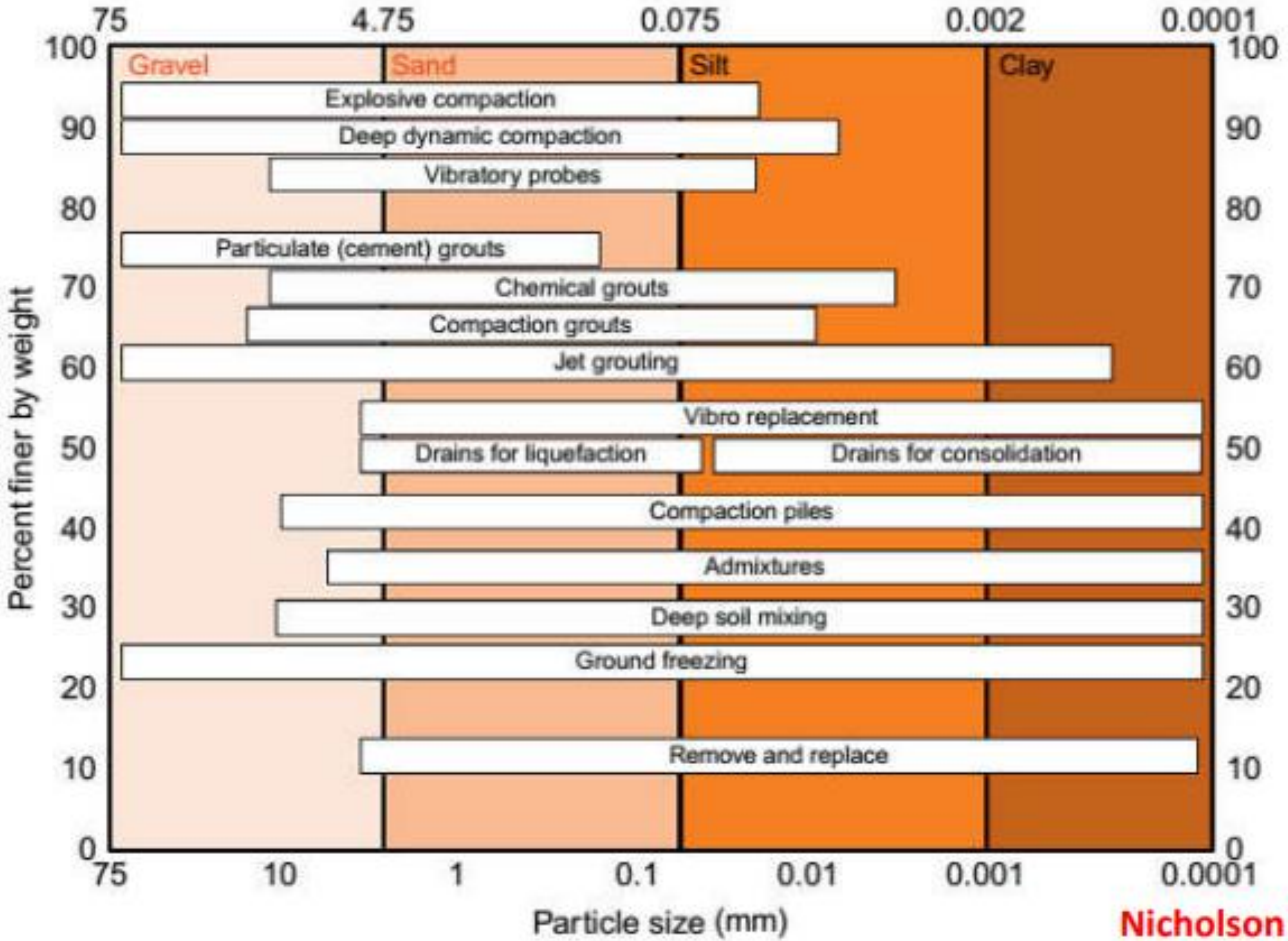
RETAINING STRUCTURES



Nicholson (2015)

A retaining wall is a structure that retains (holds back) any material (usually earth) and prevents it from sliding or eroding away. It is designed so that to resist the material pressure of the material that it is holding back.

An earth retaining structure can be considered to have the following types:

Gravity Walls

- Reinforced Gravity Walls
  - Concrete Cantilever retaining wall
  - Counter-fort / Buttressed retaining wall
  - Precast concrete retaining wall
  - Prestressed retaining wall

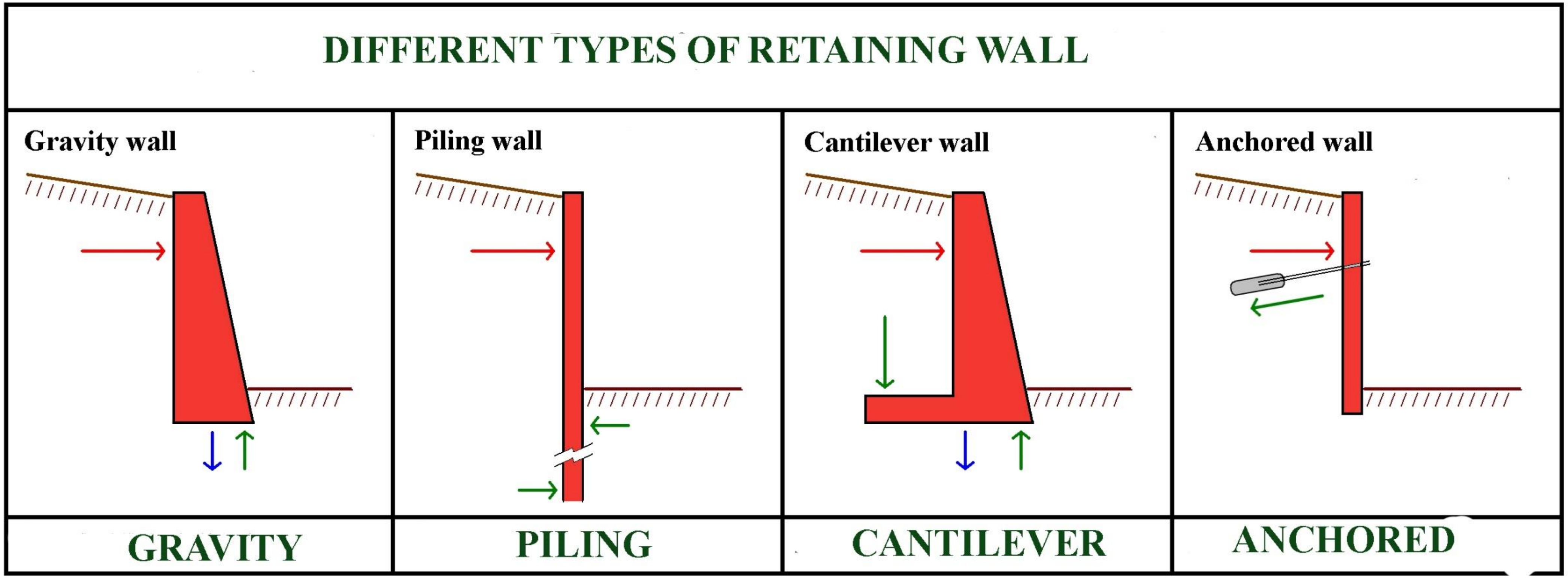
Brick - Brick Masonry retaining wall

Stone

Reinforced Soil Walls

- Reinforced Soil
- Soil Nailing

Types of Retaining Walls



Gravity Retaining Walls

It is that type of retaining wall that relies on their huge weight to retain the material behind it and achieve stability against failures.

Gravity Retaining Wall can be constructed from concrete, stone or even brick masonry.

Gravity retaining walls are much thicker in section.

Geometry of these walls also help them to maintain the stability.

Mass concrete walls are suitable for retained heights of up to 3 m.

The cross section shape of the wall is affected by stability, the use of space in front of the wall, the required wall appearance and the method of construction.

Reinforced Retaining Walls

Reinforced concrete and reinforced masonry walls on spread foundations are gravity structures in which the stability against overturning is provided by the weight of the wall and reinforcement bars in the wall. The following are the main types of wall:

Concrete Cantilever retaining wall

A cantilever retaining wall is one that consists of a wall which is connected to foundation. A cantilever wall holds back a significant amount of soil, so it must be well engineered. They are the most common type used as retaining walls. Cantilever wall rest on a slab foundation. This slab foundation is also loaded by back-fill and thus the weight of the back-fill and surcharge also stabilizes the wall against overturning and sliding.

