Invited Talk

CE504 Slope Stability and Retaining Structures

IIT Mandi

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Gabion Walls

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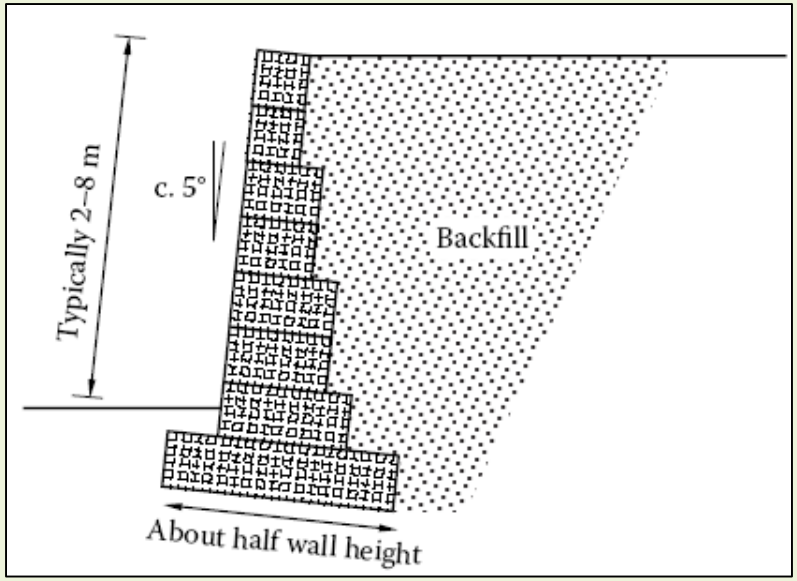
Retention Systems and Typologies

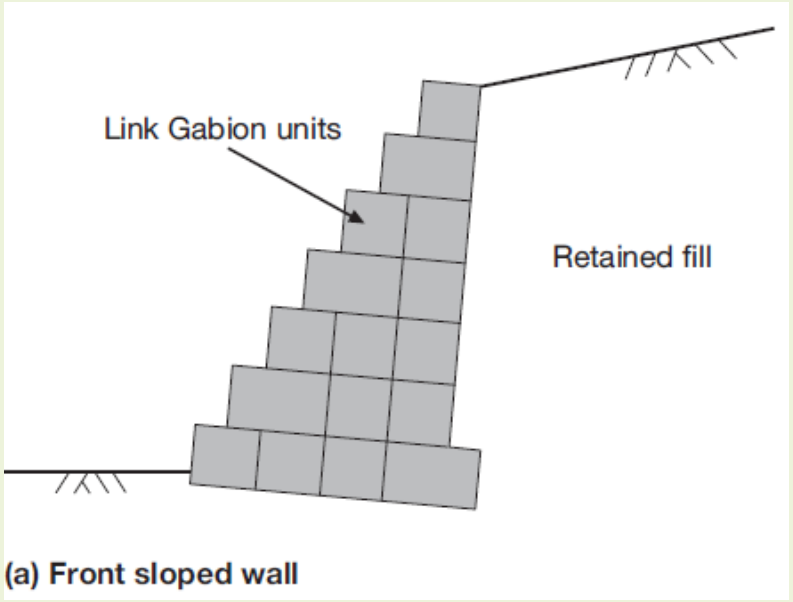
- **Retention systems**
  - Structures built to retain vertical or near vertical earth slopes and resist lateral thrusts
  - Retention of water, natural soil or fill soil
- **Rigid retention systems**
  - Masonry Retaining Walls
  - Gravity Retaining Walls
  - Semi-gravity retaining walls
- **Semi-rigid retention systems**
  - Cantilever retaining walls
  - Counterfort retaining walls
- **Embedded flexible retention systems**
  - Cantilever Sheet pile walls
  - Anchored bulkheads
  - Bored pile walls
- **Surficial Flexible Retention System**
  - Crib Walls
  - Interlocking Block / Porcupine walls
  - Gabion Walls
- **Composite Retention Systems**
  - Reinforced Soil (MSE) Walls
  - Anchored Earth Walls
  - Soil Nailed / Nailed Soil Slopes

Surficial Flexible Retention Systems

- **Gabion Wall**
  - Gabion consist of a box made of wire or plastic mesh that is used as a basic building unit
  - Filled with in-situ coarse granular material such crushed rock and cobbles
  - Advantageous for flexibility and material transportation to remote areas (only wire mesh is needed to be transported)
  - Particularly good at absorbing impact energy, and are often used as rock fall barriers
  - Possible to repair when damaged, and is recyclable and reusable

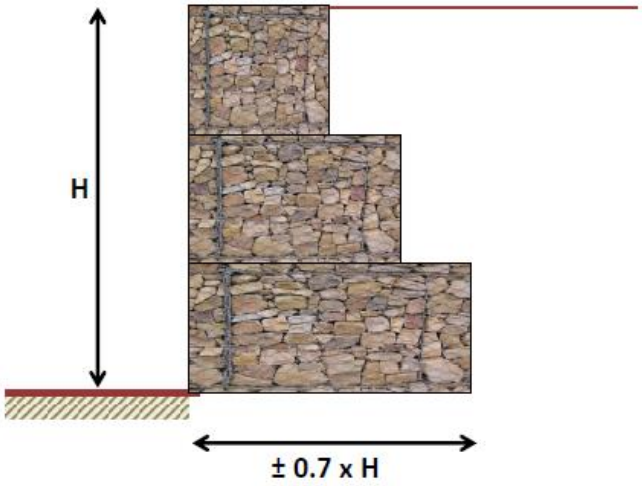


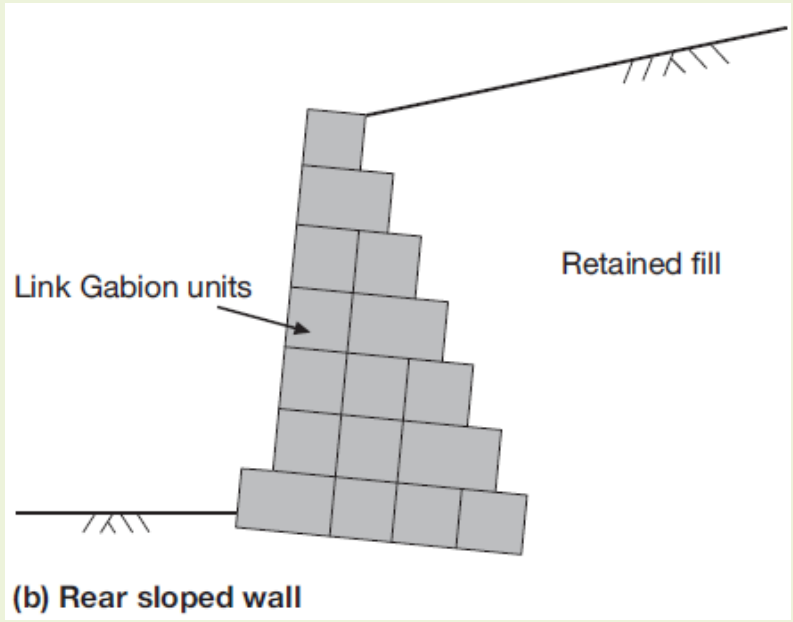
Gabion Walls



(a) Front sloped wall

Mass gravity structures *e.g. Gabions*



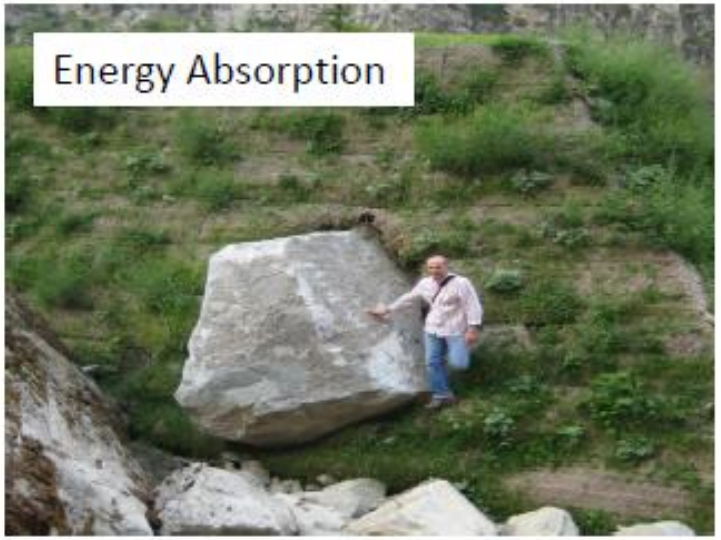


(b) Rear sloped wall

Why Gabion Systems?

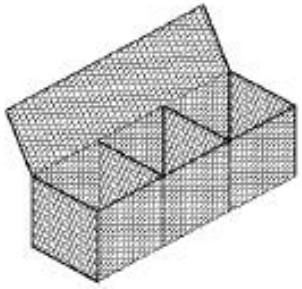
- **Flexible** – Unlike welded mesh, concrete blocks, concrete mats or reinforced concrete, double twist woven mesh Gabions & Terramesh systems are able to accommodate substantial differential settlement

Why Gabion Systems?

