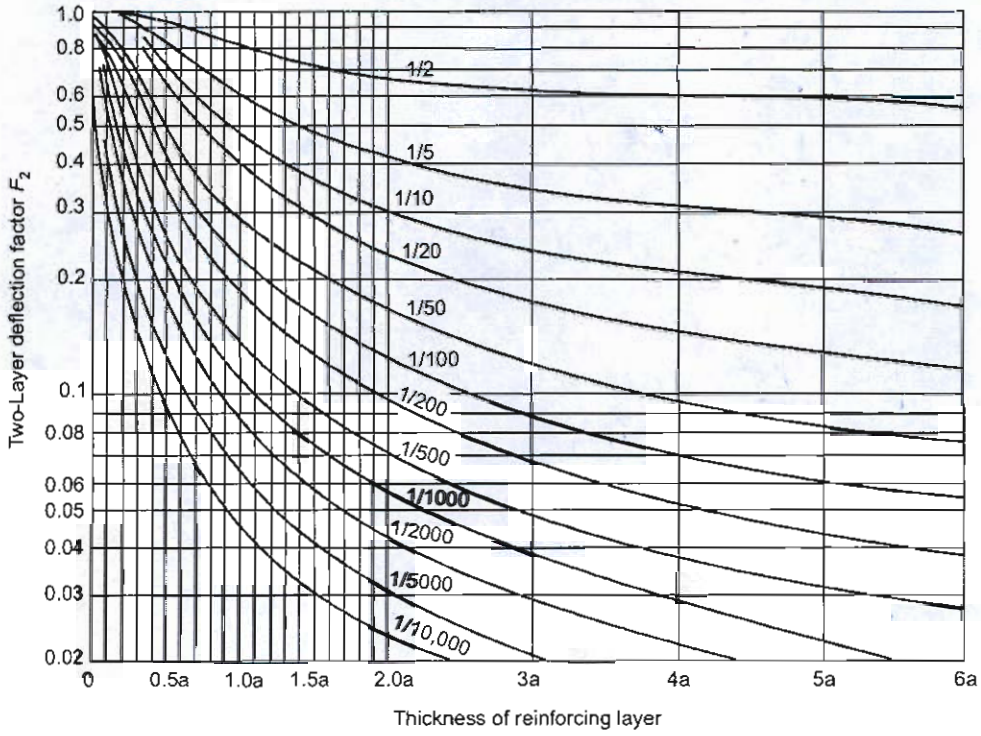
$Y_2 = -676.5\ m$

Length AB $= \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}$

$= \sqrt{(633.33 + 511.5)^2 + (490.833 + 676.5)^2}$

$AB = 1436.28\ m$

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

(i) ~~a = 15 cm~~ Plate Load Test

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

$$0.5 = 1.18 \times \frac{1.25 \times 15}{E_s} \times F_2 \quad \{\text{subgrade } F_2 = 1\}$$

$$\boxed{E_s = 44.25 \text{ kg/cm}^2}$$

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

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

$$\boxed{F_2 = 0.25}$$

and ~~$\frac{h}{a} = $~~

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

$$h = 1.33a$$

$$\boxed{\frac{E_s}{E_p} = \frac{1}{500}}$$

Now ~~Type to~~ Wheel Load Test

$$p = \frac{P}{\pi a^2}$$

$$a = \sqrt{\frac{P}{p\pi}} = \sqrt{\frac{4100}{6 \times \pi}} = 14.748 \text{ cm}$$

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

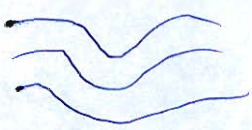
$$0.5 = 1.5 \times \frac{6 \times 14.748}{44.25} \times F_2$$

$$\boxed{F_2 = 0.16628} \quad \text{and} \quad \boxed{\frac{E_s}{E_p} = \frac{1}{50}}$$

from graph; $\frac{h}{a} = 2.2$

$h = 2.2 \times 14.748$

$h = 32.4456$ cm

(ii) Basis	Rigid Pavement	Flexible Pavement
→ Flexural rigidity	It has very high flexural rigidity (EI)	→ It has negligible flexural rigidity. (15)
→ Layers	It has usually 3 layers namely subgrade, Base course and Surface course	→ It has 4 layers namely subgrade, Sub base course, Base course and surface course
→ Failure transmission	~~It fail due The failure of subgrade do Not have its~~  The failure is not transmitted to top layer.	→ The failure of subgrade is transferred to top layer 
→ Life and maintainance	It has higher initial cost but also have high life along with low maintainance.	→ It has lower initial cost but have higher maintainance and low life period.
→ Surface course	It is made of PCC or RCC	→ It is Bituminous layer. concrete at top

failure	Mud pumping is one of the failure of rigid pavement.	Rutting and fatigue are primary failures

(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]

① $R_{ruling\ minimum\ speed} = \dfrac{V^2_{ruling}}{127\,(e_{max} + 0.15)}$

$R_{RMR} = \dfrac{(110)^2}{127(0.07 + 0.15)}$

$e_{max} = 0.07$ for flat terrain

$R_{RMR} = 433.07\ m$

② Design of super elevation:

$e + f = \dfrac{V^2}{225R}$

$e = \dfrac{110^2}{225 \times 433.07}$

$e = 0.124 > 0.07$

∴ provide $e_{max} = 0.07$ and check f

$e + f = \dfrac{V^2}{127R}$

$f = 0.1499$ Check OK

∴ $e = e_{max} = 0.07$

~~* Extra widening of pavement~~

~~(1) $W_e = \frac{n\ell^2}{2R}$ ∴ $R > 300$ m, no need of extra widening.~~

(3) Extra widening

(R = 433.07 m)

