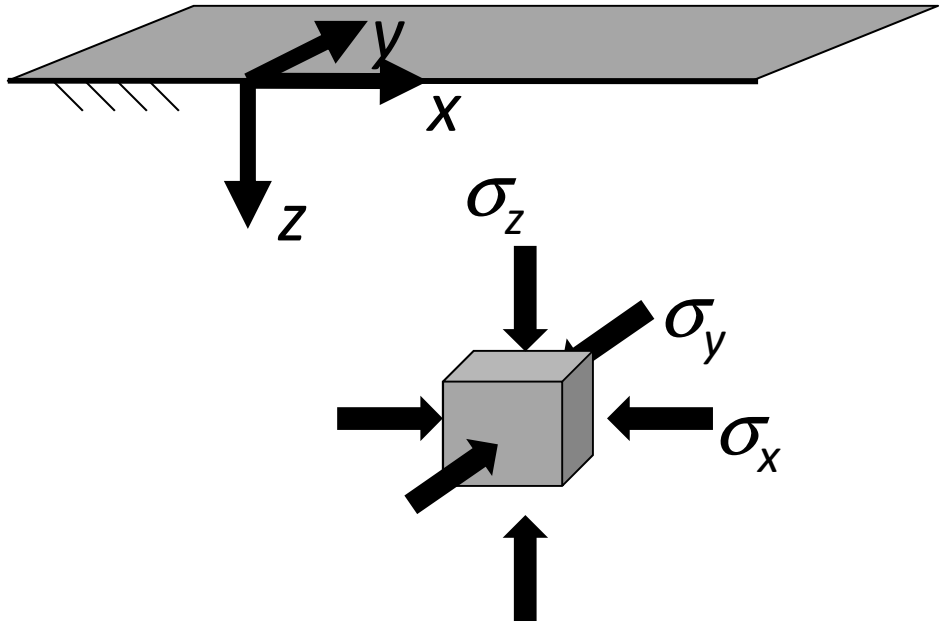
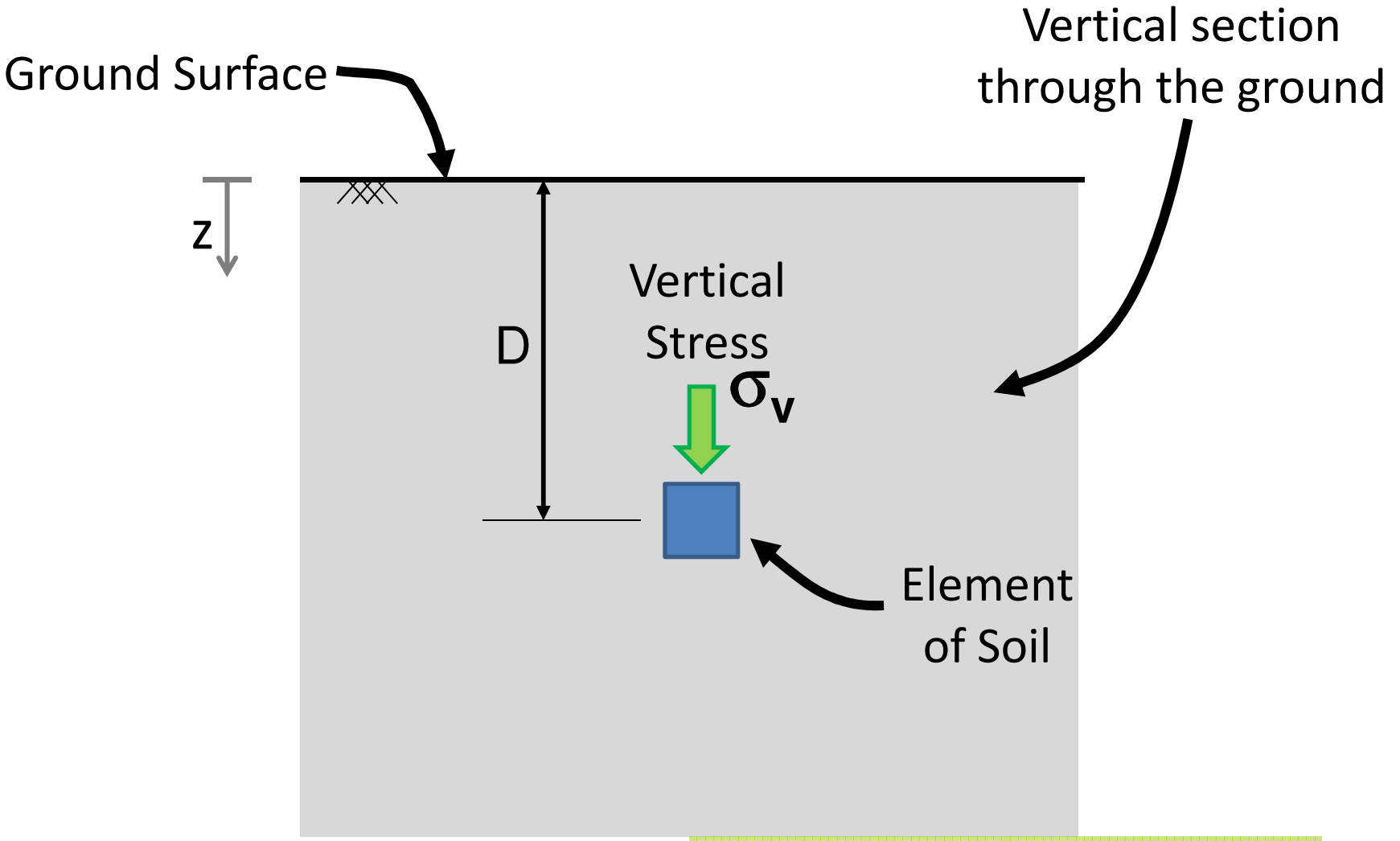
Stress in Soil

Total Stress & Effective Stress

Vertical Soil Stresses

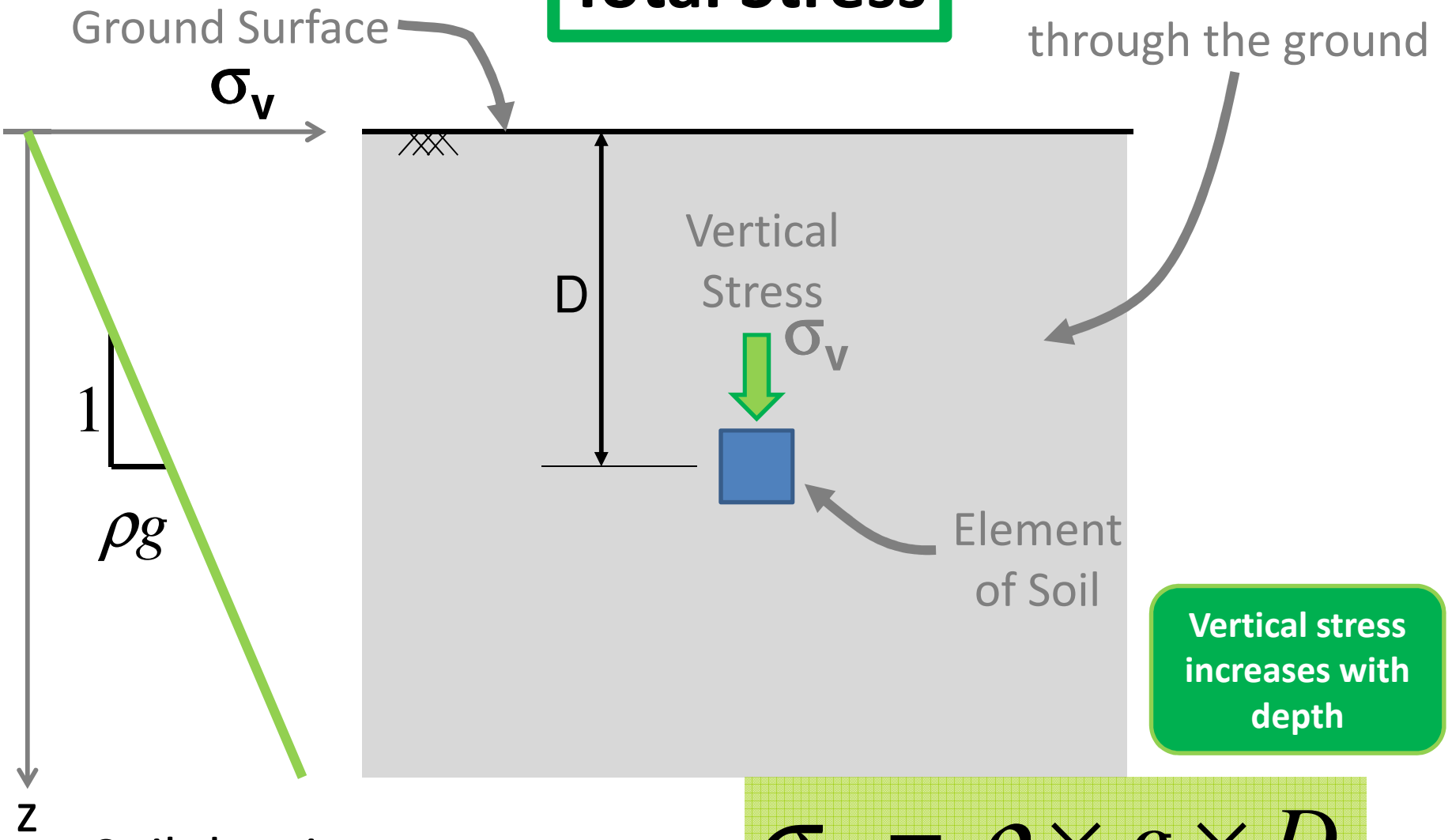




Soil density = ρ

$$\sigma_v = \rho \times g \times D$$

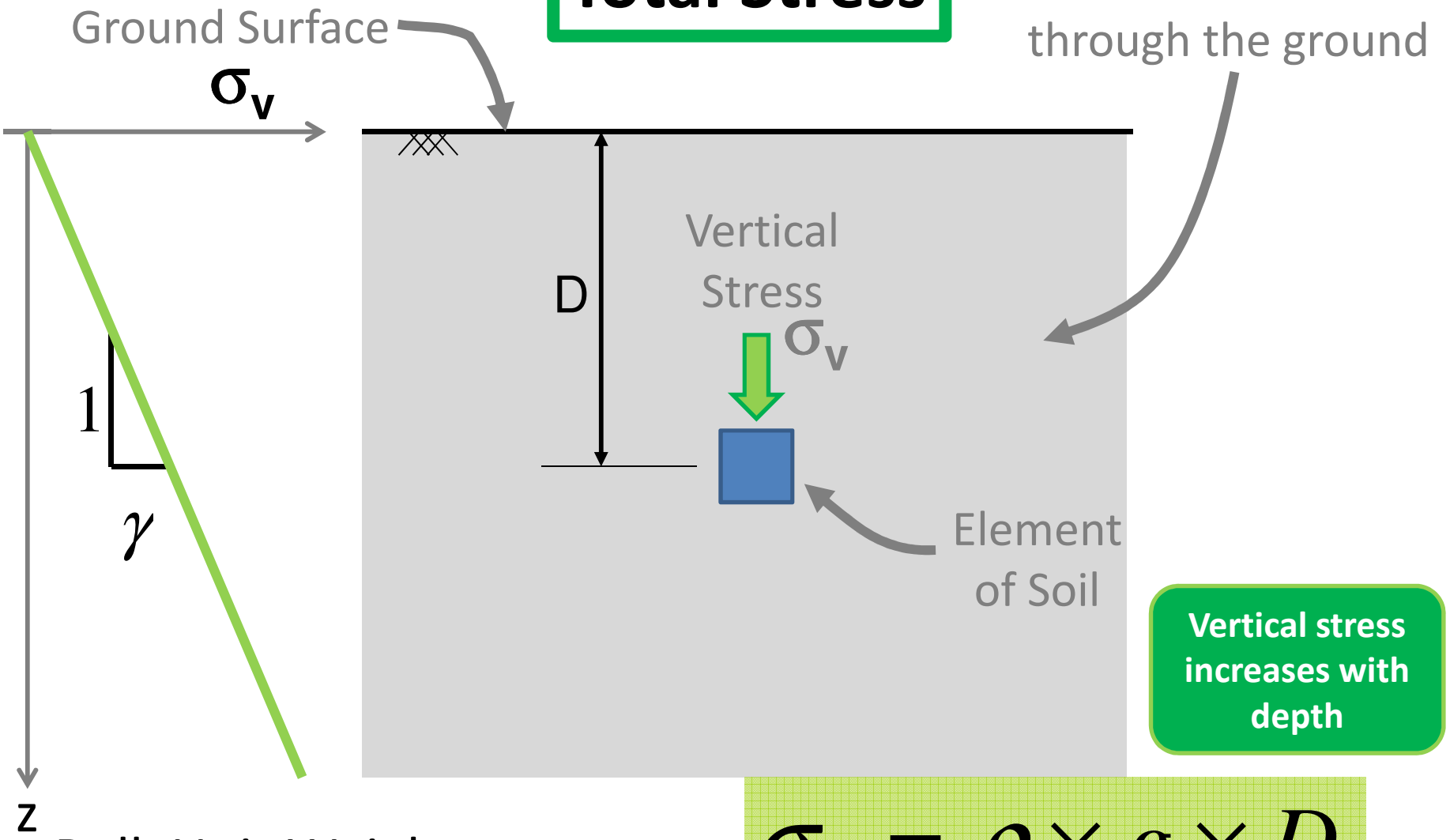
Total Stress



Vertical stress increases with depth

$$\sigma_v = \rho \times g \times D$$

Total Stress



Vertical stress increases with depth

Bulk Unit Weight = ρg = γ

$$\sigma_v = \rho \times g \times D$$

Water

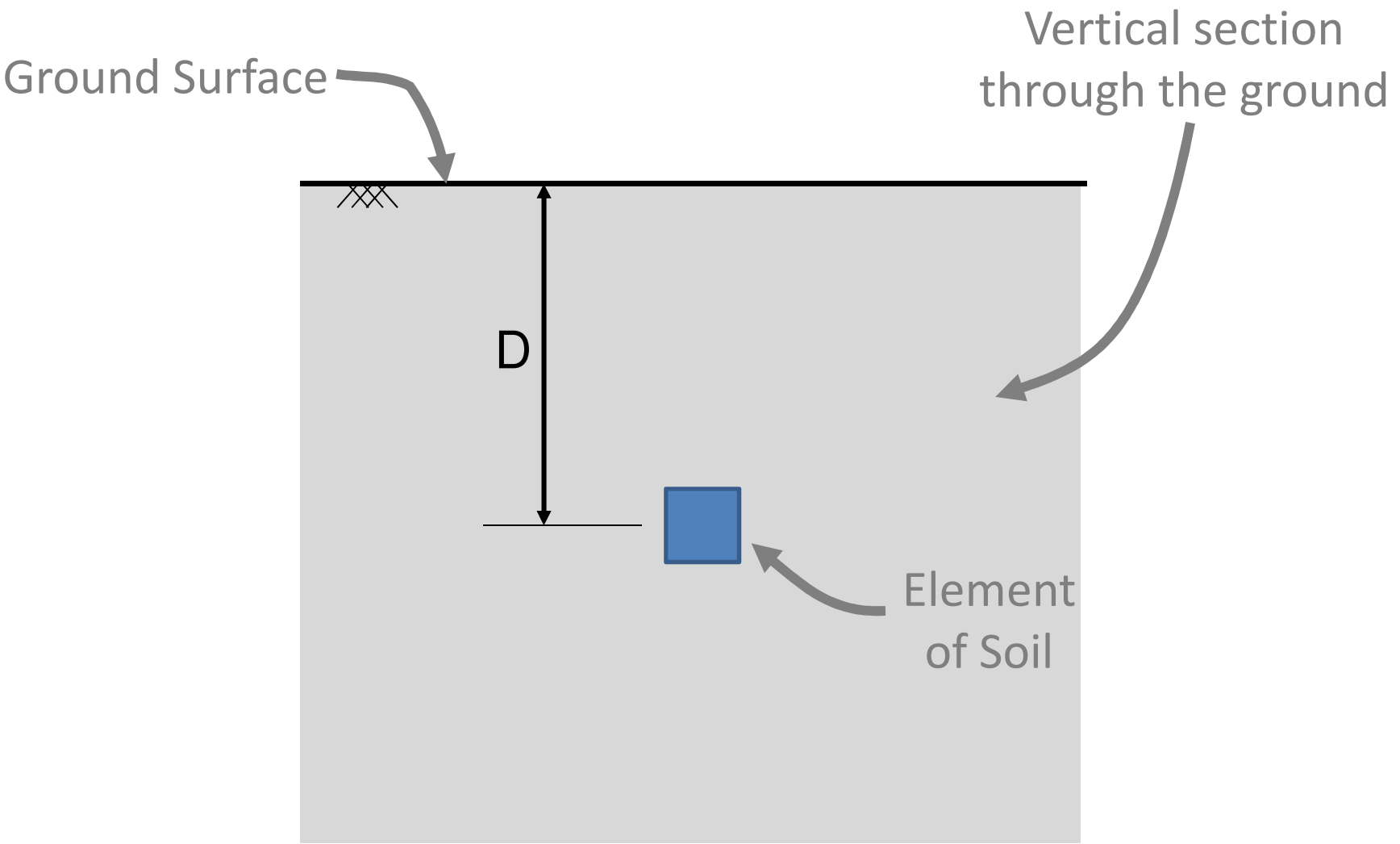
Density = 1000 kg/m^3

CANNOT sustain shear

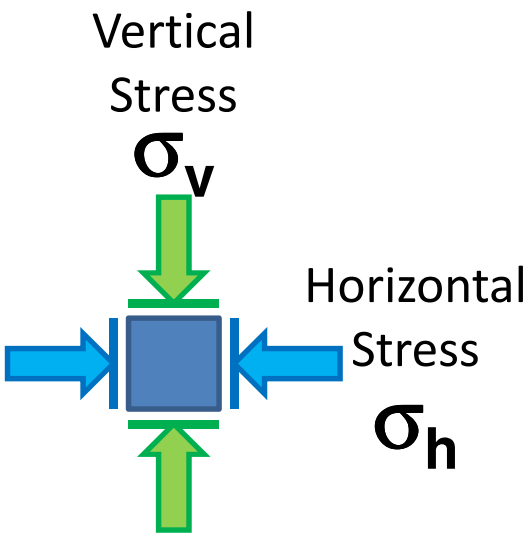
Incompressible

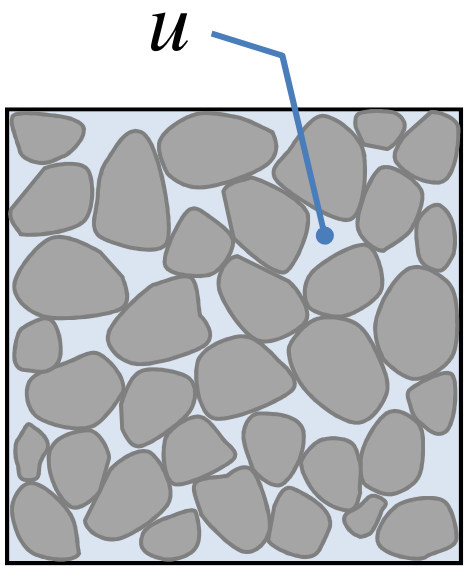
Exerts an equal pressure in ALL directions

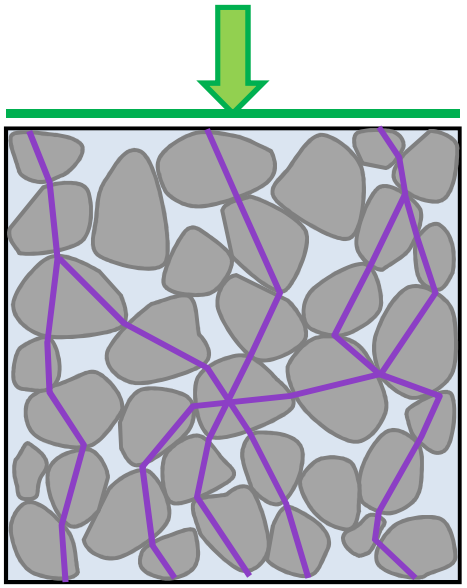
Effective Stress



Effective Stress







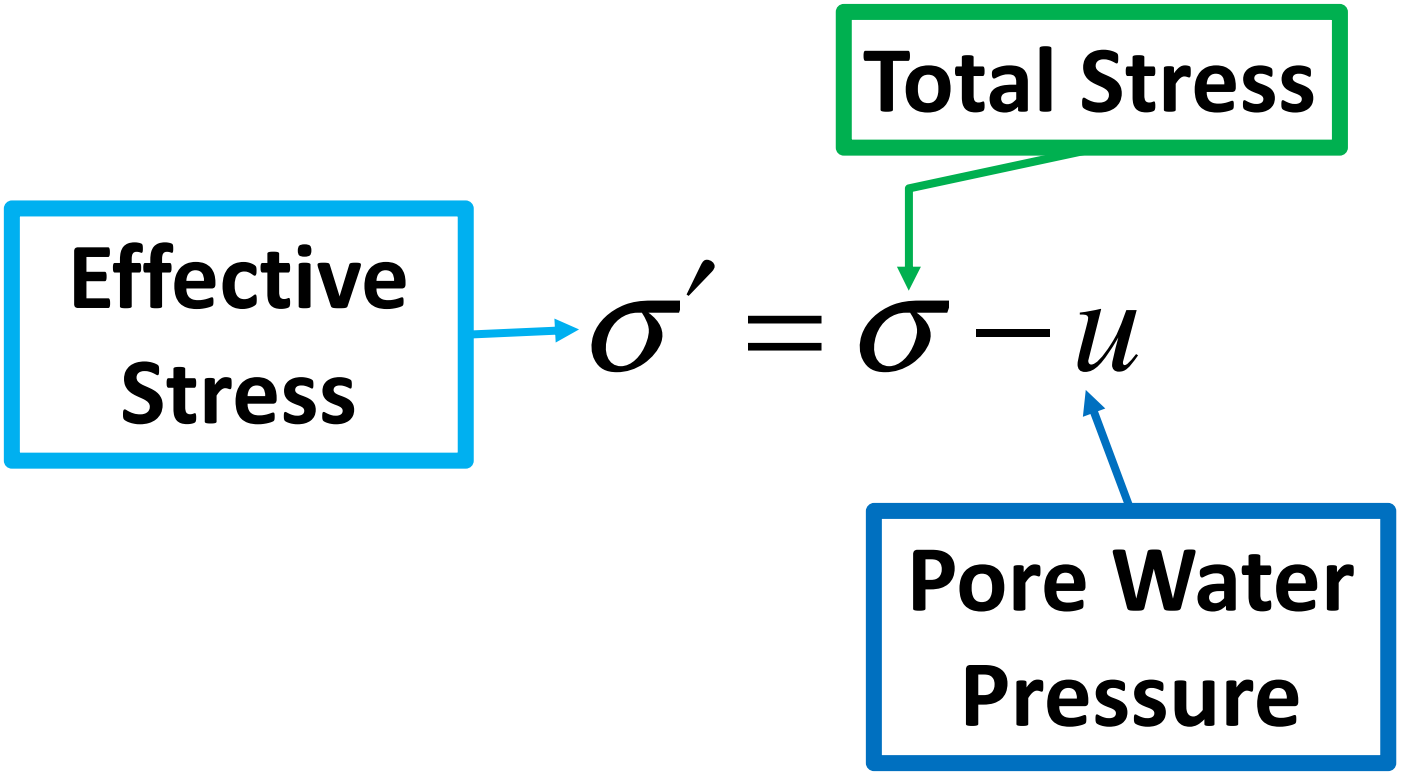
Total Stress;
The sum of all the stresses acting on the soil element.

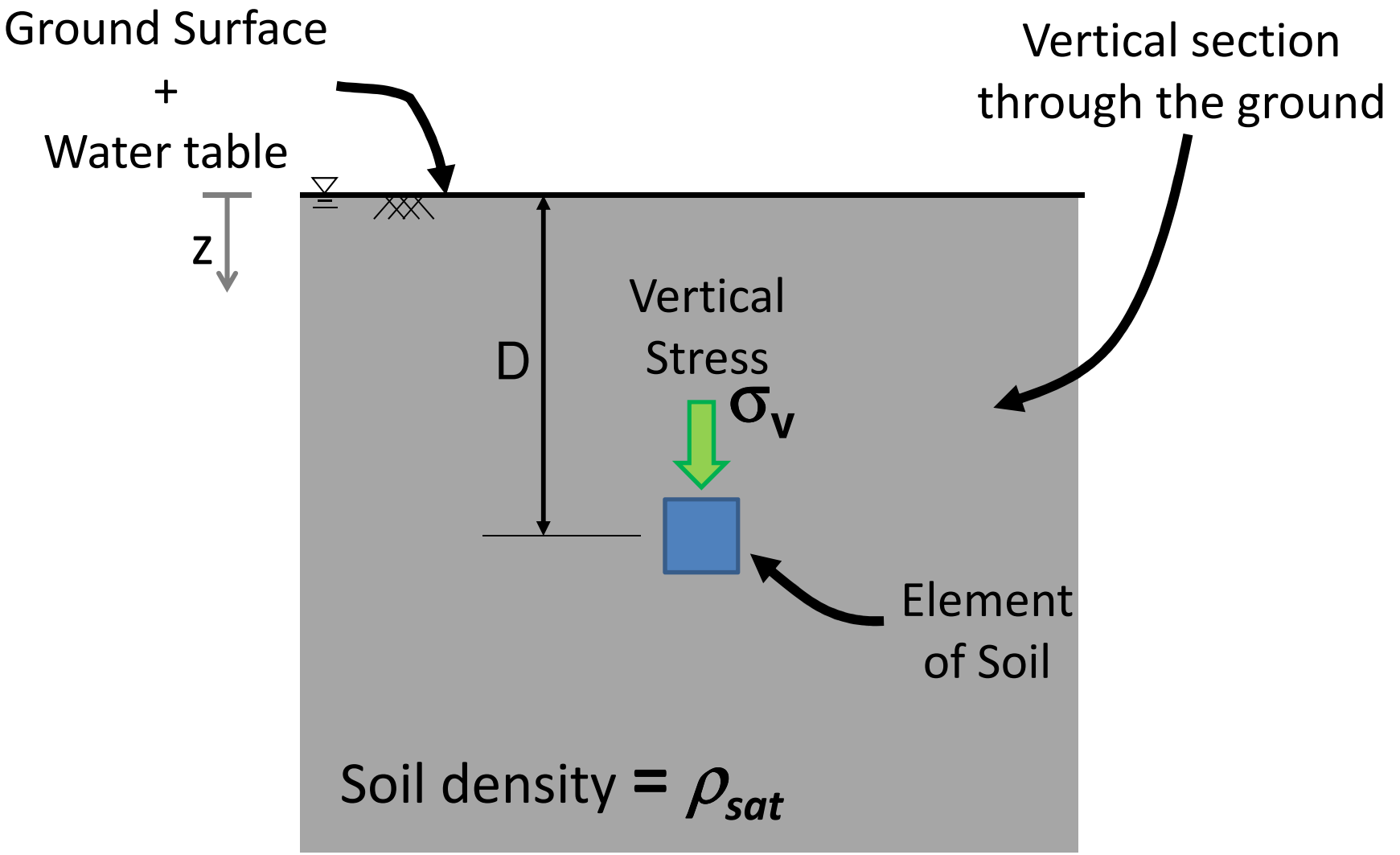
Pore Water Pressure

Effective Stress;
The stress supported by the soil skeleton.

