Assignment : 2

Q1 (a) Rankine earth pressure Theory :
For active stage :-

$\sigma_3 = \sigma_h \qquad \sigma_1 = \sigma_v$

$\therefore \sigma_v = \sigma_h \tan^2\left(45^\circ + \frac{\phi}{2}\right)$

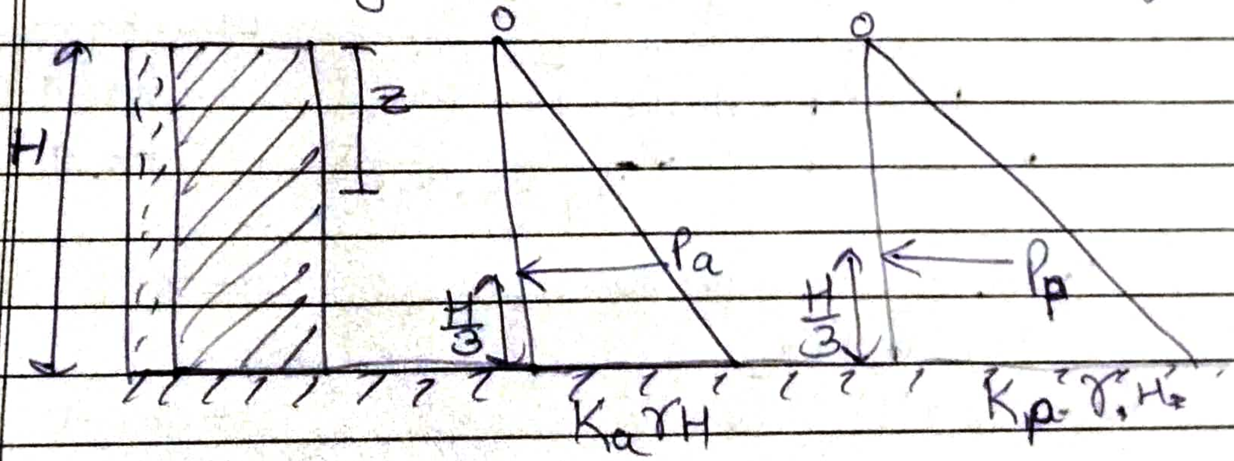
$$\frac{\sigma_h}{\sigma_v} = \cot^2(45 + \phi/2) = K_a$$

$$\Rightarrow K_a = \frac{1 - \sin\phi}{1 + \sin\phi}$$ } Active earth pressure coefficient

$\therefore \sigma_h = K_a \sigma_v$

$\boxed{\text{Active earth pressure } p_a = K_a \sigma_v}$ ☆☆☆

Case I : Dry / Moist Cohesionless Backfill.



1) $\sigma_v = \gamma z$

$p_a = K_a \sigma_v$

$= K_a \gamma z$

at $z = 0$, $p_a = 0$

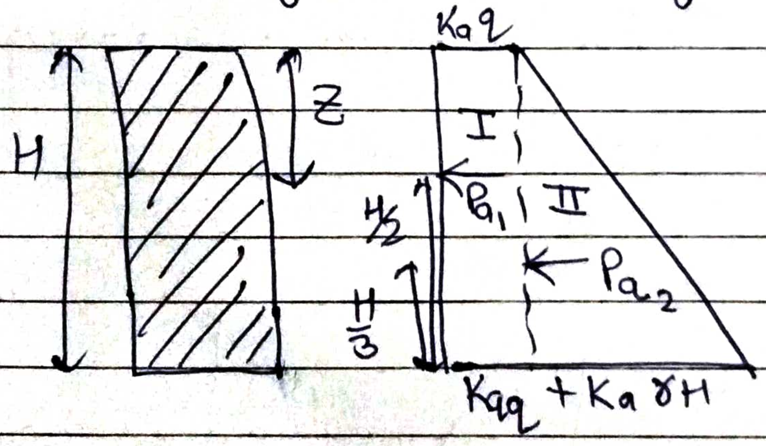
$z = H$, $p_a = K_a \gamma H$

Total earth pressure on unit length of wall

$P_a = \frac{1}{2} K_a \gamma H^2$

$z = H/3$ from Base

Case II: Backfill with Uniform Surcharge.