~~Even if the extra widening is not required as $R > 300$ m but I am calculating it as follows:~~

$$W_e = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

assuming $\ell = 6.1$ m

$$= \frac{4 \times (6.1)^2}{2 \times 433.07} + \frac{110}{9.5\sqrt{433.02}}$$

$$W_e = 0.7282 \text{ m}$$

(4) Length of transition curve

(1) As per introduction of centrifugal acceleration

$$C = \frac{80}{75+V} = 0.4324$$

$$C = 0.5 \text{ m/sec}^3$$

$$\therefore L_{TC} = \frac{0.0215\, V^3}{CR}$$

$$= \frac{0.0215 \times 110^3}{0.5 \times 433.02}$$

$$L_{TC} = 132.186 \text{ m}$$

(2) As per introduction of SG;

$W + W_e = 3.75 \times 4 + 2 \times 2 + 0.7282$

↓

paved shoulder → nos = 2 in divided carriageway

$W + W_e = 19.7282$

$N = 150$

assuming rotation about inner edge

$L_{TC} = \ell N (W + W_e)$

$L_{TC} = 2070146$ m Ans

(3) Min

$L_{TC_m} = \frac{2.7 V^2}{R}$

$= 78.43$

17

(9i) Advantages of traffic signal

a) Cost of intersection at different grade is higher which is eliminated

b) Traffic signal can help the passage of pedestrian

(ii) Disadvantage of Traffic Signal

a) Slows down the traffic and hence the travel time increases

b) It will require continuous monitoring to check the flow and accordingly change the phase times or cycle times.

(iii) Requirements for provision of intersection at grade

(1) min volume > 1000 veh/hr

max volume < 3000 veh/hr

(2) The intersecting traffic is more than 80% or right turning traffic is more than 30%.

(3) The speed for urban intersection is 30 kmph and speed for rural area intersection 40 kmph

(4) The entry width should be reduced to slow down incoming traffic and exit width should be increased to exit traffic quickly.

Do not write this m

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 mm^2

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/m^2

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

Radius of the Earth = 6370 km

[20 marks]

(1) $P_0 = 95\ N$ $T_0 = 18°C$

W of tape = $0.025\ kg/m \times 30\ m$
$= 0.75\ kg$
$= 7.3575\ N$

$E = 14.8 \times 10^4 \times 10^6\ \frac{kN}{m^2}$

$E = 14.8 \times 10^4\ \frac{N}{mm^2}$

Span (1)

(1) Temp correction $C_T = l_0\,\alpha\,(T_m - T_0)$
$= 29.988\,(0.9 \times 10^{-6})\,(15 - 18)$
$= -8.09676 \times 10^{-5}\ m$

(2) Pull correction $C_{pull} = \frac{-(P_m - P_0)\,l_0}{AE}$
$= \frac{(155 - 95)\,29.988}{3.35 \times 14.8 \times 10^4}$

$C_{pull} = 3.629 \times 10^{-3}\ m$

(3) Pull sa correction due to sag $C_{sag} = \frac{-W^2 l_0}{24 P_m^2}$
$= \frac{-7.3575^2 \times 29.988}{24 \times 155^2}$
$= -2.815 \times 10^{-3}\ m$

④ Correction due to slope = $\frac{-h^2}{2l_0} = \frac{-(0.346)^2}{2l_0} = -1.996 \times 10^{-3}$ m

- ~~Span~~ ~~Correction~~ -

$l = MV + C$

$= 29.988 + C$

$l_1 = 29.9867$ m

Span ②

① $C_T = -29.895\,(0.9 \times 10^{-6})(15 - 18) = -8.07165 \times 10^{-5}$ m

② $C_{pull} = \frac{(155 - 95)\,29.895}{3.35 \times 14.8 \times 10^4} = 3.6177 \times 10^{-3}$ m

③ $C_{sag} = -\frac{7.3575^2 \times 29.895}{24 \times 155^2} = -2.8066 \times 10^{-3}$ m

④ Correction due to slope = $-\frac{(0.214)^2}{2 \times 29.895} = -7.659 \times 10^{-4}$ m

14

$l = MV + C$

$l = 29.895 + C$

$l_2 = 29.8949$ m

Span ③

① $C_T = -8.05626 \times 10^{-5}$ m

② $C_{pull} = 3.61089 \times 10^{-3}$ m

③ $C_{sag} = -2.80127 \times 10^{-3}$ m

④ $C_{slope} = -1.5999 \times 10^{-3}$ m

~~Span ④~~ $l_3 = 29.837$ m

~~① CT =~~

~~② Cpull~~

Span ④

① $C_T = -8.0757 \times 10^{-5}$ m

② $C_{pull} = 3.6196 \times 10^{-3}$ m

③ $C_{sag} = -2.808 \times 10^{-3}$ m

④ $C_{slope} = -1.8783 \times 10^{-4}$

$l_4 = 29.907$ m

Correct length of Base cone = $l_1 + l_2 + l_3 + l_4$

$l = 119.6256\,m$

Correction for reduction to MSL

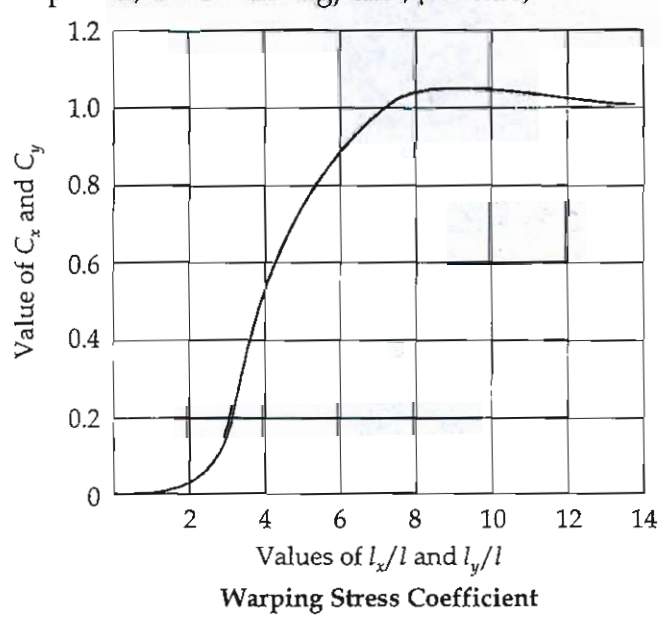
$C_{MSL} = -\frac{h_0 l_0}{R}$

$C_{MSL} = -\frac{120 \times 119.6256}{6370000}$

$l_{MSL} = 119.6233\,m$

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:

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

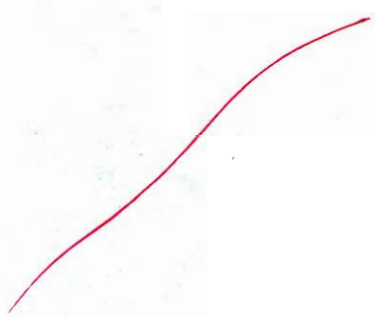


Warping Stress Coefficient

(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.

