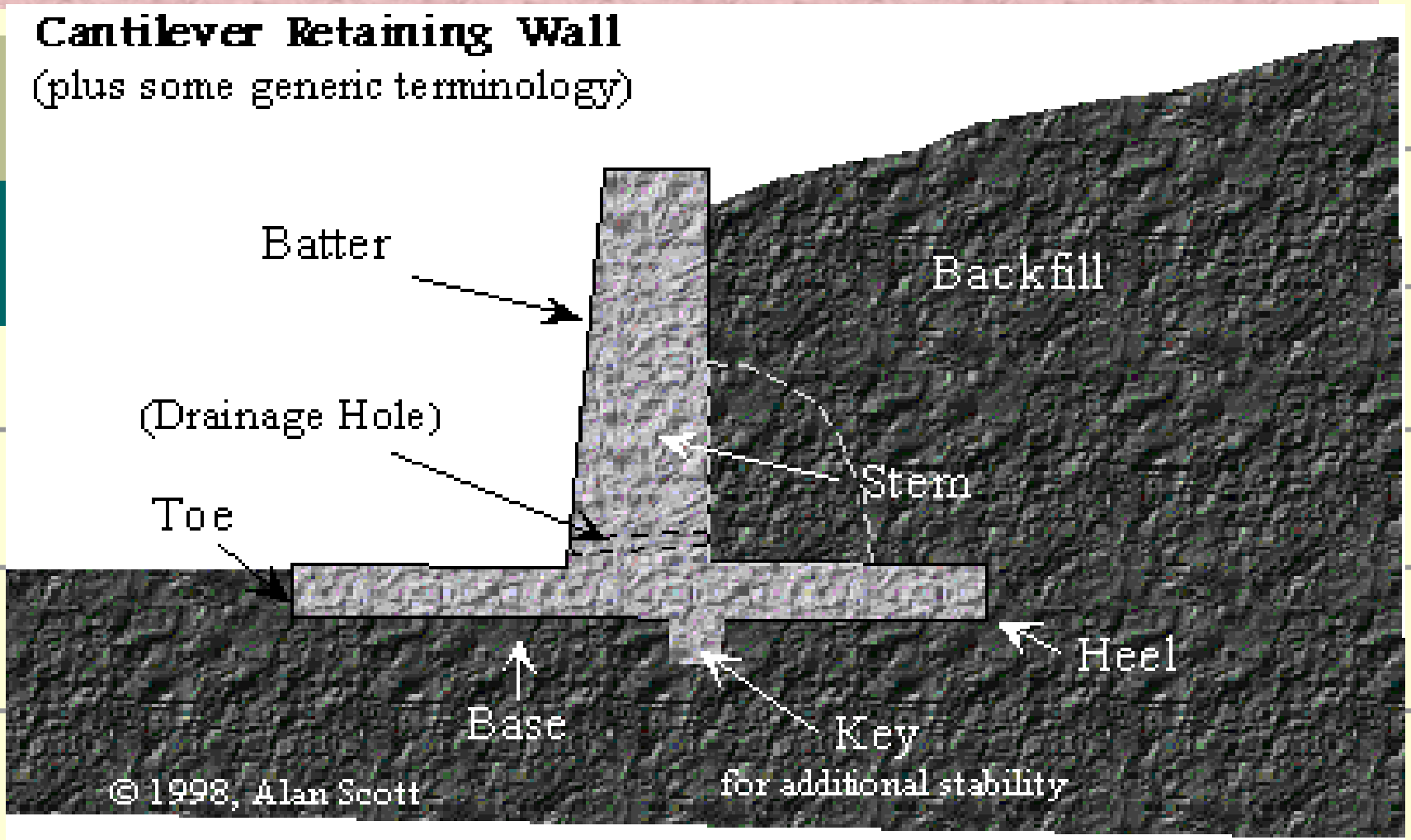
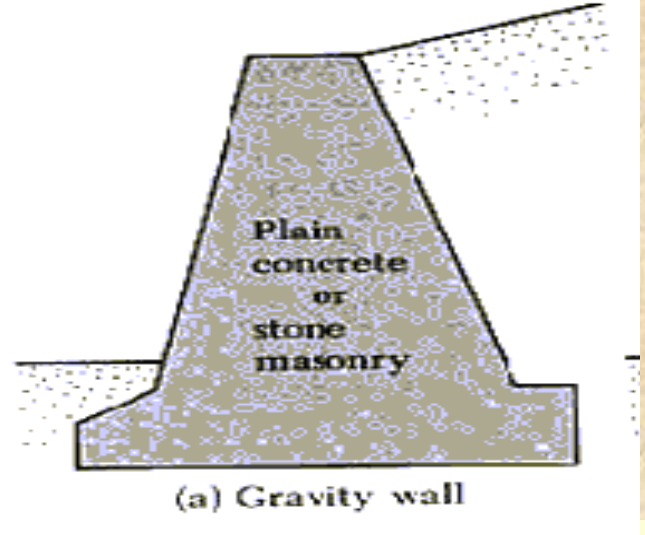
8. Lateral Earth Pressure



- Retaining walls are structures used to provide stability of earth or other material where conditions disallow the mass to assume its natural slope.

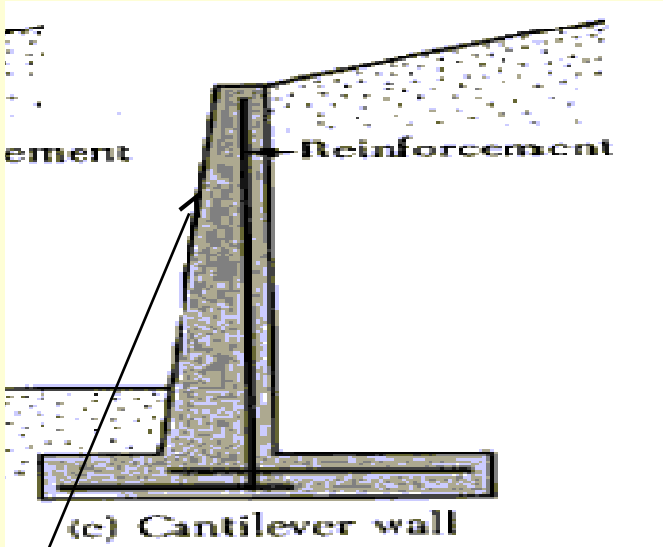
- Common Types of retaining walls
- **Gravity walls:-**
  - **made of plain concrete or stone masonry**
  - **depends upon its weight for stability**



