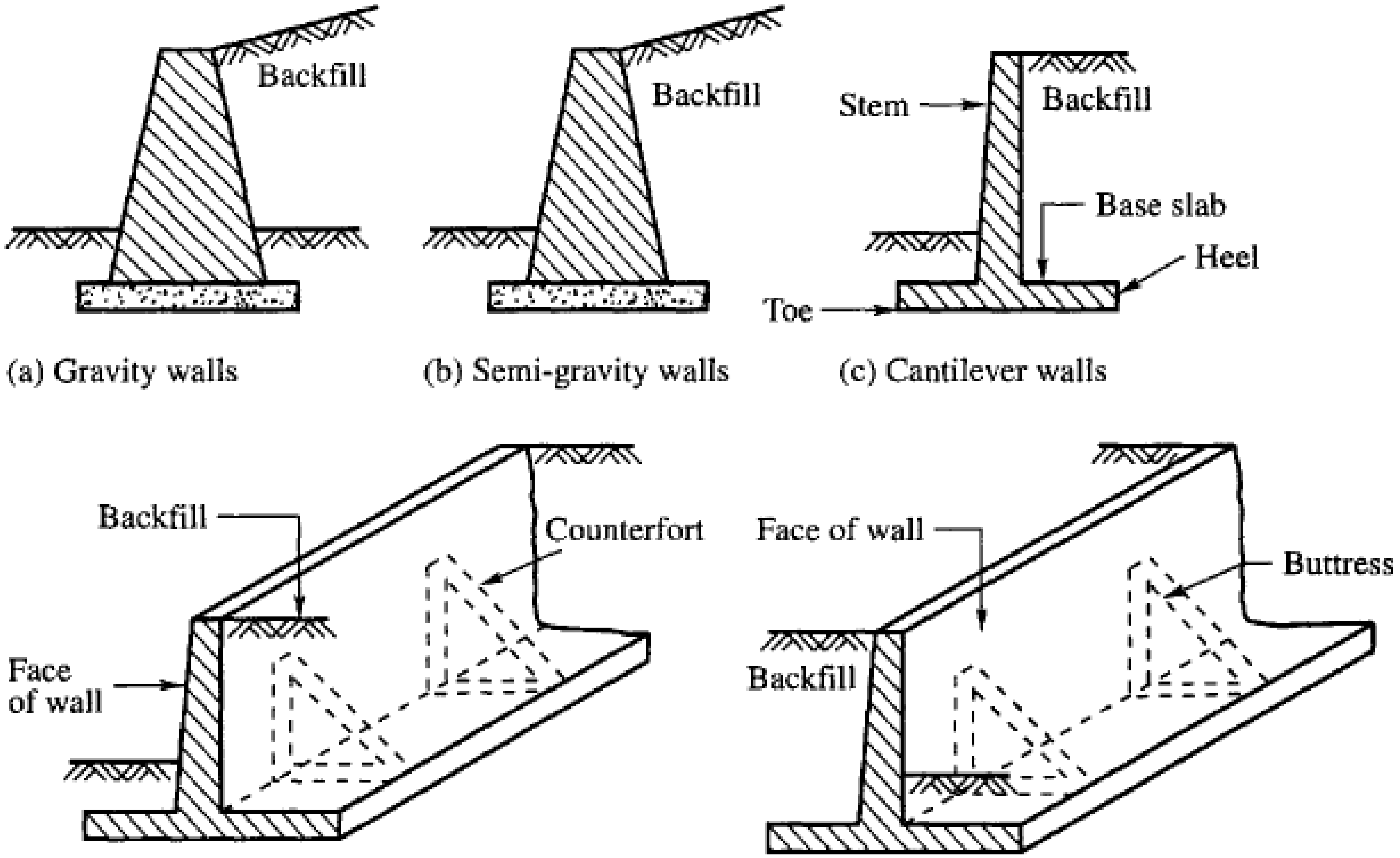
Earth pressure

Introduction

- **Retaining wall**: it is a structure used to maintain the ground level at different elevation.
- The material retained or supported by structure is called **backfill** which may have its top surface horizontal or inclined.
- The position of the backfill lying above a horizontal plane at elevation of the top of wall is called surcharge and its inclination to the horizontal is called surcharge angle beta.



(a) Gravity walls

(b) Semi-gravity walls

(c) Cantilever walls

(d) Counterfort walls

(e) Buttressed walls

Earth Pressure

- The force which is on the retaining wall when the soil is retained at a slope steeper than it can sustain by virtue of its shearing strength.
- The magnitude of earth pressure is a function of the magnitude and nature of the absolute and relative movements of the soil and the structure.

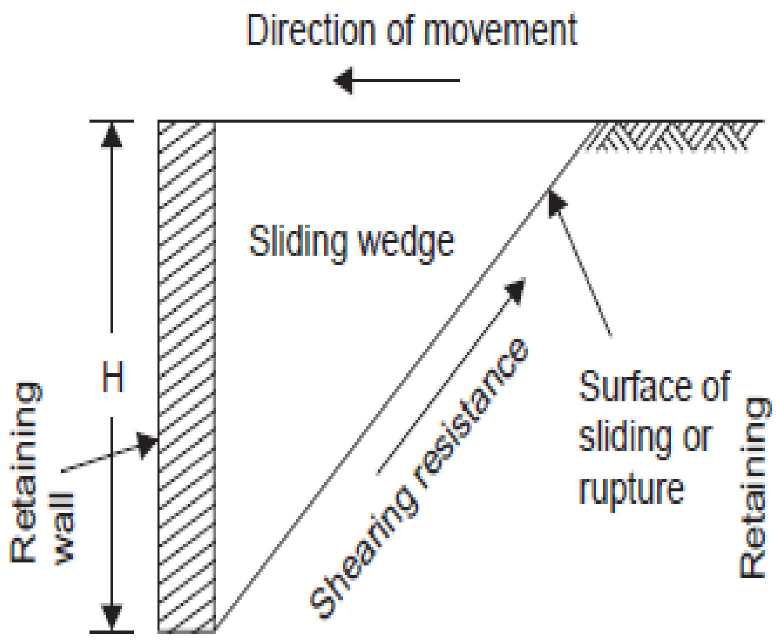
Types of lateral earth pressure

1. Active earth pressure
2. Passive earth pressure
3. Earth pressure at rest

Active earth pressure

- When the retaining wall moves away from the backfill, earth pressure on the back of the wall decreases and become minimum, with further movement of the wall pressure does not decreases. This minimum pressure is known as active earth pressure.

