EARTH RETAINING STRUCTURE AND COFFER DAM

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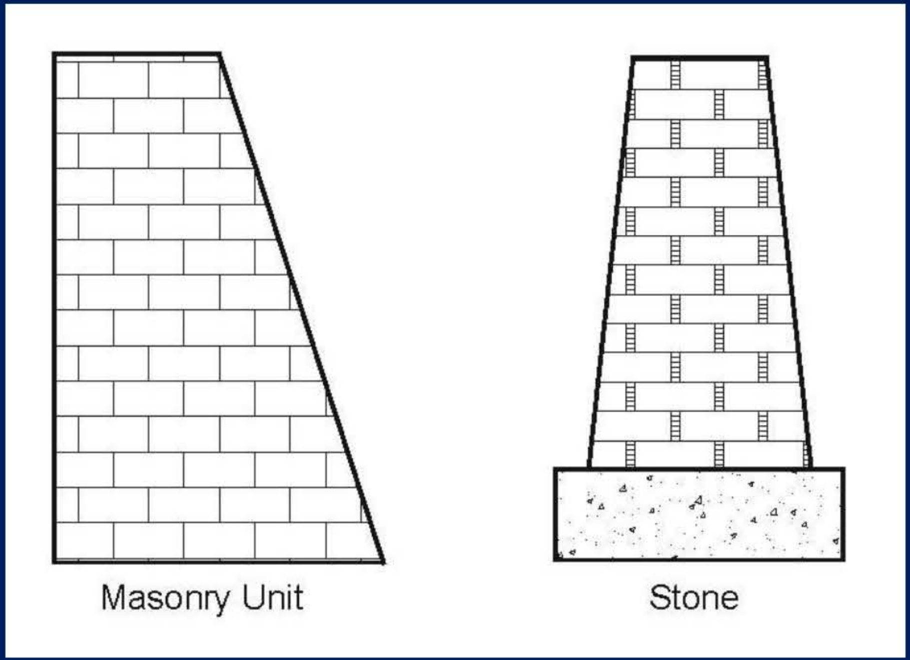
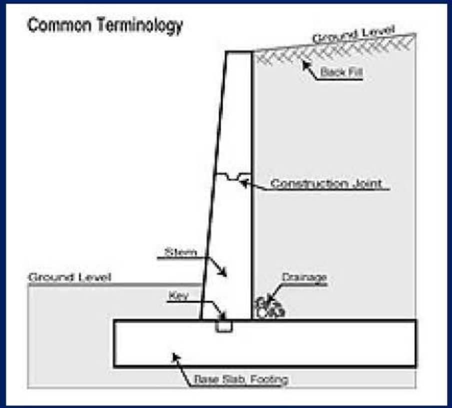
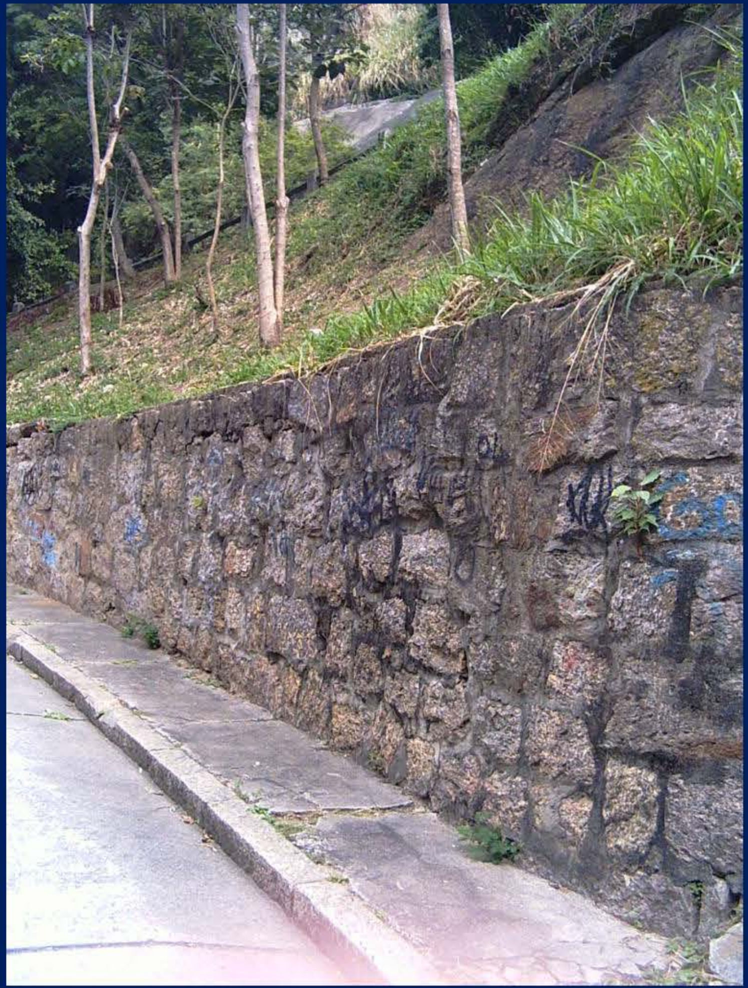
- Flexible Retaining Structures
  - Sheet pile wall and its classification
  - Analysis of sheet pile wall (cantilever sheet pile wall and anchored sheet pile wall)
  - Introduction to gabion wall
- Types and proportioning of earth retaining structures
- Stability analysis of earth retaining structures
- Coffer dam

STABILITY ANALYSIS OF EARTH RETAINING STRUCTURES

- The stability of a gravity wall is due to the self weight of the wall and passive resistance developed in front of the wall.
- Reinforced concrete walls are more economical to gravity walls because the backfill itself provides most of the required dead loads.

