Module 4 – Reinforced Soil Systems

Introduction To Geosynthetics In Transportation

Prepared by

GMA Geosynthetic Materials Association

July 2007

For the Local Technical Assistance Program

IFAI INDUSTRIAL FABRICS Association International

- **The Geosynthetic Materials Association (GMA)** represents all segments of the geosynthetics industry
  - Manufacturers
  - Companies that test or supply material or services to the industry

- GMA activities further the acceptance and use of geosynthetic materials in a variety of applications.
  - Trade association
  - Bimonthly magazine
  - Conferences and trade show

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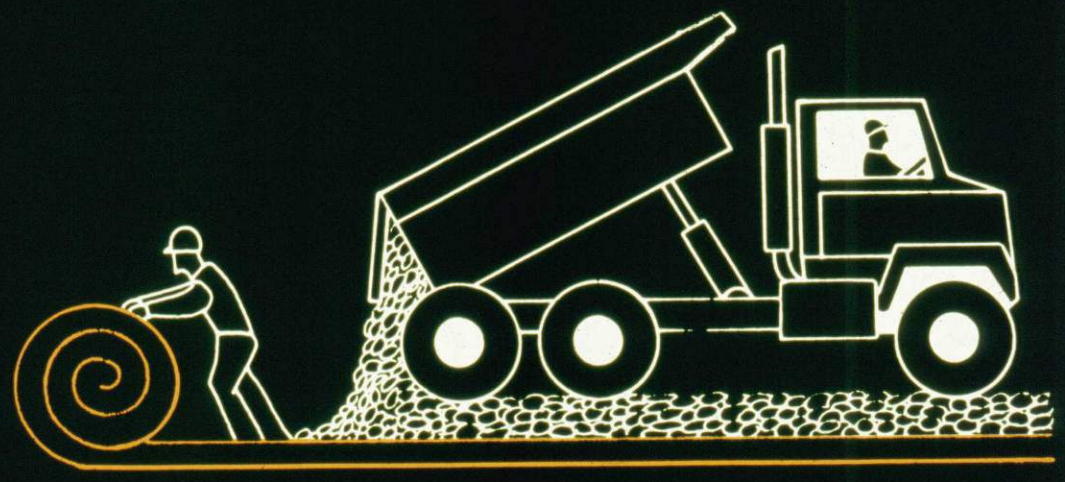
In 2007 Geosynthetics magazine (formerly GFR) enters its 25th year of publication.

Preface

- This short-course introduces geosynthetics from the perspective of practical application.
- It is intended to serve as a general reference in the field for those who are building structures that include geosynthetics.



Geosynthetics

The most versatile and cost-effective ground modification materials.

Contents

- **Introduction**
- **Geosynthetic Functions**
- **Geosynthetic Materials**
- **Geosynthetic Applications**
  - Reinforced Soil Systems
- **Simplified Generic Specifications**

Introduction to Geosynthetics

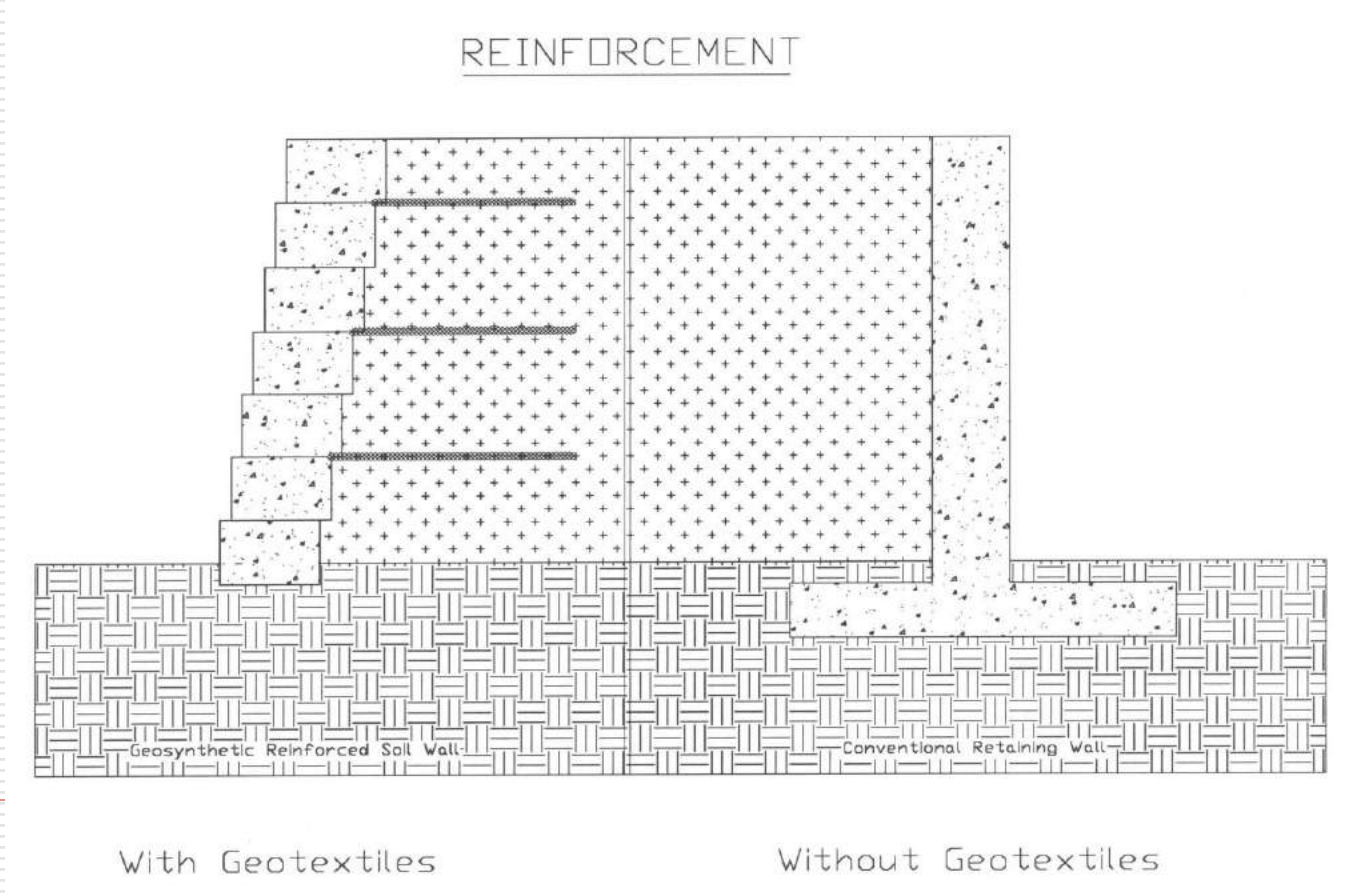
Geosynthetics, including:

- Geotextiles
- Geomembranes
- Geonets
- Geogrids
- Geocomposites
- Geosynthetic clay liners

…Are often used in combination with conventional materials, offer numerous advantages over traditional materials

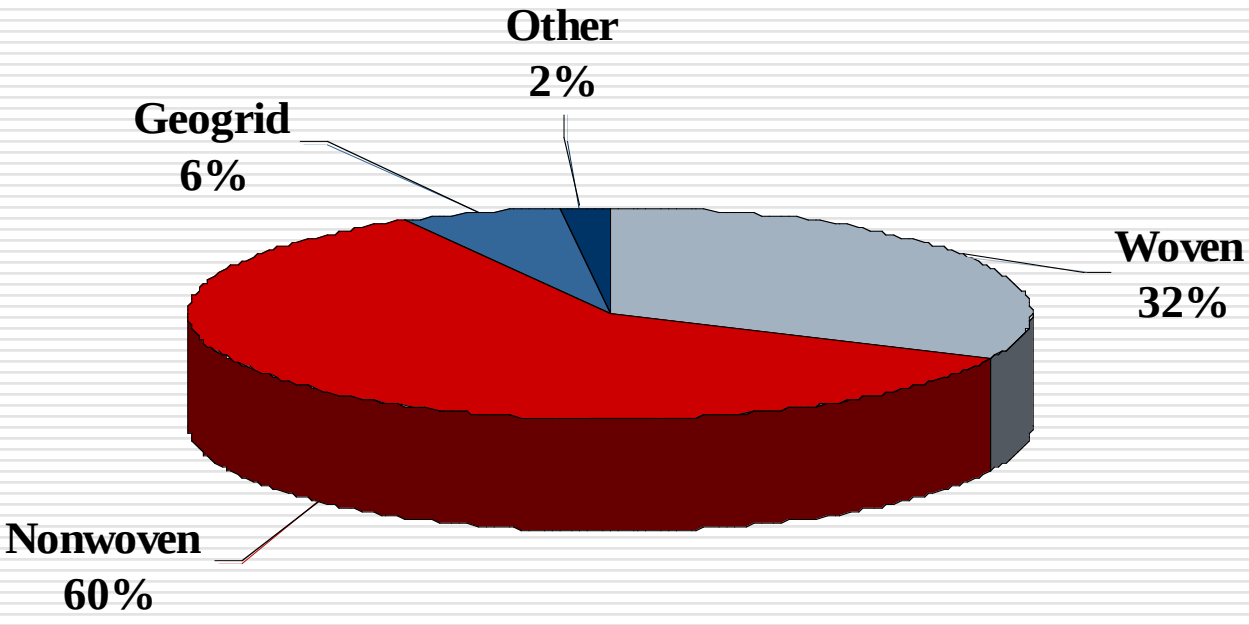
Geosynthetic Reinforcement

A geosynthetic performs the reinforcement function when it contributes a tensile force within the soil mass.