$\sigma_v = q + \gamma z$

$p_a = K_a \sigma_v$

$= K_a(q + \gamma z)$

$= K_a q + K_a \gamma z$

Total earth pressure.

$P_a = P_{a_1} + P_{a_2}$

$P_a = K_a q H + \frac{1}{2} K_a \gamma H^2$

at $z = 0$ $p_a = K_a q$

at $z = H$, $p_a = K_a q + K_a \gamma H$

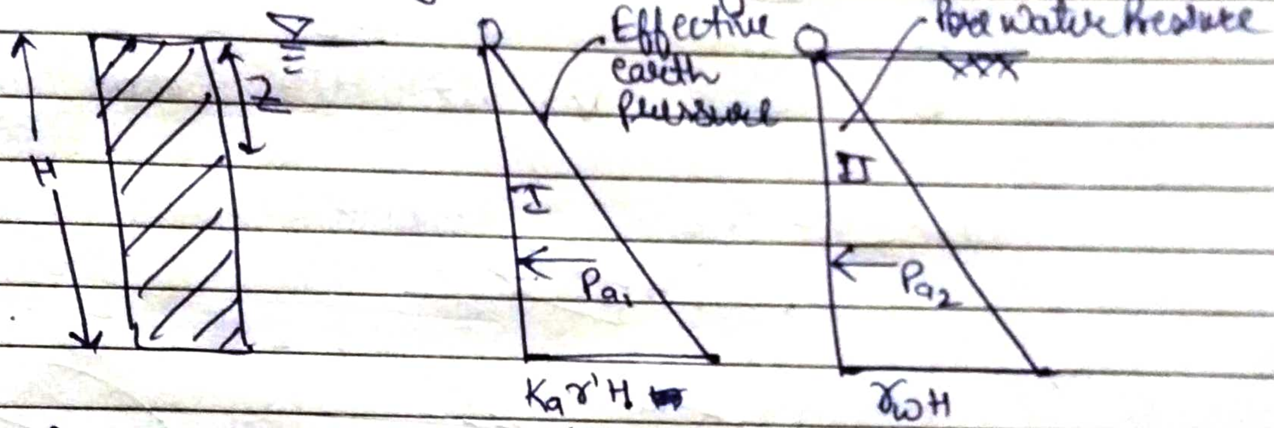
P_{a_1} will act at $H/2$

P_{a_2} will act at $H/3$

Pa will act at

$$z = \frac{P_{a_1} \times H/2 + P_{a_2} \times H/3}{P_{a_1} + P_{a_2}}$$

Case III: Submerged backfill



1) $\sigma_v = \bar{\sigma}_v + U = \gamma' z + \gamma_w z$

2) $p_a = K_a \bar{\sigma}_v + U$

$$p_a = \underbrace{K_a \gamma' z}_{\text{Effective earth pressure}} + \gamma_w z$$ will not be multiplied by Ka.

at $z = 0$ $\quad p_a = 0$

at $z = H$ $\quad p_a = K_a \gamma' H + \gamma_w H$

Total earth pressure on unit length of wall

$$P_a = P_{a_1} + P_{a_2}$$

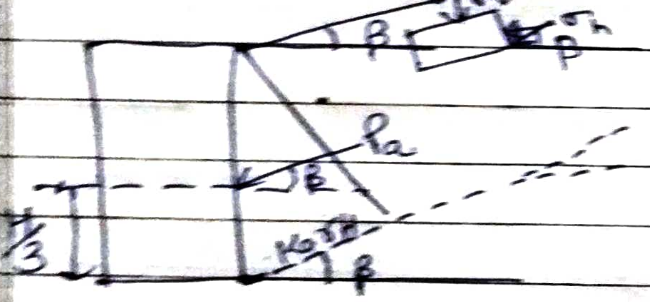
$$= \frac{1}{2} K_a \gamma H^2 + \frac{1}{2} K \gamma_w H^2$$