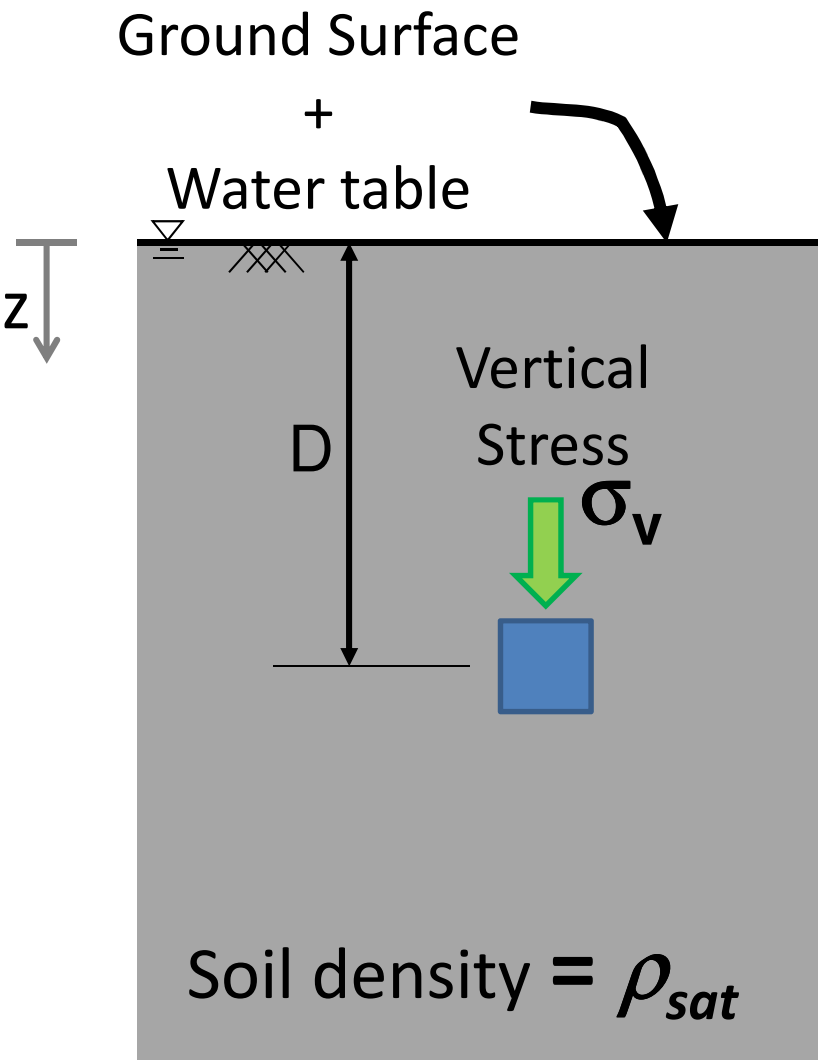
Effective Stress

All measureable effects of a change in stress, such as compression, distortion and change in shearing resistance of a soil are exclusively due to changes in the effective stresses acting on it.





$$\sigma'_v = (\rho_{sat} \times g \times D) - (\rho_{water} \times g \times D)$$



$$\gamma = \rho \cdot g$$

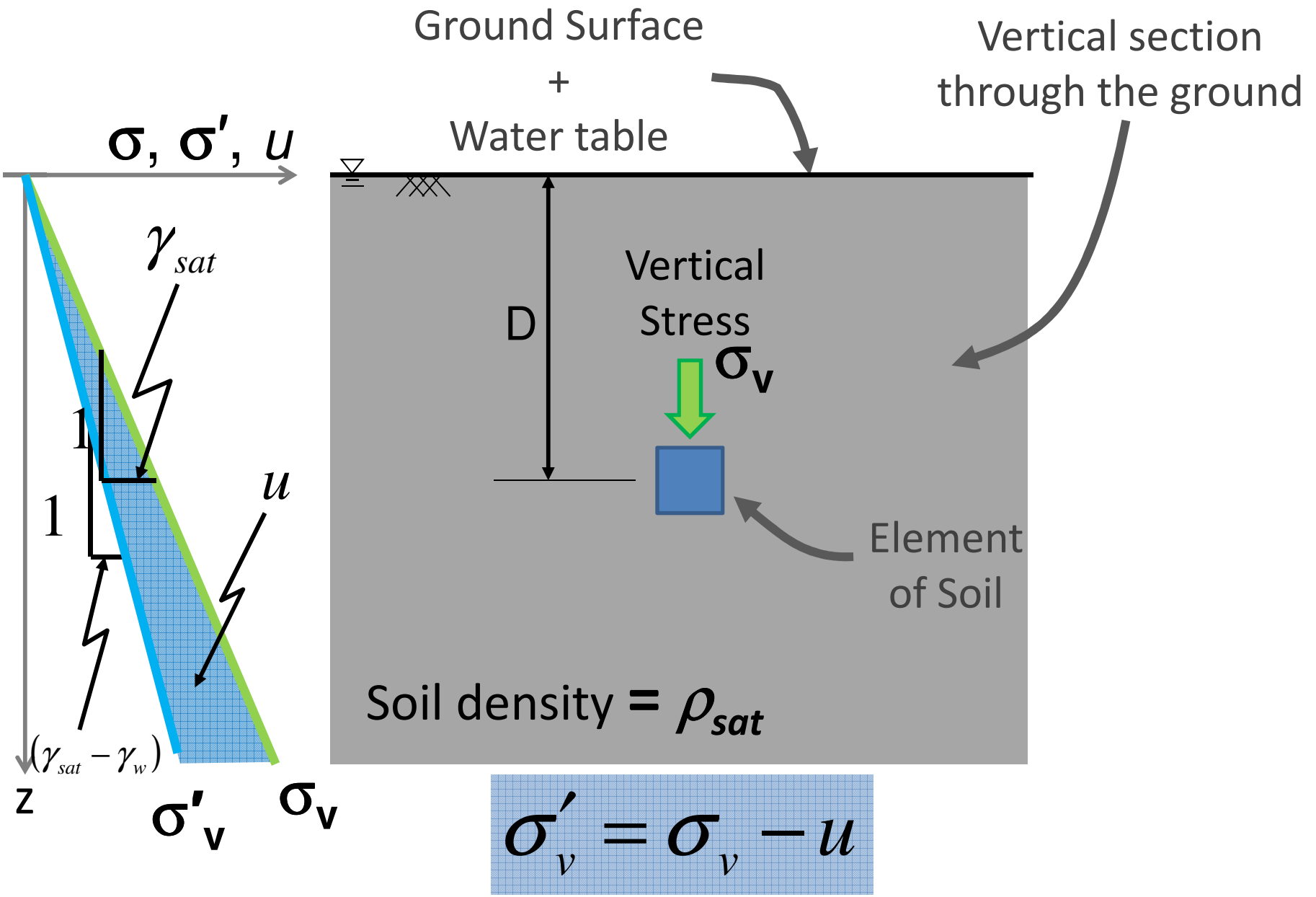
Total Stress, σ_v

$$\sigma'_v = (\gamma_{sat} D) - (\gamma_{water} D)$$

Effective Stress

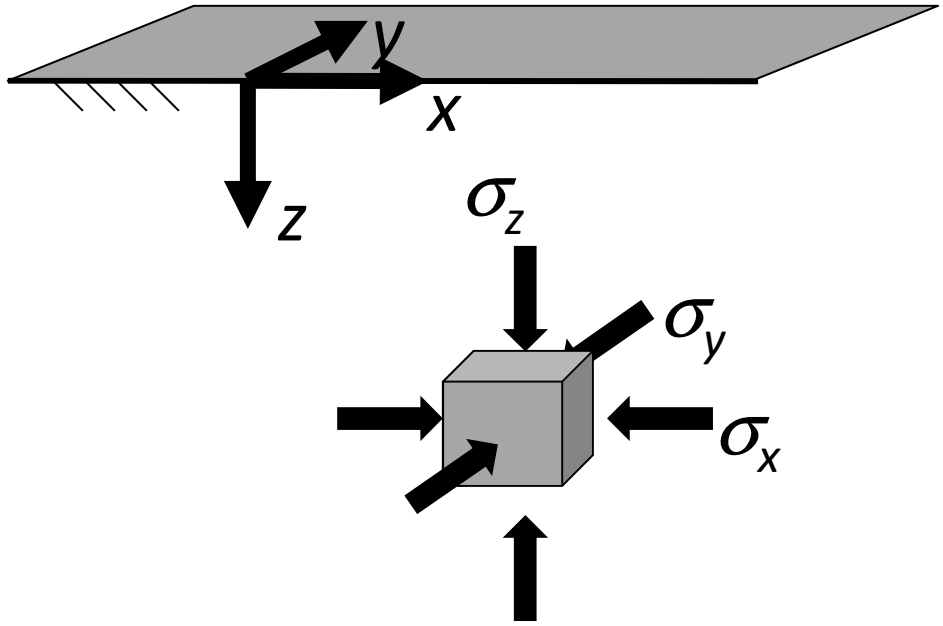
Pore Water Pressure *u*

$$\sigma'_v = (\rho_{sat} \times g \times D) - (\rho_{water} \times g \times D)$$



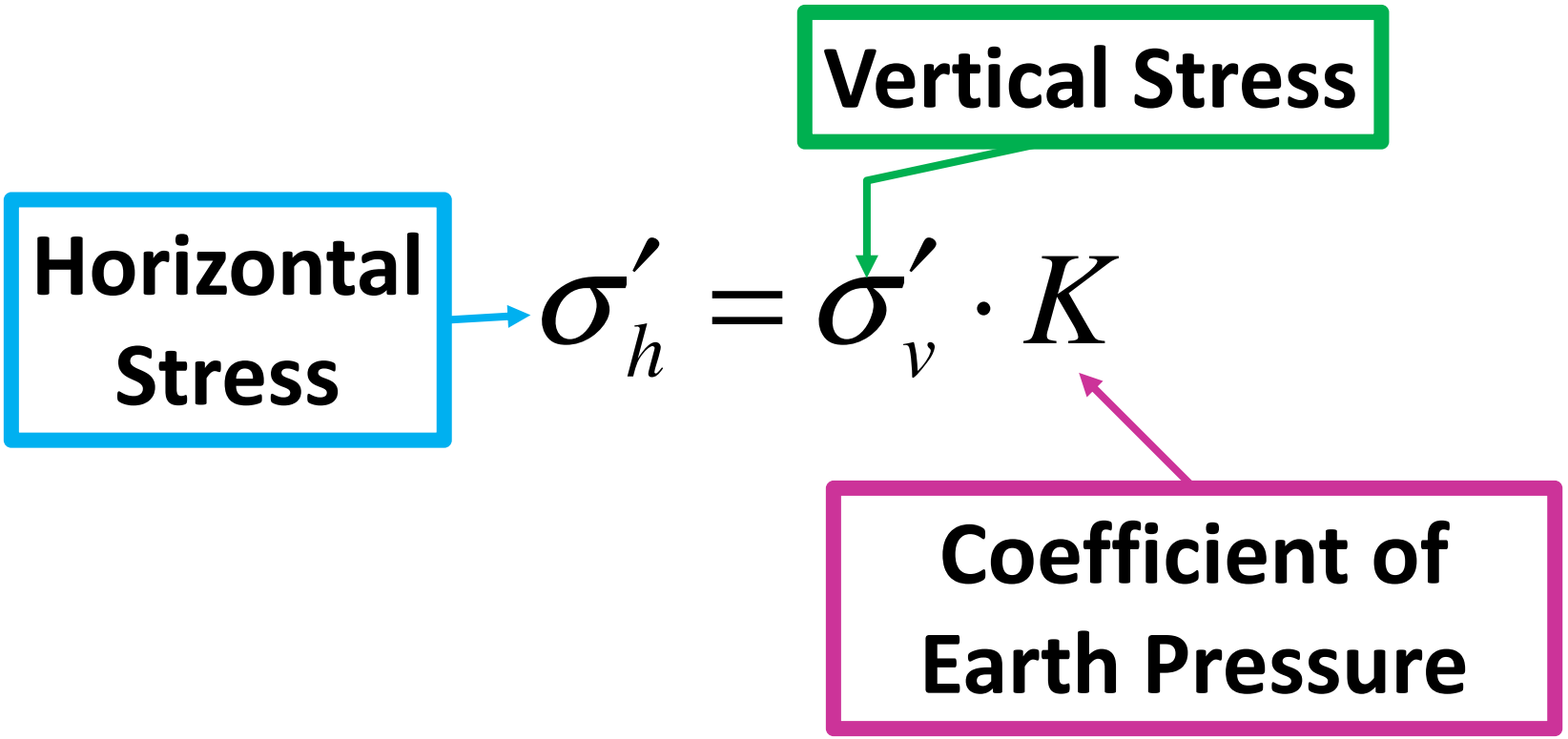
$$\sigma'_v = \sigma_v - u$$

Horizontal Soil Stresses



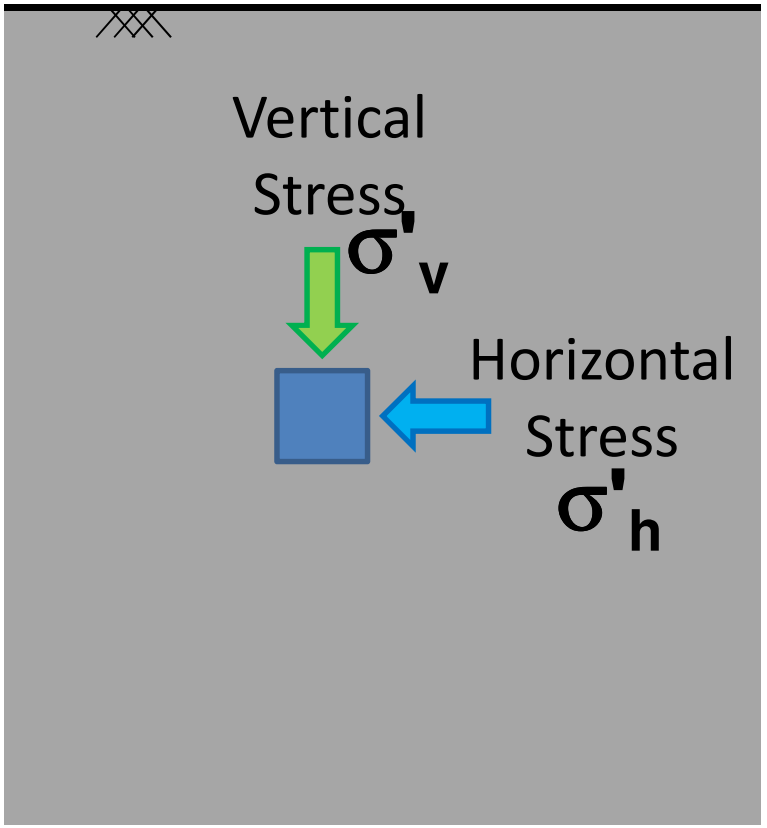
Horizontal Soil Stresses

Difficult to calculate…



Horizontal Soil Stresses

In undisturbed natural ground:



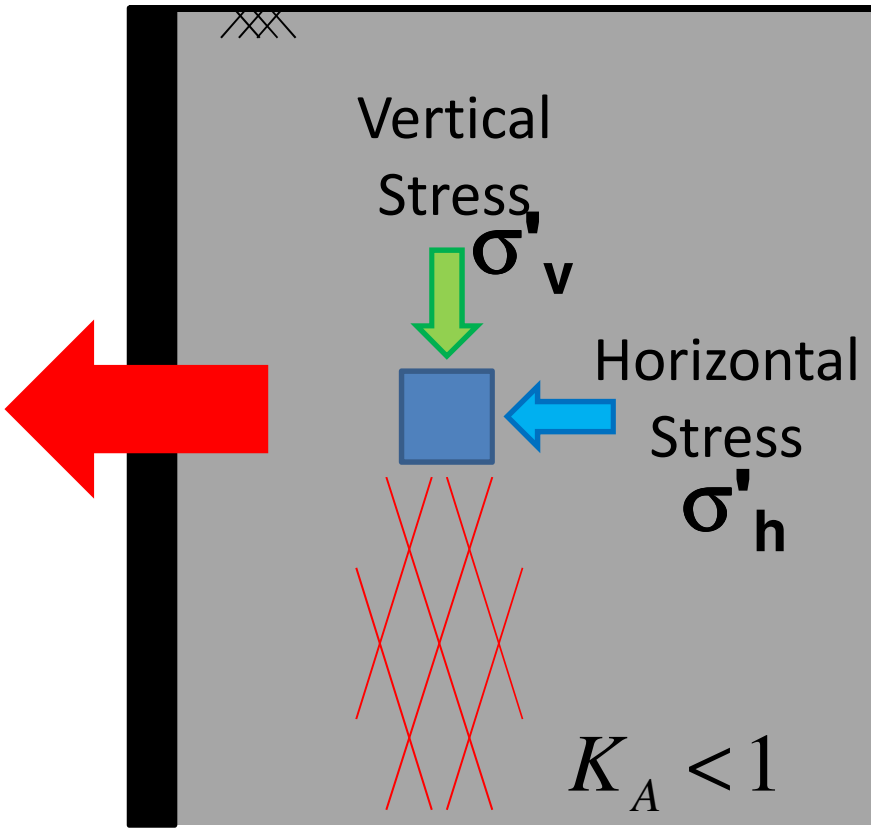
Horizontal Stress (at rest)

Vertical Stress (at rest)

$$\sigma'_{h0} = \sigma'_{v0} \cdot K_0$$

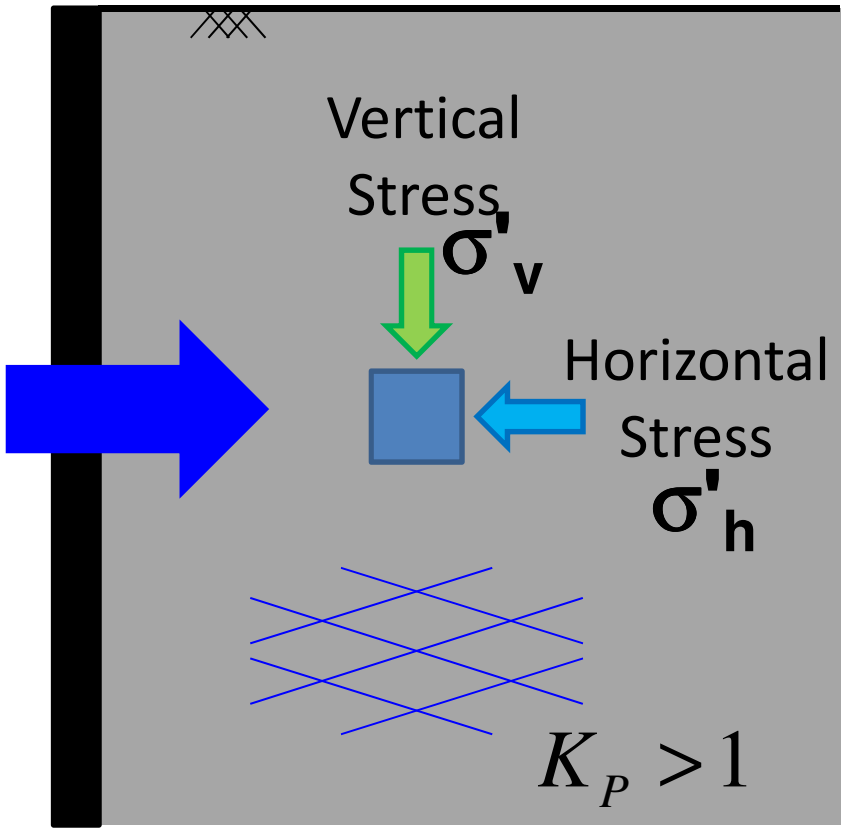
Coefficient of Earth Pressure at rest

Horizontal Soil Stresses



Active

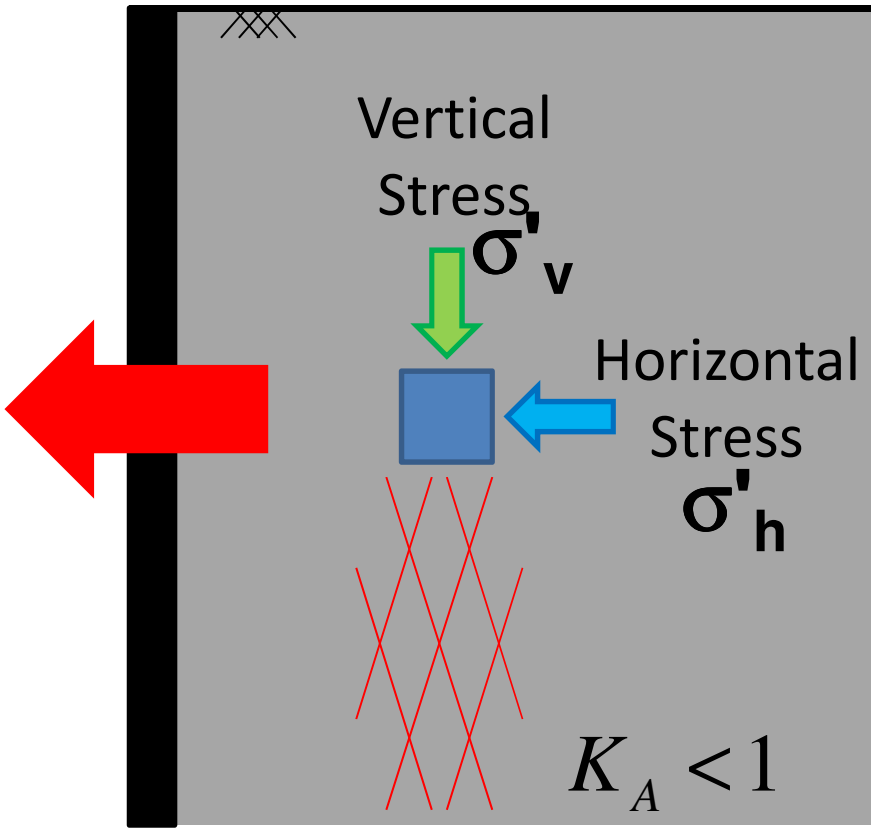
$$\sigma'_h = \sigma'_v \cdot K_A$$



Passive

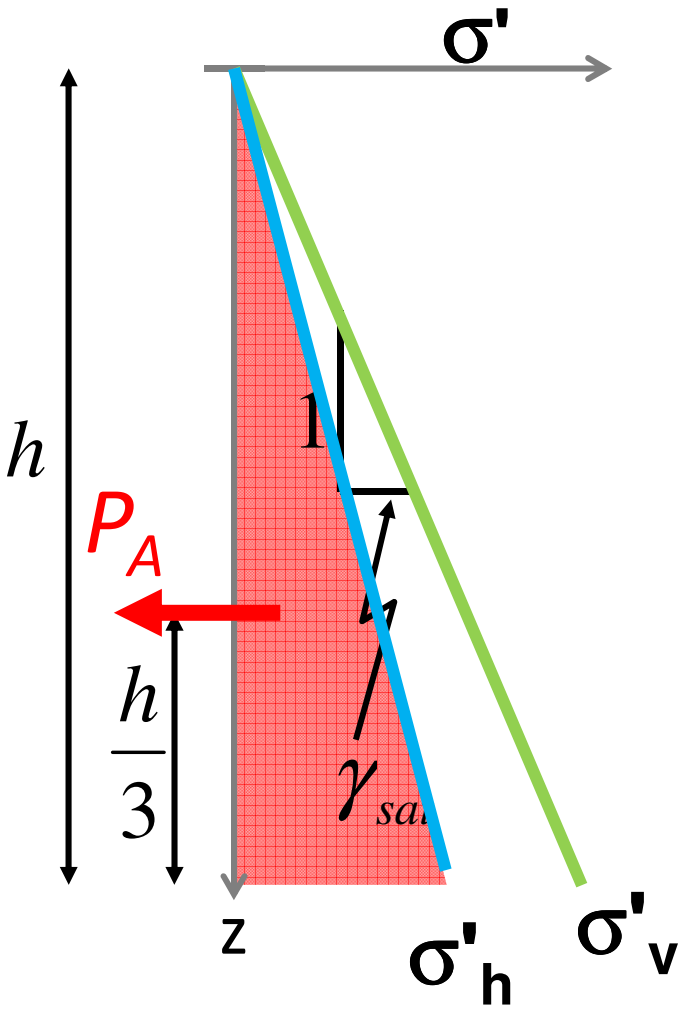
$$\sigma'_h = \sigma'_v \cdot K_P$$

Horizontal Earth Pressures

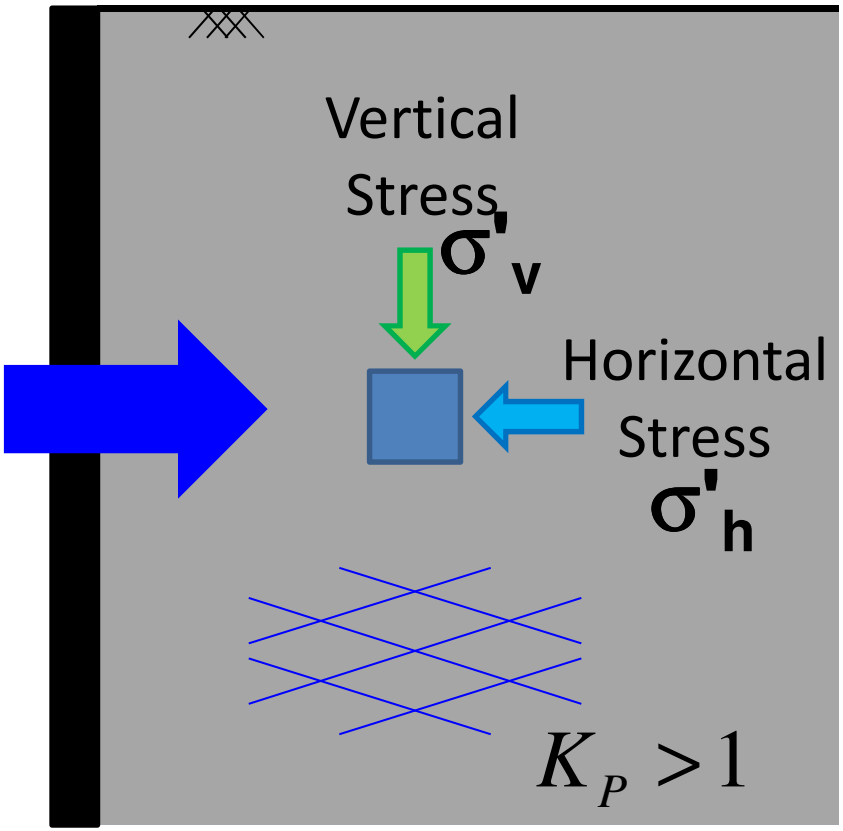


Active

$$\sigma'_h = \sigma'_v \cdot K_A$$

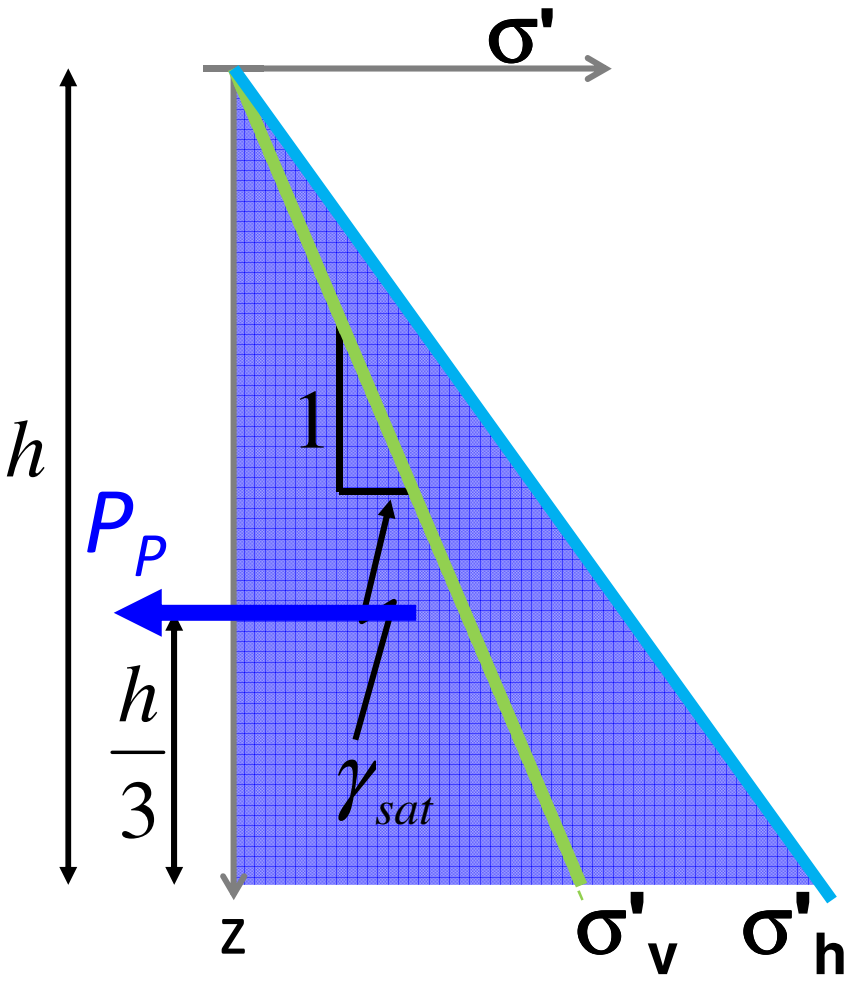


Horizontal Earth Pressures



Passive

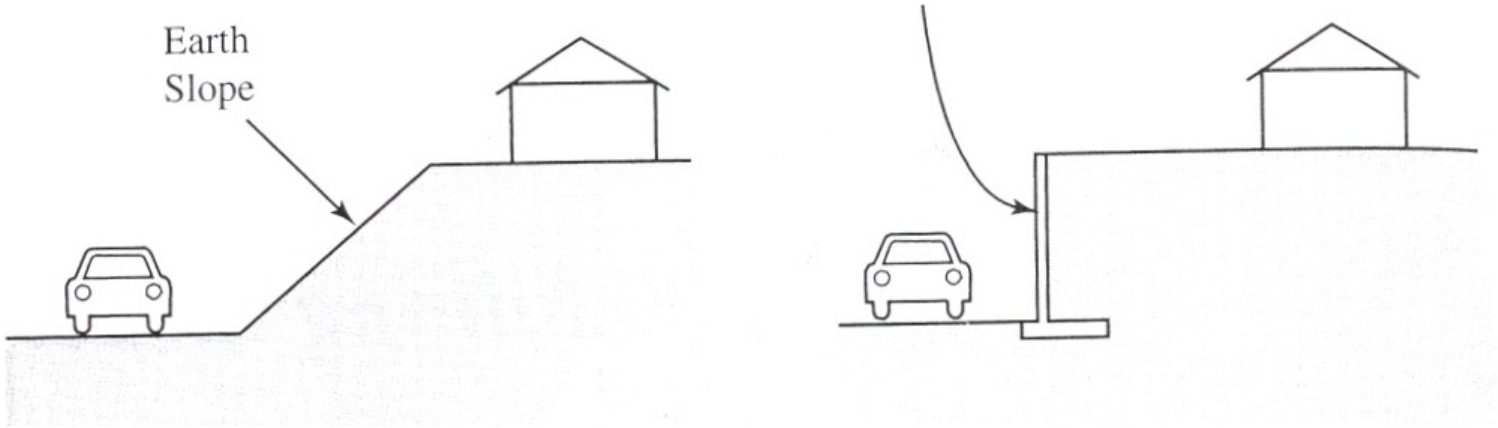
$$\sigma'_h = \sigma'_v \cdot K_P$$



Slopes and Retaining Walls

Function

To support slopes that are too deep or too steep to stand unsupported



(Coduto, 2001)

Angle of Repose

The inclination that a natural slope will safely stand at.

