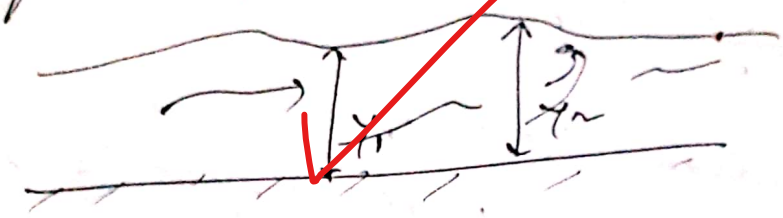
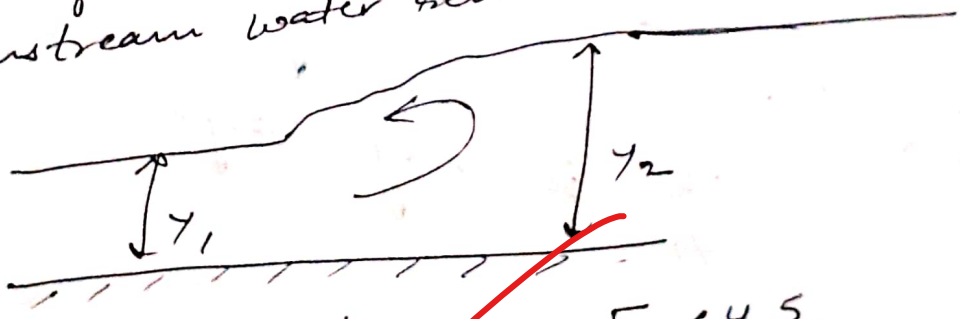
8-1

(a) Hydraulic jumps are classified into following categories on the basis of Froude Number and energy of dissipation.

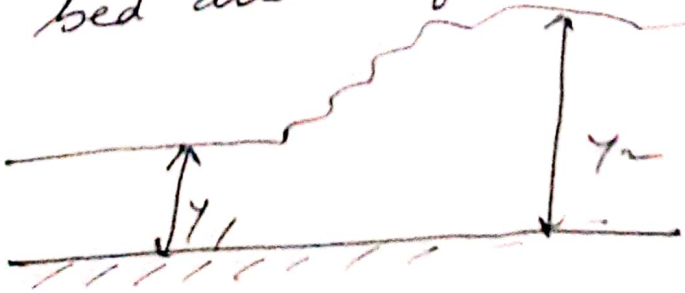
(i) Undular Jump $1 < F < 1.7$,
Energy dissipation $< 5\%$.
Sequent depth ratio $\frac{y_2}{y_1} \approx 1$



(ii) Weak Jump $1.7 < F < 2.5$
Energy dissipation (5-20%)
Series of small rollers forms on the jump surface, downstream water remains smooth.



(iii) Oscillating jump $2.5 < F < 4.5$,
Energy dissipation (20-45)%
Entering water oscillates in a random manner between bed and surface.



(iv) Steady jump $4.5 < F < 9$

Energy dissipation (45-70)%.

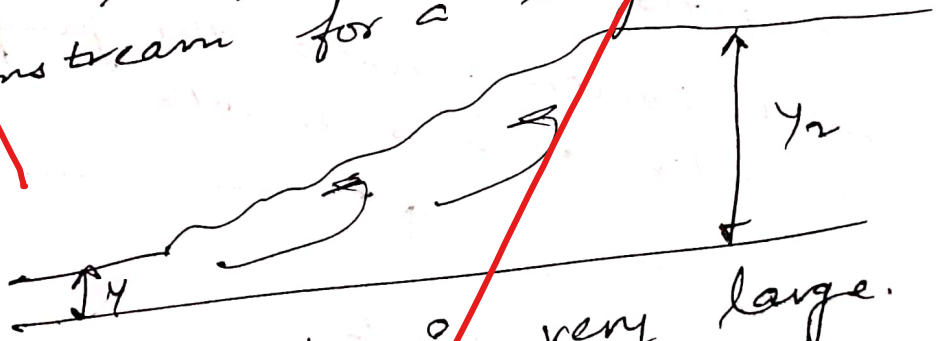
Well established jump, downstream surface is smooth.

(v) Strong (Choppy) Jump

$F > 9$

Energy dissipation > 70%.

Due to this jump, water surface is very high, rough and choppy, continues downstream for a long distance.



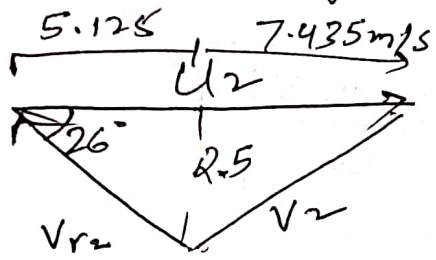
$\frac{y_2}{y_1}$ is very large.