LATERAL EARTH PRESSURES



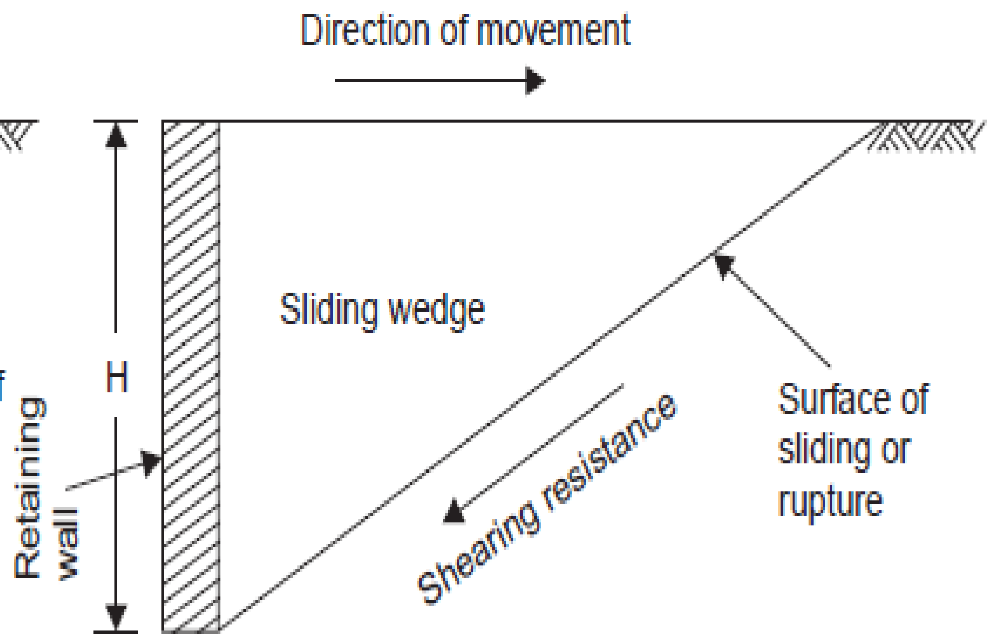


Fig. Conditions in the case of active earth pressure

Fig. Conditions in the case of passive earth resistance

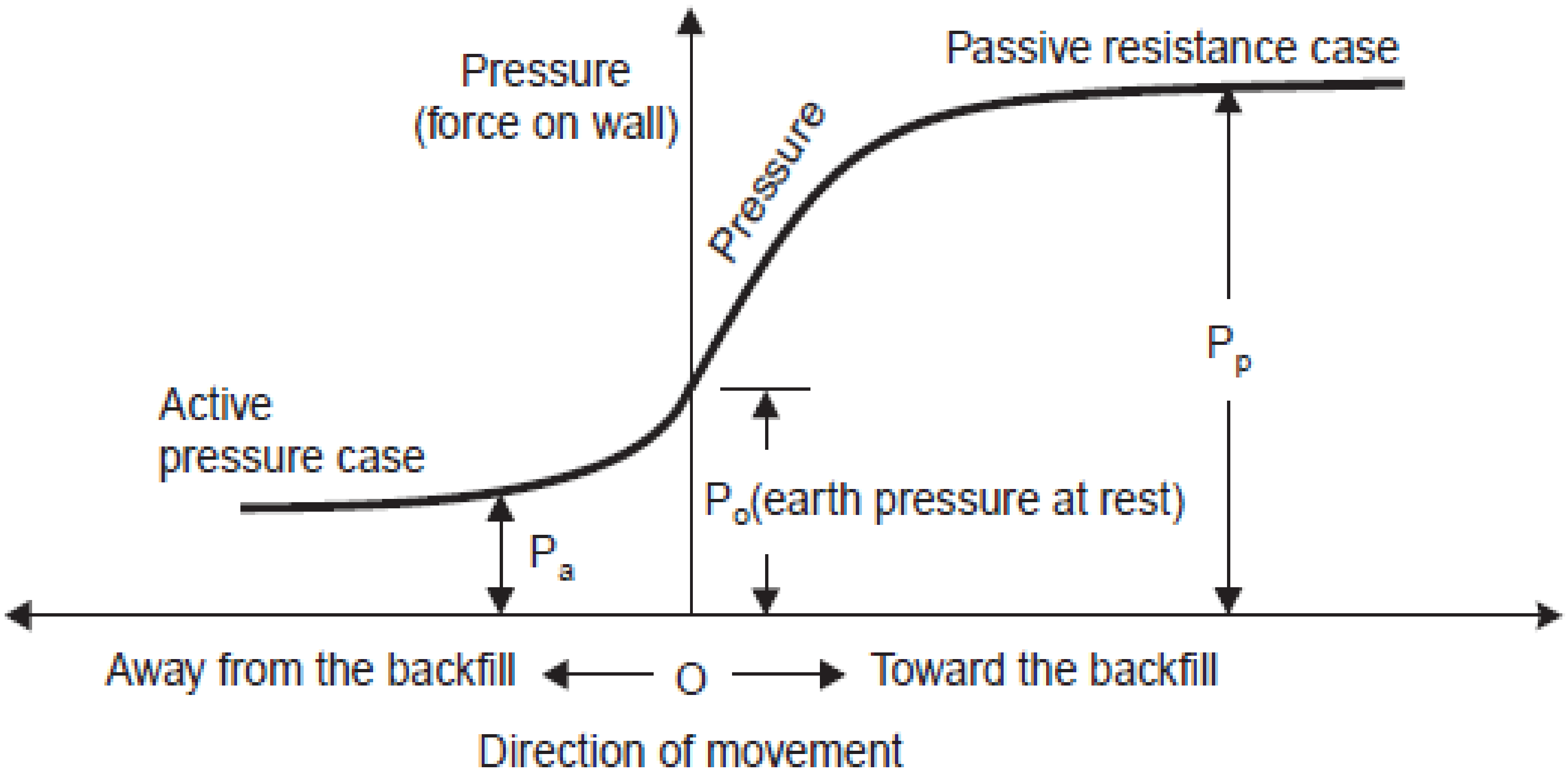
Passive earth pressure

- When the retaining wall moves towards the backfill, earth pressure on the back of the wall increases and becomes maximum, with further movement of the wall pressure does not increases.
- This maximum pressure is known as passive earth pressure.

Earth pressure at rest

- When the soil mass is not subjected to any lateral movement, the lateral pressure is called earth pressure at rest.
- This occur when retaining wall is firmly fixed at its top and not allowed to move or rotate.