(a) Gravity wall

Cantilever walls

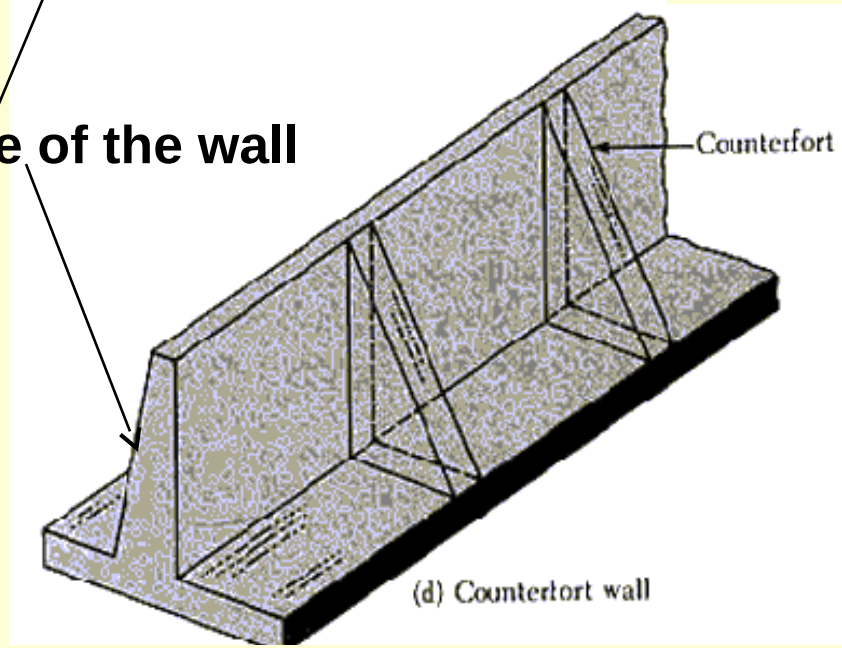
- made of reinforced concrete material
- inverted T-shaped in section each projecting acts as a cantilever.



- Counterfort walls
  - made of reinforced concrete materials
  - consists of cantilever wall with vertical brackets known as counterfort placed behind face of wall
- Buttress walls

  same as counterfort except that the vertical brackets are on the opposite side of the backfill

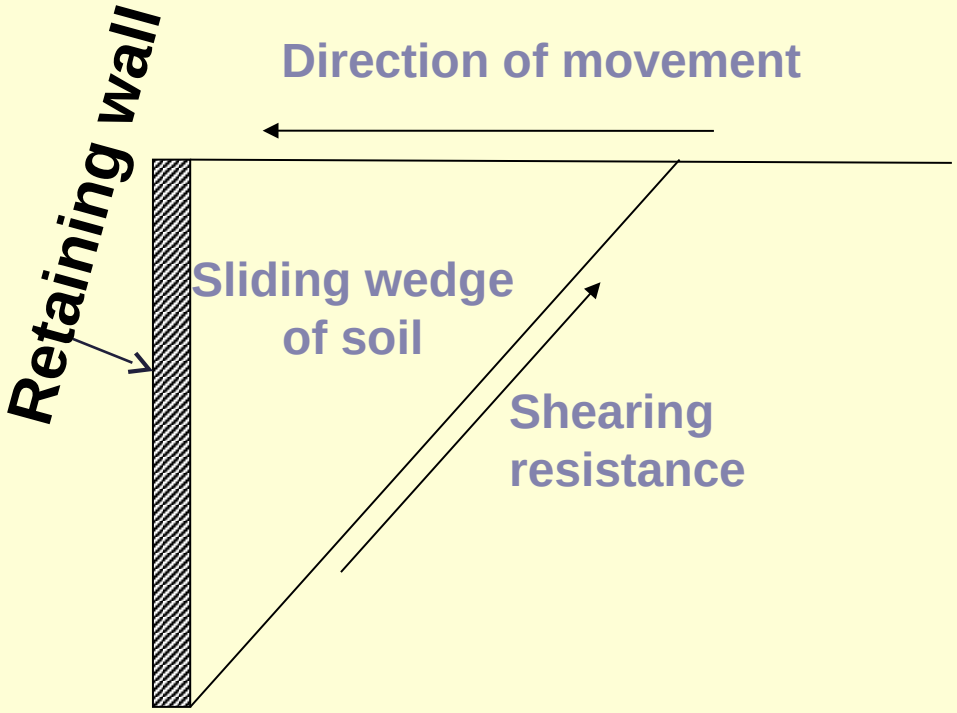
Face of the wall



LATERAL EARTH PRESSURE

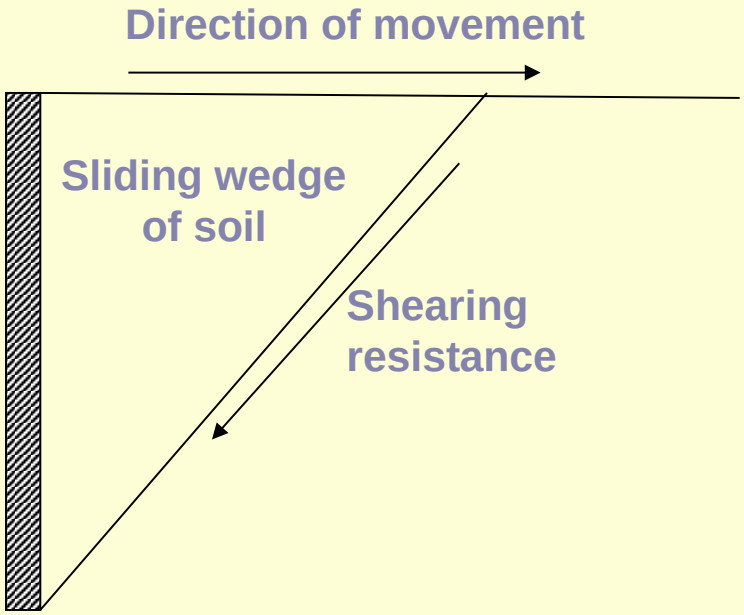
- Proper design and construction of retaining structures require a through knowledge of the lateral forces interacting between the retaining structures and the soil masses retained.
- These lateral forces are due to lateral earth pressure.
- DIFFERENT TYPES OF LATERAL EARTH PRESSURES
- There are three distinct kinds of lateral soil pressures;
  - Active lateral earth pressure
  - Passive lateral earth pressure
  - Earth pressure at Rest.