Q-1
(b)

Outer dia = 1.2m (D_o)
Inner dia = 0.6m (D_i)
Manometric head = 6m

Now, $u_2 = \frac{\pi \times 1.2 \times 200}{60} = 12.56$ m/sec

Radial velocity of flow = 2.5 m/sec



Outlet velocity triangle

thus, $V_{w_2} = 7.435$ m/sec.

Hence, manometric efficiency

$\eta_m = \frac{gH_m}{V_{w_2} u_2} = \frac{9.81 \times 6}{7.435 \times 12.56} \times 100 = 63.03^0$ Ans.

Minimum speed to start pumping

$\left(\frac{\pi N}{60}\right)^2 [D_o^2 - D_i^2] \geq 2gH_m$

$\left(\frac{\pi N}{60}\right)^2 [1.2^2 - 0.6^2] \geq 2 \times 9.81 \times 6$

$N \geq 199.39$ rpm Ans.

thus, N=

Q-1

(c) Reservoir Capacity = 500 ha-m

Area of Catchment = 125 km²

Annual sediment production = 0.03 ha-m/km²

Thus total annual sediment production

= 0.03 × 125 = 3.75 ha-m

$\eta\% = \frac{\text{Total sediment deposited}}{\text{Total inflow of sediment}}$

Thus inflow = $0.12 \times 125 \times 10^6$ m³

= 1500 ha-m

$\therefore C/I = \frac{500}{1500} = \frac{1}{3} = 0.33$

from table,

$\eta\% = 95 + \frac{1}{0.2} \times 0.03 = 95.15\%$

Total sediment deposited annually

= 0.9515 × 3.75 = 3.568 ha-m

To reduce the capacity by 10% of 500 ha-m.

i.e. 50 ha-m.

no. of years required = $\frac{50}{3.568}$ = 14 years

Probable life = 14 years Ans

Q-1

(d) Per capita supply = 200 lpcd.

Year	Population	Increase	Incremental Increase
1940	23798624		
		23179701	
1950	46978325		−15371589
		7808112	
1960	54786437		873274
		8681386	
1970	63467823		−3071788
		5609598	
1980	69077421		

$\bar{Y} = -5856701$

$\bar{X} = 11319699.25$

≈ 11319700

Thus, $P_{2000} = P_{1980} + n\bar{X} + \frac{n(n+1)}{2}\bar{Y}$

$n = 2$

$\therefore P_{2000} = 69077421 + 2 \times 11319700 + \frac{2 \times 3}{2} \times (-5856701)$

$P_{2000} = 74146718$

Thus domestic water requirement

$= 74146718 \times 200 = 14829343$ MLD Ans.

$= 1.4829 \times 10^{10}$ l/day

Q-1

(c) Different forms in which chlorine is added

1) As free chlorine - Chlorine gas as such is added to the water, which forms HOCl which is most destructive agent for bacteria.

But HOCl is formed when pH is slightly below 7, thus pH < 7 for effective formation of HOCl.

(2) Chloramines - This is the mixture of chlorine and ammonia, Ammonia being added first and then chlorine, so as to avoid formation of any cancer causing agent.

- It is less effective than chlorine (25 times less), but provides good safety against future recontamination.

(3) Chlorine dioxide (ClO_2) → 2.5 times stronger than free chlorine.

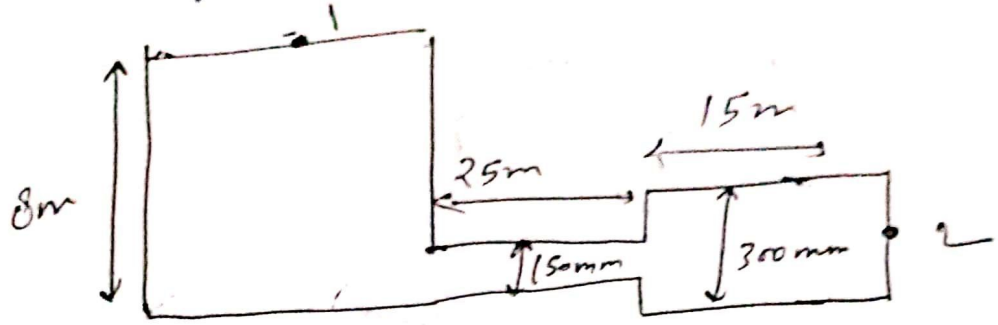
$2NaClO_2 + Cl_2 \rightarrow 2NaCl + 2ClO_2$

Highly unstable, hence, should be used immediately.

It doesn't form HOCl / Chloramines. Used as primary disinfectant.

