RETAINING WALLS

BY

K.P.VINEETH

Contents

* **What is retaining wall**
* **Parts of retaining wall**
* **Types of retaining wall**
* **Earth pressures**
* **Principles of the design of retaining wall**
* **Drainage of back fills**
* **Theories required to solve problem**
* **Design of retaining wall**

What is a Retaining wall?

Retaining wall is a structure used for maintaining the ground surfaces at different elevations on either side of it.

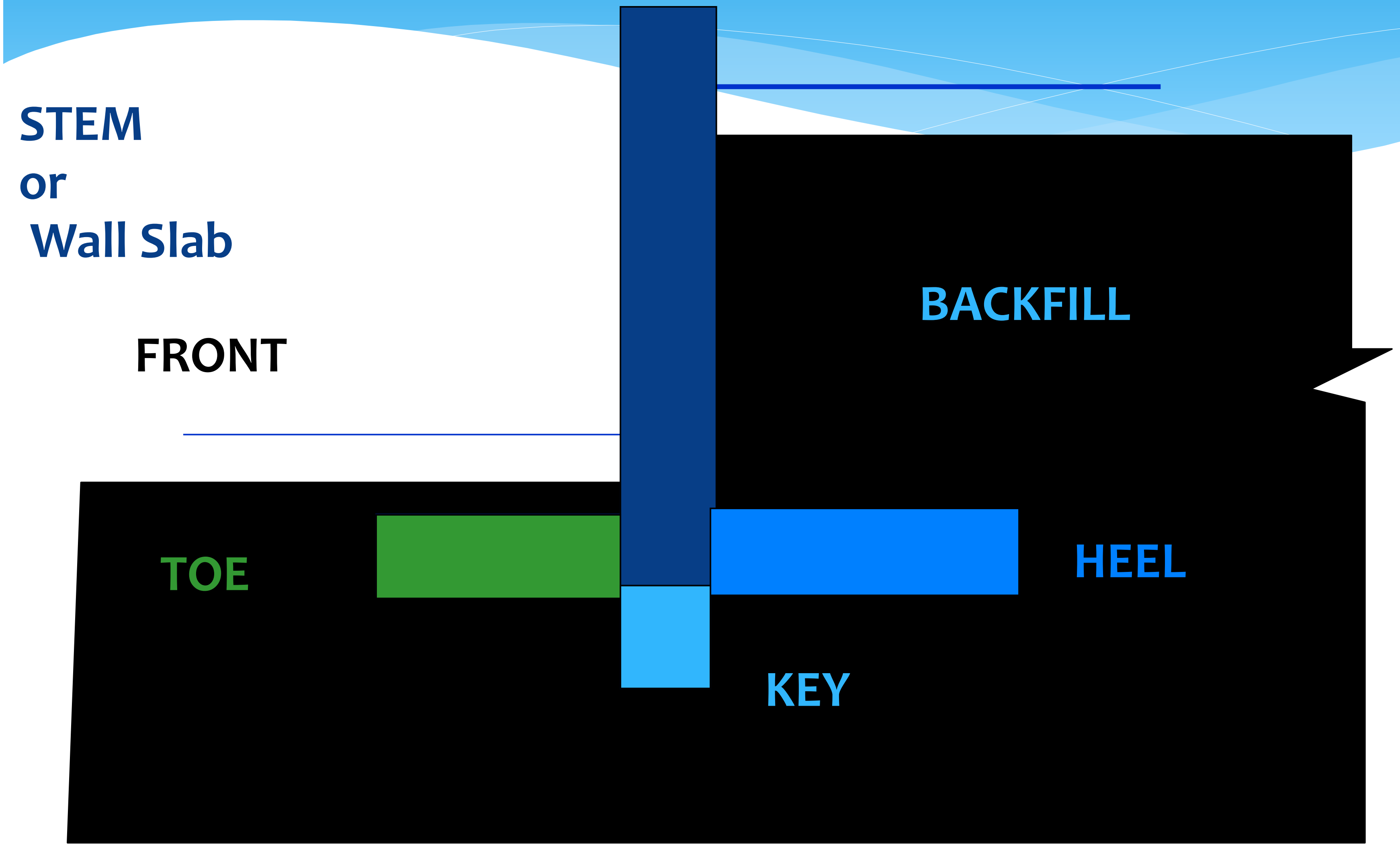
All permanent walls and components shall be designed for a minimum service life of 75 years.

Corrosion protection is required for all permanent and temporary walls in aggressive environments.

Retaining walls are usually built to hold back soil mass.

They are also provided to maintain the grounds at two different levels.

PARTS



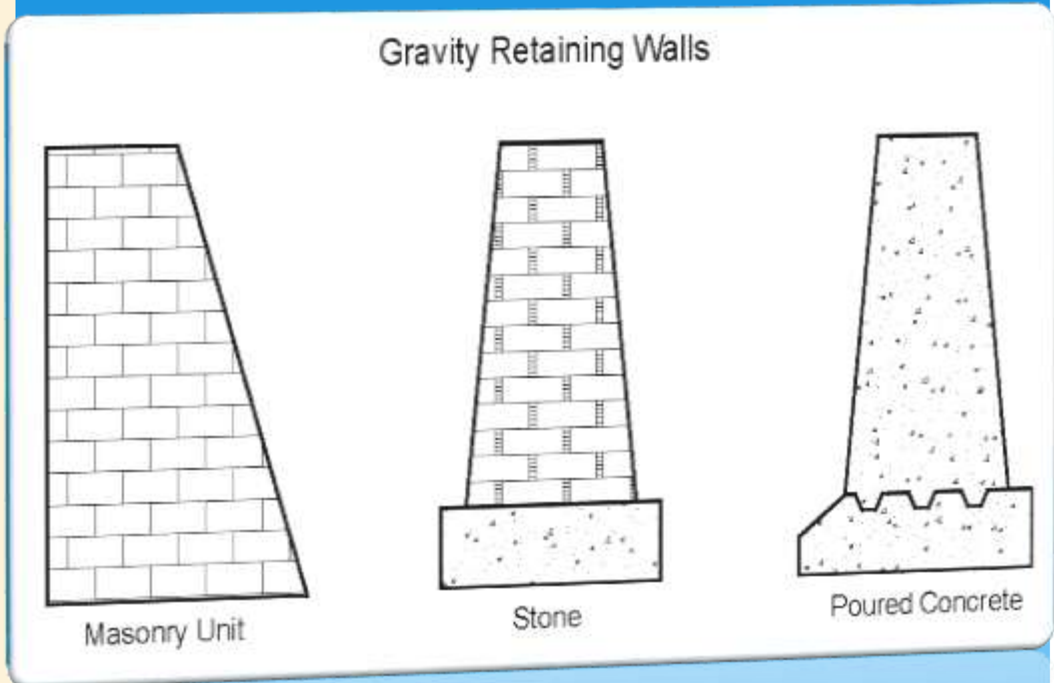
Types of retaining walls

1. **Gravity Retaining Walls**
2. **Semi-Gravity Retaining Walls**
3. **Cantilever Retaining Walls**
4. **Counter fort Retaining Walls**

Gravity Walls

* The “gravity wall” provides stability by virtue of its own weight , and therefore, is rather massive in size.
* It is usually built in stone masonry, and occasionally in plain concrete

- The thickness of wall is also governed by need to eliminate or limit the resulting tensile stress to its permissible limit .
- Plain concrete gravity walls are not used for heights exceeding about 3m, for obvious economic reasons.



