SAKET

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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 rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	48
Q.2	45
Q.3	58
Q.4	
Section-B	
Q.5	46
Q.6	
Q.7	
Q.8	49
Total Marks Obtained	246

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) Representation is excellent.
(2) Accuracy is very good.
(3) Overall performance is very good.

Section A : Highway Engineering + Surveying and Geology

Q.1 (a) Write short notes on:

(i) Kerbs

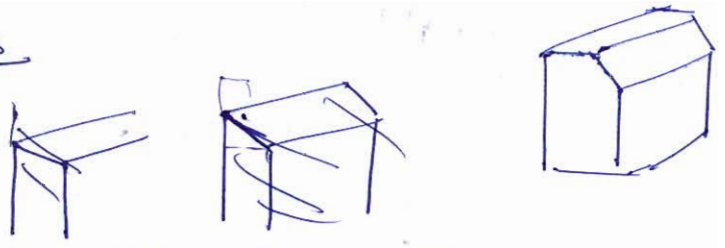
(ii) Camber

(iii) Pavement uneveness

(iv) Shoulders

[12 marks]

1) Kerbs



Kerbs are small concrete blocks layed at edges of pavement, to seperate pedestrian traffic from vehicle traffic. different sizes of kerb are available based on their application in parking area, footpath and level of safety, restriction. types

2) camber

c/s of pavement

→ It is cross slope provide on pavement, for sideways movement of rainwater.

Its value

→ Based on Type of pavement, and rainfall level in area,

IRC recommended values are

c/c paveme	Heavy rainfall	moderate ra
Thick bituminous	2%	1.7%
Thin bitumious	2.5%	2%
WBM / Gravel	3%	2.5%
earther road	4%	3%

iii) Pavement unevenes

↳ It is measure of discomfort to passenges while ~~veh~~ ~~recv~~ vehicular movement due to various reason ~~as~~ defects or pavem such

↳ In India It is measur by Bump Integrato (cm/km)

$BI = 630 (IRI)^{1.12}$

↳ IRI ⇒ International Roughness Index.

iv) shoulders are compacted paved/unpaved area around pavement, provided for:

① Emergency stopping of vehicles.

② It provides lateral support to the pavement, preventing from ~~effect~~ defects such as edge breaking etc.

~~cambers~~ ~~of~~ camber for shoulder

= camber of pavement + 0.5%.

Asper IRC.

also camber for shoulder ≯ 3%.

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 minimum sight distance required for a vehicle to stop, after seeing obstruction. It is sum of lag distance and Braking distance required

It is given as follows

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

Lag distance — Braking distance

2) Intermediate sight distance

It is twice of the stopping sight distance. It is provided when for a particular road we Overtaking sight distance can't be provided

$$ISD = 2 \times SSD$$

ii)

$V_1 = 80$ km/h $\quad \eta_B$ (Braking eff) $= 60\% = 0.6$

$V_2 = 60$ km/hr

$t_r = 2.5$s $\quad \therefore$ minimum sight distance (OD) required for head on collision will be sum of SSD required for both vehi.

$f = 0.35$

$$D = SSD_1 + SSD_2$$

$$= \left[0.278 V_1 t_r + \frac{V_1^2}{254(\eta_B f)}\right] + \left[0.278 V_2 t_r + \frac{V_2^2}{254(\eta_B f)}\right]$$

$$D = 0.278(80+60)(2.5) + \left[\frac{80^2}{254(0.6\times0.35)} + \frac{60^2}{254(0.6\times0.35)}\right]$$

$D = 284.776\,m$

$\Rightarrow$ minimum sight distance for head on collision in given condition

(b)

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 at	Readings at (m) P	Q
P	1.701	0.805 m
Q	2.427	1.285

$h_P = 1.701$ $h'_P = 0.805$

$h_Q = 2.427$ $h'_Q = 1.285$

h' $\Rightarrow$ reading when instrument at Q

h $\Rightarrow$ reading when instrument at P

$\therefore$ so here

$$RL_P - RL_Q = \frac{(h_Q - h_P) + (h'_Q - h'_P)}{2}$$

$$203.135 - RL_Q = \frac{(2.427 - 1.701) + (1.285 - 0.805)}{2} = \Delta h$$

$\Delta h = 0.603$

$\therefore$ RL$_Q$ = 202.532 m

Here Error = Measure Value - True value.

$E_{cur} + E_{Ref} + E_{coll} = h_Q - (h_P + \Delta h)$

$0.0673d^2 + E_{ref} + \left(\frac{0.002}{100}\right)(1200) = 2.427 - (1.701 + 0.603)$

$(0.0673)(1.2)^2 + E_{ref} + 0.024 = 0.123$

$\therefore \boxed{E_{ref} = 2.088 \times 10^{-3}}$

$\therefore$ error due to refraction on staff reading is 2.088×10^{-3}

Here E_{cur} ⇒ Error due to curvature

E_{coll} ⇒ Error due to collimat

E_{ref} ⇒ Error due to refract

(X)

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]

Base elemen

① source of energy radion

② object (whose informatio is nee

③ sensor (to sense the interacted radiai

④ processin unit (TO proces the data and interpr. creative result

① passive remote sensi

- Here the sourc o of radiation / energy is sun
- It can only be done during day

Active remote sensing

- Her the source of radiation, and sensors are attached on same unit
- can be done at any time

(6)

② Disadvantage of

- errors due to noise, are difficult to remo
- realised skilled Labours and is costly
- susceptile to error due to weather changes.