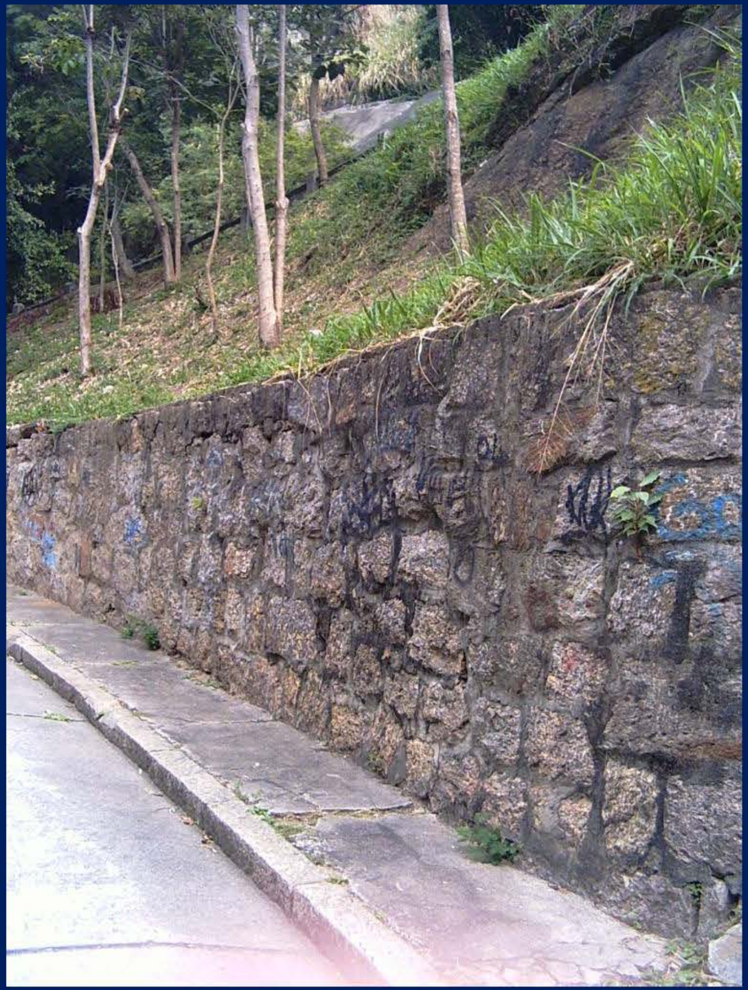






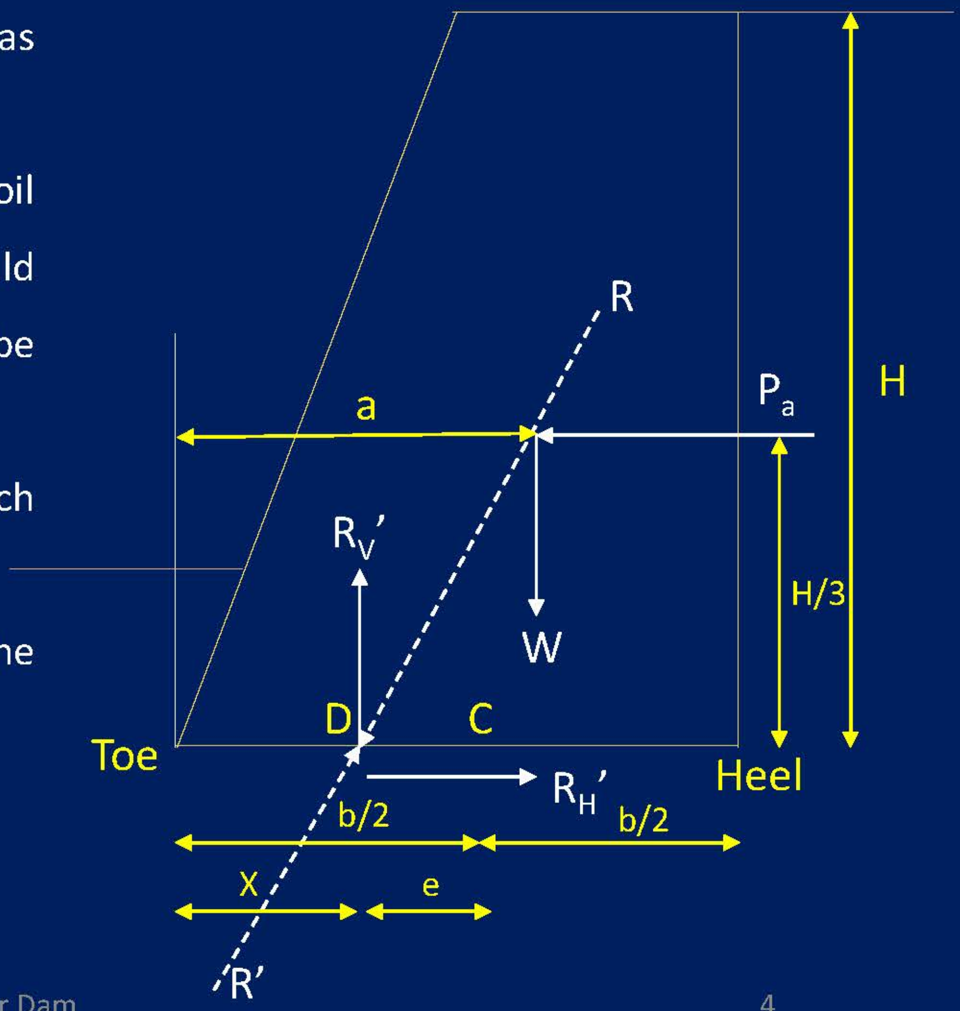
STABILITY ANALYSIS OF RETAINING WALLS

- For stability, a retaining wall should satisfy the following conditions:
  - The wall should be stable against sliding. The factor of safety against sliding should be minimum of 1.5.
  - The wall should be stable against overturning. For granular backfill, the factor of safety against overturning shall be minimum of 1.5. For cohesive backfill the factor of safety against overturning shall be minimum of 2.
  - The base of wall should be stable against bearing capacity failure. For granular backfill, the factor of safety against bearing capacity failure shall be a minimum of 2. For cohesive backfill, the factor of safety against bearing capacity failure shall be minimum of 3.



STABILITY ANALYSIS OF EARTH RETAINING STRUCTURES

- For stability, a retaining wall should satisfy the following conditions:
  - The resultant of all the forces should fall within the middle third of the base as shown.
  - The front face of the wall is subjected to a passive pressure below the soil surface. However, it is doubtful weather the full passive resistance would develop. Moreover, the passive pressure is small and therefore it may be neglected. This gives more conservative design.
  - The weight W of the wall and the active pressure P_a have their resultant R which strikes the base at point D.
  - There is an equal and opposite reaction R’ at the base between the wall and the foundation.
  - R’ is resolved into the vertical and horizontal components R_V’ and R_H’.



STABILITY ANALYSIS OF EARTH RETAINING STRUCTURES

- For the equilibrium of the system, $R_V' = W$ and $R_H' = P_a$
- The moment equation is used to determine the eccentricity 'e' of the force R_V' relative to the center 'c' of the base of the wall.
- Taking moment about 'Toe'

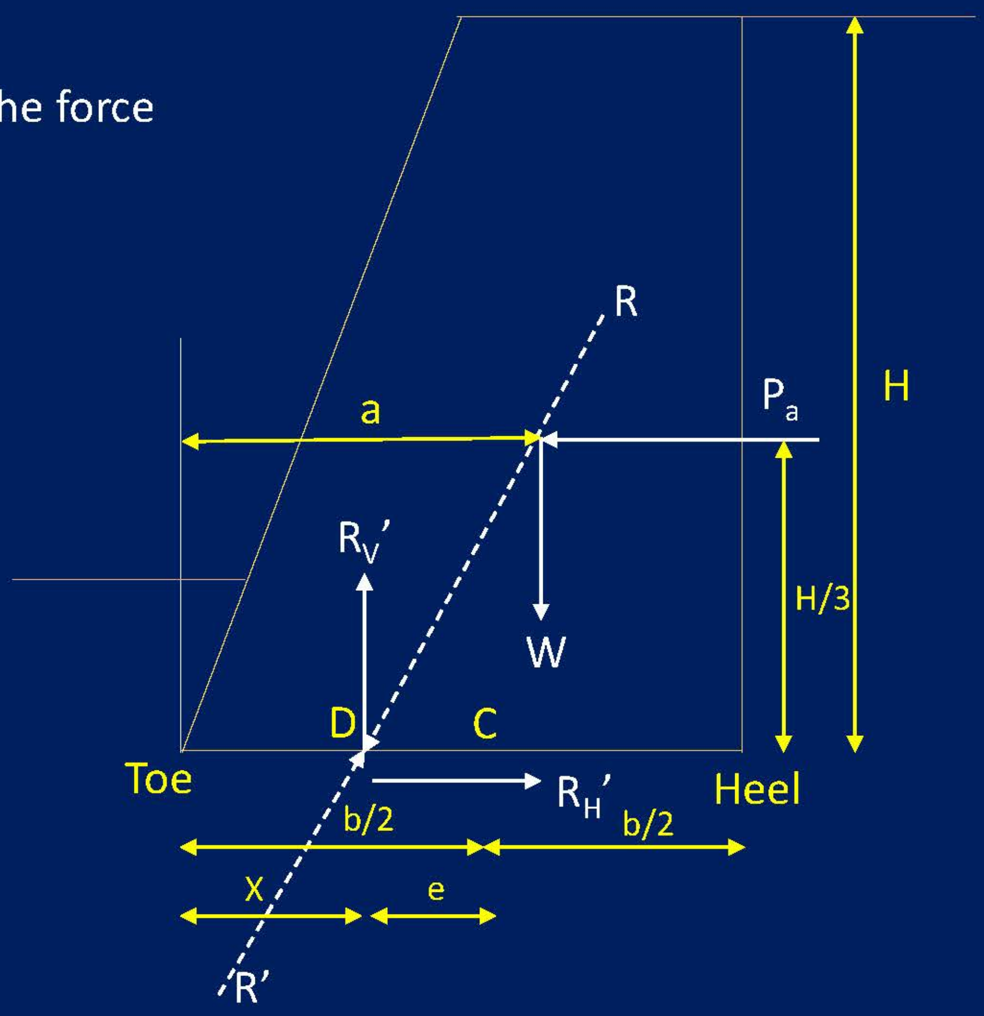
$$R_V' * x - W * a + P_a * \frac{H}{3} = 0$$