Reinforced Soil Retaining Walls

Mechanically stabilized earth walls are those structures which are made using steel or **GeoTextiles** soil reinforcements which are placed in layers within a controlled granular fill. Reinforced soils can also be used as retaining walls, if they are built as:

- As an integral part of the design
- As an alternative to the use of reinforced concrete or other solutions on the grounds of economy or as a result of the ground conditions
- To act as temporary works
- As remedial or improvement works to an existing configuration.

This category covers walls which use soil, reinforced with reinforcing bars, to provide a stable earth retaining system and includes **reinforced soil** and **soil nailing**.

Anchored Earth walls

Any wall which uses facing units tied to rods or strips which have their ends anchored into the ground is an anchored earth wall. The anchors are like abutments. The cables used for tieing are commonly high strength, prestressed steel tendons. To aid anchorage, the ends of the strips are formed into a shape designed to bind the strip at the point into the soil.

Sheet Pile Walls

Steel sheet pile walls are constructed by driving steel sheets into a slope or excavation upto the required depth. Their most common use is within temporary deep excavations. They are considered to be most economical where retention of higher earth pressures of soft soils is required. It cannot resist very high pressure.

Earth Pressure

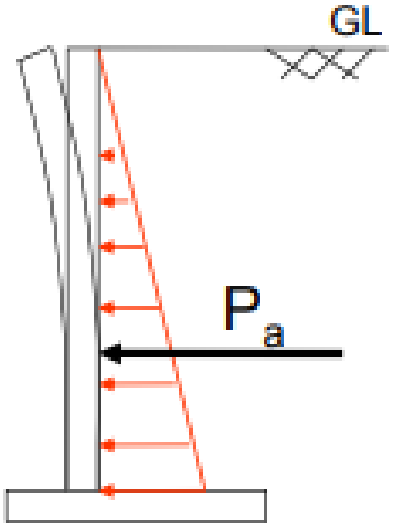
Earth pressure is the pressure exerted by the retaining material on the retaining wall. This pressure tends to deflect the wall outward.

Types of earth pressure :

- Active earth pressure or earth pressure (Pa)
- Passive earth pressure (Pp).

Factors affecting earth pressure

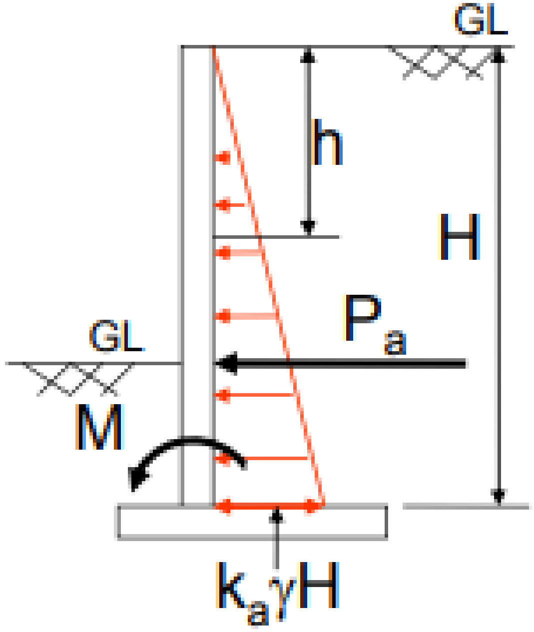
- type of backfill,
- height of wall
- soil conditions



Variation of Earth pressure

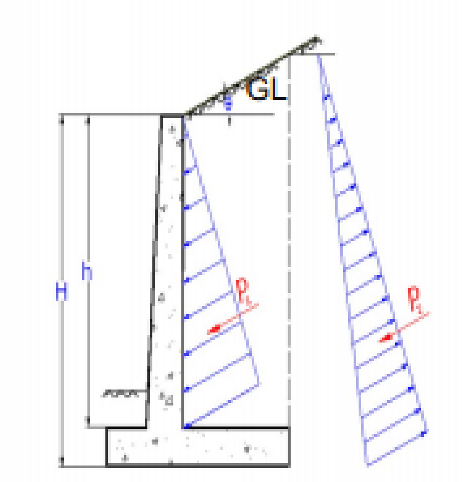
Soil conditions:

- Dry leveled back fill
- Moist leveled backfill
- Submerged leveled backfill
- Leveled backfill with uniform surcharge
- Backfill with sloping surface



H=stem height

For dry backfills



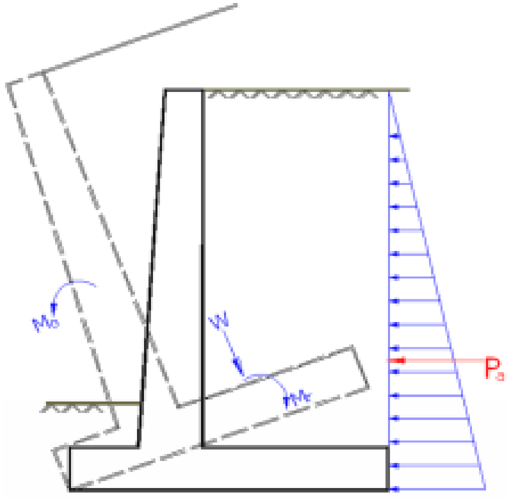
For inclined surfaces

$$k_a = \cos\theta \left[\frac{\cos\theta - \sqrt{\cos^2\theta - \cos^2\phi}}{\cos\theta + \sqrt{\cos^2\theta - \cos^2\phi}} \right]$$

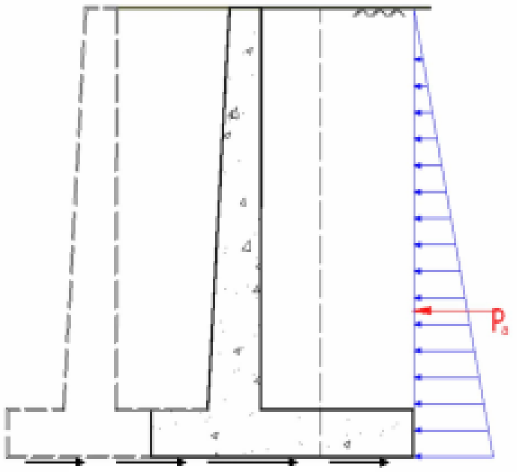
Where θ=Angle of surcharge

Stability requirements of RW

- It should not overturn
- It should not slide
- It should not subside, i.e Max. pressure at the toe should not exceed the safe bearing capacity of the soil under working condition