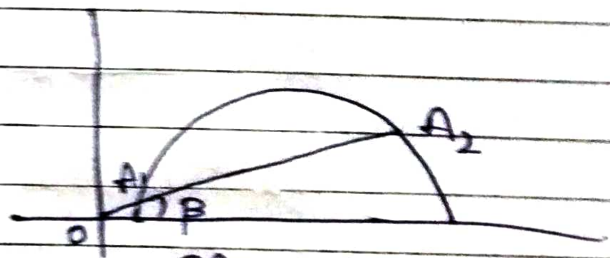
P_{a_1} will be at $H/3$

P_{a_2} will be at $H/3$

P_a will act at $H/3$ from Base

Case IV :- Backfill with sloping surface.





$OA_1 = \sigma_h$

$OA_2 = \sigma_v$

$$P_a = \frac{1}{2} K_a \gamma H^2$$

P_a will act at $H/3$ from Base at angle 'β' with the horizontal.

Value of K_a

$$K_a = \cos\beta \left[\frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}} \right]$$

Q1 (b) Active earth pressure: During the active stage wall moves away from the backfill and the portion of the backfill just behind the wall leaves the rest of the soil mass and moves along with the wall. this portion of the backfill which moves along with the wall is known as failure wedge.

Passive earth pressure: In passive stage, if the wall moves towards backfill the shearing resistance of the soil builds up against the wall which results in increase of pressure on the walls.

Active earth pressure of cohesive soil:
Cohesive soils are partially self supporting soils and active pressure exerted by them on the wall is comparatively less than cohesionless soil.

* from stress relationship of soil.

$$\sigma_1 = \sigma_3 \tan^2\left(45 + \frac{\phi}{2}\right) + 2c \tan\left(45' + \frac{\phi}{2}\right)$$

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<u>For active Stage</u>:

$\sigma_1 = \sigma_v \qquad \sigma_3 = \sigma_h$

$\Rightarrow \sigma_v = \sigma_h \tan^2\left(45+\frac{\phi}{2}\right) + 2c\tan\left(45+\frac{\phi}{2}\right)$

$\Rightarrow \sigma_v \cot^2\left(45+\frac{\phi}{2}\right) = \sigma_h + 2c\cot\left(45+\frac{\phi}{2}\right)$

$\Rightarrow \sigma_h = \sigma_v \cot^2\left(45+\frac{\phi}{2}\right) - 2c\cot\left(45+\frac{\phi}{2}\right)$

$\because \cot^2\left(45+\frac{\phi}{2}\right) = K_a = \frac{1-\sin\theta}{1+\sin\theta}$

