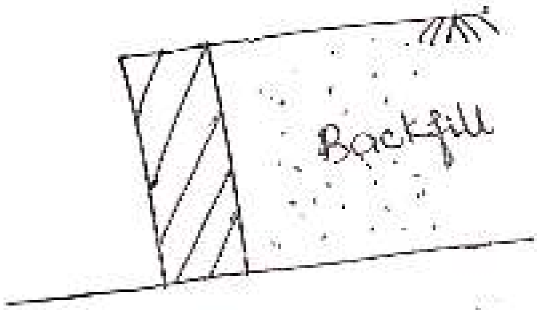
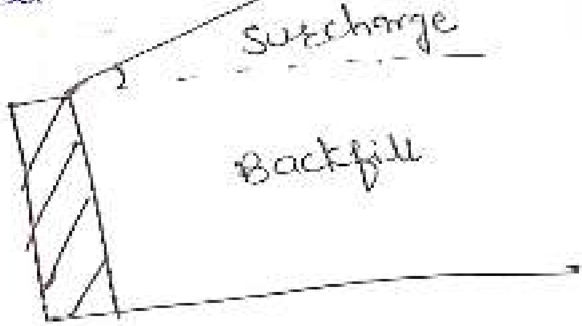
Chapter 9
EARTH PRESSURE

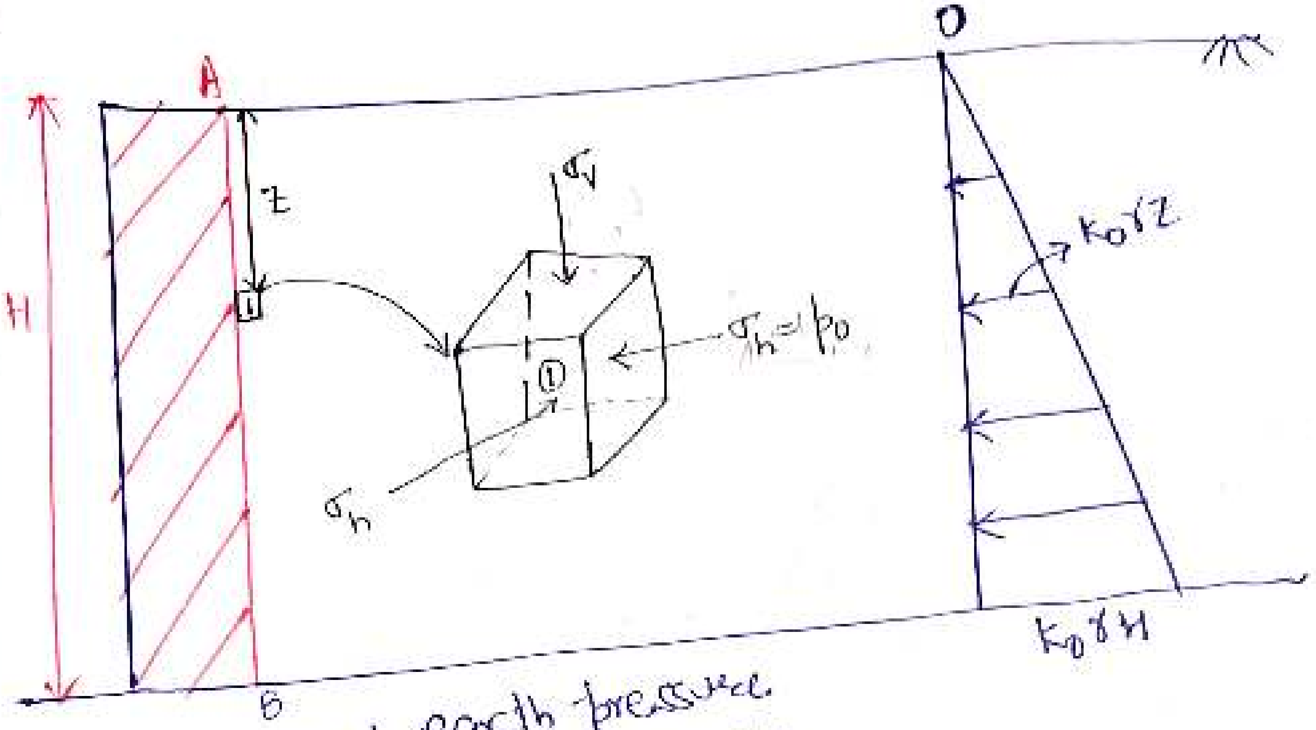
- In the designing of retaining wall, sheet pile wall and other retaining structures, pressure exerted by retained material should also considered. This pressure exerted by retained material is termed as Earth pressure and retained material is termed as Backfill. Backfill may have its top surface horizontal or inclined.





Earth pressure at rest condition:-

- If the wall is rigid and unyielding then soil retained by it is in the stage of rest and there is no displacement or deformation then pressure exerted by the soil on the wall is termed as Earth pressure at rest condition.



σ_v = vertical earth pressure

σ_h = lateral Earth pressure

$$\boxed{\frac{\sigma_h}{\sigma_v} = \text{Earth pressure coefficient} = K}$$

At Rest condition,

lateral strain $(\epsilon_h) = 0$

$$\epsilon_h = \frac{\sigma_h}{E} - \frac{\mu \sigma_h}{E} - \mu \frac{\sigma_v}{E} = 0$$

$$\sigma_h (1-\mu) = \mu \sigma_v$$

$$\frac{\sigma_h}{\sigma_v} = \frac{\mu}{1-\mu} = K_0$$

Earth pressure coefficient at Rest condition

$$\boxed{K_0 = \frac{\mu}{1-\mu}}$$ **

$\because \frac{\sigma_h}{\sigma_v} = K_0 \Rightarrow \sigma_h = K_0 \cdot \sigma_v = p_0$

⇒ Earth pressure at Rest condition

$$\boxed{p_0 = K_0 \sigma_v} \; {**}$$

⇒ On the wall

1.) At any depth z; $\sigma_v = \gamma \cdot z$
2) Earth pressure $p_0 = K_0 \sigma_v = K_0 \cdot \gamma \cdot z$
3) At $z = 0$ [Point A] $p_0 = 0$
at $z = H$ [Point B] $p_0 = K_0 \cdot \gamma \cdot H$

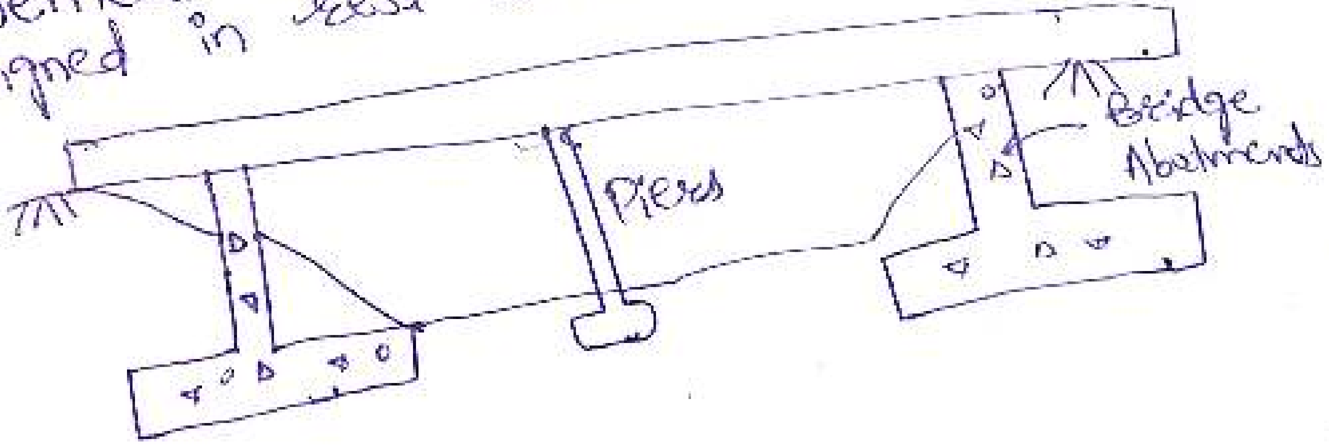
Note 1 :-

For pure sand — Jacky $\boxed{K_0 = 1 - \sin\phi}$
For O.C soil — $K_0 = (K_0)_{N.C\ soil} \sqrt{O.C.R}$ Ratio
O.C.R = over consolidation Ratio

Type of soil	K_0
Dense sand	0.4 – 0.45
Loose sand	0.45 – 0.5
Compacted soil	0.7 – 0.8
N.C.C	0.5 – 0.6

Note 2 :-

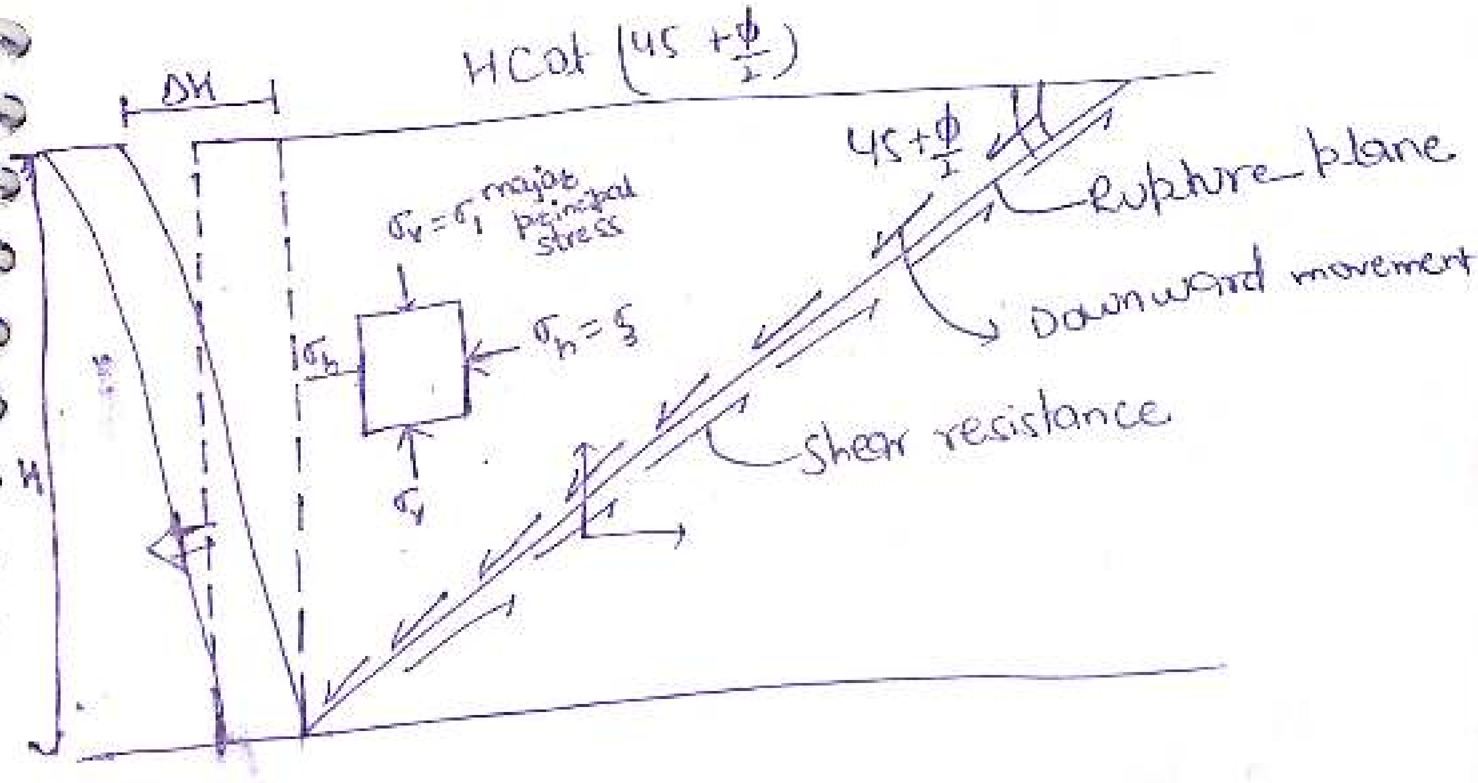
Basement wall and Bridge Abutments are designed in rest condition.



