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ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-3

Geo-technical & Foundation Engineering [All Topics]

Highway Engineering-1 + Surveying and Geology-1 + Strength of Materials-2 + Environmental Engineering-2 [Part Syllabus]

Name : .....

Roll No :

Test Centres	Student's Signature
Delhi ☑ Bhopal ☐ Jaipur ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ 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	53
Q.2	—
Q.3	48
Q.4	27
Section-B	
Q.5	28
Q.6	—
Q.7	—
Q.8	31
Total Marks Obtained	187

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

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Name : Shubham kumar

Roll No : C E 2 3 M T D L A 0 0 5

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Delhi ☑ Bhopal ☐ Jaipur ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Hyderabad ☐	Shubham kumar

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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.

- Good work in geotech.
- Keep it up.
- Improve accuracy.
- Improve presentation

Section A : Geo-technical & Foundation Engineering

Q.1 (a) A partially saturated soil from an earth fill has a natural water content of 19% and a bulk unit weight of 19.33 kN/m^3. Assuming the specific gravity of soil solids as 2.7, compute the degree of saturation and Void ratio. If subsequently the soil gets saturated, then determine the dry density, buoyant unit weight and saturated unit weight of soil.

[12 marks]

$w = 0.19$

$\gamma_b = 19.33$

$G = 2.7$

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

$\gamma_b = \frac{(G+eS)\gamma_w}{1+e}$

$19.33(1+e) = 2.7(1+w) \times 9.81$

$0.729(1+e) = 1.19$

$1+e = 1.631$

$e = 0.631$

$S = \frac{0.19 \times 2.7}{0.631} = 0.813$

If $S = 1$

$\gamma_d = \frac{G\gamma_w}{1+e}$; $19.33 = \frac{(2.7+e)\times 9.81}{1+e}$

$= \frac{2.7 \times 9.81}{1.752}$

$= 15.12 \text{ kN/m}^3$

$1.97(1+e) = (2.7+e)$

$1.97 + 1.97e = 2.7 + e$

$0.97e = 0.729$

$e = 0.752$

12

$\gamma_{sat} = \frac{(G+e)\gamma_w}{1+e} = 19.33 \text{ kN/m}^3$

$\gamma' = \gamma_{sat} - \gamma_w$

$= 19.33 - 9.81$

$= 9.52 \text{ kN/m}^3$

$\gamma_{sat} = \frac{(G+e)\times 9.81}{1+e}$

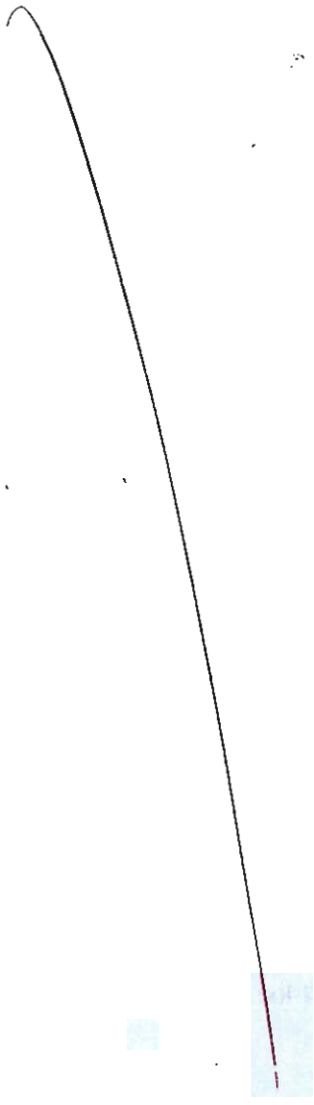
$= \frac{(2.7+0.631)\times 9.81}{1.631} = 20.03 \text{ kN/m}^3$

$\gamma_d = \frac{G\gamma_w}{1+e} = \frac{2.7 \times 9.81}{1.631} = 16.24 \text{ kN/m}^3$

$\gamma' = \gamma_{sat} - \gamma_w$

$= 20.03 - 9.81$

$= 10.22 \text{ kN/m}^3$



Q.1 (b) The following data were recorded in a falling head permeability test.
Sample thickness = 2.75 cm
Diameter of soil sample = 8.2 cm
Diameter of stand pipe = 9.5 mm
Initial head of water in stand pipe = 100 cm
Water level in the stand pipe after 3 hours 35 minutes = 75 cm
Determine the coefficient of permeability if void ratio of sample = 0.73. What will be its value if void ratio of sample is increased to 0.91?

[12 marks]

$$k = \frac{L}{t}\frac{a}{A}\ln\left(\frac{h_1}{h_2}\right)$$

$a = \pi/4 \times (0.95)^2$

$A = \pi/4 \times (8.2)^2$

$t = 215$ min

$$k = \frac{2.75}{215\times 60} \times \frac{0.95^2}{8.2^2} \times \ln\left(\frac{100}{75}\right)$$

$= 8.231\times10^{-7}$ cm/sec at $e = 0.73$

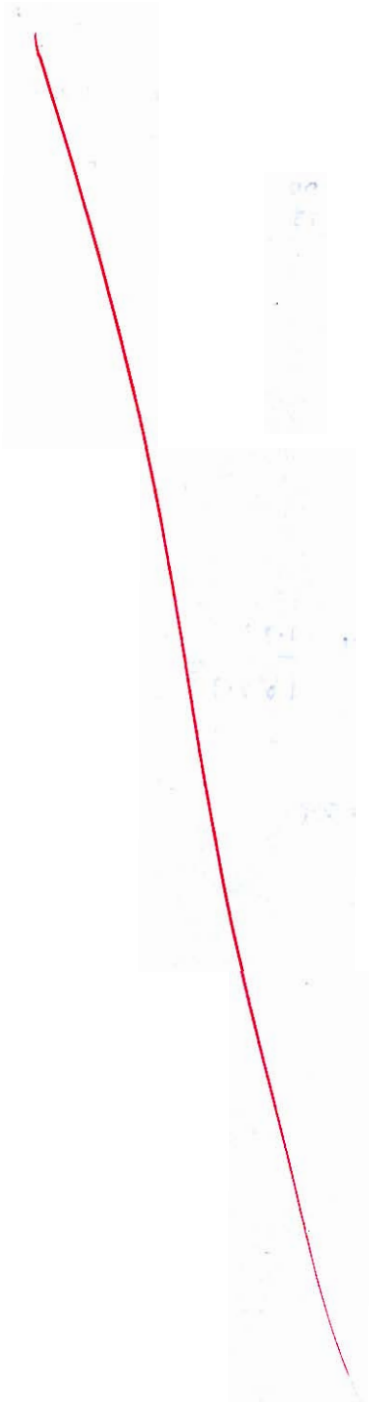
$$k = \frac{L}{K_A}\cdot\frac{\gamma_w}{\mu}\cdot\frac{e^3}{1+e}\cdot d^2$$

$$k \propto \frac{e^3}{1+e}$$

$$\frac{8.231\times10^{-7}}{k_2} = \left(\frac{0.73^3}{1.73}\right) \times \frac{1.91}{(0.91)^3}$$

$k_2 = 1.444\times10^{-6}$ cm/sec

12



Q.1 (c) (i) Write short notes for the following:

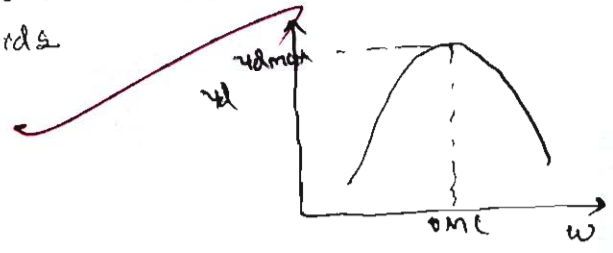
1. Effect of water content on compaction of soil.
2. Effect of compaction over permeability of soil.
3. Stabilization of soil using calcium chloride.

(ii) A layer of saturated clay is 6 m thick and lies under a newly constructed building. The weight of sand overlying the clay layer is 254 kN/m^2 and the new construction increases the overburden pressure by 112 kN/m^2. If the compression index is 0.5, compute the settlement if water content is 45% and specific gravity of solid particles is 2.7.

[6 + 6 marks]

(i) (1) Effect of water content

As we increase water content firstly dry density increases upto OMC & after that starts decreasing because water is replacing soil solids



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(2) Effect of compaction

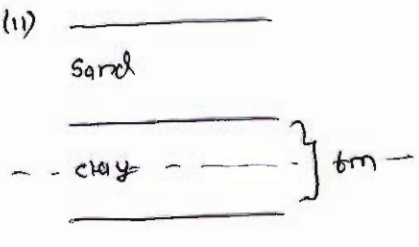
→ As we increase the compactive effort permeability decreases because flocculant structure converted into dispersed structure which has less permeability

(3) Stabilisation of soil using CaCl2

→ It is a type of salt which reduces the liquid limit & plasticity index of the soil & modify its properties

6

(ii)



$\sigma_{sand} = 254\ kN/m^2$

$\Delta\sigma = 112\ kN/m^2$

$C_c = 0.5, \quad w = 0.45, \quad G = 2.7$

$\gamma_{sat} = \frac{(G+e)\gamma_w}{1+e} \qquad e = wG = 1.215$

$= \frac{(2.7+1.215)\times 9.81}{2.215}$

$= 17.34\ kN/m^3$

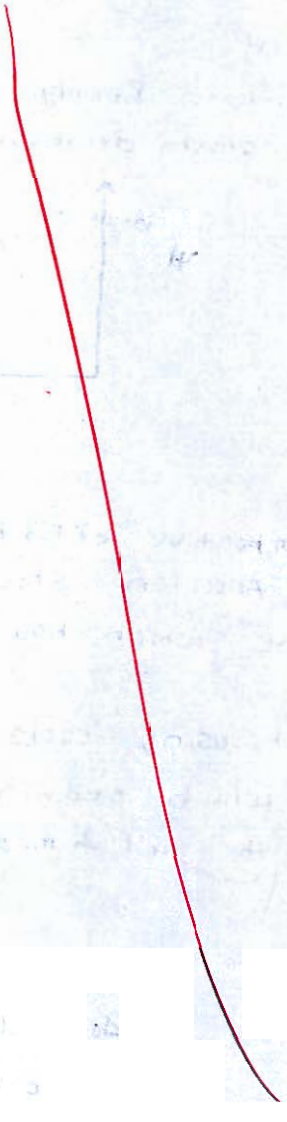
$\sigma_0' = 254 + 17.34\times 3$

$= 306.02\ kN/m^2$

$\Delta\sigma' = 112\ kN/m^2$

$\Delta H = \frac{H_0 C_c}{1+e_0}\log\left(\frac{\sigma_0+\Delta\sigma'}{\sigma_0'}\right) = \frac{6\times 0.5}{2.215}\log\left(\frac{306.02+112}{306.02}\right)$

$= 0.183\ m = 183\ mm$



Q.1 (d) (i) Describe methods of foundation design in swelling soil to reduce the swelling effects.

(ii) Explain negative skin friction in case of piles.

[8 + 4 marks]

(i) methods of foundation design in swelling soil to reduce swelling effects are as follows

(1) Isolate the structure from swelling soil

→ Here we construct under reamed piles which is isolated and reduces the swelling effect by providing anchorage with its belled piers.

