What is a Retaining wall?

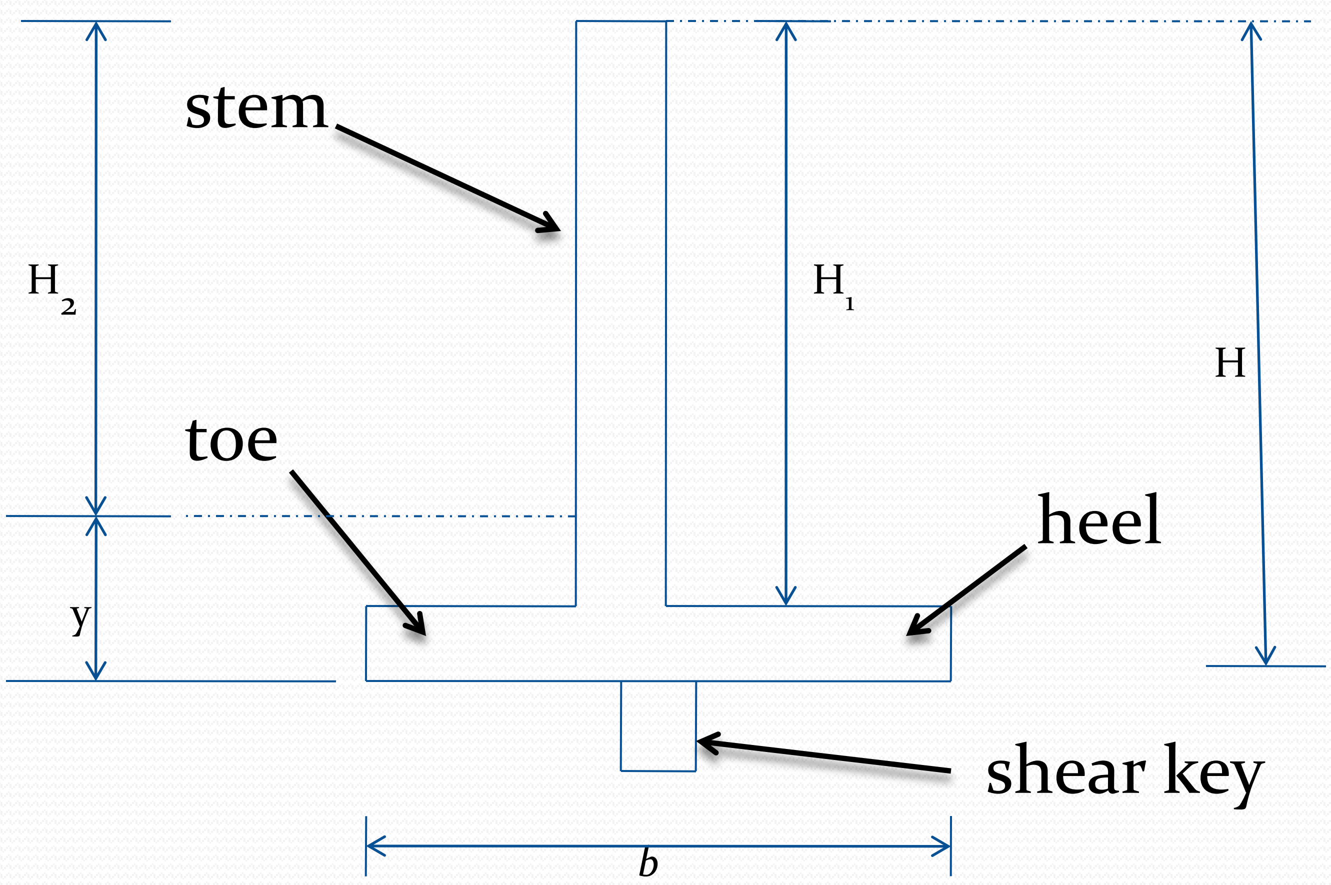
- Retaining wall is a structure used for maintaining the ground surfaces at different elevations on either side of it.

