1. In a site investigation to determine the depth of ground water table, the water in a borehole was bailed to a depth of **8 m** below the ground level and the recorded rise in the water level in the borehole are as follows: $\mathbf{h_1 = 50\ cm}$ in the first 24 hrs, $\mathbf{h_2 = 30\ cm}$ in the second 24 hrs, $\mathbf{h_3 = 20\ cm}$ in the third 24 hrs. Using Hvorslev's method, compute the depth of the ground water table at that site the measured data.

2. In a thermal power plant, an existing vertical rigid retaining wall of height **5 m** needs to be redesigned for laying out a monorail track with rail load of 50 kN/m. If the retaining wall was supporting a dry cohesionless backfill with friction angle = $\mathbf{35^0}$, wall friction angle = $\mathbf{23^0}$. Compute graphically the minimum distance from the crest of the wall face at which the rail track can be placed so that no excess active earth pressure acts on that existing retaining wall. Use Culmann's graphical construction.

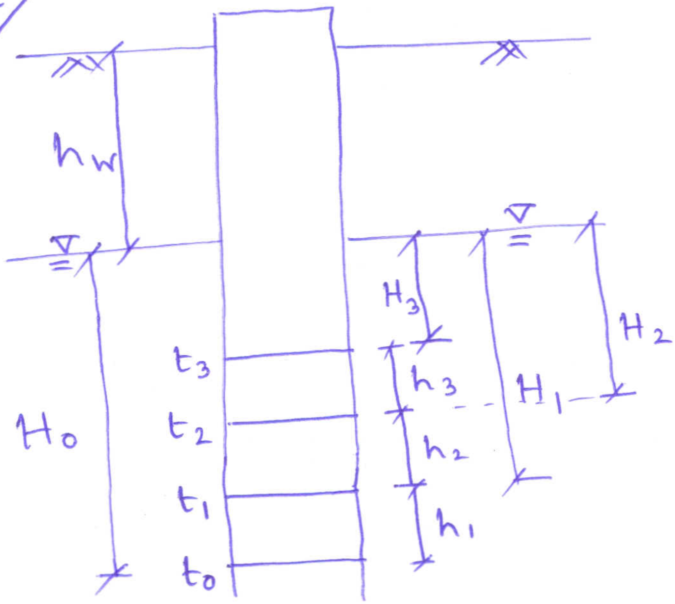
3. A shallow strip footing needs to be designed at **1 m** depth below the ground level in a purely dry cohesive soil with unit cohesion of **60 kPa** and unit weight of $\mathbf{18\ kN/m^3}$. Calculate ultimate bearing capacity, net ultimate bearing capacity, allowable bearing capacity using both Terzaghi's theory and Indian design code recommendation. Adopt factor of safety as **3.0**. If the proposed plan dimension of the footing can carry. Also calculate the critical depth of vertical cut without any lateral support using Rankine's theory and Terzaghi's theory under active state of earth pressure.

4. Starting from the first principle by using Rankine's earth pressure theory and two wedges failure mechanism with Rankein's active and passive zones, derive the expression for different bearing capacity factor for a shallow strip footing in a generalized c-ϕ soil.

5. Terzaghi's theory was used to design a shallow strip footing which was placed at **1.5 m** below the ground level with width of footing as **2 m**. Water table was found at **1.5 m** below the ground level and the unit weight soil above water table was measured as $\mathbf{16\ kN/m^3}$ and the saturated unit weight of the same soil below water table was ontained as $\mathbf{19\ kN/m^3}$. Shear properties of soil were $\mathbf{c = 5\ kPa}$ and $\mathbf{\phi = 37^0}$. Calculate the net ultimate load which the footing can carry per unit length of the footing.

******** END ********

1)



$h_1 = 50 \text{ cm} = 0.5 \text{ m}$

$h_2 = 30 \text{ cm} = 0.3 \text{ m}$

$h_3 = 20 \text{ cm} = 0.2 \text{ m}$

Using Hvorslev's method,

$$H_0 = \frac{h_1^2}{h_1 - h_2} = \frac{0.5^2}{0.5 - 0.3} = 1.25 \text{ m}$$

$$H_2 = \frac{h_2^2}{h_1 - h_2} = \frac{0.3^2}{0.5 - 0.3} = 0.45 \text{ m}$$

$$H_3 = \frac{h_3^2}{h_2 - h_3} = \frac{0.2^2}{0.3 - 0.2} = 0.4 \text{ m}$$

$\therefore$ $h_{w_1} = 8 - H_0 = (8 - 1.25) \text{ m} = 6.75 \text{ m}$.