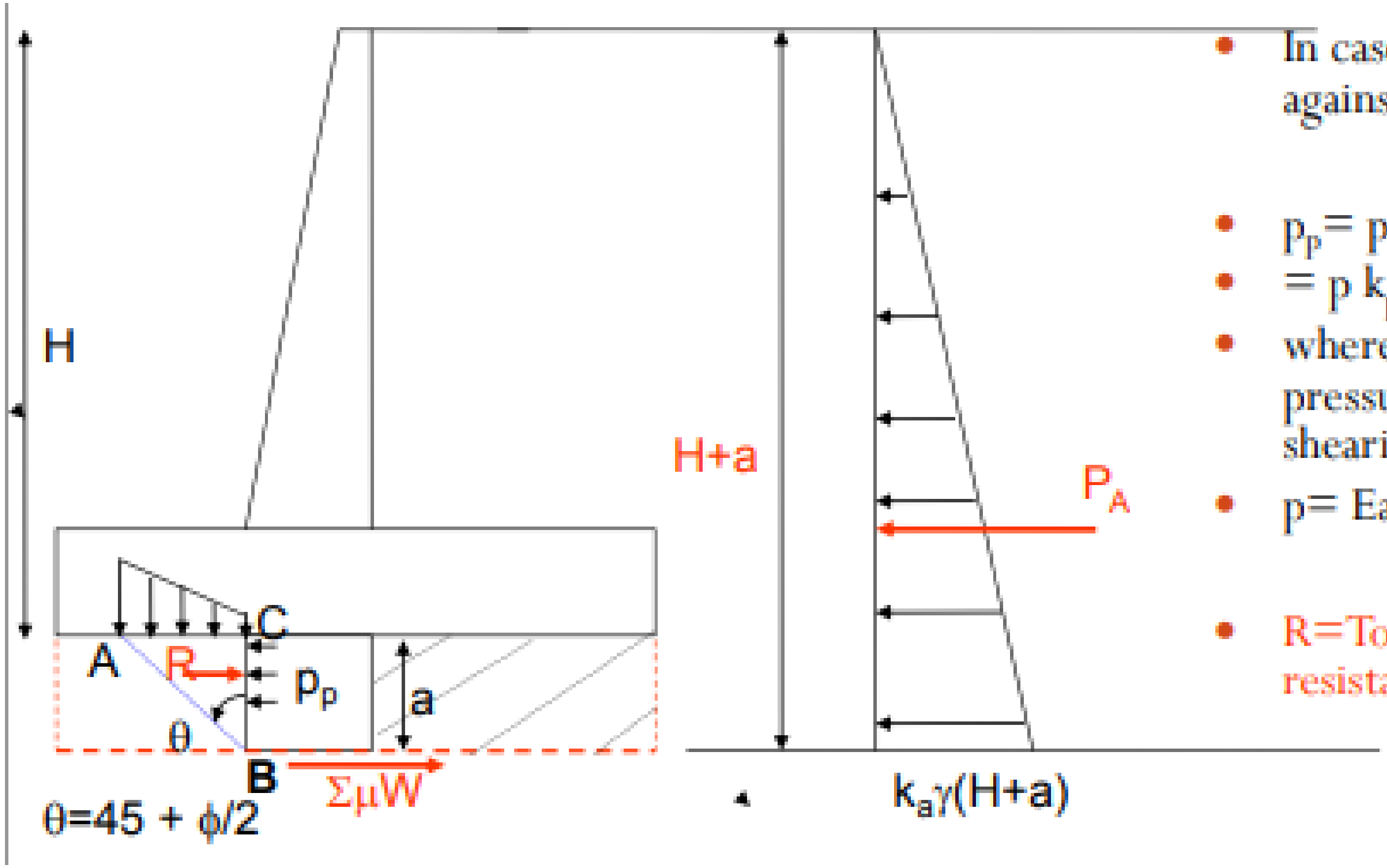


OVERTURNING OF WALL



SLIDING OF WALL

Design of Shear Key



- In case the wall is unsafe against sliding
- $p_p = p \tan^2 (45 + \phi/2)$
- $= p\, k_p$
- where p_p = Unit passive pressure on soil above shearing plane AB
- p= Earth pressure at BC
- R=Total passive resistance=$p_p$xa

Design of Shear Key

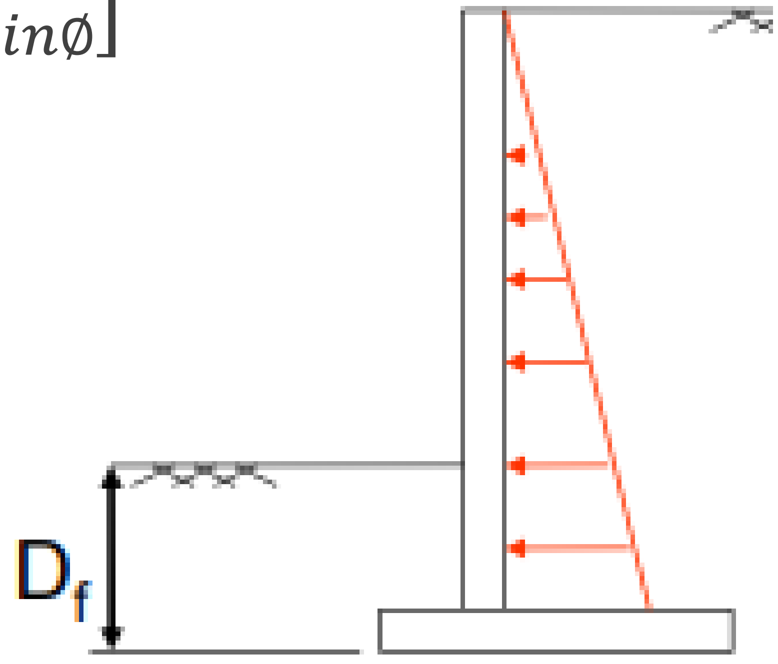
- If $\sum W$ = Total vertical force acting at the key base
- ϕ = shearing angle of passive resistance
- R = Total passive force = p_p x a
- P_A = Active horizontal pressure at key base for H+a
- $\mu \sum W$ = Total frictional force under flat base

- For equilibrium, $R + \mu \sum W = FOS \times P_A$

- $FOS = (R + \mu \sum W)/P_A \geq 1.55$

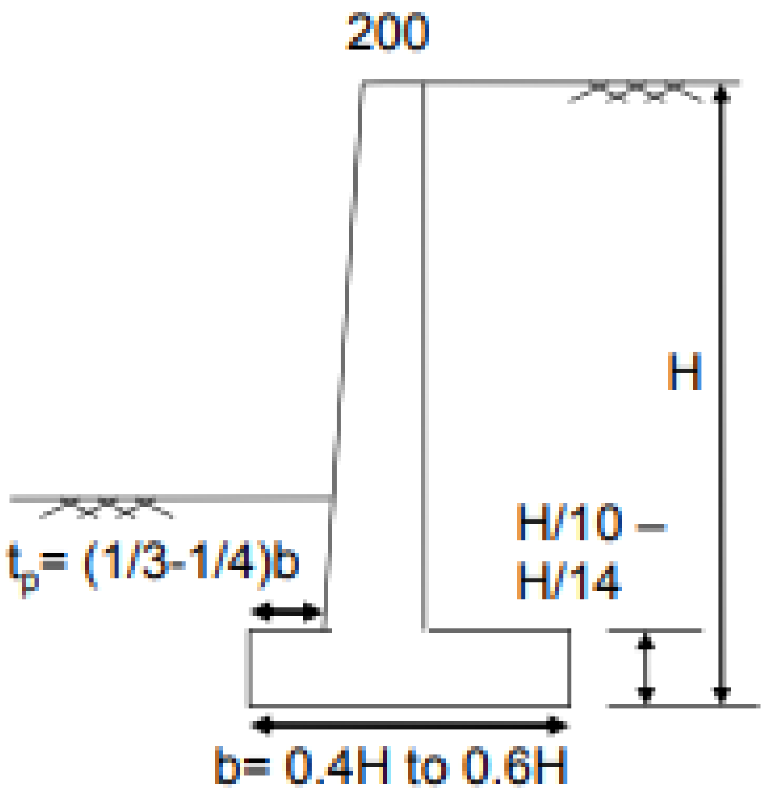
Depth of foundation

$$D_f = \frac{Allowable\ Bearing\ Capacity\ of\ Soil}{\gamma}\left[\frac{1-sin\emptyset}{1+sin\emptyset}\right]$$