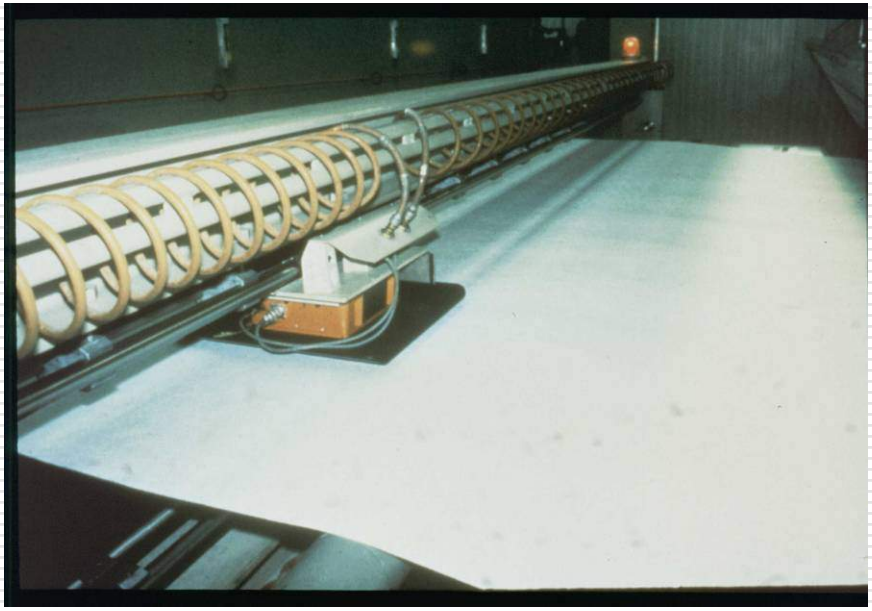
Geosynthetic Categories

Geotextiles – both woven and nonwoven – make up the largest percentage of geosynthetics used in transportation applications.



USA Market

Geotextiles



Geotextiles, like other geosynthetics, are manufactured in state-of-the-art facilities using sophisticated equipment.

Geotextiles

Polymers

- Almost all are polyester or polypropylene.
  - Polypropylene is lighter than water (specific gravity of 0.9), strong and very durable.
  - Polyester is heavier than water, has excellent strength and creep properties, and is compatible with most common soil environments.

Structures

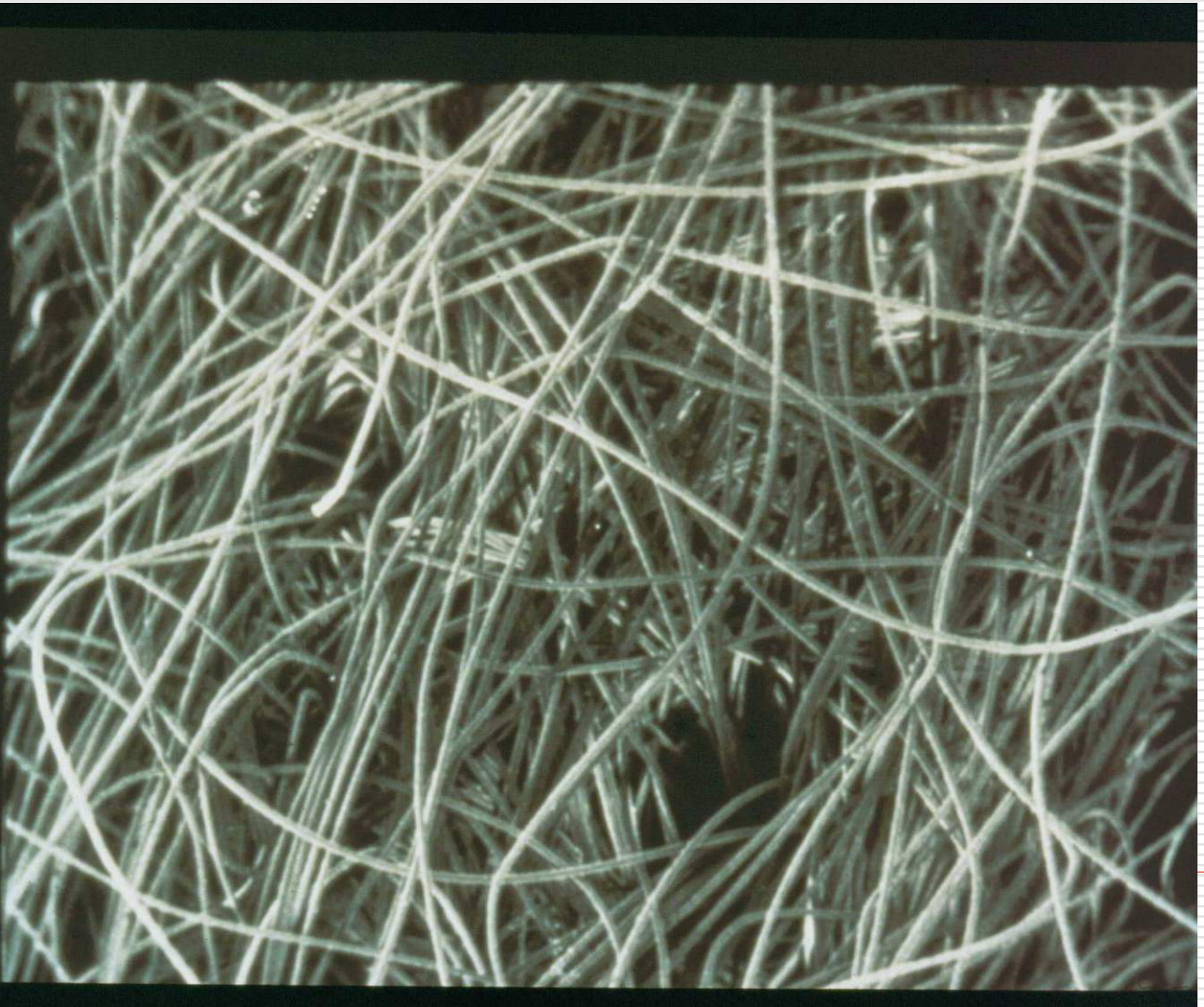
- Nonwoven
- Woven
- Other
  - Knitted
  - Stitch bonded

Nonwovens

- Manufactured from (short) staple fibers or continuous filaments randomly distributed in layers onto a moving belt to form a "web".

- The web then is needled or heat and pressure bonded to interlock the fibers.

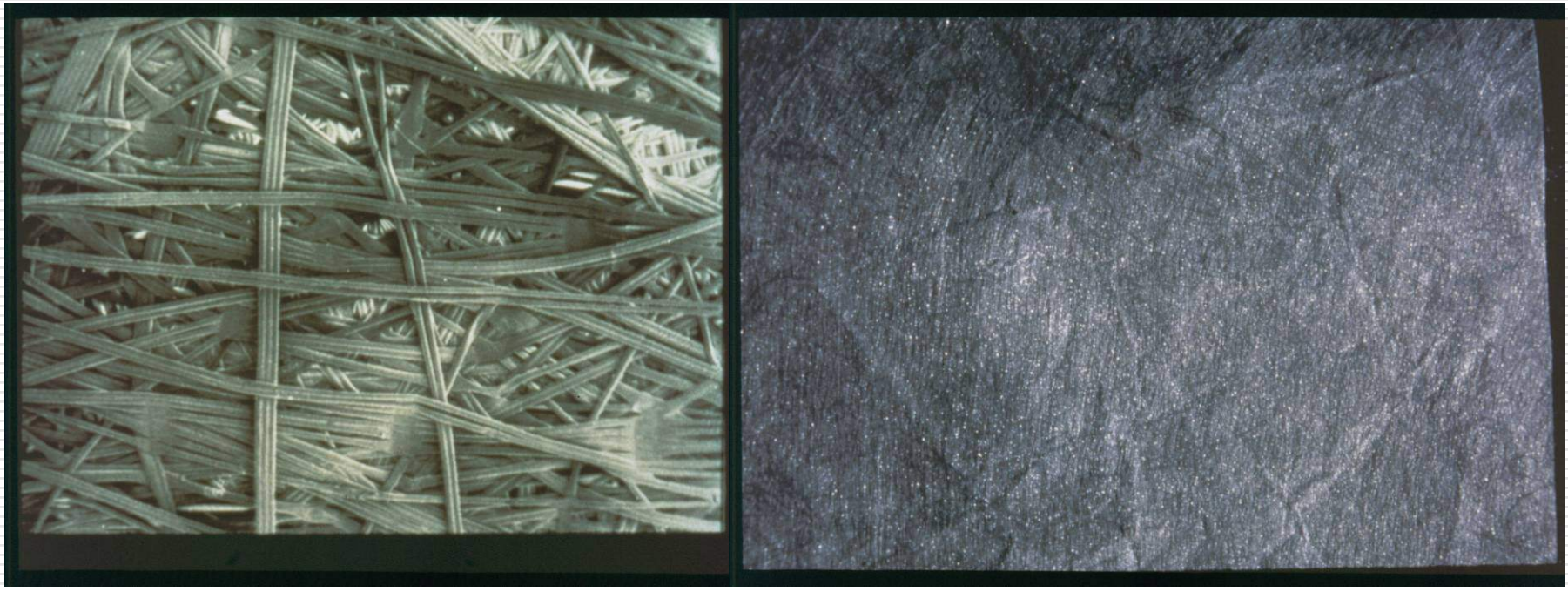
Needle-punched Nonwoven Geotextiles



Needle-punched nonwovens are “felt-like” and very flexible.

