Geotechnical Engineering (18CV54)

Module – 3: Lateral Earth Pressure

Introduction:

- In the design of retaining walls, sheet piles or other earth retaining structures, it is necessary to compute the lateral pressure exerted by the retained mass of soil.
- The question of finding out the lateral earth pressure against retaining walls is one of the oldest in the civil engineering field.
- A retaining wall or structure is used for maintaining the ground surfaces at different elevations on either side of it.

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Definition:

Retaining wall: a retaining structures is a permanent or temporary structures which is used for providing lateral support to soil masses or other materials.

Back fill: the material retained or supported by the structure, which may have its top surface horizontal or inclined.

Surcharge: the position of the back fill laying above a horizontal plane at the elevation of the top of a wall is called the surcharge and its inclination is called surcharge angle.

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Definition:

Lateral Earth Pressure: when the earth pressure acts on the side of a retaining wall, it is known as the lateral earth pressure.

The magnitude of the lateral earth pressure depends upon the movement of the retaining wall relative to the backfill and upon the nature of the soil.

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Plastic Equilibrium in Soils:

- A body of soil is said to be in plastic equilibrium if every point of it is on the verge of failure.
- Rankine investigated the stress conditions corresponding to those states of plastic equilibrium which can be developed simultaneously throughout a semi-infinite mass of soil acted on by no force other than gravity.
- The stress condition during plastic equilibrium can be represented by the following Mohr-Coulomb equation:

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Plastic Equilibrium in Soils:

$$((\sigma_1 - \sigma_3) / 2) - ((\sigma_1 + \sigma_3 / 2) \text{ x } \sin \Phi = c \cos \Phi - (1)$$

Or

$$\sigma_1 = 2c \tan (45° + \Phi/2) + \sigma_3 \tan^2 (45° + \Phi/2) - (2)$$

Where,

σ_1 and σ_3 = major and minor principal stresses at any point in the soil mass, at failure.

- If c =0 then equation (2) reduces to

$$\sigma_1 / \sigma_3 = \tan^2 (45° + \Phi/2)$$

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Plastic Equilibrium in Soils:

- The ratio of the horizontal stress σ_h to the vertical stress σ_v is called the co-efficient of earth pressure K.
- When the soil is in active state of plastic equilibrium, $\sigma_h = \sigma_3$ and $\sigma_v = \sigma_1$.

$$\sigma_1 / \sigma_3 \text{ (or) } \sigma_v / \sigma_h = \tan^2 (45° + \Phi/2)$$

$$\sigma_h / \sigma_v = K_a = (1 / \tan^2 (45° + \Phi/2)) = \cot^2 (45° + \Phi/2) = (1 - \sin \Phi) / (1 + \sin \Phi)$$

Where, K_a = co-efficient of active earth pressure

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Plastic Equilibrium in Soils:

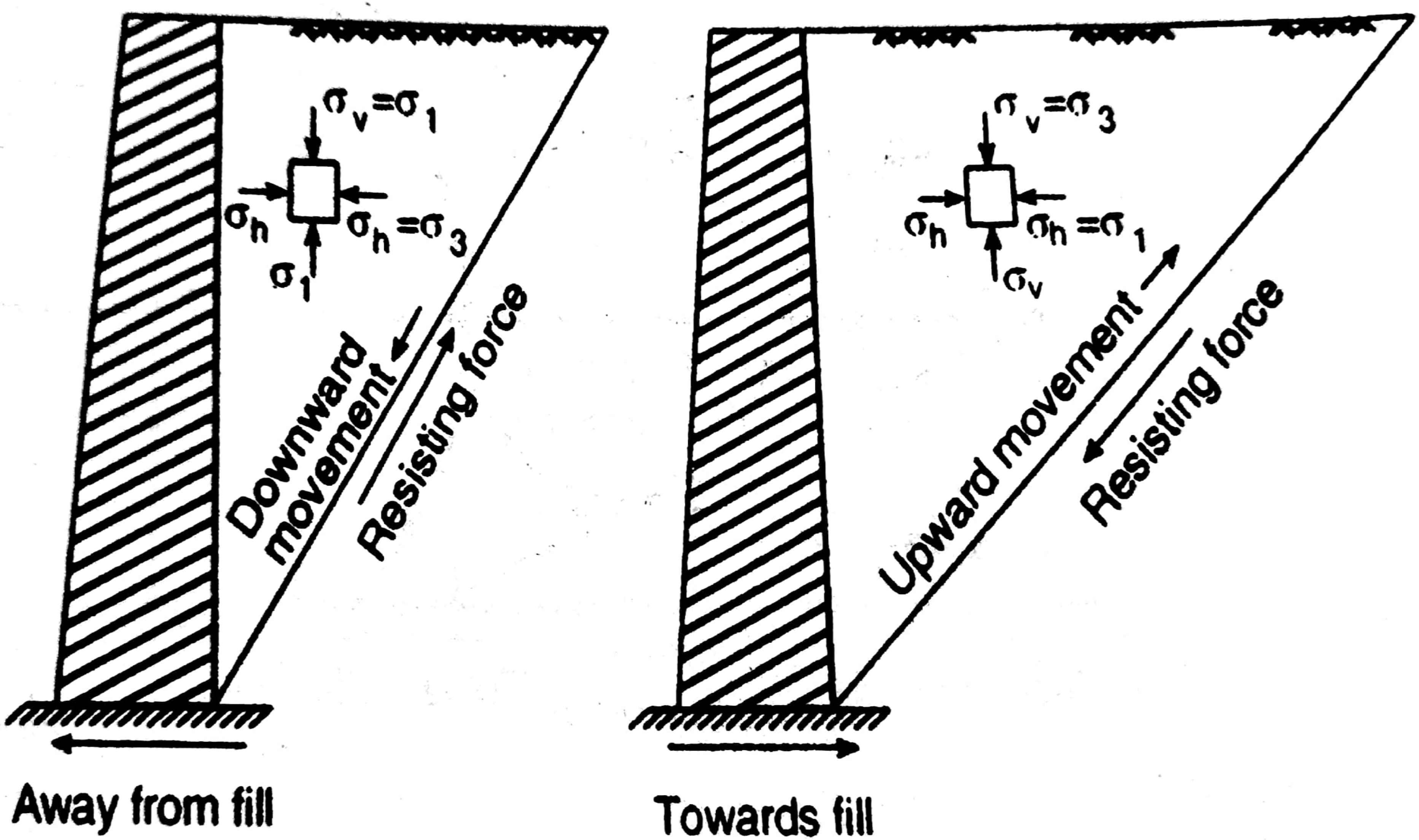
- Similarly, in passive state, $\sigma_h = \sigma_1$ and $\sigma_v = \sigma_3$

$$\sigma_1 / \sigma_3 \text{ (or) } \sigma_h / \sigma_v = \tan^2 (45° + \Phi/2)$$

$$\sigma_h / \sigma_v = K_p = (\tan^2 (45° + \Phi/2)) = (1 + \sin \Phi) / (1 - \sin \Phi)$$

- When the soil is at elastic equilibrium (i.e. at rest) the ratio of horizontal to vertical stress is called the co-efficient of earth pressure at rest.

$$\sigma_h / \sigma_v = K_o$$



(a) Active state

(b) Passive state

FIG. 20.2 ACTIVE AND PASSIVE EARTH PRESSURE.

