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ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-2

Highway Engineering + Surveying and Geology [All Topics]

Geo-technical & Foundation Engg. - 1 + Environmental Engg. -1 [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 rc sheets at the end of this bool f these pages after cor mination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	49
Q.2	49
Q.3	49
Q.4	—
Section-B	
Q.5	45
Q.6	—
Q.7	—
Q.8	56
Total Marks Obtained	248

Signature of Evaluator Yuvraj

Cross Checked by .....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

(1) Improove answer presentation skills.

(2) Practice more and more questions.

Very good, keep it up

Section A : Highway Engineering + Surveying and Geology

Q.1 (a) Write short notes on:

(i) Kerbs

(ii) Camber

(iii) Pavement uneveness

(iv) Shoulders

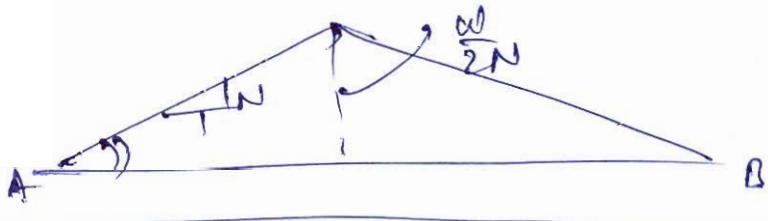
[12 marks]

(i) Kerbs:

These are provided at the edge of pavement to provide lateral stability to pavement moreover they are coloured white & Black alternatively, this induces a distribance to driver while driving, this distribance help driver to drive in particular straight path.

(ii) Camber:

it is gradient provided in lateral dirn for drainage purpose



1 in N
camber
W - width of pavement

	Heavy rain	Light rain
CC roads	2%	1.7%
Thin Bituminous road	2.5%	2%
water macadam road	3%	2.5%
earthern roads	4%	3%.

As per IRC

(vi) Roughness :

→ It is undulation per kilometer of road length.

→ It is measured By Bump Integrator.

→ unit : (mm/km)

→ $BI = 630 (IRI)^{0.12}$

mm/km m/km

→ It is used to ~~design road~~ corrected road undulation

(vii) Shoulder :

→ A 2.5m width extra space is provided on road for emergency purpose.

→ Its camber should be

- 0.5% + (camber of road)
- 3%

(modern)

08

Q.1 (b) (i) Define stopping sight distance and intermediate sight distance.

(ii) Calculate the minimum sight distance required to avoid a head-on collision of two cars approaching from the opposite directions at 80 kmph and 60 kmph. Assume a reaction time of 2.5 seconds, coefficient of longitudinal friction of 0.35 and a brake efficiency of 60 percent, for both the cars.

[4 + 8 = 12 marks]

(i) Stopping sight Distance

→ it is the minm distance required on the road by the driver to stop his/her vehicle due to the obstruction ahead his/her vehicle.

$$SSD = 0.278 V t_r + \frac{V^2}{254(f \pm g)}$$

Design speed | 2.5 sec | coeff of friction | gradient

Intermediate sight Distance

→ ISD = (2 SSD)

→ it is the distance provided when road length is restricted.

→ when overtaking sight distance is not been able to be provided, Intermediate sight distance is provided.

→ OSD > ISD > SSD

(ii) $V_1 = 80$ kmph , $V_2 = 60$ kmph

$t_r = 2.5$ sec

$f = 0.35$

$\eta_B = 0.6$

03

$SSD = (SSD_1 + SSD_2)$

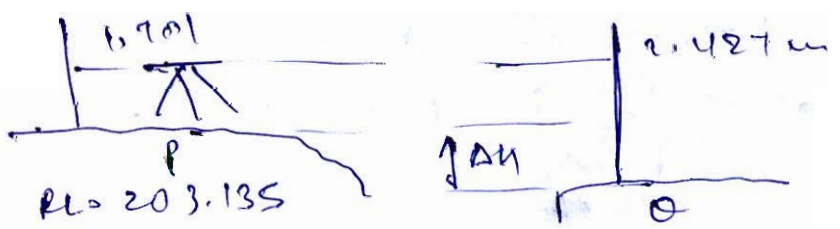
$= 0.278\, K_1 t_R + \frac{V_1^2}{254(48f)} + 0.278\, K_2 t_R + \frac{V_2^2}{254(48f)}$

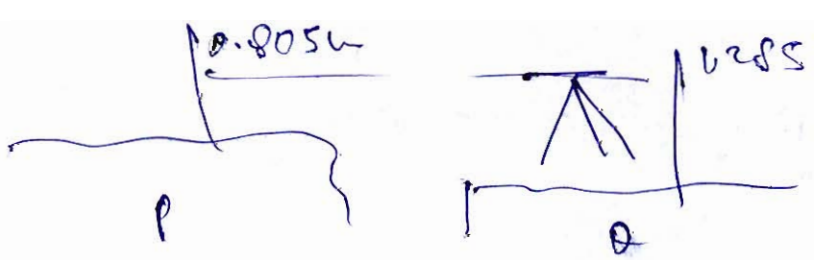
SSD = 284.77 m

08

Q.1 (c) Two stations P and Q were on either side of a river 1200 m apart. The instrument was kept near P and the readings on the staff kept at P and Q were 1.701 m and 2.427 m respectively. The instrument was then shifted to Q and the readings on the staff held at P and Q were 0.805 m and 1.285 m respectively. If the reduced level of P is 203.135 m, then find the RL of Q. Also, find the error due to refraction if the collimation error of the instrument is 0.002 m in 100 m.

[12 marks]





$\Delta H = \frac{(2.427 - 1.201) + (1.285 - 0.805)}{2}$

$= 0.603\ m$

$RL\ Q = (RL\ P - \Delta H) = 202.552\ m$

(Net misclosure) = ($\varepsilon_{adj} + \varepsilon_R + \varepsilon_{coll}$)

$2.427 - (1.201 + 0.603) = +0.0785 (1.2)^2 + \varepsilon_R + \frac{0.002}{100} \times 1200$

2.304

$\varepsilon_R = -0.01404\ m$

12

Q.1 (d) (i) What are the basic elements involved in electromagnetic remote sensing?
(ii) What is the difference between passive and active remote sensing?
(iii) What are the various disadvantages of remote sensing?

[4 + 4 + 4 = 12 marks]

(ii)

Passive	Active
→ when sun is used as a energy/ electromagnetic radiation source.	→ when remote sensor emits electromagnetic radiation by itself.

(iii) Advantages

1. Land use:
2. Archeological survey
3. Topography of land
4. Defence - movement of troops
5. mitigation purpose,
6. Earthquake & tsunami prediction.
7. Disaster prediction

06

(i) remote sensing is the art of determining information about any surface through electromagnetic radiation.

~~Basic~~ main element in remote sensing is electromagnetic radiations. It could be passive or Active

Improve answer presentation skills

Q.1 (e) Spot speed studies were carried out at a certain stretch of a highway with mixed traffic flow and the consolidated data collected are given below.

Speed range, kmph	No. of vehicles observed
0 to 10	10
10 to 20	20
20 to 30	68
30 to 40	90
40 to 50	205
50 to 60	250
60 to 70	120
70 to 80	40
80 to 90	30
90 to 100	17

Determine:

(i) the upper and lower speed limits for installing speed regulation sign at this road stretch, and

(ii) the design speed for checking the geometric design elements of the highway.

[12 marks]

mean speed	No. of veh	Cum veh	% cum
5	10	10	1.176
15	20	30	3.53
25	68	98	11.53
35	90	188	22.11
45	205	393	46.23
55	250	643	75.64
65	120	763	89.76
75	40	803	94.47
85	30	833	98
95	17	850	100

(i) upper speed = 85% percentile speed

$$= 55 + \frac{(65-55)}{(89.76-75.64)} \times (85-75.64)$$

$$= 61.62 \text{ kmph}$$

lower speed = 15% percentile speed

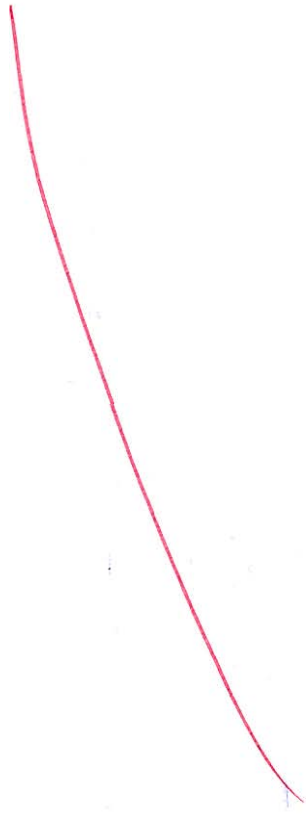
$$= 25 + \frac{(35-25)}{(22.11-11.53)} (15-11.53)$$

$$= 28.28 \text{ kmph}$$

(ii) Design speed = 98% speed

$$= 85 \text{ kmph}$$

12



Q.2 (a) (i) The following figures were extracted from a "level field book", some of the entries being illegible. Insert the missing figures, check your results, and re-book all the figures using the "rise and fall" method.

Station	B.S.	I.S.	F.S.	Rise	Fall	R.L.	Remarks
1	2.285					232.46	B.M No. 1
2	1.650		×	0.020			
3		2.105			×		
4	×		1.960	×			
5	2.050		1.925		0.300		
6		×		×		232.255	B.M. No. 2
7	1.690		×	0.340			
8	2.865		2.100		×		
9			×	×		233.425	B.M. No. 3

(ii) A plan drawn to a scale of 1 cm = 20 m has shrunk such that a line originally 10 cm long has shrunk to length of 9.78 cm. A line AB which measures 18.7 cm on paper now has to be set out on the ground. To what length should it be set, if the 20 m chain available for measurement is 0.015 m too long?

[15 + 5 = 20 marks]

(i)

Sta	BS	IS	FS	Rise	Fall	RL	Remarks
1	2.285					232.46	BM
2	1.650		2.265	0.02		232.48	
3		2.105			0.455	232.025	
4	1.625		1.960	0.145		232.17	
5	2.050		1.925		0.300	231.87	
6		1.665		0.385		232.255	
7	1.690		1.325	0.340		232.595	BM
8	2.865		2.100		0.41	232.185	
9			1.625	1.24		233.425	
10							BM

(prev Reading − This Read), Rise / Fall

(2.285 − x) = 0.02 m

Check:

ΣRise − ΣFall = 2.13 − 1.165 = 0.965

ΣBM − Σ FS = 12.165 − 11.2 = 0.965 } Same

last RL − first RL = 0.965

13

show one sample calculation

(ii) Scale 1. $k = 20m$

Shrunk factor = $\frac{9.78}{10}$

New scale = $\frac{1cm}{20 \times \frac{10}{9.78} m}$

$= \frac{1cm}{20.449 m}$

Length of ground = $18.7 \times 20.449 m$

$L' = 382.413 m$

(wrong length)

$L l = L' l'$

$20 \times L = 382.413 \times 20.615$

$L = 382.6998 m$

corrected length

05

Q.2 (b) The consolidated data collected from speed and delay studies by floating car method on a stretch of urban road of length 4.0 km running North-South are given below.

Determine the average values of (i) volume, (ii) journey speed and (iii) running speed of the traffic stream along each direction.

Trip No.	Direction of trip	Journey time min-sec	Total stopped delay min-sec	No. of vehicles overtaking	No. of vehicles overtaken	No. of vehicles from opposite direction
1	N–S	6–30	1–40	4	7	270
2	S–N	7–16	1–40	5	3	180
3	N–S	6–40	1–50	4	2	280
4	S–N	7–50	2–10	2	1	200
5	N–S	6–10	1–30	3	5	230
6	S–N	8–24	2–20	3	4	170
7	N–S	6–40	1–40	2	5	300
8	S–N	7–30	1–10	2	2	150

[20 marks]

(2) Average values

Trip	Dirⁿ	Journey time	Delay	Overtaking	Overtaken	Opposite
(1)	N-S	390 sec	110 sec	3.25	4.75	270
(2)	S-N	465 sec	110 sec	3	2.5	175

N–S :

$q = \frac{n_a + n_y}{t_a + t_w}$

$n_a = 175$

$n_y = 3.25 - 4.75$

$= -1.5$

$t_w = 390$

$t_a = 465$

$q = 0.2029$ veh/s

$q = 730.52$ veh/Hr

$\bar{t} = t_w - \frac{n_y}{q} = 397.39$ sec

Journey speed $= \frac{D}{\bar{t}} = 10.065$ m/s

Pump speed = $\frac{D}{t - \text{Delay}}$ = 13.45 m/s

Q-N :

$n_q = 270$

$n_y = 2 - 2.5 - 0.5$

$t_0 = 465$

$t_a = 390$

$q = 0.3163$ veh/s

$q = 1138.947$ veh/Hr

$\bar{t} = t_0 - \frac{n_y}{q}$ = 463.42 sec

Journey speed = $\frac{D}{\bar{t}}$ = 8.63 m/s

Pump speed = $\frac{D}{\bar{t} - \text{Delay}}$ = 11.317 m/s

18

Q.2 (c) (i) Write short notes on the following tests for aggregates:

1. Los Angeles abrasion test
2. Impact test

Also, mention their respective recommended values for pavement construction.

(ii) A Marshall specimen is prepared for bituminous concrete with a bitumen content of 5% by weight of total mix. The theoretical and the measured specific gravity of the mix are 2.45 and 2.35 respectively. If the bitumen has a specific gravity of 1.02, then what is the percent voids in mineral aggregate filled with bitumen (VFB)?