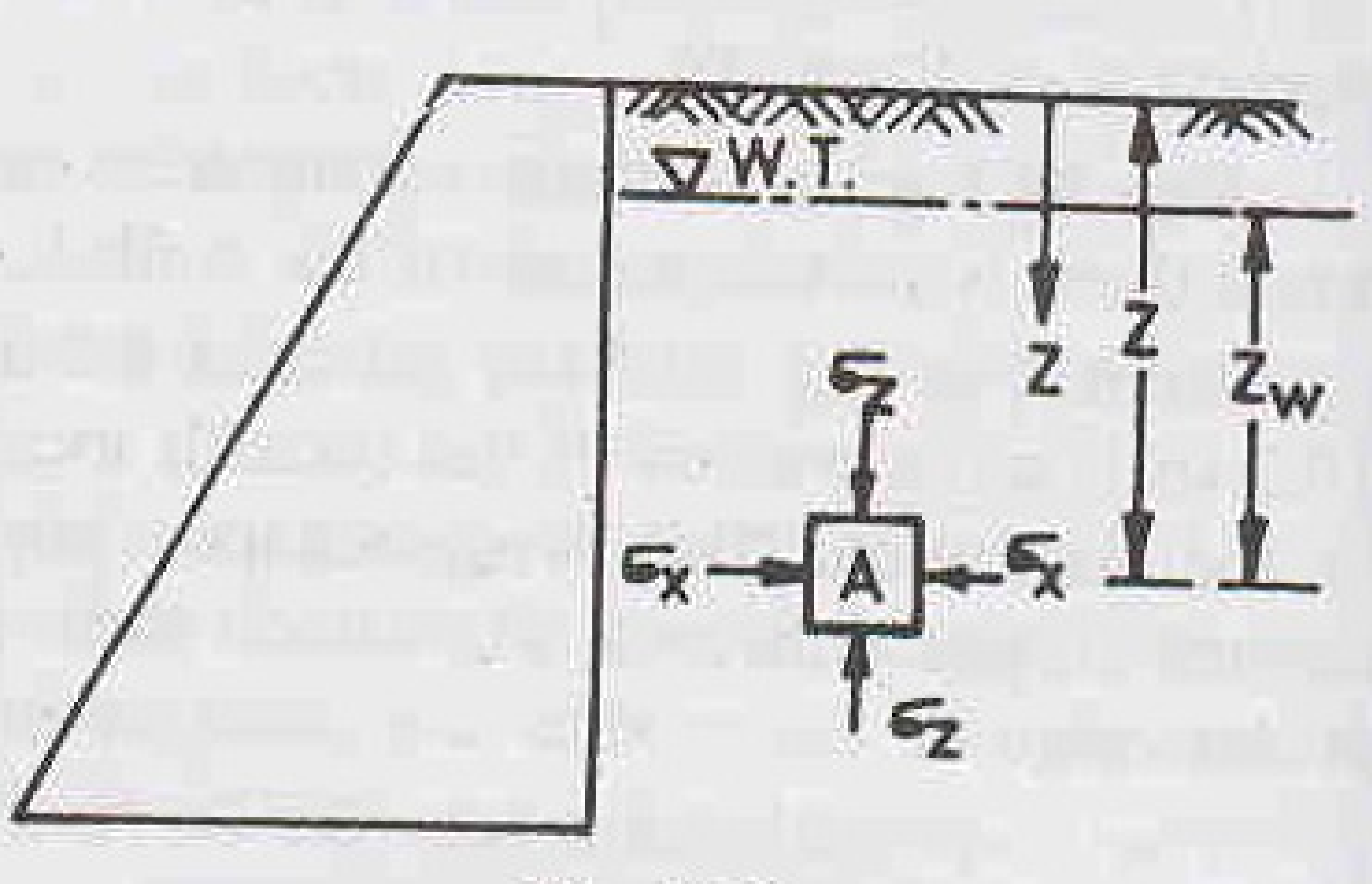
Effect of Wall Movement on Earth Pressure



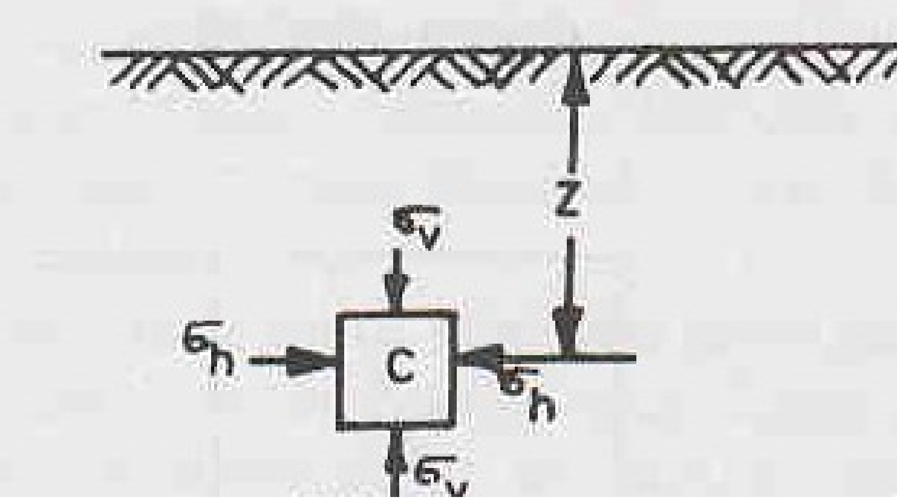
Earth Pressure At Rest

Table 12.1 Typical Values of K_o

Soil	K_o
Dense sand	0.40 - 0.45
Loose sand	0.45 - 0.50
Mechanically compacted sand	0.8 - 1.5
Normally consolidated clay	0.5 - 0.6
Overconsolidated clay	1.0 - 4.0