$h_{w_2} = 8 - (h_1 + h_2) - H_2 = (8 - 0.5 - 0.3 - 0.45) \text{ m}$

$= 6.75 \text{ m}$.

$h_{w_3} = 8 - (h_1 + h_2 + h_3) - H_3 = 6.6 \text{ m}$.

$\therefore$ Depth of G.W.T. $h_w = \dfrac{h_{w_1} + h_{w_2} + h_{w_3}}{3} = 6.7 \text{ m}$. Ans

Ques 2:

Given:

Height of Retaining wall = 5m

Rail load = 50 KN/m

Backfill properties:

Unit weight = 18 KN/m³

(ϕ) Soil friction angle = 35°

(ψ) wall friction angle = 23°.

So angle between active earth pressure and vertical = $90° - \psi$

$= 90° - 23$

$= 67°$

Steps: for Culman graphical approach:

1.) Make vertical line of 10 cm for vertical retaining wall of 5m for scale of 1m = 2cm

2.) Then draw a line bf from toe of wall at angle of 'ϕ' from horizontal.

3.) Then draw a line bg ~~and~~ at angle of 67° from line bf

4.) Divide the line segment af into for parts that is ac_1, c_1c_2, c_2c_3, c_3c_4

5.) Mark a point d_1 on line bf equivalent to the weight of ac_1 and then draw parallel line to line bg passing from d_1 and intersecting line bc_1 at point e_1

6.) do similarly for wedge abc_2, abc_3 and abc_4 and we get e_2, e_3 and e_4 corresponding points

7.) Join b, e_1, e_2, e_3 & e_4 and we get the curve 'C'

8.) Make tangent to curve C which is parallel to line bf and mark the point on curve C as e

9.) Then draw a line be which intersects line af at C, Now bc is actual failure plane

10.) Put rail load of 50 KN/m on point C_1 and mark a point d_1' which is equivalent to unit weight of wedge abc and rail load.

unit weight of wedge $abc_1 = \frac{1}{2} \times \gamma \times ab \times ac_1$

bd_1 is equivalent to $\frac{1}{2} \times \gamma \times ab \times ac_1$

Now there is rail load also.

so total weight = unit weight + rail load

$$= \frac{1}{2} \times \gamma \times ab \times ac_1 + 50$$

and bd_1' is equivalent to $\frac{1}{2}\gamma \times ab \times ac_1 + 50$

so

$$bd_1' = \frac{bd_1}{\frac{1}{2} \times \gamma \times ab \times ac_1} \left[\frac{1}{2}\gamma \times ab \times ac_1 + 50\right]$$

$$= bd_1 + \frac{50 \times bd_1}{\frac{1}{2} \times \gamma \times ab \times ac_1}$$

Previously we are taking $bd_1 = ac_1$

then

$$bd_1' = bd_1 + \frac{50}{\frac{1}{2} \times 18 \times 10}.$$

$$= bd_1 + 0.55$$

Similarly do for other wedges also

11> Repeat the procedure and we get the another curve C'