[15 + 5 = 20 marks]

(ii)

$W_B = 0.05\, W_T$

$G_t = 2.45$

$G_M = 2.35$

$G_B = 1.02$

air void $(V_a) = \dfrac{G_t - G_M}{G_t} \times 100$

$= 4.08\%$

Bitumen void $(V_b) = \dfrac{W_B}{G_B} \times \dfrac{G_M}{W_T} \times 100$

$= 0.05 \times \dfrac{2.35}{1.02} \times 100$

$= 11.52\%$

$VFB = \left(\dfrac{V_b}{V_b + V_a}\right) = 73.845\%$

05

(i) (1) Los Angeles test :

→ used to determine Hardness of aggregates

→ Los Angeles apparatus used

→ 500 revolution is given by putting 10-15 steel Balls with aggregates

→ After revolution, aggregates are sieved through 2.36mm sieve.

Los Angeles test factor	$= \frac{W_2}{W_1}$	W_2 → weight of agg passed through 2.36mm sieve; W_1 → initial weight

< 30% (surface course)

< 50% (base course)

08

(2). Impact test :

→ used to determine toughness of aggregates

→ IS no. of blows given by standard weight of 14.9kg to the aggregate sample

Impact value	$= \frac{W_2}{W_1}$	W_2 → wt of agg. passed through 2.36m sieve; W_1 → initial wt

IV < 30% (surface)

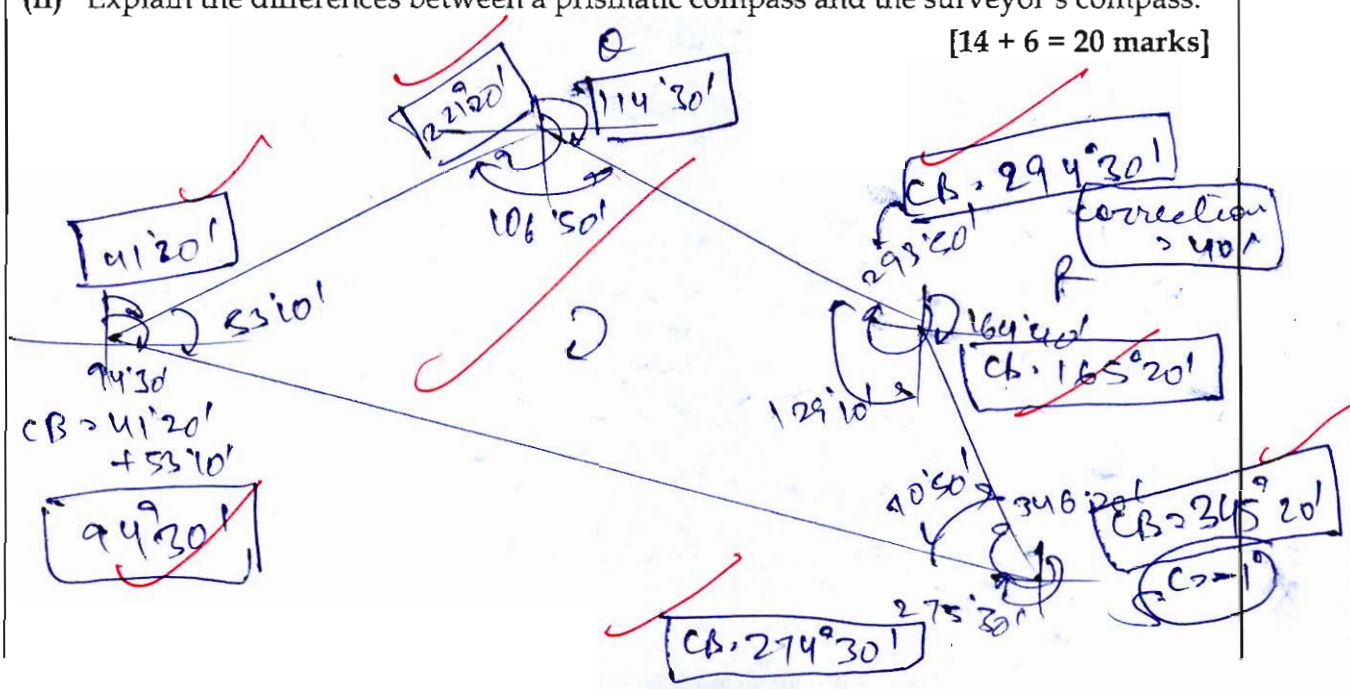
< 35% (base)

Q.3 (a) (i) The whole circle bearings of the lines of a closed traverse are given below. Check the bearings for local attraction. Correct the bearings by calculating the included angles.

PQ : 41°20′	QP : 221°20′
QR : 114°30′	RQ : 293°50′
RS : 164°40′	SR : 346°20′
SP : 275°30′	PS : 94°30′

(ii) Explain the differences between a prismatic compass and the surveyor's compass.

[14 + 6 = 20 marks]



	Int Angles
P	53°10'
Q	106°50'
R	129°10'
S	70°50'
	360°00°

No correction in Internal Angles

	|FB − BA|
PQ	180°
QR	179°20'
SQ	181°40'
SP	181°

Reference Bearings

PQ = 41°20'
QP = 221°20'

Corrected Bearing on Diagram

Included Angles

P = 306°50'
Q = 253°10'
R = 230°50'
S = 289°10'

12

(ii)

Prismatic compass	Surveyor's compass
→ Floating ring, graduation are inverted	→ Fixed dial, graduation are straight.
→ Sight, reading can be done simultaneously	→ First sighting, then reading.
→ Broad Aluminium Needle.	→ Sharp needle
→ Least count : 10'	→ Least count : 5'
→ No need of tripod.	→ Tripod is mandatory
→ Used nowadays	→ conventional instrument.

05

Q.3 (b) **(i)** Using the data given below, calculate the wheel load stresses at interior, edge and corner regions of a cement concrete pavement using Westergaard's stress equations. Also determine the probable location where the crack is likely to develop due to corner loading.

Wheel load, P = 5000 kg

Modulus of elasticity of cement concrete, $E = 3 \times 10^5$ kg/cm^2

Pavement thickness, h = 20 cm

Poisson's ratio of concrete, $\mu = 0.15$

Modulus of subgrade reaction, $k = 6.0$ kg/cm^3

Radius of contact area, a = 15 cm.

(ii) What are the differences between flexible pavement and rigid pavement?

[16 + 4 = 20 marks]

(i) P = 5000 kg; E = 3×10^5; H = 20 cm
μ = 0.15; K = 6 kg/cm²; a = 15 cm

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

$$S_e = \frac{0.529P}{h^2}\left(4\log\frac{l}{b} + 0.359\right)$$

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

10

$$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4} = 76.42 \text{ cm}$$

$$b = \sqrt{1.69a^2 + h^2} - 0.675a$$

$$b = 17.44 \text{ cm}$$

$a < 1.724h$

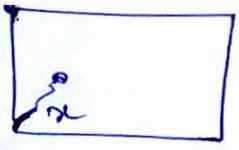
$15 < 34.48$ (Ok)

$S_i = 14.56$ kg/cm²

$S_e = 20.92$ kg/cm²

$S_c = 20.12$ kg/cm²

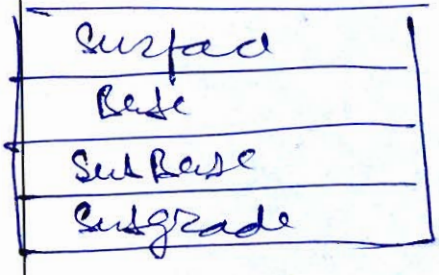
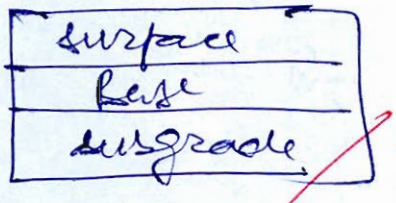
location of crack x = ?



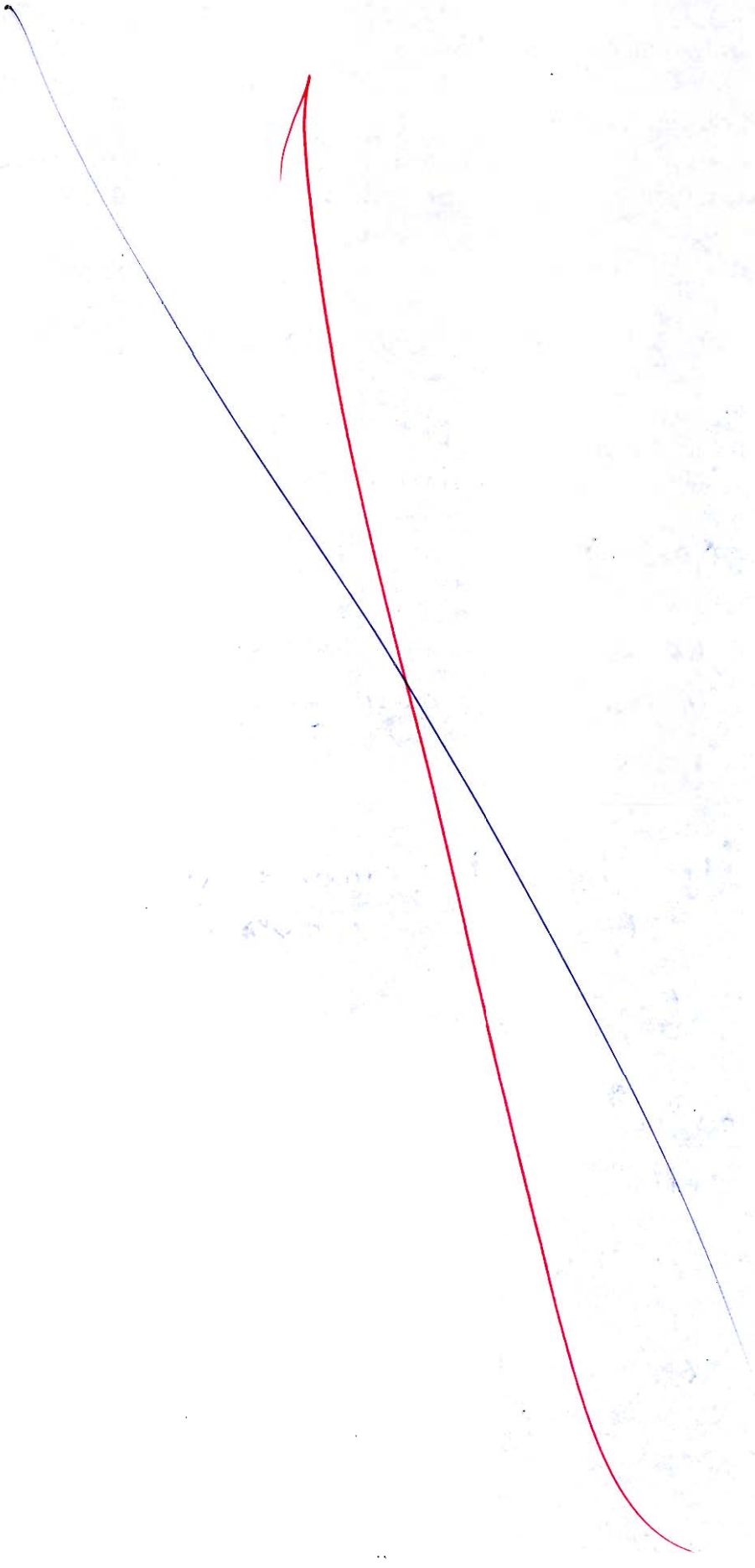
$$x = 2.5\,\ell\sqrt{15 \times 76.4}$$

$$x = 87.35 \text{ cm}$$

(ii)

	Flexible	Rigid
(1)	Flexural rigidity is less compared to Rigid	(1) Flexural rigidity is more
(2)	construction 	(2) construction 
(3)	No joints are used for expansion & contraction	(3) Longitudinal & transverse joint required.
(4)	Any failure in subgrade is reflected onto surface	(4) Any failure in subgrade does not reflect on surface due to Beam Action
(5)	Low initial cost & high maintainence cost	(5) High initial cost & low maintainence cost

04



Q.3 (c) **(i)** Explain the following terminologies used in theodolite surveying.

1. Face right
2. Face left
3. Swing the telescope
4. Line of collimation
5. Telescope inverted

(ii) A steel tape of weight 20 N is 30 m long at a temperature of 16°C and a pull of 50 N when laid on a flat surface. Find the correct length of the tape at a field temperature of 28°C and under a pull of 120 N. If in the above condition, a base line is measured and the recorded length of the line is 640 m then find the correct length of the base line.

Take $\alpha = 12 \times 10^{-6}/°C$ and $E = 2 \times 10^5$ N/mm^2, A = 7.5 mm^2.

[10 + 10 = 20 marks]

(ii)

$P_{std} = 50N$ $\quad P_M = 120N$

$T_{std} = 16°C$ $\quad T_M = 28°C$

$C_{temp} = L\alpha\Delta T$

$= 640 \times 12 \times 10^{-6} \times (28 - 16)$

$= 0.09216$ m

$C_{pull} = \frac{(P_M - P_{std})L}{AE} = \frac{(120 - 50) \times 640}{7.5 \times 2 \times 10^5}$

$= 0.02986$ m

$C_{sag} = -\frac{w^2 L^3}{24 P_M^2}$

$= -0.74$ m

10

$C_{total} = -0.617$ m

$L_{corrected} = 639.383$ m

(i)

(1) Face right: when the telescope of theodolite is on the right side, then reading taken is known as face right reading.

(2) Face left: when the telescope of theodolite is on the left side, then reading taken is known as face left reading.

(3) Swing: Rotating the theodolite in horizontal plane along vertical axis is called swinging of telescope

(4) Line of collimation: It is the line of sight or line that passes through eye piece & objective lens of telescope.