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]

Speed range	mean speed (km/hr)	No of vehicle (n)	(a) cummulative no of veh	cummulati % $\left(\frac{a}{850}\times 100\right)$	
0-10	5	10	10	1.17	
10-20	15	20	30	3.53	
20-30	25	68	98	11.53	} → 15%
30-40	35	90	188	22.12	
40-50	45	205	393	46.23	
50-60	55	250	643	75.65	} → 85%
60-70	65	120	763	89.76	
70-80	75	40	803	94.47	
80-90	85	30	833	98	} → 98%
90-100	95	17	850	100	

$\Sigma n = 850$

For speed regulation

∴ upper ~~speed~~ speed limit (USL) is speed below which 85% of veh travel

Lower speed limit is speed below which 15% of veh travel

∴ From above table

$$USL = 55 + \frac{(65-55)}{(89.76-75.65)} \times (85-75.65)$$

$$USL = 61.63 \text{ km/h}$$

$$LSL = 25 + \frac{(35-25)}{(22.12-11.53)} * (15-11.53)$$

$$LSL = 28.28 \text{ km/hr}$$

Design speed for checking geometric design eleme is 98% speed, From above table.

$\therefore$ $V_{desig} = 85$ km/hr

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]

Station	BS	IS	FS	Rise	Fall	RL	Remq
1	2.285					232.46	BM-1
2	1.650		2.265	0.020			
3		2.105			0.455		
4	1.625		1.960	0.145			
5	2.050		1.925		0.300		
6		1.665		0.385		232.255	BM-2
7	1.690		1.325	0.340			
8	2.865		2.100		0.41		
9			2.01	0.495		233.425	BM 3

$\Sigma BS = 12.165m$ $\Sigma FS = 11.585$ $\Sigma Fall = 1.165$

$\Sigma Rise = 1.745$

Here Δ = Previous reading - current reading

= rise or fall

If Δ = +ve ⇒ rise

Δ = -ve ⇒ fall.

$(RL)_1 + \Sigma(Rise/Fall) = RL_2$

Check

$\Sigma BS - \Sigma FS = \Sigma Rise - \Sigma Fall = Last\ RL - First$

(a) (b) (c)

Here a = 0.58

b = 0.58

c = 233.425 - 232.46

11)

OS (original scale) = $\frac{1\text{cm}}{20\text{m}}$.

Shrinkage (SR) ratio = $\frac{9.78\text{ cm}}{10\text{cm}}$

Shrunkes scale = OS × SR

$= \frac{9.78}{10} \times \frac{1\text{cm}}{20\text{m}} = \frac{1\text{cm}}{\left(\frac{200}{9.78}\right)\text{m}}$

$\therefore$ $\frac{\text{map length}}{\text{Field length}} = \text{Scale Shrunk}$.

$\frac{18.7}{\text{field length}} = \frac{1\text{cm}}{\left(\frac{200}{9.78}\right)\text{m}}$

Field length = 382.413m (L)

$\therefore$ L` = length to be set

d` = 20.015

d = 20 m $\quad \therefore \quad d \times L = d' \times L'$

$20 \times 382.413 = (20.015) \times L'$

$L' = 382.126\text{ m}$

5

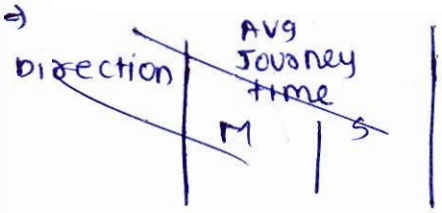
Q.2 (b) The consolidated data collected from speed and delay studies by floating car method on a stretch of urban road of length 4.0 km running North-South are given below.

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	Avg Journey time (	Delay Avg	No of Overtaking	No of Overtaken veh	Vehicle from opposite direction (na)
N–S	6.5 min	1.67 min	3.25	4.75	270
S–N	7.75 min	1.83 min	3	2.5	175

For N–S $n_y = \frac{3.25 - 4.75}{2} = -1.5$

S–N $n_y = 3 - 2.5 = 0.5$

For N–S

① ~~Flow~~ Volum ~~(veh/hr)~~ (veh/min)

$q =$ · $n_a = 270$ $t_a = 7.75$

$n_y = -1.5$ $t_w = 6.5$

~~$q = n_a t_y$~~ ~~For S–N~~

$n_a = 175$

$\Rightarrow q = \frac{n_a + n_y}{t_a + t_w} = \Rightarrow q_{ns} = \frac{270 + -1.5}{7.75 + 6.5}$

$q_{ns} = 18.84$ veh/min

For S-N direction

$n_a = 175$

$n_y = 0.5$

$t_a = 6.5$

$t_w = 7.75$

$$q_{S-N} = \frac{175 + 0.5}{6.5 + 7.75}$$

$$q_{S-N} = 12.31 \text{ veh/min}$$

ii) Journey time.

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

For ~~N-S~~

$$\bar{t}_{NS} = 6.5 - \frac{(-1.5)}{18.84}$$

$$= 6.58 \text{ min}$$

$$\bar{t}_{SN} = 7.75 - \frac{(0.5)}{12.31}$$

$$= 7.71 \text{ min}$$

$\therefore$ Journey speed $= \frac{\text{Total distance}}{\text{Journey time}}$

$$V_{JS\ (N-S)} = \frac{4000}{6.58} = 607.9 \frac{m}{min}$$

$$V_{JS\ (S-N)} = \frac{4000}{7.71} = 518.81 \frac{m}{min}$$

16

iii) Running time = Journey time − delay

(t_R)

$$(t_R)_{N-S} = 6.58 - 1.67 = 4.91 \text{ min}$$

$$(t_R)_{SN} = 7.71 - 1.83 = 5.88 \text{ min}$$

$\therefore$ Running speed $= \frac{\text{Total distance}}{\text{Running time}}$

$$(V_{RS})_{N-S} = \frac{4000}{4.91} = 814.66 \frac{m}{min}$$

$$(V_{RS})_{S-N} = \frac{4000}{5.88} = 680.27 \frac{m}{min}$$

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]

Los angles abrasion test

↳ this test is use to know about resistance of aggregat to abrasion from the vehicular movement

↳ To stimulate condition of 6-12 steel balls with ~~agg~~ specific aggregat are rotated at ~~300~~ 33 rpm, 500 total revolution in steel cylinder

$$\text{Abrasion value} = \frac{\text{Loss of weight of Agg}}{\text{Initial weigh}} \times 100$$

↳ For ~~surface cource~~ ~~30%~~
basecourse ~~AV~~ ≯ 30%.