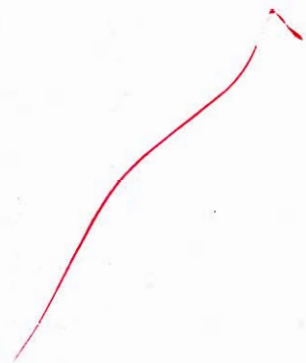
1.735, 1.625, 1.580, 1.250, 1.115, 2.010, 1.325, 1.055, 1.095, 0.955. Show also the arithmetical check.

[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.

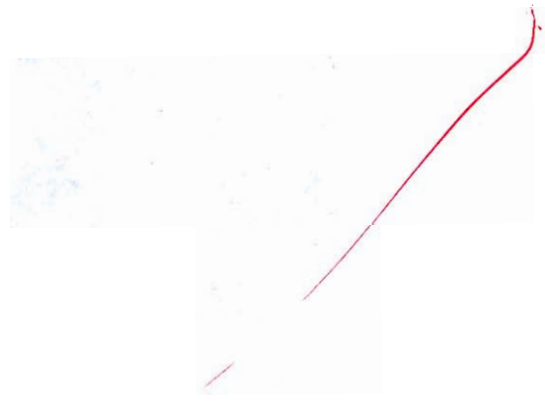
[20 marks]



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]

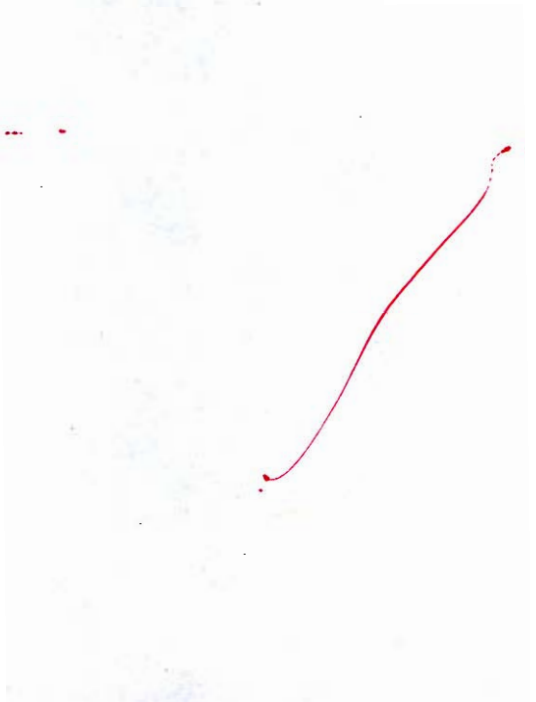


.4 (a) **(i)** Adjust the angular error in the observations (if any) and calculate the bearings of the traverse lines in the following systems if whole circle bearing of the line *AB* is 30°:

Traverse station	Included angle
A	120°35′00″
B	89°23′40″
C	131°01′00″
D	128°02′20″
E	94°54′40″
F	155°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:

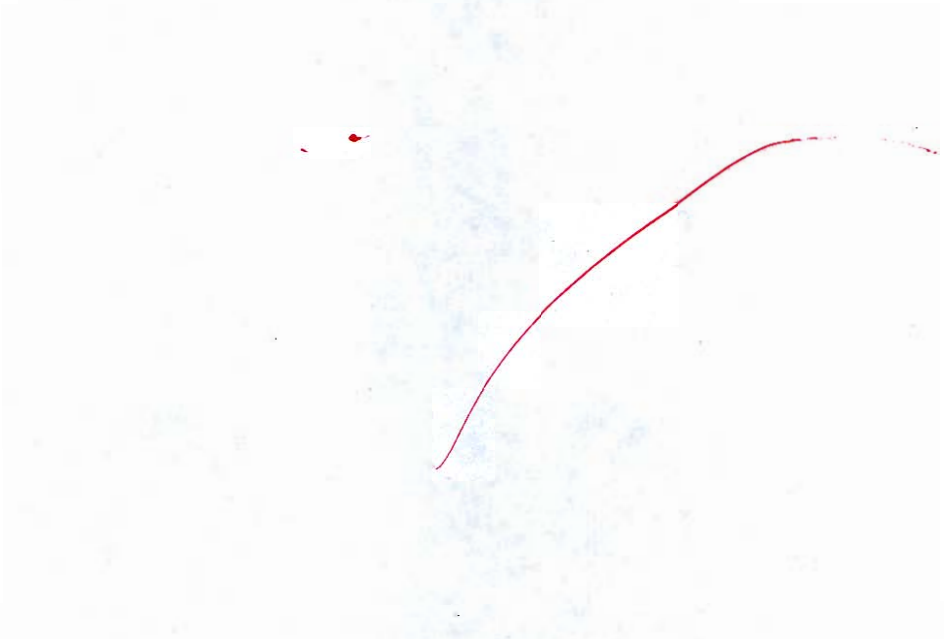
Speed Range (kmph)	No. of Vehicles observed
0 – 10	12
10 – 20	35
20 – 30	55
30 – 40	60
40 – 50	140
50 – 60	230
60 – 70	320
70 – 80	95
80 – 90	45
90 – 100	28

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]



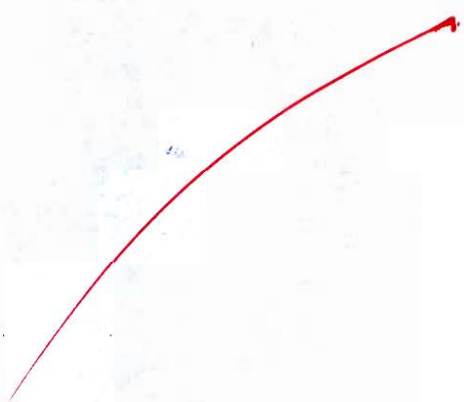
Q.4 (c) A tachometer fitted with an anaclitic lens was set up at station B and the following observations were recorded. The value of the multiplying constant is 100.