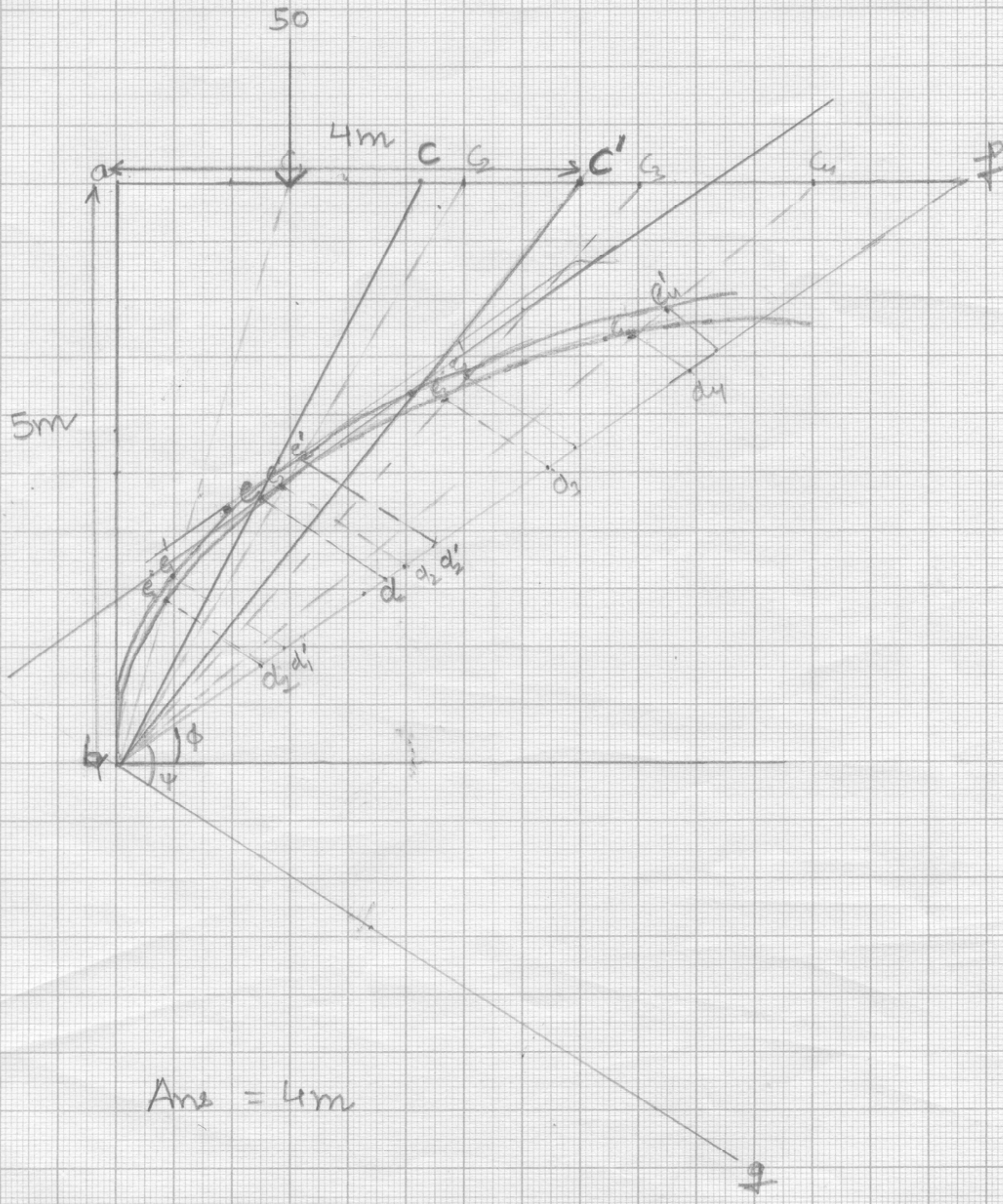
12> Mark the point on curve C' at which tangent of curve C intersect. Let that point be G.

13) Extend the line bG which intersects the horizontal surface at C'

14) So ac' is the minimum distance which is equal to 4m from crest of wall face at which rail track can be placed.

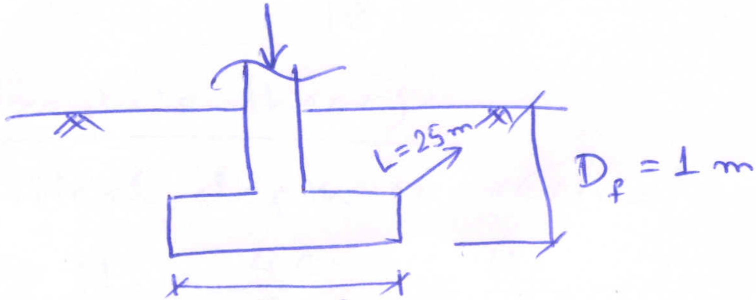
Ques2

1m = 2cm



Ans = 4m

3)



$C = 60\ kPa$

$\gamma = 18\ kN/m^3$

$\phi = 0^\circ$ ($\because$ pure clay)

$\frac{L}{B} \gg 1 \Rightarrow$ Strip footing

$\frac{D_f}{B} < 1 \Rightarrow$ shallow footing

As per Terzaghi's theory,

for $\phi = 0^\circ$, $N_c = 5{\cdot}7$, $N_q = 1{\cdot}0$ & $N_\gamma = 0{\cdot}0$

$$\therefore\ q_{ult} = cN_c + qN_q + \frac{1}{2}\gamma B N_\gamma$$

$$= (60 \times 5{\cdot}7) + (18 \times 1) \times 1 + 0$$

$$= 360\ kPa$$

$$q_{nu} = q_{ult} - \gamma D_f = 360 - 18 = 342\ kPa$$

$$q_{all} = \frac{q_{nu}}{F.S.} = \frac{342}{3} = 114\ kPa$$

$$Q_{all} = (114 \times 2 \times 25)\ kN = 5700\ kN$$

As per IS code,

for $\phi = 0^\circ$, $N_c = 5{\cdot}14$, $N_q = 1{\cdot}0$ & $N_\gamma = 0{\cdot}0$

$$\therefore\ q_{ult} = 326{\cdot}4\ kPa$$

$$q_{nu} = 308{\cdot}4\ kPa$$

$$q_{all} = 102{\cdot}8\ kPa \qquad \therefore\ Q_{all} = 5140\ kN.$$ Ans

3) Contd.