- Retaining walls provide lateral support to vertical slopes of soil. They *retain* soil which would otherwise collapse into a more natural shape. The retained soil is referred to as *backfill.*

Types of retaining walls:

- **Gravity Retaining Walls**
- **Semi-Gravity Retaining Walls**
- **Cantilever Retaining Walls**
- **Counter fort Retaining Walls**

Cantilever Retaining Wall:



Forces acting on the retaining wall:

- ***Lateral forces***: Earth pressure due to backfill and surcharge.
- ***Vertical forces***:

  Acting downwards:

  Self weight of the retaining wall ;
  Weight of soil above heel slab.

  Acting upwards:

  Force due to soil pressure underneath the base slab.

Earth pressures:

(a) ***On stem:*** Earth pressure on the stem from backfill (active earth pressure) varies linearly. According to Rankine's theory at depth '*h*' below the top of wall is given by

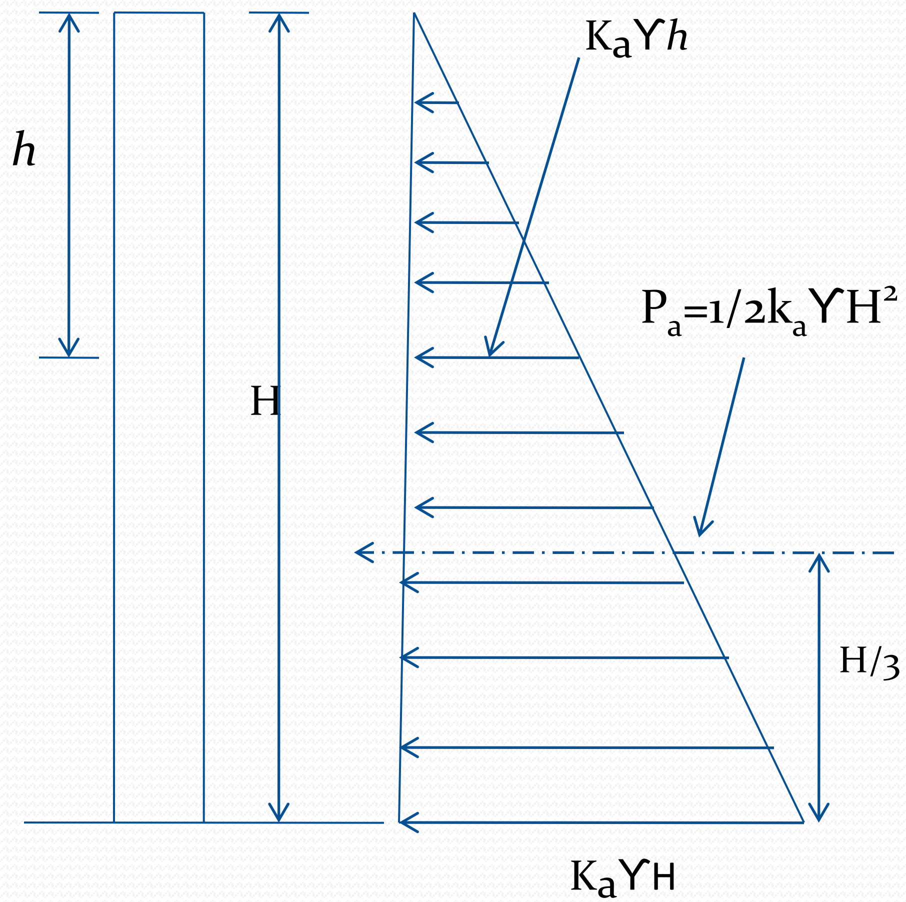
$$p_a = k_a \Upsilon h$$

where k_a = Coefficient of active earth pressure

$$k_a = \frac{1-\sin\Phi}{1+\sin\Phi}$$

Φ= Angle of internal friction of soil

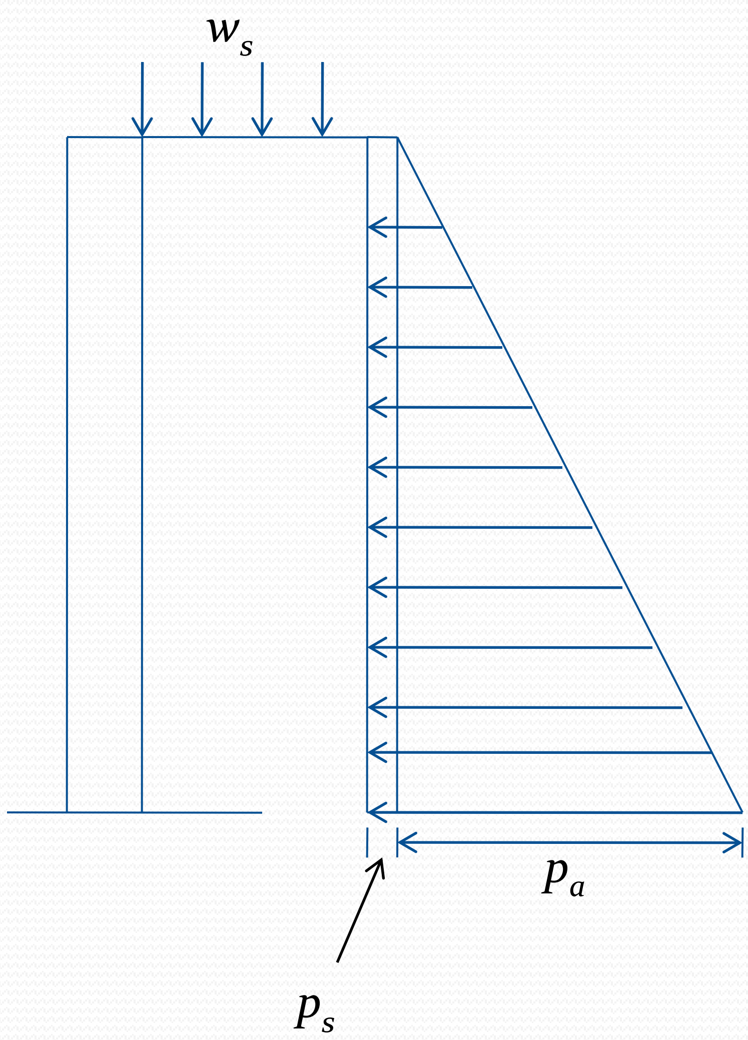
Υ= Unit weight of back fill



Incase of backfill with surcharge;

- The surcharge on backfill may be due to traffic load on top of back fill or due to a structure near it.
- If w_s is the surcharge pressure on horizontally finished back fill, then uniform effect of surcharge on stem is given by;

$$p_s = k_a\, w_s$$



If backfill is sloping;

- For sloping black fill, the pressure on stem is parallel to top surface and is given by;