Station	Station sighted	Bearing	Vertical angle	Staff readings (m)
B	A	325°30′	+3°20′	0.750, 1.000, 1.250
	C	55′30′	+2°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

- Triaxial test is done to determine the shear strength of the soil specimen under various conditions and of various type of soil.

Conditions such as:

(1) Unconsolidated undrained test (quick test) – Q (UU)

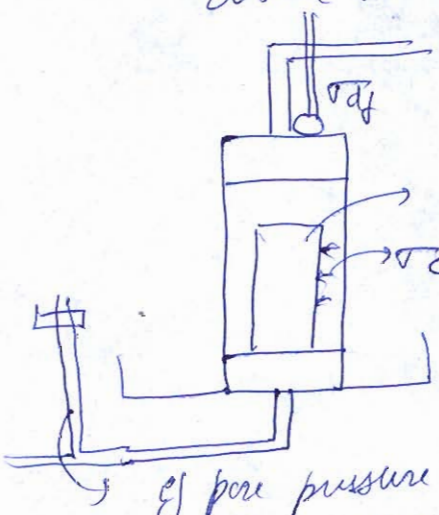
- To analyze the stability of clayey soil for short term.
- The drainage valves are closed on shearing as well as confining stage.

(2) Consolidated Drained test – S (CD)

- To analyse stability of soil in long term.
- Drainge valve are open on both confining and shearing stage.

(3) Consolidated Undrained test (CU test) – R

- To analyse stability of the soil foundation / embankment which is there for a long term but stability is to be checked for the new rapid loading.
- Drainage valve is open in confining stage and closed on shearing stage.



specimen inclosed in rubber membrane.

If pore pressure is to be measured while undrained condition.

Method:

→ (1) In Confining Stage

The confining pressure is applied with the help of water surrounding the specimen. The valve are closed of the stage is unconsolidated and opend in consolidation case.

(2) Deviatoric stage

The deviatric stage is applied with the help of axial force which shear the specimen. The condition that are maintained are undrained and drained.

Merits of triaxial test

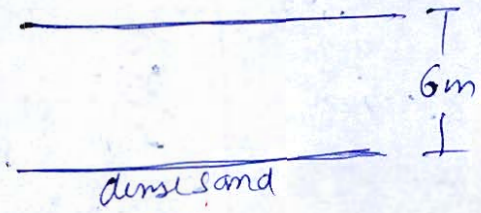
(1) The shearing (failure) surface is unknown initialy.
(2) Different type of soils can be tested to find shear strength of soil unlike other tests.
(3) The different type of field condition can be maintained in lab namely UU, CD, CU. So long term and short term stability can be checked.
(4) Test can be done at different confining pressure.

Demerits of triaxial test

(1) It is a time taking process. One one side UU take 10-20 mins while CD can take days.
(2) Need a specialized technical person to perform this test.

5 (b) A 6 m thick clay layer (e_0 = 1.05, C_c = 0.40, C_α = 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 m²/year. Calculate the total settlement (in mm) after 20 years, assuming primary consolidation is complete at U = 95%.

[12 marks]



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

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

$e_0 = 1.05$ $C_c = 0.4$ $C_\alpha = 0.025$

(1) $\Delta H = \dfrac{H_0 C_c}{1+e_0} \log_{10}\left(\dfrac{\bar{\sigma}_0 + \Delta\bar{\sigma}}{\bar{\sigma}_0}\right)$

$\Delta H = \dfrac{6 \times 0.4}{1+1.05} \log_{10}\left(\dfrac{125+75}{125}\right)$

$\Delta H = 238.96$ mm → primary consolidation

(2) $T_v = C_v \dfrac{t}{d^2}$

$T_v = \dfrac{3.5\ m^2}{year} \times \dfrac{20\ years}{(6)^2}$

$T_v = 1.9444$

$1.9444 = 1.783$

95% consolidation;

$T_v = 1.783 - 0.933 \log_{10}(100-95)$

$T_v = 1.1308$

$1.1308 = C_v \dfrac{t}{d^2}$

$1.1308 = 3.5 \times \dfrac{t}{(6)^2}$

$t = 11.6317$ years

∴ the 95% is assumed to be complete consolidation and it completes in 11.6317 years

Secondary settlement

$$S_s = \frac{H_{100}\, C_\alpha}{1+e_{100}} \log_{10}\left(\frac{t}{t_{100}}\right)$$

$H_{100} = 6 - 0.238$

$H_{100} = 5.762$ m

$$C_\alpha = \frac{\Delta e}{\log\left(\frac{200}{125}\right)}$$

$\Delta e = 0.08164$

$e_{100} = 0.968$

$$S_s = \frac{5.762 \times 0.025}{1+0.968} \log_{10}\left(\frac{20}{11.6317}\right)$$

$S_c = 0.017229$

$S_s = 17.23$ mm

∴ Total settlement = 238.96 + 17.23 (primary + secondary)

Total settlem = 256.19 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]

Given : $(BOD)_{5(20°)} = 110$ mg/l

$$(BOD)_t = (BOD)_u \left(1 - 10^{-k_d t}\right)$$

$$110 = (BOD)_u \left(1 - 10^{-0.1 \times 5}\right)$$

$BOD_u = 160.87$ mg/l → ultimate BOD

Now temp 37°C

$$(k_d)_{37} = k_{d_{20}} (1.047)^{T-20}$$

$$(k_d)_{37} = 0.1\,(1.047)^{17}$$

$$(k_d)_{37} = 0.218$$

$(BOD)_{1,37^\circ} = BOD_u (1 - 10^{-k_{D_{37^\circ}} t})$

$(BOD)_{1,37^\circ} = 160.27 (1 - 10^{-0.218 \times 1})$

$(BOD)_{1day}^{37^\circ C} = 63.488 \text{ mg/L}$

12

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]

(1) Population of colony = 100 < 300
One septic tank is sufficient.