Rankine's theory

Critical depth of vertical cut.

$$H_c = \frac{4c}{\gamma \sqrt{K_a}} \qquad \text{here, } K_a = 1.0$$

$$= \frac{4 \times 60}{18} = 13.3 \text{ m.}$$

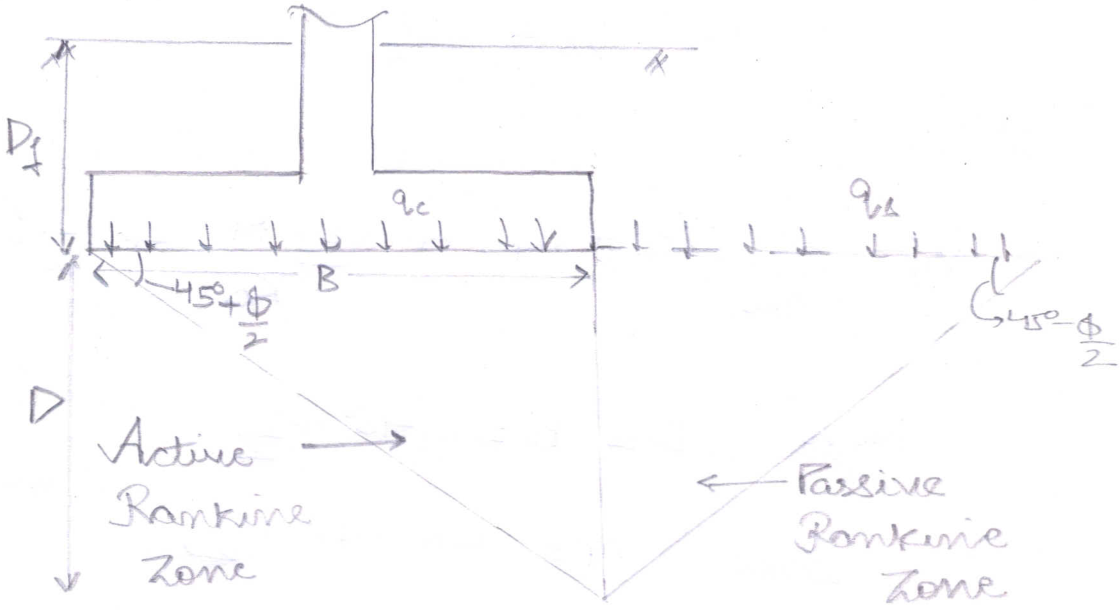
Terzaghi's theory.

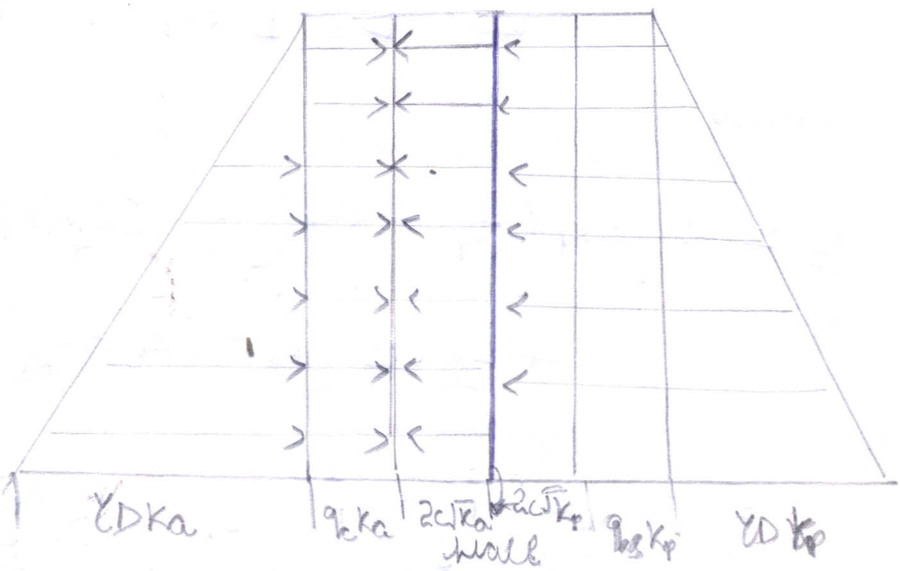
Critical depth of vertical cut.

$$H_c = \frac{4c}{\gamma \sqrt{K_a}} - \frac{H_c}{2}$$

$$\therefore H_c = \frac{2}{3} \times \frac{4 \times 60}{18} = 8.89 \text{ m.}$$ Ans

Ans 4.