Available from: http://uregina.ca/~sauchyn/geog323/engineer.html

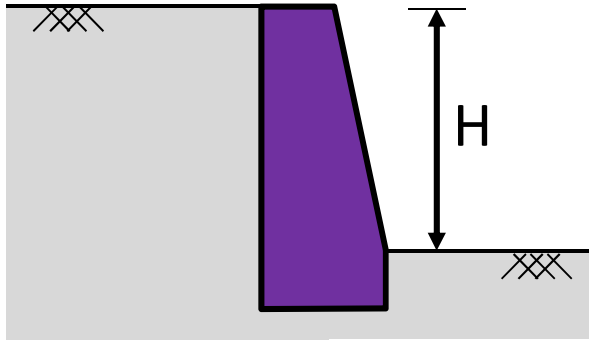
Engineered Slopes

To have a slope steeper than the angle of repose, or a vertical cut, we need to support the soil with a retaining wall.

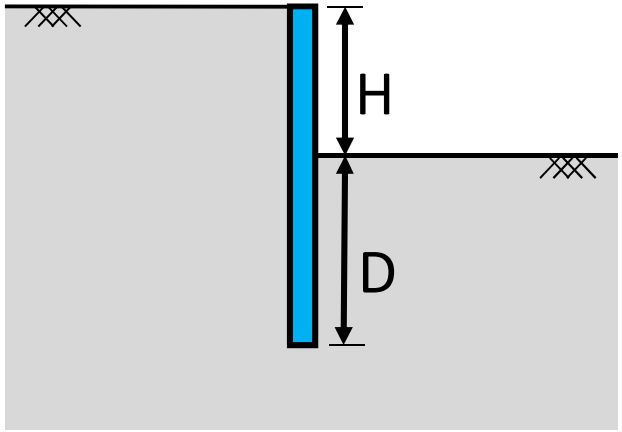
Gabion Wall

Retaining Walls

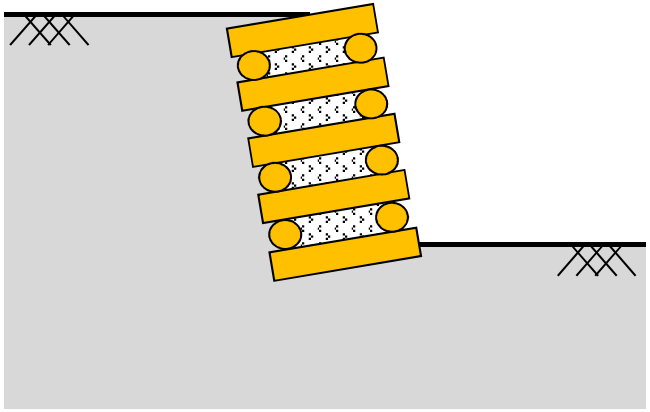
Gravity



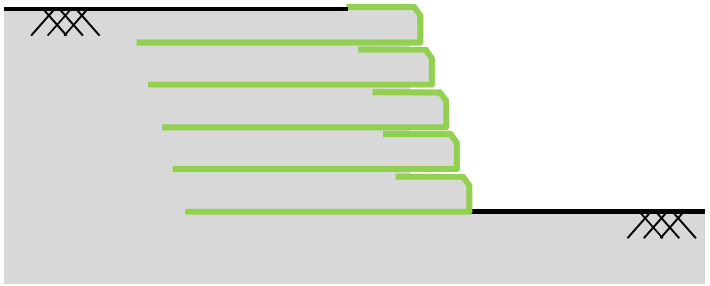
Cantilever



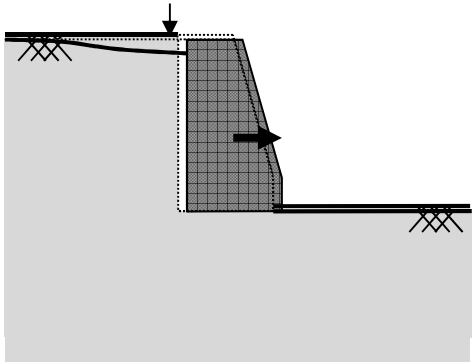
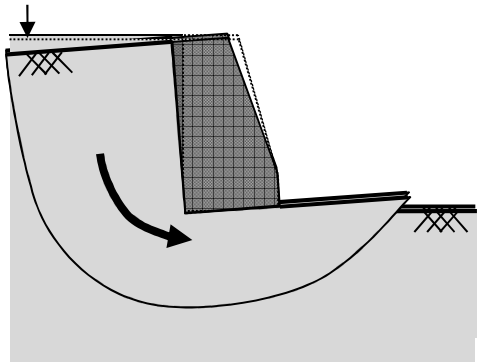
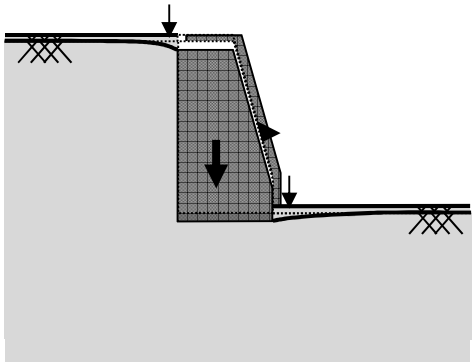
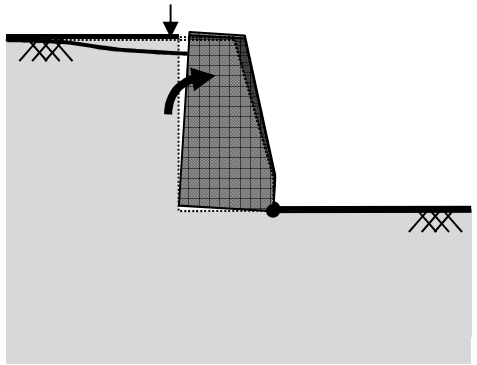
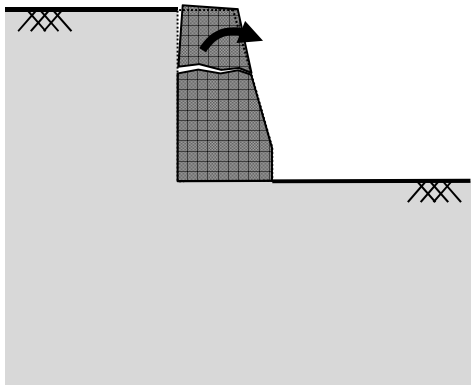
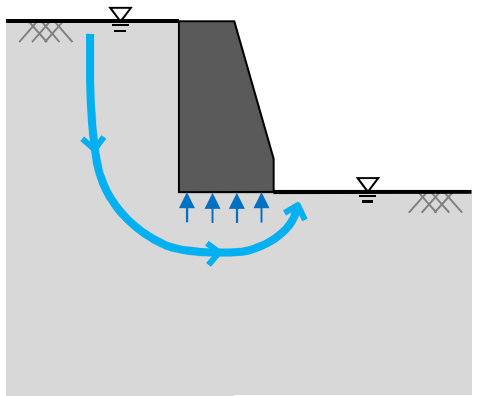
Crib



Reinforced Earth



Design Requirements

- Overall Stability
- Ground Movements
- Wall Integrity
- Water Flow

Atkinson, J. (2007) *The Mechanics of Soils and Foundations*. 2nd Ed., Spon Press. [Section 1.6]

Gravity Retaining Walls

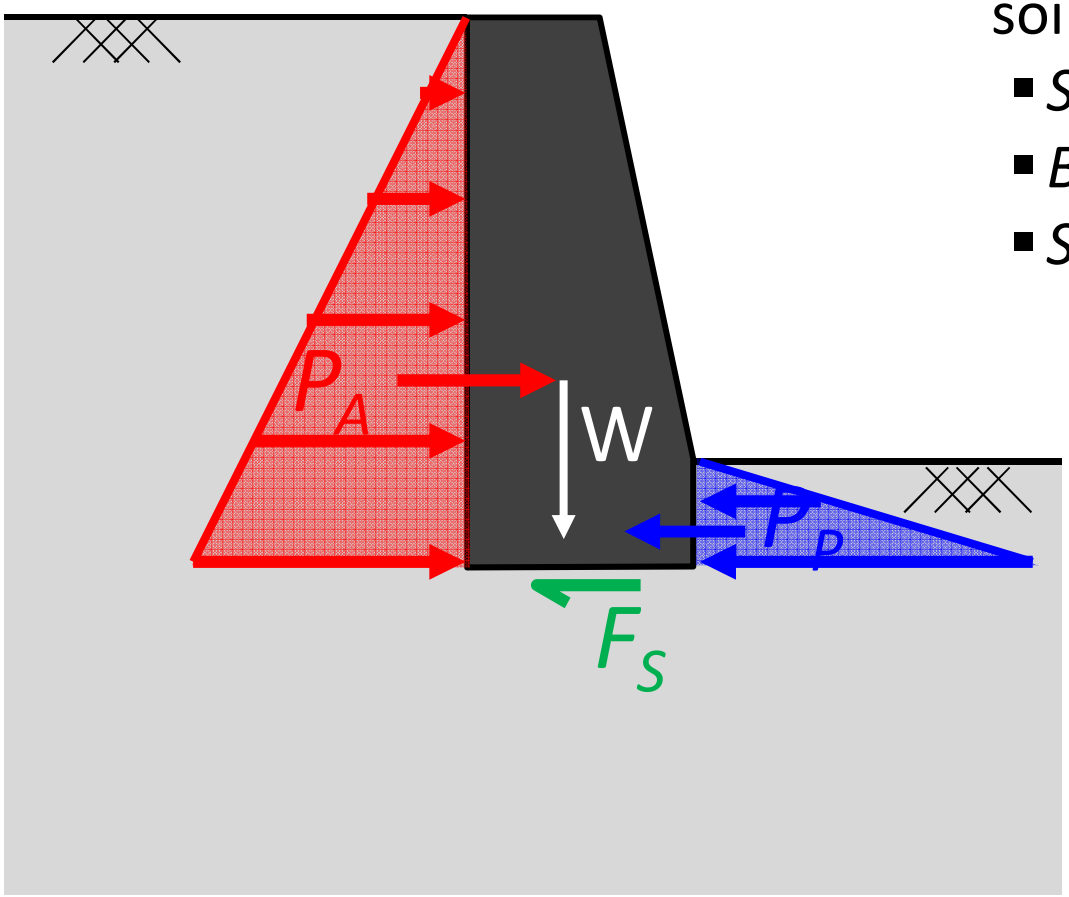
Applications

- Steeper slope that the natural soil will allow
- Vertical soil slope

Examples:

- Transport Embankments
- Landscaping

Forces

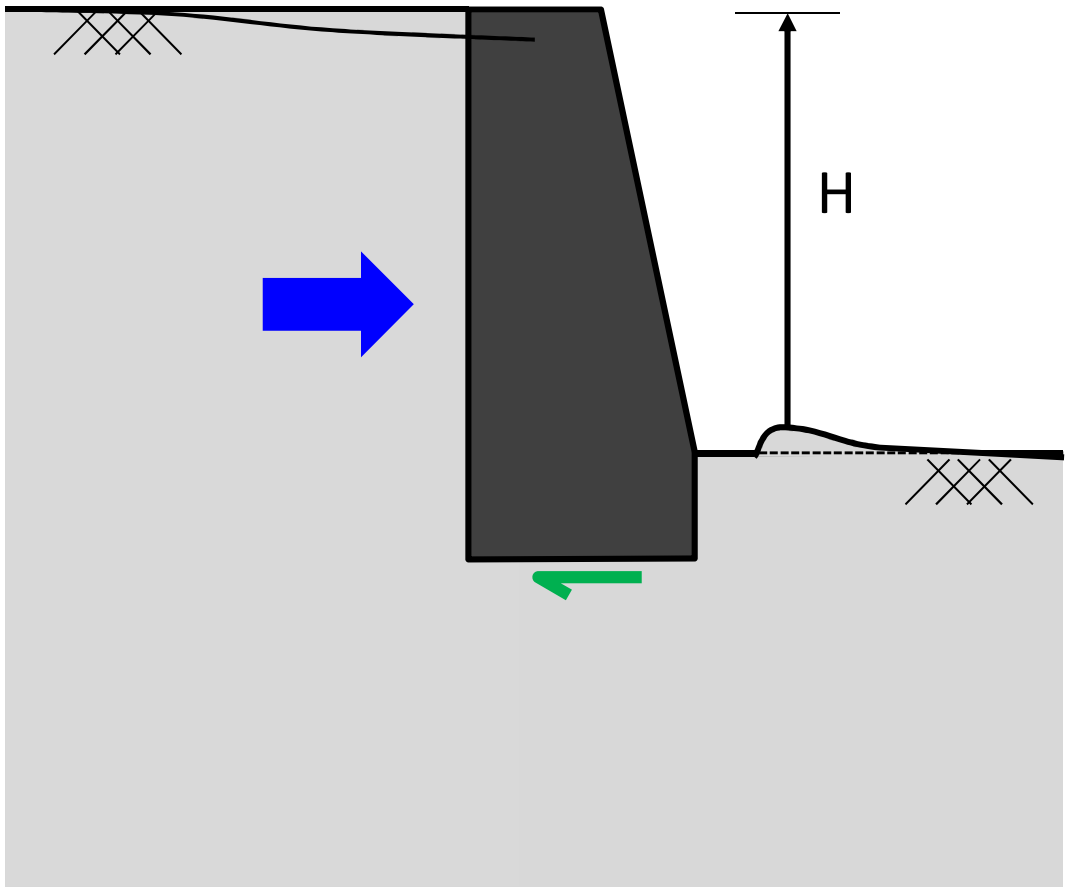


The *Active Earth Pressure* (P_A) exerted by the retained soil is resisted by…

- *Self-weight*
- *Base shear resistance*
- *Some embedment depth*

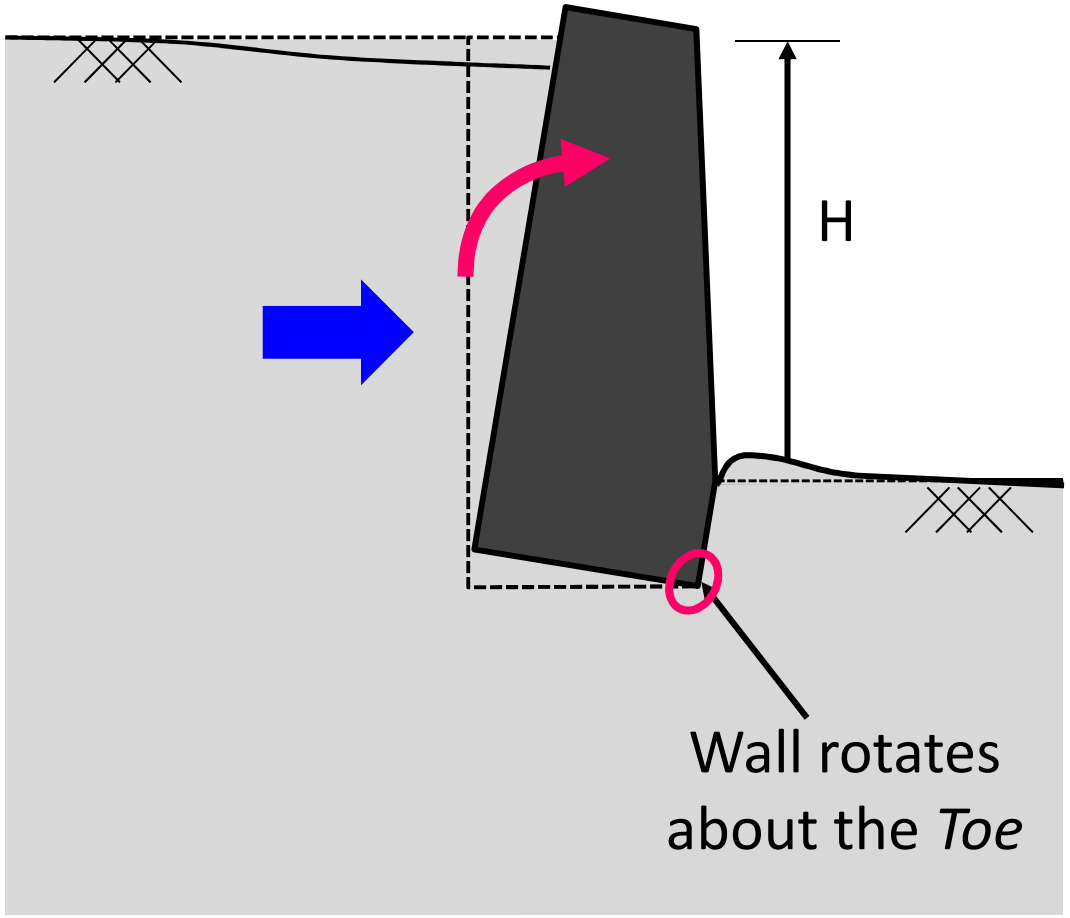
Failure Mechanisms

- Sliding



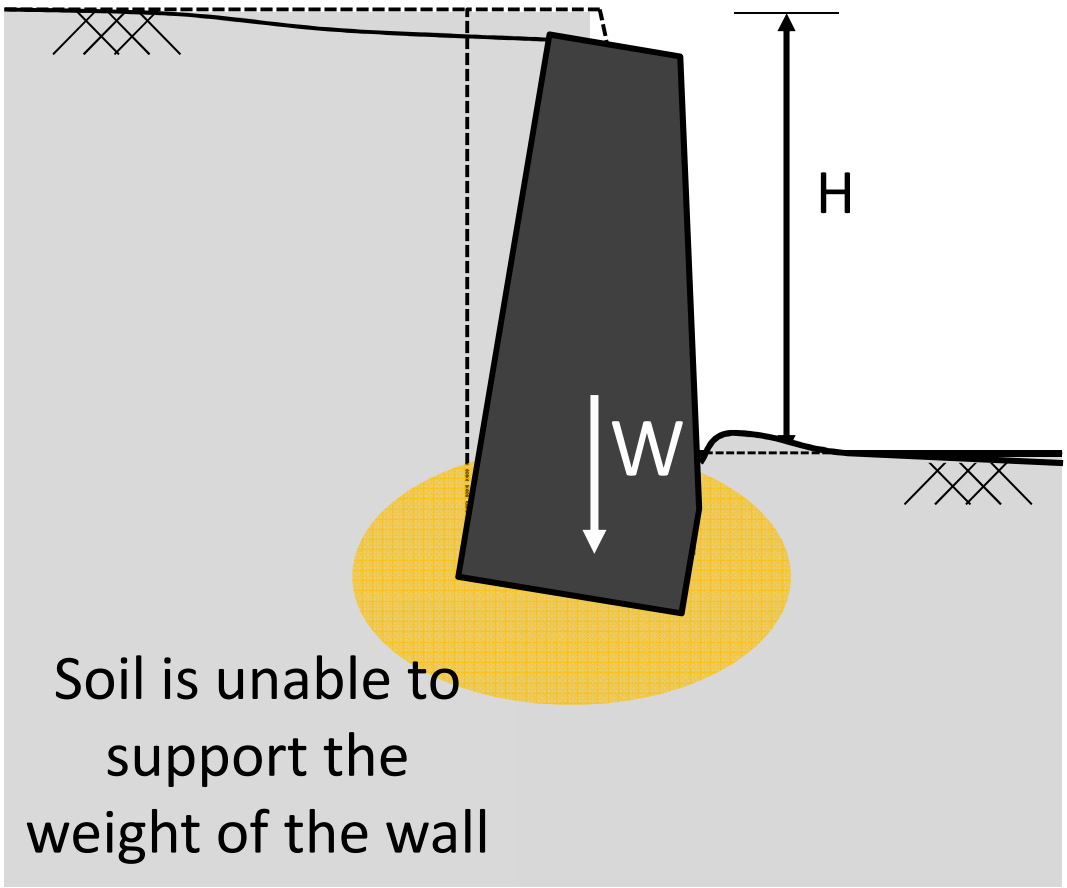
Failure Mechanisms

- Sliding
- Over-turning



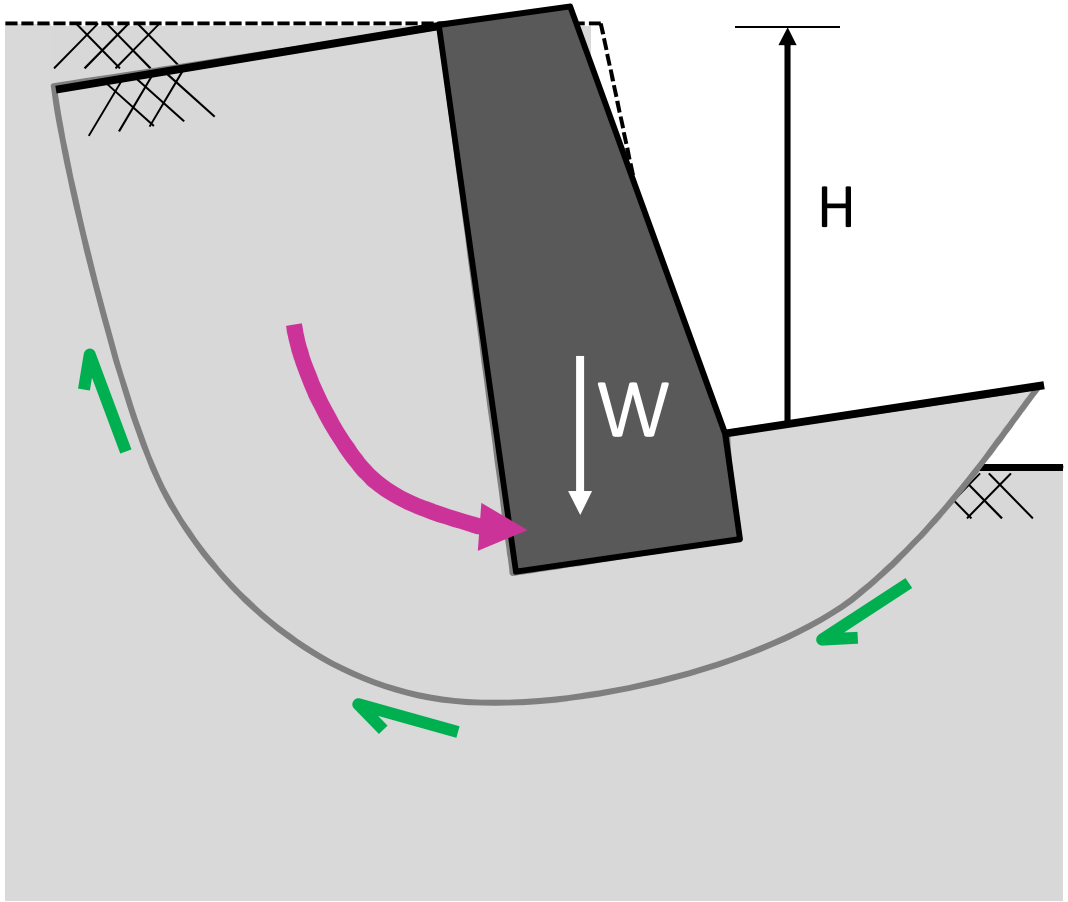
Failure Mechanisms

- Sliding
- Over-turning
- Bearing Capacity



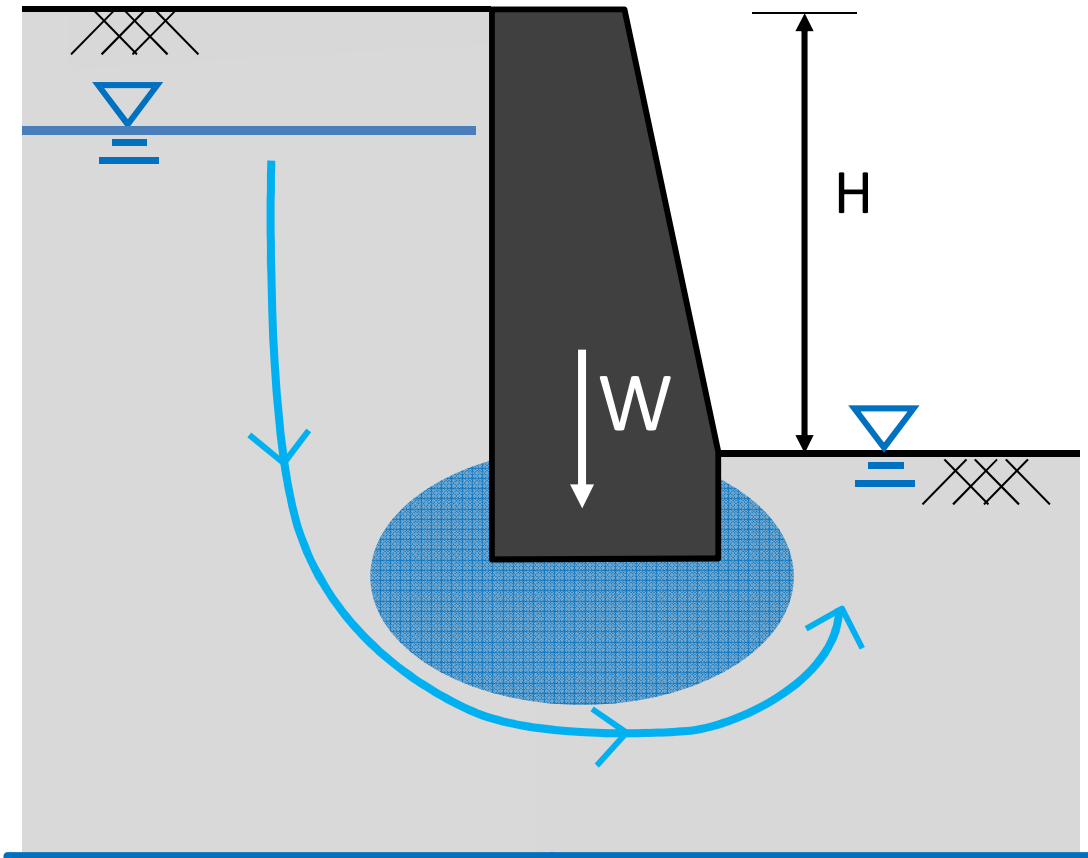
Failure Mechanisms

- Sliding
- Over-turning
- Bearing Capacity
- Overall Instability



Failure Mechanisms

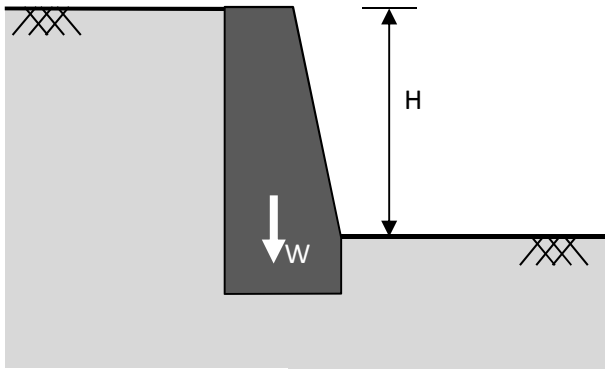
- Sliding
- Over-turning
- Bearing Capacity
- Overall Instability
- Hydraulic Failure



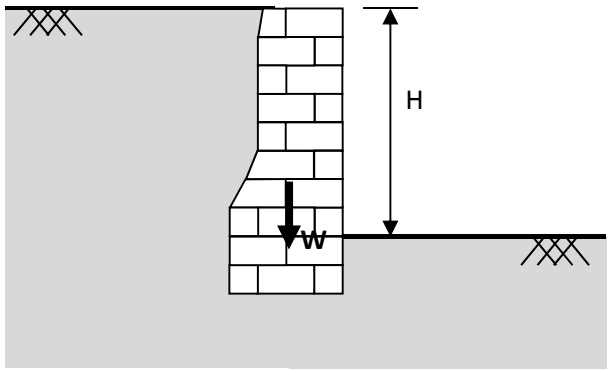
Flow around the wall can cause piping and erosion	High water pressures can reduce effective stress in the soil