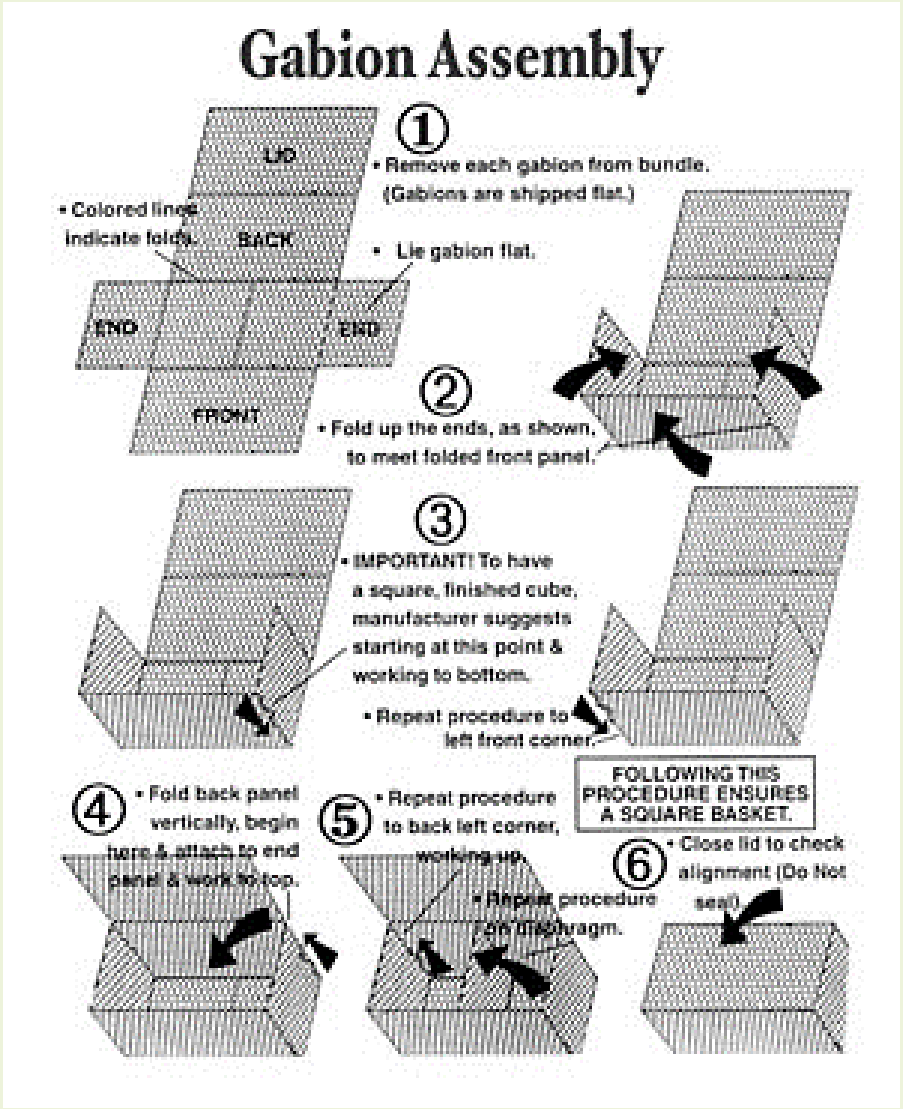


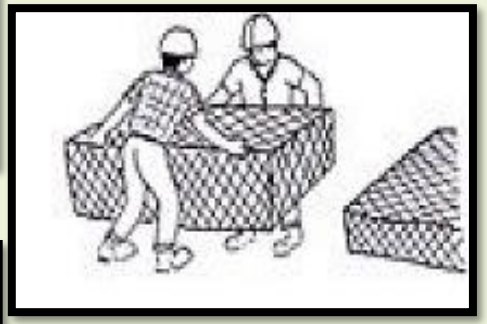
Gabions

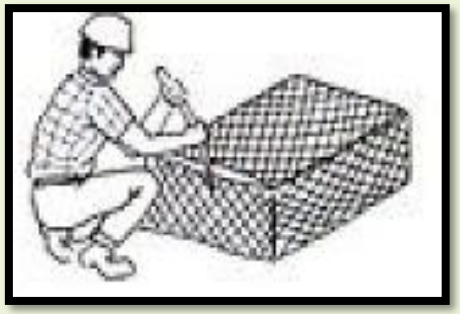
Gabions are flexible cages made of hexagonal double twist heavily galvanised mild steel woven wire mesh with an additional polymer coating if required. These units are laced together, packed with selected stone and act as building blocks. They are used in the construction of retaining walls, weirs, culvert inlet/outlet and other civil structures.



Gabion Preparation



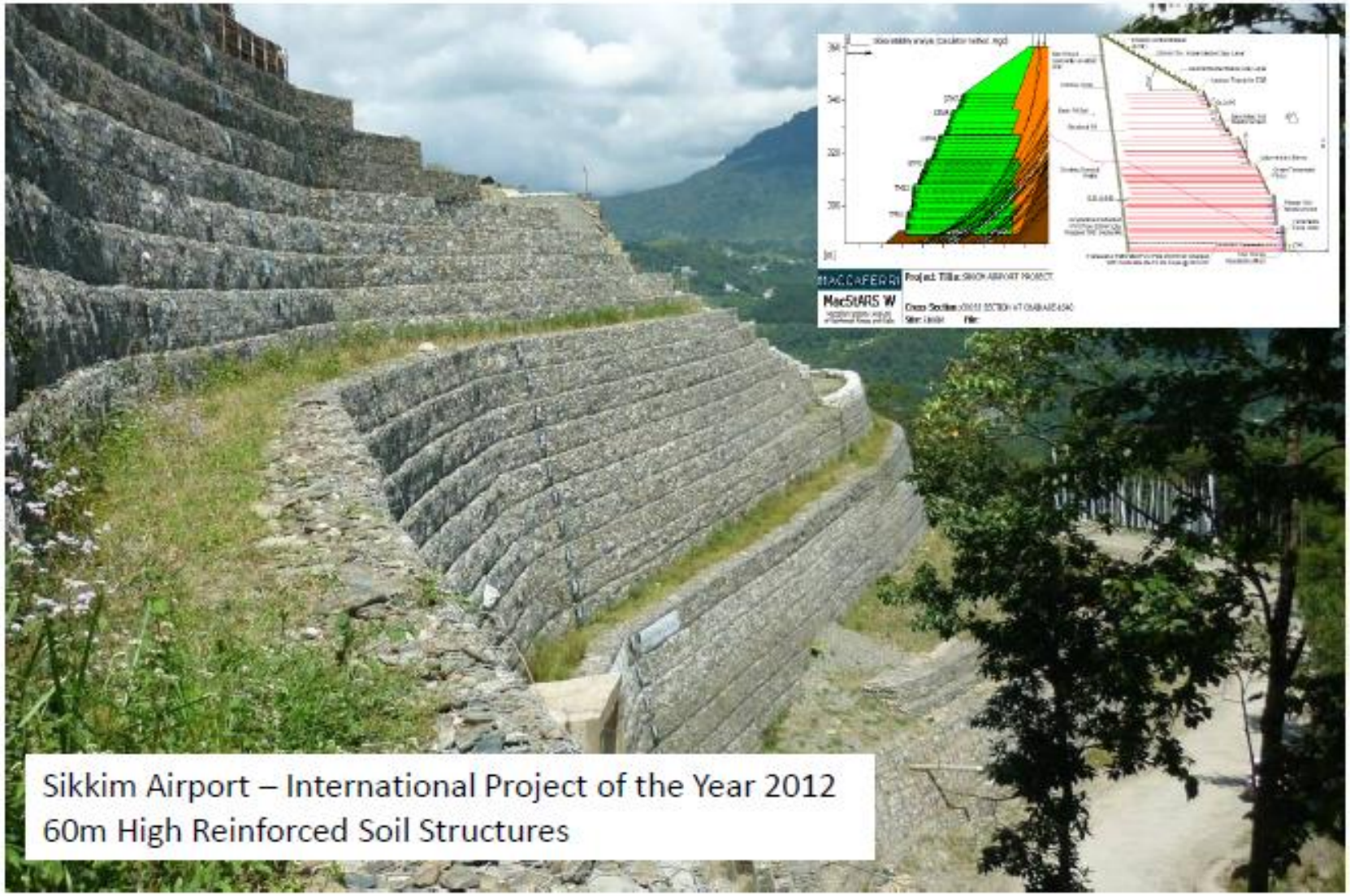




Gabion-faced Anchored Structures

Gabions are commonly used as a flexible facing to soil nailed/anchored structures. They offer all the inherent benefits of a traditional Gabion /Terramesh structure

Sikkim-Pakyong Airport



Sikkim Airport – International Project of the Year 2012
60m High Reinforced Soil Structures

