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ESE 2019 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-2: Transportation Engineering + Surveying and Geology, Geo-technical & Foundation Engg-1 + Environmental Engg-1

Name : .....

Roll No : C E 1 9 M B D L B 7 4 6

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Student's Signature

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. 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.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	29 − 1 = 28
Q.2	
Q.3	43
Q.4	47 − 4 = 43
Section-B	
Q.5	37 − 4 = 33
Q.6	
Q.7	54 − 1 = 53
Q.8	
Total Marks Obtained	210 − 10 = 200

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

Good accuracy But Can do Better

* Good Presentation.

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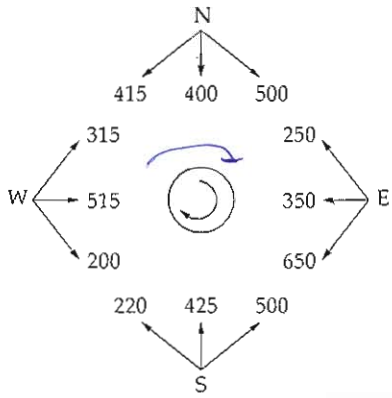
Section A : Transportation Engineering + Surveying and Geology

Q.1 (a) The width of a carriage-way approaching an intersection is given as 14 m. The entry and exit width at the rotary is 8 m. Determine the capacity of the rotary for the traffic flow as shown in the figure.



[12 marks]

$W = \frac{e_1 + e_2}{2} + 3.5$

Given $e_1 = e_2 = 8m$

finding weaving ratio for all

$P_{NE} = \frac{b+c}{a+b+c+d}$

$b+c$ = weaving Traffic

$a+b+c+d$ = Total Traffic

$P_{NE} = \frac{400 + 415 + 515 + 500}{500 + (400+415) + (515+500) + 200}$

$= 0.7233$

$P_{ES} = \frac{[(350) + 250] + [400 + 200]}{650 + 350 + 250 + 400 + 200 + 415}$

$= 0.529$

$P_{SW} = \frac{425 + 500 + 350 + 415}{220 + (425 + 500) + (350 + 415) + 250}$

$= 0.782$

$$P_{wp} = \frac{515 + 200 + 425 + 250}{315 + (515 + 200) + (425 + 250) + 500}$$

$$= 0.63$$

So $P_{man} = 0.782$

Rotary Capacity

$$= \frac{280w\left(1 + \frac{e}{w}\right)\left(1 - \frac{P}{3}\right)}{\left(1 + \frac{w}{L}\right)}$$

$\because$ L must be $> 4w$

$\simeq 56M$ ✗

$e = \frac{e_1 + e}{2} = 8M$ ✓

$w = 14M$ ✗

$$Cap = \frac{280 \times 14\left[1 + \frac{8}{14}\right]\left[1 - \frac{0.782}{3}\right]}{\left[1 + \frac{14}{56}\right]}$$

$= 3643.43$ PCU/hr ✗

8

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Q.1 (b) (i) Define remote sensing. Explain the terms passive remote sensing and active remote sensing.

(ii) Explain the concept of global positioning system.

[6 + 6 marks]

Remote Sensing → it is the technique of locating any point on the ground and finding about its properties without making contact to it. This technique is called remote sensing. Sensors are used to find the Prop. of soil, rocks or other parameters of land.

Principle =?, Diagram?

Active RS → when Energy source is used for finding the properties in anything by sensor it is called active Remote Sensing, example - use of laser lights

Passive Remote Sensing - when energy source is Sun only then Remote

Sensing type is called Passive remote sensing in this no external source of energy is used

Example — RADAR

(4)

(iii) GPS → This is technique to find the position of any point on ground. in this technique min 4 satelites are required for finding all the coordinates of any point at any time. and There must be no hinderence to satelite wave in reaching to receiver and Transmitter

(3)

Explain with Diagram Also

Q.1 (c) Determine the warping stresses at interior, edge and corner, for a 25 cm concrete pavement with 15 metre transverse joints; width of lane is 3.6 metres. The modulus of sub-grade reaction (k) is 2.8 kg/cm^3. Assume temperature differential for day conditions to be 1°C per cm for computing warping stress. Take the following values of various factors:

Thermal coefficient of concrete 'α' = 8×10^{-6} per °C

Modulus of elasticity of concrete 'E' = 2.8×10^5 kg/cm^2

Poisson's ratio, $\mu = 0.15$

Radius of contact area = 16 cm,

Warping stress coefficient, $C_1 = 1.03$, $C_2 = 0.35$

(Use Bradbury method)

[12 marks]

Radius of relative stiffness

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

$$= \left[\frac{2.8 \times 10^5 \times 25^3}{12 \times 2.8 (1 - 0.15^2)}\right]^{1/4}$$

$$= 107.43 \text{ cm}$$

now

warping stress

$$\sigma_{interior} = \frac{E\alpha T}{2}\left(\frac{C_1 + \mu C_2}{1-\mu^2}\right)$$

$\because T = 1°C/cm = 25°C$

$$= \frac{2.8 \times 10^5 \times 8 \times 10^{-6} \times 25}{2}\left[1.03 + \frac{0.15 \times 0.35}{1 - 0.15^2}\right]$$

$$= \boxed{31 \text{ kg/cm}^2}$$

$$S_{edge} = \text{Max of}\left[\frac{C_h E \alpha T}{2}, \frac{C_v E \alpha T}{2}\right]$$

$$= \text{Max of}\left[\frac{1.03 \times 2.8 \times 8 \times 10^{-6} \times 25}{2}, \frac{0.35 \times 2.8 \times 8 \times 10^{-6} \times 25}{2}\right]$$

$$= \text{Max of}\left[28.84,\ 9.8\right]$$

$$= \boxed{28.84 \text{ kg/cm}^2}$$

$$S_{corner} = \frac{E \alpha T}{3(1-\mu)}\sqrt{\frac{q}{\ell}}$$

q = radius = 16 cm

$$= \frac{2.8 \times 10^5 \times 8 \times 10^{-6} \times 25}{3(1-0.15)}\sqrt{\frac{16}{107.43}}$$

$$= \boxed{8.475 \text{ kg/cm}^2}$$

12

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Q.1 (d) A chimney 120 m high appears at the principal point of a vertical photograph. On the next vertical photograph, taken shortly after, the base of the chimney is on the x-axis and 82.5 mm to the left of the principal point. The photographs are 200 mm × 200 mm. The flying height of the aircraft was 780 m and the focal length of the camera was 125 mm. Determine

(a) the distance of the top of the chimney from the y-axis on the second photograph.

(b) the percentage overlap between the two photographs.

