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India's Best Institute for IES, GATE & PSUs

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 ☐	2.

don't miss this in exam

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	52
Q.2	58
Q.3	55
Q.4	
Section-B	
Q.5	43
Q.6	
Q.7	
Q.8	46
Total Marks Obtained	254

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

IMPORTANT INSTRUCTIONS

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

DONT'S

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

DO'S

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

Remarks:

1. Presentation is excellent.
2. Accuracy is very good.
3. Theory portion is attempted very well.
4. Just keep on revising.
5. Very Good work.

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) Kerb.

→ Kerb are the elevated portion on the edges of the pavement such that vehicles cannot cross the edge

→ Kerbs are also useful for the pedestrain walk without any risk.

(ii) Camber

→ Camber is elevation of center of road

→ it depends on type of pavement and rainfall condition.

→ Camber is provided to have free drainage for rainfall water

(iii) pavement uneveness

→ It is the undulations of the road per 1Km.

→ It is measured by bump indicator

→ it gives information about the pavement surface Quality

Bump indicator – mm/km.

(iv)

Shoulders

These are extra width provided on the pavement road inorder to give stability.

→ min width of shoulder = 2.5m.

→ camber of shoulder = camber of road + 0.5% to 3%.

→ during emergency failure vehicle can stop on shoulder.

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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]

(ii) $(SSD)_{required} = SSD_1 + SSD_2$

SSD_1 for car 1

$$SSD = ut + \frac{u^2}{2gf\eta} = 80 \times \frac{5}{18} \times 2.5 + \frac{\left(80 \times \frac{5}{18}\right)^2}{2 \times 9.81 \times 0.35 \times 0.6}$$

$$= 55.55m + 119.85$$

$$= 175.4m.$$

SSD_2 for car 2

$$SSD = V_2 t + \frac{V_2^2}{2gf\eta} = 60 \times \frac{5}{18} \times 2.5 + \frac{\left(60 \times \frac{5}{18}\right)^2}{2 \times 9.81 \times 0.35 \times 0.6}$$

$$= 41.67 + 67.418$$

$$= 109.08m.$$

$$\therefore (SSD)_{min} = SSD_1 + SSD_2$$

$$= 175.4 + 109.08$$

$$= 284.48m.$$

(i) SSD It is the min distance required by the observer to stop the vehicle when he saw the obstruction on the road inorder to avoid collision.

ISD
It is the min distance provided when there is insufficient length is present for overtaking i.e (OSD).

Generally ISD = 2SSD

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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]

instrument	staff reading	
	P	Q
P	1.701	2.427
Q	0.805	1.285 m.

$$\Delta H = \frac{(Sp - Sq) + (Sp' - Sq')}{2}$$

$$= \frac{(1.701 - 2.427) + (0.805 - 1.285)}{2} = -0.603 \text{ m}.$$

∴ elevation difference b/w P & Q = 0.603 m.

∵ P readings are small P is at higher elevation.

$(RL)_P = 203.135m$

$(RL)_Q = (RL)_P - 0.603$

$= 202.532m.$

at instrument at P

$(S_{true})_A = 1.701$

$(S_{true})_B = 1.701 + 0.603 = 2.304.$

error = Measure (S_B) − True B

$= 2.427 - 2.304$

$(error)_{total} = 0.123m.$

$e_{collimation} = 0.002 \rightarrow 100m.$

for 1200m $e_{coll} = \frac{0.002}{100} \times 1200$

$= 0.02um.$

$e_{curvature} = +0.07857D^2$

$= +0.07857(1.2)^2 = +0.11314um.$

(12)

$e_{total} = e_{coll} + e_{cur} + e_{ref}$

$0.123 = 0.024 + 0.11314 + e_{ref}$

$e_{ref} = -0.01414m.$

∴ e_{ref} should be negative Hence o(c)

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]

(i) uniform energy resource
Non interfering medium
multiple end user.
high technology systems.
continous emitters.

(ii) in passive Remote sensing we use the light from natural resource that is sun

In Active remote sensing we use artificial light which is made by human.

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(iii) Disadvantages

→ High intial cost
→ technology is difficult to learn
→ Need high skilled operator.
→ Need huge infrastructure.
→ every object cannot interfere with the given frequency wavelength.