Active Earth pressure :-

- During the active stage, wall moves away from the backfill and the portion of the backfill just behind the wind leaves the rest of the soil mass and moves along with the wall. This portion of the backfill is termed as failure wedge.
- The resistance of the soil due to its shear strength is mobilized ~~and~~ upward and outward direction on the rupture surface which decreases the pressure on the wall. This decrease in pressure takes place upto an extent when entire shear resistance is mobilized. The minimum pressure acting on the wall in this stage is termed as Active Earth pressure.
- The strain required in this stage is in the order of 0.2% to 0.5%.

0.2% → Dense sand; 0.5% → Loose sand



Rankine's Theory :-

For cohesionless soil

In plastic equilibrium :-

$$\sigma_1 = \sigma_3 \tan^2\left(45+\frac{\phi}{2}\right) + 2\cancel{c}^{0} \tan\left(45+\frac{\phi}{2}\right)$$

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

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

$$\Rightarrow \frac{\sigma_h}{\sigma_v} = \frac{1}{\tan^2\left(45+\frac{\phi}{2}\right)} = k_a$$

Active earth pressure coefficient:-

$$\boxed{k_a = \cot^2\left(45+\frac{\phi}{2}\right) = \frac{1-\sin\phi}{1+\sin\phi}} ****$$

$$\because \frac{\sigma_h}{\sigma_v} = k_a \Rightarrow \sigma_h = k_a \cdot \sigma_v = p_a$$

Bell taken forward the Rankine's Theory for cohesive soil

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

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

$\left\{\because \cot^2\left(45+\frac{\phi}{2}\right) = k_a\right\}$

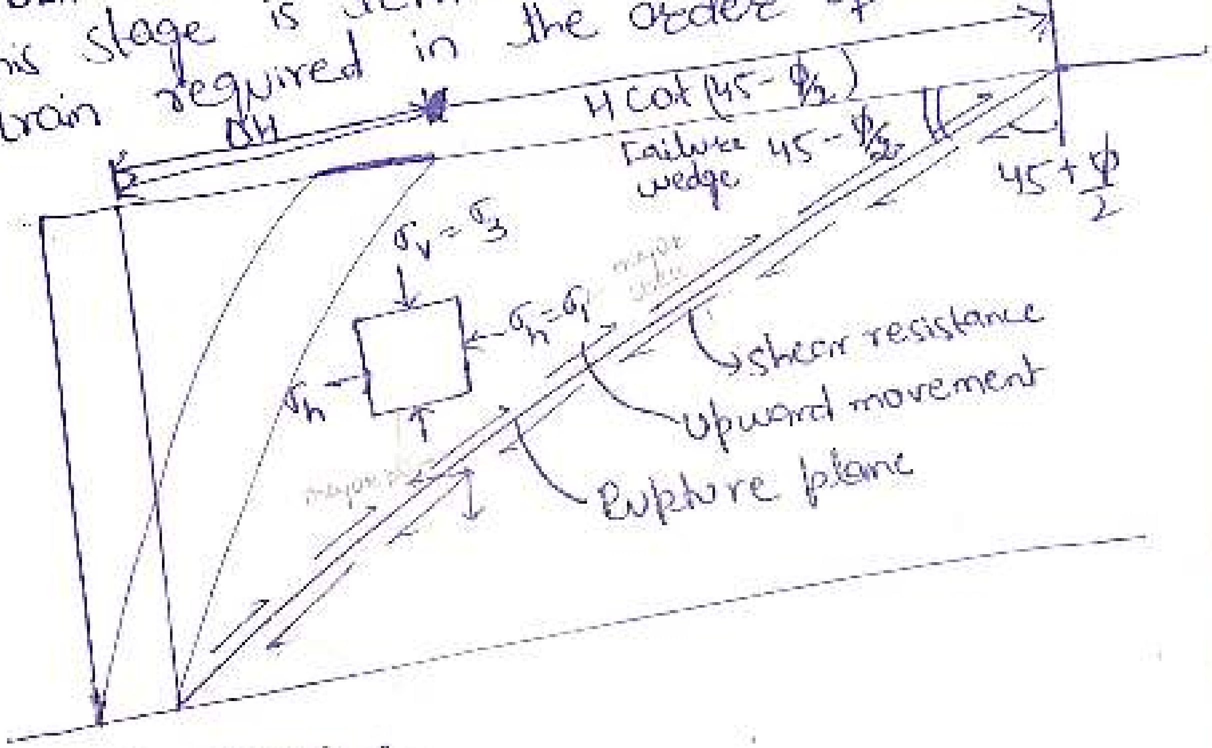
$$\Rightarrow \sigma_v \cdot k_a = \sigma_h + 2c\sqrt{k_a}$$

Active Earth pressure, ******

$$\boxed{p_a = K_a \sigma_v - 2c\sqrt{K_a}}$$

PASSIVE EARTH PRESSURE :-

If wall moves towards the backfill, then entire shear resistance builds up against the wall, due to which pressure on the wall increases. The pressure on the wall increases upto the extent when entire shear resistance is mobilized. The maximum pressure acting on the wall in this stage is termed as passive earth pressure. Strain required in the order of 2% to 15%.



Rankine's Theory :-

For cohesionless soil,

In Plastic equilibrium :-

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

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

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

Passive earth pressure coefficient

$$\boxed{k_p = \tan^2\left(45+\frac{\phi}{2}\right) = \frac{1+\sin\phi}{1-\sin\phi}}$$ *****

$\because \frac{\sigma_h}{\sigma_v} = k_p \Rightarrow \sigma_h = k_p \sigma_v = p_p$

Bell taken forward the Rankine's Theory for cohesive soil :-

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

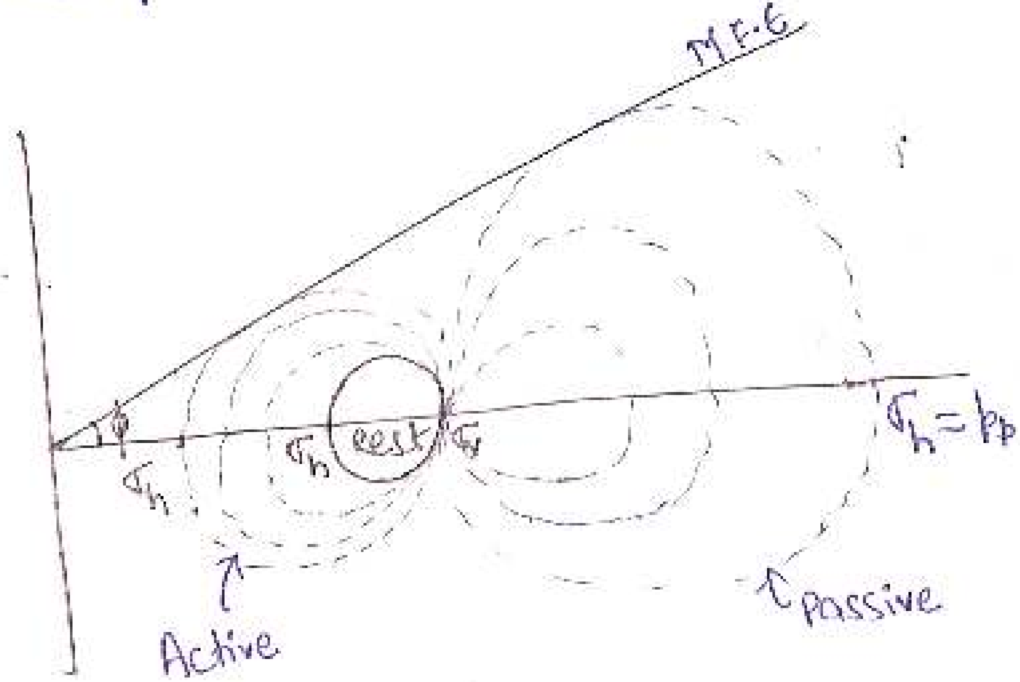
$$\sigma_h = \sigma_v k_p + 2c\sqrt{k_p} \qquad \because \tan^2\left(45+\frac{\phi}{2}\right) = k_p$$

