Module 1 – Separation, Stabilization & Base Reinforcement

Introduction To Geosynthetics In Transportation

Prepared by

Geosynthetic Materials Association

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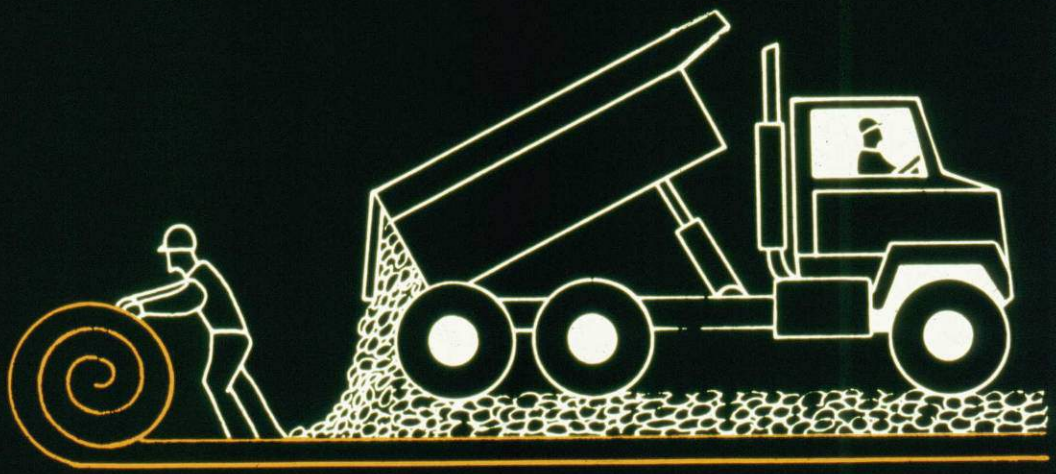
In 2007 Geosynthetics magazine (formerly GFR) enters its 25th year of publication.

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 to Geosynthetics

Geosynthetics, including:

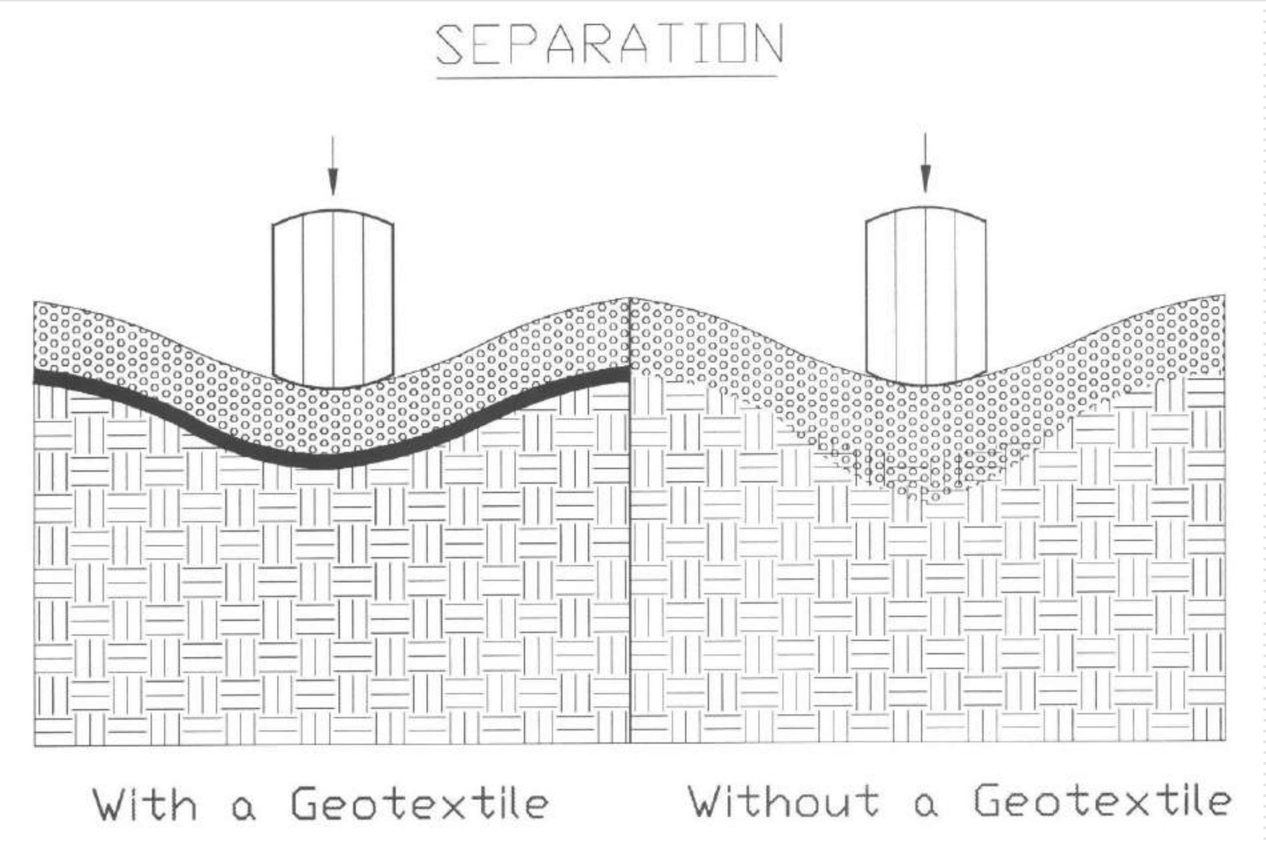
- Geotextiles
- Geomembranes
- Geonets
- Geogrids
- Geocomposites
- Geosynthetic clay liners

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

Geosynthetic Separator

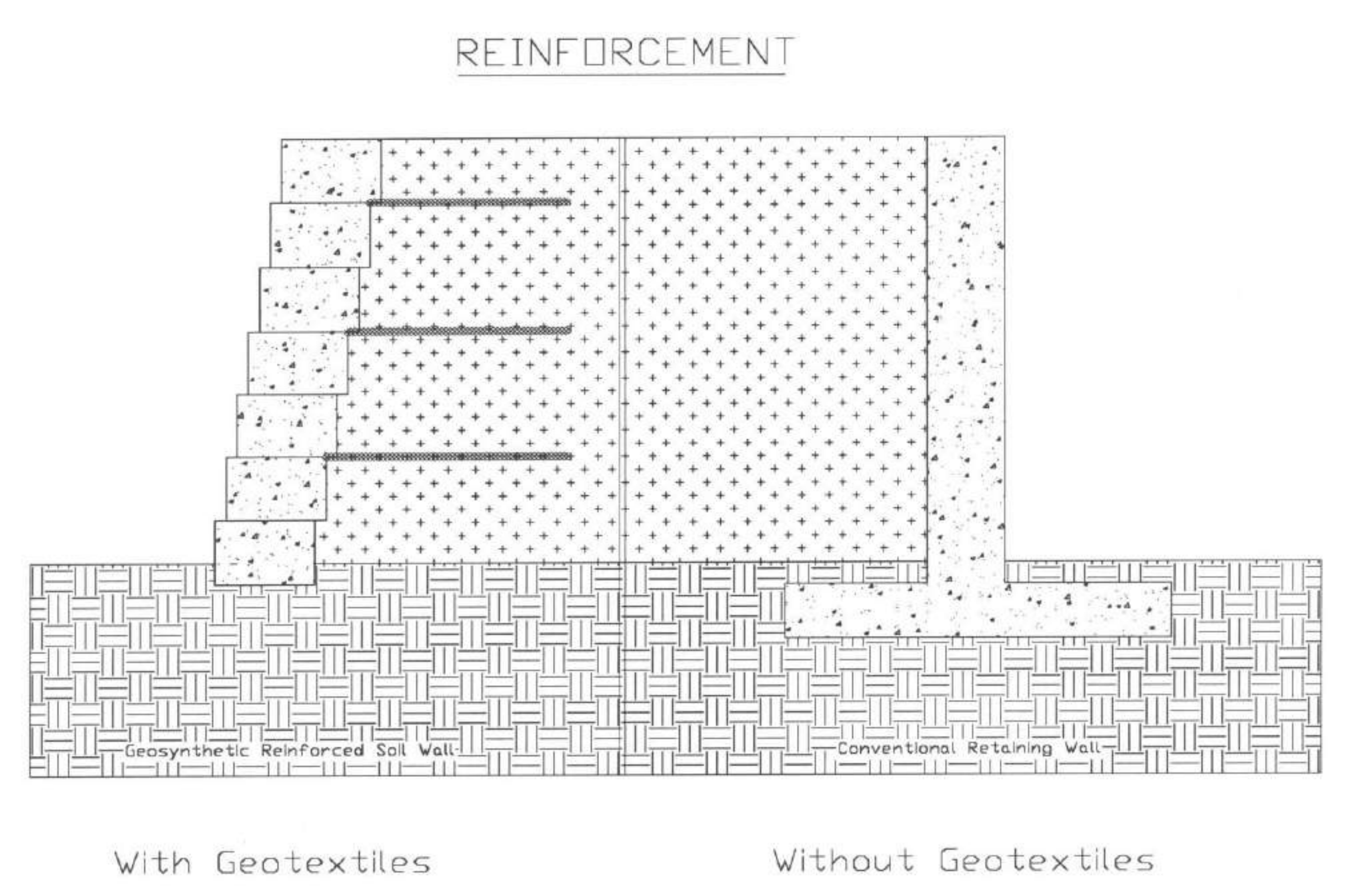
Geosynthetics can perform numerous functions, including the separation function.