[12 marks]

$$S = \frac{f}{H-h} = \frac{125\,mm}{780M-120}$$

$$\Delta = \frac{1}{5280}$$

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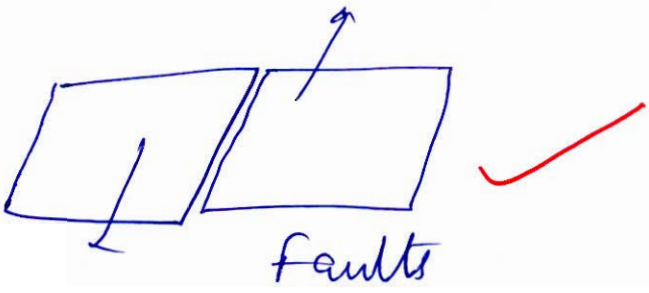
Q.1 (e) Explain the following:

1. Folds
2. Faults
3. Joints
4. Unconformity

[12 marks]

Explain ?



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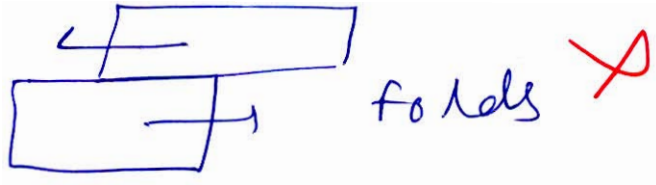

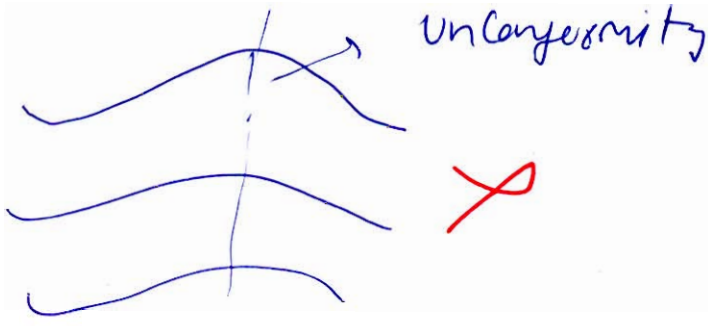

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Q.2 (a) (i) What are the various types of failures in flexible and rigid type of pavements? Explain the causes of failures.

(ii) The specific gravities and weight proportions for aggregate bitumen are given in the table below for the preparation of Marshall Mix Design. The volume and weight of one Marshall specimen was found to be 450 cc and 1050 gm. Assuming absorption of bitumen in aggregate to be zero, find percent air void (V_V), percent volume of bitumen (V_B), voids in mineral aggregate (VMA), and voids filled with bitumen (VFB).

Item	Coarse Aggregate	Fine Aggregate	Filler	Bitumen
Weight (in gm)	820	1300	435	100
Specific gravity	2.6	2.52	2.45	1.05

[12 + 8 marks]

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Q.2 (b) Design the size and spacing of dowel bars at an expansion joint of concrete pavement of thickness 25 cm. Given the radius of relative stiffness is 70 cm. Design wheel load is 4000 kg. Load capacity of the dowel system is 40% of design wheel load and diameter of dowel bar is 2.5 cm. Joint width is 2 cm and the permissible stress in shear, bending and bearing in dowel bars are 1000, 1400 and 100 kg/cm^2 respectively.

[20 marks]

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Q.2 (c) The following consecutive readings were taken with a level and 4-metre levelling staff on a continuously sloping ground at common interval of 30 m.

0.855 (on A), 1.545, 2.335, 3.115, 3.825, 0.455, 1.380, 2.055, 2.855, 3.455, 0.585, 1.015, 1.850, 2.755, 3.845 (on B)

The RL of A was 380.500 m. Make entries in a Level Book and apply the usual checks. Determine the gradient of AB.

[20 marks]

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Q.3 (a) The 15 minute-traffic counts on cross roads *A* and *B* during peak hour are observed as 178 and 142 vehicles per lane respectively approaching the intersection in the direction of heavier traffic flow. If the amber times required are 3 and 2 seconds respectively for two roads based on approach speeds, design the signal timings by trial cycle method. Assume an average time headway of 2.5 seconds during green phase.

[20 marks]

Trial Cycle Method

Assuming Trial Cycle C_o = 50 seconds ✓

in road a no. of vehicles in 15 mins = 178 ✓

total no. of Vehicles to be Pass in One Cycle = $\frac{178}{900} \times 50$

time headway = 2.5 seconds

so time reqd to Pass One Cycle Vehicle = $\frac{178}{900} \times 50 \times 2.5$

= 24.72 sec ✓

So G_A = 24.72 — (1)

in same way Green time reqd for road B

$G_B = \frac{142}{900} \times 50 \times 2.5$

= 19.722 sec ✓ — (2)

~~$G_A = R_B + A_B$~~

A_A = 3 sec A_B = 2 sec ✓

By this cycle

$W_A = 24.72$ $A_A = 3$ sec

$R_B = W_A + A_A = 27.72$

$R_A = W_B + A_B = 21.722$

Total Cycle $= W_A + A_A + R_A$

$= W_A + A_A + W_B + A_B$

$= \boxed{49.444}$

this is less than ~~exact~~ what we have taken

so now taking new Trial cycle $= \boxed{45}$ sec

new $W_A = \frac{178}{500} \times 45 \times 2.5$

$= 22.25$

$W_B = \frac{142}{500} \times 45 \times 2.5$

$= 17.75$ seconds

$A_A = 3$ sec $A_B = 2$ sec

Total Cycle Time $= W_A + A_A + W_B + A_B$

$= 22.25 + 3 + 17.75 + 2$

$= \boxed{45}$

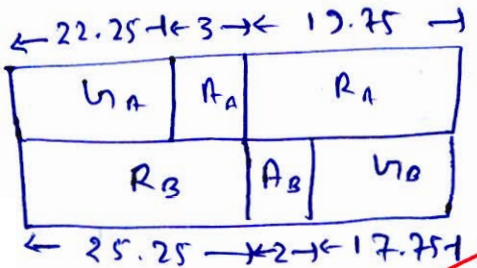
same as taken

so cycle time $= 45$ sec

$W_A = 22.25$ $A_A = 3$ sec

$W_B = 17.75$ $A_B = 2$ sec

Phase diagram



all in seconds

20

Good

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Q.3 (b) (i) The following data pertains to the number of commercial vehicles per day for the design of a flexible pavement for a highway:

Type of vehicle	No. of vehicles/day	VDF
2 axle trucks	2500	4
Tandem axle trucks	500	5

For four lane single carriageway the rate of traffic growth is 5% per annum for both the types of vehicles, determine the cumulative number of standard axle load repetitions for a design life of 10 years.

(ii) What are the different types of traffic survey conducted?
What is the purpose of Origin and destination (O–D) survey?
In what way these data are utilized by a highway engineer?

(iii) A plate load test is carried out on subgrade soil using a 300 mm radius rigid plate. A load of 5 tonnes resulted in a deflection of 1.2 mm. Determine the elastic modulus of the soil, if the Poisson's ratio is 0.5.