$\Rightarrow \sigma_h = K_a\sigma_v - 2c\sqrt{K_a}$

Active Earth Pressure $= \boxed{P_a = K_a\sigma_v - 2c\sqrt{K_a}}$ **

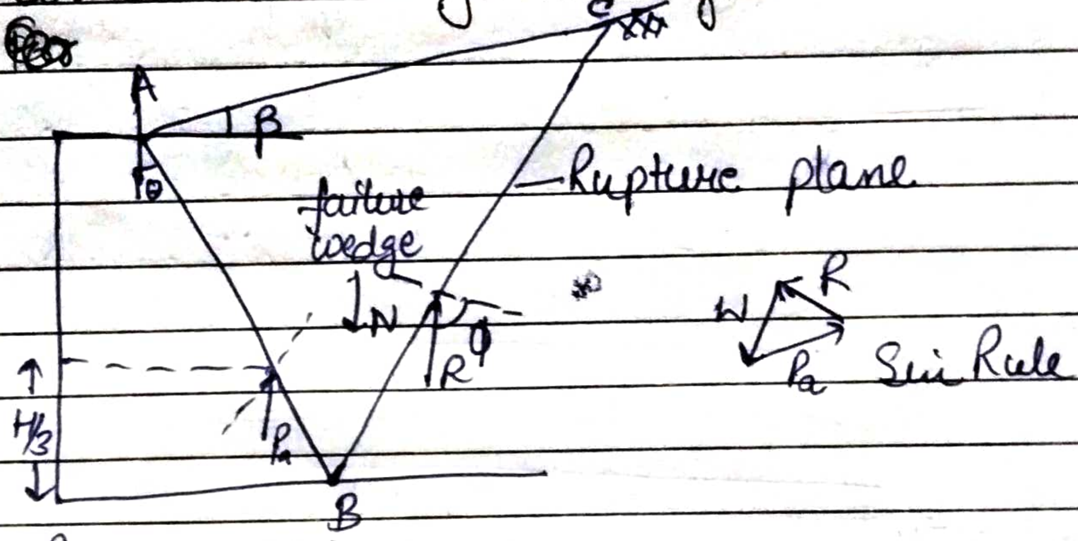
~~Total Earth Pressure~~

$$\cancel{P_p = P_{p_1} + P_{p_2}}$$

$$\cancel{= \frac{1}{2} K_p \gamma H^2 + 2c\sqrt{K_p} \cdot H}$$

$$\cancel{\bar{z} = \frac{P_{p_1} \times H/2 + P_{p_2} \times H/3}{P_{p_1} + P_{p_2}}}$$

Q2 (a) Coulomb's wedge theory :-



$$P_a = \frac{1}{2} K_a \gamma H^2$$

P_a will act at $\frac{H}{3}$ from Base at an angle of δ with the normal to the face of wall.

$$K_a = \frac{\sec\theta \cdot \cos(\phi - \theta)}{\sqrt{\cos(\theta+\delta)} + \sqrt{\frac{\sin(\delta+\phi)\sin(\phi-\beta)}{\sin(\beta-\theta)}}}$$

where β = angle of backfill surface
ϕ = internal angle of friction of soil.
θ = angle made by vertical with inclined face of wall.
δ = Angle of friction between wall and soil

for Smooth wall $\delta = \phi/3$
for Ordinary retaining wall $\delta = \frac{2\phi}{3}$
for Rough soil $\delta = \frac{3}{4}\phi$

The critical height H_c of an unsupported vertical cut in cohesive soil is given by

$$H_c = \frac{4c}{\gamma} \tan\alpha$$

As $\phi = 0$, $\tan\alpha = \tan(45° + \phi/2) = 1$

$$c = \frac{H_c \gamma}{4} = \frac{4 \times 20}{4} = 20 \text{ kN/m}^2$$

(i) Total active earth pressure is given

$$P_a = \frac{1}{2} \gamma H \cot^2\alpha - 2cH \cot\alpha$$

$$= \frac{1}{2}(20)(8)^2(1) - 2 \times 20 \times 8 \times 1$$

$$= 640 - 320 = 320 \text{ kN/m}$$

(ii) Total passive earth pressure is given by equation

$$P_p = \frac{1}{2} \gamma H \tan^2\alpha + 2cH \tan\alpha$$

$$= \frac{1}{2}(20)(8)^2 \times 1 + 2 \times 20 \times 8 \times 1$$

$$= 640 + 320 = 960 \text{ kN/m}$$

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Q5 The active earth pressure for a saturated clay ($\phi_u = 0$) is given.

$$P_a = \gamma_{sat} \cdot z - 2c_u \quad (1)$$

and the height of tension cracks is given

$$z_0 = \frac{2c_u}{\gamma_{sat}} \quad (2)$$

For the top soil, $\gamma_{sat} = 18\ KN/m^3$, $c_u = 18\ KN/m^2$
for the bottom soil, $\gamma_{sat} = 20\ KN/m^3$, $c_u = 24\ KN/m^2$