Types – Gravity Retaining Walls

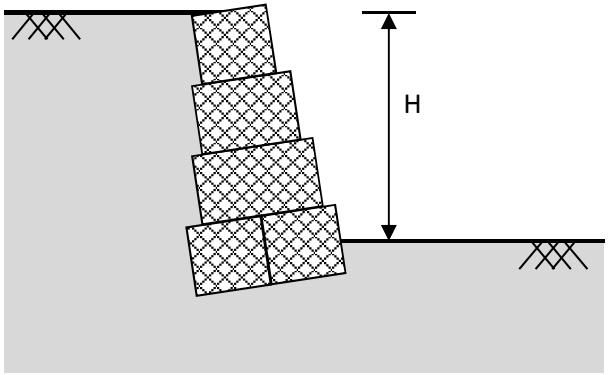
Mass Concrete



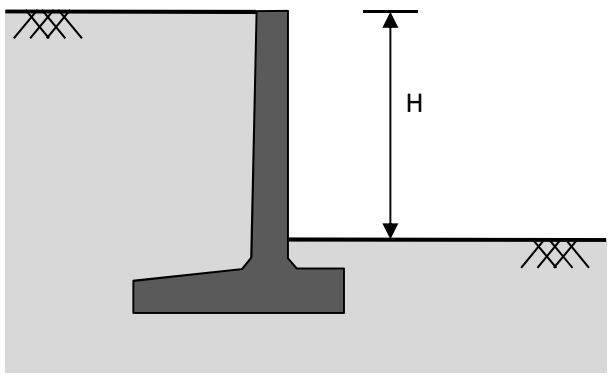
Masonry



Gabions

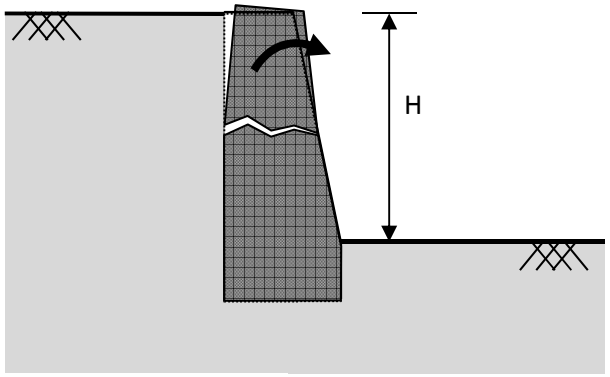


L-shaped RC

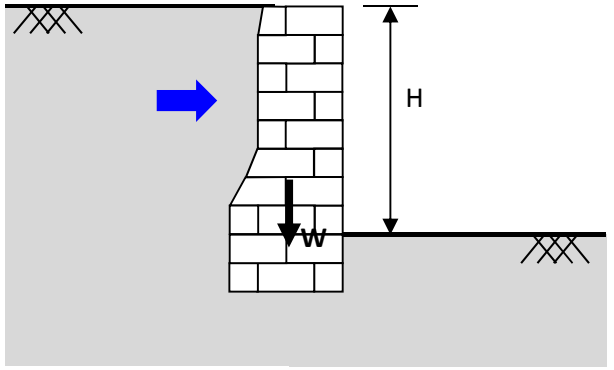


Internal Stability

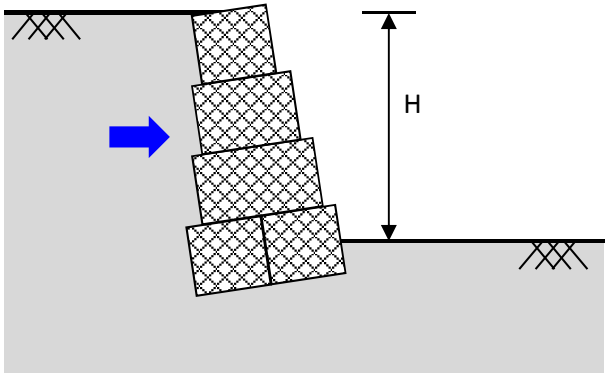
Mass Concrete



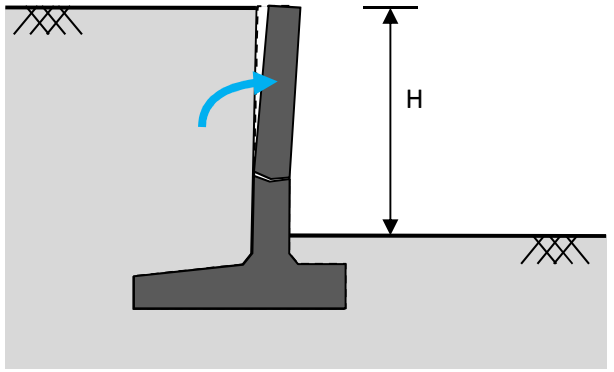
Masonry



Gabions



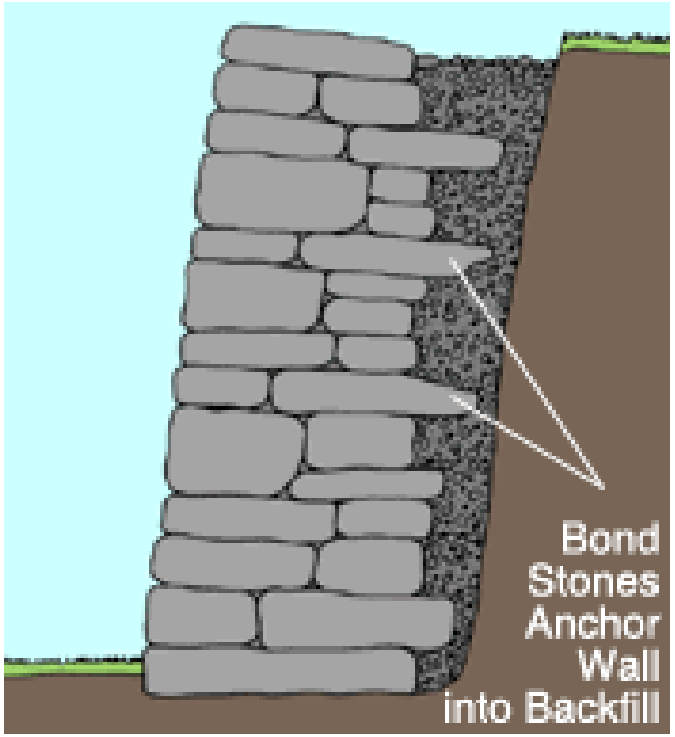
L-shaped RC



Masonry retaining walls

(Above)
http://prospectrockpermaculture.files.wordpress.com/2012/06/masonry-22.jpg

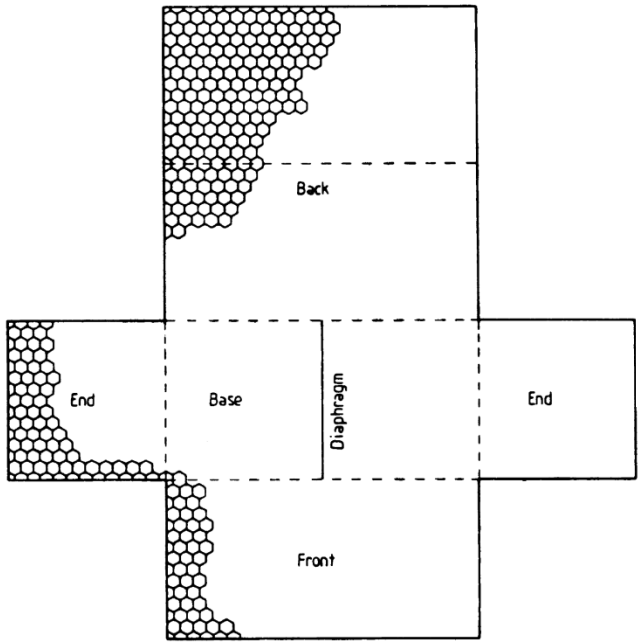
(Below)
http://hyderabadghar.com/homeneeds/mansonry10.php

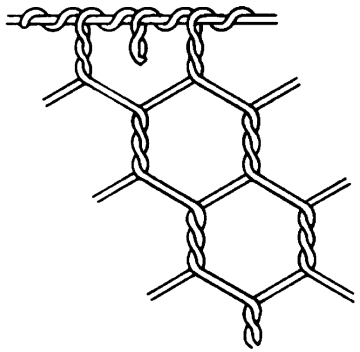


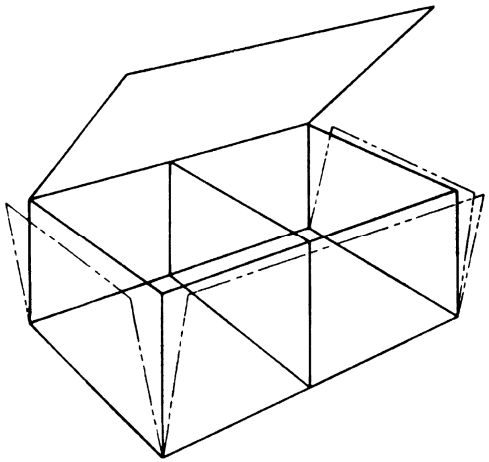
Masonry retaining walls

Pre-cast units

Gabion



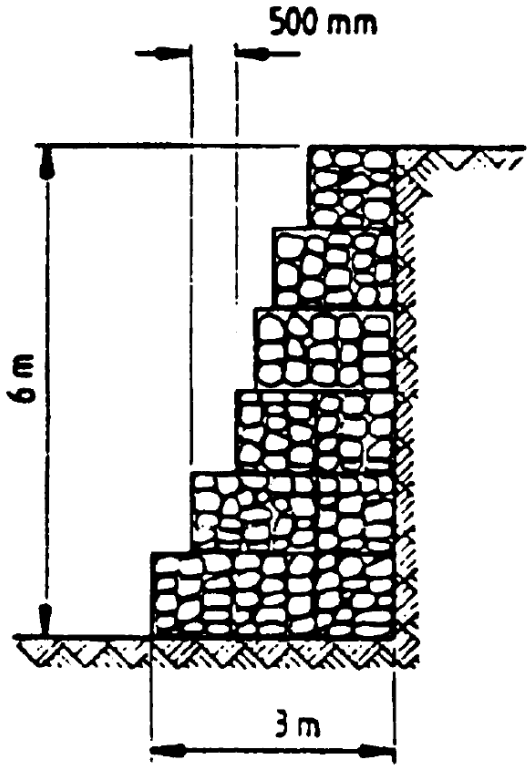




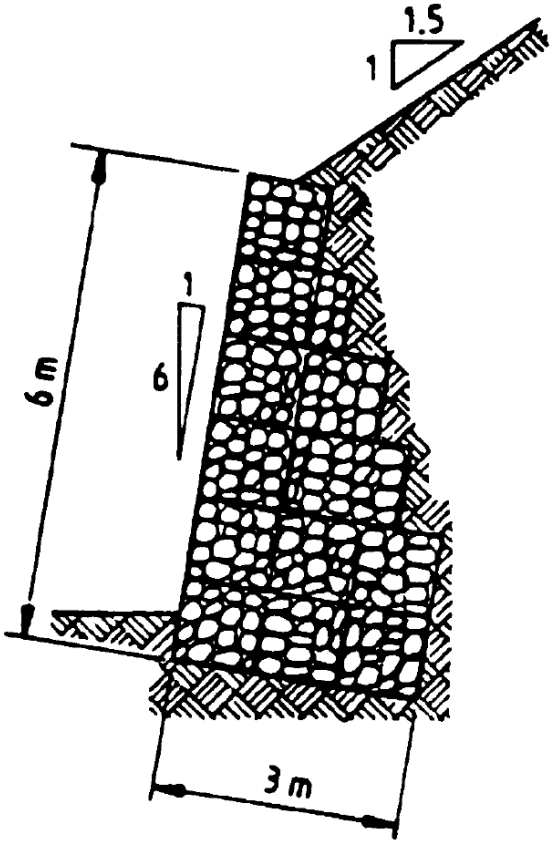
- Wire cages
- Filled with stone
- Assembled to form a gravity retaining wall

BSi (1994) BS 8002 Code of Practice for Earth retaining structures. British Standards Institution.

Gabion



Stepped Front



Stepped Back

BSi (1994) BS 8002 Code of Practice for Earth retaining structures. British Standards Institution.

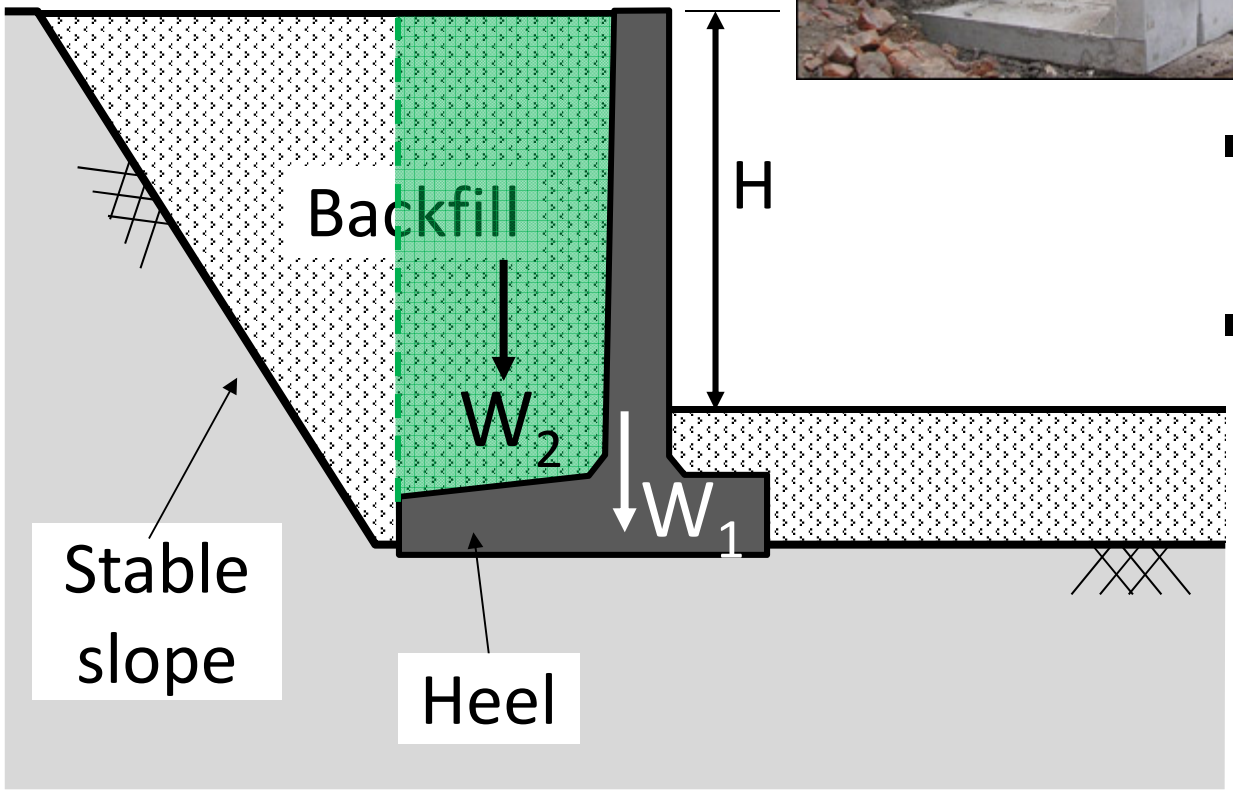
Gabion

(Above)
http://www.maccaferri.co.uk/media/om_www/uk/Images/Products/Retaining%20Structures/gabion_04.jpg

(Below)
http://www.maccaferri.co.uk/media/om_www/uk/Images/Products/Retaining%20Structures/gabion_02.jpg

L-Shaped Reinforced Concrete

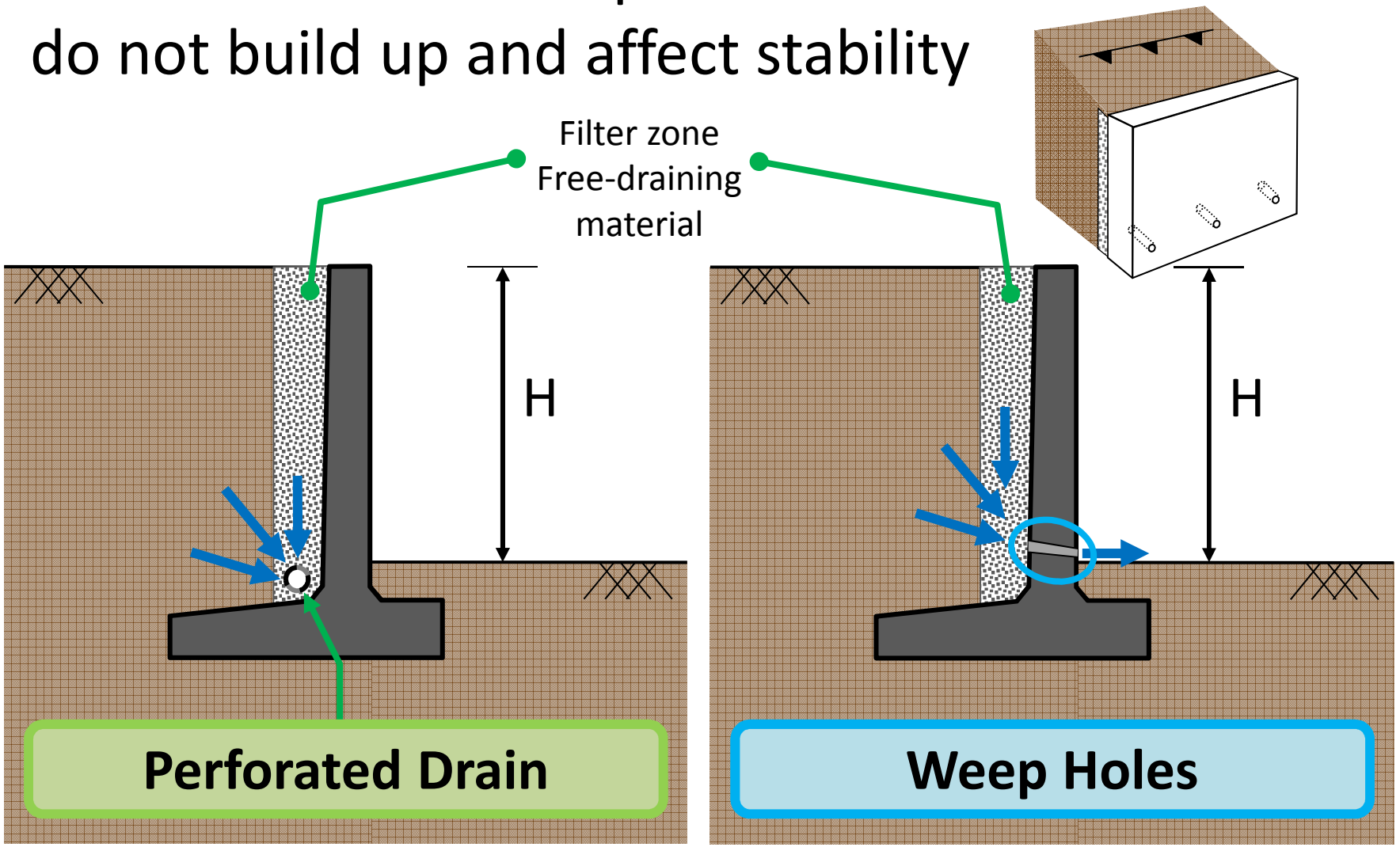
Supports Tension



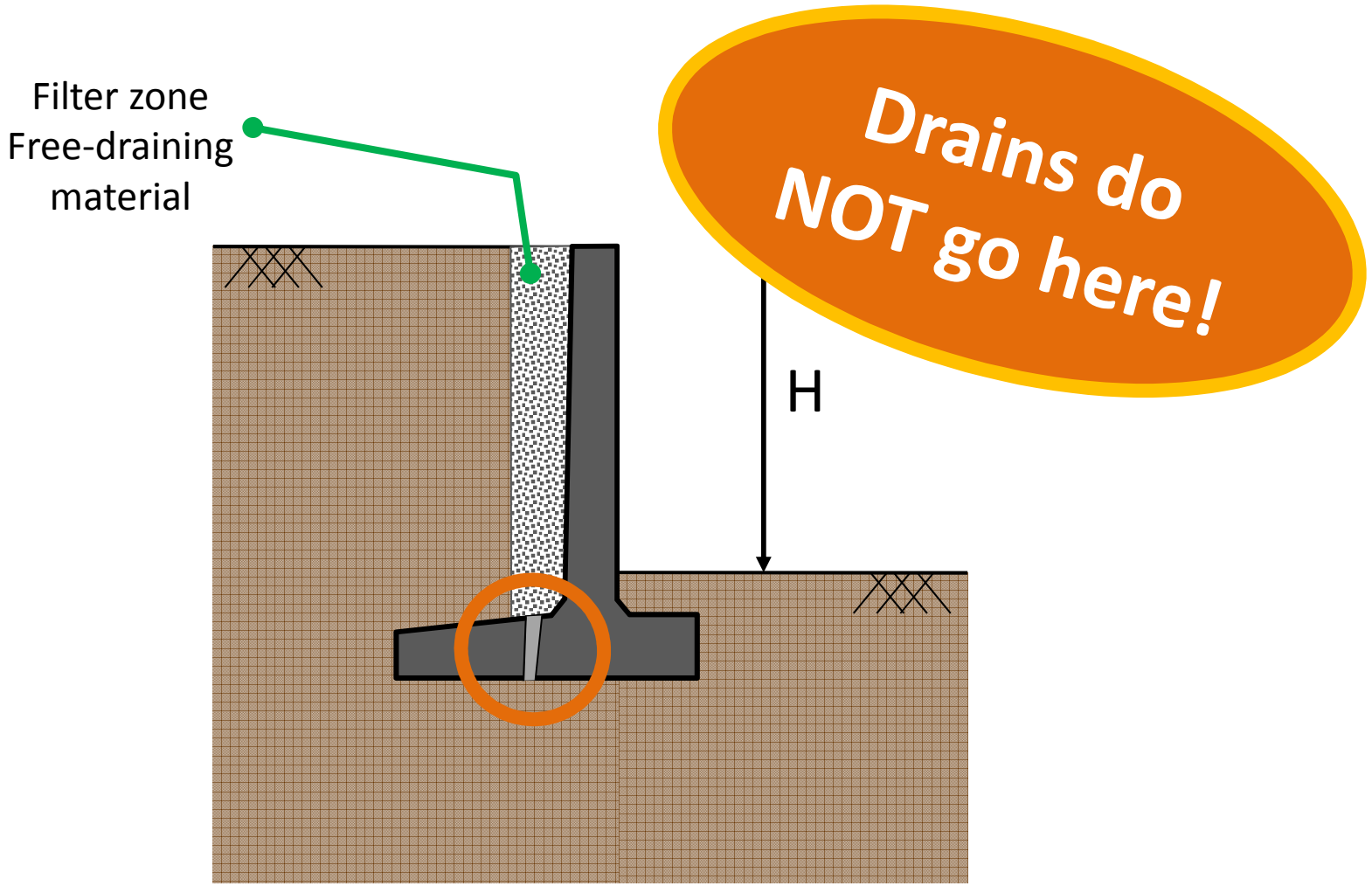
- Weight of wall
- Weight of backfill overlying the heel

Drainage

To ensure that water pressures behind the wall do not build up and affect stability



Drainage



Cantilever Retaining Walls

Applications

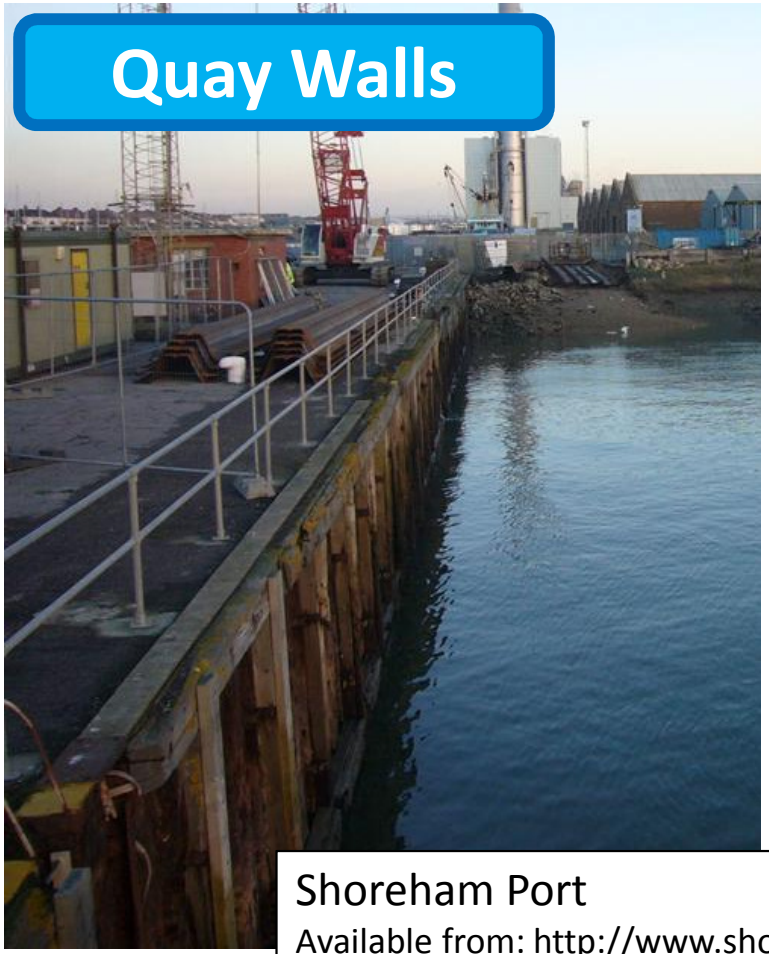
Basements

Cork City Development
Available from: http://www.triton-chemicals.co.uk/newsblog/wp-content/Halfmoon-Street-Cork-Web.jpeg

Excavations

Eastside Accommodation

Quay Walls



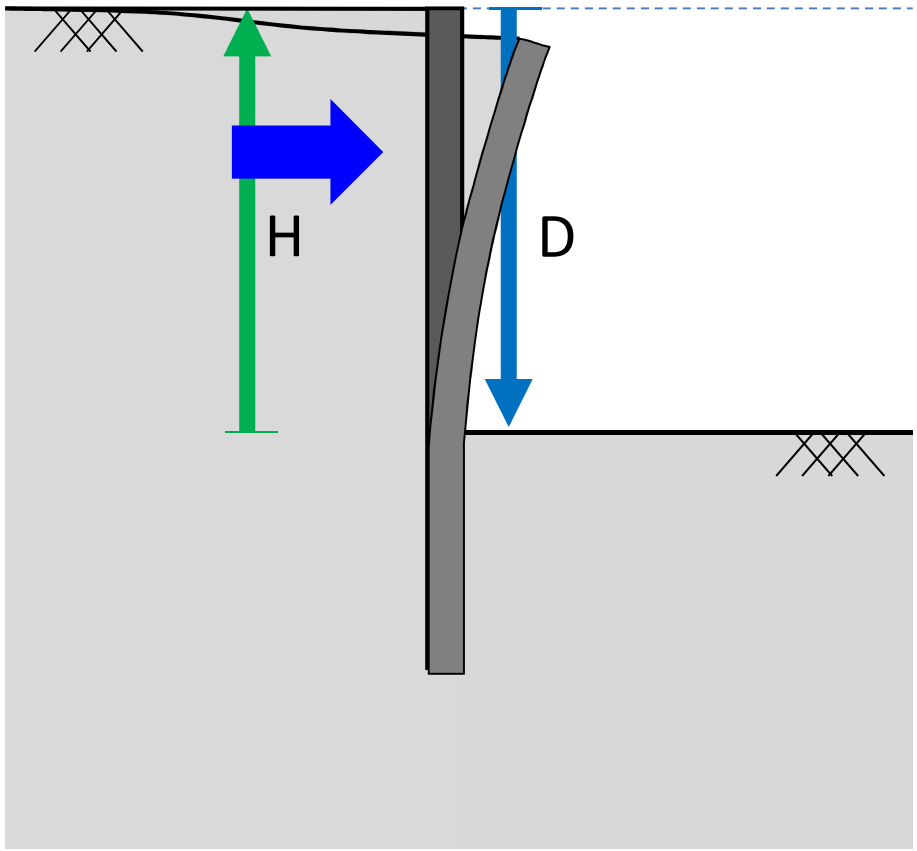
Shoreham Port
Available from: http://www.shoreham-port.co.uk/Write/Images/P1030095.JPG

Design

- Depth of excavation/Height of retained soil
- Strength and stiffness of wall
- Support
- Water-tightness

Strong/Stiff

Weak/Soft

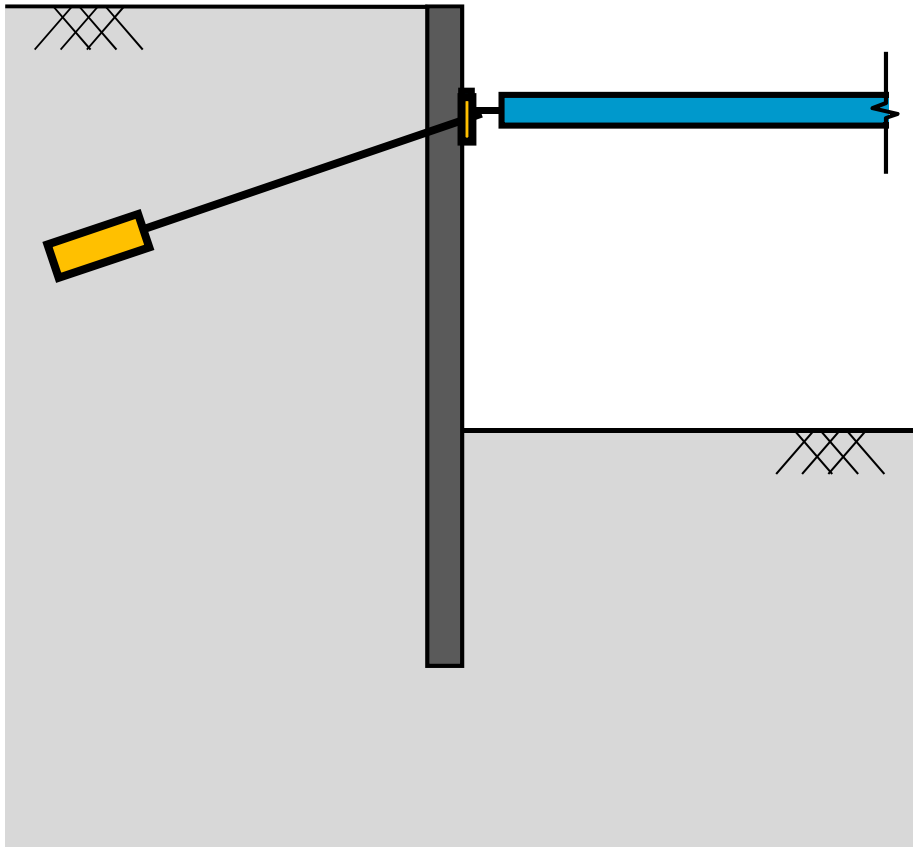


Design

- Depth of excavation/Height of retained soil
- Strength and stiffness of wall
- Support

