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TALK PROGRAMME
ON
REINFORCED SOIL STRUCTURES
IN
EMBANKMENTS
FOR
NEPAL ENGINEERS ASSOCIATION

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For 135 years, Officine Maccaferri has researched, designed and developed solutions to solve problems related to the Civil Engineering and Construction Market.

Officine Maccaferri's worldwide headquarters are located in Bologna, Italy. The Company has on-the-ground operations in almost 100 countries worldwide and employs 2,181 people.

The Company promotes the most sophisticated high-quality products – including woven hexagonal wire mesh steel products, geosynthetics, fibers – on all five continents.

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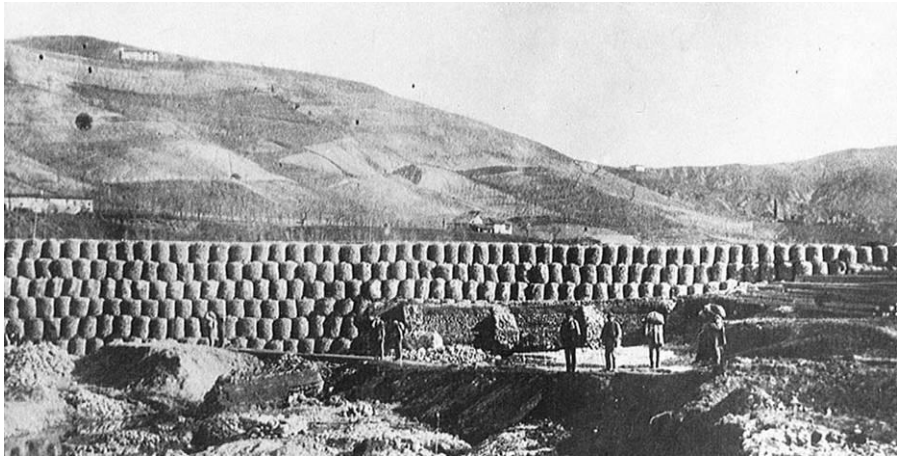
Maccaferri successfully used mechanically woven gabions to protect Reno river bank



1894
BANK PROTECTION ALONG RIVER RENO
IN CASALECCHIO, ITALY

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ORGANIZATION AND STRUCTURE

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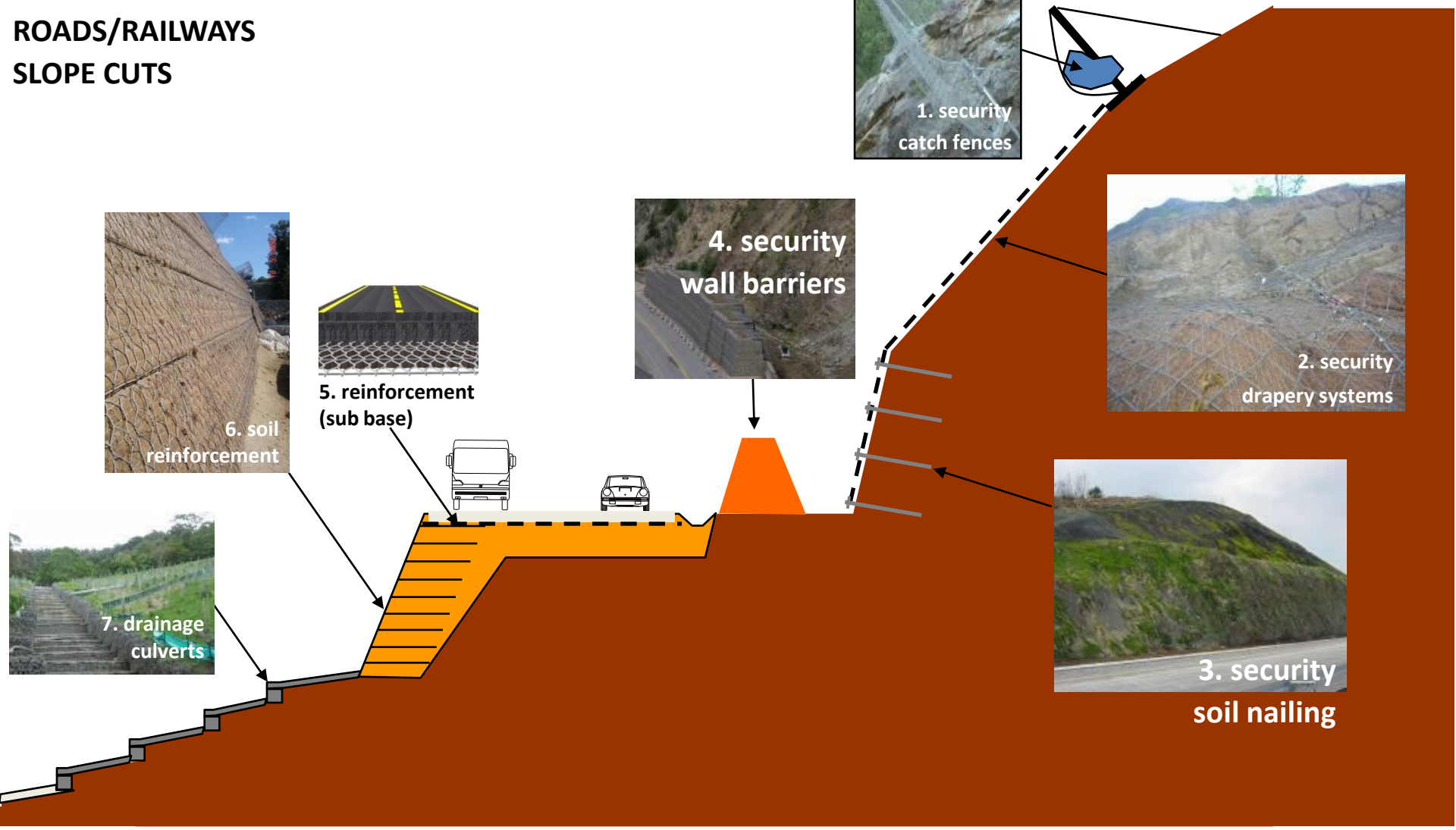
APPLICATION SECTORS	SOLUTIONS
Hydraulic	River Training in Longitudinal and Lateral Structures, Wave Energy Reduction, Beach Nourishment
Geotechnical	Retaining Wall Systems & Slope Stabilization, **Reinforced Soil Wall Application**, Rockfall protection, Landfills & Soil Conservation.

Total Solution: Hill Roads….

ROADS/RAILWAYS
SLOPE CUTS



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RETAINING STRUCTURES

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RETAINING STRUCTURES

RIGID

- Concrete
- Masonry

FLEXIBLE

- Gabions
- Reinforced Soil Structures

DRY WALL AND EARTHEN EMBANKMENT

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REINFORCED SOIL STRUCTURES

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SOIL REINFORCEMENT

Basic Principles: Reinforced Soil

- Soil is strong in compression (when confined) but weak in tension

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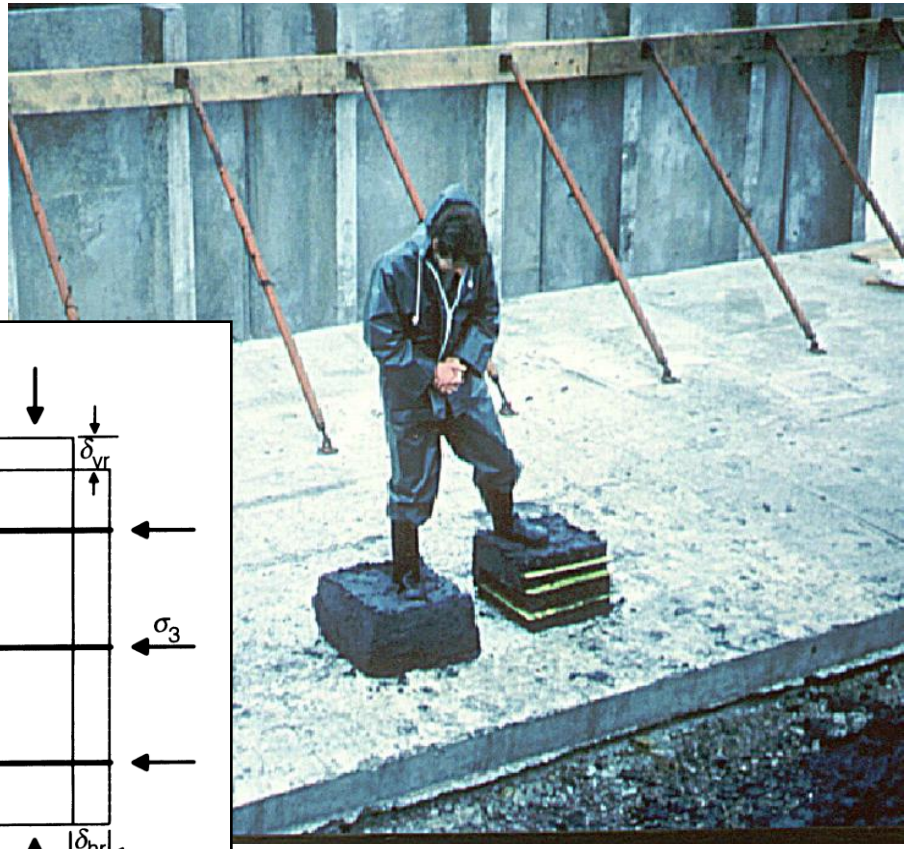
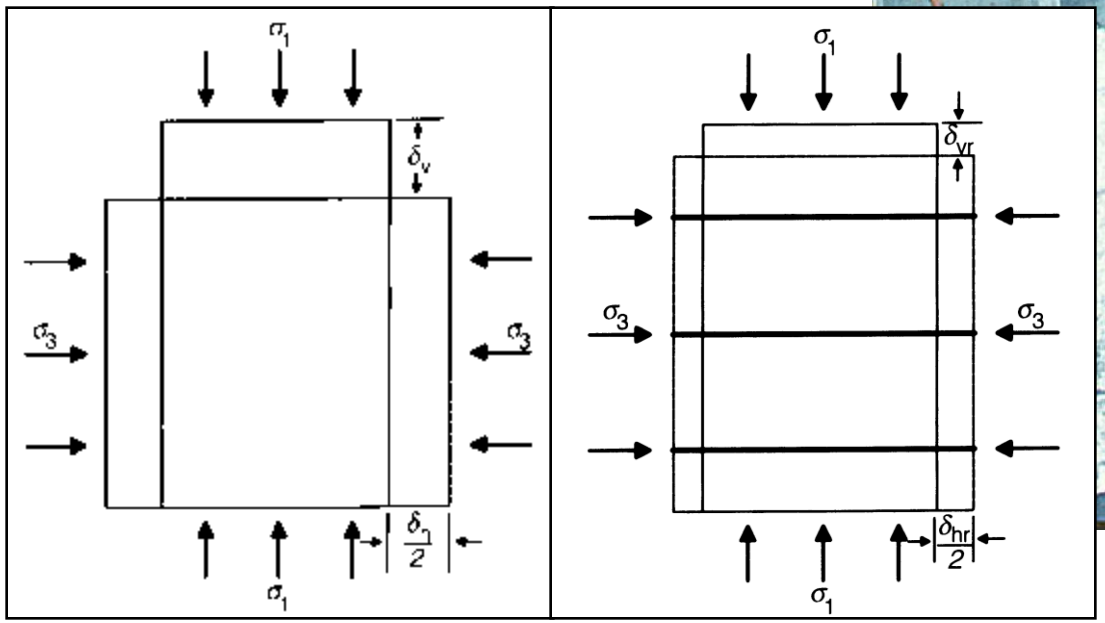
Basic Principles: Reinforced Soil

- Resistance to tensile strain can be provided by reinforcement





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Basic Principles: Reinforced Soil

- Interaction between reinforcement and soil is by friction or mechanical interlock

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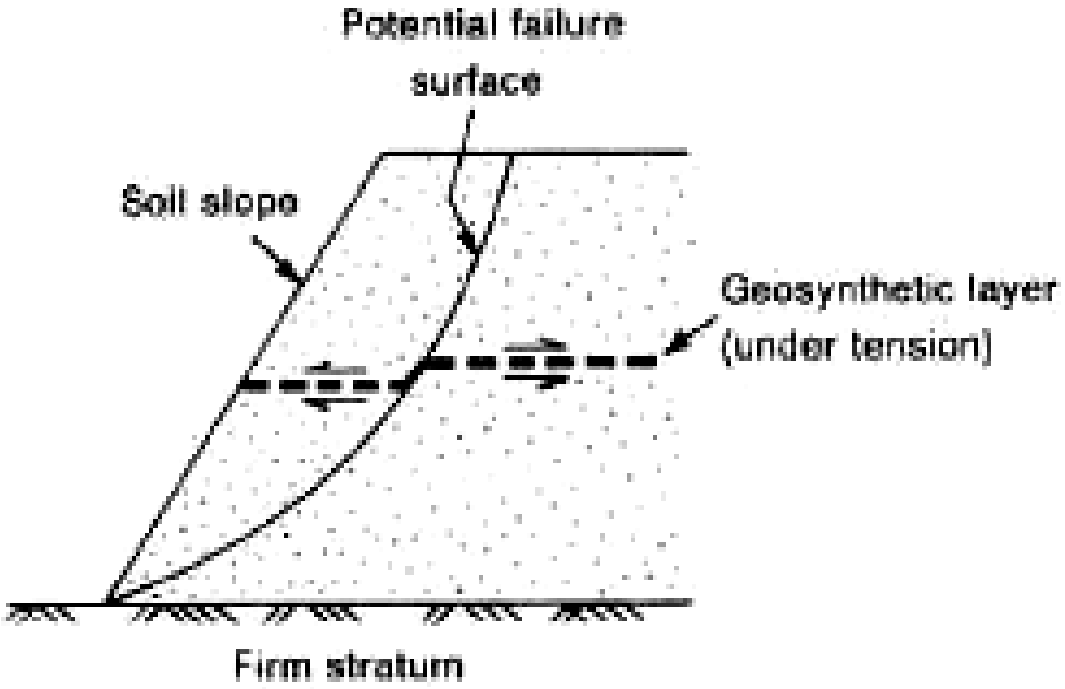
Basic Principles: Reinforced Soil



Reinforcement Function

[Courtesy : S.K. Shukla, Geosynthetics and their Applications]