In roadways, a separator keeps the base aggregate and the subgrade from mixing.



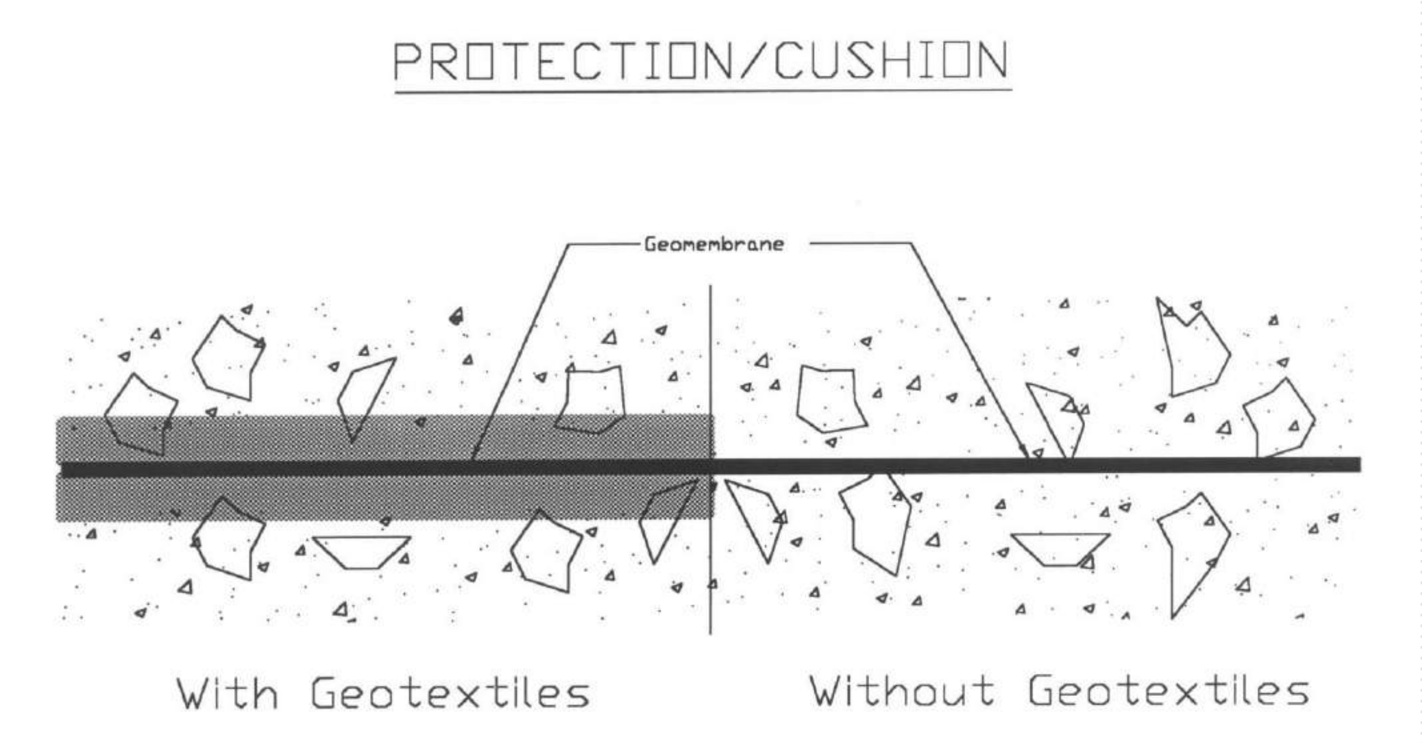
Geosynthetic Reinforcement

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



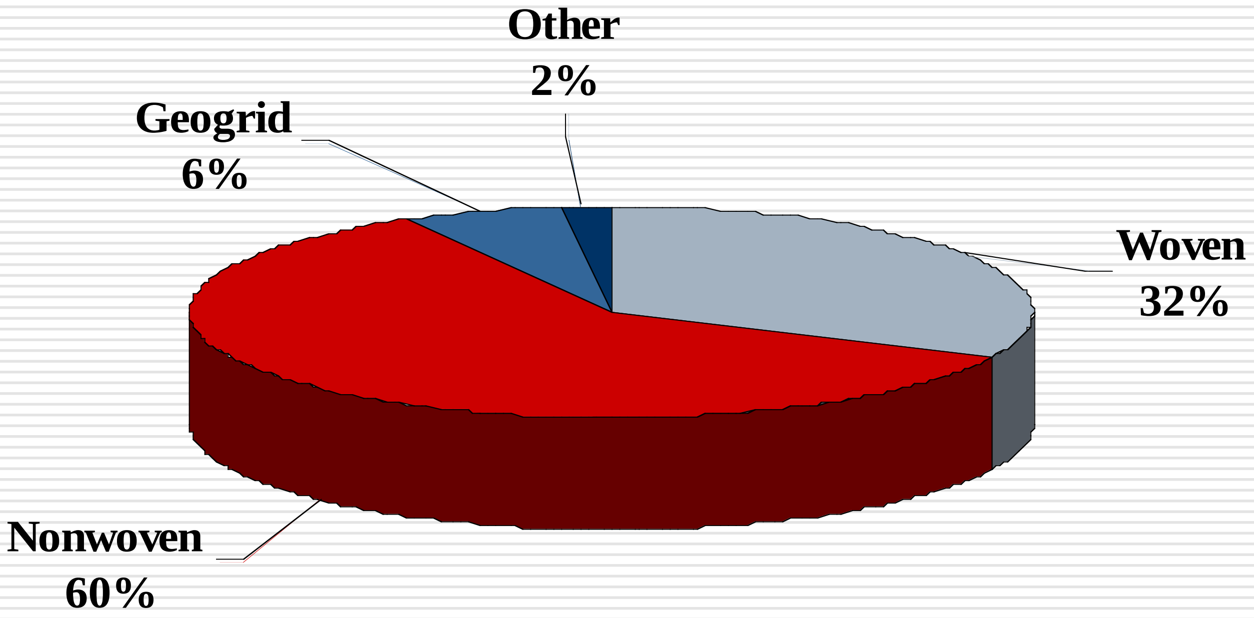
Geosynthetic Cushion / Protection

A geosynthetic performs the cushion/protection function when it alleviates or distributes the stresses and strains transmitted to the material to be protected.



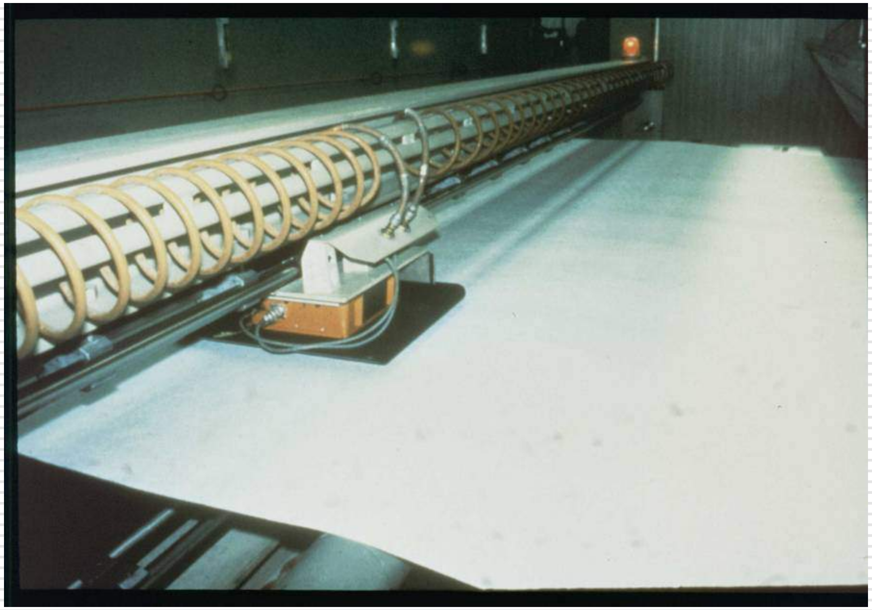
Geosynthetic Categories

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.