From eq^n (1)
when $z = 0$ $P_a = -2c_u = -2 \times 18 = -36\ KN/m^2$

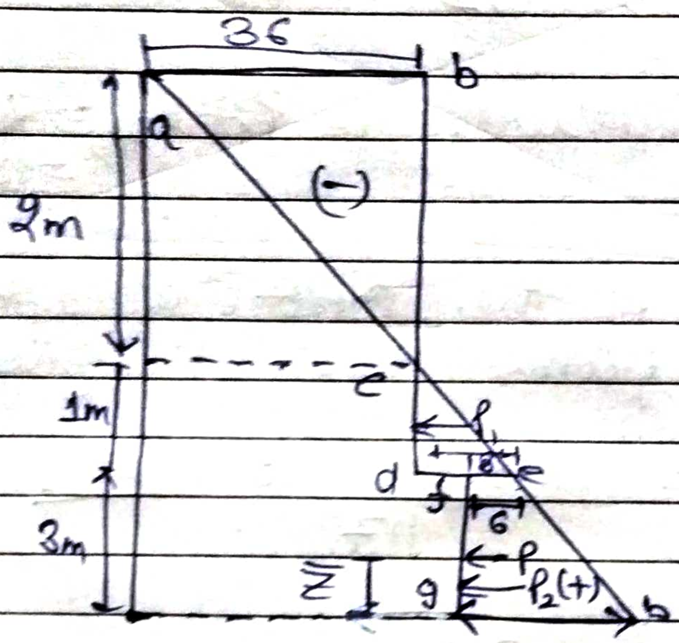
$$z_0 = \frac{2c_u}{\gamma_{sat}} = \frac{2 \times 18}{18} = 2m$$

$z = 3m$, $P_a = (18 \times 3) - (2 \times 18) = 18\ KN/m^2$ (upper soil)
$z \geq 3m$, $P_a = (18 \times 3) + 20(z-3) - (2 \times 24) =$
$54 + 20(z-3) - 48$

$z = 3m$, $P_a = 54 - 48 = 6\ KN/m^2$ (lower soil)

$z = 6m$, $P_a = 54 + 20(6-3) - 48 = 66\ KN/m^2$

the pressure distribution is shown as



Assuming that the tension cracks have been developed the net active pressure will be equal to the area of the positive pressure diagram

$$P_1 = \frac{1}{2} \times 1 \times 18 = 9\ KN/m$$

Acting $3 + \frac{1}{3} = 3.33m$ from the base.

$$P_2 = \frac{6+66}{2} \times 3 = 108\ KN/m$$

Acting at $\frac{3}{3}\left(\frac{2\times 6+66}{6+66}\right) = 1.083\,m$

from the base.