(2) Provide a structure which can withstand the effect of swelling soil

(3) Reduce the swelling effect of soil by modifying its properties which are as

(a) mechanical stabilisation

(b) cement ''

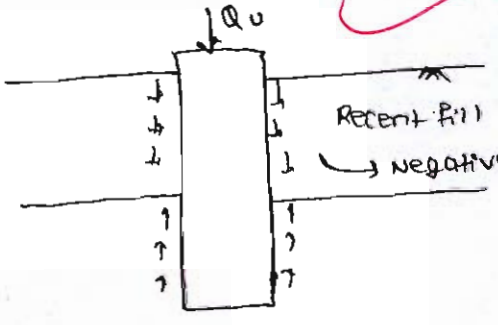
(c) Lime ''

(d) chemical ''

5

(ii) Negative skin friction in piles

when a non compacted layer of soil, or recent fill or due to sudden drawdown of water table level, the skin friction (neg) which is providing resistance against load now acts in opposite direction which reduces the ultimate load carrying capacity of pile



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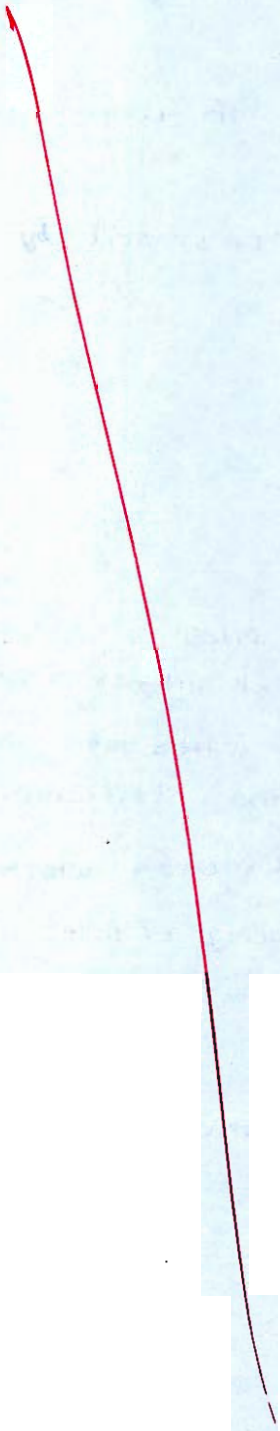
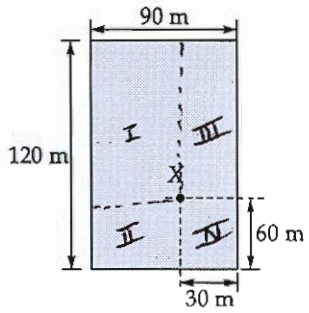


Q.1 (e) The plan of a proposed soil heap is shown in the figure below. The heap will stand on a thick deposit of soft clay having Poisson's ratio of 0.5 with E-value 13.5 MN/m^2. The uniform pressure on the soil may be taken as 175 kN/m^2. Determine the immediate settlement under the point marked 'x' at the surface of the soil.



Shape of loaded area	Influence factor			
	Flexible			Rigid
	Center	Corner	Average	
Circular $\left[\frac{L}{B}\right]$ rectangular	1	0.64	0.85	0.8
1.0	1.12	0.56	0.95	0.9
1.5	1.36	0.68	1.20	1.09
2.0	1.53	0.77	1.31	1.22
5.0	2.10	0.05	1.83	1.68
10.0	2.52	1.26	2.25	2.02
100.0	3.38	1.69	2.96	2.70

[12 marks]

$S_i = q B \frac{(1-\mu^2)}{E} I_f$

(I) $L = 60\,m$, $B = 60\,m$, $\frac{L}{B} = 1$, $I_f = 0.56$

(II) $L = 60\,m$, $B = 60\,m$, $I_f = 0.56$

(III) $L = 60\,m$, $B = 30\,m$, $\frac{L}{B} = 2$, $I_f = 0.77$

(IV) $L = 60\,m$, $B = 30\,m$, $\frac{L}{B} = 2$, $I_f = 0.77$

$S_i = \frac{q(1-\mu^2)}{E} [B_1 I_{f_1} + B_2 I_{f_2} + B_3 I_{f_3} + B_4 I_{f_4}]$

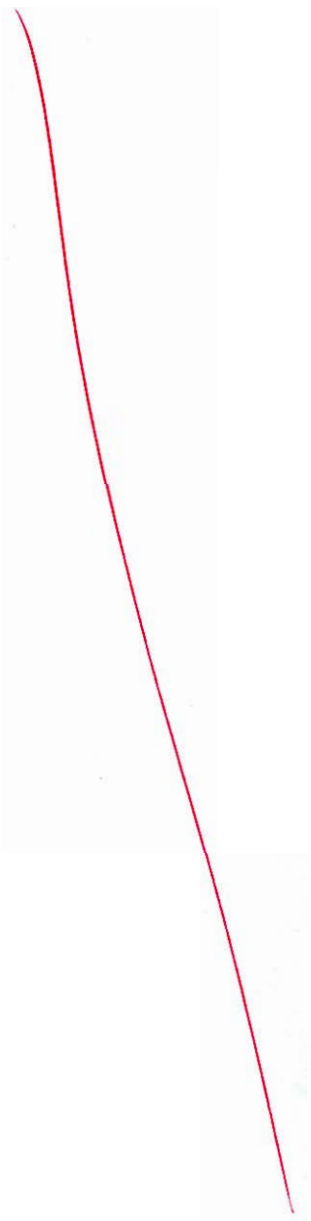
$= \frac{175 \times (1-0.5^2)}{13.5 \times 10^3} \times [60 \times 0.56 \times 2 + 30 \times 0.77 \times 2]$

$= 1.1025\,m$

12

Q.2 (a) A wall of 6 m height retains backfill of dry granular soil that weighs 18.5 kN/m^3 has a level surface. When there is no surcharge above the fill, the overturning moment caused by the total active pressure at a point at a base of the wall is 150 kN/meter length of wall. The specifications permit certain amount of uniformly distributed surcharge but state that surcharge must not increase overturning moment by more than 75%. What surcharge can be allowed if the angle of wall friction is 25°?

[20 marks]



Q.2 (b) A 2.5 m square footing carries a safe load of intensity 400 kN/m^2 at a depth of 1 m in sand. The saturated unit weight of sand is 20 kN/m^3 and the unit weight above the water table is 17 kN/m^3. The shear strength parameters are $c = 0$, $\phi = 38°$. Compute the factor of safety with respect to shear failure for the following cases:

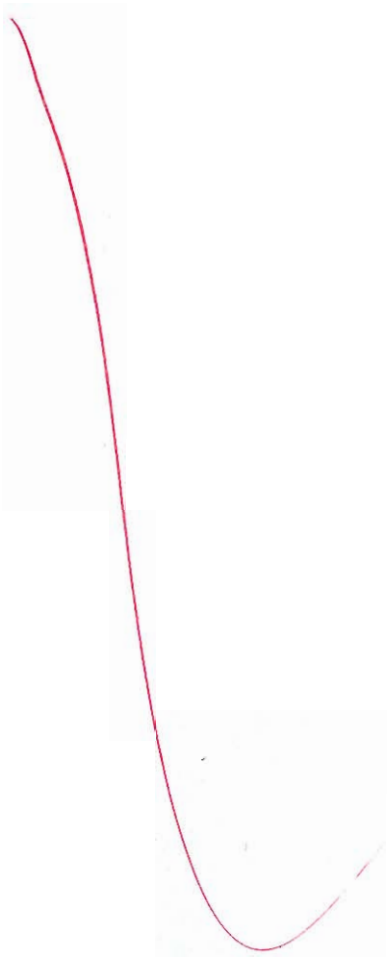
(i) The water table is at 5 m below ground level.

(ii) The water table is at 1 m below ground level.

(iii) The water table is at ground level and there is a seepage, acting vertically upwards under a hydraulic gradient of 0.2.

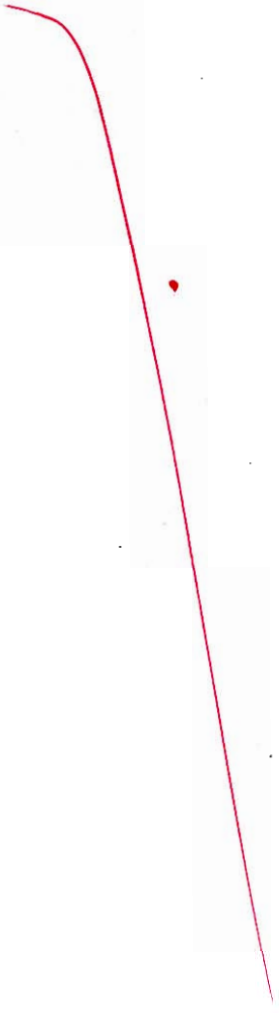
(Take, $N_q = 66.34$ and $N_\gamma = 77.2$)

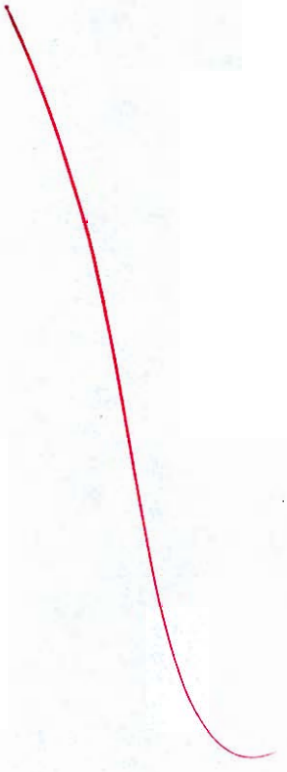
[20 marks]



Q.2 (c) Derive the expression for change in pore pressure in terms of Skempton's parameters.

[20 marks]





Q.3 (a) (i) A saturated soil has a compression index $C_C = 0.263$. Its void ratio at a stress of 150 kN/m^2 is 1.89 and its permeability is 3.3×10^{-8} cm/sec. Compute the change in void ratio if the stress is increased by 109.5 kN/m^2. For a soil stratum of 4.5 m thick what will be the total settlement? Also determine the time required for 80% consolidation to occur if drainage is one way. (Take $\gamma_w = 9.81$ kN/m^3)

[12 marks]

$C_c = 0.263$ $\quad e$ $\quad K = 3.3 \times 10^{-8}$ cm/sec

150 KN/m^2 $\quad$ 1.89

$\downarrow$

$\Delta\sigma = 109.5$ KN/m^2

$$\frac{\Delta H}{H} = \frac{\Delta e}{1+e_0} \qquad C_c = \frac{-\Delta e}{\log\left(\frac{\sigma_1}{\sigma_0}\right)}$$

$$\Delta e = C_c \times \log\left(\frac{\sigma_1}{\sigma_0}\right)$$

$$= 0.263 \times \log\left(\frac{150 + 109.5}{150}\right)$$

$$= 0.063$$

$H = 4.5$ m

$$\Delta H = \frac{H_0 \Delta e}{1+e_0} = \frac{4.5 \times 0.063}{2.89} = 0.0975 \text{ m}$$

Drainage one way

$H = 4.5$ m $= d$

$$T_{v90} = 1.781 - 0.933 \log_{10}(100 - U) = \frac{C_v t}{d^2}$$

$K = C_v m_v \gamma_w$

$$m_v = \frac{a_v}{1+e_0} = \frac{0.063}{109.5 \times 2.89} = 1.99 \times 10^{-4} \frac{m^2}{KN}$$