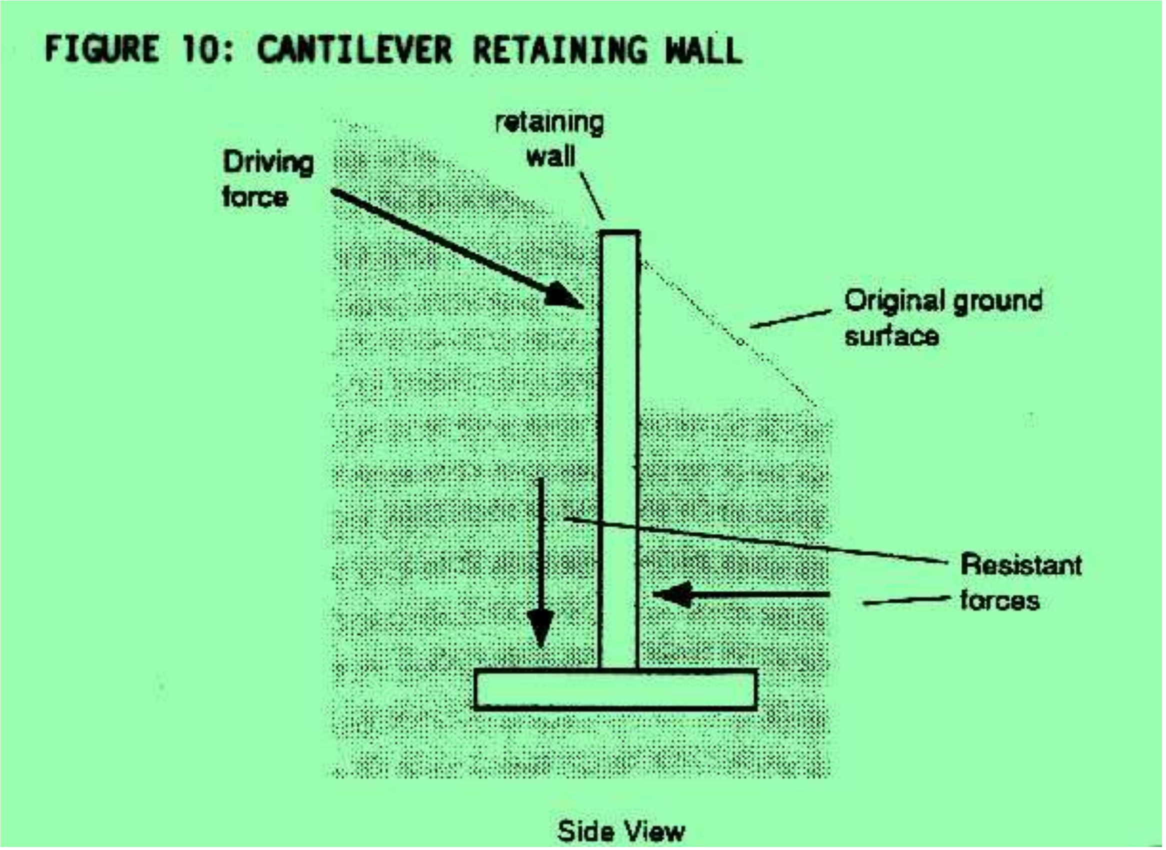
- ✓ Stress developed is very low.
- ✓ These walls are so proportioned that no tension is developed anywhere and the resultant of forces remain within the middle third of the base.

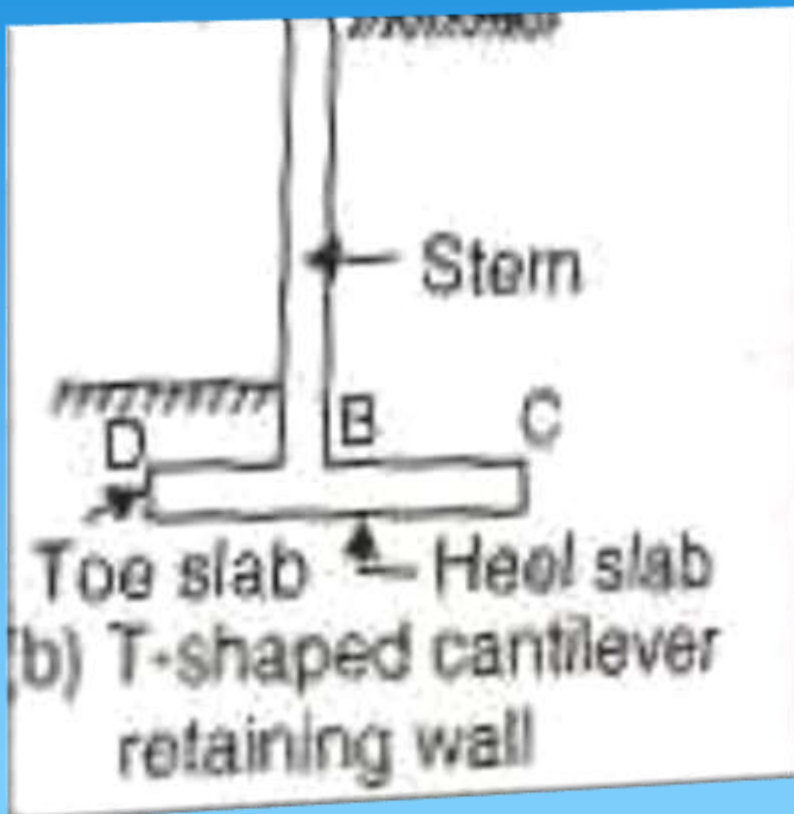
Semi-Gravity Walls

- ✓ Semi-gravity walls resist external forces by the combined action of self weight, weight of soil above footing and the flexural resistance of the wall components.

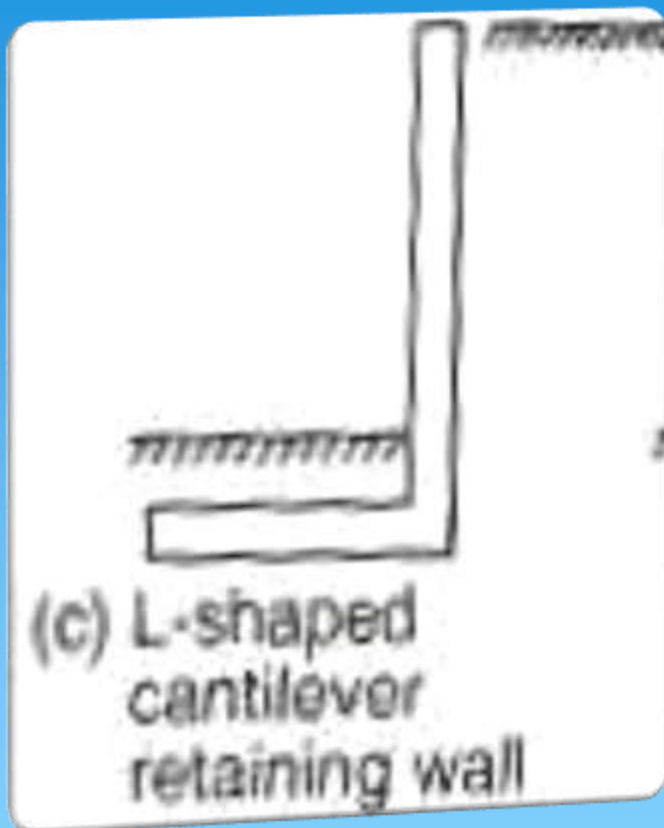
- ✓ concrete cantilever wall is an example and consists of a reinforced concrete stem and a base footing.
- ✓ These walls are non-proprietary.

Cantilever Wall

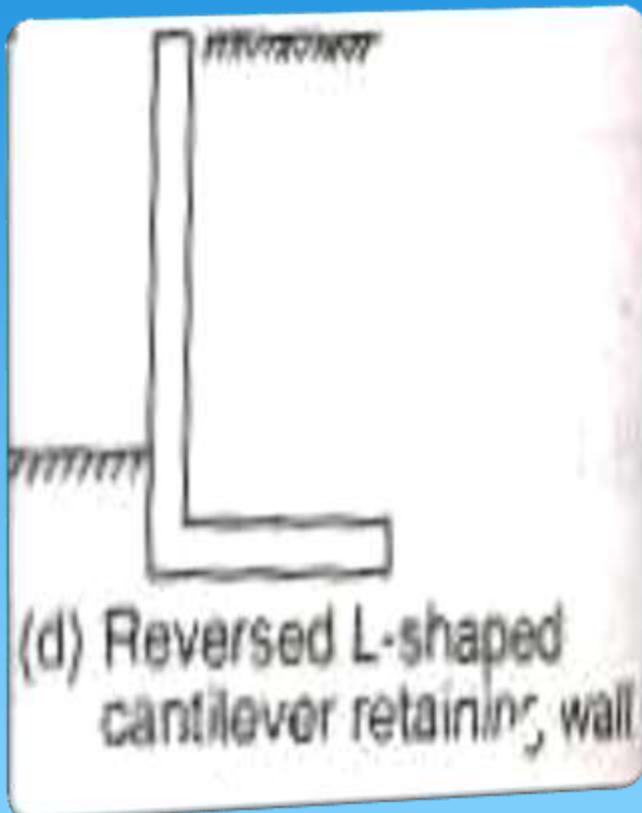




- The “Cantilever wall ” is the most common type of retaining structure and is generally economical for heights up to about 8m.
- The structure consists of vertical *stem* , and *a base slab*, made up of two distinct regions, viz., a *heel slab and a toe slab*



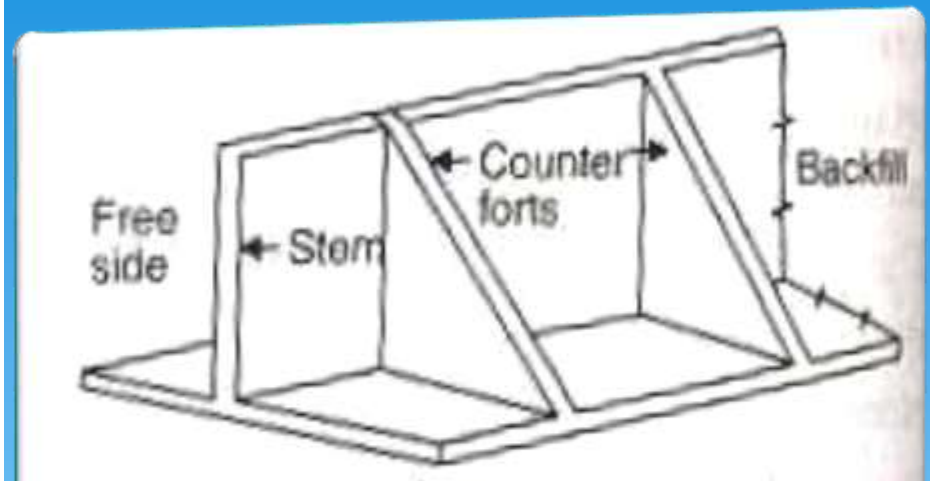
- **“Stem”** acts as a **vertical cantilever** under the **lateral earth pressure**
- **“Heel slab”** acts as a horizontal cantilever under the **action of weight of the retained earth (minus soil pressure acting upwards from below)**
- **“Toe slab ”** acts as a **cantilever** under the **action of resulting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



- It resists the horizontal earth pressure as well as other vertical pressure by way of bending of various components acting as cantilevers.
- May be L shaped or T shaped.