Heatbonded Nonwoven Geotextiles

Heat-bonded nonwovens are thinner and have greater stiffness.

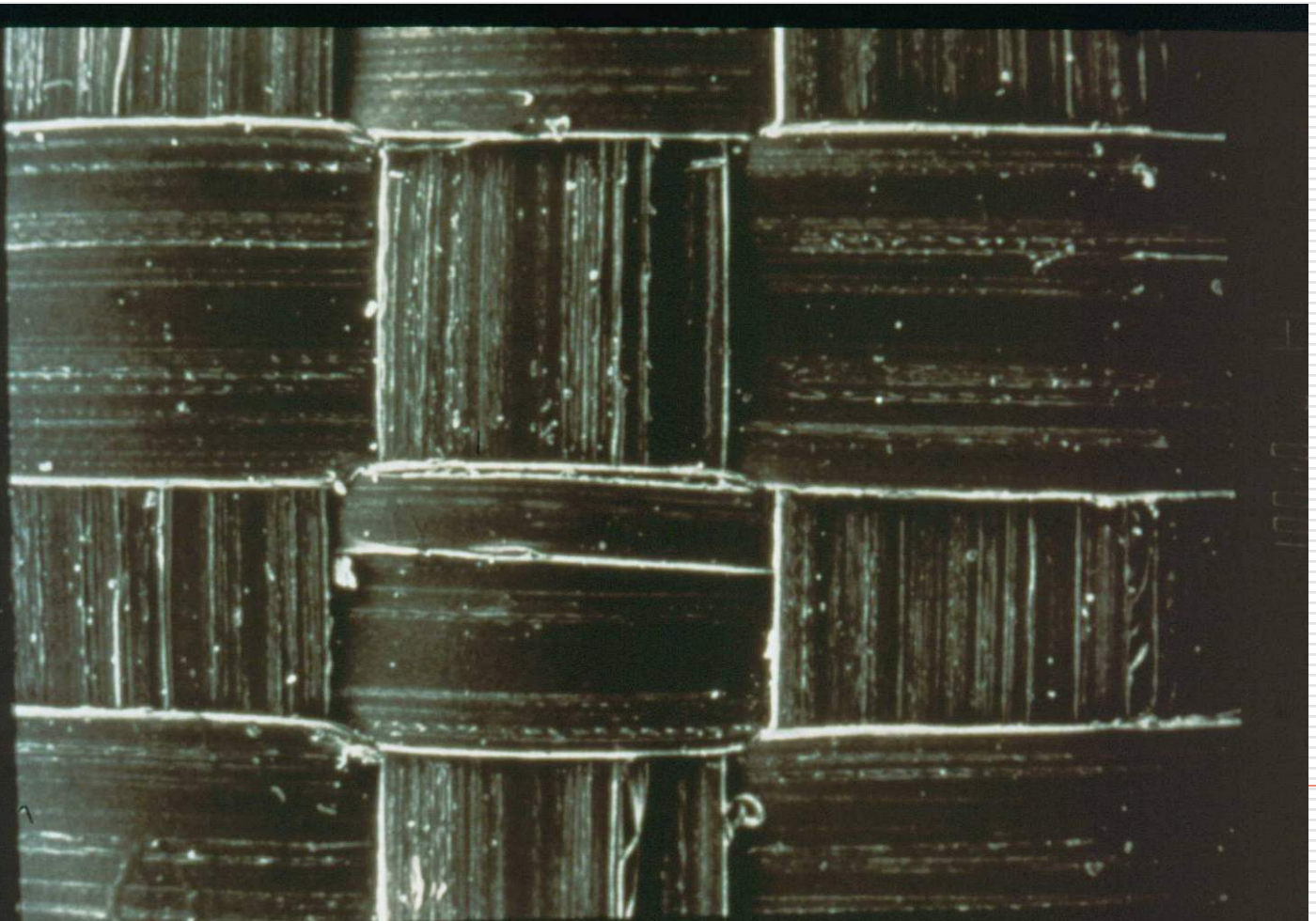


Wovens

- Weaving is a process of interlacing yarns to make a fabric.

- Woven geotextiles are made from weaving slit film, monofilament, or multifilament yarns.

Slit Film Woven Geotextiles



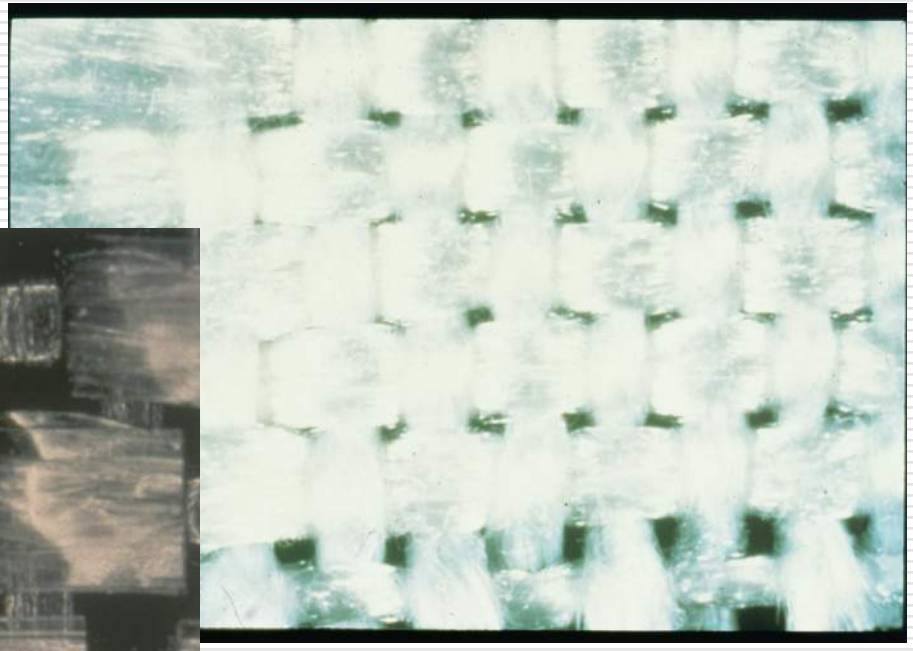
Slit film woven geotextiles provide economical separation of materials.

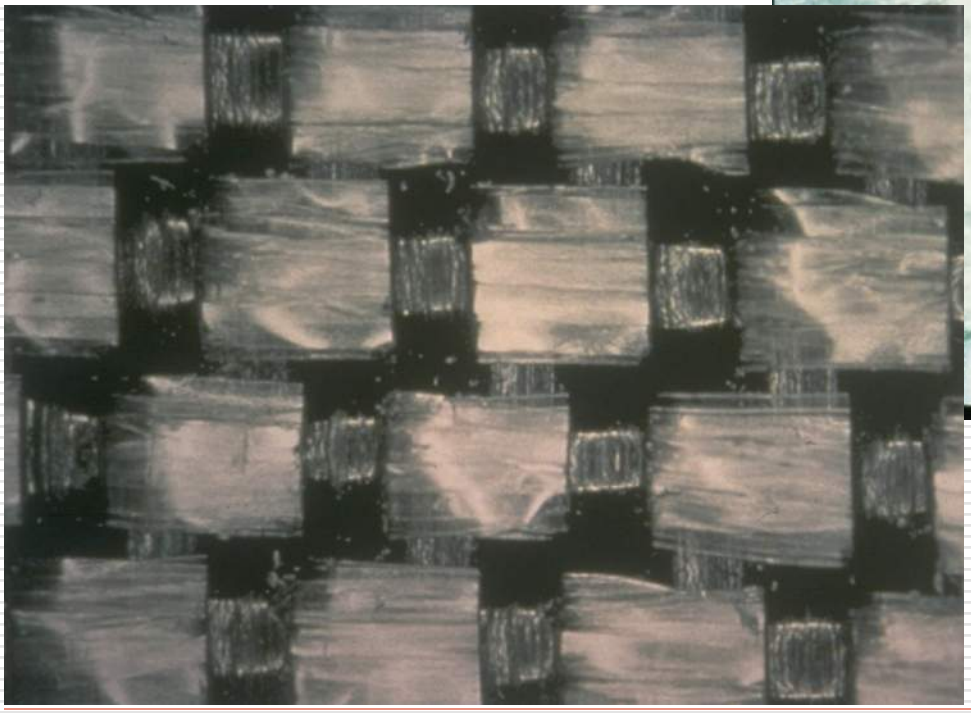
Monofilament Woven Geotextiles

Monofilament woven geotextiles provide enhanced filtration properties.

Fibrillated and Multifilament Woven Geotextiles

Multifilament woven geotextiles provide enhanced tensile strength.