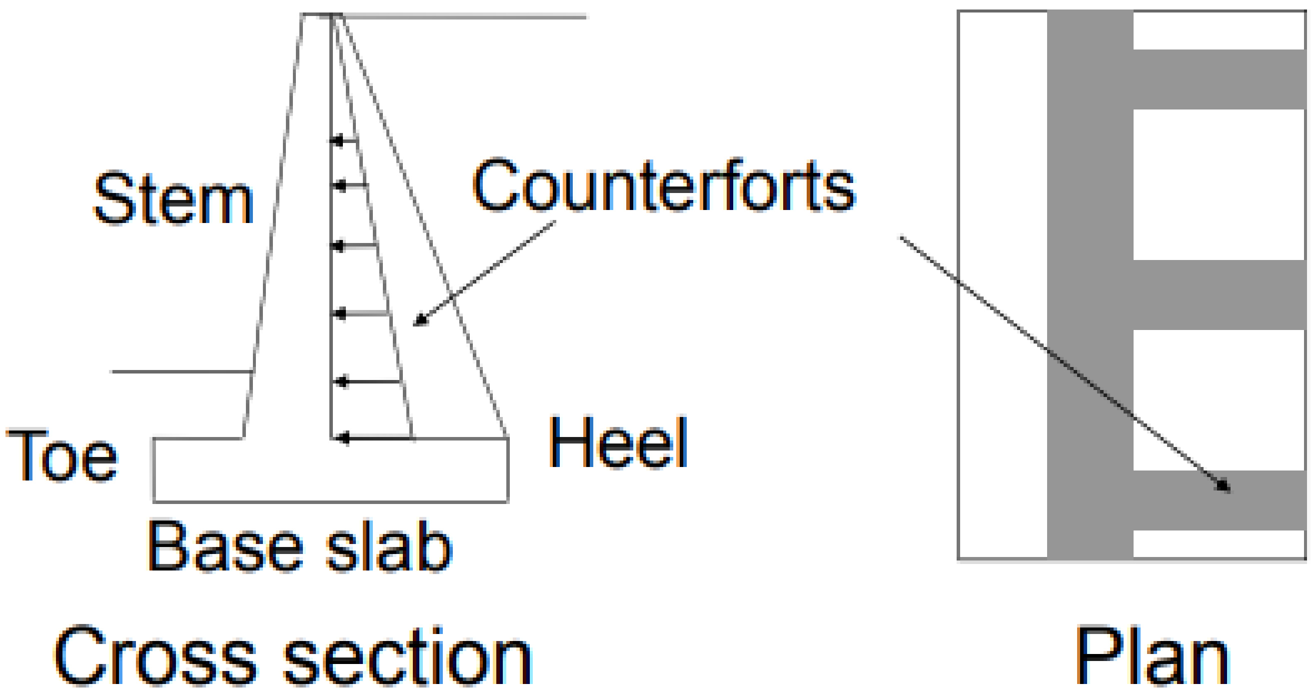
Preliminary Design

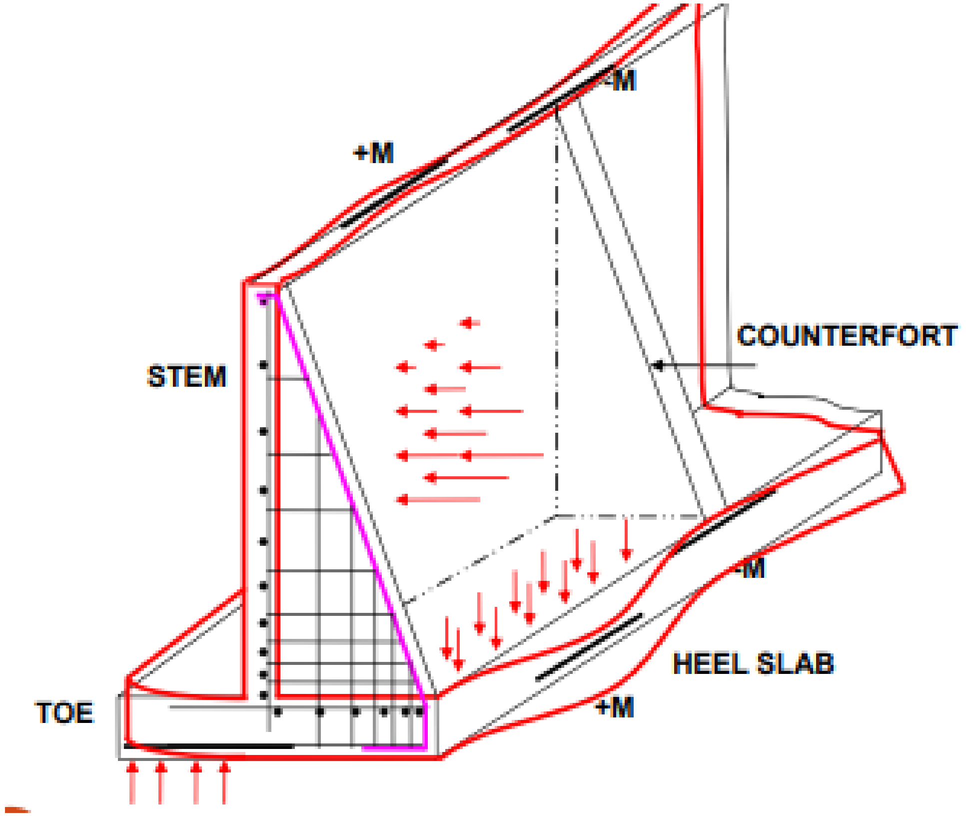
- Stem: Top width 200 mm to 400 mm
- Base slab width b= 0.4H to 0.6H, 0.6H to 0.75H for surcharged wall
- Base slab thickness= H/10 to H/14
- Toe projection= (1/3-1/4) Base width



Counterfort Retaining Wall

- When H exceeds about 6m,
- Stem and heel thickness is more
- More bending and more steel
- Cantilever-T type-Uneconomical
- Counterforts-Trapezoidal section
- 1.5m -3m c/c





-M
+M
COUNTERFORT
STEM
-M
HEEL SLAB
+M
TOE

Design of Stem

The stem acts as a continuous slab

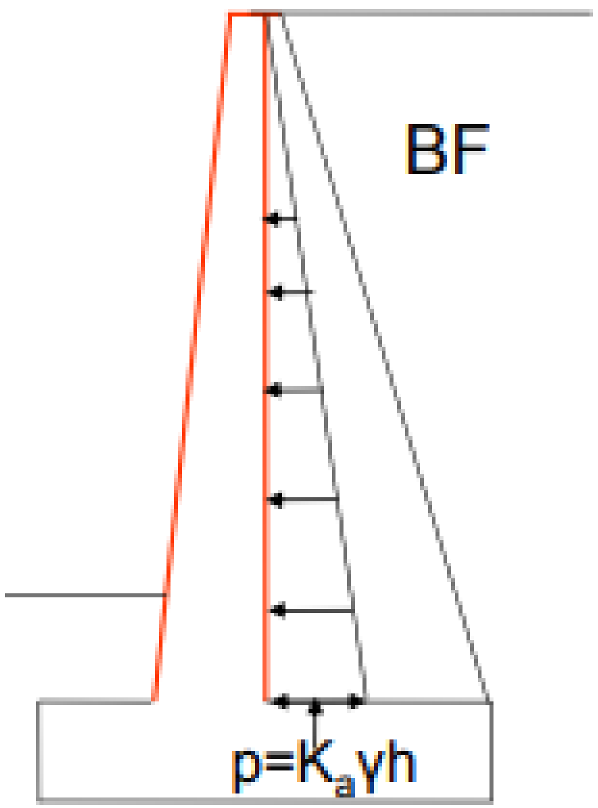
Soil pressure acts as the load on the slab.

Earth pressure varies linearly over the height

The slab deflects away from the earth face between the counterforts

The bending moment in the stem is maximum at the base and reduces towards top.

But the thickness of the wall is kept constant and only the area of steel is reduced.



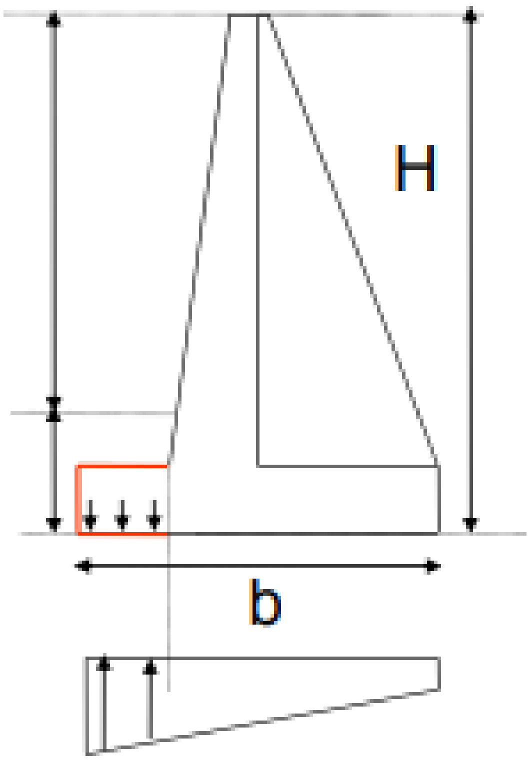
Maximum Bending Moments for Stem

- Maximum +ve B.M= $pl^2/16$
- (occurring mid-way between counterforts)
- and
- Maximum -ve B.M= $pl^2/12$
- (occurring at inner face of counterforts)