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]

Avg speed	vehicles	cumulative vehicles	percentile of cumulative vehicles
5	10	10	1.17
15	20	30	3.529
25	68	98	11.529] V15
35	90	188	22.11]
45	205	393	46.235
55	250	643	75.647] V85
65	120	763	89.764]
75	40	803	94.470
85	30	833	98
95	17	850	100.
	850		

(i) upper speed limit is 85 percentile.

$$\frac{89.764-75.647}{65-55} = \frac{89.764-85}{65-V}$$

$V = 61.625$ kmph ⇒ upper speed limit

(ii) lower speed limit is 15th percentile

$$\frac{22.11-11.529}{35-25} = \frac{22.11-15}{35-V}$$

$V = 28.28$ kmph ⇒ lower speed limit

(ii) design speed = 98th percentile

Good = V_{design} = 85 kmph.

(12) Very nice representation

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)

Station	BS	IS	FS	Rise	Fall	RL	Benchmark
1	2.285					232.46	
2	1.650		2.265	0.020		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	
8	2.865		2.100		0.41	232.185	
9			1.625	1.24		233.425	
	EB.S = 12.165		Ef.S = 11.2	Erise = 2.13		Efall = 1.165	

Check

$EB.S = Ef.S = 12.165 - 11.2 = 0.965m$

$Erise - Efall = 2.13 - 1.165 = 0.965m$

Last RL - first RL = $233.425 - 232.46 = 0.965m$.

Sample calculation

$(BS)_1 - (FS)_2 = 0.02$

$2.285 - x = 0.02$

$x = 2.265m$. then $(RL)_2 = (RL)_1 + rise$

$(RL)_2 = 232.46 + 0.02$

$= 232.48m$.

$(BS)_2 - (FS)_3$ = Fall/rise

$1.605 - 2.105 = y \Rightarrow y = -0.455m$ (-ve indicate Fall).

Fall = 0.455m.

(iii)

$SF = \frac{\text{Measured length}}{\text{corrected length}} = \frac{9.78}{10}$.

$= 0.978$

$\therefore$ corrected length on map $= \frac{18.7cm}{0.978}$.

$= 19.12cm$.

$\therefore$ Corrected length on Ground $= 19.12 \times 20 = 382.413m$

Chain is 0.015m long

$\therefore$ Final corrected length $= \frac{L' \times l'}{l}$

$= \frac{20.015}{20} \times 382.413$

$= 382.6998m$.

Final Length of AB = 382.6998m.

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]

Direction	JT	delay	overtaking	overtaken	opposite
N-S.	6:30	1:40	3.25	4.75	270
S-N	7:45	1:50	3.	2.5	175

N-S

$n_a = 175$ $\quad n_y = 3.25 - 4.75 = -1.5$

$t_a = 7:45 = 465\,sec$ $\quad t_w = 6:30 = 390\,sec$

(i) volume $= q = \dfrac{n_a + n_y}{t_a + t_w}$

$= \dfrac{175 - 1.5}{465 + 390} = 0.2029$ veh/sec

$= 12.17$ veh/min.

(ii) Journey time $(\bar{t}_j) = t_j - \dfrac{n_y}{q}$

$= 390 - (-1.5)/0.2029$

$= 397.39\,sec$

Journey speed $= \frac{4000}{397.39} = 10.065$ m/s.

(iii) running time = tj - delay

$= 397.39 - 100 = 297.39$ sec

running speed $= \frac{4000}{297.39} = 13.45$ m/sec

S-N direction

$\eta_a = 270$ $\eta_y = 3 - 2.5 = 0.5$ $t_a = 390$ sec

$t_w = 465$ sec.

(i)

$q = \frac{\eta_a + \eta_y}{t_a + t_w} = \frac{270 + 0.5}{390 + 465} = 0.3163$ veh/sec

$= 18.98$ veh/min.

(ii) Journey time $(\bar{t}_j) = t_j - \frac{\eta_y}{q}$

$= 465 - \frac{0.5}{0.3163}$.

$= 463.4198$ sec

Journey speed $= \frac{4000}{463.419} = 8.63$ m/s.

(iii) running time $= 463.419 - 110$ sec $= 353.419$ sec.

running speed $= \frac{4000}{353.419} = 11.32$ m/s.

$= 11.32$ m/sec.