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Active Earth Pressure:

- Let us consider a retaining wall which holds back a mass of soil. According to this we can define the active earth pressure as follows:
- "When the wall moves away from the backfill, a portion of the backfill located next to the retaining wall tends to break away from the rest of the soil mass and tends to move downwards and outwards relative to the wall. There is a resultant decrease in earth pressure takes place".

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Passive Earth Pressure:

- Let us consider a retaining wall which holds back a mass of soil. According to this we can define the active earth pressure as follows:
- "When the wall moves towards the backfill, the soil is compressed and the earth pressure gradually increases because the shearing resistance built up in direction towards the wall. Any further movement of the wall does not increases the pressure".

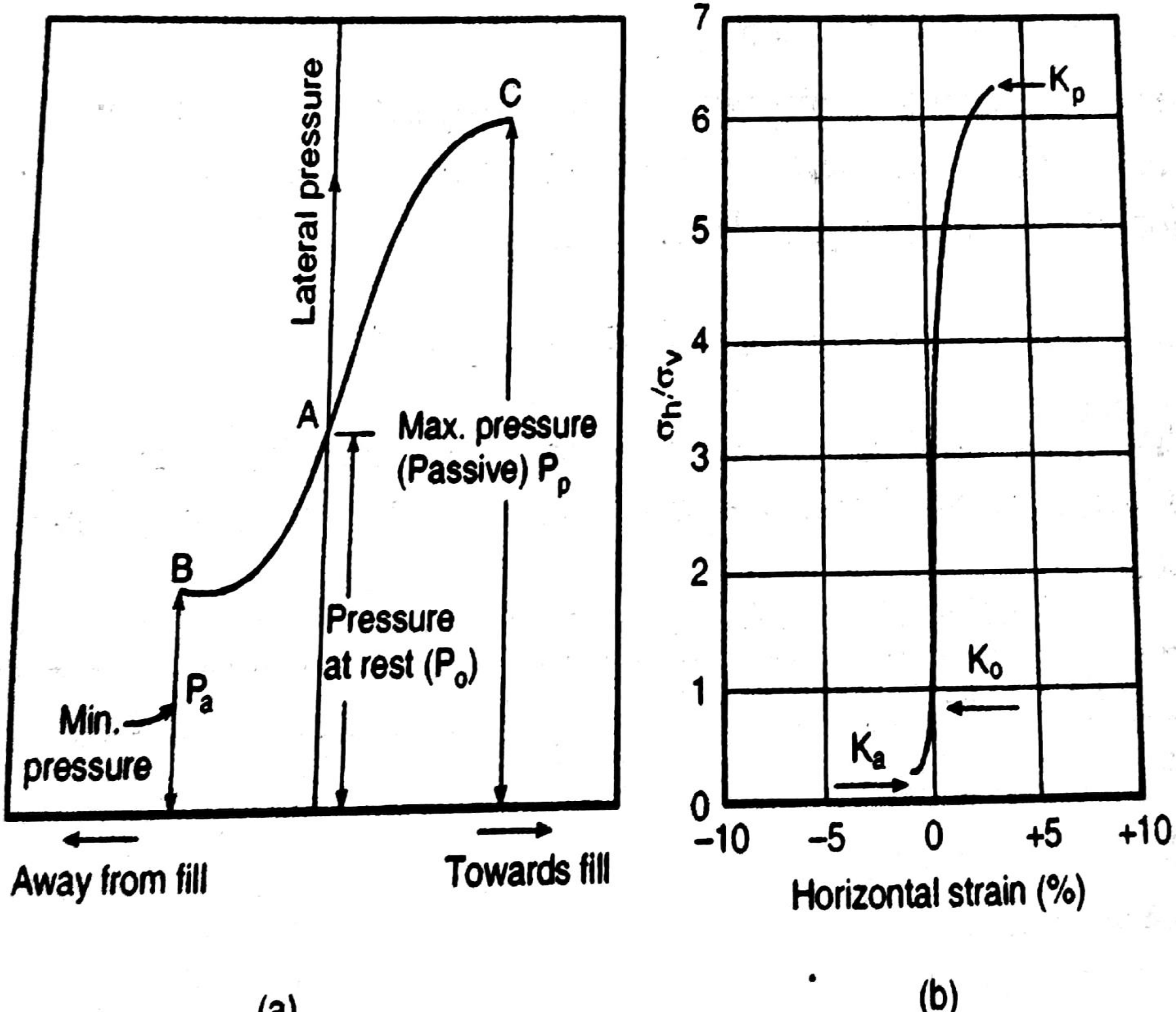

FIG. 20.3. VARIATION OF EARTH PRESSURE AND CO-EFFICIENTS OF EARTH PRESSURE WITH THE MOVEMENT OF THE WALL.

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Earth Pressure at Rest:

- If the wall is static i.e., if it does not move either to the right or left of its initial position, the soil mass will be in static equilibrium.

$$K_o = 1 - \sin \Phi$$

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Earth Pressure Theories:

There are two types of earth pressure theories namely:

- Rankine’s Earth Pressure Theory.
- Coulomb’s Earth Pressure Theory.

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Rankine's Earth Pressure Theories:

- The soil mass is semi-infinite, isotropic, homogenous, dry and cohesionless.
- The ground surface is a plane which may be horizontal or inclined.
- The back of the wall is vertical and smooth.
- The wall yields about the base and thus satisfies the deformation condition for plastic equilibrium.
- The soil is in a state of plastic equilibrium during active and passive earth pressure conditions.

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Rankine's Earth Pressure Theories:

Limitations:

- The retaining walls are constructed of masonry or concrete and hence the back of the wall is never smooth, due to this frictional forces develops.
- Due to frictional forces at the wall face, the resultant pressure must be parallel to the surface of the backfill.
- The direction of the resultant earth pressure is not correct.

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Rankine's Earth Pressure Theories:

The following cases of cohesionless backfill will now be considered:

- Dry or moist backfill with no surcharge.
- Submerged backfill.
- Backfill with uniform surcharge.
- Backfill with sloping surface.
- Inclined back and surcharge.