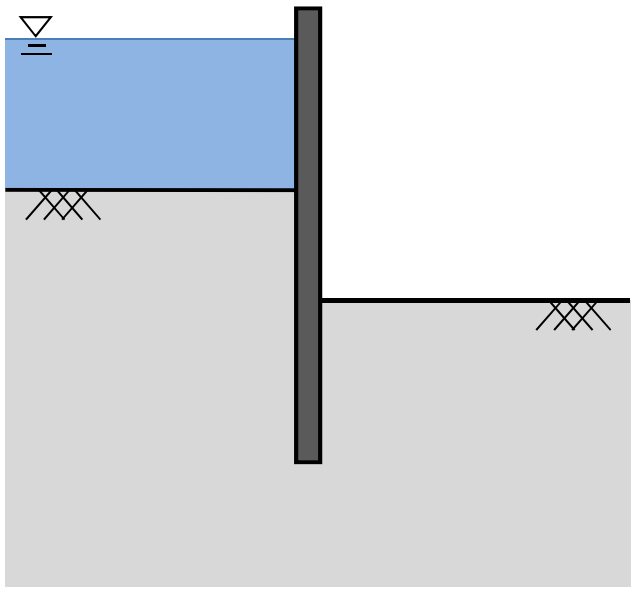
Prop/Bracing

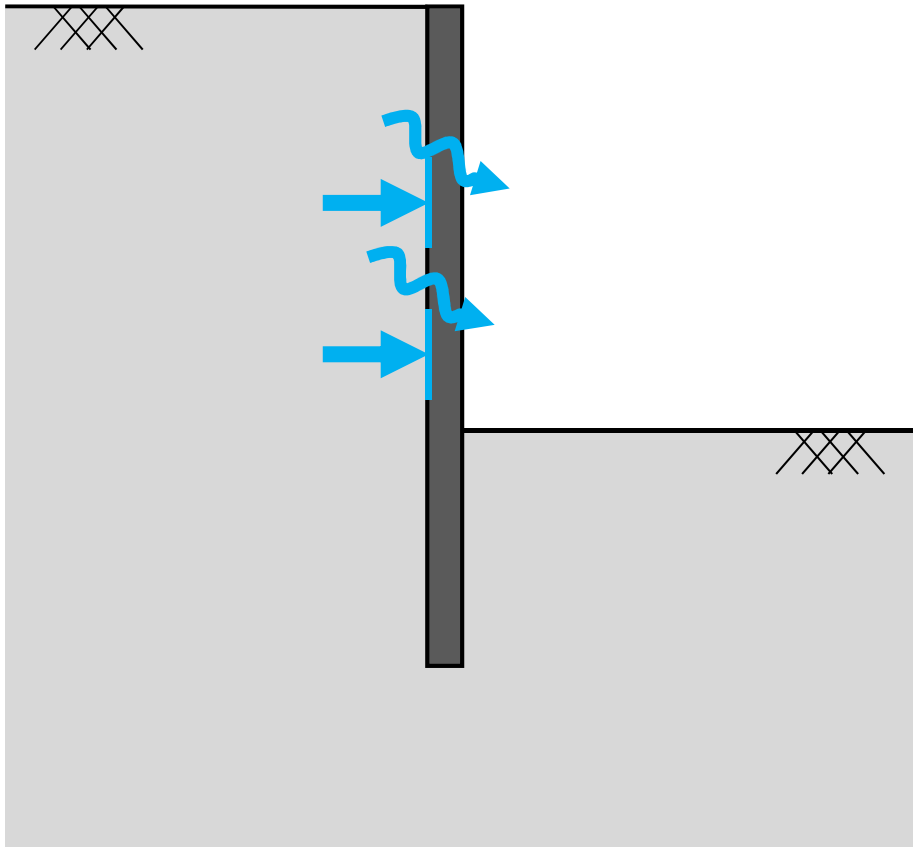
Tieback Anchor



Design

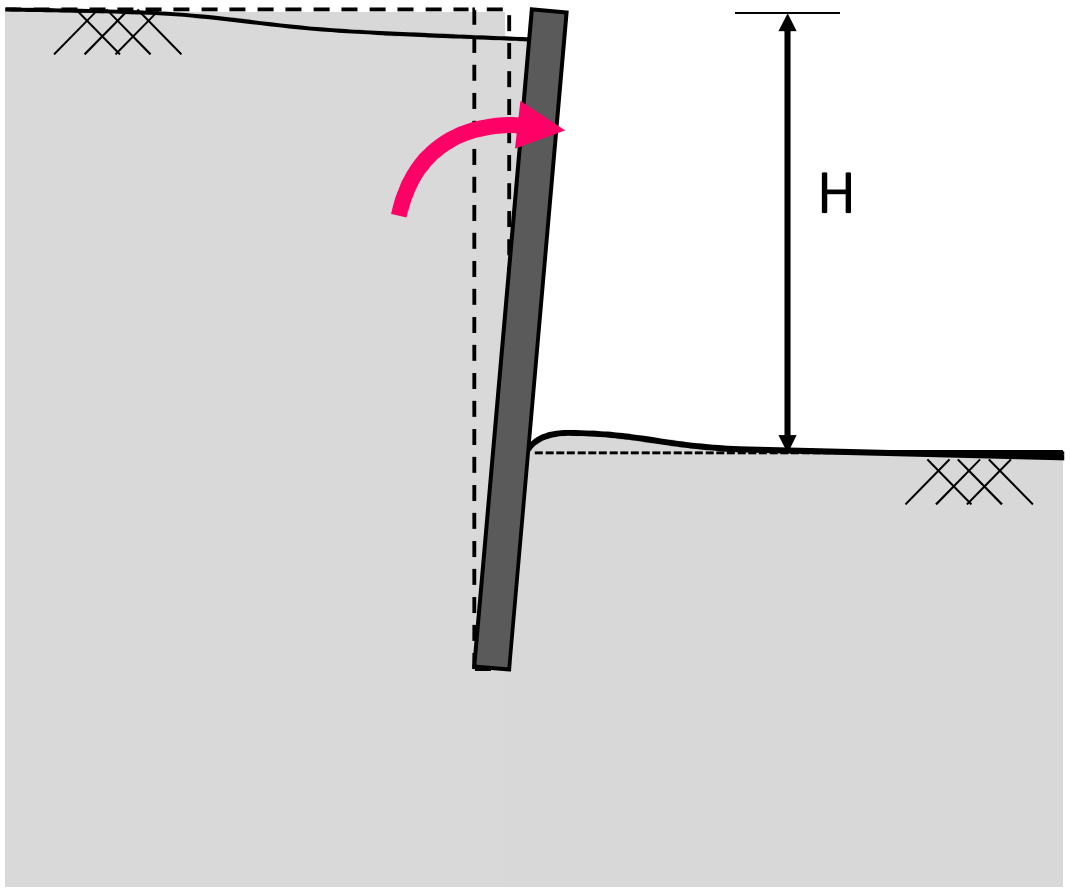
- Depth of excavation/Height of retained soil
- Strength and stiffness of wall
- Support
- Water-tightness





Failure Mechanisms

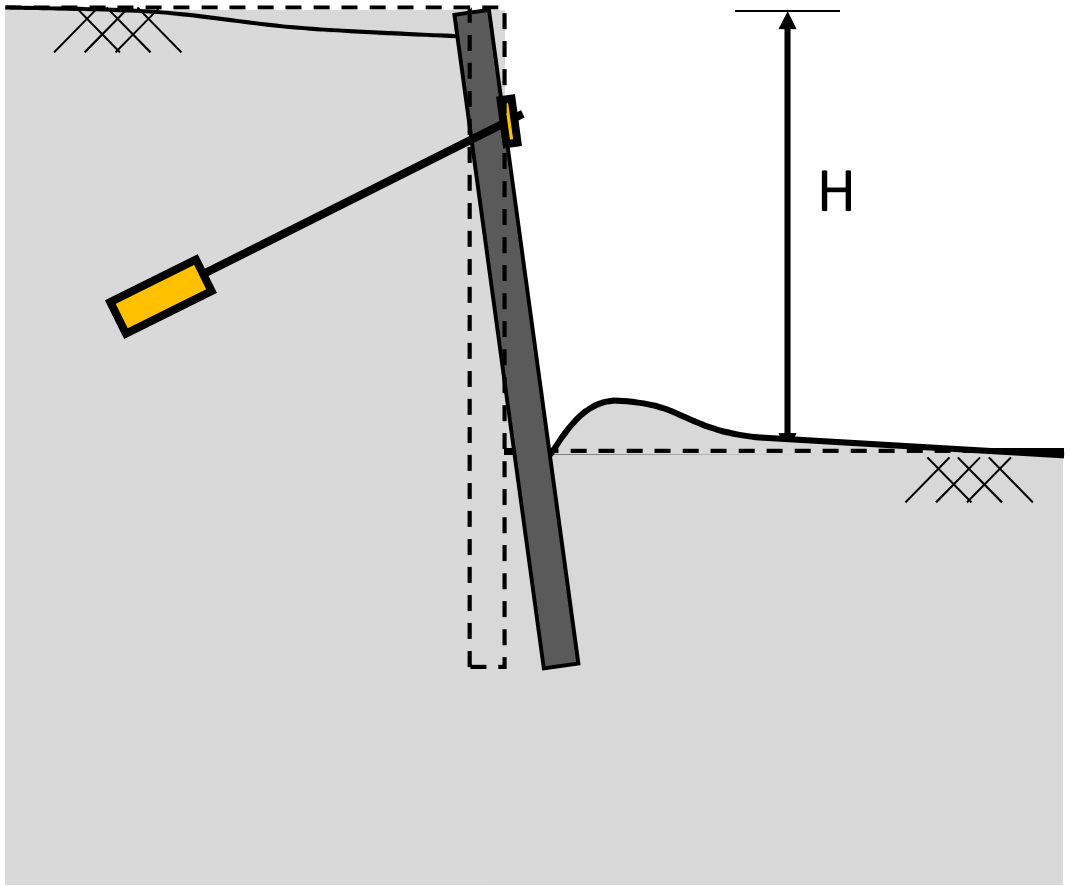
- Forward Rotation



Failure Mechanisms

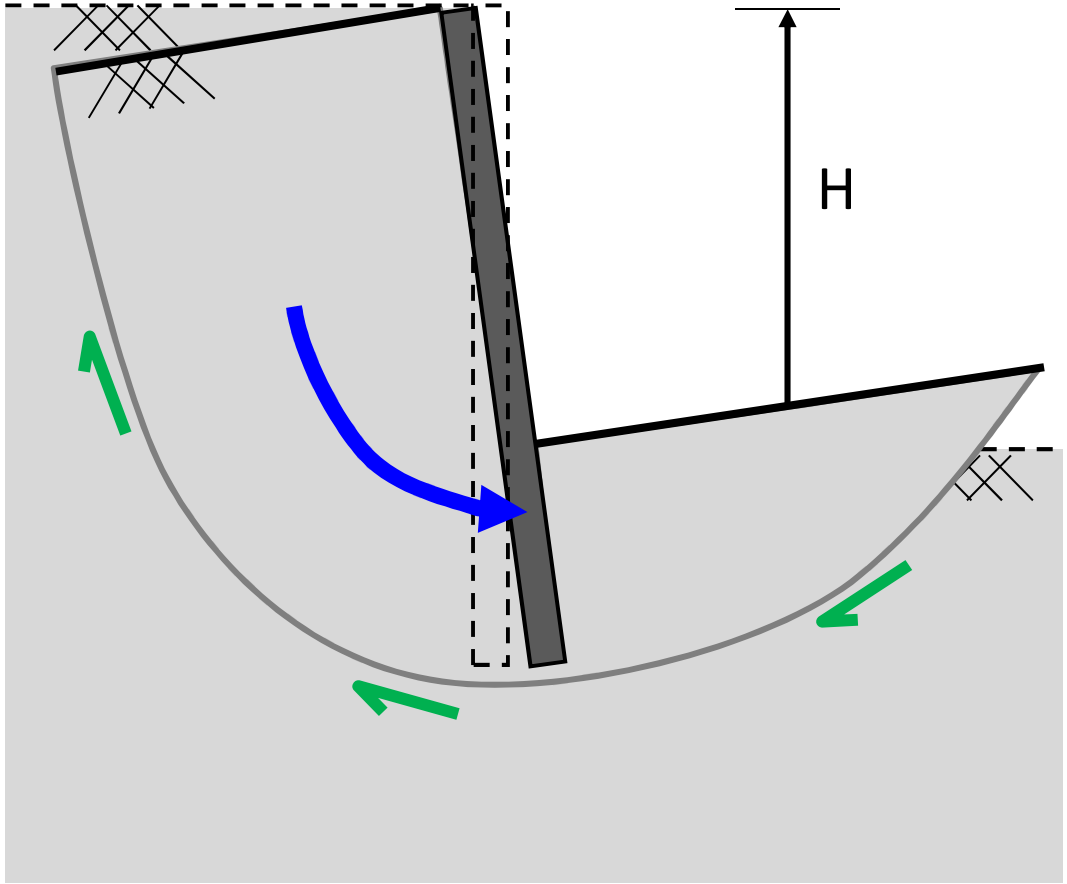
- Forward Rotation

- Failure at Top



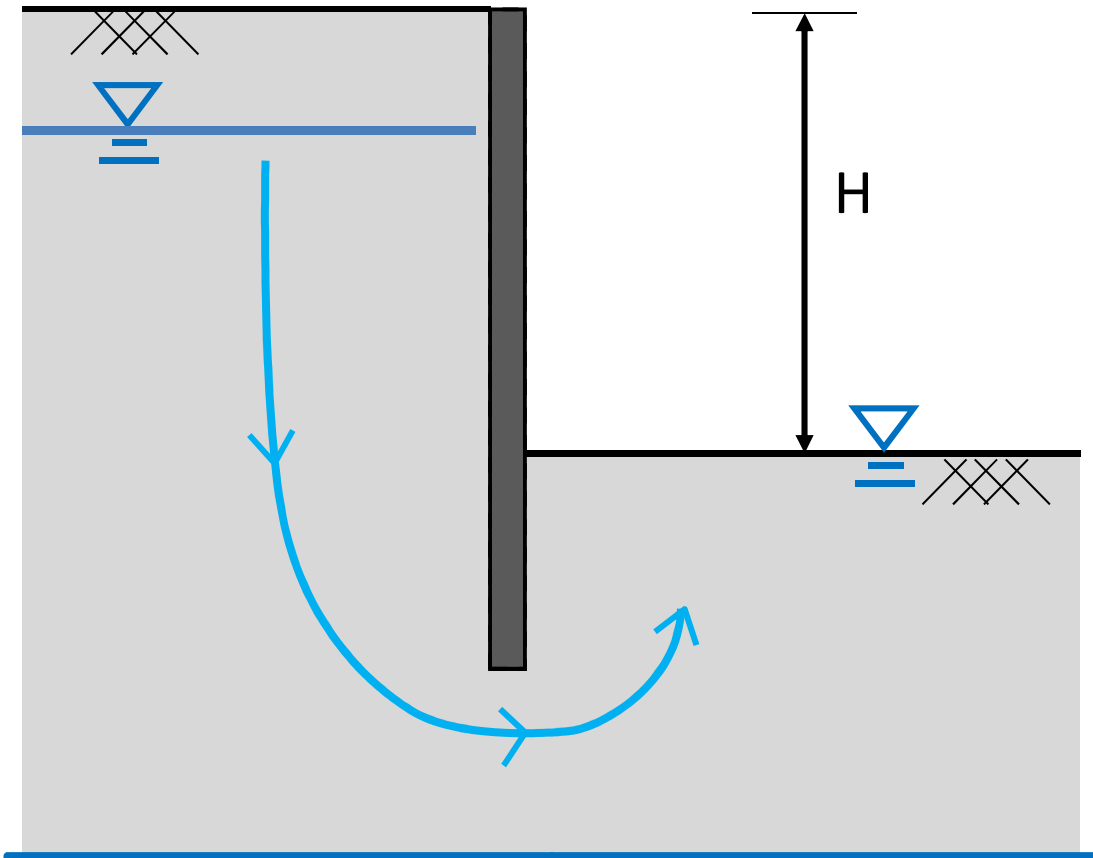
Failure Mechanisms

- Forward Rotation
- Failure at Top
- Overall Instability



Failure Mechanisms

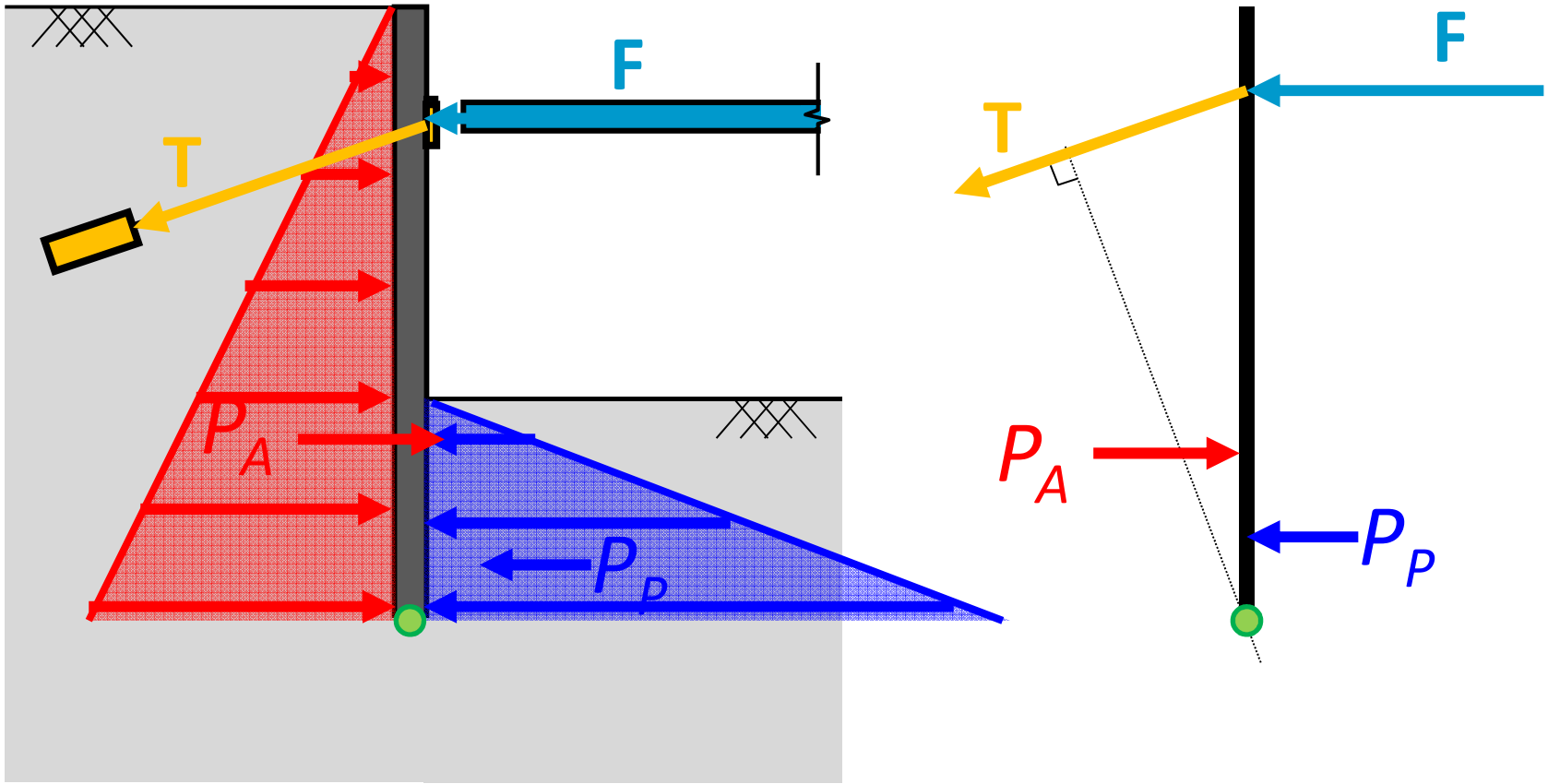
- Forward Rotation
- Failure at Top
- Overall Instability
- Piping Erosion



Flow around the wall can cause piping and erosion	High water pressures can reduce effective stress in the soil

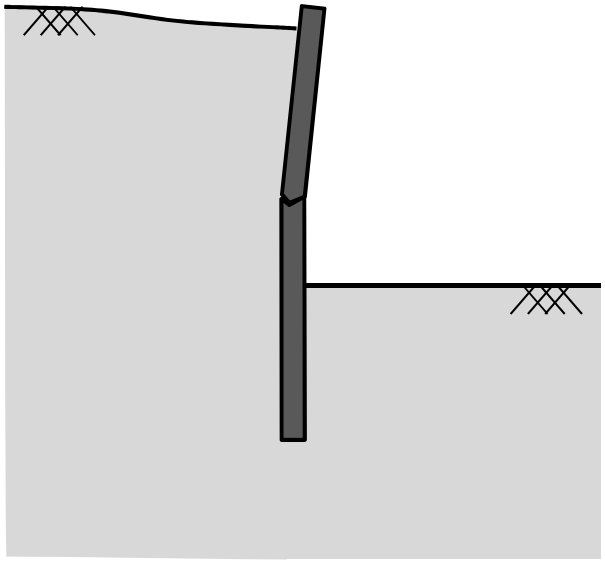
How do they work?

Taking moments about the toe of the wall

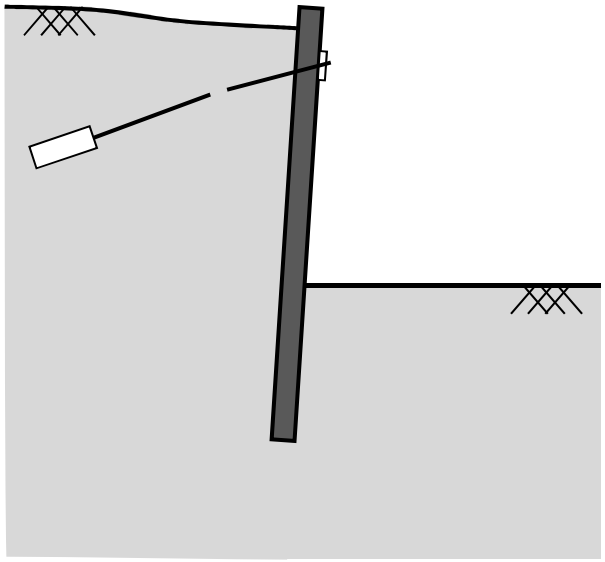


Structural Failure

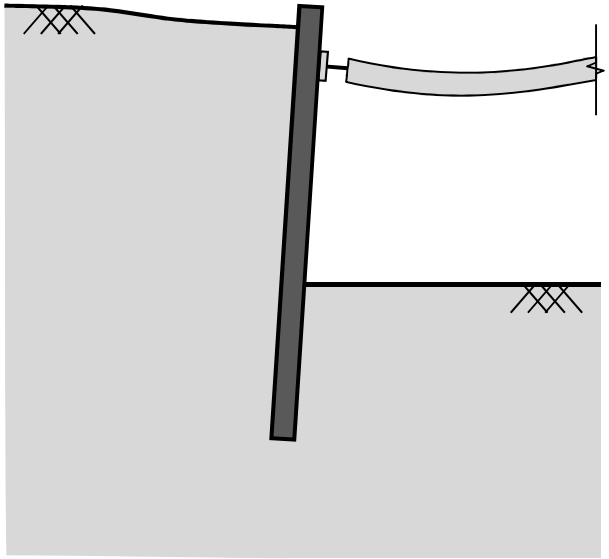
Wall Failure



Anchor failure

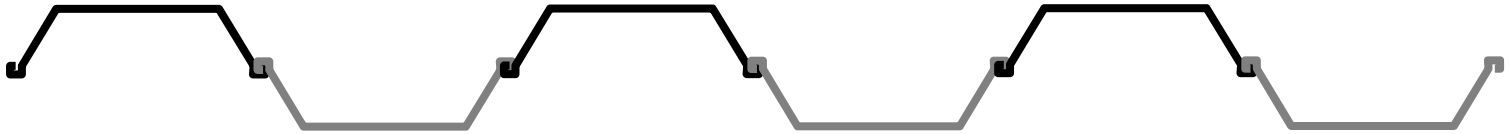


Prop Failure

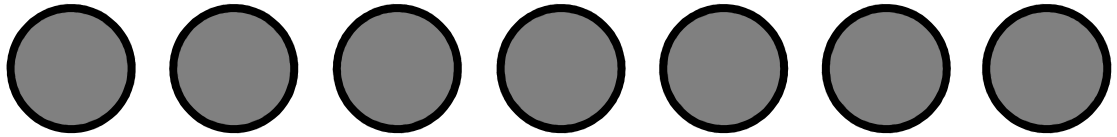


Types – Cantilever Retaining Walls

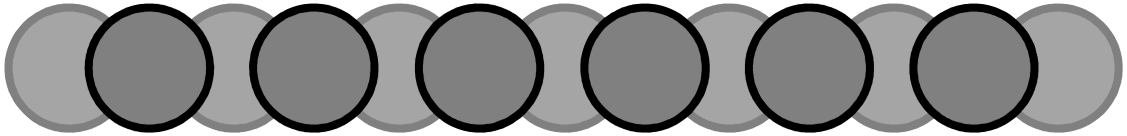
Sheet Pile



Contiguous Piles

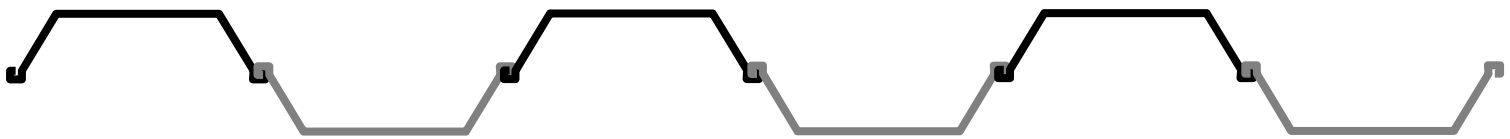


Secant Piles



Diaphragm

Sheet Pile Walls

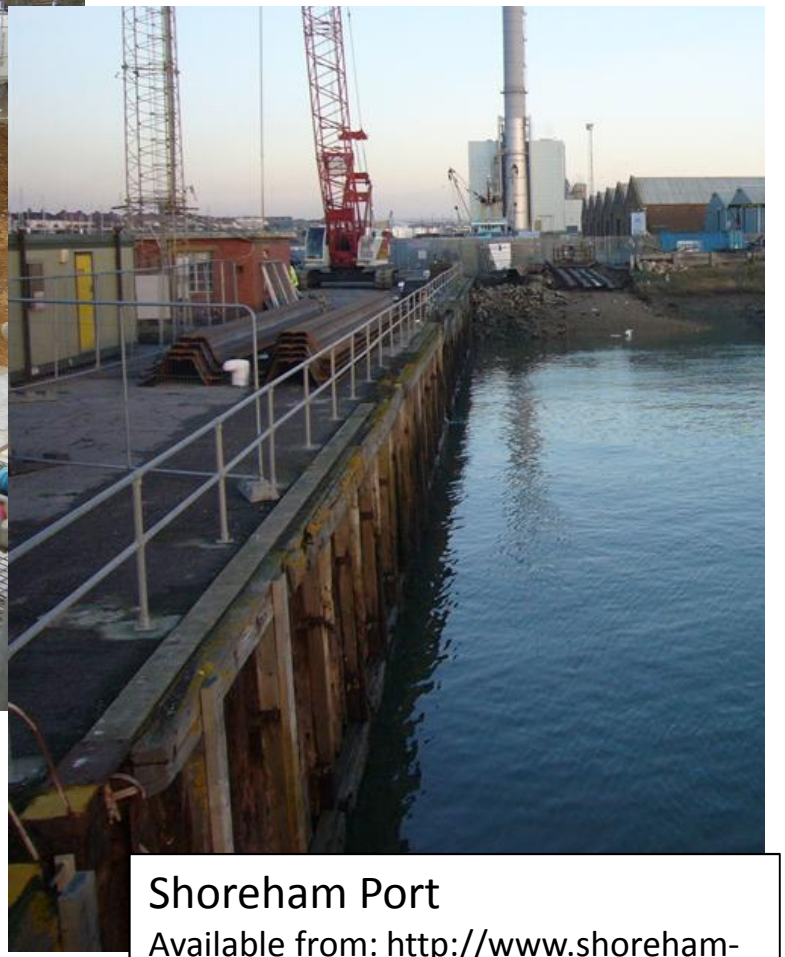


Sheet Pile Walls

Excavations

Eastside Accommodation

Quay Walls



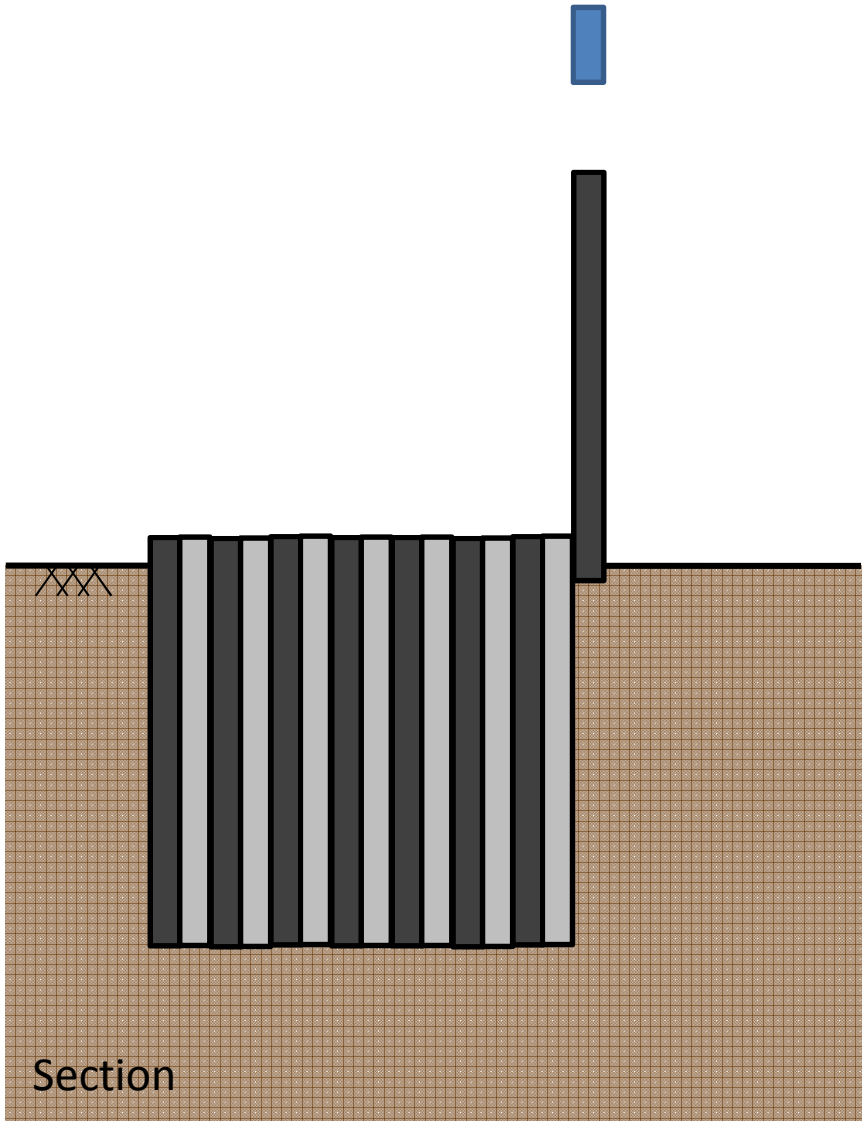
Shoreham Port
Available from: http://www.shoreham-port.co.uk/Write/Images/P1030095.JPG