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)

$$V_a = \frac{G_t - G_m}{G_t} \times 100$$

$$= \frac{2.45 - 2.35}{2.45} \times 100$$

$$= 4.08\%$$

$$V_b = \frac{\% W_b}{G_b} \times G_m$$

$$= \frac{5\%}{1.02} \times 2.35 = 11.5196\%$$

$$\therefore \quad VMA = V_a + V_b = 4.08 + 11.5196$$

$$= 15.5996\%$$

$$VFB = \frac{V_b}{VMA} \times 100$$

$$= \frac{11.5196}{15.5596} \times 100$$

$$= 73.845\%$$

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① Los Angels abrasion test

→ it is used to find the Abrasion value of the aggregate.

→ in this the aggregates are kept in cylinder and the cylinder is revolved at 33rpm

→ After 500 revolution the aggregates are sieve with 1.7mm sieve.

$$\text{Abrasion value} = \frac{w_2}{w_1} \times 100.$$

w_2 = wt passing through 1.7mm sieve

w_1 = wt of aggregates taken which passes through 12mm and retained. 10mm

recommended values
Base course - 30%.
sub base - 45%.

② Impact test

→ it is used to find the toughness value of aggregates used in the contruction.

→ In this the weight of 14kg lifted 38cm and given 25 blows.

→ the aggregates now seived with 2.36mm sieve

$$AIV = \frac{w_2}{w_1} \times 100.$$

w_2 = wt passing through 2.36mm sieve.

recommended values

sub base = 45%.

base course = 40%.

w_1 =

Intial wt of aggregates that passes through 12mm and retained on 10mm sieve

(4)

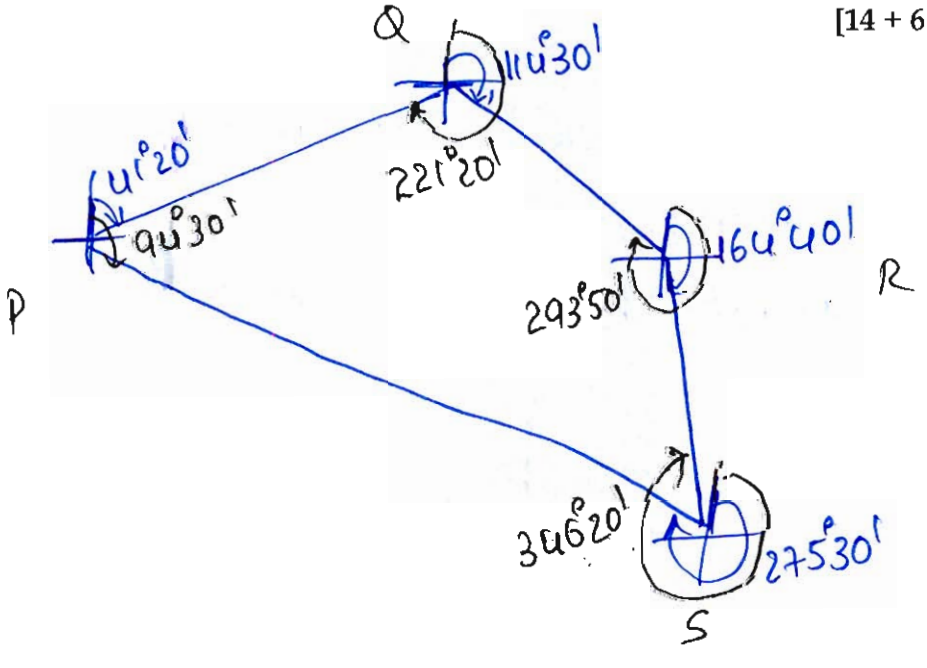
Q.3 (a) **(i)** The whole circle bearings of the lines of a closed traverse are given below. Check the bearings for local attraction. Correct the bearings by calculating the included angles.