[8 + 8 + 4 marks]

(i) VDF of Mixed Traffic

$$= \frac{2500 \times 4 + 500 \times 5}{2500 + 500}$$

$$= 4.1667$$

LDF for 4 lane Single Carriageway = 0.4

$r = 5\%$. LSF = 1

n = Time = 10 yrs

AADT = 3000

$$CSA = \frac{AADT \times VDF \times 365\left((1+r)^n - 1\right) \times LDF \times LSF}{r}$$

$$= \frac{3000 \times 4.1667 \times 365\left[1.05^{10} - 1\right] \times 0.4}{0.05}$$

$$= 22.955 \times 10^6 \text{ CSA}$$

$$= 22.955 \text{ MSA}$$

MSA = Million Std. axles

8

(ii) Different type of Traffic Surveys

- Traffic Volume Survey
- spot speed surves
- Origin & destination Survey
- speed and delay studies
- Vehicular characteristics Survey.
- Accident studies
- Parking studies

Origin and destination Survey:-

This test is Conducted to find the By Pass road alignment or designing of Rapid Transit System this technique is used. by OKD Survey data desire lines are drawn which tell us the maximum traffic routes based on these dates new route can be designed or

existing routes can be Improved.
- by this survey Points of Generation of Traffic, different Points, different vehicles Travel times are noted, their purpose is noted. and then system is designed accordingly

5

(iii) Plate load test on subgrade

so ~~flexible~~ soil Rigid plate type test in this case

$$D = 1.18 \frac{Pa}{E_r} \times f$$

but survey on subgrade layer

so for subgrade layer survey $f = 1$

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$$\Delta = 1.18 \frac{pq}{E_r}$$

$\Delta = 1.2\,mm$

$p = 5$ tonnes $= 5000\ kg$

plate size = 300 mm radius

p = stress on plate

$$p = \frac{5000\ kg}{\pi \times 30^2} = 1.768\ kg/cm^2$$

q = radius of plate

$= 30\ cm$

$$\frac{1.2}{10} = \frac{1.18 \times 1.768 \times 30}{E_r}$$

$$E_r = 521.56\ kg/cm^2$$

(4)

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Q.3 (c) In a closed traverse the following lengths and bearings were measured:

Side	Length (m)	Bearing
AB	130.00	N 38° 42′ W
BC	180.00	N 45° 30′ E
CD	163.00	N 62° 34′ E
DE	265.65	–
EA	–	S 75° 00′ W

Compute the missing length and bearing.

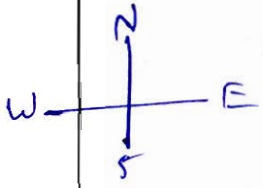
[20 marks]

for a closed Traverse

Σ latitude $= 0$ Σ departure $= 0$

taking length of EA $= h$

Bearing of DE $= \theta$



First Converting all CB into WCB

AB	N 38°42′ W	= 321°18°
BC	N 45°30′ E	45°30′
CD	N 62°34′ E	62°34′
DE	θ	θ
EA	S 75°W	255°

Σ latitude $= 0$

$130 \cos 321°18' + 180 \cos 45°30' + 163 \cos 62°34' + 265.65 \cos\theta + h \cos 255° = 0$

$302.716 + 265.65 \cos\theta - 0.258h = 0$ — (1)

Σ departure $= 0$

$160 \sin 321°18' + 180 \sin 45°30'$

$+ 163 \sin 62°34' + 265.65 \sin\theta$

$+ x \sin 255° = 0$

$173.016 + 265.65 \sin\theta + (-0.966\, x) = 0$ — (2)

from eqn (1) and (2)

$(0.2588x - 302.716)^2 + (0.966x - 173.016)^2 = 265.652$

by solving eqn.

$x = 149.278$ metre

So length of EA = 149.278 m

Now by eqn (1) and (2)

$\cos\theta = -0.9941$

~~$\sin\theta = -28.81$~~

$\sin\theta = -0.1084$

$\tan\theta = +0.1091$

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θ = 6.2231

= 6° 13' 23'

but Sinθ, Cosθ both negative

so Bearing is in Third Quardr.

Bearing = 180° + 6°13'23'

~~DE= 180° 13' 23"~~

Length of EA = ~~149.278m~~

(6)

Correct Approach but wrong Calculation

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Q.4 (a) (i) What are the various equipments used in highway construction? Mention their specific uses?

(ii) Calculate the group index value of a soil sample for highway pavement design. The results obtained by analysing soil subgrade sample collected from site are as follows:

- Soil passing through 0.075 mm sieve = 60%
- Liquid limit = 40%
- Plastic limit = 15%

(iii) Differentiate between:

1. tar and bitumen
2. cutback bitumen and bitumen emulsion?

[8 + 6 + 6 marks]

Ans- (i) · Various equipments :-

① Grader → This is used for levelling of material spreaded on road which can be subgrade soil or GSB material. With help of grader horizantal plane is prepared.

(ii) Rollers → different types of roller are used in highway const. for compaction

- → Smooth wheeled roller
- → Pneumatic wheeled roller
- → Sheep foot roller
- → Vibrating roller

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Pneumatic wheeled roller is used for all type of material whether sheep foot roller is used for cohesive type of soils compaction.

(iii) Paver → This is used for laying of Bituminous Concrete or DBM (Pre mixed on the road).

(iv) Other than above mentioned various other equipment are used.

→ Transit mixer (for CC roads)
→ Screed Vibrator (for CC roads)
→ Cutter (for Providing Contraction Joint) (5)
→

(ii) Group Index

a = 0.75 mm Passed − 35
= 60 − 35 = 25 (< 40)

b = 0.75 mm Passed − 15
= 60 − 15 = 45
but $b < 40$ so
$b = 40$

$C = LL - 40 = 40 - 40 = 0$

$d = PI - 10$

$= (40 - 15) - 10$

$= 15$

so

~~GI = 0.29c~~

$GI = 0.29 + 0.005\,ac + 0.01\,bd$

$= (0.2 \times 25) + 0 + 0.01 \times 40 \times 15$

$= 5 + 6$

$\boxed{GI = 11}$ Poor soil

6

(iii) Tar and bitumin

Tar	bitumin
→ it is Prepared from destructive distillation of Tar Coal & wood	- it is Prepared from fraction distillation of Petrolium
→ Carbon Content is high	→ Carbon Content is lower
→ soluble in water	→ soluble in CCl_4 and CS_2
→ Temperature susceptibility is high	→ Temperature susceptibility is low

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Tar	bitumen
→ Viscocity is lower Then bitumen	- Viscocity is higher then Tar
→ not used for high Moisture Condition	- Can tolerate moisture Condition

(2)

(iii) Cut back

- it is Prepared from mixing of bitumen into Solvents like petrol kerosene extra to get high viscocity

→ 3 types are there

→ SC (slow Curing)

MC (Medium Curing)

RC (Rapid Curing)

Emulsion

→ it is Prepared by mixing the water into Bitumen with help of Emulsifiers

There types

SS (slow setting)

MS (Med. setting)

RS (Rapid setting)

(2)