$$x = \frac{W * a - P_a * \frac{H}{3}}{R_V'}$$

Where, x is the distance of point 'D' from the Toe.

$$e = \frac{b}{2} - x$$

Where, b is the width of the base.



STABILITY ANALYSIS OF EARTH RETAINING STRUCTURES

- For safe Design
  - No Sliding Condition

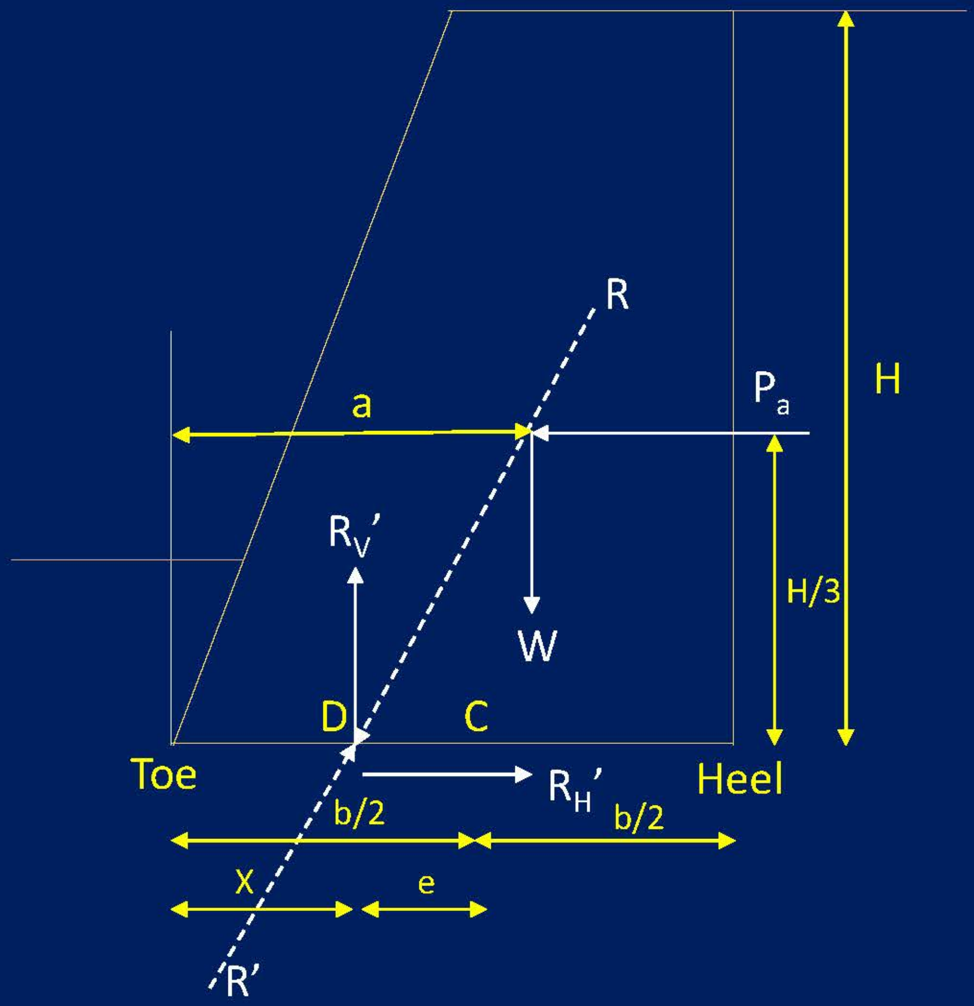
    $\mu R_V > R_H$

    Where, R_V and R_H are vertical and horizontal components of R respectively.

    Factor of Safety against sliding is given by,

    $F_s = \frac{\mu R_V}{R_H}$

    A minimum factor of safety of 1.5 against sliding is generally adopted.



STABILITY ANALYSIS OF EARTH RETAINING STRUCTURES

- For safe Design
  - No Overturning

The wall must be safe against overturning about toe.