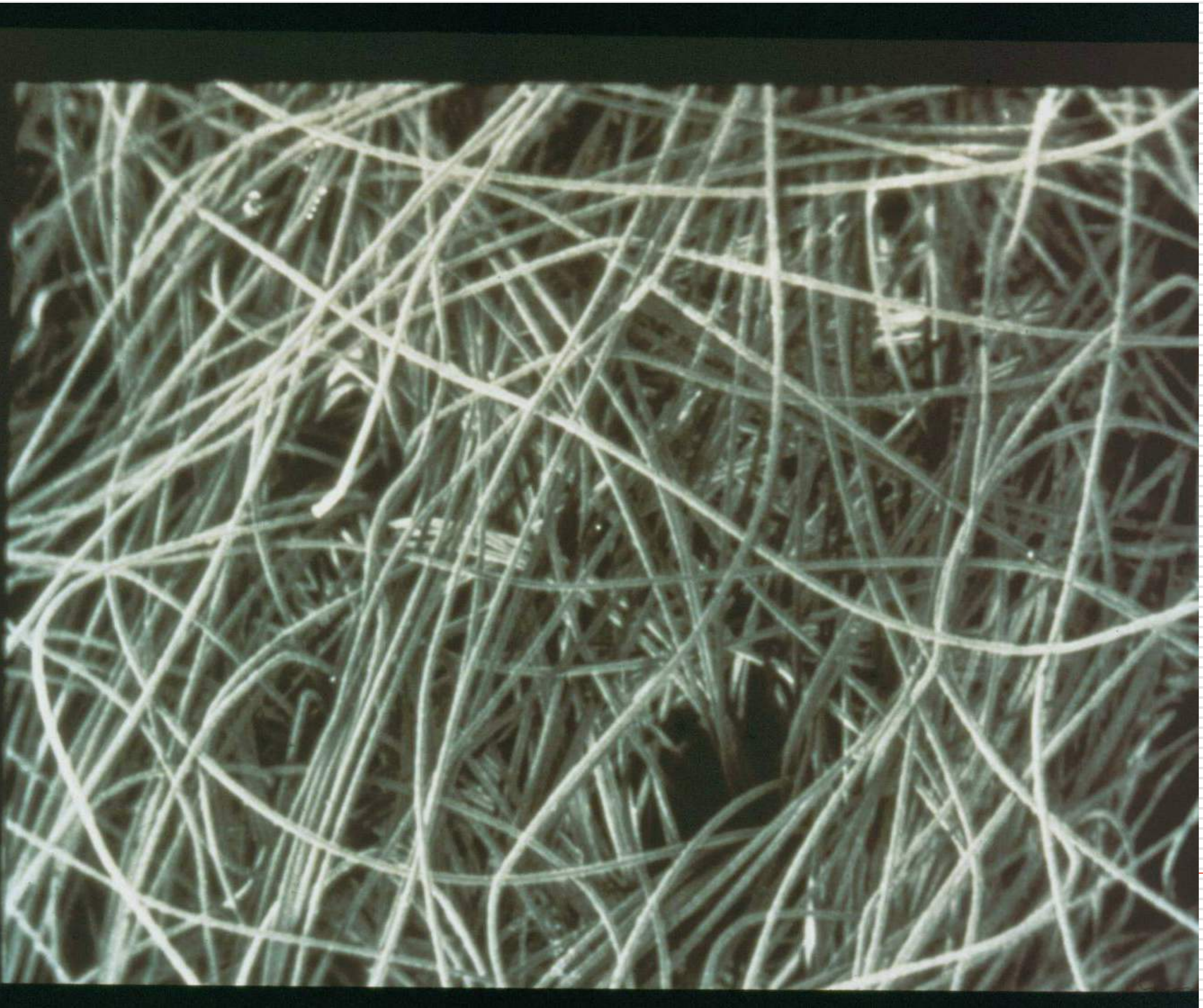
Structures

- 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.

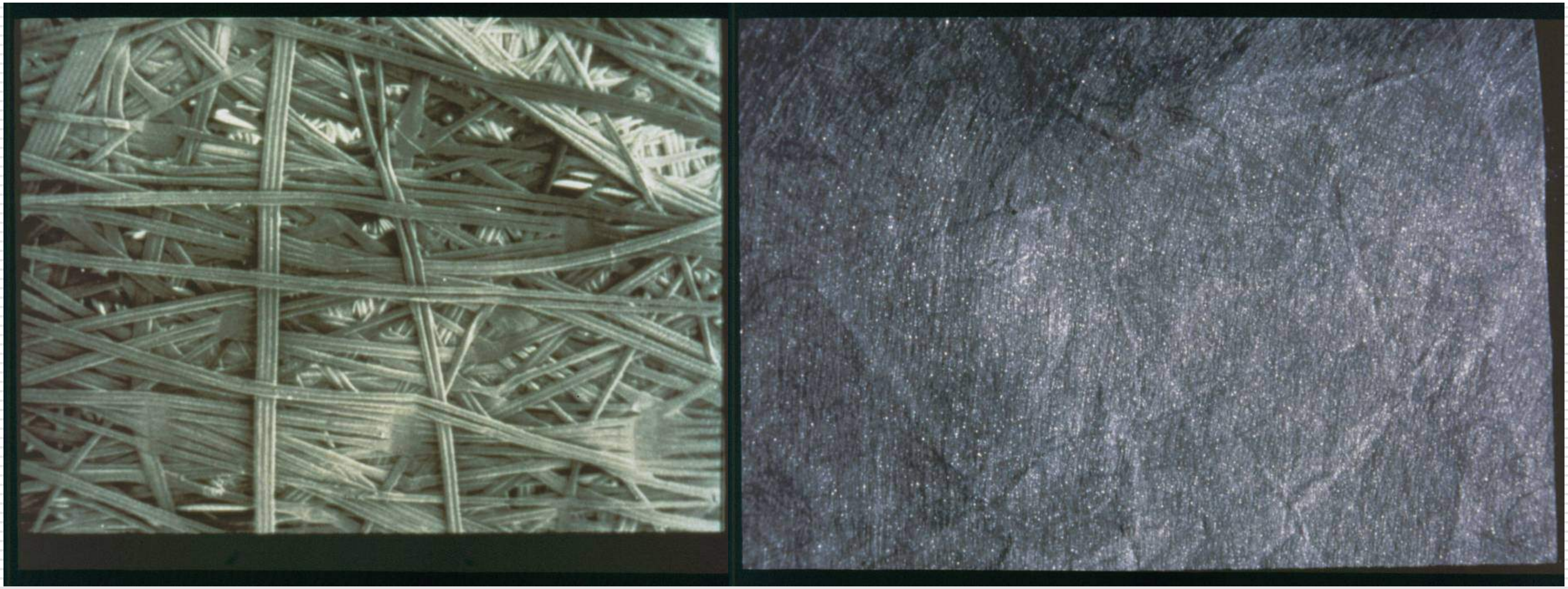
Needle-punched Nonwoven Geotextiles



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

Heatbonded Nonwoven Geotextiles

Heat-bonded nonwovens are thinner and have greater stiffness.