(2) Volume of septic tank

$V =$ (Sewage inflow $\times D_t$ + Rate of deposition $\times$ desludging inter

and sewage inflow = $\frac{120 \text{ litres}}{\text{day-capita}} \times 100$

$= 12000 \text{ litres/day}$

$= 120 \text{ m}^3/\text{day}$.

Rate of deposition = $\frac{30 \text{ lit}}{\text{day}} \times \frac{1000}{\text{year}}$

$= 3000 \frac{\text{liters}}{\text{year}}$

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

$V = 120 \times 1 + 3 \times 1$

$V = 15\ m^3$ (1000 liters OK)

$A = \frac{V}{H}$

$A = \frac{15}{1.5}$

$A = 10 m^2 = LB$

and $\frac{L}{B} = \frac{4}{1}$

$\frac{10}{B} = 4B$

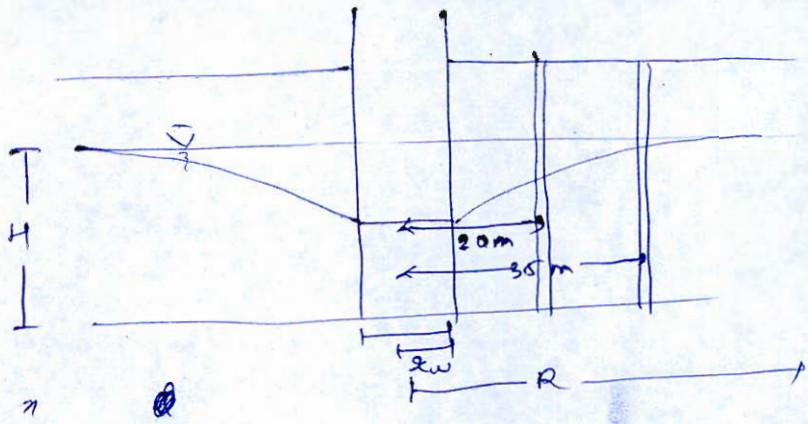
$B = 1.581\ m$

$L = 6.324\ m$

12

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]



$Q = KiA$ (Darcy law)

$Q = K \times \frac{dh}{dr} \times 2\pi r \times h$

$$\int_r^R \frac{Q\,dr}{r} = \int_h^H K 2\pi \, dh \, h$$

$$Q[\ln(r)]_r^R = K 2\pi \left[\frac{h^2}{2}\right]_h^H$$

$$Q \ln\left(\frac{R}{r}\right) = \pi K (H^2 - h^2)$$

$$Q = \frac{\pi K (H^2 - h^2)}{\ln R/r}$$

permiability for unconfined aquifer

$$K = \frac{Q \ln\left(\frac{R}{r}\right)}{\pi (H^2 - h^2)}$$

R → Radius of influence
H → height of water table

(10)

$Q = 7.5$ litre/sec
$= 648$ m³/day

$r_2 = 35$ $h_2 = 12.5$
$r_1 = 20$ $h_1 = 12$

$$K = \frac{648 \times \ln(35/20)}{\pi (12.5^2 - 12^2)}$$

$K = 9.4227$ m/day

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:

(a) The coefficient of permeability (k) of the soil in m/day.

(b) The height of the water level in the standpipe after an additional 25 minutes of testing.

(c) The total time required for the water level to drop to 15 cm.

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

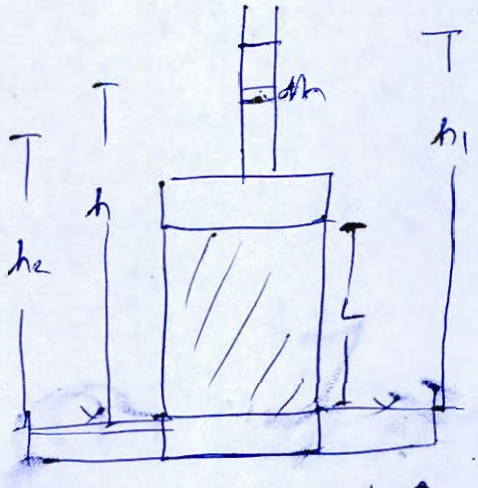
(P) Assumptions:

① Darcy law is applicable

② Soil is homogenous and isotropic

③ the flow is laminar ($R_e < 1$)

Derivation : Falling Head permeability test
(Applicable for - fine grained soil)



Area of falling tube a, soil sample A;

Volume of water seepage due to the permeability in dt time = $-a\,dh$

discharge = $-a\frac{dh}{dt}$

and $Q = KiA$

$$-a\frac{dh}{dt} = K \times \left(\frac{h}{L}\right) A$$

$$\int_{h_1}^{h_2} -a\frac{dh}{h} = \int_0^t K\frac{dt}{L} A$$

$$a \ln\left(\frac{h_2}{h_1}\right) = \frac{KtA}{L}$$

$$\boxed{K = \frac{aL}{At} \ln\left(\frac{h_1}{h_2}\right)}$$

8

Q11

$L = 20\,cm = 0.2\,m$

$D = 10\,cm = 0.1\,m \Rightarrow A = \frac{\pi}{4}(0.1)^2$

$a = \frac{\pi}{4}(0.01)^2$

$h_2 = 80\,cm$

$h_1 = 50\,cm$

$t = 15\,min$

$$K = \frac{aL}{At}\ln\left(\frac{h_1}{h_2}\right)$$

$$= \frac{\frac{\pi}{4}(0.01)^2 \times 0.2}{\frac{\pi}{4}(0.1)^2 \times \left(\frac{15}{60\times24}\right)} \times \ln\left(\frac{80}{50}\right)$$

