



Retaining Walls



What is a retaining wall?

- A retaining wall is a structure designed to support and hold back soil or rock from a slope or vertical grade.



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- A retaining wall is a structure designed to support and hold back soil or rock from a slope or vertical grade.
- Retaining walls are commonly used in construction and landscaping.



Key Functions of Retaining Walls

Soil Retention: The primary purpose of a retaining wall is to retain soil at different elevations, preventing it from sliding or eroding.



Key Functions of Retaining Walls

Erosion Control: By holding back soil, retaining walls help control erosion caused by water runoff, especially on steep slopes.

Key Functions of Retaining Walls

Levelling Land: They create flat areas in hilly or uneven terrain, making it suitable for construction, landscaping, or agricultural use.





Key Functions of Retaining Walls

Drainage Management Many retaining walls incorporate drainage systems to manage water flow and prevent hydrostatic pressure buildup behind the wall.



Key Functions of Retaining Walls

Aesthetic Appeal: Retaining walls can enhance the visual appeal of a landscape by creating terraced areas and allowing for creative design options.

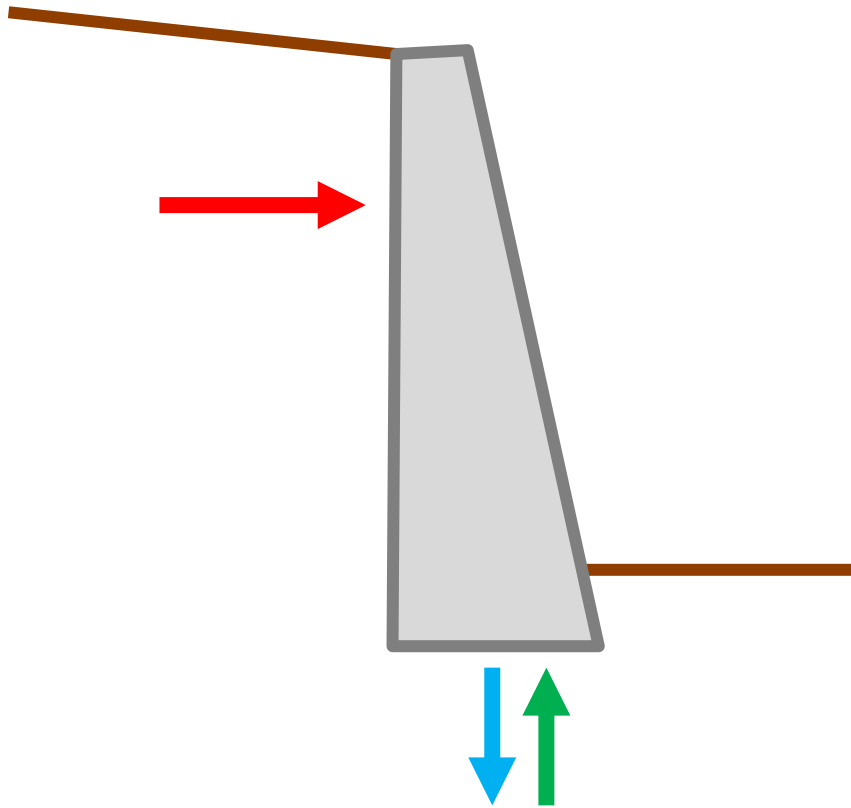
Types of Retaining Wall

There are 5 main types of Retaining Wall:

Types of Retaining Wall

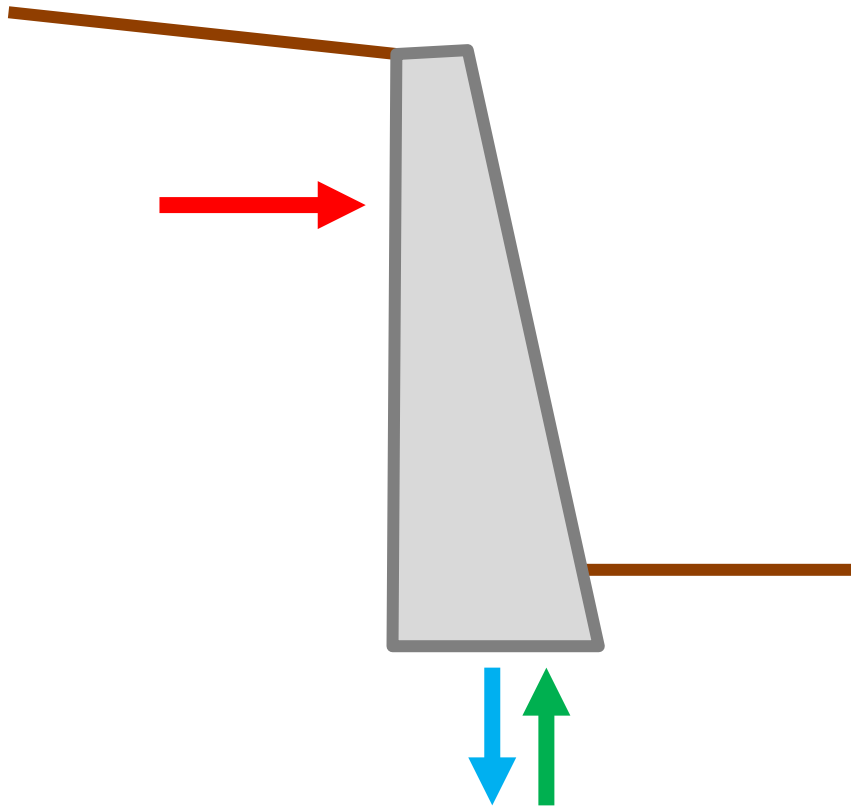
There are 5 main types of Retaining Wall:

- Gravity
- Cantilever
- Embedded
- Anchored
- Stabilised



Gravity Walls

- Gravity retaining walls use the gravitational force of their own weight to resist the lateral earth pressure from the soil behind them, which prevents toppling and sliding.



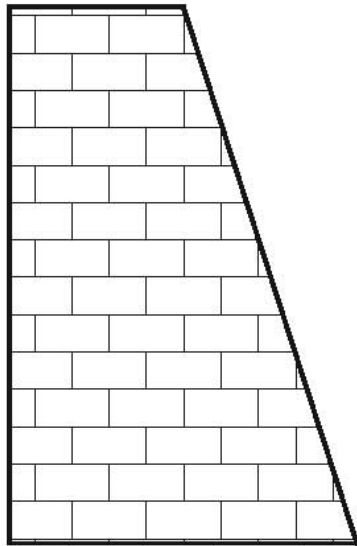
Gravity Walls

- Gravity retaining walls use the gravitational force of their own weight to resist the lateral earth pressure from the soil behind them, which prevents toppling and sliding.
- They are the simplest and earliest recorded type of retaining wall.

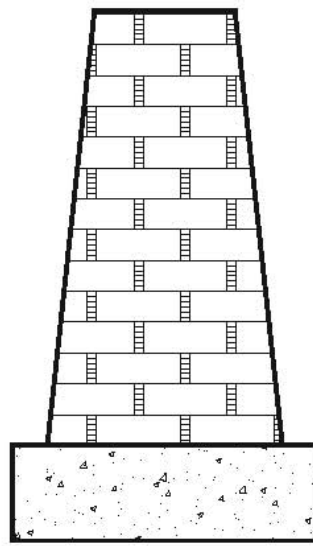
Gravity Retaining Walls

Gravity Walls

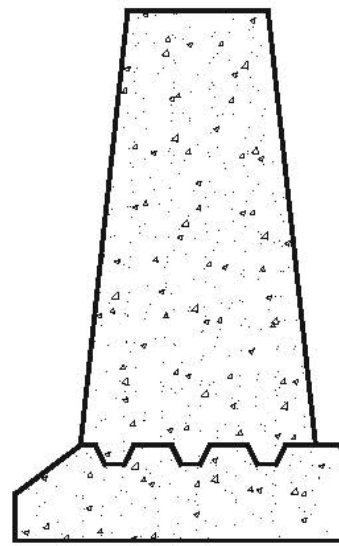
- Often built of concrete, masonry, brick, blocks or mass cast-in-situ concrete.