Applications of Gabions









Applications of Gabions

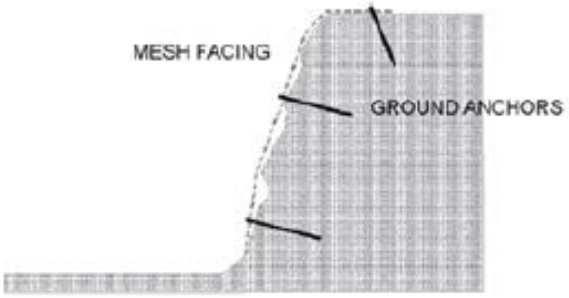
Mass Gravity Retaining Walls

Gabion Revetments

Free Standing Walls

Gabion Cladding

Rockfall Protection

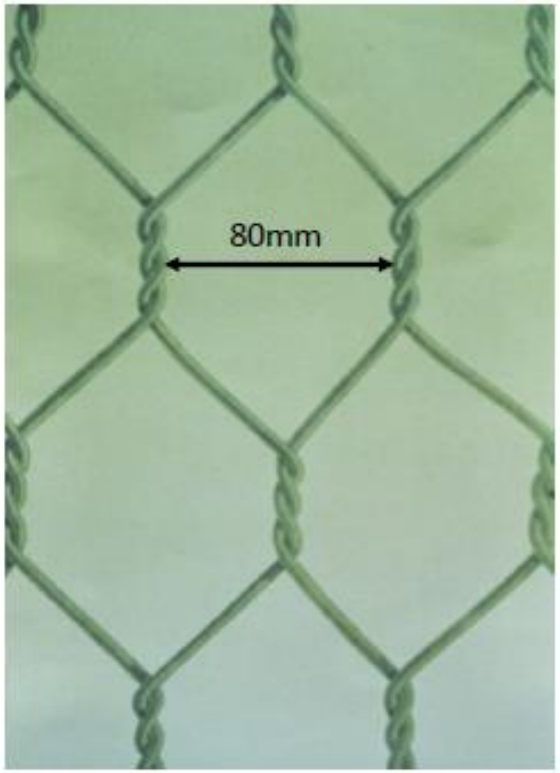


Gabion Applications-Weir Structures

Gabion: Individual System Components

Woven Mesh

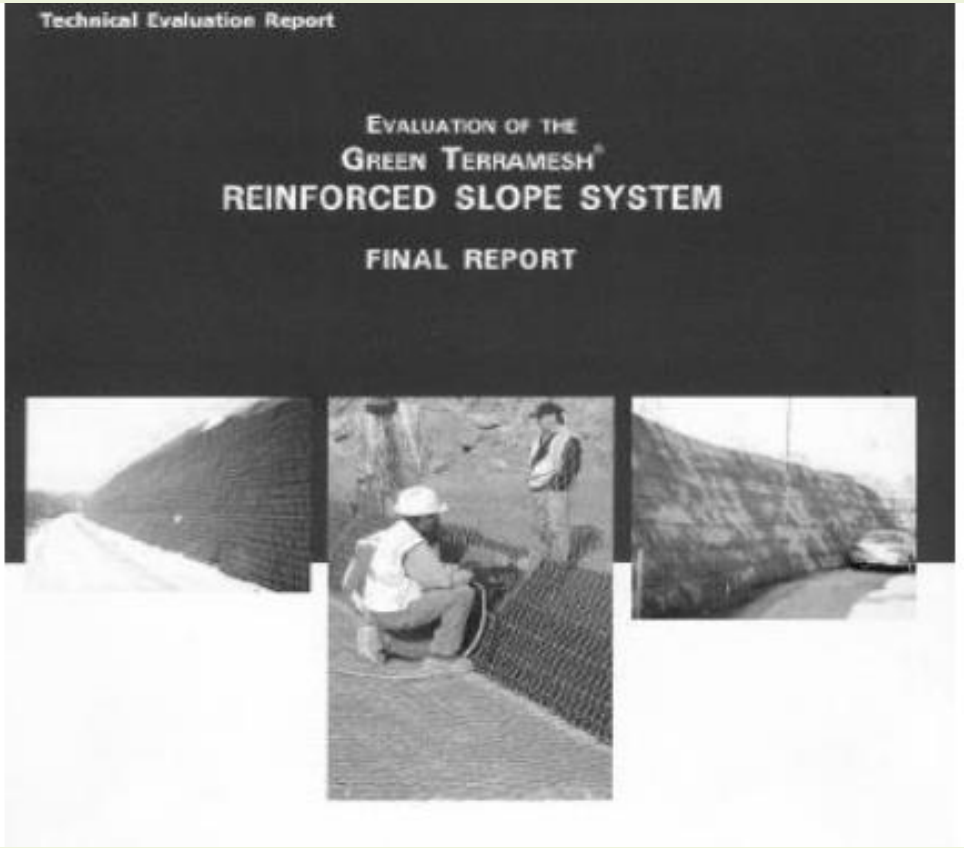
Gabions and Terramesh:
Mesh Type 80 (80 x 100 nominal)
2,7mm mesh wire (3.7mm o/d with polymer coating). Double twist for stress transfer around a wire breakage



Gabion: Individual System Components

Woven Mesh

Mesh selection tools are available depending on the required working life: BBA certificate, EN 10233-3, ASNZS 4534 technical specification, HITEC report and independent test certificates



Gabion: Individual System Components

Geotextile Separator

A geotextile will not perform its function if it is damaged and it's proven that they incur the most damage during installation

If they can withstand installation damage, they generally withstand the in service stresses

We recommend a minimum strength class C (e.g. Bidim A34) be used with mesh systems. It has the required energy absorption (installation damage resistance), permeability and is sufficiently abrasion resistant

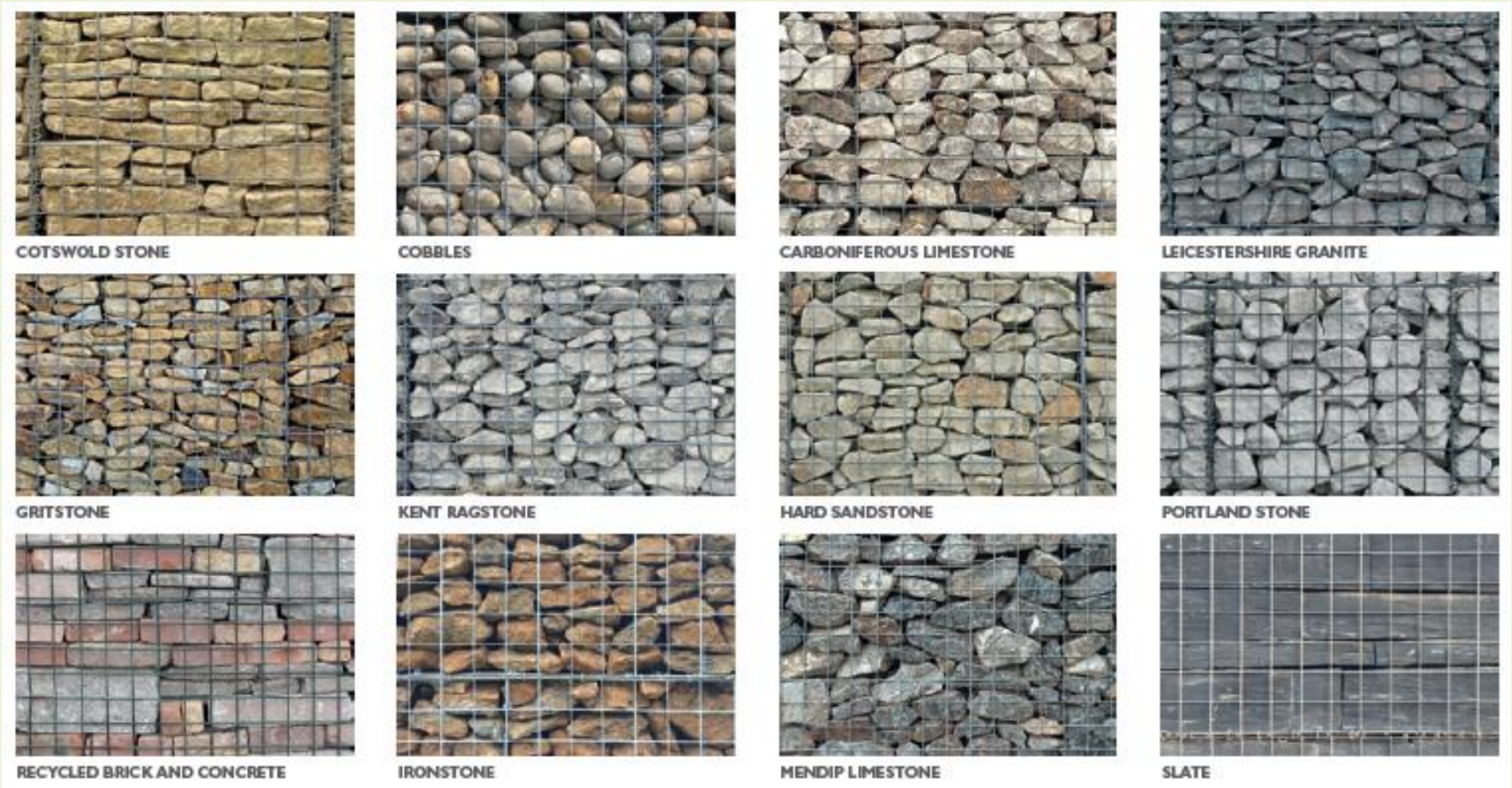
Gabion: Individual System Components

Rock Fill

Rock must be clean, sufficiently durable, non friable and not show any signs of weathering (AS 2758.4 – 2000)
The rock should be evenly graded between 1.5D to 3D (Between 100mm and 250mm normally suffices) and be angular to provide interlock

Type of rock	kg/m³	Suitability
Basalt	2900	Considered Acceptable
Granite	2600	
Hard Limestone	2600	
Calcareous Pebbles	2500	
Dolerite	2400	
Hard Sandstone	2300	Needs further checks
Soft Limestone	2200	

Gabion: Individual System Components



Gabion: Individual System Components

Foundation

The foundation should be:

- Stripped of topsoil/organic material
- Level and compacted
- Sloped if constructing an angled wall
- If on smooth bedrock or concrete, advisable to incorporate shear keys to minimise sliding issues

We want to ensure:

- Uniform foundation pressure
- Minimal differential settlement

Gabion: Individual System Components

Backfill

Compacted in lifts to the required effort as per the specification

- Heavy compaction equipment not closer than 1-1.5m to back of structure
- Walk behind compaction equipment directly adjacent to structure
- Take care not to damage the mesh or geotextile
- Backfill immediately after completing one layer of Gabions/Terramesh

Failure of Gabion Systems

Failures happen, HOWEVER the majority of them are avoidable

Failures are typically as a result of:

- Incorrect products/materials
- Poor designs & inadequate design information
- Sub-standard installation/construction techniques
- Inexperienced supervision
- System misconceptions