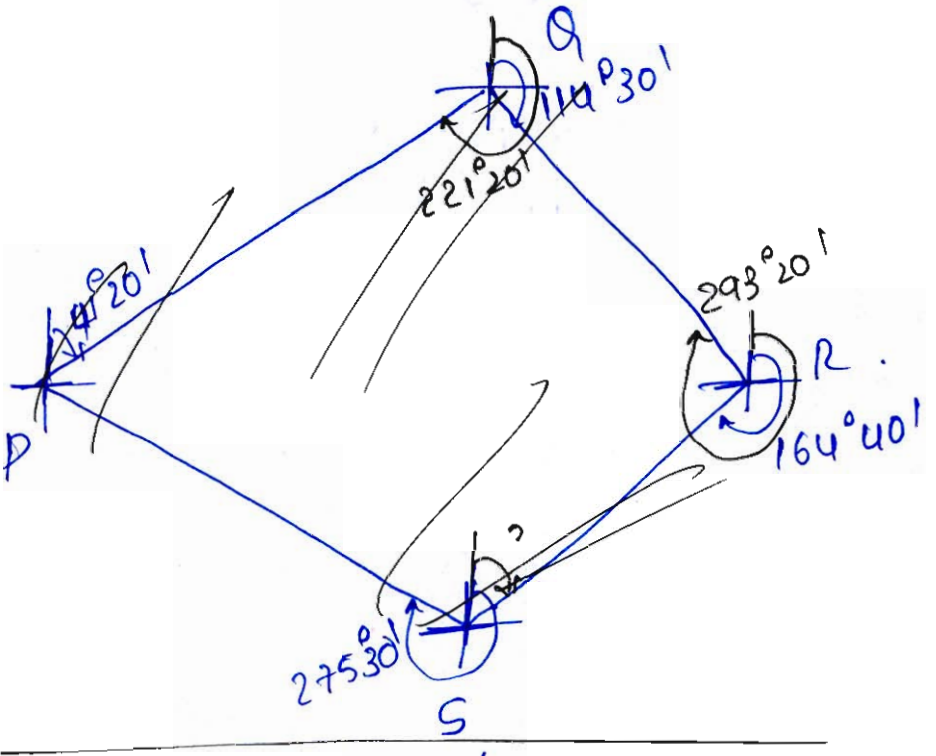
PQ : 41°20′	QP : 221°20′
QR : 114°30′	RQ : 293°50′
RS : 164°40′	SR : 346°20′
SP : 275°30′	PS : 94°30′

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

[14 + 6 = 20 marks]

(i)





Internal Angle.		FB	BB	$\lvert FB-BB \rvert$
$P = 53°10'$	PQ	$41°20'$	$221°20'$	180
$Q = 106°50'$	QR	$114°30'$	$293°50'$	$179°20'$
$R = 129°10'$	RS	$164°40'$	$346°20'$	$181°40'$
$S = 70°50'$	SP	$275°30'$	$94°30'$	181
360				

$\therefore$ sum of internal angles $= (2n-4)\times 90$

$= 360°$

FB & BB of line PQ, are $180°$

$\therefore$ stations P, Q, are free from LA.

$\therefore$ reading from P, Q are true

Q → BB of PQ = 221°20'
→ FB of QR = 221°20' − 106°50'
= 114°30'

R → BB of QR = 114°30' + 180° = 294°30'
→ FB of RS = 294°30' − 129°10' = 165°20'

S → BB of RS = 165°20' + 180 = 345°20'
→ FB of SP = 345°20' − 70°50' = 274°30'

P → BB of SP = 274°30' − 180 = 94°30'
→ FB of PQ = 94°30' − 53°10' = 41°20'

Hence ok.

(ii)

Prismatic compass	Surveyor Compass
→ Broad shape need	→ Edge shape needle
→ prism is used for taking readings	→ readings are taken directly
→ sighting and reading of values are simultaneous.	→ Non simultaneous.
→ values are encraved	→ values are directly visible.
→ cannot use without tripod.	→ can use without tripod

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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) Stress due to load

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

$$l = \left(\frac{Eh^3}{12k(1-\mu^2)}\right)^{1/4}.$$

$$l = \left(\frac{3\times10^5\times20^3}{12\times6(1-0.15^2)}\right)^{1/4} = 76.417\text{ cm}.$$

$$b = \sqrt{1.6a^2+h^2}-0.675h \quad \because a < 1.724h.$$

$$= \sqrt{1.6(15)^2+20^2}-0.675(20)$$

$$= 14.068\text{ cm}.$$

$$S_i = \frac{0.316\times5000}{20^2}\left(4\log_{10}\left(\frac{76.417}{14.068}\right)+1.069\right)$$

$$= 15.831\text{ kg/cm}^2.$$

$$S_e = \frac{0.572P}{h^2}\left(4\log_{10}\left(\frac{l}{b}\right) + 0.359\right)$$