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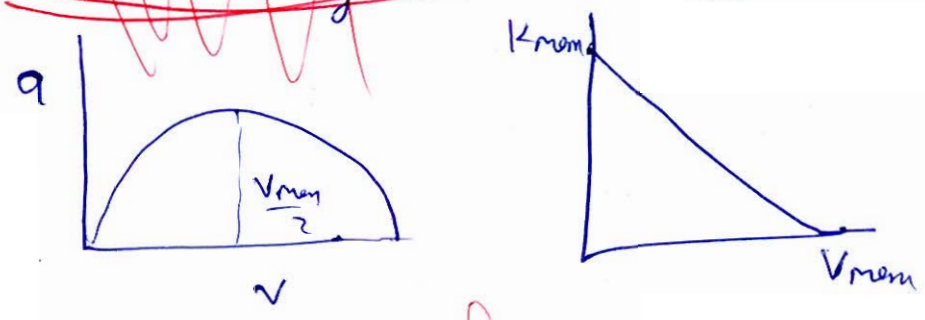
Q.4 (b) **(i)** Derive the expression of traffic density when the highway is operating at maximum capacity as per

1. Greenberg's model
2. Greenshield's model

(ii) A car travelling at 22.22 m/sec is overtaking another moving at 16.67 m/sec on a two lane undivided highway. Assuming the acceleration of the overtaking car as 0.7 m/sec^2, calculate (i) minimum overtaking sight distance; and (ii) minimum and desirable length of overtaking zones.

[8 + 12 marks]

(i) Greenberg's model Greenshield



as per Greenberg

$$\frac{V}{V_{max}} + \frac{K}{K_J} = 1$$

where V_{max} = free flow speed

K_J = Jam density of vehicles $= \left(\frac{1000}{5}\right)$

and $q = KV$

now for max capacity

$q = KV$

@ $q = K\left(1 - \frac{V}{V_{max}}\right) K_J \times V$

for max $\frac{dq}{dV} = 0$

in $1 - \frac{2V}{V_{max}} = 0$

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$$V = \frac{V_{max}}{2} \quad -(1)$$

at $V = \frac{V_{max}}{2}$ $\quad k = \frac{k_J}{2}$

so $q = kV$

$$\boxed{q = \frac{k_J V_{max}}{4}}$$

(ii) as per Greenberg Green shield's model

$$\frac{V}{V_{max}} = \ln\left(\frac{k_J}{k}\right)$$

now $q = kV$

$$q = k V_{max} \ln\left(\frac{k_J}{k}\right)$$

for maximum capacity

$$\frac{dq}{dk} = 0$$

$$V_{max}\left[k \times \left[\frac{k}{k_J} \times -\frac{k_J}{k^2}\right] + \ln\frac{k_J}{k}\right] = 0$$

$$\ln\frac{k_J}{k} = +1$$

$$\boxed{k_J = e^{+1} k}$$

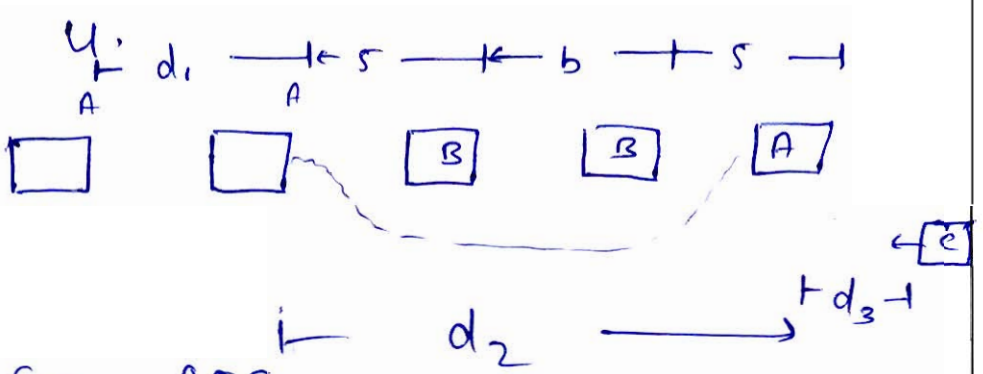
~~$k = e k_J$~~ $\quad \boxed{k = \frac{k_J}{e}}$

$V = V_{max}$

$$\boxed{q_{max} = \frac{V_{max} k_J}{e}}$$

(4)

(ii)



For OSD

$d_1 = V_B \times t$ $\quad t = 2$ sec reaction tm

$d_1 = 16.67 \times 2 = 33.34$ M

$d_2 = b + 2s$

where min^m spacing

$s = 0.7 V_B + 6$

0.7 time

$s = 0.7 \times 16.67 + 6$

6m = vehicle length

$s = 17.67$ metre

$T = \sqrt{\frac{45}{9}} = \sqrt{\frac{4 \times 17.67}{0.7}}$

$T = 10.05$ seconds

$d_2 = b + 2s$

$= V_b T + 2s$

$= 16.67 \times 10.05 + 2 \times (17.67)$

$= 202.87$ M

Do not write in this margin

$d_3 = V_c T$

$V_c = V_A$ for design

$d_3 = 22.22 \times 10.05$

$= 223.311\ M$

$OSD = d_1 + d_2 + d_3$

$= 33.34 + 207.87 + 223.311$

Min^m $OSD = 459.52\ M$

new Minimum desirable length of OSD zones

$= 3\,OSD - 5\,OSD$

$= 1378.56\ M$ to $2297.6\ M$

Min^m OSD zone $= 1378.56\ M$

Draw Diagram also.

(12)

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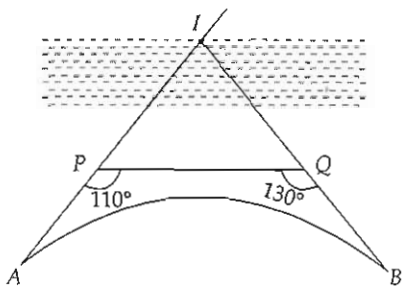
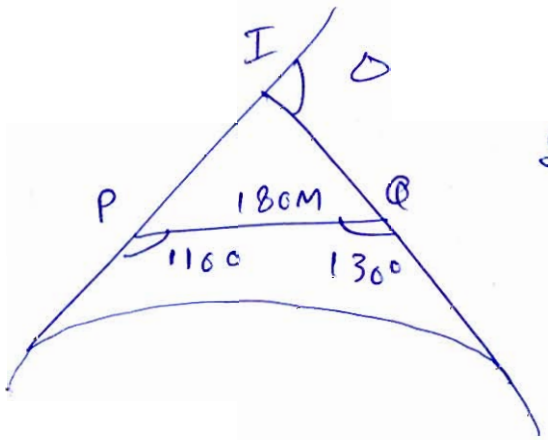
Q.4 (c) **(i)** Two straights *AI* and *BI* intersect at an inaccessible point *I*. Two points *P* and *Q* are selected on lines *AI* and *BI*, respectively. Length of *PQ* = 180 m, angle *APQ* = 110° and angle *PQB* = 130°, as shown in the diagram below. The two straights are to be joined a by curve of 500 m radius. Chainage of point *P* is 2500 m. Calculate the necessary data for setting of curve.