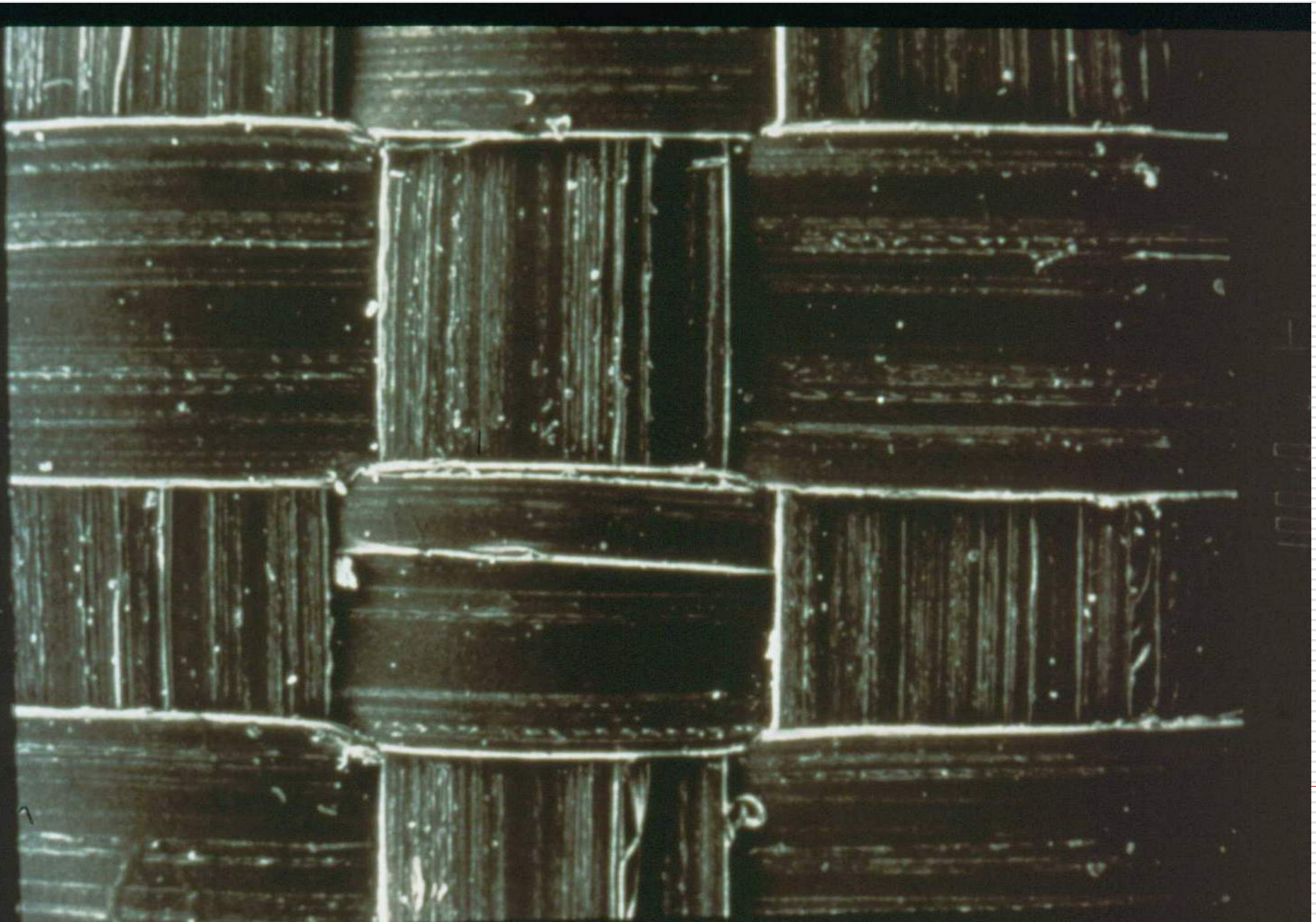


Wovens

- 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



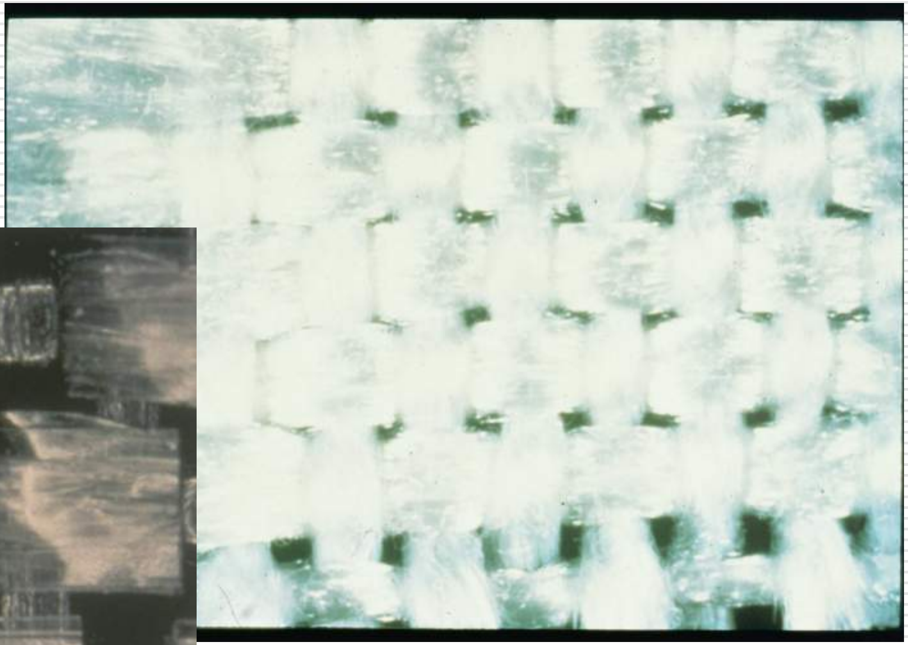
Slit film woven geotextiles provide economical separation of materials.

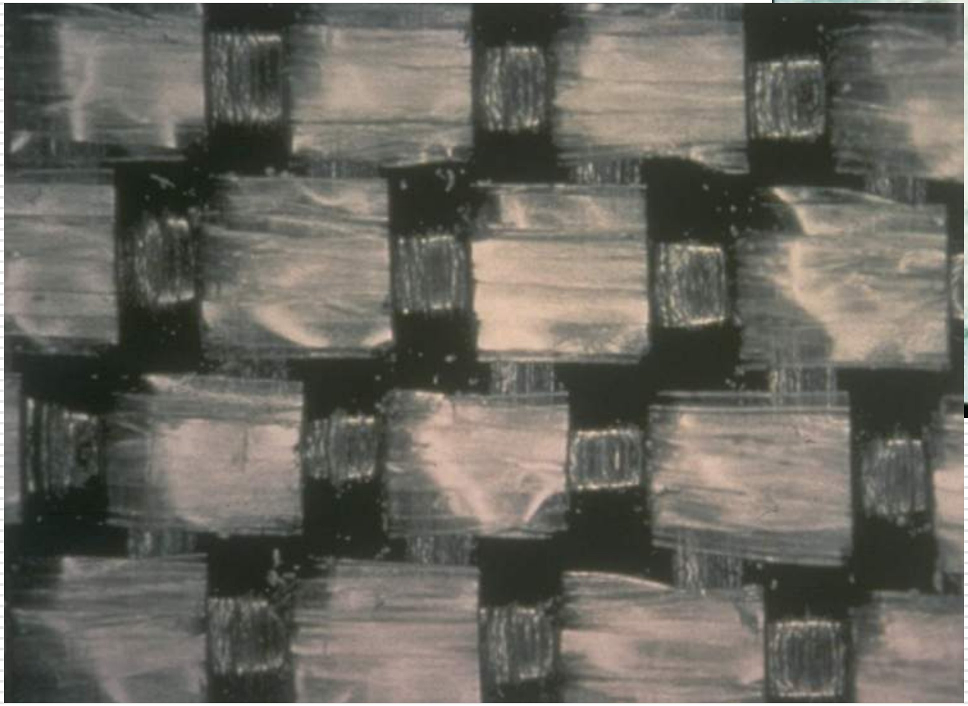
Monofilament Woven Geotextiles

Monofilament woven geotextiles provide enhanced filtration properties.

Fibrillated and Multifilament Woven Geotextiles

Multifilament woven geotextiles provide enhanced tensile strength.





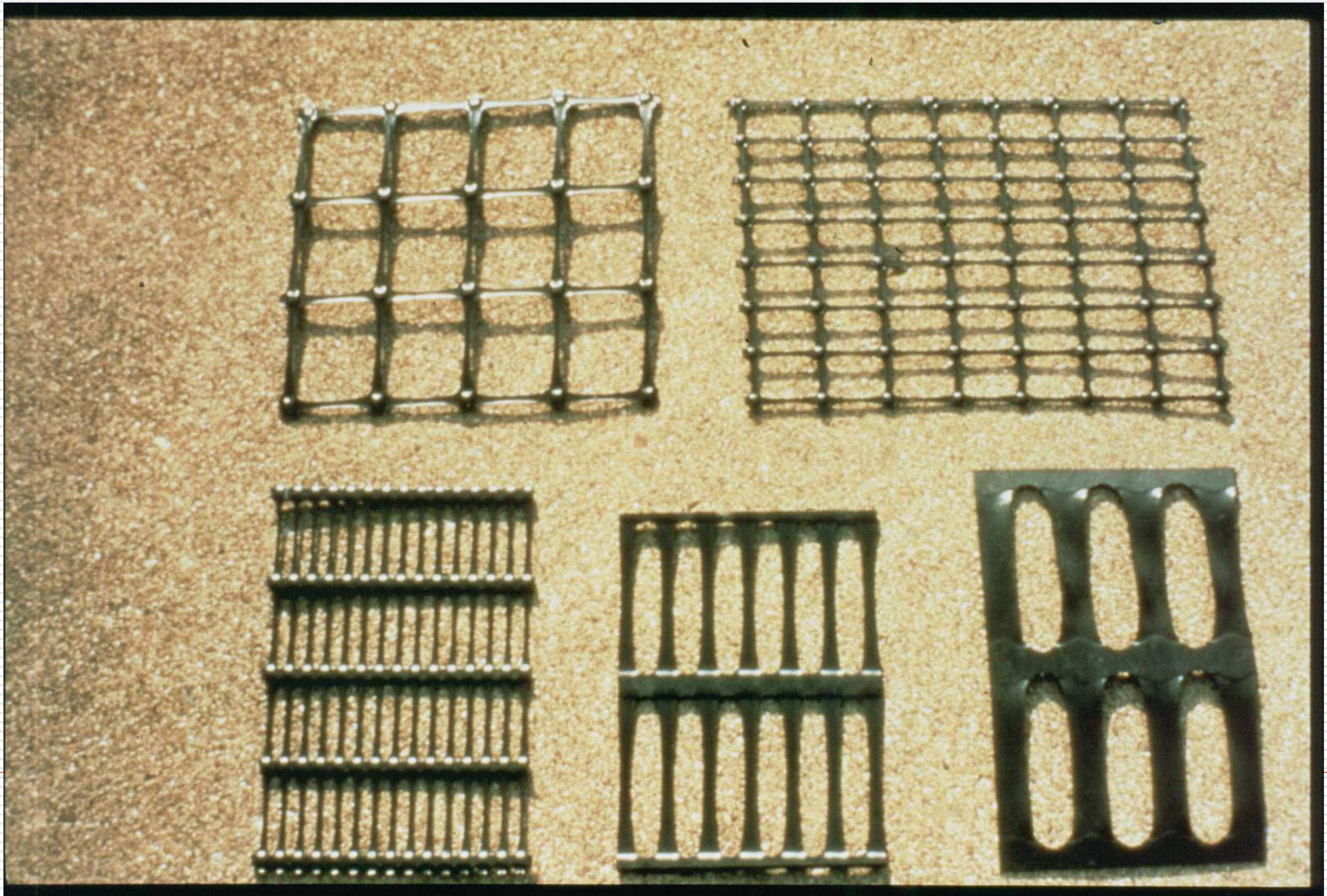
Geogrids

- 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.