$$= \frac{0.572 \times 5000}{20^2}\left(4\log_{10}\left(\frac{76.417}{14.068}\right) + 0.359\right)$$

$$= 23.58 \text{ kg/cm}^2$$

$$S_{corner} = \frac{3P}{h^2}\left(1 - \left(\frac{ar_2}{l}\right)^{0.6}\right)$$

$$= \frac{3 \times 5000}{20^2}\left(1 - \left(\frac{15\sqrt{2}}{76.417}\right)^{0.6}\right)$$

$$= 20.11 \text{ kg/cm}^2.$$

possible location of crack from corner

$$= 2.58\sqrt{al}$$

$$= 2.58\sqrt{15 \times 76.417}$$

$$x = 87.349 \text{ cm}.$$

(ii)

Flexible	rigid
→ Grain to Grain load transfer	→ slab action.
→ $EI = 0$	→ $EI = \infty$
→ 4 layers (subgrade, subbase, base, wearing course	→ 3 layers (subgrade, base, wearing course)
→ stage construction is possible	→ stage construction is not possible
→ rutting & fatigue are problems	→ mud pumping is problem.
→ Not subjected to thermal stress	→ subjected to thermal stress.
→ high maintainance cost low intial cost	→ high intial cost, low maintainance cost
→ Ex Bitumen road	→ Ex concrete road

(P)

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) $T_o = 16°C$, $P_o = 50$ KN } standard condition on flat surface means no catenary.

$C_{Temp} = \alpha L(T_m - T_o)$

$= 12 \times 10^{-6} \times 30 \times (28-16)$

$= 4.32 \times 10^{-3}$ m.

$= 0.432$ cm.

$C_{pull} = \frac{(P_m - P_o)L}{AE} = \frac{(120-50) \times 30 \times 10^3}{7.5 \times 2 \times 10^5} = 1.4$ mm

$= 0.14$ cm.

Assuming there sag in the field which was absent in intial case (i.e at standardisation)

$C_{sag} = \frac{-w^2L}{24P_m^2} = \frac{-20^2 \times 30}{24 \times 120^2} = -3.47$ cm.

$C_{Net} = 0.432 + 0.14 - 3.47$

$= -2.9$ cm

Corrected length $= 30 - 2.9/100 = 29.971$

corrected length $= \frac{30 \times 640}{29.971} = 640.619\text{m}$.

$\frac{29.971 \times 640}{30} = 629.38\text{m}$

without considering sag

CNet = 0.432 + 0.14 cm

= 0.572 cm.

$L_{corrected} = 30 + \frac{0.572}{100} = 30.00572\text{m}$.

final corrected total length $= \frac{30 \times 640}{30.00572}$

$= 639.8779\text{m}$.

(i) 2) Face left

when the vertical circle lies left of the observor

→ It is bubble up and normal case

1) face right

when the vertical circle is right side of observor while taking reading

→ it is bubble down and inverted condition.

3) swing

→ rotating the telescope in horizontal direction about vertical axis is called swing of telescope.

→ Now vertical circle changes its direction

4) Line of collimation

Line passing through center of Diaphragm, optical center and eye piece and continuation

5) Telescope inverted:- Telescope rotated vertically about horizontal axis is telescope inverted.

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 andvolume 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]

$w.c = 12\%$. $\gamma_{d\,max}$ at 20%.

saturation = 42%.

$G = 2.65$

$e S = wG$

$e(0.42) = 0.12(2.65)$

$= 0.75714$.

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

$$= \frac{9.81(2.65 + 0.757(0.42))}{1+0.757}$$

$= 16.571\ kN/m^3$.

$$\gamma_{bulk} = \frac{W}{V}$$

$$16.57 = \frac{100}{V_{soil}}$$

$$\Rightarrow V_{soil} = \frac{100}{16.57} = 6.035 m^3.$$

water content to be added = $\gamma_d V(\omega_1 - \omega_2)$

$= \frac{16.57}{1.12} \times 6.035 \left(\frac{20-12}{100}\right)$

$= 7.14 KN.$

volume of water added = $\frac{wt}{\gamma_w}$

$= \frac{7.14}{9.81}$

$= 0.728 m^3.$

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]

$h = 14(Q)^{0.27}$

$H = 14($ $Q = 0.4 MLD.$

$H = 14(59.7)^{0.27}$

$= 42.23m.$

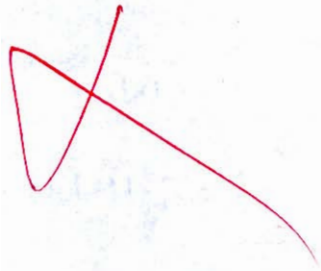
$H = 72(Q)^{0.3}.$

$= 72(0.52)^{0.3}.$

$= 59.174m.$

12

$\therefore$ Ht of chimney = 59.174m



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]

(ii) Vane shear test

→ It consists of blades around the central rod of certain ht.