Counterfort Wall

- Stem and Heel slab are strengthened by providing counterforts at some suitable intervals.
- The stability of the wall is maintained essentially by the weight of the earth on the heel slab plus the self weight of the structure.



(e) Counterfort retaining wall

- 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 counterforts.

Counterfort wall are placed at regular intervals of about1/3 to ½ of the wall height, interconnecting the stem with the heel slab.

Type equation here.

The counterforts are concealed within the retained earth on the rear side of the wall.

This wall is economical for heights above (approximately) 7m.

The counterforts subdivide the vertical slab (stem) into rectangular panels and support them on two sides(suspender-style), and themselves behave essentially as vertical cantilever beams of T-section and varying depth.

EARTH PRESSURES

- PRESSURE AT REST
- ACTIVE EARTH PRESSURE
- PASSIVE EARTH PRESSURE

PRESSURE AT REST

When the soil behind the wall is prevented from lateral movement (towards or away from soil) of wall, the pressure is known as earth pressure at rest.

PRESSURE AT REST

This is the case when wall has a considerable rigidity.

Basement walls generally fall in this category.

ACTIVE EARTH PRESSURE

If a retaining wall is allowed to move away from the soil accompanied by a lateral soil expansion, the earth pressure decreases with the increasing expansion.

ACTIVE EARTH PRESSURE

A shear failure of the soil is resulted with any further expansion and a sliding wedge tends to move forward and downward. The earth pressure associated with this state of failure is the minimum pressure and is known as active earth pressure.

PASSIVE EARTH PRESSURE

If a retaining wall is allowed to move towards the soil accompanied by a lateral soil compression, the earth pressure increase with the increasing compression in the soil.

Principle of the design of retaining wall

SLIDING:

Ability of the retaining wall structure to overcome the horizontal force applied to the wall

Factor of safety = 1.5

OVERTURNING:

Ability of the retaining wall structure to overcome the overturning moment created by the rotational forces applied to the wall.

Factor of safety = 1.5

BEARING CAPACITY:

Ability of the underlying soil to support the weight of the retaining wall structure.

Factor of safety = 2.0

* **NO TENSION:**

There should be no tension at the base of the wall.