- Where 'l' is the clear distance between the counterforts
- and 'p' is the intensity of soil pressure

Design of Toe Slab

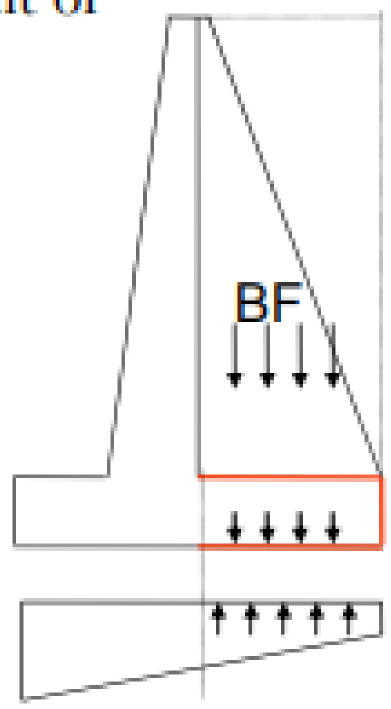
- The base width=b =0.6 H to 0.7 H
- The projection=1/3 to 1/4 of base width.
- The toe slab is subjected to an upward soil reaction and is designed as a cantilever slab fixed at the front face of the stem.
- Reinforcement is provided on earth face along the length of the toe slab.
- In case the toe slab projection is large i.e. > b/3, front counterforts are provided above the toe slab and the slab is designed as a continuous horizontal slab spanning between the front counterforts.



Design of Heel Slab

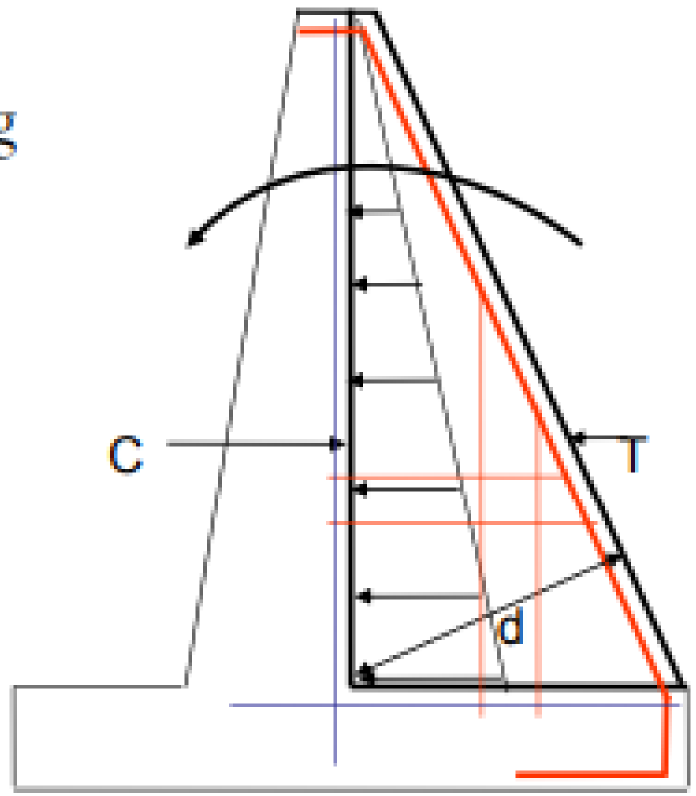
- The heel slab is designed as a continuous slab spanning over the counterforts and is subjected to downward forces due to weight of soil plus self weight of slab and an upward force due to soil reaction.

- Maximum +ve B.M= $pl^2/16$
- (mid-way between counterforts)
- And
- Maximum -ve B.M= $pl^2/12$
- (occurring at counterforts)



Design of Counterforts

- The counterforts are subjected to outward reaction from the stem.
- This produces tension along the outer sloping face of the counterforts.
- The inner face supporting the stem is in compression. Thus counterforts are designed as a T-beam of varying depth.
- The main steel provided along the sloping face shall be anchored properly at both ends.
- The depth of the counterfort is measured perpendicular to the sloping side.



Reinforced Earth Walls

A Mechanically Stabilized Earth (MSE) retaining wall is a composite structure consisting of alternating layers of compacted backfill and soil reinforcement elements, fixed to a wall facing.

The stability of the wall system is derived from the interaction between the backfill and soil reinforcements, involving friction and tension.

The wall facing is relatively thin, with the primary function of preventing erosion of the structural backfill. The result is a coherent gravity structure that is flexible and can carry a variety of heavy loads.

Soil : Strong in compression

Reinforcement : Strong in tension (steel, concrete, glass fiber, rubber, geotextile …)

Reinforced Earth Wall


01/07/2005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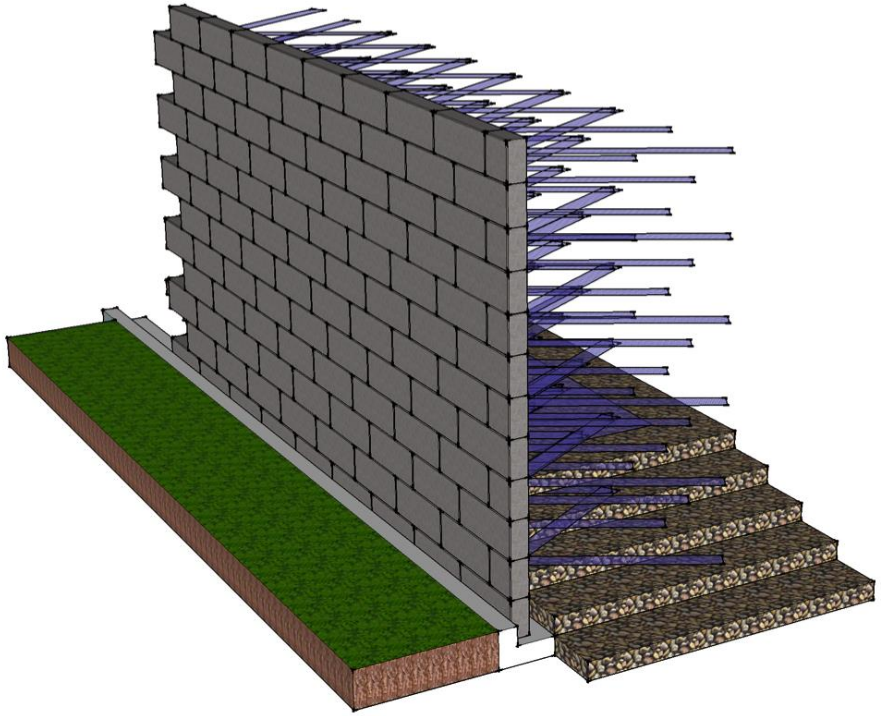
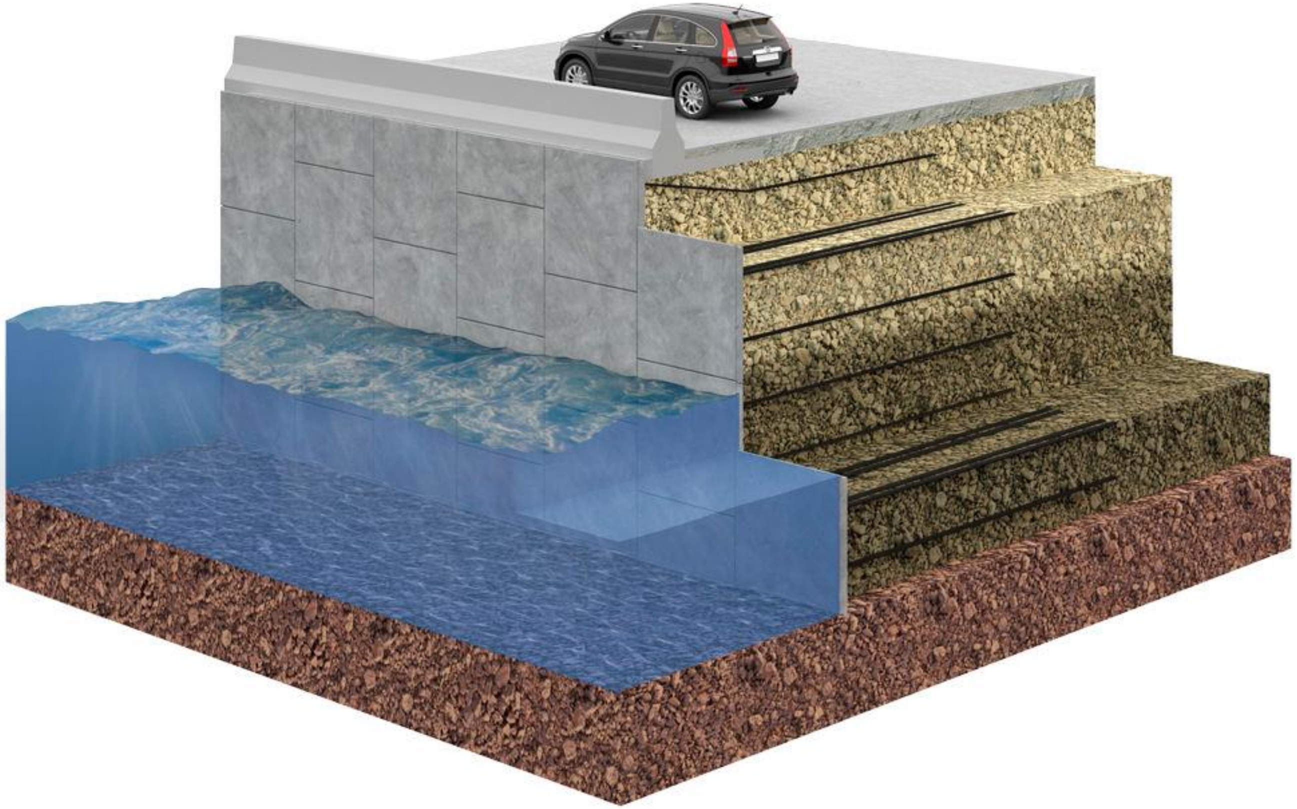
Reinforced Earth Walls