•**Consider a retaining wall, which holds back a mass of clean, dry, cohesionless sand.**



active pressure case

This pressure is termed as active pressure because the weight of the backfill is responsible for the movement of the wall.



passive pressure case

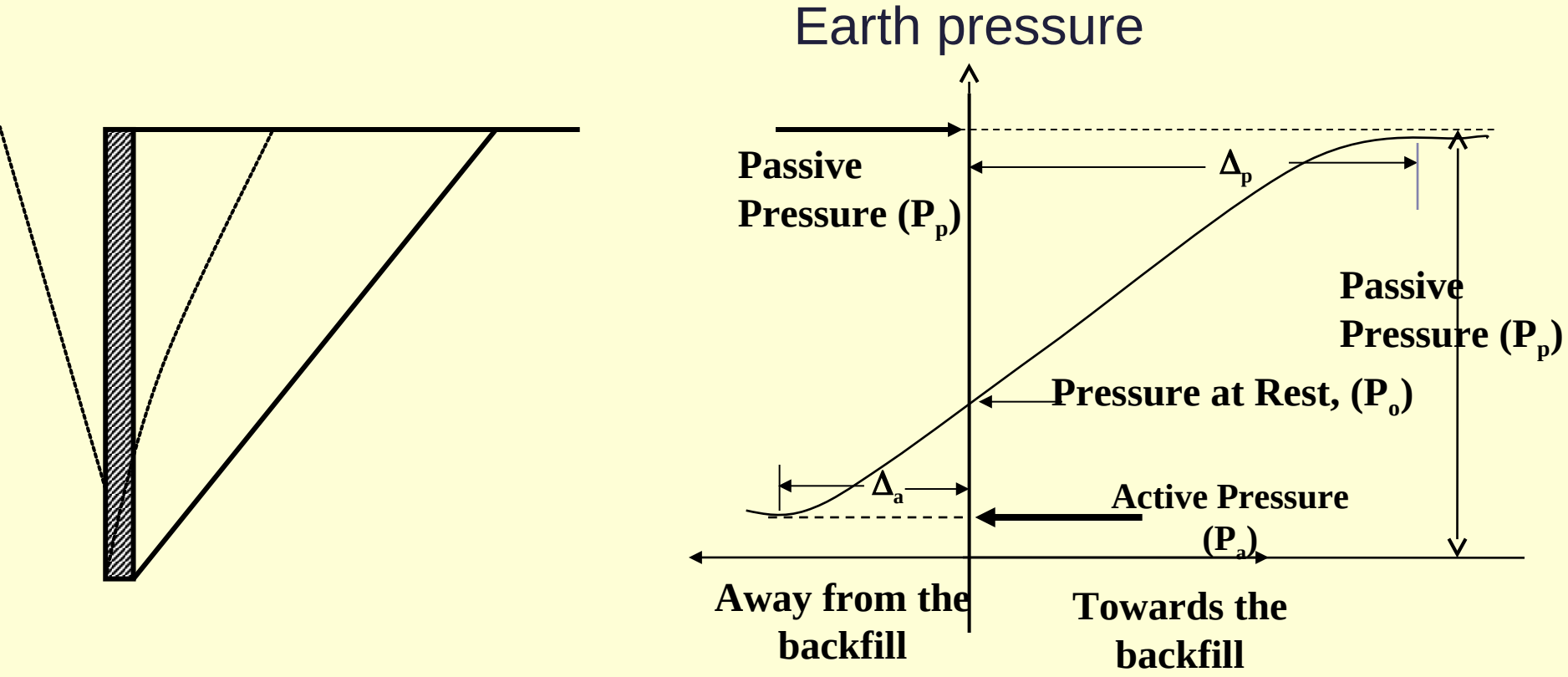
This pressure is called passive because the weight of the backfill opposes the movement of the wall.

Earth pressure at Rest.

- **The pressure, which develops at zero movement of the wall, is called earth pressure at rest.(example is the basement retaining walls which are restrained against the movement by the basement slab at the top.)**
- **Its value somewhat larger than the value of active pressure but it is considerably less than the passive pressure.**

VARIATION OF LATERAL EARTH PRESSURE WITH WALL MOVEMENT

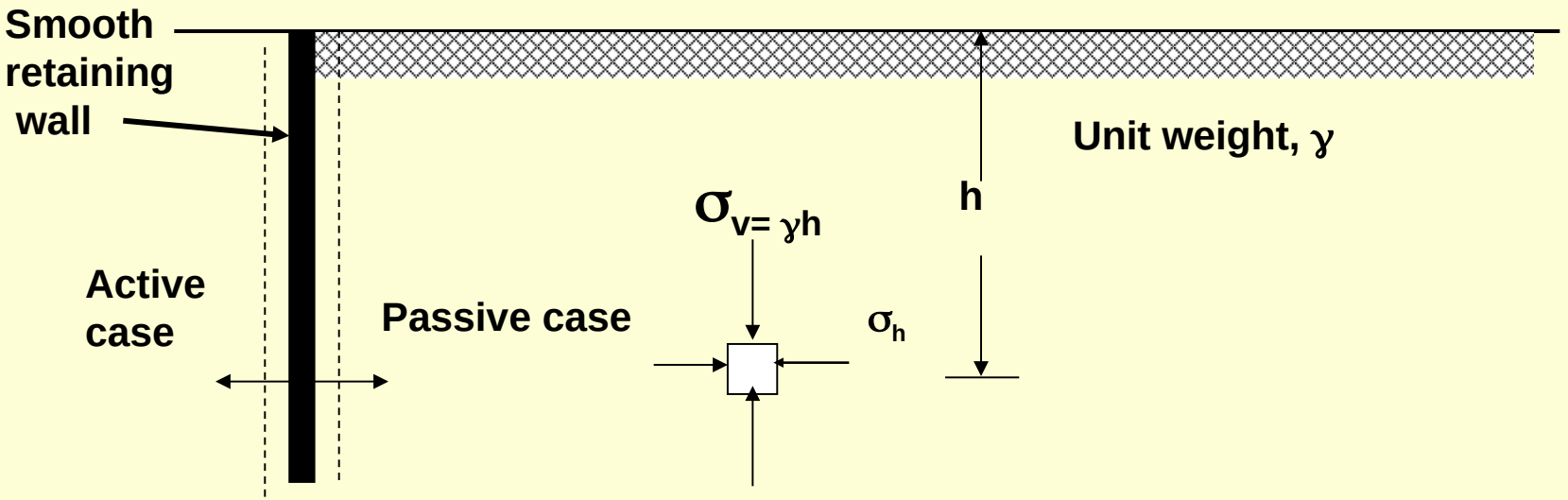
- **Consider a rigid retaining wall with a plane vertical face backfilled with cohesionless soil.**