(5) Telescope inverted:
Making the telescope face right or face left when initial telescope was face left or face right using transiting is called telescope Inverted

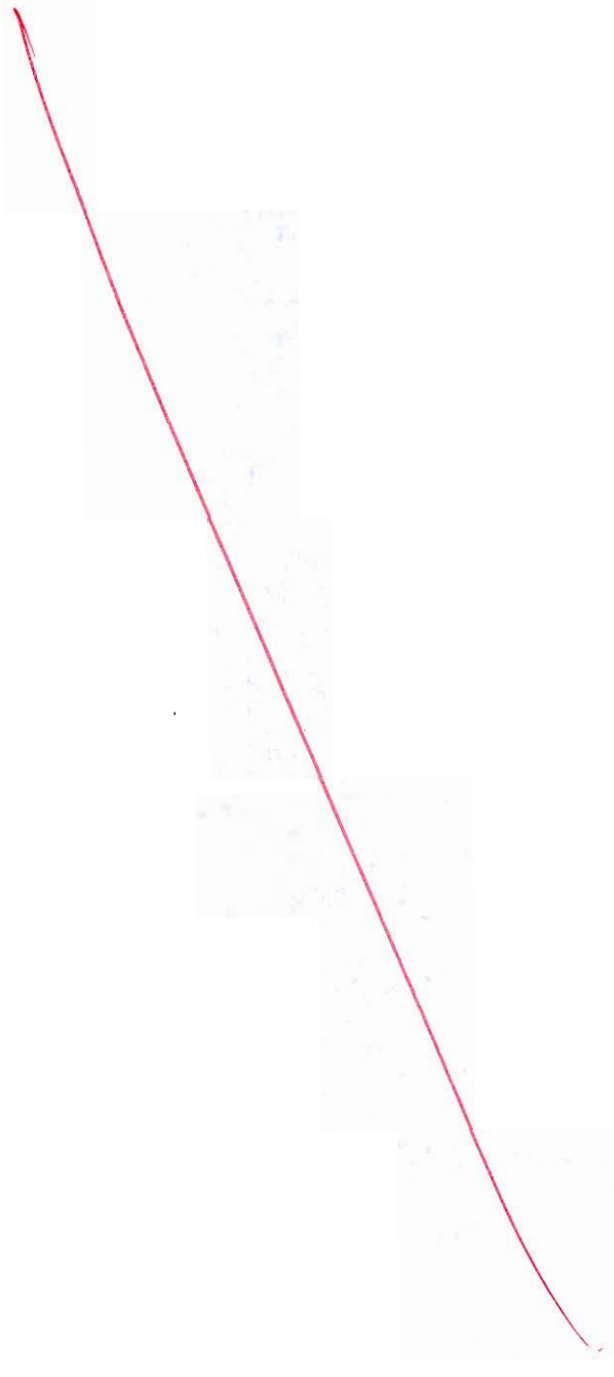
08

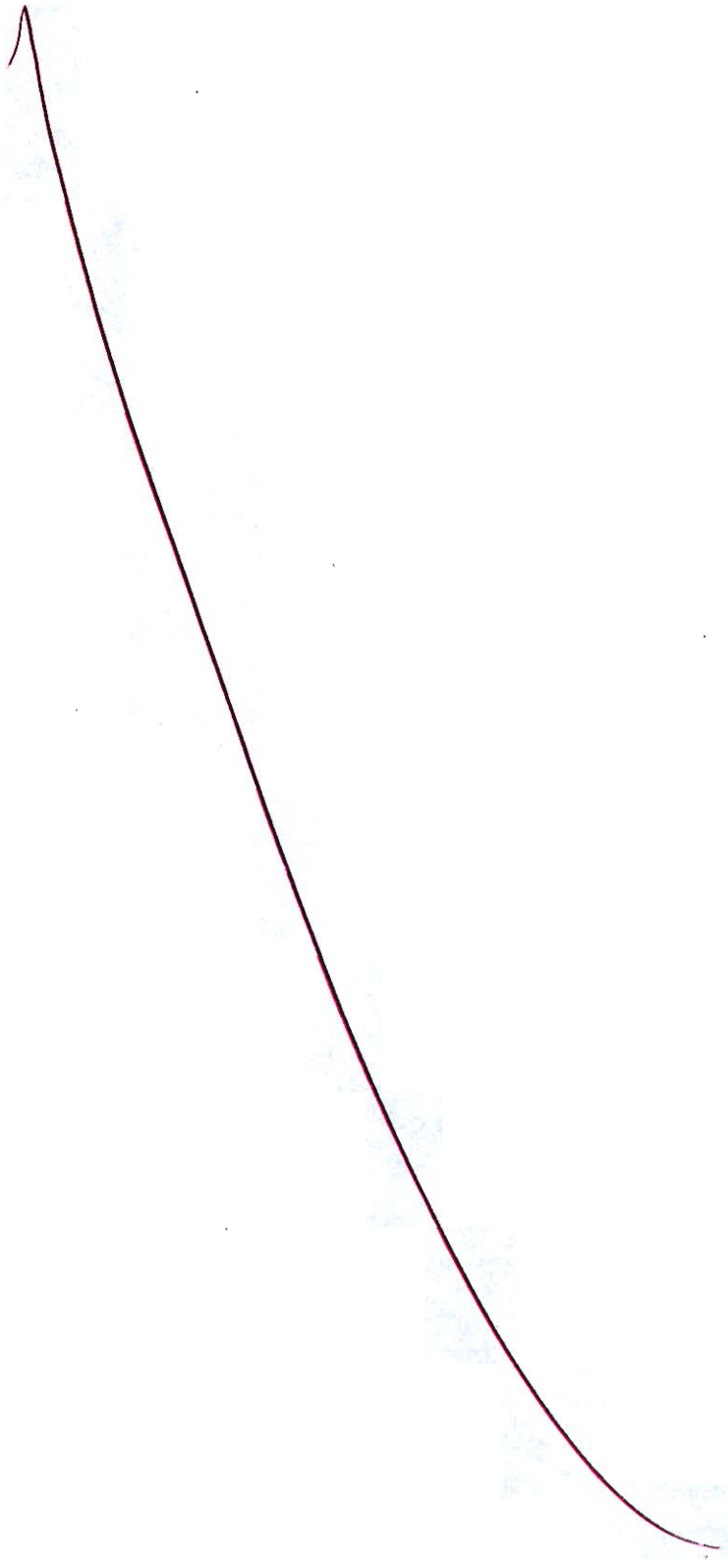
Q.4 (a) **(i)** Explain the basic principle of triangulation and also explain with figure different types of triangulation systems.

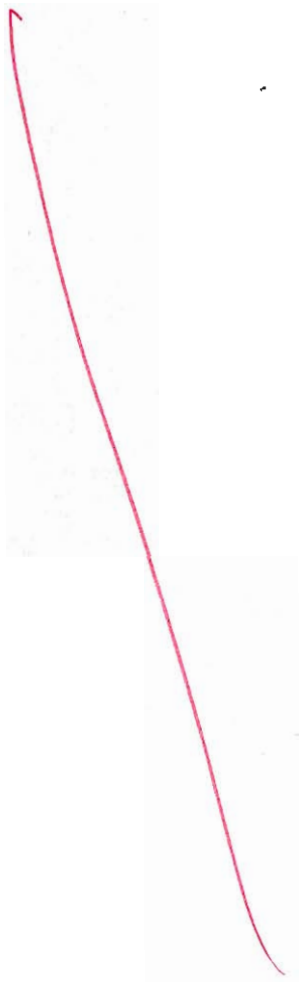
(ii) Find the length and bearing of line BC from the partial data available for transverse ABCDA.

Line	AB	BC	CD	DA
Length (m)	156.5	-	234.8	203.1
Bearing	78°40′	-	251°18′	3°45′

[8 + 12 = 20 marks]



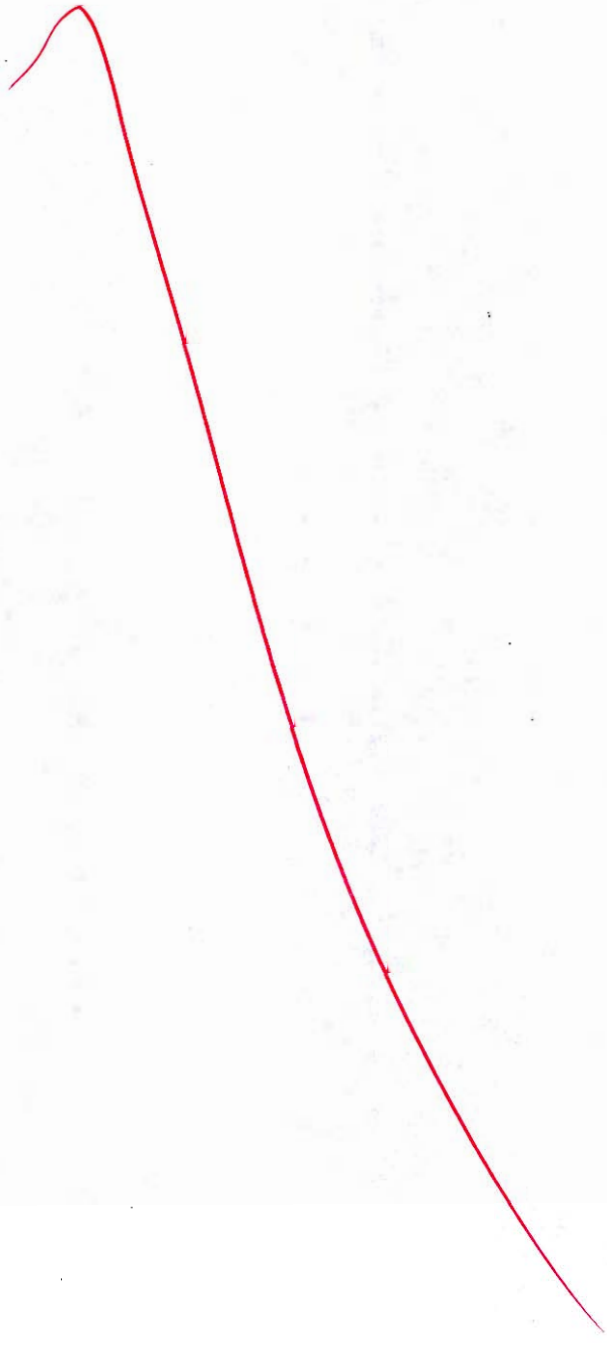


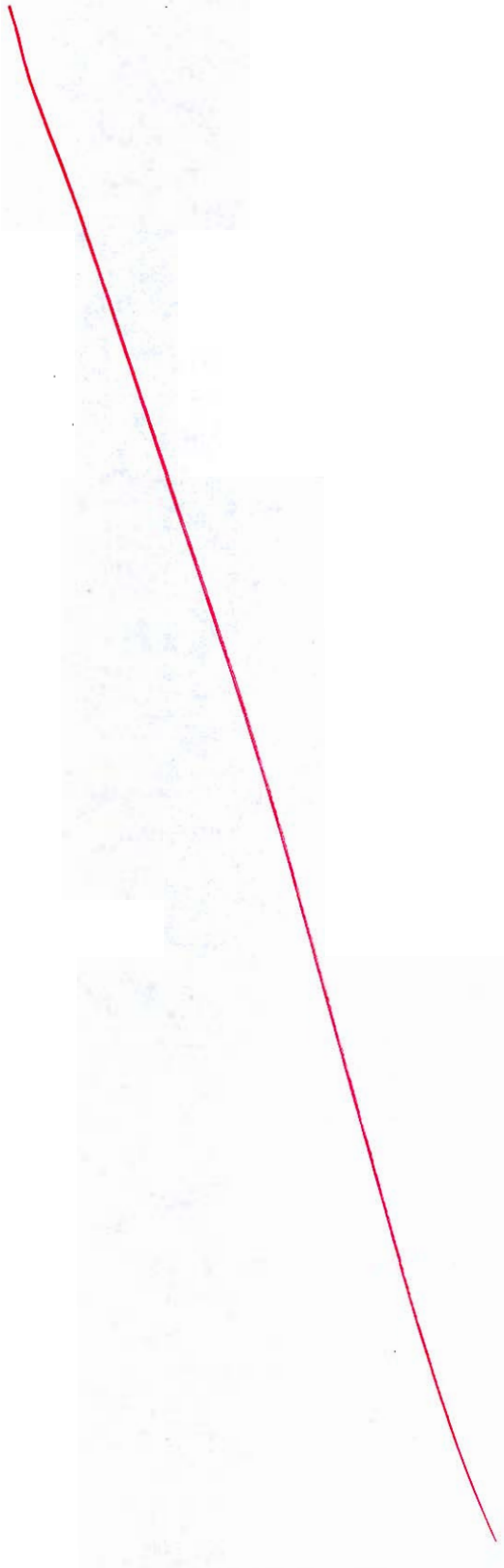


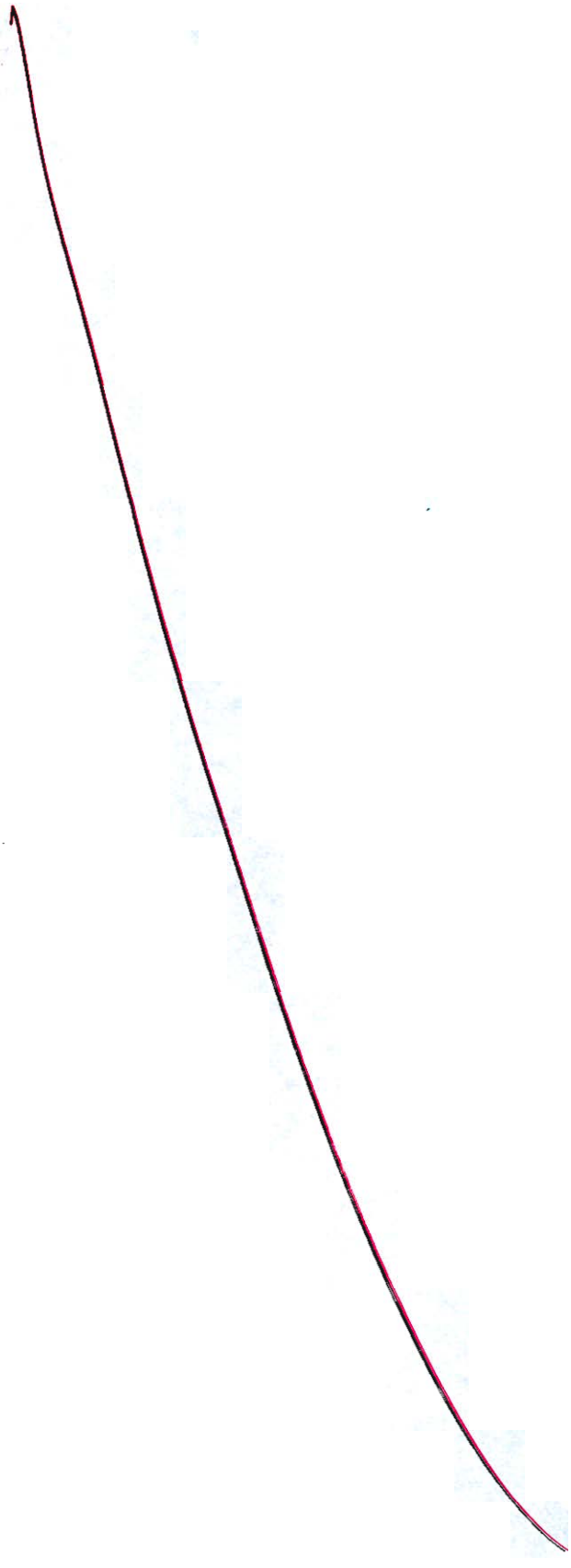
Q.4 (b) (i) A vertical summit curve is to be designed when two grades, $+\frac{1}{50}$ and $-\frac{1}{60}$ meet on a highway. The stopping sight distance and overtaking sight distance required are 150 m and 650 m respectively. But due to site conditions, the length of vertical curve has to be restricted to a maximum value of 500 m if possible. Calculate the length of summit curve needed to fulfil the requirements of (1) stopping sight distance (2) overtaking sight distance or atleast intermediate sight distance.