Failure of Gabion Systems

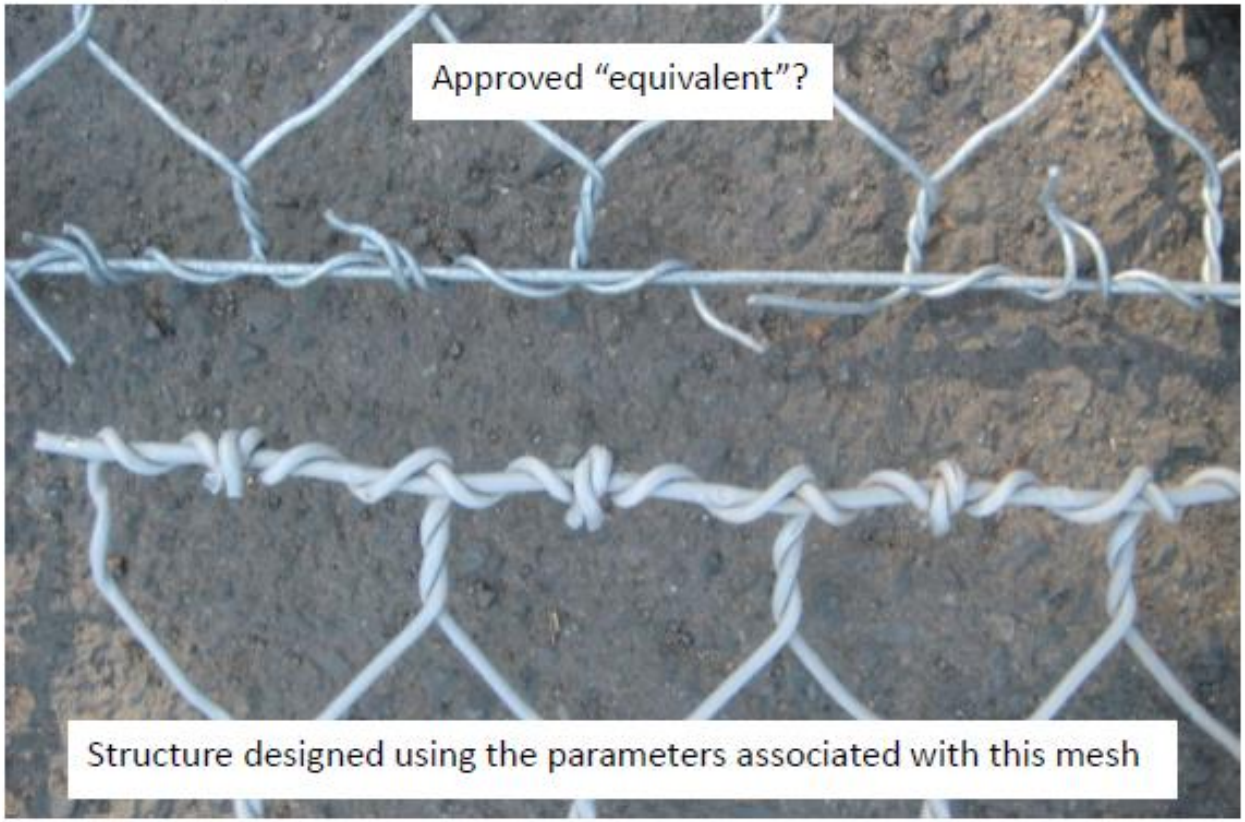
Issues With System Components

Welded Mesh

Failure of Gabion Systems

Issues With System Components

Poor Quality Woven Mesh



Failure of Gabion Systems

Issues With System Components

Wrong grade / type of geotextile

Failure of Gabion Systems

Issues With System Components

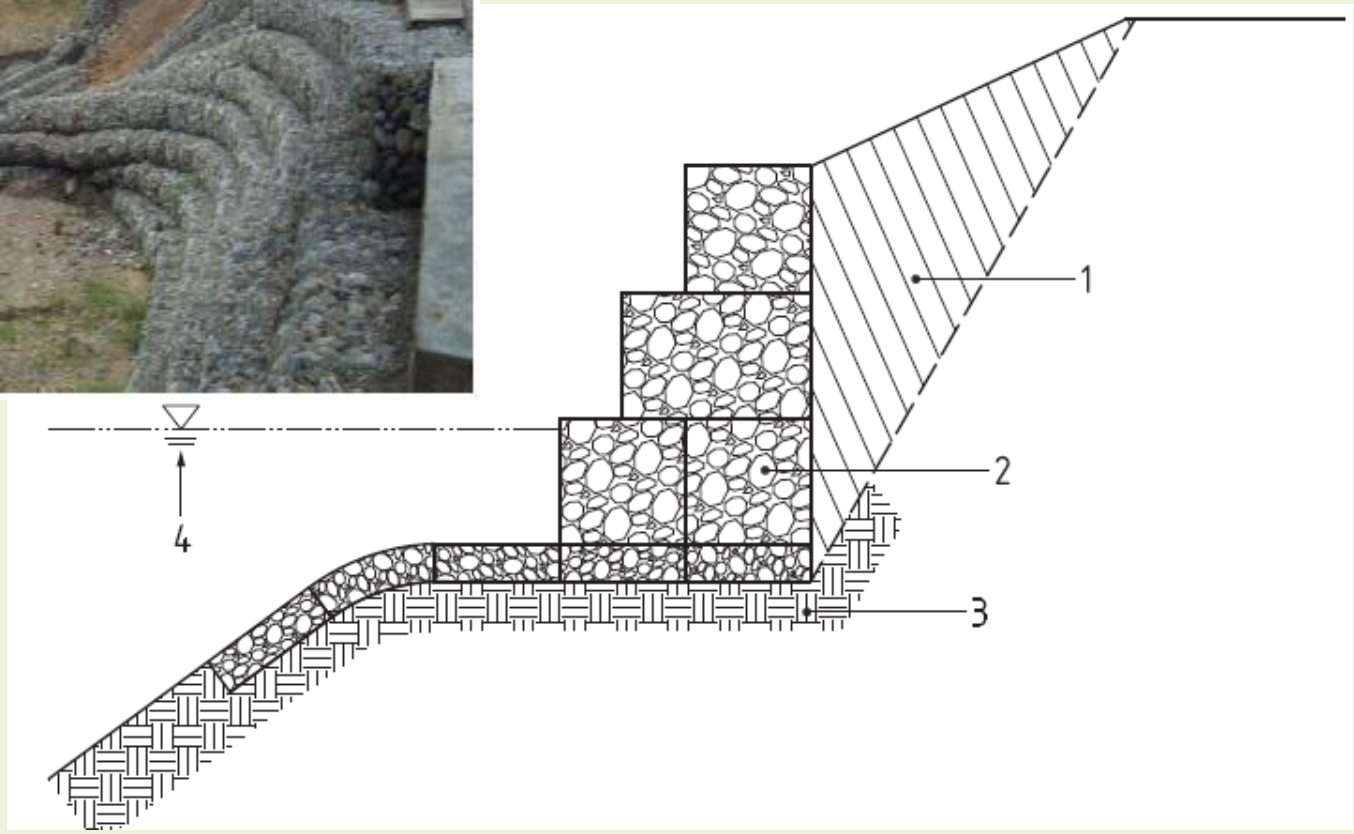
Incorrect Rock Fill Grading – too small and too big

Failure of Gabion Systems

Issues With Design Details

Inadequate scour protection

Failure of Gabion Systems



Failure of Gabion Systems

Issues With Design Details

Outflanking

Failure of Gabion Systems

Issues With Design Details

Insufficient embedment

Failure of Gabion Systems

Issues With Design Details

No geotextile separator

Failure of Gabion Systems

Issues With Design Details

Poor foundation preparation

Failure of Gabion Systems

Issues With Design Details

Drainage behind the reinforced block

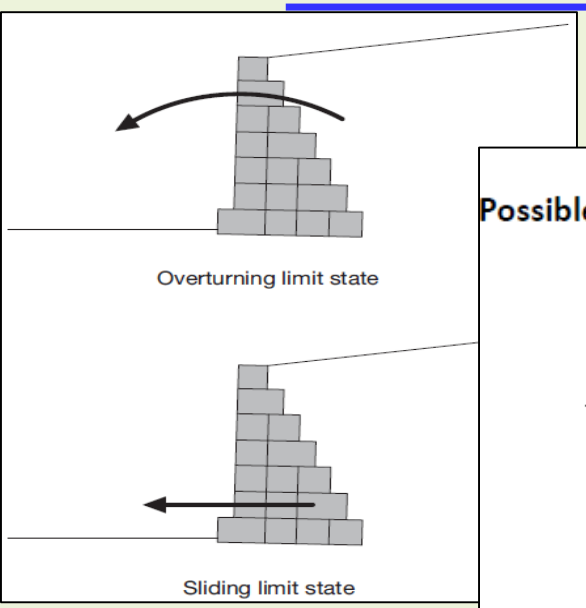
Failure of Gabion Systems

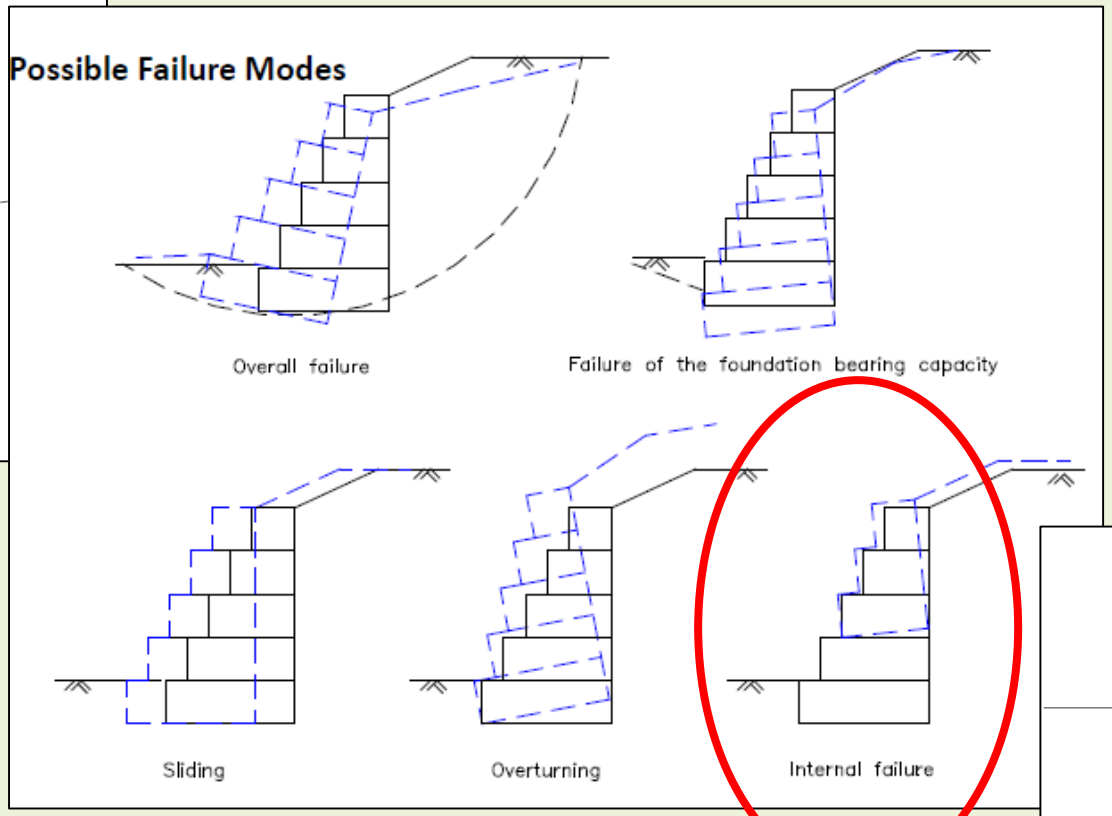
Issues With Design Details

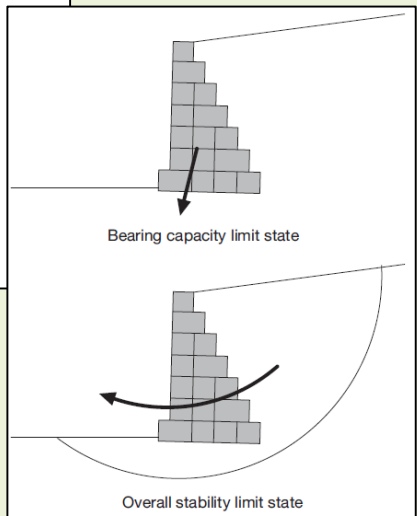
Poor construction techniques and lack of experienced site supervision