Sheet Pile Walls

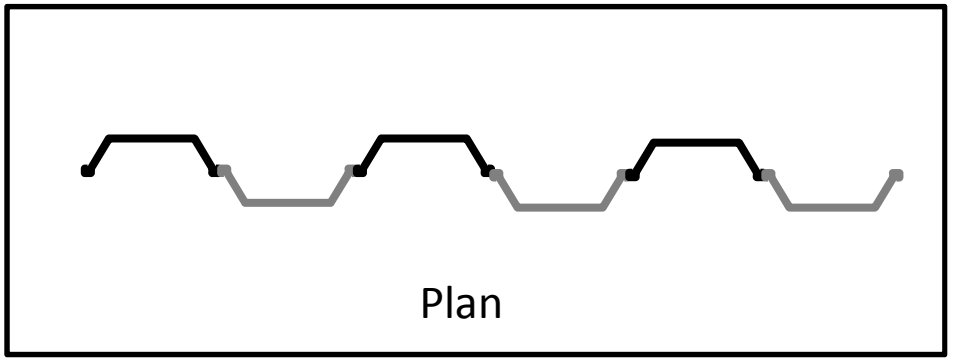
Eastside Accommodation

- Interlocking steel sections
- Water-tight
- Can be Driven into most soils

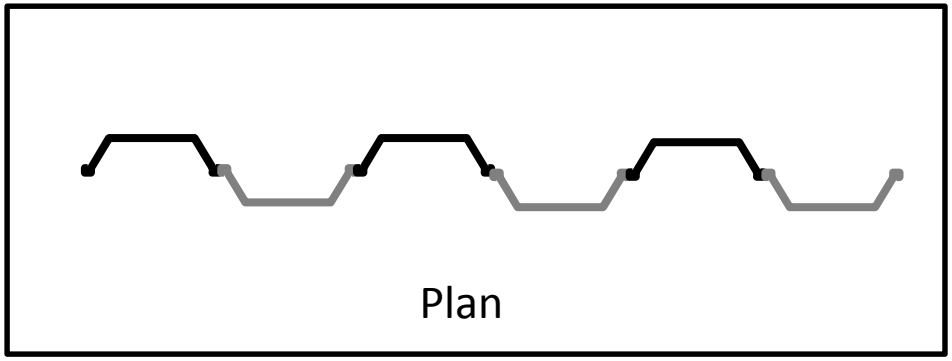
Installation

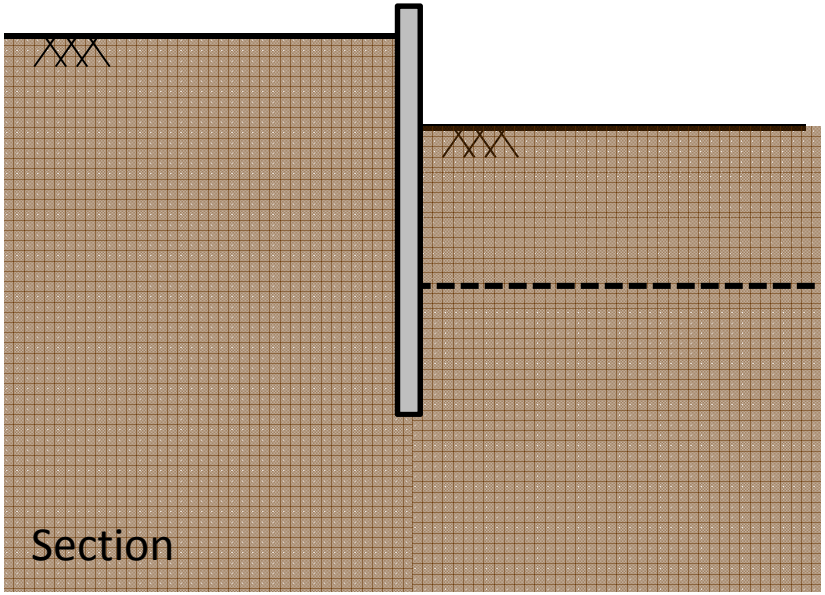


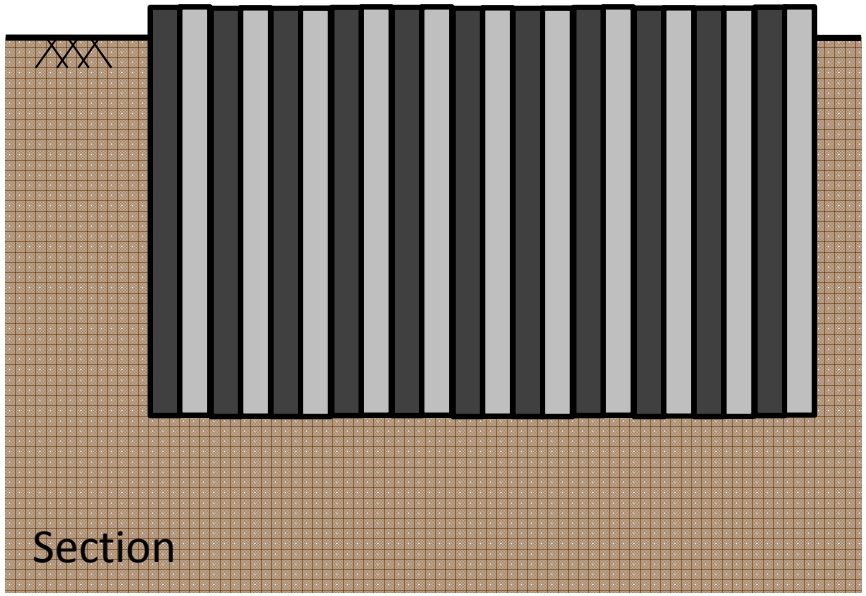
Available from: http://www.evanspiling.co.uk



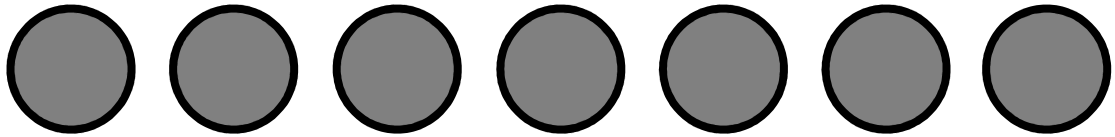
Installation







Contiguous Pile Walls



Contiguous Piled Walls

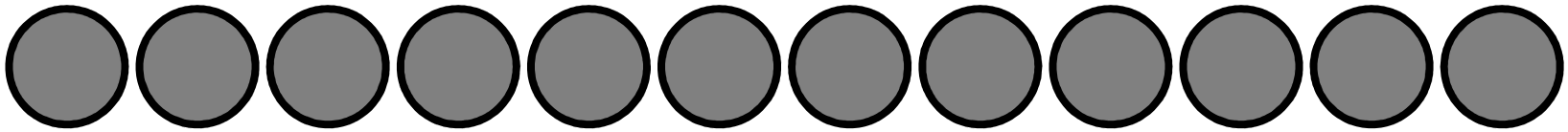
Available from:
http://www.amplusltd.com/upldimages/Contiguous%20piled%20wall%20-%20Genesis%20IMG_0030.jpg

Excavations

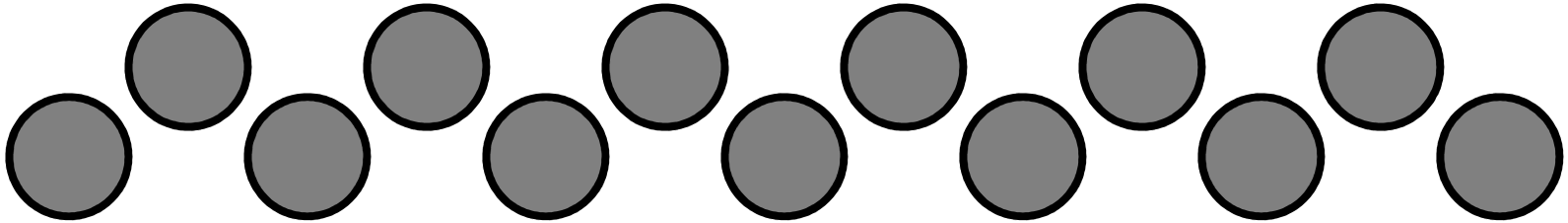
- Construct in Dry and Stable soil
- Consists of a line of bored piles
- Can be single or double rowed
- **NOT** water-tight!

Construction Sequence

Plan



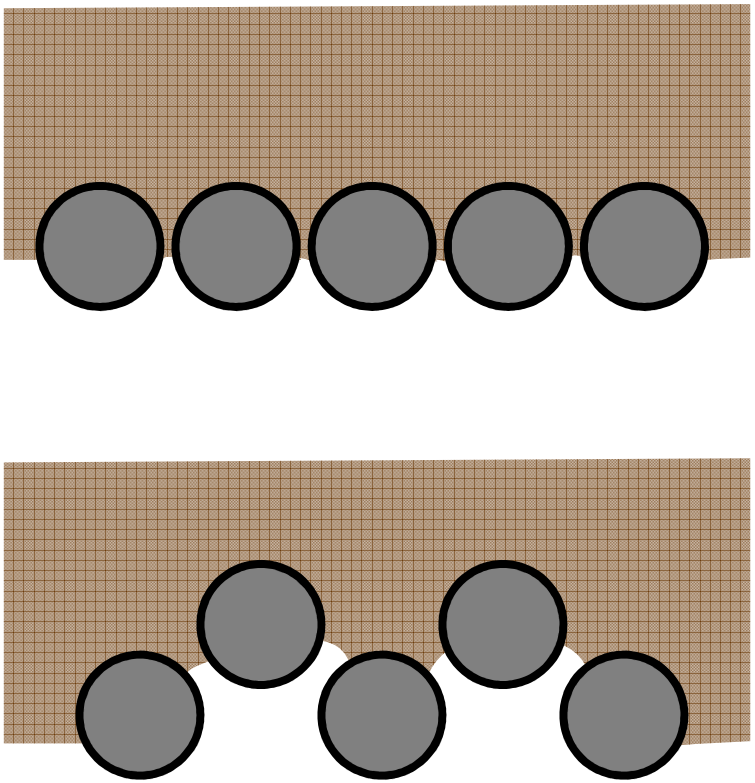
Single rowed



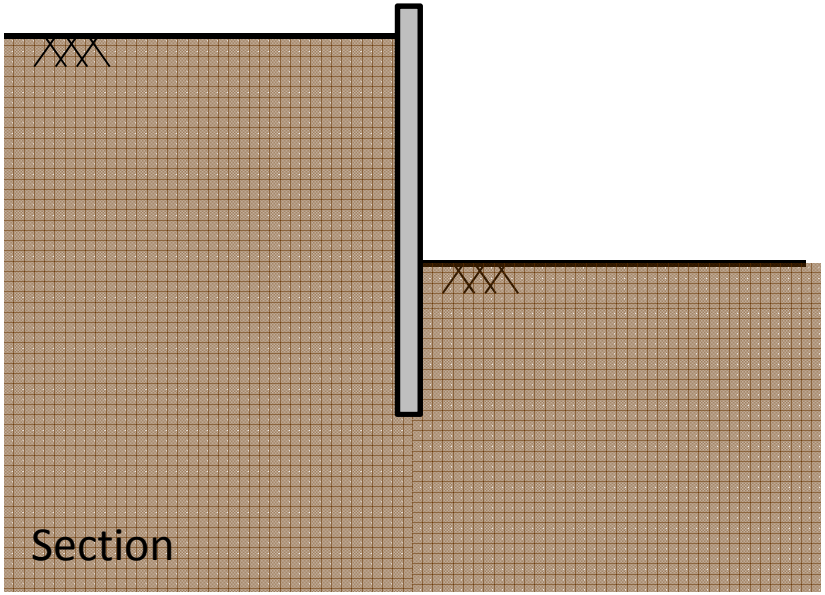
Double rowed

Construction Sequence

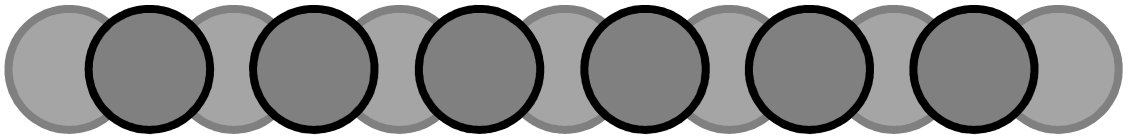
Plan



Section



Secant Pile Walls



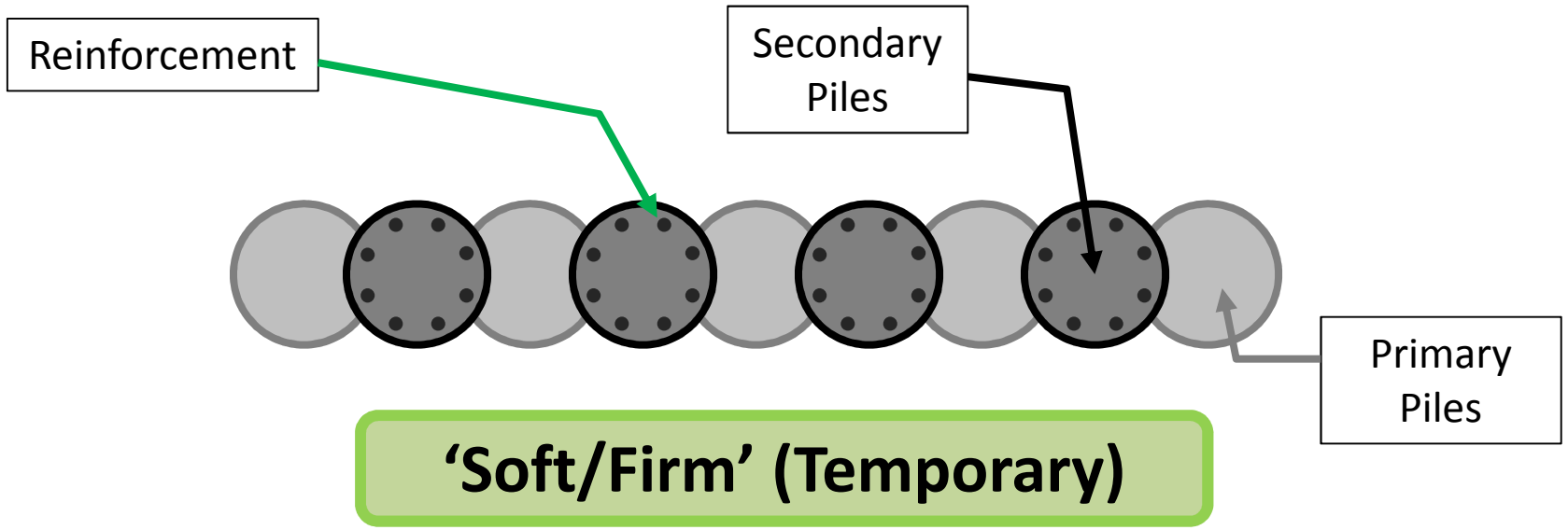
Secant Piled Walls

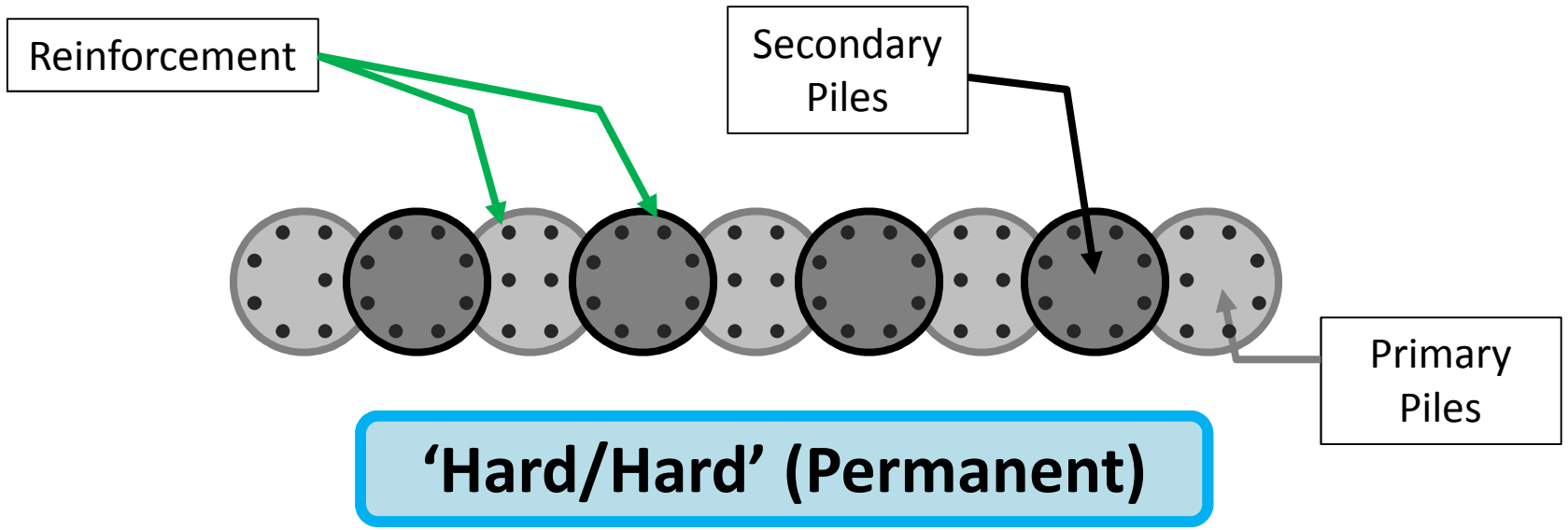
Available from:
http://www.amplusltd.com/upldimages/ISecant%20piled%20wal%20-%20Battricks%20-MG_0042.jpg

- Can be used as permanent or temporary works
- Consists of line of interlocking piles

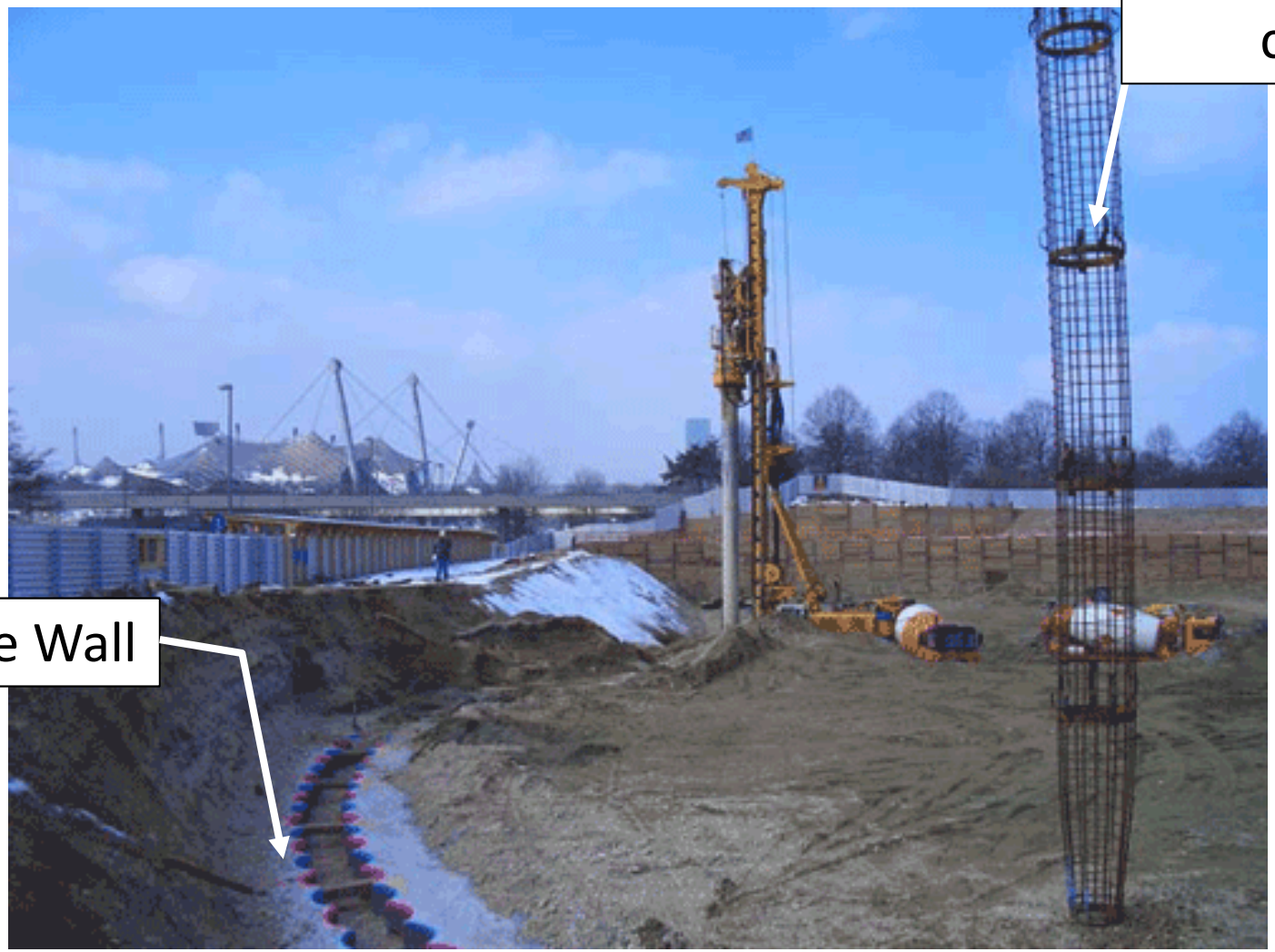
  [Primary piles are secanted (cut-in-to) by the secondary piles]
- Water-tight and no soil movement into excavation

Construction Sequence

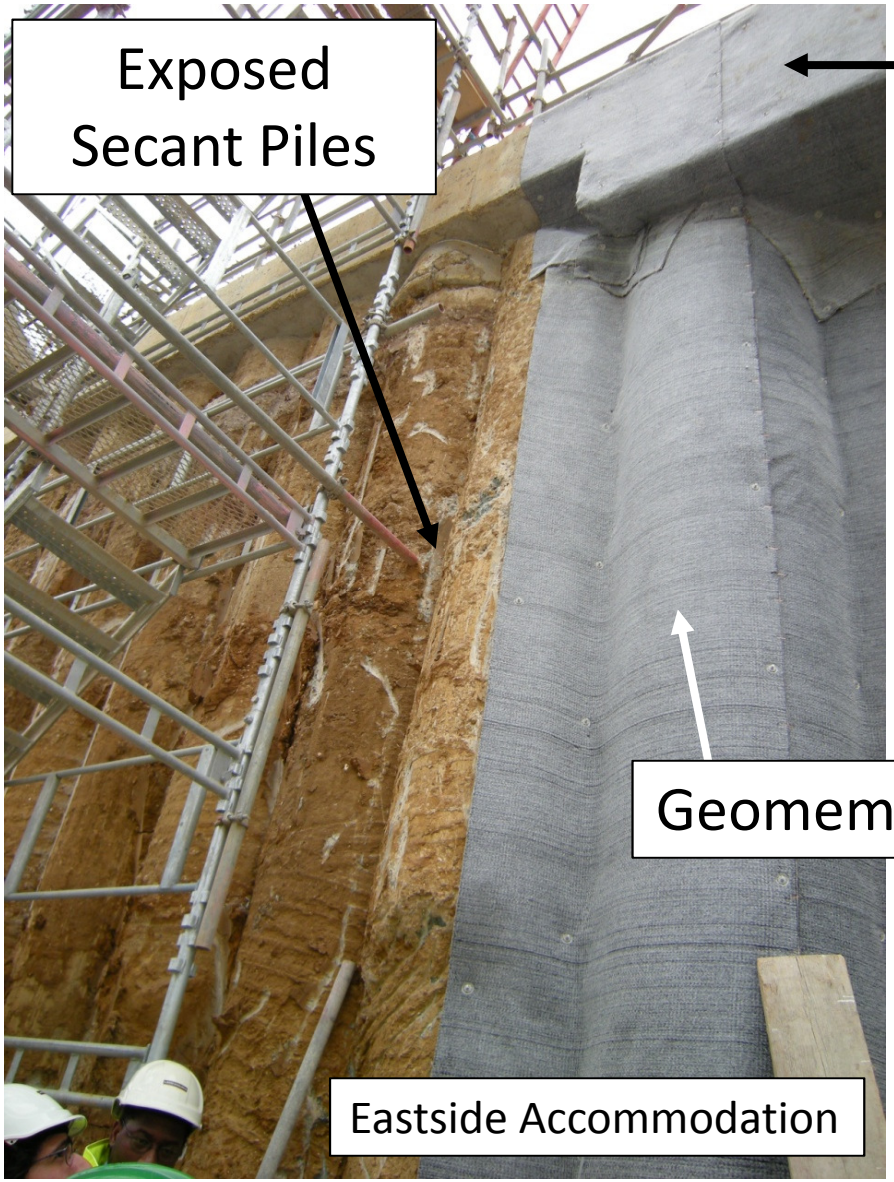




Installation



Geomembrane



Waterproof Geomembrane prevents water from entering the excavation

Diaphragm Walls

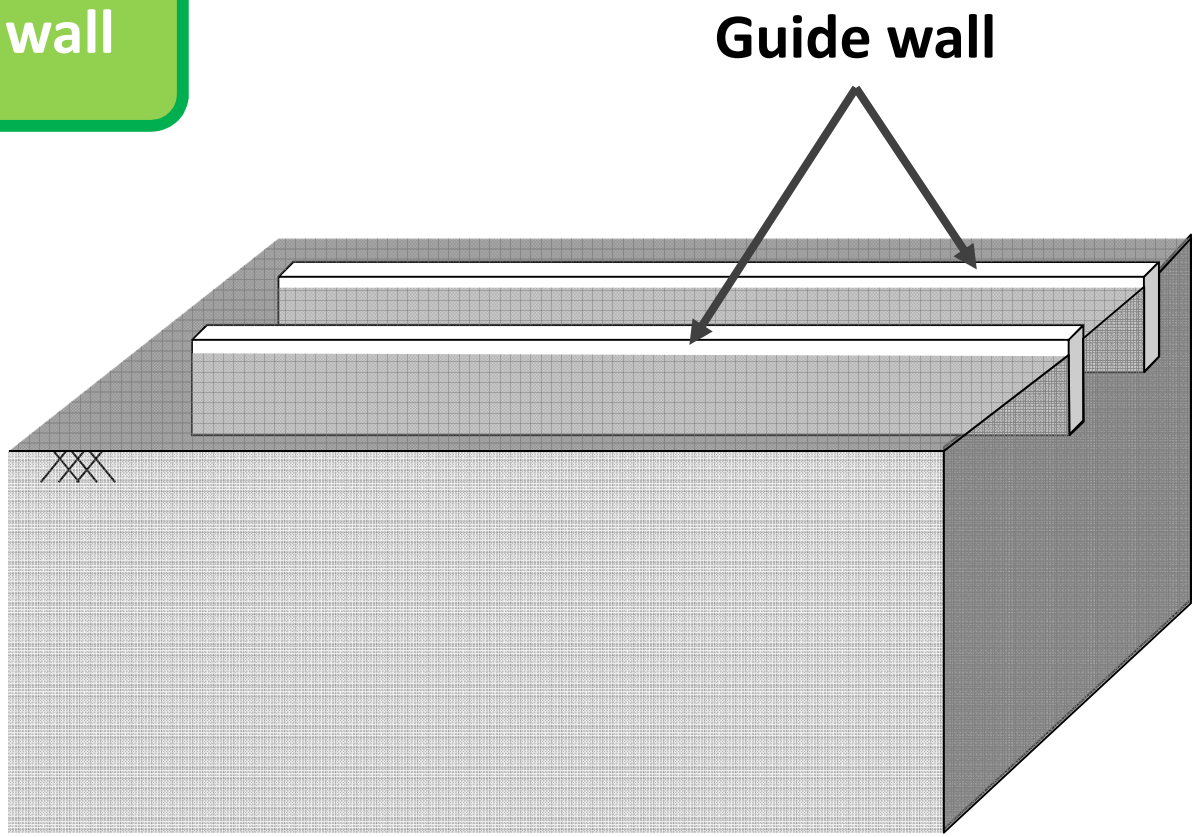
Diaphragm Walls

- Used where there is:
  - **high groundwater level** or
  - in **unstable soils**
- Provides effective groundwater control and soil retention
- Minimal vibration during construction