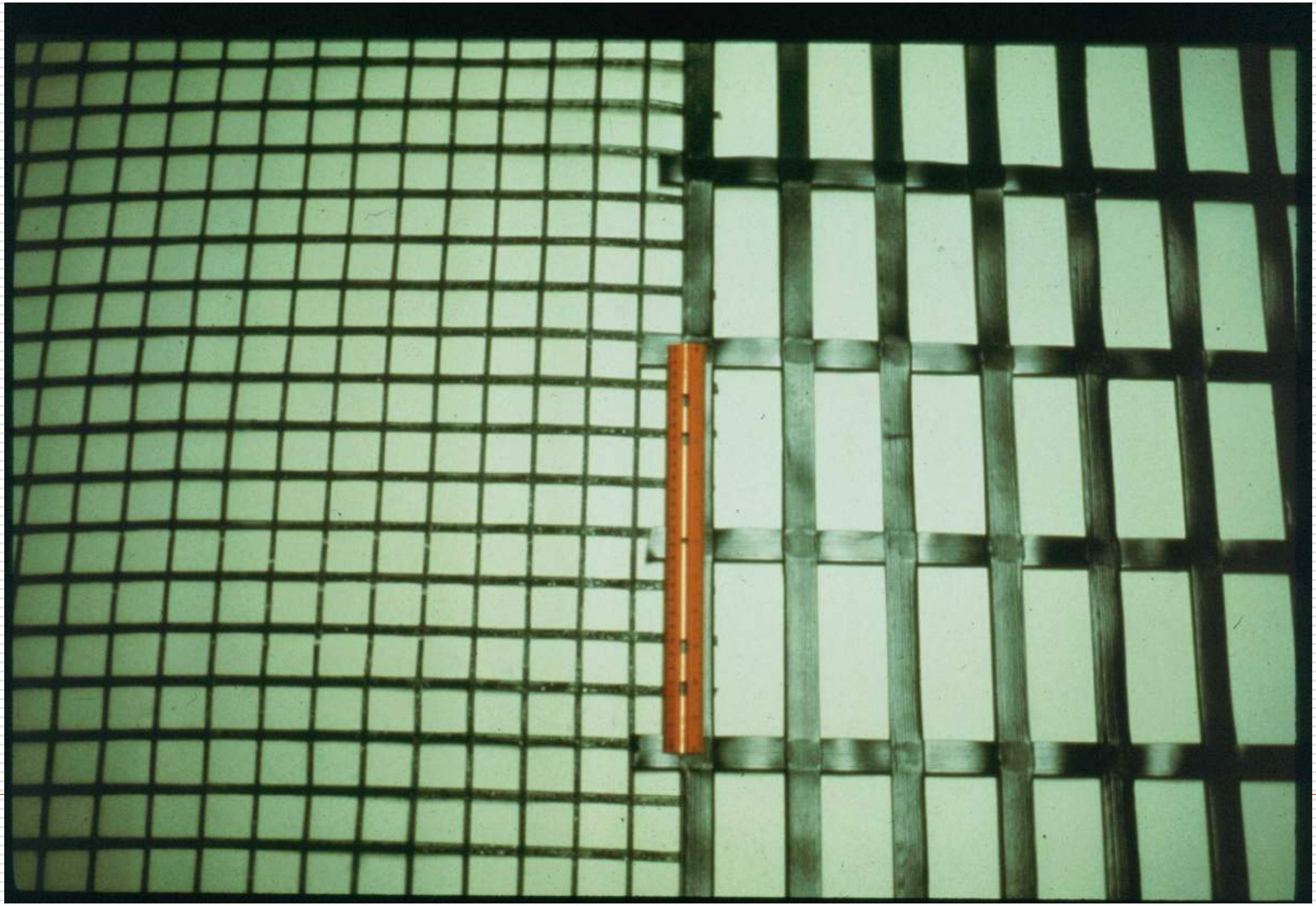
- The resulting grid structure possesses large openings (called apertures) that enhance interaction with the soil or aggregate.

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

Punched/Drawn Geogrid

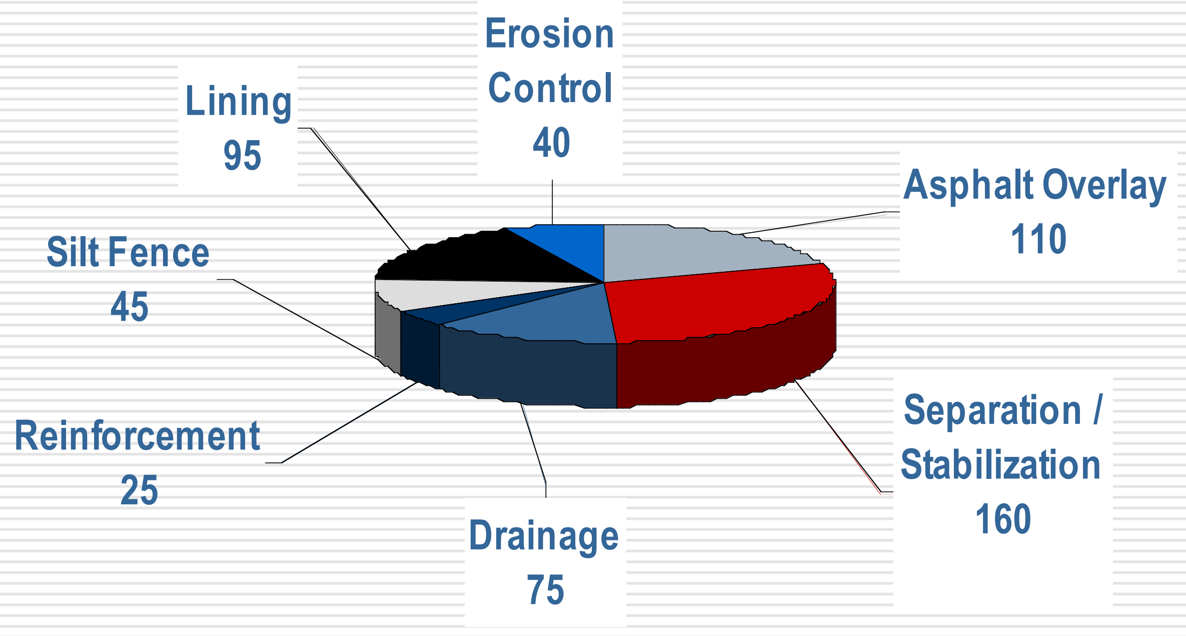


Woven/Coated Geogrid



Estimated Annual North American Geotextile Market (in millions of square yards)

An approximate breakdown of geotextile and geotextile-related product use in the US by application.

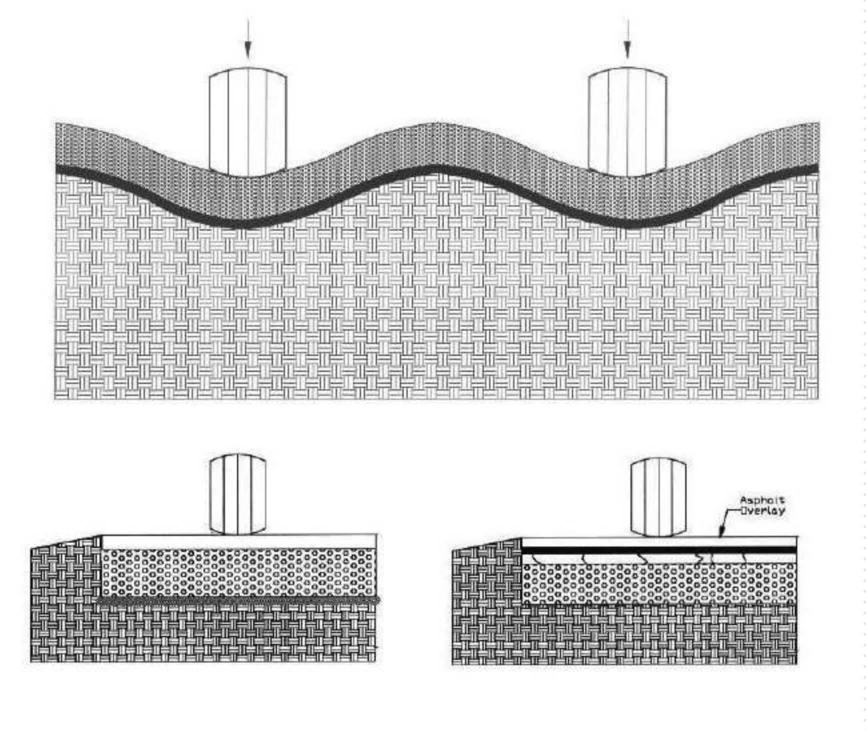


USA Market

Geosynthetics In Roads & Pavements

Subgrade separation and stabilization, base reinforcement, overlay stress absorption and reinforcement

As shown previously, the largest use of geotextiles is in road applications, including separation/stabilization and asphalt overlay applications.