(ii) A valley curve is formed by a descending grade of 1 in 30 meeting an ascending grade of 1 in 40. Design the length of valley curve to fulfil both comfort condition and head light sight distance requirements for a design speed of 90 kmph. Assume allowable rate of centrifugal acceleration, C = 0.6 m/sec^3.

[10 + 10 = 20 marks]







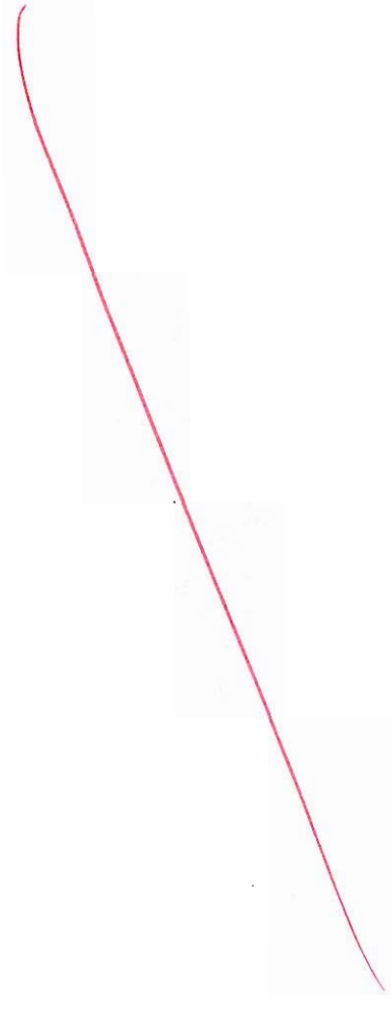
Q.4 (c) (i) Given below are the perpendicular offsets that were taken from a chain:

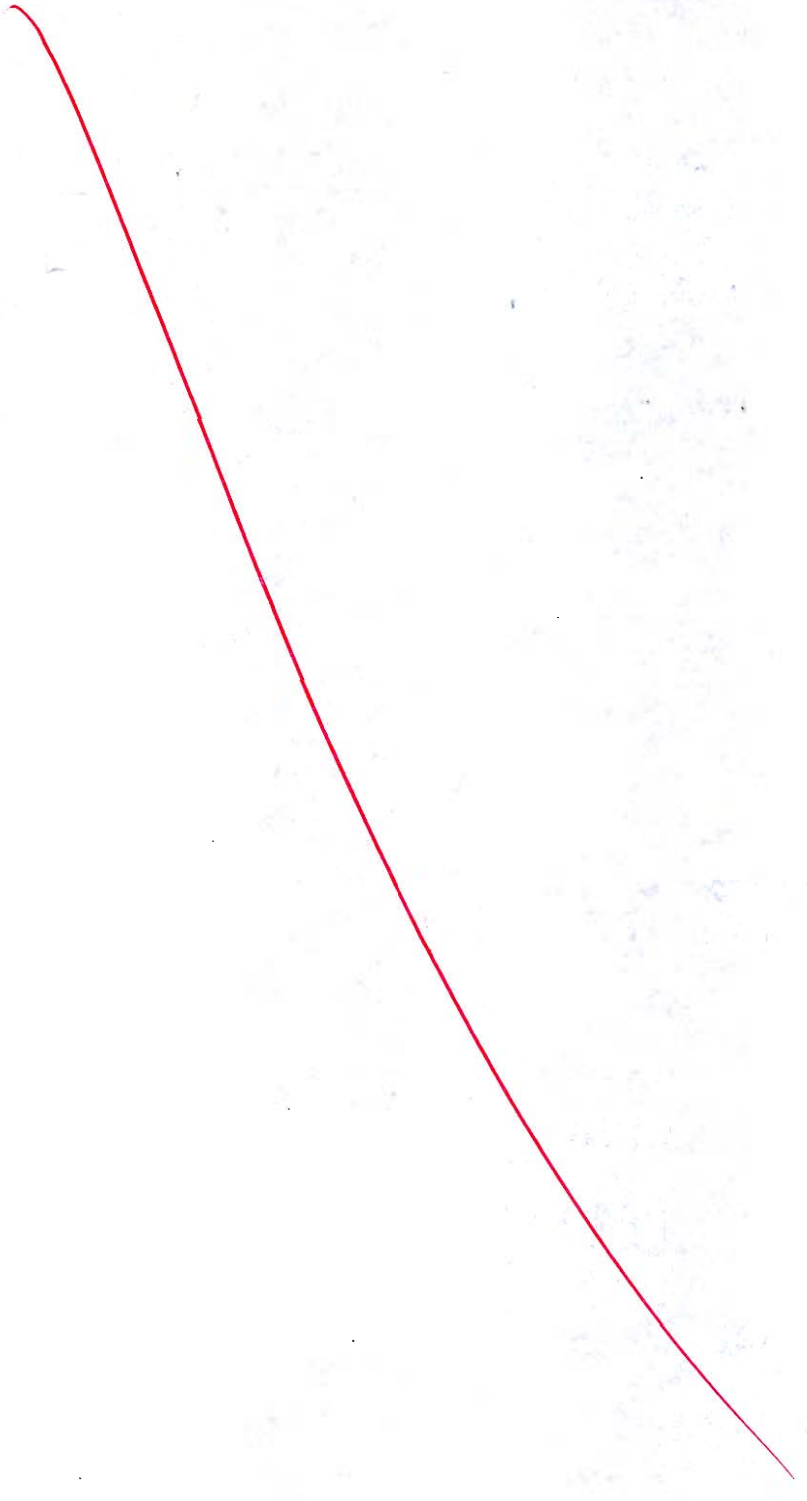
Chainage (m)	0	30	60	90	120	150	180	210
Offset length (m)	0	7.42	6.27	9.40	8.42	8.21	8.96	7.84

Compute the area between the chain line and irregular boundary using Simpson's rule.

(ii) In a pair of overlapping vertical photographs, the mean distance between two principal points both of which lie on the datum is 6.5 cm. At the time of photography, the air craft was 600 m above the datum. The camera has a focal length of 150 mm. In the common overlap, a tall chimney 100 m high with its base in the datum surface is observed. Determine difference of parallax for top and bottom of chimney.

[10 + 10 = 20 marks]





Section B : Geo-technical & Foundation Engg. - 1 + Environmental Engg. -1

Q.5 (a) The natural water content of a sample taken from a soil deposit was found to be 12%. It has been calculated that the maximum density for the soil will be obtained when the water content reaches 20%. Find the void ratio of soil in its natural state and volume of 100 kN of soil in its natural state. Also, compute how much of water must be added to each 100 kN of soil (in its natural state) in order to increase the water content to 20%. The degree of saturation in its natural state was 42% and G = 2.65. **[12 marks]**

$e = ?$ $\gamma_{Bulk} = ?$

$G = 2.65$

$w = .12$ $\quad w' = .2$

$S = .42$

$Se = wG$

$.42 \times e = .12 \times 2.65$

$\boxed{e = 0.757}$

$$\gamma_{Bulk} = \left(\frac{G + Se}{1+e}\right)\gamma_w$$

$$= \left(\frac{2.65 + .42 \times .757}{1.757}\right) 9.81$$

$$= 16.57 \text{ kN/m}^3$$

volume for 100 kN $= \dfrac{100}{16.57}$

$\boxed{= 6.035 \text{ m}^3}$

Weight of solid:

$$W_s = \left(\frac{W_T}{1+w}\right)$$

$$W_s = \frac{100}{1+.12} = 89.28 \text{ kN}$$

$\boxed{W_w = 10.714 \text{ kN}}$

final:

$$W_s = \frac{W_T'}{1+w'} \qquad W_T' = 107.136 \text{ kN}$$

$W_w' = W_T' - W_s = \boxed{17.856 \text{ kN}}$

weight of water added = $W_1' - W_2$

= 7.142 kN

vol of water added = $\frac{7.142}{9.81}$ = 0.728 m^3

V = 728 litres

12

Q.5 (b) A factory uses 4,00,000 litres of furnace oil (specific gravity 0.97) per month. If for one million litres of oil used per year, the particulate matter emitted is 3.0 tonnes per year, SO_2 emitted is 59.7 tonnes per year, NO_x emitted is 7.5 tonnes per year, hydrocarbons emitted are 0.37 tonnes per year, and carbon monoxide emitted is 0.52 tonnes per year, then calculate the height of the chimney required to be provided for safe dispersion of the pollutants? (Assume 300 working days and 24 hours per day)

[12 marks]

Height of chimney = ?

H_{min} = 30 m

By SO_2 :

$H_1 = 74 \times \left(\frac{59.7 \times 10^3}{300 \times 24}\right)^{0.3}$

H_1 = 139.58 m

By ppm

$$H_2 = 14\left(\frac{3}{300\times24}\right)^{0.27}$$

$$= 1.71\ m$$

$H =$ { ~~139.58 m~~ / 1.71 m

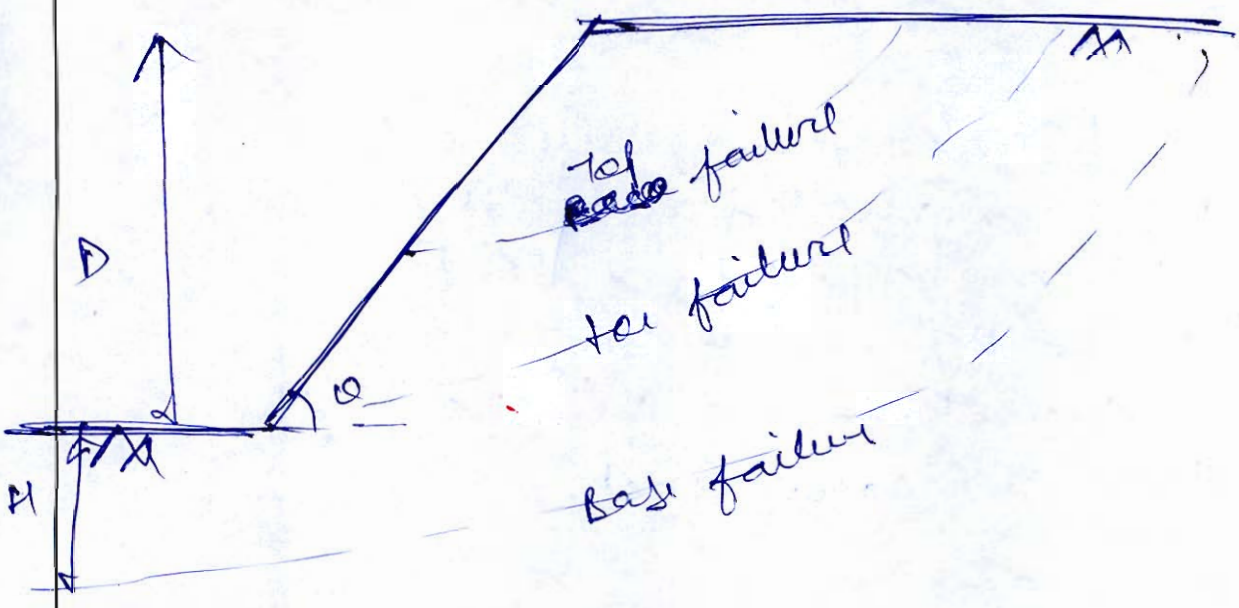
max = 30 m

H = 1.71 m (provided)

Q.5 (c) (i) What are the probable types of failure of a finite slope?
(ii) With the help of neat sketch, explain vane shear test.

[5 + 7 = 12 marks]

(i)



① Top failure:

→ The top portion of finite slope may fail when the soil posses high strength at Base & low strength at top.