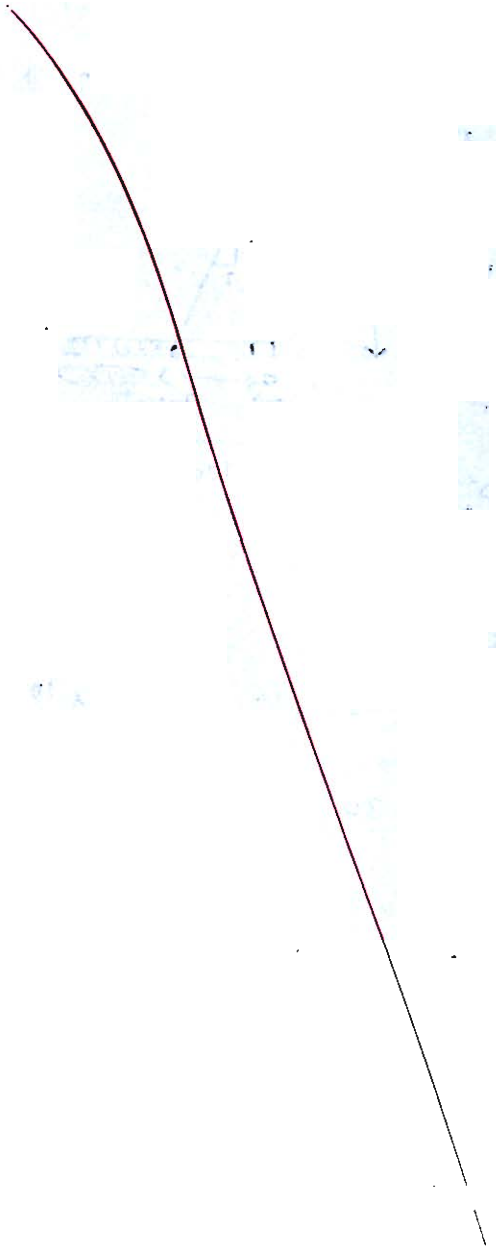
$$C_v = \frac{K}{m_v \gamma_w} = \frac{3.3 \times 10^{-8} \times 10^{-2}}{1.99 \times 10^{-4} \times 9.81} \frac{m^2}{sec}$$

$$= 0.169 \times 10^{-6} \text{ m}^2/\text{sec}$$

$$1.781 - 0.933 \log 20 = \frac{0.169 \times 10^{-6} \times t}{4.5^2}$$

$$t = \frac{0.567 \times 4.5^2 \times 10^6}{0.169 \times 86400} \text{ days}$$

$$= 786.53 \text{ days}$$

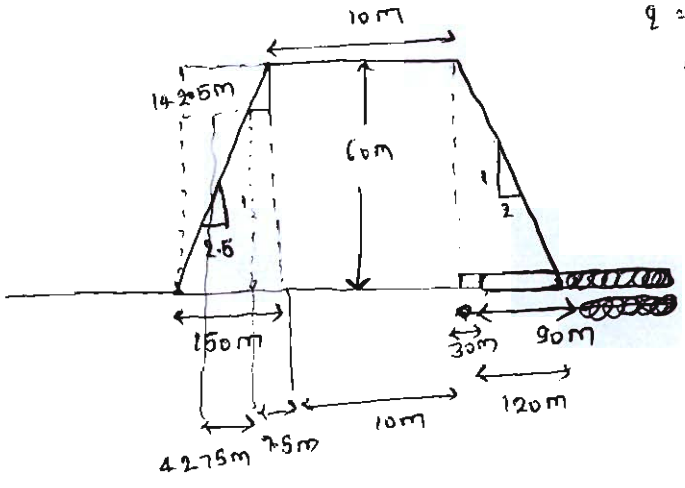


Q.3 (a) **(ii)** Calculate the seepage through an earthen dam resting on an impervious foundation. The relevant data are given below:

Height of the dam = 60 m
Upstream slope = 2.5 : 1 [H : V]
Downstream slope = 2 : 1 [H : V]
Feeboard = 3 m
Crest width = 10 m
Length of drainage blanket = 90 m

Coefficient of permeability of the embankment material in
X-direction = 8×10^{-7} m/s
Y-direction = 6×10^{-7} m/s

[8 marks]



$q = K' S$

$S = \sqrt{D^2 + H^2} - D$

$H = (60 - 3) = 57$ m

$K' = \sqrt{K_x K_y} = \sqrt{48 \times 10^{-14}} = 6.93 \times 10^{-7}$ m/sec

$D = 42.75 + 7.5 + 10 + 30$

$= 90.25$ m

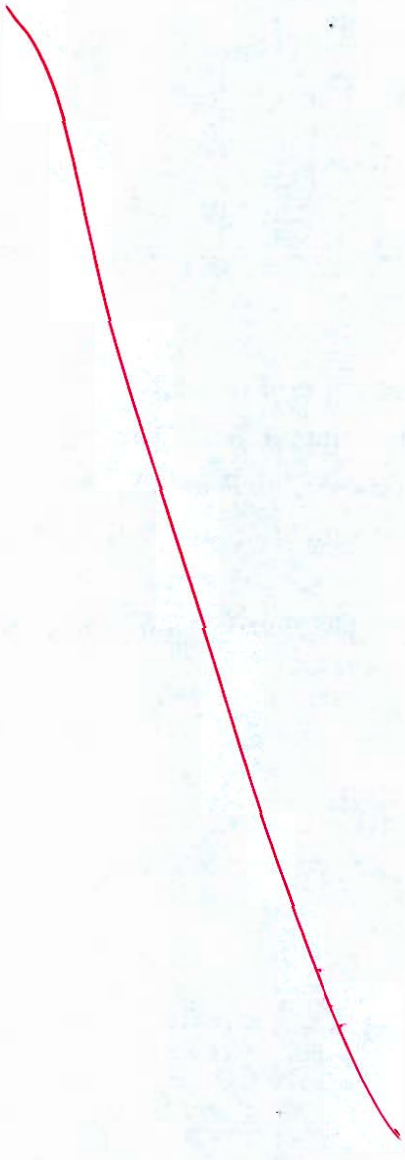
$S = \sqrt{90.25^2 + 57^2} - 90.25$

$= 16.49$ m

$q = K' S$

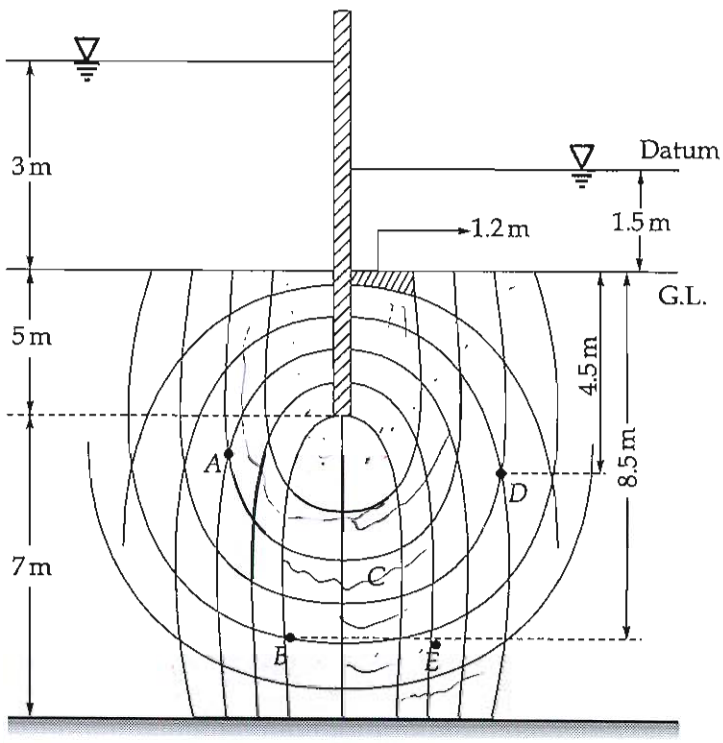
$= 6.93 \times 10^{-7} \times 16.49$ m³/s/m

$= 114.256 \times 10^{-7}$ m³/s/m



Q.3 (b) (i) A sheet pile is driven upto a depth of 5 m in a bed of sand having coefficient of permeability in x-direction and z-direction equals to 0.002 cm/sec and 0.0025 cm/sec respectively. An impervious clay layer exists at a depth of 12 m below the ground level. The sheet pile is retaining water upto 3 m on upstream side and upto 1.5 m on downstream side as shown in figure.

(Take, $\gamma_w = 9.81$ kN/m^3)



Determine:

1. The quantity of seepage loss per unit width.
2. The seepage pressure at the points A, B, C, D and E.
3. The pore water pressure at the points B and D.
4. Exit gradient when minimum distance between equipotential lines at downstream ends is 1.2 m.
5. Factor of safety against piping. Given, $G = 2.67$ and porosity $(\eta) = 0.35$.

[15 marks]

$H = 3 - 1.5 = 1.5\ m$

$K' = \sqrt{0.002 \times 0.0025} = 2.236 \times 10^{-3}\ cm/sec$

(1) $q = KH \frac{N_F}{N_d}$

$N_F = 6$

$N_d = 12$

$q = 2.236 \times 10^{-3} \times 1.5 \times 10^{-2} \times \frac{6}{12}\ m^3/sec/m$

$= 1.677 \times 10^{-5}\ m^3/s/m$

(2) Seepage pressure $= h\gamma_w$

$h = H - n\Delta h$

$\Delta h = \frac{H}{N_d} = \frac{1.5}{12} = 0.125$

At A, $h_A = 1.5 - 3 \times 0.125 = 1.125$

$P_S = 1.125 \times 9.81 = 11.036\ kN/m^2$

At B, $h_B = 1.5 - 5 \times 0.125 = 0.875$

$P_S = 0.875 \times 9.81 = 8.584\ kN/m^2$

At C, $h_L = 1.5 - 6.5 \times 0.125 = 0.6875$

$P_S = 0.6875 \times 9.81 = 6.744\ kN/m^2$

At D, $h_D = 1.5 - 10 \times 0.125 = 0.25$

$P_S = 0.25 \times 9.81 = 2.4525\ kN/m^2$

At E, $h_E = 1.5 - 8 \times 0.125 = 0.5$

$P_S = 5 \times 9.81 = 4.905\ kN/m^2$

(3) $U_B = h_w \gamma_w$

$h = 0.875$

$h_d = -10$

$h = h_d + h_w$

$h_w = h - h_d = 0.875 + 10$

$= 10.875$

$U = 10.875 \times 9.81$

$= 106.68\ kN/m^2$

$U_D = h_w \gamma_w$

$h = 0.25$

$h_d = -6$

$h_w = 6.25$

$U = 6.25 \times 9.81$

$= 61.3125\ kN/m^2$

12

(4) $i_{crit} = \frac{dh}{g} = \frac{0.125}{1.2} = \frac{1}{9.6}$

(5) $FOS = \frac{i_c}{i_{crit}}$

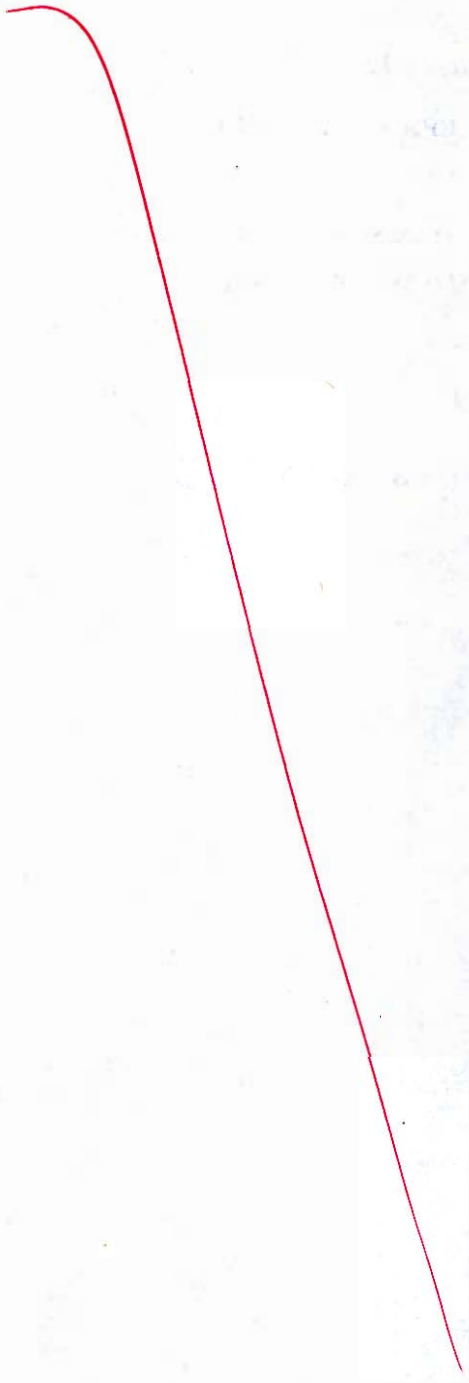
$i_c = \frac{(G-1)}{1+e} = (G-1)(1-n)$

$= (2.67-1)(1-0.35)$

$= 1.67 \times .65$

$= 1.0855$

$FOS = \frac{1.0855}{1} \times 9.6 = 10.42$



Q.3 (b) (ii) Write Terzaghi's guidelines for the design of protective filter along with their respective significance.