(ii) *P* and *Q* are two points 367 m apart on same bank of a river. The bearings of a tree on the other bank observed from *P* and *Q* are N36°25'E and N40°35'W respectively. Find the width of river if bearing of *PQ* is S86°35'E?

[10 + 10 marks]

(i)



~~110 + 130°~~

=

deviation angle

Δ = ?

$\Delta = (180 - 110) + (180 - 130)$

$= 120°$

new PQ = 180M

$$\frac{PI}{\sin \angle PQI} = \frac{PQ}{\sin \angle PIQ}$$

$$\frac{PI}{\sin 50} = \frac{180}{\sin 60}$$

$PI = 97.3\,M$

new length of Tangent

$AI = R \tan \frac{\Delta}{2}$

$= 500 \times \tan \frac{120}{2}$

$= 866.025\ M$

Chainage of I = Chainage of P + PI

$= 2500 + 97.3$

$= 2597.3M$

Chainage of A = $2597.3 - 866.025$

$= 1731.275M$

new for setting of Curve

length of curve $= \frac{2\pi R}{360} \times \Delta$

$L_c = 1047.19M$

new Chainage of B = A chainage $+ L_c$

$B = 2778.465M$

(6)

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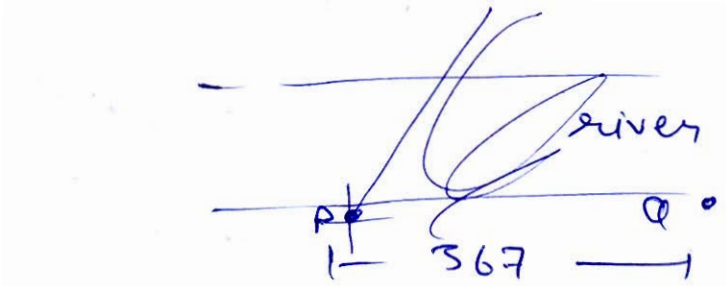
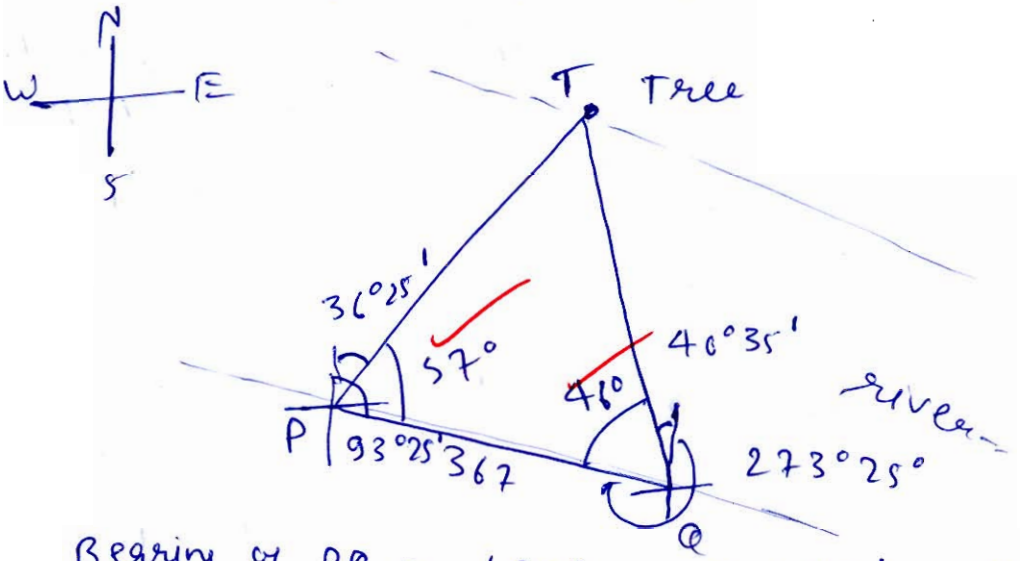
(ii)



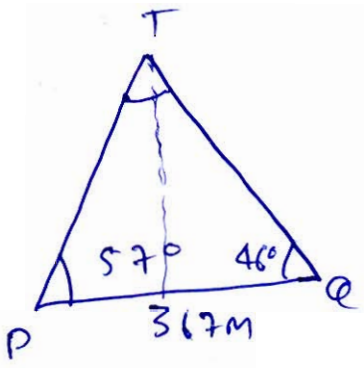


Bearing of PQ = 180° − 86°35' = 93°25'

angle ∠TPQ = 57°

angle ∠TQP = 360° − (273°25' + 40°35')

= 46°0'0"



width of river = ⊥ dist of T from PQ

∠PTQ = 77°

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$$\frac{PT}{\sin 46^\circ} = \frac{TQ}{\sin 57} = \frac{PQ}{\sin 77}$$

$$PT = \frac{\sin 46 \times 367}{\sin 77}$$

$$PT = 270.94 \text{ metre}$$

width of River from Geometry

$$= PT \sin 57^\circ$$

$$= 270.94 \sin 57$$

$$= 227.23 \text{m}$$

width of river = 227.23m

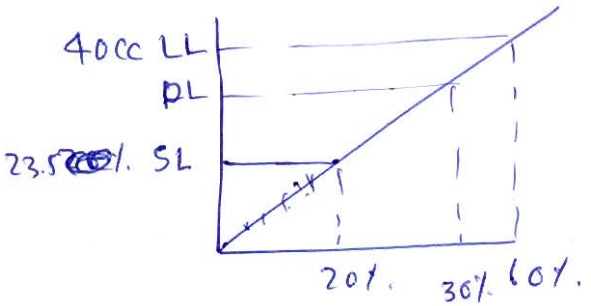
10

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

Q.5 (a) The laboratory tests on a soil sample reported to the values of liquid limit, plastic limit and shrinkage limit as 60%, 30% and 20%, respectively. If the sample of this soil at liquid limit has a volume of 40 c.c. and its volume measured at shrinkage limit was 23.5 c.c., determine the specific gravity of the solids. What is the shrinkage ratio?