② Toe failure:

→ Toe portion of finite slope may fail when soil posses good strength at top & Base moreover if $\theta > 53^\circ$ ⇒ toe failure is generally observed

05

③ Base failure:

→ Most common failure
→ Generally Happen Because of low strength at Base

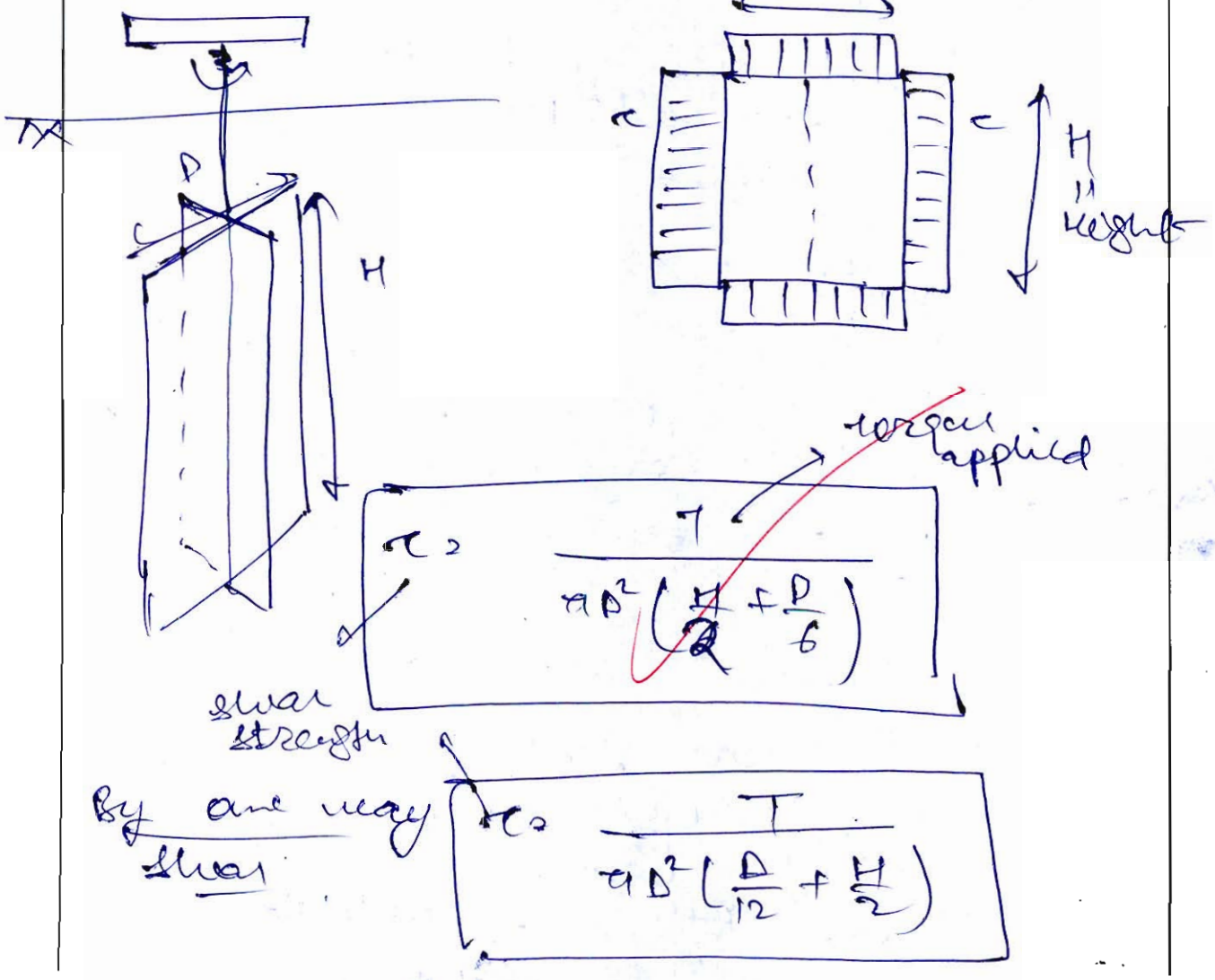
Depth factor = $\frac{H+D}{H}$ if DF > 1 :→ Base failure

(ii) Vane shear test

→ Field test
→ used to determine shear strength of soft clay, sensitivity and liquid limit.
→ Not for sands & stiff soils.
→ vane is inserted into the soil, torsion is applied, resistance provided by soil is measured.
→ use the standard formula, shear strength is calculated.

05

Two way
Cast

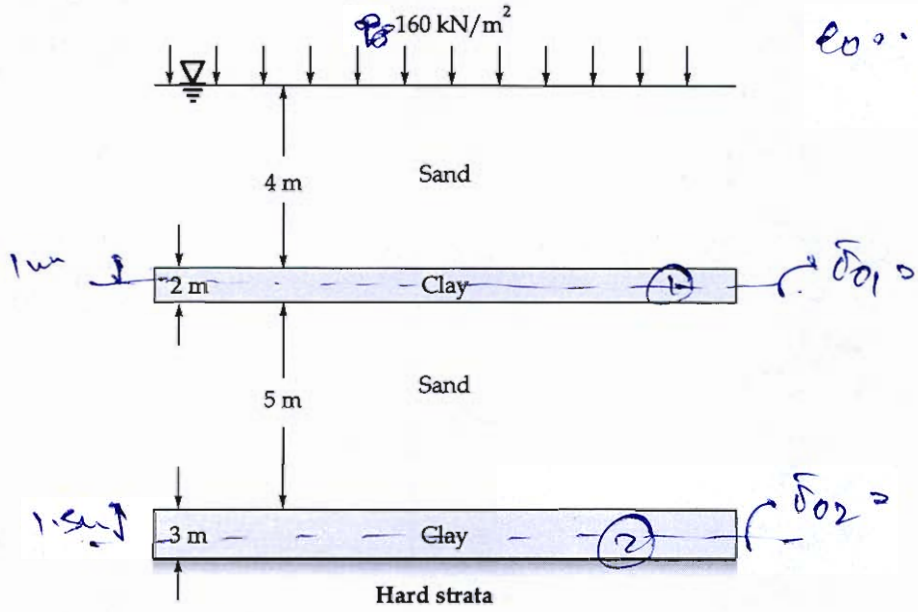


By one way
Shear

$\tau = \frac{T}{\pi D^2\left(\frac{D}{12}+\frac{H}{2}\right)}$

Q.5 (d) Figure below shows a soil profile consisting of two layers of clay and two layers of sand, all of which is completely submerged. Compute the total settlement under a uniform load of 160 kN/m^2, well distributed over a large area. Given the following soil properties:

- For sand layers, γ_{sat} = 21 kN/m^3 → γ'_{sand} = 11.19 kN/m^3
- For clay layers, w = 40%, C_c = 0.24, G = 2.7



$e_0 = .4 \times 2.7 = 1.08$

[12 marks]

$\gamma'_{clay} = \left(\frac{2.7}{1+.4\times2.7}\right)9.81 = 8\ kN/m^3$

$\bar{\sigma}_{o1} = (4\times11.19 + 1\times8) = 52.76\ kPa$

$\bar{\sigma}_{o2} = (4\times11.19 + 2\times8 + 5\times11.19 + 1.5\times8) = 128.71\ kPa$

$\Delta\bar{\sigma} = 160\ kPa$

12

$\Delta H_1 = \frac{H_0 C_c}{1+e_0} \log\left(\frac{\bar{\sigma}_{o1} + \Delta\bar{\sigma}}{\bar{\sigma}_{o1}}\right)$ (2m)

$= 139.75\ mm$

$\Delta H_2 = \frac{H_2 C_c}{1+e_0} \log\left(\frac{\bar{\sigma}_{o2} + \Delta\bar{\sigma}}{\bar{\sigma}_{o2}}\right)$ (3m)

$= 121.44\ mm$

$\Delta H_{total} = (\Delta H_1 + \Delta H_2) = 261.198\ mm$

Q.5 (e) Write short notes on the following coagulants used in coagulation aided sedimentation:

(i) Alum

(ii) Copperas

(iii) Sodium aluminate

[12 marks]

(i) Alum ($Al_2(SO_4)_3 . 18H_2O$ — MM = 666 g)

→ works best in pH = (6.5 – 8.5)

→ requires Alkalinity for reaction

→ Induces permanent Hardness

→ Induces Acidity to water

→ Highly efficient

→ Commonly used in practise

$Al_2(SO_4)_3 . 18H_2O + 3Ca(HCO_3)_2$

↓ from Hardness

$2Al(OH)_3 + 3CaSO_4 + 6CO_2$ ← Acidity

$+ 18H_2O$

(ii) Copperas: ($FeSO_4 . 7H_2O$) MM = 278 gm

→ forms ppt of $Fe(OH)_3$

→ requires Alkalinity as lime

→ induces permanent Hardness.

→ works in pH > 8.5

→ if lime added first, 1 mol lime is needed for 1 mol Copperas

→ if lime added second, 2 mol lime is needed for 1 mol copperas.

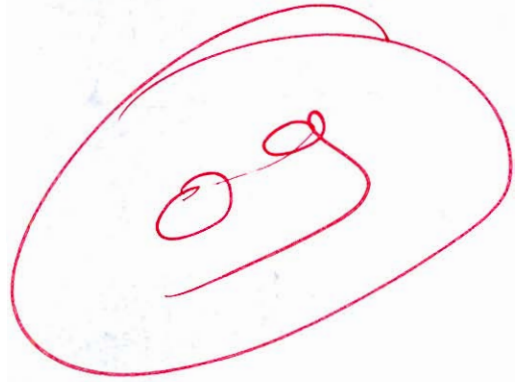
(3) Sodium Aluminate ($Na_2Al_2O_4$)

→ Deduct requires Alkalinity

→ It deduct reduces Hardness, But it reacts with Hardness & reduces it

→ costly

→ Used where No or zero Hardness is desired. Eg, Boilers.

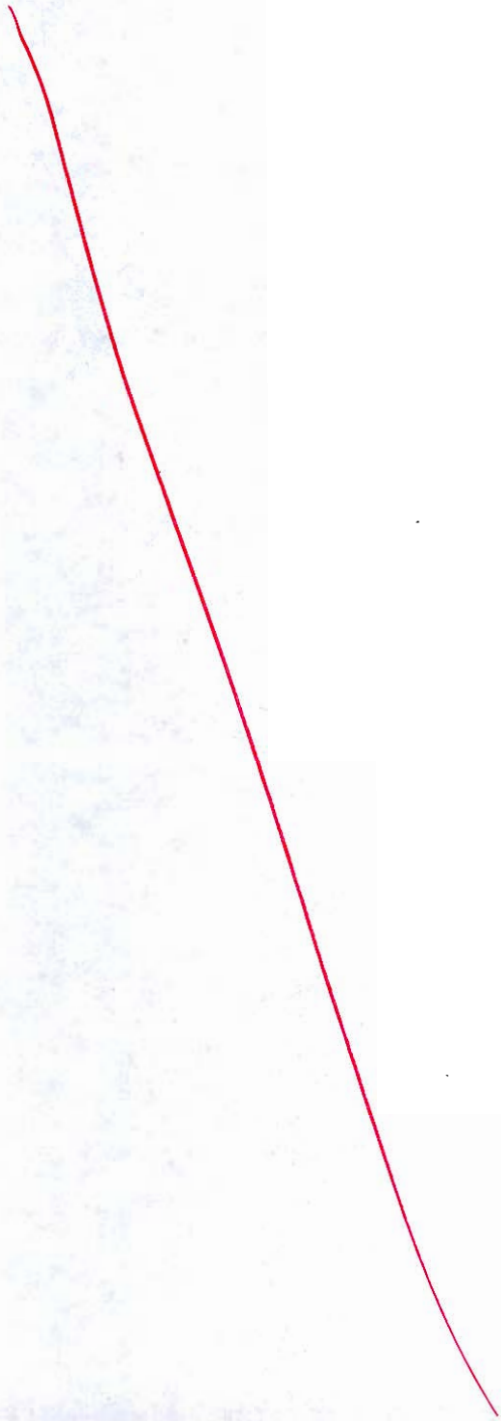


Q.6 (a) (i) A square raft of 4 m × 4 m carries a load of 300 kN/m^2. Determine the vertical stress increment at a point 6.0 m below the centre of loaded area using Boussinesq's theory. Compare the result with that obtained by equivalent point load method and with that obtained by dividing the area into 4 equal parts, the load from each of which is assumed to act through it's centre.

(ii) For the following projects, would you prefere to compact the soil on the dry side of OMC or on the wet side of OMC? Explain with suitable reasons.