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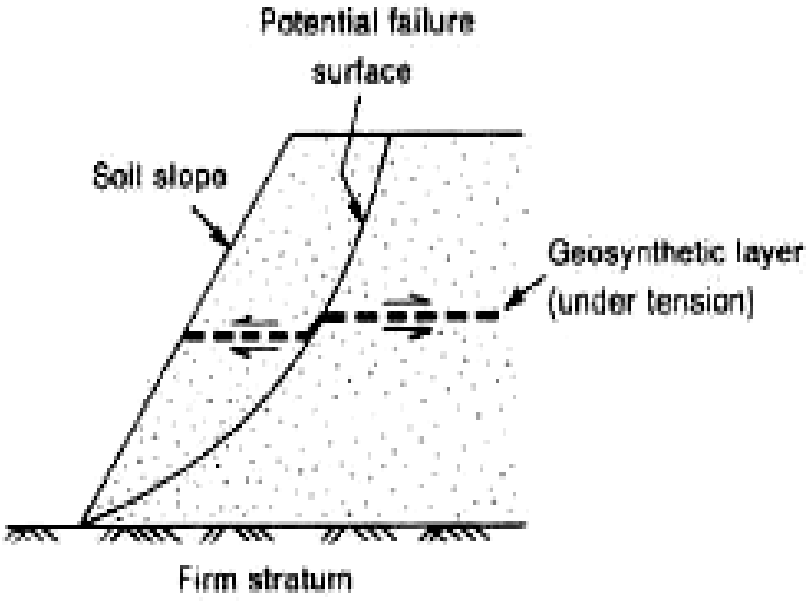
Basic Principles: Reinforced Soil

- Resistance against shear stress: Strength of reinforcing material
- Resistance against pull out: Friction between soil and reinforcing material



Reinforcement Function

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Basic Principles: Reinforced Soil

- Resistance against shear stress: Strength of reinforcing material
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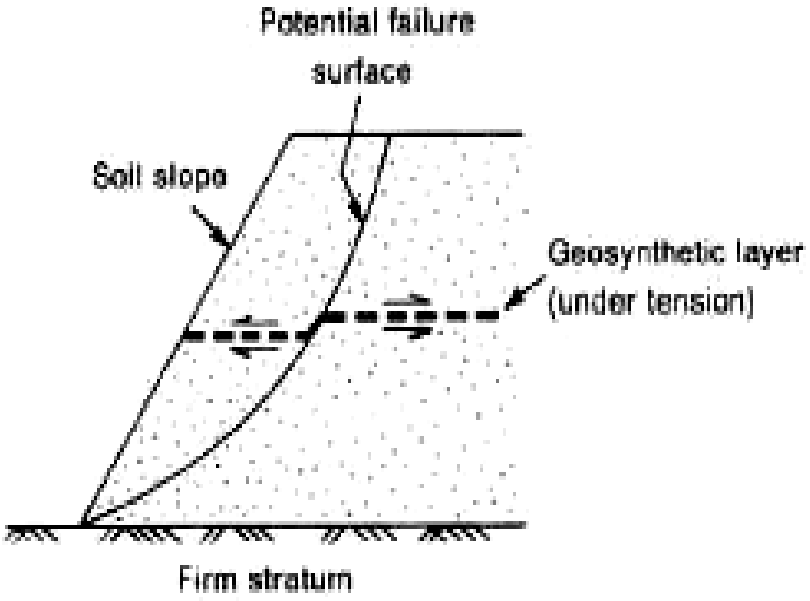

Reinforcement Function

ANCIENT USE OF SOIL REINFORCEMENT

EARLY USE OF GEOTEXTILES

Ziggurat- Reinforced Soil Structure using Natural Straw

The Great Wall Of China was constructed using Reeds to reinforce bricks

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ANCIENT USE OF SOIL REINFORCEMENT

Early Examples of use of natural Materials

- Wooden Fascines, Cotton
- Straw, Natural Fibers

Limitations:

- Poor Durability
- Not suited for permanent / long term performance.
- Variable material property inhibits assured designs.

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WHAT IS A SOIL REINFORCEMENT ?

It is the generic term for reinforcement inclusions inserted into ground or incorporated into fill providing tensile strength and/or shear resistance

WHAT IS A SOIL REINFORCEMENT LAYER ?

As reinforcement layer has to be intended a single layer, a multiple layer or any different solution providing reinforcement obtained with industrial products

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Which type of reinforcements materials are available ?

Metallic reinforcements

Geosynthetics reinforcements

Other type of reinforcements

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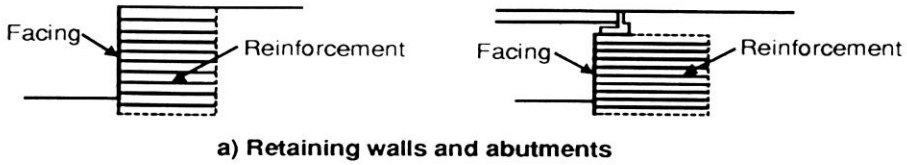
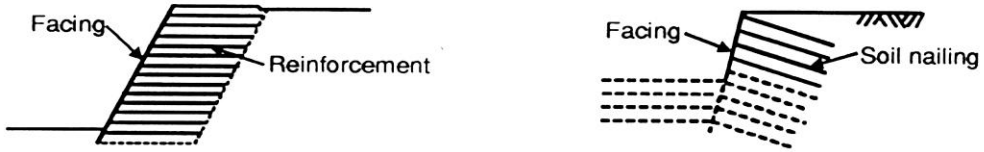
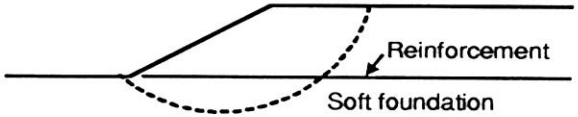


a) Retaining walls and abutments

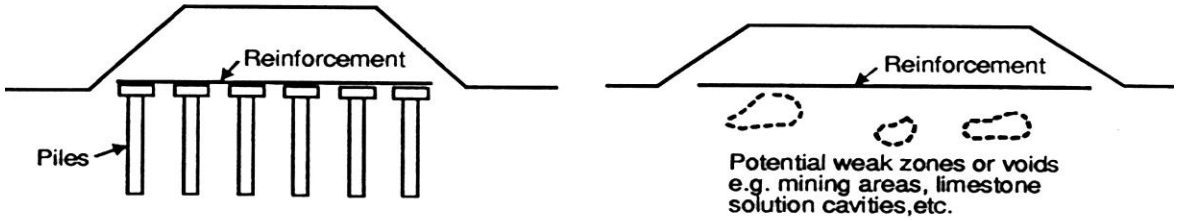


b) Fill slopes

c) Soil nailed slopes

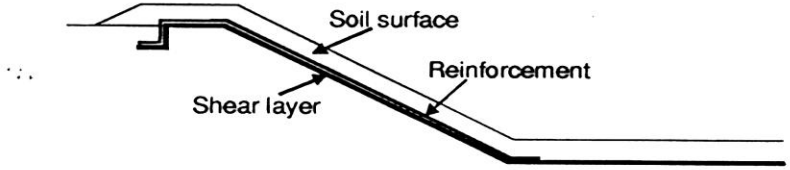


d) Basal reinforcement on soft foundations



e) Basal reinforced piled embankments

f) Basal reinforcement spanning voids



g) Interface shear layers

ALL soils develop tensile strength during shear deformation, consequently the reinforcement can develop tensile force when placed in ANY soil. However, it requires much less reinforcement to stabilize good quality garnular soils than mixed or clay soils.

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REQUIREMENTS OF REINFORCEMENT MATERIALS

STRENGTH

The reinforcement MUST have sufficient strength to support the force required to achieve the equilibrium in the soil.

STIFFNESS

The reinforcement MUST have sufficient stiffness so that the required force can be mobilised at the tensile strain which is compatible with the allowable deformation in the soil. The magnitude of allowable tensile strain depend on the application.

DURABILITY

The influence of time MUST be considered togheter with environmental conditions experienced by the geosynthetic reinforcement in the soil. The distinction between short, medium and long term applications is relevant.

BOND

The geosynthetic reinforcement has to remain in equilibrium with the surroinding soil, and MUST bond sufficiently to transmit the reinforcement forces to the soil. The type of soil is relevant.

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Partial safety factors according to BS 8006/1995 :

Tdesign = Tcreep / fm

Tcreep = T short term tensile strength / fcreep

$$f_m = f_{m1} \times f_{m2}$$

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Table : Partial material factors for reinforcements (After BS 8006 : 1994)

Principal factor	Component factor	Intended purpose
f_{m1}	f_{m11}	Manufacture; to cover the possible reductions in the capacity of the material as a whole compared with the characteristic value deduced from the control test specimens and possible inaccuracy in the assessment of the resistance of a structural element resulting from modelling errors.
	f_{m12}	Extrapolation of test data; to take account of the confidence of the long term capacity assessment. This factor may vary with the required service life of the structure.
f_{m2}	f_{m21}	Susceptibility to damage; to take account of damage during construction. This factor may be derived from site damage tests.
	f_{m22}	Environment; to take account of different rates of degradation due to environmental conditions.

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Metallic reinforcements:

TERRAMESH units manufactured with double twisted meshes done with PVC steel wires coated with a polymeric protection.

Available two types of facings:

- ➔ **GREEN FACING**
- ➔ **GABION FACING**

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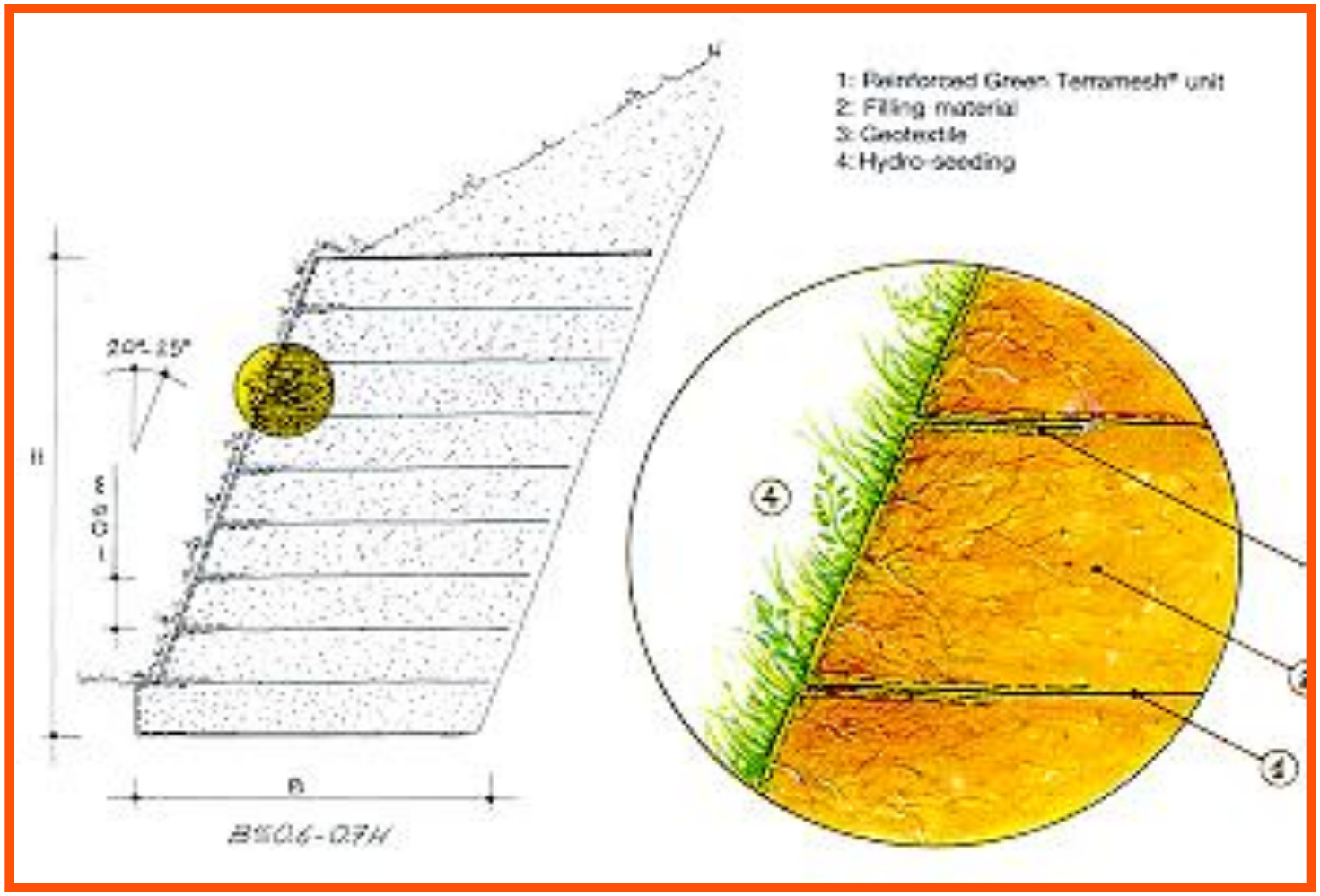
TERRAME SHSYSTEM