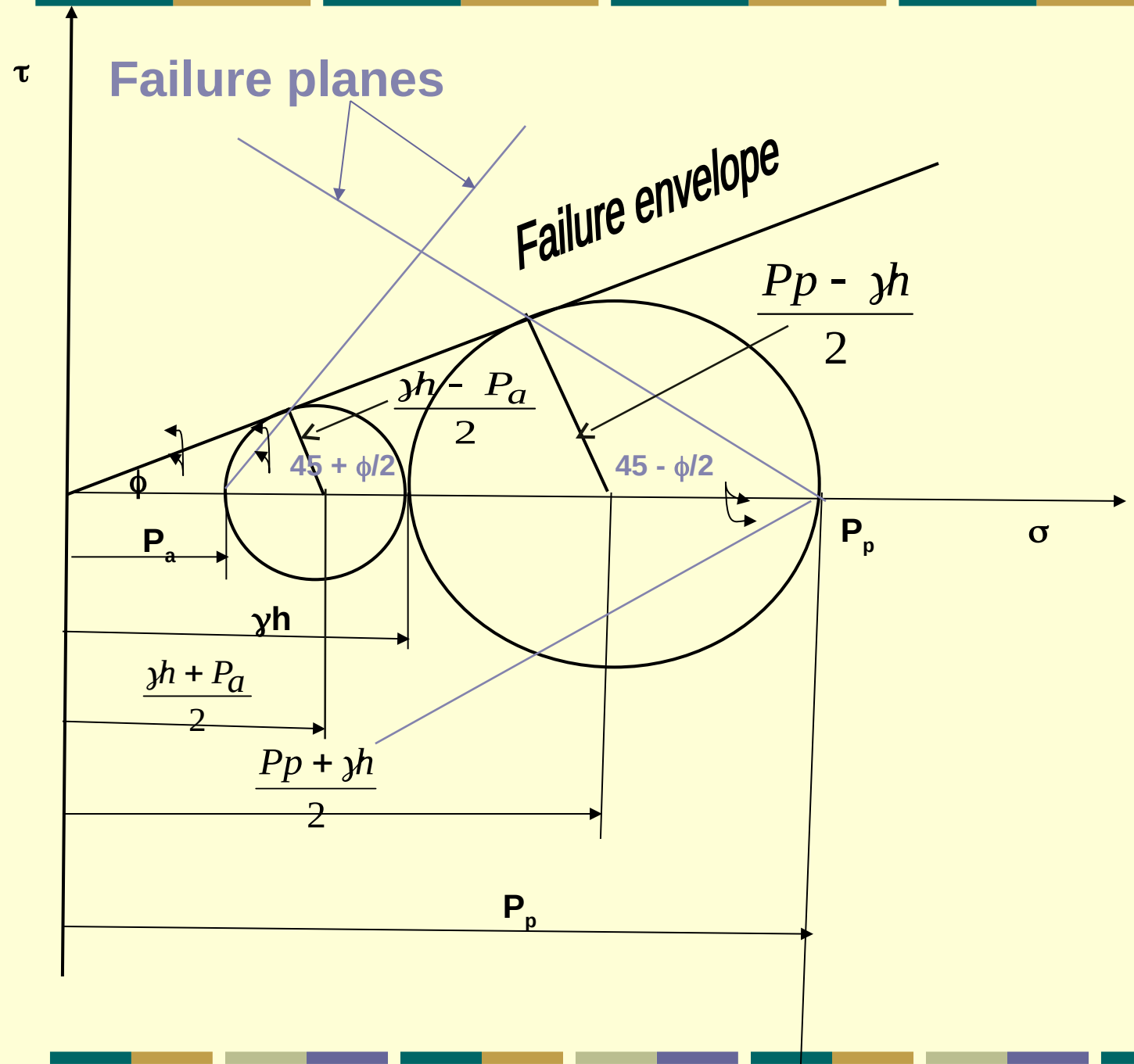
RANKINE'S EARTH PRESSURE THEORY

- The following assumptions were made by Rankine for the derivation of earth pressure.
  - The soil mass is homogeneous and semi-infinite
  - The back of the retaining wall is smooth and vertical
  - The soil element is in the state of plastic equilibrium*.
- *A mass of soil is said to be in a state of plastic equilibrium if failure is about to occur simultaneously at all points within the mass.

Relationships Between Vertical Pressure and Active and Passive Earth Pressures at State of Plastic Equilibrium.



Failure planes



Active Pressure

$$\sin\phi = \frac{\gamma h - P_a}{\gamma h + P_a} \quad \Rightarrow \quad (\gamma h + P_a)\sin\phi = \gamma h - P_a$$

$$P_a \sin\phi + P_a = \gamma h - \gamma h \sin\phi \Rightarrow P_a = \gamma h \frac{1 - \sin\phi}{1 + \sin\phi} \Rightarrow P_a = \gamma h\, k_a$$

where $k_a = \frac{1 - \sin\phi}{1 + \sin\phi} = \tan^2\left(45 - \frac{\phi}{2}\right)$