(12)

Impact test

↳ This test gives idea about the toughnes of aggregates, That is resistance or ~~loss in weight~~ to impact loading

↳ ~~for this less aggregat passing through~~

$$\text{Impact value} = \frac{\text{Loss of weight of agg}}{\text{Initial weight}} \times 100$$

recommended value.

↳ for surface course ≯ 45%.
for Base coure ≯ 30%

(i) $W(\%)_b = 5\%$.

$G_t = 2.45$

$G_m = 2.35$

$G_b = 1.02$.

∴ ~~Vol~~ Volume of bitumen in mix

$$V_b = W(\%)_b \times \frac{G_m}{G_b}$$

$$= (5)\left(\frac{2.35}{1.02}\right)$$

$$\boxed{V_b = 11.519\%}$$

~~Voids in~~ % air void $(V_a) = \left(\frac{G_t - G_m}{G_t}\right) \times 100$

$$= \left(\frac{2.45 - 2.35}{2.45}\right) \times 100$$

$$= 4.082\%.$$

∴ ~~Voids in~~ M

$$VFB = \frac{V_b}{V_a + V_b} \times 100 = \frac{11.519}{11.519 + 4.082} \times 100$$

$$\boxed{VFB = 73.83\%.}$$

↳ percent voids filled with bitumen.

5

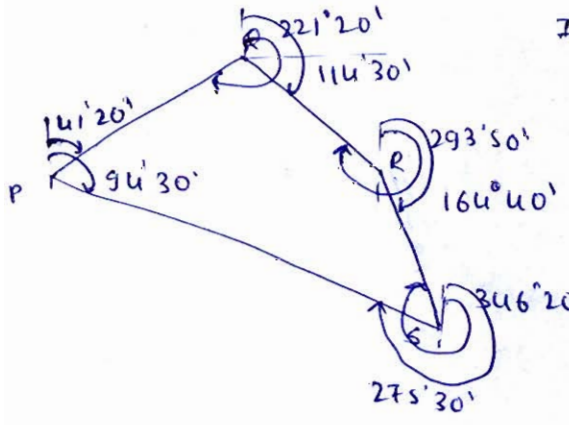
Q.3 (a) **(i)** The whole circle bearings of the lines of a closed traverse are given below. Check the bearings for local attraction. Correct the bearings by calculating the included angles.

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)



Interval angle	Calculation
∠P	94°30' − 41°20' = 53°10'
∠Q	221°20' − 114°30' = 106°50'
∠R	293°50' − 164°40' = 129°10'
∠S	346°20' − 275°30' = 70°50'

Σ Interval angle = 360°

Also designate sum of Internal angle = (2n − 4) × 90
= (2(4) − 4) 90 = 360°

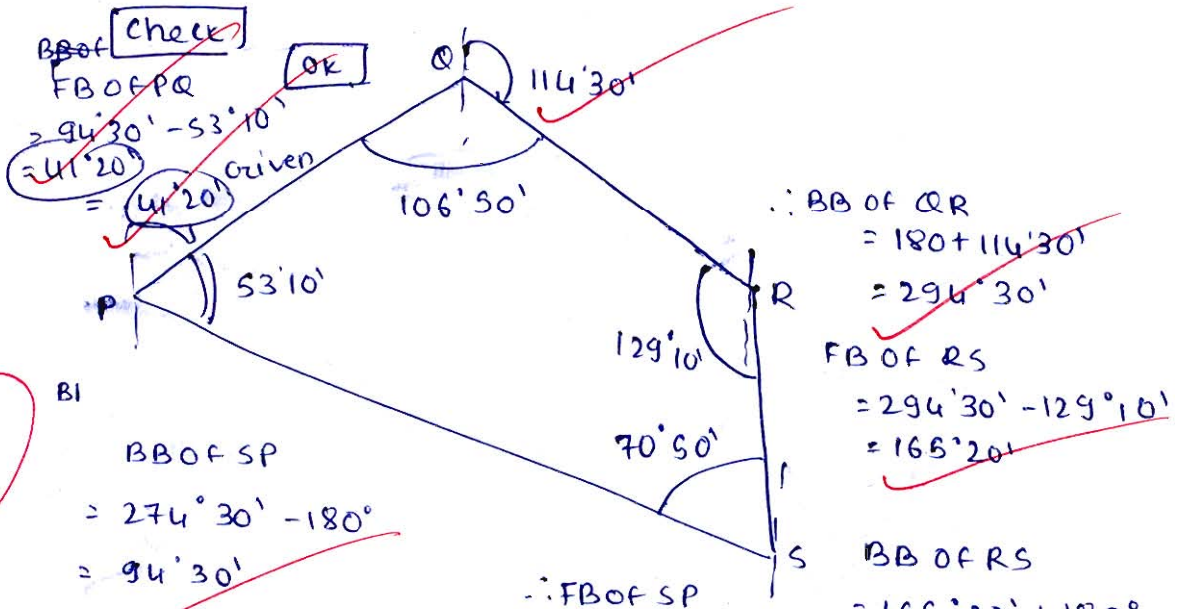
OK

at station	For line	~~|FB − BB|~~ |BB − FB|
P	PQ	|221°20' − 41°20'| = 180°
Q	QR	|293°50' − 114°30'| = 179°20'
R	RS	|346°20' − 164°30'| = 181°40'
S	SP	|94°30' − 275°30'| = 181°