when the eccentricity (e) is greater than b/6 , tension develops at the heel

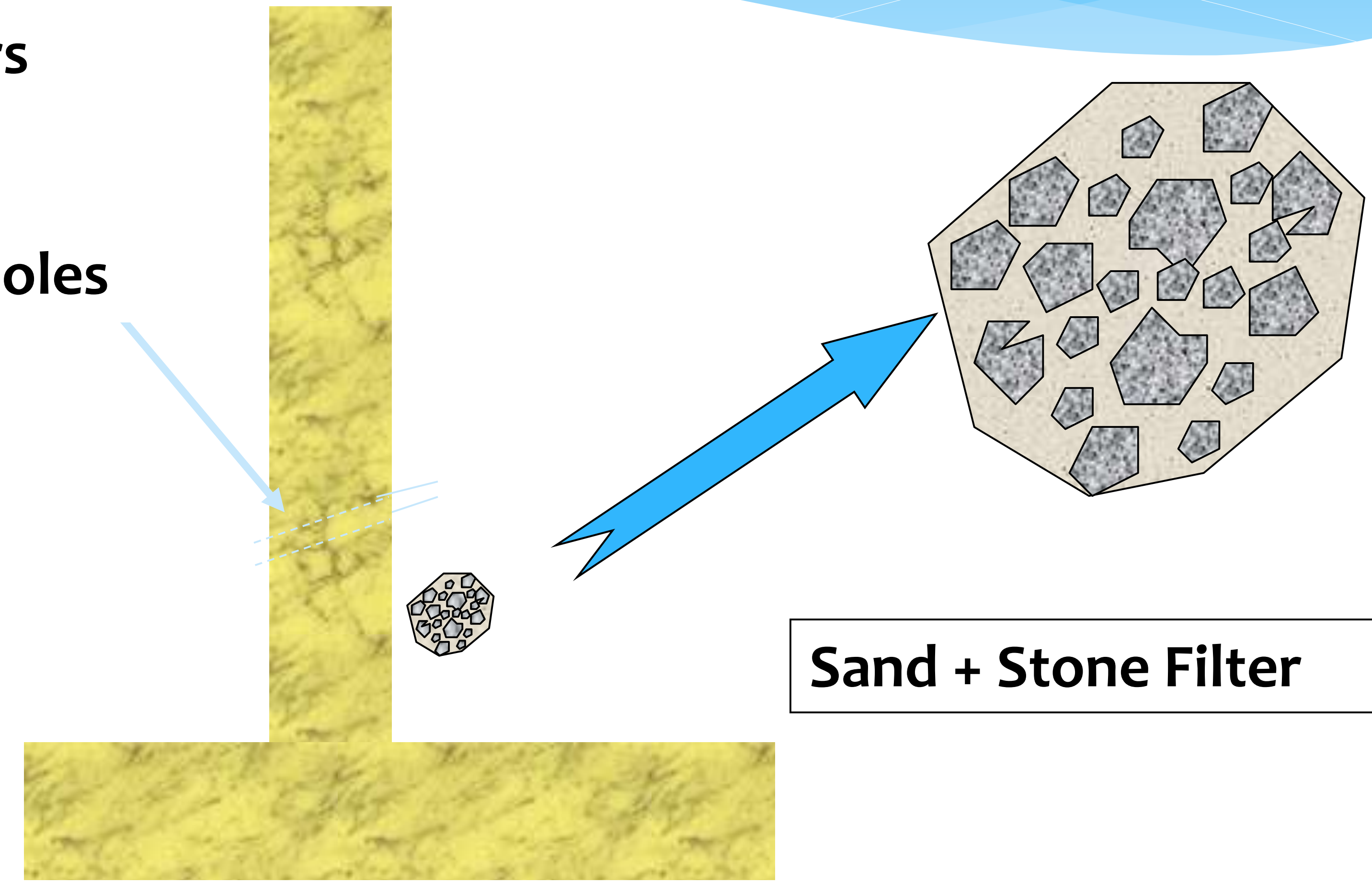
DRAINAGE OF THE BACK FILL

DRAINAGE

Weepers

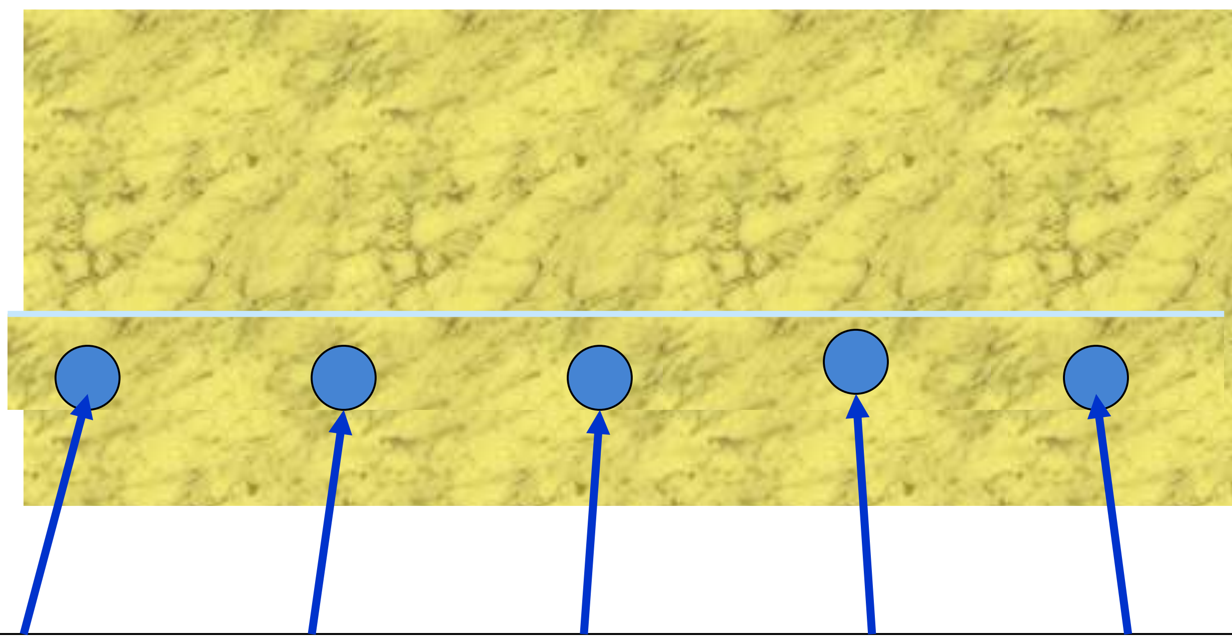
Or

Weep Holes



Sand + Stone Filter

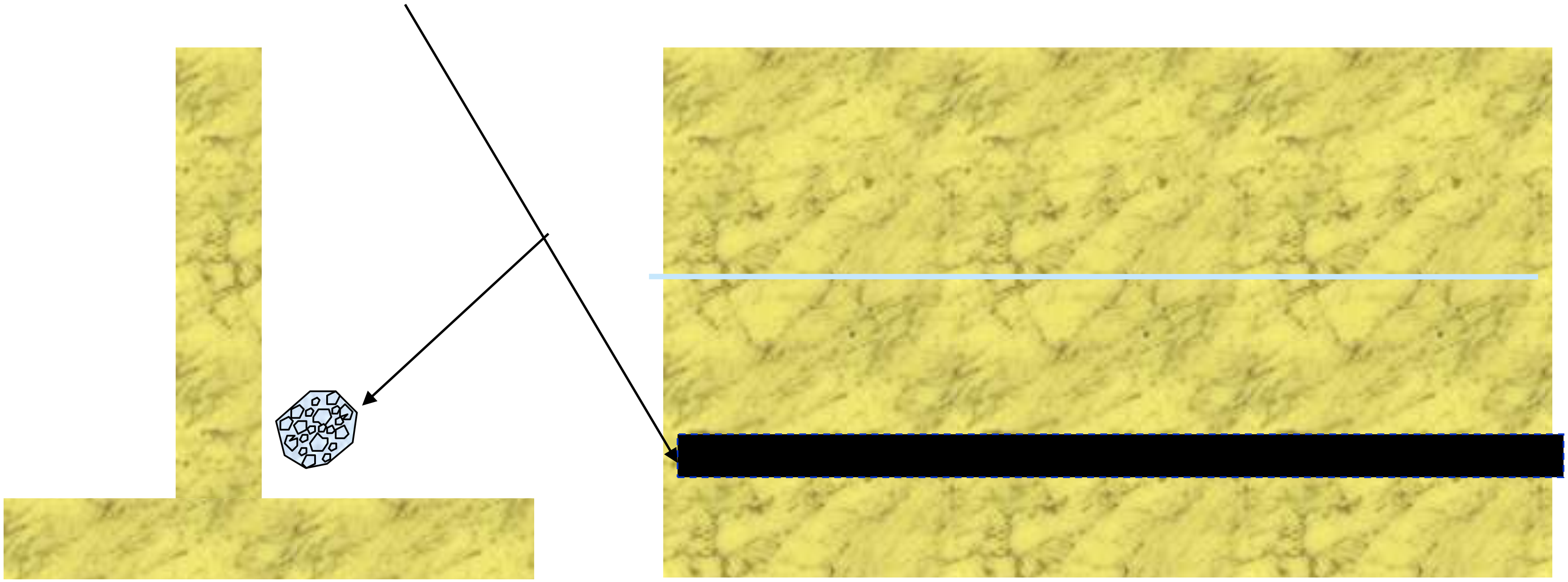
DRAINAGE



Drainage Pipes f 100-200 mm @ 2.5 to 4 m

DRAINAGE (Alternate)

Perforated Pipe



Suited for short walls

RANKIE'S THEORY

<u>**Assumptions**</u>

- **The soil mass is semi-infinite, homogeneous, dry and cohesionless**
- **The ground surface is plane which may be horizontal or inclined.**
- **The back of the wall is vertical and smooth(No shearing stresses are developed between the wall and soil).**
- **The wall yields about the base and satisfies the deformation conditions for plastic equilibrium.**

When soil surface is horizontal:

$$P_a = K_a \gamma H$$

Where,

P_a=Intensity of active earth pressure trying to move the wall away from the wall

K_a=Co-efficient of active earth pressure

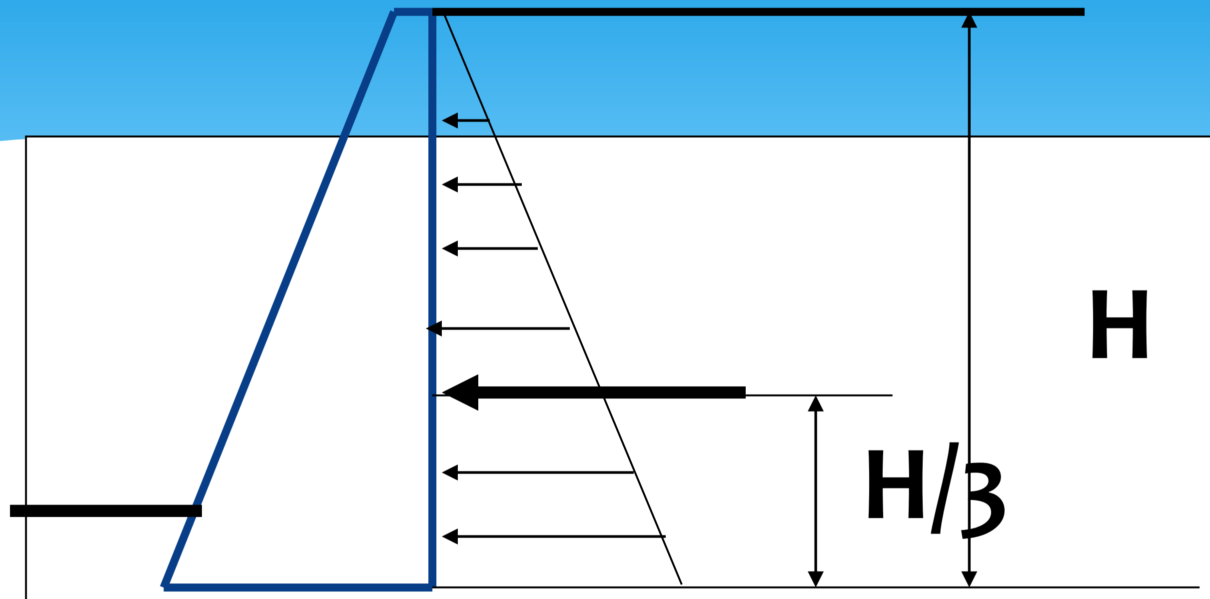
$=\frac{1-sin\phi}{1+sin\phi}$, ϕ= Angle of friction for the backfill

γ =Unit weight of soil (Backfill)

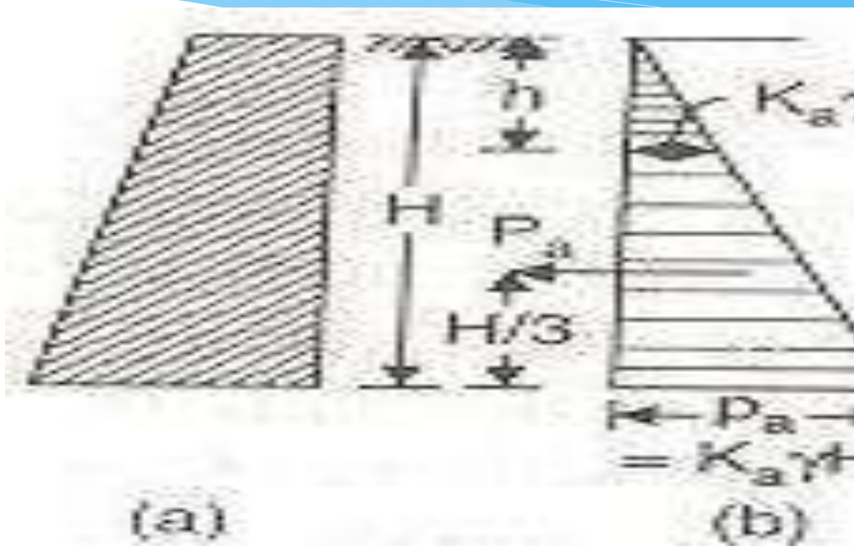
H=height of the retaining wall

h=Any height below the ground surface

$$\delta = 0$$



$$C_{ah} = \frac{1-\sin\phi}{1+\sin\phi}$$



Total Earth Pressure or resultant force per unit length of the wall,

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

acting at $\frac{H}{3}$ above the base of retaining wall.