[5 marks]

$$\frac{D_{15}\ (\text{Filter})}{D_{85}\ (\text{Protected Soil})} < 5$$

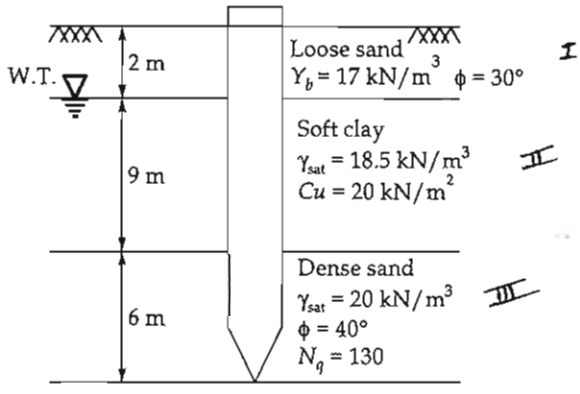
It governs the upper limit of size of soil particle in filter

$$4 < \frac{D_{15}\ (\text{Filter})}{D_{15}\ (\text{Protected Soil})} < 20$$

this governs lower limit of size of soil particle in filter

$$\frac{D_{50}\ (\text{Filter})}{D_{50}\ (\text{Protected Soil})} < 25$$

Q.3 (c) Determine the ultimate pile-load capacity of 50 cm diameter pile shown in the figure below:



The angle of friction between pile and soil is 0.75 times of angle of internal friction of soil. The earth pressure coefficient for loose sand is 1 and for dense sand is 2. Adhesion factor for soft clay is taken as 1.

[20 marks]

$\delta = 0.75\phi$ $\alpha = 1$

$K_{loose} = 1$

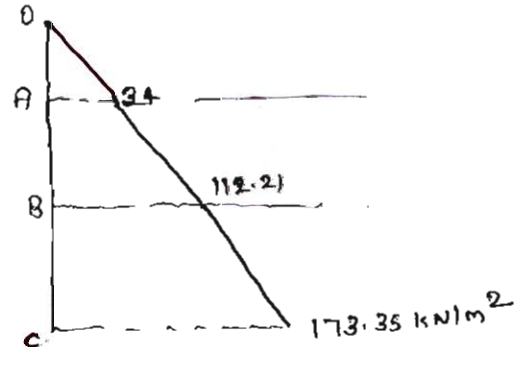
$K_{dense} = 2$

(I) Loose sand

$q_{sf} = \alpha \bar{c} A_s =$

$L = 15 \times 0.5 = 7.5\text{m} > 2\text{m}$ No arching effect

$q_{sf} = K \times$ Earth pressure



$\sigma_B' = 34 + (18.5 - 9.8) \times 9$

$= 112.21$ kN/m^2

$\sigma_C' = 112.21 + (20 - 9.8) \times 6$

$= 173.35$ kN/m^2

$q_{sf_1} = \tan(0.75 \times 30) \times 1 \times \left(\frac{0+34}{2}\right) = 7.04$ kN/m^2

$Q_{sf_1} = 7.04 \times \pi \times 0.5 \times 2 = 22.11$ kN

(II) $q_{sf_2} = \alpha \bar{c} A_s$

$= 1 \times 20 \times \pi \times 0.5 \times 9$

$= 282.6$ kN

(III) $L = 20 \times 0.5 = 10\text{m} > 1\text{m}$ No arching effect

$q_{sf_3} =$ Earth pressure

$= \tan(0.75 \times 40) \times 2 \times \left(\frac{112.21 + 173.35}{2}\right)$

$= 164.86$ kN/m^2 > 100 kN/m^2

$Q_{sf3} = 100 \times \pi \times 0.5 \times 6$

$= 942\ kN$

$q_{eb3} = q\,N_q$

$= 173.35 \times 180$

$= 22535.5\ kN/m^2 > 11000\ kN/m^2$ for normal silica sand

$Q_{eb3} = 11000 \times \frac{\pi}{4} \times 0.5^2$

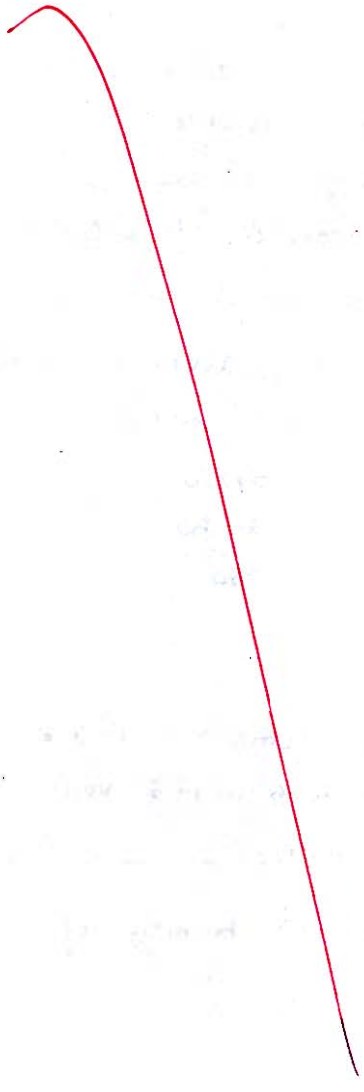
$= 2158.75\ kN$

2

$Q_{total} = Q_1 + Q_2 + Q_3$

$= 22.11 + 282.6 + 942 + 2158.75$

$= 3405.46\ kN$



Q.4 (a) (i) Explain in brief about free swell test and bulking of sand.

(ii) A group of nine piles, 12 m long and 250 mm in diameter is to be arranged in a square form in a clay soil with an average unconfined compressive strength of 60 kN/m^2. Work out the centre to centre spacing of the piles for a group efficiency factor of 1. Neglect bearing at the tip of piles.

(Assume adhesion factor $\alpha = 0.9$)

[8 + 12 marks]

(i)

(1) Free swell test

$$\text{Free swell (\%)} = \frac{\text{final volume} - \text{initial volume}}{\text{initial volume}} \times 100$$

In this test we firstly note the initial volume of soil sample & then allowed it to swell, after that we record the final volume & then we estimate the free swell (%) to check its swelling behaviour

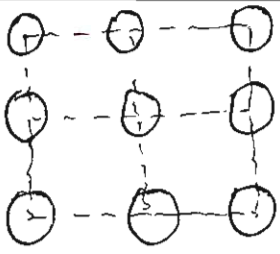
	free swell (%)
montmorillonite	>1200
illite	30 - 40
kaolinite	>80

4

(2) Bulking of sand

When a sand mass is dumped loosely, sand gets moistened & water enters in its void & its volume increases due to the effect of capillary tension which is further known as bulking of sand.

(ii)



$L = 12m$

$D = 0.25\ m$

$q_u = 60 = 2\omega$

$\omega = 30\ kN/m^2$

$\alpha = 0.9, \quad \eta_g = 1$

$S = ?$

$B = 25 + d$

$B = 25 + 0.25$

$\eta_g = \dfrac{Q_{ug}}{nQ_{un}} = 1$

$nQ_{un} = g \times [\alpha \bar{c} A_s + g c A_b]$

$= g\left[0.9 \times 30 \times 17 \times 0.25 \times 12 + g \times 30 \times \frac{\pi}{4} \times 0.25^2\right]$

$nQ_{un} = 2408.282\ kN$

$Q_{ug} = 1 \times \bar{c} \times A_s + g c A_b$

$= 1 \times 30 \times 48 \times 12 + g \times 30 \times B^2$

$Q_{ug} = 270B^2 + 1440B$

$Q_{ug} = nQ_{un}$

$270B^2 + 1440B = 2408.282$

$270B^2 + 1440B - 2408.282 = 0$

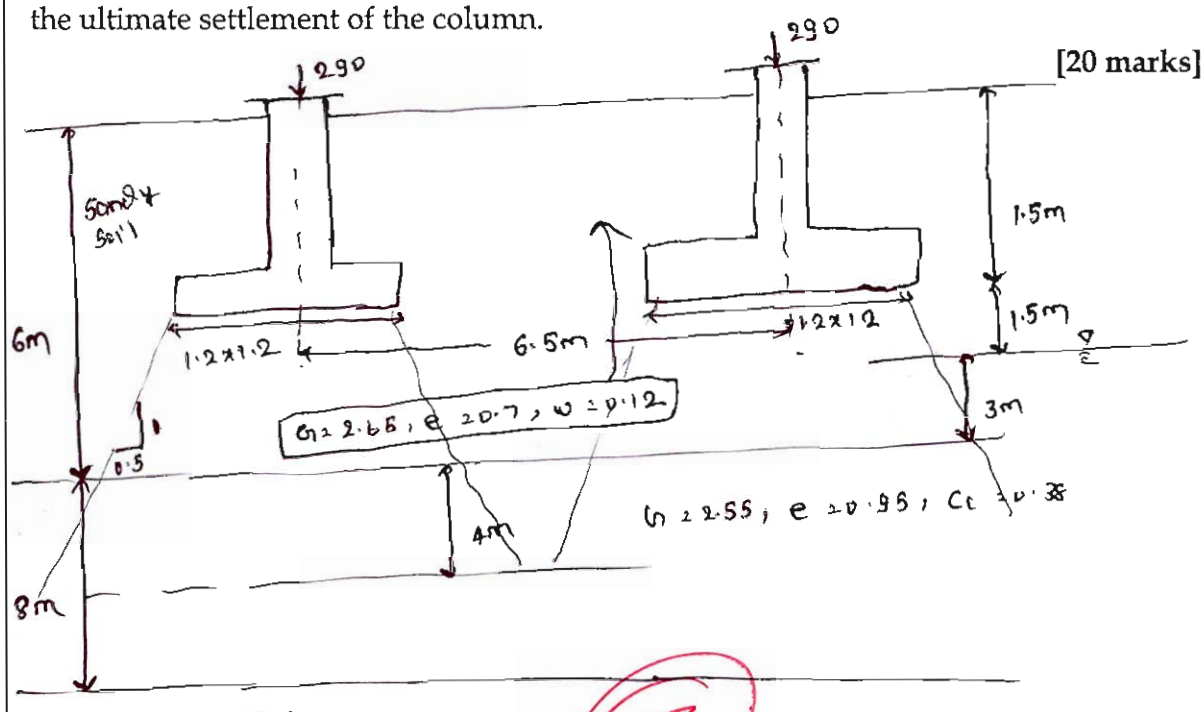
$B = 1.34, -6.67$ (x)