Pressure Diagram

Take $\Sigma P_h = 0$ i.e horizontal total pressure on wall is equal to zero.

For this

$$q_c K_a D - 2cD\sqrt{K_a} + \frac{1}{2}\gamma D_f^2 K_a = q_s K_p D + 2cD\sqrt{K_p} + \frac{1}{2}\gamma D^2 K_p.$$

or

$$q_c K_a - 2c\sqrt{K_a} + \frac{1}{2}\gamma D K_a = q_s K_p + 2c\sqrt{K_p} + \frac{1}{2}\gamma D K_p.$$

as $q_s = \gamma D_f$

then

$$q_c = \frac{2c}{K_a}(\sqrt{K_a} + \sqrt{K_p}) + \frac{\gamma D_f K_p}{K_a} + \frac{1}{2}\gamma D \frac{(K_p - K_a)}{K_a}$$

Now $D = B\tan\left(45^\circ + \frac{\phi}{2}\right)$

and $K_p = \tan^2\left(45^\circ + \frac{\phi}{2}\right)$

so $D = B\sqrt{K_p}$, $K_a = \frac{1}{K_p}$

then

$$q_c = c\left[2K_p\left(\frac{1}{\sqrt{K_p}} + \sqrt{K_p}\right)\right] + \gamma D_f K_p^2 + \frac{1}{2}\gamma B\left[K_p^{1.5}\left(K_p - \frac{1}{K_p}\right)\right]$$

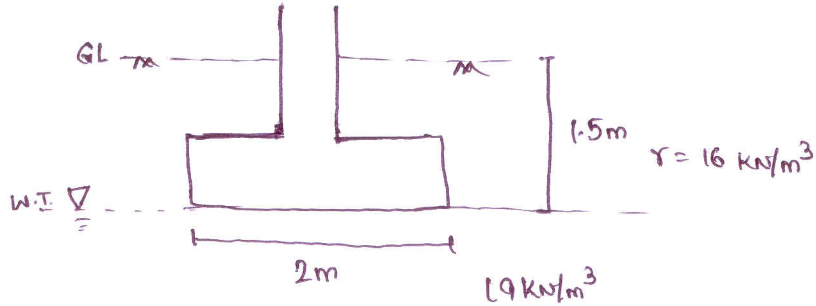
$$= c\underbrace{\left[2(K_p^{0.5} + K_p^{1.5})\right]}_{N_c} + \gamma D_f \underbrace{K_p^2}_{N_q} + \frac{1}{2}\gamma B\underbrace{\left[K_p^{2.5} - K_p^{0.5}\right]}_{N_\gamma}$$

$$\Rightarrow \quad N_c = 2\left(K_p^{1.5} + K_p^{0.5}\right)$$

$$N_q = K_p^2$$

$$N_\gamma = \left(K_p^{2.5} - K_p^{0.5}\right)$$

(5)



$C = 5\text{ kPa}$

$\phi = 37°$

Solution:

$\phi = 37°\ (>36°)$. So General Shear Failure will take place

∴ According to Terzaghi's Bearing Capacity Equation,

Net ultimate Bearing Capacity, $q_{nu} = CN_c + \gamma D_f N_q + 0.5\gamma' B N_\gamma - \gamma D_f$

$$\therefore q_{nu} = CN_c + (N_q - 1)\gamma D_f + 0.5\gamma' B N_\gamma$$

For $\phi = 37°$,

$N_c = 72.96 \approx 73$

$N_q = 57.36$

$N_\gamma = 65.6$

$$\therefore q_{nu} = 5 \times 73 + (57.36 - 1)\, 16 \times 1.5 + 0.5 \times (19 - 10) \times 2 \times 65.6$$

$$= 2308.04\ \text{kN/m}^2$$

Net ultimate load which the footing can carry per unit length of the following = 2308.04 × 2

= 4616.08 KN/m

≈ 4616.10 KN/m