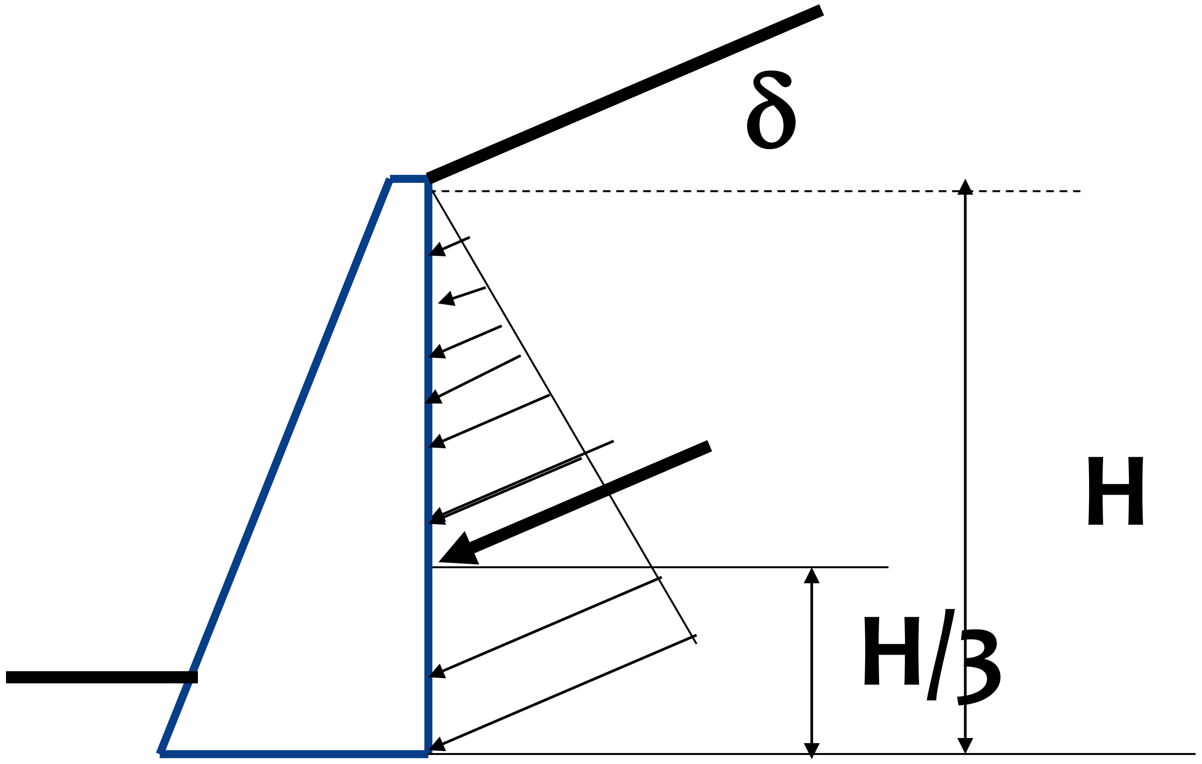
When soil surface is inclined:

- The intensity of lateral earth pressure

$$P_a = \gamma H \,.\, \mathrm{Cos}\beta \, \frac{\mathrm{Cos}\beta - \sqrt{\mathrm{Cos}\beta^2 + \mathrm{Cos}\phi^2}}{\mathrm{Cos}\beta + \sqrt{\mathrm{Cos}\beta^2 - \mathrm{Cos}\phi^2}}$$

or $$P_a = K_a \gamma H$$

Where, $$K_a = \mathrm{Cos}\beta \, \frac{\mathrm{Cos}\beta - \sqrt{\mathrm{Cos}\beta^2 + \mathrm{Cos}\phi^2}}{\mathrm{Cos}\beta + \sqrt{\mathrm{Cos}\beta^2 - \mathrm{Cos}\phi^2}}$$



$$C_a = \cos\delta \frac{\cos\delta - \sqrt{\cos^2\delta - \cos^2\phi}}{\cos\delta + \sqrt{\cos^2\delta - \cos^2\phi}}$$

Coulomb’s Theory

Assumptions

- **The back fill is homogeneous, dry ,cohesionless , isotropic and ideally plastic material.**
- **The slip surface is plane which passes through the heel of the wall.**
- **The wall surface is rough. The resultant earth pressure on the wall is inclined at an angle of δ to the normal to the wall, where δ is the angle of the friction between the wall and the backfill.**
- **The sliding wedge itself acts as rigid body.**

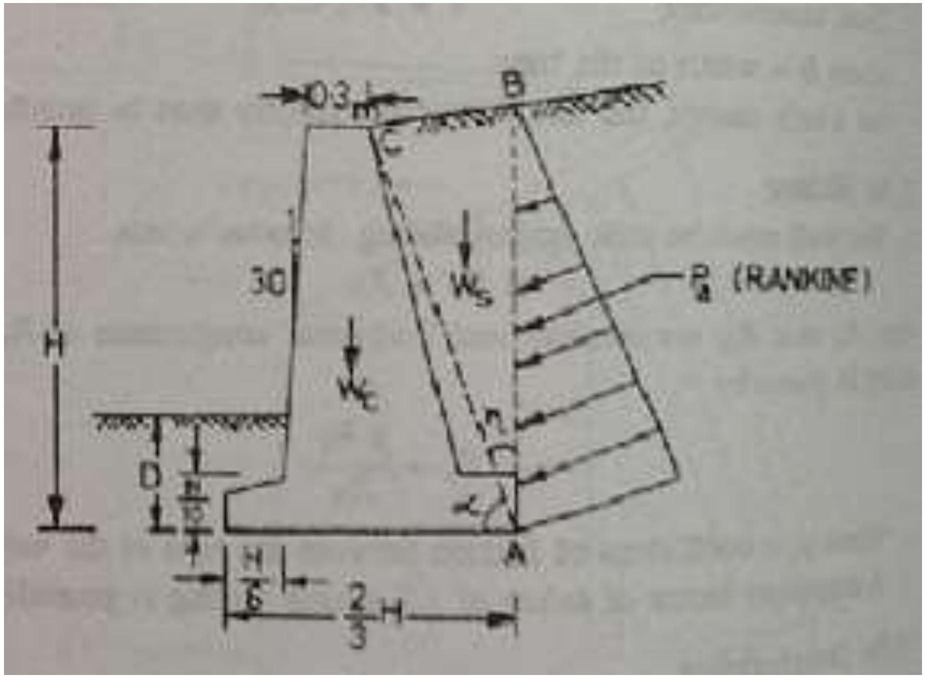
$$K_A = \frac{\sin^2(\alpha + \phi)}{\sin^2\alpha \sin(\alpha - \delta)\left[1 + \sqrt{\frac{\sin(\phi + \delta)\sin(\phi - \beta)}{\sin(\alpha - \delta)\sin(\alpha + \beta)}}\right]^2}$$

where K_A *is the active earth pressure coefficient.*

DESIGN OF RETAINING WALLS

General proportions of gravity retaining wall

When surface is inclined:



$$\eta = (45° + i/2) - \phi'/2 - \sin^{-1}\left(\frac{\sin i}{\sin \phi'}\right)$$

where i is the angle of surcharge.

The angle α which the line AC makes with the horizontal is given by,

$$\alpha = \left(45° + \frac{\phi'}{2}\right) - \frac{i}{2} + \sin^{-1}\left(\frac{\sin i}{\sin \phi'}\right)$$

When $i = 0$, the value of α is equal to $(45° + \phi'/2)$ (Fig. 20.4).

When surface is horizontal:

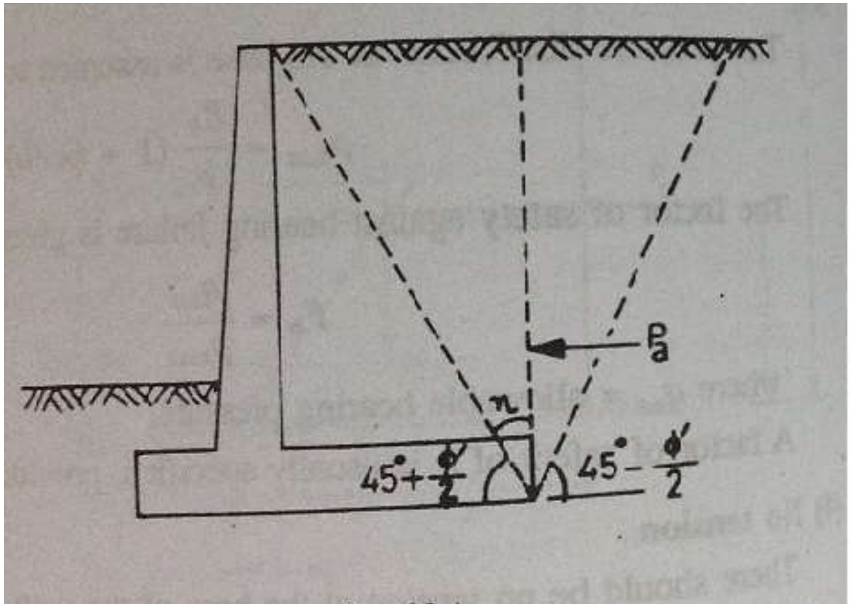
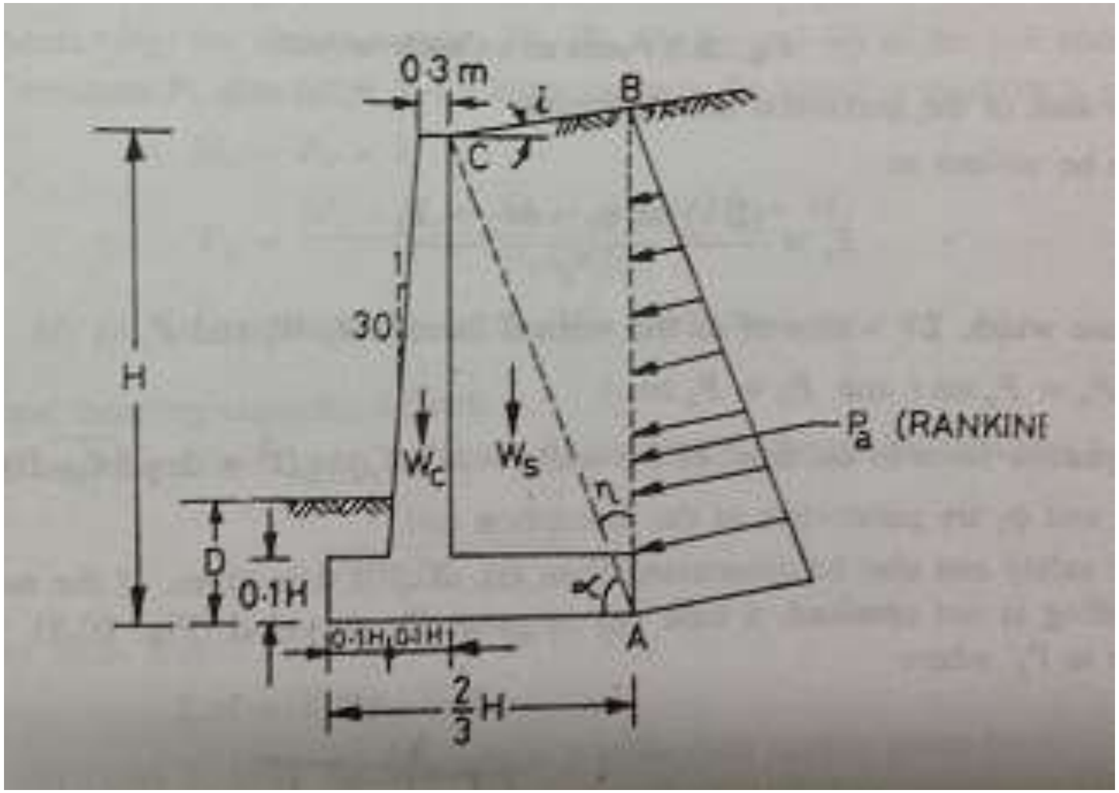


Fig. 20.4.

General proportions of cantilever retaining wall

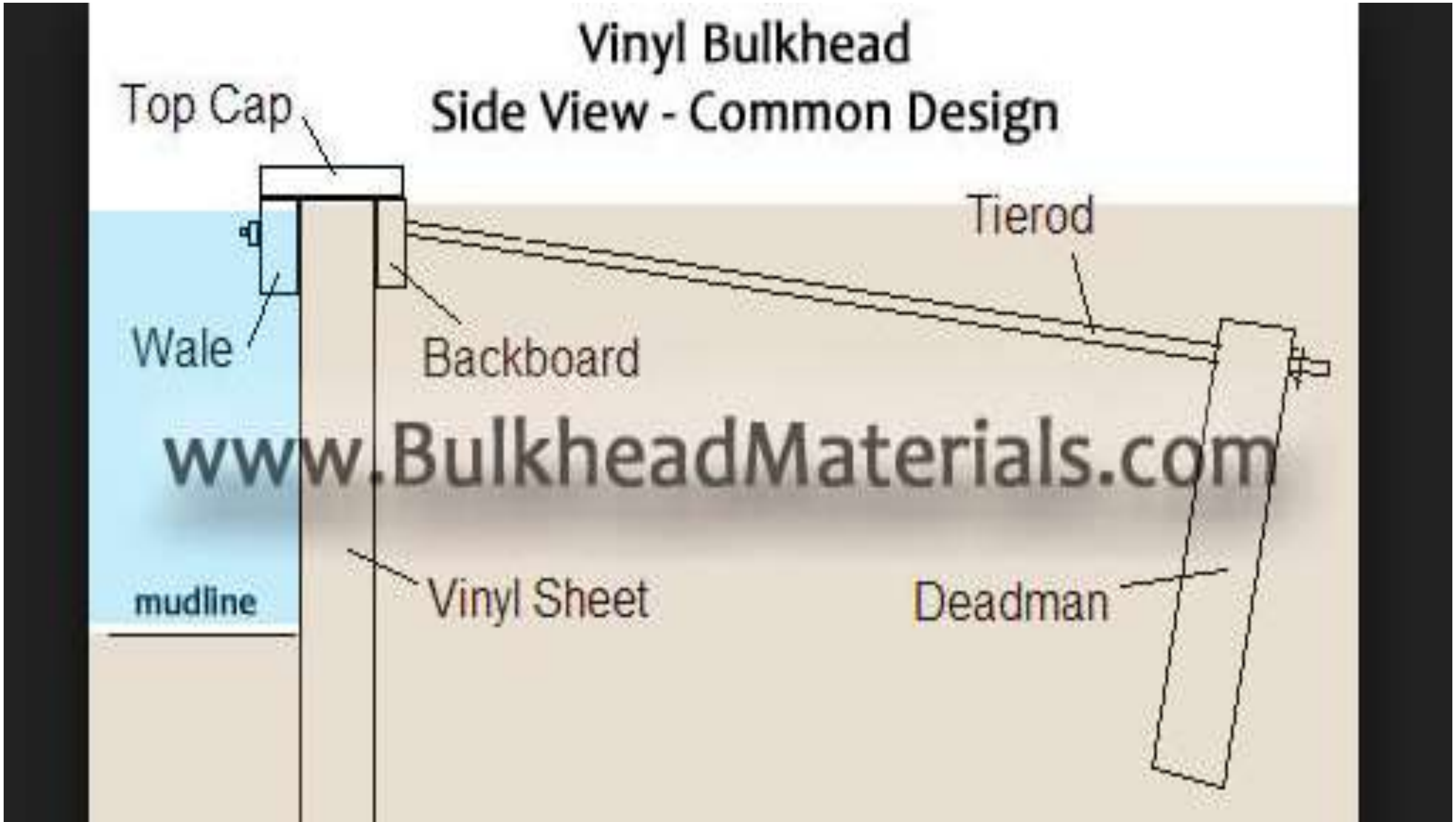


BULK HEADS

* **Bulkheads are very similar in design and construction as standard retaining walls. The primary difference in definition between a bulkhead and retaining wall is that a bulkhead is retaining earth on one side, and is partially surrounded by water on the other.**

Materials

* Materials used in the construction of bulkheads vary, but generally are the same as those used for the construction of the piers.
* Masonry is often used as a bulkhead material. Masonry can take the form of brick, block, or poured concrete.


Vinyl Bulkhead
Side View - Common Design
Top Cap
Tierod
Wale
Backboard
www.BulkheadMaterials.com
mudline
Vinyl Sheet
Deadman

Disadvantage:

- **The largest problem with the bulkhead systems is erosion of the backfill area. As the backfill begins to erode, the granular surface is affected, as is the drainage. The increase in hydrostatic pressure, coupled with the lateral forces of the earth itself, tend to push the units over.**

Anchored Bulkhead

What is anchored bulkhead?

If tie rods or anchor rods are anchored close to the upper ends of sheet pile walls, the sheet pile walls are called bulkheads or anchored sheet pile walls. The tie or anchor rods are buried in the backfill at a considerable distance from the back of the wall. The ties or anchored rods reduce the lateral deflection, the bending moment and the depth of penetration.

Anchored bulkhead are extensively used in water front structures. They are constructed by driving a row of sheet pile to the required depth. The soil in front of the wall is dredged out to required depth in front of the wall and behind the wall it is backfilled by suitable soil. The wall is supported at the top by tie rods and at the bottom by passive earth resistance.

How Anchored Bulkhead determined?