W.T.
Z
Z
Z
W
σz
σx
A
σx
σz



Z
σv
σh
C
σh
σv

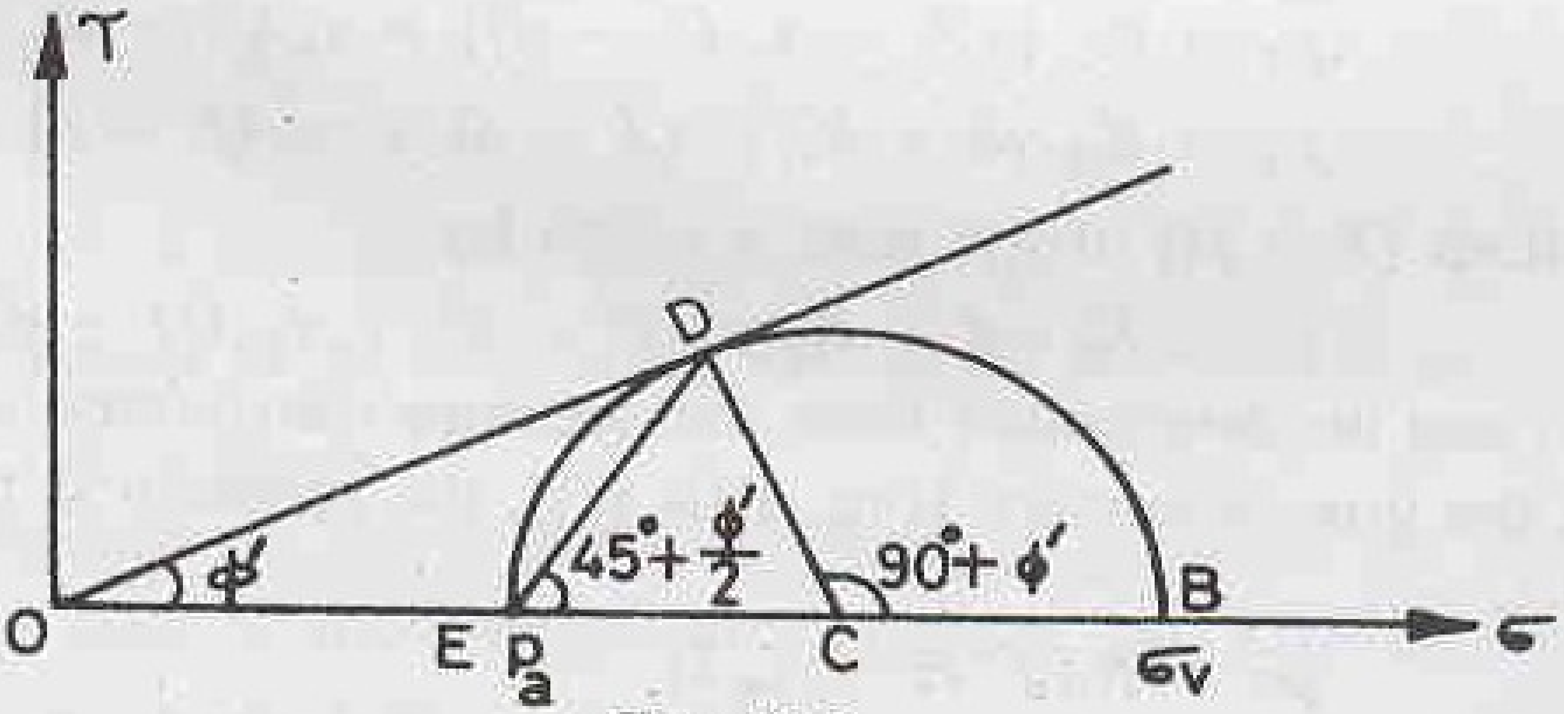


Fig. 19.6.

$$p_a = OE = OC - CE$$

$$CE = CD = OC \sin \phi',$$

$$p_a = OC - OC \sin \phi' = OC\,(1 - \sin \phi')$$

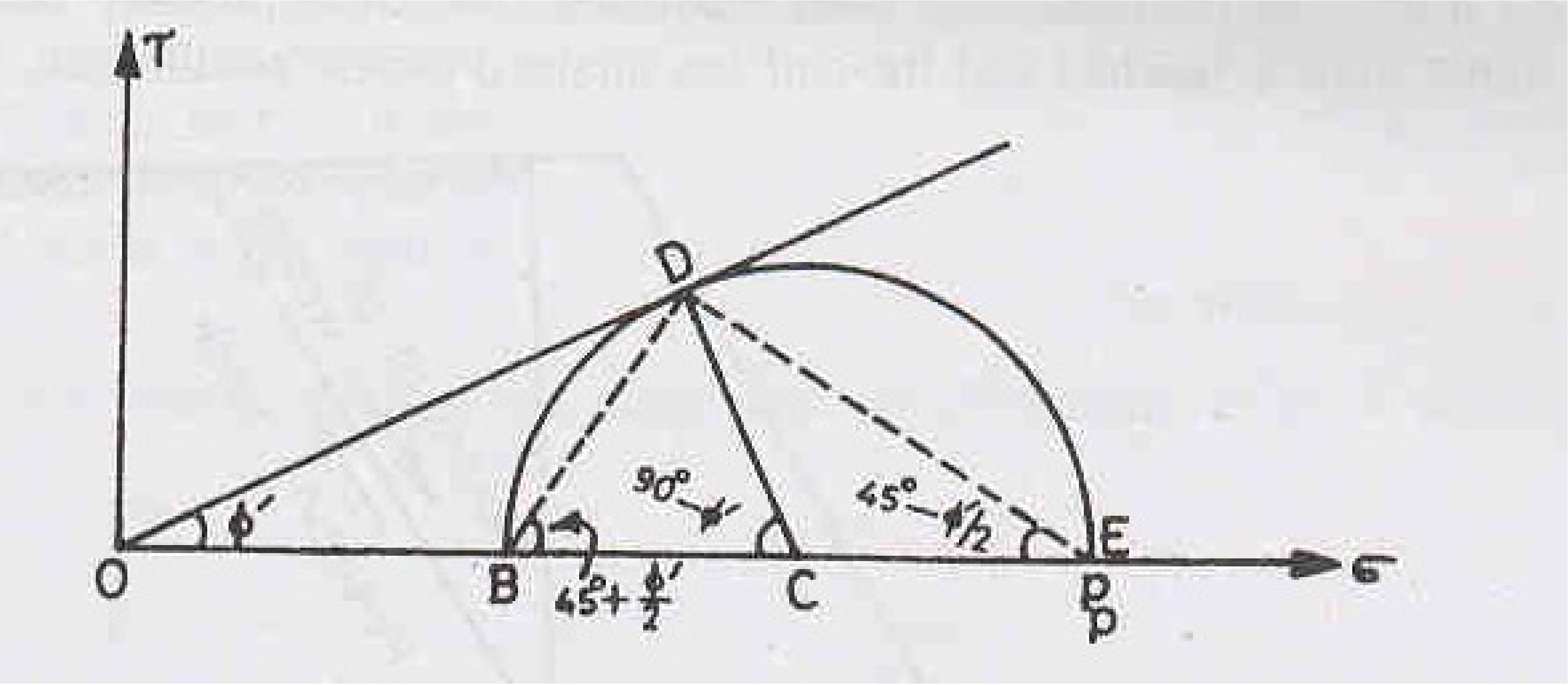
$$\sigma_v = OB = OC + CB = OC + OC \sin \phi'$$