Reinforced Soil Structures: Terramesh System

Green Terramesh



Reinforced Soil Structures: Green Terramesh

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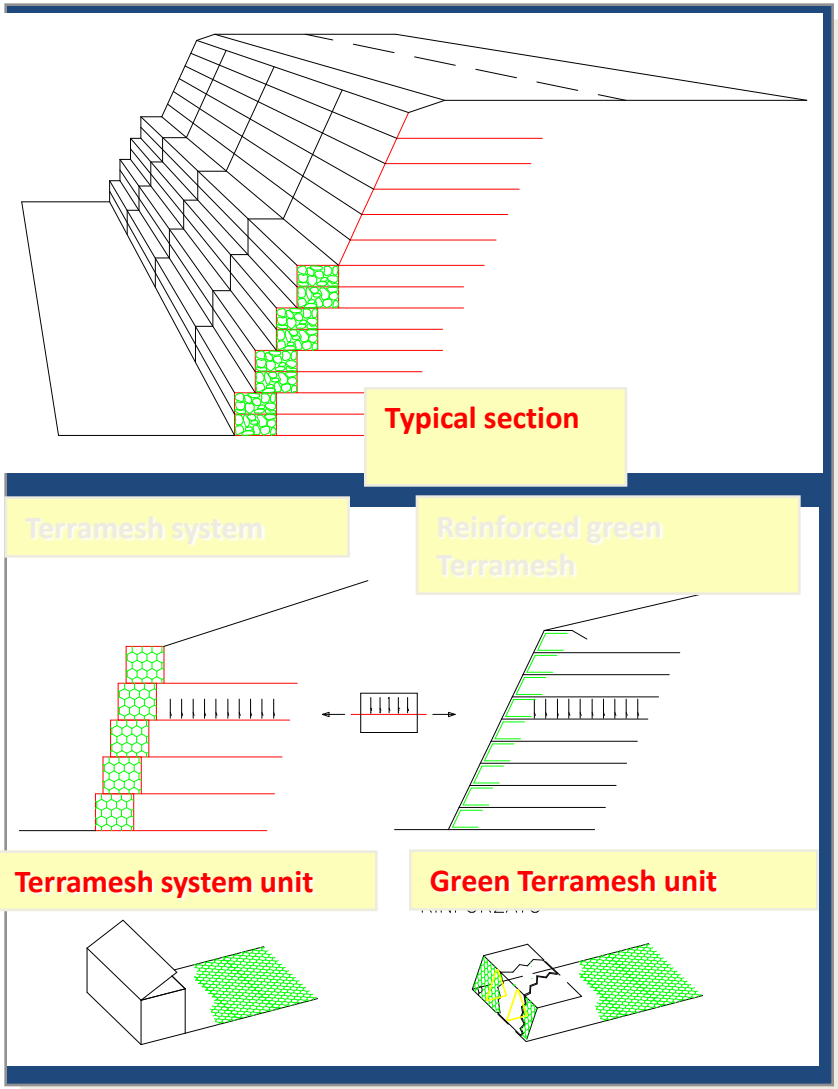
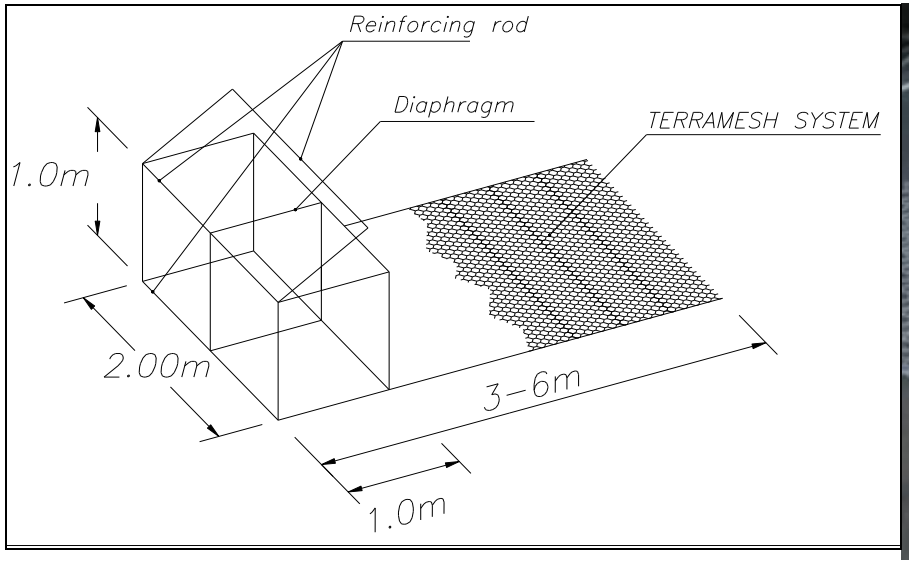
REINFORCED SOIL STRUCTURES

It is a structural system where the reinforcement acts with the soil to provide a resistance

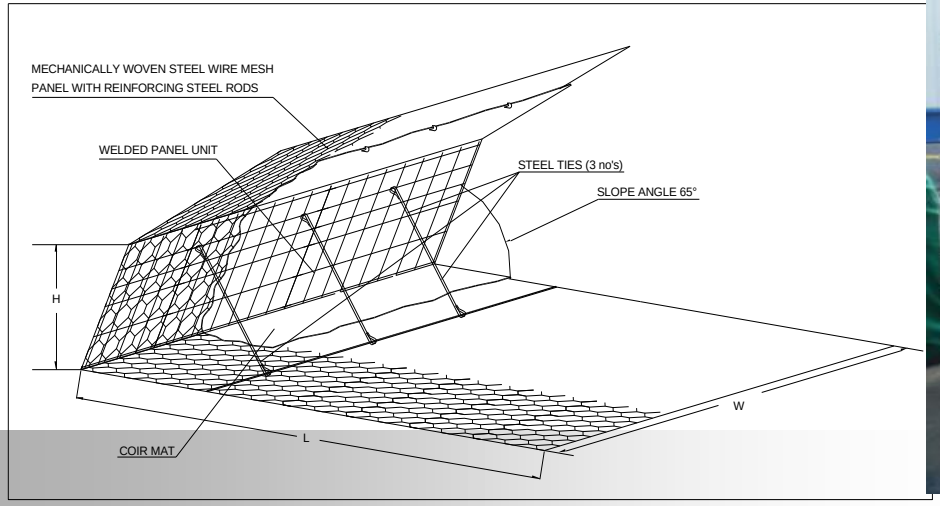
The principle on which Terramesh System or Green Terramesh is based is to combine the wiremesh reinforcement ability by successive layers with the soil



TERRAMESH SYSTEM



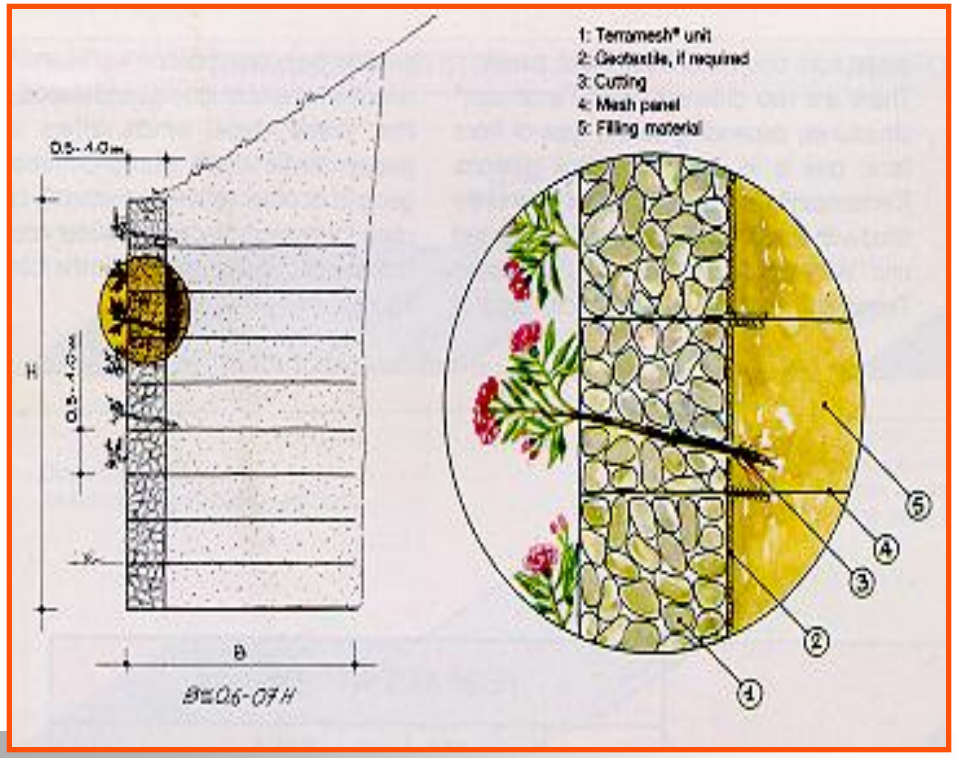
GREEN TERRAMESH

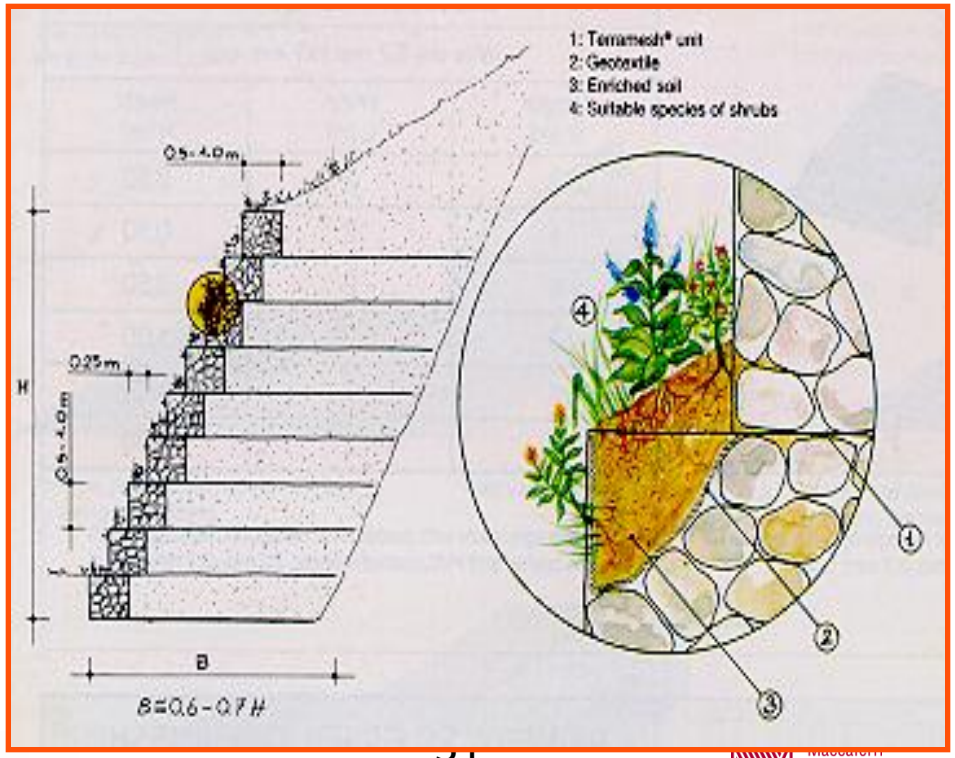


Terramesh System

Terramesh ® System - Structure consisting of an external face, stone filled gabion type, continued as a double twist mesh panel, both PVC coated. They can be built with a stepped or vertical face, with or without a batter.

They are specially designed for sites and situations where it is necessary to reconstitute the soil mass.





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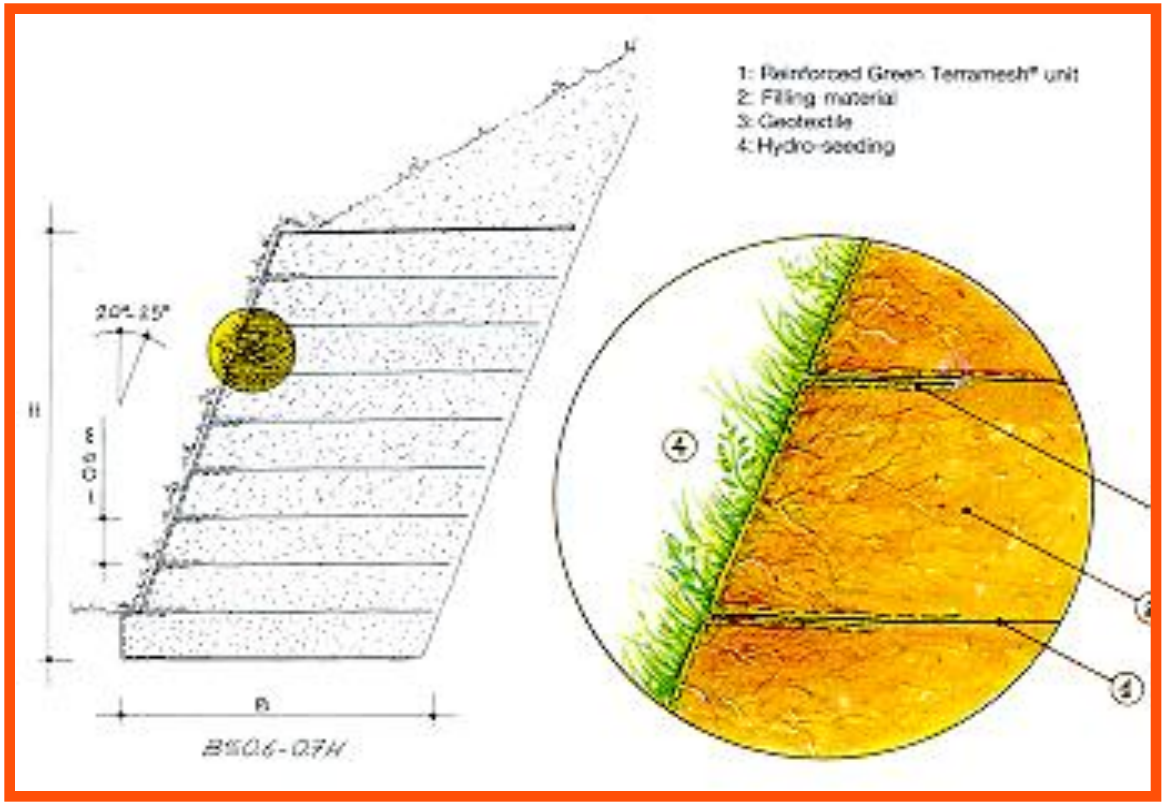
Green Terramesh

Green Terramesh ® System - Similar to the other Terramesh but without the gabion type face, its external surface is always inclined and it is made using hexagonal netting with a structural function and with bio-degradable mat to retain soil particles and also to help grow vegetation.



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GEOSYNTHETIC REINFORCEMENTS

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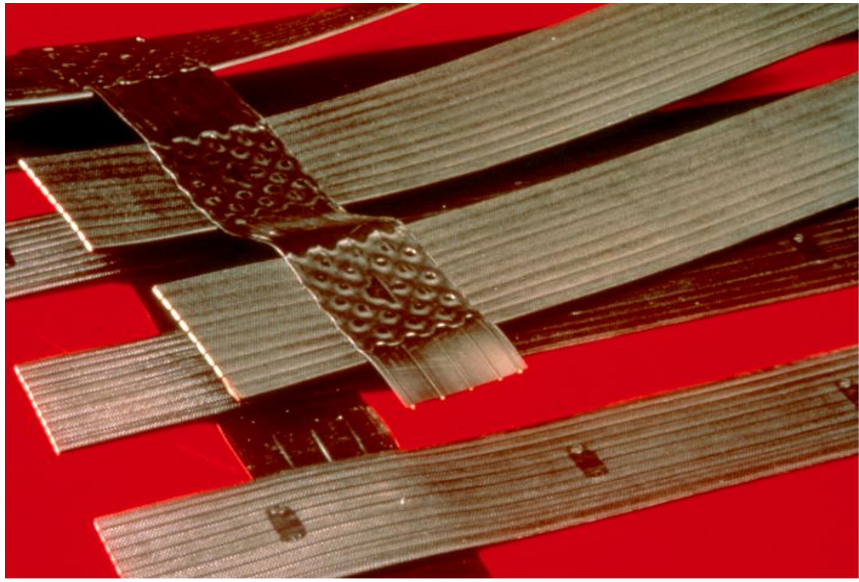
GEO-PRODUCTS: AS SOIL REINFORCEMENT

PARA-LINK

- Para-links have planar structure consisting of monoaxial array of geo-synthetic strips



- Para-link has good uni-directional strength – 100kN/m to 1350kN/m.
- Bi-directional strength can be obtained by installing two layers at right angles to each other.