[12 marks]

Sem



new shrinkage limit

$$w_s = w - \frac{\left(V_1 - V_d\right) \times \gamma_w}{W_1 - W_2}$$

here in this case

$V_1 = 40 \quad w_1 = 0.60$

$V_2 = 23.5 \quad w_2 = 0.20$

$\gamma_w = 1 g/cc$

but

shrinkage ratio $R = \frac{V_1 - V_d}{V_d}$

$= \frac{40 - 23.5}{23.5}$

$= \boxed{0.702}$

and $\boxed{w_s = \frac{1}{R} - \frac{1}{G}}$

$0.20 = \frac{1}{0.702} - \frac{1}{G}$

$G =$

Do not write in this margin

Shrinkage Ratio $R = \frac{V_1 - V_d}{V_d}$

$= \frac{(w_1 - w_2)}{\frac{40 - 23.5}{23.5}} = \frac{40 - 23.5}{0.60 - 0.20} = 1.755$

Shrinkage limit $w_s = \frac{1}{R} - \frac{1}{G} \Rightarrow 0.20 = \frac{1}{1.755} - \frac{1}{G}$

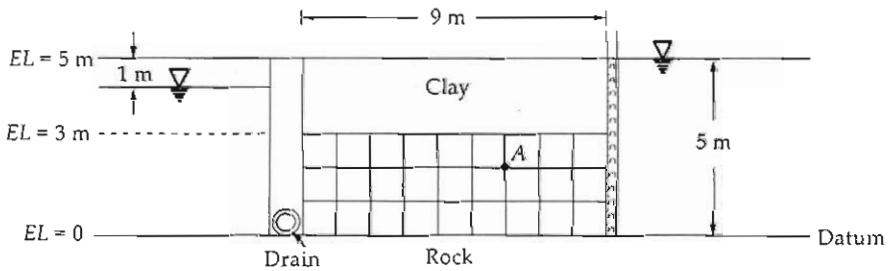
$G = 2.704$

So shrinkage ratio = 1.755

specific gravity = 2.704

12

Q.5 (b) The confined flow occurs towards a long land drain (perpendicular to the plane of the page as shown) through a layer of soil with permeability $k = 10^{-6}$ m/s sandwiched between clay and rock, both of which may be considered to be impermeable. The water level at the location of the drain is 1 m below the ground level. At a point 9 m away from the drain, the water table is at ground level.



The phreatic surface is above the top of the soil and the flow is confined by the impermeable clay. A simple square flownet is shown in figure. Determine the pore pressure at *A* as indicated in the diagram. Also determine rate of flow per unit length into the drain (from one side).

[12 marks]

as per diagram

$\Delta H = 5 - 4 =$ 1 metre

$N_f = 3 \quad N_d = 9$

rate of flow per unit length

$q = K H \frac{N_f}{N_d}$

$= 10^{-6} \times 1 \times \frac{3}{9} = 0.33 \times 10^{-6}$ m³/s per m length

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and to find Pore Pressure at A.

loss of head from top point to A $= H \times \left(\frac{N_d \text{ upto } q}{N_d \text{ total}} \right)$

$= 1 \times \frac{3}{9} = \frac{1}{3}$ metre

so head available at A $= 5 - \frac{1}{3} = 4.67$ mets

so Pore Pressure $= \gamma_w \times h$

$= 4.67 \times 9.81$

$= 45.81$ kN/m²

26.19

6

Q.5 (c) A city has following recorded population :

1951	50000
1971	110000
1991	160000

Estimate: (i) the saturation population, and (ii) expected population in 2011.
(Use Logistic Curve Method)

[12 marks]

$$\therefore \text{Saturation Population} = \frac{2P_0P_1P_2 - P_1^2(P_0+P_2)}{P_0P_2 - P_1^2}$$

where $P_0 = 50000$

$P_1 = 110000$

$P_2 = 160000$

$$P_s = 10^4 \times \left[\frac{2\times5\times11\times16 - 11^2(5+16)}{5\times16 - 11^2}\right]$$

$$= 190487.8$$

$$\simeq 190488$$

now for population in 2011

$$P_t = \frac{P_s}{1 + M\ln^{-1} nt}$$

here $M = \frac{P_s - P_0}{P_0} = 2.809$

$$n = \frac{1}{t}\ln\left[\frac{P_0(P_s - P_1)}{P_1(P_s - P_0)}\right]$$

taking time in decades

$$n = \frac{1}{20}\ln\left[\frac{50000(190488 - 110000)}{110000(190488 - 50000)}\right]$$

$$= -1.345$$

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for Population in 2011

time = 6 decade

$$P_{2011} = \frac{190488}{1 + 2.809\, ln^{-1}(-1.3455 \times 6)}$$

$P_{2011} = 190321.25$

$P_{2011} = 190322$

181496

6+1 = 7

Q.5 (d) In an experiment on the removal of carbon dioxide from water sprayed into the air in spherical droplets 5 mm in diameter, the initial supersaturation of the water with CO_2 was 25.8 mg/*l*. After 1.2 seconds of exposure, this was reduced to 11.2 mg/*l*. Find the coefficient of gas transfer (in cm/hr). Assuming rate of gas absorption to be proportional to the degree of under saturation in the absorbing liquid. The following equation governs the rate of gas absorption

$$C_t - C_0 = (C_s - C_0)\left[1 - e^{(-K_g t)}\right]$$

C_s = saturation concentration of gas in water,
C_t = concentration at time t
C_0 = concentration at time t = 0
K_g = proportionality factor (time^{-1})

[12 marks]

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Q.5 (e) Explain various noise rating systems.

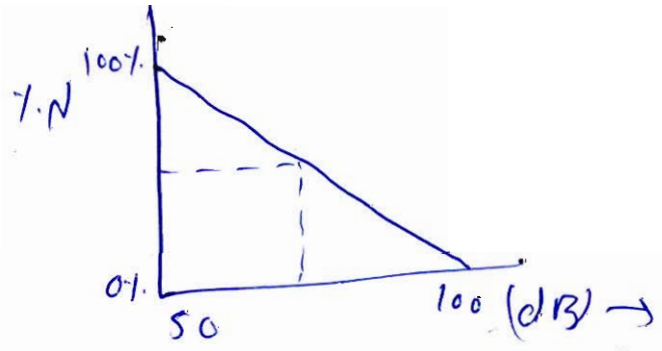
[12 marks]

Two types of rating systems are in use

(1) L_d Concept

(2) Leq. Concept

(1) L_d Concept :- L_d represents the % level of noise below L (dB) Frequency



by this Concept any Sound Pressure level in decibals and Corresponding % time less than that noise level can be found out

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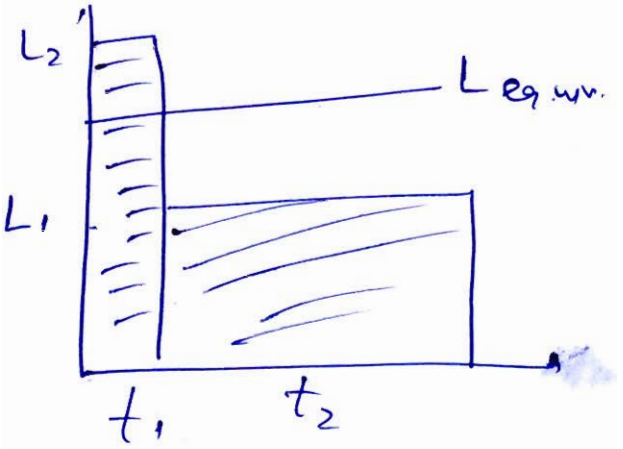
(ii) Equivalent Concept →

Equivalent represents the Energy level Produced will be same as sound level Taken for given time



$$\text{Equivalent} = 10 \log_{10}\left[10^{L_1/10} \times \frac{t_1}{\Sigma t} + 10^{L_2/10} \times \frac{t_2}{\Sigma t} + \cdots\right]$$

$$\text{Equivalent} = 10 \log_{10} \sum \frac{t_i}{\Sigma t} 10^{L_i/10}$$

Equivalent Produces the same energy in time t as Produced by source 1 and 2.