Passive Earth pressure, *****

$$\boxed{p_p = k_p \sigma_v + 2c\sqrt{k_p}}$$

Note 1 :- $k_a \cdot k_p = 1$

Note 2 :-



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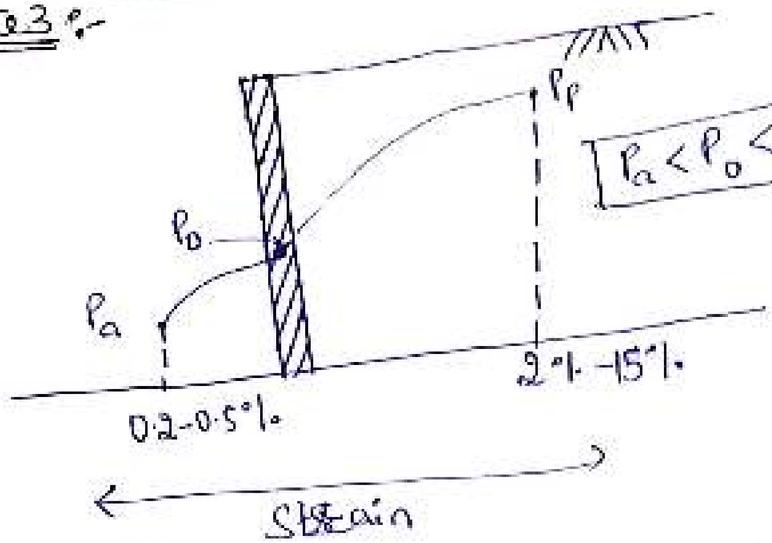
Note3:-



$\boxed{P_a < P_0 < P_p}$

$$\left\{\begin{array}{l}\text{Strain in Active} = \dfrac{\Delta H}{H\cot(45+\phi/2)} \simeq 0.2 \text{ to } 0.5\% \\ \text{Strain in Passive} = \dfrac{\Delta H}{H\cot(45^\circ-\phi/2)} \simeq 2 \text{ to } 15\%\end{array}\right\}$$

⇒ RANKINE'S EARTH PRESSURE THEORY:-

ASSUMPTIONS:-

(i.) Soil is homogenous, Isotropic, semi-infinite, elastic, dry and cohesionless.

(ii.) The ground surface is planer which may be horizontal or inclined.

(iii.) The face of wall in contact with backfill is vertical and smooth.

(iv.) Soil is in the state of plastic equilibrium in passive and active earth pressure condition.

(v.) The rupture surface is planer.

Case I :- Dry | Moist Cohesionless Backfill

Moment = force × Distance

Step 1 :- σ_v at any depth z ; $\sigma_v = \gamma z$

Step 2 :-

$$\boxed{\begin{aligned} p_0 &= k_0 \sigma_v \\ p_a &= k_a \sigma_v - 2c\sqrt{k_a} \\ p_p &= k_p \sigma_v + 2c\sqrt{k_p} \end{aligned}}$$

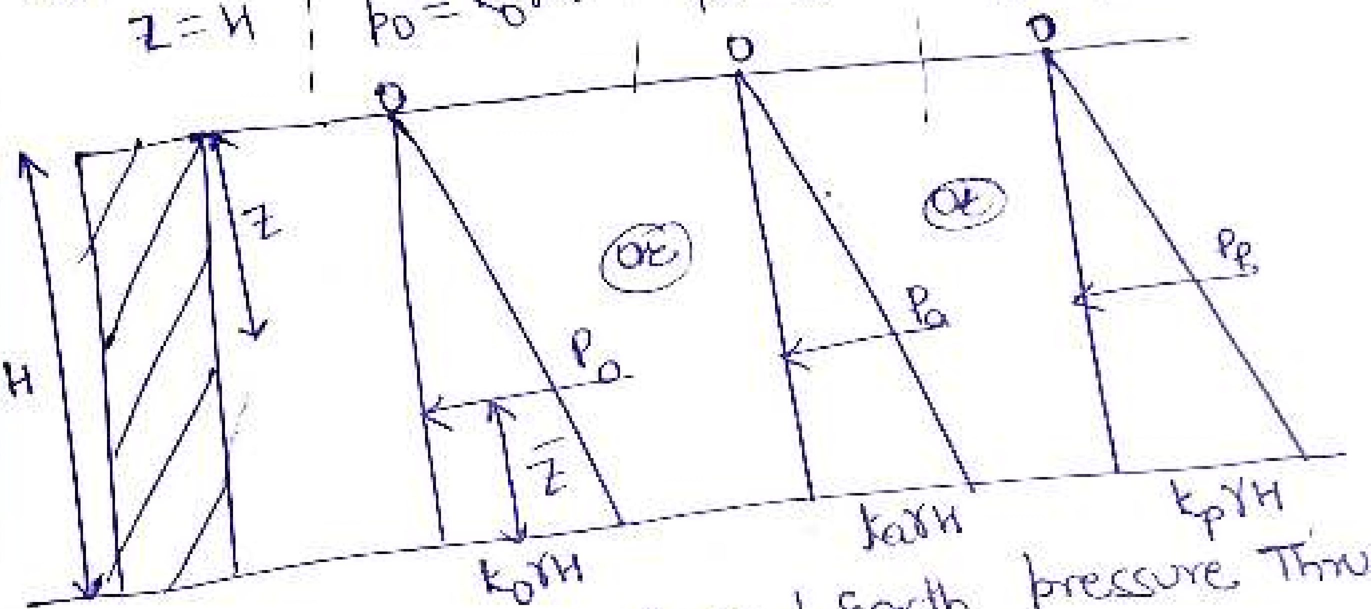
$= k_0 \gamma z$

$= k_a \gamma z$

$= k_p \gamma z$

Step 3 :-

At $z = 0$	$p_0 = 0$	$p_a = 0$	$p_p = 0$
$z = H$	$p_0 = k_0 \gamma H$	$p_a = k_a \gamma H$	$p_p = k_p \gamma H$



Step 4 :-
Total Earth pressure force | Earth pressure Thrust on unit length of wall :-

$$P_0 = \frac{1}{2} k_0 \gamma H . H \quad , \quad P_a = \frac{1}{2} k_a \gamma H^2 \quad , \quad P_p = \frac{1}{2} k_p \gamma H^2$$

Step 5 :-
Line of Action
P will act at $\bar{z} = \frac{H}{3}$ from base

Case II :- cohesionless back-fill with uniform Surcharge :-

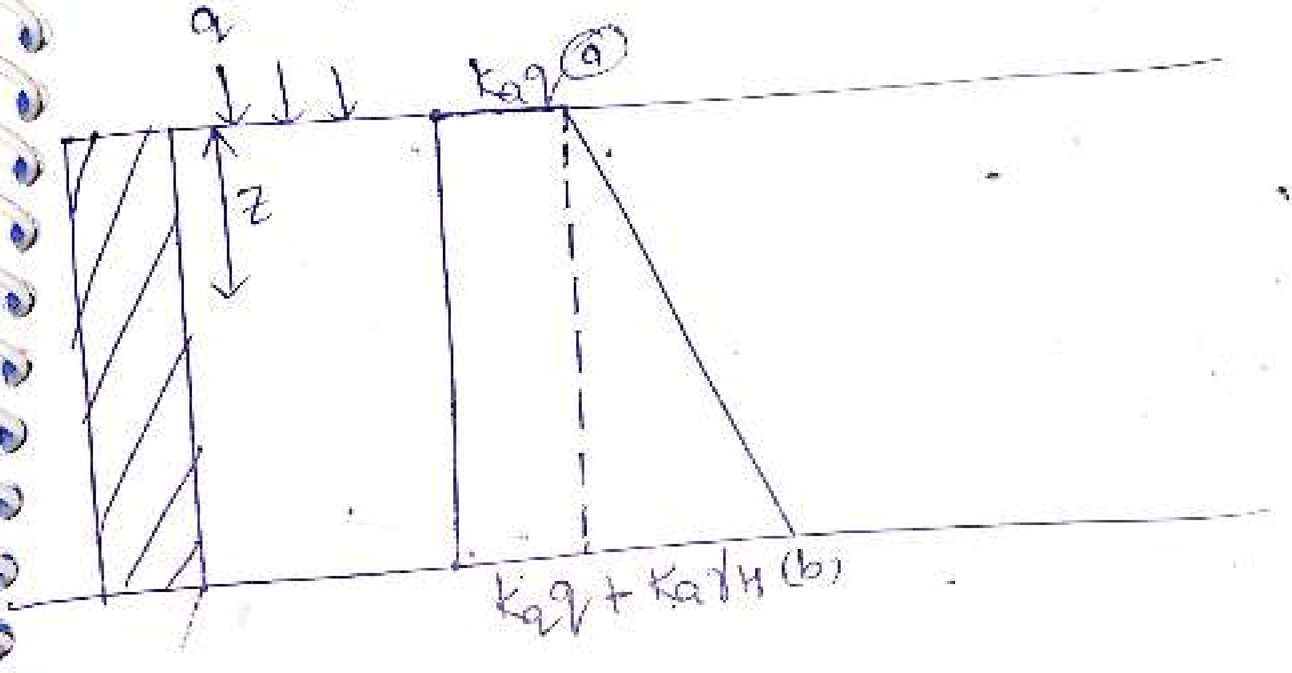
Step 1 :- σ_v at any depth z ; $\sigma_v = q + \gamma z$

Step 2 :- $\boxed{\begin{aligned} p_0 &= k_0 \sigma_v \\ p_a &= k_a \sigma_v - 2c\sqrt{k_a} \\ p_p &= k_p \sigma_v + 2c\sqrt{k_p} \end{aligned}}$ $\begin{aligned} &= k_0 q + k_0 \gamma z \\ &= k_a q + k_a \gamma z \\ &= k_p q + k_p \gamma z \end{aligned}$

Step 3 :-

At $z = 0$, $p_a = k_a q$

$z = H$, $p_a = k_a q + k_a \gamma H$



Step 4 :-

$$P_a = \frac{1}{2}(a+b)H \quad kN/m$$

Step 5 :-

$$\bar{z} = \left(\frac{2a+b}{a+b}\right)\frac{H}{3} \text{ from base.}$$

Case III :- Submerged Backfill :-

Step 1 :- $\bar{\sigma}_v = \bar{\sigma}_v + \gamma_w \to$ will not multiplied by K_a or K_p