→ The apparatus is forcedly bar-driven into the ground

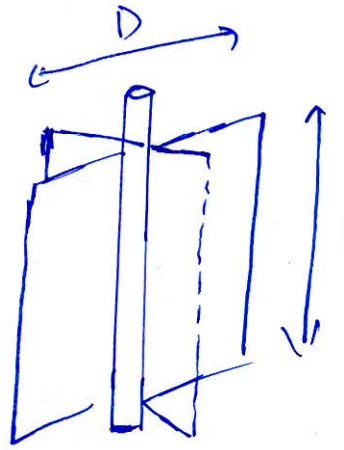
→ The apparatus is then rotated at u° per min so that the soil will get sheared.

→ by this we can find how much torque is applied and we can find the shear strength of soil

→ it is generally used in the marine soil, silt & clay.

→ Liquid limit also can be found by this.

D = dia of blades
H = Ht of blades.



(5)

$T = T_1 + T_2$ → by sides.
from bottom

$T = C_u \pi D^2 \left(\frac{D}{6} + \frac{H}{2}\right)$ → two sides shearing

$T = C_u \pi D^2 \left(\frac{D}{12} + \frac{H}{2}\right)$ → one side shearing

(i) failure of finite slope

they are three types of failures

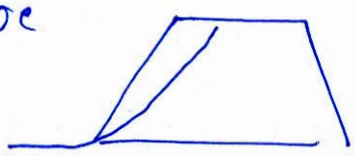
1) face failure
2) toe failure
3) base failure.

Face failure

→ Failure surface will be at the face of slope
→ Soil below base is undisturbed

Toe failure

→ Failure crack surface is at toe
→ Depth factor = 1.

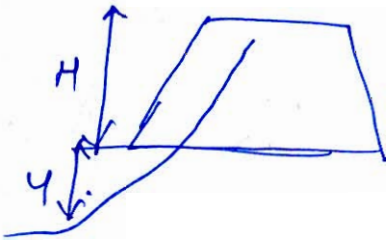


(3)

base failure

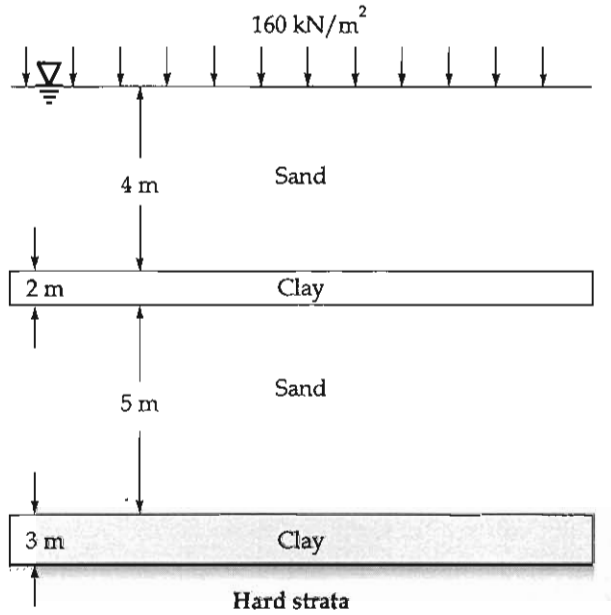
→ failure is beneath the structure
→ Depth factor is greater than 1
→ more dangerous compare to All

$$\text{Depth factor} = \frac{H+y}{H}$$



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
- For clay layers, w = 40%, C_c = 0.24, G = 2.7



[12 marks]

$\Delta H = (\Delta H_1) + \Delta H_2$

top clay bottom clay.

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

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

$= 9.81 ($

$\sigma_1 = 21(4)$.

$e_s = wG$.

$e(1) = 0.4(2.7)$

$e = 1.08$.

$\gamma_{clay} = \frac{9.81(2.7+1.08)}{2.08} = 17.8271 kN/m^3$.