Masonry Unit

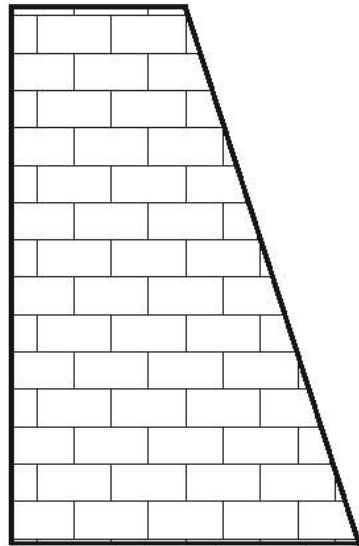


Stone

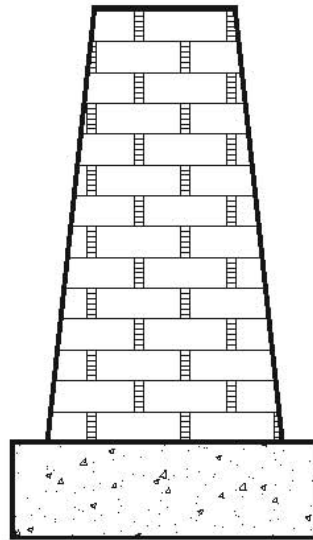


Poured Concrete

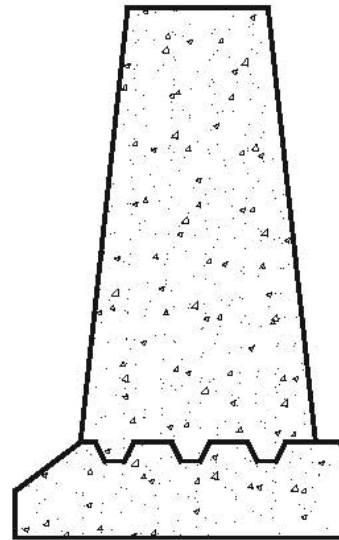
Gravity Retaining Walls



Masonry Unit



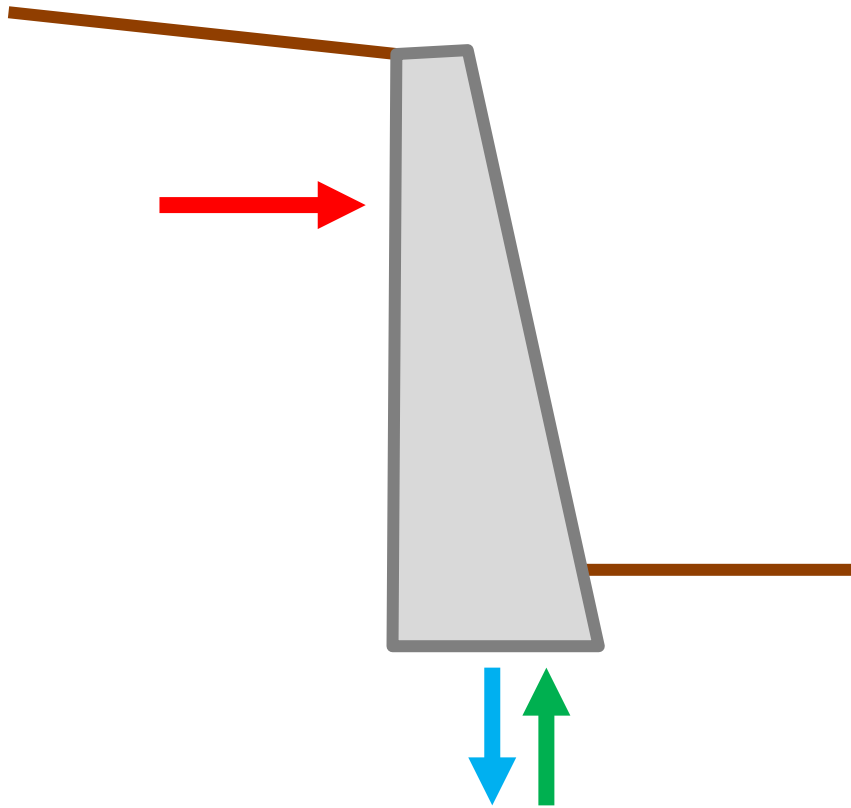
Stone



Poured Concrete

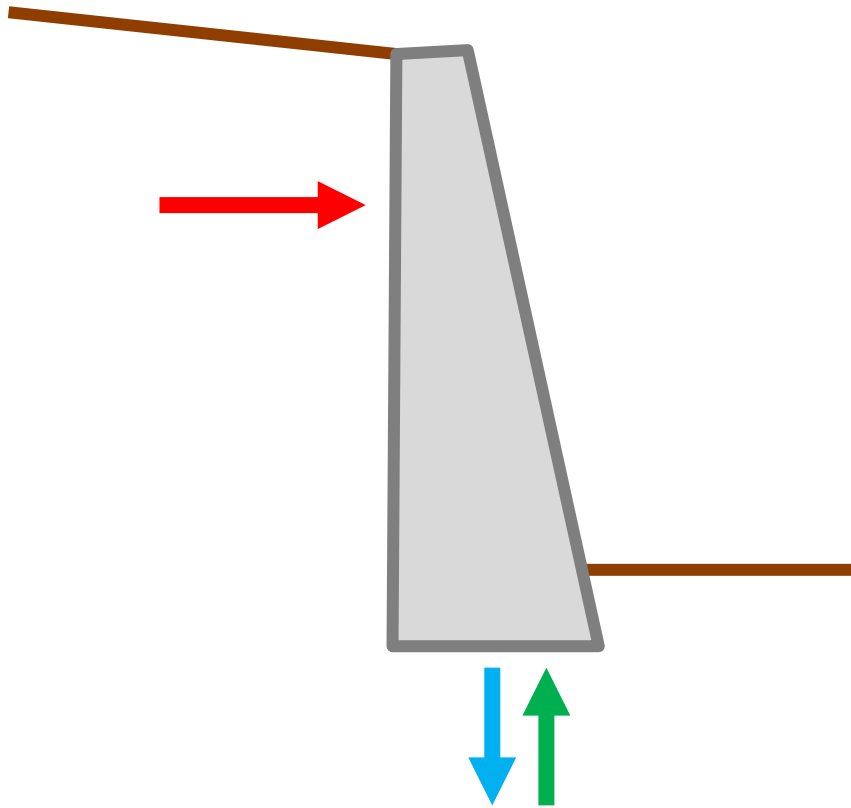
Gravity Walls

- Often built of concrete, masonry, brick, blocks or mass cast-in-situ concrete.
- These hard-wearing structures rely on their large weight to resist toppling and sliding caused by the lateral earth pressure from the soil behind them.



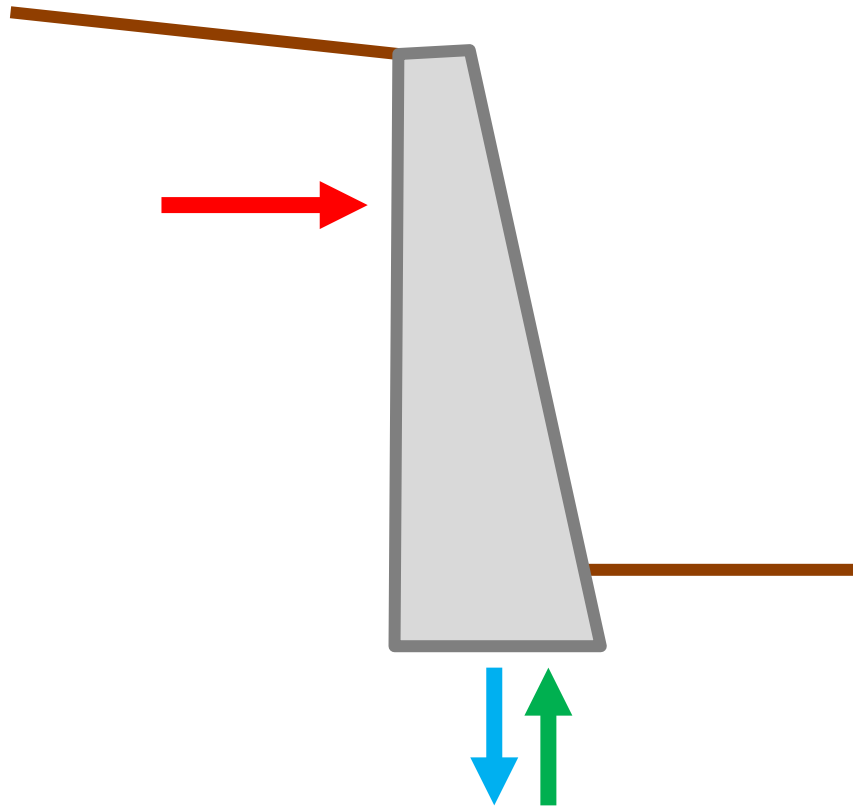
Gravity Walls

- Gravity retaining walls are typically designed to be wider at their base, with sloped faces, enabling them to resist the higher lateral earth pressures at depth.



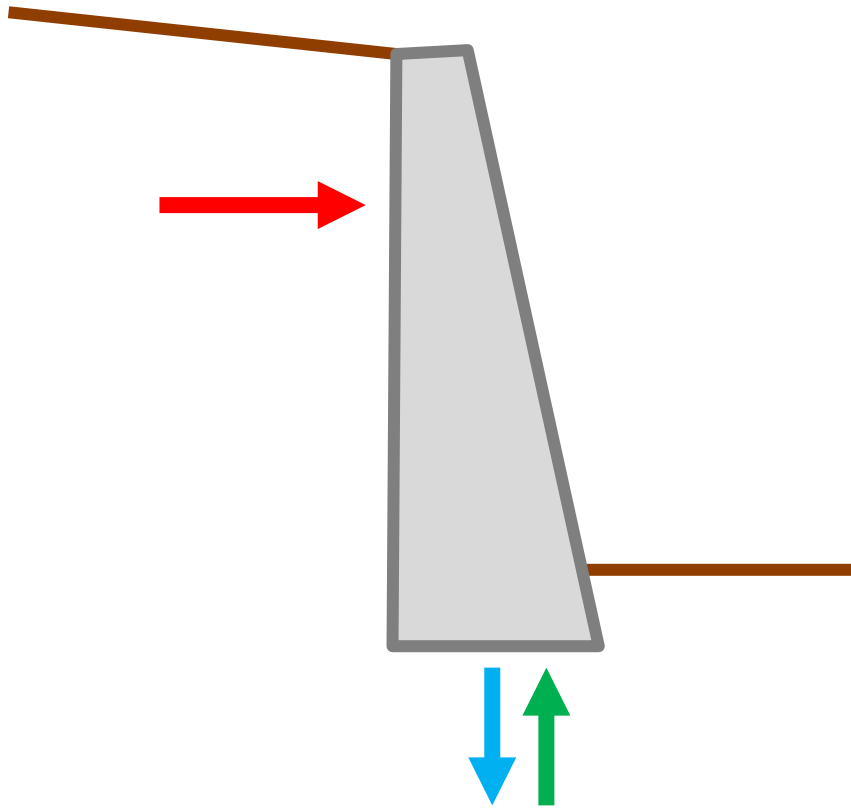
Gravity Walls

- Gravity retaining walls are typically designed to be wider at their base, with sloped faces, enabling them to resist the higher lateral earth pressures at depth.
- As such, this type of retaining wall is easy to build and suitable for retained heights of up to about 3m.



Gravity Walls

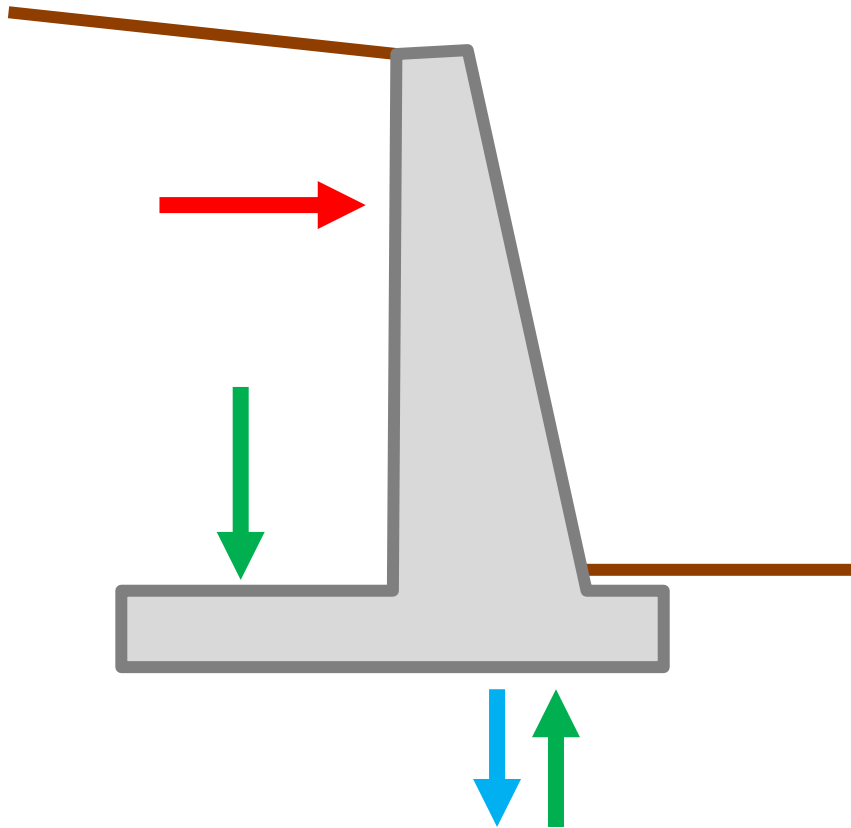
- If built any higher, the retaining structures tend to take up too much space and can end up being too heavy for the ground below, leading to bearing capacity failure.