k_a = Coefficient of active earth pressure

Passive Pressure

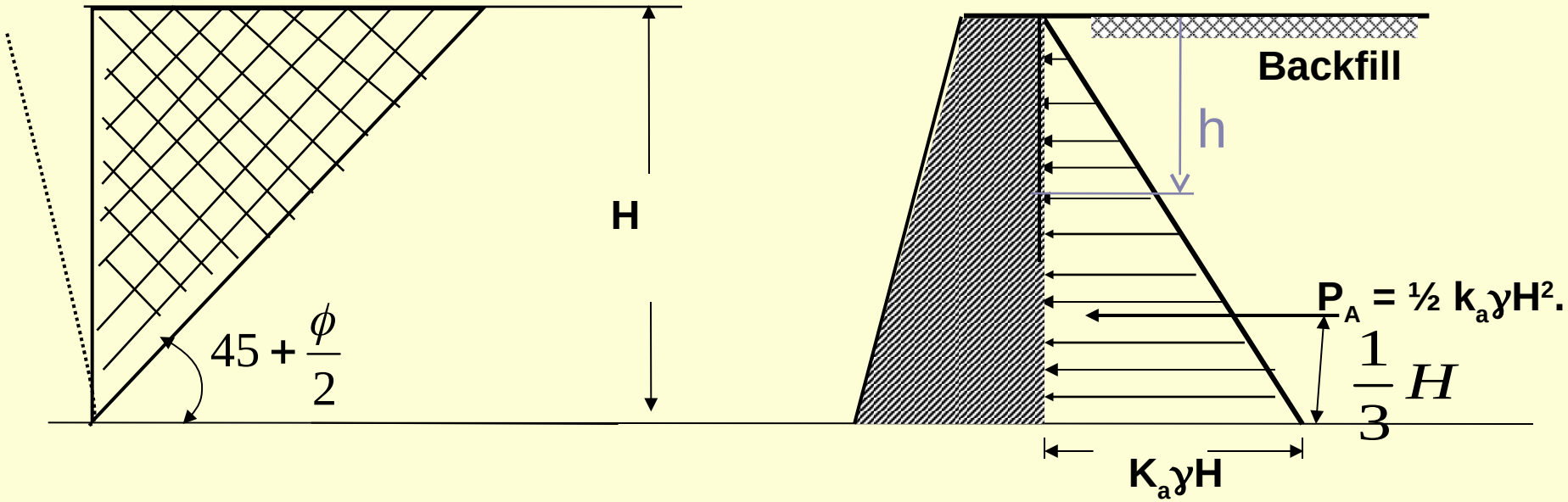
$$\sin\phi = \frac{Pp - \gamma h}{Pp + \gamma h} \Rightarrow (P_p + \gamma h)\sin\phi = P_p - \gamma h \Rightarrow P_p = \gamma h \frac{1 + \sin\phi}{1 - \sin\phi} \Rightarrow P_p = \gamma h K_p$$

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

K_p = Coefficient of passive earth pressure

TOTAL LATERAL EARTH PRESSURE AGAINST A VERTICAL WALL WITH THE SURFACE HORIZONTAL.

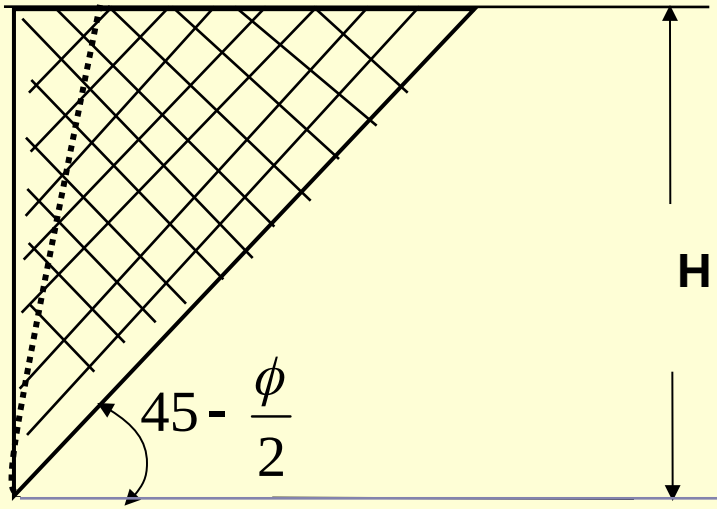
Active Earth Pressure

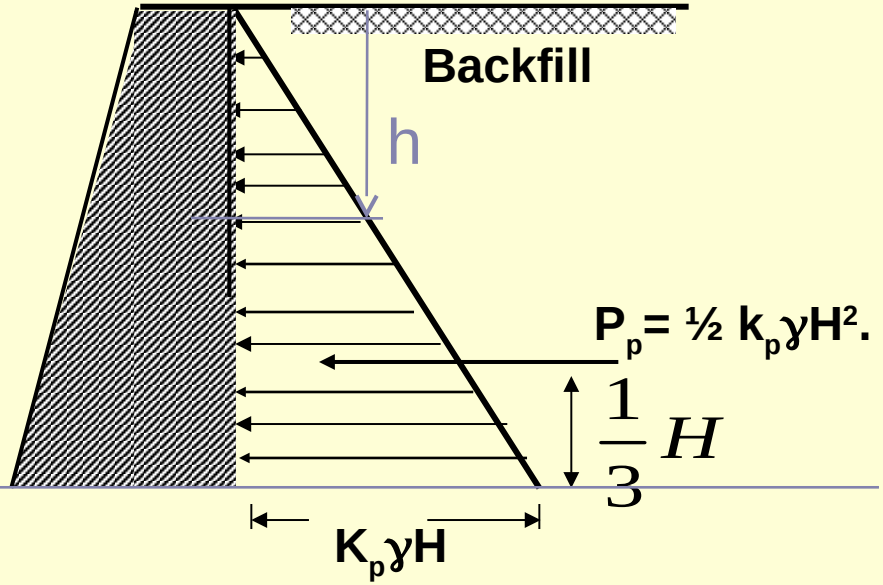


The total active lateral pressure force per unit length of the wall is given by

$$P_A = \int_0^H Ka\gamma h\,dh = ½\ k_a\gamma H^2.$$

Passive Earth Pressure





The total passive lateral pressure force per unit length of the wall is given by $P_p = \int_0^H Kp\,\gamma h\,dh$ **= ½ $k_p \gamma H^2$.**