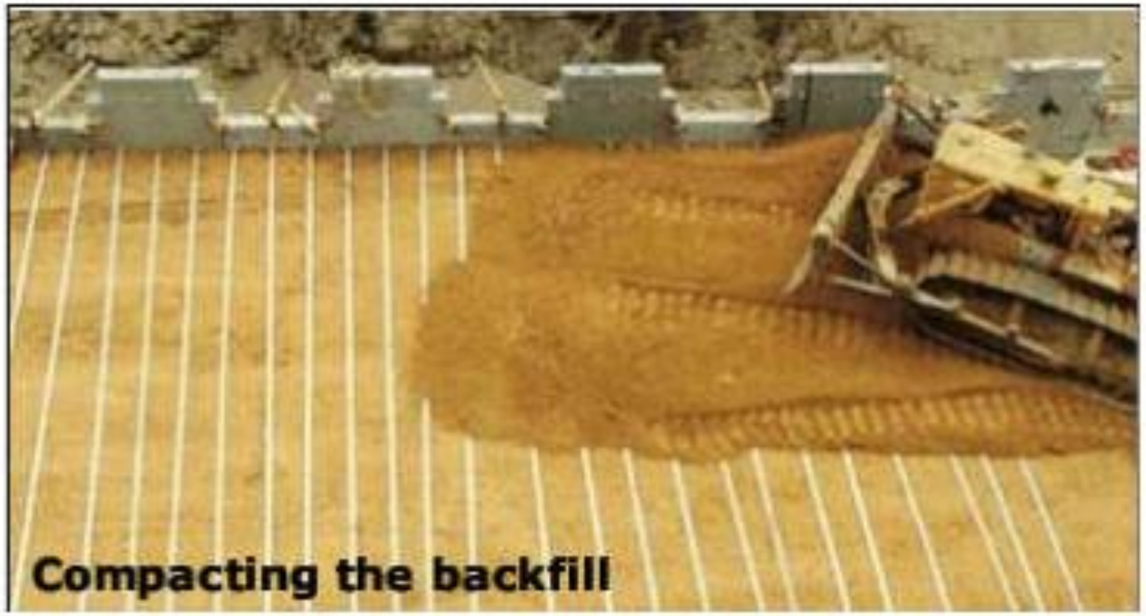


Reinforced Earth Walls

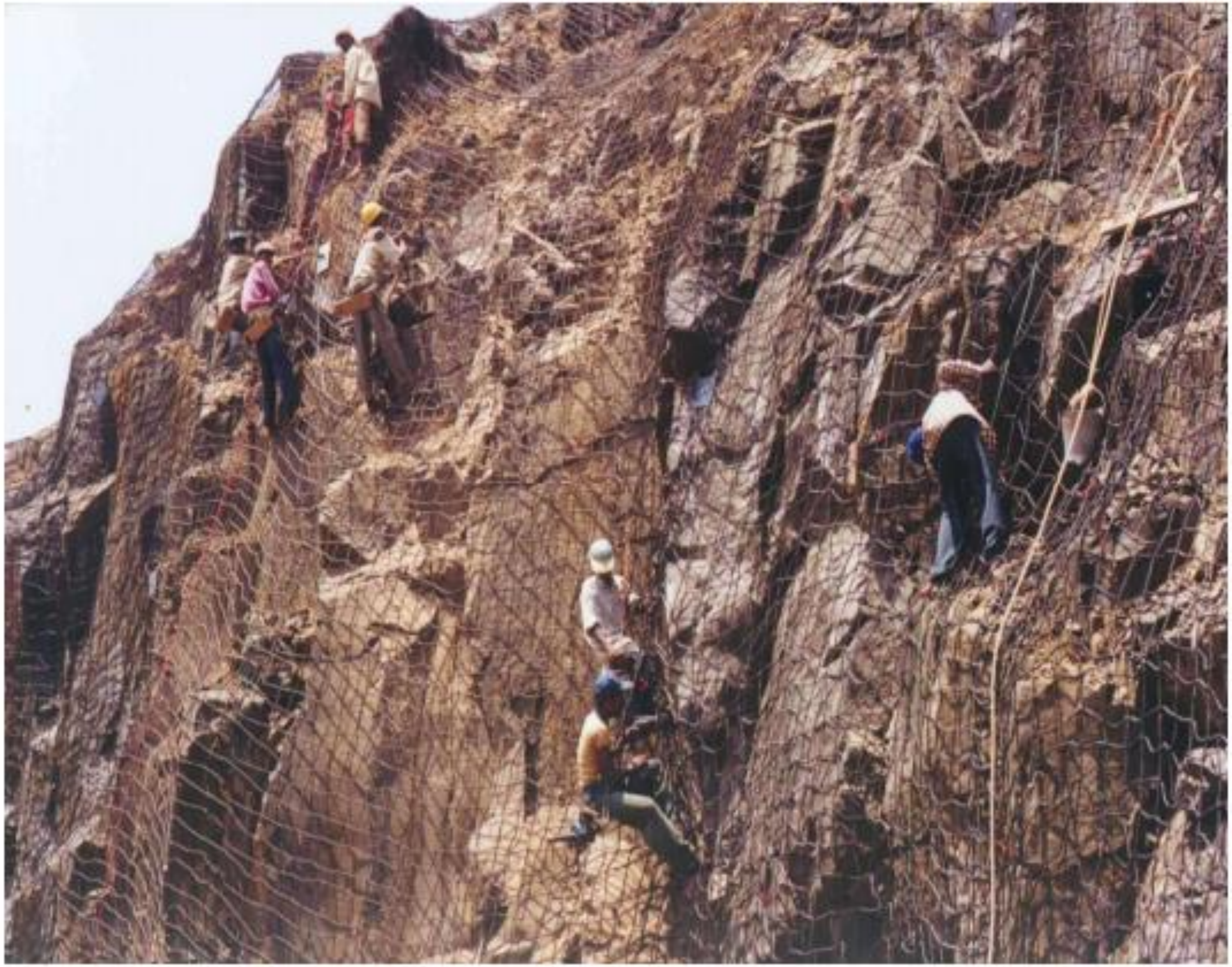
https://www.youtube.com/watch?v=HIeBFFmwis4

Installing the front facing panels

Attaching strip reinforcement to the facing panel



Compacting the backfill



COASTAL EROSION

Reinforced Soil Zone

- It should be granular, cohesion less material, not too much silt or clay having particle size not more than 125 mm.