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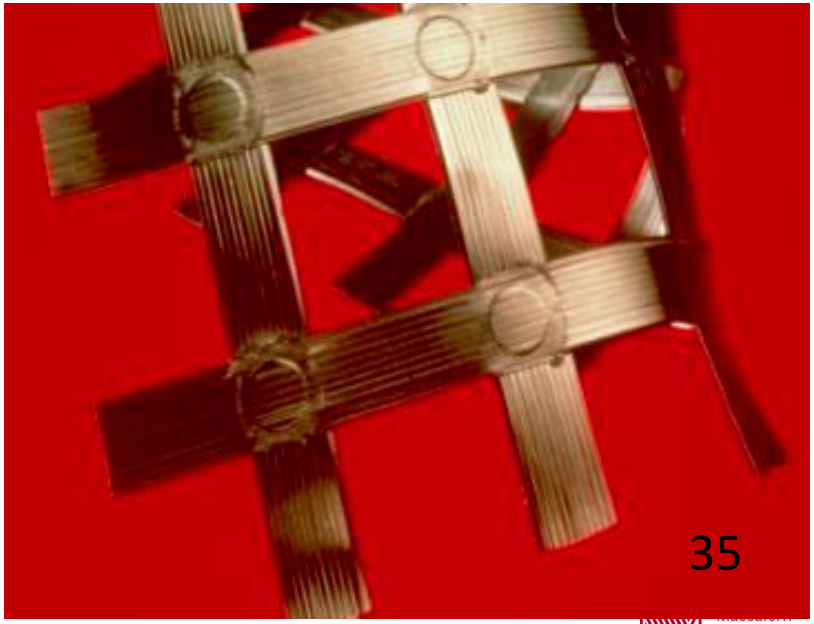
GEO-PRODUCTS: AS SOIL REINFORCEMENT

PARA-GRID

- **Para-Grid have planar structure consisting of Biaxial array of geo-synthetic strips.**
- **Para-Grid has good bi-directional strength.**
- **Longitudinal Strength – 30kN/m to 200kN/m.**
- **Transverse Strength – 5kN/m to 100kN/m.**



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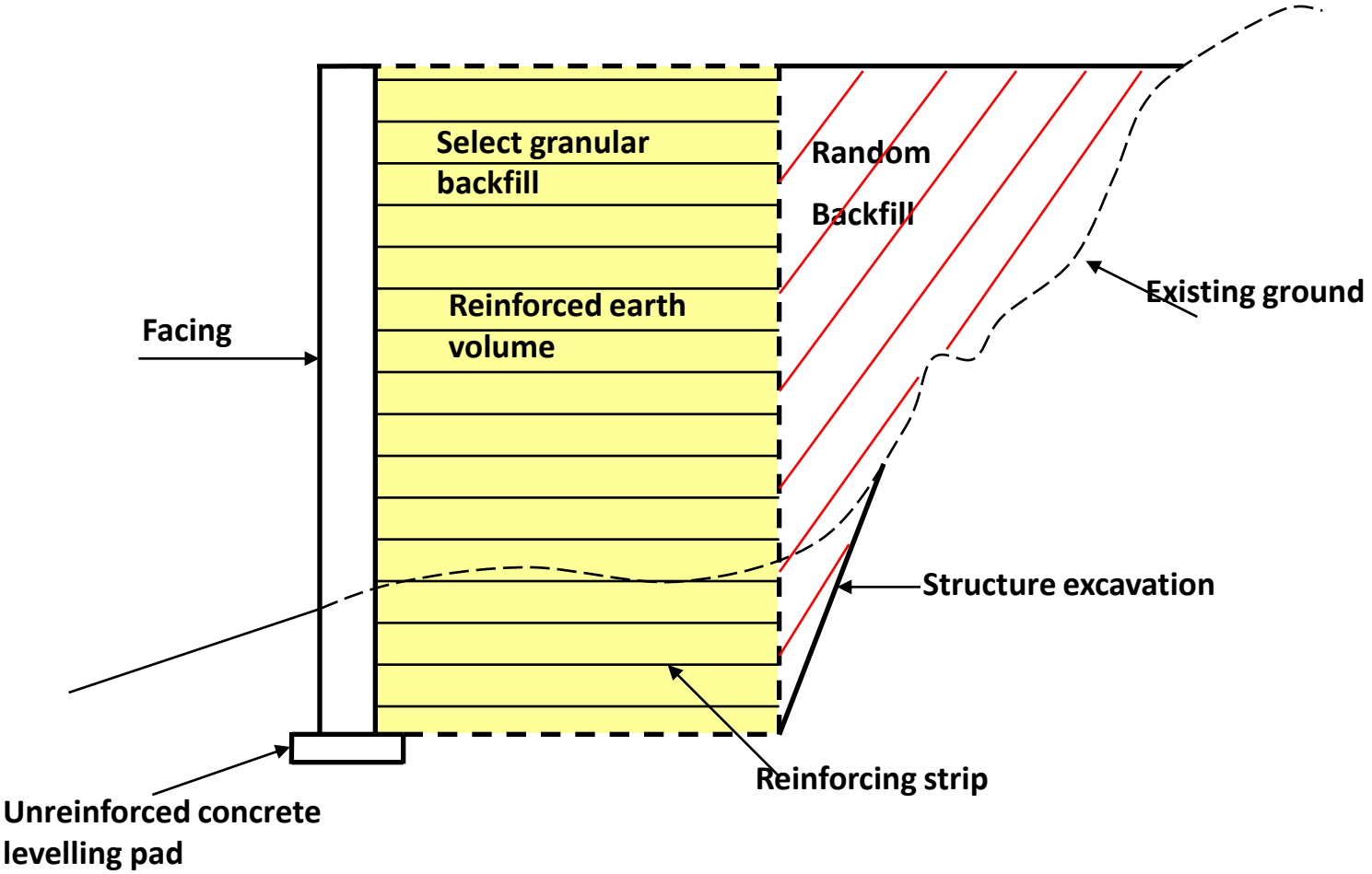
Components of Para-Link / Para-Grid / Para-Web Reinforced Soil Structure



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PARAWEB REINFORCED SOIL STRUCTURES

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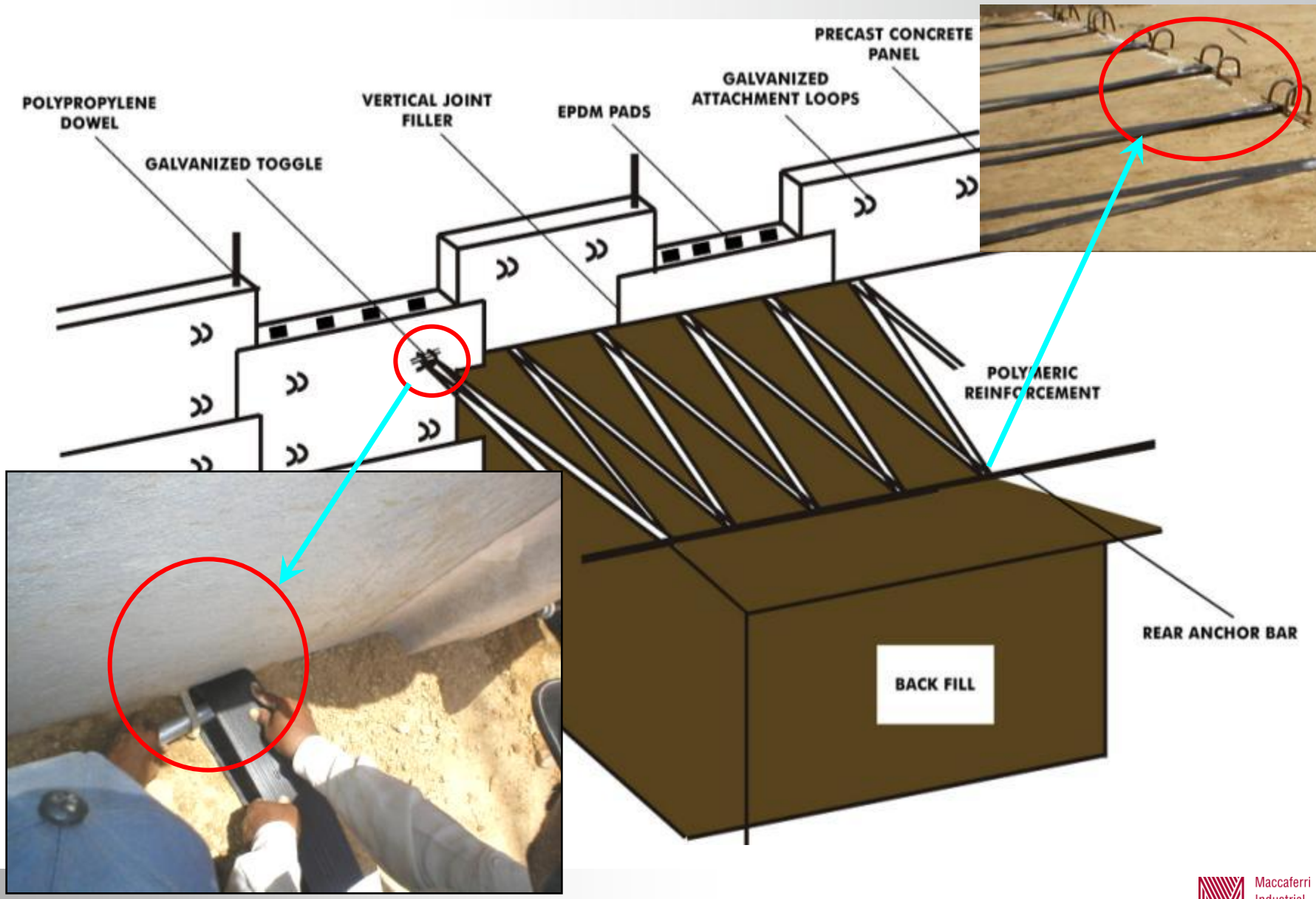
ParaWeb RS Wall



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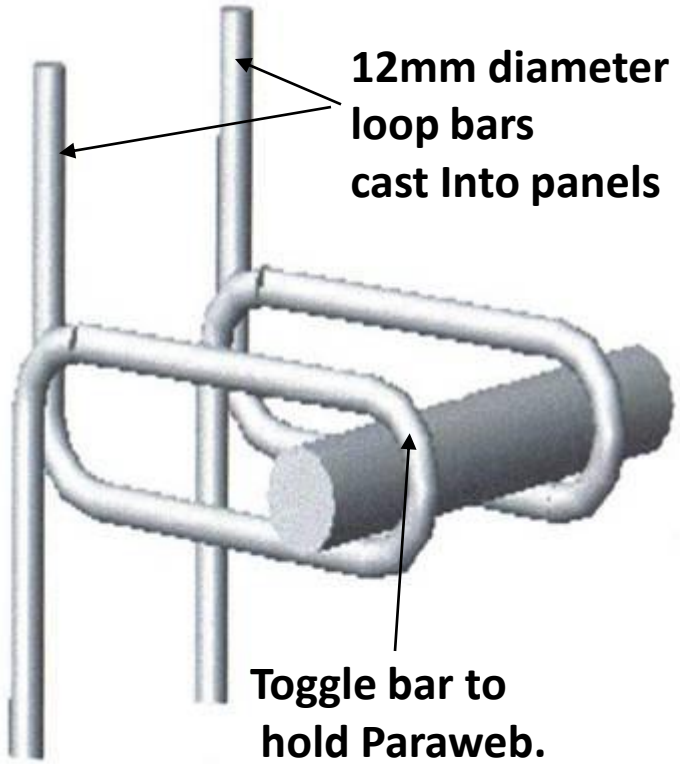
Paraweb Layout

ParaWeb to Panel Connections Details



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PARAMESH SYSTEM

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BACKGROUND OF DEVELOPMENT OF PARAMESH SYSTEM

- Developed in late 90's by Officine Maccaferri, Italy.
- Development of this system stems from the need to analyze how a more efficient use of the reinforcements will work in favor of the overall project's economy.
- It is now well established that, for structures higher than 10m, there is a large potential for cost effectiveness in using wire mesh and grids combined, in place of a 100% Geogrids or a 100% steel mesh reinforcement solution only.

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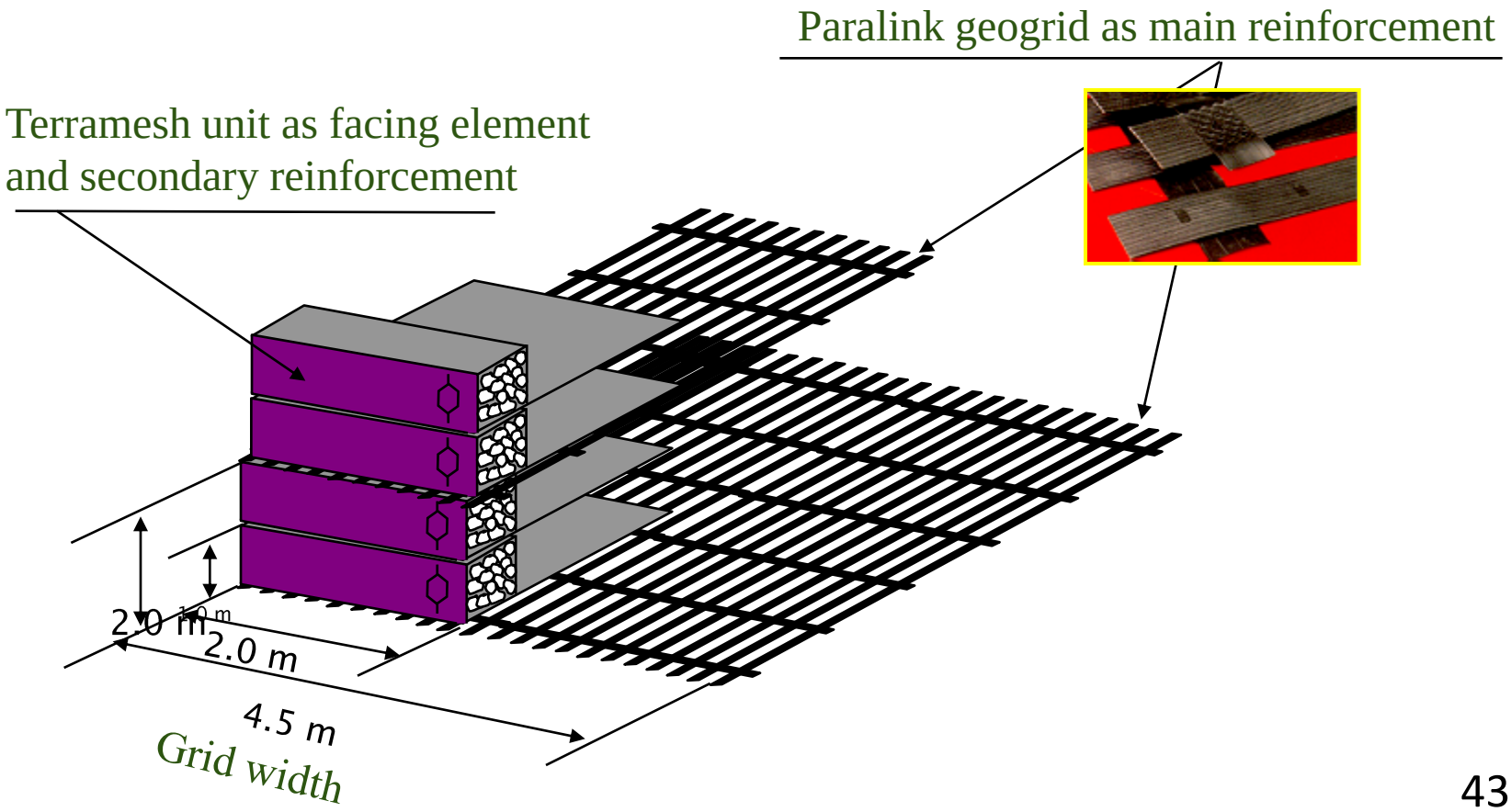
TERRAMESH SYSTEM (TMS) WITH GEOGRID