Q-2

(a) Length of pipe = 40 m



Coefficient of friction $f = 0.01$

Friction factor $= 4f = 0.04$

Head causing flow = 8m

Applying energy equation between 1 and 2

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_L$$

$P_1, V_1, P_2 = 0, Z_2 = 0$

$$8 = \frac{Q^2}{2g A_2^2} + 0 + h_L$$

$\therefore$ 8 = loss of entry + friction loss + sudden enlargement

$$+ \frac{V_2^2}{2g}$$

$$A_1 = \frac{\pi}{4} \times 0.15^2 = 0.0176 m^2$$

$$A_2 = 0.0706 m^2$$

$$\therefore 8 = \frac{0.5 \times Q^2}{2g \times 0.017^2} + \frac{0.04 \times 25 \times Q^2}{12.1 \times 0.15^5} + \frac{0.04 \times 15 Q^2}{12.1 \times 0.3^5}$$

$$+ \frac{Q^2}{2g \times 0.0706^2} + \frac{(V_1 - V_2)^2}{2g}$$

$$\frac{(V_1 - V_2)^2}{2g} = \frac{Q^2}{2g}\left(\frac{1}{A_1} - \frac{1}{A_2}\right)^2$$

On solving the above equation,

$\therefore$ $Q = 0.0786\ m^3/sec$

Rate of flow = 78.6 litres per sec.

Q-2

6 (ii) Area = $50\ km^2$

Population = 200 heads/ha

Thus, total population = 200×5000

$= 10^6$

Avg rate of sewage flow = 300 lpcd.

Thus peak rate of sewage flow

$$= 1.5 \times \frac{300 \times 10^6 \times 10^{-3}}{86400} = 5.208\ m^3/sec$$

Rainfall runoff = 15mm/24 hr.

$= 0.015 \times 50 \times 10^6 / 86400 = 8.68\ m^3/sec.$

Thus total flow = $5.208 + 8.68$

$= \boxed{13.88\ m^3/sec}$

~~Let diameter of~~ ;

Thus capacity of sewer should be $\boxed{13.88\ m^3/sec}$

Minimum velocity as per Shield's formula,

$$V = \sqrt{\frac{8g}{f}}\sqrt{Kd(G-1)}$$

$$V = \sqrt{\frac{8 \times 9.81}{0.012}}\sqrt{0.04 \times 10^{-3} \times (2.65 - 1)} = \boxed{0.66\ m/sec}$$

Minimum velocity of flow required

= 0.66 m/sec

Q-2

C

(i)

Tipping bucket raingauge - It is one of a kind of recording raingauge. the rainwater is first collected on a collector and then passed to ~~collector~~ funnel. → The funnel discharges the water in two compartment bucket, when one bucket fills up another one comes beneath the funnel.

— Used in hilly / inaccessible areas

— Intensity of rainfall is measured.

Weighing bucket type - Weight of rain in the bucket is recorded. the increasing weight helps in recording increased quantity of collected rain with time.

— Provides mass curve of rainfall

Natural-syphon type - Rainfall is collected by funnel shaped collector and lead into float chamber due to this float which rise and fall attached to the float records the elevation of float on a rotating drum.

— Gives mass curve of rainfall.

(ii) Causes of inconsistency of rainfall

(a) Shifting of raingauge station to new station
(b) Change in ecosystem due to calamities
(c) Occurence of observational error
(d) Neighbourhood of the station undergoing major change.

In double mass curve technique
- A group of stations is selected.
- Average of rainfall is recorded of stations and put in reverse chronology
- Calculated accumulated precipitation and accumulated values of group of stations.
- Graph is plotted between ΣP_x and ΣP_{av}.
- Break in slope indicates inconsistency.

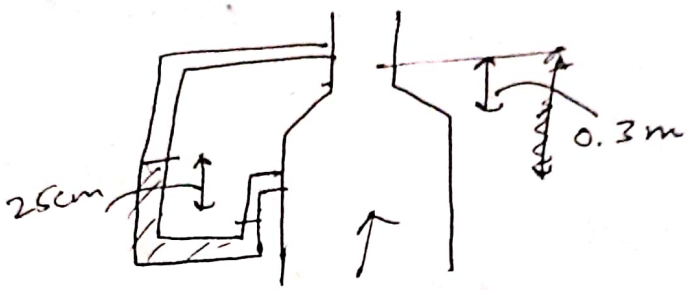
Correct reading after change in slope

$= M_{cr} \times \frac{\text{Previous slope}}{\text{New slope.}}$

Q-3

(a) Given, 30cm×15cm venturimeter.