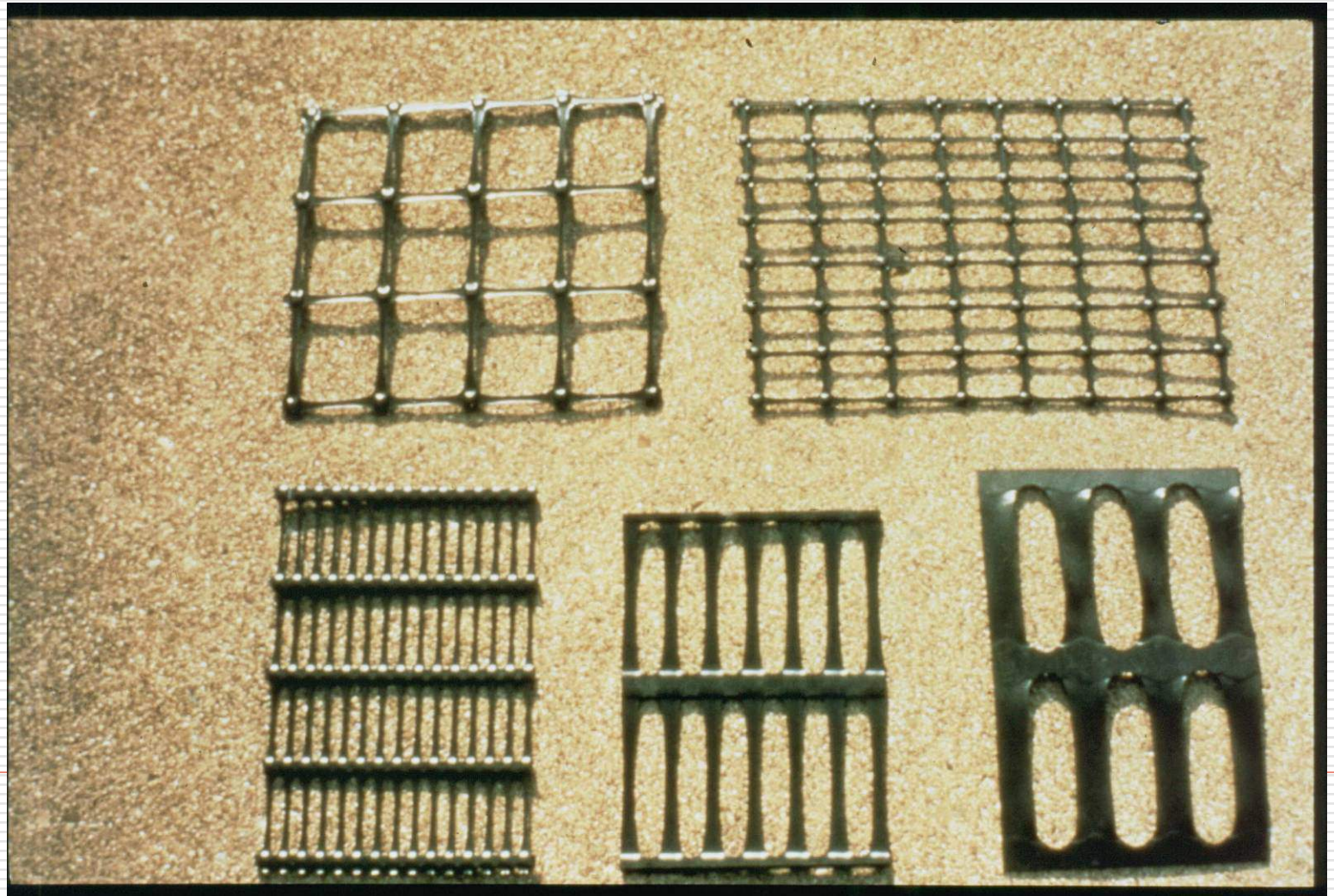
Geogrids

- Geogrids are single or multi-layer materials usually made from extruding and stretching high-density polyethylene or polypropylene or by weaving or knitting and coating high tenacity polyester yarns.

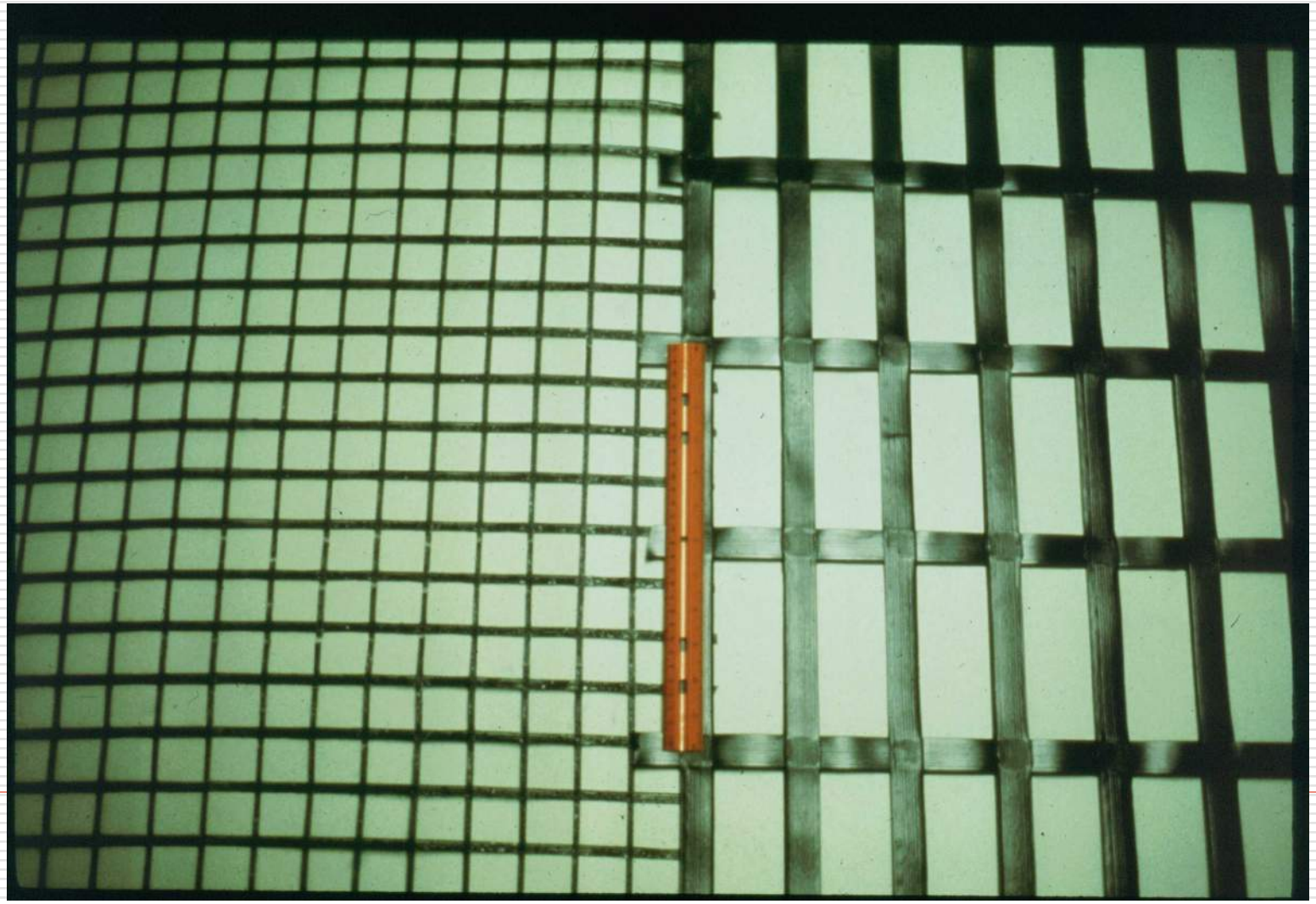
- The resulting grid structure possesses large openings (called apertures) that enhance interaction with the soil or aggregate.

- The high tensile strength and stiffness of geogrids make them especially effective as soil and aggregate reinforcement.

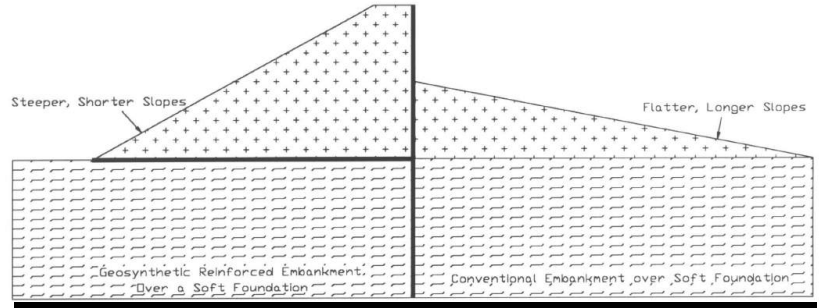
Punched/Drawn Geogrid



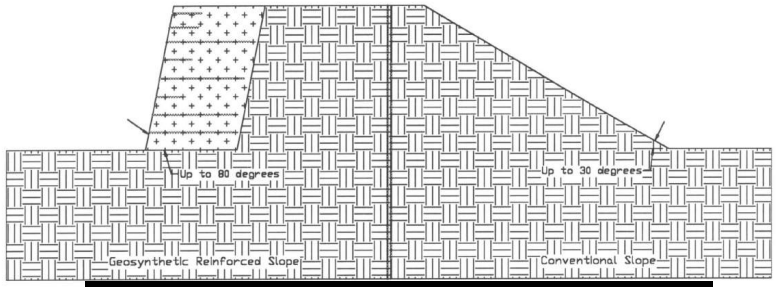
Woven/Coated Geogrid



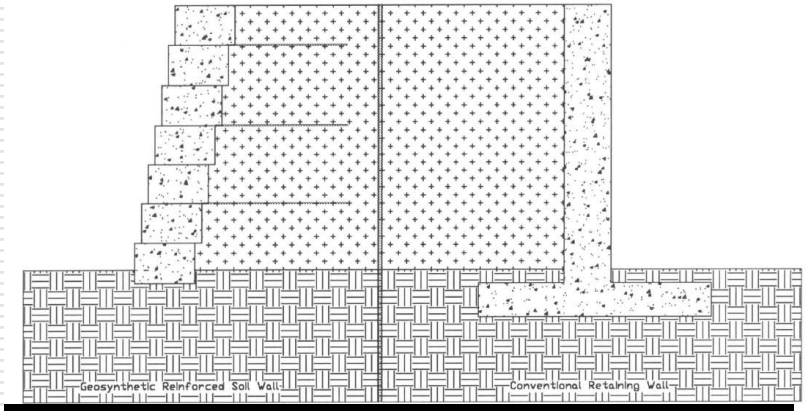
Geosynthetics In Reinforced Soil Systems



Embankments over Soft Foundations



Reinforced Steepened Slopes



Mechanically Stabilized Earth Walls

Geosynthetic reinforced soil systems include . . .