Gravity Walls

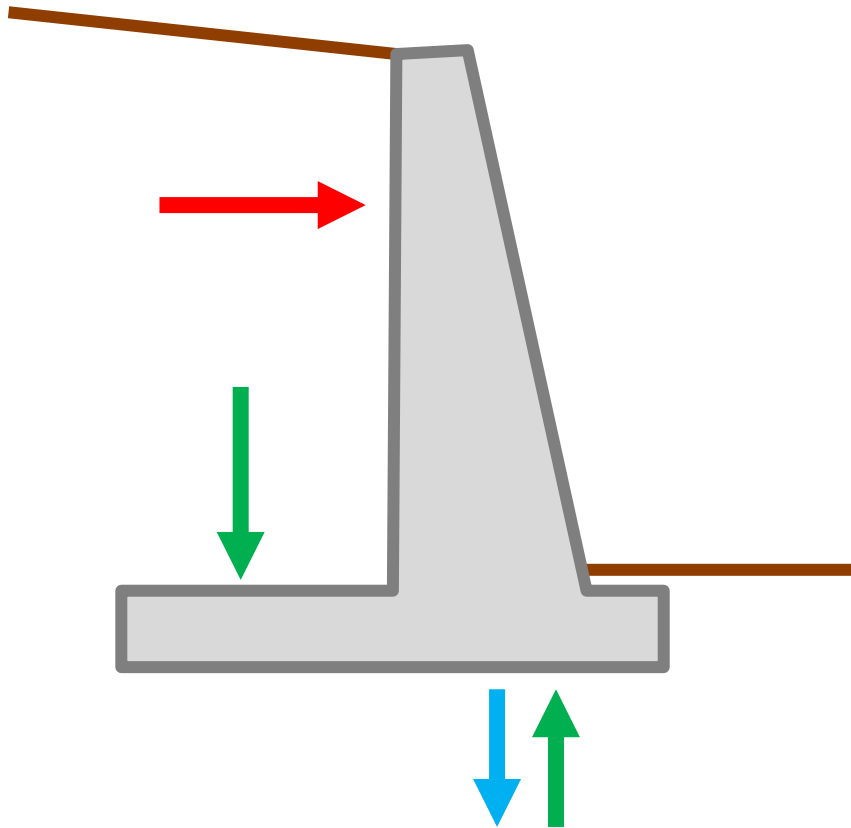
- If built any higher, the retaining structures tend to take up too much space and can end up being too heavy for the ground below, leading to bearing capacity failure.
- Ultimately, this can result in the wall failing to retain soil.

Cantilever Walls



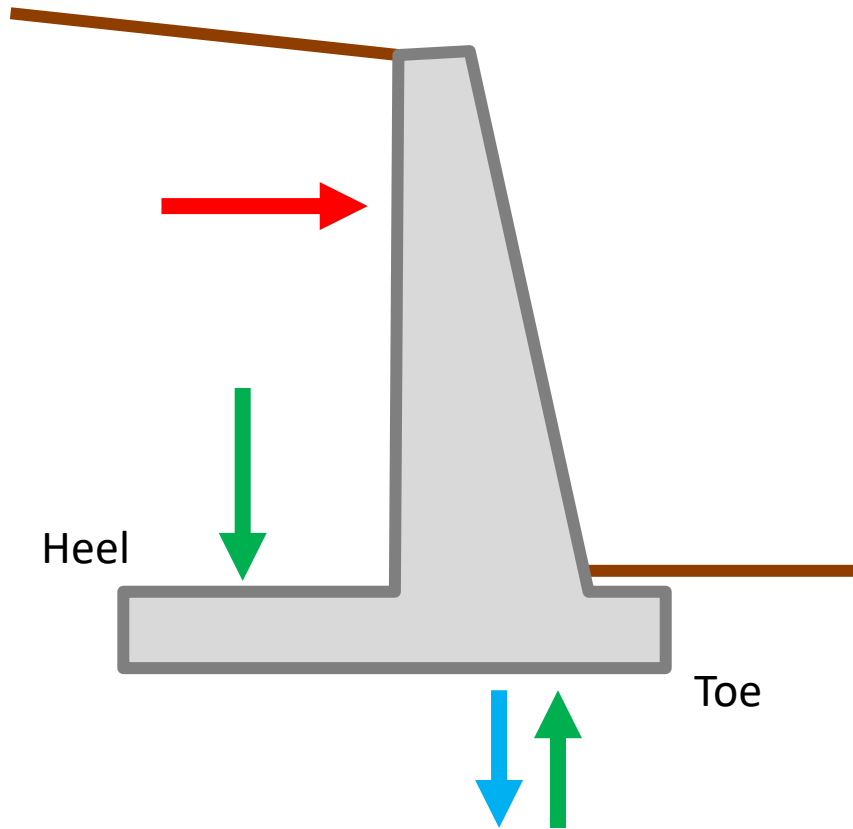
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Cantilever Walls



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- The base slab sits under backfill

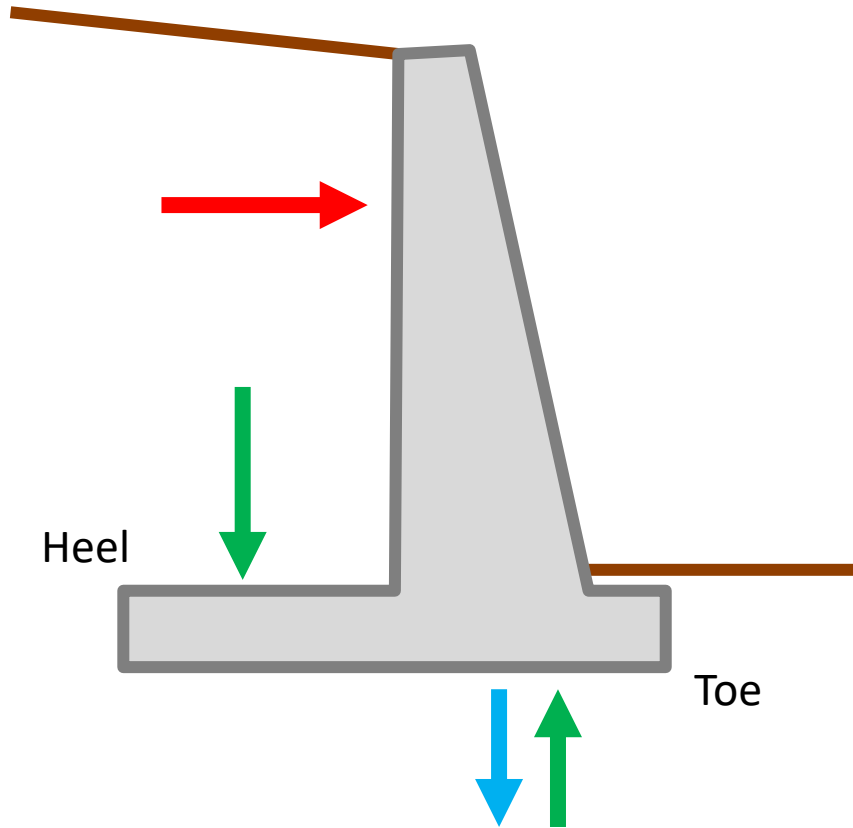
Cantilever Walls



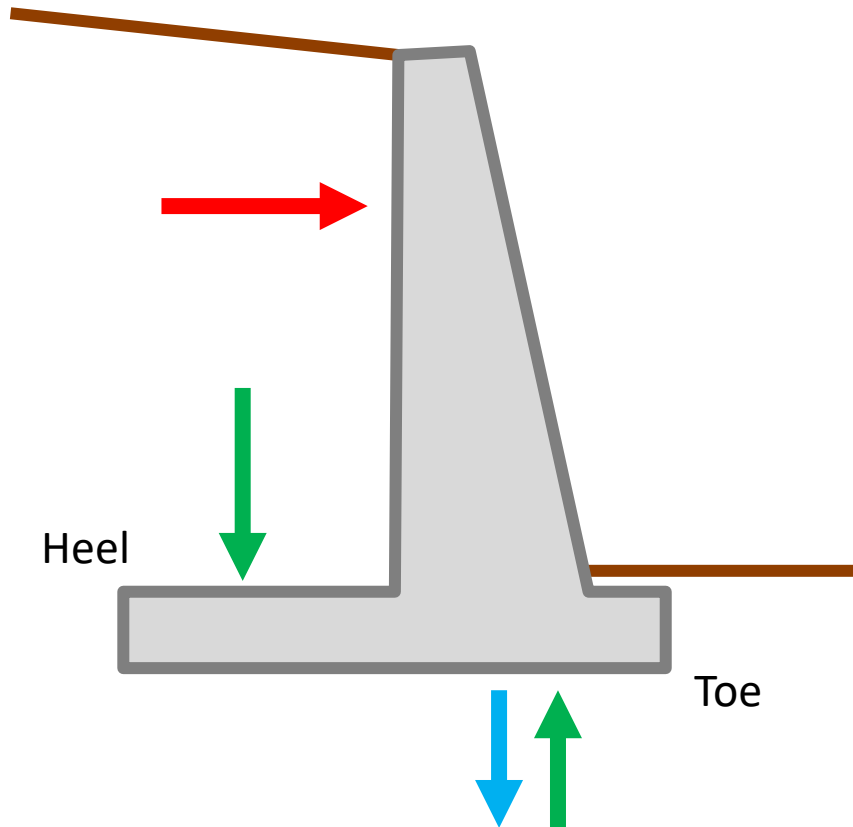
- Cantilever walls are generally constructed from reinforced concrete and consist of a stem and a base slab.
- The base slab sits under backfill
- The base slab has two parts: the heel and the toe.

Cantilever Walls

- The wall leverages its base slab.