$\bar{\sigma}_v = \gamma' z \qquad u = \gamma_w z.$

Step 2 :-

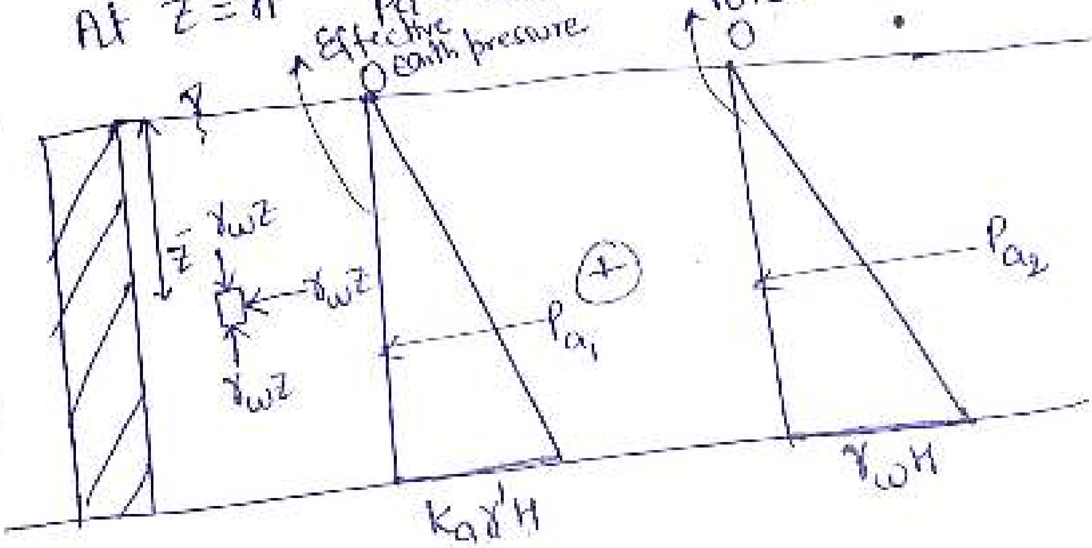
$$\boxed{\begin{aligned} p_0 &= K_0 \bar{\sigma}_v + u \\ p_a &= K_a \bar{\sigma}_v - 2\cancel{c}^{0}\sqrt{K_a} + u \\ p_p &= K_p \bar{\sigma}_v + 2\cancel{c}^{0}\sqrt{K_p} + u \end{aligned}} \begin{aligned} &= K_0 \gamma' z + \gamma_w z \\ &= K_a \gamma' z + \gamma_w z \\ &= K_p \gamma' z + \gamma_w z \end{aligned}$$

effective stress below GWT Take γ'
total stress below GWT Take γ_{sat}
For pore pres. Take γ_w

Step 3 :-

At $z = 0 \qquad p_a = 0$

At $z = H \qquad p_a = K_a \gamma' H + \gamma_w H$



Step 4 :-

$P_a = P_{a_1} + P_{a_2} = \frac{1}{2} K_a \gamma' H^2 + \frac{1}{2} \gamma_w H \cdot H$

Step 5 :- $\bar{z} = \frac{H}{3}$ from base

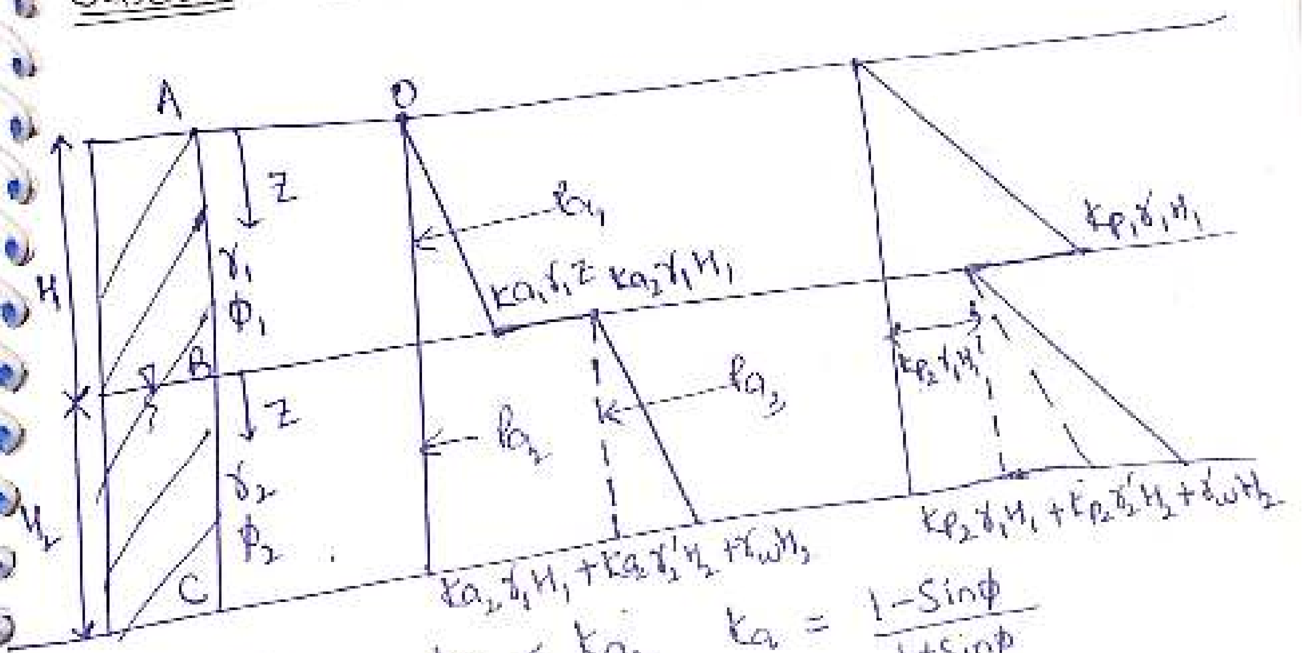
Similarly can be calculated for Rest & Passive condition.

Note :-
Water will exert equal pressure in all directions at particular depth ($\gamma_w z$) in

∴ Submerged condition, which will not be multiplied by K_a or K_p (Pascal's law)

- Water pressure is not considered for design of retaining wall because it may cause uneconomy in construction thus weep holes are provided in the retaining wall.
- If water is present in both side of retaining wall then effect of water pressure will be cancelled out.

Case IV :- Stratified Backfill :-



$\phi_1 > \phi_2$ $\quad k_{a_1} < k_{a_2}$ $\quad k_a = \dfrac{1-\sin\phi}{1+\sin\phi}$

$k_{p_1} > k_{p_2}$ $\quad k_p = \dfrac{1+\sin\phi}{1-\sin\phi}$

In soil ① At depth z below point A

1) $\sigma_v = \gamma_1 z$

2) $p_a = k_{a_1}\sigma_v - 2c_1^{\,0}\sqrt{k_{a_1}} = k_{a_1}\gamma_1 z$

$p_p = k_{p_1}\sigma_v + 2c_1^{\,0}\sqrt{k_{p_1}} = k_{p_1}\gamma_1 z$

③ At $Z = 0$	$p_a = 0$	$p_p = 0$
$Z = H_1$ [B]	$p_a = k_{a_1} \gamma_1 H_1$	$p_p = k_{p_1} \gamma_1 H_1$

<u>In soil ② At depth Z below point B</u>

(1.) $\bar{\sigma}_v = \gamma_1 H_1 + \gamma_2' Z \qquad u = \gamma_w Z$

(2) $p_a = k_{a_2} \bar{\sigma}_v - 2\cancel{c_2}^{\,0} \sqrt{k_{a_2}} + u = k_{a_2}(\gamma_1 H_1 + \gamma_2' Z) + \gamma_w Z$

$p_p = k_{p_2} \bar{\sigma}_v + 2\cancel{c_2}^{\,0} \sqrt{k_{p_2}} + u = k_{p_2}(\gamma_1 H_1 + \gamma_2' Z) + \gamma_w Z$

(3.) At $Z = 0$	$p_a = k_{a_2} \gamma_1 H_1$	$p_p = k_{a_2} \gamma_1 H_1$
$Z = H_2$ [C]	$p_a = k_{p_2} \gamma_1 H_1 + k_{p_2} \gamma_2' H_2 + \gamma_w H_2$	$p_p = k_{p_2} (\gamma_1 H_1 + \gamma_2' H_2) + \gamma_w H_2$

(4.) Total earth pressure in $\frac{kN}{m}$

$P_a = P_{a_1} + P_{a_2} + P_{a_3}$

$P_{a_1} = \frac{1}{2} \cdot k_{a_1} \cdot \gamma_1 \cdot H_1 \cdot H_1$ will act at $z_1 = H_2 + \frac{H_1}{3}$

$P_{a_2} = k_{a_2} \gamma_1 H_1 \cdot H_2 \qquad z_2 = \frac{H_2}{2}$

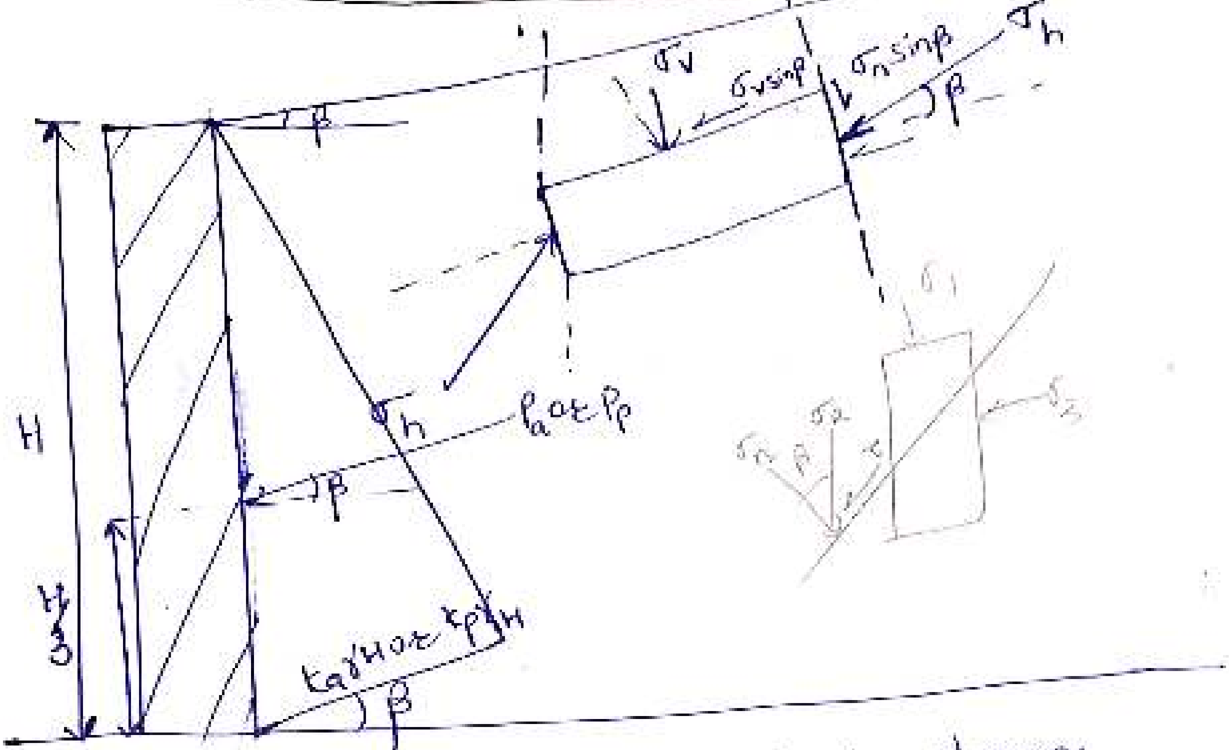
$P_{a_3} = \frac{1}{2} (k_{a_2} \gamma_2' H_2 + \gamma_w H_2) \cdot H_2 \qquad z_3 = \frac{H_2}{3}$