(where space is restricted and vertical structure is required)



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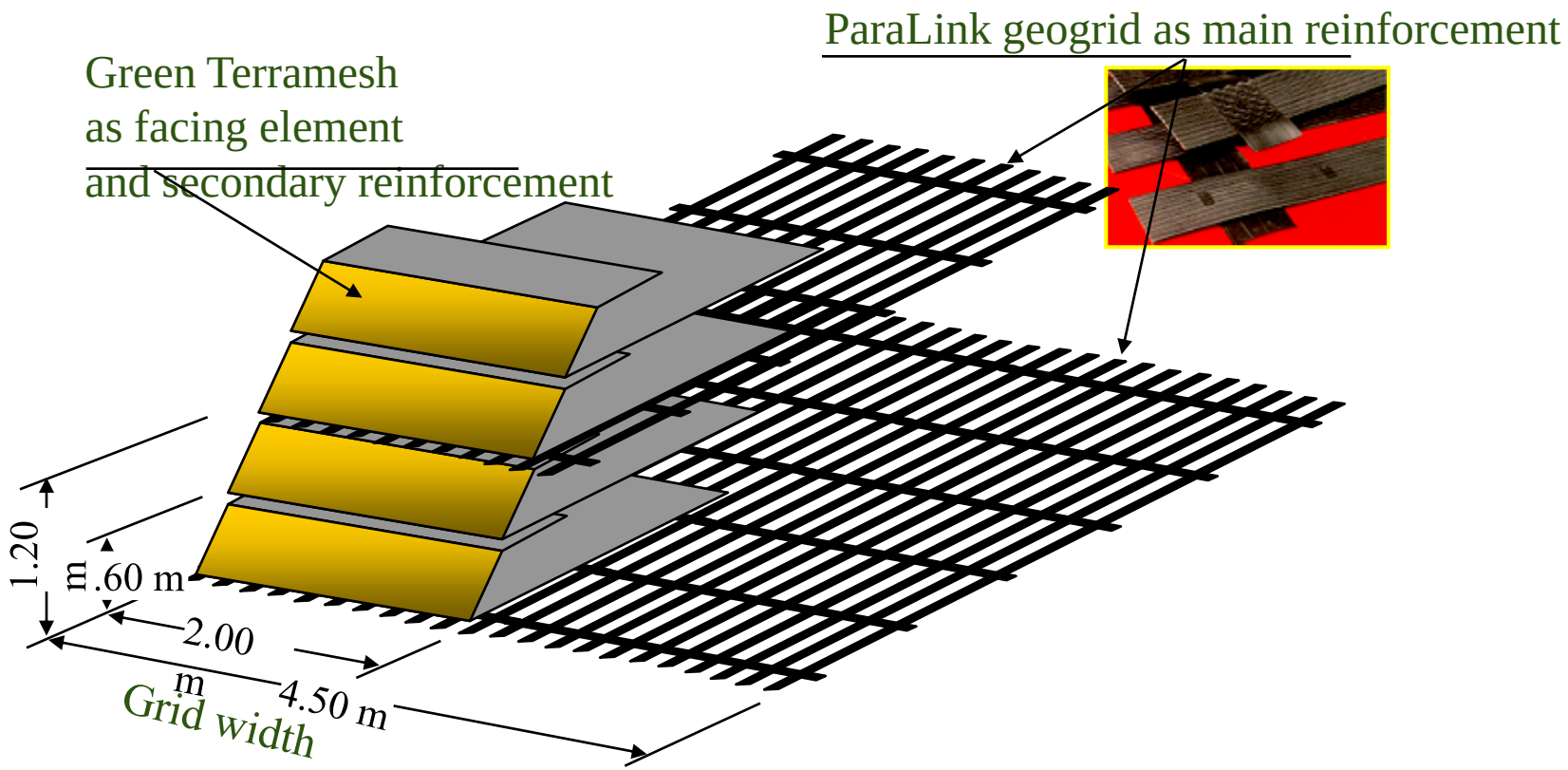
GREEN TERRAMESH (GTM) WITH GEOGRID

(where space is available and hence sloped structure can be provided)



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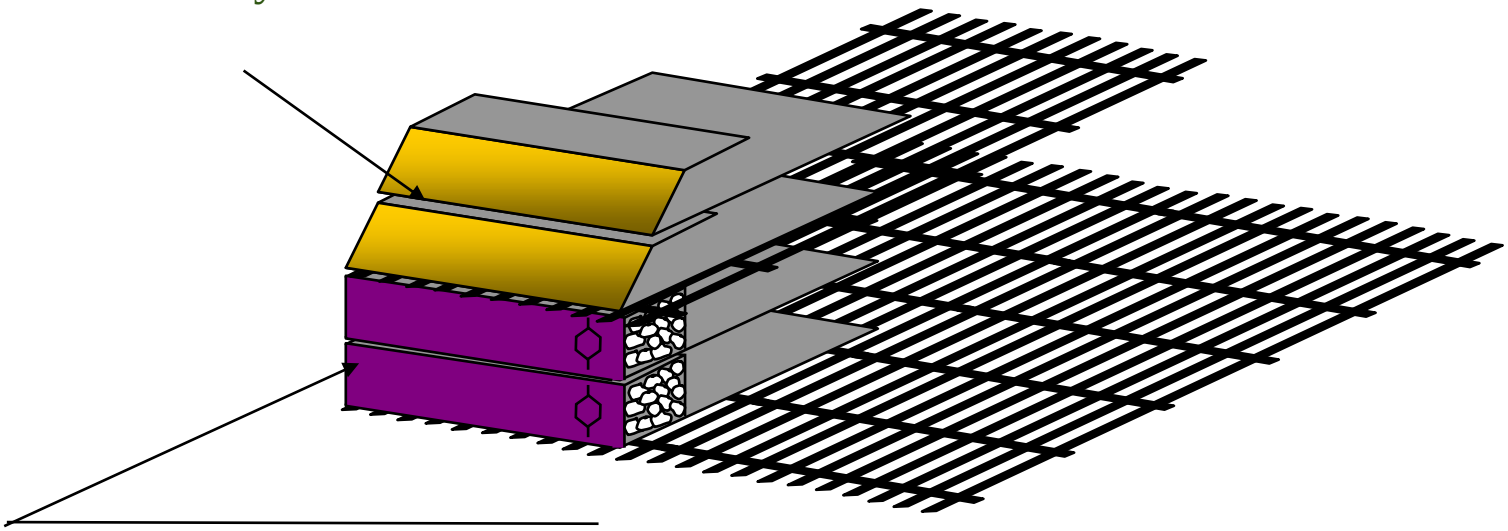
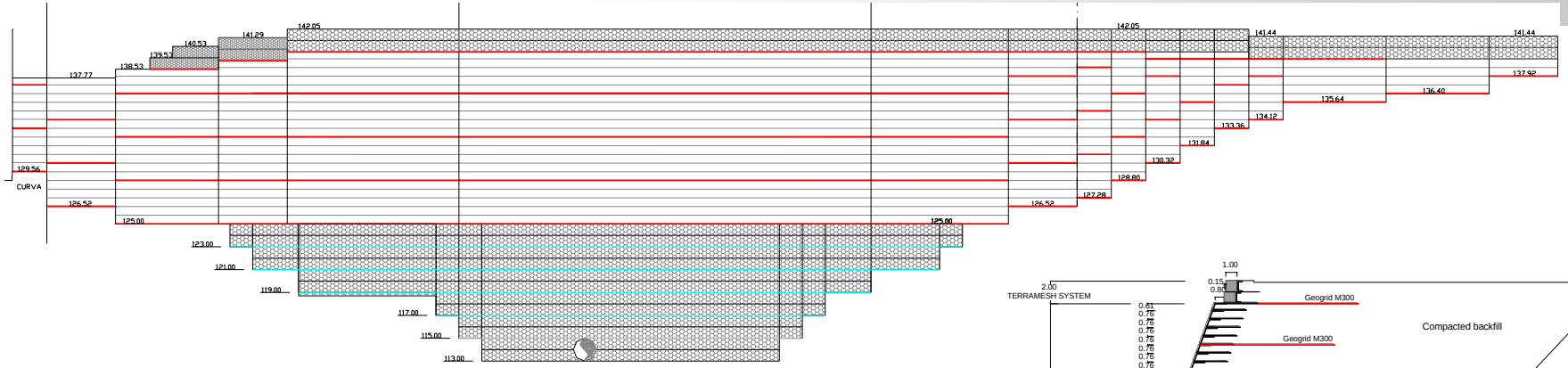
COMBINED TMS & GTM) WITH GEOGRID

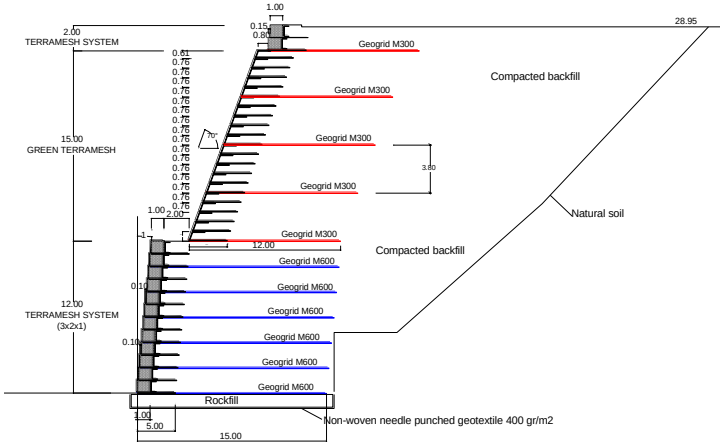
Green Terramesh
as facing element
and secondary reinforcement



Terramesh unit as facing element
and secondary reinforcement

COMPONENTS OF RS STRUCTURE





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Landscape and soil protection

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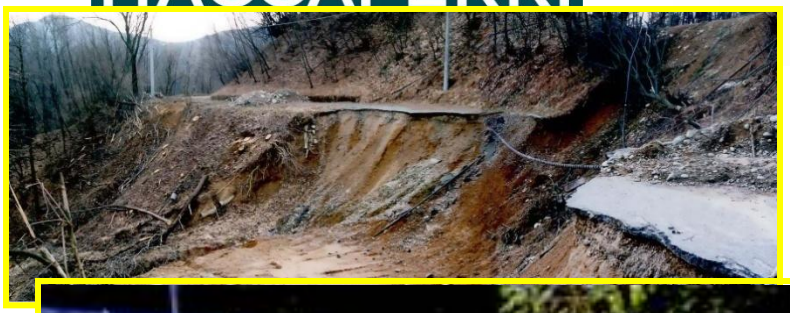

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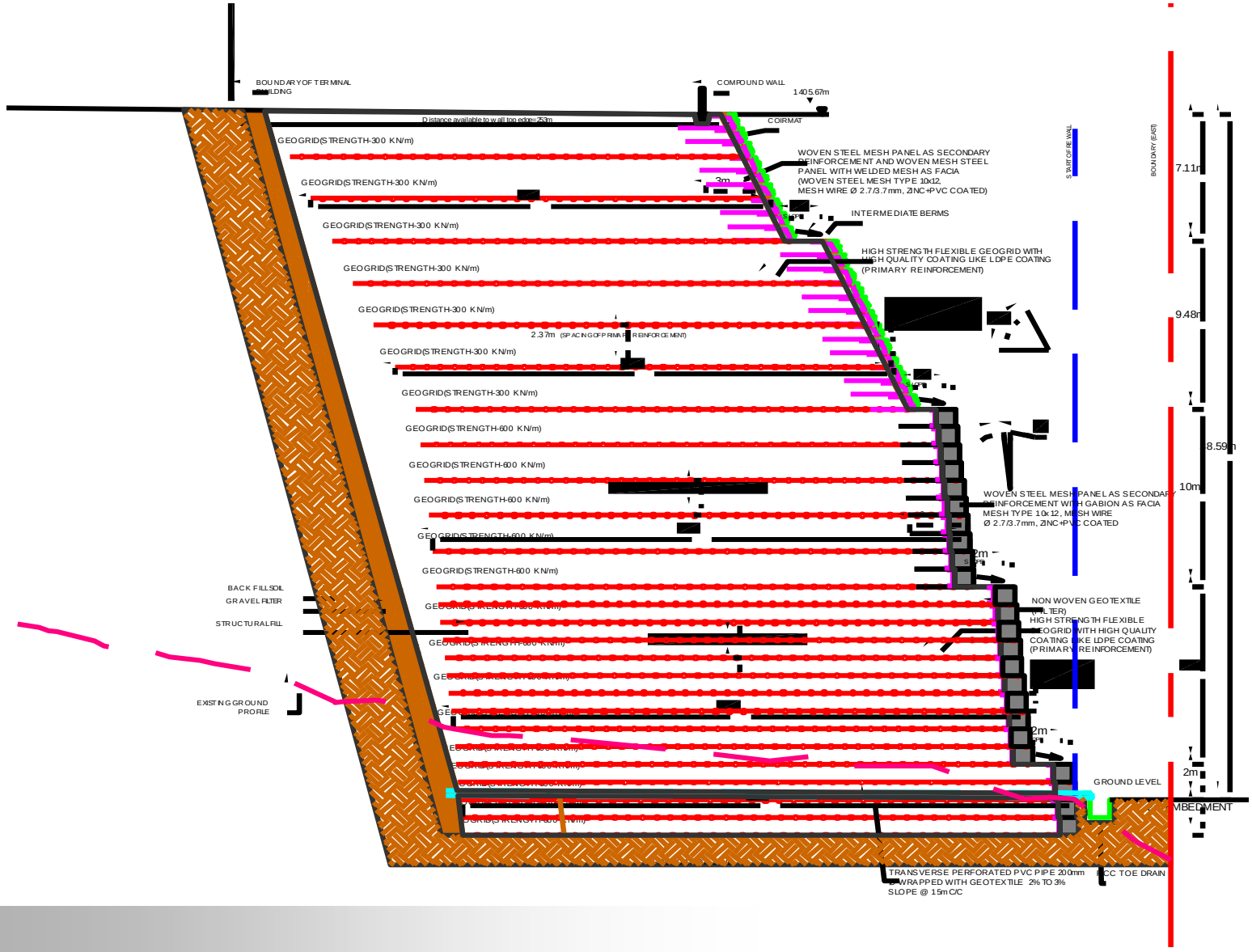