For factor of safety against overturning,

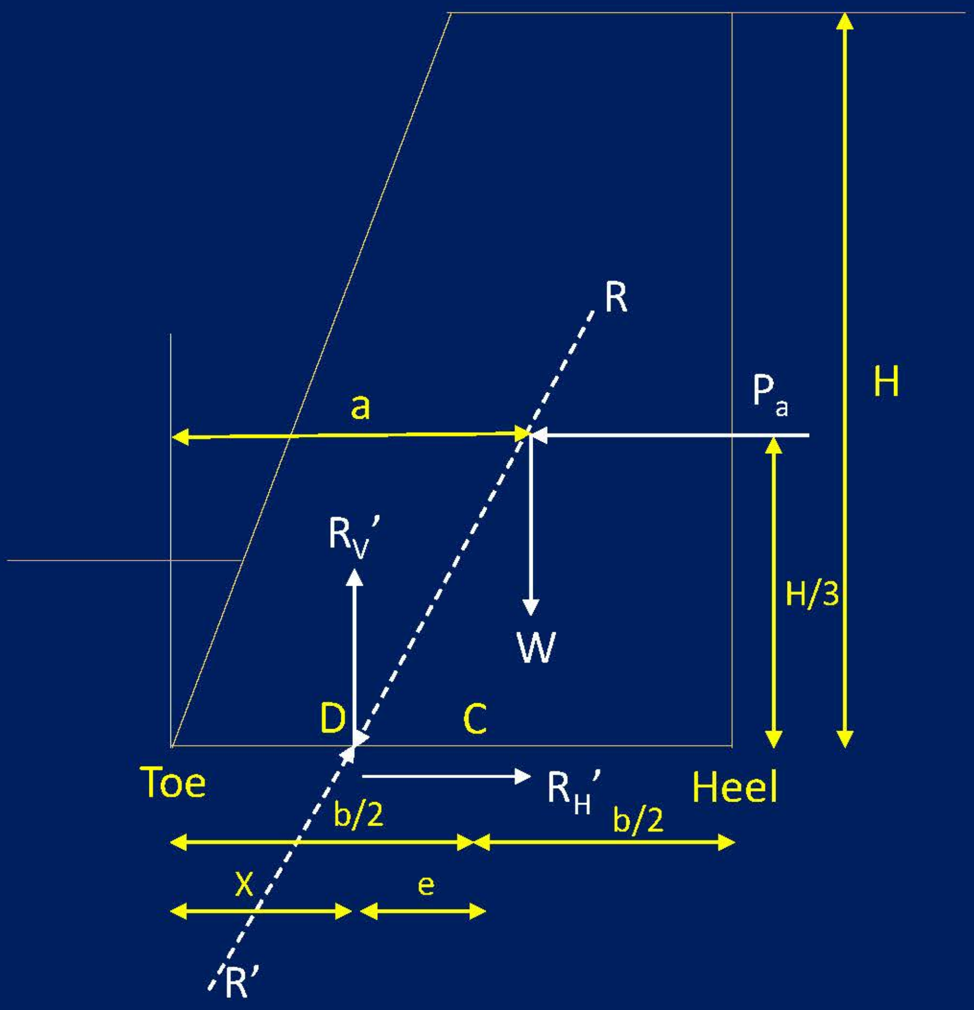
$F_O = \frac{\sum M_R}{\sum M_O}$

where, $\sum M_R$ = Sum of resisting moment about toe.

$\sum M_O$ = Sum of overturning moment about toe.

$F_O = \frac{W * a}{P_a * \frac{H}{3}}$

The factor of safety against overturning is between 1.5 to 2.



STABILITY ANALYSIS OF EARTH RETAINING STRUCTURES

- For safe Design
  - Resistance against Bearing Capacity Failure

    The pressure caused by R_V at the toe of the wall must not exceed the allowable bearing capacity of the soil. The pressure distribution at the base is assumed to be linear.

    The maximum pressure is given by:

    $$P_{max} = \frac{R_V}{b}\left[1 + \frac{6e}{b}\right]$$

    The minimum pressure is given by:

    $$P_{min} = \frac{R_V}{b}\left[1 - \frac{6e}{b}\right]$$

    The factor of safety against bearing is $F_b = \frac{q_{na}}{P_{max}}$

where, q_{na} = allowable bearing capacity. A minimum FOS of 2 is adopted for granular soils and a minimum FOS of 3 is adopted for cohesive soils.

STABILITY ANALYSIS OF EARTH RETAINING STRUCTURES

- For safe Design
  - No Tension
    - There should be no tension at the base of the wall. When the eccentricity ‘e’ is greater than $\frac{b}{6}$, tension develops at the heel.
    - The tensile strength of the soil is very small and the tensile crack would develop.

$$P_{min} = \frac{R_V}{b} [1 - \frac{6e}{b}]$$

When, $e = \frac{b}{6}$, $P_{min} = 0$

When, $e > \frac{b}{6}$, $P_{min} = -ve$

Tension will be developed and the heel of the wall gets lifted up.

In such case, maximum stress is given by: $\frac{4}{3}[\frac{R_V}{b-2e}]$

A masonry gravity wall as shown in figure is designed to support cohesionless soil. The unit weight of masonry wall is 23.4 KN/m^3. The soil at the front and back of the wall is the same and have the same properties as given in figure. Calculate the FOS of wall against overturning assuming 50% of the passive resistance is mobilized.

solution:

At level A

Pressure due to overburden = 0

Pressure due to surcharge $= K_a * 10$

$= 0.307 * 10$

$= 3.07$ KN/m^2

Total Pressure $= 3.07$ KN/m^2

At level B

Pressure due to overburden $= K_a * \gamma * 5$

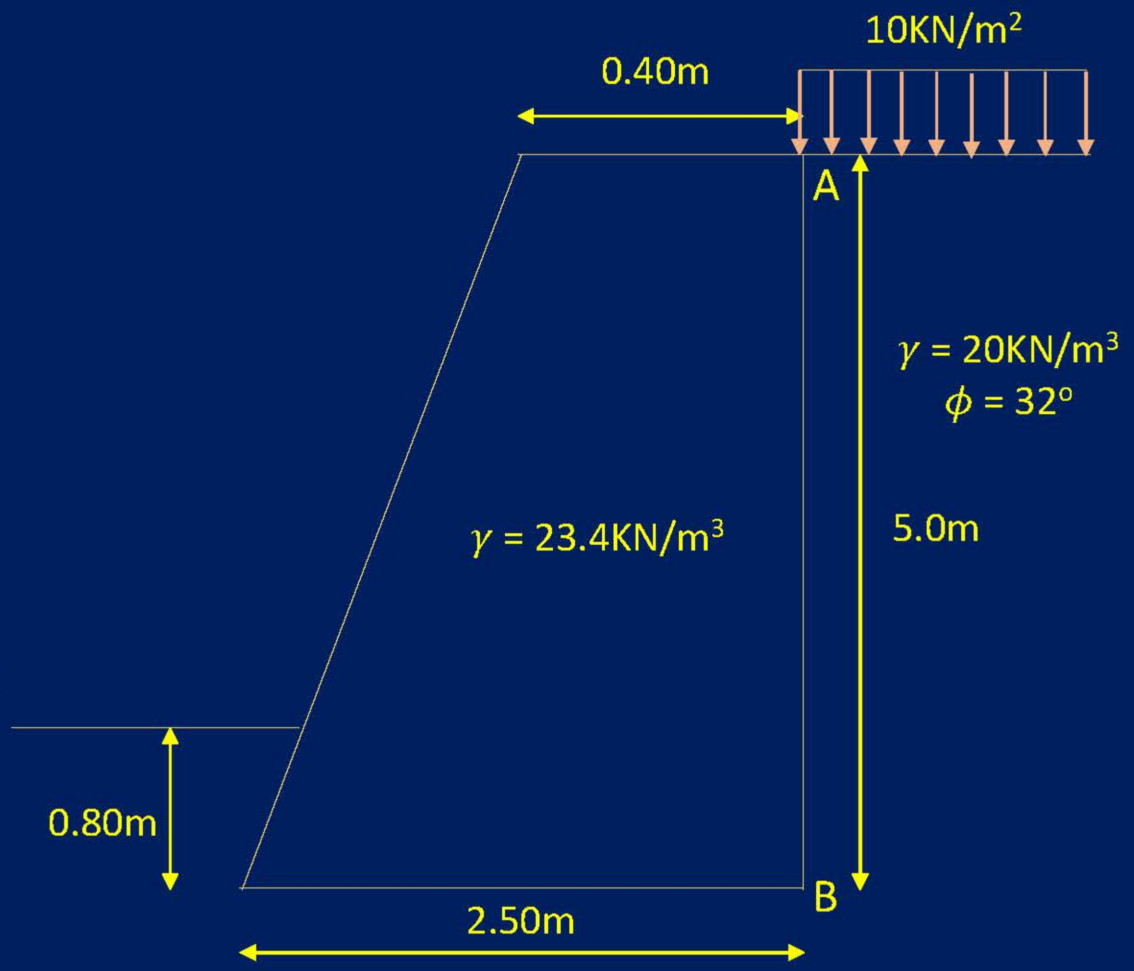
$= 0.307 * 20 * 5$

$= 30.70$ KN/m^2

Pressure due to surcharge $= K_a * 10$

$= 3.07$ KN/m^2

Total Pressure $= 33.77$ KN/m^2



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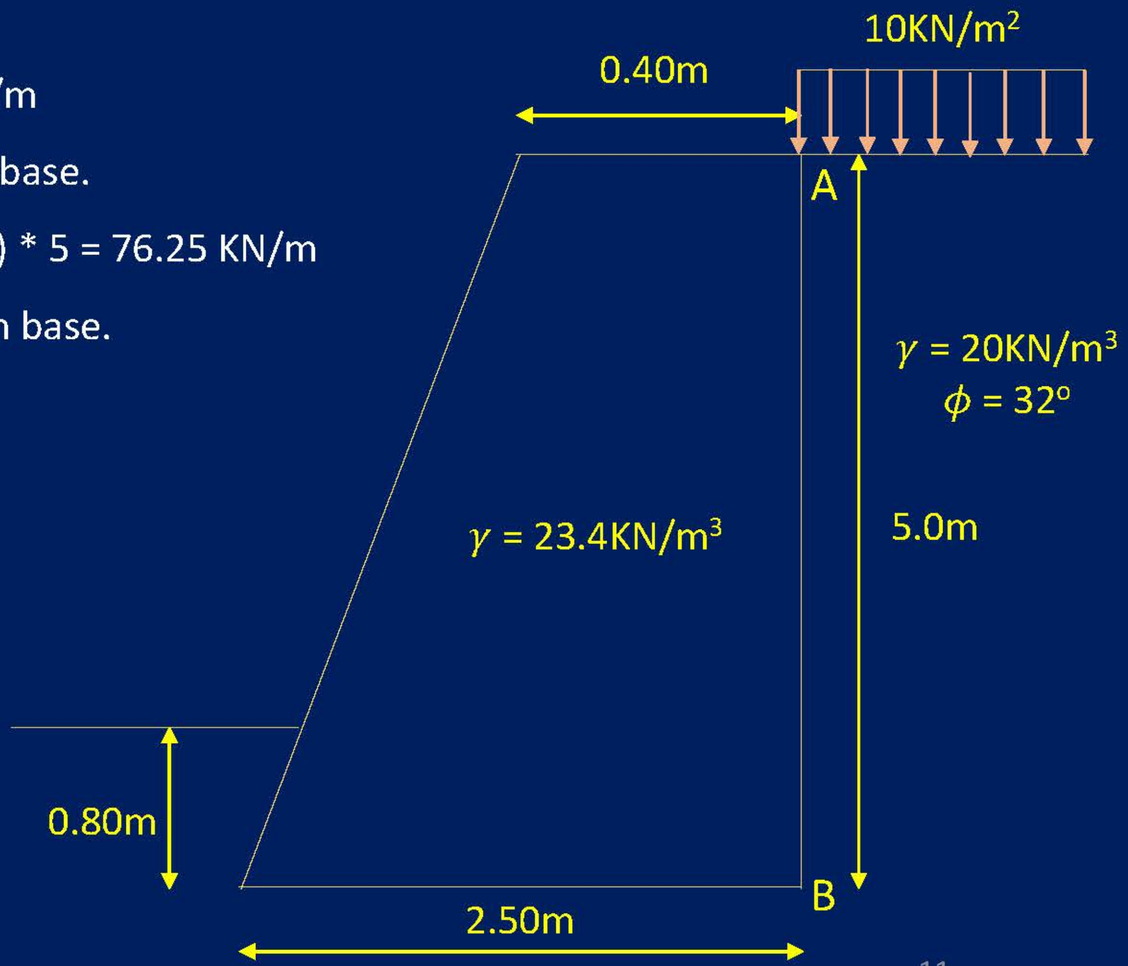
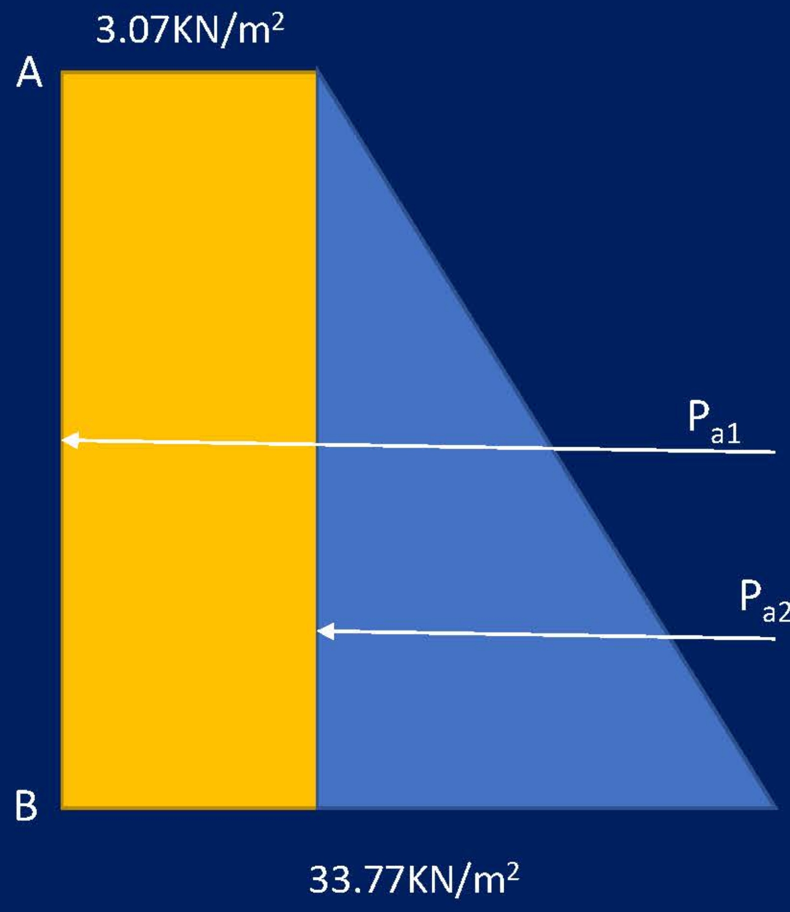
$P_{a1} = 3.07 * 5 = 15.35$ KN/m

at 2.5 m from base.

$P_{a2} = 0.50 * (33.77 - 3.07) * 5 = 76.25$ KN/m

at 1.67 m from base.





A masonry gravity wall as shown in figure is designed to support cohesionless soil. The unit weight of masonry wall is 23.4 KN/m^3. The soil at the front and back of the wall is the same and have the same properties as given in figure. Calculate the FOS of wall against overturning assuming 50% of the passive resistance is mobilized.

$p_p = K_p \gamma H = 3.25 * 20 * 0.80 = 52\ KN/m^2$

$P_p = 0.50 * 52 * 0.80 = 20.80\ KN/m$

at $\frac{0.80}{3}$ m from base.