SG of oil = 0.9



Now, $a_1 = \frac{\pi}{4} \times 0.3^2 = 0.0706 m^2$

$a_2 = \frac{\pi}{4} \times 0.15^2 = 0.0176 m^2$

$C_d = 0.98$ (given)

Piezometric head difference $= h = \left(\frac{13.6}{0.9} - 1\right) \times 0.25$

Thus, discharge through venturimeter

$$Q = \frac{0.98 \times 0.0706 \times 0.0176 \sqrt{2 \times 9.81 \times \left(\frac{13.6}{0.9} - 1\right) \times 0.25}}{\sqrt{0.0706^2 - 0.0176^2}}$$

$Q = 0.148 m^3/sec$

Discharge of oil $= 0.148 m^3/sec.$ Ans

Now, ~~applying~~ energy

Piezometric head difference $= \left(\frac{13.6}{0.9} - 1\right) \times 0.25$

$$\frac{P_A}{0.9 \times 9.81} - \frac{P_B}{0.9 \times 9.81} - 0.3 = 3.527$$

$$(P_A - P_B) = (3.527 + 0.3) \times 0.9 \times 9.81$$

20

Pressure difference = 33.78 kPa Ans.

Q-3

b (ii) Given, Field capacity Fc = 44%.

Wilting point, Ø = 22%.

Effective root zone depth = 0.30m

Avg moisture content = 35%.

Avg daily ET = 5mm/day.

Maximum available water

$$= \frac{(44-22)}{100} \times 0.3 = 0.066\ m$$

$$= 6.6\ cm$$

75% depletion is allowed, in moisture,

Q-3

(c) Given, population = 30000

Dairy waste = 3MLD

BOD = 1100 mg/l

Sugar mill

2.4MLD

BOD = 1500 mg/l

Domestic sewage

= 240 lpcd = 240×30000 = 7.2MLD

BOD = 72gm/day.

OEF = 10%

Minimum dry weather flow = 4500 lps

= $4.5 m^3/sec$.

DO (saturated) = 9 mg/l

DO (minimum) = 4 mg/l.

$K_D = 0.1 day^{-1}$, $K_R = 0.3 day^{-1}$

Domestic BOD = $72 gm/day = \frac{72000}{7.2 \times 10^6} \times 30000$

= 300 mg/l

thus, equivalent BOD

$= \frac{300 \times 7.2 + 1500 \times 2.4 + 1100 \times 3}{(7.2 + 2.4 + 3)}$ = 719.04 mg/l

adopting total OEF = 10%.

thus, total discharge of sewage

$= 1.1 [7.2 + 3 + 2.4]$ = 13.86MLD

= $0.16 m^3/sec$

Now, critical DO deficit = 9.4
= 5 mg/l

f = self purification constant = $\frac{K_1}{K_2}$ = 3

thus, DO of mixture (initially)

= $\frac{0.16 \times 0 + 4.5 \times 9}{4.5 + 0.16}$ = 8.69 mg/l [assuming DO in sewage = 0]

Initial deficit = 9 - 8.69 = 0.31 mg/l = D_o

thus,

$$\left[\frac{L_o}{D_o f}\right]^{f-1} = f\left[1 - (f-1)\frac{D_o}{L_o}\right]$$

$$\left[\frac{L_o}{5 \times 3}\right]^{2} = 3\left[1 - \frac{2 \times 0.31}{L_o}\right]$$

$$L_o = 25.67 \text{ mg/l}$$

where L_o is the initial ultimate BOD of the mixture.

$$BOD_{5,\,mix} = 25.67\,(1 - 10^{-0.1 \times 5})$$

$$= 17.455 \text{ mg/l}$$

Assuming initial BOD of river be 0.

$$17.455 = \frac{BOD_{mix} \times 0.16 + 0}{4.5 + 0.16}$$

$$BOD_{mix} = 508.376 \text{ mg/l}$$

Thus, degree of treatment required

$$= \frac{719.04 - 508.376}{719.04} = 29.29\%$$

Q-5 (a) Since, interior angles are not affected by bearings hence, no correction in bearings is required

$\angle P$ = FB of PQ − BB of TP

$\angle P = 142.5 - 239 + 360° = \boxed{263.5°}$

$\angle Q$ = FB of QR − BB of PQ (±360° if required)