(5.) <u>Line of Action</u>

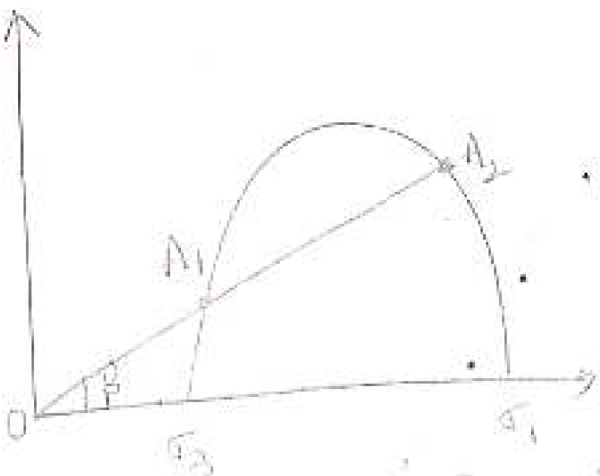
$$\bar{Z} = \frac{P_{a_1} z_1 + P_{a_2} z_2 + P_{a_3} z_3}{P_{a_1} + P_{a_2} + P_{a_3}}$$

if $\phi_2 > \phi_1$, then diagrams will Interchange.

Case II :- Soil mass with Inclined Backfill or Surcharge :-



Assumption :- σ_h and σ_v are conjugate stresses.



$OA_1 = \sigma_h$ $\quad OA_2 = \sigma_v$ Active

$OA_1 = \sigma_v$ $\quad OA_2 = \sigma_h$ Passive

→ $P_a = \frac{1}{2} K_a \gamma H^2$ or $P_p = \frac{1}{2} K_p \gamma H^2$

→ P_a or P_p will act at $\frac{H}{3}$ from base at an angle of 'β' with horizontal.

Value of K_a and K_p

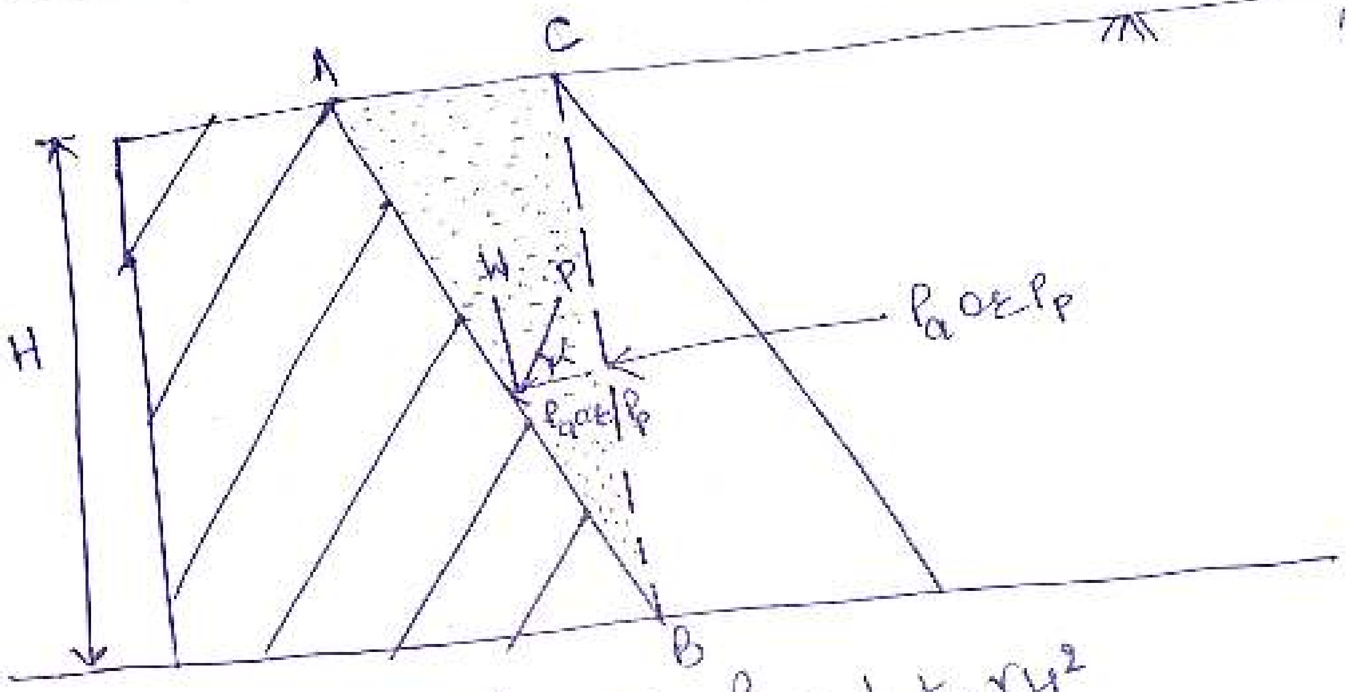
$$K_a = \cos\beta \left[\frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}} \right]$$

if this in formula of Pa above then here it is not used

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

Note :- $K_a \cdot K_p = \cos^2\beta$

Case 6 :- Inclined wall with horizontal backfill :



→ $P_a = \frac{1}{2} K_a \gamma H^2$ or $P_p = \frac{1}{2} K_p \gamma H^2$

→ P_a or P_p will act at $\frac{H}{3}$

→ Resultant Earth Pressure

$P = \sqrt{W^2 + P_a^2}$ or $P = \sqrt{W^2 + P_p^2}$

P will act at $\frac{H}{3}$ from base at an angle of α with horizontal.

$$\alpha = \tan^{-1}\left(\frac{W}{P_a}\right) \quad \text{or} \quad \alpha = \tan^{-1}\left(\frac{W}{P_p}\right)$$

$W \rightarrow$ weight of wedge ABC.

Active and passive Earth Pressure for Cohesive Soil :-

- Rankine Theory was taken forward by Bell in cohesive soil. As cohesive soils are self supporting soils, active pressure exerted by them on the wall is comparatively less than cohesionless soil but passive pressure exerted by them is comparatively more than cohesionless soil.

Case I Dry / Moist cohesive soil (Active stage)

(1.) σ_v at any depth z ; $\sigma_v = \gamma z$

(2.) $p_a = K_a \sigma_v - 2c\sqrt{K_a} = K_a \gamma z - 2c\sqrt{K_a}$

(3.) at $z = 0$ $\quad p_a = -2c\sqrt{K_a}$

$z = H$ $\quad p_a = K_a \gamma H - 2c\sqrt{K_a}$

Let at z_c $\quad p_a = K_a \gamma z_c - 2c\sqrt{K_a} = 0$

$$z_c = \frac{2c\sqrt{K_a}}{K_a \gamma}$$

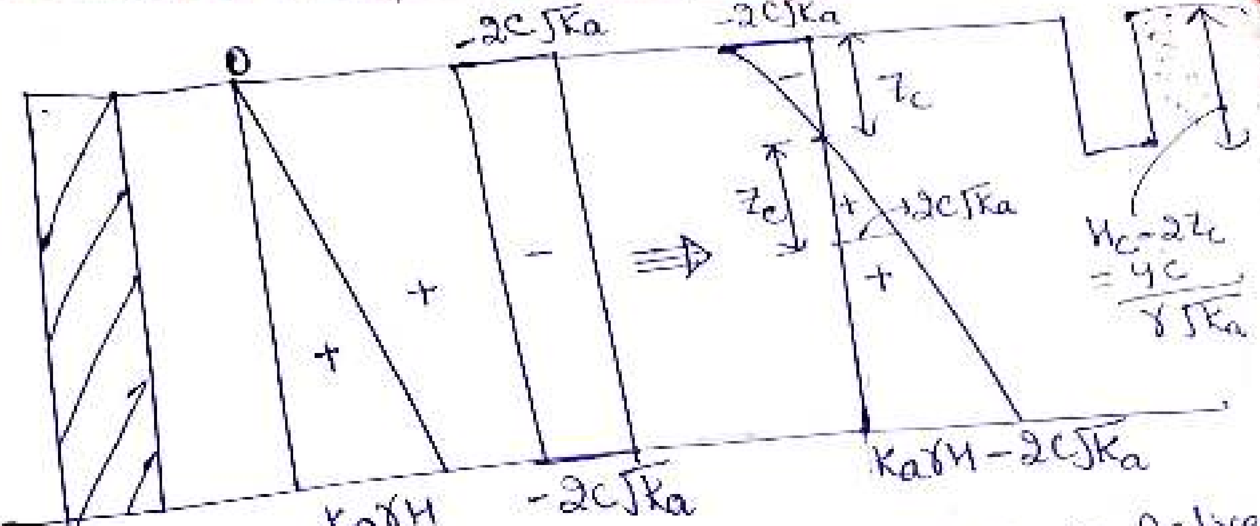
$$z_c = \frac{2c}{\gamma\sqrt{K_a}}$$

Question

Total earth pressure at base = 0

Total earth pressure is zero at z_c

Total pressure at base = $-2c\sqrt{K_a}$



Note:-

1. Total Net pressure in cohesive soil in Active stage upto the depth of ($2z_c = H_c$) is zero hence these cohesive soil can stand with their vertical face up, upto this depth without any lateral support thereby this depth of $2z_c$ is termed as Critical depth of unsupported cut