8

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Q.6 (a) (i) What are the methods for obtaining flow nets? Briefly explain any two of them.

(ii) In a falling head permeability test on a soil sample 12.2 cm high and 44.41 cm^2 in cross-sectional area, the water level in a stand pipe of 6.25 mm internal diameter dropped from a height of 75 cm to 24.7 cm in 15 minutes. Find the coefficient of permeability of soil.

[14 + 6 marks]

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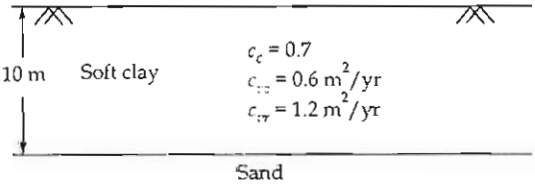
Q.6 (b) For the soil profile shown in the figure below compute:

(i) The time required for 90 percent consolidation of the soft clay without sandwicks.

[For $u < 60\%$, $T_v = \frac{\pi}{4}\left(\frac{u}{100}\right)^2$ and for $u \geq 60\%$, $T_v = 1.781 - 0.933\log_{10}(100 - u)$]

(ii) The time required for 90 percent consolidation with sandwicks. (Ignoring the effect of vertical consolidation) $\left[\text{Take, for } \frac{R}{r} = 10.6,\ T_{90} = 0.455,\ \text{where } R = \frac{1.06s}{2}\right]$

(iii) Also find the average degree of consolidation due to combined effect of vertical and radial flow for the time calculated in part (ii). Comment on the result.



Given that the spacing of sandwicks is 1 m on a triangular grid and the diameter of sandwicks is 100 mm.

[20 marks]

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Do not write in this margin

Q.6 (c) At a construction site, a 3 m thick clay layer is followed by a 4 m thick gravel layer which is resting on an impervious rock. A load of 25 kN/m^2 is applied suddenly at the surface. The saturated unit weight of the soils are 19 kN/m^3 and 20 kN/m^3 for the clay and gravel layers respectively. The water table is at the surface. Draw diagrams showing variation with depth of total, neutral and effective stress in the soil layers.

[20 marks]

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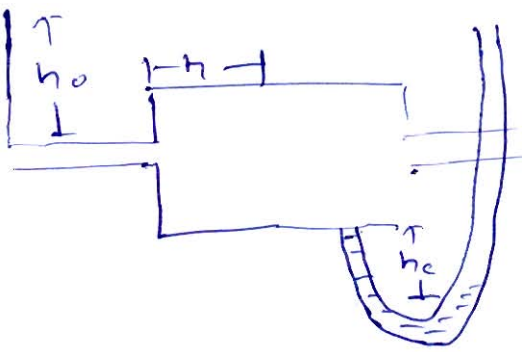
Q.7 (a) **(i)** In a capillary permeability test conducted in two stages under a head of 50 cm and 200 cm, in the first stage the wetted surface rose from 20 mm to 80 mm in 6 minutes. In the second stage it rose from 80 mm to 200 mm in 20 minutes. If the degree of saturation is 90% and porosity is 30%, determine the capillary head and the coefficient of permeability.

(ii) The representative liquid limit and plastic limit values of a saturated normally consolidated clay deposit are 50% and 20% respectively. The saturated unit weight of the soil is 19 kN/m^3. Estimate the undrained shear strength of the soil at a depth of 10 m from ground surface. Water table is at 5 m below the ground surface.

[10 + 10 marks]

Ans- (i)



In Capillary Permeability test

$$\frac{h_2^2 - h_1^2}{t_2 - t_1} = \frac{2k}{n s}(h_0 + h_c)$$

h_2 h_1 → position of wetted surface

k = Permeability

n = Porosity

S = deg of Saturation

h_c = head of capillary

h_0 = head applied

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in first steps

$h_0 = 50$ cm

$$\frac{8^2 - 2^2}{6} = \frac{2k}{0.3 \times 0.9}[50 + h_c]$$

$$k(50 + h_c) = 1.35 \quad -(1)$$

here $k =$ cm/min

$h_c =$ cm

$h_0 = 200$ cm

$$\frac{20^2 - 8^2}{20} = \frac{2k}{0.3 \times 0.9}[200 + h_c]$$

$$k(200 + h_c) = 2.268 \quad -(2)$$

By eq (1) and (2)

$h_c = 170.588$ cm $\quad k = 6.12 \times 10^{-3}$ cm/min

$k = 6.12 \times 10^{-3}$ cm/min

$k = 1.02 \times 10^{-6}$ m/sec

10

(ii) $PI = 50\% - 20\% = 30\%$

new $\frac{C}{\bar{\sigma}} = 0.11 + 0.0037\, I_p$

here $\bar{\sigma}$ = effective stress at 10m

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$\bar{\sigma} = 19 \times 10 - 9.81 \times 5$

$= 140.95 \text{ kN/m}^2$

5M

5M

$\frac{c}{\bar{\sigma}} = 0.11 + 0.0037(I_p\%)$

$I_p = 30\%$

$\frac{c}{\bar{\sigma}} = 0.221$

$c = 0.221 \times 140.95 = 31.15 \text{ kN/m}^2$

Cohesion or Undrained shear strength $\boxed{C = 31.15 \text{ kN/m}^2}$ (10)

Q.7 (b) (i) What are the criteria of design of gravity retaining wall?

(ii) An embankment is being built of a soil whose effective shear strength parameters are : $c' = 100 \text{ kN/m}^2$ and $\phi' = 20°$. Unit weight of soil is equal to 17 kN/m^3. The pore pressure parameters A and B as determined by the triaxial shear test are 0.6 and 0.8 respectively. The height of the embankment has just been raised from 5 m to 8 m. Determine the shear strength of the soil at the base of the embankment. It can be assumed that the dissipation of pore-pressure during this stage of construction is negligible and the lateral pressure at any point is half of vertical pressure.