For PQ, $\angle$ |FB − BB| is 180°

∴ bearing from so station P & Q are free from local attraction

∴ Assuming P & Q are reference station,



∴ BB of QR = 180 + 114°30' = 294°30'

FB of RS = 294°30' − 129°10' = 165°20'

BB of RS = 165°20' + 180° = 345°20'

BB of SP = 274°30' − 180° = 94°30'

∴ FB of SP = 345°20' − 70°50' = 274°30'

14

Prismatic	Surveyor compas
① It gives whole circle Bearing	① It gives bearing in QSB
② It has least count of 30'	② It has least count of 15'
③ Sighting and reading can be done simultaneously	③ Sight reading can't be done simultaneously
④ Reading are inverted on graduate ring which is reverse	④ Readings are straight (not inverted)

(5) Graduated ring is free to move

(6) Can ~~manual~~ keep compass on hand and take the reading

(5) Reading are ~~on~~ engrave or attache to compass and are not free to move

(6) Tripod arrangement star is require to take reading.

6

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) Given

$P = 5000$ kg $\quad K = 6$ kg/cm^3

$E = 3 \times 10^5$ kg/cm^2 $\quad a = 15$ cm

$h = 20$ cm

$\mu = 0.15$

∴ Radius of relative stiffness

$$l = \left[\frac{Eh^3}{12K(1-\mu^2)}\right]^{1/4} = \left[\frac{(3\times10^5)(20)^3}{(12)(6)(1-0.15^2)}\right]^{1/4}$$

$$\boxed{l = 76.417 \text{ cm}}$$

Radius of relative bending resistance (b)

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

$(15\text{cm}) < (1.724)(20)$

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

$$\boxed{b = 14.068 \text{ cm}}$$

wheel load stresses

at Interior

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

$$= \frac{(0.316)(5000)}{20^2}\left[4\log_{10}\left(\frac{76.417}{14.068}\right) + 1.069\right]$$

$$\boxed{S_i = 15,835 \frac{\text{kg}}{\text{cm}^2}}$$

at edge

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

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

$$\boxed{S_e = 23.587 \frac{kg}{cm^2}}$$

at corner

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

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

16

$$\boxed{S_c = 20.12 \text{ kg/cm}^2}$$

distance at which crack is likely to develop from corner

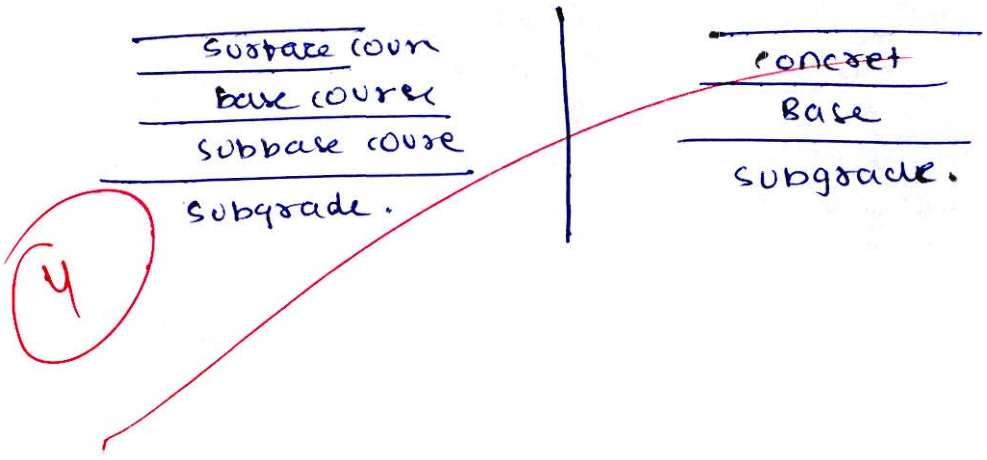
$$d = 2.58\sqrt{al}$$

$$= 2.58\sqrt{(15)(76.417)}$$

$$\boxed{d = 87.35 \text{ cm}}$$

ii)

Flexible pavement	Rigid pavement
① It has bad Flexural rigidity	① It has very good Flexural rigid
② resist load by grain + grain transfer	② resist load by bending action of slab
③ Rutting and Fatigue are general issues face	④ Mud pumping is major issue here
④ No Joints are reauire tobegi	⑤ Joints like, Expansion, contraction are, to be given
⑤ Less constructions cost, high maintainance cost	⑥ High construction cost and less maintainance cost.



4

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]

(8)

① Face ~~left~~ right

└ ~~It~~ Theodolite is said to be Face right when while taking reading vertical circle index lies right side of observer

② Face left

└ Theodolite is said to be Face left when while taking reading vertical circle index lies left of observer.

Avg of face righ, and face left reading is used to eleminate error due principal lineo of Theodolit not satisfying desegnate ang

③ swinging of telescope

└ ~~Horizont~~ movement of telescope in Horizontal plane is called swinging of Telescop

④ ~~It~~ Line of collimation

└ ~~Line~~ Also called Line of sight, passing through centre of eyepiec and objective ~~lens~~ Of telescope

⑤ Telescope Inverted

└ A telescope is said to be inverted when vertical circle lies towards right of observer.