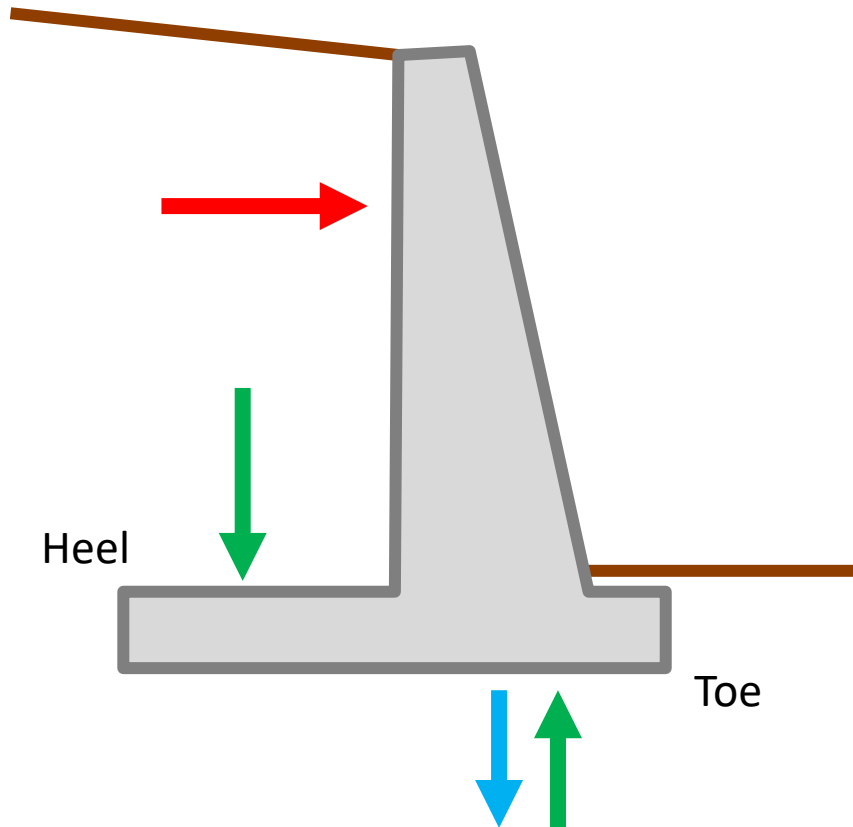


Cantilever Walls



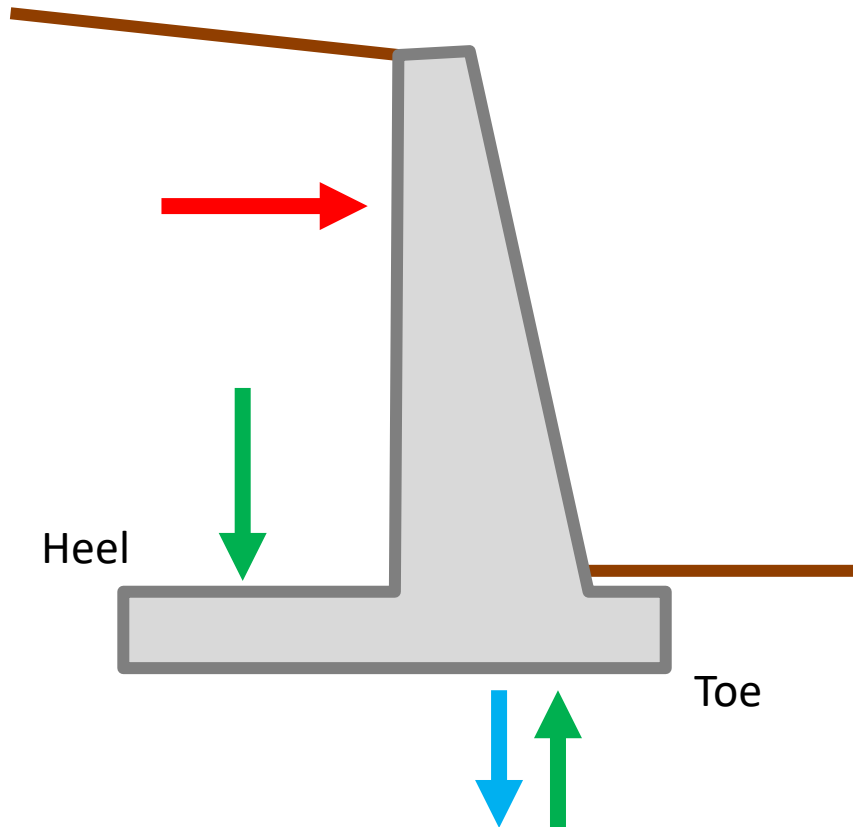
- The wall leverages its base slab.
- The weight of the soil on the heel helps to counteract the overturning moment created by the lateral earth pressure.

Cantilever Walls



- A big advantage of cantilever walls compared to other retaining wall types is that they take up little space once built and are suitable for retained heights of up to 5m.

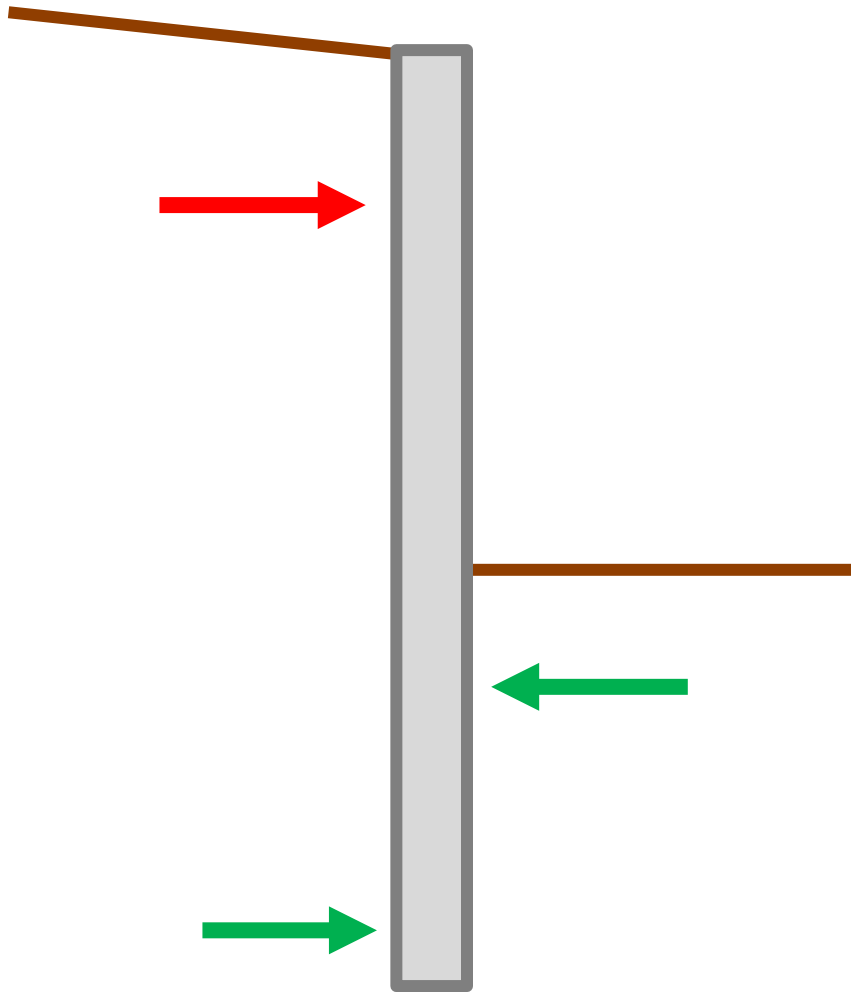
Cantilever Walls



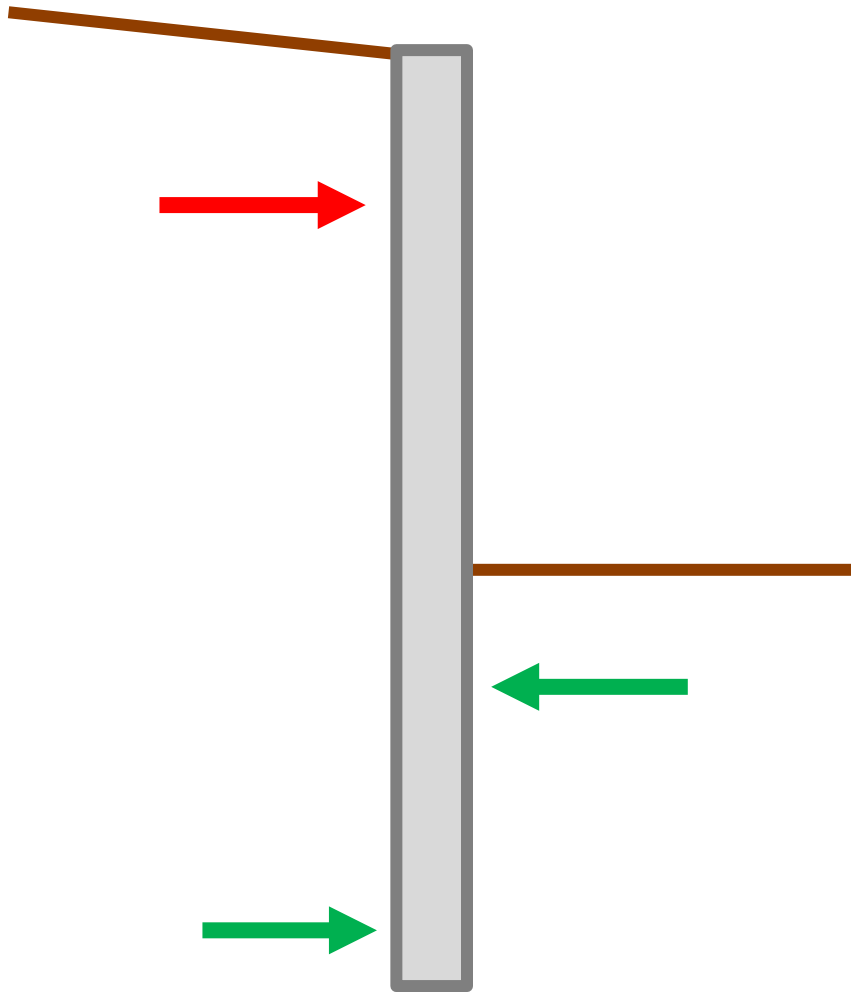
- A big advantage of cantilever walls compared to other retaining wall types is that they take up little space once built and are suitable for retained heights of up to 5m.
- However, construction does require space behind the wall, so these retaining walls are not particularly suited to supporting existing slopes unless temporary support is provided during construction.

Embedded Retaining Wall

- Embedded walls are made from steel, vinyl, or wood planks that are driven into the ground.