Earth Pressure at Rest

The lateral pressure is given by $P_o = k_o \gamma H$ and the corresponding total lateral pressure force per unit length of the wall is given by $P_o = ½ k_0 \gamma H^2$

where K_o = Coefficient of earth pressure at rest condition

According to Jaky (1944), K_0 is given by: $k_O = 1 - Sin\phi$

RANKINE'S LATERAL EARTH PRESSURE THEORY FOR DIFFERENT BACKFILL CASES

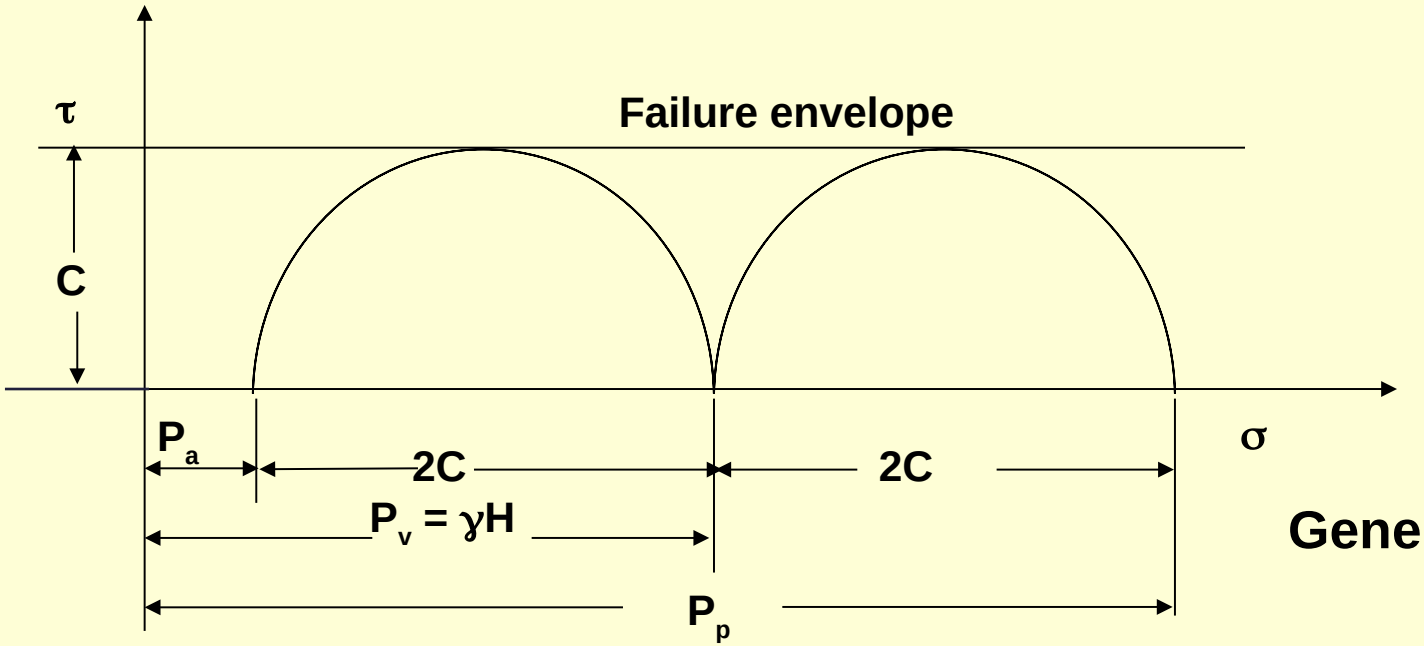
- Lateral Earth Pressure of Partially Submerged Cohesionless Soil.
- Lateral Earth Pressure of Cohesionless Soil Carrying Uniform surcharge
- Lateral Earth Pressure of Cohesionless Soil on Sloping Back wall
- Lateral Earth Pressure of Cohesionless Soil with Inclined Surface

$$k_a = \cos\beta \frac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}$$

$$k_p = \cos\beta \frac{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}$$

RANKINE'S EARTH PRESSURE THEORY FOR COHESIVE SOILS

- Active and Passive Earth Pressures of Pure Cohesive Soils.
- Relationships Between Vertical and Lateral Pressures