11) Std condit
$W = 20\ N$
$L = 30\ m$
$P_0 = 50\ N$
$T_0 = 16\ ^\circ C$
$\alpha = 12 \times 10^{-6}/^\circ C$
$E = 2 \times 10^5\ N/mm^2$
$A = 7.5\ mm^2$

on Field
$P_m = 120\ N$
$T_m = 28^\circ C$.
$L = 640$

① Pull correction $(C_P) = \dfrac{(P_m - P_0)L}{AE}$

$= \dfrac{(120-50)(640)}{(7.5 \times 2 \times 10^5)\ N} = 29.87 \times 10^{-3}$

② Sag correction $(C_{sag}) = -\dfrac{W^2 L_e}{24 P_m^2}$

$= -\dfrac{(20)^2(640)}{(24)(120)^2} = -740.74 \times 10^{-3}$

③ Tempesature correction $(C_T) = L\alpha\Delta T$

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

$= 92.16 \times 10^{-3}$

L_c (corrected length of Tape) = measured length (L) + correction $(C_P + C_{sag} + C_T)$

$= 640 + (29.87 \times 10^{-3}) + (-740.74 \times 10^{-3}) + (92.16 \times 10^{-3})$

$L_c = 639.38\ m$
↳ correct length of Base line.

10

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]

Natural state soil → $G = 2.65$

$w_n = 0.12$

$S_n = \frac{42}{100} = 0.42$.

As $Se = wG$

$\therefore (0.42)(e) = (0.12)(2.65)$

$\Rightarrow \boxed{e = 0.757}$

↳ void ratio in natural state.

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

$= \frac{(2.65)(1+0.12)(9.81)}{1+0.757}$

$\gamma_b = 16.571 \frac{kN}{m^3}$

$= \frac{\text{Total weight of soil}}{\text{Total volume of soil}}$

$\therefore 16.571 = \frac{100\,kN}{\text{Volume of soil}}$

$\therefore \boxed{\text{Volume of soil} = 6.034\ m^3}$

↳ volume of 100N of natural state soil.

Here $\gamma_d = \frac{G\gamma_w}{1+e} = \frac{(2.65)(9.81)}{1+0.757}$ (dry density)

$\boxed{\gamma_d = 14.796 \frac{kN}{m^3}}$

~~Vde~~ ~~weight~~ $\gamma_d = \frac{\text{weight of soil solids}(W_s)}{\text{volume of soil}}$

$14.798 = \frac{\text{weight } W_s}{6.035}$

$W_s = 89.293\ kN$

↳ For 100 kN of natural state soil

water to be added to increas water content from 12% to 20%.

$\Delta W_w = (w_2 - w_1) W_s$

$= (0.2 - 0.12)(89.293)$

$\Delta W_w = 7.143\ kN$

↳ weight of water to be add

$\Delta V_w = \frac{7.143\ kN}{9810\ kN} = 7.282 \times 10^{-4}\ m^3$

↳ volume of wat

$= 0.7282$ 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]

Emission rate (For ~~one~~ 1ML of oil)

~~Ref~~ Particulate matter (PM) = $\frac{3\ \text{tonne}}{\text{yr}}$

$SO_2 = 59.7\ \frac{\text{tonne}}{\text{yr}} = 59.7 \times \frac{1000}{300 \times 24}\ \frac{kg}{hr} = 8.292\ \frac{kg}{hr}$

$NO_x = 7.5\ \frac{\text{tonne}}{\text{yr}}$

$HC = 0.37\ \frac{\text{tonne}}{\text{yr}}$

$CO = 0.52\ \frac{\text{tonne}}{\text{yr}}$

If height of chimney satisfies requirement for PM and SO_2 emmission, then for all other pollutant requirment will be already satisfied, Here Fuel burned per yeal $= 4 \times 10^5$ L

(1) Height of chimne requir as per $= 0.4$ ML

(1) SO_2 emission

$$h_1 = 14(Q_1)^{0.3}$$

$Q_1 \rightarrow$ rate of SO_2 emission in kg/h

$$h_1 = 14(Q_1)^{0.3}$$

$$= 14(8.292)^{0.3}$$

$$h_1 = 14(3.3168)^{0.3}$$

$$\boxed{h_1 = 20.06\ m}$$

$\Rightarrow$ For 0.4 ML

$Q = 0.4 \times 8.292$

$$\boxed{Q = 3.3168\ \frac{kg}{hr}}$$

(2) Particulate matter emission

$$h_2 = 74(Q)^{0.27}$$

$$= 74(1.2)^{0.27}$$

$$\boxed{h_2 = 77.73\ m}$$

$Q_2 \rightarrow$ rate of PM emiss (tonne/yr)

For 0.4 ML of fuel per year

$Q_2 \rightarrow 0.4 \times 3$

$= 1.2\ \frac{\text{tonnes}}{yr}$

$\therefore$ height of stack required (H)

$$H = \max \begin{cases} h_1 = 20.06 \\ h_2 = 77.73 \end{cases}$$

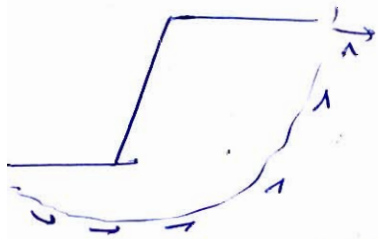
$$\boxed{H = 77.73\ m}$$

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) Probable Failure of Finite slope ar

a) Toe failure

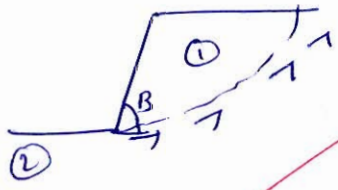


→ Failure plane

⇒ occurs whe soil below slope is weak as compare to soil

⇒ Depth ratio above >1

(b) Base Failure



occurs at

→ β > 53°

- when both soil ① & ② are of similar stre

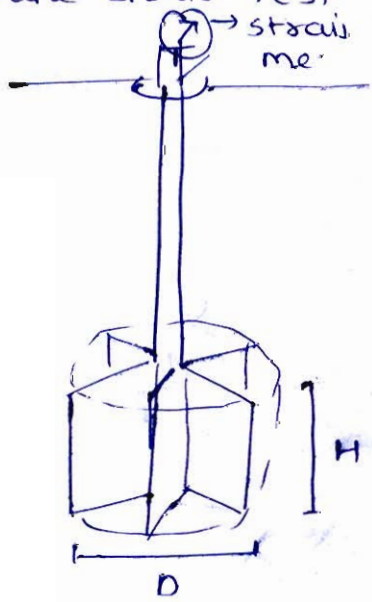
⇒ Depth ratio is 1

(c) slope Failure

occurs when slope soil is weak in strength

⇒ Depth ratio is less than 1

ii) vane shear test



⇒ This test is use to measure shear streng Liquid limit, and to determine sensit vit of soil