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Dry or Moist backfill with no Surcharge:

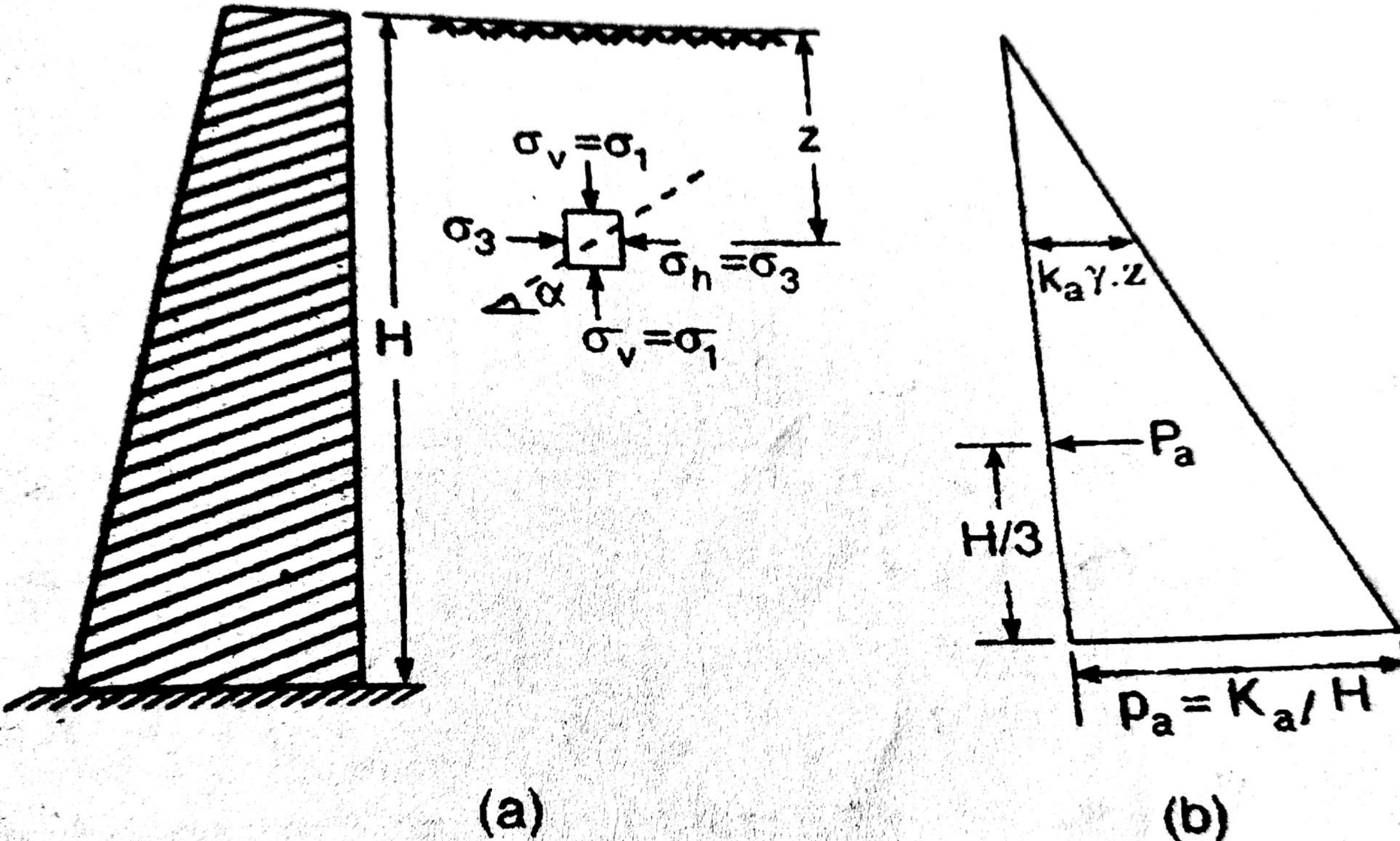

FIG. 20.4 ACTIVE EARTH PRESSURE OF DRY OR MOIST COHESIONLESS SOIL.

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Submerged Backfill:

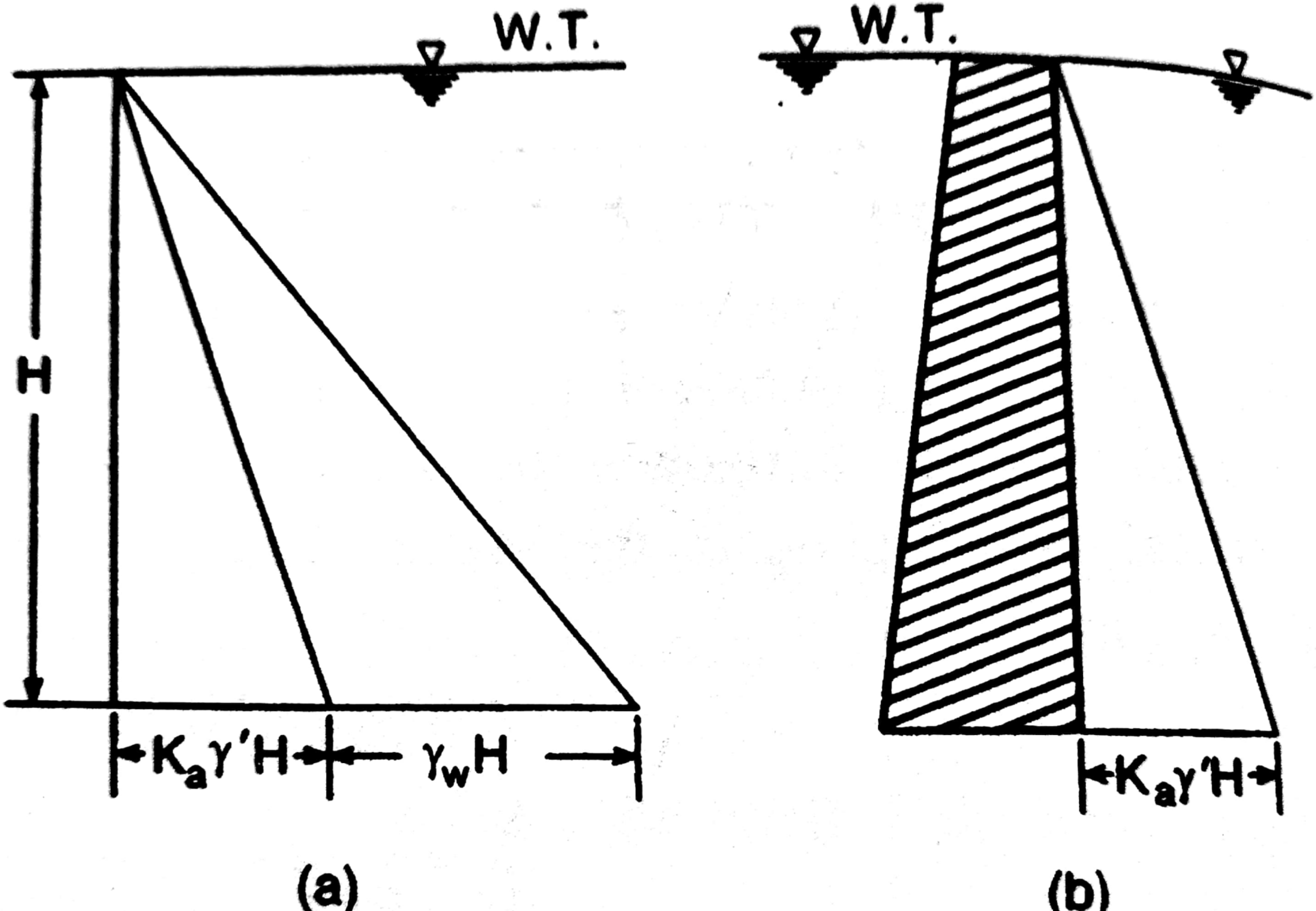

FIG. 20.5. SUBMERGED BACKFILL.