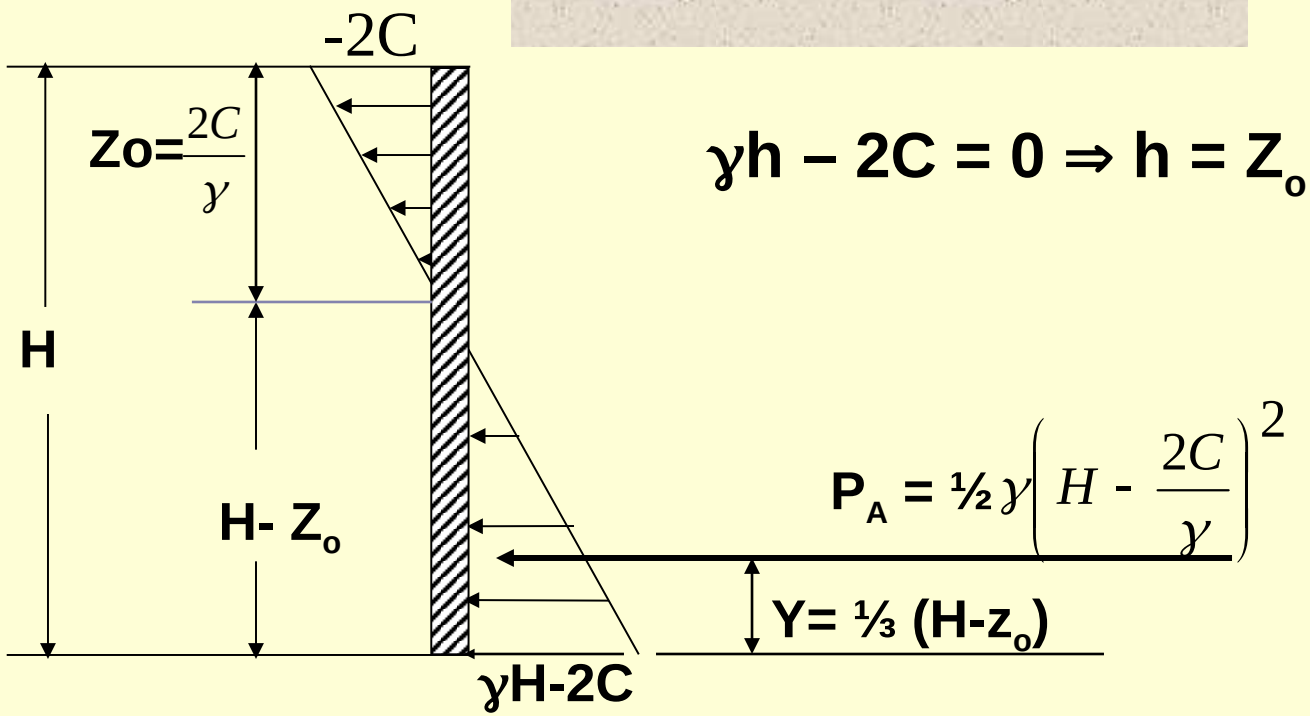


General case

$Pa = Pv - 2C = \gamma H - 2C$

$Pp = Pv + 2C = \gamma H + 2C$

Active pressure case



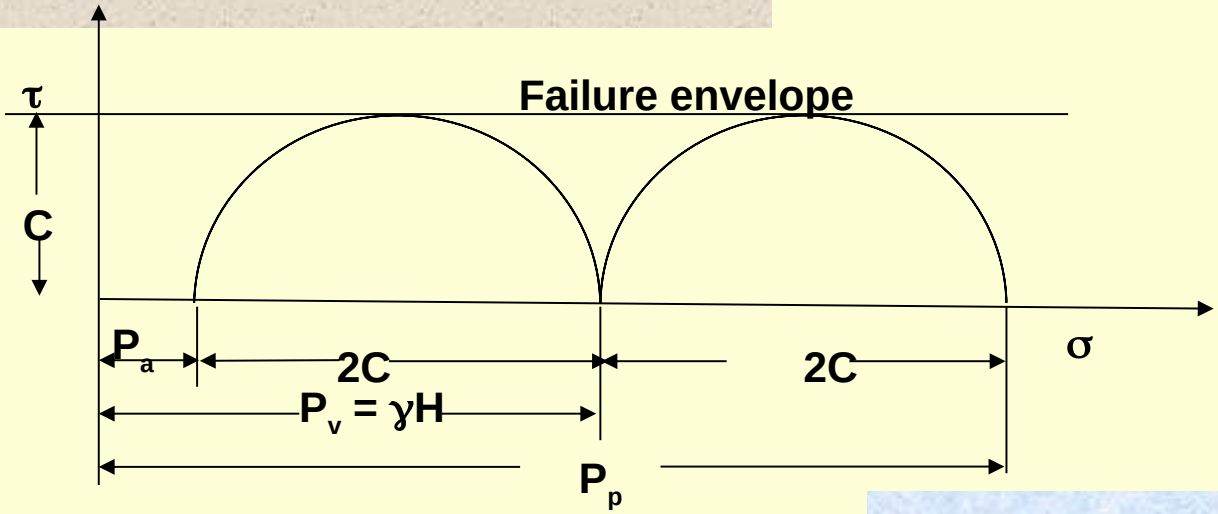
$$\gamma h - 2C = 0 \Rightarrow h = Z_o = \frac{2C}{\gamma}$$

If the wall has a height $2Z_o = H_{cr}$ the total earth pressure is equal to zero.

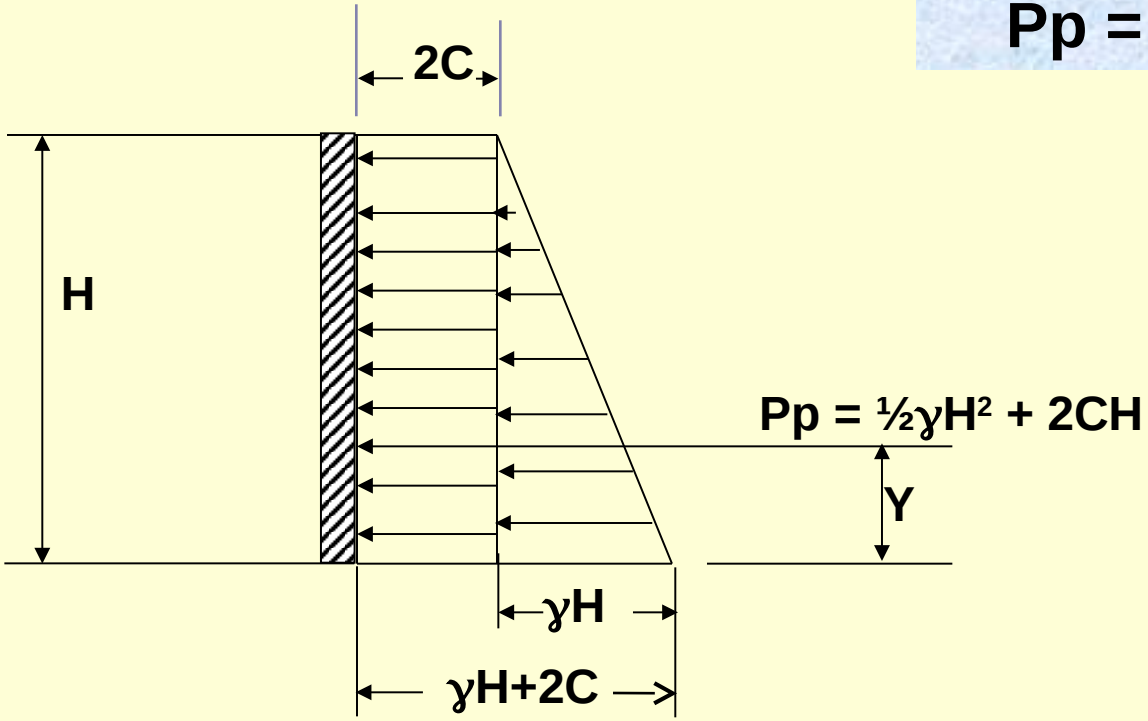
i.e., $\frac{1}{2}\gamma H_{cr}^2 - 2CH_{cr} = 0 \Rightarrow H_{cr} = \frac{4C}{\gamma} = 2Z_O$

This indicates that a vertical bank of height smaller than H_{cr} can stand without lateral support. H_{cr} is called as critical depth.