$$\sigma_v = OC\,(1 + \sin \phi')$$

$$\frac{p_a}{\sigma_v} = \frac{1 - \sin\phi'}{1 + \sin\phi'}$$

$$p_a = \left(\frac{1 - \sin\phi'}{1 + \sin\phi'}\right)\sigma_v$$

$$p_a = K_a \gamma Z$$



T
D
90° — φ'
45° — φ/2
φ'
E
O
B
45° + φ'/2
C
D
P
σ

$$p_p = OC + CE = OC + CD = OC + OC \sin\phi'$$

$$p_p = OC(1 + \sin\phi')$$

$$OB = OC - BC = OC - CD = OC - OC\sin\phi'$$

$$\sigma_v = OC(1 - \sin\phi')$$

$$\frac{p_p}{\sigma_v} = \frac{1 + \sin\phi'}{1 - \sin\phi'}$$

$$p_p = \left(\frac{1 + \sin\phi'}{1 - \sin\phi'}\right)\sigma_v$$

$$p_p = K_p \gamma Z$$

Rankine’s Theory of Earth Pressure

Assumptions:

- The backfill soil is isotropic, homogeneous and is cohesionless.
- The soil is in a state of plastic equilibrium during active and passive earth pressure conditions.
- The rupture surface is a planar surface which is obtained by considering the plastic equilibrium of the soil.
- The backfill surface is horizontal.
- The back of the wall is vertical.
- The back of the wall is smooth.

Active earth pressure by Rankine theory:

For cohesionless soil:

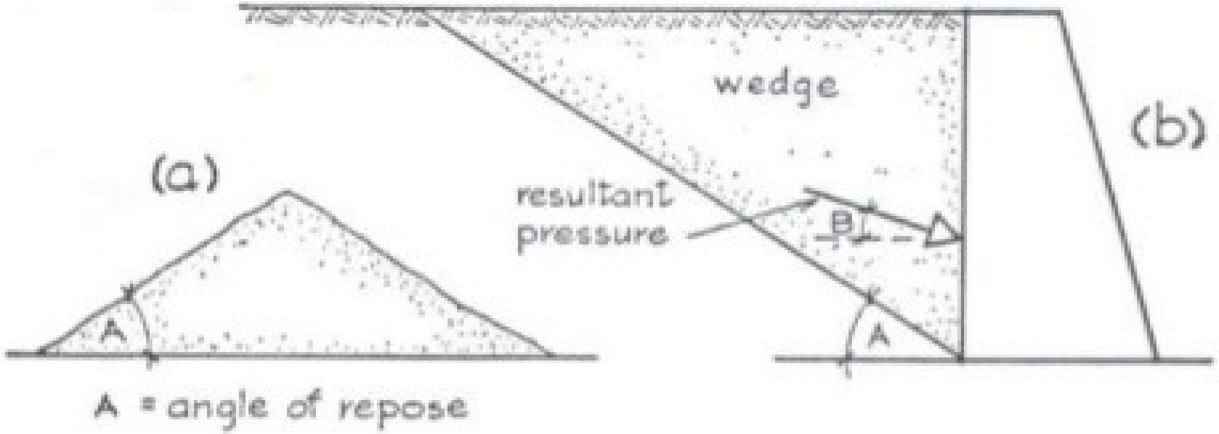
- Dry or moist backfill with no surcharge
- Submerged backfill
- Backfill with uniform discharge
- Backfill with sloping surcharge
- Inclined back and surcharge

Retaining wall

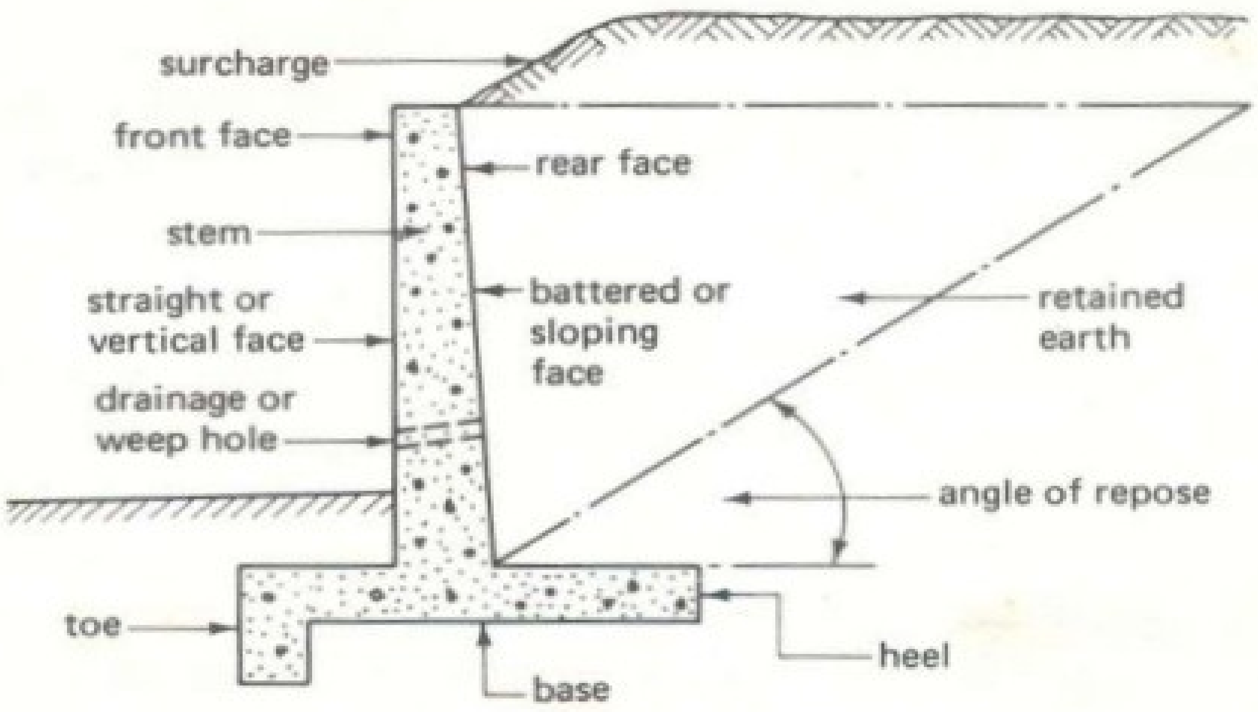
INTRODUCTION

- A retaining wall is a structure that holds or retains soil behind it.
- There are many types of materials that can be used to create retaining walls like concrete blocks, poured concrete, treated timbers, rocks or boulders.
- To retain soil at a slope which is greater than it would naturally assume, usually at a vertical or near vertical position.