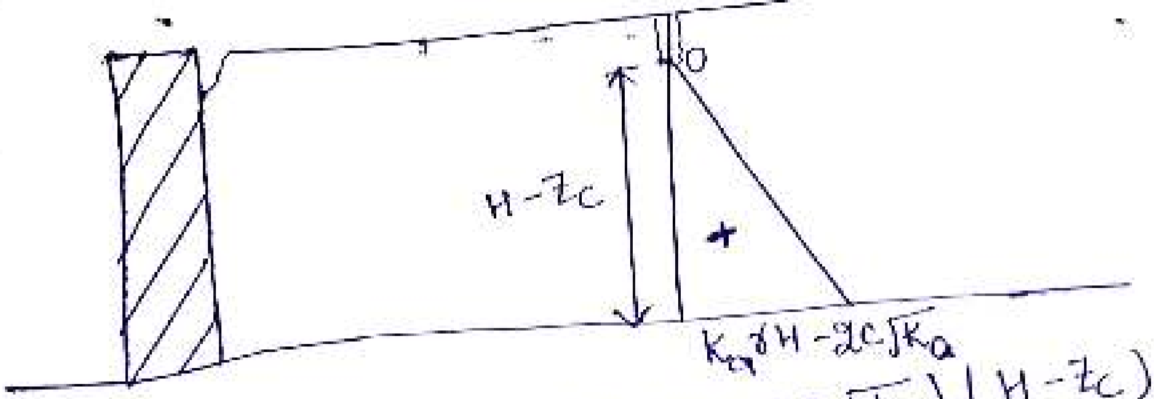
$$\boxed{H_c = 2z_c = \frac{4c}{\gamma\sqrt{K_a}}}$$

Note:-

2) Because of presence of tension, tension cracks may develop in cohesive soil as a result of which soil does not remain bonded to the face of the wall hence portion of the soil is considered to be exert no pressure on the wall.

Step:- Total active earth pressure on unit length of wall

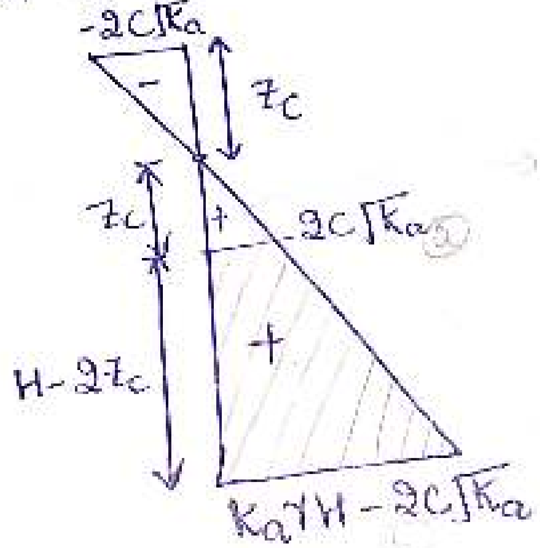
Case a:- when tension cracks are developed.



$$P_a = \frac{1}{2}\left(K_a \gamma H - 2c\sqrt{K_a}\right)(H - Z_c)$$

$$\bar{Z} = \frac{H - Z_c}{3}$$

<u>Case b</u> :-
when tension cracks are not developed



→ Area diff b/w two tension cracks

$$P_a = \left(\frac{a+b}{2}\right)(H - 2Z_c)$$

$$\bar{Z} = \left(\frac{2a+b}{a+b}\right)\cdot\left(\frac{H - 2Z_c}{3}\right)$$

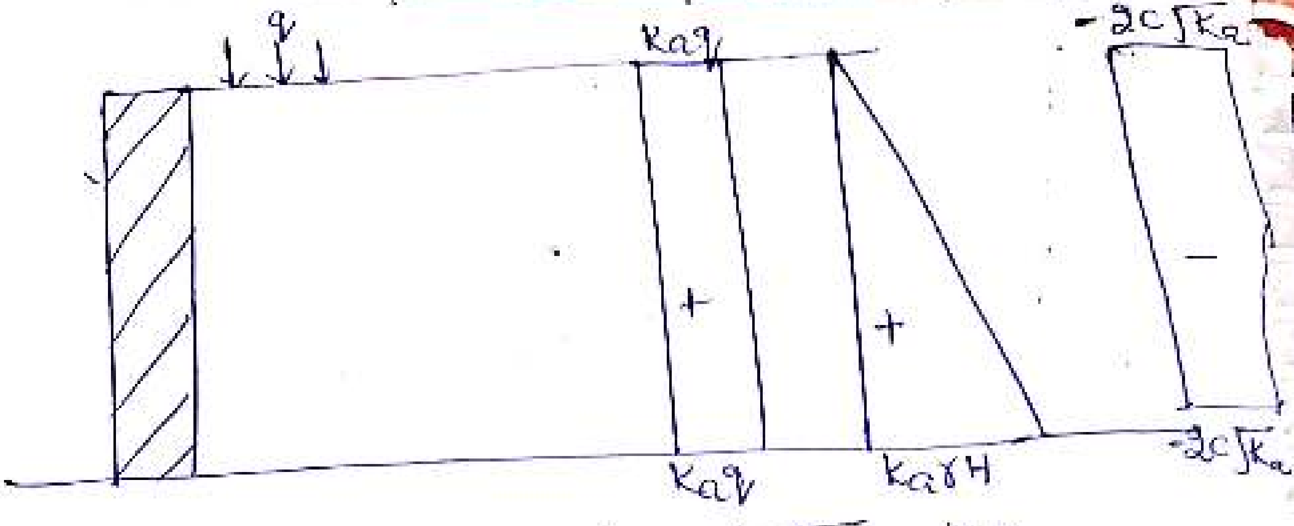
<u>Case 2</u> :- <u>Backfill with surcharge</u> :-

(1.) $\sigma_v = q + \gamma z$

(2.) $p_a = K_a \sigma_v - 2c\sqrt{K_a}$

$p_a = K_a q + K_a \gamma z - 2c\sqrt{K_a}$

p_a



Depth of tension crack $= \dfrac{2c\sqrt{K_a} - K_a q}{K_a \gamma}$

Surcharge required for no tension crack

$$q = \frac{2c\sqrt{K_a}}{K_a} = \frac{2c}{\sqrt{K_a}}$$

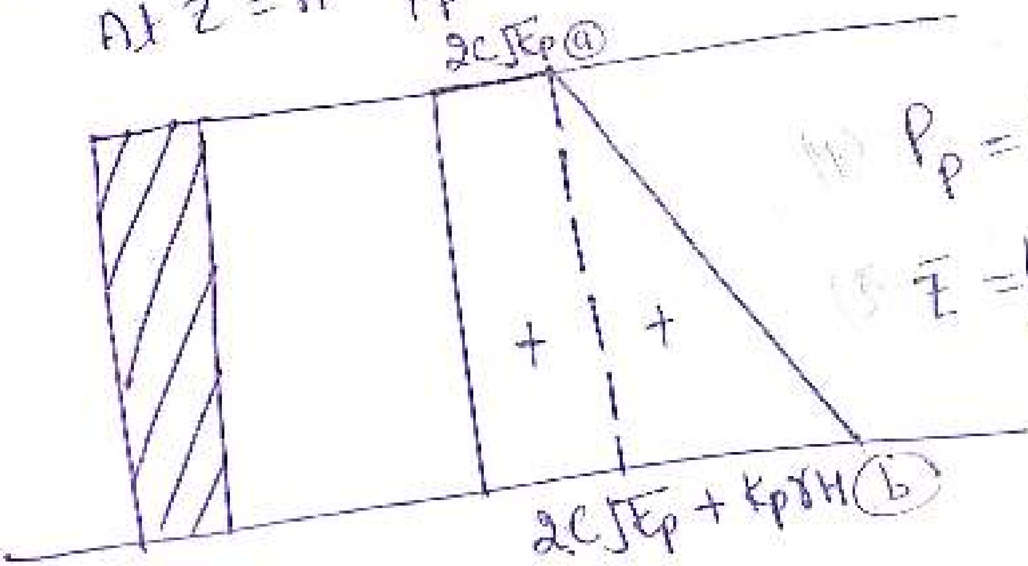
<u>Passive Earth Pressure in cohesive soil</u>:-

(1.) $\sigma_v = \gamma z$

(2.) $p_p = K_p \sigma_v + 2c\sqrt{K_p} = K_p \gamma z + 2c\sqrt{K_p}$

(3.) At $z = 0$ $\quad p_p = 2c\sqrt{K_p}$

At $z = H$ $\quad p_p = K_p \gamma H + 2c\sqrt{K_p}$



$$P_p = \left(\frac{a+b}{2}\right)H$$

$$\bar{z} = \left(\frac{2a+b}{a+b}\right)\frac{H}{3}$$

*. COULOMB'S WEDGE THEORY :-

ASSUMPTIONS :-

(1.) Soil is homogenous, isatropic, semi-infinite, elastic, dry and cohesionless.

(2.) The face of wall in contact with backfill is vertical or inclined and is rough.

(3.) The failure wedge acts as a rigid body and stresses over it are uniformly distributed.

(4.) The failure is essentially 2-D and rupture surface is planar and passes through the heel of the wall.

(5.) The location and direction of resultant thrust b/w wall and soil is known. The point of application is taken at the lower third point of the wall by assuming triangular distribution of earth pressure.

(6.) Wedge failure is considered which is under equilibrium of 3 forces :-

i) self weight of the wedge ABC.

ii) Resultant reaction (R) acts at downward angle of ϕ with normal to the rupture plane.

iii) Resultant Thrust (P_a), acts at an angle of δ with the normal to the face of the wall.