⇒ vane as shown is driven inside the soil, whose shear streng is deter mine

⇒ Torque is applied to the shaft

⇒ strain measurment is done at top of soil.

- value of strain, torque ~~need~~ at failure (sudden change) is noted

∴ shear strength is given as

Two way shear

$$\tau = \frac{T}{\pi D^2 \left(\frac{H}{2} + \frac{D}{6}\right)}$$

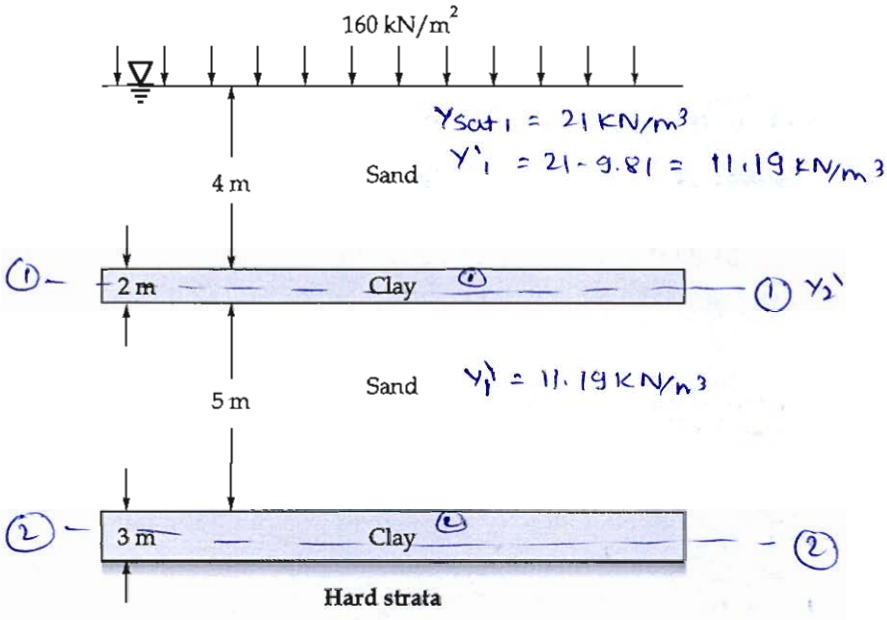
For one way shear

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

(B)

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]

For clay

$$\gamma_2' = \left(\frac{(G-1)}{1+e}\right)\gamma_w \qquad [\ se = wG \quad (1)(e) = (0.4)(2.7) \quad \therefore e = 1.08\ ]$$

$$= \frac{(2.7-1)(9.81)}{1+1.08}$$

$$\gamma_2' = 8.02 \frac{kN}{m^3}$$

① Thickness of compressible lay

$H_1 = 2m$

$H_2 = 3m$

② Intial effective over burden press

at leve ① - ① $\quad \bar{\sigma}_{o1} = (\gamma_1')(4) + (\gamma_2')(1)$

$= (11.19)(4) + (8.02)(1)$

$\bar{\sigma}_{o1} = 52.78\ kN/m^2$

at Leve ② - ② $\quad \bar{\sigma}_{o2} = \gamma_1'(4) + (\gamma_2')(2) + \gamma_1'(5) + \gamma_2'(1.5)$

$= 11.19(9) + 8.02(3.5)$

$\bar{\sigma}_{o2} = 128.78\ kN/m^2$

③ Increase in effective overburden pressu due to surcharg

at ① - ① ⇒ $\Delta\bar{\sigma} = 160\ KN/m^2$

at ② - ② ⇒ $\Delta\bar{\sigma} = 160\ KN/m^2$

④ compression index for clc

~~$C_c = 0.009(40-10)$~~ $C_c = 0.24$

Ultimate settlement is given as sum of settleme of laye ① & layer ②

$$\therefore \Delta H = \frac{H_1 C_c}{1+e} \log\left(\frac{\bar{\sigma}_{01} + \Delta\bar{\sigma}}{\bar{\sigma}_{01}}\right) + \frac{H_2 C_c}{1+e} \log\left(\frac{\bar{\sigma}_{02} + \Delta\bar{\sigma}}{\bar{\sigma}_{02}}\right)$$

$$= \frac{(2)(0.24)}{1+1.08} \log\left(\frac{52.78+160}{52.78}\right) +$$

$$+ \frac{(3)(0.24)}{(1+1.08)} \log\left(\frac{128.78+160}{128.78}\right)$$

$$= 0.13972 + 0.12140$$

$$\boxed{\Delta H = 261.12 \times 10^{-3} m}$$

↳ ultimate settlement.

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

(i) Alum

(ii) Copperas

(iii) Sodium aluminate

[12 marks]

Alum

- Chemical Formul $(Al_2(SO_4)_3 \cdot 18H_2O$
- It works in PH rand 6.5 - 8 ≠ same as that of drinking water
- ~~The st~~ It reacts with Alkalinity present in water to form sticky ppt of $Al(OH)_3$
- It produce permanent hardness, increases corrosivity of water.