[6 + 14 marks]

(i) designing of gravity dam

→ gravity dam as designed by taking the consideration that only weight of the dam will be able to take the applicable loads and moments

– all the forces are Balanced by Self weight of dam

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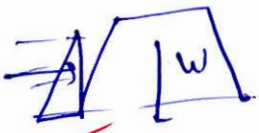


here FOS against overturn = $\frac{M_{resisting}}{M_{overturning}}$ (about Toe) > 1

for against sliding = $\frac{\mu \Sigma V}{\Sigma H}$

tension failure criteria

3

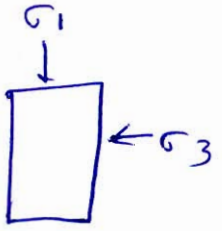
(ii) $c' = 100$ $\phi' = 20$

$A = 0.6$ $B = 0.8$

$B = \frac{\Delta u}{\Delta \sigma_3}$ $\bar{A} = \frac{\Delta u}{(\Delta \sigma_1 - \Delta \sigma_3)}$

here $\Delta \sigma_1 = (8-5) \times 17$

$= 51 \text{ kN/m}^2$



σ_3 at any Point $= \frac{1}{2}\sigma_v$

$\Delta \sigma_3 = \frac{1}{2} \times 51 = 25.5 \text{ kN/m}^2$

new $\Delta u_{total} = \Delta u_1 + \Delta u_2$

$= B \Delta \sigma_3 + AB(\Delta \sigma_1 - \Delta \sigma_3)$

$\because \bar{A} = AB$

$= 0.8 \times 25.5 + 0.6 \times 0.8 [51 - 25.5]$

$\Delta u_{total} = 32.64 \text{ kN/m}^2$

at $u_i = 0$

$u_f = 32.64 \text{ kN/m}^2$

shear strength of soil

$\tau = c' + \bar{\sigma} \tan \phi'$

at the base

$\sigma = 8 \times 17 = 136 \text{ kN/m}^2$

$u = 32.64 \text{ kN/m}^2$

$\tau = 100 + (136 - 32.64) \tan 20°$

$\tau = 137.62 \text{ kN/m}^2$

14

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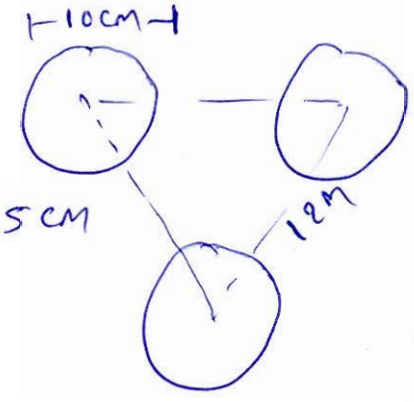
Q.7 (c) (i) Three wells, each having a diameter of 10 cm are installed at the vertices of an equilateral triangle 12 m apart in a confined aquifer. The radius of influence of each well is 400 m and coefficient of permeability K is 20 m/day. The drawdown in each well is 2 m. The thickness of the confined aquifer is 15 m. Find the discharge of each well and the percentage decrease in discharge because of well interference.

(ii) Explain socket and spigot joint in cast iron pipe with figure.

[12 + 8 marks]

Sol:-



$B = 12\,M$

$R = 400\,m$

$k = 20\,m/day$

depth of aquifer $= 15\,m$

after interference discharge in each well $\Rightarrow$

$$Q' = \frac{2\pi k D (h_2 - h_1)}{\ln\left(\frac{R^3}{r_w B^2}\right)}$$

when 3 wells are there

$$Q' = \frac{2\pi \times 20 \times 15 (2)}{\ln\left(\frac{400^3}{0.05 \times 12^2}\right)}$$

$$Q' = 235.615\ m^3/day$$

~~total discharge from~~

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discharge from one well before interference $= \frac{2\pi k D (h_1 - h_2)}{\ln \frac{R}{r_w}}$

$= \frac{2\pi \times 20 \times 15 \times 2}{\ln \frac{400}{0.05}}$

$Q = 419.475 \ m^3/day$

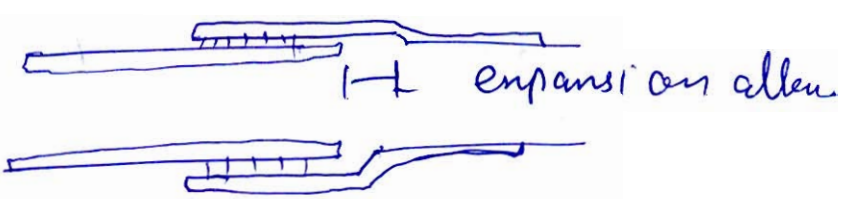
% decrease in discharge due to interference $= \frac{419.475 - 235.65}{419.475} \%$

$= 43.83\%$

12

(ii) Joints :—

Spigot Joint :—



in this type of Joint

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Expansion is also allowed. This is Commonly used Joint in Cast Iron pipe

→ for stopping leakage of water through Joint washer Made of rubber is also provided

Explain Mox

(4)

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Q.8 (a) Design a rapid sand gravity filter unit for 4 MLD of supply. 4% of filtered water is required for washing of filter and 30 minutes is lost every time in washing filter. Rate of filtration is 5000 $l/hr/m^2$. Also design the under drainage system.

[20 marks]

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Do not write in this margin

Do not write in this margin

Q.8 (b) The relationship between the available chlorine in the form of dichloramine to available chlorine in the form of monochloramine is given as

$$A = \frac{BM}{1-\left[1-BM(2-M)\right]^{1/2}} - 1$$

where A = ratio of available chlorine in dichloramine to mono chloramine.

M = molar ratio of chlorine (Cl_2) added to ammonia nitrogen present

$B = 1 - 4\, k_{eq}\, [H^+]$

where $k_{eq} = 6.7 \times 10^5$ L/mol at 25°C

A treated water has pH of 7.4 at temperature 25°C and free chlorine residual of 1.2 mg/l. Chloramine is planned to be used in the distribution system. How much ammonia is required to keep the ratio of dichloramine to monochloramine of 0.15. Assume all residual are not dissipated yet.

[20 marks]

Q.8 (c) (i) An electrostatic precipitator is to be constructed to remove fly-ash particles from stack gases flowing at 10 m^3/s. Analysis showed that the draft velocity can be taken as,

$$v = 3.0 \times 10^5 d_p \text{ m/s}$$

where d_p is the particle size in m.

Determine the plate area required to collect 0.5 μm particle with

1. 90 percent efficiency
2. 99 percent efficiency

(ii) Discuss the Autoclaving and Hydroclaving method involved for the treatment of bio-medical wastes.

[14 + 6 marks]

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○○○○

Space for Rough Work

Space for Rough Work

$$113.4 + 2.268h = 270 + 1.35h$$

$$\frac{50+h}{200+h} = \frac{1.35}{2.268}$$

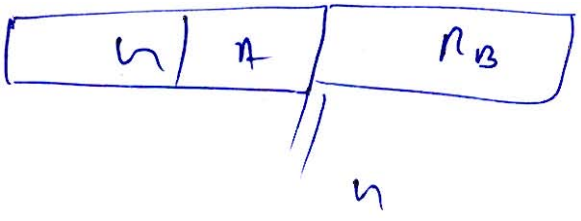
$$(50+h)\,2.268 = 1.35(200+h$$

$$h = 170.588$$

$$1.809$$

$$\frac{R^2}{r_n B}$$

$$G_A = R_A$$



1
0.5
0.4

0.75
0.6
0.45

$$\boxed{\theta = 1.68\,\frac{Pa}{E_s}}$$

a = radius of Rb

$$\cancel{\frac{2d^2 f_b}{1.5 l_d}}$$

$$\frac{2 l_d d^2 f_b}{(l_d + 1.5\delta)}$$

$$\frac{d^3 f_b}{12 l^2 (l_d + 1.5\delta)}$$