1. Homogeneous earth dam.
2. Core of an earth dam.
3. Subgrade for highways

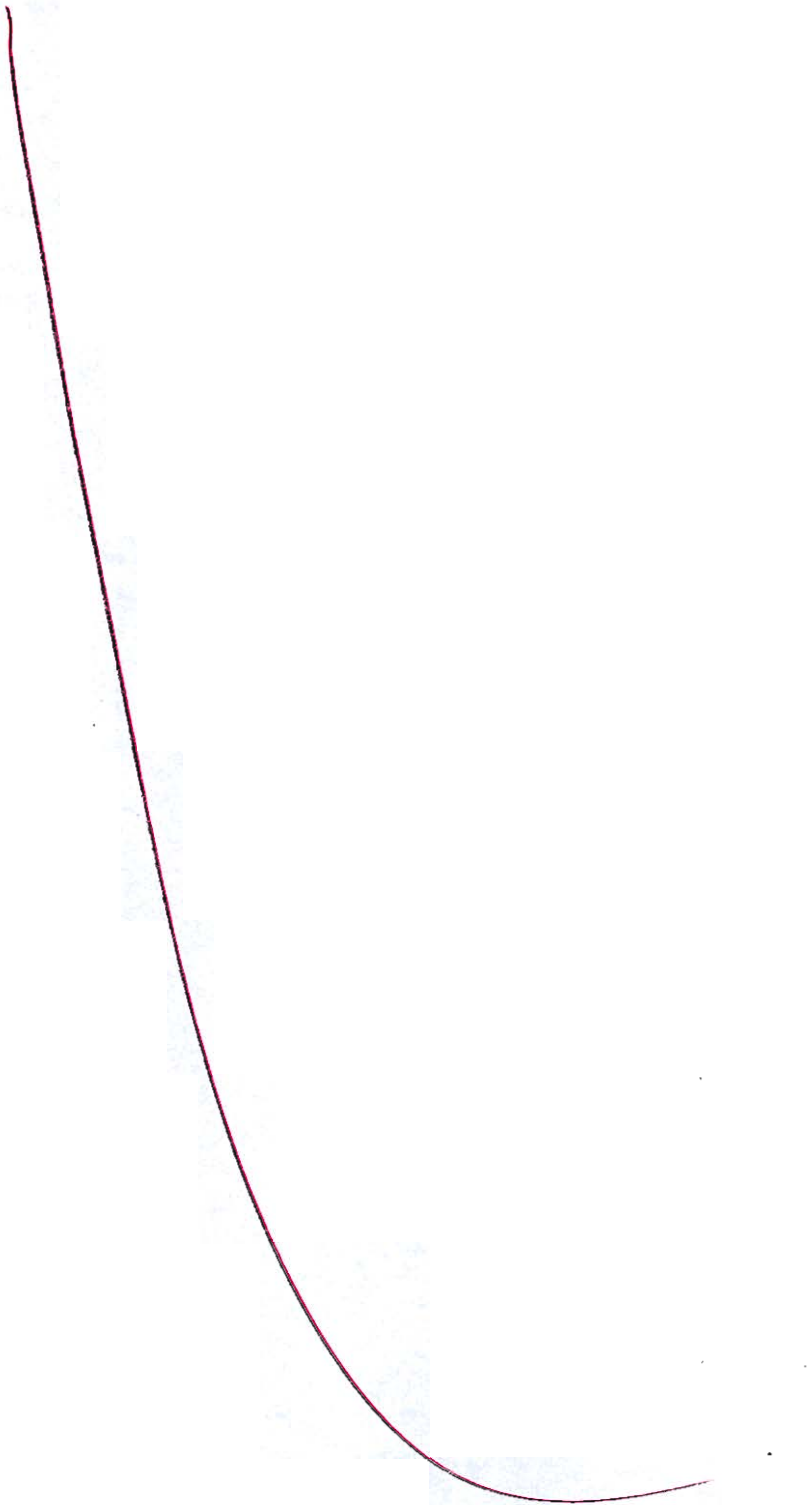
[14 + 6 = 20 marks]

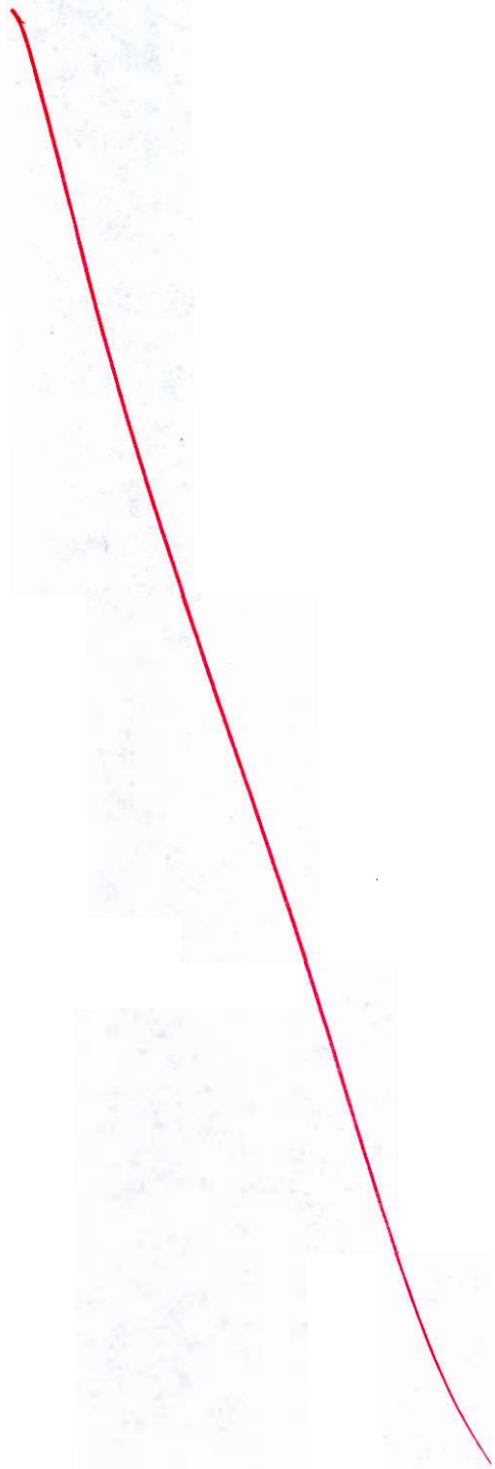


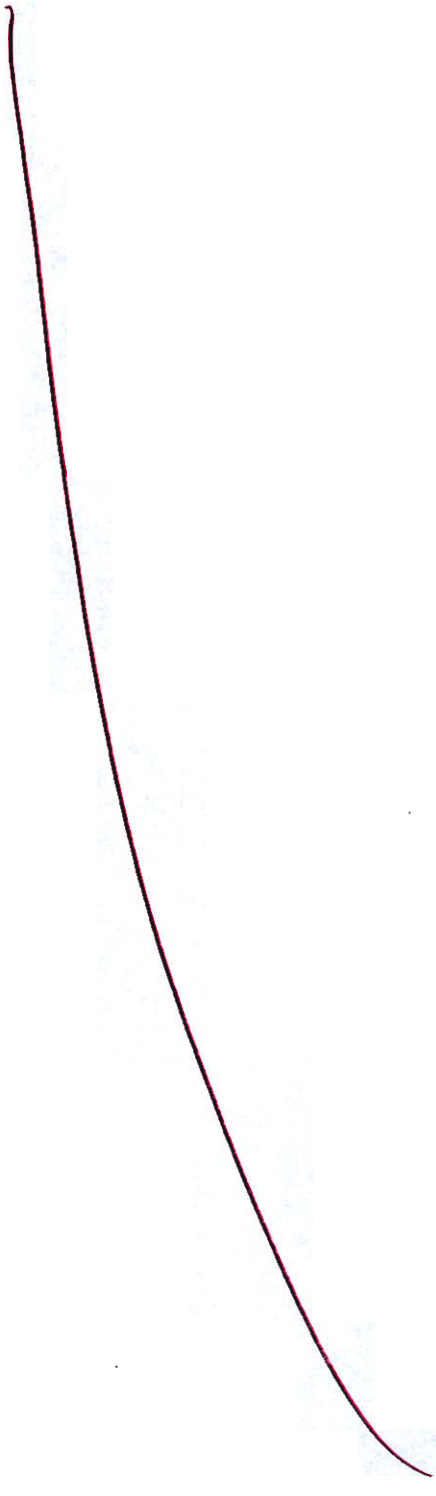
Q.6 (b) (i) Explain disposal of refuse by sanitary land filling method. Also, explain its advantages and disadvantages.

(ii) Explain the types of settling in sedimentation tank.

[15 + 5 = 20 marks]



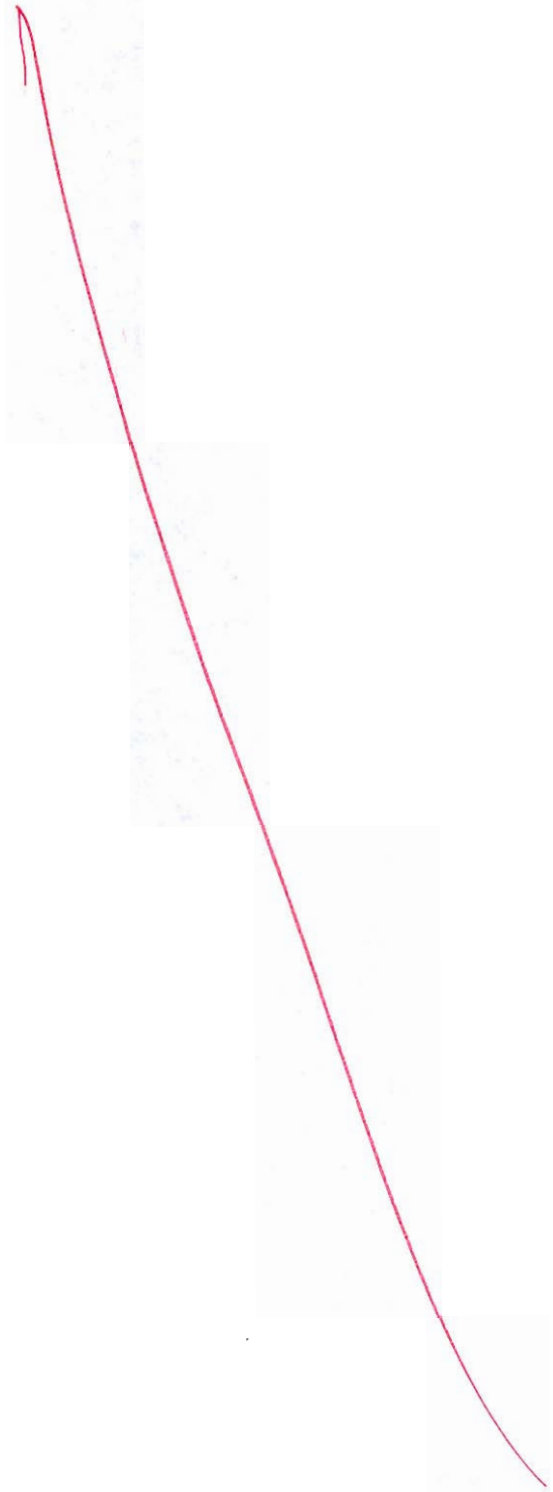


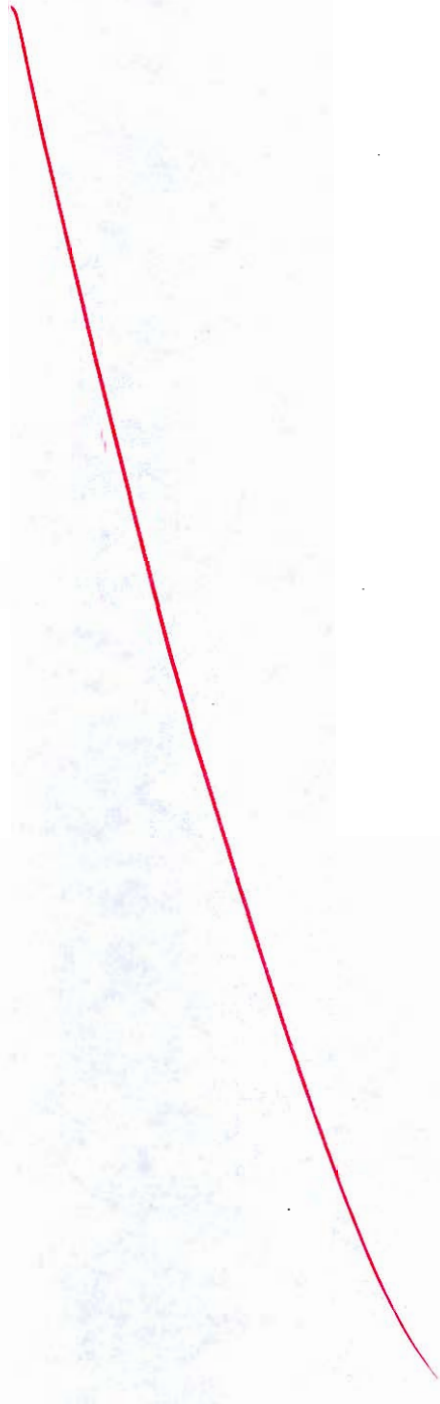


Q.6 (c) (i) Laboratory results of a soil have shown that its unconfined compressive strength is 130 kN/m^2. In a triaxial compression test, a specimen of the soil when subjected to a confining pressure of 40 kN/m^2 failed at an additional stress of 150 kN/m^2. Estimate the shearing strength of the same soil along a horizontal plane at a depth of 5 m at the site. The ground water is at a depth of 2.5 m, from the ground level. The dry unit weight of soil above water table is 16 kN/m^3 and specific gravity, G = 2.65.

(ii) Briefly explain preconsolidation pressure.

[16 + 4 = 20 marks]





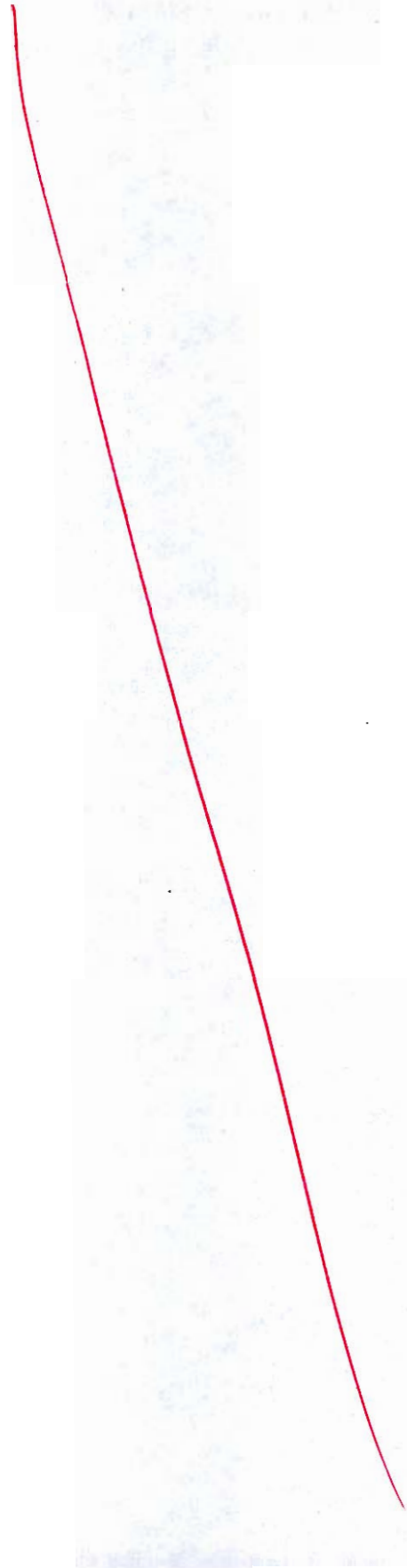
2.7 (a) Calculate the amount of hydrated lime and soda for treating 50,000 litres of water per day if the water contains the following impurities:

$CaCO_3$ = 280 ppm	NaCl = 35 ppm
$MgCl_2$ = 138 ppm	Fe_2O_3 = 55 ppm
$Mg(HCO_3)_2$ = 100 ppm	$CaSO_4$ = 110 ppm
$MgSO_4$ = 80 ppm	SiO_2 = 40 ppm

Purity of slaked lime is 86% and that of soda is 98%.