~~Copper ass~~ copperas ($FeSO_4 \cdot 7H_2O$)

- It work in pH range of > 9.5, in alkaline water, so used in Industries to treat
- → It also require alkalinit to react and Form sticky precipit
- → It produces colour, so it is not used in ~~water~~ domestic water treatment.
- → 1 mole of copperass reacts with 1 mole of alkalin if Alkalinity adde first, and 2 mole if copperass added First
- → It also produces permanent hardness in water.

9

Sodium Aluminate ($Na_2Al_2O_4$ ~~.xH2O~~)

- It react with hardness present in water to form sticky ppt
- It doesn't require alkalinity to react
- It is not used as It is very costly

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]

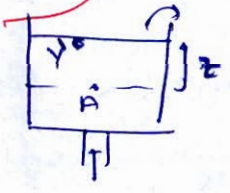
Q.8 (a) (i) What do you understand by seepage pressure and quick sand condition?
(ii) What is a flow net? Explain the properties and uses of a flow net.

[8 + 12 = 20 marks]

1') When water flows through a soil, soil oppose its flow, which cause head loss in water, Also ther exist a drag force between water and soil, This exerts seepage pressure on soil particle by water.

→ If his head loss cause, the seepage pressure $= \gamma_w h$

→ For upward flow of water it reduce effective stress, and for downward flow seepage pressure increases effect str.



At point A

$\bar{\sigma}_A = \gamma' z - i z \gamma_w$ (For upward flow) — seepage pres

$\bar{\sigma}_A = \gamma' z + i z \gamma_w$ (For downward)

when Fine sand is subjected to upward flow of water, and if at exit seepage pressure increases to such extent that it balanced the submerge weight of water, then effective stress will become zero

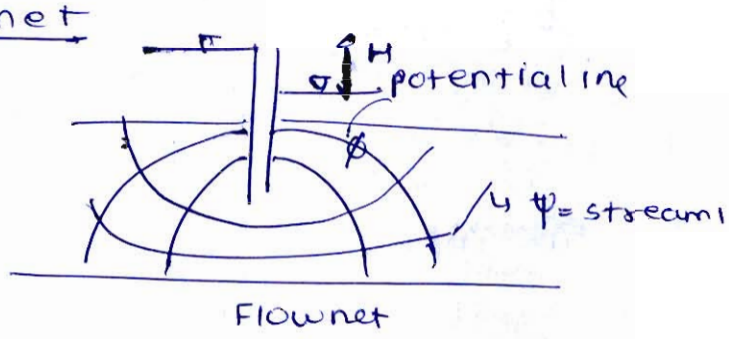
, As in case of sand, strength is function of effective stress, strength will become zero, and sand will blow with water this condition is called as quick sand condi

Here i_c (critical hyd gradie) = i exit grad

Occurs at, $i_c = i$

6

Flownet



Flownet

- It is graphical representation of potential and streamline, in ~~homoge~~ soil media
- It helps in calculation use of Flownet
  1. seepage discharge
  2. seepage pressure
  3. exit gradient
  4. pore water pressu

Properties of Flownet

- potential lines are perpendicular to streamlines
- Headloss between two continuous ~~lines~~ potential line remains same
- In homogeneous medi. potential and streamline will form curvilinear square
- differen $\psi_2 - \psi_1$ will be equal to seepage discharge per unit width.

Her $Q_{see} = K H \frac{N_f}{N_d}$

H → Head available

N_f → No. of flow channel

N_d → No of potential drop

6

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]

Given data

(A) $Q_f = 15 m^3/m^2/hr$

$q_{(avg\ demand)} = 200 l/c/d$

5% of filtered water → backwash for 30 min.

Filter unit (10×4)m → $A_f = 40 m^2$.

Treatment units are designed for max daily demand (MDD)

$MDD = 1.8 \times$ Avg demand

$= \{(1.8) \times (2.75 \times 10^5) \times (200)\} \frac{l}{d} \times \frac{1 m^3}{1000 l}$

$= 99000 \frac{m^3}{d}$

(B) Q_D ⇒ Design discharg

as 5% of water is used for backwash for 30min

∴ Time of filtration = 23.5 hor

$\therefore Q_D = \left(\frac{MDD}{0.95}\right) \times \frac{1d}{23.5h} = \left(\frac{99000}{0.95}\right)\left(\frac{1}{23.5}\right)$

$Q_D = 4434.49 \frac{m^3}{hr}$

Let A be to

$\frac{Q_D}{\text{Total Area of filter (A)}} = Q_f$

$\frac{4434.49}{A} = 15$

$\Rightarrow A = 295.63 m^2$

no of units reqd for filtration $= \frac{A}{A_f}$

$= \frac{295.63}{40}$

$= 7.39$

Say 8 unit

∴ So total number of units reqd is 9 (8 + 1 standby).

Let V_f = Upflow velocity

C_D = coeff of drag = 5.02

V_s = settling velocity $G_s = 2.5$ $d = 0.6 \times 10^{-3}$ m

$= \sqrt{\frac{4}{3}\frac{gd(G_s-1)}{C_D}} = \sqrt{\left(\frac{4}{3}\right)\frac{(9.81)(0.6\times10^{-3})(2.5-1)}{5.02}}$

$V_s = 0.0484$ m/s

Assuming headloss to be only because of soil particles, and remain same before and after back was.

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

n ⇒ porosity of undistub bed = 0.5

n' ⇒ porosit of bed after backwa

D' ⇒ Depth of bed after backwa = 0.66 m

D ⇒ Depth of undisturbe bed = 0.6 m

∴ $(1-0.5)(2.5-1)(0.6) = (1-n')(2.5-1)(0.66)$

$\Rightarrow \boxed{n' = 0.545}$

8

AIS

$n' = \left(\frac{V_f}{V_s}\right)^{0.22}$ ~~V_s = upflo~~

$0.545 = \left(\frac{V_f}{0.0484}\right)^{0.22}$

$\Rightarrow \boxed{V_f = 3.066 \times 10^{-3} \text{ m/s}}$

↳ upflow velocity

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.