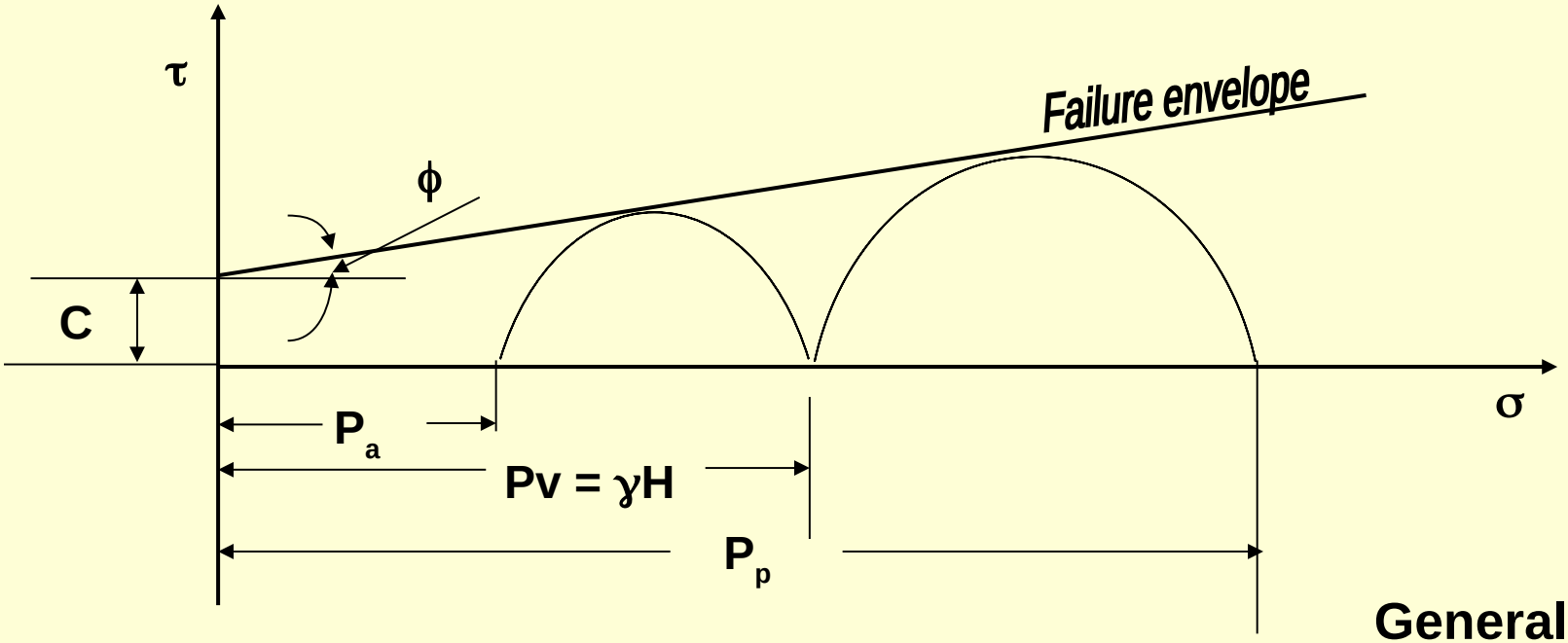
Passive pressure case



$$Pp = Pv + 2C = \gamma H + 2C$$



•Active and Passive Earth Pressures for Mixed Soils (or C-ϕ Soils)



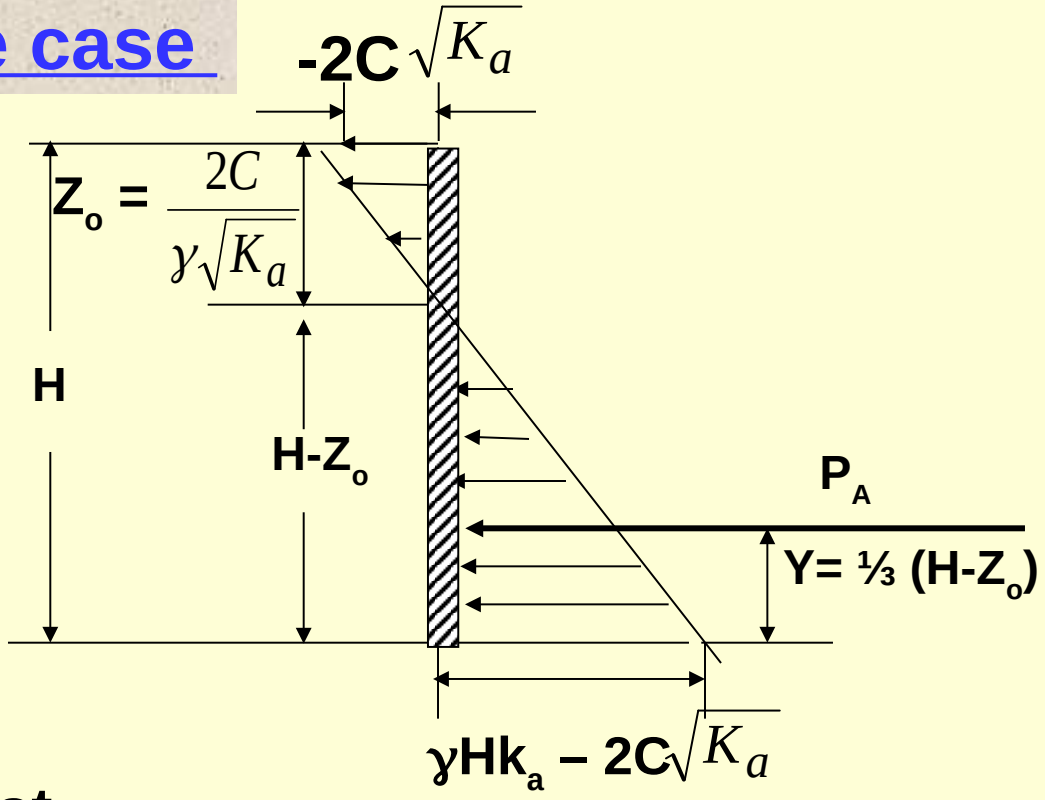
General case

$$P_a = \left(\gamma H k_a - 2C\sqrt{K_a}\right)$$

$$P_p = \gamma H K_p + 2C\sqrt{K_p}$$

Active Pressure case

$$P_a = \left(\gamma H k_a - 2C\sqrt{K_a}\right)$$



The resultant thrust

$$P_A = \tfrac{1}{2}\left(\gamma H k_a - 2C\sqrt{K_a}\right)\left(H - \frac{2C}{\gamma\sqrt{K_a}}\right)$$

$$P_A = \tfrac{1}{2}\gamma H^2 k_a - 2CH\sqrt{K_a} + \frac{2C^2}{\gamma}$$

Passive Pressure case

$P_p = \gamma H K_p + 2C\sqrt{K_p}$