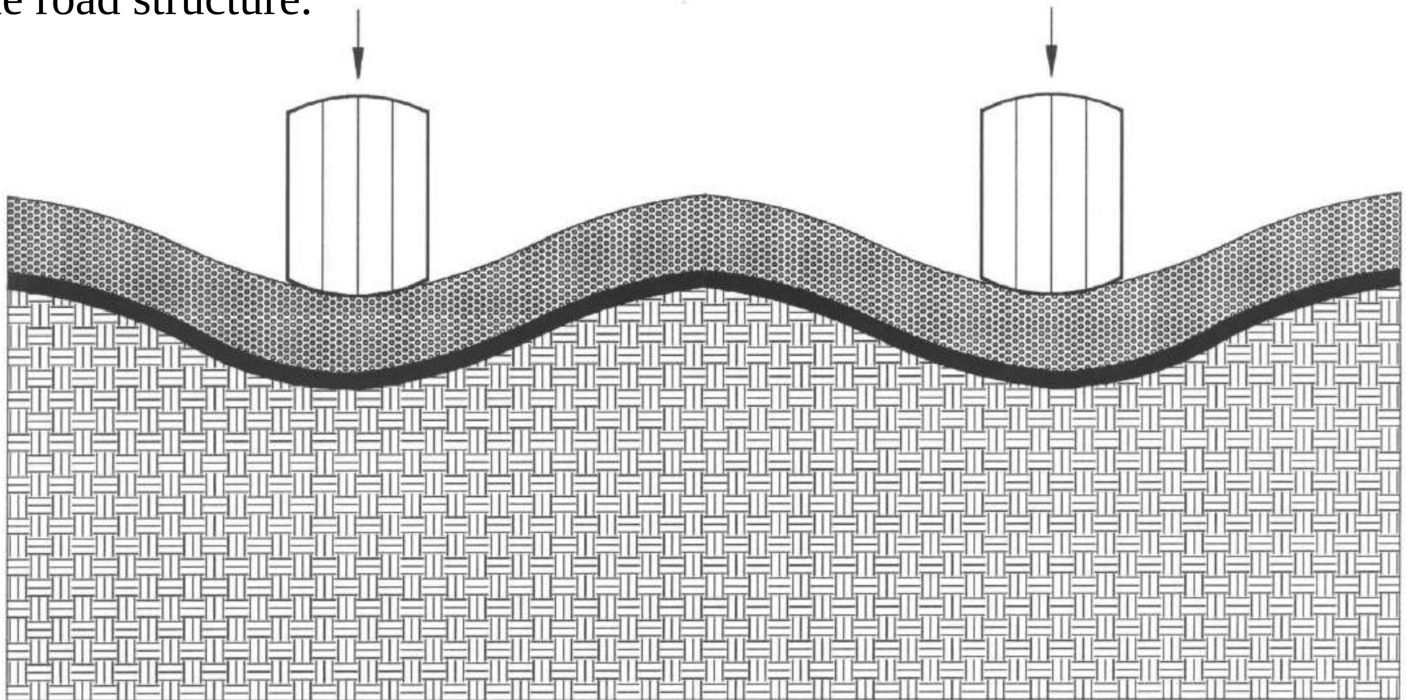
Geosynthetics In Roads & Pavements History

Though only widely recognized since the latter half of the 1900s, geotextile advantages were initially demonstrated as early as the 1930s using conventional textile materials.

Subgrade Separation & Stabilization

Geosynthetics can stabilize the road subgrade and reinforce the road base aggregate by contributing two important functions:

1. **Membrane action -** the ability of a geosynthetic material to reduce and spread stress arising from the weak subgrade.
2. **Lateral restraint,** sometimes called confinement - restraining lateral movement of both the aggregate and the subgrade, improving the strength and stiffness of the road structure.



Introduction to the Problem

The Problem:

Poor Subgrade Conditions

- Problems are encountered when the subgrade consists of soft clays, silts and organic soils.

- This type of subgrade is often unable to adequately support traffic loads – especially when wet - and must be improved.

- Typically, excavation and replacement of unsuitable materials or subgrade improvement such as chemical stabilization would be used.

- These methods are costly and time consuming.

Without Separation –
Base Stone Fouling Occurs

Fouling of the base aggregate gradually reduces the quality and strength of the base aggregate.

Rigid Pavement

Flexible Pavement

"If you combine 10 pounds of stone and 10 pounds of mud, you have 20 pounds of mud" . . . and the associated loss of support!

Base/Subgrade Separation

- At small rut depth, the strain in the geosynthetic is also small.
- In this case the geosynthetic acts primarily as a separator between the soft subgrade and the aggregate.
- A geosynthetic that survives construction will work as a separator.

Example 1:
Base Separation - Unpaved Roadway

Seasonal re-applications of aggregate on unpaved roads can be avoided if a separation geotextile is placed before the aggregate to create an all-weather, all-season road. Here is an experimental road in Oklahoma with alternating sections with and without separation fabric.

Fabric Section

6" Stone Placed Throughout

Example 1:
Base Separation - Unpaved Roadway

The photo on the left is of the aggregate road with alternating sections with and without a separation geotextile. The right photo is a close-up of a section with no separation geotextile. The fabric cost was equivalent to 1" of aggregate.

Spring Thaw

No Separation Geotextile

Example 2:
Base Separation - Paved Roadway

It is common for development to lead to increased traffic loading on and associated deterioration of existing roads, such as happened to this rural road when a new appliance factory opened.

Existing Rural Road

New Appliance Factory

Example 2:
Base Separation - Paved Roadway

Maintenance of the degraded roadway involved removal of the damaged areas and reconstruction using a separator geotextile.

Remove Fouled Sections

Install Separator

Example 2:
Base Separation - Paved Roadway

Reconstruction included compacted aggregate and an asphalt patch over the separation geotextile in the damaged area followed by an overlay of the entire roadway.

Repave Patches

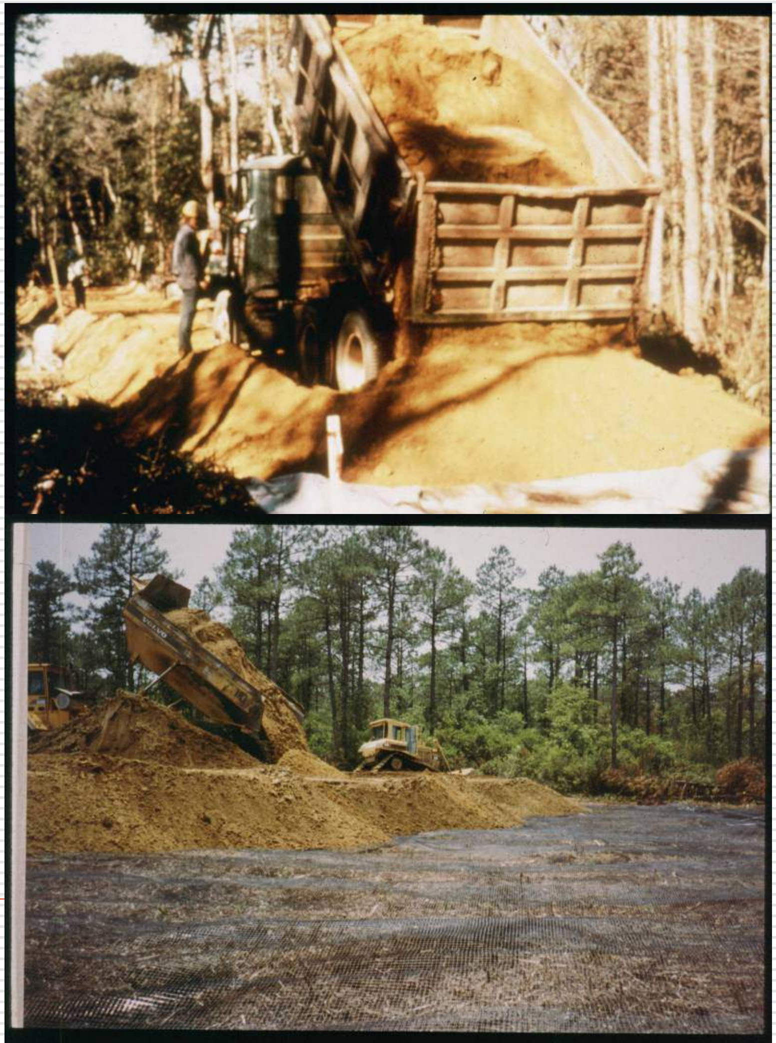
Pavement Overlay

Subgrade Stabilization

For larger rut depths, more strain is induced in the geosynthetic. In this case, considerable reduction in aggregate thickness is possible by the use of a stronger geosynthetic.

- A stabilization geotextile facilitates construction over weak subgrades

- A geogrid is effective in reducing the required fill over a weak subgrade



Subgrade Stabilization

Stabilized (rutted) roadway functions as an unpaved road or forms a working platform for a conventional paved road. Once "ruts" stabilize, the working platform stops deforming.

Unpaved Roads

Temporary Access

Stabilization

Stabilization geotextiles can be fabricated into large panels and deployed to expedite road embankment construction.