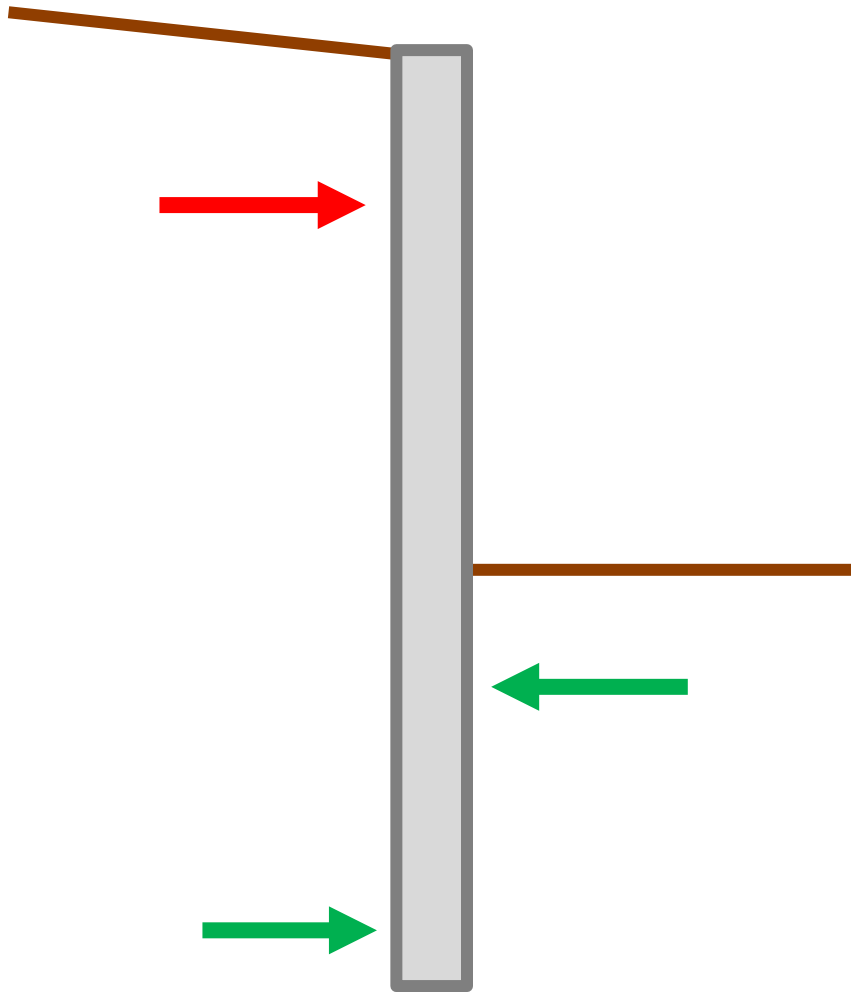
Embedded Retaining Wall



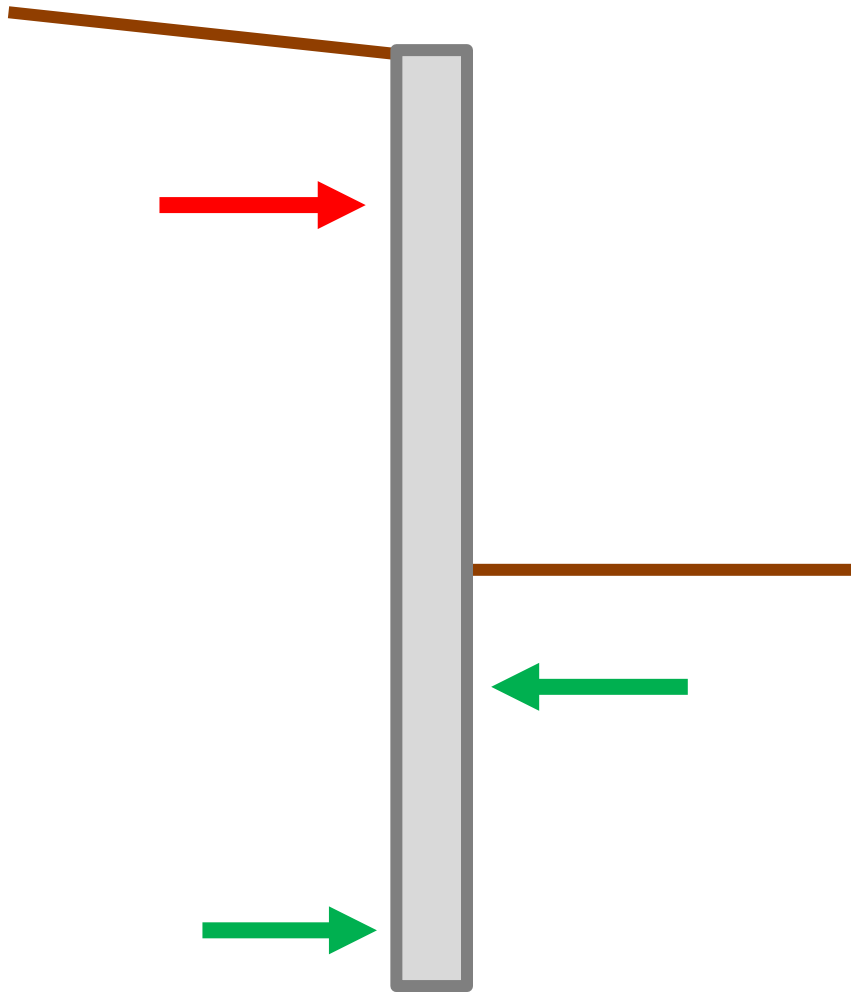
- Embedded walls are made from steel, vinyl, or wood planks that are driven into the ground.
- They are used in soft soils and tight spaces.

Embedded Retaining Wall

- The primary resistance comes from the passive earth pressure generated as the sheets are driven into the soil.



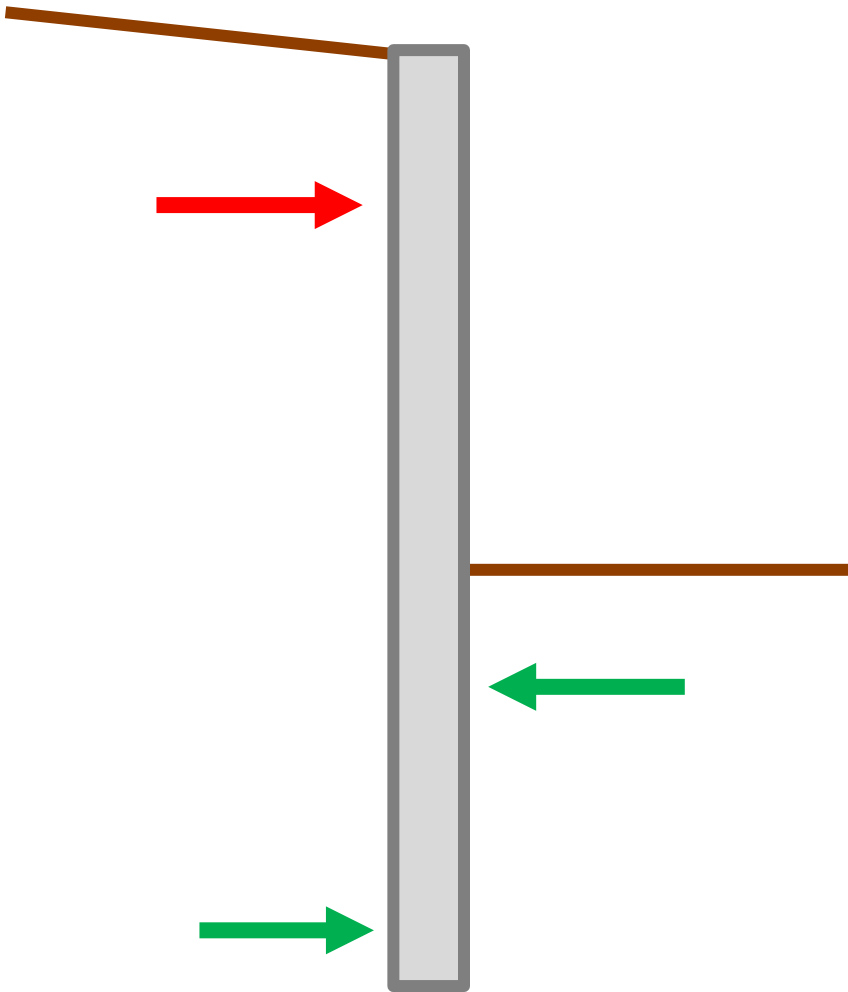
Embedded Retaining Wall

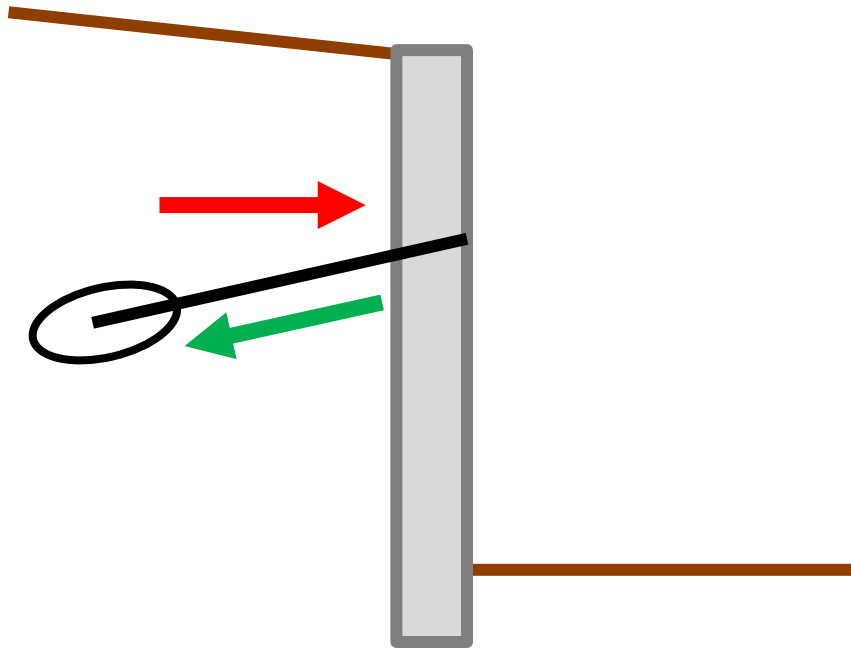


- The primary resistance comes from the passive earth pressure generated as the sheets are driven into the soil.
- The depth of penetration and the interlocking of sheets provide stability.