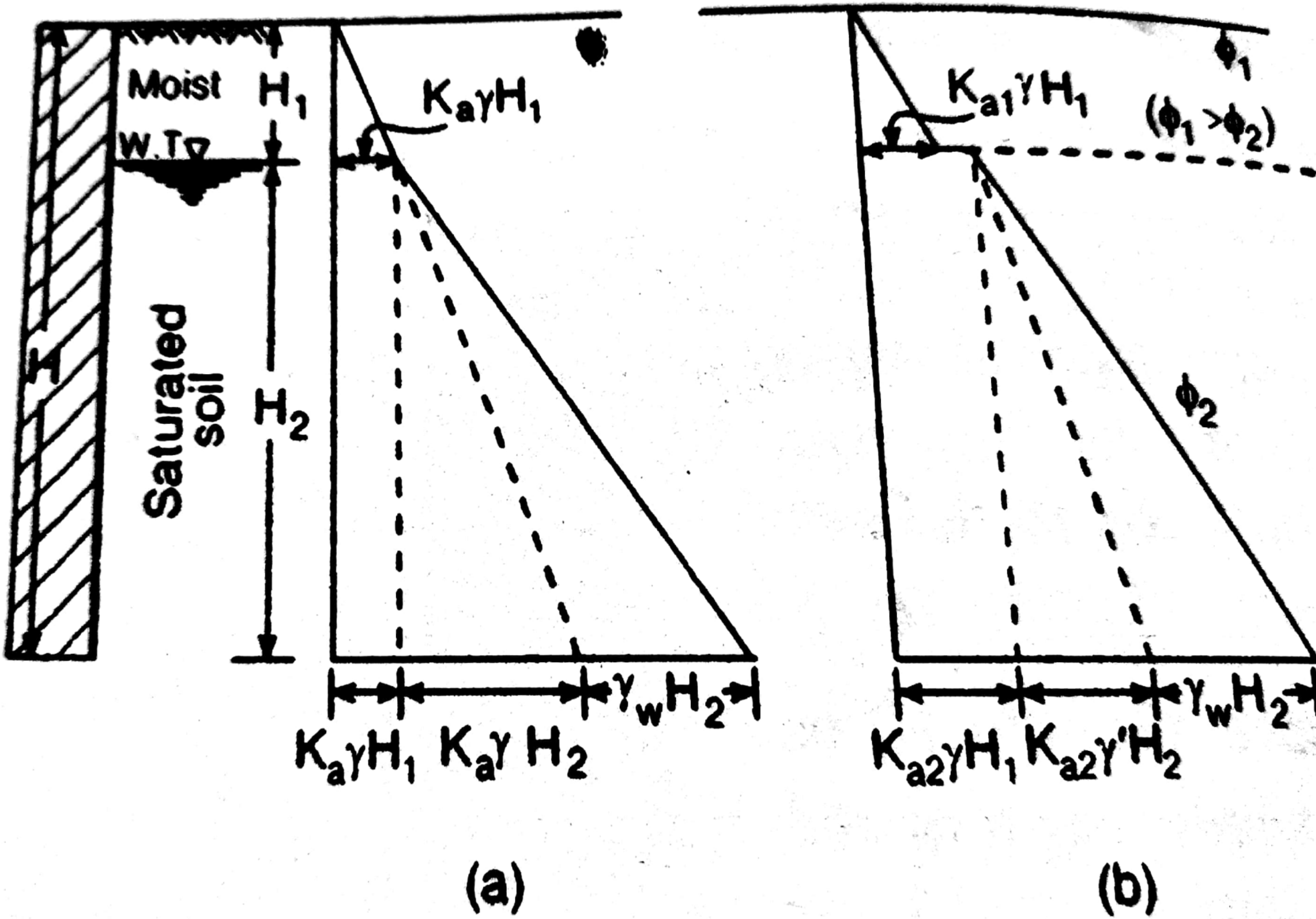

FIG. 20.6. PARTLY SUBMERGED BACKFILL

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Backfill with Uniform Surcharge:

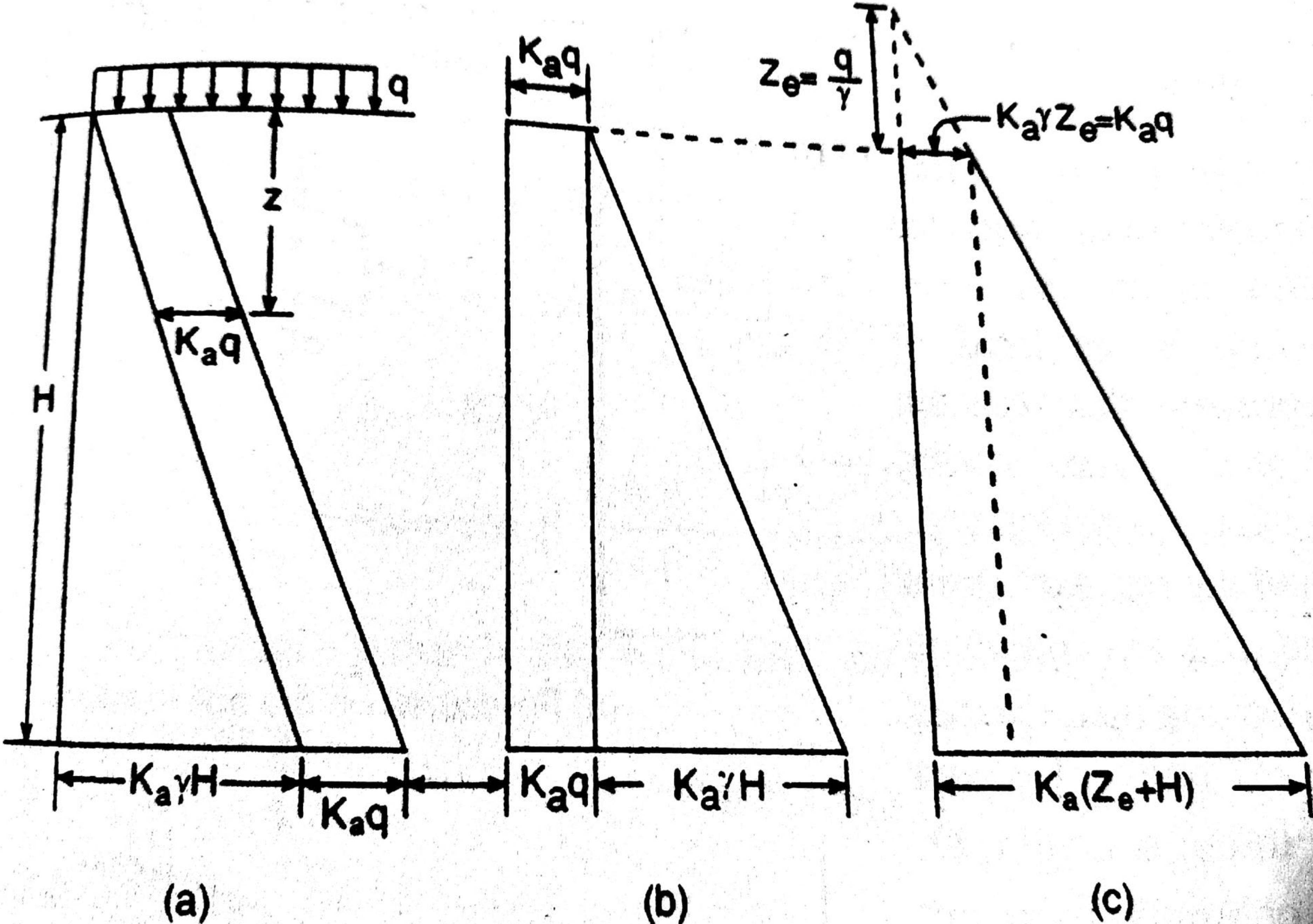

FIG. 20.7. BACKFILL WITH UNIFORM SURCHARGE.