$K = 0.09024\ m/day$ — (1)

10

height of water after additional 25 mins $t_2 = 40$ mins

$$\frac{1}{t_1}\ln\left(\frac{h_1}{h_2}\right) = \frac{1}{t_2}\ln\left(\frac{h_1}{h_2}\right)$$

$$\frac{1}{15}\ln\left(\frac{80}{50}\right) = \frac{1}{40}\ln\left(\frac{80}{h_2}\right)$$

$h_2 = 22.843\,cm$ — (2)

time required to drop to 15 cm

$$\frac{1}{15}\ln\left(\frac{80}{50}\right) = \frac{1}{t}\ln\left(\frac{80}{15}\right)$$

$t = 53.424$ mins — (3)

6 (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]

$W_1 = 715.20 gm$

W_2 (with wax) $= 725.60 gm$

$V_{displaced} = 395 ml$

~~weight of wax~~

mass of wax $= 725.60 - 715.20$

$= 10.40 g$

$\therefore$ Volume of wax $= \frac{10.40}{0.9} = 11.555 cc$

$\therefore$ Volume of sample without wax $= 395 - 11.555$

$= 384.444 cc$

$\therefore$ $\boxed{\rho_b = \frac{M_T}{V_T} = \frac{715.20}{384.444} = 1.865 g/cc}$

$w = 21.5\%$

$\therefore$ $\rho_d = \frac{\rho_b}{1+w}$

$= \frac{1.865}{1+0.215}$

$\boxed{\rho_d = 1.535 g/cc}$

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

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

$\boxed{e = 0.7718}$

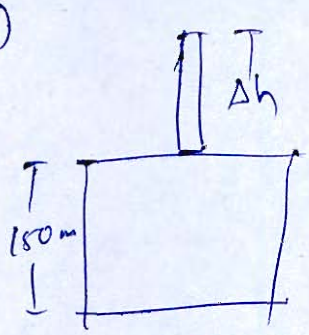
$S_r = w G$

$S \; 0.7718 = 0.215 \times 2.72$

$S = 0.7876$

$\boxed{S = 78.76\%}$

(29)



$D = 1.2\,m$
$u = 3\,m/sec$
$T_a = 25^\circ C$
$T_s = 180^\circ C$
$V_s = 14\,m/s$
$P = 950$ millibar

(4)

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

$$\Delta h = \frac{14 \times 1.2}{3}\left[1.5 + 2.68 \times 10^{-3} \times 950 \times 1.2 \left(\frac{180-25}{180}\right)\right]$$

put in kelvin

$$\Delta h = 23.1328\,m$$

Total ~~height~~ height of stack = 180 + 23.1328

$$H = 173.1328\,m$$

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 1200mg/lt. 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]

(1) 115000 kg/day → 250 m^3 waste water/day

∴ 1000 → $\frac{250\ m^3/day \times 1000}{115000}$

Waste water flow 2.1739 m^3/1000kg waste water

(2) BOD of 115000 kg → 250×10^3 litre waste with 1200 mg/L BOD

115000 kg of milk/day → $\frac{250 \times 10^3 L}{day} \times \frac{1200\ mg}{L}$

1000 kg milk → 2608698.65 mg BOD

1000 kg milk → 2.608 kg BOD

12

(3) Hyraulic equivalent of population = $\frac{250 \times 10^3 L/day}{350 lit/day/pn}$

= 714.28 capita

BOD equivalent of population = $\frac{1.2\frac{g}{L} \times 250 \times 10^3 \frac{L}{day}}{85 g/c/day}$

= 3529.411 capita.

(ii)

Year	Pop (in lacs)	x	y
1970	10		
		+5	
1980	15		+1
		+6	
1990	21		+1
		+7	
2000	28		-3
		+6	
2010	34		
		+3	
2020	37		

P_{2050} by incremental increase method

$$P_n = P_0 + n\bar{x} + \frac{n(n+1)}{2}\bar{y}$$

$$\bar{x} = \frac{5+6+7+6+3}{5} = 5.4$$

$$\bar{y} = \frac{+1+1-1-3}{4} = -0.5$$

$$P_{2050} = 37 + 3(5.4) + \frac{(3)(4)}{2} \times (-0.5)$$

(8)

$$P_{2050} = 50.2 \text{ lacs}$$

Total daily demand $= 50.2 \times 10^5 \times 140$

$= 702800000$ lit/day

$= 702.8$ MLD

7 (a) (i) With reference to Figure, determine the following:

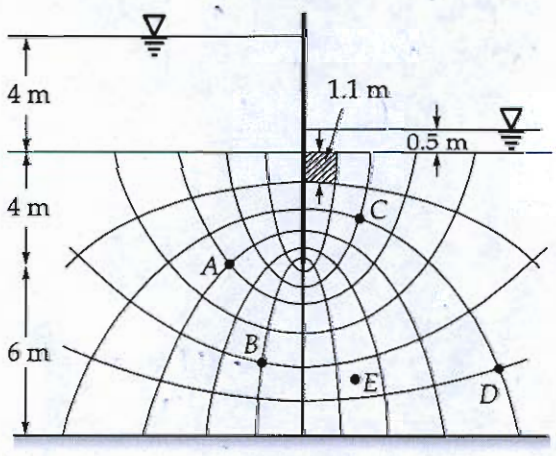
(a) The pressure heads at the points *A* and total head at *E*.