Embedded Retaining Wall

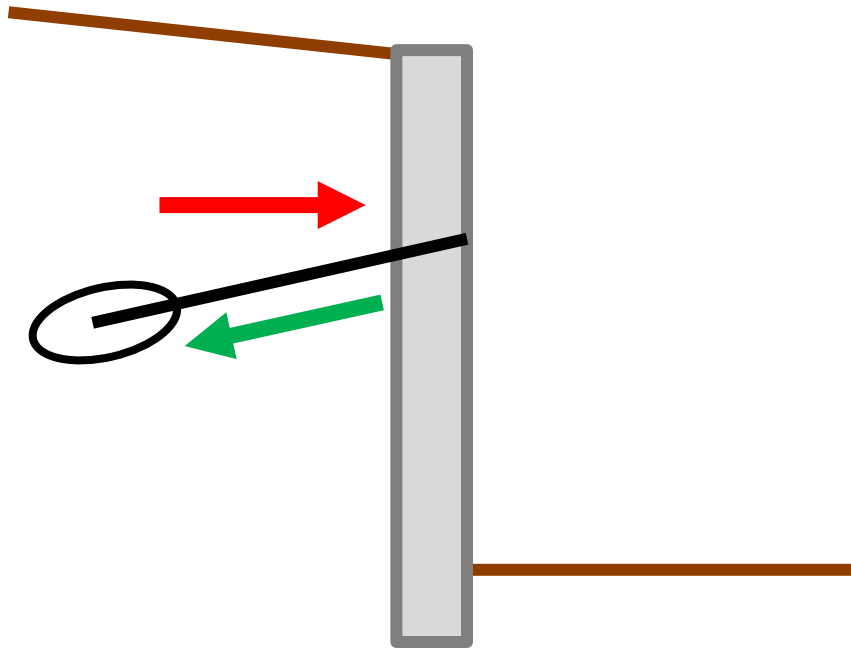
- Often used in waterfront structures, such as docks and piers, and in temporary construction to retain soil





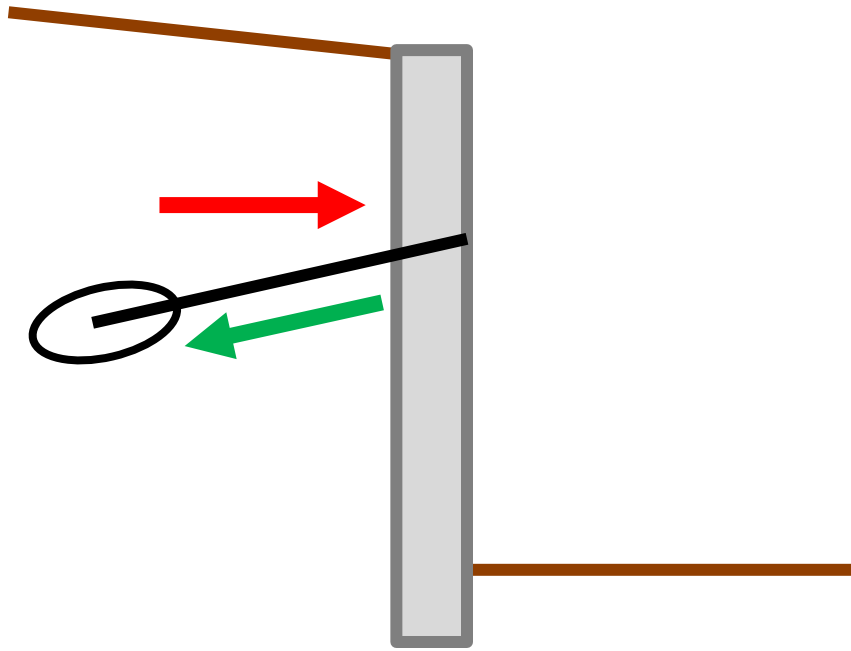
Anchored Wall

- Anchored walls can be of any of the other types but with additional support from cables or other anchors driven deep into the soil behind the wall.



Anchored Wall

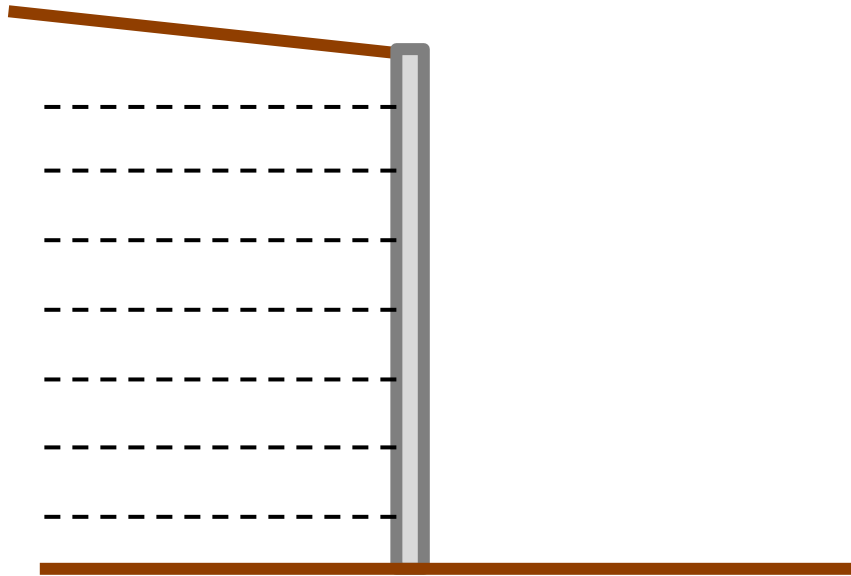
- The anchors provide additional horizontal force to resist the lateral earth pressure, allowing for the construction of taller walls.



Anchored Wall

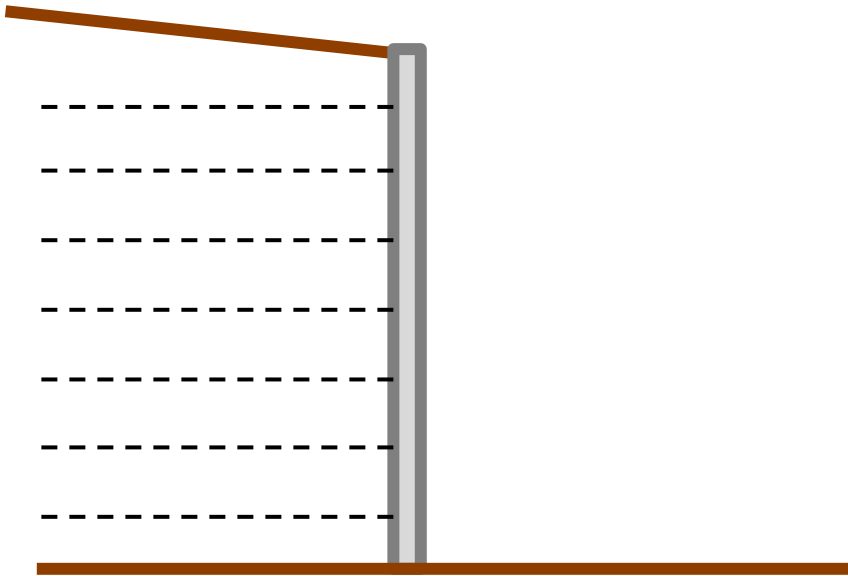
- Suitable for high walls where space constraints do not allow for the wall to be thickened, such as in urban excavation projects

Stabilised Earth Wall



- Reinforced soil retaining walls, sometimes referred to as mechanically stabilised earth walls, are constructed using layers of geogrid to reinforce the soil into a stabilised mass.

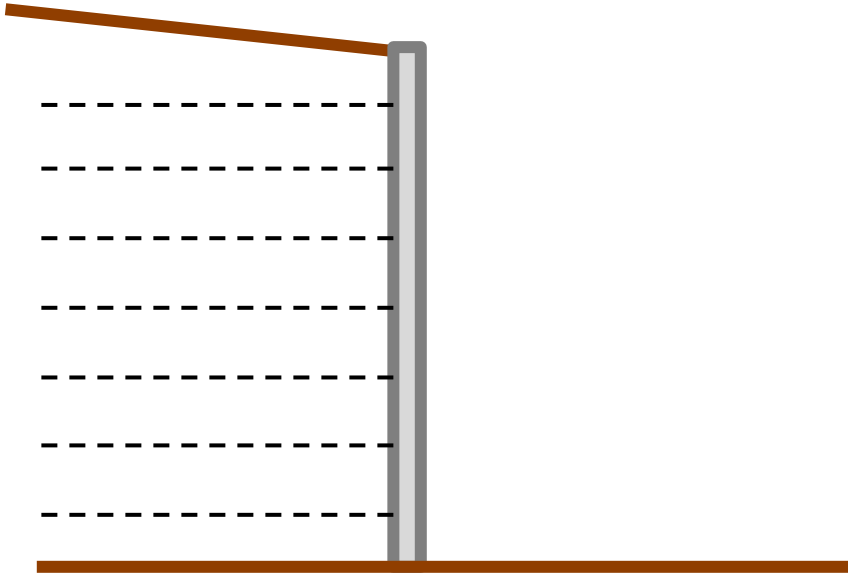
Stabilised Earth Wall



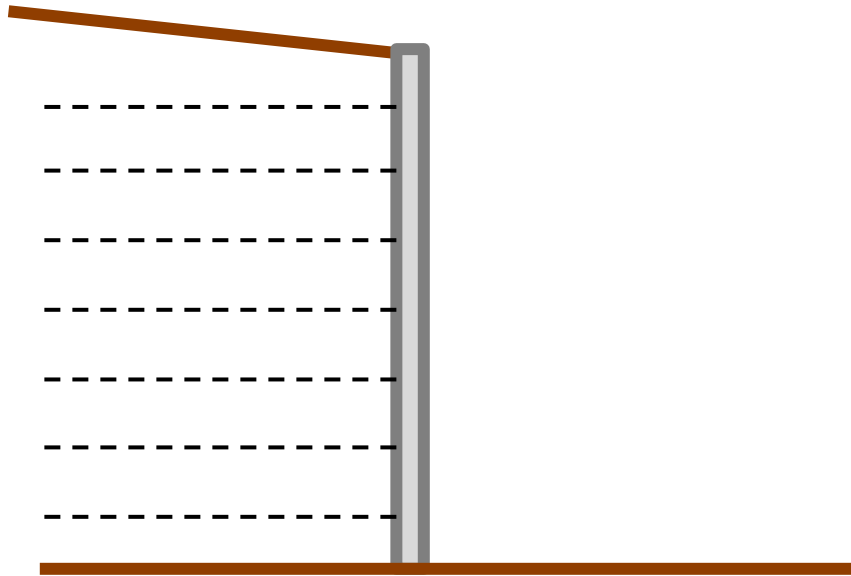
- Reinforced soil retaining walls, sometimes referred to as mechanically stabilised earth walls, are constructed using layers of geogrid to reinforce the soil into a stabilised mass.
- This increases the bearing capacity of the retaining structure, along with its resistance to differential settlement.

Stabilised Earth Wall

- The layers are compacted to ensure stability and minimise settlement.