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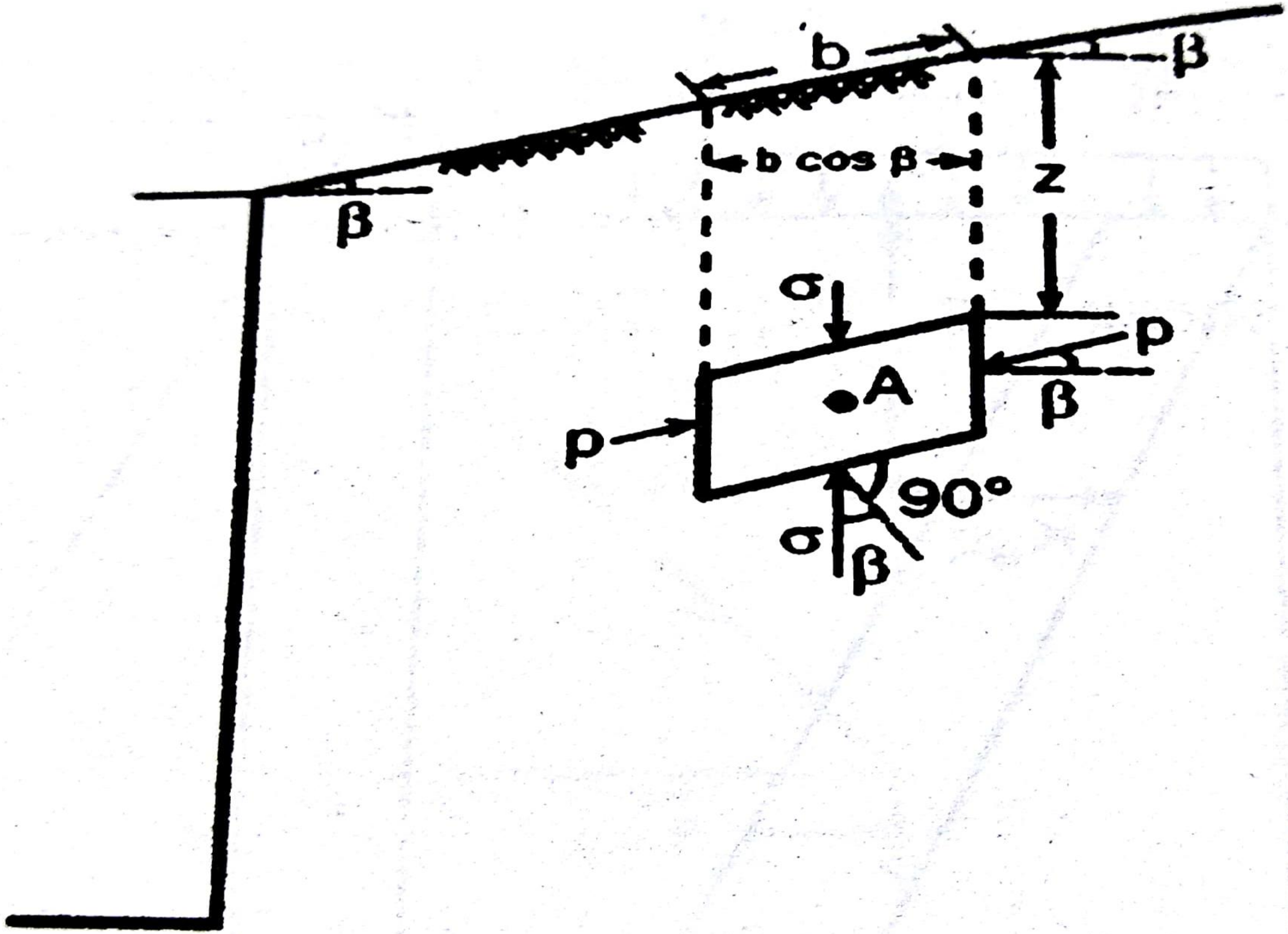
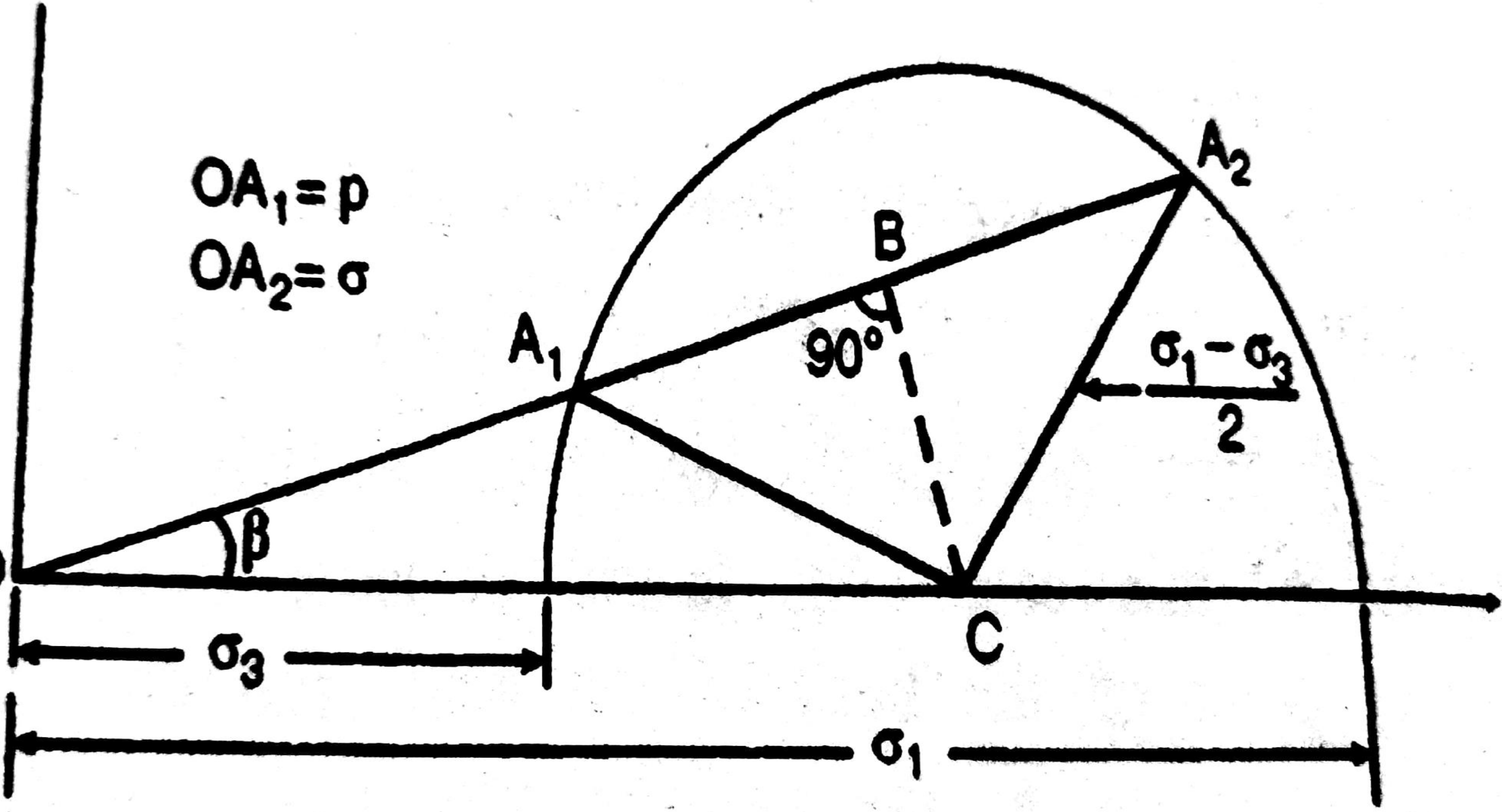
Backfill with Sloping Surface:



(a) Pressures on the soil element



(b) Mohr-circle

FIG. 20.8 CONJUGATE STRESS RELATIONSHIP.

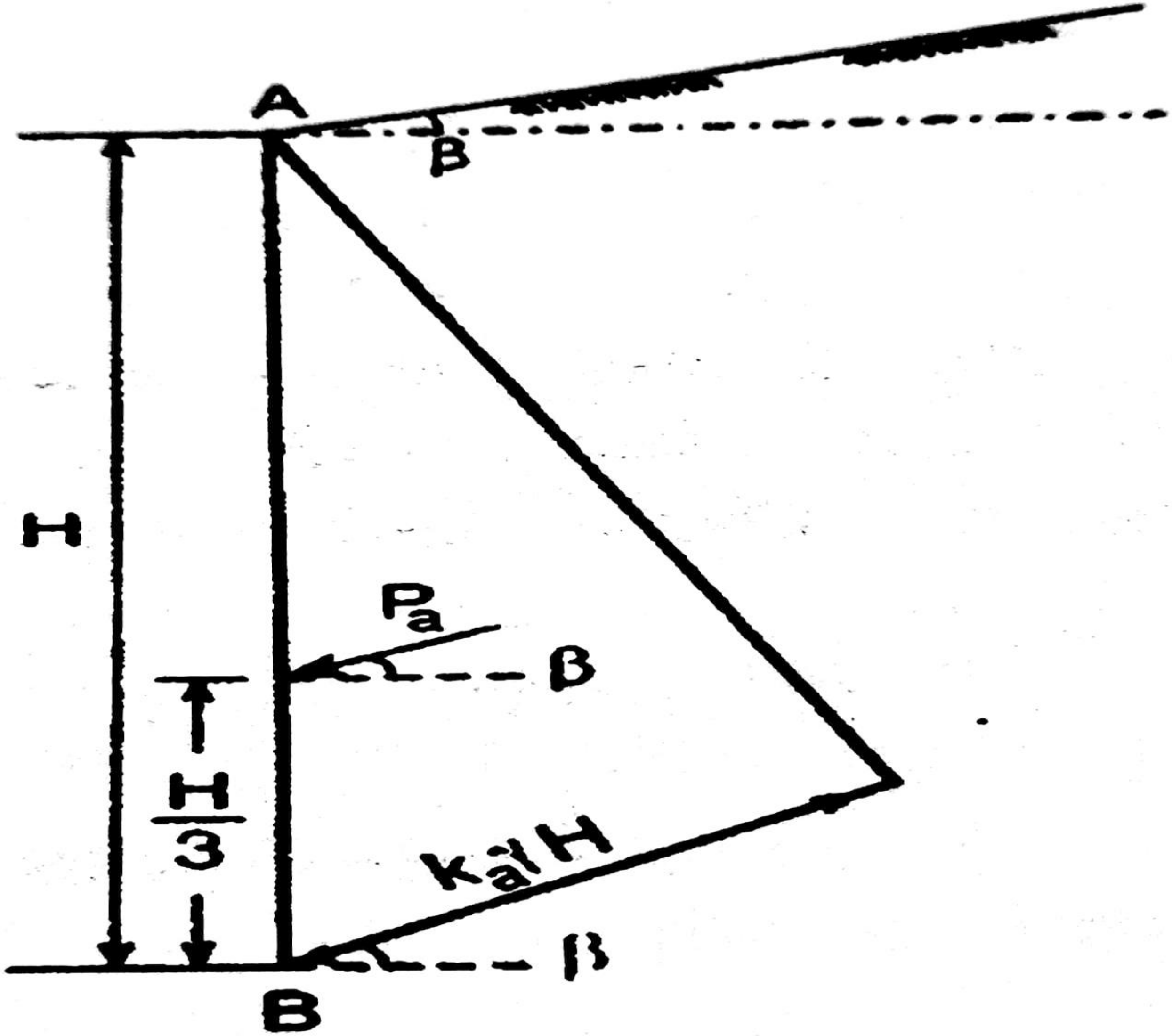


FIG. 20.9. LATERAL PRESSURE DISTRIBUTION FOR SLOPING SURCHARGE.

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Inclined back and surcharge:

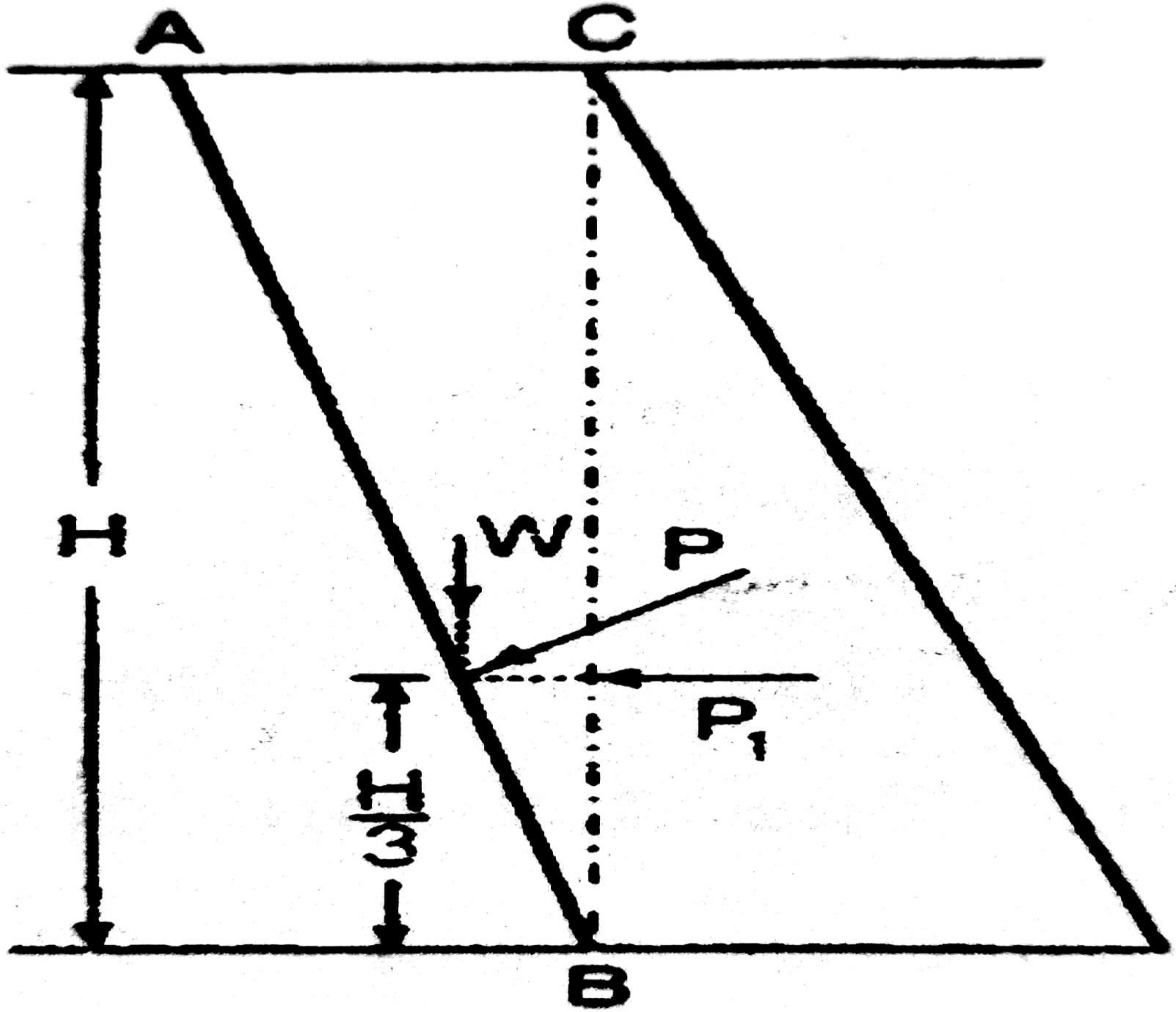

FIG. 20.10.
INCLINED BACK.

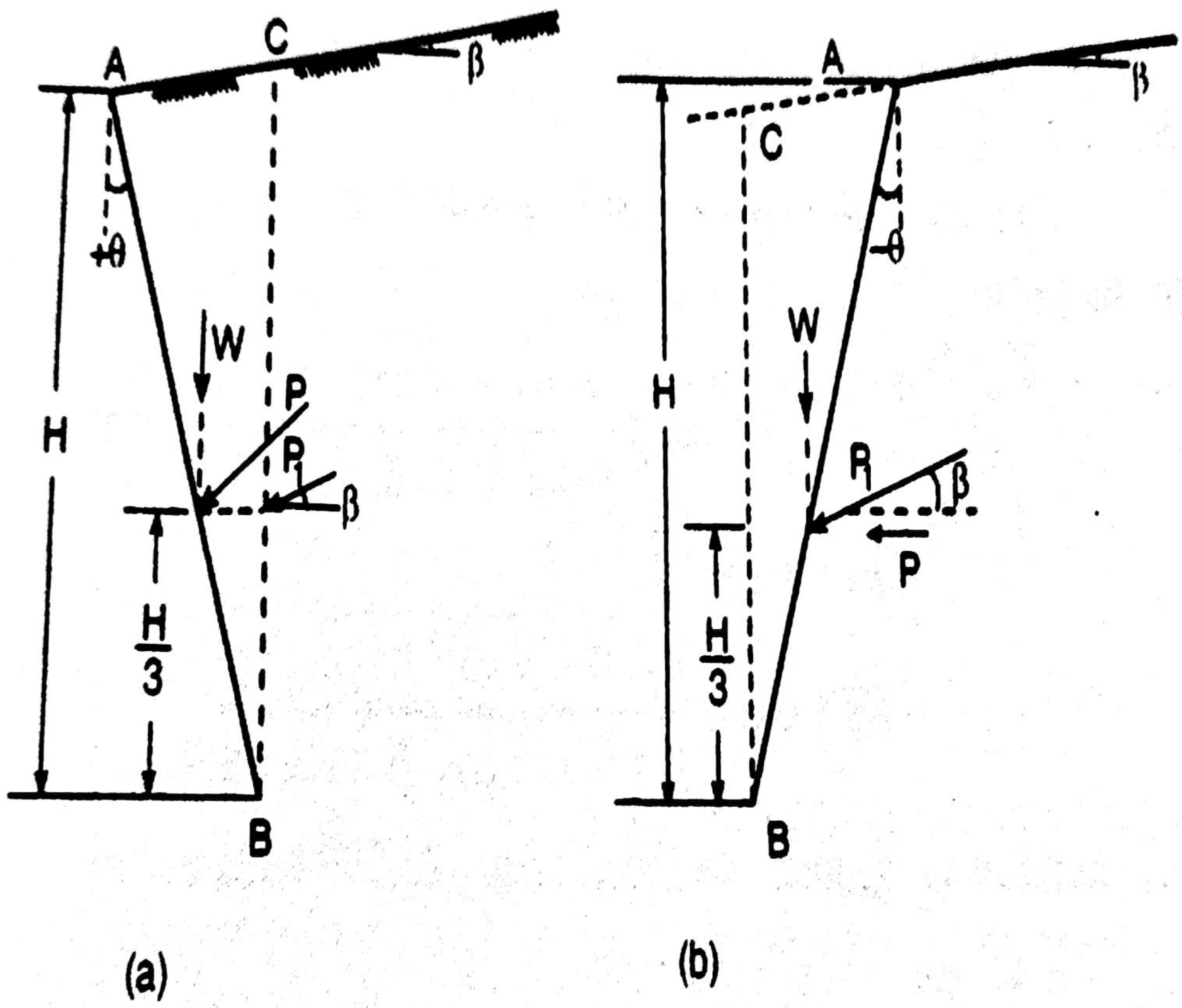

FIG. 20.11. PRESSURE ON INCLINED BACK WITH SLOPING GROUND SURFACE.

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Active Earth Pressure of Cohesive Soils:

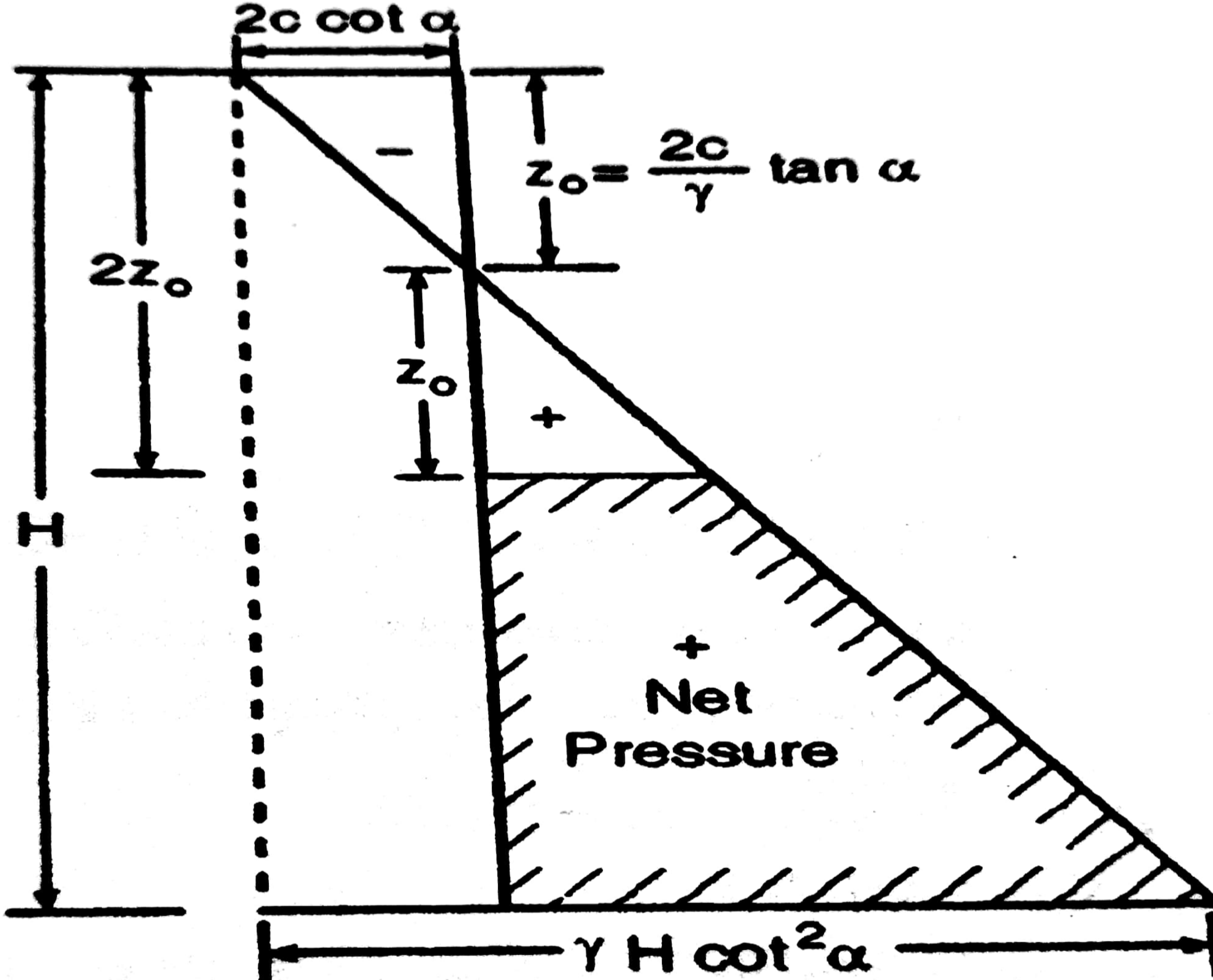

FIG. 20.12. ACTIVE EARTH PRESSURE OF COHESIVE BACKFILL.

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Passive Earth Pressure: Rankine's Theory

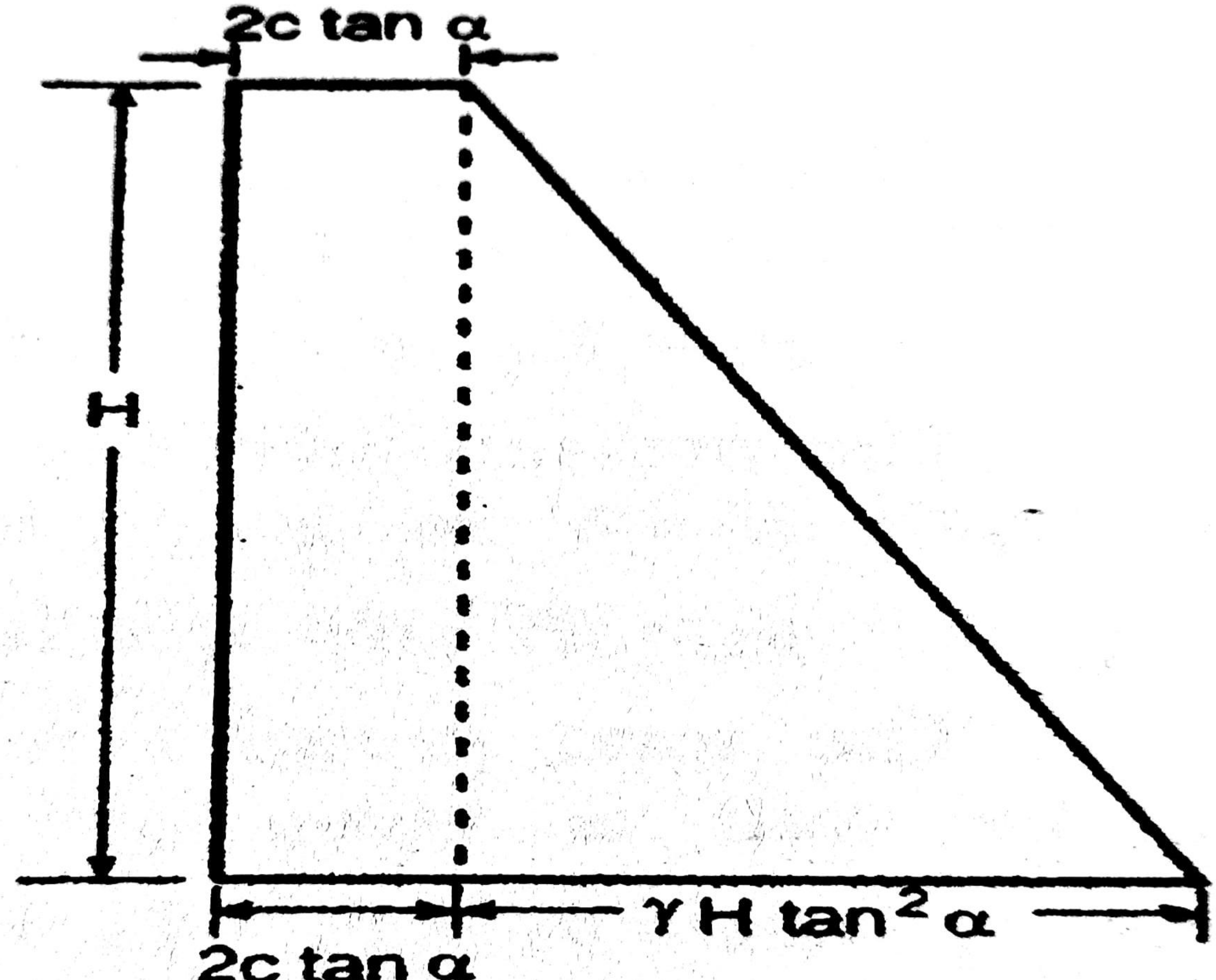

FIG. 20.13 VARIATION OF PASSIVE PRESSURE : COHESIVE BACKFILL.

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Coulomb's Earth Pressure Theories:

- The backfill is dry, cohesionless, homogenous, isotropic and elastically undeformable but breakable.
- The slip surface is plane which passes through the heel of the wall.
- The sliding wedge itself acts as a rigid body and the value of earth pressure is obtained by considering the limiting equilibrium of the sliding wedge as a whole.
- The position and direction of the resultant earth pressure are known.

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Coulomb's Earth Pressure Theories:

Limitations:

- The back of the wall is rough and a relative movement of the wall and the soil on the back which develops frictional force that influence the direction of the resultant pressure.
- The main deficiency of this theory is the assumption of planar slip surface.
- The curvature is slight in active case because of lesser friction the error can be relatively small.