$= 223.25 - 322.5 + 360°$

$= 260.75°$

$\angle R$ = FB of RS − BB of QR

$= 287 - 44.25 = 242.75°$

$\angle S$ = FB of ST − BB of RS

$= 12.75 - 193.25 + 360°$

$= 179.5°$

$12.75° - 107.75 + 360°$

$= \boxed{265°}$

$\angle T$ = FB of TP − BB of ST

$= 60 - 193.25 + 360°$

$= 226.75°$

Sum of angles $= (2n+4) \times 90°$

$= (2 \times 5 + 4) \times 90°$

$= 1260°$

But sum of angles = 1258.75°

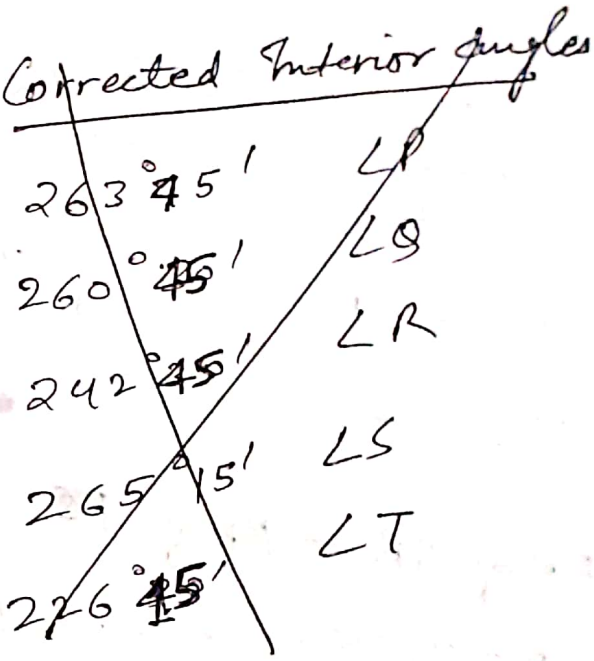
$= 1258°45'$

Correction required = +1°15'

Correction in each angle = +15'

Line	FB	BB
PQ	142.5°	322°30′
QR	223.25°	44°15′
RS	287°	107°45′
ST	12°45′	193°15′
TP	60°	239°

Corrected Interior angles



~~∠P+∠Q+∠R+∠S+∠T~~ =

Corrected angles

∠P = 263°45′

∠Q = 261°

∠R = 243°

∠S = 265°15′

∠T = 227°

∠P+∠Q +∠R+∠S+∠T

= 1260° hence O.K.

Q 5

(b) As recommended by ISSCS,

for coarse grained soil, visual examination is required

for fine-grained soil,

(i) Dilatancy test - A small saturated sample is taken into hands and shaken; the appearance and disappearance of water while shaking is a test of presence of silt, if water appears and disappears slowly, soil is clayey.

(ii) Toughness - If the soil is clayey, threads of 3mm dia can be formed by rolling on the palm, while silt being extremely friable, thread can't be formed.

(iii) Organic content and colour - If the soil colour is dark, it indicates organic matter presence in soil.

for detailed test, the soil could be heated.

(iv) If the cutting of a soil cake produces a shiny appearance, it's clayey else silty.

Other identification tests

i) Acid test - Using dilute HCl, for presence of cementation due to Calcium Carbonate in high strength sample

ii) Rubbing the ball of soil between fingers. If it feels smooth, soil is clayey, and if it feels harsh, silty.

Q-5
C

Various studies conducted in highway planning phase are:-

(i) Traffic study - The amount of traffic generated along the pre-planned highway is determined using trip modelling

(ii) Reconnaissance Survey -
The surveying of the area, without any equipments, general topography of the area, drainage system, slope etc. along the path

(iii) Preliminary study - This study is carried out using equipments, marking of the center line and exact measurements of the plan are taken

(iv) Detailed study - It requires detailed investigation of each feature that is required to be designed in a highway.

Q-5

(d) Requirements of ventilation in tunnels

(1) For the oxygen requirement to the workers in the shaft

(2) For removing the fumes created during the blasting of rocks.

(3) For removing dust due to excavation of tunnels

(4) To remove any explosive gas that might emanate during various operations.