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CASE REFERENCES

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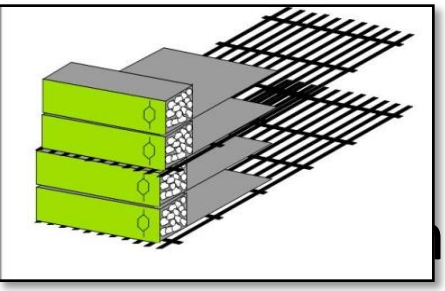
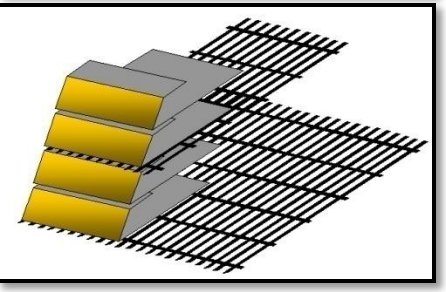
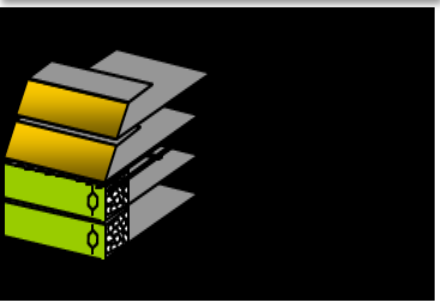
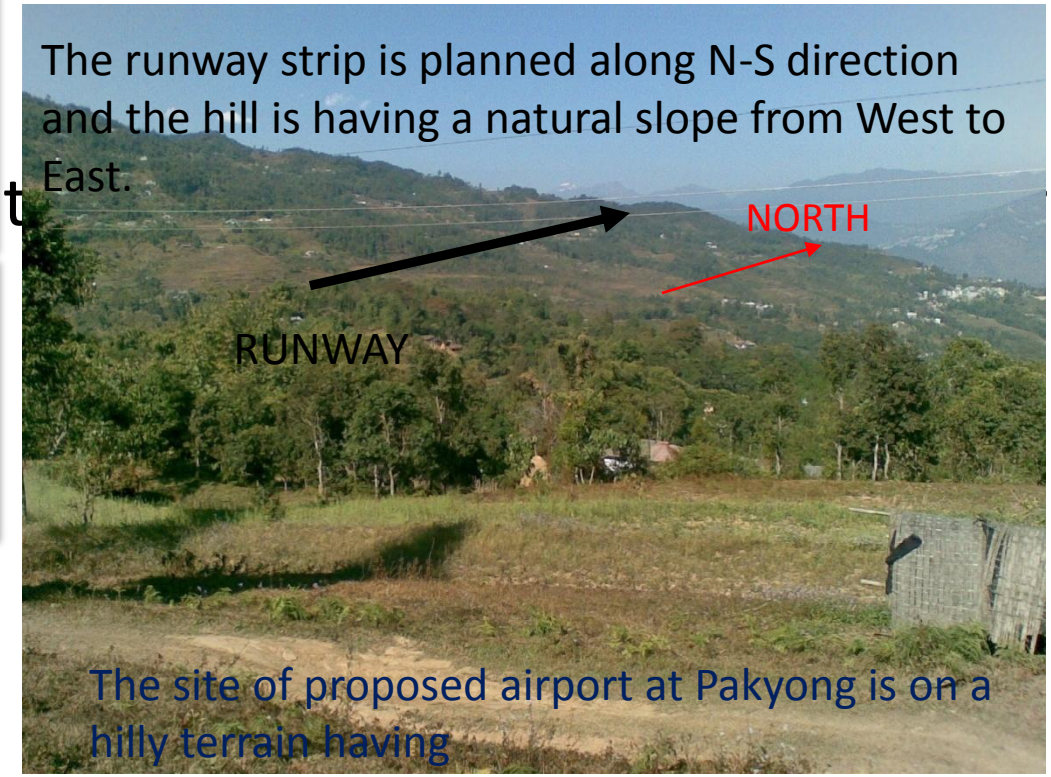
PAKYONG AIRPORT-SIKKIM










PARAMESH STRUCTURE: PAKYONG, SIKKIM, INDIA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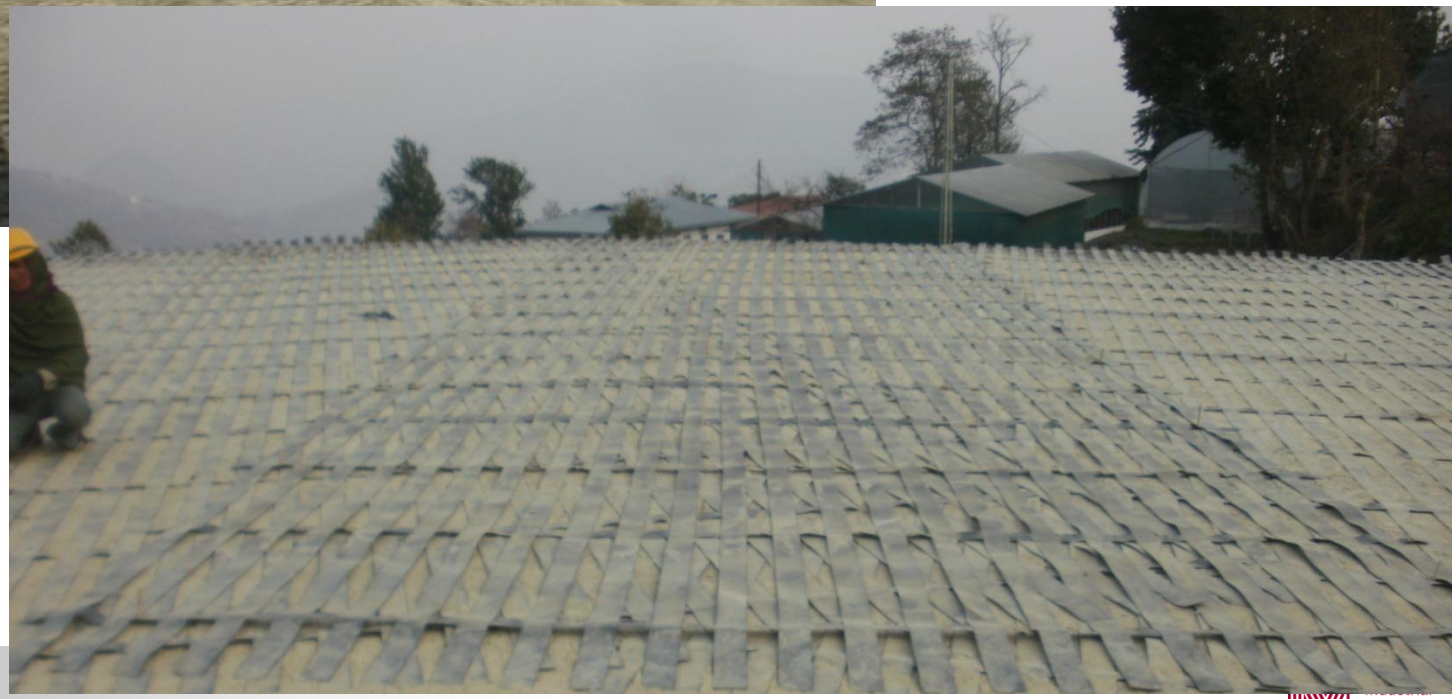


TERRAMESH WALL

TERRAMESH SYSTEM: TILGANGA, KATHMANDU, 2001

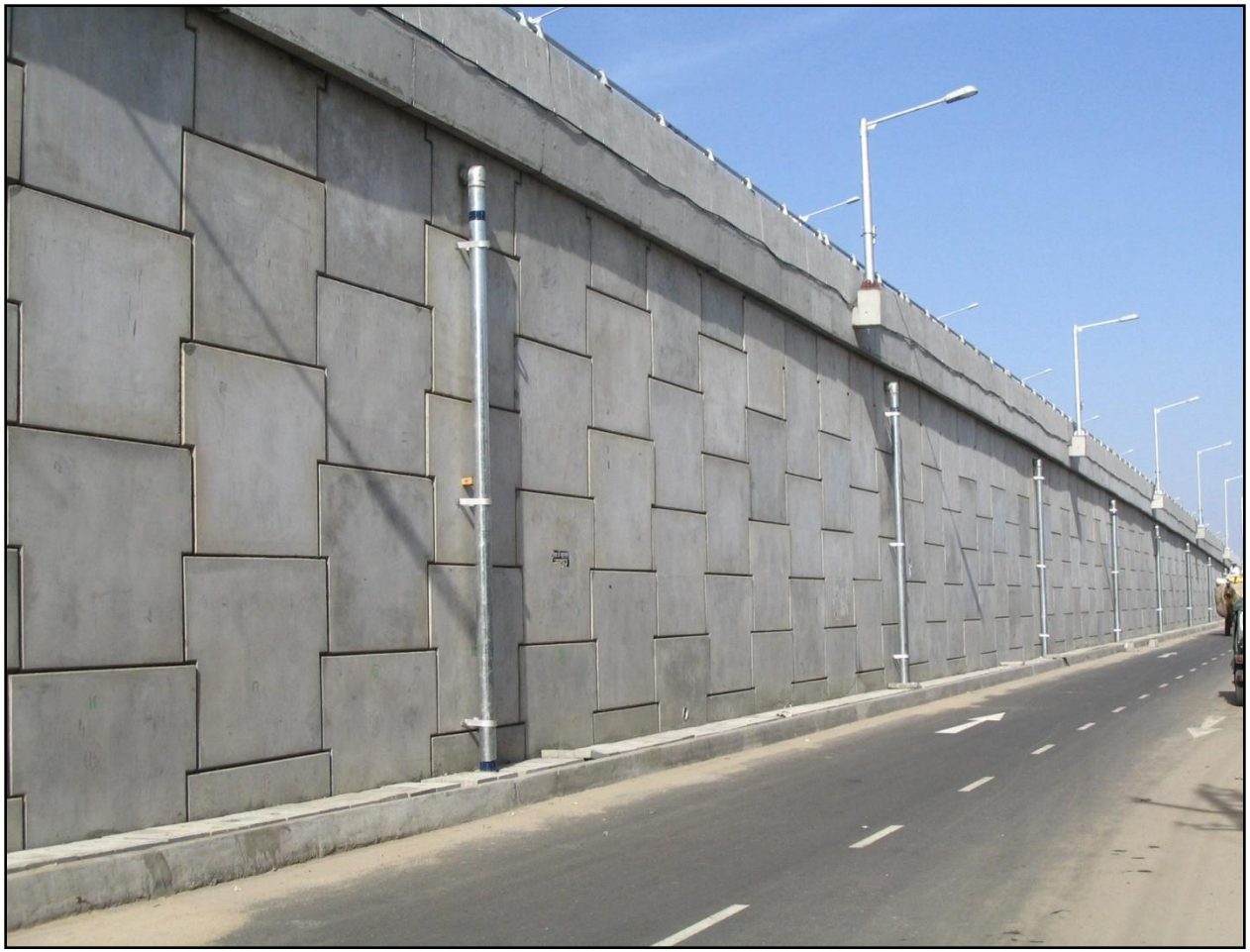
Gokarna Landfill Site, 2001

Gokarna Landfill Site, a solid waste dumping site had been found sliding from its north side. The slide had been protected with the help of Terramesh Wall having total height of 16m in 4 tiers.

Gokarna Landfill Site in 2001

Gokarna Landfill Site in 2013

Jaipur-Kishangarh Expressway, 2004



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ParaWeb RS Wall

ParaWeb Reinforced Soil Wall Structure, Kathmandu – Bhaktapur Road Widening Project, 2010

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ParaWeb Projects: External Damages

Fahaheel Expressway, Kuwait

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PARAMESH WALL FOR MOUNTAIN ROAD TO AL-JAIS, RAS AL KHAIMAH, UAE

Highest peak in UAE, Al Jais is located in the Northern Emirate of Ras AL-Khaimah which is 25 Km away from the main town. Currently Al Jais is surrounded with some local people's houses, local animals and is not much popular. But, the place is 10 degrees colder than the main cities in the UAE & hence the project owners decided to make a visitors spot there which will be able to attract the stream of tourists.

Al Jais Mountain Road Project Site (Google Earth View)

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PARAMESH WALL FOR MOUNTAIN ROAD TO AL-JAIS, RAS AL KHAIMAH, UAE

Problem:

The proposed site comprises of 36 Km of road, which is rising up to a height of 1700 meters (5577 feet). As it is one of the highest peak in UAE, construction is ought to be challenging due to large quantity of earth works involved, difficulty in access, moving up construction machineries etc. Huge amount of cutting & backfilling is required. Mostly, the material from cutting is to be used for filling.