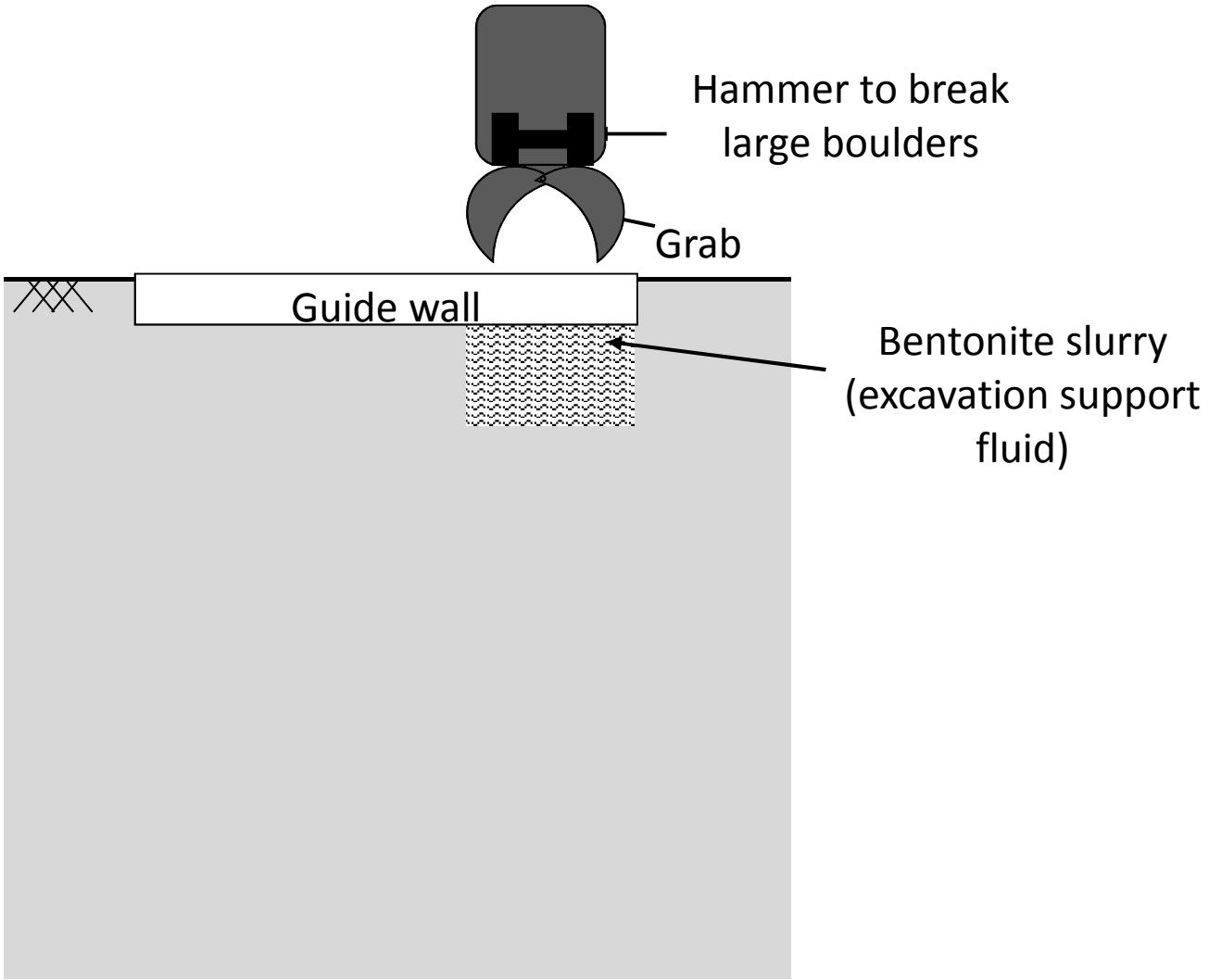
  Reduces risk of damage to adjacent properties

Construction Sequence

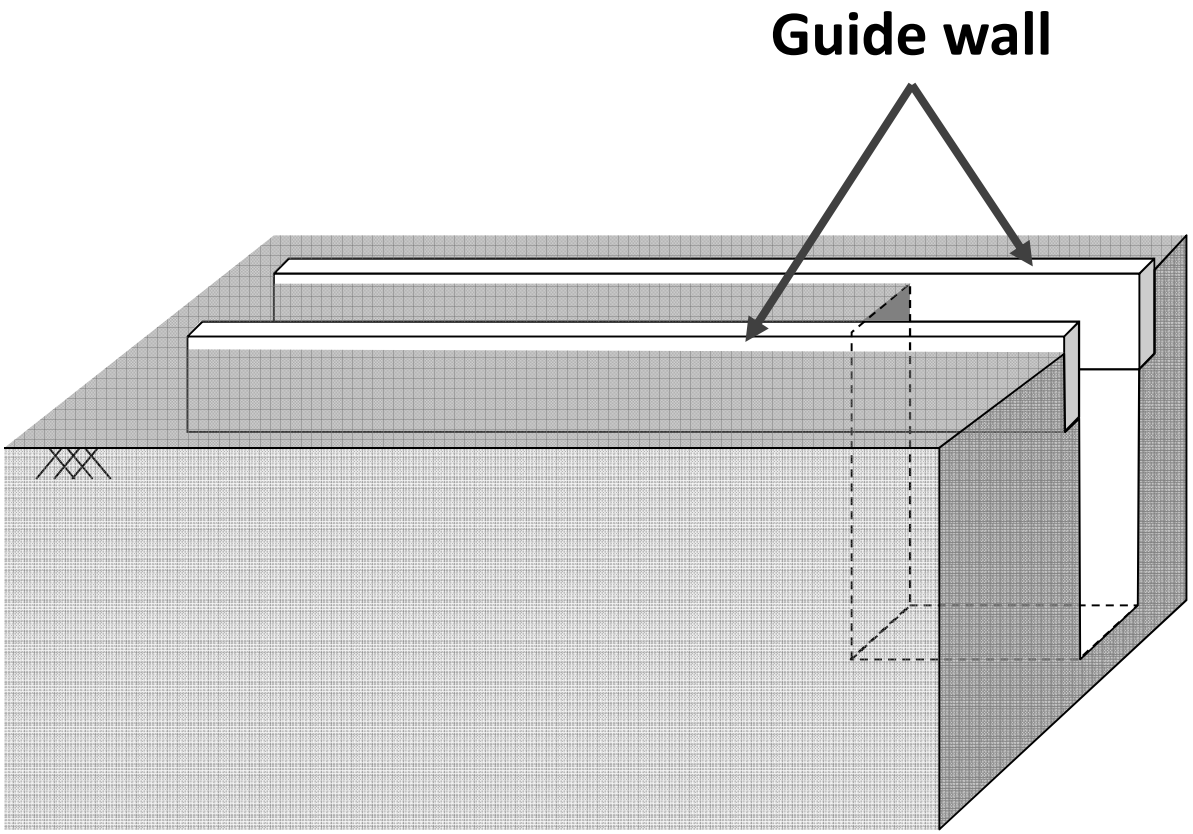
Install guide wall



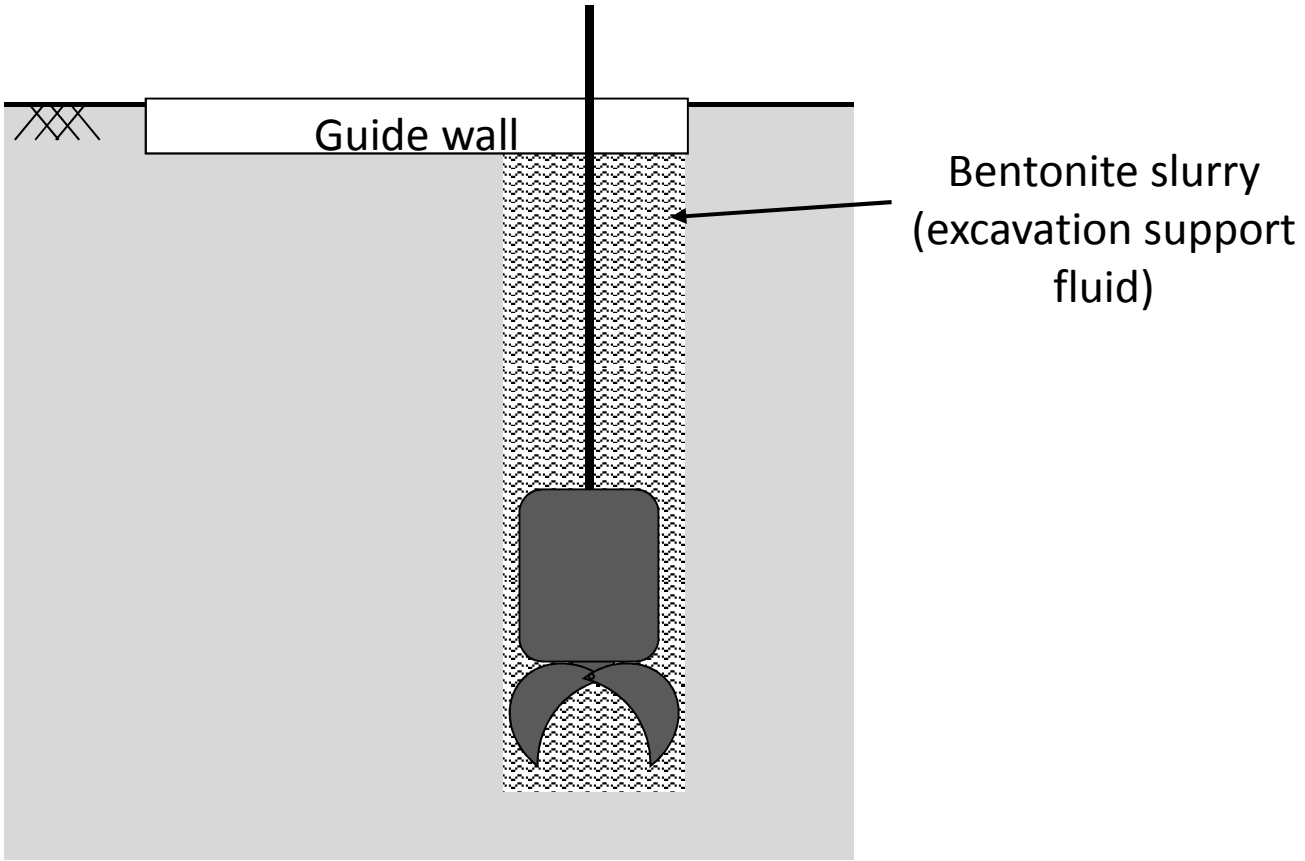
Construction Sequence



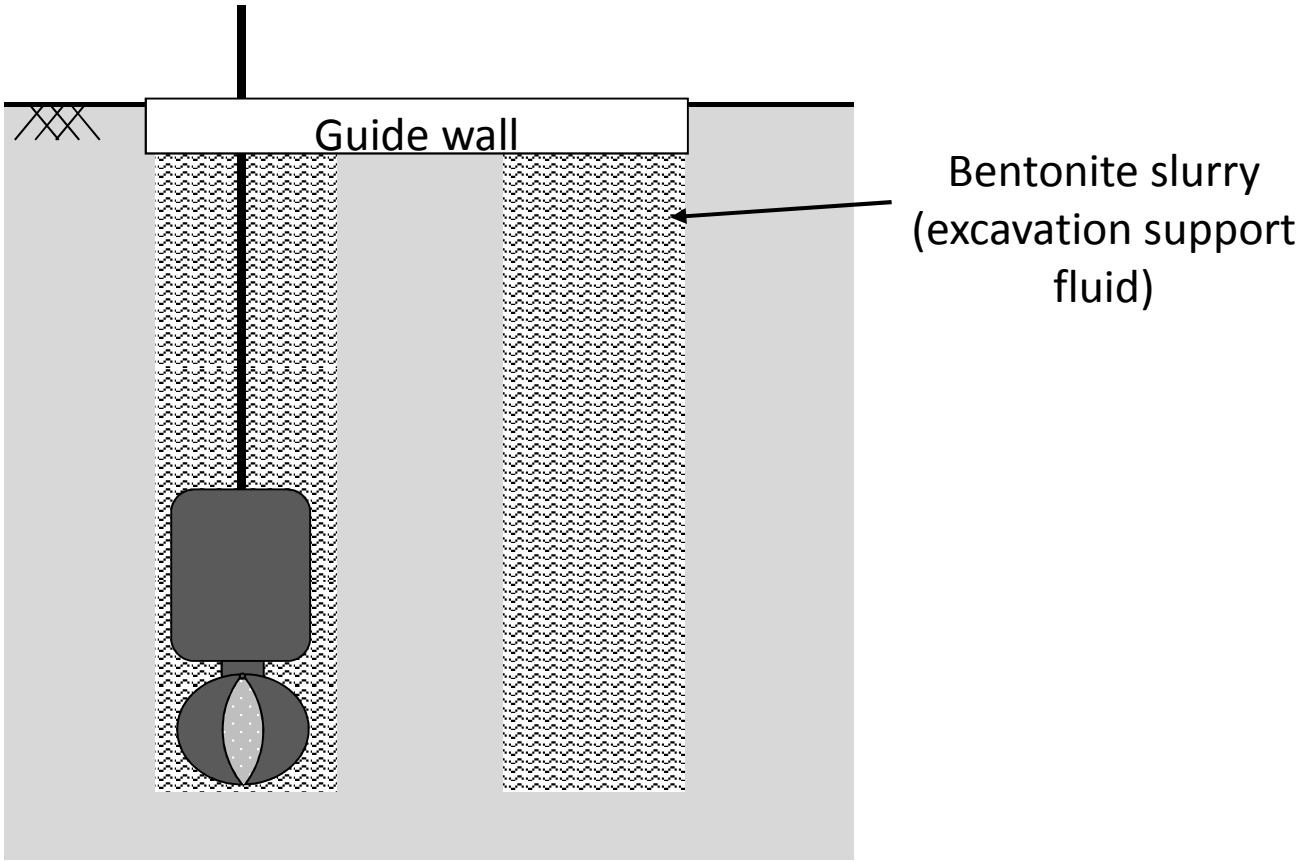
Construction Sequence



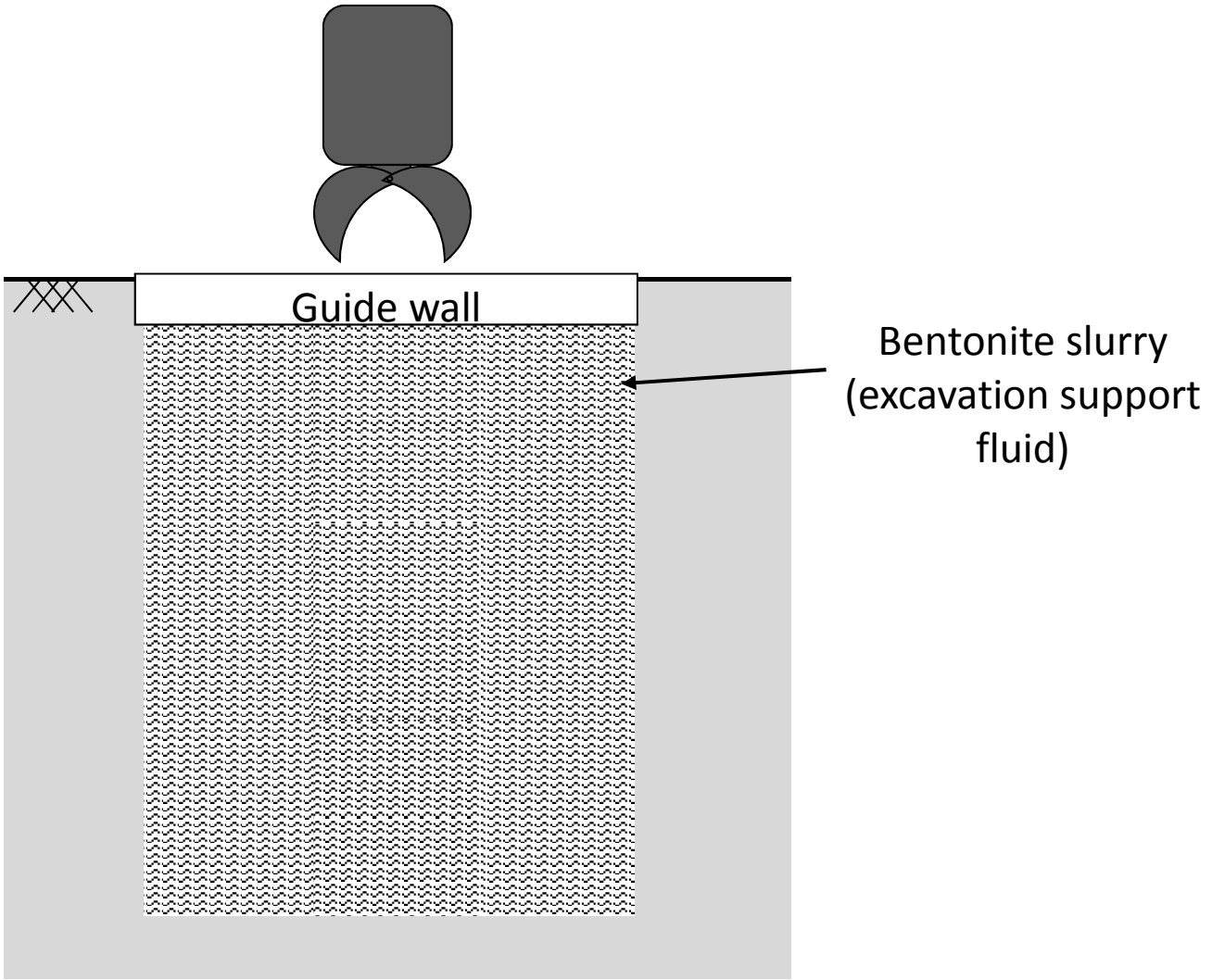
Construction Sequence



Construction Sequence

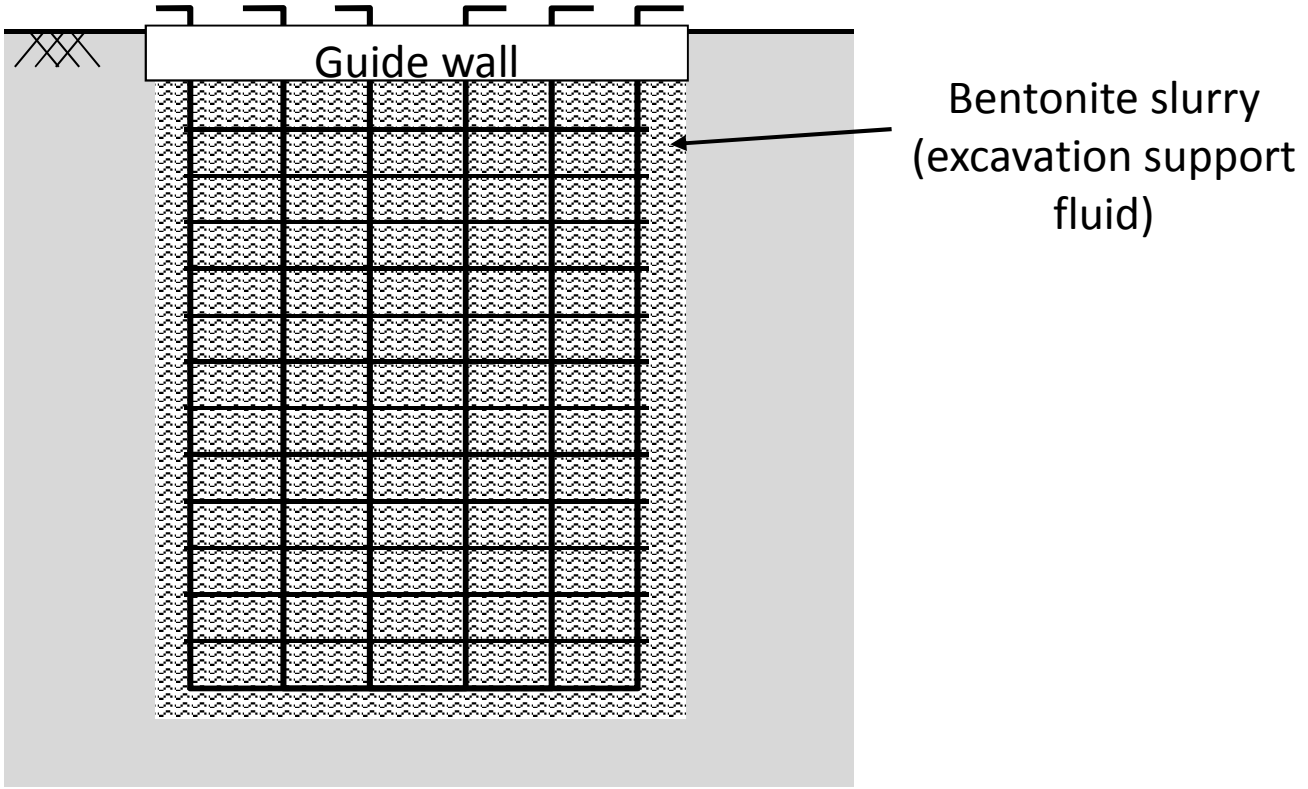


Construction Sequence



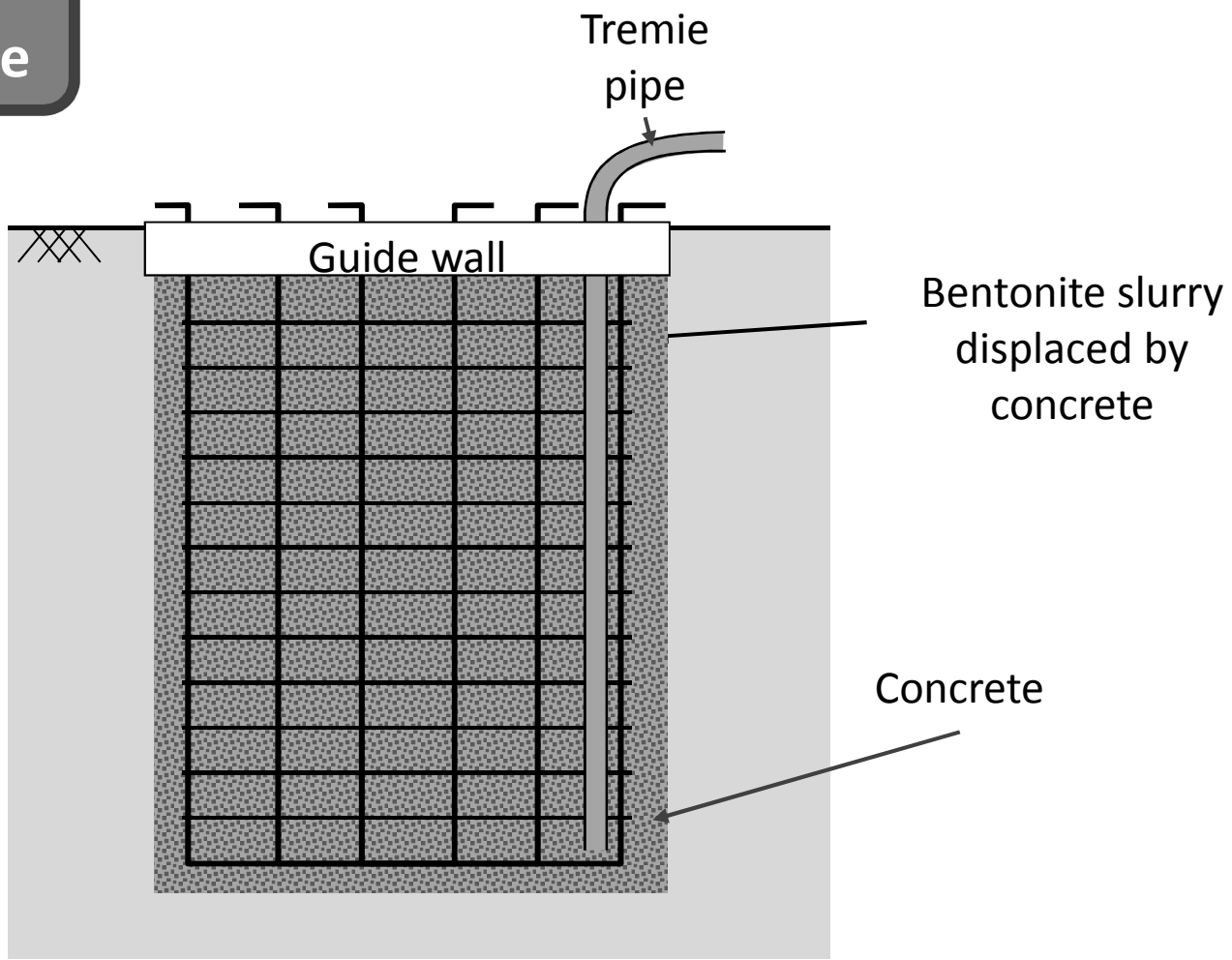
Construction Sequence

Install steel reinforcement



Construction Sequence

Pour concrete to displace Bentonite



Installation

Guide walls

Excavation…

Diaphragm wall construction in east London

Installation

…of reinforcement cage

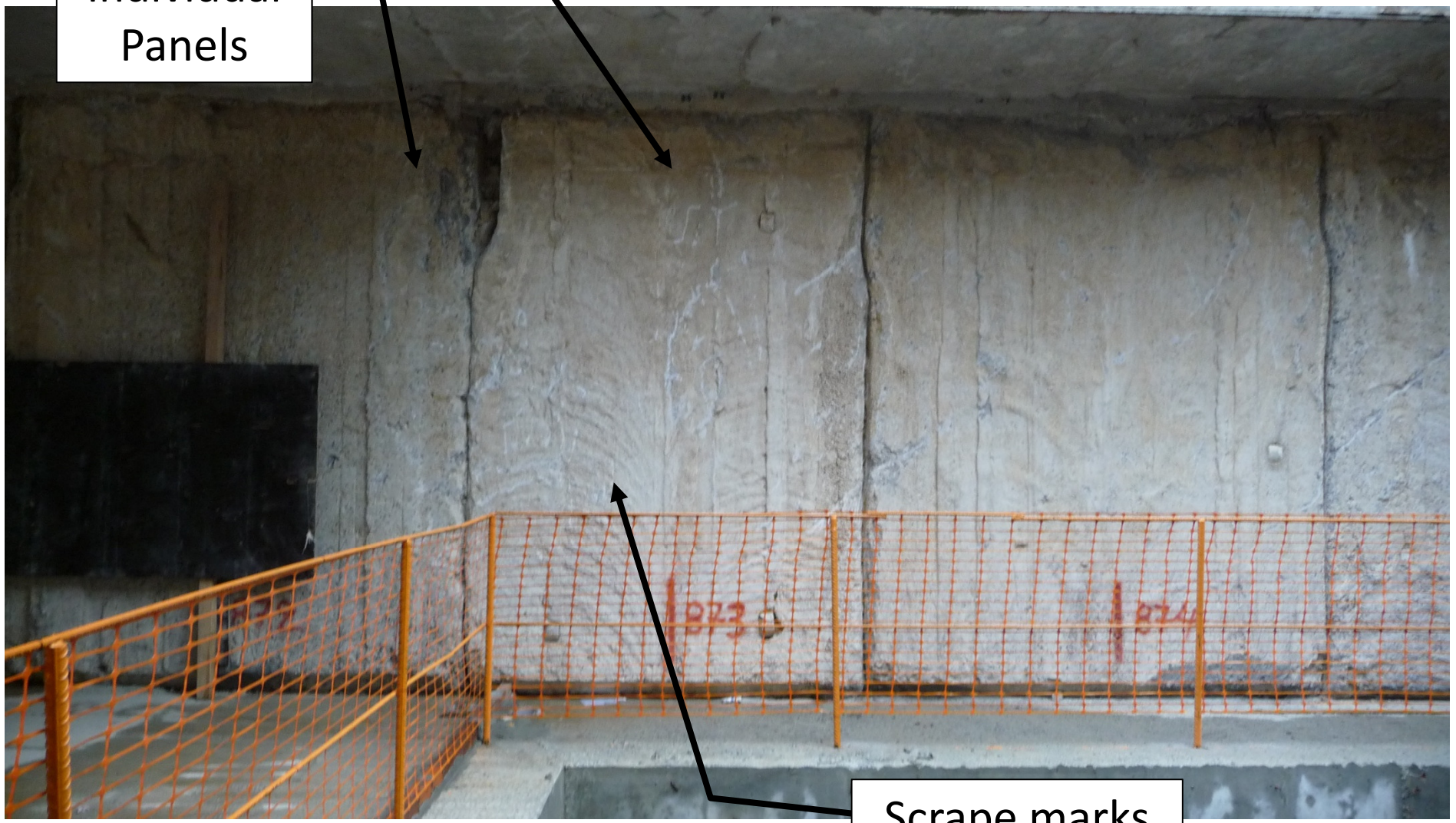
pouring of concrete…

Diaphragm wall construction in east London

Diaphragm Walls

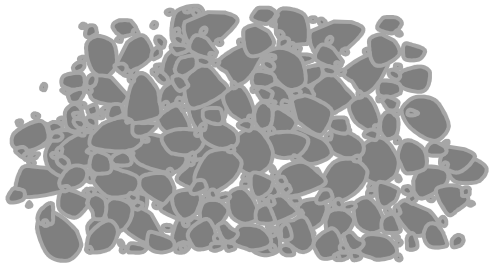
Thessaloniki Metro Station

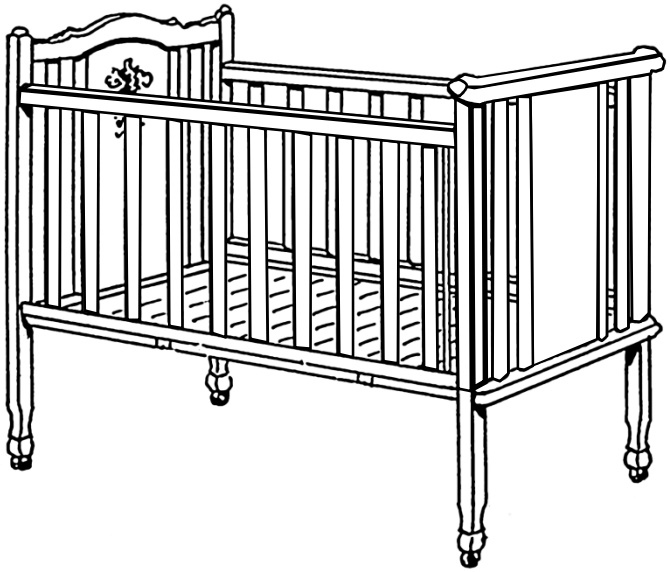
Diaphragm Walls



Crib Walls

Crib Walls





- Box-like structures
- Free-draining fill
- Assembled to form a gravity retaining wall