History

- The use of tensile inclusions in soil structures dates back several thousand years to the construction of religious structures in ancient Babylonia.
- Three decades ago Henri Vidal, a French architect, pioneered modern earth reinforcement techniques.
- These techniques involved the incorporation of tensile elements into a soil mass to complement the soil's compressive strength and to improve the mechanical properties of the soil mass.

More Recent History

- The U.S. Forest Service constructed full-scale wrapped-face walls using geotextiles in 1974 and 1975.
- The U.S. Army Corps of Engineers began using geosynthetics in reinforcement applications in 1978.
- Under FHWA sponsorship, highway departments in New York, Colorado, and Oregon constructed geotextile reinforced walls in the early 1980's.

Geosynthetic Reinforced Soil Systems

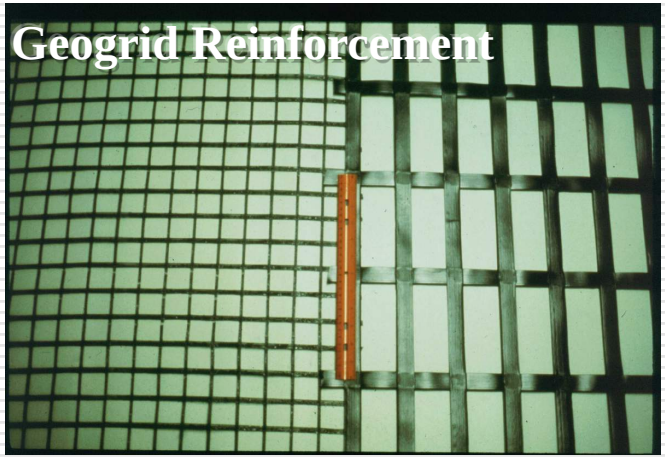
Geosynthetic reinforced soil systems are:

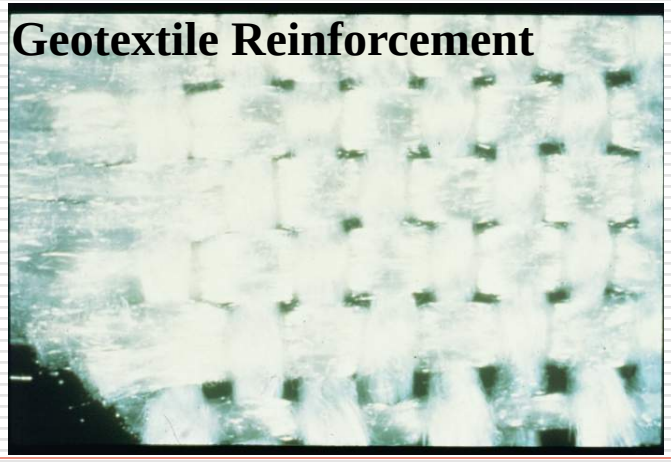
- Important in highway construction as their use reduces the required width of new right-of-way:
  - Mechanically stabilized earth walls (MSEW)
  - Reinforced soil slopes (RSS)

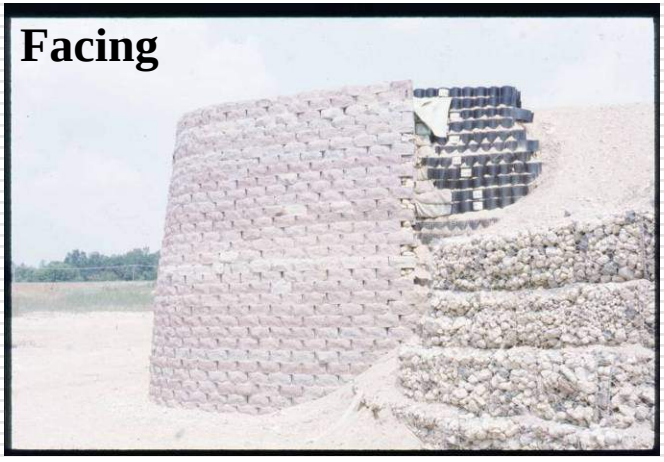
- A cost-effective alternative for constructing over low strength foundations:
  - Reinforced embankments over soft foundations (RESF)

Geosynthetic Reinforced Soil System Components

Geosynthetic reinforced soil system components include . . .

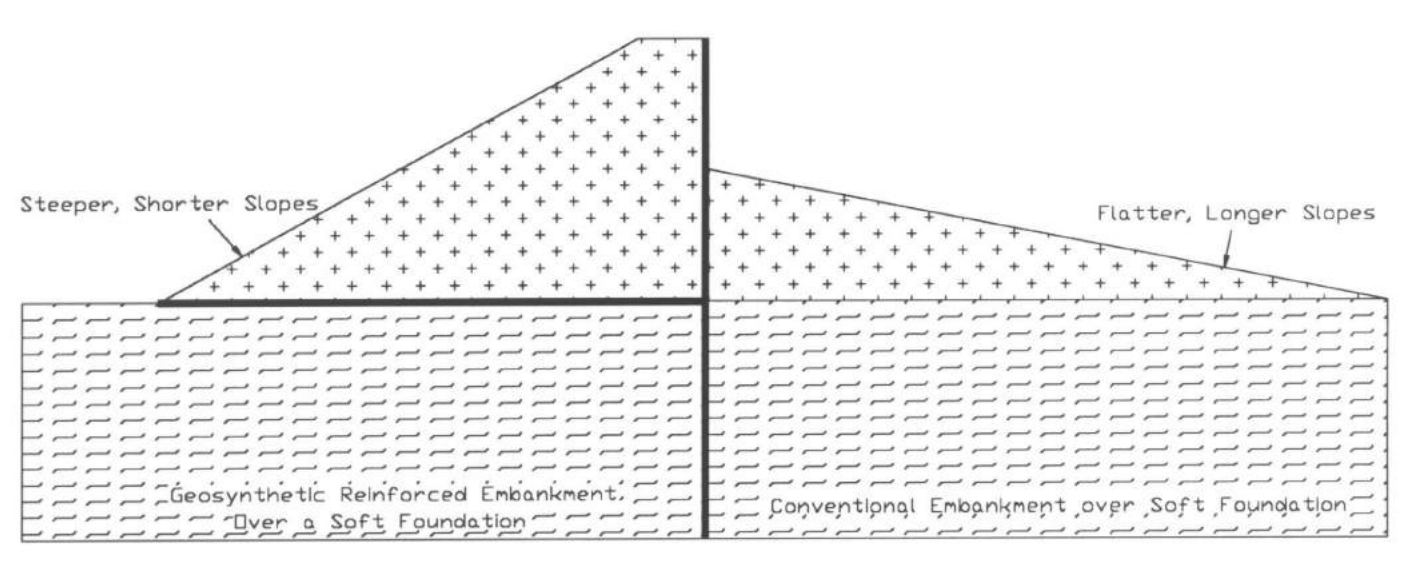






Reinforced Embankment Over Soft Foundation (RESF)

Reinforced embankments over soft foundations (RESF) provide a cost-effective means to construct large earthen structures over soft soils.



Introduction to the Problem

- Construction of embankments is costly and environmentally sensitive when very soft soils, especially in wetlands, are encountered.

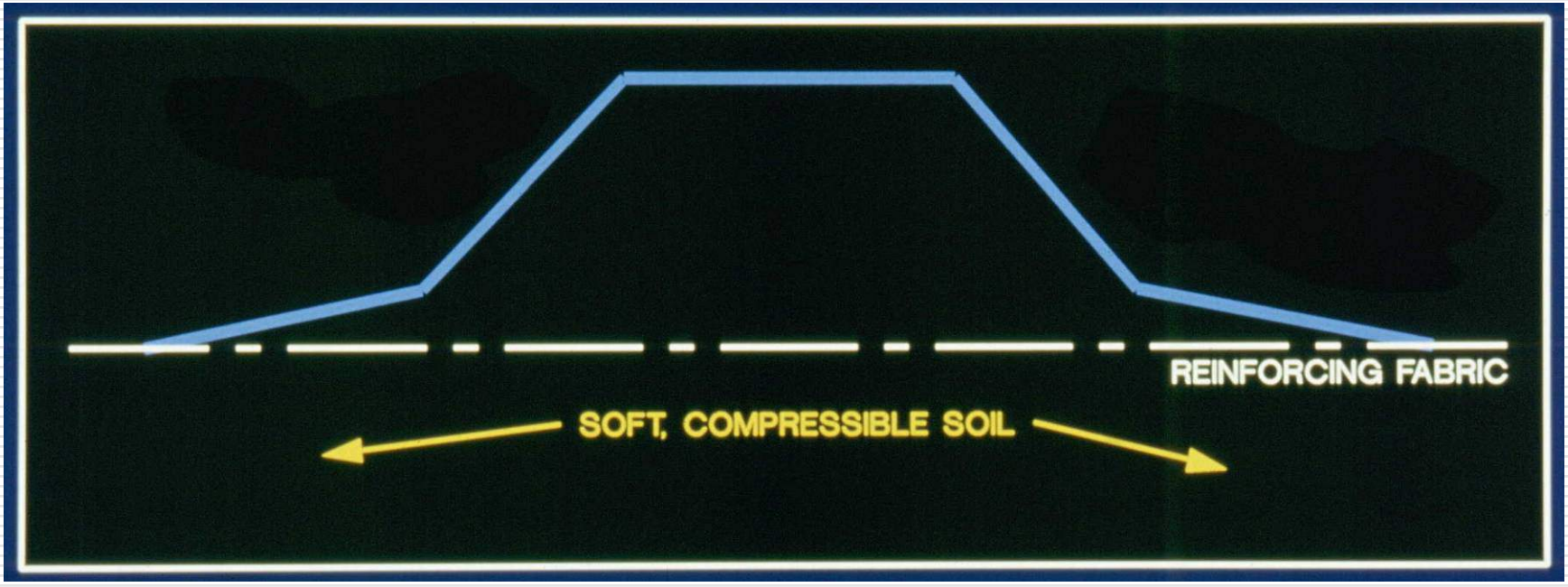
- The primary problem with these soft soils results from their low shear strength and excessive consolidation settlements requiring special construction practices and leading to high construction costs.