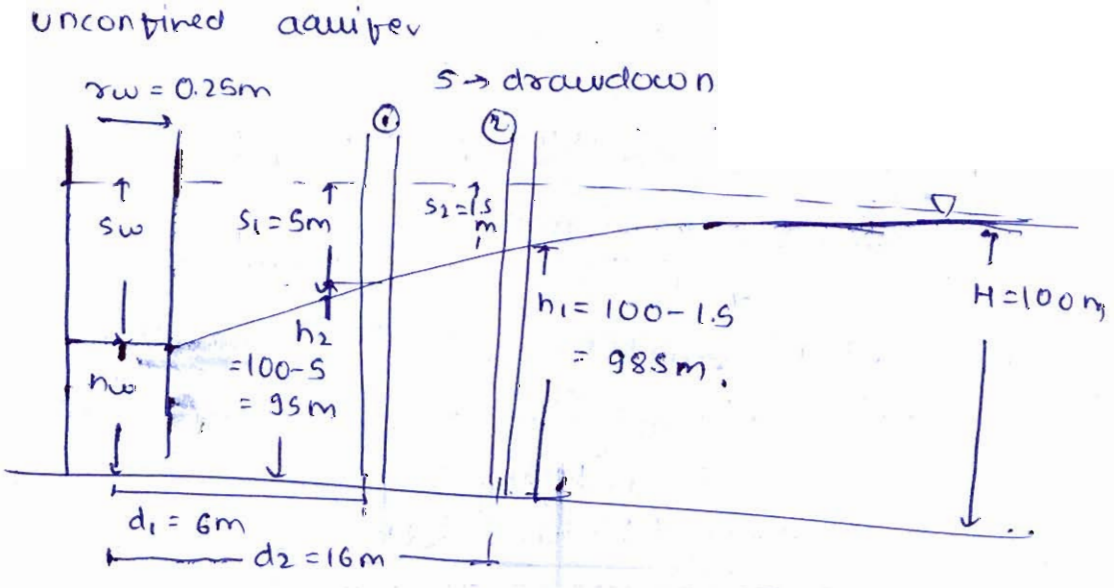
(ii) Drawdown in the well being pumped.

(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 (steady state discharg) = 1500 l/min.



Assuming Flow to reach steady state, and validity of Darcy law in aquifer (Aquife is saturated, Homogene and isotro

① By Dupits equation

$$Q = \frac{\pi K (h_2^2 - h_1^2)}{\ln\left(\frac{d_2}{d_1}\right)}$$

$$1500 \text{ l/min} = \frac{(\pi)(K)(98.5^2 - 95^2)}{\ln\left(\frac{16}{6}\right)}$$

⇒ $K = 0.691$ l/min

↳ Coeff of permeability of medium

s_w be drawdon in well at stead sta

h_w be heigh of water level in well

$h_w = 100 - s_w$

∴ By dupits equa

$$Q = \frac{\pi k (h_2^2 - h_w^2)}{\ln\left(\frac{d_2}{d_w}\right)}$$

$$1500 = \frac{(\pi)(0.691)(98.5^2 - h_w^2)}{\ln\left(\frac{16}{0.25}\right)}$$

$\Rightarrow h_w = 82.635m$

∴ $s_w = 100 - h_w$

$= 100 - 82.635$

$s_w = 17.365m$ → drawdown in well

(iii) specific capacity is defined as steady state discharge for the 1st one metre drawdown in well

so here $s_w = 1$

$h_w = 99m$

Assuming radius of influence to remain same as for above discharge

$$1500 = \frac{(\pi)(0.691)(100^2 - 82.635^2)}{\ln\left(\frac{R}{0.25}\right)}$$

$\Rightarrow R = 214.619m$

↳ Radius of influence

∴ For 1m drawdon ⇒ $h_w = 99$ $H = 100$

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

$$\therefore Q = \frac{(\pi)(0.691)(100^2 - 99^2)}{\ln\left(\frac{24.619}{0.25}\right)}$$

$Q = 94.121$ l/min

Yspecific capacity of well

iii) maximum rate at which water will be pumped will correspond to maximum drawdown which is same as heigh of water table = 100m

$\therefore h_w = 0$

$H = 100$ m $\Rightarrow Q = \frac{\pi K (H^2 - h_w^2)}{\ln\left(\frac{R}{r_w}\right)}$

$$= \frac{(\pi)(0.691)(100^2 - 0^2)}{\ln\left(\frac{24.619}{0.25}\right)}$$

$Q_{max} = 4729.69$ l/min

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iv) Drawdown corresponding to Q_{max} ~~will be equal to Real Height of well~~

By dupit eq

$$Q = \frac{\pi K (h_0^2 - h_w^2)}{\ln\left(\frac{d}{r_w}\right)}$$

For well ① $\longrightarrow$ $4729.69 = \frac{(\pi)(0.691)(h_1^2)}{\ln\left(\frac{6}{0.25}\right)}$

$\Rightarrow h_1 = 83.211$

$\Rightarrow s_{w_1} = 100 - 83.21$

$s_{w_1} = 16.789$ m

Good

For well ②

$4729.69 = \frac{(\pi)(0.691)(h_2^2)}{\ln\left(\frac{16}{0.25}\right)} \Rightarrow h_2 = 95.188$

$s_{w_2} = 100 - 95.188$

$s_{w_2} = 4.812$ m

Space for Rough Work

Space for Rough Work