Design for Separation/Stabilization

The following general conclusions can be drawn relating to a typical road base:

- A geosynthetic that functions primarily as a separator (typically when the subgrade CBR ≥ 3) will increase the allowable bearing capacity of the subgrade by 40-50% (*separation geotextiles*)

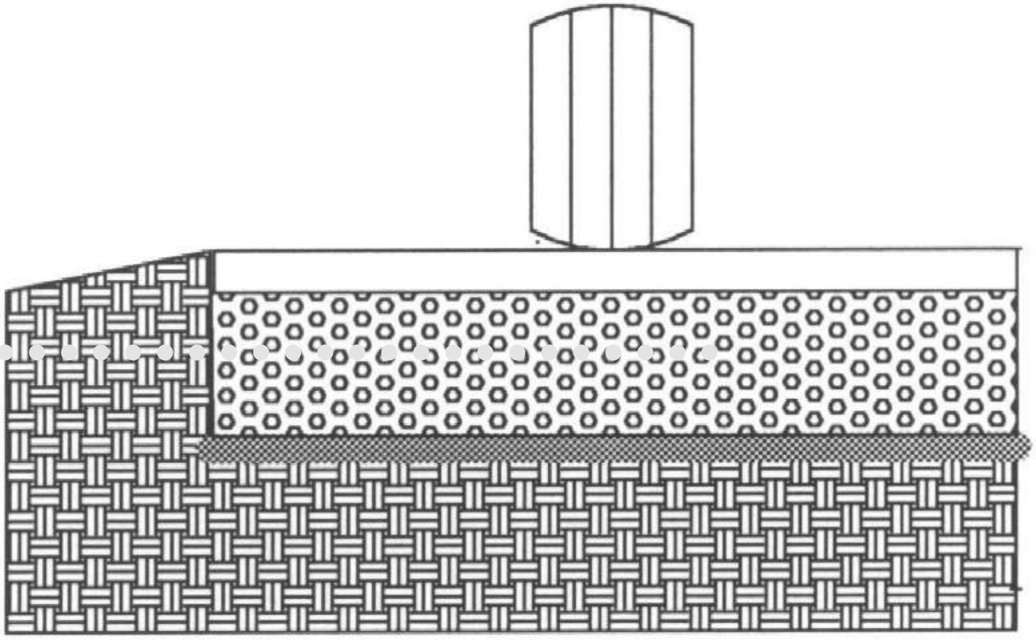
- A geosynthetic that functions primarily to provide confinement of the aggregate and lateral restraint to the subgrade (typically when the subgrade CBR < 3) will both increase the allowable bearing capacity of the subgrade and provide an improved load distribution ratio in the aggregate. The combined benefits can enhance load carrying capacity of the road by well over 50% (*stabilization geogrids or geotextiles*)

- With very weak subgrades, it is often beneficial to combine the benefits of both separation and stabilization

Base Reinforcement

- Permanent roads carry larger traffic volumes and typically have asphalt or portland cement concrete surfacing over a base layer of aggregate.

- With the addition of an appropriate geosynthetic, the Soil-Geosynthetic-Aggregate (SGA) system gains stiffness via “confinement” of the aggregate.



With a Geotextile or Geogrid

Introduction to the Problem

Poor roads often result from poor subgrades

- When the subgrade consists of soft clays, silts and organic soils (i.e. water sensitive soils) that when wet, are unable to adequately support traffic loads.
- If unimproved the subgrade will mix with the road base aggregate – degrading the road structure - whenever the subgrade gets wet.

The Geosynthetic Solution

Geogrid base reinforcement, confines and stiffens the aggregate base layer providing long-term support for the paved surface by:

- Preventing lateral spreading of the base
- Increasing confinement and thus stiffness of the base
- Improving vertical stress distribution on the subgrade
- Reducing shear stress in the subgrade

Quantifying the Geosynthetic Benefit

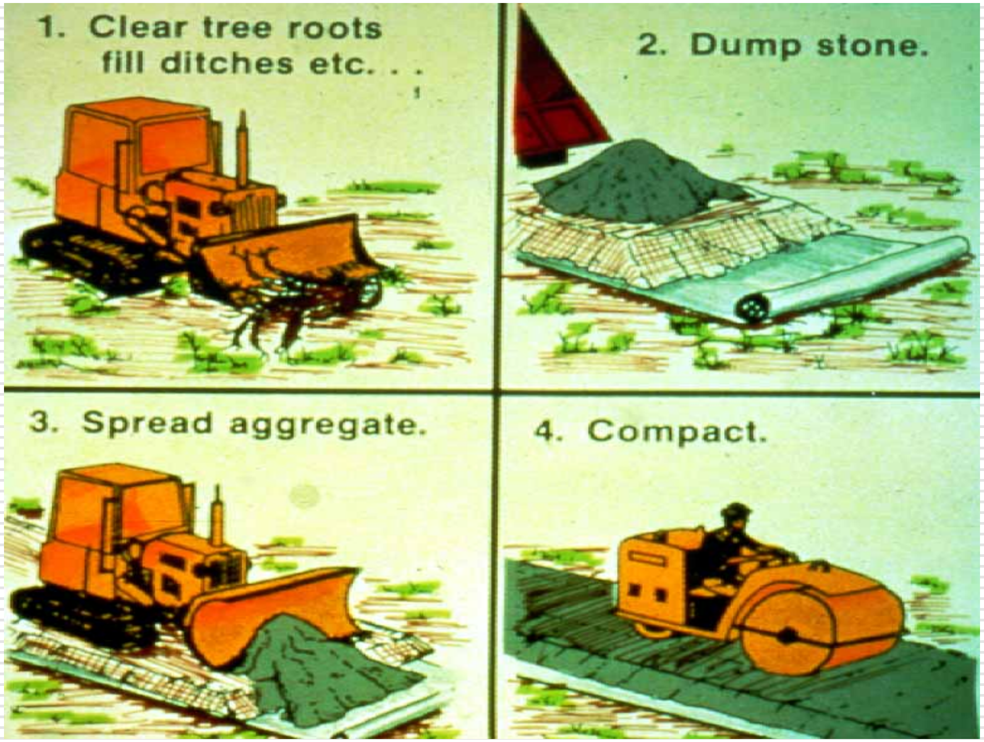
- The TBR relates the ratio of reinforced load cycles to failure (excessive rutting) to the number of cycles that cause failure of an unreinforced road section in laboratory or field tests.

- In general, geosynthetics have been found to provide a TBR in the range of 1.5 to 70, depending on the type of geosynthetic, its location in the road, and the testing scenario.

Installation of Geosynthetics For Separation, Stabilization & Base Reinforcement

Basic Construction Procedures

- Clear and grade the installation area.
- Unroll the geosynthetic on the prepared subgrade in the direction of construction traffic.
- Adjacent rolls should overlap in the direction of the construction.
- Depending on the strength of the subgrade, the overlaps may have to be sewn.
- For weaker subgrades, dump onto previously placed aggregate and then spread the aggregate onto the geosynthetic with a bulldozer.

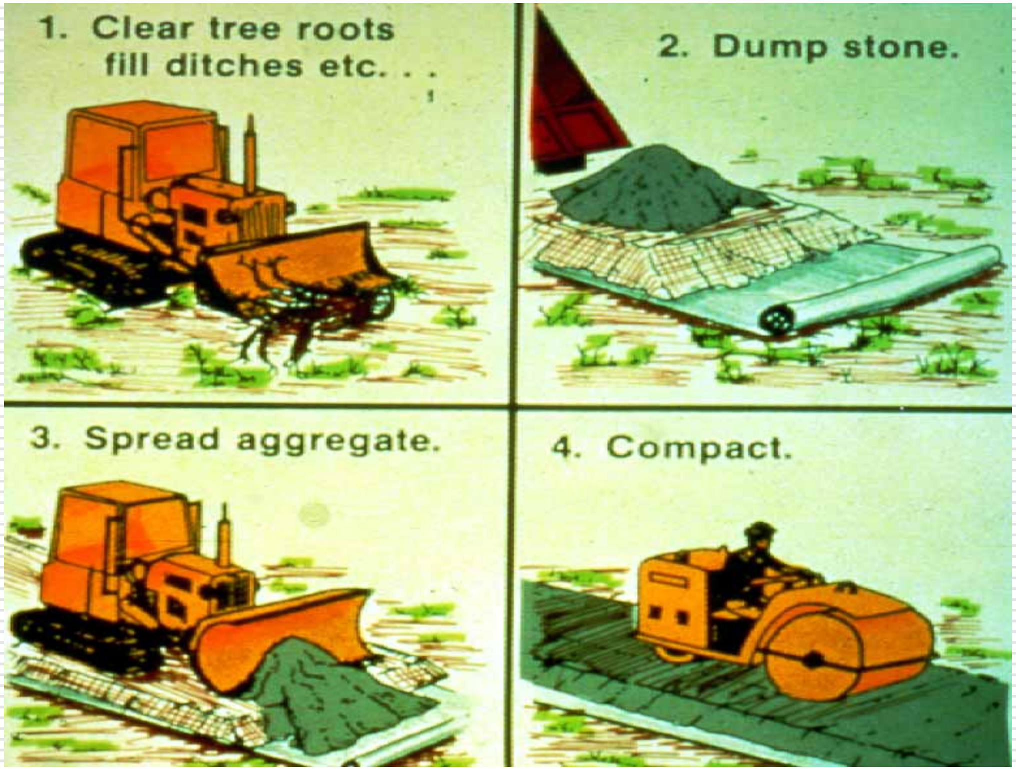


Basic Construction Procedures – Cont' d

- A sufficient layer of aggregate must be maintained beneath all equipment while dumping and spreading to minimize the potential of localized subgrade failure.

- Compact the aggregate to the specified density using a drum roller.

- Fill any ruts with additional aggregate and compact.



Clear & Grubbing

Generally site should have topsoil and all vegetation cleared, but care should be taken not to disturb subgrade excessively.	Vegetative mat may be helpful on very soft areas.