Typical Solutions

Techniques for constructing on soft foundations include:

- Removal and replacement of soft soil.
- Displacement of compressible material by end-loading.
- Staged construction - placing fill at controlled rates to allow for consolidation and strength gains.
- Installation of drains to facilitate consolidation.
- Pre-loading the site to reduce settlements of the structure and provide higher strength.
- Soft soil modification using admixtures (e.g. soil, cement, lime) or injections
- Reinforcement of the soil matrix using a structural element.

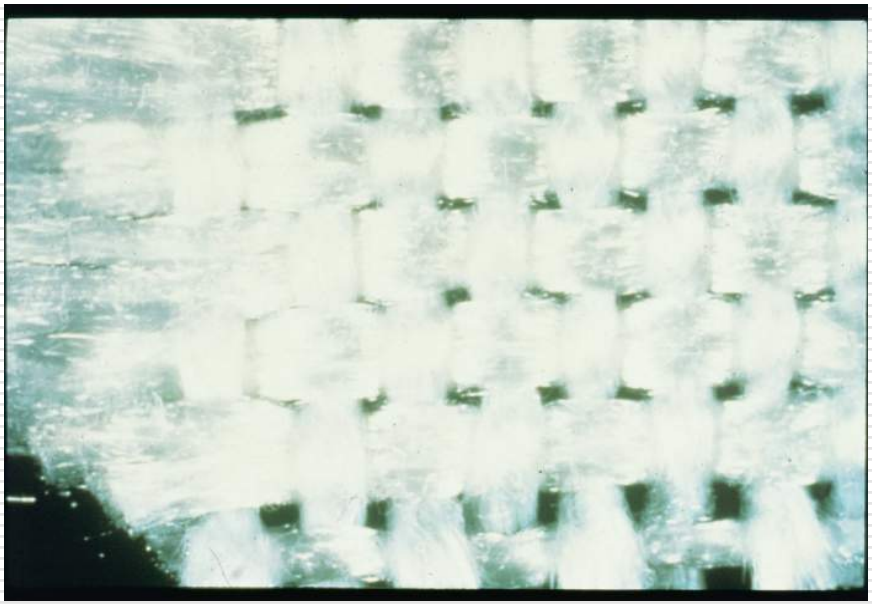
Geosynthetic Solution



Soil reinforcement has emerged as an efficient, economical and effective solution to the problem of constructing embankments over soft soils.

High-strength Geotextiles

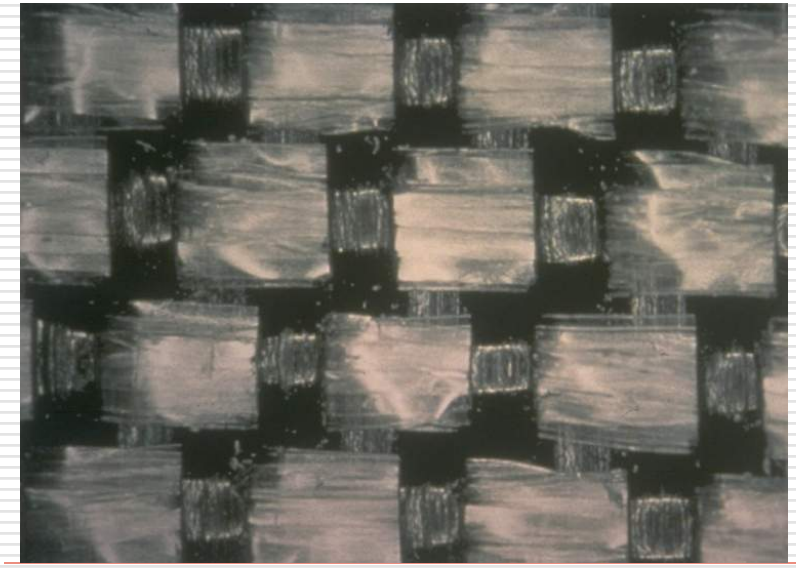
Very strong fabrics, with tensile strengths ranging from 400 lb/in to 4,500 lb/in, are placed over a prepared ground surface and earthen embankments are erected using a system of controlled height lifts to maintain uniform pressure on the subgrade.

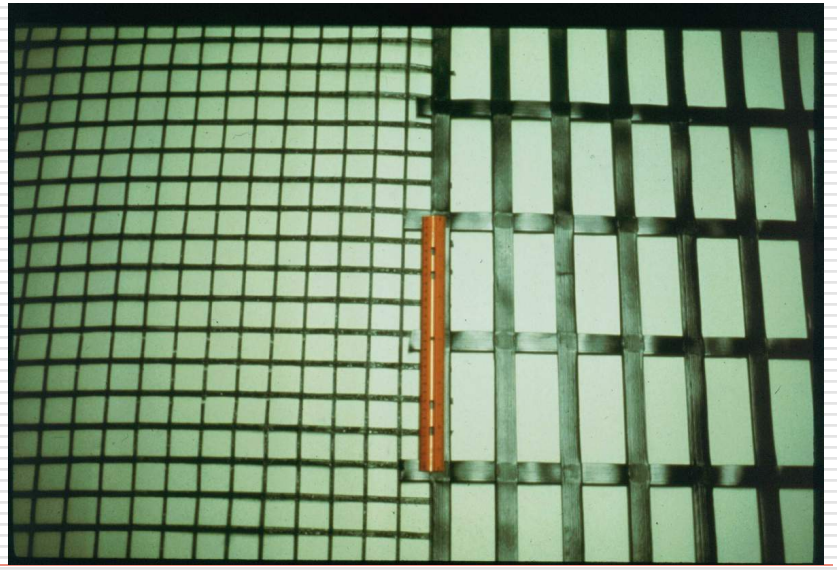


Medium Strength Geosynthetics

- Smaller embankments may also be designed and constructed using single or multiple layers of medium strength reinforcing geotextiles and geogrids.

- These geosynthetics reduce lateral displacement and improve the overall stability of the soil embankment.





RESF Construction - Deployment

Large factory-fabricated panels are deployed on the jobsite.

RESF Construction – Field Sewing

Factory-fabricated panels must still be field sewn into continuous sheets of reinforcement.

RESF Construction – Positioning

The connected panels are then positioned to assure that the reinforcement is oriented to maintain embankment stability.

RESF Construction – Backfill Placed

As the backfill is placed, the soft foundation soils begin to "mud wave."

RESF Construction – Toe Reinforcement

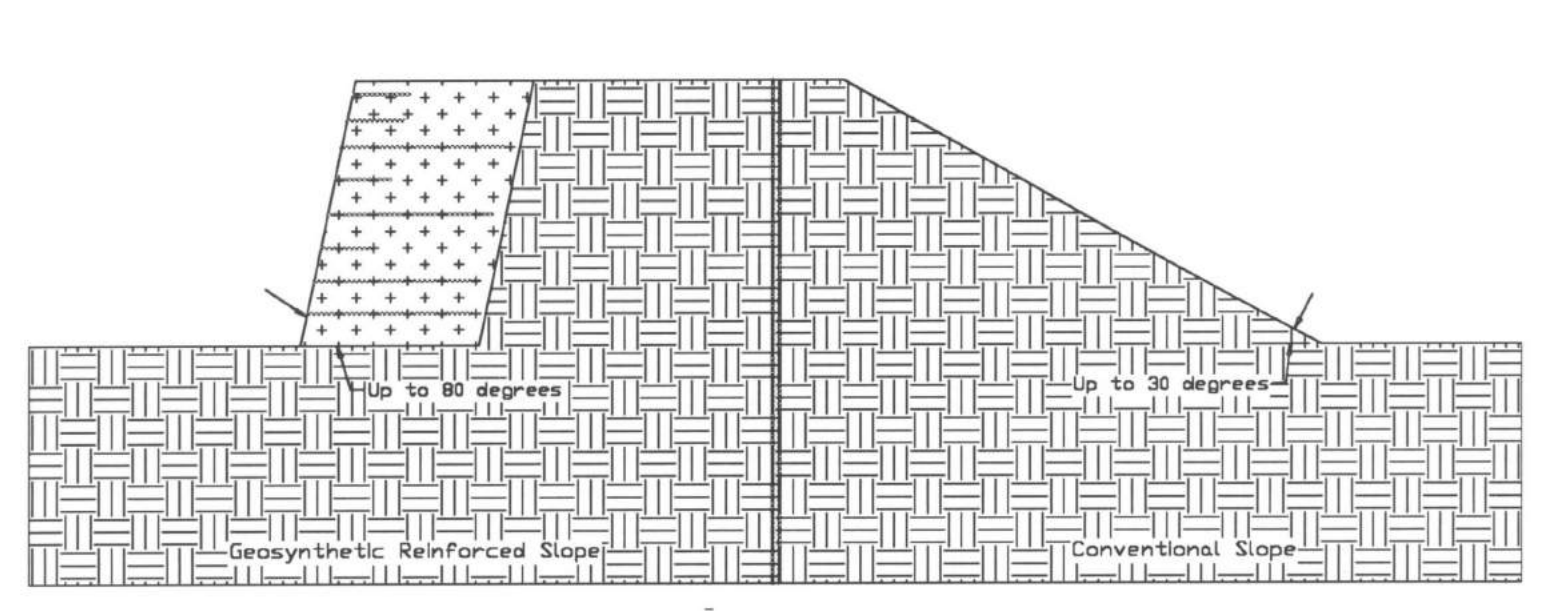
The fill thickness tapers toward the embankment toe reducing the reinforcement requirements and allowing a lighter-weight geotextile to be used under the embankment slopes.