(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]

a) ~~Ab~~ $H = 4 - 0.5$

$H = 3.5\,m$

$N_d = 12$

∴ The total head at A $= 3.5 - \frac{3}{12} \times 3.5$

$= 2.625\,m$

and Datum head $= -4.5\,m$

∴ $PH = (TH) - (DH)$

$= 2.625 + 4.5$

$(PH)_A = 7.125$

similarly for E

Total head at E $= 3.5 - \frac{7.5}{12}(3.5)$

$= 1.3125\,m$

Assumption: As E point lie on middle of the two drops; so I have assumed it have lost half of the head of per ~~head~~ drop head.

b) Exit gradient $= i_{exit} = \frac{\Delta h}{l \cdot (H/N_d)}$

$= \frac{3.5/12}{1.1}$

$i_{exit} = 0.2651$

c) FOS against piping $= \frac{i_c}{i_{exit}}$

$$i_c = \frac{G-1}{1+e} = 0.8684$$

$$FOS = \frac{0.8684}{0.2651}$$

$$\boxed{FOS = 3.2758}$$

d) $Q = KH\frac{N_f}{N_d}$

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

$$\boxed{Q = 4.0833 \times 10^{-5}\ m^3/sec \text{ /m length of sheet pile}}$$

(ii)

coarse sand

5m

25mm sample

① Lab:

$$T_{60} = C_v \frac{t}{d^2}$$

$$0.283 = C_v \times \frac{12min}{\left(\frac{0.025}{2}\right)^2}$$

$$C_v = 3.684895 \times 10^{-6}\ \frac{m^2}{min}$$

$$C_v = 5.30625 \times 10^{-3}\ \frac{m^2}{day}$$

② Field

85% consolidation.

$$T_{85} = 1.781 - 0.933 \log_{10}(100-85)$$

$$T_{85} = 0.6837$$

$$T_{88} = C_v \times \frac{t}{d^2}$$

$$0.683 = 6.30628 \times 10^{-2} \frac{m^2}{day} \times \frac{t}{(2.5)^2}$$

$$t = 322.1.23 \text{ day}$$

$$t = 8.825 \text{ years}$$

20

(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:

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

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

Bicarbonate (HCO_3^-) = 183 mg/L

Carbonate (CO_3^{2-}) = 30 mg/L

Chloride (Cl^-) = 71 mg/L

Sulphate (SO_4^{2-}) = 48 mg/L

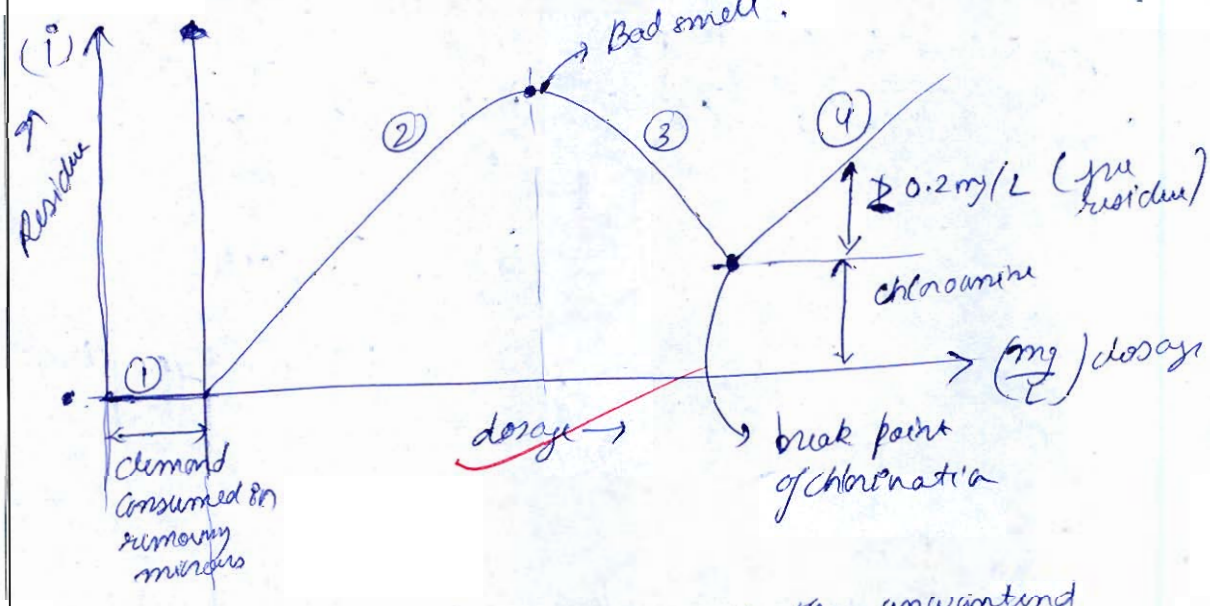
Assume that hydroxide alkalinity is absent.

(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]



(*) Chlorination is done to remove the unwanted matter and microorganisms from water and to sterilize it. ~~Demand~~

(1) Demand (1) is met which ~~is not~~ goes to remove Mn^{2+}, Fe^{2+} which are present in water.

(2) After that demand the chlorine kill microorganisms and along with it it start forming the chloro amines and ~~dis~~ chloroorganics.

~~Chlorogenics~~ Chloramital residual are good to ~~by~~ present in water as they can ~~as~~ kill the organisms.

(3) After this further chlorine is added which destroy chlorogenics and we reach the break point of chlorination. ~~After break~~

(4) After break point the chlorine added is free residual which is mixed with intention to destroy future condamination.
free residual ≯ 0.2 mg/L.