Initial Site Condition

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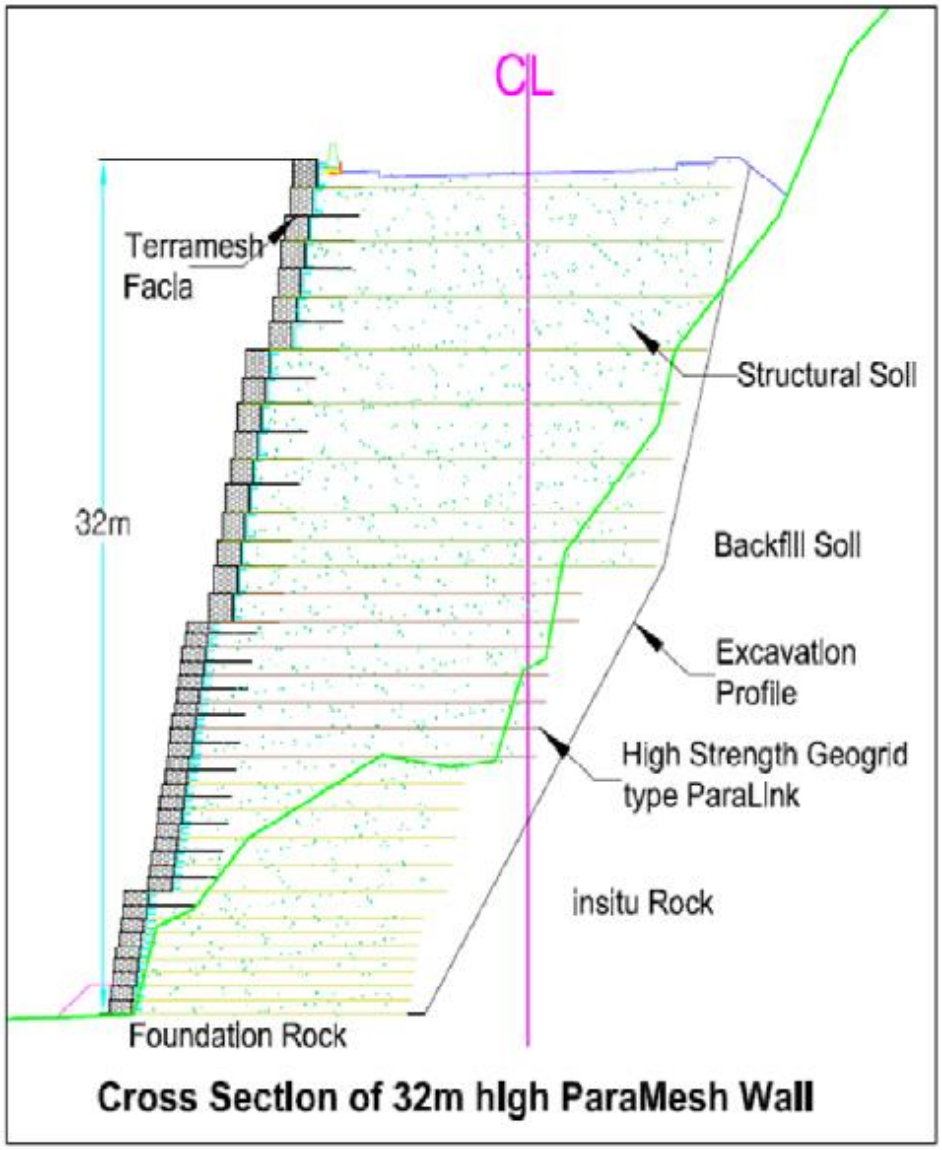
PARAMESH WALL FOR MOUNTAIN ROAD TO AL-JAIS, RAS AL KHAIMAH, UAE

The exiting site condition required the need to have a nearly vertical retaining structure between chainages 20+350 to 20+575, the highest 32 m section being at chainage 20+475. The original solution of 34 degree filling was unfeasible at this location, which otherwise could have even extended filling above the road.

Out of the different retaining wall solutions,the ParaMesh system was chosen that gives unmatched advantages required specific to a mountain road project. Typically, ParaMesh is a composite soil reinforcement system with different types of soil reinforcement used.



Cross Section of 32m high ParaMesh Wall

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PARAMESH WALL FOR MOUNTAIN ROAD TO AL-JAIS, RAS AL KHAIMAH, UAE

Completed structure; top views from highest point.

Completed Structure

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PARAMESH WALL FOR MOUNTAIN ROAD TO AL-JAIS, RAS AL KHAIMAH, UAE

Construction of initial ParaMesh layers

Construction of Paramesh Layers

Placement of separation geotextile on the rear side of Terramesh

Placement of separation geotextile on rear side of Terramesh

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PARAMESH WALL FOR INANDA DAM (EAST) ACCESS ROAD, INANDA, KZN

Problem

Part of the Inanda Dam project included the development of the road infrastructure to access the dam. The geometry of the landscape required fill embankments for the new road surfaces along the mountainous terrain.

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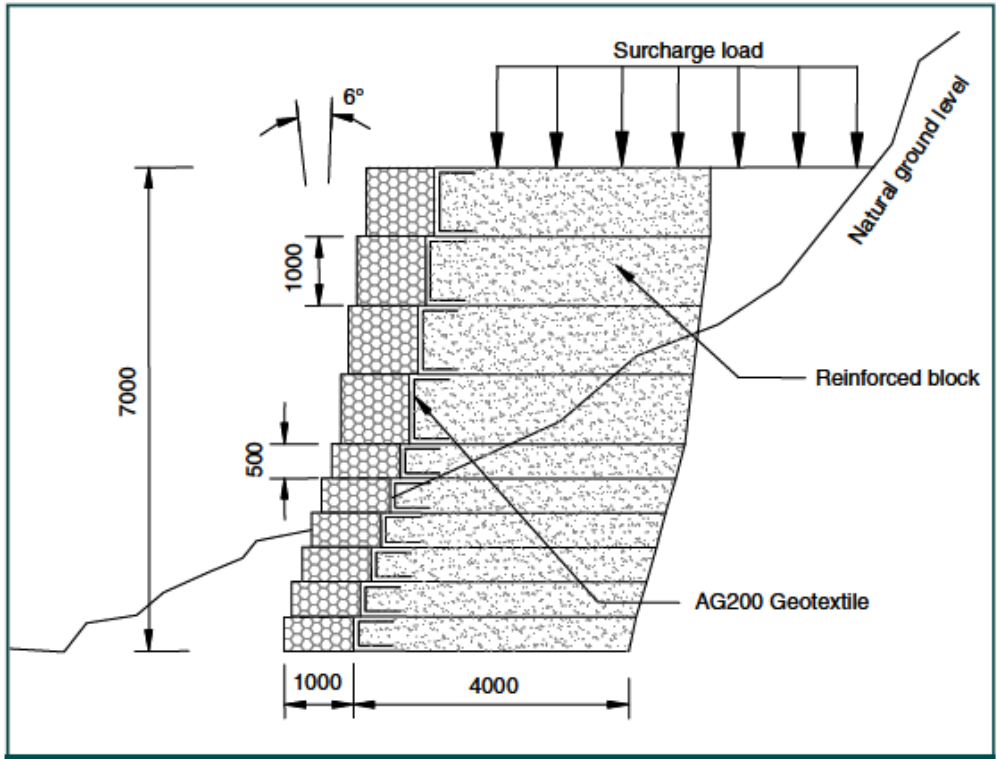
PARAMESH WALL FOR INANDA DAM (EAST) ACCESS ROAD, INANDA, KZN

Solution

The initial designs entailed a conventional mass gravity gabion structure with a large volume of rock – a quantity exceeding that available on site. The Terramesh™ System, consisting of a gabion mesh cage with a continuous mesh tail as reinforcement, was chosen as it required less rock.

The final solution consisted of a 7m high Terramesh™ structure with a 2m foundation depth. The mesh tails extended 4 metres into the earth embankment behind the gabion facing. The gabion front face consisted of horizontal steps of 220mm and vertical steps of 500mm up to a height of 2m followed by steps of 1,0m. The smaller units at the base reduced bulging and enhanced the stability of the structure.



Typical Section

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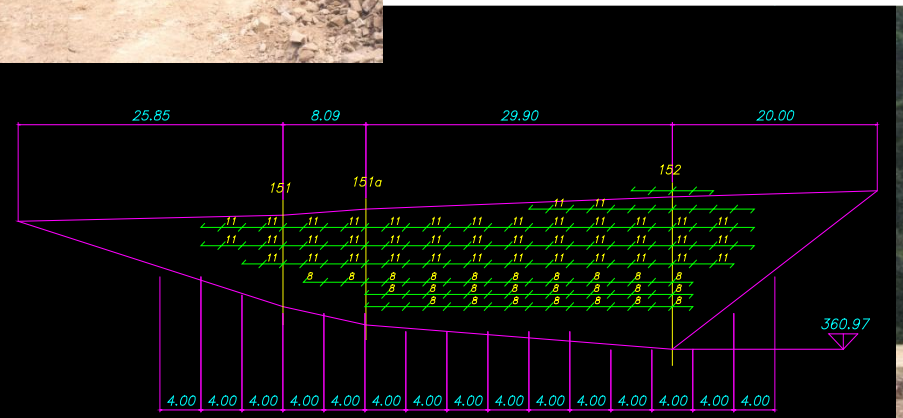
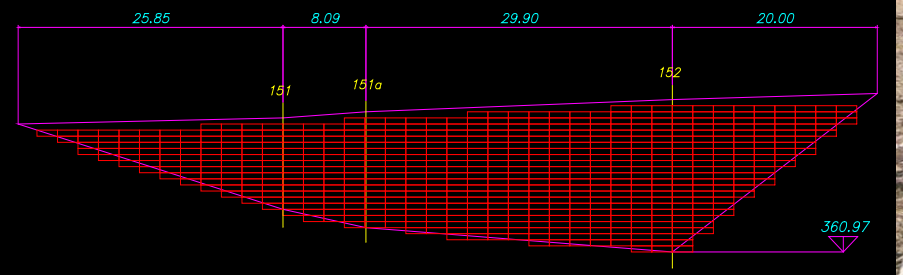
Sardegna - Italy





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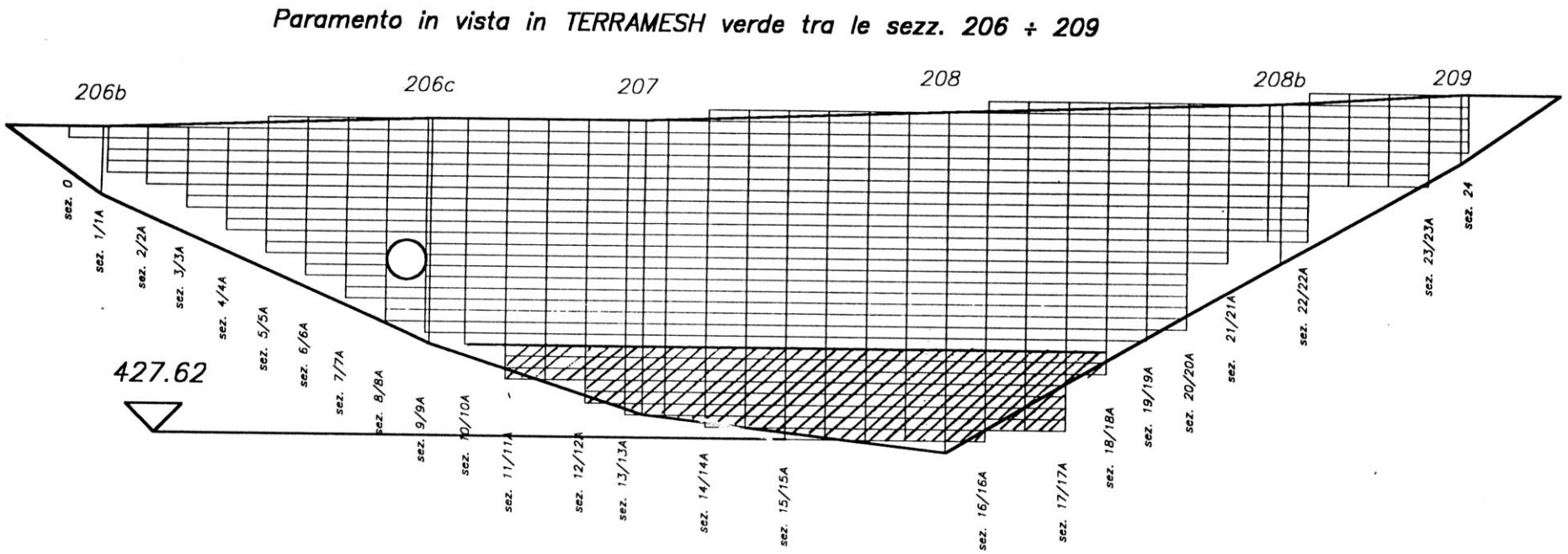
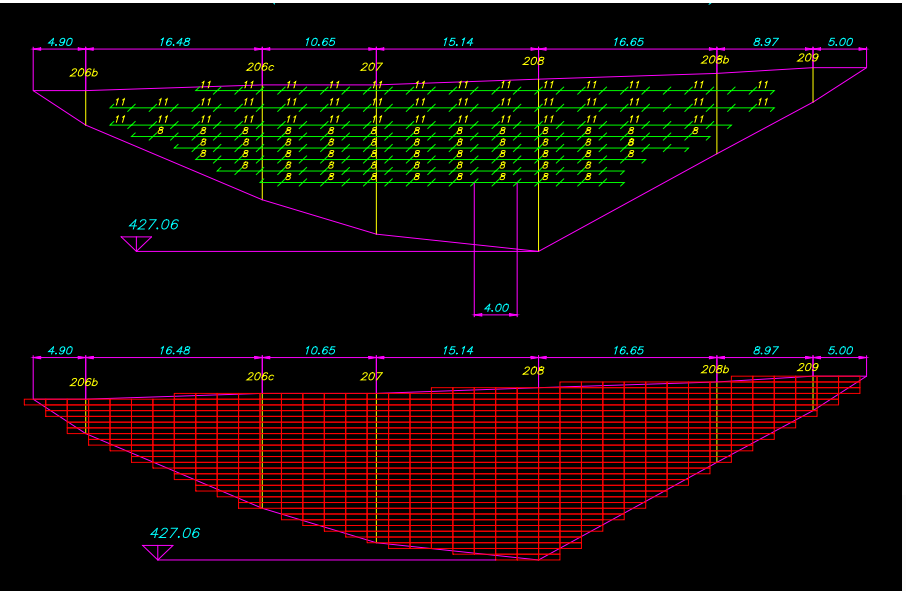
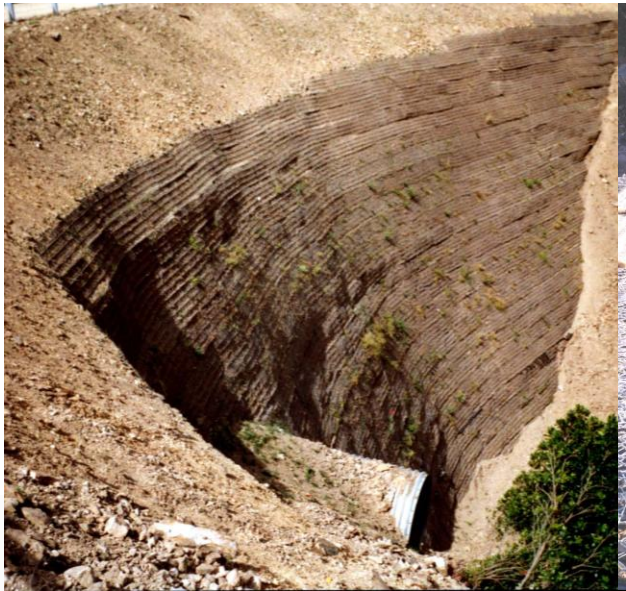
Sardegna - Italy