$B = 2S + 0.25$

$1.34 - 0.25 = 2S$

$S = 0.545\ m$

Q.4 (b) Two column footings 1.2 m × 1.2 m each, spaced at 6.5 m centre to centre and located at a depth of 1.5 m in sand layer of thickness 6 m, transmit a building load of 290 kN each. A 8 m thick compressible clay stratum is found to be present below the sand layer. Below the clay layer is found a stiff impervious stratum. The water table is existing at 3 m below the ground surface. Sandy soil is having specific gravity of 2.65, void ratio of 0.7 and moisture content (above water table) of 12%. The clay soil is having a specific gravity of 2.55, average void ratio of 0.95 and coefficient of compression of 0.38. Determine the ultimate settlement of the column. **[20 marks]**



$$\Delta H = \frac{H_0 C_c}{1+e_0} \log\left(\frac{\sigma_0' + \Delta\sigma'}{\sigma_0'}\right)$$

$$\sigma_0' = 17.13 \times 3 + 3 \times (19.33 - 9.81) + 4 \times (17.61 - 9.81)$$

$$= 111.15 \text{ kN/m}^2$$

$$\Delta\sigma' = \frac{2 \times 290 \times 1.2 \times 1.2}{(1.2 + 2 \times 0.5 \times 8.5)^2} \times \frac{1}{1.2 \times 1.2}$$

$$= \frac{8.876 \text{ kN/m}^2}{1.2^2} = 6.164 \text{ kN/m}^2$$

$$\gamma_b = \frac{(G+eS)\gamma_w}{1+e} \qquad e = \frac{wG}{S}$$

$$= \frac{(2.65 + 0.12 \times 2.65) \times 9.81}{1.7}$$

$$= 17.18 \text{ kN/m}^3$$

$$\gamma_{sat} = \frac{(2.65 + 0.7) \times 9.81}{1.7}$$

$$= 19.33 \text{ kN/m}^3$$

Clay

$$\gamma_{sat} = \frac{(G+e)\gamma_w}{1+e}$$

$$= \frac{(2.55 + 0.95) \times 9.81}{1.95}$$

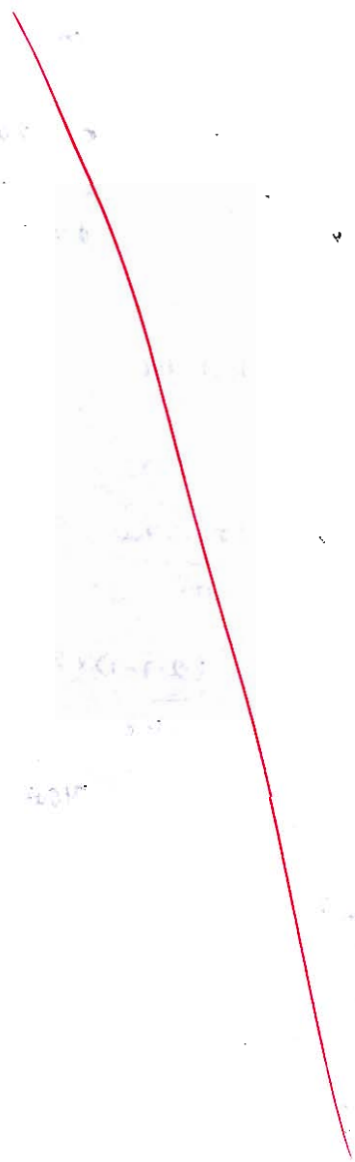
$$= 17.61 \text{ kN/m}^3$$

$$\Delta H = \frac{H_0 C_c}{1+e_0} \log\left(\frac{\sigma_1}{\sigma_0}\right)$$

$$= \frac{8 \times 0.38}{1.99} \log\left(\frac{111.15 + 6.164}{111.15}\right)$$

$$= 0.0365 \text{ m}$$

$$\Delta H = 36.543 \text{ mm}$$



Q.4 (c) A 10 m deep cutting has side slope of 1.5 : 1 (H:V). The soil was tested and found to have the cohesion of 25.7 kN/m^3 void ratio of 0.8 and angle to internal friction of 14°. Determine the factor of safety w.r.t. to cohesion, against failure of the slope, when;

(i) water level in the cut rises up to full height.

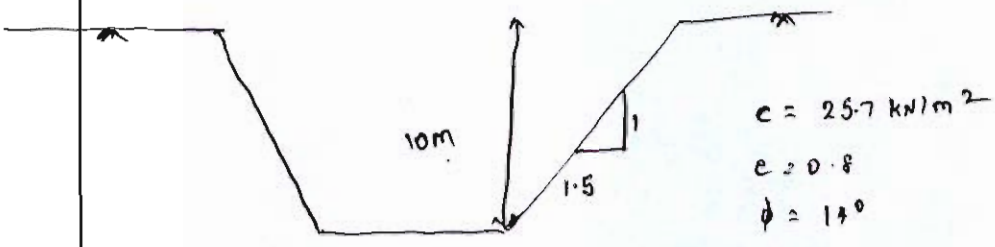
(ii) water level goes down suddenly.

Specific gravity of soil is 2.7.

For the given slope, stability numbers for different angles of internal friction is given below,

ϕ	S_n
6°	0.122
7°	0.116
14°	0.074

[20 marks]



(i) water level rises upto full ht

$$FOS = \frac{c}{C_m}$$

$$S_n = \frac{C_m}{\gamma H}$$

$$\gamma' = \frac{(G-1)\gamma_w}{1+e}$$

$$= \frac{(2.7-1)\times 9.81}{1.8} = 9.265 \text{ kN/m}^3$$

$$0.074 = \frac{C_m}{9.265 \times 10}$$

$$\gamma_{sat} = 19.075 \text{ kN/m}^3$$

$$C_m = 6.8561 \text{ kN/m}^2$$

$$FOS = \frac{c}{C_m} = \frac{25.7}{6.8561} = 3.748$$

(ii) water level goes down suddenly

$$\phi' = \frac{\gamma'}{\gamma_{sat}} \times \phi$$

$$= \frac{9.265}{9.265 + 9.81} \times 14$$

$$= 6.8^\circ \approx 7^\circ$$

By interpolating

$$S_n = 0.122 + \frac{0.8}{1} \times (0.116 - 0.122)$$

$$= 0.1172$$

$$S_n = \frac{C_m}{\gamma_{sat} H}$$

$$C_m = S_n \gamma_{sat} H$$

$$= 0.1172 \times 19.075 \times 10$$

$$= 22.356 \text{ kN/m}^2$$

20

$$FOS = \frac{C}{C_m}$$

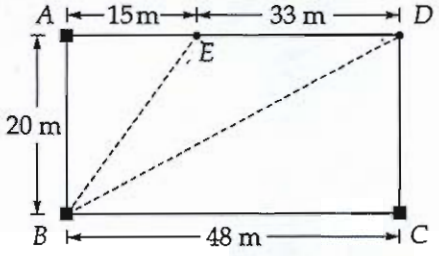
$$= \frac{25.7}{22.356}$$

$$FOS = 1.149$$

Section B : Highway Engineering-1 + Surveying and Geology-1 + Strength of Materials-2 + Environmental Engineering-2

Q.5 (a) Figure given below shows a rectangle *ABCD*, in which *A*, *B* and *C* are the stations where staff readings were obtained with a level set up at *E* and *D*. The observed readings are tabulated as shown.

Level at	Staff reading at		
	A	*B*	*C*
E	1.855	0.808	–
D	2.427	1.368	1.666



If *A* is a benchmark having an elevation of 120 m, calculate the correct elevations of *B* and *C*. Also find the missing staff reading at *C* from instrument location *E*.

[12 marks]

RLA = 120 m

Correct elevation of B =

Q.5 (b) Distinguish between Telford's and Macadam's method of road construction in terms of subgrade slope, foundation stones, base course, surface course and thickness of cross-section. Also what technological lessons do you derive from macadam pavement?

[12 marks]

	Telford road	macadam Road
Subgrade Slope	1 in 36 NO Slope	1 in 5
Foundation Stones	Large size	Not necessary
Base Course	Small crushed stones	Small crushed Stones
Surface course	Small aggregates, fillers etc	Small size Bitumen
Thickness of C-S	approx 30cm	(20 - 25) cm

6

macadam Pavement

→ It is the first pavement that provides the slope in subgrade soil

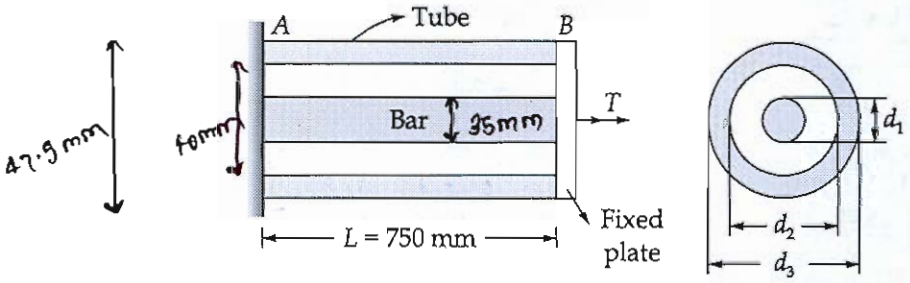
→ Large foundation Stones are not necessary in the subgrade soil

→ Proper drainage system is introduced

Q.5 (c) A solid steel bar of diameter $d_1 = 35$ mm is enclosed by a steel tube of outer diameter $d_3 = 47.5$ mm and inner diameter $d_2 = 40$ mm as shown in figure. Both bar and tube are held rigidly by a support at end A and joined securely to a rigid plate at end B. The composite bar which has a length $L = 750$ mm is twisted by a torque $T = 450$ N-m acting on the end plate. Determine:

(i) The maximum shear stress τ_1 and τ_2 in the bar and tube respectively.

(ii) The angle of rotation ϕ (in degrees) of the end plate and torsional stiffness K_T of the composite bar, assuming the shear modulus of steel as 80 GPa.



[12 marks]

$T = T_1 + T_2$

$T_1 \simeq$ Bar

$T_2 \simeq$ Tube

$\theta = \frac{T_1 L_1}{G_1 J_1} = \frac{T_2 L_2}{G_2 J_2}$

$G_1 \simeq G_2 \simeq 80$ GPa

$J_1 = \frac{\pi}{32} \times 35^4$

$J_2 = \frac{\pi}{32} \times \{47.5^4 - 40^4\}$

$\frac{T_1}{T_2} = \frac{35^4}{47.5^4 - 40^4}$

$\frac{T_1}{T_2} \simeq 0.593 \Rightarrow T_1 \simeq 0.593\, T_2$

$T_1 + T_2 \simeq 450$

$1.593\, T_2 \simeq 450$

$T_2 \simeq 282.48$ N-m

$T_1 \simeq 167.52$ N-m

(i) $Z_1 = \frac{T_1 R_1}{J_1} = \frac{167.52 \times 17.5 \times 10^{+3}}{\frac{\pi}{32} \times 35^4} \simeq$ 19.91 N/mm^2

$Z_2 = \frac{T_2 R_2}{J_2} = \frac{282.48 \times 10^3 \times 23.75}{\pi \times \{47.5^4 - 40^4\}} \times 32 \simeq$ 27.02 N/mm^2

(ii) $\theta = \frac{T_1 L_1}{G_1 J_1}$

$= \frac{167.52 \times 10^3 \times 750 \times 32}{80 \times 10^3 \times \pi \times 35^4}$

$= 0.011 \text{ rad} = 0.631^\circ$

12

$K_T = \frac{G_1 J_1 + G_2 J_2}{L}$

$= \frac{80 \times 10^3}{750} \left[\frac{\pi}{32} \times 35^4 + \frac{\pi}{32} \times (47.5^4 - 40^4) \right]$

$= 42194158.85$

Q.5 (d) Explain the importance of self cleansing velocity in designing of sewers. Derive shield's expression for self cleansing velocity in a sewer.

[12 marks]

Self cleansing velocity is that velocity in the sewer at which the settled particles are moved away with sewage water by its own velocity

Its value for 1mm inorganic particle & 5mm organic particle is 0.45 m/sec

4

Importance.