Make sure the tender specification states that the contractor must have the necessary experience to carry out the installation

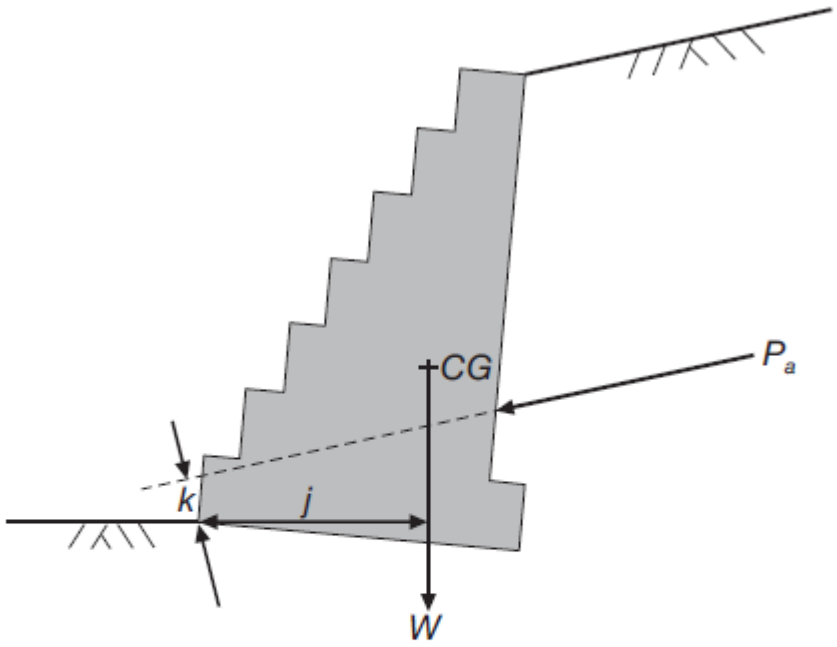
Possible Failure Modes of Gabion Systems







Stability against Overturning



Taking moments around the front toe of the wall,

$M_r \geq F_{so} M_o$

where,

$M_r = W.j$ = restoring moment due to weight of the wall,

$M_o = P_a.k$ = overturning moment due to active earth pressure acting on the wall,

F_{so} = factor of safety with regard to overturning (= 1.5).

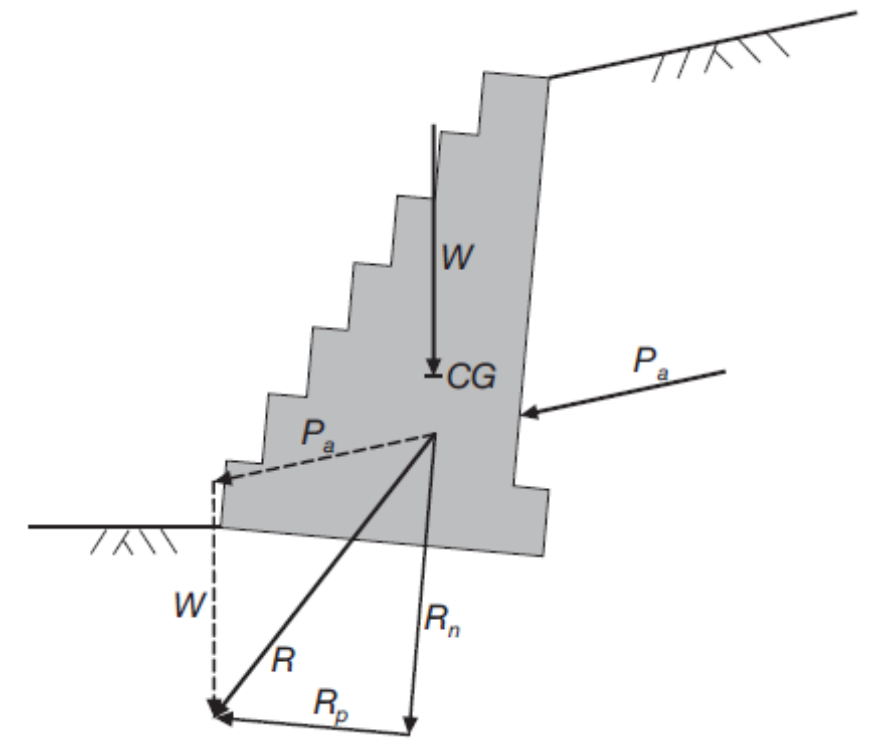
$$W = (1-\nu)\,\gamma_s\,A \quad (1)$$

where, W = the weight of the wall per metre run, ν = the void ratio of the wall rock infill (approximately 0.35), γ_s = the unit weight of the wall rock infill (see Table 7), A = the cross sectional area of the wall.

Table 7- Unit weight of gabion rock infill.

Type of rock infill	Unit weight γ_s (kN/m^3)
Basalt	27
Granite	26
Hard limestone	26
Calcareous pebbles	23
Sandstone	23
Soft limestone	22
Tuff	17

Stability against Sliding



Summing vertical and horizontal forces normal to and parallel to the base of the wall,

$R_n f \geq F_{ss} R_p$

where,

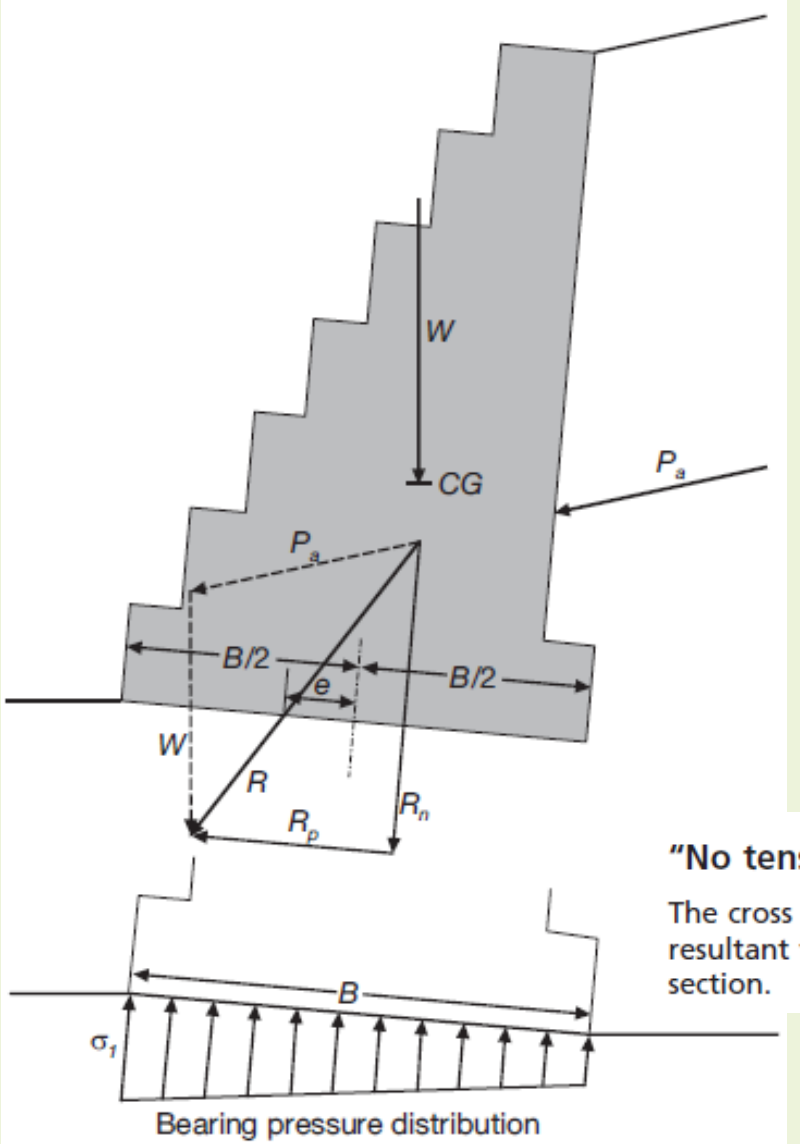
R_n = component of the resultant force R normal to the base of the wall,

f = coefficient of friction at the base of the wall (= tan ϕ', where ϕ' = friction angle of foundation soil),

R_p = component of the resultant force R parallel to the base of the wall,

F_{ss} = factor of safety with regard to sliding (=1.5).

Stability against Bearing Failure



To ensure no bearing failure,

$$\frac{q_u}{F_{sb}} \geq \sigma_1 = \frac{R_n(B+6e)}{B^2}$$

where,

q_u = ultimate bearing capacity of foundation,

F_{sb} = factor of safety against bearing failure (= 2.5),

σ_1 = maximum bearing stress on foundation,

R_n = resultant force normal to base of wall,

B = width of base of wall,

e = eccentricity of resultant force R.

"No tension" criterion for bearing pressure

The cross section of a gabion or crib wall should be proportioned so that the resultant force at any horizontal section lies within the middle third of that section.