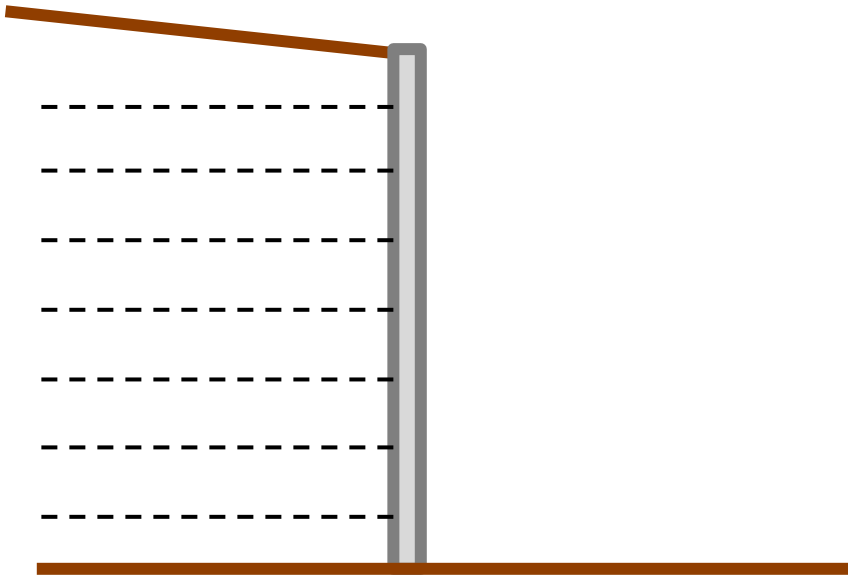


Stabilised Earth Wall



- The geotextiles enhance the shear strength of the soil by providing additional tensile strength.

Stabilised Earth Wall



- The geotextiles enhance the shear strength of the soil by providing additional tensile strength.
- This prevents soil movement and helps the wall resist lateral pressures.

Lateral Earth Pressure

- Lateral earth pressure refers to the force exerted by soil against a retaining wall.

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- This pressure plays a critical role in the design and stability of retaining walls therefore understanding how soil exerts pressure on a wall helps engineers ensure that the wall can resist this force.
- If lateral earth pressure increases to a point where it is higher than the wall can resist, it can cause the wall to collapse, topple or overturn.
- For this reason, when designing retaining walls, engineers must analyse the lateral earth pressure and factor this into their plans.

Lateral Earth Pressure

- Plasticity in the context of soil mechanics refers to the ability of soil to undergo deformation without cracking or fracturing.
- This behaviour is especially important when analysing soil behaviour under stress, such as when it's exerting pressure against a retaining wall.
- Plasticity comes into play in Rankine's Earth Pressure Theory, which is used to predict how soils behave when subjected to lateral earth pressures.

Lateral Earth Pressure

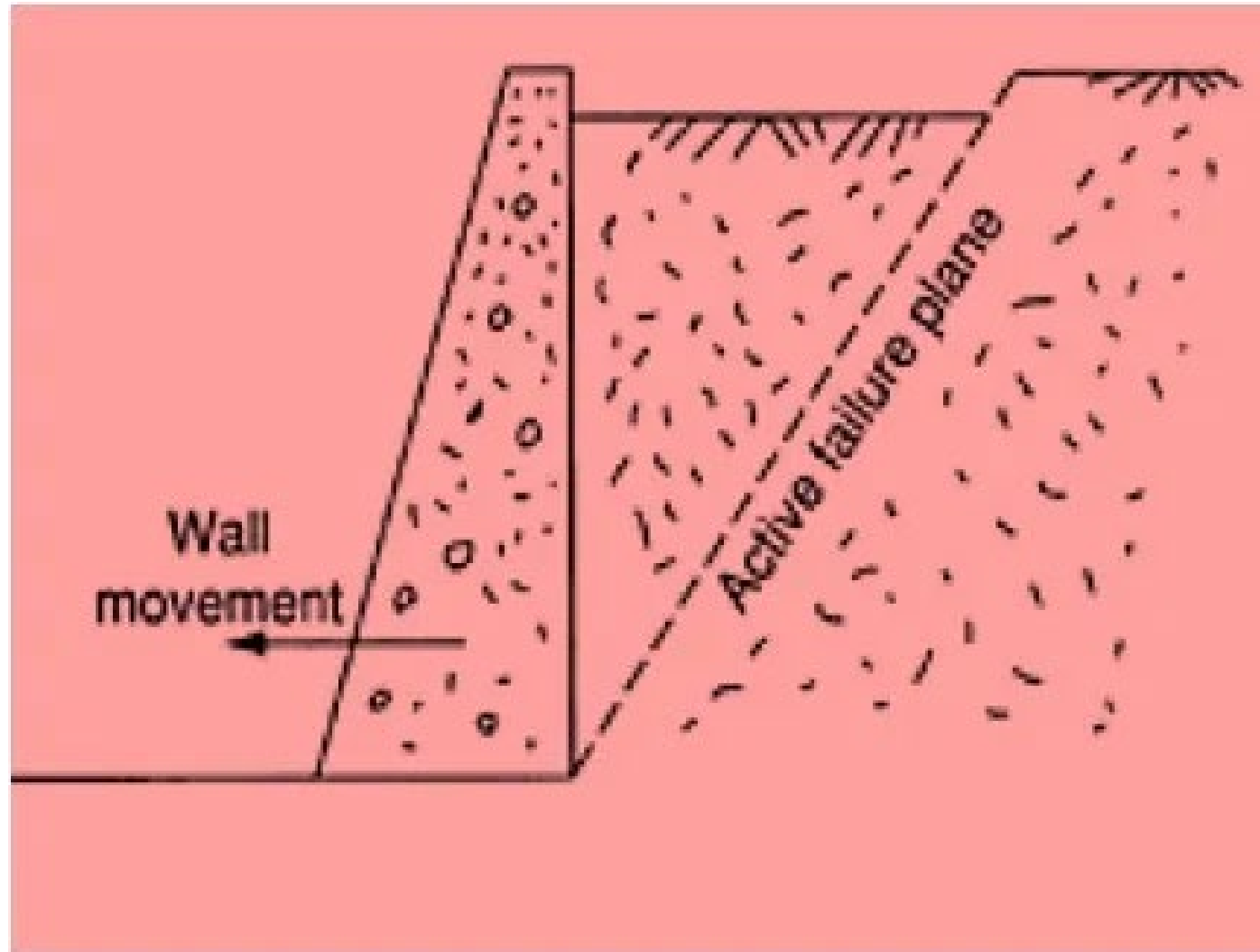
- Rankine's theory assumes that the soil behind a retaining wall can be in a state of either active failure or passive failure.
- Both failure states depend on the plasticity of the soil, i.e., the soil's ability to deform and flow when stresses are applied.

Active Earth Pressure

- Active earth pressure occurs when the retaining wall moves slightly away from the backfill (the soil retained by the wall), causing the soil to expand.
- As the soil expands, it deforms and enters a state of plasticity, where it continues to deform under stress without any further increase in resistance.
- Plastic collapse occurs when the soil reaches its active failure limit. At this point, the soil has undergone enough deformation that it cannot exert any more resistance, and it transitions to a failure state where the pressure against the wall is at its minimum active value.

Active Earth Pressure

- The active plastic collapse mechanism leads to the lowest possible earth pressure because the soil is in a fully deformed, relaxed state. The wall could potentially overturn or slide if not designed properly.
- The collapse mechanism typically involves a shear failure in the soil, which forms along a failure plane at an angle governed by the soil's internal friction angle (ϕ).



Active Earth Pressure

- Rankine's Formula

$$p_a = K_a \gamma z$$

- p_a = Active Earth Pressure
- K_a = Active Earth Pressure Co-efficient, $K_a = \frac{1 - \sin \phi}{1 + \sin \phi}$
- γ = Unit Weight of the Soil
- z = Depth Below the Soil Surface

Active Earth Pressure

- Rankine's Formula (if $c > 0$)

$$p_a = K_a \gamma z - 2c\sqrt{K_a}$$

- p_a = Active Earth Pressure
- K_a = Active Earth Pressure Co-efficient, $K_a = \frac{1 - \sin \phi}{1 + \sin \phi}$
- γ = Unit Weight of the Soil
- z = Depth Below the Soil Surface

Active Earth Pressure

- The total active thrust is the total force exerted by the soil on the wall, integrated over the entire height of the wall.

$$P_a = \frac{1}{2} K_a \gamma H^2 - 2c\sqrt{K_a}$$

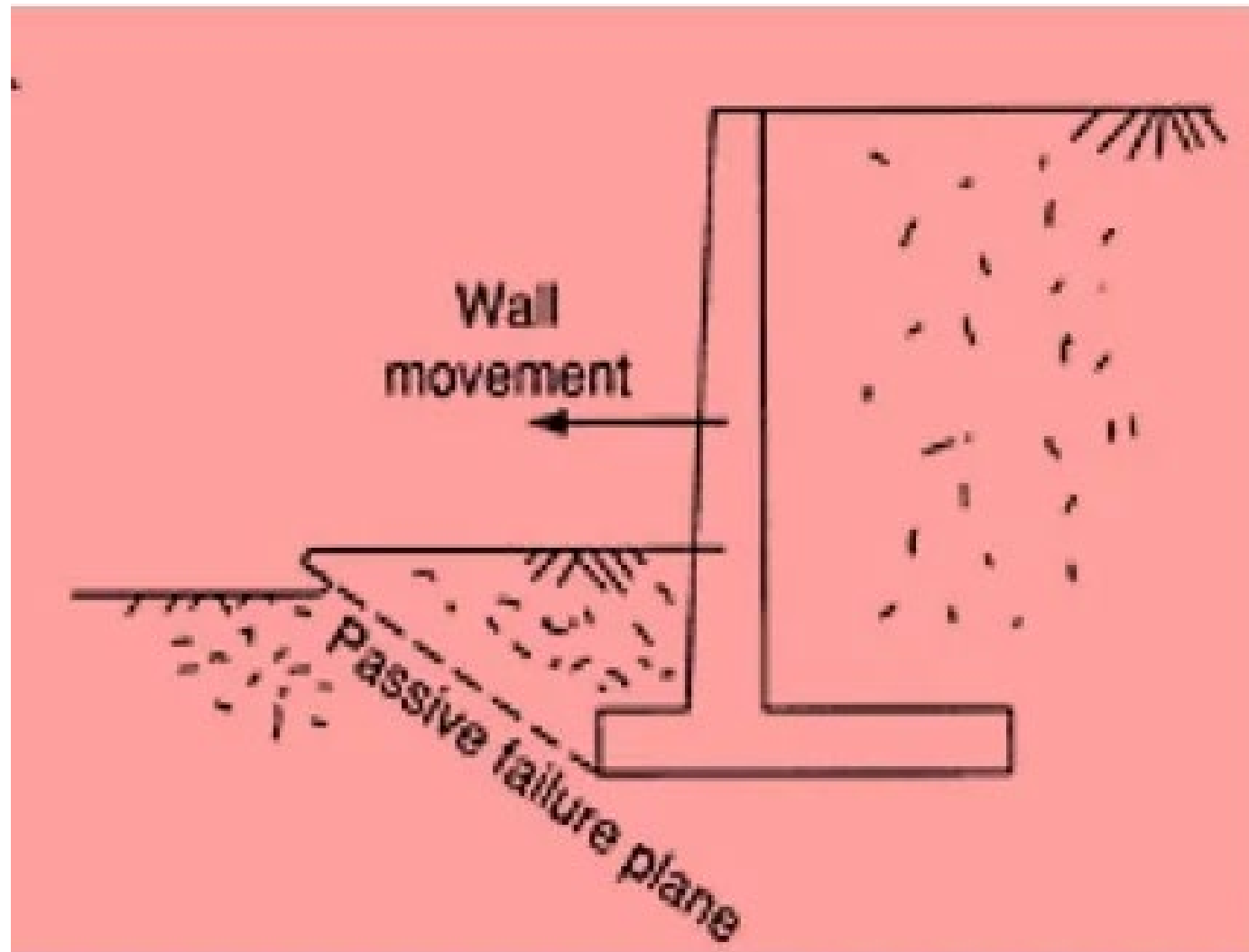
- P_a = Total Active Thrust
- K_a = Active Earth Pressure Co-efficient, $K_a = \frac{1 - \sin \phi}{1 + \sin \phi}$
- γ = Unit Weight of the Soil
- H = Height of Retaining Wall