London - UK

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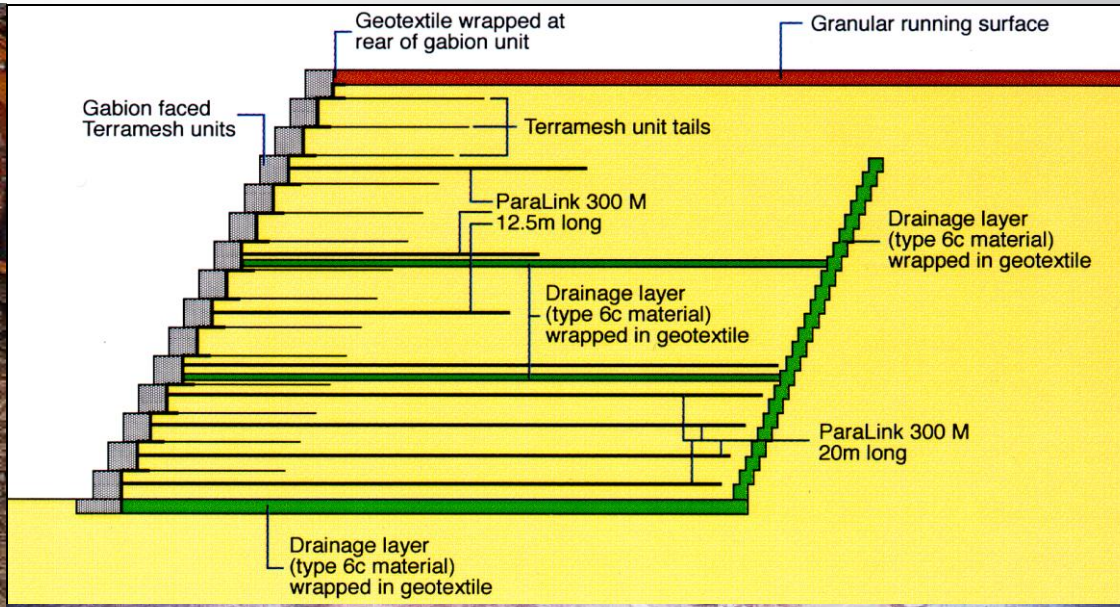

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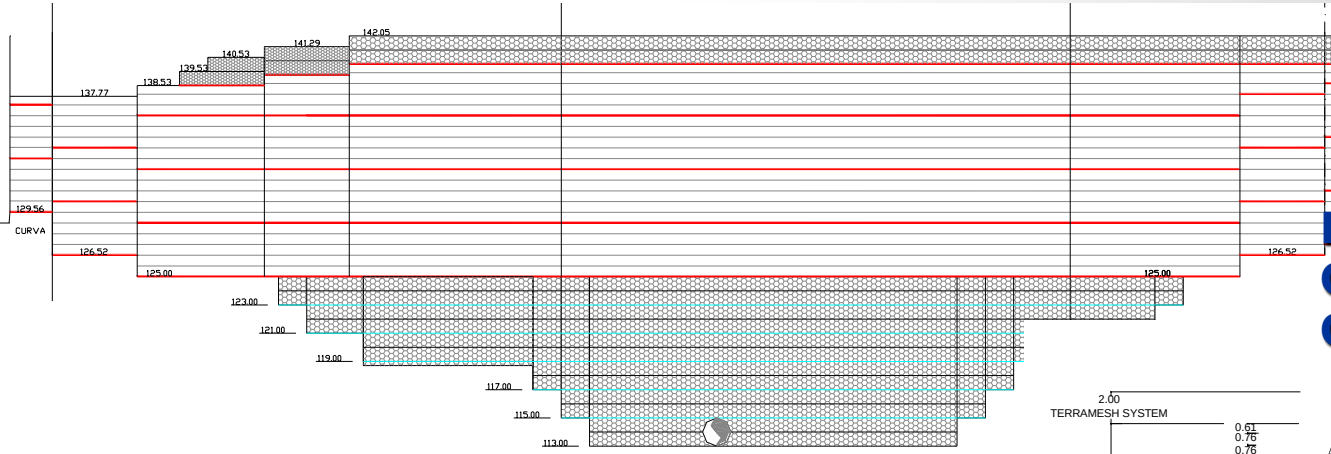
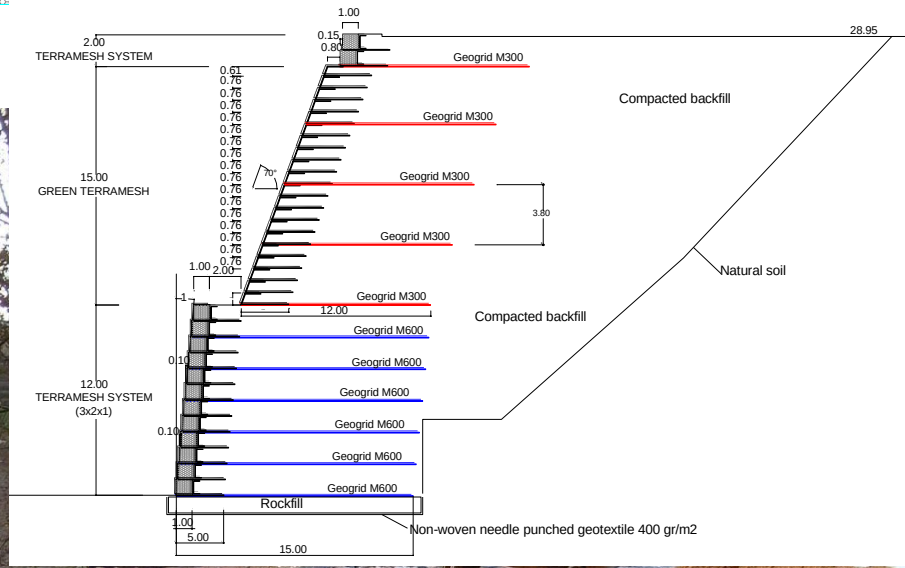
Leiria Retail Park - Portugal



Rock facing : 850 m2
Green facing : 2500 m2
Construction time: 2001



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ADVANTAGES OF REINFORCED SOIL STRUCTURES

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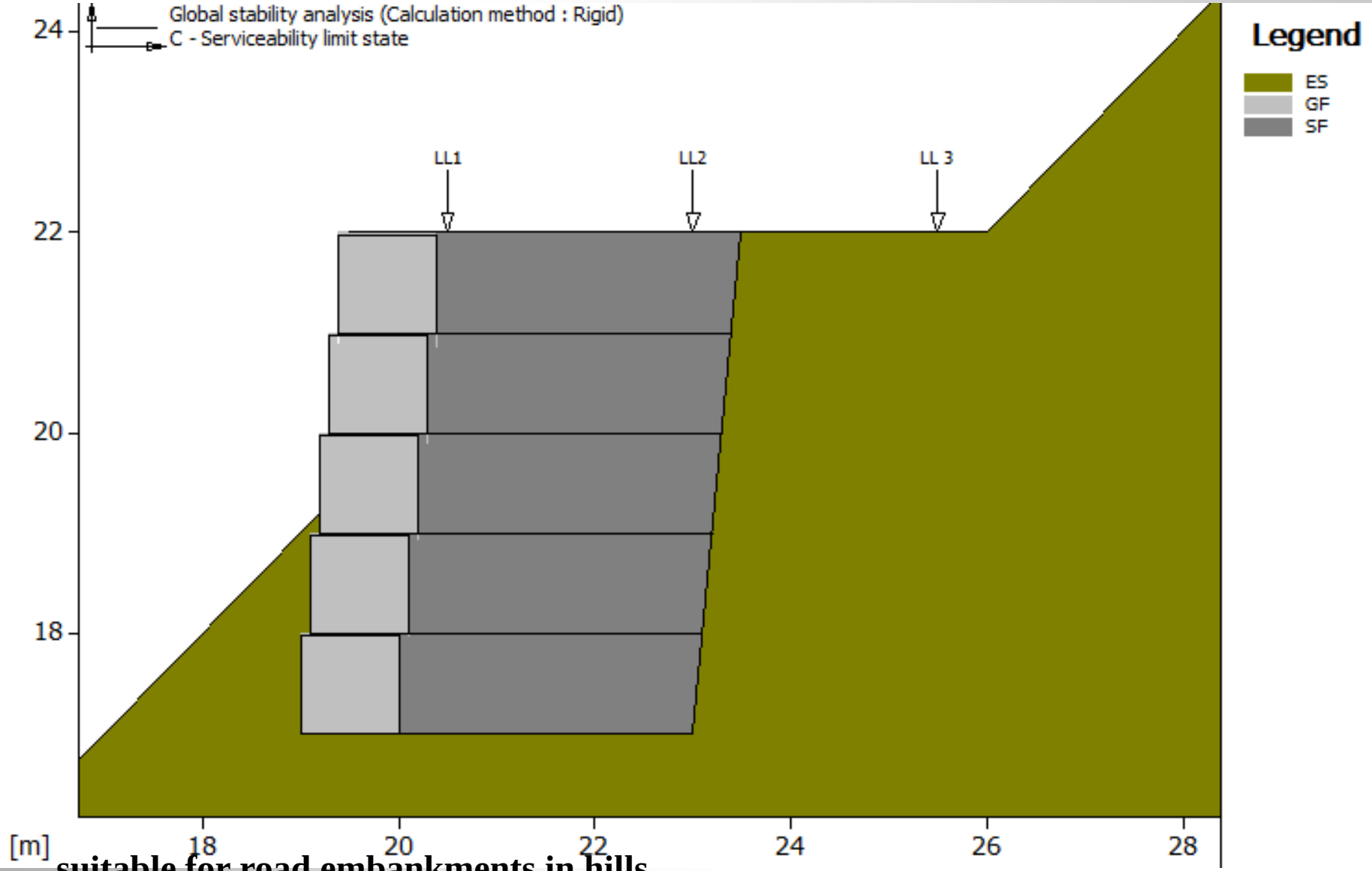

suitable for road embankments in hills

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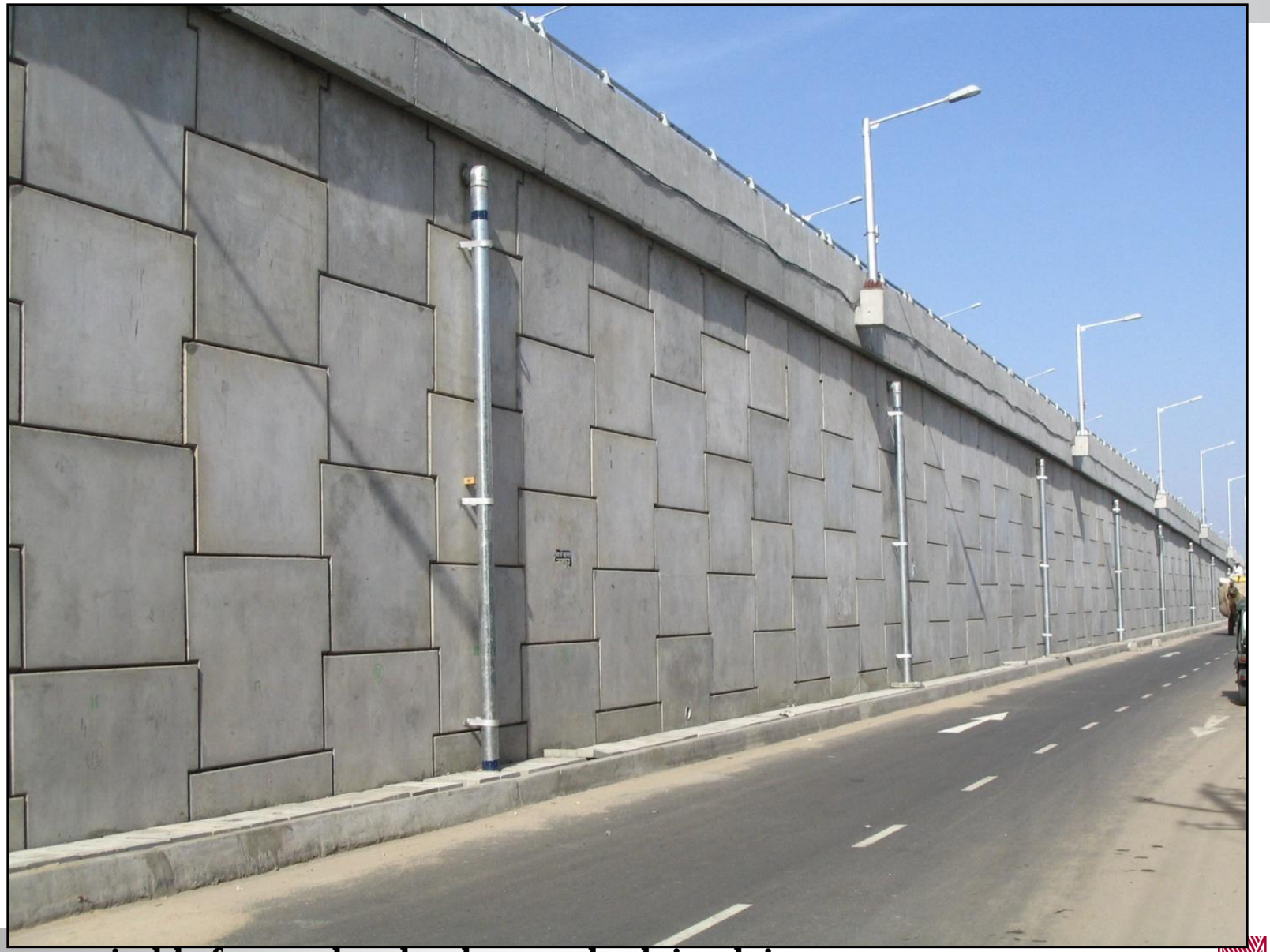

suitable for road embankments both in plain

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ADVANTAGES WITH REINFORCED SOIL STRUCTURES

- Flexible
- Facing slope up to vertical – more width with available ROW
- Facia / Asthetic view: concrete or green
- taylored product
- suitable for all applications
- easy installation
- Cost effective compared to available alternatives e.g., masonry, concrete for heights more than 5m
- Highly suitable for road embankments both in plain as well as in hills

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CONCLUSIONS.....

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THANK YOU