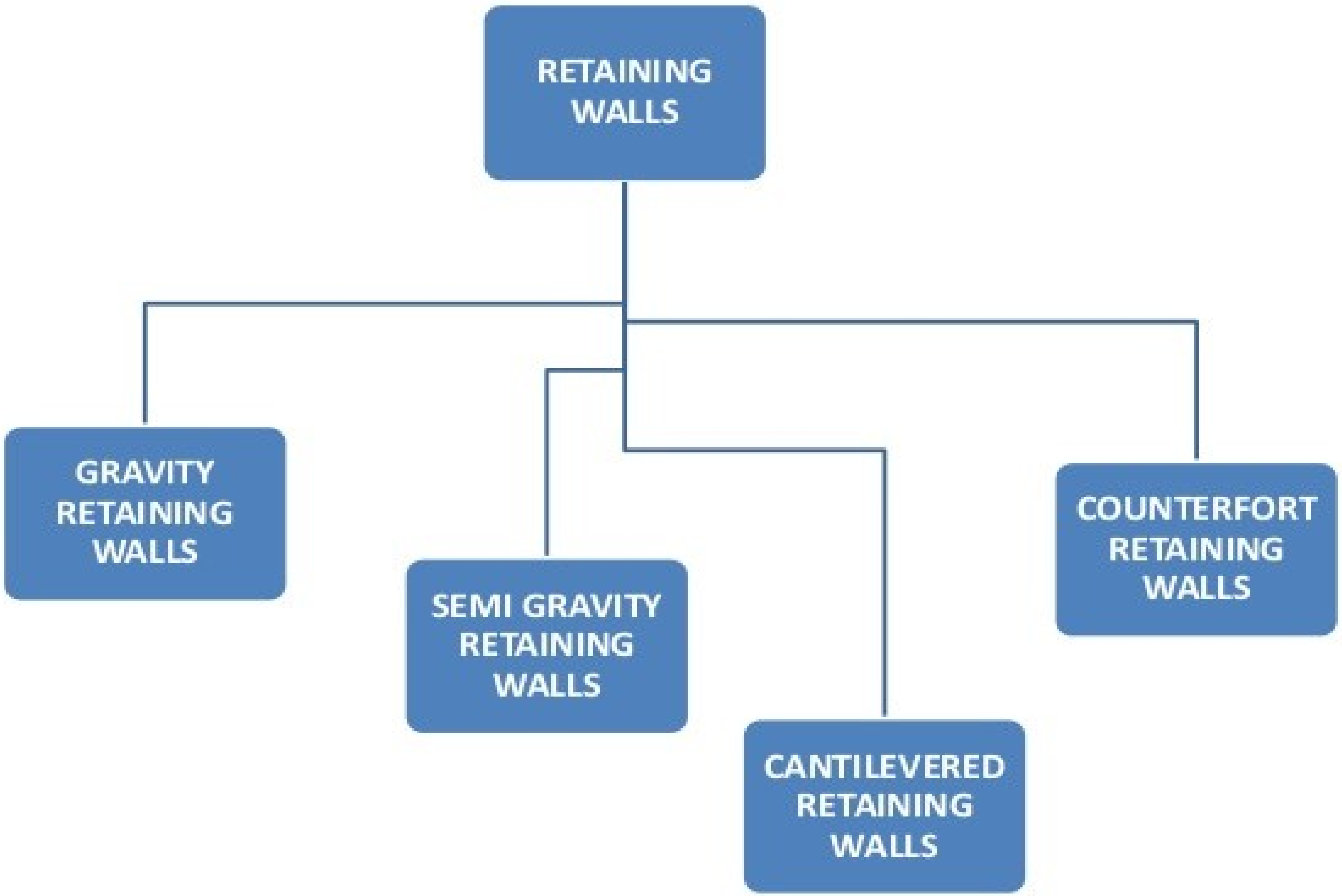
- The material retained or supported by a retaining wall is called backfill.
- Backfill may have its top surface horizontal or inclined.
- The position of the backfill lying above the horizontal plane at the elevation of top of wall is called surcharge & its inclination to the horizontal is called as Surcharge angle.
- Retaining walls have primary function of retaining soils at an angle in excess of the soil's nature angle of repose.