In anchored bulkheads the depth of penetration is determined by:

- The free earth support method
- The fixed earth support method

Free Earth Support Method:

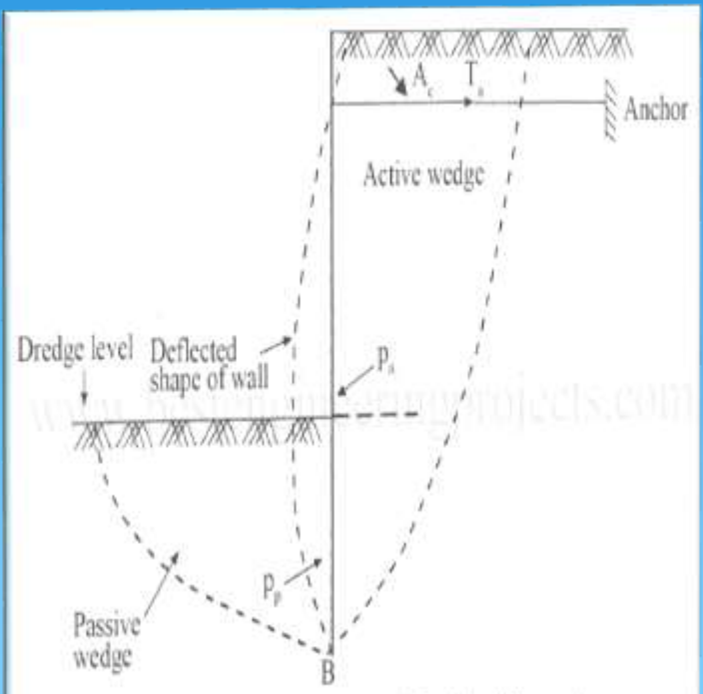


Fig 1 Anchored Sheet Piled Wall Free Earth Support

In free earth support method the depth of penetration is not sufficient to provide end restraint. The wall is assumed to be freely supported by tie rods at the top and by the passive earth resistance of soil at the bottom. The forces acting on the wall as well as the deflected shape of the wall are shown in Fig.1 below.

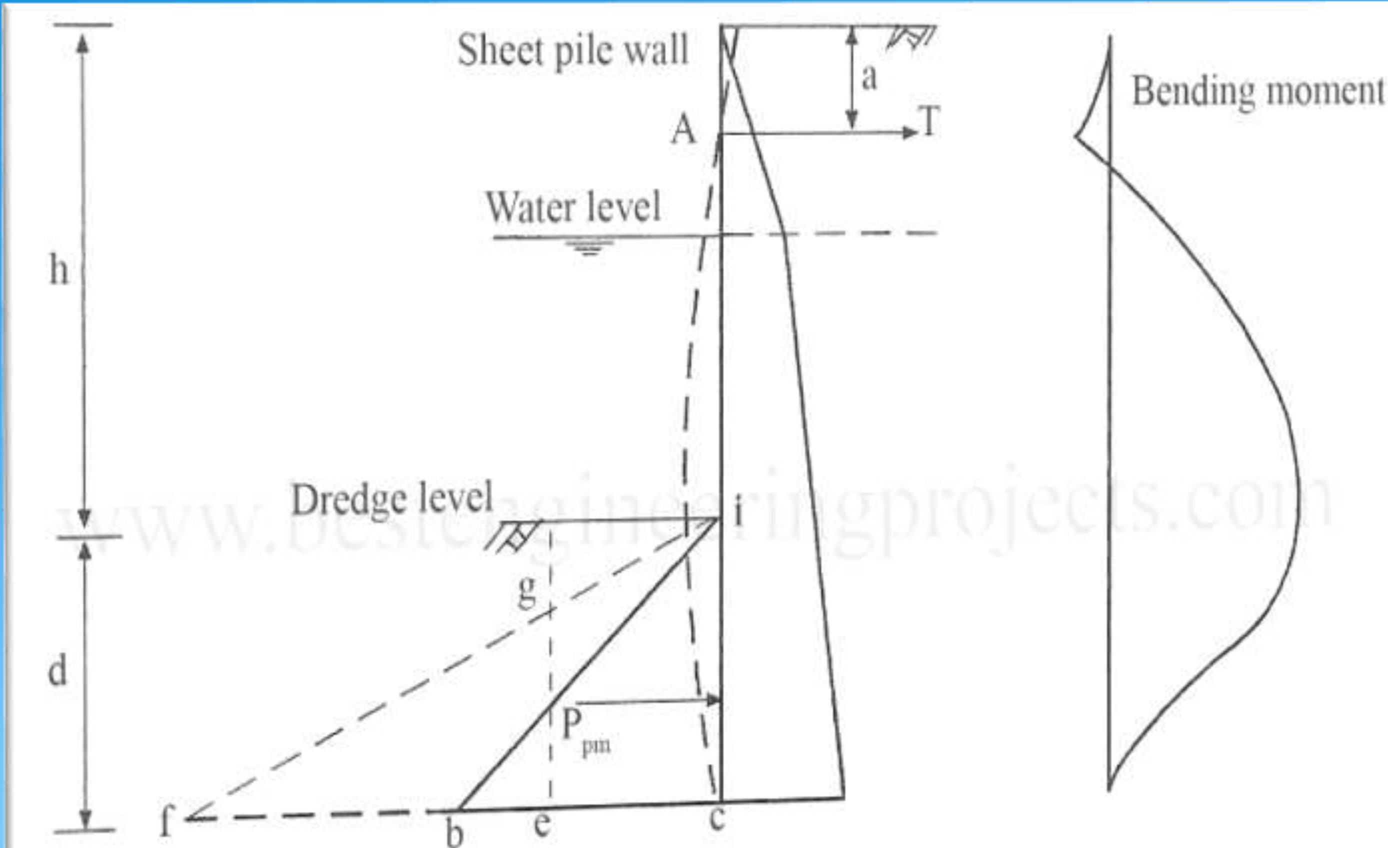


Fig 2 Anchored Sheet Pile Free Earth Support Method

T = Tension in the tie rod per unit length

d = Depth of penetration below dredge line

p_a = Active pressure in the wall

p_{pm} = Mobilized passive resistance = *ppF*

The depth of penetration d is found out by taking moment of all forces about the line of action of the tie rod.

Or, $Pa\times23(h+d)-a-Ppm\times23(d+h)-a=0$

Once d is known, the tension in the tie rod is found out by summing all the horizontal forces i.e.,

$p_a - p_{pm} - T = 0$

In order to guard excess dredging, scouring and presence of pockets of weak soils the depth of penetration is increased by 20 to 40 %. With this increasing the depth of penetration, a factor of safety of 1.5 to is ensured.

Fixed Earth Support Method:

* In fixed earth support method, the depth of penetration is adequate and soil below the dredge line provides considerable anchorage. The wall acts as propped cantilever beam and cannot rotate

  freely at its lower end as shown in Fig.3 and the point of contra flexure lies close to the dredge line.

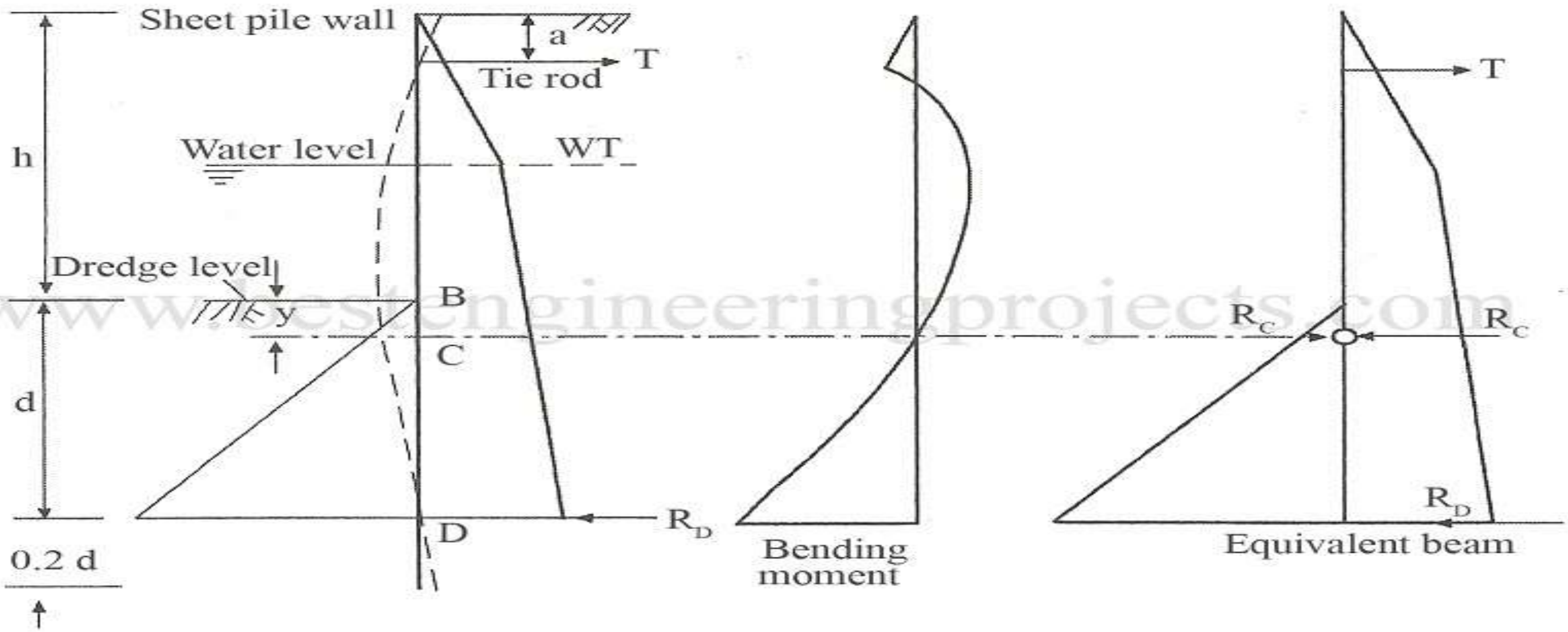


Fig 3 The Principles of Equivalent Beam Method

* Prevention of free rotation at the bottom develops full passive resistance at the back of the wall above the lower end. This resistance is replaced by a concentrated force R_D at 0.2 d above the lower end of the pile

Analysis:

In the analysis, two beams, one above the point of contraflexure and another below the point of contraflexure, are considered. The position of the point of contraflexure, y is a function of angle of internal friction of the soil ϕ. For sands, y is given by,

ϕ	20	30	40
Y	0.25h	0.08h	-0.006h

For approximate analysis 'y' may be assumed as zero and the point of contrafiexure lie at the dredge level.