Total pressure $P = P_1 + P_2 = 9 + 108$

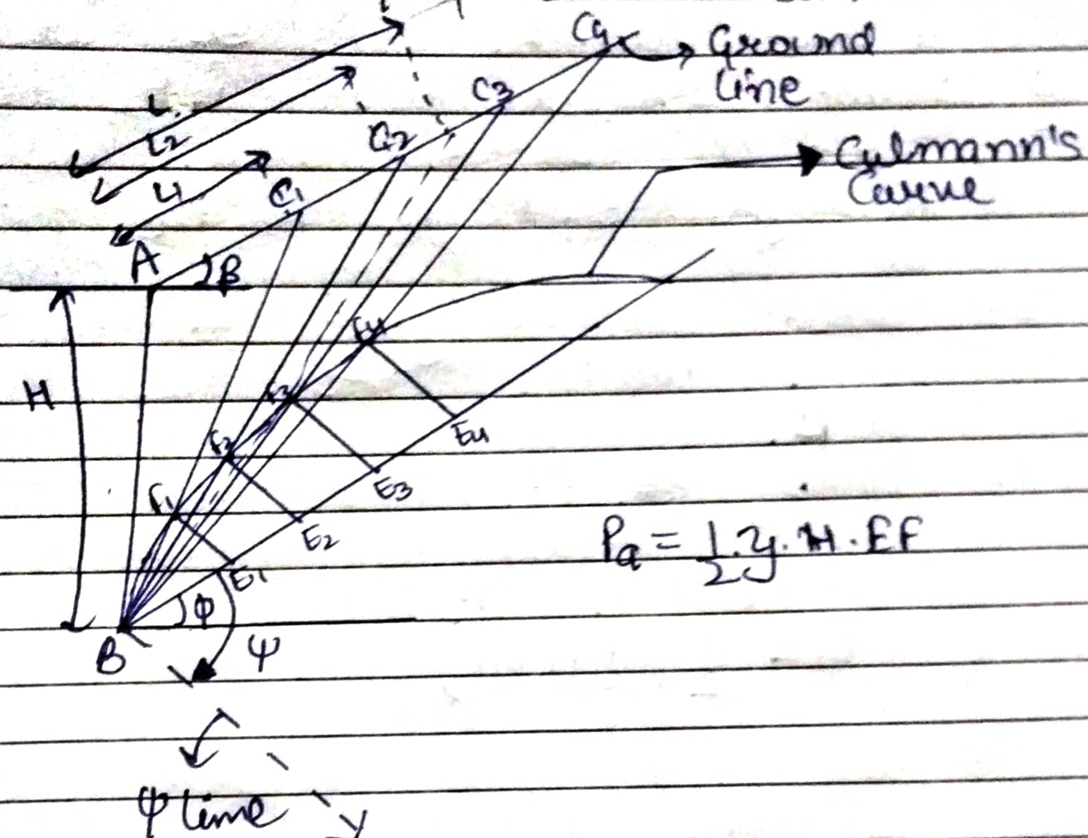
$= 117$ KN/m length.

Distance of the point of application of P from base is given by

$$\bar{Z} = \frac{(9\times 3.33)+(108\times 1.083)}{117}.$$

$$\bar{Z} = 1.26\,m$$

Q3 ⓐ Culmann's Graphical Method:



$P_a = \frac{1}{2} \gamma . H . EF$

PROCEDURE:

1. Draw Ground line, failure line and earth pressure line with β, γ, Ψ angle respectively.
2. Consider any trial wedge ABC_1 and measure length AC_1 as a L_1.
3. Calculate the weight of wedge ABC_1 and plot it at point E ie $BE_1 = L_1$.
4. Consider all such lines BC_2, BC_3, BC_4 and corresponding points E_1, E_2, E_3, E_4.

Through E_1 draw a line parallel to Ψ line which cut's BC_1 at point f_1.
Draw similar lines f_2E_2, f_3E_3, f_4E_4.
Draw a smooth curve which passes through B, f_1, f_2, f_3, f_4. This curve is called Culmann's curve.
Draw a tangent to the Culmann's curve which cuts the curve at pt F.
Draw FE line parallel to Ψ line.
Hence Active earth pressure is calculated as

$$P_a = \frac{1}{2}(\gamma H EF)$$

where γ = unit weight of soil.
So in this way we can find active earth pressure using Culmann's curve.

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Q4 (a) Gravity retaining wall:
Gravity retaining walls are constructed with mass concrete and they have massive volumn as it required to maintain stability. In general, vertical and horizontal forces are acting on the retaining wall based on the ground condition. Based on the forces acting on the retaining walls, they are check for overturning sliding and bearing.

Generally, low grade concrete is used for the construction of retaing walls as a measure to avoid thermal cracking in the immature concrete. Special attention shall be made during the mix design is done to minimize the heat of hydration.

Semi-gravity retaining walls are constructed to reduce the size of the wall or the mass of the concrete. A small portion of reinforcement is added to economize the retaining walls.

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Reinforcement is increased further to reduce the section dimension of the retaining wall.

When the height of the retaining significant and if gravity walls are constructed the cost of the construction will be considerably high. However, this can be balanced by reducing section dimensions and increasing the reinforcement area. this has to be done as an optimization process.

(Gravity Retaining Wall)