Gabion-Soil Interface Friction

- **BS 8002**

5.4.2.1 Owing to their surface roughness, the design angle of interface friction, δ_d, between the rear of a gabion wall and the retained ground should be limited to:

$$\delta_d \leq k_{membrane} \times \varphi'_d \qquad (27)$$

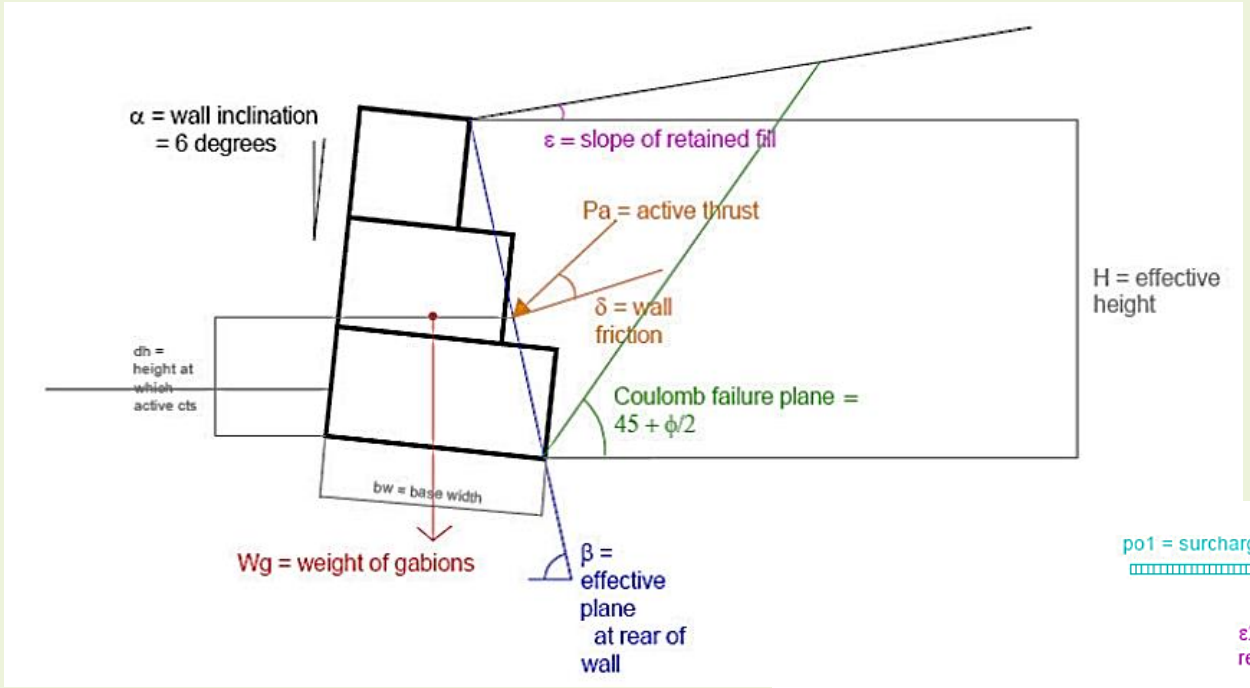
where:

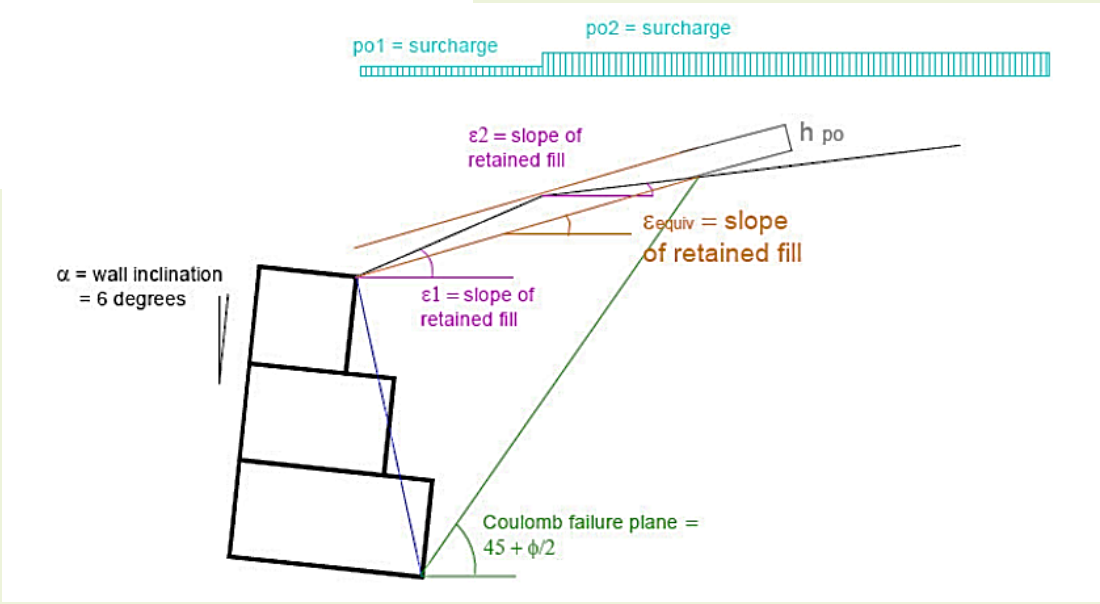
φ'_d is the design peak angle of shearing resistance of the ground; and

$k_{membrane}$ is a factor that accounts for the reduction of friction caused by the presence of a membrane placed against the rear face of the gabion wall.

5.4.2.2 For geotextile membranes, in the absence of reliable test data, the value of $k_{membrane}$ should be taken as 0.75 where the rear face of the wall is planar; otherwise it may be taken as 1.0. For other types of membrane, $k_{membrane}$ should be determined from test data.

Complex Crest Geometries





Codes to Follow

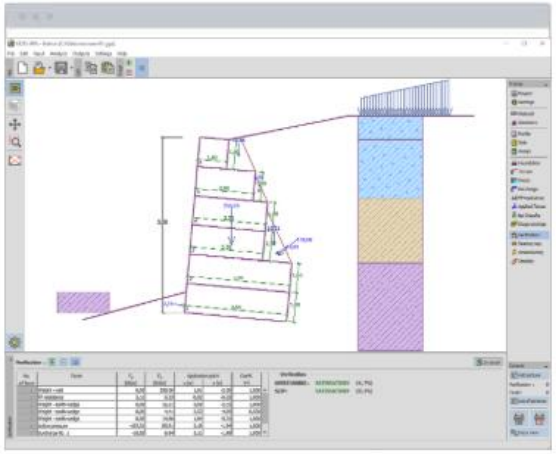
- **BS 8002: 2015**
  - Code of Practice for Earth Retaining Structures
    - Sections 5.1.4, 5.3.3, 5.4, 5.5, 5.6, 5.10.4,

- **BS EN 10223-8:2013**
  - Steel wire and wire products for fencing and netting
  - Part 8: Welded mesh gabion products

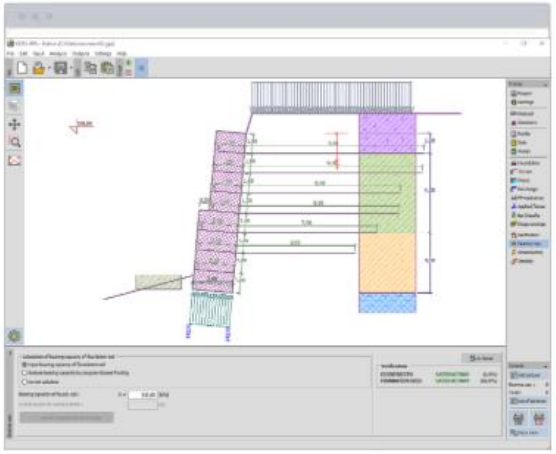
- **IRC: SP116 (2018)**
  - Guidelines for the Design and Installation of Gabion Structures
    - Gabion-Faced MSE Wall
    - Gabion Wall
    - Gabion Revetment Structures

Software

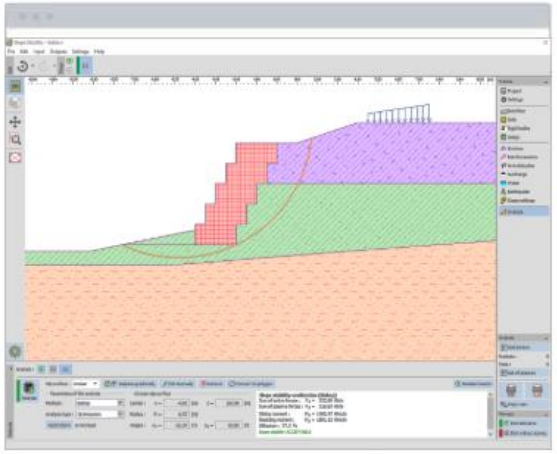
- **GEO5 Gabion Module**
  - https://www.finesoftware.eu/geotechnical-software/gabion/