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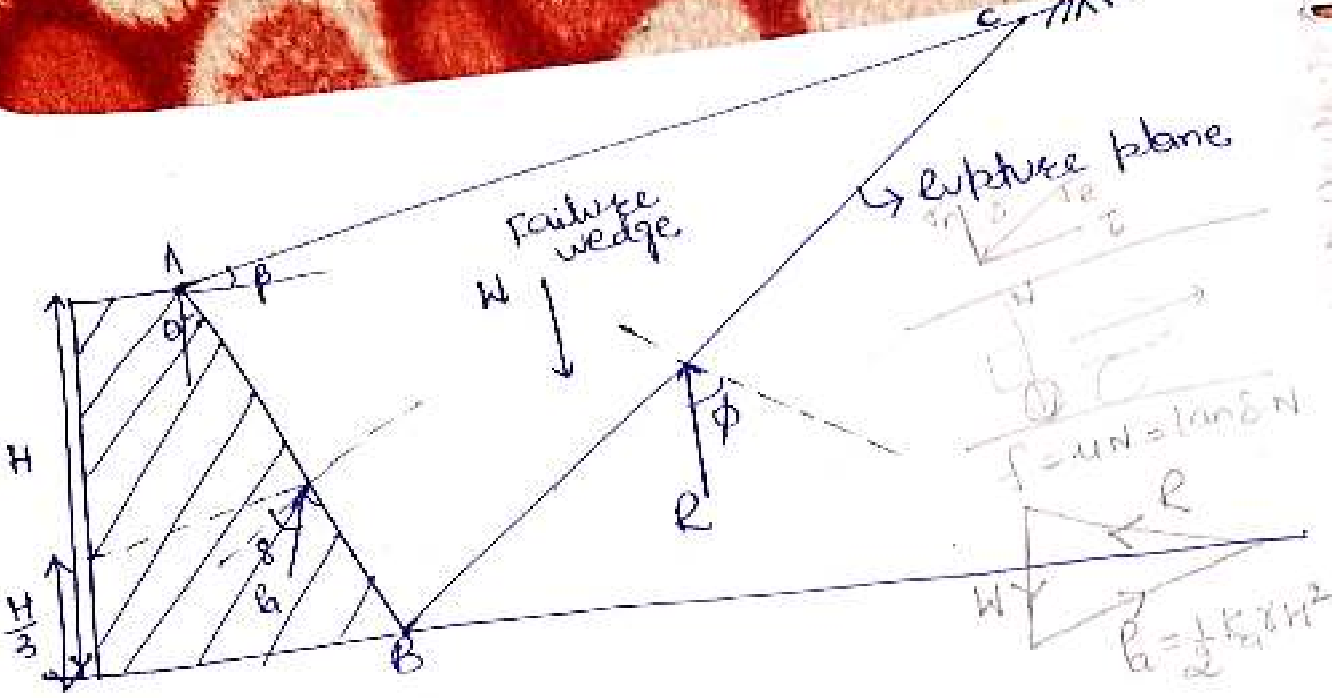


→ $P_a = \frac{1}{2} K_a \cdot \gamma \cdot H^2$

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

$$K_a = \left[\frac{\sec\theta \cdot \cos(\phi - \theta)}{\sqrt{\cos(\theta+\delta)} + \sqrt{\frac{\sin(\delta+\phi)\cdot \sin(\phi-\beta)}{\cos(\beta-\theta)}}} \right]^2$$

β → Angle of inclined backfill

ϕ → Internal Angle of friction

θ → Angle of face of wall with vertical

δ → friction angle b/w wall and soil.

Generally δ is assumed as $\frac{2}{3}\phi$.

Note :-

(1.) If wall is vertical $(\theta = 0)$.

(2.) If backfill is horizontal $(\beta = 0)$

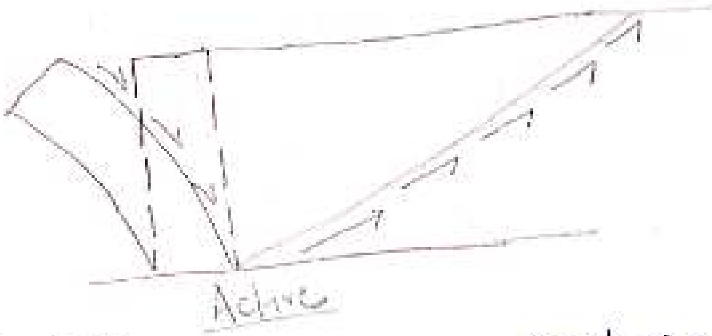
(3.) If wall is smooth then $(\delta = 0)$

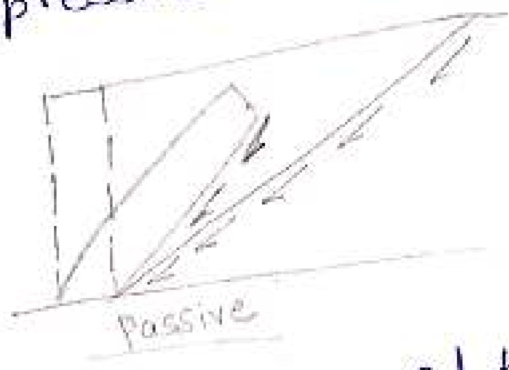
then $(k_a)_{colomb's} = (K_a)_{Rankine}$

Note.2 :-

Effect of wall friction

- The wall friction reduces the active pressure but increases the passive pressure.





Note 3 :-

In Colomb's Theory, failure plane is assumed to be planar but in actual it is spiral specially in passive case hence colomb's theory is not preferred for passive Earth pressure Analysis.

Note 4 :-

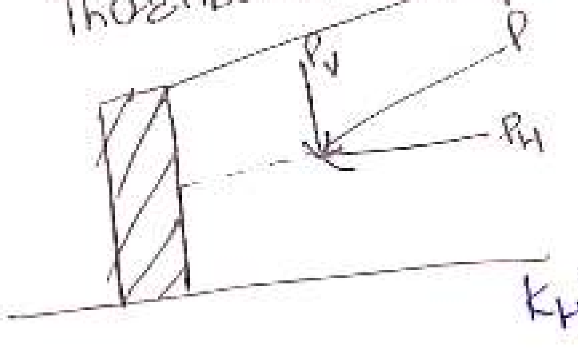
In Rankine's Theory elemental failure is considered whereas in Colomb's Theory Wedge failure is considered.

Note 5 :-

Earth pressure can also be computed using Culmann's Theory, Rebhmann's theory, Poncelet theory and Thornburn theory which are graphical in nature.

Culmann's Theory is based upon colomb's Theory.

Thornburn Theory



$P = \sqrt{P_H^2 + P_V^2}$

$P_H = \frac{1}{2} K_H H^2$

$P_V = \frac{1}{2} K_V H^2$

K_H & $K_V \rightarrow$ Earth pressure constant

Sheet pile wall :-

- Sheet pile walls consist of number of sheet piles driven side by side to form a continuous vertical wall into the medium which is used to retain the earth mass.
- sheet pile walls are generally used in water front structures, temporary construction, river training works, coffer dam, to prevent the piping failure below the dams and to prevent the failure of face of excavation.

Type of sheet pile walls :-

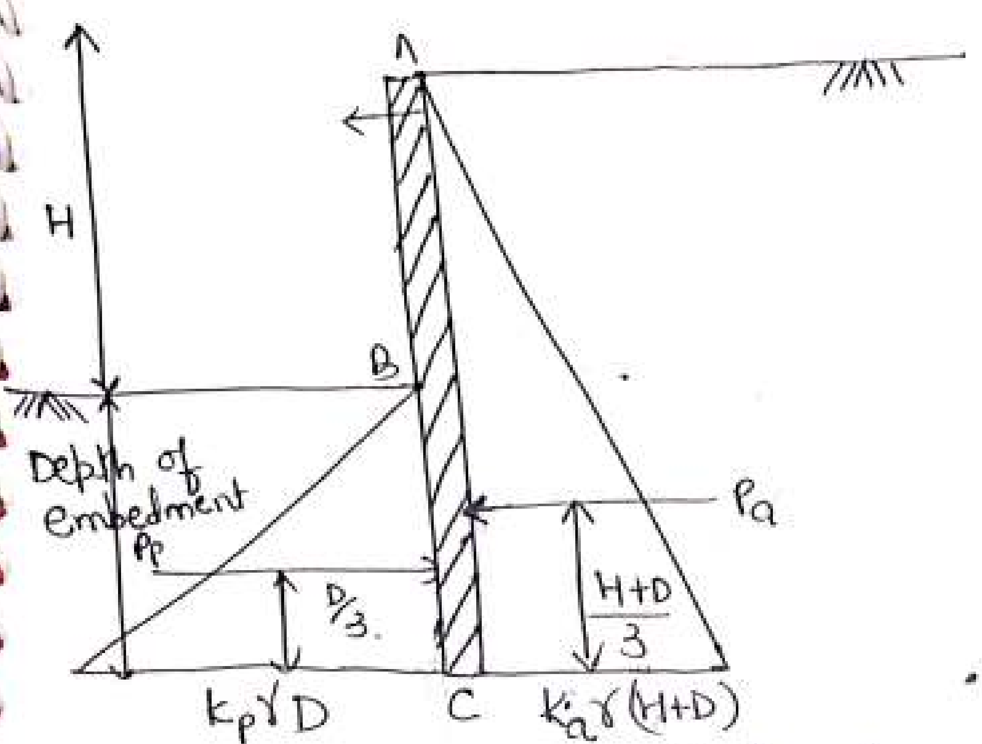
(1) Cantilever sheet pile wall :-

- In Actual, Rotation of sheet pile wall takes place about pivot point O hence sheet pile wall is subjected to -

	Right side	Left side
Active stage	ABO	OC
Passive stage	OC	OB

Case(i) :- For cohesionless soil

For simplicity in calculations sheet pile wall is assumed to rotate about base point C hence sheet pile wall is subjected to active pressure in right side ABC and also subjected to passive pressure in left side BC.



Minimum depth of embedment

$$\Sigma M_c = 0$$

$$P_p \cdot \frac{D}{3} - P_a \cdot \left(\frac{H+D}{3}\right) = 0$$

$$\rightarrow \frac{1}{2} k_p \gamma D^2 \cdot \frac{D}{3} - \frac{1}{2} k_a \gamma (H+D)^2 \cdot \left(\frac{H+D}{3}\right) = 0$$

Solve for D_{min}.