(i) Prevent the staining of sewers

(ii) Prevent wear & tear due to settled particles

(iii) Choking is Prevented

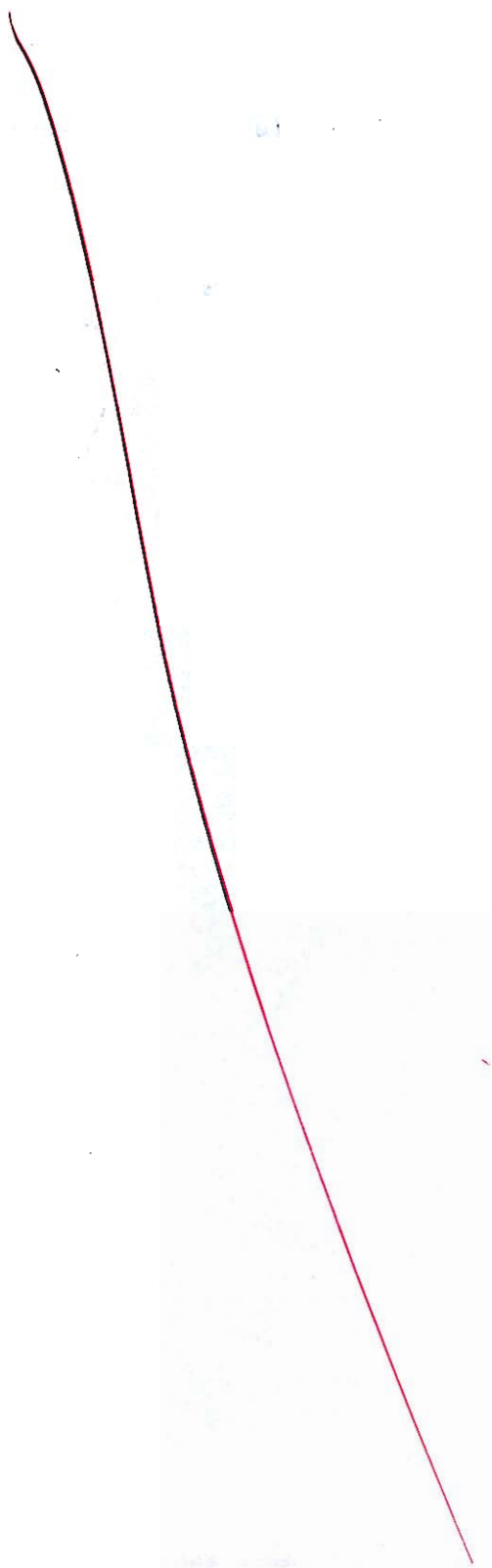
Expression of self cleansing

Chezy's

$$V_{sc} = \sqrt{\frac{8K}{f}(G-1)gd}$$

Manning's

$$V_{sc} = \sqrt{K(G-1)d} \times \frac{1}{n} R^{1/6}$$



Q.5 (e) A completely mixed activated-sludge plant is to treat 10000 m^3/d of industrial wastewater. The wastewater has a BOD_5 of 1200 mg/l that must be reduced to 200 mg/l prior to discharge to a municipal sewer. Pilot-plant analysis indicates that a mean cell-residence time of 5 days maintaining MLSS concentration of 5000 mg/l produces the desired results. The value for Y i.e. decimal fraction of food mass converted to biomass is determined to be 0.7 kg/kg and value of K_d is found to be 0.03 day^{-1}. Determine:

(i) Volume of reactor.

(ii) Mass and volume of solids wasted each day.

(iii) Sludge recirculation ratio.

Assume an underflow concentration of 15 kg/m^3 from secondary clarifier.

[12 marks]

$Q_0 = 10000\ m^3/d$

$BOD_5 = 1200\ mg/l = S_0$

$S = 200\ mg/l$

$\theta_c = 5\ days$

$X = 5000\ mg/l$

$Y = 0.7$

$K_d = 0.03$

$\frac{1}{\theta_c} + K_d = UY$

$\frac{1}{5} + 0.03 = 0.7 \times U$

$U = 0.328 = \frac{Q_0(S_0 - S)}{VX}$

(i) $V = \frac{Q_0(S_0 - S)}{X \times 0.328} = \frac{10000\ m^3/d \times 1000\ mg/l}{5000 \times 0.328\ day^{-1}}$

$= 6097.56\ m^3$

$\approx 6098\ m^3$

(ii) $R = \frac{Q_R}{Q_0} = \frac{X}{X_U - X}$

$Q_W X_U$ = mass of solids wasted

$= 15 \times 6098$

$= 91413.42\ kg$

$Q_W X_U = 6097.56\ kg/day$

volume wasted $= \frac{6097.56}{15}\ m^3/day$

$= 406.504\ m^3/day$

$Q_W X_U$

$\theta_c = \frac{VX}{Q_W X_U}$

$Q_W X_U = \frac{VX}{\theta_c}$

$= \frac{6097.66 \times 5000 \times 10^{-6}}{5 \times 10^{-3}}$

$= 6097.56\ kg/day$

~~$Q_0 + Q_R = Q_w - Q_w = Q_R$~~

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

$$Q_R = Q_0 - Q_w$$

$$= 10000 - 406.504$$

$$= 9593.496$$

$$R = \frac{10000}{9593.496} = 1.04$$

Q.6 (a) **(i)** Write a short notes on the effects of following factors in determining the stopping sight distance.

1. Efficiency of brakes.
2. Slope of the road surface.

[6 marks]

Q.6 (a) (ii) For a two-lane two-way traffic road, the following are the particulars:

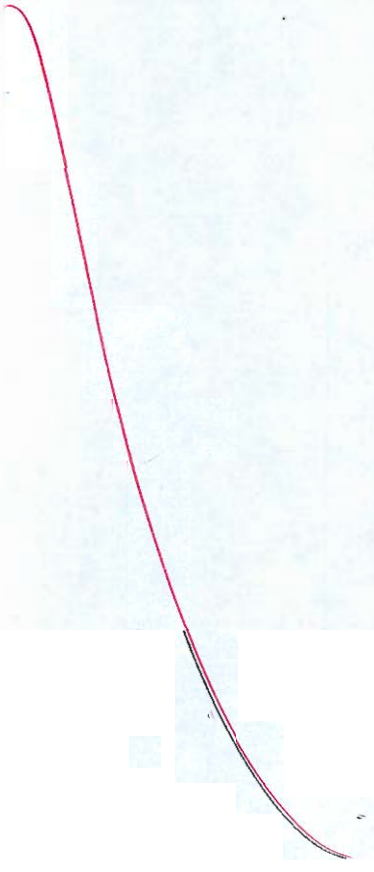
Speed of overtaking vehicle = 65 kmph
Speed difference between the vehicles = 15 kmph
Acceleration of overtaking vehicle = 3.28 kmph/sec
Perception time of driver of overtaking vehicle = 2 seconds
Length of overtaking vehicle = 6 m

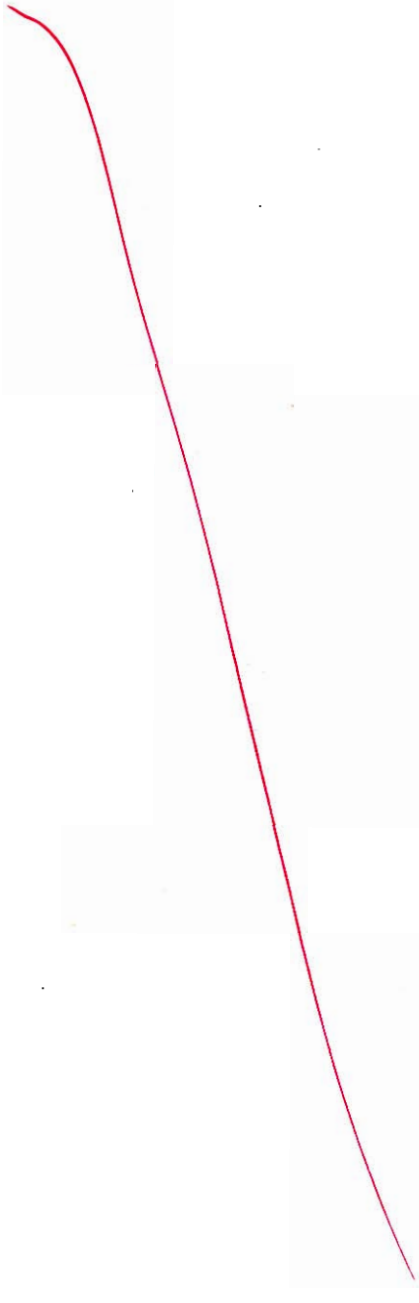
Calculate the following:

1. Length of safe OSD.
2. Minimum length of overtaking zone.
3. Desirable length of overtaking zone.

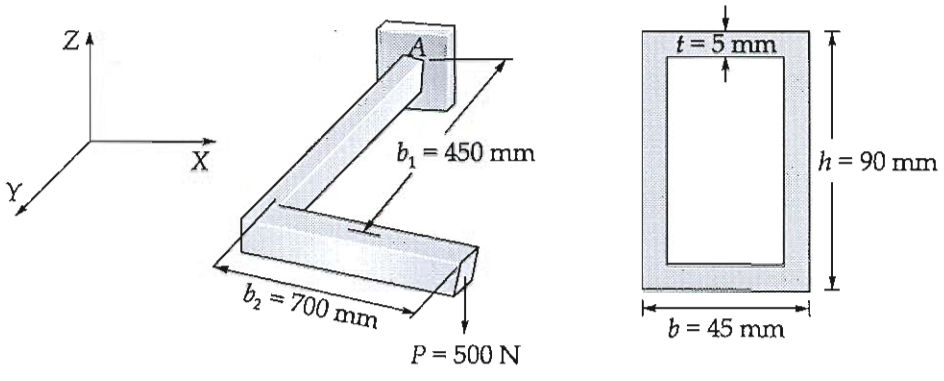
Also, draw the neat sketch of the overtaking zone showing the position of the sign posts.

[14 marks]

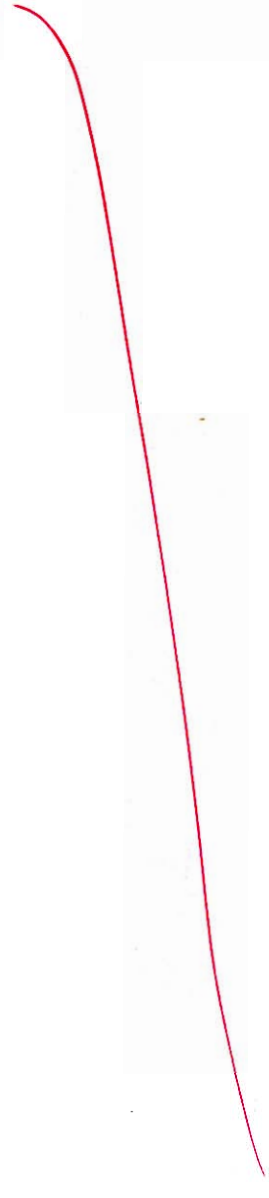


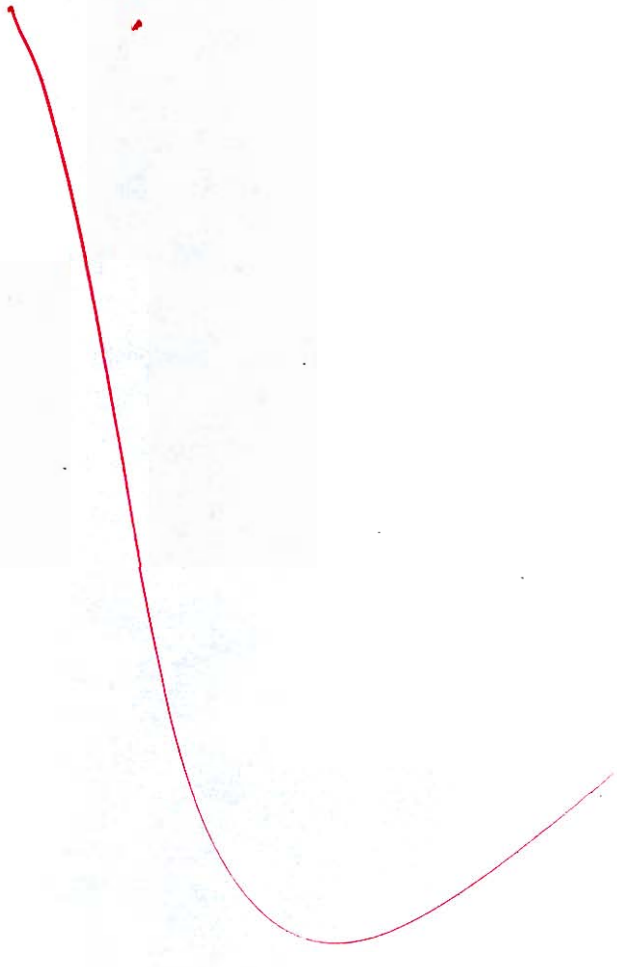


Q.6 (b) (i) An *L*-shaped bracket lying in a horizontal plane supports a load $P = 500$ N as shown in figure. The bracket has a hollow rectangular cross-section with thickness $t = 5$ mm having outer dimension $b = 45$ mm and $h = 90$ mm. The center line lengths of the arms are $b_1 = 450$ mm and $b_2 = 700$ mm. Considering only the load P, calculate the maximum tensile stress, maximum compressive stress and maximum shear stress at point A, which is located on the top of the bracket at the support.