Overturning and slip verification



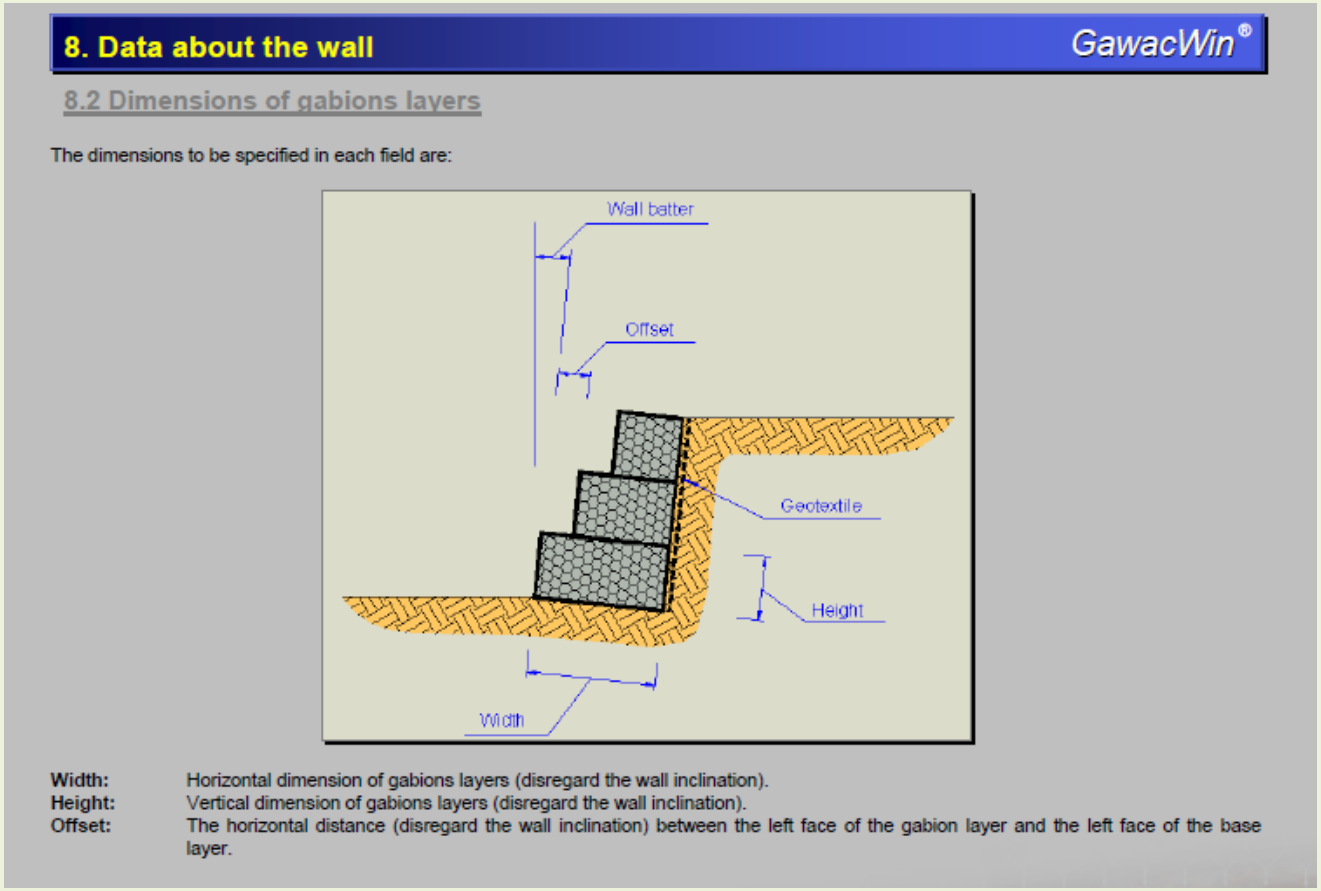
Bearing capacity verification



Global stability verification

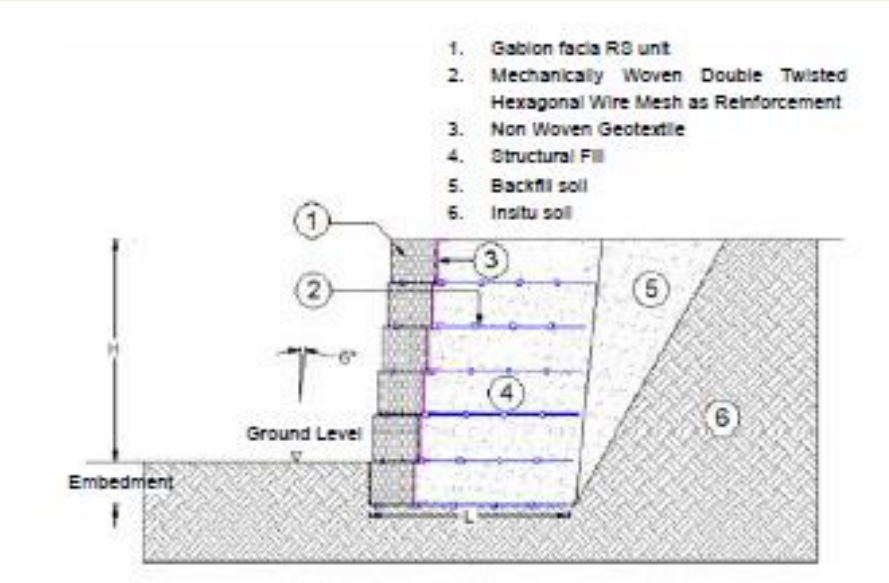
Software

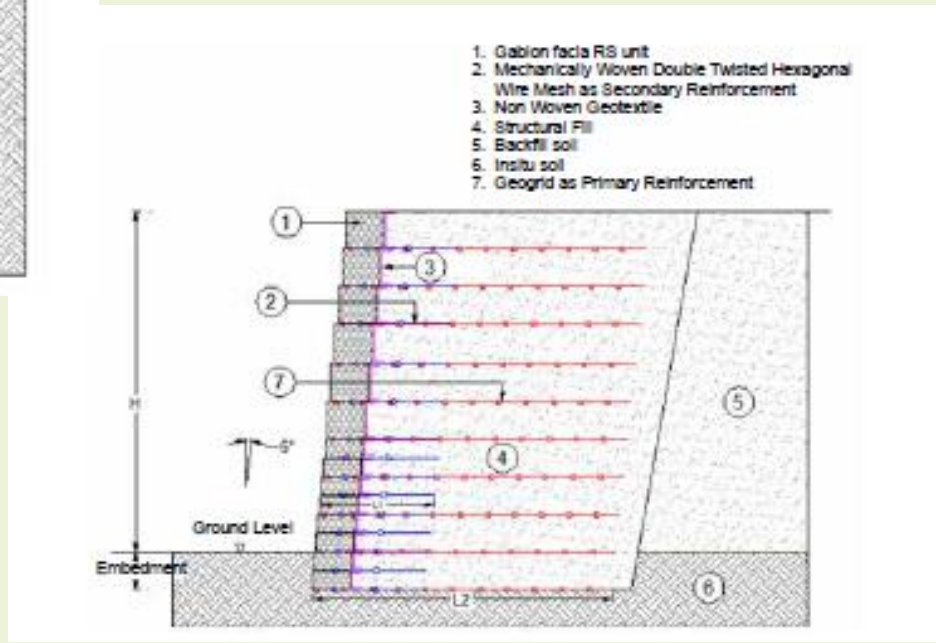
- **GAWAC – Maccaferri Software Design Suite**
  - https://www.maccaferri.com/maccaferri-software/
  - https://www.maccaferri.com/download/gawac/



Presence of Gabion – Gabion wall???

- **Gabion Facia MSE Wall**
  - Theory of MSE Wall





Gabion Wall or Gabion-Fascia MSE Wall?

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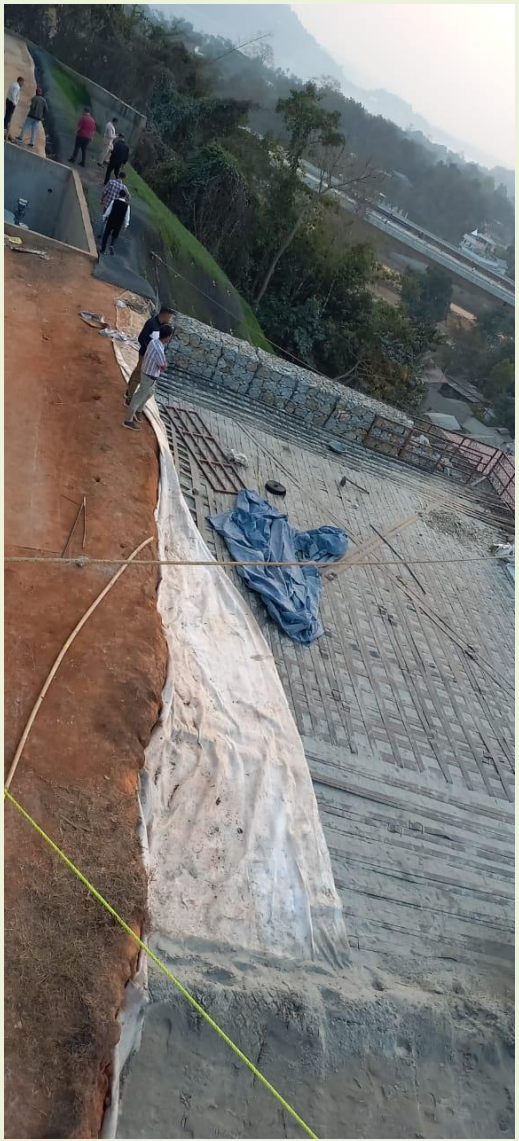

Gabion Wall or Gabion-Fascia MSE Wall?