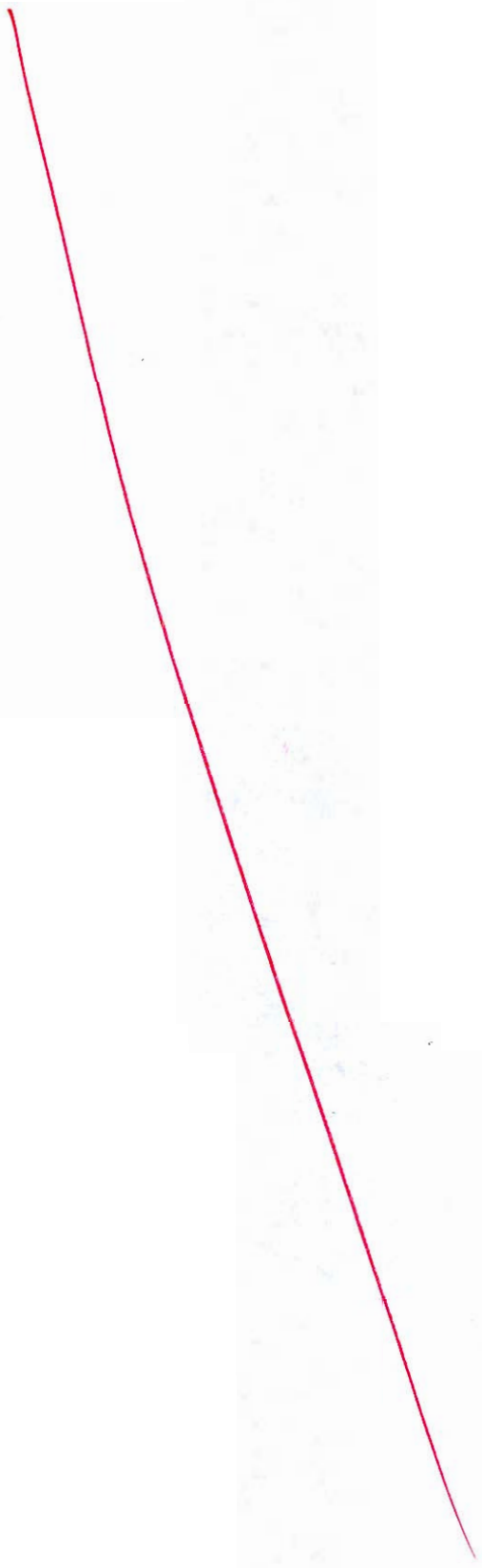
(Atomic weights in gm: Ca = 40, Mg = 24, S = 32, Cl = 35.5, C = 12, O = 16, Na = 23, Fe = 56 and Si = 26)

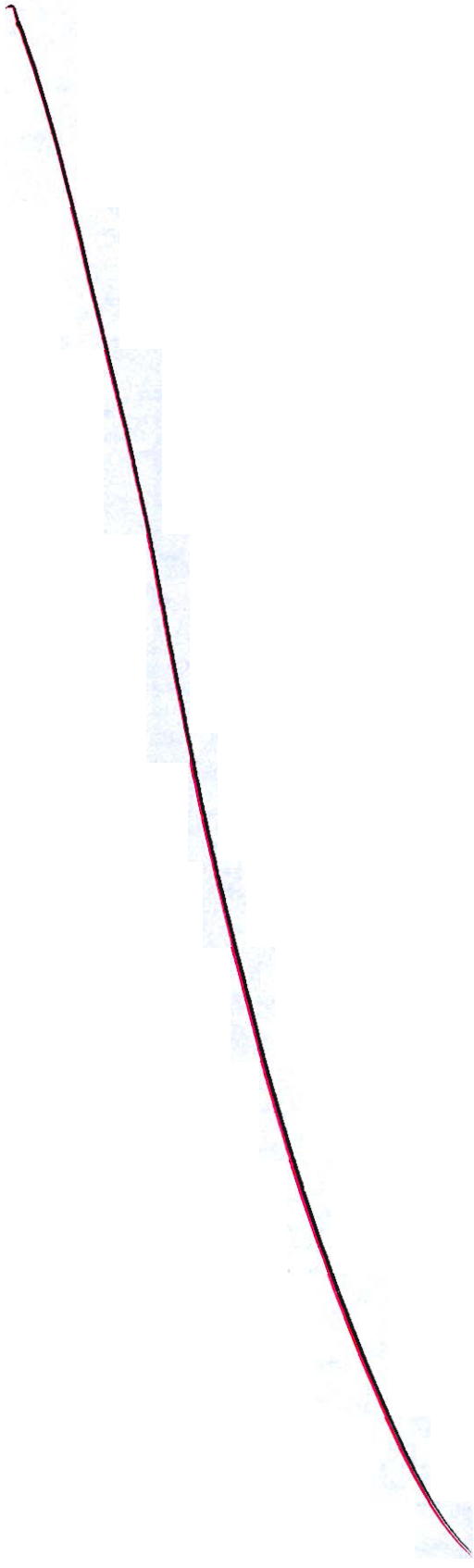
[20 marks]

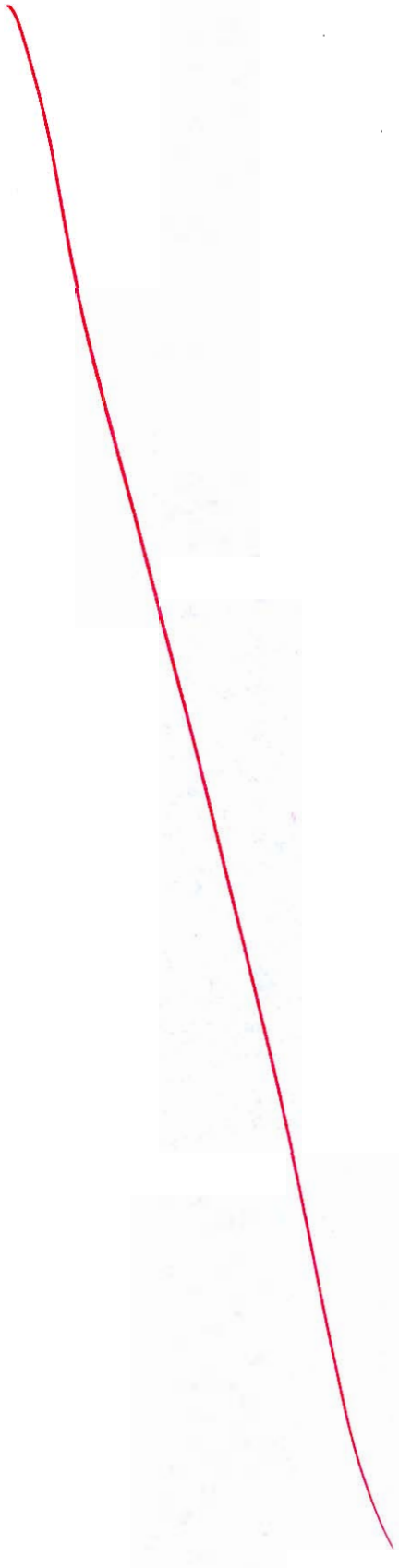


Q.7 (b) What is lateral earth pressure? With the help of diagrams explain the types of lateral earth pressure and derive the expression for coefficient of earth pressure in each case for cohesionless soil.

[20 marks]





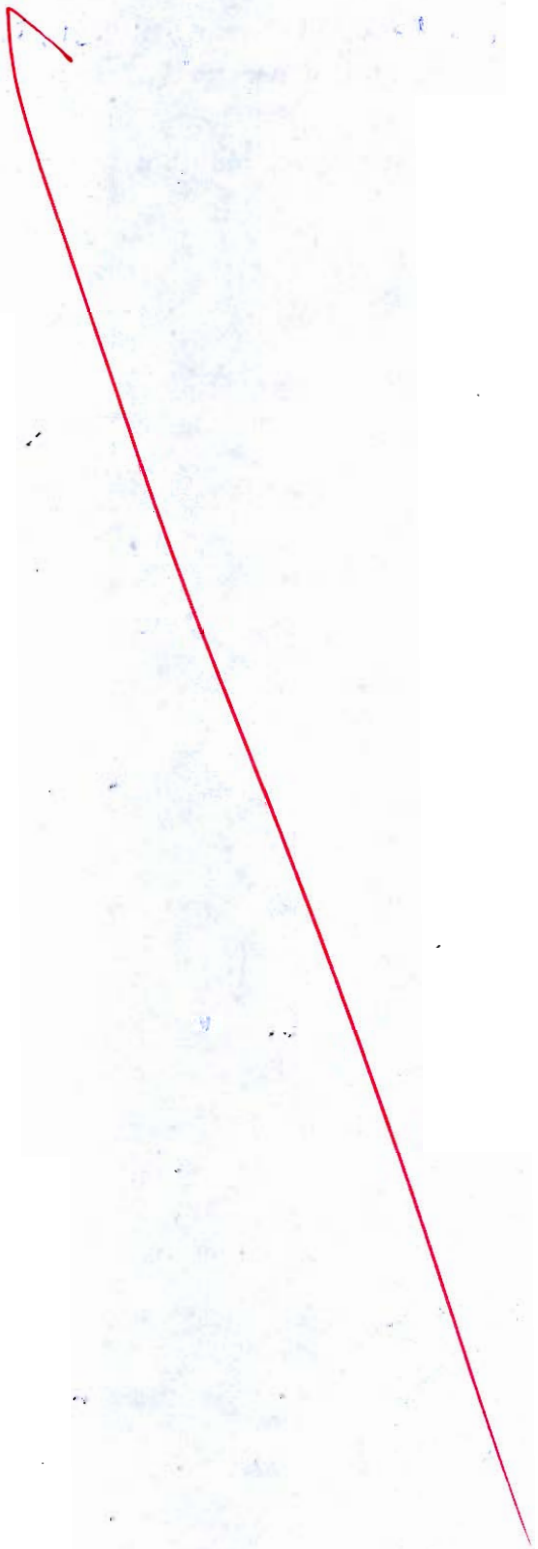


.7 (c) Following mean monthly flows were observed on a site of a screen in a typical year.

Month	Jan	Feb	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean monthly flow (cumec)	15	10	8	6	5	12	25	40	71	60	40	20

Assume that the screen flow is fully utilised for delivering water to the city to meet fixed monthly demand by diversion of the flow from storage reservior through a conduit. Find the capacity of conduit (in m^3/sec) for which it is to be designed and also determine minimum capacity (in hac.-m) of the storage reservior to ensure that all the available flow is fully utilised to meet constant monthly demand of the city.

[20 marks]



.8 (a) (i) What do you understand by seepage pressure and quick sand condition?
(ii) What is a flow net? Explain the properties and uses of a flow net.

[8 + 12 = 20 marks]

(i) **Seepage pressure :**

when water is passed through soil under any particular hydraulic gradient, water due to drag ~~induces~~ applies a pressure onto soil grain, this pressure is called seepage pressure

Seepage pressure = $i^2 \gamma_w$

i = Hyd gradient, γ_w = seepage Head

06

Quick sand condition :

At the down stream (d/s) end of dams, seepage pressure acts in upward dirn, due to which effective stress decreases. If seepage pressure equals submerged weight of soil, then effective stress becomes zero. In this case cohesionless soil looses all its shear strength and soil grain starts flowing with water this condition is known as quick sand condition.