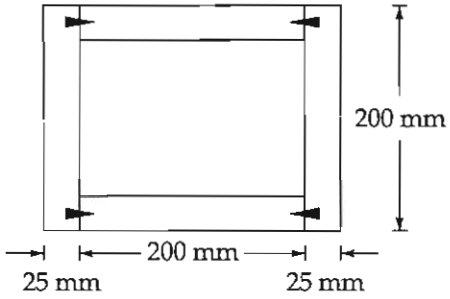


[15 marks]





Q.6 (b) **(ii)** The box beam shown in figure is made up of four 200 mm × 25 mm wooden planks connected by screws. Each screw can safely transmit a shear force of 1400 N. Estimate the minimum necessary spacing of screws along the length of the beam if the maximum shear force transmitted by the cross-section is 5 kN.



[5 marks]

Q.6 (c) (i) From the instrument kept at A, the following vertical angles were observed:

Staff at P :

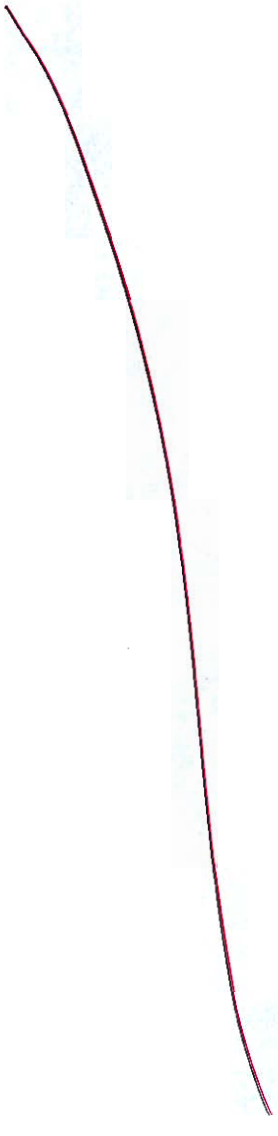
1°30′ to the 1-m mark and 6°30′ to the 4-m mark

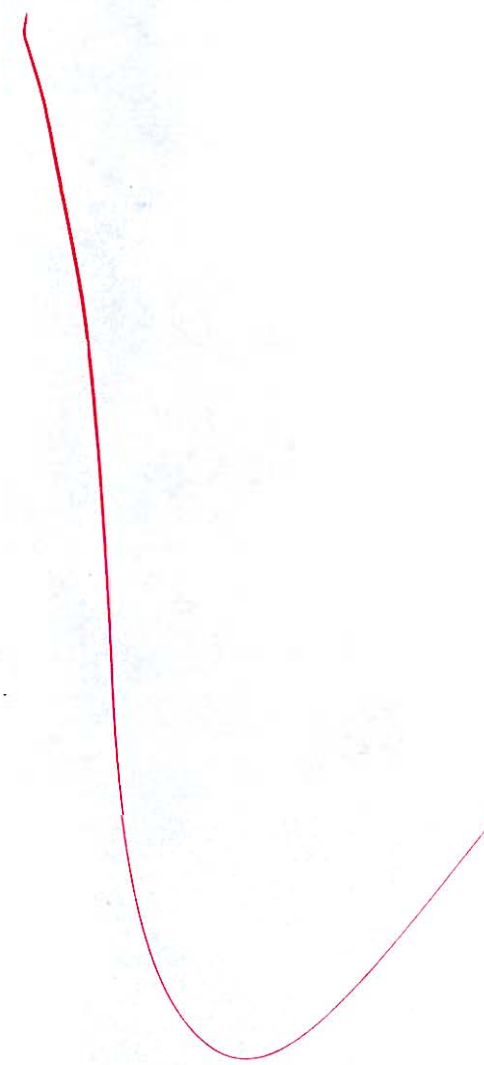
Staff at Q :

0°45′ to the 0.5-m mark and 4°30′ to the 4-m mark

The horizontal angle PAQ was measured as 61°30′ and the reading at a benchmark of R.L 902.5 m was 2.375 m. Determine the R.L of points P and Q. If a station 'R' of R.L 905.01 m is to be located along the line joining P and Q, then determine the horizontal distance of 'R' from 'A'. Assume P, Q and R lie on a uniform sloping ground.

[15 marks]





Q.6 (c) (ii) What do you understand by the term 'Magnetic declination'? What are the different variations in magnetic declination? Explain briefly.

[5 marks]

Q.7 (a) A shaft is supported in bearing 5 m apart subjected to a bending moment of 15 kNm and transmits power of 80 kW at 2.5 Hz. Find the suitable diameter for the shaft for each of the following cases:

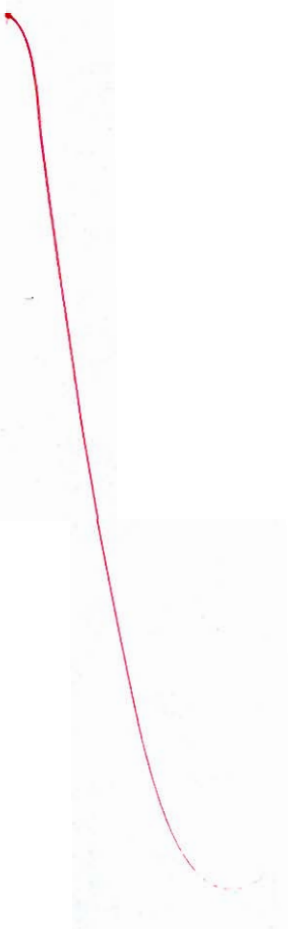
(i) The maximum direct stress shall not exceed 110 N/mm^2.

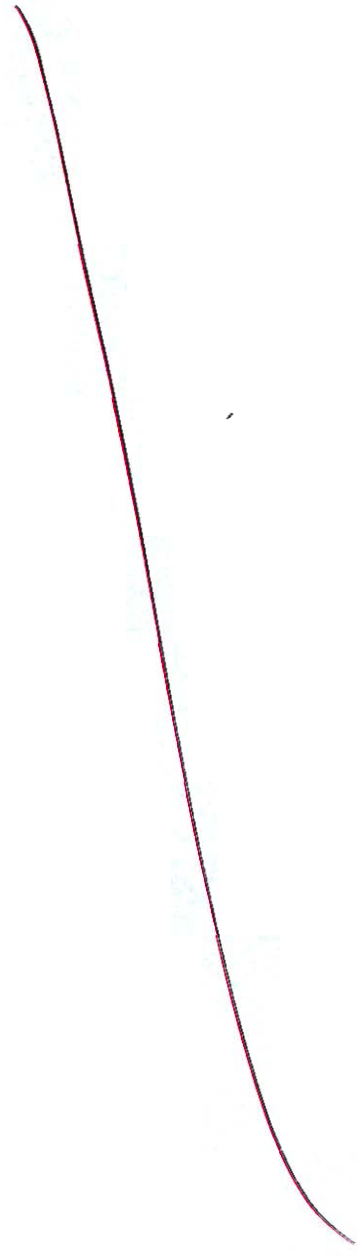
(ii) The maximum shear stress shall not exceed 55 N/mm^2.

(iii) The stress acting alone to produce the same maximum strain shall not exceed 110 N/mm^2.

(iv) The stress acting alone to store the same maximum strain energy per unit volume, shall not exceed 110 N/mm^2.

[20 marks]





Q.7 (b) (i) Explain nitrogen and sulphur cycle of oxidation of waste organic matter under aerobic conditions with help of diagrams.

[14 marks]

Q.7 (b) (ii) The 3 day 37° BOD of a sample of sewage is 300 mg/l. What will be its 5 day 25° C BOD if K_1(base e) at temperature of 20° C is 0.23 per day?

[6 marks]

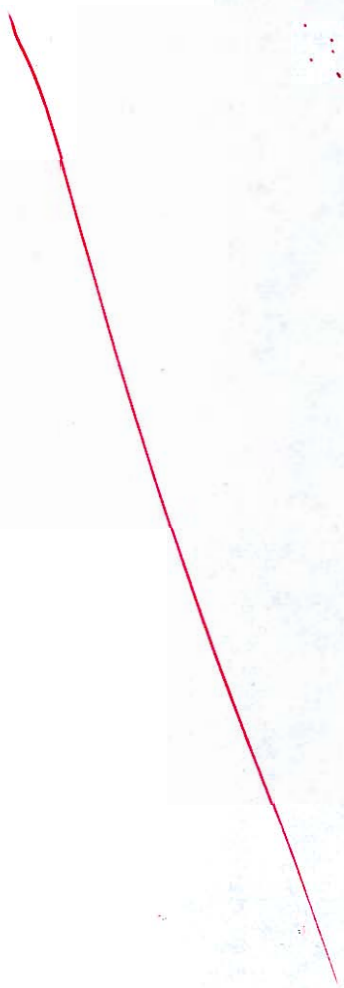
Q.7 (c) (i) A traverse *ABCDEA* was conducted and due to the difficulties in the field, the bearing of line *EA* and the length and bearing of line *DE* could not be measured. To supplement the missing quantities, ranging rods were placed at *A* and *E* and the angle *ADE* was sighted as 20°30′. It is also known that the line *EA* lies in the *N-W* quadrant. From the given data find the missing quantities.

Line	*AB*	*BC*	*CD*	*DE*	*EA*
Length (m)	302.5	288.2	199.5	Missing	201.2
Bearing	N74°15′E	S60°30′E	S30°45′W	Missing	Missing

[15 marks]

Q.7 (c) (ii) Briefly explain the operations involved in setting up the plane table.

[5 marks]



.8 (a) On a highway, a rising gradient of 1 in 50 meets a falling gradient of 1 in 400 at a reduced level of 150 m. Assume the eye level of driver to be 1.125 m above the road surface and the height of the obstacle to be 0.10 m. If the sight distance is 300 m and vertical point of curve is taken as origin, then determine:

(i) Equation of summit curve taking origin at vertical point of curve.

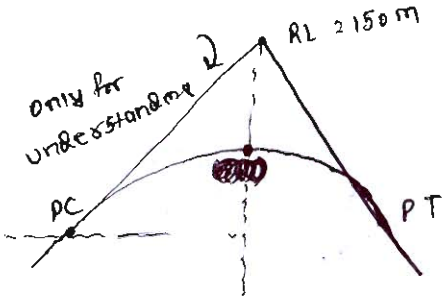
(ii) Position of summit point of curve from origin.

(iii) R.L. of vertical point of curve.

(iv) R.L. of vertical point of tangency.

(v) R.L. of point lying on curve which is just below vertical point of intersection.

[20 marks]



$N = \left| \frac{1}{50} - \left(-\frac{1}{400} \right) \right|$

$= 0.0225$

$n_1 = \frac{1}{50}$

$n_2 = -\frac{1}{400}$

(i) $y = \left(\frac{-N}{2L_S} \right) x^2 + n_1 x$

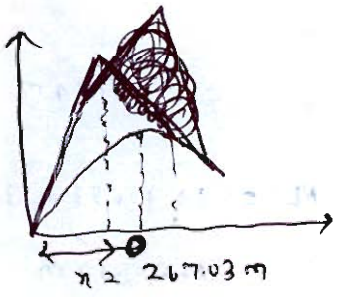
$H = 1.125$

$h = 0.1\,m$

$SD = 300\,m$

Assume $SD < L_S$

$L_S = \frac{NS^2}{(\sqrt{2H} + \sqrt{2h})^2} = \frac{0.0225 \times 300^2}{(\sqrt{2\times1.125} + \sqrt{2\times0.1})^2} = 534.06\,m > SD$



$y = \left(\frac{-0.0225}{2 \times 534.06} \right) x^2 + \frac{1}{50} x$

$= -2.1 \times 10^{-5} x^2 + \frac{1}{50} x$

(ii) $x = \frac{n_1 L_S}{N} = \frac{1/50 \times 534.06}{0.0225} = 474.72\,m$

$x = \frac{L_S}{2} = 267.03\,m$

(iii) RL of vertical pt of curve $= 150 - n_1 \times \frac{L_S}{2}$

$= 150 - \frac{1}{50} \times 267.03$

$= 144.659$ m

(iv) RL of vertical point of tangency $= 150 - n_2 \times \frac{L_S}{2}$

$= 150 - \frac{1}{400} \times 267.03$

$= 149.33$ m

(v) $y = -2.1 \times 10^{-5} n^2 + \frac{1}{50} n$

$= -2.1 \times 10^{-5} \times 267.03^2 + \frac{1}{50} \times 267.03$

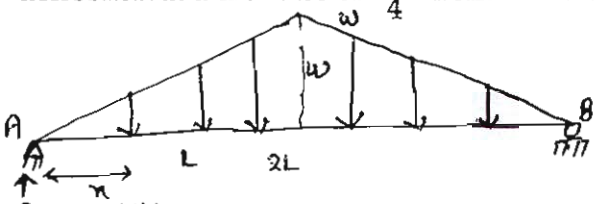
$= 3.84$ m

RL $= 144.659 + 3.84$

$= 148.502$ m

Q.8 (b) (i) A beam of uniform section and length $2L$ is simply supported at its ends and carries a symmetrical triangular loading of which the intensity varying from zero at each end to w at the centre. Determine the slope at distance $L/2$ from left end and deflection at a distance of $\frac{3L}{4}$ from left end.