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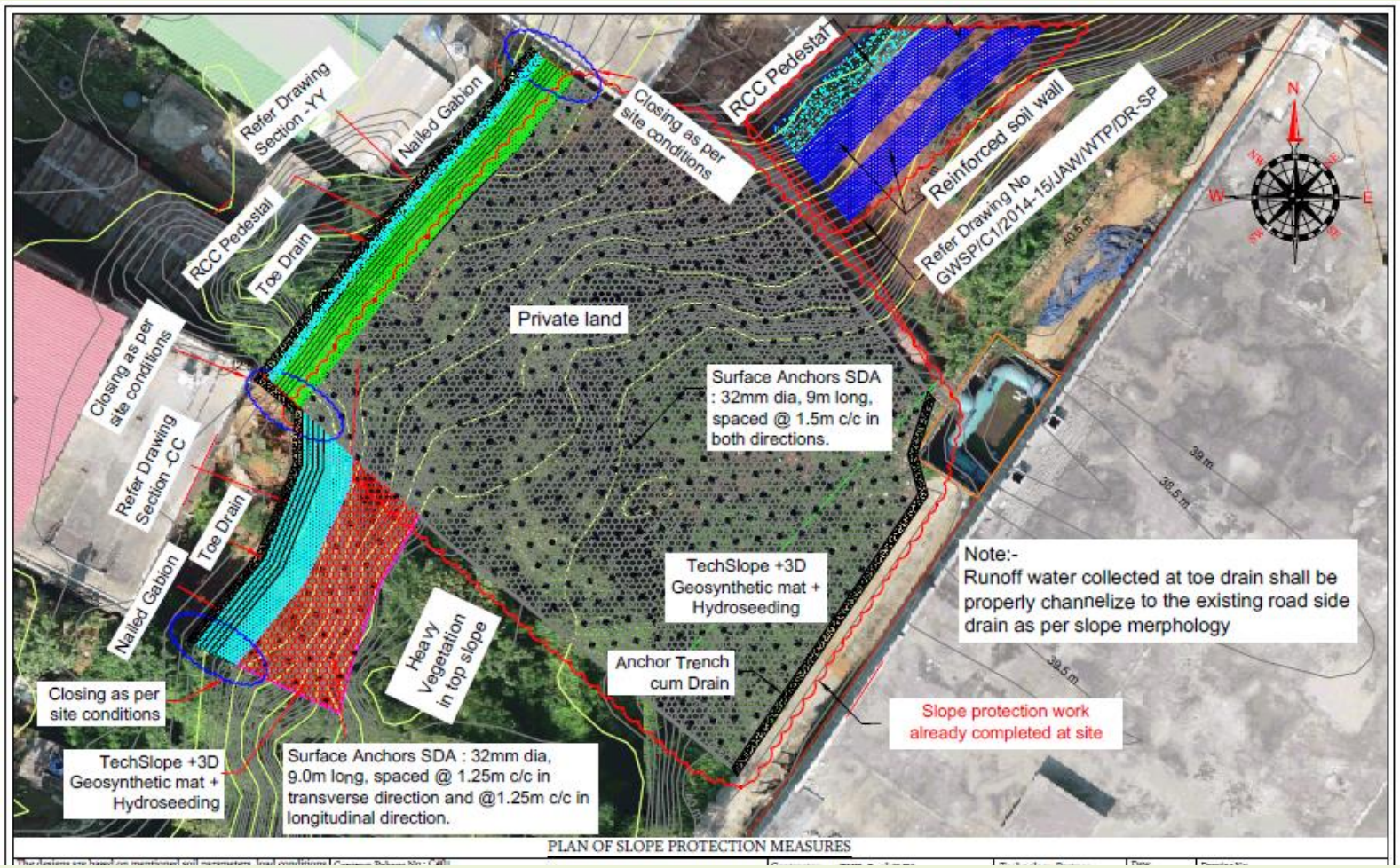
- **Nailed or Anchored Gabion Structure**
  - Theory of Reinforced Slopes



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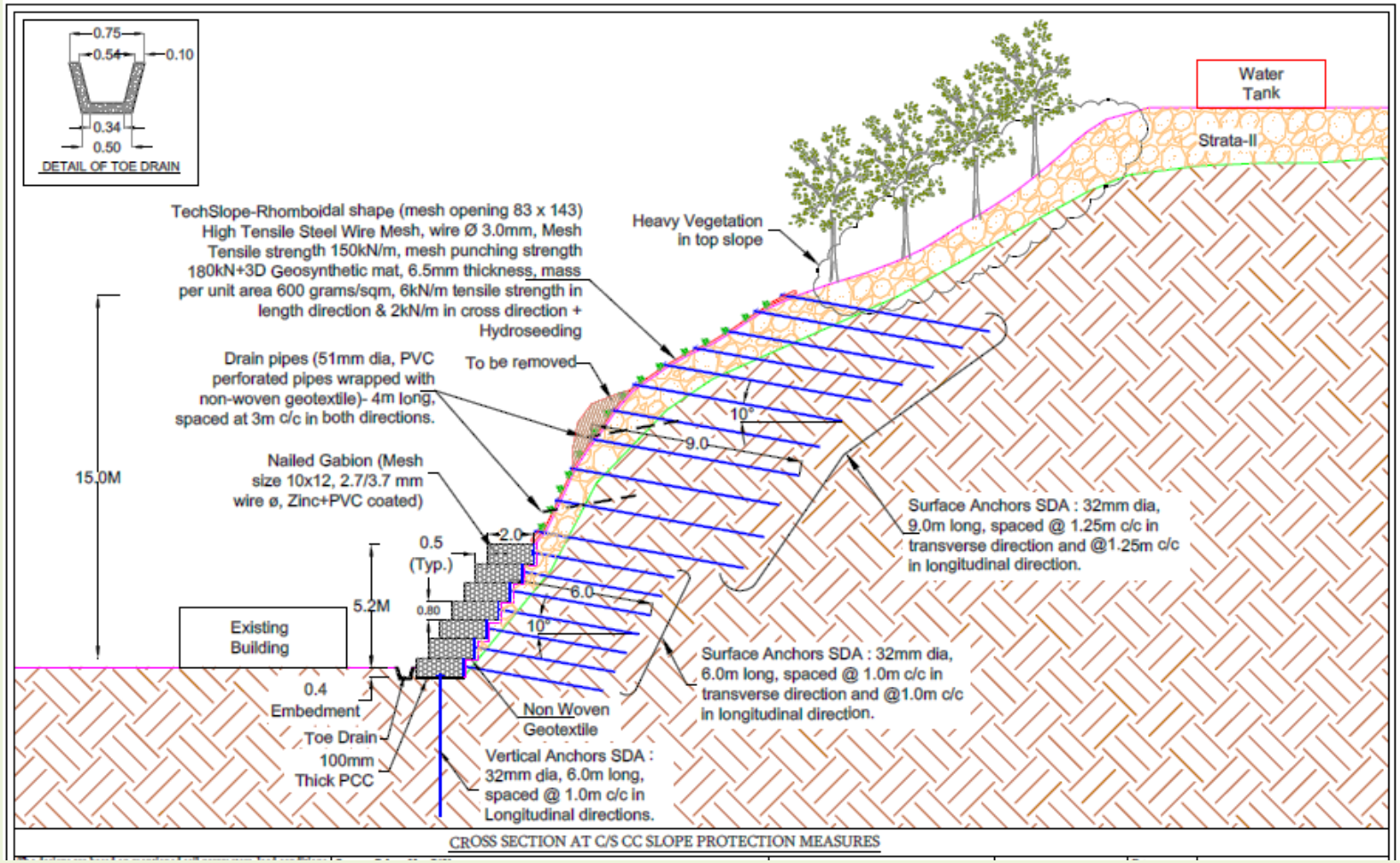

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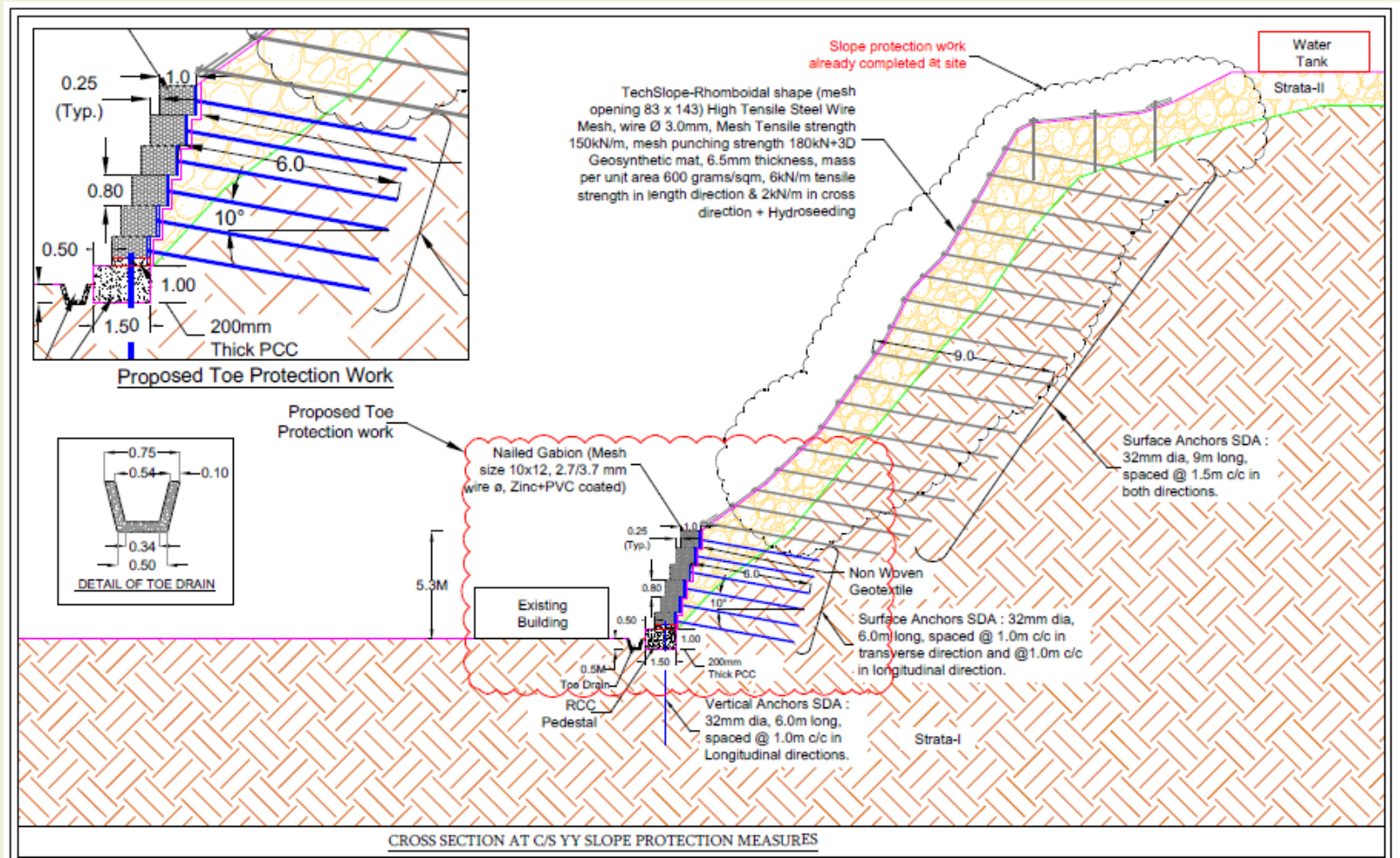

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Thank You for Patient Hearing

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