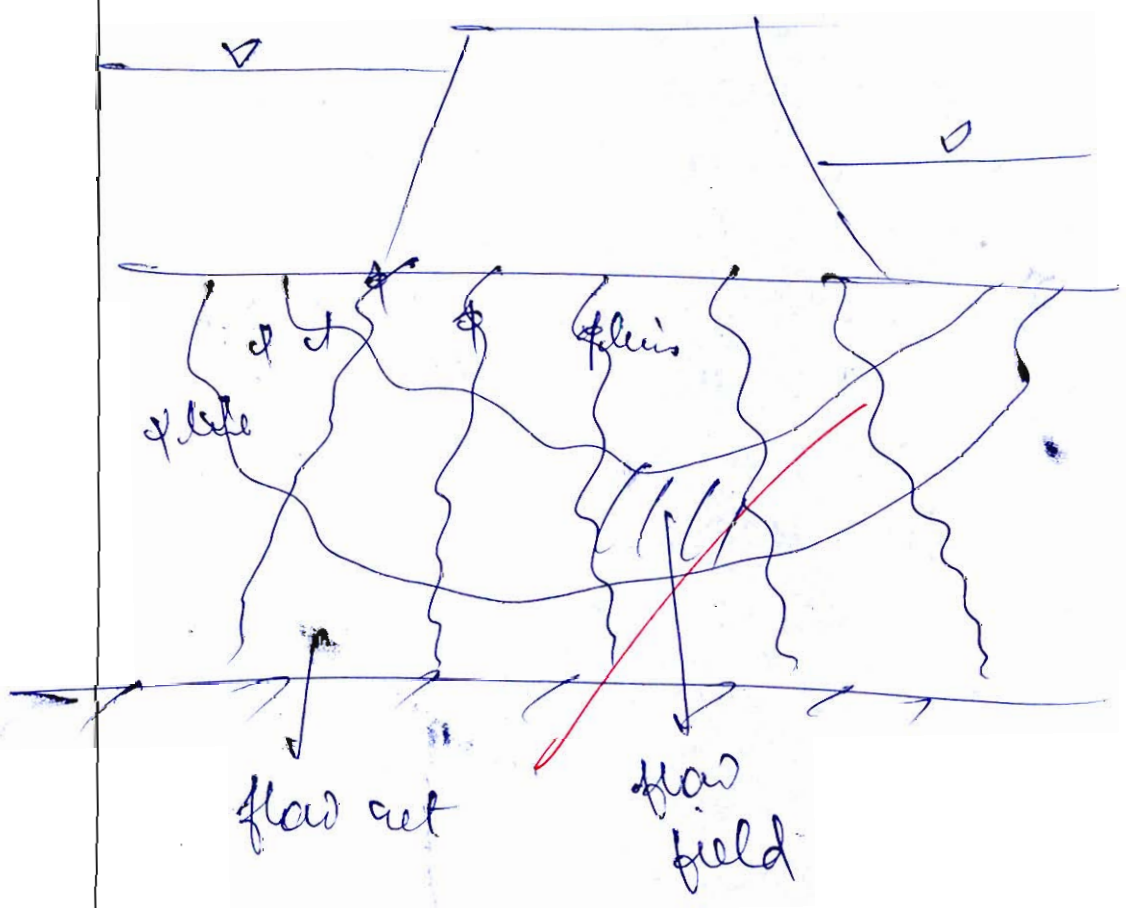
$$i_c = \frac{(G-1)}{(1+e)}$$

$$FOS = \frac{\text{Sub mt seepage pressure}}{i_{exit}} = \frac{i_c}{i_{exit}}$$

(b) Flow net is obtained by solving laplace equation for unique boundary condition.

$$\frac{\partial^2 H}{\partial x^2} + \frac{\partial^2 H}{\partial y^2} = 0$$

It is used to obtain seepage discharge, seepage head & exit gradient.



Properties of flow net

(1) Soil is homogeneous & isotropic
(2) flow is laminar
(3) Soil solids are incompressible
(4) ϕ lines & ψ lines intersect each other at 90°.
(5) Area b/w any two ψ lines is called flow channel
(6) Discharge through each flow channel is constant
(7) Head loss through each ϕ line is constant
(8). Area b/w two ϕ lines & ψ lines is called flow field. It is square for isotropic medium & rectangular for anisotropic

Use of flow net

(1) To determine seepage discharge
(2) To Determine seepage Head at various location
(3) To Determine exit gradient

10

Q.8 (b) A rapid sand filter is to be provided in a water treatment plant, to process the water for a town with a population of 2,75,000. The average water demand is 200 lt/capita/day. The rate of filtration is 15 $m^3/m^2/hour$. Allow 5% of filtered water for storage to meet the backwash requirements. Each backwashing period is of 30 min. Determine the number of filters required allowing one as a standby unit. The available surface area configuration of filter unit is 10 m × 4 m. Also, compute the up-flow velocity and head loss to expand the bed to 0.66 m from its original undisturbed depth of 0.6 m. The porosity of the bed is 0.5. Specific gravity is 2.5. The average particle size is 0.6 mm. The drag coefficient is 5.02. The flow is assumed to be transitioned flow.

[20 marks]

C = 275000 c

q = 200 lt/c/d

fr = 15 m^3/m^2/ Hour

5% Backwash

$$Q_{after\ taking\ Backwash\ \&\ peak\ factor} = \frac{1.8 \times 200 \times 275000 \times l/d}{0.95}$$

$$= 104.2\ MLD$$

$$fr = \frac{Q}{SA}$$

$$15 \frac{m^3}{m^2 hr} = \frac{104.2 \times 10^6 \frac{l}{d} \times \frac{d}{23.5 hr}}{SA\ m^2}$$

$$SA_{req} = 295.6\ m^2$$

$$SA_{each\ filter} = \frac{SA_{req}}{40} = 7.39 \approx 8$$

provide 1 filter as stand by

$$\boxed{4 \times 9}$$

$D = 0.6\text{cm}$ $\quad D' = 0.66\text{cm}$

$n = 0.5$

$G_s = 2.5$

$d = 0.6\text{mm}$

$C_D = 5.02$

Assuming no impurities in filter.

$H_{LP} = H_{LB}$

$(1-n)(G_s-1)D = (1-n')(G_s-1)D'$

$(1-0.5)\times 0.6 = (1-n')\,0.66$

$n' = 0.545$

$n' = \left(\frac{V_B}{V_s}\right)^{0.22}$

$V_s = \sqrt{\frac{4}{3}\frac{gd(G_s-1)}{C_D}}$

$V_s = \sqrt{\frac{4}{3}\times\frac{9.81\times 0.6\times 10^{-3}\times 1.5}{5.02}}$

$V_s = 0.048\text{m/s}$

$0.545 = \left(\frac{V_B}{0.048}\right)^{0.22}$

$V_B = 3.068\times 10^{-2}\text{ m/s}$

$V_B = 3.068\ \frac{\text{mm}}{\text{s}}$

20

Q.8 (c) A 0.5 m diameter gravity well is being pumped at a steady rate of 1500 lt/min. The drawdowns of 5 m and 1.5 m are observed in the nearby observation wells, at distances of 6 m and 16 m from the well being pumped, after the steady state has been reached. Assume the well to be fully penetrating and the bottom of well is 100 m below the undisturbed ground water level and that all the point observed lie on the Dupit's curve.

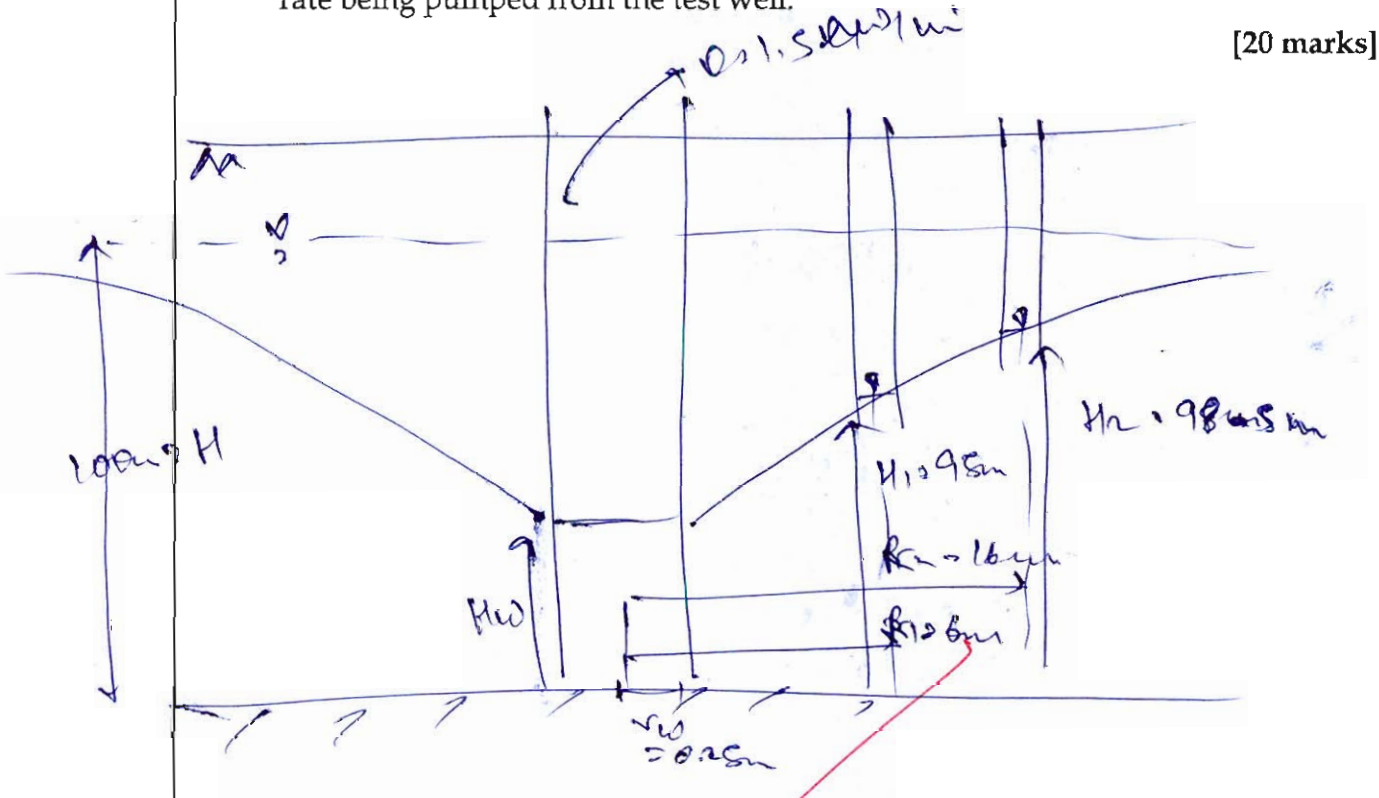
(i) Determine coefficient of permeability of medium.

(ii) Drawdown in the well being pumped.

(iii) Compute the specific capacity and maximum rate at which water can be pumped from this well.

(iv) Compute the drawdown in the observation well corresponding to the maximum rate being pumped from the test well.

[20 marks]



$$Q = \frac{\pi K (H_2^2 - H_1^2)}{\ln\left(\frac{R_2}{R_1}\right)}$$

$$\frac{1.5}{60}\ \frac{m^3}{s} = \frac{\pi K (98.5^2 - 95^2)}{\ln\left(\frac{16}{6}\right)}$$

$$K = 1.15 \times 10^{-5}\ m/s$$

(b) $Q = \dfrac{\pi K (H_2^2 - H_w^2)}{\ln\left(\frac{R_2}{r_w}\right)}$

$H_w = 82.64\ m$

$s_w = 17.35\ m$

(c) Assuming R = Radius of influence to be constant.

$Q = \dfrac{\pi K (H^2 - H_2^2)}{\ln\left(\frac{R}{R_2}\right)}$

$R = 24.62\ m$

$Q_{max} = \dfrac{\pi K (H^2 - 0^2)}{\ln\left(\frac{R}{r_w}\right)}$

$Q_{max} = 0.0787\ m^3/s$

$S_c = \dfrac{\pi K (H^2 - (H-1)^2)}{\ln\left(\frac{R}{r_w}\right)}$

$S_c = 1.566 \times 10^{-3}\ m^3/s$

specific capacity

(a)

(i)

$$Q_{max} = \frac{\pi k (H_1^2 - O^2)}{\ln\left(\frac{R_1}{r_w}\right)}$$

$H_1 = 87.48m$

$S_1 = 12.52m$

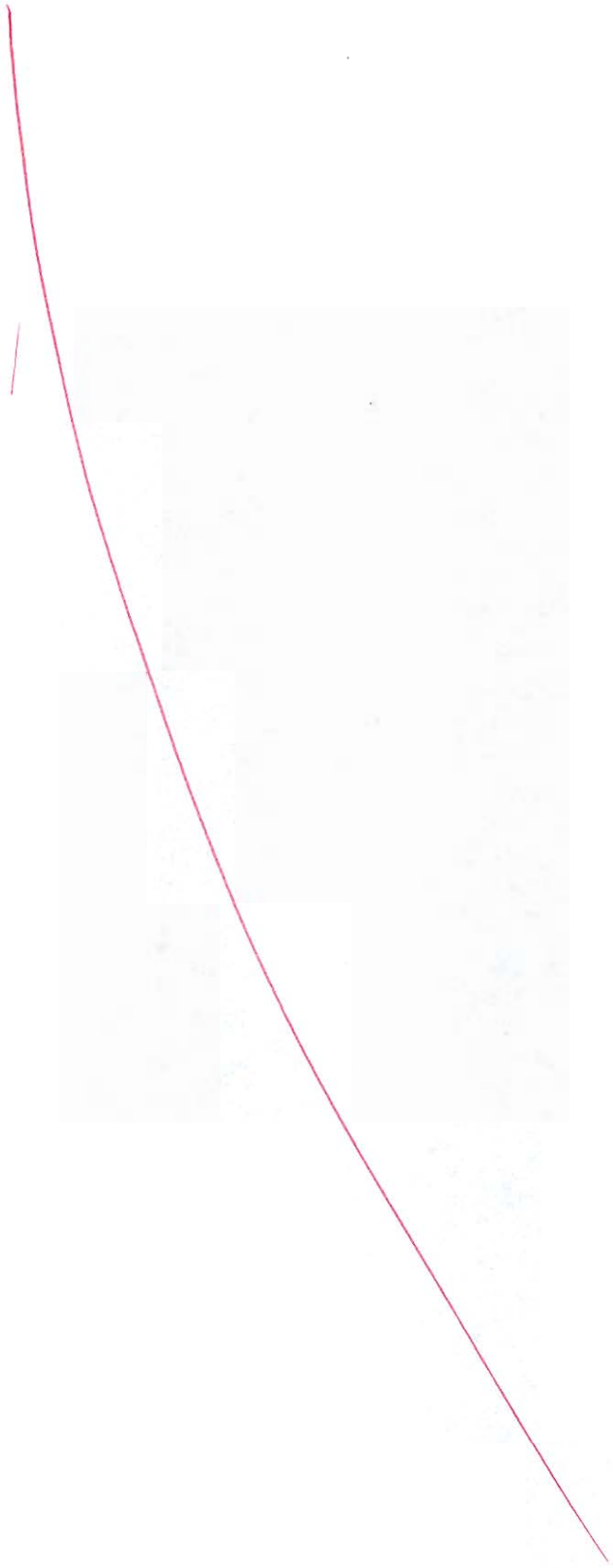
$$Q_{max} = \frac{\pi k (H_2^2 - O^2)}{\ln\left(\frac{R_2}{r_w}\right)}$$

$H_2 = 90.18m$

$S_2 = 4.82m$

20

Space for Rough Work



Space for Rough Work