[12 marks]



$R_A = \frac{w \times 2L}{2}$

$\frac{d^2y}{dx^2} = \frac{M}{EI}$

$\frac{w}{L} = \frac{w_x}{x} \Rightarrow w_x = \frac{wx}{L}$

$M_x = -\frac{1}{2} x \times \frac{wx}{L} \times \frac{x}{3} = -\frac{wx^3}{6L} + \frac{wL}{2} x + \frac{wL}{2} x$

$R_A = \frac{\frac{1}{2} \times 2L \times w}{2} = \frac{wL}{2}$

$EI \frac{d^2y}{dx^2} = \frac{wL}{2} x - \frac{wx^3}{6L}$

$EI \frac{dy}{dx} = \frac{wL}{2} \frac{x^2}{2} - \frac{wx^4}{24L} + C_1$

At $x = L$, $\frac{dy}{dx} = 0$

$EI \times 0 = \frac{wL}{2} \times \frac{L^2}{2} - \frac{w}{24L} \times L^4 + C_1$

$0 = \frac{wL^3}{4} - \frac{wL^3}{24} + C_1$

$C_1 = \frac{wL^3}{24} - \frac{wL^3}{4} = \frac{wL^3 - 6wL^3}{24} = -\frac{5wL^3}{24}$

$EI\,y = \frac{wL}{4} x^2 - \frac{wx^4}{24L} - \frac{5wL^3}{24}$

$EI \frac{dy}{dx} = \frac{wL}{4} x^2 - \frac{wx^4}{24L} - \frac{5wL^3}{24}$

Slope at $L/2$

$EI \frac{dy}{dx} = \frac{wL}{4} \times \frac{L^2}{4} - \frac{w}{24L} \times \frac{L^4}{16} - \frac{5wL^3}{24}$

$= \frac{wL^3}{16} - \frac{wL^3}{384} - \frac{5}{24} wL^3$

$\theta|_{L/2} = -\frac{19wL^3}{128EI}$

12

$$EI\,y = \frac{wL}{4} \times \frac{x^3}{3} - \frac{w}{24L} \times \frac{x^5}{6} - \frac{5wL^3}{24} x + C_2$$

at $x = 0$, $y = 0$

$C_2 = 0$

$$EI\,y = \frac{wL}{12} x^3 - \frac{w x^5}{120L} - \frac{5wL^3 x}{24}$$

At $x = 3L/4$

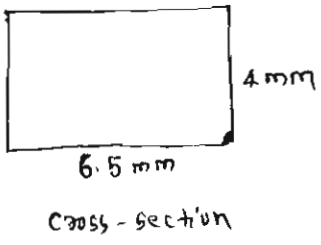
$$EI\,y = \frac{wL}{12} \times \frac{27L^3}{64} - \frac{w}{120L} \times \frac{243L^5}{1024} - \frac{5wL^3}{24} \times \frac{3L}{4}$$

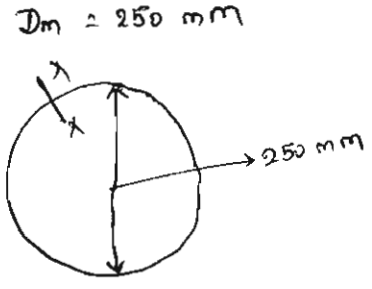
$$= -\frac{wL^4}{40960}\,5041$$

$$y\Big|_{\frac{3L}{4}} = -\frac{5041}{40960} \frac{wL^4}{EI}$$

Q.8 (b) (ii) A steel ring of rectangular cross-section 6.50 mm wide by 4 mm thick has a mean diameter of 250 mm. A narrow radial saw cut is made and tangential separating forces of 4 N are applied at the cut in the plane of the ring. Determine the additional separation due to these forces. Take $E = 2.1 \times 10^5$ N/mm^2.

[8 marks]





$\Delta = \frac{PL}{AE}$

$P = 4N$

$L = 2\pi r$

$= 2 \times 3.14 \times 125$

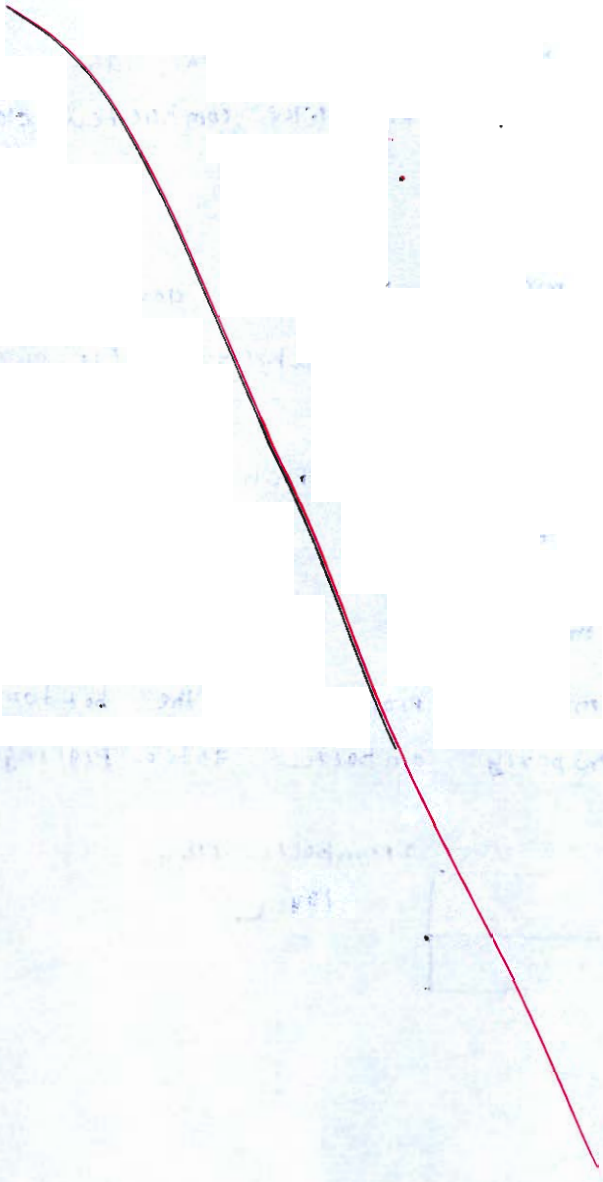
$= 785$ mm

$A = 6.5 \times 4$

$= 26$ mm^2

$\Delta = \frac{4 \times 785}{26 \times 2.1 \times 10^5}$ mm

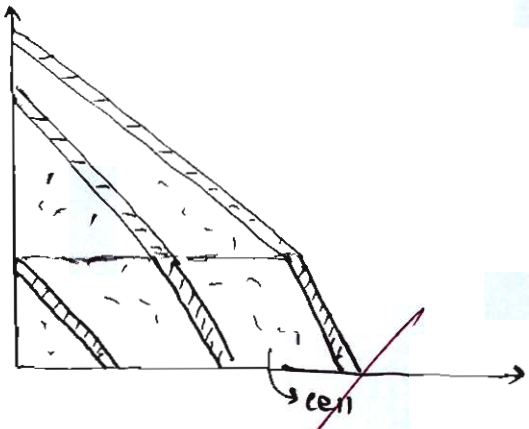
$= 5.751 \times 10^{-4}$ mm



Q.8 (c) (i) What are different methods used for land filling in dry areas? Discuss them. **[10 marks]**

Different mtds used for land filling in dry areas

(i) cell by cell land fill mtd



In this mtd msw is filled up and in the last of day it is covered by good fill earth like compacted clay layers, sealants etc.

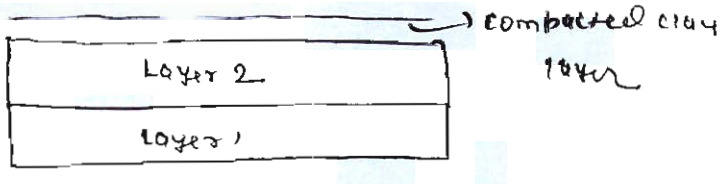
(ii) Direct dumping of msw in low lying areas

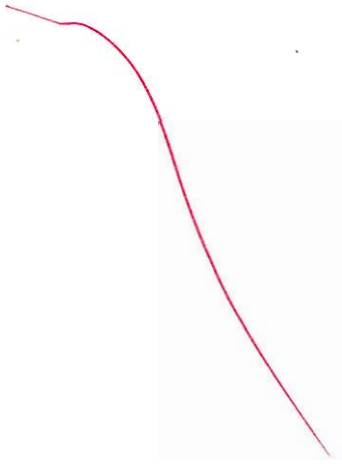
→ Here a suitable area is selected which is far away from cities & msw is dumped.

→ Here gases produced creates the problem for the people who used live nearby

(iii) Layer by layer land fill mtd

→ Here one layer of msw is plated over the bottom layer of msw & properly compacted after plating it





.8 (c) (ii) Determine the amount of air required to oxidise completely 500 kg of waste having the chemical equation $C_{50}H_{100}O_{40}N$.
(Assume oxygen in air is 23 percent by mass)

[10 marks]

$C_{50}H_{100}O_{40}N + O_2 \longrightarrow CO_2 + H_2O + NO_2$

$C + O_2 \longrightarrow CO_2$

12 gm 32 gm

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$

2 gm 16 gm

$\frac{1}{2}N_2 + O_2 \longrightarrow NO_2$

14 gm 32 gm

$C(kg) = \frac{50}{191} \times 500 = 130.89\ kg$

$H(kg) = \frac{100}{191} \times 500 = 261.78\ kg$

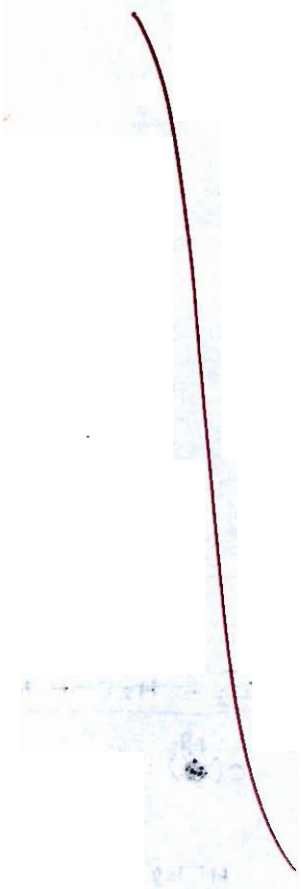
$O(kg) = \frac{40}{191} \times 500 = 104.712\ kg$

$N(kg) = \frac{1}{191} \times 500 = 2.62\ kg$

Amt of air req. $= \left[\frac{32}{12} \times 130.89 + \frac{32}{14} \times 2.62 + \frac{16}{2} \times \left(261.78 - \frac{2}{16} \times 104.712\right)\right] \times \frac{1}{0.23}$

$= \frac{2344.556}{0.23}\ kg$

$= 10193.72\ kg$



OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work