RESF Construction – Final Grades

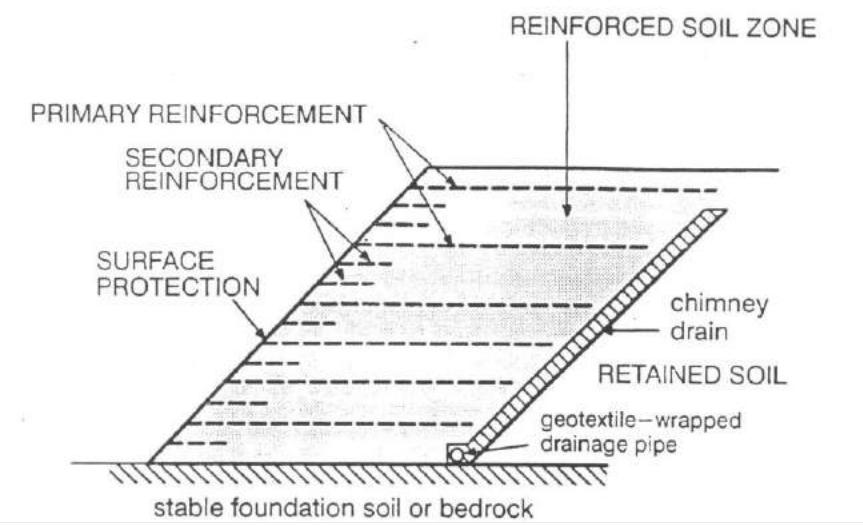
The completed embankment is taller and has steeper side slopes than would be possible without reinforcement or alternative stabilization.

Reinforced Steepened Slope (RSS)

Reinforced steepened slopes (RSS) provide a cost-effective means to achieve more efficient grade changes than are possible with conventional unreinforced slopes.

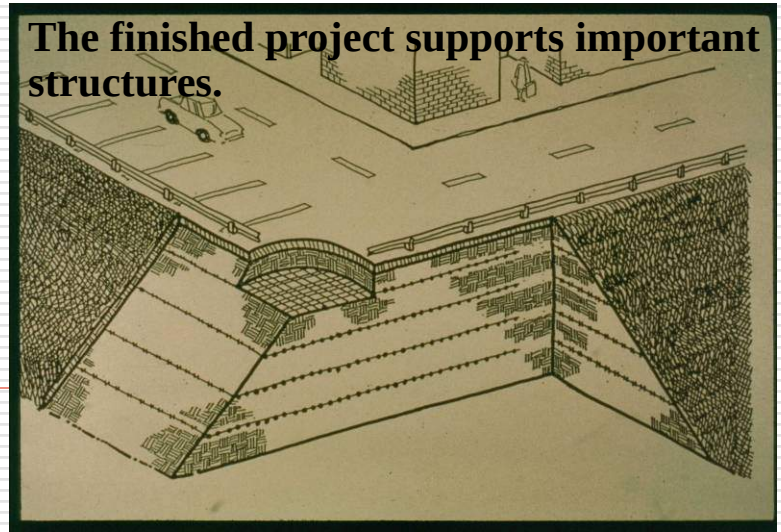


Details of RSS Systems



- Foundation - stable soil upon which the slope is constructed.
- Retained Soil - soil remaining beyond the limits of the excavation.
- Drainage - installed at the limits of the reinforced soil zone to collect ground water seepage.
- Reinforced Soil - soil placed in lifts between reinforcement layers to create the sloped structure.
- Reinforcement – geotextile or geogrid placed between soil lifts to provide tensile forces to resist instability.
- Surface Protection - erosion resistant covering of the finished slope.

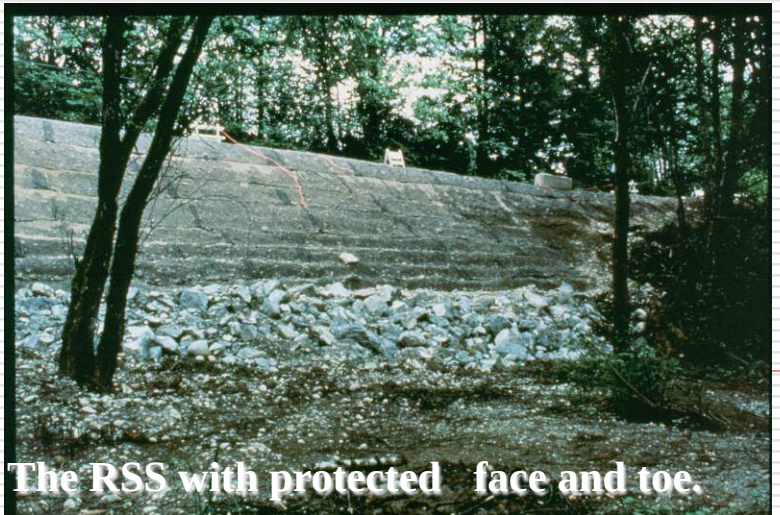
RSS Construction - New



RSS Construction - Repair

A slope repair that must support a roadway.

An RSS is constructed using conventional equipment.

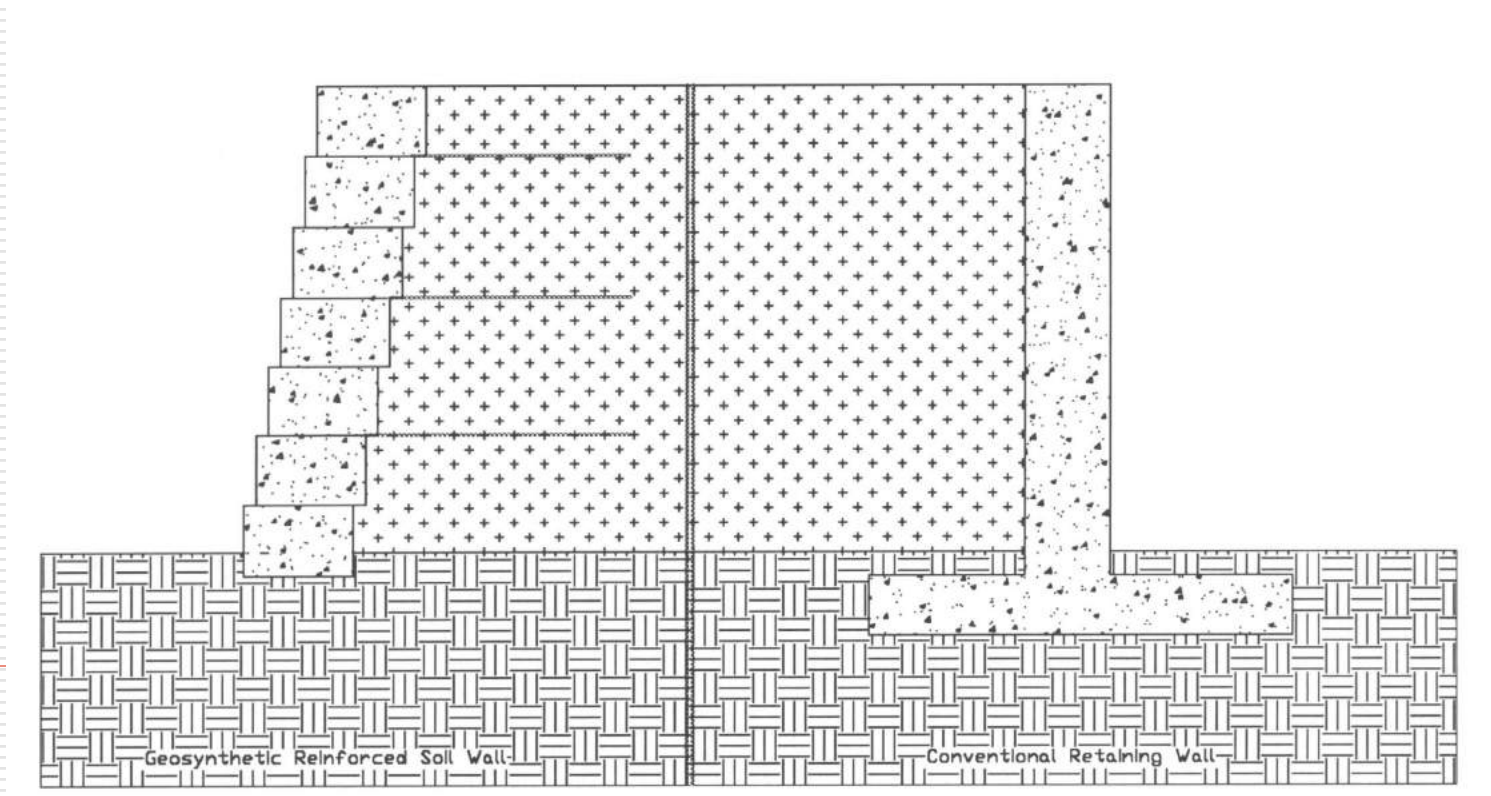


The RSS with protected face and toe.