By considering the upper beam, the unknown forces R_C and T can be found out by $\sum M$ and $\sum H = 0$.

. In the case of lower beam as shown in Fig.3 force R_D and depth of penetration d are not known.

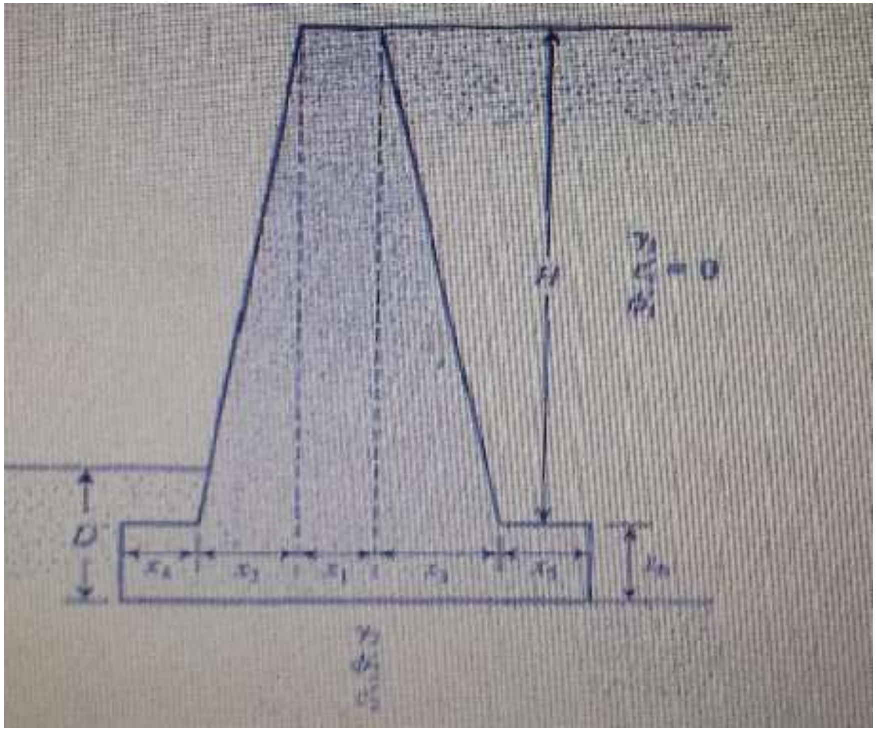
. By taking moment of all forces about the base of the pile the depth of penetration can be

found out. The depth of penetration thus obtained by fixed earth support methodis increased by 20 to 40 %.

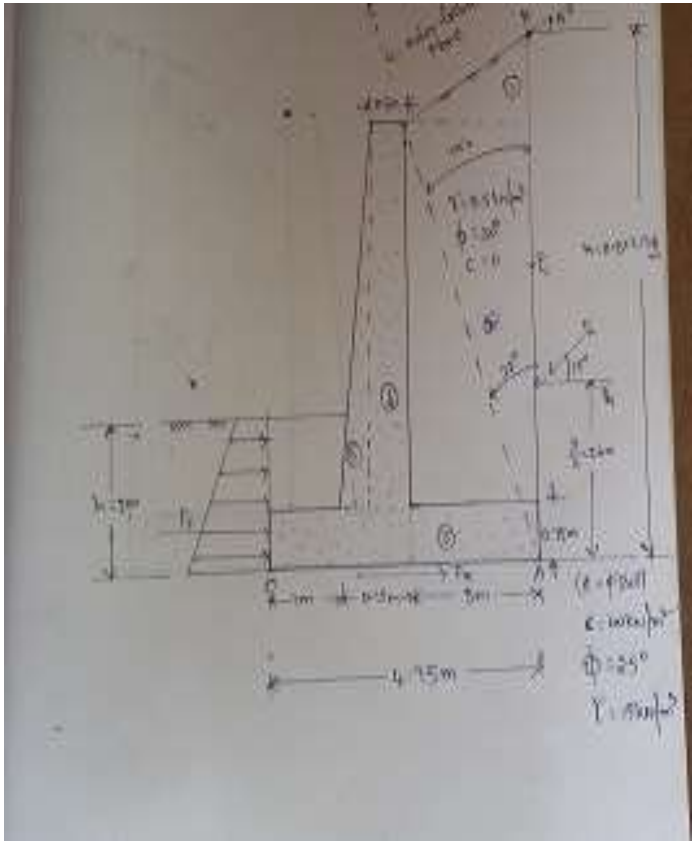
Questions

1.Check the stability of a cantilever concrete retaining wall having a stem thickness of 0.4m uniform throughout, 6.0m height bed block thickness 0.8 m and a projection of 2.5 m on the heel side and 1.5 m on the toe side. The unit weight of the wall material is 25kN/m3. The soil has a unit weight of 18 kN/m3 and an angle of internal friction of 360.Take in to account a uniform surcharge on the ground of 50kN/m2. The ground level on the toe side is 1.2 m high above the base of the wall

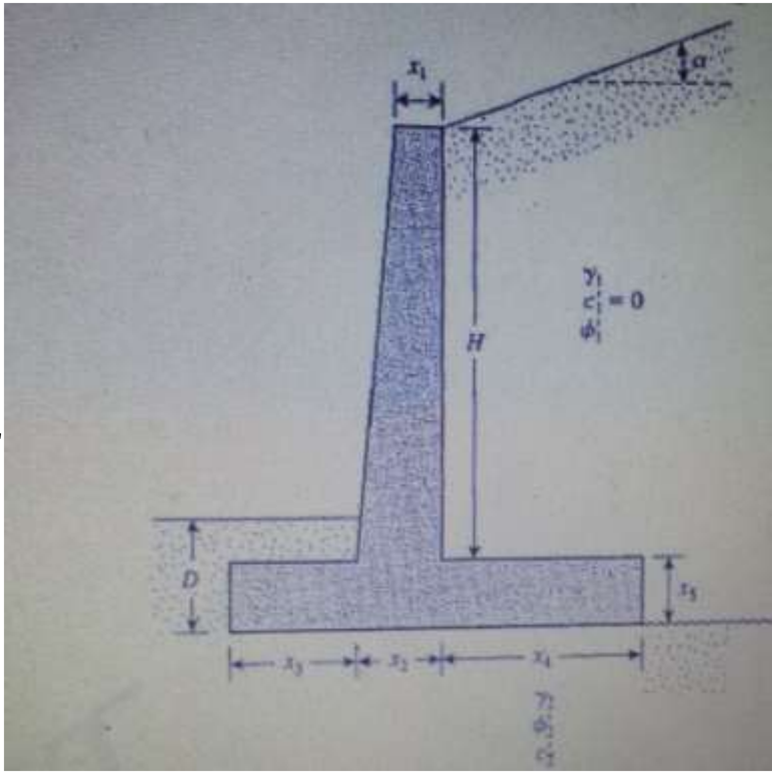
2.A gravity retaining wall is shown in Fig. 3. Calculate the factor of safety with respect to overturning and sliding, given the fallowing data:Wall dimensions: H = 6 m, x1 = 0.6 m, x2 = 2m, x3 = 2 m, x4 = 0.5 m, x5 = 0.75 m,x6 =0.8m, D = 1.5 m.Soil properties: $\gamma 1$ = 16.5kN/m3,φ 1' = 320, 2 = 18kN/m3,φ 2' = 22, c2'=40kPa. Use the Rankine active earth pressure in your calculations.



3.Figure 1 shows a section of a cantilever wall with dimensions and forces acting there on. Check the stability of the wall with respect to (a) overturning, (b) sliding, and (c) bearing capacity.



4.For the cantilever retaining wall shown in Fig. 2, let the fallowing data be given:Wall dimensions: H = 6.5 m, x1 = 0.50 m, x2 = 1.2 m, x3 = 1.35 m, x4 = 2.1 m, x5 = 1.0 m,D = 2.0 m, Φ= 150.Soil properties: 1 = 19.5kN/m3, φ1' = 360, 2 = 17.0 kN/m3, φ2' = 10, c2'= 50 kPa.Calculate the factor of safety with respect to overturning, sliding and bearing capacity.




PowerPlugs
Templates for PowerPoint
Thank you!