$\sigma_1 = 21(4) + 17.827(1) + 9.81(5)$

$= 52.777 kN/m^2$.

$\Delta H_1 = \frac{2}{1+1.08} \times 0.24 \log\left(\frac{52.77+160}{52.77}\right) = 0.1397m$

$= 139.736mm$.

for bottom clay

$$\Delta H_2 = \frac{H}{1+e_0} C_c \log\left(\frac{\sigma_2+\Delta\sigma}{\sigma_2}\right)$$

$$\sigma_2 = \gamma_{sand}(9) + \gamma_{clay}(2+1.5) - \gamma_w(12.5)$$

$$= 21(9) + 17.827(3.5) - 9.81(12.5)$$

$$= 128.77 \text{ kN/m}^3.$$

$$\Delta H_2 = \frac{3}{1+1.08} \times 0.24 \log\left(\frac{128.77+160}{128.77}\right)$$

$$= 121.409 \text{ mm}$$

$$\therefore (\Delta H)_{total} = \Delta H_1 + \Delta H_2$$

$$= 121.41 + 139.736$$

$$\Delta H = 261.146 \text{ mm}$$

12

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

→ it is the cheapest coagulant

→ it is generally used in India

pH range 6.5–8

→ it introduce Non carbonate hardness and fres the pH of the water.

→ $Al_2(SO_4)_3 \cdot 18H_2O$ is Alum whose molecular wt = 666

→ it removes odour, taste and colour.

(ii) Copperas

→ pH range <6.5 and >8.5.

→ cannot produce floc in coloured water.

→ $FeCl_3$ and $Fe_2(SO_4)_3$ are called as chlorinated copperas.

→ sufficient alkalinity must be present.

→ It introduces hardness in water.

(iii) Sodium Aluminate $NaAlO_2$

→ It is independent of pH

→ it can produce good floc even in the coloured water also.

→ It is expensive compare to others.

→ main problem is it requires sufficient alkalinity otherwise it cannot produce flocs.

(9)

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]

Q.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]

Q.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]

Q.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]

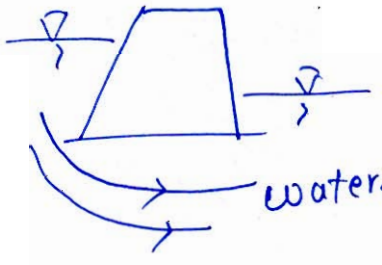
Seepage pressure

(i) → when there is a head difference exist between two points, a hydraulic gradient develops and water starts moving from higher head to lower head.

→ when water moves in soil, it exerts some pressure on soil which is called seepage pressure

→ this is also called as frictional drag on the soil particles.

→ Generally this seepage pressure is observed under the dam.



Quick sand condition

→ during the upward flow condition when the submerged wt of soil is equal to the seepage pressure then the effective stress will be zero for the soil

→ if $\bar{\sigma} = 0$ then soil losses its shear strength.

6

→ Generally Quick sand condition occur in the cohesionless soil only.

→ In reality Quick sand cannot happen in Gravel because it require large discharge

→ Quick sand is not type of sand, it is hydraulic condition.

(ii) Flow net

⇒ Flow net contains the equipotential lines and flow lines.

⇒ Flow net is used to find solution for the discharge under the dam

⇒ equipotential lines are lines having same head

→ Flow lines the flow takes places. In b/w

Flow field is square for isotrophic and curvilinear square for non isotrophic

⇒ The discharge through every flowfield is constant.

properties

→ It depends on boundary condition only
→ it is independent of permeability
→ Flow takes place b/w flow lines called flow channel
→ discharge is constant in flow channel & Flow field

uses

10

→ It is used to find uplift pressure
→ Seepage pressure can be found
→ exit gradient, uplifthead also found.

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]

$Q_{total} = Q_{percapita} \times population$

$= 2,75,000 \times 200$

$= 55 \times 10^6 l/day$

$Q_{avg} = 55 MLD$

$Q_{max} = 1.8\, Q_{avg} = 1.8 \times 55$

$= 99 MLD \rightsquigarrow$ filtered water for supply

Given 5% of filtered water is used for backwash

$\therefore$ Total $Q_{required} = \frac{99}{0.95}$

$= 104.21 MLD \rightsquigarrow$ Total water reqd.