The RSS supports a public roadway.

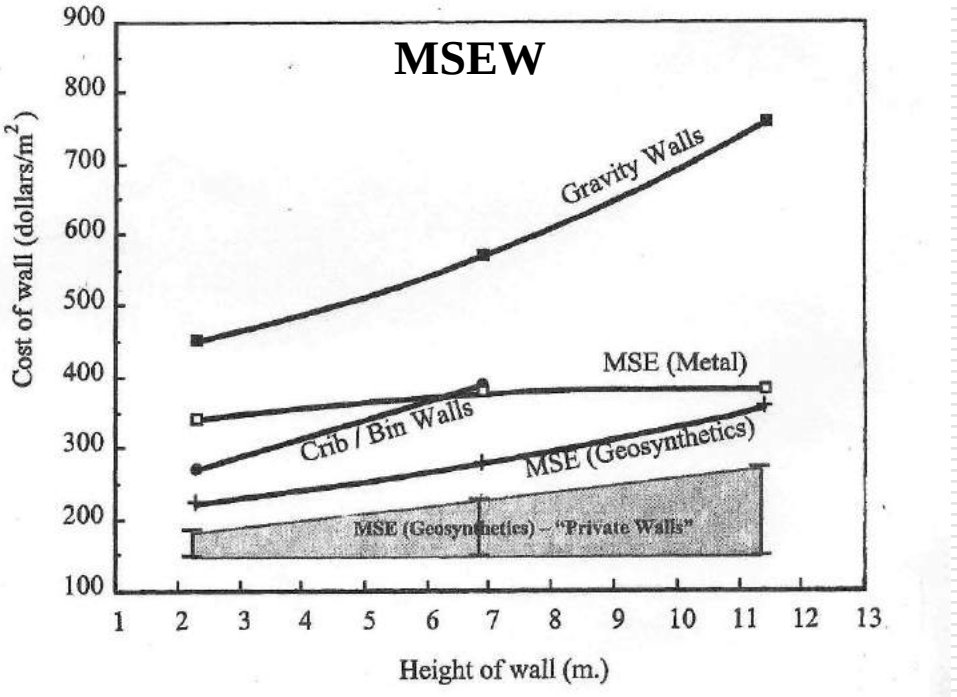
Mechanically Stabilized Earth Walls (MSEW)

- Conventional retaining walls are gravity structures which must be massive enough to resist the destabilizing forces of the retained fill.
- Reinforced soil walls create gravity retaining structures out of the fill itself by incorporating geosynthetic reinforcement into the design.



Why MSEW Retaining Walls?

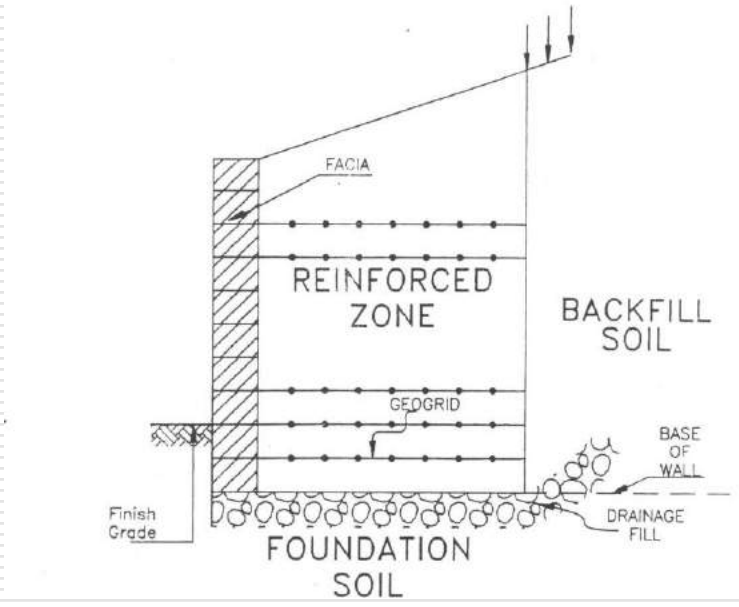
Though there are many types of retaining walls, geosynthetic reinforced soil walls (MSEW) provide vertical grade changes at significantly less cost than conventional retaining walls.



(Figure is courtesy the Geosynthetics Institute)

Details of an MSEW System

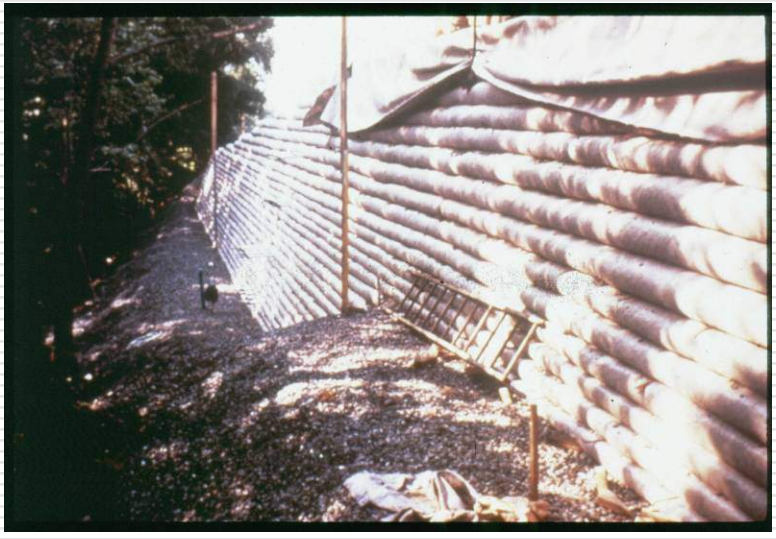
- **Foundation** - stable soil upon which the slope is constructed.
- **Retained Soil** - soil remaining or placed beyond the limits of the excavation.
- **Drainage** - installed at the limits of the reinforced soil zone to collect ground water seepage.
- **Reinforced Soil** - soil placed in lifts between reinforcement layers to create the sloped structure.
- **Reinforcement** – geotextile or geogrid placed between soil lifts to provide tensile forces to resist instability.



- **Facia** - The nearly vertical covering, or face, of the reinforced zone which provides the desired appearance and retains near surface soils. A sufficient connection must be provided between the facia and the geosynthetic reinforcement.

MSEW Construction – Wrapped Face

The first MSE walls used "wraparound" techniques.



The wrapped face was protected with shotcrete

MSEW Construction – Block Facing

- More recent walls commonly use masonry block units.
- MSE walls have geosynthetic reinforcement layers.

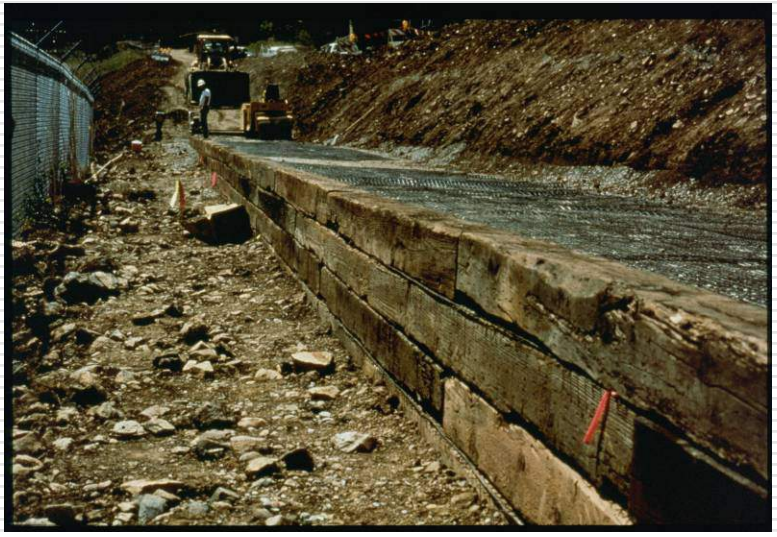
MSEW Construction – Block Facing

- Backfill placed over reinforcement layer.
- One of numerous, attractive block facing options.

MSEW Construction – Other Facia

- Geocellular confinement system faced MSE wall.

- MSE wall with timber facing.



Specification for Reinforce Soil Systems*

(*The specification of “critical” geosynthetic applications will generally require the input of a qualified engineering professional)

Project-specific Design Required For Reinforced Soil Systems

- Reinforced soil structures are “critical” applications of geosynthetics and, thus, should not use “standard” specifications. A knowledgeable engineer should design and specify each application.

Questions

THINK

GMAtechline@ifai.com

Thank You!

For more information go to www.gmanow.com