(5) For exhaust gases emitted by diesel operations

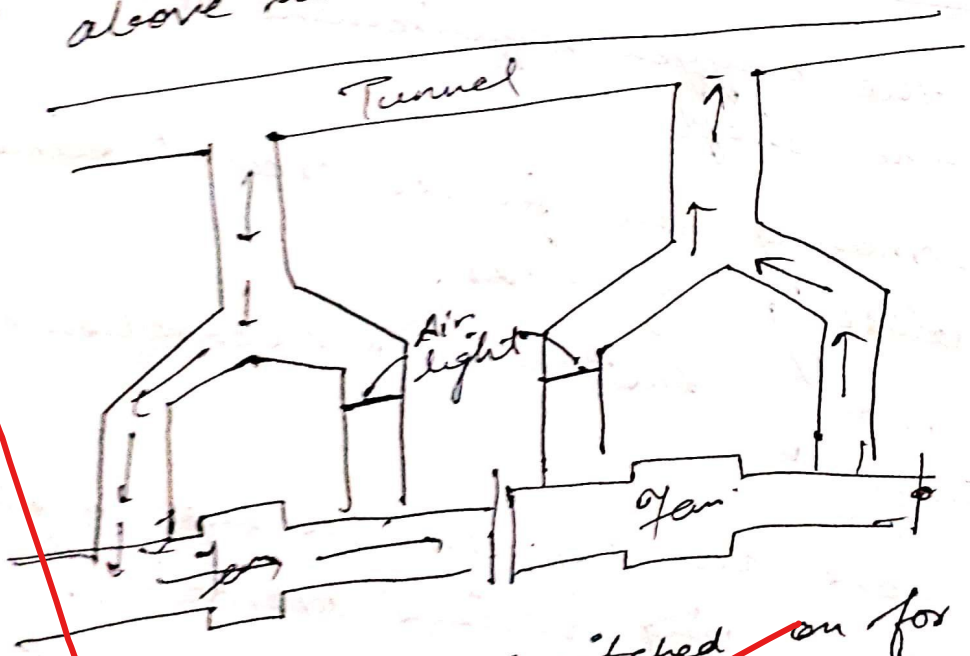
Methods of ventilation in tunnels

Mechanical

1) **Blowing** – By blowing the air inside the tunnel using blowers. Fresh air is forced in using fans, disadvantage is that fumes and gases need to travel a very large distance before leaving.

2) **Exhaust** – These force out the poisonous gases and dusts from inside using exhaust fans.

3) **Blowing and Exhaust** – It is a combination of above two.



Exhaust system is switched on for 15–30 min and then blowers are operated for fresh air

Natural ventilation

is by drilling shaft (vertical)

Q-5

(e) Dry soil with 10% water.

$G = 2.68$

Specimen volume $= \frac{\pi}{4} \times 0.15^2 \times 0.125$

$= 0.0022\ m^3$

$a_c = 6\% \Rightarrow S = 94\%$ = Degree of saturation.

Let weight of dry soil be W_s.

weight of water added = 10% of W_s

$= 0.1 W_s$

Total weight $= 1.1 W_s$.

Now, $\gamma_{bulk} = \left(\frac{G+Se}{1+wG/S}\right)\gamma_w$.

$\therefore \frac{1.1 W_s}{2.208.93} = \frac{2.68(1+0.1)}{1+\frac{2.68\times0.1}{0.94}}$

Weight of solids (dry soil) = 4606.56 g

$= \boxed{4.606 \text{ kg}}$

mass of wet mixture $= 1.1 \times 4.606$

$= \boxed{5.066 \text{ kg}}$ Ans

Now, $S.e = w.G$

Void ratio, $e = \frac{0.1\times2.68}{0.94} = \boxed{0.285}$ Ans.

Dry density $= \frac{2.68\times1}{1+0.285} = \boxed{2.085 \text{ g/cc}}$ Ans

Q-8

a (i) The separation or cutting of rail due to friction and abnormal heavy load is called wear.

Various types of wear of rails

Wear on top or head

1) The metal from top of rail flows and forms projections which are called burns. Causes are:

- Corrosion of metal of rails
- Impact of heavy loads
- Heavy load concentrated on very small area.

2) Wear at end of rails

Battering of rails - At the expansion joint, the wheels of the train have to take a jump, imparting blow at the ends rendering the rails battered.

3) Wear at side of head

Most destructive type of wear, occurs on rail laid on curves.

Causes are: due to centrifugal force along the curvature, grinding action is caused.

Remedies to reduce wear

1) Use of special alloy steel (especially high Manganese)
2) Good maintenance of track, loosening of bolts should be prevented
3) Reduction of expansion gap, but not beyond certain limit
4) Use of lubricating oil

Q-8

a (ii) To overcome temperature stress, breathing length is required.