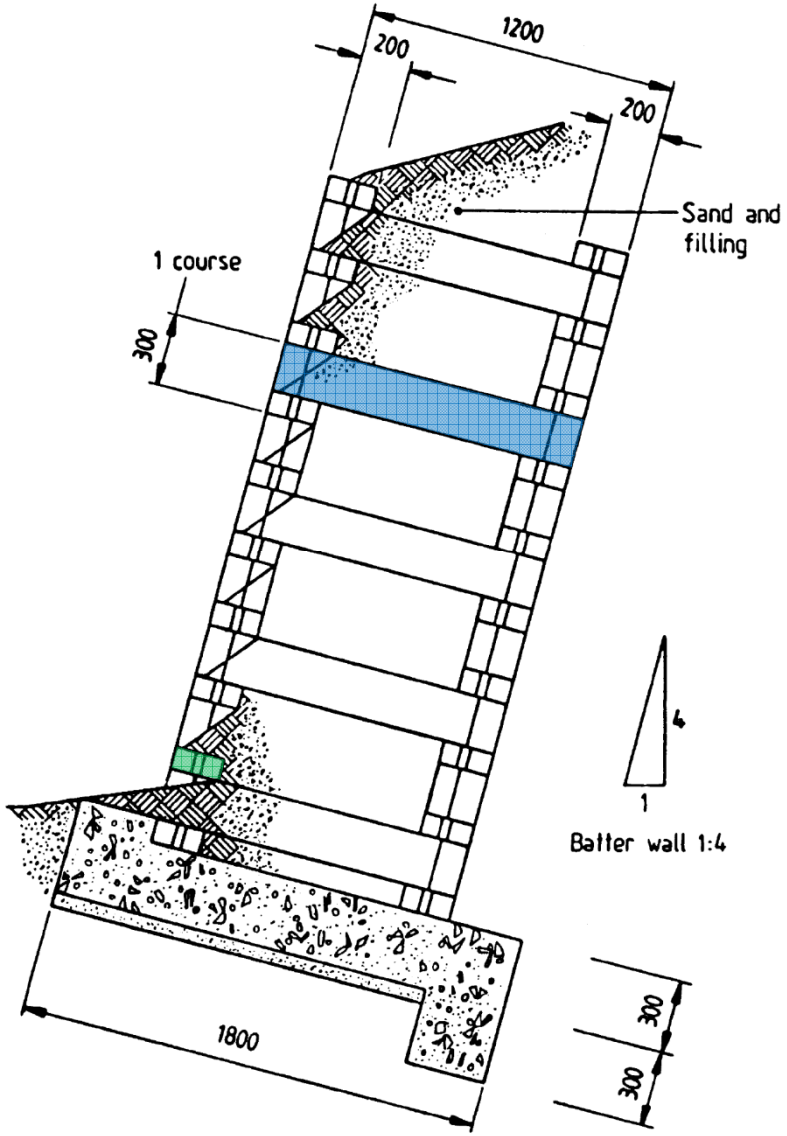
Wikipedia (2013) Crib. [Online], Available from: http://upload.wikimedia.org/wikipedia/commons/e/e1/Crib_%28PSF%29.png

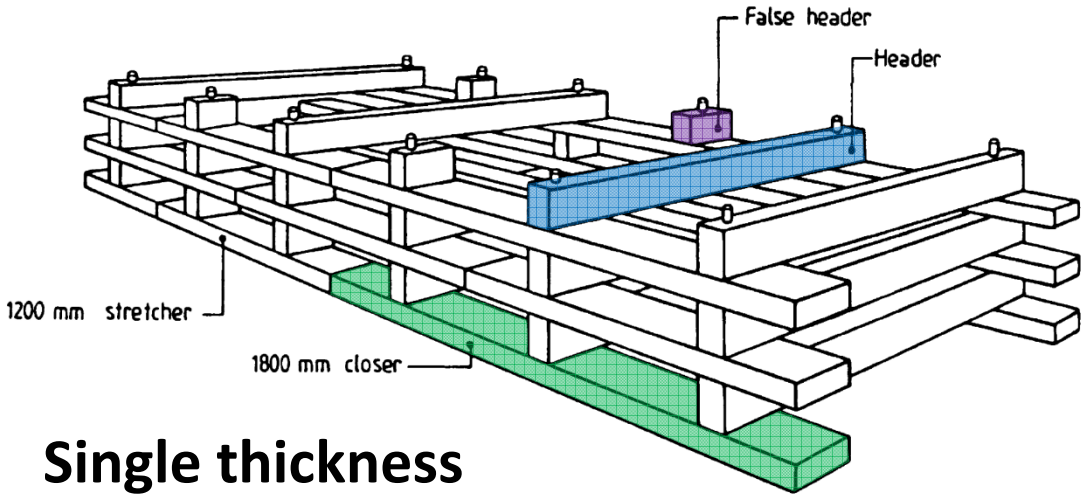
Crib Walls

Wooden Crib Wall

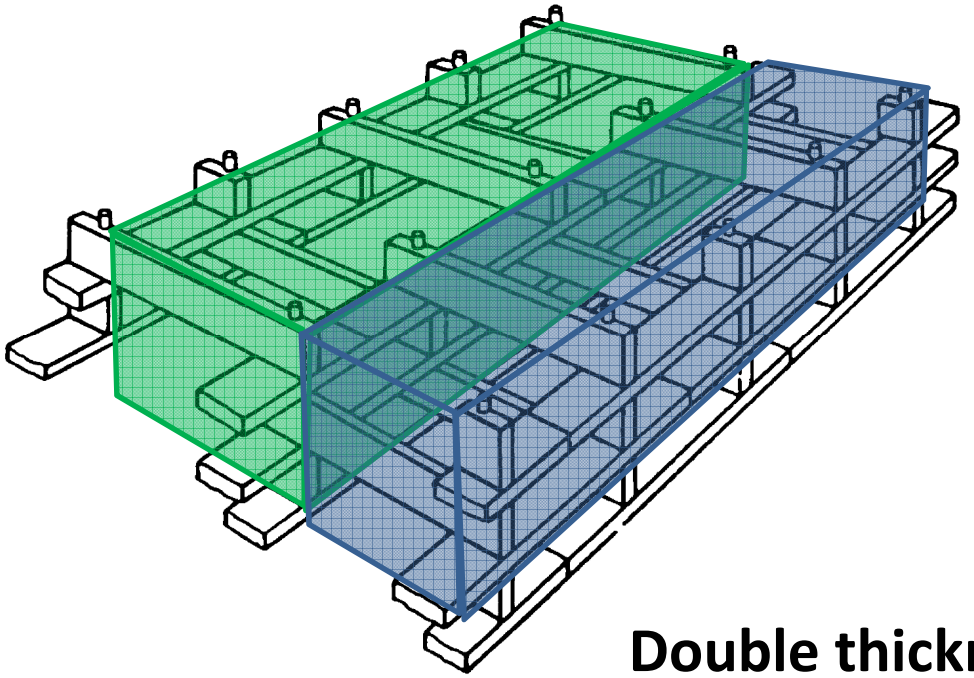
Pre-Cast Concrete Crib Wall

Crib Walls





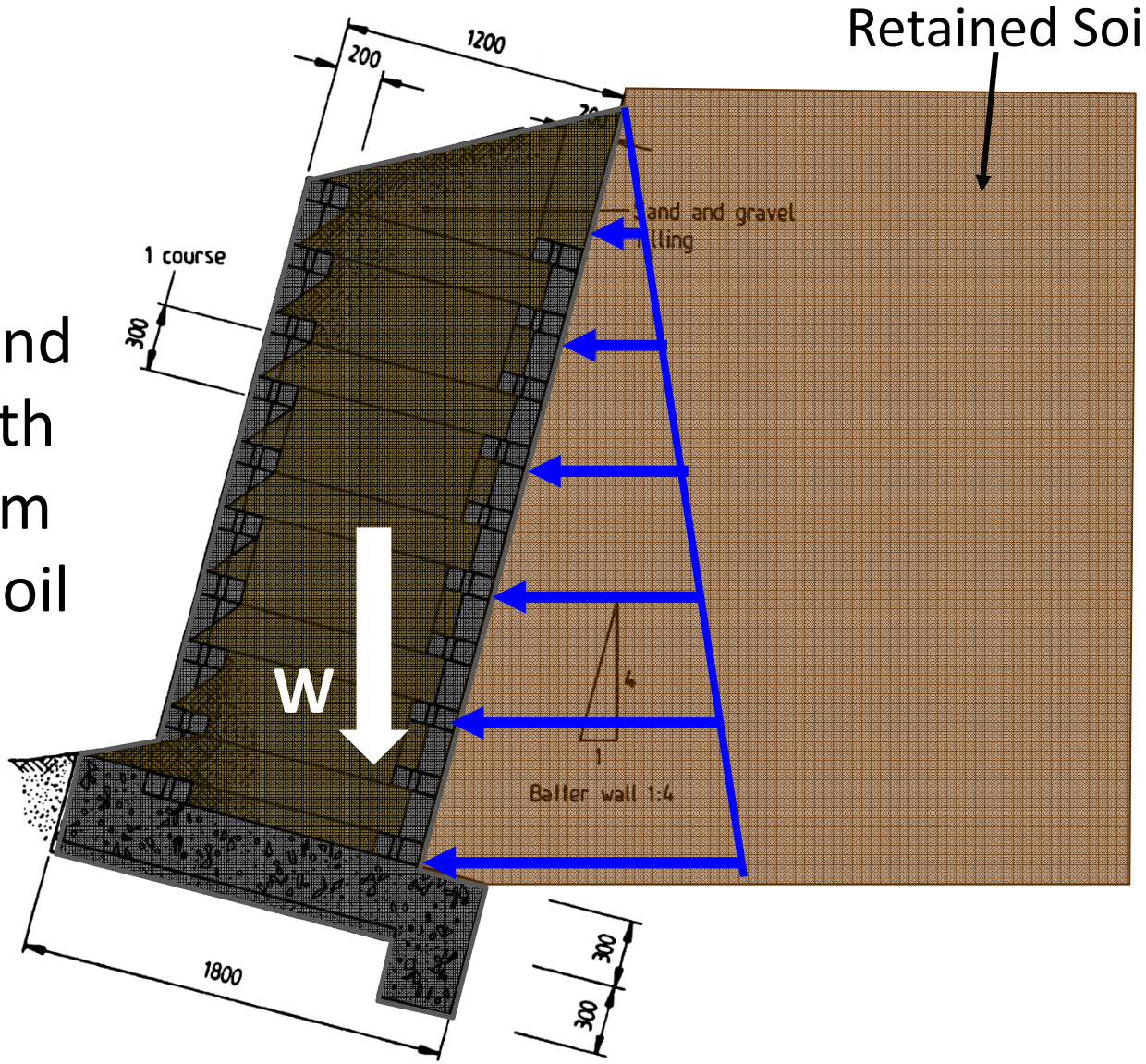
Single thickness



Double thickness

Crib Walls

Mass of crib and fill resists earth pressures from the retained soil

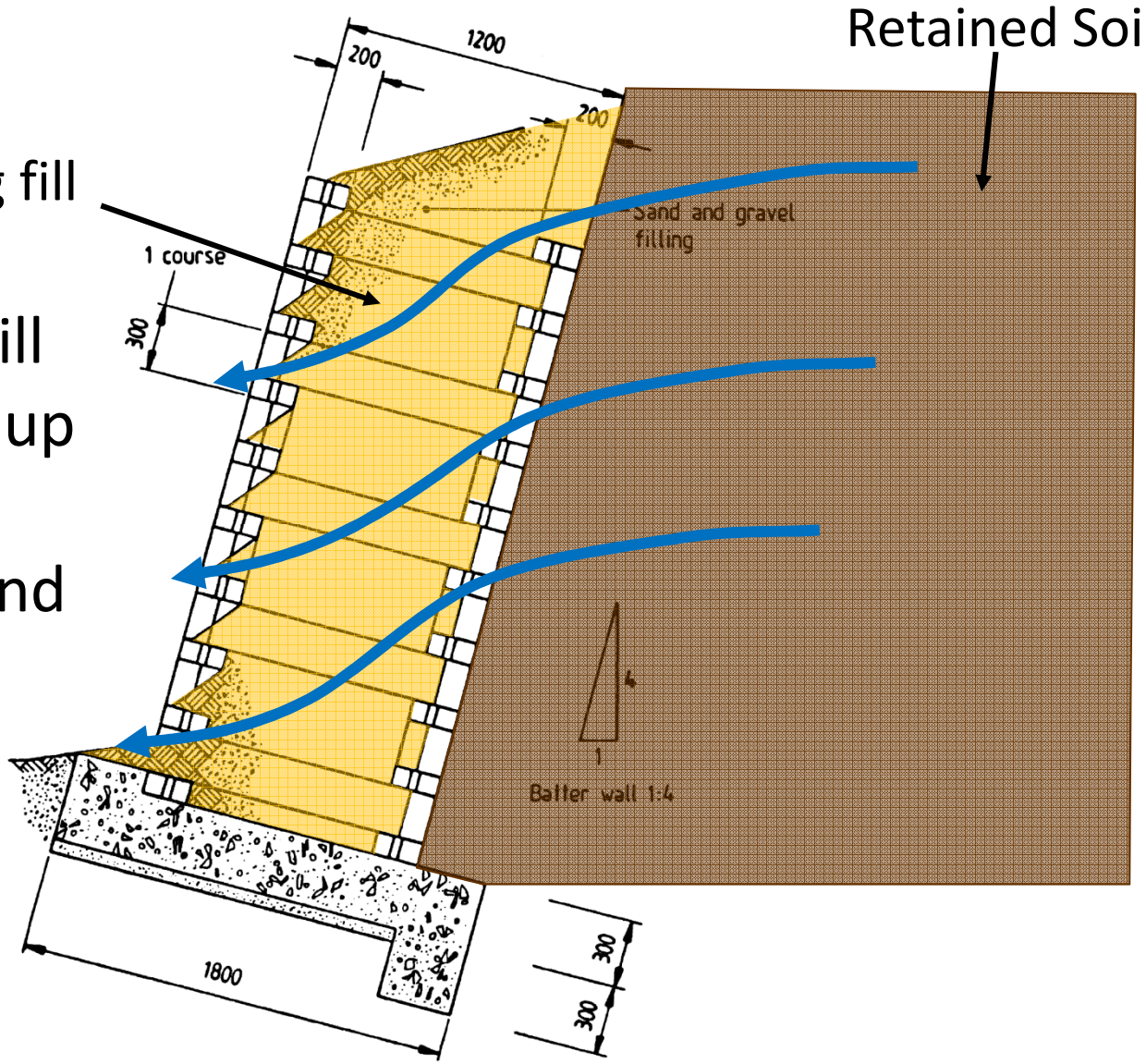


BSi (1994) BS 8002 Code of Practice for Earth retaining structures. British Standards Institution.

Crib Walls

Free-draining fill

Free-draining fill prevents build up of pore water pressures behind wall



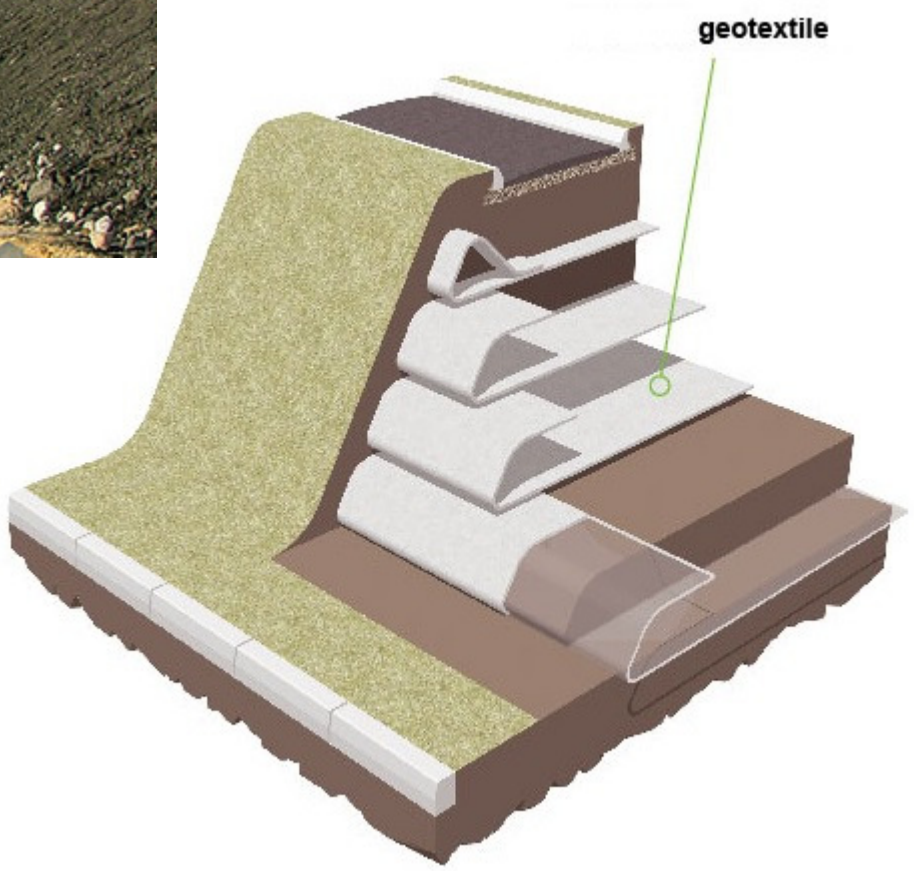
BSi (1994) BS 8002 Code of Practice for Earth retaining structures. British Standards Institution.

Reinforced Soil Walls

Reinforced Earth

(Above)
http://www.retainingsolutions.com.au/images/walls/steepened/slide1.jpg

(Below)
http://www.terramgeosynthetics.com/images/diagrams/soil-reinforcement/08-876-Soilreinforcement-textile.jpg



The reinforcement…

(Left) http://www.tensarcorp.com/Systems-and-Products/Tensar-geogrids/~/media/Images/Gallery/US/Spectra-Triax/Spectra_Photo10.ashx?mw=600

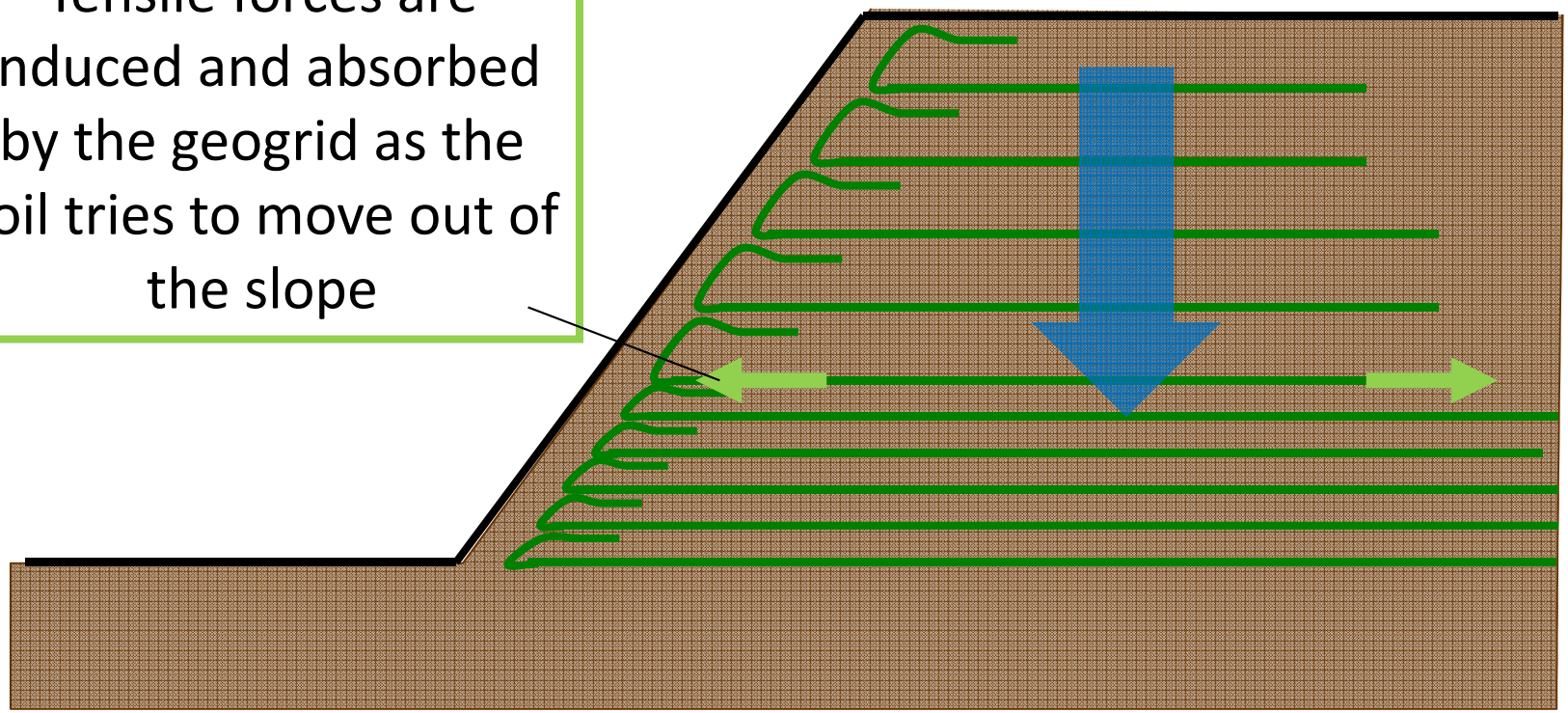
http://www.hfgeosynthetics.com/Uploads/201305/51a883b38e3cf.jpg

Geogrid – provides tensile capacity

The reinforcement…

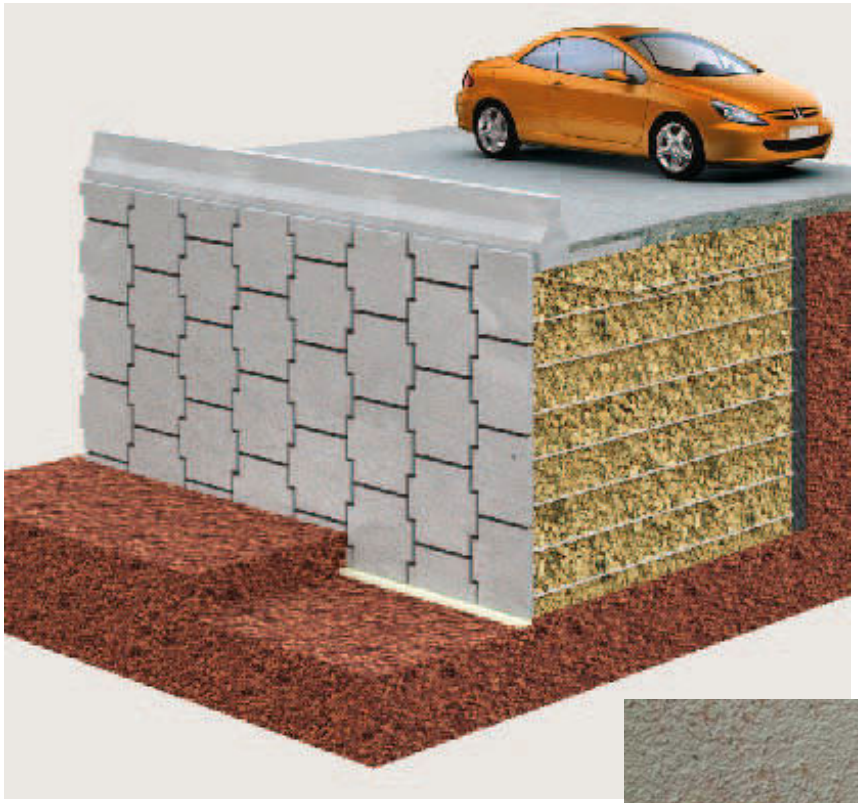
Decreasing geogrid spacing with depth

Tensile forces are induced and absorbed by the geogrid as the soil tries to move out of the slope



Geogrid – provides tensile capacity

Reinforced Walls



(Left) Available from: http://img.archiexpo.com/images_ae/photo-g/reinforced-earth-retaining-wall-61496-3911749.jpg

(Below) Available from: http://www.reinforcedearth.co.uk/lib/img/content/earth-walls/soil-reinforcement/tc-steel.jpg

Could use reinforcement **strips** instead of **sheets**

Vertical concrete face tied into reinforced soil

Reinforced Walls

(Above) :
http://www.thehindu.com/multimedia/dynamic/00746/CB07-ROAD_746814f.jpg

(Below)
http://www.recocanada.com/images/full/technology-structural-facin.jpg

Learning Outcomes

Retaining Walls

Learning outcomes

1. Explain the purpose of a retaining wall
2. Describe (with the aid of sketches) the forces acting on retaining walls.
3. Explain the principle of:
    a) Cantilever
    b) Gravity

    …retaining walls.
4. Discuss the failure mechanisms for:
    a) Cantilever
    b) Gravity

    …retaining walls.
5. Describe 4 types of cantilever retaining wall and explain their construction processes.
6. Describe the 2 main types of gravity retaining walls.