(D) (i) Total alkalinity =
Alkalinity is due to presence of HCO_3^-, CO_3^{2-}
∴ Alkalinity as $CaCO_3$ = $\left[\frac{[HCO_3^-]}{61} + \frac{[CO_3^{2-}]}{30}\right] \times 50$

$= \left[\frac{183}{61} + \frac{30}{30}\right] \times 50$

= 200 mg/L as $CaCO_3$ (ANS)

(ii) Total hardness
↳ due to Ca^{2+}, Mg^{2+}

Total Hardness as $CaCO_3$ = $\left[\frac{[Ca^{2+}]}{20} + \frac{[Mg^{2+}]}{12}\right] \times 50$

$= \left(\frac{60}{20} + \frac{24}{12}\right) \times 50$

= 200 mg/L as $CaCO_3$ ANS

(iii) Carbonate hardness = min {TH, TA}
= min {280, 200}
= 200 mg/l as $CaCO_3$ ANS

10

Non Carbonate Hardness = TH − CH
= 280 − 200
= 50 mg/l as $CaCO_3$ ANS

Do writ this

Q.7 (c) (i) Explain the mechanism of Coagulation in reference to water treatment.

(ii) A mechanically mixed flocculation tank having dimensions 32 m × 10 m × 4.8 m is proposed to handle a flow of 80 MLD. The tank is provided with rectangular paddles of size 10 m × 0.35 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 1.0×10^{-6} m^2/s.

[8 + 12 = 20 marks]

(i) Mechanisms of Coagulation

a) Ionic compression :- As the coagulant is added to the water, the coagulant having (two) charge tend to compress the Ionic layer around the colloidal particles and reduce stern potential. Initially, due to the Ionic layer they were having tendency of stability but as soon as coagulation ~~togo~~ charge concentration increases and Ionic layer compression happen the Vandewall forces start dominating and particle tend to form heavy particle by floc formation Thus it will the settlement.

b) Sweep coagulation : When coagulation aided sedimentation is done. The coagulant after initial fast mixing form dense flocs which have neutralized charge of colloid particle. Now they will attach to colloid and form bigger flocs and settle the colloids.

c) Charge neutralization:

When the coagulant is added, it tend to form Al^{3+} which during fast mixing neutralize colloids and thus reducing (decreasing) the stability of colloids and now colloids can settle after flock forming.

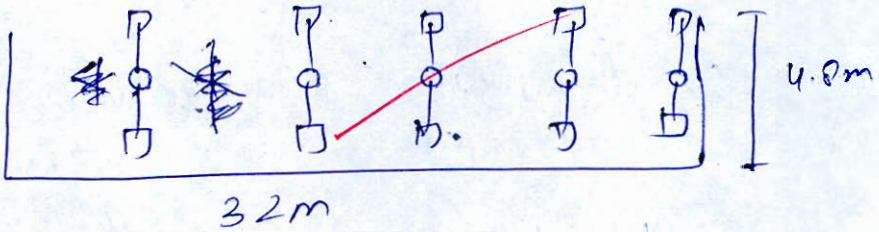
d) Interparticle Bridging

The coagulant tend to form the long chain. Even polymers can be used instead. They tend to form long chain, particle get attached to those chains and as it got heavier they tend to settle.

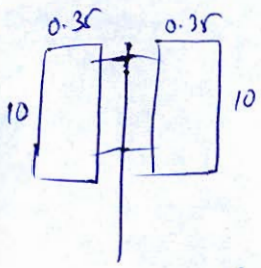
ii)

$Q = 80\ MLD$

Flocculation tank volume = $1536\ m^3$



$N = 32\ rpm$



$$P = C_D \frac{1}{2} \rho u^2 \times A_p \times u$$

$$P = C_D \frac{1}{2} \rho u_r^3 A_p$$

$$A_p = \underset{\text{total 5 paddles}}{5} \left(\underset{\text{2 paddles}}{2} (0.35 \times 10) \right) = 35\ m^2$$

$$u_r = u - u_w$$
$$= u - 0.6u$$
$$= 0.4 \times 0.6283$$
$$u_r = 0.2513\ m/sec$$

$$u = \frac{\pi DN}{60}$$

$$u = \frac{\pi (2 \times 2) \times 3}{60} = 0.6283$$

$$P = 1.8 \times \frac{1}{2} \times 1000 \, (0.2513)^3 \times 35$$

$$\boxed{P = 499.90 \text{ Watt}}$$

(ii) $D_t = \frac{V}{Q}$

$$= \frac{1536}{80 \times 1000 \text{ m}^3/\text{day}}$$

$$= 0.4608 \text{ hour}$$

$\boxed{D_t = 27.648 \text{ min}}$ OK (Range 10–40 min)

(iii) $G = \sqrt{\frac{P}{\mu V}}$

$$G = \sqrt{\frac{499.90}{10^{-3} \times 1536}}$$

$\boxed{G = 18.04 \text{ sec}^{-1}}$

OR range (10–75 sec^{-1})

$\frac{\mu}{\rho} \cdot D$

$\mu = 10^{-6} \times 1000$

$\mu = 10^{-3} \frac{\text{N-s}}{\text{m}^2}$

(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:

$\phi = 30°$, $e = 0.72$, $G = 2.67$, $\mu = 0.35$.

(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:

(i) Discharge capacity of the pump required during peak summer (m^3/s)

(ii) 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]

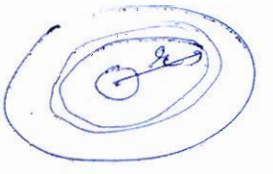
OOOO

Space for Rough Work

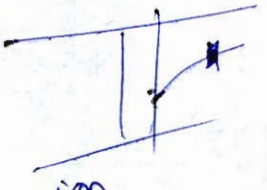
Space for Rough Work

Space for Rough Work

Space for Rough Work

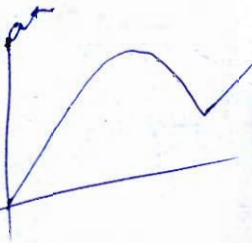


$Q = kiA$



$$Q = \frac{\pi K (H^2 - h^2)}{\ln(R/r)}$$

Zonic compression
sweep coagulation
Charge neutralization
Inter particle
Bridging



$$Q \ln\left(\frac{R}{r}\right) = \pi k (H^2 - h^2)$$

$Q = kiA$

$$Q = k h \left(\frac{dh}{dr}\right) \times 2\pi r \, dr$$

$2\pi r h \cdot \frac{dh}{dr}$

$Q \ln r$