Passive Earth Pressure

- Passive earth pressure occurs when the retaining wall moves towards the backfill, causing the soil to compress and offer resistance.
- As the wall pushes into the soil, the soil gets denser and resists the movement. The soil continues to deform plastically until it reaches a point of maximum resistance, known as passive plastic collapse.
- At this stage, the soil can no longer increase its resistance, and the wall experiences the maximum possible lateral pressure from the soil.

Passive Earth Pressure

- The passive plastic collapse state is a condition where the soil is fully compressed, and the wall is on the verge of failure due to the enormous pressures being exerted by the soil. If the forces exceed the capacity of the wall, it may fail by crushing or overturning.
- This failure also involves shear deformation, but instead of the soil expanding, it compresses along a failure plane at a steeper angle than in active failure.



Passive Earth Pressure

- Rankine's Formula

$$p_p = K_p \gamma z$$

- p_p = Passive Earth Pressure
- K_p = Active Earth Pressure Co-efficient, $K_p = \frac{1 + \sin \phi}{1 - \sin \phi}$
- γ = Unit Weight of the Soil
- z = Depth Below the Soil Surface

Passive Earth Pressure

- Rankine's Formula (if $c > 0$)

$$p_p = K_p \gamma z + 2c\sqrt{K_p}$$

- p_p = Passive Earth Pressure
- K_p = Active Earth Pressure Co-efficient, $K_p = \frac{1 + \sin \phi}{1 - \sin \phi}$
- γ = Unit Weight of the Soil
- z = Depth Below the Soil Surface

Passive Earth Pressure

- The total passive thrust is the total force exerted by the soil on the wall, integrated over the entire height of the wall.

$$P_p = \frac{1}{2} K_p \gamma H^2 + 2c\sqrt{K_p}$$

- P_p = Total Passive Thrust
- K_p = Active Earth Pressure Co-efficient, $K_p = \frac{1 + \sin \phi}{1 - \sin \phi}$
- γ = Unit Weight of the Soil
- H = Height of Retaining Wall

At-Rest Earth Pressure

- At-rest earth pressure occurs when the wall does not move, and the soil remains in a static condition.
- The pressure exerted on the retaining wall is somewhere between active and passive pressures.
- This is usually applicable for rigid walls that are constrained and cannot move, like basement walls or bridge abutments.
- It is higher than active pressure but lower than passive pressure.

At-Rest Earth Pressure

- Jaky's Formula

$$\sigma_h = K_o \gamma H$$

- σ_h = Lateral Earth Pressure
- K_o = At-Rest Earth Pressure Co-efficient $K_o = 1 - \sin \phi$
- γ = Unit Weight of the Soil
- H = Height of Retaining Wall

Quick Summary

- Earth pressure is the force the soil exerts on a retaining wall.
- Plasticity describes the soil's ability to deform without breaking.
- Rankine's theory explains how much pressure soil applies, depending on whether the wall moves away (active pressure, low) or towards the soil (passive pressure, high).

The wall needs to be designed to handle these pressures to avoid failure.

Factors Influencing Earth Pressure

Several factors affect the magnitude and distribution of earth pressure against a retaining wall:

- Soil Type

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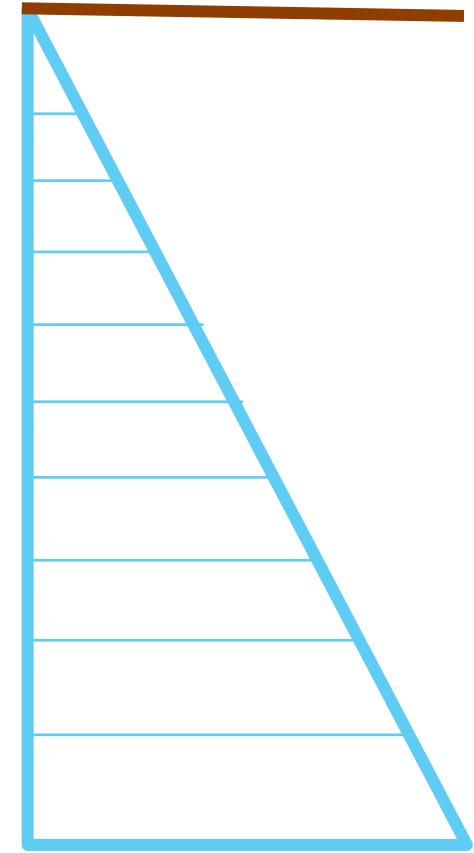
- Soil Type
- Soil Moisture

Hydrostatic Pressure

The hydrostatic pressure due to the water in the soil pores must be considered in addition to the active or passive pressure.

$$P_w = \frac{1}{2} \gamma_w H^2$$

- P_w = Hydrostatic Pressure
- γ = Unit Weight of Water
- H = Height of Retaining Wall



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- Soil Moisture
- Wall Movement

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Factors Influencing Earth Pressure

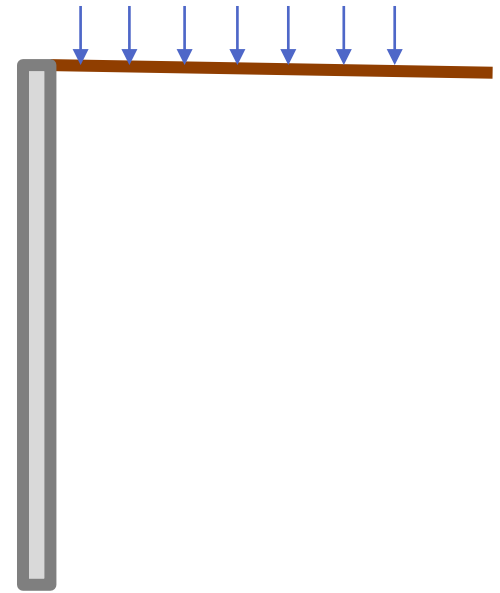
Several factors affect the magnitude and distribution of earth pressure against a retaining wall:

- Soil Type
- Soil Moisture
- Wall Movement
- Height of the Wall
- Surface Loads

Surface Loads

A surcharge is an additional load applied at the soil surface, such as from vehicles, equipment, or other structures. When a surcharge (q) is applied uniformly on the surface of the soil behind the wall, it increases the lateral pressure on the wall.

In Rankine's theory, this surcharge pressure acts horizontally on the wall and is given by:



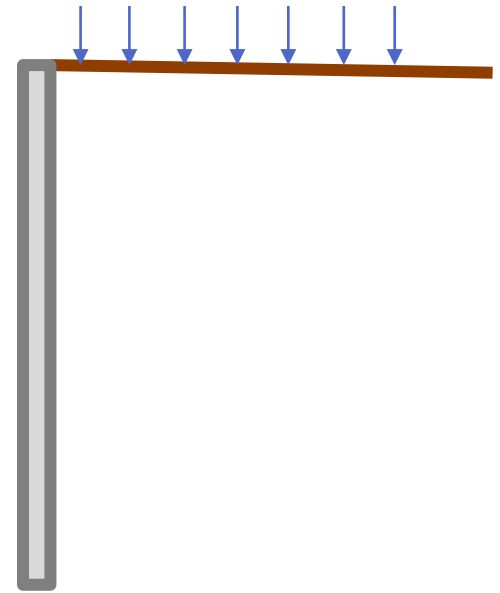
Surface Loads

For Active Earth Pressure:

$$p_{sur} = qK_a$$

For Passive Earth Pressure:

$$p_{sur} = qK_p$$



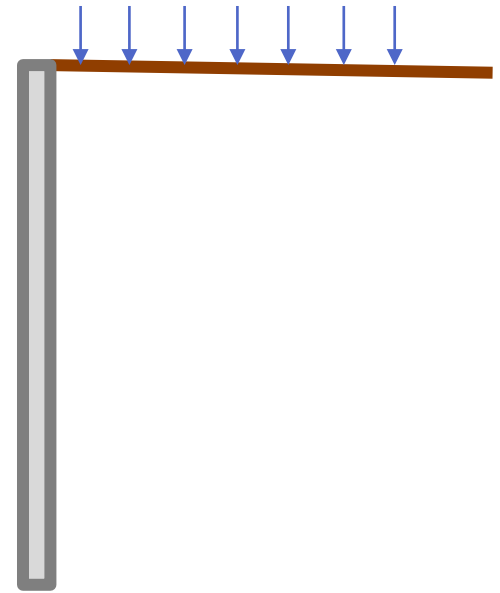
Surface Loads

The total earth pressure with a surcharge at any depth z in active conditions becomes:

$$p_{Tot} = p_a + p_{sur} = \gamma z K_a + q K_a - 2c\sqrt{K_a}$$

For Passive Earth Pressure:

$$p_{Tot} = p_p + p_{sur} = \gamma z K_p + q K_p + 2c\sqrt{K_p}$$



Practical Implications

- Retaining walls need to be designed to resist active earth pressure if slight movements are allowed.

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- Retaining walls need to be designed to resist active earth pressure if slight movements are allowed.
- If the wall is rigid and cannot move, it must be designed for at-rest pressure.
- Walls must also consider potential passive resistance to avoid failure from ground movements or forces applied towards the wall.