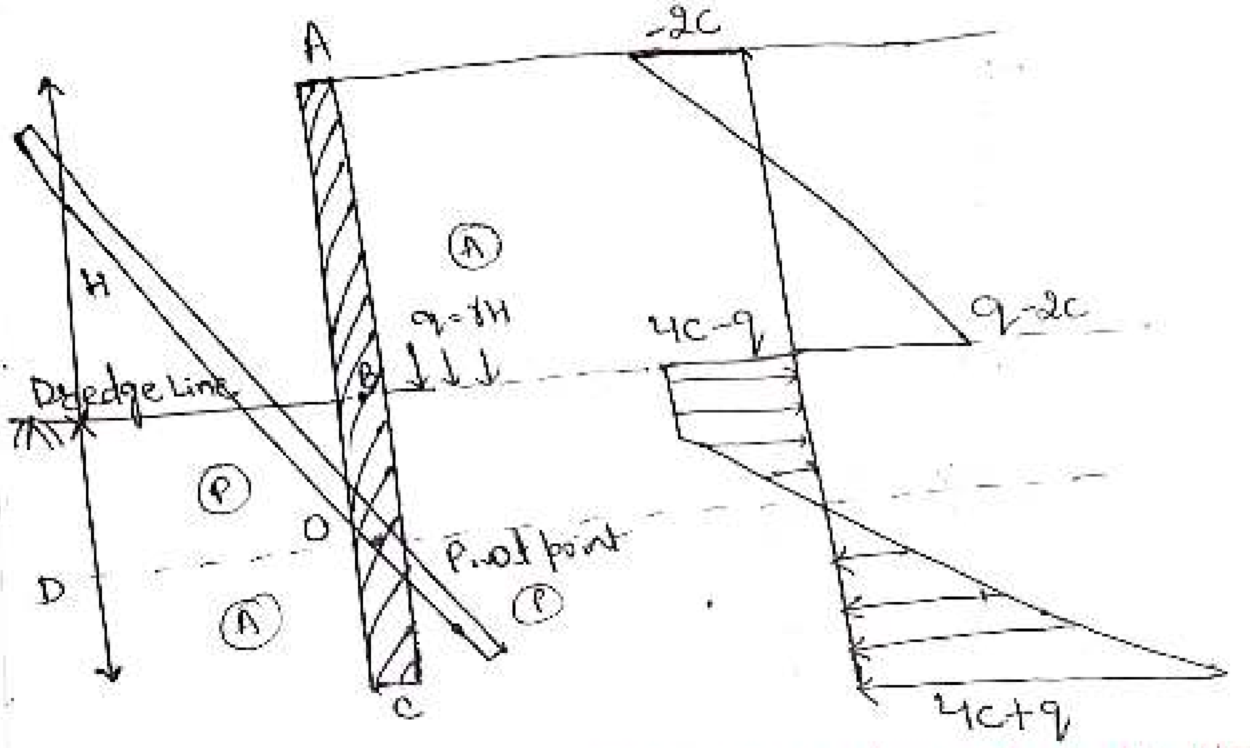
$\Rightarrow$ If F.O.S is given

$$F.O.S = \frac{M_R}{M_0} = \frac{P_p \cdot D/3}{P_a \cdot \left(\frac{H+D}{3}\right)} = \frac{\frac{1}{2} k_p \gamma D^2 \cdot \frac{D}{3}}{\frac{1}{2} k_a \gamma (H+D)^2 \cdot \left(\frac{H+D}{3}\right)}.$$

Solve for D_{safe}.

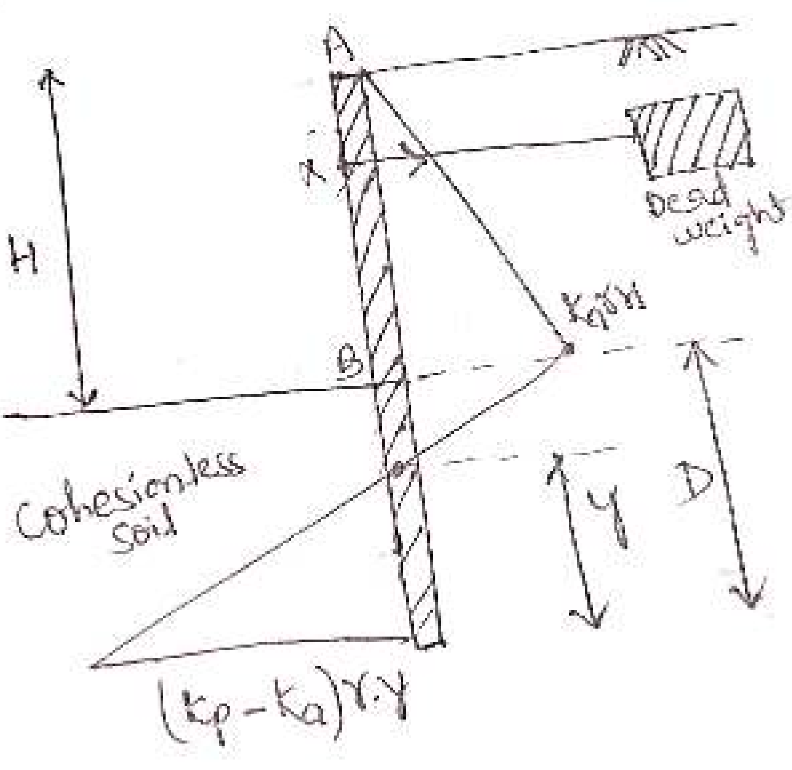
Case B:) In cohesive soil / clay ($\phi = 0^\circ$) $k_a = k_p = 1$

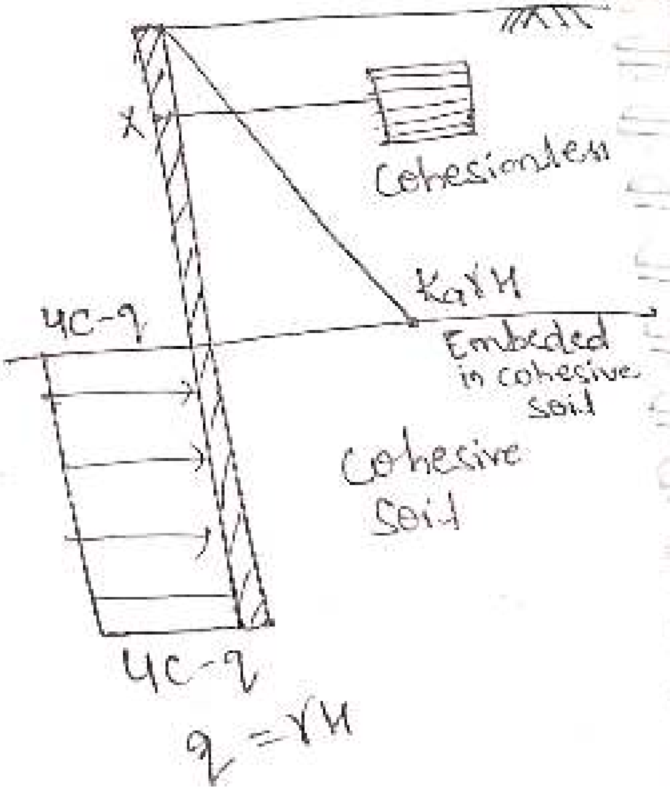
Assume the rotation about pivot O



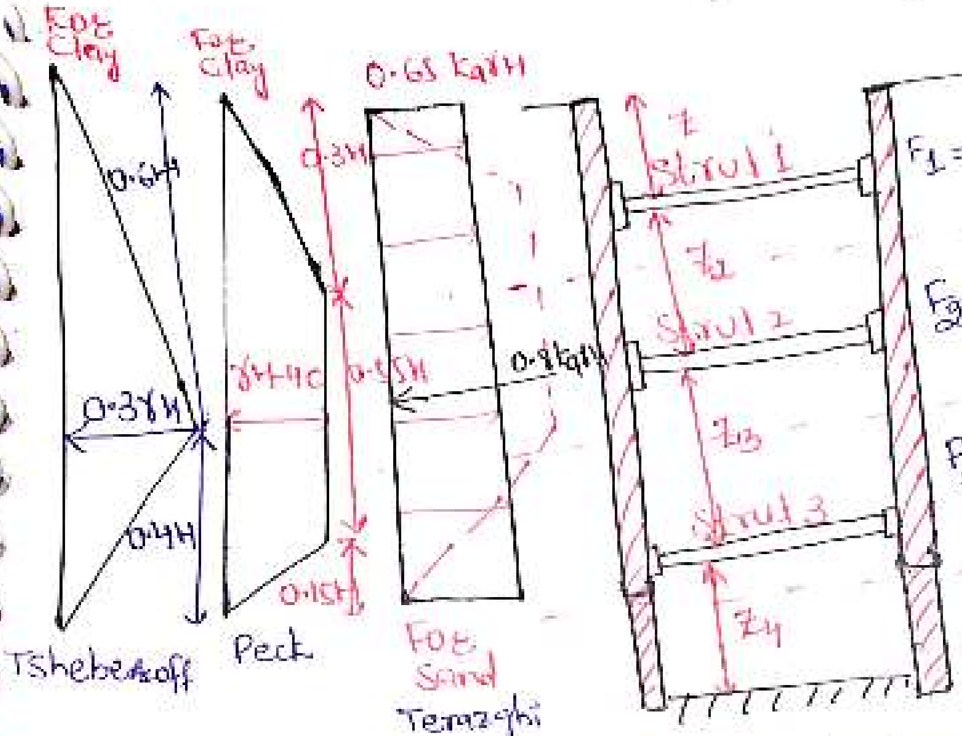
2) Anchored Sheet Pile (Anchored bulk Head) :-

For Information only





(3) BRACED SHEETING (Determination of strut load):-



$$F_1 = \underbrace{0.65 K_a \gamma H}_{\text{Pressure}} \times \underbrace{\left(Z_1 + \frac{Z_2}{2}\right) b}_{\text{Area}}$$

$$F_2 = 0.65 K_a \gamma H \times \left(\frac{Z_2 + Z_3}{2}\right) b$$

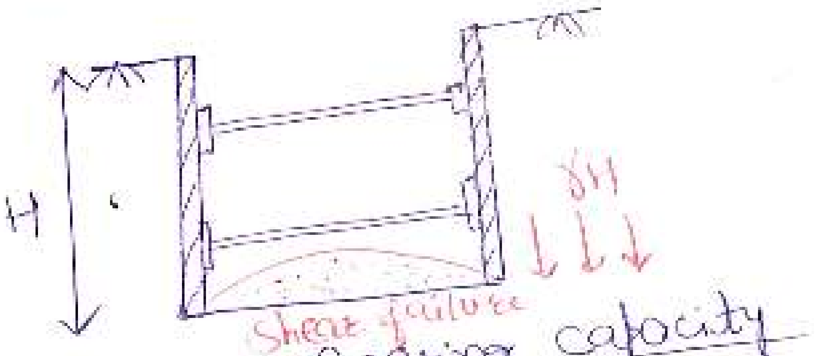
$$F_3 = 0.65 K_a \gamma H \left(\frac{Z_3 + Z_4}{2} \times b\right)$$

$\frac{Z_4}{2}$ → will be taken by soil

lateral spacing b/w struts → b

Note:-

F.O.S against heaving in Braced cut



$$F.O.S = \frac{\text{Bearing capacity}}{\text{Applied pressure}} = \frac{C N_c}{\gamma H}$$