- Plasticity Index (PI) shall not exceed 6.

- The materials shall be substantially free of shale or other soft, poor durability particles.

- The material shall have a magnesium sulfate soundness loss (or an equivalent sodium sulfate value) of less than 30 percent after four cycle.

- The fill material must be free of organic matter and other deleterious substances, as these materials not only enhance corrosion but also result in excessive settlements.

- Pea gravel (a backfill material of good quality in terms of both friction and drainage)is recommended to prevent buildup of high lateral pressures from the compaction and to prevent facing panel movement.

Benefits of MSE

Flexibility to accommodate high differential settlement and several feet of total settlement

Bearing pressure is distributed over a wide foundation area

Extreme wall heights can be achieved

Extreme loads can be carried (bridge abutment footings, cranes)

High resistance to seismic and other dynamic forces

Free-draining, due to granular backfill and open panel joints

Form liners or elaborate murals can customize the aesthetics

Soil reinforcing strips can easily accommodate obstructions within the MSE backfill volume

Very versatile. Special design can allow for nearly any geometry

Rapid, predictable, and repetitive construction

Superior finished wall alignment

Mechanical connection of soil reinforcements to facing units

Advantages of Reinforced Earth Walls

Exceptional Wall Heights

High load-carrying capacity

Structural flexibility

Fast-track construction

Minimum working area

Long-term durability

Cost effectiveness

Aesthetic appearance

Disadvantages of Reinforced Earth Walls

Non availability of suitable fill material

Suitable design criteria

- Corrosion, deterioration and degradation

Shared responsibility

Material suppliers, designers, contractors and engineers

Design and construction practice

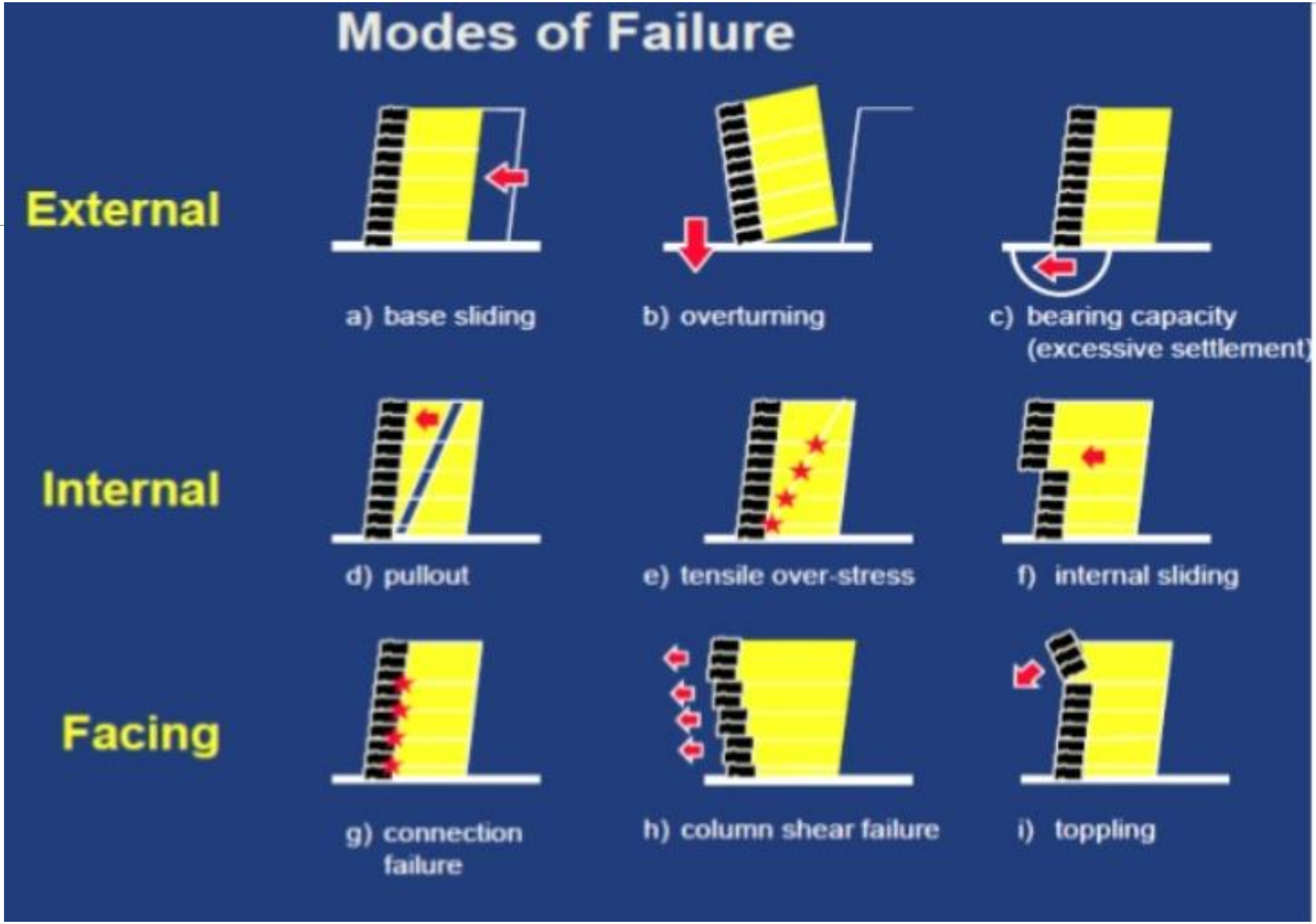
Standardization of specifications, and contracting practices

Design of Reinforced Earth Wall

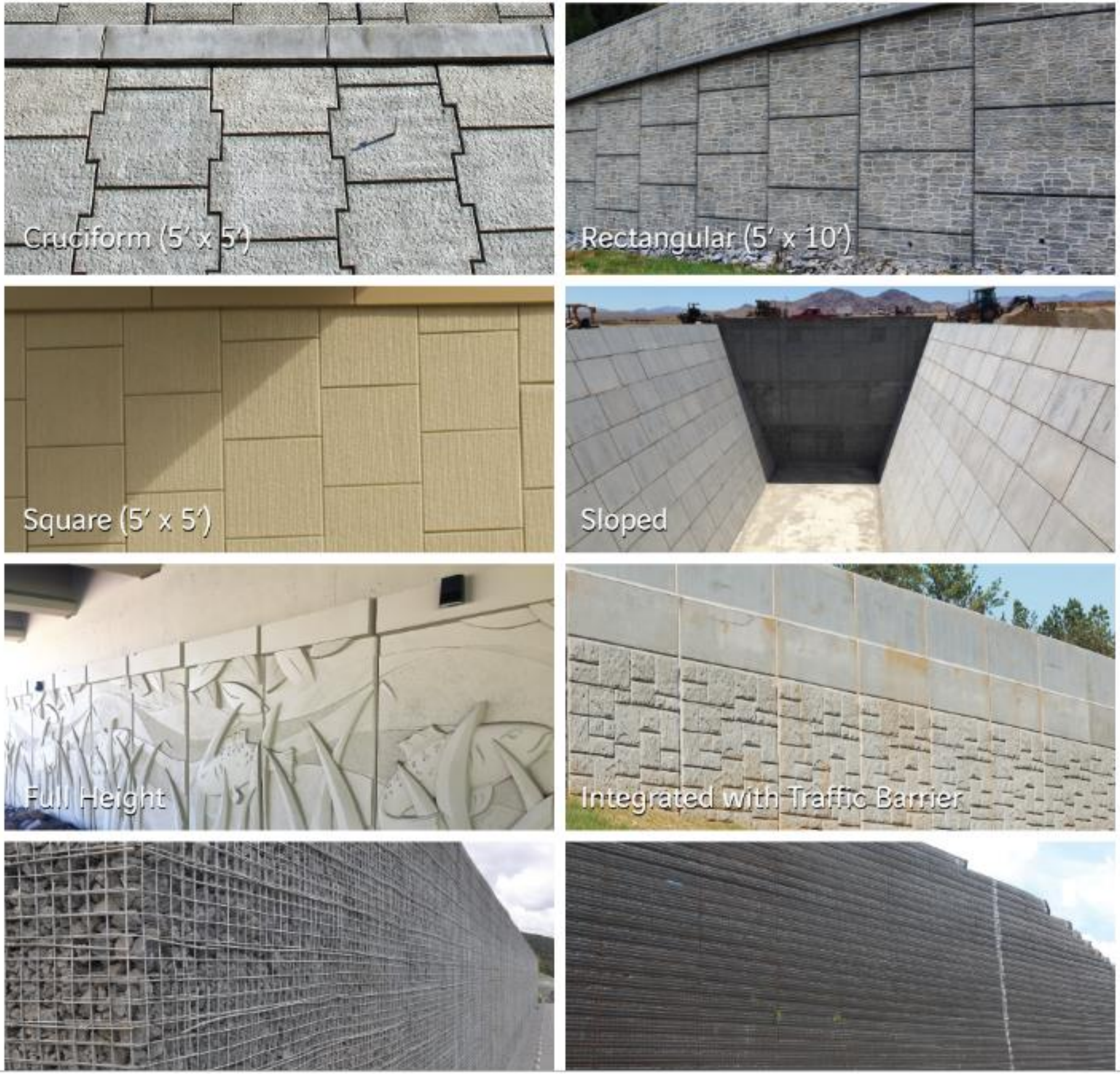
External stability : It consider the reinforced structure as whole and check the stability for sliding, overturning, bearing/tilt and slip by considering the effects of dead loads, other loads (live load, dynamic load etc.) and forces acting on the structure.