PARTS OF A RETAINING WALL

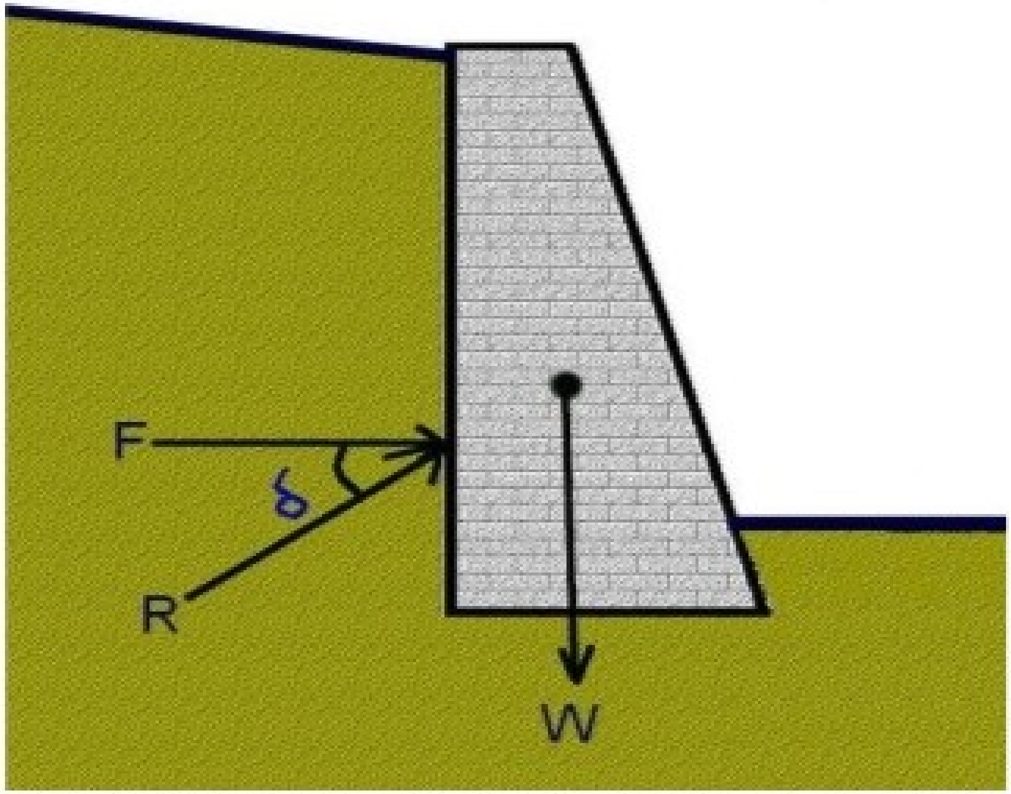


Retaining wall terminology


RETAINING WALLS
GRAVITY RETAINING WALLS
SEMI GRAVITY RETAINING WALLS
CANTILEVERED RETAINING WALLS
COUNTERFORT RETAINING WALLS

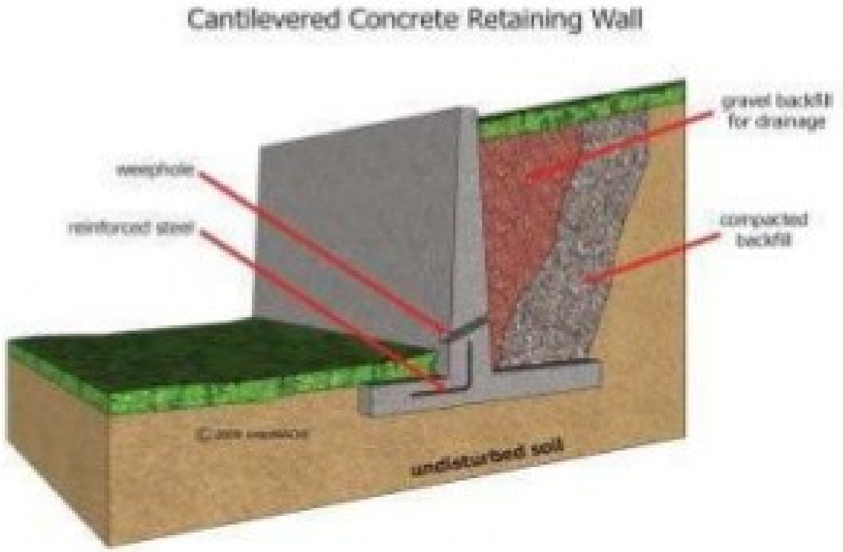
GRAVITY WALLS

- The "gravity wall" resists the earths pressure exerted by backfill by its own self weight (dead load) .
- It is usually built in stone masonry, and occasionally in plain concrete.
- provides stability by virtue of its own weight , and therefore, is rather massive in size
- Plain concrete gravity walls are not used for heights exceeding about 3m, for economic reasons

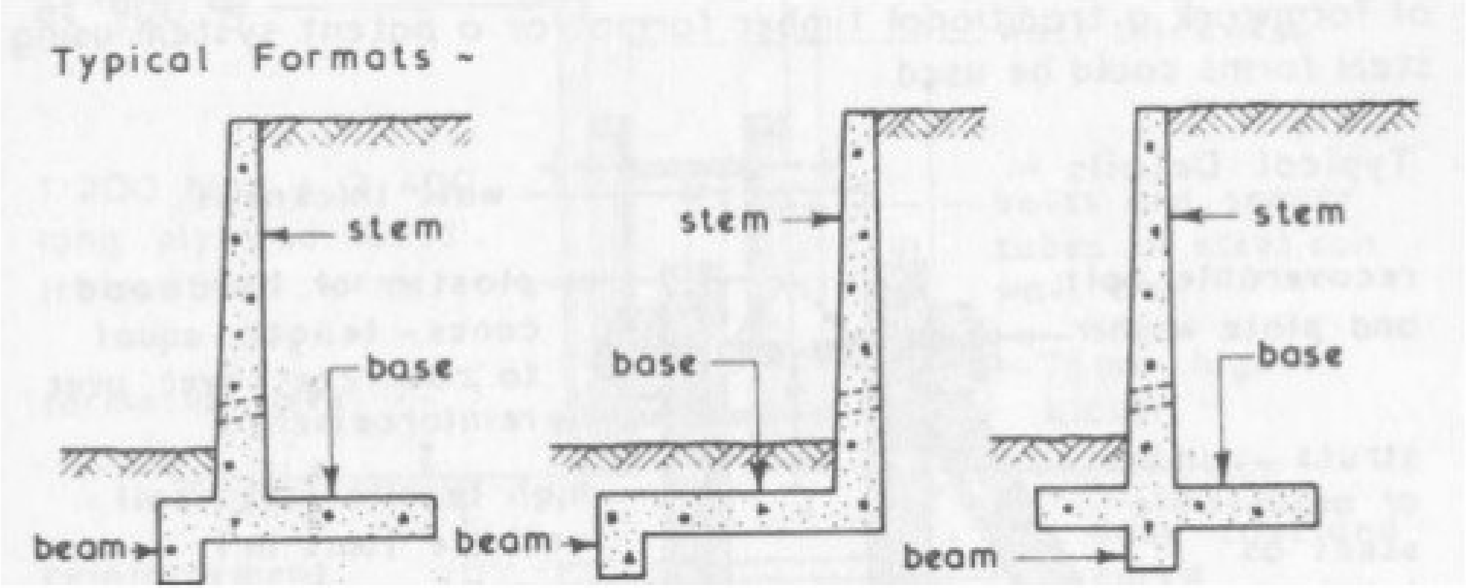


CANTILEVERED RETAINING WALLS

- The "**Cantilever wall** " is the most common type of retaining structure and is generally economical for heights up to about 8m.
- The structure consists of vertical stem , and a base slab, made up of two distinct regions, viz., a heel slab and a toe slab.