Seaming/Overlap

- Rolls of geotextiles must be overlapped, sewn, or jointed as required
- Overlap
  - CBR=1-2   2-3 ft
  - CBR>2   1-1.5 ft
  - Pin or staple overlaps

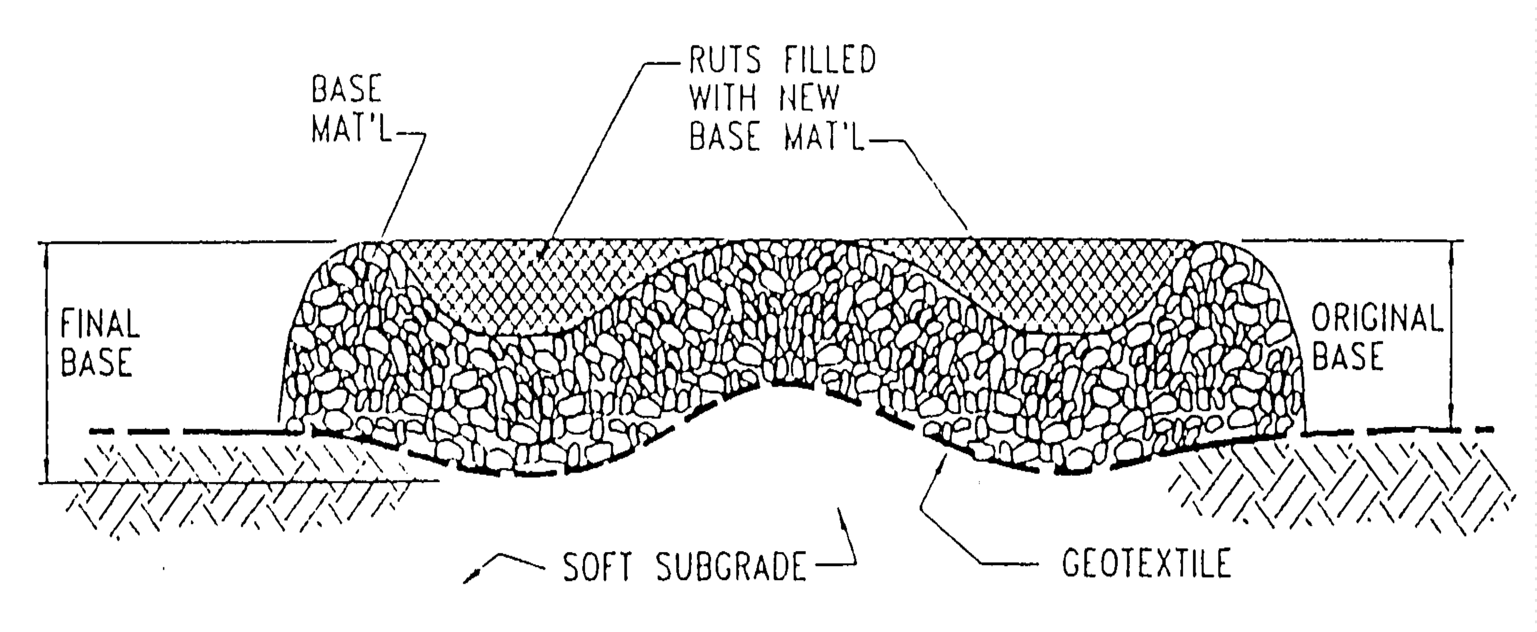
Aggregate Placement

- Construction vehicles should not drive on fabric
- First lift should be placed at minimum 12” thickness
- Rut depths should be less than 3”
- Initial lift should be compacted by tracking-additional lifts with smooth drum vibratory

Stone Selection

- Stone should be crushed with 10%-15% fines content
- Clean stone lacks strength
- Clean stone can be placed over “working platform”

Repair of Rutting



Fill any ruts with additional aggregate and compact.

Surfacing

A surface treatment such as an asphalt layer or a double or triple-treatment can be placed once the base course is complete and structurally sound.

Simplified Generic Specifications For Routine Applications*

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

Specification Criteria:

- Construction Survivability
- In-Service Performance

- Geotextiles for routine applications are easily specified by using generic specifications such as AASHTO M288 and FHWA FP-03.
- The specifications use common geotextile properties to specify geotextiles based on empirical evidence of construction survivability and in-service performance over three decades.
- The FP-03 specifications are available for downloading at no charge at **www.wfl.fha.dot.gov/design/specs/fp03.htm**.

Simplified Generic Specifications For Routine Applications – FP03

FP-03 specifications rely on a single table for each application that addresses both survivability-related properties and in-service performance-related properties.

- **Survivability & Performance Properties**
  - Table 714-1 – Subsurface Drainage
  - **Table 714-2 – Separation**
  - **Table 714-3 – Stabilization**
  - Table 714-4 – Permanent Erosion Control
  - Table 714-5 – Temporary Silt Fence
  - Table 714-6 – Paving Fabric

(All values in tables, with the exception of AOS, represent minimum average roll values in the weakest principal direction.)

FP03, Table 714-2
Separation Geotextile Requirements

	Test Methods	Units	Specifications[1]		
			Type II-A	Type II-B	Type II-C
Grab strength	ASTM D 4632	*N*	1400 / 900	1100 / 700	800 / 500
Sewn seam strength	ASTM D 4632	*N*	1260 / 810	990 / 630	720 / 450
Tear strength	ASTM D 4533	*N*	500 / 350	400[3] / 250	300 / 175
Puncture strength	ASTM D 4833	*N*	500 / 350	400 / 250	300 / 175
Burst strength	ASTM D 3786	*kPa*	3500 / 1700	2700 / 1300	2100 / 950
Permittivity	ASTM D 4491	sec^{-1}	0.02	0.02	0.02
Apparent opening size	ASTM D 4751	mm	0.60[2]	0.60[2]	0.60[2]
Ultraviolet stability	ASTM D 4355	%	50% retained strength after 500 hours exposure		

1. The first values in a column apply to geotextiles that break at < 50% elongation (ASTM D 4632). The second values in a column apply to geotextiles that break at ≥ 50% elongation (ASTM D 4632).
2. Maximum average roll value.
3. The minimum average tear strength for woven monofilament geotextile is 245 N.

FP03, Table 714-2 provides both survivability and performance properties for geotextiles used for separation. Yellow designates the equivalent of the M288 specification default.

Separation Geotextile Types

Survivability:

- Default geotextile selection is Type II-B. Type II-A should be specified when extra durability during construction is desired.
- Engineer may specify a Type II-C geotextile from Table 714-2 based on one or more of the following:

1. Engineer has found Type II-C geotextiles to have sufficient survivability based on field experience.
2. Engineer has found Type II-C geotextiles to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field test section constructed under anticipated field conditions.
3. Aggregate cover thickness of the first lift over the geotextile exceeds 300 mm and the aggregate diameter is less than 50 mm.
4. Aggregate cover thickness of the first lift over the geotextile exceeds 150 mm, aggregate diameter is less than 30 mm, and construction equipment contact pressure is less than 550 kPa.

Separation Geotextile Types – Cont’d

In-Service Performance:

- Default values are given in Table 714-2 for the geotextile type selected based on survivability.
- Permittivity of the geotextile should be greater than that of the soil ($\Psi g > \Psi s$). The engineer may also require the permeability of the geotextile to be greater than that of the soil ($kg > ks$).

FP03, Table 714-3
Stabilization Geotextile Requirements

	Test Methods	Units	Specifications[1] Type III-A	Type III-B
Grab strength	ASTM D 4632	*N*	1400 / 900	1100 / 700
Sewn seam strength	ASTM D 4632	*N*	1260 / 810	990 / 630
Tear strength	ASTM D 4533	*N*	500 / 350	400[3] / 250
Puncture strength	ASTM D 4833	*N*	500 / 350	400 / 250
Burst strength	ASTM D 3786	*kPa*	3500 / 1700	2700 / 1300
Permittivity	ASTM D 4491	sec^{-1}	0.02	0.02
Apparent opening size	ASTM D 4751	mm	0.43[2]	0.43[2]
Ultraviolet stability	ASTM D 4355	%	50% retained strength after 500 hours exposure	

(1) The first values in a column apply to geotextiles that break at < 50 percent elongation (ASTM D 4632). The second values in a column apply to geotextiles that break at ≥ 50 percent elongation (ASTM D 4632).

(2) Maximum average roll value.

(3) The minimum average tear strength for woven monofilament geotextile is 245 N.

FP03, Table 714-3 provides both survivability and performance properties for geotextiles used for stabilization. Yellow designates the equivalent of the M288 specification default.

Stabilization Geotextile Types

Survivability:

- Default geotextile selection is Type III-A
- Engineer may specify a Type III-B geotextile from Table 714-2 based on one or more of the following:

    1. Engineer has found the class of geotextile to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field test section constructed under anticipated field conditions.
    2. Engineer has found the class of geotextile to have sufficient survivability based on field experience.

Stabilization Geotextile Types – Cont’d

In-Service Performance:

- Default values are given in Table 714-2 for the geotextile type selected based on survivability.
- Permittivity of the geotextile should be greater than that of the soil ($\Psi g > \Psi s$). Engineer may also require the permeability of the geotextile to be greater than that of the soil ($kg > ks$).

Questions

THINK **GMAtechline@ifai.com**

Thank You!

Geosynthetic Materials Association

For more information go to www.gmanow.com