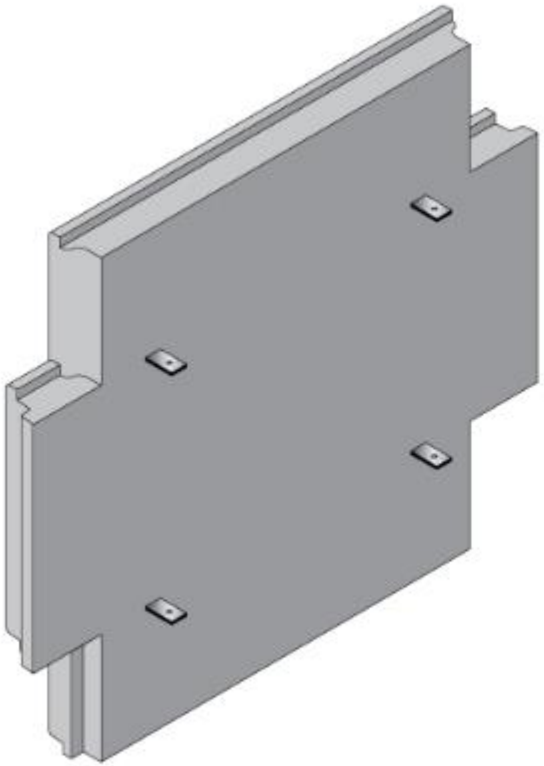
Internal stability:

It cover internal mechanism (tension and pull out failure) such as shear within the structure , arrangement and behavior of the reinforcement and backfill. It checks the stability for each reinforcement layers and stability of wedges within the reinforced fill

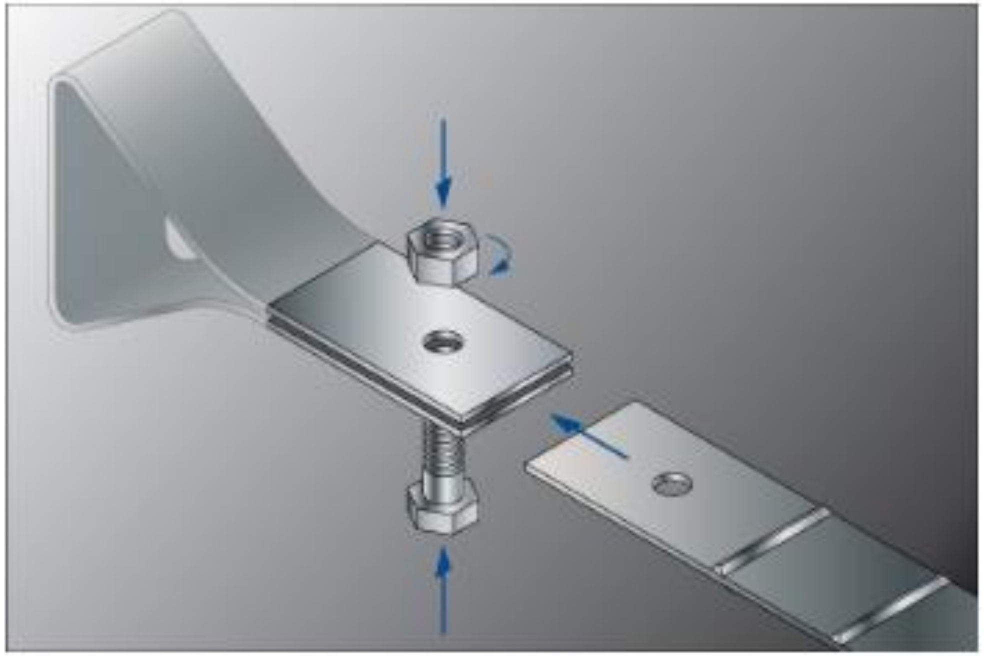

Modes of Failure
External
a) base sliding
b) overturning
c) bearing capacity (excessive settlement)
Internal
d) pullout
e) tensile over-stress
f) internal sliding
Facing
g) connection failure
h) column shear failure
i) toppling

Facing Elements





Back face of Cruciform panel with embedded tie strips.



Reinforcing strip connection at back face of panel.

	Index Properties					
GEOGRID PROPERTIES	UX1100	UX1400	UX1500	UX1600	UX1700	UX1800**
Tensile Strength @ 5% Strain (kN/m (lb/ft))	27 (1,850)	31 (2,130)	52 (3,560)	58 (3,980)	75 (5,140)	95 (6,510)
Ultimate Tensile Strength (kN/m (lb/ft))	58 (3,970)	70 (4,800)	114 (7,810)	144 (9,870)	175 (11,990)	210 (14,390)
Junction Strength (kN/m (lb/ft))	54 (3,690)	66 (4,520)	105 (7,200)	135 (9,250)	160 (10,970)	180 (12,340)
Flexural Stiffness (mg-cm)	500,000	730,000	5,100,000	6,000,000	9,075,000	9,500,000
	Load Capacity					
GEOGRID PROPERTIES	UX1100	UX1400	UX1500	UX1600	UX1700	UX1800
Maximum Allowable (Design) Strength (kN/m (lb/ft))	21.2 (1,450)	25.6 (1,760)	41.8 (2,860)	52.7 (3,620)	64.1 (4,390)	74.1 (5,080)
	Recommended Allowable Strength Reduction Factors					
GEOGRID PROPERTIES	UX1100	UX1400	UX1500	UX1600	UX1700	UX1800
Minimum Reduction Factor for Installation Damage (RF_{ID})	1.05	1.05	1.05	1.05	1.05	1.05
Reduction Factor for Creep for 120 yr design life (RF_{CR})	2.60	2.60	2.60	2.60	2.60	2.70
Minimum Reduction Factor for Durability (RF_D)	1.00	1.00	1.00	1.00	1.00	1.00

Kalınlık	ASTM D 5199	mm	0.75 - 3.00
Yoğunluk	ASTM D 1505	g/cm³	≥ 0.94
Akma dayanımı	ASTM D 6693 type IV	kN/m	12-45
Akma uzaması	ASTM D 6693 type IV	%	≥ 12
Kopma dayanımı	ASTM D 6693 type IV	kN/m	24-80
Kopma uzaması	ASTM D 6693 type IV	%	≥ 750
Yırtılma dayanımı	ASTM D 1004	N	95-380
Delme dayanımı	ASTM D 1603	N	280-1000
Oksidasyon indüksiyon zamanı (OIT)	ASTM D 3895	dk.	≥100

Malzemeler 7 - 9.5 m eninde ve 100 - 200 m uzunluğunda rulolar halinde sevk edilmektedir.