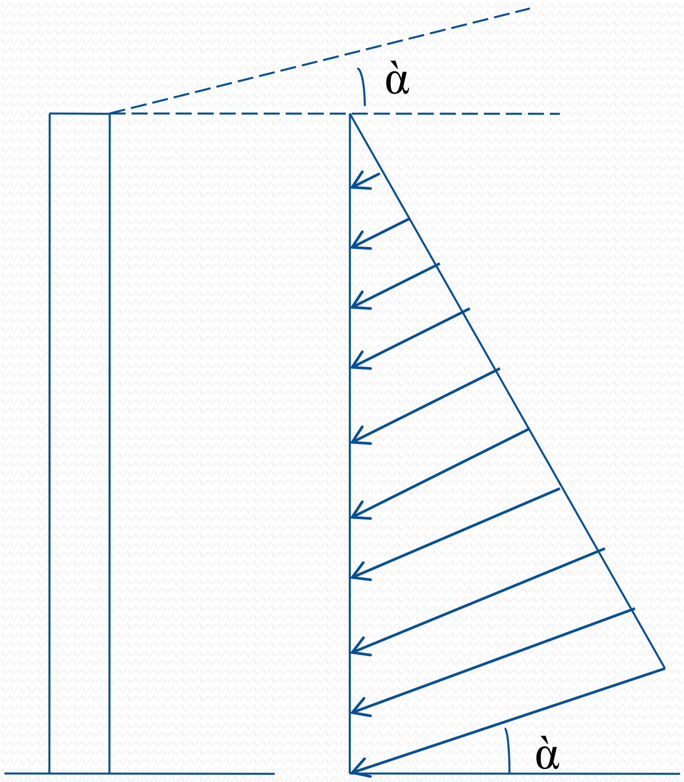
$$p_a = k'_a \Upsilon h$$

$$k'_a = \cos\alpha \; \frac{\cos\alpha - \sqrt{\cos^2\alpha - \cos^2\Phi}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\Phi}}$$

where,

'α' is angle of slope of backfill with horizontal.(*also reffered as surcharge angle)*

k' is coeff. Of active earth pressure for such case.



Stability Conditions:

- A retaining wall must be stable as a whole, and it must have sufficient strength to resist the forces acting on it.
- In order that the wall may be stable, the following conditions should be satisfied:

i. *The wall must be strong enough to resist the bending moment and shear force.*
ii. *The wall should not overturn.*
iii. *Maximum pressure at base should not exceed the SBC of soil.*
iv. *The wall should not slide due to lateral pressure.*

Design of RCC Cantilever Retaining walls:

- The depth of foundation depends on the properties of soil. The minimum depth of foundation is calculated from *Rankine*'s formula as

$$y_{min} = q_0 k_a^2/\Upsilon$$

'q_o' is SBC of soil.

'Υ' is the unit weight of soil on which footing is resting.

'k_a' is the coefficient of active earth pressure.

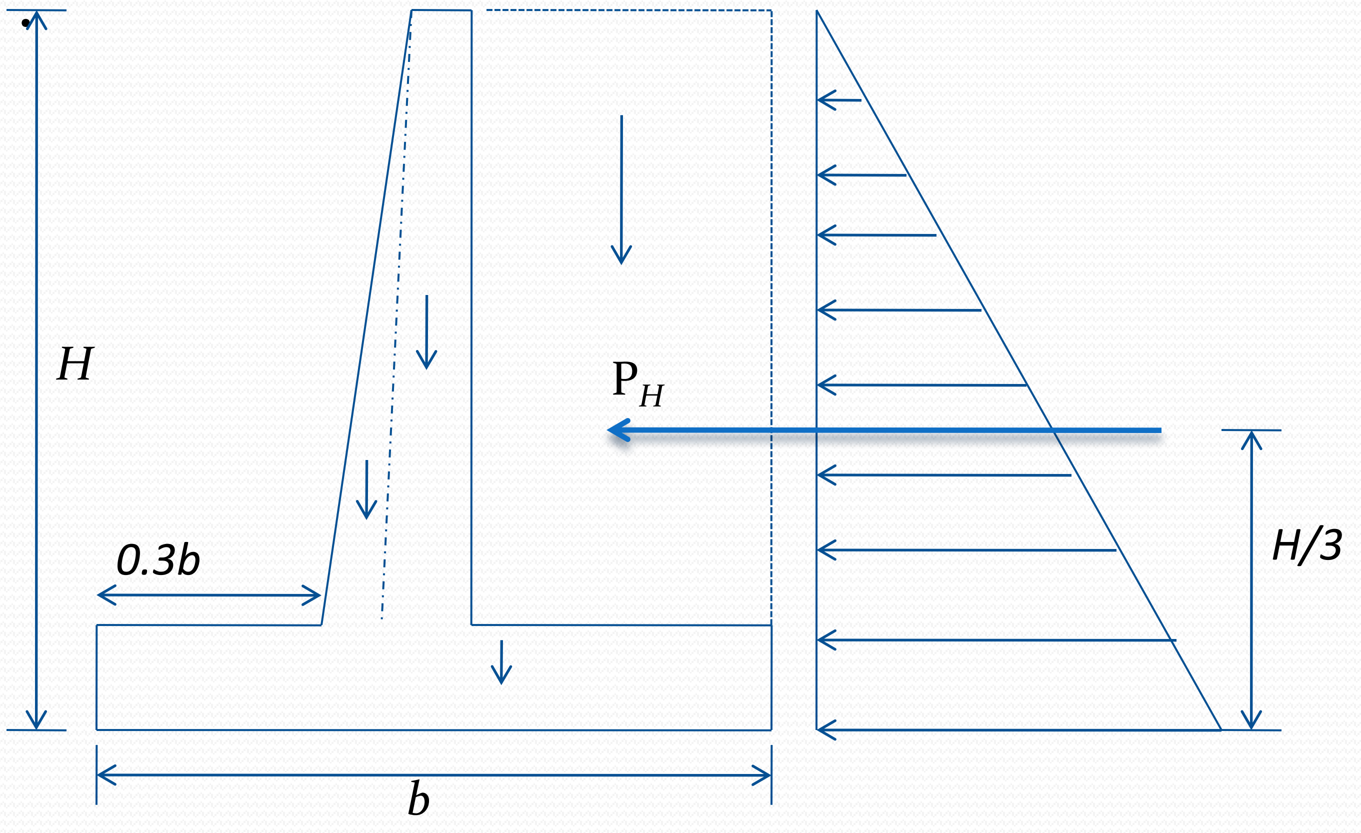
Preliminary Dimensions:

- The tentative proportions of the cantilever retaining wall may be obtained based on experience and optimization studies.

- Set the preliminary dimensions of retaining wall

- Base width, *b* = 0.48H *to* 0.56H
- Toe projection = 0.3 *b*
- Thickness of base slab = Thickness of stem = H/12
- Top width of stem = 150 *mm* *to* 300 *mm*

Diagrammatic Representation:



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.

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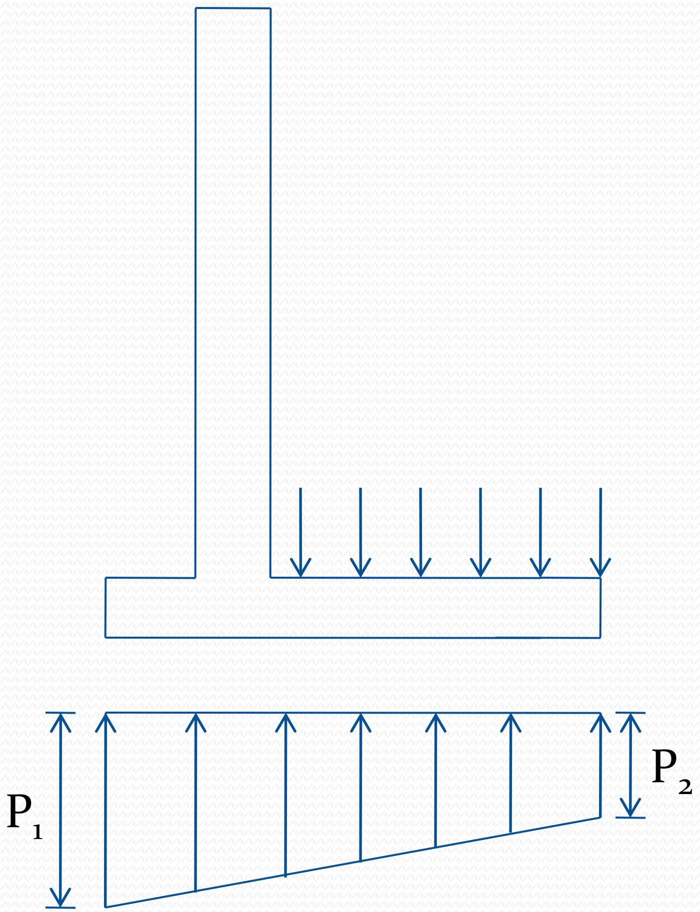


Design of stem:

- 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:

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

- 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:

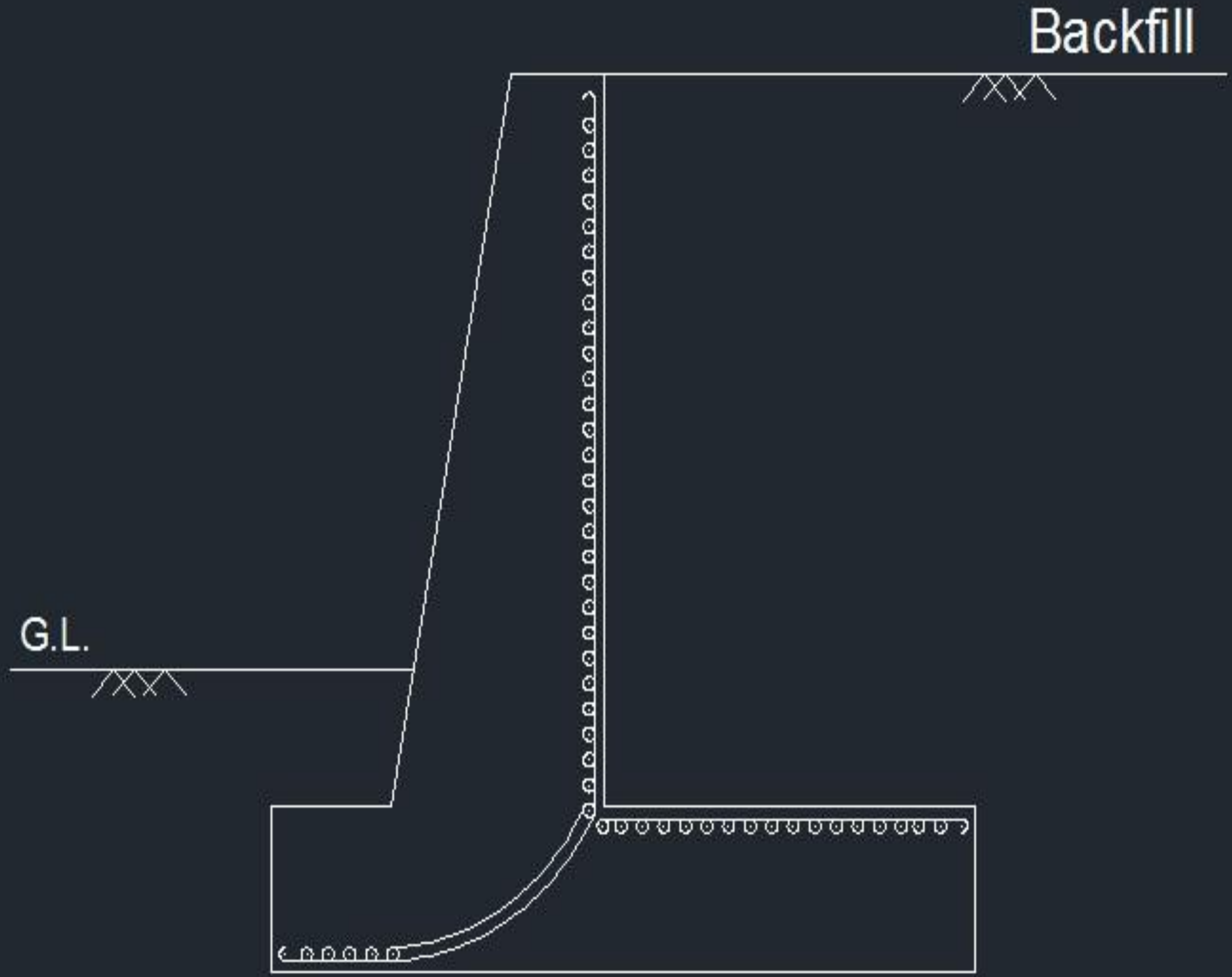
- Calculate the ultimate BM for *1 metre* width of heel slab.
- For calculation of BM,

  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*.


Backfill
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