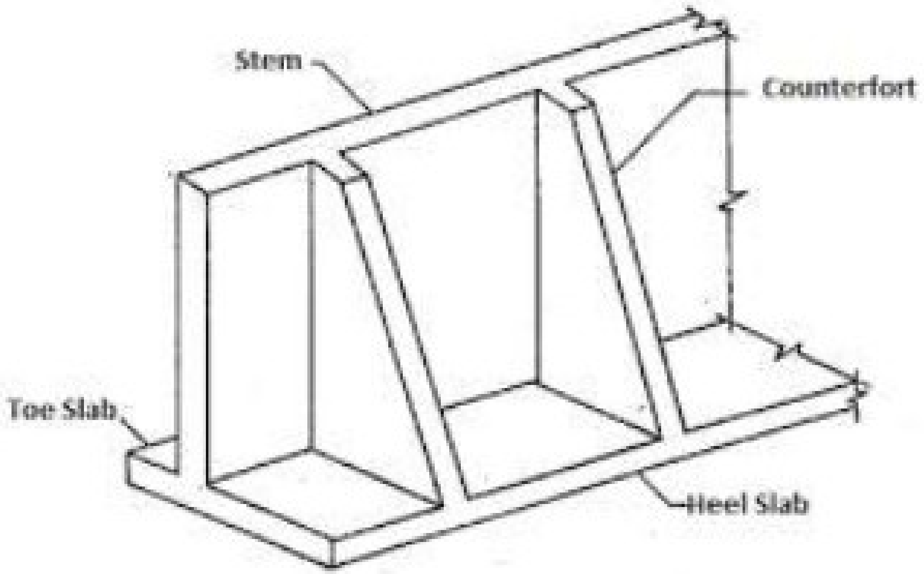


- “Stem” acts as a vertical cantilever under the lateral earth pressure
- “Heel slab” acts as a horizontal cantilever under the action of weight of the retained earth (minus soil pressure acting upwards from below)
- “Toe slab ” acts as a cantilever under the action of resulting soil pressure acting upward.



COUNTERFORT RETAINING WALLS

- For large heights, in a cantilever retaining wall, the bending moments developed in the stem, heel slab and toe slab become very large and require large thickness.
- The bending moments can be considerably reduced by introducing transverse supports, called counter-forts.



Check for Overturning :

- The lateral loads (earth pressure) causes overturning moment (M_o) about the toe.
- The weight of backfill, surcharge, self weight of retaining wall cause stabilizing moment (M_s) about the toe.
- The factor of safety against overturning is given by ;

$$(Fos)_o = M_s/M_o$$

- The factor of safety should not be less than 1.4.
- As per IS 456-2000 recommendations, only 0.9 times the characteristic dead load shall be considered

$$(Fos)_o = 0.9M_s/M_o$$

Check for Sliding :

- The lateral earth pressure on stem tries to slide the retaining wall away from back fill.
- This lateral force is resisted by frictional force between base slab and the soil below it.
- Maximum frictional force is given by

$$F = \mu \Sigma W$$

where, ΣW is the total downward load.

- If P_H is the total horizontal pressure, then factor of safety against sliding is given by

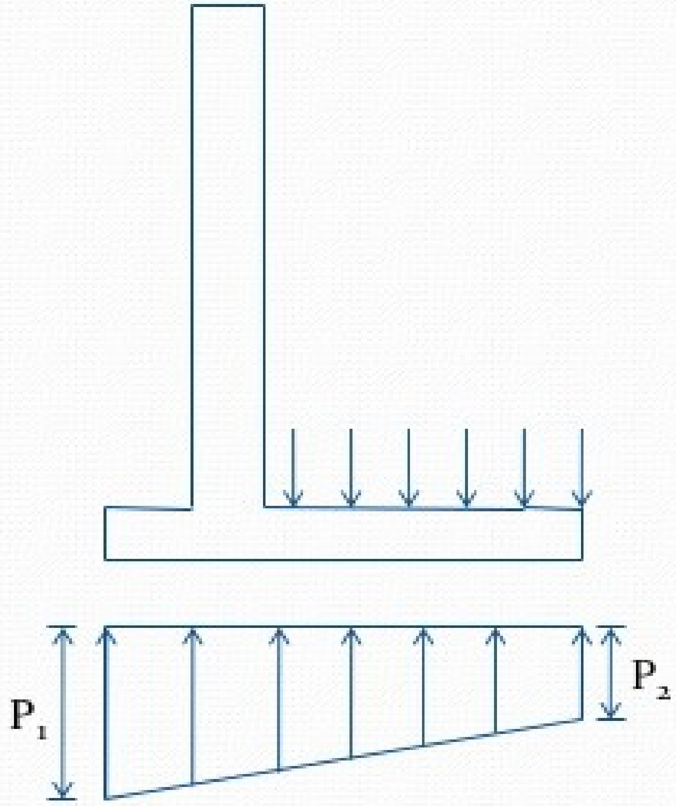
$$(Fos)_s = \mu \Sigma W / P_H$$

- As per IS 456-2000 recommendations, the factor of safety should not less than 1.4 and only 0.9 times characteristic dead load is to be considered

$$(Fos)_s = 0.9\mu \Sigma W / P_H$$

Check for Soil Pressure:

- The soil pressure varies linearly with more pressure on toe and less pressure on the end of heel.
- P1 (*max.*) < SBC of soil.
- P2(*min.*) > 0.



Design of stem:

- Calculate the max. factored BM on stem due to lateral earth pressure. This calculated BM < M_u (*lim.*).
- If cal.BM > M_u (*lim.*) ; increase the thickness of base of stem and redesign.
- Accordingly, calculate the area of steel required;

$$M_u = .87 f_y A_{st} d (1 - f_y A_{st}/f_{ck} bd)$$

- Provide bars of app. diameter (Φ) and calculate spacing as:

$$S = \frac{\Pi \Phi^2/4}{A_{st}} * 1000$$

- Spacing should be min. of the following:

  (1) 0.75d (2) 300*mm* (3) Calculated Spacing
- Provide *distribution steel.*
- Check for *development length* and *shear.*

Design of toe slab:

- Calculate the ultimate BM for *1 metre* width of toe slab.
- For calculation of BM,
  The weight of soil above toe slab is neglected.
  The two forces considered are:
  (1) Upward soil pressure;
  (2) Downward weight of toe slab.
- Provide reinforcement accordingly.
- Provide *distribution steel.*
- Check for *development length* and *shear.*

Design of heel slab:

- Calculate the ultimate BM for *1 metre* width of heel slab.
- For calculation of BM,

  The three forces considered are:

  (1) Upward soil pressure;

  (2) Downward weight of heel slab;

  (3) Weight of the soil above heel slab.
- Provide *main steel* and *distribution steel* accordingly.
- Apply check for *development length* and *shear*.