$W_1 = \gamma * V_1$

$W_1 = \gamma * A_1 * 1$

$W_1 = 23.4 * 0.50 * (2.5\text{-}0.4) * 5 = 122.85\ KN/m$

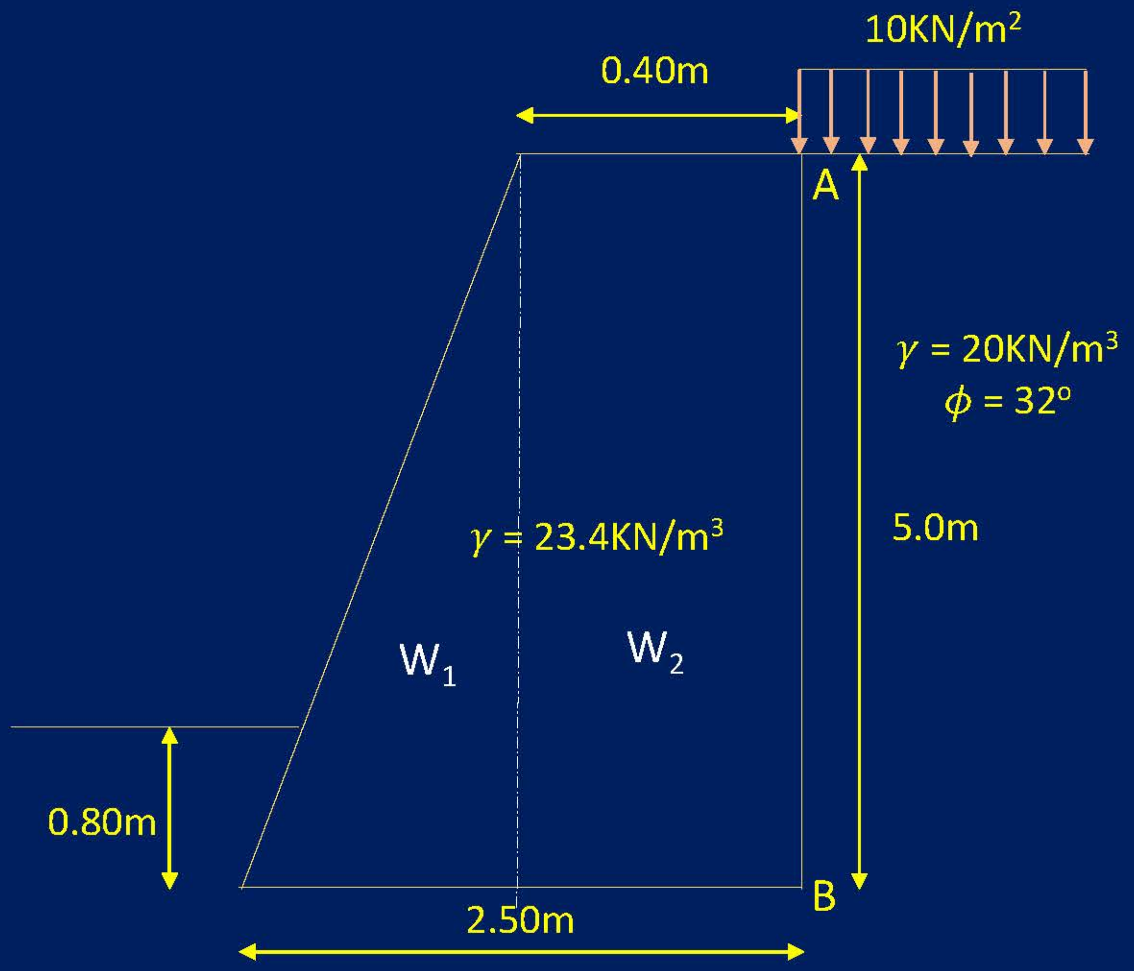
at 1.4 m from toe.

$W_2 = \gamma * V_2$

$W_2 = \gamma * A_2 * 1$

$W_2 = 23.4 * 0.40 * 5 = 46.8\ KN/m$

at 2.3 m from toe.



A masonry gravity wall as shown in figure is designed to support cohesionless soil. The unit weight of masonry wall is 23.4 KN/m^3. The soil at the front and back of the wall is the same and have the same properties as given in figure. Calculate the FOS of wall against overturning assuming 50% of the passive resistance is mobilized.

Forces	Horizontal	Vertical	Moment Arm	Restoring Moment	Overturning Moment
W_1		122.85	1.4	171.99	
W_2		46.8	2.3	107.64	
P_{a1}	15.35		2.5		38.38
P_{a2}	76.25		1.67		127.34
P_P	20.80*0.50		0.267	2.77	
Total				282.41	165.72

$$F_O = \frac{\sum M_R}{\sum M_O}$$

$$F_O = \frac{282.41}{165.72}$$

$F_O = 1.70 > 1.50$ (Safe)

Determine the Factor of Safety against sliding, overturning and maximum and minimum pressure under the base of the cantilever retaining wall as shown in figure. The approximate shear strength parameter for the soil are c = 0 and Φ = 41°. The unit weight of soil and concrete are 16 KN/m³ and 24 KN/m³ respectively. The water table is below the base of the wall. Take δ = 27° on the base of the wall. Safe bearing capacity of the soil below the base is 500 KN/m². Take height to be 6 m.

solution:

At level A

Pressure due to overburden = 0

Pressure due to surcharge $= K_a * 35$

$= 0.208 * 35$

$= 7.27\ KN/m^2$

Total Pressure $= 7.27\ KN/m^2$

At level B

Pressure due to overburden $= K_a * \gamma * 6$

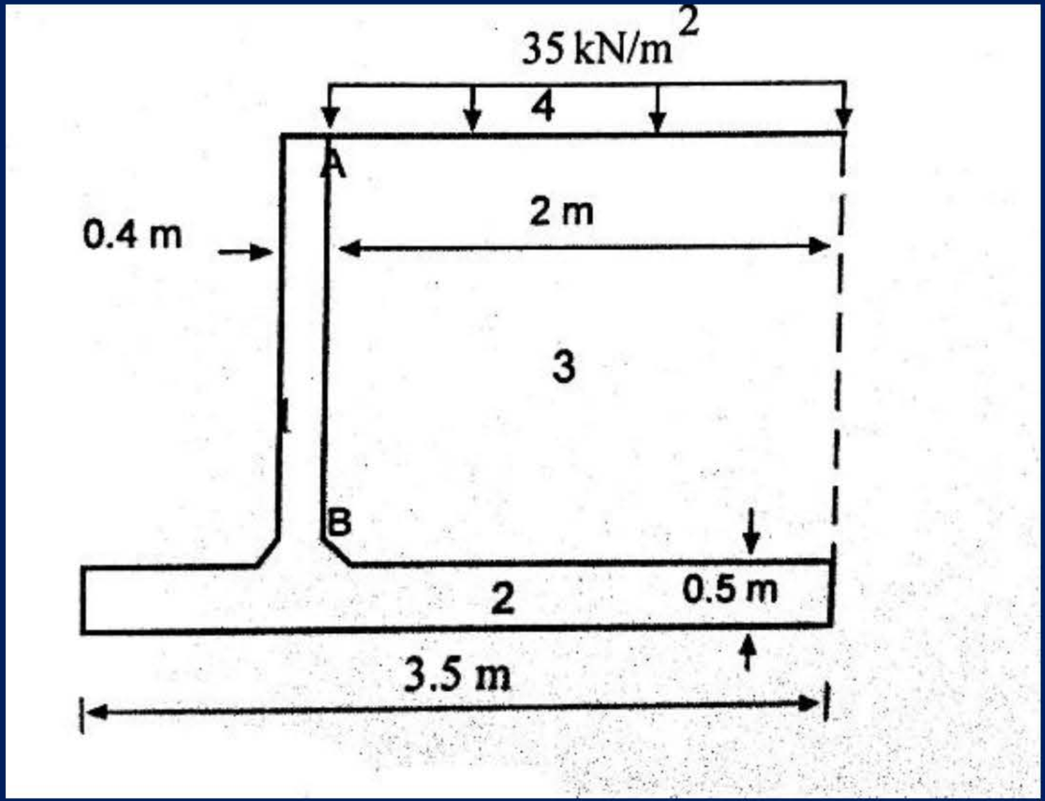
$= 0.208 * 16 * 6$

$= 19.97\ KN/m^2$

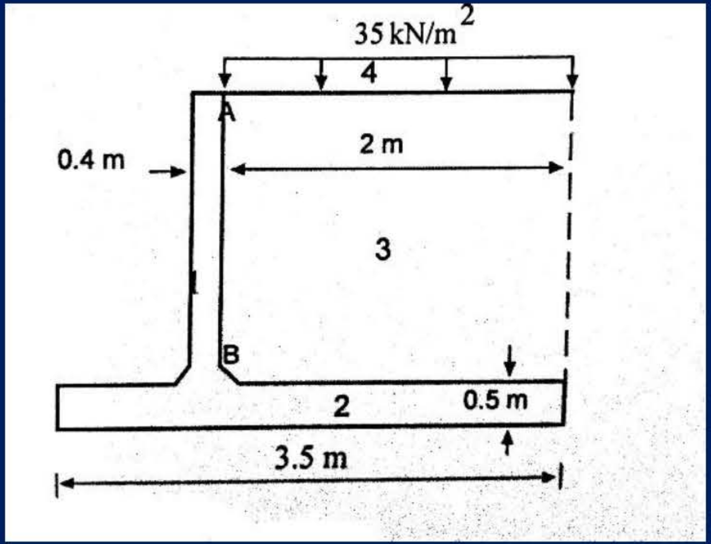
Pressure due to surcharge $= K_a*35$

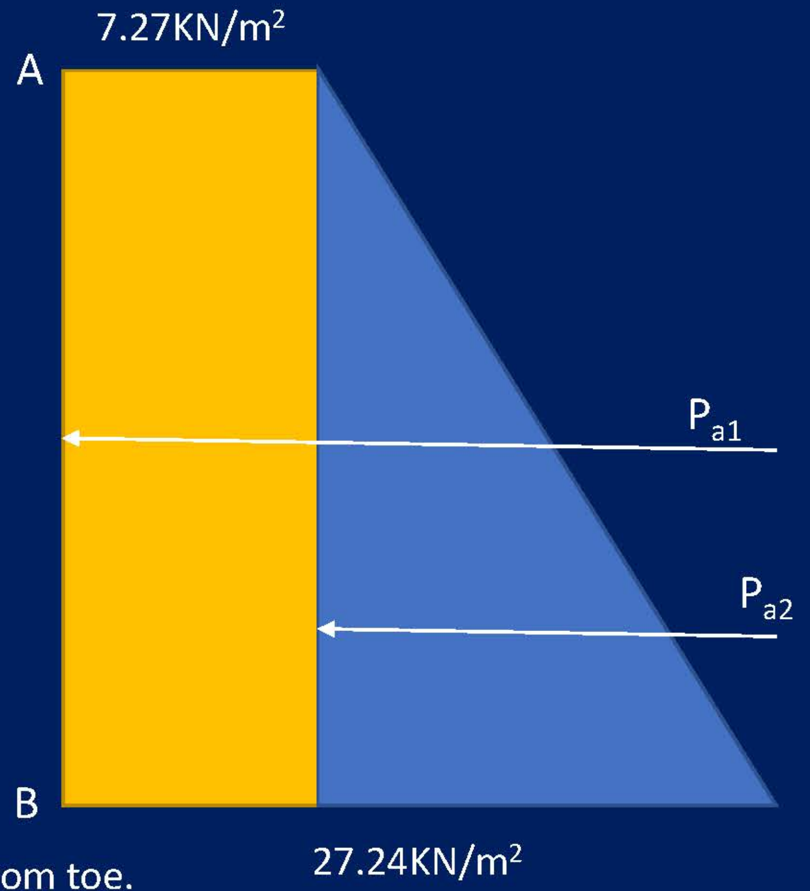
$= 7.27\ KN/m^2$

Total Pressure $= 27.24\ KN/m^2$



Determine the Factor of Safety against sliding, overturning and maximum and minimum pressure under the base of the cantilever retaining wall as shown in figure. The approximate shear strength parameter for the soil are c = 0 and $\Phi = 41^{o}$. The unit weight of soil and concrete are 16 KN/m^3 and 24 KN/m^3 respectively. The water table is below the base of the wall. Take $\delta = 27^{o}$ on the base of the wall. Safe bearing capacity of the soil below the base is 500 KN/m^2. Take height to be 6 m.





$P_{a1} = 7.27 * 6 = 43.62$ KN/m

at 3 m from base.

$P_{a2} = 0.50 * (27.24 – 7.27) * 6 = 59.91$ KN/m

at 2 m from base.

$W_1 = \gamma * V_1$

$W_1 = 24 * 0.40 * 5.50 * 1$

$W_1 = 52.80$ KN/m

at 1.30 m from toe.

$W_2 = \gamma * V_2$

$W_2 = 24 * 0.50 * 3.50 * 1$

$W_2 = 42$ KN/m

at 1.75 m from toe.

$W_3 = \gamma * V_3$

$W_3 = 16 * 5.5 * 2$

$W_3 = 176$ KN/m

at 2.50 m from toe.

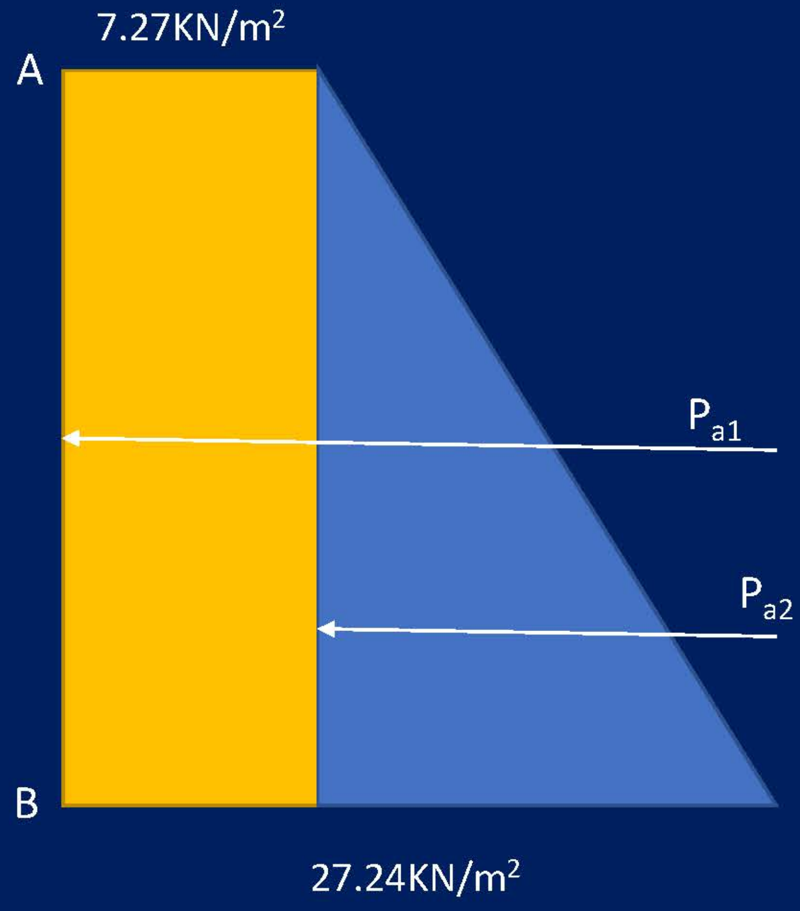
$W_4 = 35 * 2$

$W_4 = 70$ KN/m

at 2.50 m from toe.