Stress in each rail due to temp increase

$= E \times \delta T = 21.5 \times 10^5 \times 1.15 \times 10^{-5} \times 30$

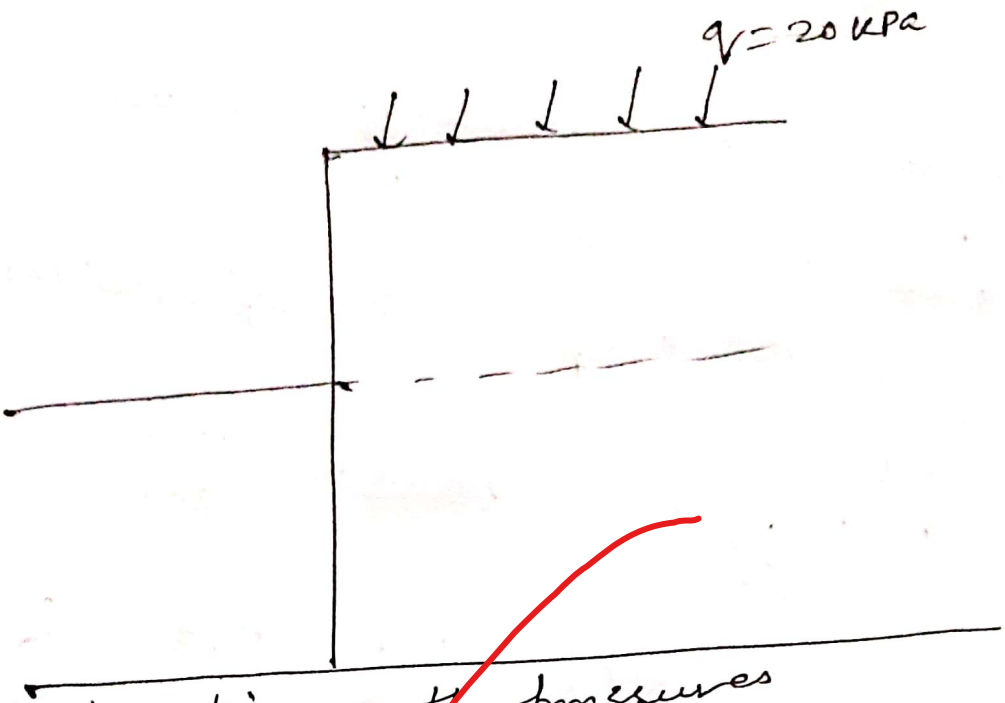
$= 741.75 \text{ kg/cm}^2$

Force developed in each rail

$= 741.75 \times 60 = 44505 \text{ kg}$

Rail length required $= \frac{44505}{700} = \boxed{63.57 \text{ km}}$

Q-8
(b)

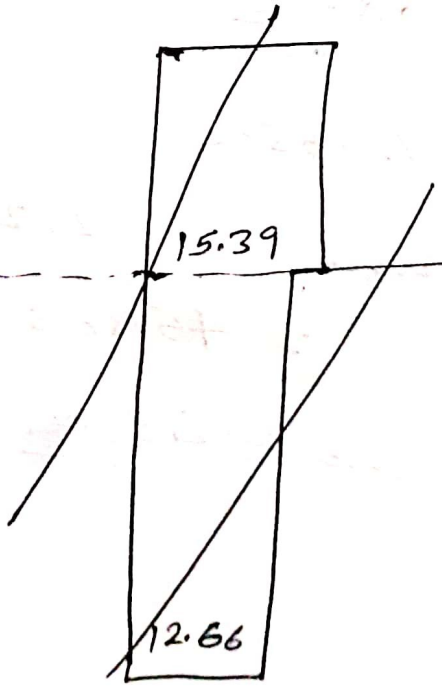


Coefficient of active earth pressures

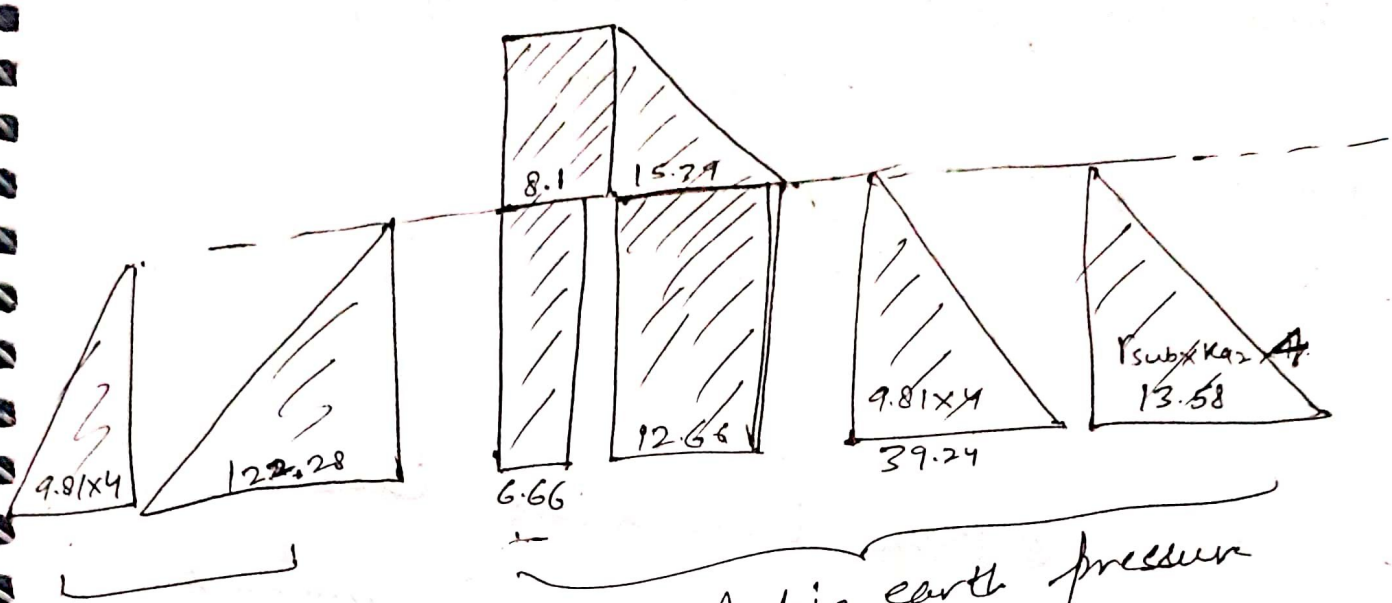
$$K_{a_1} = \frac{1-\sin 25^\circ}{1+\sin 25^\circ} = 0.405$$