$\therefore (SA)_{required} = \frac{Q}{ROF}$

$= \frac{104.21 \times 10^3\ m^3}{\frac{23.5 hr}{15\ m^3/m^2/hr}}$ 30min for backwash

$= 295.63\ m^2$

Area of each filter $= 10 \times 4 = 40 m^2$.

No of filters required = $\frac{295.6}{40}$

$= 7.4 \approx 8$ no.

∴ provide 9 filters → 8 working + 1 stand by

Head loss due to expansion

$$H_b = z(1-n)(S-1) = z_e(1-\eta_e)(S-1)$$

$z_e = 0.66m$

Assuming porosity given is for expanded bed.

$(\eta_e) = 0.5$

$H_b = 0.66(1-0.5)(1.5)$

$= 0.495m$.

$H_b = 0.495m$.

$$(U_B)_{upflow} = V_s(n_e)^{4.5}$$

$$V_s^2 = \frac{4}{3}\frac{(S-1)gd}{C_D}$$

$$V_s^2 = \frac{4}{3}\frac{(1.5)\times 9.81 \times 0.6 \times 10^{-3}}{5.02}$$

$V_s = 0.048 m/s$

∴ $U_B = V_s(n_e)^{4.5}$

$= 0.0484(0.5)^{4.5}$

$= 2.14 \times 10^{-3} m/sec$

$V_B = 2.14 mm/sec$

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

use this one

porosity is given in question

also find head loss

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]

$Q = 1.5 m^3/min$. $H = 100m$.

Given it unconfined aquifer

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

$H_1 = H - S_1 = 100 - 1.5 = 98.5m$ $R_1 = 16m$

$H_2 = H - S_2 = 100 - 5 = 95m$ $R_2 = 6m$

$1.5 = \frac{\pi K (98.5^2 - 95^2)}{\ln(16/6)}$.

$\frac{1.5 \times \ln(16/6)}{\pi(98.5^2 - 95^2)} = K$.

$K = 6.914 \times 10^{-4} m/min$. $= 0.115 \times 10^{-4}$ m/sec

3

(ii) Drawdown in well.

$1.5 = \frac{\pi (6.914 \times 10^{-4}) \times (98.5^2 - H^2)}{\ln(16/0.25)}$

$H_w = 82.647m$.

$S_w = 100 - H_w = 100 - 82.647 = 17.35m$.

3

(iii) for specific capacity we need to radius of influence

$$Q = \frac{\pi K (H^2 - H_1^2)}{\ln(R/R_1)}$$

$$1.5 = \frac{\pi (6.914 \times 10^{-4}) (100^2 - 98.5^2)}{\ln(R/\frac{98.5}{16})}$$

$$R = 24.624 m.$$

$$\text{Sp capacity} = \frac{\pi K (100^2 - 99^2)}{\ln(R/r_w)}$$

$$= \frac{\pi (6.914 \times 10^{-4})(100^2 - 99^2)}{\ln(24.624/0.25)}$$

$$= 0.0941 m^3/min$$

max rate that can be obtained

$$Q = \frac{\pi K (100^2 - 0^2)}{\ln(R/r_w)} = \frac{\pi (6.914 \times 10^{-4}) (100^2 - 0^2)}{\ln(24.624/0.25)}$$

$$= 4.732 m^3/min.$$

$Q_{max} = 4.732 m^3/min$.

7

(iv) draw down in observation well

@ $R_1 = 16m$.

$$Q = \frac{\pi K (H_0^2 - H_1^2)}{\ln(R_0/R_1)}$$

$$4.732 = \frac{\pi (6.914 \times 10^{-4})(H_1^2)}{\ln(16/0.25)}$$

$$4.732 = \frac{\pi (6.914 \times 10^{-4})(100^2 - x^2)}{\ln\left(\frac{24.624}{16}\right)}$$

$$x = 95.188m.$$

$\therefore$ drawdown @ $R = 16m = 100 - 95.188$

$= 4.812m.$

(15)

@ $R = 6m$

$$Q = \frac{\pi K (100^2 - h^2)}{\ln\left(\frac{24.624}{6}\right)} = 4.732.$$

2

$$h = 83.198m.$$

$\therefore$ drawn dow @ $R = 6m = 100 - 83.198$

$= 16.8m.$

■■■■

Space for Rough Work

Space for Rough Work