Determine the Factor of Safety against sliding, overturning and maximum and minimum pressure under the base of the cantilever retaining wall as shown in figure. The approximate shear strength parameter for the soil are c = 0 and Φ = 41°. The unit weight of soil and concrete are 16 KN/m³ and 24 KN/m³ respectively. The water table is below the base of the wall. Take δ = 27° on the base of the wall. Safe bearing capacity of the soil below the base is 500 KN/m². Take height to be 6 m.

Forces	Horizontal	Vertical	Moment Arm	Restoring Moment	Overturning Moment
W_1		52.80	1.30	68.64	
W_2		46.8	1.75	73.50	
W_3		176	2.50	440	
W_4		70	2.50	175	
P_{a1}	43.62		3.00		130.86
P_{a2}	59.91		2.00		119.82
Total	103.53	340.80		757.14	250.68



a) Factor of Safety Against Sliding

$$F_s = \frac{\mu R_V}{R_H}$$

μ = Tanδ

μ = Tan27° = 0.509

$$F_s = \frac{0.509 * 340.80}{103.53}$$

F_s = 1.68 > 1.50 (Safe)

Determine the Factor of Safety against sliding, overturning and maximum and minimum pressure under the base of the cantilever retaining wall as shown in figure. The approximate shear strength parameter for the soil are c = 0 and Φ = 41°. The unit weight of soil and concrete are 16 KN/m³ and 24 KN/m³ respectively. The water table is below the base of the wall. Take δ = 27° on the base of the wall. Safe bearing capacity of the soil below the base is 500 KN/m². Take height to be 6 m.

b) Factor of Safety Against Overturning

$$F_O = \frac{M_R}{M_O}$$

$$F_O = \frac{757.14}{250.68} = 3.02 > 1.50 \text{ (Safe)}$$

c) Maximum Pressure

$$P_{max} = \frac{R_V}{b}\left[1 + \frac{6e}{b}\right]$$

$$P_{max} = \frac{340.80}{3.50} * \left[1+\frac{6e}{b}\right]$$

$$e = \frac{b}{2} - x$$

$R_V * x = \sum M$

340.80 * x = (757.14 – 250.68)

x = 1.48 m

$$P_{max} = \frac{340.80}{3.50} * \left[1+\frac{6(\frac{3.50}{2}-1.48)}{3.50}\right]$$

P_{max} = 140.70 KN/m²

Determining the value of x

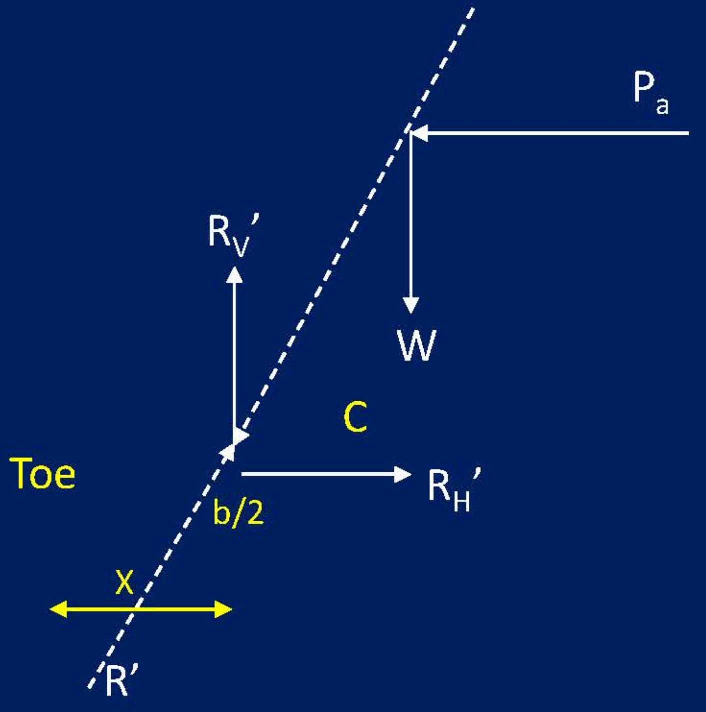
$\sum M_{toe} = 0$

$R_V'*x + (P_{a1}*3)+(P_{a2}*2) – (W_1*1.30) – (W_2*1.75) – (W_3*2.50) – (W_4*2.50) = 0$

340.80*x + (250.68) – (757.14) = 0

340.80*x = 757.14 – 250.68

X = 1.48 m



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b) Factor of Safety Against Overturning

$$F_O = \frac{M_R}{M_O}$$

$$F_O = \frac{757.14}{250.68} = 3.02 > 1.50 \text{ (Safe)}$$

Forces	Horizontal	Vertical	Moment Arm	Restoring Moment	Overturning Moment
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P_{a2}	59.91		2.00		119.82
Total	103.53	340.80		757.14	250.68

c) Maximum Pressure

$$P_{max} = \frac{R_V}{b}\left[1 + \frac{6e}{b}\right]$$

$$P_{max} = \frac{340.80}{3.50} * \left[1+\frac{6e}{b}\right]$$

$$e = \frac{b}{2} - x$$

$$R_V * x = \sum M$$

340.80 * x = (757.14 – 250.68)

x = 1.48 m

$$P_{max} = \frac{340.80}{3.50} * \left[1+\frac{6(\frac{3.50}{2}-1.48)}{3.50}\right]$$

$$P_{max} = 140.70\ KN/m^2$$

d) Minimum Pressure

$$P_{min} = \frac{R_V}{b}\left[1 - \frac{6e}{b}\right]$$

$$P_{min} = \frac{340.80}{3.50} * \left[1-\frac{6(\frac{3.50}{2}-1.48)}{3.50}\right]$$

$$P_{min} = 52.58\ KN/m^2$$

e) Factor of safety against bearing capacity failure

$$F_b = \frac{q_{na}}{P_{max}}$$

$$F_b = \frac{500}{140.70} = 3.55 > 2 \text{ (Safe)}$$

Determining common point of application of vertical forces from toe.

$W_1 * 1.30 + W_2 * 1.75 + W_3 * 2.50 + W_4 * 2.50 = (W_1 + W_2 + W_3 + W_4) * z$
Where, z is the distance from toe
z= 2.22 m

Determining common point of application horizontal forces from toe.

$P_{a1} * 3 + P_{a2} * 2 = (P_{a1} + P_{a2}) * a$
Where, a is the distance from toe
a = 2.42 m