$$K_{a_2} = \frac{1-\sin 30}{1+\sin 30} = 1/3$$

Coeff. of passive earth pressure $= \frac{1}{K_{a_2}} = 3$



Pressure diagrams



Total active earth pressure

$= 8.1\times2+6.66\times4+0.5\times15.39\times2+12.66\times4+39.24\times0.5\times4 + 0.5\times13.58\times4$

$= 16.2+26.64+15.39+50.64+78.48+27.16$

$= 214.51$ kN/m length of wall.

Location from bottom $= \dfrac{16.2\times5+26.64\times2+15.39\times4.66+50.64\times2+78.48\times\frac{4}{3}+27.16\times\frac{4}{3}}{214.51}$

$= 2.089$ m from bottom

Total passive earth pressure

$= \frac{1}{2}\times122.28\times4+\frac{1}{2}\times9.81\times4\times4 = \boxed{323.04\text{ kN}}$

Location $= \dfrac{244.56\times4/3+78.48\times4/3}{323.04} = \boxed{1.33\text{ m}}$ from bottom

Resultant force = 323.04 − 214.51

= 108.53 kN

Location of resultant force

$$\bar{Y} = \frac{323.04 \times 1.33 - 214.51 \times 2.089}{108.53}$$

= −0.17 m

i.e., 0.17 m beneath the base.

Ratio of passive moment to active moment

Passive moment = 323.04 × 1.33 = 429.64 kNm/m

Active moment = 214.51 × 2.089 = 448.11 kNm/m

Ratio = $\frac{429.64}{448.11}$ = **0.958** Ans.

Q-8

(c) Given 15-min traffic counts.

Road 1
178 veh/15min
A = 3s

Road 2
142 veh/15min
A = 2s

Average time headway = 2.5sec.

Let Cycle time be C.

In a cycle time of C, no. of vehicles approaching

Road 1 = $\frac{178}{15\times60} \times C$ Road 2 $\frac{142C}{900}$

Green time for road 1 $\frac{178C}{900} \times 2.5 = G_A$

for road 2 = $\frac{142C}{900} \times 2.5$ G_B

Thus, $C = \frac{178C}{900} \times 2.5 + 3 + \frac{142C}{900} \times 2.5 + 2$

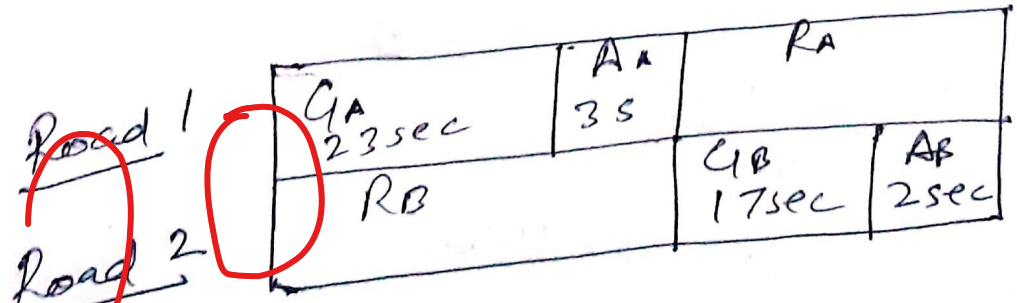
Let's take cycle time = 45seconds

Thus, $G_A = \frac{178 \times 2.5 \times 45}{900} = 22.25sec$

$G_B = 17.75sec$

Total cycle time = 22.25 + 17.75 + 3 + 2
= 45 secs as assumed.

Hence cycle time = 45sec



$q_r = 20$ KPa